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FARMING, FISHING, FORESTRY AND HUNTING IN AN ERA OF CHANGING CLIMATE

HEARING

BEFORE THE

SUBCOMMITTEE ON GREEN JOBS
AND THE NEW ECONOMY

OF THE

COMMITTEE ON
ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE

ONE HUNDRED THIRTEENTH CONGRESS

SECOND SESSION

JUNE 3, 2014

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C O N T E N T S

FARMING, FISHING, FORESTRY AND HUNTING IN AN ERA OF CHANGING CLIMATE

TUESDAY, JUNE 3, 2014

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
SUBCOMMITTEE ON GREEN JOBS AND THE NEW ECONOMY,
Washington, DC.

The subcommittee met, pursuant to notice, at 10:02 a.m. in room 406, Dirksen Senate Building, Hon. Jeff Merkley (chairman of the subcommittee) presiding.

Present: Senators Merkley, Wicker, Whitehouse, Sessions, Inhofe, and Vitter.

OPENING STATEMENT OF HON. JEFF MERKLEY, U.S. SENATOR FROM THE STATE OF OREGON

Senator MERKLEY. I call this hearing of the Green Jobs and the New Economy Subcommittee to order.

Just yesterday, the President made a historic announcement moving forward with the proposal to tackle the single largest source of climate pollution in the United States: coal-fired power plants. This action could not have come too soon. What we are seeing already are real impacts of climate change, impacts that are being felt today on the ground. It is no longer a conversation about hypothetical events or computer models, what might or might not happen in the future, it is a conversation about the real costs to our natural resources in our rural communities and our economy right now.

A few weeks ago, the National Climate Assessment came out with the most up-to-date review of climate science and particularly focused on the impacts we were already seeing across the United States. This report combines the expertise of dozens of the most preeminent scientists to conduct a comprehensive review of the scientific literature to illuminate both the climate impacts we are starting to see today and the types of impacts we can expect to see in coming years.

What was notable on that report is how much impact we are already seeing in sectors that are critical to our rural communities and their economies, such as farming, fishing, forestry, and hunting.

These impacts aren't always straightforward, as we will hear from some of our witnesses today. Climate change is one of many challenges facing these sectors. It is playing an increasingly important role in making existing challenges such as drought and disease even worse. The long term trend toward warmer and shorter

winters is allowing more insects like bark beetles to survive the cold, causing massive tree die-outs in forests across the country and making forests more susceptible to larger and more intense wildfires.

For a State like Oregon, where so much of our rural economy depends on a vibrant forest sector, this trend is very troubling. The warmer, shorter winters are also decreasing the amount of snow pack, leaving less water for farmers to use during the growing season. In Oregon, the snow melt is a critical component of irrigation water since so little rain falls during the summer months. This year, for example, Klamath County in Oregon has seen one of the worst droughts on record, after record droughts in 2001, 2010 and 2013, demonstrating the devastation we can expect to see as severe and intense droughts becoming more common.

The decrease in snow pack also means that our streams are warmer and drier during the summer months, which is impacting freshwater fishing. Less snow melt and hotter summers are expected to contribute to a significant decline in salmon populations.

Our ocean fishermen have been dealing with the effects of climate change, too. Warming oceans are causing fish to migrate, and oceans are absorbing much of the carbon dioxide emitted into the atmosphere. This causes water to gradually become more acidic, which has had devastating impacts on northwest oyster farmers whose oyster seeds, which are the baby oysters, are dying in those more acidic waters.

This is why we are holding a hearing today, to hear directly from those who work in these sectors, and whose livelihoods depend on us taking strong action to prevent the impacts of climate change from getting worse.

The witnesses we have invited here to testify are people who have first hand experience working in the farming, fishing, and forestry sectors. We will also hear from two of our minority witnesses who will present their viewpoints as climate change skeptics.

Finally, I would like to extend a special gratitude to our colleague, Senator Jon Tester, who is here to speak on this subject. Not only is the Senator from a State that will be impacted by climate change, but he is a farmer himself. We will ask Senator Tester to speak as soon as the opening statements are completed. With that, I will turn this over to Ranking Member Senator Wicker to give his opening remarks.

OPENING STATEMENT OF HON. ROGER WICKER, U.S. SENATOR FROM THE STATE OF MISSISSIPPI

Senator WICKER. Thank you very much, Mr. Chairman, for holding this hearing. I will note that it is our first hearing together as a subcommittee. I also want to thank all of our witnesses for being here today, our first witness, and the panel that will follow. As we discuss the impact of climate on farming, fishing, forestry, and hunting, we must not neglect the effects that draconian climate regulations would have on these industries.

Yesterday, as part of the President's climate action plan, EPA Administrator Gina McCarthy announced a new set of rules to regulate carbon dioxide emissions from existing power plants. These regulations would have little effect on the climate, but the rules

would have a negative effect on the livelihood of all energy users, including farmers, foresters, and fishermen, who are the focus of today's hearing. The President's costly regulations mean that farmers who irrigate their crops by pump would face higher utility bills. Foresters would pay more for electricity to turn their timber into building materials and paper, products that are essential to our economy.

These industries already face a myriad of challenges in a difficult economic environment, but at what cost are we going to hurt these economic sectors in the pursuit of aggressive, but dubious, climate regulations?

The costs to these industries are sure to go up. The benefits are not. Farmers are said to be on the front line of climate change because they are most likely to be affected by altering weather patterns. In a recent scientific, peer reviewed study that examined U.S. crop producers' perceptions of climate change, researchers found there is little belief among farmers that climate change will have a negative effect on crop yields.

In fact, in my home State of Mississippi, corn and soybean yields are at record high levels. Farmers have been managing their crops effectively and adapting to variable climate conditions for generations and generations. This is nothing new. Unfortunately, this generation will now have to cope with high electricity costs because of questionable climate regulations. For farmers who properly manage their land, a changing climate is not the problem, but burdensome regulations that increase the cost of farm production are.

America's forests provide many benefits and services to society, including clean water, recreation, wildlife habitat, and a variety of forest products. Need we be reminded that carbon dioxide is required for photosynthesis, the process by which these forests use sunlight to grow? Plants tend to grow better under conditions of higher CO_2 levels. Scientists have dubbed this effect CO_2 fertilization.

The economic impact of our forests must not be overlooked. Forestry in Mississippi is a $14 billion industry and supports more than 63,000 full- and part-time jobs. Healthy, productive, and well-managed forests cover more than 60 percent of my home State. These healthy forests support industry that employs 25 percent of Mississippi's manufacturing workforce. Given the current depressed market for forestry goods, higher prices for electricity would only worsen industry problems for foresters who properly manage their trees. Changing climate is not the problem, but onerous regulations that increase the cost of forestry production are.

I am struck, Mr. Chairman and my fellow Senators, with the increasing number of academics who are willing to come forward and say yes on some of this conventional wisdom. They are skeptics. I ask to put into the record, at this point, Mr. Chairman, a transcript of an interview yesterday afternoon on WTOP with Dr. Peter Morici, a University of Maryland professor at the Robert H. Smith Business School.

Senator MERKLEY. Without objection.

[The referenced information follows:]

Transcript: WTOP Interview with Dr. Peter Morici on June 2nd, 2014

ANCHOR: Let's go in depth now with University of Maryland professor Peter Morici. He's with the Robert H. Smith Business School. How are you, Peter?

MORICI: I'm fine ,thank you

ANCHOR: You write that free market decisions have reduced co2 emissions by more than nine percent in five levels. Of course we should celebrate that, but is it enough and will the free market ensure that we do more of that without the government stepping in?

MORICI: Well the market will certainly take us in that direction. Our newfound abundance of natural gas is already pushing out coal. The President's goal is 17%, we're more than halfway there with more than half the time to go. So a lot of this is just going to needlessly raise costs, but more importantly, much more importantly the President's goal, the amount of carbon dioxide we will save, China makes up with additional emissions in only 18 months. It already emits twice of what we emit with an economy half the size. It increases its emissions at a very quick pace every year. Unless China joins all the United States is doing is shipping jobs there where there are no regulations and people can pollute all they want and produce products cheaply.

ANCHOR: And by the way, in China's largest cities where you can't breathe.

MORICI: Yes, but remember co2 emissions is very different than smog. And the environmentalist right now want to confuse that issue saying you certainly don't want smog and asthma and things like that. Co2 emissions is about the greenhouse effect and rising temperatures. The reality is if the President's goals are met and similar goals are met in Europe, we are still going to have the ice caps melts the global temperatures are going to rise and the sea level is going to rise and we're going to have to mitigate against the effects, the sinking in south Florida, fortifying New York City, and so forth. That's going to cost us money and with an economy growing so slowly as it has from the burden of all these regulations we simply won't have the money.

ANCHOR: Now you're concerned a lot about China, but the thought is that if the U.S. doesn't do something countries like China and India definitely won't cut emissions.

MORICI: Well we're already doing something and China's not joining in. It doesn't appear that China will follow any examples whether we're talking about trade or the use of its navy or what have you. China seems much more inclined to be just out for itself, go it alone, bully other nations and not cooperate. I think it's a fool's journey into the night to think that setting a good example will cause China to follow. Climate change is a global problem.

ANCHOR: The question is though what else do we do? We can't just keep cranking out our own smog and our own pollutants…you understand my point? We ueed to do something.

MORICI: We are doing something, but the trick is to do something that matters, that has an effect. The President is touting this as a solution, and it's not. In order to have a solution to

global warming you have to bring China into the game and being nice with China, setting an example with China is not the answer. We've seen that on trade, we've seen that on military issues, we've seen that on nuclear proliferation, and we've seen it on this issue. It is very foolish to think that this is a solution we will bare these costs, the temperatures will go up anyway, but in the process we will grow more slowly and be less able to compete and to solve our cities' problems in terms of fortifying them against the rising sea level. We're going to have to deal with the rising sea level whether or not we do this. The question is will we have an economy that can bare what will be the truly large burden, much larger than this one.

ANCHOR: Thank you, Peter.

Senator WICKER. Let me just point out, in the final minute, Mr. Chairman, Professor Morici says a lot of this, speaking of the President's new plan yesterday, is going to needlessly raise costs, but more importantly, much more importantly, the President's goal, the amount of carbon dioxide we will save, China makes up with additional emissions in only 18 months. Because, I want to point out, "Remember CO_2 emissions are very different than smog, and the environmentalists right now want to confuse that issue, saying, you certainly don't want smog and asthma and things like that." CO_2 emissions are about the greenhouse effect and rising temperatures.

When asked about the thought that if the U.S. doesn't do something, countries like China and India definitely won't, Professor Morici says, "Well, we are already doing something, and China is not joining us." He says, "It is a fool's journey into the night to think that setting a good example will cause China to follow." The anchor says, "Well, we need to do something," and Professor Morici says, "We are doing something, but the trick is to do something that matters, that has an effect. The President is touting this as a solution, and it is not." Finally, he concludes, "We are going to have to deal with the rising sea level whether we do this or not. The question is: will we have an economy that can bear what will be the truly large burden, much larger than this one?"

I thank you again, Mr. Chairman, for holding this hearing. We should be creating jobs and strengthening the economy, not hindering it.

[The prepared statement of Senator Wicker follows:]

STATEMENT OF HON. ROGER WICKER,
U.S. SENATOR FROM THE STATE OF MISSISSIPPI

I would like to thank the Chairman for holding this hearing—our first together. I would also like to thank the witnesses for being here today. I look forward to your testimony this morning.

As we discuss the impact of climate on farming, fishing, forestry, and hunting, we must not neglect the effects that draconian climate regulations would have on these industries.

Yesterday, as part of the President's Climate Action Plan, EPA Administrator Gina McCarthy announced a new set of rules to regulate carbon emissions from existing power plants. Although these regulations would have a dubious effect on changing the climate, I am fearful the rules would have a negative impact on the livelihood of all energy users, including the farmers, foresters, and fishermen who are the focus of today's hearing.

The President's costly regulations mean that farmers who pump irrigate their crops would face higher utility bills. Foresters would pay more for electricity to turn their timber into building materials and paper, products that are ubiquitous in our economy. These industries already face myriad challenges in a difficult economic environment. At what cost are we going to hurt these economic sectors in the pursuit of aggressive climate regulations? The costs to these industries are assured to go up, but the benefits are not.

Farmers are said to be on the "front line" of climate change because they are most likely to be affected by altering weather patterns. In a recent scientific peer reviewed study that examined U.S. crop producers' perceptions of climate change, researchers found that there is little belief among farmers that climate change will have a negative effect on crop yields.

In fact, in my home State of Mississippi, corn and soybean yields are at record high levels. Farmers have been managing their crops effectively and adapting to variable climate conditions for generations and generations. This is nothing new. Unfortunately, this generation will have to cope with higher electricity costs because of questionable climate regulations. For farmers who properly manage their land, a changing climate is not the problem, but burdensome regulations that increase the cost of farm production are.

America's forests provide many benefits and services to society, including clean water, recreation, wildlife habitat, carbon storage, and a variety of forest products. I would also remind my colleagues that carbon dioxide is required for photosynthesis, the process by which these forests use sunlight to grow. Plants tend to grow better under conditions of higher CO_2 levels. Scientists have dubbed this effect "CO_2 fertilization."

The economic impact of our forests must not be overlooked. Forestry in Mississippi is a $14 billion industry and supports more than 63,000 full- and part-time jobs. Healthy, productive, and well managed forest covers more than 60 percent of my home State. These healthy forests support industry that employs 25 percent of Mississippi's manufacturing workforce. Given the current depressed market for forestry goods, higher prices for electricity would only worsen industry problems. For foresters who properly manage their trees, a changing climate is not the problem, but onerous regulations that increase the cost of forestry production are.

In a difficult economic environment, the stakes are high for responsible policymaking—not impractical and misguided climate regulations. We should be creating jobs and strengthening the economy, not destroying it. Our hardworking farmers, foresters, and fishermen deserve it.

I would like to thank our witnesses for testifying today. We look forward to hearing your views.

Senator MERKLEY. Thank you.

Senator Sessions.

OPENING STATEMENT OF HON. JEFF SESSIONS, U.S. SENATOR FROM THE STATE OF ALABAMA

Senator SESSIONS. Thank you, Mr. Chairman.

The conversation is not over. Good discussions need to be held; we need to ask ourselves what the true facts are, and we will do so. A growing number of scientists are demonstrating the falsity of many of the allegations that have been made as a result of warming temperatures and climate change. We simply have to be honest about that. Our economy is exceedingly fragile. It is very fragile.

The average median income for working Americans today is $2,400 below what it was in 2007. We have fewer people working today than we had in 2007. Unemployment remains high, and we simply cannot regulate an imposed cost on American industry to the extent to which they cannot compete in the world market and damage our economy. Only a healthy economy in free nations has the environment consistently improved. Unhealthy economies in totalitarian countries have the worst record by far of environmental issues.

Mr. Chairman, I see Mr. Ashe will testify. I am pleased in his written statement; at least, he did not repeat his previous statement before this committee that we are having more frequent and severe storms, flooding, droughts, and wildfires. Now, that is not sod. When I asked him about it, he gave anecdotes. He submitted not one scientific report to justify that statement which many scientific reports rejected. President Obama has twice claimed that temperatures are rising faster than predicted, even over the last 10 years, he said. In fact, temperatures have flattened over the last 15 years, well below the average computer models for environmental expectations.

All I am saying is, I don't know, maybe this is a temporary pause in some of the climate change that has been projected. Maybe temperatures will rise again, but they are not rising like the experts predicted today, and we have more scientists like Dr. Smith of Forestry today that will puncture some of the irresponsible statements that are being made about forestry.

Mr. Chairman, I grew up in the country, near Vredenburgh, Alabama, and you understand the timber industry. I guess the sawmill in Vredenburgh was one of those classic, big sawmills. I saw logs hauled in front of my house all the time, but all that land has been replanted. It is being managed exceedingly well today; farmers and timber owners are managing better than ever. Scientifically, in each one of those trees, as they grow, they suck carbon out of the atmosphere; a dead and dying tree, once it dies, it emits carbon back into the atmosphere. Harvesting it and making it this wood and putting it in this building for a hundred years, has reduced carbon in the atmosphere. Wood and forests are one of the very best ways we can reduce CO_2 in the atmosphere. It just is, so I feel strongly about that.

With regard to hunting and wildlife, behind my house was a little creek. I calculated one time that I spent a year of my life in and around that creek, swimming in it, playing in it, fishing in it. Behind that creek, there are miles of just basically forest. We saw very few deer and very few turkeys. In Alabama today, you visit people in my area of the State and talk to friends and you leave your home at night and they will say, watch out for the deer. Deer are everywhere; they are eating people's gardens. They are almost a pest, because of better management, or I don't know why. People are hunting better, they are managing their lands better, and we have a clear, without a doubt, increase in game in Alabama today, and I think throughout the rest of the country.

So we have made a lot of progress; we need to continue to make progress. I look forward to the hearing today, and I have another hearing in Judiciary involving the amending of the First Amendment to limit people's ability to speak out in elections, so I am going to oppose that in a little bit. Thank you, Mr. Chairman, I appreciate this good hearing.

Senator MERKLEY. Thank you, Senator.

Senator Inhofe.

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

Senator INHOFE. Thank you, Mr. Chairman.

I have to tell you, Senator Sessions, that my wife is upset because the deer are eating her begonias. You know my wife well enough to know that if she's not happy, I am not happy, so I have a stake in this.

[Laughter.]

Senator INHOFE. First of all, I am glad that Clay Pope is here from Oklahoma. I appreciate your coming, Clay; you and I have worked together with Frank Lucas on some of our small dam rehabilitation projects, and I look forward to hearing your testimony, although I have already read it and I won't be able to stay for it. That does not mean I don't love you, anyway.

All we talk about around here since Barbara Boxer became chairman of this committee is trying to make people believe that the world is coming to an end. This is the 31st, 31st, hearing this committee has had, I am talking about the whole committee now, on global warming since Senator Boxer came in as Chairman, and with each one, the polling data has declined. It started off as a No.

1 or No. 2 issue. The last Gallup poll said it was number 14 out of 15.

I have to say that I know Oklahoma's global warming regulations are no friend of farmers. It is interesting that the title of this hearing is Farming, Fishing, Forestry, and Hunting. With farming, you can come to Oklahoma and talk to farmers, and they will tell you that this is really a crisis that we are in the middle of right now, considering all these regulations. In fact, I am going to quote Tom Buchanan; he is president of the Oklahoma Farm Bureau. He told me just yesterday, "They will have a devastating effect if these regulations go into effect on the farmers of rural Oklahoma. It will be our No. 1 concern and No. 1 issue." That is the Oklahoma Farm Bureau that is speaking.

Let me express my concern with the EPA's just announced regulations. For existing plants, and we understood our new plants, that was a little bit different, that was very costly, but existing would be even more so. The figures that we have is that it would require power plants around the country to reduce their greenhouse emissions by 30 percent to 2005 levels. We have done our own study for a long period of time going all the way back to right after Kyoto was never submitted for ratification. We had found that the cost of it, and this comes from Wharton School, it comes from MIT, it comes from Charles Rivers Associates, is between $300 billion and $400 billion a year. That would be the largest tax increase in history.

We know that the Chambers came out with the amount of money it is going to cost in jobs and all that. For decades, the environmental left has pushed to enact the cap and trade, and again, Congress has rejected it. We have tried, we have had this before Congress now about 12 times; it has been rejected every single time, and each time, by a larger margin. The first one was 2003; that was the McCain-Lieberman bill, and 2 years later, it was rejected by an even larger amount.

So it used to be the No. 1, and now it is the No. 14 concern, and it is a very light concern. Regardless, the President is pushing this regulatory thing.

We don't have to look any further thank Obama's model to come up with a conclusion. He talks about his green dream being Germany. You and I were just there, not long ago, I say to Senator Sessions, and that country is about 3 years ahead of us in coming through with all these regulations; had it continued a war in fossil fuels like our President Obama has had since he's been in office. Their costs for electricity have doubled since they started that program 3 years ago. Doubled. It is now three times the cost per kilowatt hour of what we have here in this country.

We know the American people know that the rule will be expensive, and it is very alarming that we have to do this.

To stay within my timeframe, I am going to have to submit the whole statement for the record. If this is true, if we are now in a spell, in a period of time, 15 years, where there has been no increase in temperature, and they are now saying that this might be the coldest year in the weather the year. All that is a matter of record, then why does this all of a sudden surface as an issue? I will tell you why it surfaced. There's a guy right here, his name

is Tom Steyer. He has come out and he has documented that he is a multi-billionaire, he is going to put a hundred million dollars into the legislative process to try to resurrect global warming as an issue. Fifty million of this is his own money, and he'll raise the other $50 million.

And I can tell you right now that it is not going to work. I know it is a lot of money, and it is going to candidates who are going to be supporting global warming and all that stuff, so we know that it is going to have an impact. And it is a lot of money, but the people of America won't buy it. I would say this: I have already made an announcement, Mr. Chairman that, and there's a possibly I could be chairing this committee again, that when these regulations are finalized, I am going to offer a CRA, Congressional Review Act, on each one of them. Because that is the only way that we can have people get on record of either supporting or rejecting this. I have a feeling that we are going to be able to stop it in spite of $50 million.

By the way, I ask unanimous consent for this article to be put in the conclusion of my opening statement. Thank you, Mr. Chairman.

[The prepared statement of Senator Inhofe follows:]

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

First, I'd like to say that it is good to see Clay Pope here today. He and I have worked closely together with Congressman Frank Lucas on the small dam rehabilitation program, which helps ensure the ongoing operation of important flood control structures and dams throughout Oklahoma.

This is the 31st hearing this committee has had on global warming since Senator Boxer became chairman, and with each one the polling shows that the American people care less and less about the issue.

I have to say that I know Obama's global warming regulations are no friend of farmers. Tom Buchanan, president of the Oklahoma Farm Bureau told me just yesterday that they "will have a devastating impact on farmers and rural Oklahomans."

Let me express my concern with the EPA's just announced greenhouse gas regulations for existing power plants.

This rule will require power plants around the country to reduce their greenhouse gas emissions by 30 percent by 2030 compared to 2005 levels, and it is going to come at an enormous cost. It's a form of cap and trade, which we all know costs between $300 billion and $400 billion per year.

The Chamber of Commerce recently conducted a study on a similar design of regulations and concluded they would cause the loss of $51 billion in GDP and 224,000 jobs each year.

For decades, the environmental left has pushed for the enactment of cap and trade legislation, but time and again Congress has rejected it. And it's no wonder—Americans rank climate change as the 14th most important issue out of 15.

Regardless, the President is pushing the regulatory construct of a cap and trade program he couldn't implement legislatively.

We don't have to look any further than Obama's model: Germany, to see where this path leads. Germany has pushed aggressive policies that are taking their nation away from traditional fuels and nuclear power and toward alternatives. Now they're trying to reverse course, but it's already too late. Germany has doubled the cost of electricity and prices are 300 percent higher than they are here in the United States. EPA's rules will push us in the same direction.

The American people know that this rule will be expensive, which is why the President is pivoting to tout the rule's benefits to human health. But this is especially alarming because EPA has itself admitted that greenhouse gases "do not cause direct adverse health effects such as respiratory or toxic effects."

To make matters worse, the new greenhouse gas regulations will not do anything to mitigate global CO_2 levels. We know this because Lisa Jackson, the President's

first EPA Administrator, told us at this committee that "U.S. action alone will not impact world CO_2 levels." So it is the largest tax increase in history with no benefit.

Between 1998 (which is about the same time the Senate began debating global warming) and 2013, there has been no increase in global surface temperatures. No one disputes this; it has been cited by the IPCC, Nature magazine and the Economist.

Normally, that would make me wonder why the President is pushing regulations. But then I remember Tom Steyer, the new poster child of the environmental left. He's the one who promised to direct $50 million of his own money try to resurrect the dead issue of global warming. That's a lot of money, but the American people won't buy it.

I've already announced that I will file a CRA on all the onerous regulations once they are finalized, and I have a feeling that next year we'll have the votes to do it.

[The referenced article follows:]

POLITICO

Tom Steyer planning $100 million campaign push

By: Andrew Restuccia

February 18, 2014 09:36 AM EDT

Liberal billionaire Tom Steyer is laying plans to go big in the 2014 election.

The former hedge fund manager is hoping to spend $100 million — $50 million from his personal fortune and $50 million from other donors — to make climate change a top-tier issue in the election, The New York Times is reporting.

A person close to Steyer confirmed the $100 million figure to POLITICO but cautioned that it is not a ceiling.

Steyer and his group NextGen Climate Action have emerged over the last year as a major player in the growing world of money and politics, a realm in which court decisions such as the Supreme Court's *Citizens United* ruling have tossed out much of the old rulebook.

(PHOTOS: Climate skeptics in Congress)

He spent millions on the 2013 Massachusetts Senate and Virginia governor's races, helping Democrats Ed Markey and Terry McAuliffe prevail, and has become one of the most outspoken opponents of the proposed Keystone XL oil pipeline. The group has also showed signs it's willing to go after Democrats who support Keystone, possibly including vulnerable Louisiana Sen. Mary Landrieu.

On Wednesday, Steyer's home will be the site of a Democratic Senatorial Campaign Committee fundraiser, with scheduled attendees including Senate Majority Leader Harry Reid and Rhode Island Sen. Sheldon Whitehouse, one of the Hill's most outspoken climate advocates.

Steyer's ambitious $100 million plan would rocket him into the big leagues. As the Times put it, the move would make NextGen "among the largest outside groups in the country, similar in scale to the conservative political network overseen by Charles and David Koch."

(Also on POLITICO: Full energy and environment policy coverage)

Steyer has said for months that he wants to get involved in the 2014 mid-terms, but until now his plans have been vague. Steyer, who has largely self-funded his previous campaigns, is actively seeking to recruit big donors. He pitched Democratic donors and wealthy environmentalists on his 2014 plans in February at his ranch in California, according to The Times.

While Steyer hasn't outlined a full list of his 2014 targets, the Times says early contenders include the Florida governor's race and the Iowa Senate race.

And in the latest signal that rejecting Keystone will be one of his top priorities going into the election, Steyer will brief people attending Wednesday's DSCC event about new polling about the pipeline, the person close to Steyer said. The polling will be released publicly Thursday.

Besides Reid and Whitehouse, senators scheduled to attend include Patrick Leahy of Vermont, Ben Cardin of Maryland, Mark Udall of Colorado, Jeanne Shaheen of New Hampshire and Jeff Merkley of Oregon.

The Wednesday evening dinner fundraiser is being co-hosted by longtime San Francisco-based climate and Democratic donors Susie Tompkins Buell and her husband Mark Buell, as well as Lorna and Wade Randlett. Wade Randlett is chairman and co-founder of Enagra Holdings, a holding company for renewable energy projects.

Darren Goode contributed to this report.

Senator MERKLEY. Thank you, without objection, your time has expired.

We are now going to hear from Senator Tester. We are delighted to have you with us today, both in your roles of U.S. Senator and observer of effects on the ground at Montana and as a generational farmer.

OPENING STATEMENT OF HON. JON TESTER,
U.S. SENATOR FROM THE STATE OF MONTANA

Senator TESTER. Thank you, Chairman Merkley and Ranking Member Wicker.

I would just like to say before I get into my prepared remarks, I don't know Tom Steyer from a bar of soap, but I would be more than happy to work with anybody on the roster today or anybody else to put some transparency on the dark money that comes under these elections. I know this isn't a hearing about elections and dark money, but if we want to save our democracy, I think that is the first step. I think that we could really get to the bottom of a lot of this stuff that is going on as far as influencing our political agenda here in Washington, DC.

Senator INHOFE. Since my name was used, I can react. This isn't dark. This is light. This is something that everybody knows. It is out there, it is been in all the publications. That means that much to some people. I just want to clarify that.

Senator TESTER. Then let's get rid of that and the dark money, too.

Mr. Chairman, I first of all appreciate your having me here today, along with Ranking Member Wicker. It feels like we should be on Crossfire, Roger, but we will do it here. I am not a lawyer, I am not a scientist, I am a U.S. Senator, but more importantly, I am a farmer. The impacts of climate change are felt far and wide and I believe we need to take responsible steps to mitigate the impacts. What those steps are, some came out by the EPA yesterday of some folks who have some other ideas. I am more than happy to listen to them. The EPA released a proposal for reducing carbon emissions from existing power plants. They went with a State-based solution. I think that is smart to our problems and I will work to ensure this proposal works for Montanans in my home State.

I think refusing to act to protect clean air, clean water, is not a viable option. I think in the long term, and in the short term, it is going to cost jobs, and a way of life. As I said a minute ago, I am a third generation farmer. I farm in north central Montana. I have seen the impacts of climate change first-hand. This does not mean I have people that farm the land; this means that I do it with my wife. We finished seeding 2 weeks ago last Saturday.

This piece of land was homesteaded by my grandfather, and we have farmed it for the last 40 years, my wife and I, my folks 35 years before that, and my grandparents 35 years before that. For the average American, particularly those of us from rural America the political conversation about climate change seems worlds away. For us, we have had warmer winters, we have had more extreme weather events, and they are already presenting new challenges for a way of life.

Now, do I say those statements because I read an article in some magazine? No, I say it because this is what I have seen on the farm. Let me give you an example. My dad farmed from 1943 to 1978 and he never got a hailstorm that allowed him to collect more than his premium that he paid for that hail insurance. I have been hailed out four times in the last 35 years. In this month alone, I should say last month, we are in June now, in the month of May, we have seen severe hailstorms all over the State of Montana totally irregular, totally out of character. These are storms that usually would hit in July or August. They are storms that break out windows of cars, that break fences, golf-ball sized hail or bigger. We have had up in my neck of the woods, just south of my place, to down in Billings, 230 miles south of that.

At the turn of 1999 to 2001, we have a reservoir in a place my dad built in the late 1940s, and when he dug it, it filled up with water. In 1999, 2000, 2001, it dried up for the first time ever. If you take a look at what is going on as far as disaster assistance, and I appreciate some of the comments made by the Senators on the roster, and how this could affect our timber industry, how this could affect—I am talking about the new EPA regulations—how this could affect agriculture.

Twenty years ago, the Forest Service spent 13 percent of its budget on fighting fires. And I can almost guarantee you that 20 years ago, that budget was a heck of a lot smaller than it is today, and they spent 13 percent of it. Now it is 40 percent, and they still have to transfer half a billion dollars to cover costs. We are going to spend more than $15 billion on Hurricane Sandy relief efforts alone. I cannot think of a time we have had a hurricane hit New York. But it did with Sandy.

I think today's hearing appropriately focuses on the experiences of farmers, ranchers, sportsmen and women that they are going through. And I think unfortunately the stories are often overlooked, underreported, or not reported at all. As a Nation, I think we need to start paying attention because these experiences are important if we are going to have a debate here in Washington, DC, and we are going to listen. Scientists tell us that climate change will bring shorter, warmer winters, and in Montana I see it. When I was younger, frequent bone chilling winds whipped across the prairies, 30 below for 2 weeks at a time was not an exaggeration. Now, it seems like if we have temperatures below zero, it is the exception.

Do you want me to cut it off now, has this been 5 minutes already? My God. Sorry about that.

Senator MERKLEY. It moves quickly, but I think we'd like to hear the rest.

Senator TESTER. OK, I apologize. I usually don't do this.

Changes in the weather are forcing Sharla and I to look at different ways to operate our farm. To be honest with you, it is more difficult to figure out how. We haven't had a gentle rain this month of May. May is our wettest month. We finished planting those crops 2 weeks ago; they are not going to come out of the ground until we get some moisture. This is pretty abnormal. We have had droughts before, but this is abnormal stuff.

The end of bitter winters, you think, gosh, it is less oil you are going to have to heat the house, or propane or whatever you are doing it. But the fact is those winters, and the lack of cold winters is a lot of little beasts called soft fly show up, and if you don't deal with the soft fly by adding another operation into how you, by swathing your wheat ahead of time, it can take as much of the crop as a hailstorm would, three-quarters of it quite easily, and it is very time sensitive. The dead trees, many of which litter our national forests, as you go south of Flathead Lake, our forests are dead. Combining with historic drought and the wildfire season is longer and hotter, and it is rougher, and it costs more money to fight.

These stories go down the list and I can just tell you that a couple years ago, we flew into, down around by Billings they were having record floods. The next year, the same people whose houses were underwater 1 year ago were being burned out the next. Same land. I don't know what is going on. I don't know if the Earth is getting warmer, I don't know if we are just in a cycle. But I can tell you, we can talk about all the things that need to be done here, and we can talk about how it is going to impact farmers and ranchers and sportsmen and all that, but if we end up passing on a climate to our kids that doesn't allow our kids to move forward with an economy that will help support, I think we are making a huge mistake.

Now, last year we had a record crop. I can tell you right now it is going to be a pretty open summer for me if we don't get some rain pretty damn quick. Those kinds of variations in weather farmers always talk about as being normal, but this is above anything that I have ever seen in my 57 years on this place. By the way, I lived within a hundred miles of that place until I got this job. That is where I have spent my entire life. I have seen things happen in our climate that I have never, ever, ever seen before. Maybe it is just happenstance, maybe it is just choice, maybe if we ignore it, it will go away.

But I think that if we can put a man on the Moon in 10 years, we can certainly, going off of 2005 standards, reduce the amount of CO_2 going into the air by 30 percent in 25 years. I don't think it is that much of a stretch.

Is coal going away? I don't think so. Not for a while. By 2030, nearly a third of our energy will still be coal. I don't think that is a bad thing.

So, Mr. Chairman, I appreciate your having this hearing. Ranking Member Wicker, you know that I have a tremendous respect for you, and I appreciate your contribution to this. I think we have a choice as people who serve in the Senate and the House. We can do nothing, or we can try to find solutions that help drive our economy forward and address issues of climate. If we do nothing, then we are wrong. Think about that. Just think about that. Means there is going to be a lot of hungry people.

With that sobering thought, I will say thank you for the opportunity to testify. I very much appreciate it. I apologize I ran over by damn near double, but such is life. Ashe will have to cut his way back.

[Laughter.]

Senator MERKLEY. Senator, thank you very much for your testimony and giving this kind of direct, on-the-ground impression of these effects from hail, to fires to new pests to fewer, as you put it, bone chilling winds. Indeed the point of this hearing was to hear about effects on the ground, and we are going to now have witnesses to take a look across America. We really appreciate your giving your sense. Thank you.

I would like to invite Director Dan Ashe of the U.S. Fish and Wildlife Service to join us. Dan has had a long career in public service. Prior to being director, he served as the Service's Deputy Director for Policy, as a science advisor, and as the Chief of the National Wildlife Refuge System. Mr. Ashe spent 13 years as professional staff on the former Committee on Merchant Marine and Fisheries in the House of Representatives and earned his graduate degree in Marine Affairs from The University of Washington.

He is here today to give us a perspective on how we can expect to see climate change impacting our natural resources that are key to sustaining our fishing and hunting economies. It is terrific to have you. Welcome.

STATEMENT OF HON. DAN ASHE, DIRECTOR, U.S. FISH AND WILDLIFE SERVICE

Mr. ASHE. Thank you, Chairman Merkley. Thank you, Ranking Member Wicker.

It is a privilege to be here before this subcommittee, and thank you for the opportunity to testify today, really in behalf of America's sportsmen and women.

As Americans, we are extraordinarily blessed and among these blessings are the natural landscapes and the healthy, abundant, native fish and wildlife that they support. Today's blessings are largely due to the leadership and the foresight of yesterday's hunters and anglers, good people, and professional managers who found the will and the ability to face the great challenges of their day. It may have been the Dust Bowl in the 1930s or pesticide use in the 1950s and 1960s and wetlands destruction in the 1970s and 1980s. These women and men found the will and the way to work with Congress and others to address those challenges.

Today, I am really proud of my country and my colleagues in public service. In 1990, I was a committee staff member in the House of Representatives, worked with the House Marine and Merchant Fisheries Committee, the House Science Committee, and others, and this committee, in the Senate, to enact the Global Climate Change Research Program Act. A few years ago we worked with our State colleagues and other partners to develop the National Fish Wildlife and Plants Adaptation Strategy.

Just recently, we saw the most recent National Climate Assessment, and then yesterday the EPA proposing reasonable and effective regulation of greenhouse gas emissions. So I feel like our country finally has the information and the wherewithal and is finding the will to address this great challenge.

Hunting and fishing are vital components of the Nation's economy, especially in many rural areas. In 2011, Americans spent $145 billion on wildlife related recreation, nearly 1 percent of the Nation's gross domestic product. The changing climate system is af-

fecting hunters and anglers today, and it is darkening the prospects for hunters and anglers tomorrow. Shorter winters and earlier springs are disrupting delicate waterfowl migrations that have evolved over eons.

Drought and water scarcity are increasing, jeopardizing populations of native fish and aquatic species in dozens of watersheds. Rising water temperatures are reducing habitat and altering breeding and spawning opportunities for many species of fish. Milder winters are increasing the prevalence of parasites and disease. That can have decimating effects on big game and forest habitat while enabling invasive species to spread into new areas and displace native wildlife.

In Oregon and across the Pacific Northwest, climate change poses a major threat to salmon, a vital element of the region's economy and culture. A study published in 2013 concludes that coastal Coho salmon, a federally listed species, faces a significant climate driven risk to future sustainability. The scale and intensity of these current and future climate change impacts pose a serious threat to America's hunting and fishing traditions, and in turn to the benefits they provide to wildlife and people.

Faced by these threats, the Administration is taking significant steps to ensure forward thinking and effective conservation of fish, wildlife, and plants and their habitats. This includes strategic planning through the President's Climate Action Plan, the National Fish Wildlife and Plants Adaptation Strategy, as I mentioned before, which we developed in cooperation with our State colleagues and tribal colleagues. Our survival and quality of life as a species in inextricably linked to the health of ecosystems which also provide clean air, clean water, food, shelter, and employment for the world's human population.

How and whether we choose to respond here and now will determine the kind of world that we leave to our descendants, including whether we pass them a world that has a place for the great traditions of angling and hunting that we are able to practice today.

Mr. Chairman, I want to thank you and the subcommittee for holding this hearing and calling attention to this important and pressing issue.

[The prepared statement of Mr. Ashe follows:]

TESTIMONY OF DAN ASHE, DIRECTOR,
U.S. FISH AND WILDLIFE SERVICE, DEPARTMENT OF THE INTERIOR
BEFORE THE SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
SUBCOMMITTEE ON GREEN JOBS AND THE NEW ECONOMY
FARMING, FISHING, FORESTRY, AND HUNTING IN THE ERA OF CHANGING CLIMATE

June 3, 2014

Introduction

Chairman Merkley and Members of the Subcommittee, I am Dan Ashe, Director of the U.S. Fish and Wildlife Service (Service), within the Department of the Interior (Department). Thank you for the opportunity to testify on the impact of climate change on America. My testimony will discuss the value of hunting and fishing to society and the economy, the deep roots of these activities in our conservation legacy, and the concerns we have about how climate change may affect hunting and fishing resources and management.

Hunting and Fishing in America

Hunting and fishing are important to tens of millions of Americans. The pursuit of these passions, a way of life for many, has a long history and is key component of the nation's economy.

The nation's sportsmen and women, their passion for the outdoors, and their commitment to ensuring a future for fish and wildlife populations are the foundation of our current commitments to protecting and sustainably managing these resources for all Americans to enjoy. For more than a century, hunters and anglers have worked tirelessly to ensure an abundance of game and the enforcement of wildlife laws to protect wildlife populations, and they have consistently supported funding these efforts through license and user fees on the equipment used in the field. As we assess the consequences of climate change to hunting and fishing, we should always give due consideration to the sustained efforts and investments of sportsmen and women, and the Congress, to restoring and maintaining wildlife populations in this country.

The notion of wildlife as a public resource formed the cornerstone of what is now known as the North American Model of Wildlife Conservation—a system that keeps wildlife as a public and sustainable resource, scientifically managed by professionals and agencies such as the Service and our state counterparts. The guiding principles of the North American Model are simple: the nation's fish and wildlife resources belong to all Americans and they must be managed sustainably, so that current and future generations can enjoy their abundance. Hunters and anglers are a backbone of the model's success.

The U.S. Fish and Wildlife Service's Role in Providing Hunting Opportunities

Providing hunting, fishing, and outdoor recreation opportunities to the American people is a central function of the agency. The Service provides these opportunities in a number of ways.

The Service administers the National Wildlife Refuge System, which contains 556 refuges and 38 wetland management districts found in every state and territory in the nation. The National Wildlife Refuge System Improvement Act, enacted in 1997, was the first legislation to state explicitly that compatible wildlife-dependent recreation (hunting, fishing, wildlife observation, wildlife photography, environmental education and interpretation) should not only receive priority consideration in refuge planning and management, but that it is "directly related to the mission of the National Wildlife Refuge System." This organic act for the Refuge System was supported by a broad coalition of hunting groups and environmental organizations, and received overwhelming bipartisan support in the Congress.

Tens of millions of visitors enjoy the Refuge System each year. These members of the public come to their refuges to fish, hunt, hike, or just be outdoors. In a world that is becoming more urbanized, national wildlife refuges are more valuable than ever as places where fish, wildlife—and people—can thrive.

The Refuge System provides some of the most outstanding hunting opportunities in the country; opportunities available to every American with the ability and desire to get outside and hunt. Most refuge hunting programs complement and are coordinated with hunting programs administered by states. There are 335 refuges with hunting programs and 271 with fishing programs. There were nearly 2.5 million hunting and 7 million fishing visits to refuges in FY2013. The Service is committed to strengthening and expanding hunting and fishing opportunities wherever those activities are compatible with the primary mission of the refuges on which they would occur.

The Service also supports fish and wildlife conservation and hunting and fishing through management of migratory bird hunting, administration of the Federal Migratory Bird Hunting and Conservation Stamp (Duck Stamp), and through successful partnership efforts like the North American Waterfowl Management Plan and the Wildlife and Sportfish Restoration Program.

Economic Value of Hunting and Fishing

The nation's natural resources, including water, fish and wildlife, and forests, are among our most valuable economic assets. According to the 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (Survey), Americans spent $145 billion on wildlife-related recreation in 2011. This represents approximately one percent of the nation's gross domestic product. Specifically, expenditures from sportsmen and women rose totaled $89.8 billion in 2011 with $41.8 billion spent on fishing and $33.7 billion spent on hunting-related activities.

In 2011, 90.1 million Americans, or close to 38 percent of the nation's population, participated in wildlife-related recreation. Of those individuals, sportsmen and women accounted for 37.4 million in 2011 – 33.1 million Americans fished, and 13.7 million Americans hunted.

A 2013 Economic Study in a Service report entitled "Banking on Nature" documented the substantial economic activity generated by recreational visits to the National Wildlife Refuges System. In FY 2011, 46.5 million people visited refuges. Their spending generated $2.4 billion of sales in regional economies. As this spending flowed through the economy, over 35,000

people were employed and $792.7 million in employment income was generated. About 72 percent of total expenditures were generated by non-consumptive activities on refuges. Fishing accounted for 21 percent and hunting 7 percent. Refuge recreational spending generated about $342.9 million in tax revenue at the local, county, state and Federal level.

The recent surveys demonstrated that the numbers of Americans enjoying the outdoors, and the value of hunting and fishing to the economy, have increased. The effects of climate change have the potential undermine these important activities.

Climate Change Impacts to Hunting and Fishing

Climate change is among the greatest challenges to the conservation of fish, wildlife, and plants—including many species that are fished or hunted. In recent testimony before the Committee on Environment and Public Works and the EPW Subcommittee on Oversight, the Service provided information on the effects of climate change and the ramifications to natural resources management. The Earth's average surface temperature is increasing and this has and will likely continue to erode habitat quality and sustainability for fish and wildlife species and may cause abrupt changes to entire ecosystems in some cases. According to the U.S. Global Change Research Program's just-issued National Climate Assessment,[1] significant changes in the U.S. climate over the past 50 years have occurred, including increases in average temperatures and shifts in rainfall and storm patterns. Climate change acts upon large landscapes and ecosystems and exacerbates the impact of other stressors such as habitat fragmentation or loss due to land use changes, invasive species, fish and wildlife disease, wildfire, floods, and drought.

Accelerated climate change is impacting many species right now, and is contributing to changes in the character and functionality of habitats upon which species depend to breed, migrate, and over-winter. We are learning that climate change is affecting wildlife diseases, is facilitating the spread of detrimental invasive species, and is disrupting critical relationships between certain species and their food sources (e.g., the specialized timing of migrations that historically coincides with the emergence of food sources like seeds or insects). These changes will affect the distribution and abundance of sport fish and game birds and mammals, and may result in novel assemblages of species and habitats that do not currently exist on the landscape, which in turn would impact wildlife management.

As the climate changes, habitat areas for many species will likely expand while habitat available for other species will likely shrink or otherwise be altered. Species' distribution shifts in response to climate change can lead to a number of new challenges for state, tribal and federal natural resource managers, such as the arrival of new pests, the disruption of ecological communities, and the loss of species particularly valued by people from some areas. This is true for species that are hunted and fished, and that are integral to outdoor life in America.

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[1] Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.

Because climate change is affecting wildlife, there are serious ramifications to the people and industries that depend on wildlife, including the hunting, fishing, recreational boating and wildlife viewing industries and Native American tribes who rely on these resources for cultural and subsistence purposes. Climate change will likely have negative effects on, for example: hunting and fishing guides; boating concessionaires; beneficiaries of license revenues; and industries that support hunters and anglers.

Changing climates can alter the emergence of valuable food sources and the availability of important water resources for migrating waterfowl. Warmer water temperatures will likely reduce habitat and alter breeding/spawning opportunities for numerous fish species. Milder winters will likely increase the prevalence of parasites and pathogens that have already negatively impacted big game. These are just a few of the many impacts that climate change is having on the wildlife that forms the foundation of our hunting and fishing economy and heritage.

Impacts on Fishing

Rising temperatures, reduced flows, and reduced oxygen levels will likely affect fishes and their habitats, especially those adapted to colder waters. Popular cold-water species such as brook trout and cutthroat trout will be displaced in many areas. Such displacements mean that many trout species will be lost from lower-elevation and lower-latitude streams: publications cited in the recent National Climate Assessment projected a loss of 47 percent of habitat for all trout species in the interior western United States by the year 2080.[2] The Assessment goes on to note that in the oceans, transitions from cold-water fish communities to warm-water communities have already occurred in commercially important harvest areas.

Alterations in stream temperatures will also likely shift breeding and spawning seasons, as well as hatching times for new fish fry. Warmer temperatures may cause fry of many species to emerge sooner, resulting in reduced survival.[3]

In addition to shifts in habitat and migration/breeding patterns, warmer waters are likely to facilitate increases in disease transmission and prevalence.[4] Similar to displacements by warm-water species, warmer waters can enable parasites and pathogens to persist in areas that were previously unavailable. Along with increased disease prevalence, increased temperatures have

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[2] Wenger, S. J., D. J. Isaak, C. H. Luce, H. M. Neville, K. D. Fausch, J. B. Dunham, D. C. Dauwalter, M. K. Young, M. M. Elsner, B. E. Rieman, A. F. Hamlet, and J. E. Williams, 2011: Flow regime, temperature, and biotic interactions drive differential declines of trout species under climate change. Proceedings of the National Academy of Sciences, 108, 14175–14180, doi:10.1073/pnas.1103097108 cited in: Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.

[3] L. G. Crozier, A. P. Hendry, P. W. Lawson, T. P. Quinn, N. J. Mantua, J. Battin, R. G. Shaw and R. B. Huey. 2008. Potential responses to climate change in organisms with complex life histories: evolution and plasticity in Pacific salmon. Evol. Appl. 1(2): 252-270.

[4] California Department of Fish and Game, Partnership for Interdisciplinary Studies of Coastal Oceans, Channel Islands National Marine Sanctuary, and Channel Islands National Park. 2008. Channel Islands Marine Protected Areas: First 5 Years of Monitoring: 2003–2008. Airamé, S. and J. Ugoretz (Eds.). 20 pp.

been shown to result in reduced immunity and increased susceptibility of fish to diseases.[5,6] Diseases may spread more rapidly, reproduce quicker, and have more damaging effects on host populations.

Impacts on Hunting - Waterfowl

There is increasing evidence that climate change is having an impact on waterfowl populations; the habitats they use for breeding, migration stopover, and wintering; and the timing of migration. Climate change impacts to waterfowl are likely to increase in the future, and will be exacerbated by land-use change and other stressors causing further impacts to waterfowl populations.

One of the most important waterfowl breeding areas in North America is the Prairie Pothole Region on the United States/Canadian border in the northern Great Plains. The Prairie Pothole Region contains millions of shallow depressions that fill with water each spring, providing breeding habitat for millions of ducks, migratory birds, and other wildlife. Retrospective modeling by wetland experts in the US Geological Survey, South Dakota State University, and the University of Illinois have shown that 20th century climate change has already caused changes in wetland conditions by shortening their hydroperiod and reducing their productivity. Modeling of future conditions in the Prairie Pothole Region project that there will be major reductions in water volume, shortening of hydroperiods, and less-dynamic vegetation for prairie wetland complexes.[7] As a result, many of the ponds could dry up or be wet for shorter periods of time, reducing their suitability for breeding and likely contributing to an overall negative impact on duck populations.

Across the country, climate change is expected to affect the timing and distance of waterfowl migration. Warmer fall and winter temperature in northern regions may lessen the need for waterfowl to fly as far south to find open water and suitable food. Several recent studies suggest that some waterfowl species are arriving on the wintering grounds later in the season and in reduced numbers over recent decades. Some species have taken this to an extreme. The winter distribution of Pacific brant, a small, dark sea goose, has shifted northward from low-temperate areas such as Mexico to sub-Arctic areas as Alaska's climate has warmed over the last four decades.[8] This overall trend could affect hunting opportunities in more southerly wintering areas. On their northward spring migration, the close match between migratory timing and the spring growth of plant foods makes geese particularly vulnerable to the impact of climate

[5] M Gallana, M.P. Ryser-Degiorgis, T Wahli, H. Segner. 2013. Climate change and infectious diseases of wildlife: Altered interactions between pathogens, vectors and hosts. Current Zoology. 2013; 59(3): 427 – 437.
[6] Ashley D. Ficke, Christopher A. Myrick, Lara J. Hansen. 2007. Potential impacts of global climate change on freshwater fisheries. Reviews in Fish Biology and Fisheries, Volume 17, Issue 4, pp 581-613.
[7] Brett A. Werner, W. Carter Johnson, and Glenn R. Guntenspergen. 2013. Evidence for 20th century climate warming and wetland drying in the North American Prairie Pothole Region. Ecology and Evolution 3(10): 3471–3482.
[8] David H. Ward, Christian P. Dau, T. Lee Tibbitts, James S. Sedinger, Betty A. Anderson and James E. Hines. 2009. Change in Abundance of Pacific Brant Wintering in Alaska: Evidence of a Climate Warming Effect? ARCTIC
Vol. 62, No. 3 (September 2009): 301–311.

change.[9] These mismatches have been documented in Europe, and may soon be documented in the U.S.

Impacts on Hunting – Big Game

Climate change will also affect terrestrial animals. Big game species in certain areas are already being adversely affected.

For example, associated stressors related to warmer temperatures, are decimating moose populations in Minnesota and New Hampshire. At Agassiz National Wildlife Refuge in Minnesota, the moose population has decreased by 90 percent since the mid-1980s.[10] During that same timeframe, the moose population plummeted across northwest Minnesota by 98 percent.[11] Heat can affect moose directly by reducing body weights, pregnancy rates, and increased vulnerability to predators and disease. [12]
The moose population has declined by 40 percent in New Hampshire in the last decade. Many New Hampshire cows have been under the weight necessary to successfully bear calves the last few years and are producing fewer calves than they did a decade ago. Warmer winters have also caused spikes in New Hampshire tick populations, contributing to declines in the population. Ticks leave moose weakened from blood loss, and many die of anemia. Ticks also leave moose more vulnerable to exposure in the winter as their attempts to rub off the ticks leaves them with hairless patches. Individual moose have been documented to be infested with 150,000 ticks—five times more than normal.[13]

National Fish, Wildlife, and Plants Climate Adaptation Strategy

The President's Climate Action Plan (Plan) released in June 2013 serves as a blueprint for responsible national and international action to slow the effects of climate change using existing authorities. The Plan recognizes the importance of protecting natural resources and promoting resilience in fish and wildlife and their habitats.

The Service is committed to meet the goals of this important plan by continuing to reduce our carbon emissions, implement adaptation measures, and engage key stakeholders and constituencies, including sportsmen and women. Adaptation forms the core of the Service's response to climate change and means strategic, science-based management actions, including

[9] R. H. Drent, G. Eichhorn, A. Flagstad, A. J. Van der Graaf, K. E. Litvin, and J. Stahl. 2007. Migratory connectivity in Arctic geese: spring stopovers are the weak links in meeting targets for breeding. J Ornithol (2007) 148 (Suppl 2):S501–S514.
[10] Personal Communication with Agassiz NWR biologist, May 2014.
[11] Minnesota DNR. 2011. Minnesota Moose Research and Management Plan. Minnesota Department of Natural Resources
[12] Murray, D.L., Cox, E.W., Ballard, W.B., Whitlaw, H.A., Lenarz, M.S., Custer, T.W. Barnett, T., and Fuller, T.K.2006. Pathogens, nutritional deficiency, and climate change influences on a declining moose population. Wildlife Monographs No. 166
[13] Anthony R. Musante, Peter J. Pekins & David L. Scarpitti. 2010. Characteristics and dynamics of a regional moose Alces alces population in the northeastern United States. Wildl. Biol. 16: 185-204

regulatory and policy changes that will help reduce the impacts of climate change on fish, wildlife, and their habitats.

Additionally, in March of 2013, the National Fish, Wildlife, and Plants Climate Adaptation Strategy (Strategy) was released. This Strategy presents a unified approach—reflecting shared principles and science- based practices—for reducing the negative impacts of climate change on fish, wildlife, plants, our natural resource heritage, and the communities and economies that depend on them. The Strategy was developed with input from a wide variety of sources, with multiple opportunities for public input, and was shaped by comments from more than 55,000 Americans.

The Strategy does not prescribe any mandatory or regulatory requirements, but is designed to coordinate government-wide fish and wildlife climate change adaptation efforts and to build on growing efforts beyond Federal and State agencies to understand, track, and reduce impacts of a changing climate on the nation's valuable fish, wildlife, and plants. It outlines a roadmap of key steps needed to help safeguard the nation's natural resources in the face of these challenges, and is a key component of efforts by Federal, State and Tribal governments and non-governmental entities to reduce the risks and impacts of climate change.

The Strategy also describes opportunities for numerous sectors to address these challenges and then describes how its goals and strategies may be implemented with coordination across the Federal government, States, tribes and other entities. It provides guidance about what further actions are most likely to promote natural resource adaptation to climate change, and describes mechanisms that will foster collaboration for effective action among resource managers and stakeholders.

The Service is no co-leading a Joint Implementation Working Group (JIWG) with the National Oceanic and Atmospheric Administration (NOAA) and the Great Lakes Indian Fish and Wildlife Commission to promote implementation of the Strategy. The White House Council on Environmental Quality is also supporting this effort. The JIWG includes representation from most of the agencies that participated in development of the Strategy (15 Federal, 5 State, and one inter-Tribal commission) and will be responsible for reporting on implementation and for future revisions of the Strategy. The Service will continue implementing the Strategy within its own programs and working with the many other agencies involved in Strategy implementation.

Conclusion

Hunting, fishing, and general outdoor recreation are part of the fabric of America. These pursuits are a major component of the nation's economy and provide tens of millions of American's with the invaluable benefit of connecting with nature.

The Service's responsibilities cover a wide range of natural resources that we are charged to conserve, protect, manage, and make available for public use through Federal statutes. Many of these resources are managed for public use, including hunting and fishing. Climate change is affecting fish and wildlife species' health, abundance, and distributions. The long term ramifications of these effects to hunting and fishing are of great concern and must be considered

as the nation plans for and reacts to the effects of climate change. The Service is highly aware of the challenges presented by these effects and looks forward to working with this Subcommittee and the Congress to continue to address these issues.

We thank Chairman Merkley and the Subcommittee for holding this hearing and the opportunity to testify on this important issue, and are happy to provide response to questions.

Senator MERKLEY. Thank you. We will now have 5 minute periods for questions, comments.

Just to summarize, what you are seeing from your expertise within the Fish and Wildlife Service are effects on the ground right now?

Mr. ASHE. There is no doubt, Senator, that we are seeing effects of changing migration patterns in our waterfowl. We are seeing changing, increasing parasitism and decreasing reproductive rates in big game species like moose in the southern extent of their range. We are seeing rising water temperatures which reduces the habitat quality and availability for cold water fishes, so there is no doubt that we are seeing these impacts across the board.

Senator MERKLEY. So let me take just a couple pieces of that. Let me start with the diseases related to big game.

One of our Senators from New Hampshire was showing a picture recently of a moose with clumps on its back and pointed out that those big lumps, if you will, big black lumps, were actually big infestations of ticks. It was not cold enough to kill them, and they were carrying them year-round and this was resulting in both disease and a continuous loss of blood, if you will, from the ticks, and thus an impact on the moose populations.

Is that one of the most prominent examples of impact on big game, or what else are we seeing?

Mr. ASHE. We are definitely seeing that. We have a refuge in northern Minnesota, Agassiz National Wildlife Refuge. We have seen a 98 percent reduction in the moose population at Agassiz Refuge. We have seen a severe reduction in moose population throughout the State of Minnesota and so they are no longer hunting moose in Minnesota.

The reason is the rising average temperature in the summertime places physiological stress on the animal, so they are not reproducing the way that they used to. Plus, we are seeing these pests, like ticks in New Hampshire, which are able to have multiple generations now during the spring, the summer, the fall, and fewer of them are being killed off by severe winters. So the animals are besieged by pests which put further physiological stress on the animals.

So throughout the southern range of moose, we are seeing declines in the population. So in States like New Hampshire, decline in the population. That represents a lost opportunity for the American sportsman.

Senator MERKLEY. So you said 98 percent loss, so 49 out 50 of moose that were there before are gone. That is a pretty dramatic collapse. Is that over just a few years? Have we had seen that in earlier periods of just a few years of variation in temperatures, that the moose population crashed and then resurged, have we ever seen anything like this before?

Mr. ASHE. We have not seen anything like this before. We have always had warm spells where you would have a summer of two consecutively where you would then have a depression in the population. They would rebound then as the weather returned to a normal pattern.

But what we are seeing now is that steadily rising temperature in the summertime, so that the mean temperature in the summer

is now putting physiological stress on the animals which is affecting their reproduction.

Senator MERKLEY. Let me turn to your comments about migration patterns for waterfowl and specifically ducks. What is causing the ducks to modify their direction? Are the pools that they would land in disappearing, or what is going on?

Mr. ASHE. Migratory birds like waterfowl again have a very delicate and refined migration pattern that has evolved over eons. So what we are seeing, look at it from the perspective of a hen mallard, who is leaving her wintering grounds, maybe in Yazoo National Wildlife Refuge in Mississippi, and is heading toward American prairies. She is stopping along the way, feeding and resting; she has a very narrow window.

When she gets to the prairies, she is looking for a place, a small pothole or wetland to make a nest. In prehistoric times, if that didn't exist in South Dakota, she would go to North Dakota and then she would go to Saskatchewan, and she would fly until she found that habitat.

What we are doing is, human development, we are constraining the habitat. So we have agricultural development, we have oil and gas, energy development, that is constraining her ability of habitats. So now she's much more restricted in terms of where she can go. So if she doesn't make that decision in about a 2-week window of time, she is not going to have a successful nesting season.

What we are seeing is birds are leaving later, they are migrating later, in the spring, they are migrating earlier in the spring, they are migrating later in the fall, so their basic pattern is changing because of their response to weather, we believe. Then the habitat availability for her is shrinking. What the climate assessment tells us is that wet areas will get wetter and dry areas will get drier.

So as wildlife managers, we are now looking at a more complicated picture. How do we put that habitat on the ground for that hen mallard? What we have to do is be able to look into the future because we are not just responsible for today's waterfowl hunters, we are responsible for tomorrow's waterfowl hunters. We have to be able to think about habitat 10 and 20 and 30 years from now. We need to recognize that the climate is changing, that the habitat needs of waterfowl are going to change, their migratory patterns are going to change. We need to understand that better so that we can provide the opportunity for hunters in the future.

Senator MERKLEY. Thank you very much for your testimony, I appreciate it.

Senator WICKER. Thank you, Mr. Chairman. In absentia, thank you to Senator Tester for coming. We do appear occasionally on Crossfire and enjoy trying to match wits.

I am sorry Senator Tester is experiencing hailstorms, increased hailstorms. I think he made a very telling statement, though, when he said, I don't know what is going on. I am not sure what is going on. But I know that scientists of good will disagree about what is going on. I would say to you, Dr. Ashe, and Mr. Chairman, Gail and I have lived on 521 Magnolia Drive, Tupelo, Mississippi, for over 32 years. The lady that built the house before us planted Saint Augustine grass over 50 years ago, and for the first time this winter, I experienced winter kill of my Saint Augustine grass.

Now, I don't know what is going on. But the fact of the matter is, that I can play anecdotes all day, I will just say that it was somehow the cold and the ice and winter got to my Saint Augustine grass that hadn't happened in 50 years on Magnolia Drive. I don't know what that proves except that we can give anecdotes that don't really have much anything to do with science.

Let's talk about the migration of the ducks. Mr. Ashe, it is my understanding that because of the increased demand for corn used in ethanol production, we are seeing reduction of available breeding grounds in Midwest wetlands and grassland for ducks in Mississippi and Louisiana flyways. Don't you think that there is an impact caused by the fuel standards on hunting species, and don't you think this is an unforeseen consequence of Congress interjecting itself into the markets?

Mr. ASHE. Senator, thank you. I would say we are seeing what Ducks Unlimited and others are calling a crisis in the prairies. If you think about the States of North Dakota and South Dakota, which are really the heart of waterfowl production for the United States of America. We have energy development, Bakken Oil Fields, squeezing from the west and we have agriculture development squeezing from the east. So there is no doubt that we are seeing widespread and unprecedented conversion of habitat.

Senator WICKER. If I can interject, because that clock is ticking, part of that reduction in habitat is putting more of the land into corn to respond to this public policy decision that the Federal Government has made. That is a fact, is it not?

Mr. ASHE. Certainly a part of the demand is related to use for ethanol, but the market is a global market for corn and soybean. The global market is what is driving the demand for that commodity.

What is important for us to realize is that climate change lies over that, so as we are trying to maintain and now restore and protect habitat for migrating waterfowl, we have the increasing complexity associated with changing climate and the disruption of their migratory behavior. If you think again about that hen mallard as she is migrating, if the temperatures are warmer, think about you or me. If we were making a journey of some 2,000 miles and the temperature is now a degree and a half warmer than she was evolved to tolerate. The prospect now is for temperatures to rise throughout the end of the century.

So she, from a thermodynamic standpoint, she not only has to make that trip with less habitat, she going to have to make that trip in a hotter world. It is a strenuous endeavor. Migration is a strenuous and risky endeavor for any species, and now we are increasing the stress on that animal to make that trip. She has to make it every year, she has a tight time schedule, she has demanding food and energy requirements, and we are making that journey harder for her.

Senator WICKER. I realize, Mr. Director, this is not a climate issue, but I am merely trying to point out that you are concerned about the migration of ducks, as am I, as are our people in Mississippi, particularly along the river counties and the delta counties. I would just submit to you that there is a lot more to it than increasing of temperatures by one degree or one and a half degrees.

I am going to want to take a second round with this witness, Mr. Chairman, so I will yield back to you for questions if you would like, but I would like to take a second round.

Senator MERKLEY. Thank you. Are you going to be able to stay with us through the second panel as well?

Mr. ASHE. Yes.

Senator MERKLEY. OK, terrific. Why don't you go ahead and take your second 5 minutes?

Senator WICKER. OK, well, let me ask you this, Mr. Director. Do you just dismiss altogether the scientific evidence that Senator Sessions mentioned this morning that global temperatures have flat-lined for the last 15 years, do you dismiss that as being inaccurate?

Mr. ASHE. I do, sir.

Senator WICKER. So you have a disagreement with the scientists who have demonstrated that we basically have flat-lined.

Mr. ASHE. There is no scientific disagreement. If what people are doing is taking 1998, which was a high year for temperature, and then they are either looking from 1998 to 2013 and they are saying there is no rise in temperature. You can't look at a temperature record that does go up and down and so you will have warm years, relatively warmer and relatively cool years. You can't pick 1 year out of a 150-year data base and say, well, if I use 1995 which was a particularly warm year, and I compare all the succeeding years to that, there has been no increase in temperature.

If you look at the complete temperature record, there is no doubt that temperatures are rising and the temperatures have risen during the course of the last decade. The last decade is the warmest decade on record. When you look objectively and completely at the scientific record, there is no disagreement. The National Climate Assessment reflects that science, that large consensus body of science.

Senator WICKER. Do you acknowledge that the Earth's climate has been changing up and down for tens of thousands of years?

Mr. ASHE. Millions of years.

Senator WICKER. Millions of years, OK. And that has been irrespective of carbon dioxide content on the atmosphere, is that correct?

Mr. ASHE. Carbon dioxide content of the atmosphere has changed over time, and has been correlated with by looking at the carbon dating record, has been correlated with increasing and decreasing temperatures. But what we are seeing now and which again science clearly points to, is that human-based emissions of greenhouse gases are driving concentrations in the atmosphere that have not been seen for hundreds of thousands of years.

Senator WICKER. Are you suggesting that every time over the last million years that temperatures have gone up, it is been due to carbon dioxide?

Mr. ASHE. I am not testifying, I can't say every time, but what scientists have confirmed looking back into the paleontological record is that ice age, warm periods and cold periods have been associated with elevated and decreased levels of carbon dioxide in the atmosphere.

Senator WICKER. Let me ask you about forest management. You won't be here during panel two. Dr. David South, in his prepared

testimony says policymakers who halt active forest management and kill green harvesting jobs in favor of a hands-off approach contribute to the buildup of fuels in the forest, and this eventually increases the risk of catastrophic wildfires. Also, James Walls on panel two will say because of past management of fire suppression, the worst neighbor a timberland owner can have is a national forest.

How would you respond to that, and basically in a nutshell the argument is by refusing to allow the underbrush there is this buildup of fuels and this intensifies forest fires, how do you respond to that? They have a point.

Mr. ASHE. I would not say that U.S. Forest Service is a poor neighbor. I don't think they have a point about that. I would say that the build up of fuels in our Nation's forests, public and private, has been a challenge for us. So whether it is a national forest, Bureau of Land Management lands, a national wildlife refuge, a national park, a State park, or State wildlife management area, fire management is a challenge for any land manager.

I would say the greatest need in that regard is funding for preventative management. In this year's budget, the President has proposed a so-called fire fix that allows us to begin to treat fires like other natural disasters and gives us more flexibility to do what you are calling for Senator, which is to do prescriptive management of our Nation's forests.

Senator WICKER. Part of that would be removing the fallen trees and the underbrush that amounts to fuel for forest fires?

Mr. ASHE. In some cases. As a wildlife manager, sometimes deadfall and understory is a good thing for wildlife management. But in some cases, managing forests, as Senator Merkley knows, in the Pacific Northwest, we are working together with our State and Federal colleagues on ecological forestry, which involves many of the principles that you are speaking of, which is getting, do thinning, do understory management. I think good, improved forest management is an important aspect of our adaptation to changing climate. It is an important aspect of wildlife management in providing the habitat that our game species are going to need in the future.

So I agree with you that that is an important adaptation for us to take. We need better capacity to do that and knowing what we now know about climate change and what the future is going to look like.

Senator WICKER. The Chairs agree to indulge me on one other question.

There's a strategic plan for responding to climate change that includes increased data collection initiatives to increase awareness and habitat conservation programs. How much money and how many employees is this going to take, and will this negatively impact other fish and wildlife service programs?

Mr. ASHE. I am not sure what strategy you are talking about.

Senator WICKER. OK. Well, let me ask you: does Fish and Wildlife Service have a strategic plan for responding to climate change?

Mr. ASHE. We do have a climate change strategic plan, and as I mentioned before, one of the outgrowths of that plan is the Na-

tional Fish Wildlife and Plants Adaptation Strategy and it identifies a number of common sense steps that we can take.

Senator WICKER. My question is about the cost of this and whether employees will be taken away from other programs and placed into this initiative.

Mr. ASHE. No, because they are basically synonymous with good management, as you have identified with forest management. What we need to do is we need to provide our managers, our Federal and State and tribal managers with the tools they need to do better forest management better range management with the scientific information that they need. It will cost, it will take additional capacity to do this, but it needs to be done.

Senator WICKER. Where is that additional capacity going to come from?

Mr. ASHE. I think as the President has provided in the specific context of fire management, as I said, the President has provided in this year's budget that 30 percent of the funds for suppression should come from the disaster funding ceiling. That will free up dollars for us to do more preventative management for fire. I think we know we have common sense approaches to find and build the capacity that you are talking about, and I think the President has proposed one such step in his 2015 budget.

Senator MERKLEY. Thank you, I will take my 5-minute turn then.

I would like to say that that Forest Service plan makes a lot of sense, because what we have had with the large fires has been complete depletion of the Forest Service and then trying to restore the funds for every other function they have other than fighting fires. And that is not treating emergencies as emergencies, and just a huge disruptive factor in the ordinary work of the Forest Service. That is a terrific proposal. I commend the Forest Service for it.

You mentioned in your testimony that some of the migrations that are occurring and specifically you mentioned the Pacific brant, and that it has migrated, its range has changed dramatically. Can you just explain what is going on there?

Mr. ASHE. Sure. Pacific brant is a small goose, and Pacific brant have range that are breeding grounds in the Arctic. And they range, they migrate historically, down to Mexico; winter in Mexico or summer in Mexico. And what we are seeing increasingly is brant are staying in Alaska throughout the breeding season.

So what that creates is a potential that we will have a disruption, that we will have a severe weather event and the birds will not have migrated and will take a big population reduction. So these changes in migratory patterns put more uncertainty into the game for the wildlife managers. If we are facing more uncertainty, the way we typically deal with that is that we reduce opportunity. I think that is the restriction that we are looking at.

Senator MERKLEY. My impressions were, seeing this in studies of lots of species some of my colleagues have talked about the migrating lobsters, so on and so forth, so this is not just one particular, lots of ocean species are things that are changing.

Mr. ASHE. Across the board, we are seeing changes in the blooming of flowers, the green-up in Alaska tundra in the springtime. We are seeing changes in migratory patterns as we have talked about.

We are seeing changes in habitat availability for cold water fish. While one study in 2012 of cold water fishes estimates that by 2100, we can see a reduction of 50 percent in habitat availability for cold water fishes, trout, salmon, a loss of as much as six and a half million angler days, and as much as $6.5 billion in economic activities. These changes are not inconsequential for sportsmen and women.

Senator MERKLEY. Thank you. I want you to take a look at a chart on the surface temperature issue that was raised. This chart shows change in surface temperature from 1970 through 2013. It basically shows that there is about a .6 degree Celsius change in just that 44-year period. One can draw impressions about this. I have another chart here that has a line that simply represents kind of the rising direction of temperature. But I wanted to specifically emphasize the second chart, which shows the rising temperatures in a series of steps, and because a number of folks have commented and said, well look, this last bar is flat, and it is flat over a period of approximately 10 to 12 years, and therefore nothing to worry about.

But when you see this chart, going backward, we see a series of periods where the average temperature keeps increasing by steps, if you will. Is there any reason to think that if we are looking at this chart 10 years from now, that we will see a new step that is lower than the step we are at now, is there any reason to think, no issue here, that this trend is not going to continue?

Mr. ASHE. I am not aware of any scientific study that predicts a decline in temperature from this point forward. Your observation, as I was saying in response to Senator Wicker's statement, is you look at the long term temperature record, it is unequivocal that temperatures are rising and that predictions are for the temperatures to rise and the rate of temperature increase to rise in the future.

Senator MERKLEY. Thank you very much for your testimony. I appreciate it very much, and your bringing the expertise of your agency to bear on these broad trends that we are experiencing.

Senator WICKER. Mr. Chairman, I wonder if there is any reason to believe that if we raise electricity rates on American farmers and ranchers by double digits that that line is going to change one way or the other?

Senator MERKLEY. Is that something you want to speculate on?

Senator WICKER. I have already speculated.

Senator MERKLEY. I will note that I have entered into the record an analysis looking at future power costs. It actually anticipates a reduction, but that is maybe for another hearing, or another debate and discussion.

[The referenced material was not received at time of print.]

Senator MERKLEY. Let's turn to our second panel, if they could come forward.

Welcome. It is great to have you all, I am happy to introduce our second panel of witnesses. We have a very diverse group that includes three individuals who will talk about how climate change is impacting their area of expertise. We also have two minority witnesses who will present their perceptions as climate change skep-

tics. I will go ahead and introduce everyone now, and then we will proceed with the testimony.

Our first witness is Jim Walls, who I am particularly delighted to have here, from Oregon. Jim serves as the Executive Director of Lake County Resources Initiative, an organization dedicated to improving forest management on national forests and expanding the use of renewable energy in rural communities. He has been a leader in forestry and clean energy in Oregon, working to foster more collaborative approaches to forest management, as well as working to make and attract more biomass, geothermal, hydro, solar and wind energy projects to Lake County.

Our second witness is Clay Pope; he is a fourth generation wheat farmer and cattle rancher in northwest Oklahoma and also serves as the State Association Executive Director of the Oklahoma Association of Conservation Districts. Clay served in the Oklahoma House of Representatives from 1994 through 2004. Welcome.

Our third witness is Daniel Cohen. Daniel is a commercial fisherman and owner of Atlantic Capes Fisheries, a scallop harvesting and marketing company based out of New Jersey, but it does business on both coasts.

David South is a retired professor of Forestry at Auburn University, where he also earned his Ph.D. in forestry. Mr. South also served as Director for the Southern Forest Nursery Management Cooperative.

David Legates, our final witness, is a joint associate professor of Geography at the University of Delaware. He is also the former director of the Center for Climatic Research at the University of Delaware.

Welcome everyone, and Mr. Walls, if you could kick off the testimony, the show is yours.

STATEMENT OF JAMES WALLS, EXECUTIVE DIRECTOR, LAKE COUNTY RESOURCES INITIATIVE

Mr. WALLS. Thank you, Mr. Chairman, and fellow members, it is a privilege to be here and an honor.

As said my name is Jim Walls. I run a small non-profit in Lake County, Oregon, concentrating on Federal forest lands and renewable energies. We are 78 percent government land-owned in our county, and that is over 8,500 square miles, so it is big, it is bigger than some eastern States.

Within that, like many communities with forests over the past three decades, we have suffered high unemployment, poverty rates and stuff due to policies on our national forest. We look at renewable energy as a way to change that economy and bring new green jobs to the forefront.

When discussing climate change on forests, I can't separate the actions of past forest management and the impacts of climate change. They are both in the same treatments, will have the same effects, and that is we under-thin, take the understory and remove it, and remove that amount so there is a more back to a natural area, a natural stand condition that was pre-European. That is also the strategy we need to use for climate change. So they are intertwined.

In our case, I would like to point out that over the past decade, what has that meant in our forests. In 10 years, the first fire was the Winter Rim Toolbox fire, we lost 100,000 acres. Then we had a beetle kill of over 350,000 acres. Then in 2012, we had the Barry Point fire, 93,000 acres. In less than a decade, we have now lost 24 percent of the Fremont, part of the Fremont-Winema National Forest. If we keep this rate up, because fires are getting more intense, insects are getting more intense, because of the warmer climate change. If we keep this up, we will lose, in three decades, our whole forest, and I think that is a real and severe threat to us.

It is not only a threat to our industry in timber. It is a threat to our agricultural industry, too. We average 10 to 20 percent moisture during the winter; our summers are hot and dry, normally. Without that snowpack, we don't have agriculture. We don't have irrigational water. All you have to do is look to our neighbors in the Klamath Basin this year and what is going to happen there. And even in Lake County, we are seeing reduced irrigation rates because of the drought, droughts that we have never seen this severe before.

I think we can debate the climate change, long term, short term, all that. I personally say, it is here, and the risk is way too high just to ignore those few, that you might be right that it is not happening. And I hope we don't go there. By using renewable energy I feel that we can offset that. We have developed a plan in Lake County by all the ones that we have done an economic analysis and feasibility study on. We will offset 93 percent of the fossil fuel emissions in a decade in Lake County. And we will do it economically.

So as we go forward with this debate, I would hope that we look at the things like that that make economic sense. Now, can renewables compete with hydro? No. Could it compete with other forms of coal and industry? Solar, the cost of a panel now is very cheap. It is reducing all the time. Wind is there. And as we invest in these, more and more of them will become competitive at other rates throughout the country. And it is a way to turn our jobs around.

I ask you one thing, is to change the definition, which Senator Merkley will co-sponsor with Senator Wyden on, on the renewable energy. Biomass off Federal lands is not considered a renewable energy source. That reduces our investment. We have two companies looking at locating in Lake County. We only have supply for one, so hopefully one of those will make it, and that is a cellulosic jet-fuel company, and then a biomass energy production company. With that definition, they do not want to invest, because it is not considered renewable. So please do change that, Senate Bill 536, and get that passed so we change that definition. It does not make sense to me.

The other thing I would like to say is that we need to increase the scale of getting treatments. I mentioned, and Senator Wicker, you said my full testimony about the worst neighbors, the Forest Service. It is not because we don't know what to do, it is the length of time and the amount we are getting done. And we need to increase, rather than treating 3,000 to 4,000 acres of land that is overstocked, that we would be treating 20,000 acres a year. And

that we get to 100,000 acres in NEPA, and not just doing small acres projects at a time.

So we don't want to skip any environmental rules or do anything like that. We want to do it ecologically sound and economically as well. As we move on, I hope you also look at the fire spending that was mentioned. We cannot get ahead of this or achieve our goals of those acres if we don't deal with fire borrowing that occurs every year. And as these fires get more intense and hotter, we need to look at that. And Senate Bill 1875, I hope you endorse that bill and get that through. Because it is far cheaper to treat the forest land than it is to suppress fire. And they are increasing.

The other thing that climate change has done in the thicker forest is that it keeps the snow from hitting the ground. We get large amounts of evaporation rate in those thicker forests, so our snowpack is reduced. That is the other fact.

So I do see by implementing and by doing common sense things today such as renewable energy, we can make some great impacts and then what is after that; let's make the more challenging stuff.

Thank you.

[The prepared statement of Mr. Walls follows:]

Statement of James K. Walls, Executive Director for
Lake County Resources Initiative

U.S. Senate Environment and Public Works subcommittee on Green Jobs and the New Economy

June 3, 2014

It is an honor to be here and testify before this distinguished committee. My name is Jim Walls and I am the Executive Director of Lake County Resources Initiative, a non-profit that works on natural resource projects that includes federal forest management, biomass, geothermal, solar, wind and small hydro projects. Our goal and economic diversification strategy is to make Lake County Oregon's Most Renewable Energy County and become a net exporter of renewable energy. Lake County is 78% federal lands with the Fremont-Winema National Forests and Bureau of Land Management being the biggest landowners. Lake County is in the south central dry interior of the state of Oregon. The Fremont portion of the National Forest lies roughly between the towns of Lakeview, Klamath Falls and Bend, Oregon just north of the California/Oregon border. The major tree species include ponderosa pine, western juniper, lodgepole pine, and at higher elevations white fir. Most of these trees are adapted to summer drought and extreme temperature fluctuations due to the arid nature of the region (FNF 2003). The 10-20 inches average precipitation occurs from the autumn through the spring and as a result the summers are dry and hot (Oregon State University 2003). At the height of timber removals Lake County supported 5 mills; today one remains, the Lakeview Collins Company Sawmill. As a result of the curtailment of timber harvesting, Lake County was the only county in Oregon that experienced a net job loss during the 1990's (Kauffman 2001).

When discussing climate change impact on forest, the actions we take to help prepare a forest for climate change are the same measures we are using to restore forests to more of what they were before fire suppression. Predictions are that the dry Ponderosa type forests are going to become even dryer and warmer. As a result of past management forest composition and natural fire disturbance regimes have been dramatically altered, increasing the risk of abnormally intense wildfires, insects, and disease that will devastate the remaining old-growth stands and other forest ecosystem components. Many areas have missed 7 to 10 fire return intervals, and mature forests of large, widely spaced trees have declined more that 50 percent from historical levels. Combine climate change of warmer dryer years, insects are not curtailed by cold winters and fires become larger and significantly more devastating. Climate change also means less snow pact, with the dense trees catching the snow in the limbs where substantial evaporation occurs.

I thought I have had the privilege two other times in DC to testify and maybe someone else should be given the opportunity. Then I was told that the hearing would be on impacts of climate change on forests. In my opinion we are on the verge of losing our National Forests to catastrophic fires and insects because of our past management and climate change. This impact is not confined to just eastside forest in Oregon but it extends east to South Dakota, North to Montana and South to New Mexico. The impact of climate change is just not on the forest but also agriculture as snow pack reduces the amount of water available for irrigation.

In our case, the direct impact of climate change and past forest management over the past decade has resulted in the loss of 100,000 acres to the Winter Rim/toolbox fire, 350,000+ acres to Mountain Pine Beetle and just in 2012 92,977 acres to the Barry Point Fire. In a decade we have lost 24% of the Fremont part of the Fremont-Winema National Forest. This year we are facing the worst drought that anyone can remember and have already had the first fire of the year, in May! At this rate it will only take 3 decades before we impact the whole Fremont part of the Fremont-Winema National Forest, 1.5 million acres.

As with any fires in the West, they burn in a mosaic pattern and varying intensity. My organization has been running a forest monitoring team since 2002 and one of the things we study is the impact of catastrophic fires

on soils. Those areas of fire that are the hottest often exceed 400 degrees and actually melt the soil or what we call plasticizing the soil. On these worst sites water will not even soak into the soil and it will be over 6 decades before trees will start to grow again naturally. Fires contribute significant amount of CO2 and while brush does capture CO2, it is nothing like trees. If the trend continues where will the Collins Companies get material for the sawmill into the future, the loss of our last mill would be. When you look to the east from the edge of the Fremont National Forest the next tree is the Black Hills in South Dakota, is climate change going to push the desert west?

Because of past management and fire suppression the worst neighbor a timberland owner can have is a National Forests. As a result of overstocked conditions on National Forest and the lack of cold winters to kill insects private land bordering National Forests are in danger of being lost, in the case of the 2012 Barry Point Fire just one landowner the Collins Companies lost over 20,000 acres of forest land. On private lands, owners invest in the future by thinning out trees and controlling insects but on National Forests if it does not make money it does not get done, there is no investment into the future.

We have a forest collaborative called the Lakeview Stewardship Group comprised of National, Regional and local environmental groups along with industry, local leaders and local citizens who have agreed upon how to manage our National Forest. As a result the Collins Companies have a 10 year Stewardship contract and we were awarded the nation's largest Collaborative Forest Landscape Restoration Act dollars of $3.5 million/year for 9 years. The CFLRA was a bipartisan effort and we thank you so much for that but we need to have the same effort with Climate Change. Even with all this we are not at a scale of treatments that would assist this forest to adapt to climate change. We need to get to a scale of treating fire class 3 forest stands to over 20,000 acres/year and doing NEPA at a 100,000 acre scale. We also need to stop the fire borrowing from other programs as we will never get ahead at this rate. Please support S.1875. The cheapest way to deal with fire to treat ahead of a fire, not suppression. Doing these treatments creates and protects old growth, restores more natural low burning type fires, help forests adapt to Climate Change and provide jobs. We need to do all this with no additional budgeted dollars and the same number of Forest Service employees. Forest Service employees on the Fremont-Winema National Forest are working with us to accomplish this goal.

To get where we need to be I also ask your help to deal with the language in the Energy Independence and Security Act of 2007 (Public Law 110–140; 121 Stat. 1492) that defines biomass for applicability to the Renewable Fuels Standard excluding woody biomass from federal lands. How ironic is it when a person can stand on a property line with one foot on private land and the other on federal land, one is consider renewable and the other is not. As my 9 year old grandson who does not like change would say, *grandpa that is just stupid.* I plead with you to be a leader to change this. Without changing this definition there will be no private investment into technology that can use all the small diameter material that will be produced as a result of getting our National Forests back to a condition that is natural. Definitions of biomass in national energy policy should include Federal sources of woody biomass with the appropriate ecological safeguards in place. Senator Wyden introduced S.536 (w/ Senator Merkley co-sponsorship) on 3/5/09 to amend the EPA's definition of "renewable, please reintroduce that bill.

Another way to help mitigate Climate Change impacts is converting to renewable energy. In Lake County we have a plan to implement every kind of renewable energy except ocean wave. We did a report on all the renewable energy that could be developed in Lake County and it showed that we could offset 93% of all fossil fuel emissions in Lake County. In areas like ours that do not have natural gas, it is economical and a job creator. Implementing biomass energy, biomass thermal and/or biofuels from small material removed from the forest to adapt to climate change can produce 75-100 new green jobs in each community across the country that implement renewable energy. This July we will be going publicly with the CO2 report and holding meeting in the county to develop an action plan to offset off all the fossil fuel emissions.

What if 18,000 communities like ours did something similar, what kind of impact could we collectively have on climate change. Climate change is occurring and a vast majority of scientist agree. Now it is coming out that the impacts are happening now and faster than originally thought. We are seeing more severe weather events and as a result communities around the world are going to be impacted. There is no dealing with Climate Change tomorrow, we need to start now, why not do something that is economically viable and a job creator as the first step. Renewable energy and forest management cannot solve the total problem but it is economical and ecologically correct so it is a place where we can immediately start making a difference.

Thank you for the honor and time to present here today.

Environment and Public Works Committee Hearing
June 3, 2014

Follow-Up Questions for Written Submission

Questions for Walls

Questions from:

Senator Jeff Sessions

1. All else being equal, would increasing the number of board-feet harvested from U.S. National Forests each year, over the long-run, reduce the severity of wildfires?

Most definitely but in addition to increasing board-feet it would increase smaller material being generated that would be expressed in bone-dry-tons (BDT). It takes approximately 7,920 BDT / Mega Watt per year of wood chips for a biomass plant. Biomass energy is a job creator, a 15-30MW plant would employ 25 at the plant and 50-75 in the woods. Congress would need to change the EPA biomass energy definition to classify biomass off federal lands as renewable energy.

2. Would increasing timber harvests in Lake County, OR, improve the local economy?

Lake County is 8,500 square miles and 78% government money. Increasing timber harvest would allow second shift at the mill and increase the number of independent loggers in the woods.

3. What are the principal reasons why timber harvests have decreased from national forests in recent years?

Lack of FS personnel, environmental law suites and planning time are major contributors to decreased harvest. Here in Eastern Oregon we have achieved agreement on forest management with many of the environmental groups and as a result have very few law suites. Currently 60% of dollars appropriated for forest management goes to planning or NEPA. This ratio needs to be reversed minimally and we can accomplish that without sacrificing environmental laws.

Senator MERKLEY. Thank you very much, Mr. Walls.
Mr. Pope.

STATEMENT OF CLAY POPE, STATE ASSOCIATION EXECUTIVE DIRECTOR, OKLAHOMA ASSOCIATION OF CONSERVATION DISTRICTS

Mr. POPE. Chairman Merkley, Ranking Member Wicker, and members of the committee, thank you very much for allowing me the chance to come before you today and speak about climate change and the challenges facing agriculture on the Southern Plains.

First, let me say we have always had wild weather on the Southern Plains. I think Oklahoma Native Will Rogers put it best when he said "If you don't like the weather in Oklahoma, wait a minute; it will change." What is different, though, is the frequency and strength of the weather events that we are now seeing. Basically, our crazy weather has been put on steroids. The drought we have been suffering through for the last 5 years is a perfect example of this, and it is had a drastic impact on agriculture. In Oklahoma alone, we have seen a reduction in the cattle herd over 10 percent. By the first of this year, the cattle inventory in the United States had shrunk to its lowest level since 1951. And over 80 percent of these reductions happen in two States: Oklahoma and Texas.

But the effects of the drought aren't just limited to livestock. In Oklahoma, we may be looking at the fourth year in a row where at least 50 percent of the State's cotton acres will be abandoned, and as bad as the cotton situation is, however, the real story is wheat. This year's wheat harvest is expected to be the lowest since 1957. It is estimated that the amount of wheat harvested in 2014 will be 40 percent of what was cut in 2013, and that crop was 30 percent below what was cut in 2012.

Now, this drop in production isn't just due to the drought. A late season freeze also took its toll on Oklahoma's wheat crop. Now, late season freezes aren't anything new, but what is new, though, is the frequency. This is the third time in 5 years that a late freeze has impacted Oklahoma's wheat crop. Clearly, we have a problem. The question is what do we do about it?

Well, the secret, Senators, in my opinion, is in the soil. Improving the health of our soil is a key to helping agriculture both mitigate and adapt to climate change. Our farm ground has lost between 60 to 80 percent of the organic matter that was present in the soil at initial plow-up. This is important because it is organic matter that feeds the microbial community of bugs, bacteria and fungus under the soil; therefore, my first and best line of defense against climate change. Every 1 percent increase in organic matter in the soil can triple that soil's water holding capacity. That equals on average to an additional 25,000 gallons of water available per acre for growing crops.

By converting then to cropping systems that also incorporates cover crops, we can greatly increase the infiltration rate of watering our farm ground while at the same time, reducing the amount of moisture lost to evaporation when that land is tilled, exposed to the sun. This helps our farms better weather the droughts that are being exacerbated by climate change while providing more mois-

ture for growing crops. This increase in soil moisture also helps restore balance to the overall water cycle, which in turn increases stream flow, making more water available for humans and wildlife. By using no-till we can also greatly reduce soil erosion while at the same time reducing runoff from agricultural land. This not only protects the soil, it also reduces non-point source pollution in our streams and rivers.

In addition, that same 1 percent increase in organic matter can, on average, make available up to $700 worth of additional nutrients per acre for growing crops. By improving the health of our soil, we can help plants more effectively absorb the nutrients available in the ground, helping us increase yields, and feed an ever growing planet. And as we do all this; we are also lowering carbon dioxide levels in the atmosphere. No-till can sequester on average roughly half a metric ton of carbon per acre per year.

Now, we all know plants breathe in carbon dioxide and breathe out oxygen. That carbon dioxide is then stored in the soil in the form of organic matter. When you restore soil health, you help agriculture adapt to climate change while you improve water quality, while you improve wildlife habitat, while you increase yields, and at the same time, sequester carbon dioxide in the soil. This is something we need to do. And through the Farm Bill Conservation Program, USDA and RCS have the ability to help producers do it.

Unfortunately, as budgets tighten, financial assistance through these programs and the funding for technical assistance continue to shrink. During the Dust Bowl it was determined that it was in the public's interest to keep the farm ground in the Southern Plains in production. Through the partnership of the Federal and State governments and local conservation districts, the tide of dust was turned back. This partnership has the ability to address climate change in the same manner that they addressed the Dust Bowl, if they have the necessary resources.

Even with these tools, though, researchers need to determine what kinds of technologies are best suited to help agriculture adapt to climate change. The USDA started this process by the formation of the regional climate hubs. They hold great promise that will go unrealized if that they aren't provided with the resources necessary to do their job.

As we focus on the droughts though, we can't lose sight of the fact that floods will come again. In fact, droughts and floods have a tendency to come together in Oklahoma. Take the Hammond Flood in 1934. Happened in the middle of the Dust Bowl and it spurred the Federal Government to build small watershed dams through USDA, something Senator Inhofe alluded to earlier. Oklahoma alone has over 2,100 of these structures, most of which are in need of rehabilitation. When this work takes place, many of these could be made into reservoirs for nearby communities to help with water shortages and the flash floods made worse by climate change. With the passage of the Farm Bill, funding was authorized to do this work. Unfortunately, NRCS rules State can only be used to repair existing structures to their current size. This doesn't have to be the case. A change in the rules would allow Federal funds to be made available to help several of our communities with new water sources.

In addition, when you look at the opportunities outlined in the original Flood Control Act, purposes like water quality and quantity, flood mitigation and wildlife enhancement, you see this program as another tool the USDA already has that can help our country better adapt to climate change.

In closing, I would reiterate: Southern Plains agriculture is facing some serious challenges from climate change. The good news is, though, is that the USDA has some tools to cope with this challenge, and there is a path forward. The question is, will we take it?

Thank you for allowing me to speak today, I will be happy to answer any questions.

[The prepared statement of Mr. Pope follows:]

Testimony of Clay Pope,

Farmer and Rancher from Loyal, Oklahoma

and Executive Director of the Oklahoma Association of Conservation Districts

Chairman Merkley, Ranking Member Wicker and members of the Committee,
Thank you for the opportunity to come before you today and speak about the current challenges facing agriculture on the southern plains due to the changing climate, the additional difficulties we anticipate seeing in the future, and what steps need to be taken to adapt these current problems and possibly mitigate some of their causes.

First the bad news.....

It's clear that climate change is having an impact on southern plains agriculture. From drought, to late freezes, wildfires and heavy rain events, we are seeing the effects of the changing climate and the challenges it is creating for those tasked with producing food and fiber in this region of the country. The southern plains has always has its fair share of wild weather. Oklahoma Native Will Rogers best summed this up in the 1930's when he famously said "If you don't like the weather in Oklahoma, wait a minute and it'll change." Wild weather swings are nothing new in tornado alley. We have always had droughts and we have always had floods; many times in the very same year. What is different, however, is the frequency and strength of these weather extremes.

Let's start with the most current example of these challenges; the prolonged drought now affecting my region of the country.

It's almost impossible to read any newspaper from Oklahoma, Texas, Western Kansas, Eastern New Mexico or South East Colorado without seeing a story about the ongoing drought that continues to hold this region in its grip. For nearly five years, much of the Southern Plains has suffered from below normal precipitation and above average temperatures. In Southwest Oklahoma especially, many areas have received well below 70% of their average rainfall over this time period and communities are suffering from critical water shortages. For agriculture, this low level of precipitation has resulted in a reduction of crop yields and the liquidation of livestock herds due to both the lack of forage and to the loss of water for animal consumption.

In Oklahoma alone we have seen a reduction in the cattle herd of over 10%. In Texas this number is over 20%. From 2011 to 2012 the total number of beef cattle in these two states shrank by close to 1 million head. This reduction is still declining. As of January 1 of this year, the total cattle inventory in

the United States has shrunk to its lowest level since 1951 with over 80% of these reductions happening in Oklahoma and Texas.

With this drop in the cattle herd there has been a corresponding impact on other parts of the beef industry in this region as well. In February, 2013, Cargill announced that it was closing its Plainview, Texas beef processing plant due to the shrinking number of cattle in the area and the increasing cost of feed. In October of that same year, the company announced that they would be shuttering their Lockney, Texas feedlot for the same reasons. Just this month Cargill has put forward a plan to lay off roughly 300 workers from its Dodge City, Kansas beef processing facility due to the tight supply of cattle. All of these actions have an impact not only on the beef industry, but on the local economy as well. The Plainview plant alone is estimated to contribute roughly $1.1 billion in the economy of the county in which it is located. As one observer wryly commented "I wouldn't want to own a house in Plainview right now."

The effects of the drought are not just limited to the livestock industry however. Crop production in this region of the country is also suffering from this extreme weather. In Oklahoma alone, we may well be looking at the fourth year in a row where at least 50% of the state's cotton acres will be abandoned. This could also be the fourth year in a row where not enough surface and ground water is available to irrigate cotton in Southwest Oklahoma. This would effect not just cotton production but the service industries that are supported by the cotton harvest as well. Several cotton gins that have been temporarily closed for at least 3 years now will probably never re-open. Machinery dealerships, parts stores, car dealerships, feed and chemical dealers all will feel the impact of this drought and many jobs will be lost.

As bad as the cotton situation is however, the real story is the coming wheat harvest. Oklahoma is currently expecting to harvest the lowest wheat crop since at least 1957. It is estimated that in 2014, 62.7 million bushels of wheat will be harvested in my home state. That's a reduction of over 40% from the amount of wheat harvested in 2013. It should also be noted that the 2013 harvest was 30% below that of 2012.

In 2013, Oklahoma accounted for roughly 5% of the nation's wheat crop with 115.5 million bushels harvested at a value of around $727 million. This year roughly half of that wheat will be gone. The impact of this will reverberate throughout the economy of rural Oklahoma and will add to an increase in the price of food in the grocery store, especially if we see problems develop with the wheat crop in other countries.

It should be pointed out that this drop in wheat production was not due to drought alone. A late season freeze also took its toll on the wheat crop in Oklahoma. While late freezes, like droughts and floods, are

nothing new on the southern plains, what is new is the frequency with which these events are happening. This will be the third time in five years that a late season freeze has drastically impacted the Oklahoma wheat crop. Timely rains in 2013 helped insure that the wheat would better weather the drought, but a late freeze that spring at least in part accounted for the 25% reduction in bushels harvested when compared to the previous year.

Flooding is another fact of life in my part of the world that seems to have become more violent with climate change. Droughts and floods have a tendency to come together in Oklahoma and a look at my state's history should give us concern for what the near future may hold in store. Most people don't realize what was at that time the worst flood in Oklahoma's history actually happened in the middle of the Dust Bowl of the 1930's. The Hammon flood of 1934, named for the small Western Oklahoma town where 17 people lost their lives during a late April flash flood, actually helped spring board our nation into taking action in the construction of small watershed dams to help protect farm ground from massive erosion and to help guard human life and personal property. This was a wise move on the part of the Federal government because climate change is making sure more damage is on the way. Clearly, climate change is causing problems for southern plains agriculture. The question is, what can we do about it?

That's where we get to the good news.....

Agriculture, I believe, has the potential not only to adapt to the challenges brought on by climate change, but in doing so can also help mitigate a goodly portion of the causes of the greenhouse effect while at the same time increasing yields to feed an ever growing world, protecting our farmland and our citizens from flash flooding and providing many communities with additional drinking water supplies.....and the United States Department of Agriculture through the Conservation Title of the Farm Bill, the authorizing legislation of The Watershed Protection and Flood Prevention Act (PL-566) and through the recent creation of the Agricultural Research Service (ARS) regional Climate Hub already has the tools necessary to make much of this happen.

But the true secret it seems is in the soil.

Improving the health of our soils in the United States is the key to helping agriculture both mitigate and adapt to climate change. From the first cut of the plow until today, our farm ground has lost between 60% to 80% of the organic matter that was present at the time of settlement. This is important because its organic matter that feeds the microbial community under the soil and it is this community of bugs, bacteria and fungus that bind soil together, allows for the transfer of water through the soil structure, sequesters carbon dioxide into the ground and that makes nutrients more available to growing crops. Every teaspoon of soil contains over 1 billion life forms, most of which we didn't even know existed less

than a decade ago and it's these life forms that constitute agricultures first and best defense against climate change.

According to research from Kansas State University, every one percent increase in organic matter in the soil can triple that soils water holding capacity. That equals, on average, an additional 25,000 gallons of available water per acre for growing crops. Oklahoma State University has estimated that this increase in the water holding capacity of the soil in my state alone is the equivalent of a 3 inch rain. All this from increasing the ability of the soil to hold water when it does rain and by reducing the amount of water lost to evaporation during the summer months. Through the conversion of conventional tilled crop production to no-till cropping systems that also incorporate cover crops, we can greatly increase the infiltration rate of water in our farm ground while at the same time we reduce the amount of moisture lost to evaporation when the land is tilled and when the summer sun shines on bare crop land. By holding on to more moisture when it does rain and by reducing the amount of water we lose to heat, we can help our cropping systems better weather the cycles of drought that are being exacerbated by climate change while providing more moisture for growing crops in summer months. This increase in soil moisture also helps to restore balance to the overall water cycle which in turn has been shown to increase average stream flow, thus making more water available for human use and wildlife habitat. The same practices we would undertake on the land to accomplish this increase in soil moisture also have the added benefit of reducing the amount of soil erosion lost during heavy rain events-another challenge that is growing due to climate change. By reducing or eliminating tillage through minimum till and no-till crop production and by incorporating cover crops in rotation with traditional crops like winter wheat, we can greatly reduce the impact of sheet, gully and rill erosion to our farm ground while at the same time reducing the amount of run-off from agricultural land, thus not only protecting our soil, but also reducing non-point source pollution in our streams, rivers and lakes. According to information from the Environmental Protection Agency (EPA) every dollar spent implementing good conservation practices in a watershed saves cities and towns downstream, on average, $20 in water treatment costs. By improving the health of the soil we can help address both erosion and water quality concerns at the same time—challenges both made worse by climate change.

In addition, this same one percent increase in organic matter can, on average, make available up to $700 worth of additional nutrients per acre for growing crops according to information from Ohio State University. That's free fertilizer that is available to agriculture producers when they undertake the very practices necessary to adapt to climate change. Over the millennia, the microbial community in our soil has evolved in concert with the plant and animal community that occupies the space above ground. Through this cycle nature has created a system where the life both above and below ground has a symbiotic relationship with each other. The bugs, bacteria and fungus that live in healthy soil interact with the root systems of growing plants, helping them more effectively utilize the nutrients made available in the soil. It's been estimated that as much as 60% of the fertilizer applied to farm land today is wasted due to the lack of a healthy microbial soil community. By improving the health of the soil we can help plants more effectively absorb the nutrients available in the ground while reducing the need for

chemical fertilizer, especially through the incorporation of legume cover crops that restore nitrogen to the soil naturally and through the inclusion of additional plant species in cover crop mixes that mine other available nutrients such as phosphorus from the soil and make them more available for the plants that follow the cover crops in rotation. This increase in turn can help us maintain existing yields and holds the potential to help us increase yields in the future to help feed an ever growing world population.

Clearly the practice of converting from conventional till farming to no-till and the incorporation of cover crops in rotation with traditional crops such as winter wheat hold great promise in helping our agriculture system adapt to climate change. The truly exciting part is that these same practices designed to help better prepare farm ground for droughts and floods also have the potential to help reduce overall carbon dioxide levels in the atmosphere.

According to research conducted by Kansas State University, no-till crop production on the southern plains can sequester, on average, roughly .5 metric tons of carbon per acre per year. A study released by the Worldwatch Institute in 2009 estimated that by better managing our agricultural land we could potentially sequester close to 25% of the world's carbon dioxide emission every year. While the size of this potential carbon sink is unclear, what is clear is that a change in farming practices to include greater use of no-till and cover crops can reduce carbon dioxide levels while improving the health of the soil while helping us adapt to wild weather extremes.

We all know that plants breathe in carbon dioxide and breathe out oxygen through photosynthesis. This carbon dioxide is then stored or "sequestered" in the soil through the root system of the plant and through the residue that breaks down on the surface of the ground when the plant dies in the form of organic carbon. Organic carbon makes up roughly 60% of soil organic matter. As you increase organic matter in the soil, you restore soil health. As you restore soil health you help agriculture adapt to climate change. As you help agriculture adapt to climate change you help improve water quality, improve wildlife habitat and you help increase the fertility of the soil to potentially increase yields while at the same time helping to reduce the level of excess carbon dioxide in the atmosphere.

This is clearly something we need to do. The great thing is we already have the tools to do it with. Through Farm Bill Conservation Title programs such as the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP), the USDA Natural Resources Conservation Service (NRCS) has the ability to help farmers and ranchers convert to no-till agriculture and to incorporate cover crops in their farming operations. By sharing the cost of adopting this technology with agriculture producers, NRCS can help bring about many of the changes necessary to assist southern plains agriculture in adapting to the extreme weather events brought about by climate change. The challenge, however, is that as federal budgets continue to tighten, the availability of assistance funding through programs such as EQIP, and more importantly the funding for the technical assistance necessary to help agriculture producers determine what kind of cover crop mixes and technological changes best fit their operations continues to diminish.

Currently, less than 20% of all the crop land in Oklahoma is farmed using no-till methods, a percentage far below that of the states in the upper Midwest. Even fewer acres are planted in cover crops. There are many reasons for this—cost of equipment, the comparatively low value of winter wheat when

compared to crops such corn and soybeans, the lack of knowledge concerning viable cover crop options that can grow in the hot summers of the southern plains, the fear of losing winter grazing for beef cattle if ground is rotated out of winter wheat production, and the general cultural bias toward conventional till farming. The only way to overcome these challenges in my opinion is through financial and technical assistance targeted to the improvement of soil health in the same manner resources were targeted toward the reduction of soil erosion during the days of the Dust Bowl.

In the 1930's the Federal Government determined it was in the public's interest to keep the farm ground of the southern plains in production. For this reason the original soil conservation act was passed, model legislation was sent to the states for the formation of local conservation districts and state governments were encouraged to create state conservation agencies. Through this partnership, the tide of dust was turned back and the land stayed in production. Even today, during a drought that is now worse than the one which caused the Dust Bowl, we have yet to see the return of dust storms on par with what our country experienced in the 1930's—dust storms that would originate in Oklahoma and Texas but that would eventually cover cities like Washington D.C. and New York with the soil of the southern great plains. The partnership of the Soil Conservation Service (now NRCS), local conservation districts and state conservation agencies helped bring about the changes that tamed the Dust Bowl. I believe this partnership and the conservation programs in the farm bill have the ability to help address climate change in the same manner we addressed the Dust Bowl if we are wise enough to use them and if we are willing to give them the resources necessary to accomplish the job.

Even with these initiatives, however, research has to be conducted to determine what kinds of cover crops and what farming technologies are best suited to help southern plains agriculture adapt to the new climate realities we are facing. Again, USDA has started the process of providing this research through the formation of the Agricultural Research Service Regional Climate Hubs. These Hubs are charged with the delivery of information to farmers and ranchers that will help them adapt to climate change and weather variability. The Hubs also are tasked with building capacity within USDA to provide information and guidance on technologies and risk management practices at regional and local scales. If our efforts to adapt to climate change are to be successful, these facilities must be give the tools they need and the freedom necessary to determine what farming practices will work and what ones won't. Facilities like the Southern Plains Regional Climate Hub in El Reno, Oklahoma hold great promise in helping agriculture producers determine what cover crop mixes will work during hot Oklahoma summers and how to incorporate livestock management into their use on crop land. This promise, however, will go unrealized if they are not provided with the necessary resources.

As we focus today on drought however, we cannot lose sight of the fact that the rains will come again, and when they do, they likely will come with a vengeance. We must maintain and expand on the system of upstream flood control structures we currently have in the southern plains if we are to protect both our farm land and our communities from the ravages these future flash floods will cause. As I stated earlier, the Federal Government first began building upstream flood control projects through the USDA

small watershed program in response to the Hammon Flood of 1934. Today Oklahoma alone has over 2,100 upstream flood control structures that each year save our state over $80 million in flood damage that does not happen because of the protection they provide. Most of these structures were built with a 50 year design life and today are in need of rehabilitation. When this rehabilitation takes place, many of these structures could be expanded to become reservoirs for nearby towns and rural water districts. Again, the Conservation Title of the Farm Bill has provided the Federal Government with the authority to undertake this activity. Through the passage of this act, over $600 million was authorized to match local and state funding at the rate of 65% to 35% for the rehabilitation of these aging structures.

Unfortunately, rules currently in place at NRCS state that these federal funds can only be used to repair existing structures at their current size. If a dam is to be enlarged to provide water for nearby communities, state or local governments must cover 100% of the cost of this expansion. This does not have to be the case. Under the original language of PL-566 (the authorization statute of The Watershed Protection and Flood Prevention Act) NRCS has the legal authority to cost-share for the full expansion to make an existing structure into a reservoir. A simple change in the rules for this helpful program would make it a much better tool to help with climate change adaptation by potentially supplying several of our communities with new water supplies.

In addition, the flexibility and opportunity to build resilience to climate change on a watershed scale within the watershed program at USDA is almost unlimited. Planning and implementation guidelines for The Watershed Protection and Flood Prevention program set watershed boundaries as areas up to 250,000 acres. While smaller in scale than other well know watershed based boundaries such as the Chesapeake Bay or Mississippi River Basin initiatives, the benefits that that are provided in these smaller watersheds are significant and can be expanded upon. When you look at the purposes outlined in the original act, purposes such as watershed protection, flood mitigation, water quality improvements, soil erosion reduction, municipal and industrial water supply, irrigation, water management, fish and wildlife enhancement, hydropower, and sediment control, you quickly see that this program is yet another tool that USDA has ready access to that can help my region of the country better adapt to the challenges created by climate change.

In closing, I would reiterate that agriculture in the southern plains is on the front lines of the effects of a changing climate. The drought we have suffered through for almost 5 years now is but one example of the weather extremes that will only be exacerbated as we move forward into the future. We have much work to do if we are to insure that this region of the country will have the ability to continue to be a major provider of food and fiber for the United States and beyond.

There is good news, however. Through the efforts of NRCS to help improve the health of our soil, through the use of the research hubs created by ARS to determine what cropping systems and technology can best help us adapt to climate change, and through proper utilization of the existing small watershed program at USDA, we have tools that can help us better adapt to the problems this new reality is creating and will continue to create into the future. The challenge for you and your colleges is

to do your part to make sure these initiatives and others like them have the resources they need to accomplish their goals. There is a path forward. The question is will we take it.

Thank you for allowing me the chance to speak to you today. I would be happy to answer any questions.

Senator MERKLEY. Thank you, very much, Mr. Pope.
Mr. Cohen.

STATEMENT OF DANIEL COHEN, OWNER, ATLANTIC CAPES FISHERIES

Mr. COHEN. Thank you very much for the opportunity to address the committee as we evaluate the impact of climate change on our environment and livelihoods and for the next generations.

The fishing and agriculture industry of the United States is, especially the shellfish industry, is extremely susceptible to increases in ocean temperature and ocean acidification. Like canaries in the coal mine our shellfish agriculture industry has already been significantly impacted and is the harbinger of the consequences of human use of fossil fuels and CO_2 increases in our atmosphere.

I am Daniel Cohen, president of Atlantic Capes Fisheries, a second generation fishing industry. Today, we operate vessels on the east coast and the west coast with facilities in New Jersey, Maryland, Rhode Island, Massachusetts, and the Pacific Northwest. We are focused on scallops, crabs, clams, and squid. And I have spent a considerable amount of time in fisheries research in the academia and the National Marine Fisheries Service raising over a million dollars per year with the Mid-Atlantic Fisheries Management Council in primary science in conjunction with Rutgers University, Virginia Institute of Marine Sciences, National Marine Fisheries Service and Cornell University.

About 15 years ago, recognizing that the wild harvests of our commercial fishermen sells would be capped to make certain that we had sustainable harvests for the future, and with these sustainable capped harvests, there would not be enough fish protein for a growing world population that then was 6 billion, now 7 billion soon, will be 9 billion, the industry begins looking more and more toward aquaculture to meet those rising needs. I will use examples today, but not anecdotes, but what actually what has happened to industry and then backed up with scientific research to bring what is actually happening. And I am going to do that with four examples that are really just examples, and we can talk more about others. These examples are coming from three sources: one, changes slowly over time and bottom temperature changes in the ocean; two, rising ocean acidity from carbon dioxide in the atmosphere going into the oceans as a pCO_2 sink, raising levels of ocean acidification; and three, changes in ocean currents, which the scientists have ascribed to changes in bottom temperature.

I have four examples: surf claim fisheries on the east coast, oyster hatcheries and farming in Oregon and Washington, and the food fishery in North Carolina to Rhode Island, and the scallop farming in British Columbia. The surf of clam fishery was historically centered off the coast of Virginia up through New Jersey. The robust New Jersey fishery in New Jersey landed over 50 percent of the surf clams for the entire country and surf clams are the No. 1 ingredient in, obviously, clam chowder, which was and I think still is the No. 1 soup served in restaurants in the country and are also enjoyed as fried and buttered clam strips.

As outlined in the written evidence I have given in addition, bottom temperature rise was first identified after a National Marine

Fisheries Service survey determined a large die off of surf clams off of Virginia, Rutgers and VIMS, scientists have determined it was due to bottom temperature changes. Cooler waters in New England saw greater spawning off New England. Clam plants have shut in Virginia and Maryland and New Jersey and new plants opened in Massachusetts and Rhode Island, showing a shift in the population of the clams due to bottom temperature rise documented by Rutgers, and therefore change in jobs.

In the Pacific Northwest, we have seen large ocean acidification. In our written testimony is that of George Waldbusser from Oregon State University documenting over $110 million worth of losses to the hatchery industry alone where now they are having to buffer all their water similar to the way you buffer yourself with Tums because of ocean acidification. The only way they have been able to have successful hatcheries in the last few years because of major problem mid-part in 2000 when we discovered the problem coming from ocean acidity.

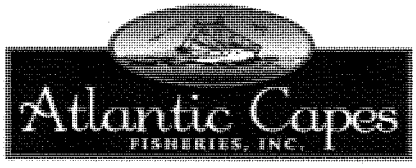
In 2013 in British Columbia there was a major die-off, 90 percent of all the scallops being raised offshore. Three year classes were killed including my company. I sustained alone a $10 million loss. The scientists there, which are continuing to research this right now, believe that the ocean is the highest level of ocean acidification which were recorded last summer weakened the animals to become more susceptible to endemic disease.

In terms of the fluke fishery, you have evidence in my written testimony mostly documented by an article that is being released today by the Daily Climate that is documenting work by National Marine Fisheries Service and NOAA, documenting temperature changes in the east coast affecting the migration and distribution of the fluke fishery. The fluke fishery in completely rebuilt because of good management practices by Mid-Atlantic Council. But because the distribution of those fluke are moving slowly north, the traditional way you traditionally fished off of North Carolina are now being fished off of New York and further north. Therefore there is a user conflict now of State by State allocation of the fluke fishery and recreational commercial conflict, all a consequence of change in distribution due to documented bottom temperature change.

I am going to conclude by saying that I believe that it is irrefutable that climate change is happening, that leaders of the east coast fishing industry along with myself have formed a company called Fisherman's Energy specifically to try, similar to what was testified here, to try to also adapt. We propose to build offshore wind farms and these are just examples that we as a society must take to be actually agents of change rather than victims of change.

Thank you, I would be happy to answer questions whenever you'd like.

[The prepared statement of Mr. Cohen follows:]



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June 3, 2014

Testimony of Daniel Cohen to Subcommittee on Green Jobs and the New Economy of Senate Environment and Public Works Committee

Thank you for the opportunity to address your committee as you evaluate the impact of climate change on our environment and livelihoods. These are important issues for society to grapple with. The choices we collectively have made and will make over the coming years regarding these issues will impact the quality, security, and lifestyle of our children and subsequent generations. The fishing and aquaculture industry of the US, especially the shellfish industry, are extremely susceptible to increases in ocean temperature and ocean acidification. Like "canaries" in the coal mine, our shellfish aquaculture industry has already been significantly harmed and are a harbinger of the unintended consequences of human use of fossil fuels and CO2 increases in our atmosphere and oceans, which have resulted in increases in ocean temperature and ocean acidification.

I am Daniel Cohen, President of Atlantic Capes Fisheries, Inc. I am second-generation in the fishing industry and have spent the past forty years building a vertically integrated commercial fishing enterprise. Beginning as wild fishermen and purchasing my first fishing vessel in 1978, today we operate 23 vessels, primarily on the East Coast, from the Canadian line to North Carolina. We operate offloading facilities in Maryland, New Jersey, and Massachusetts and harvest and process scallops, clams, and crabs in Massachusetts and Rhode Island.

Over the past 40 years I have spent a significant portion of my time in public roles working with fisheries managers on the state and federal level as well as working with academia to pioneer and implement collaborative research in fisheries. I am the Chairman of the NFI-Scientific Monitoring Committee, which in conjunction with the Mid-Atlantic Fisheries Management Council, raises over $1million dollars annually from the fishing industry of the Mid-Atlantic to pursue collaborative research with the National Marine Fisheries Service and academic institutions such as Rutgers University, Virginia Institute of Marine Sciences, Cornell University, and others. My company is a founding member of the first and only National Science Foundation funded science center combining the fishing industry, NOAA-NMFS, and academia – co-chaired by Southern Mississippi University and Virginia Institute of Marine Sciences.

Atlantic Capes Fisheries, Inc. is primarily a wild harvest commercial fishery whose main dollar value and volume consists of East Coast Sea Scallops, Surf Clams, Fluke, Squid, and Sea Bass.

About 15 years ago, recognizing that wild fisheries would be capped to assure the public that wild capture fisheries harvests were sustainable and renewable, we began our first efforts in shellfish aquaculture. With a rising world population (then 6 billon, now 7 billion, and projected soon to be 9 billion) wild sustainable fisheries could not and will not be sufficient to meet the public's demand for protein. Raising shellfish as a form of farming can be an environmentally friendly and efficient source of protein for the public.

Rutgers University had been developing disease resistant strains of east coast oysters in an attempt to rebuild oyster populations that had been decimated in the 1950's by two diseases. At the request of Rutgers University we began the first demonstration oyster farm in New Jersey using hatchery raised oysters and employing the French "bag and rack" method of oyster farming. Our Cape May Salt Oysters have been commercially successful and are now served in fine restaurants, including here in Washington, DC. In 2011 we expanded our shellfish aquaculture by investing in the largest operating commercial scale sea scallop farm in North America, located in Qualicum Beach on Vancouver Island, British Columbia.

Today I want to briefly introduce you to the changes occurring in our oceans which are having and will have in the future significant impacts on our economy, jobs, food supply, and quality of life. These impacts relate to:

1) Increases in ocean temperature, which most scientists attribute to climate change from greenhouse gasses warming the atmosphere;
2) Increases in ocean acidity due to the increases in carbon dioxide in the atmosphere ending up in our oceans and measured as the partial pressure of CO2 (pCO2); and
3) Changes in ocean currents and upwelling which scientists believe are being caused by changes in ocean temperature.

While the impacts are broad and effect the entire marine environment, I have assembled a few specific examples to provide to you a broad picture of the types of impacts and potential responses that we as commercial fishermen, shellfish farmers, and society face. The examples that I will use are:

1) Surf clam fishery on the East Coast;
2) Oyster hatcheries and farming in Oregon and Washington;
3) Scallop farming in British Columbia; and
4) Fluke fishery from North Carolina through Rhode Island.

I will conclude with a short introduction to an adaptive response to our society's energy and climate issues, which I am personally leading on the East Coast.

The surf clam fishery was historically centered off the coast of Virginia up through New Jersey. With a robust inshore New Jersey fishery, New Jersey landed more than 50% of the entire surf clams in the country. Surf clams are the primary ingredient in clam

chowder and are also enjoyed as breaded clam strips. As outlined in the Wallace & Associates summary that I have included with my testimony, surf clams are an ideal candidate to observe the negative impact of bottom temperature change, since they are sedentary non-migrating animals (while fish have tails and can swim). The first real indication of a problem in the surf clam fishery was identified in a tri-annual NOAA-NMFS survey of clam populations which identified an unexplained significant die-off of surf clams off the coast of Virginia. Research funded by the clamming industry and conducted by Rutgers University and the Virginia Institute of Marine Sciences determined that the die-off was due to changes in bottom ocean temperature that made the environmental niche in the area untenable for surf clam survival. Subsequent die-offs of inshore New Jersey surf clams followed this trend. Further, temperature related changes in surf clam populations have resulted in an increase in surf clam populations in the cooler waters off the coast of Massachusetts. The impact has not only been to the animals. Surf clam processing plants have closed in Virginia, Maryland, and New Jersey with a loss of jobs, while, at the same time, new plants have opened in Massachusetts....a migration of jobs following the movement of bottom temperature and the increase of the clam resource in New England's cooler waters and the decrease in population in the Mid-Atlantic due to bottom temperature rise.

The Pacific Northwest is home to the largest hatchery based oyster industry in the US. This hatchery based industry grows Pacific Oysters to augment wild harvests. As outlined in a white paper that I have included with my testimony is the work of George Waldbusser, Professor at Oregon State University. Professor Waldbusser findings indicate that the hatchery industries of Oregon and Washington State lost at least $110 million dollars due to ocean acidification. The oyster industry must continue to be negatively impacted by rising levels of ocean acidity because juvenile shellfish are impeded in establishing their shells in a more acidic environment. The hatcheries in the Pacific Northwest have adapted by "buffering" their hatchery and nursery waters, the equivalent to using "Tums" to buffer an acidic stomach. Although buffering can be done in a controlled hatchery to a limited extent, we can't buffer the entire ocean.

In 2013, British Columbia scallop farmers growing hatchery reared sea scallops experienced a 90% mortality of three year classes during grow-out in the ocean. In full disclosure this includes a $10 million loss experienced by my company in our British Columbia scallop farm. High levels of pCO2 (ocean acidity) were measured in the ocean waters at the same time. While the actual cause of the mortality has not be determined with 100% accuracy by the scientists, the hypothesis is that ocean acidity weakened the animals thereby making them more susceptible to endemic and underlying disease. I have included in my written testimony an October 2013 Power-point presentation in which the Pacific Northwest and British Columbia shellfish industry have banded together with the Indian Native Bands (who have invested in shellfish aquaculture) to seek Canadian government, US Government, and / or NGO funding to undertake a multi-year genomic program to develop heartier and more resistant broodstock that will be adapted for survival in a more acidic ocean environment. To date that funding has not been secured and the future of this nascent industry is in question.

My last example is the East Coast Fluke fishery, as highlighted in a technical article to be released publicly today by the Daily Climate, written by Marianne Lavelle, and attached as part of my written testimony. As outlined in the article, and documented by NOAA and NMFS studies, the center of the bio-mass of summer flounder, an important

commercial and recreational fishery, has been slowly migrating north as bottom temperatures have been slowly but continually warming. While the fluke stocks are healthy and fully rebuilt, due to sustainable management by the Mid-Atlantic Fishery Management Council, the movement in their geographic distribution has increased conflict between commercial and recreational fishermen as well as created conflict in the state by state allocation of the fishery. Diesel fuel, a non-renewable resource consumed by vessels which must steam further north to catch their fish, is being wasted to deliver the fish to southern ports. The change in spatial distribution is causing societal conflict over access and allocation of this valuable and important resource. Again, this is a harbinger of things to come in other fisheries and resources, unless we can somehow stop the current changes in use of fossil fuels and the creation of greenhouse gases.

I want to conclude by outlining one adaptive change the fishing industry has undertaken to help address these issues. On the East Coast I am one of the founders of a company formed by East Coast fishing industry leaders to propose and build offshore windfarms. While opposed to built structures in the ocean these fishing industry leaders banded together to be agents of change rather than victims of change. Seeing firsthand the impact of climate change on their businesses, and being concerned with solving energy issues for future generations without reliance on fossil fuels, Fishermen's Energy began in 2008 to propose to build a demonstration offshore windfarm off the coast of Atlantic City. On May 7th of this year the US Department of Energy announced that the team lead by Fishermen's Energy was awarded a $47 million Grant to help build a $200million windfarm off the coast of Atlantic City. Fishermen's Energy hopes to build this first project in 2016.

As I have outlined in my verbal and attached written testimony, the changes in ocean temperature and ocean acidity are real. Their impacts are real. Without a concerted collaborative effort between the fishery / aquaculture industry, academia, and government our marine food supply is threatened. How will we feed 9 billion people? Only with a well-funded and well thought out adaptive response, species by species, environmental niche by environmental niche, can we assure success. We have significant challenges ahead. Will our industry, government, and NGO communities rise to this collective societal challenge? Our children and future generations are dependent upon how well we collectively respond to these challenges.

Thank you,
Daniel Cohen

WALLACE & ASSOCIATES

May 28, 2014

Mr. Daniel Cohen, President
Atlantic Capes Fisheries
Cape May, New Jersey

Re: Effects of warming ocean temperature of Atlantic Surf Clams in the North Atlantic

Dear Mr. Cohen,

Ocean temperatures on the East Coast of the United States from North Carolina to the Canadian border have increased by about 1°-2° C over the last 20 years according National Marine Fisheries Service's, Northeast Fishery Science Center, document titled, "Description of the 2008 Oceanographic Conditions on the Northeast U.S. Continental Shelf" (Reference Number; Document 09-12).

Surf clams are bivalves that are naturally occurring in the marine waters of the continental shelf off shore of the northeast United States in large numbers. They are commercially valuable and are one of the highest populated marine species of the northeast region. Surf clams live approximately 25 years and are found in temperate waters from the coastal shore to about 120 feet of water depth in the ocean.

The surf clam landings from all areas in 2013 were about 2.6 million bushels with an ex vessel landed value of more than 40 million dollars and total value of the, value added products, of more than 450 million dollars, and providing an estimated 1900 jobs.

Surf clams are water temperature sensitive in all life stages. From the time they are free swimming larvae to where they settle and grow to adults. Because they are bivalves they do not move more than a few hundred feet in their life time. Therefore, they are good barometers for understanding changes in the ocean environment, partieularly water temperature.

As the water temperature increases on the continental shelf, this causes the surf clam population to migrate slowly to deeper colder water and move further north. In Virginia a large beds of surf clams died because of warmer water and the reduction of plankton, their food source.

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Other beds of surf clams died off as far away as the inshore beds in northern New Jersey, with warm water being the primary factor according to a group of studies by Eric Powell from Rutgers University and Roger Mann from Virginia Institute of Marine Sciences which were directly funded by the surf clam industry.

There is evidence that the surf clam population is being effected in all life stages by warmer ocean temperatures. The young are having a difficult time developing to young adults in the Mid-Atlantic because of the lack of food and warmer water temperatures. It appears that they are being stunted in growth because there food source is limited by the change in the environment. Older adults are not growing to the size that their ancestors 25 years ago and their body weight is also less...

Why are these observations important to the surf clam population? Water temperature is having a profound effect in the physiology of the population and is also affecting the plankton population which is the food source for the surf clam population. There is scientific evidence there may be an effect on the very young adults to create shell material necessary to make the transition from a free swimming larvae to a sedentary animal because of the changes in the pH or ocean acidification. The acidity of the ocean is increasing because of the greater amount of carbon dioxide (CO2) in the atmosphere.

The surf clam fishery historically has operated in the Mid-Atlantic region. Now the fishery and the industry that supports it is moving northward. This is because as the water temperature increases, the surf clam population at the southern end of their range has drastically been reduced because of warmer water temperature and a lack of food supply. This has effected both the off-shore surf clam stocks and populations in the inshore waters of New Jersey and New York. The surf clam population inshore New Jersey has being adversely effected by the population collapse with the preponderance of evidence that the problem is temperature related. In New York State the surf clam population is not as stressed as in New Jersey but there are signs that the animals are under pressure demonstrated by slower growth and lighter body weight. This demonstrates that the population of surf clams are moving further offshore to deeper cooler water and further to the north.

The clam processing industry that removes the clam meat from the shell is also moving north where much of the surf clam landings are now takes place. Today a significant portion of surf clams are being harvested and processed in New England unlike ten years ago when all of the surf clam shucking plants were in Virginia, Maryland, Delaware and New Jersey.

There are changes in the surf clam population because these animals cannot move but their larvae will settle and grow in only an environment conducive areas to their life cycle requirements. The next generation of clams move from one area to another reacting to changes in the marine environment which is a slow but observable process over time. The more rapidly the environmental regime changes, the more it effects the environment required for the bivalve population to survive. The surf clam food source of plankton essential for their survival is

marked by the change in temperature too. As the water temperature changes these species are found in areas that they did not occupy before and the older ones as they die are not being replaced where they traditionally were found.

I hope you find this information helpful.

Sincerely,

David H. Wallace

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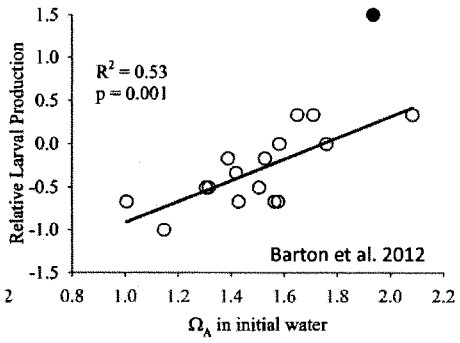
Background and Status of Ocean Acidification Impacts on Pacific Northwest Shellfish, with a particular focus on Oysters

The Pacific Northwest, and Washington State in particular, is one of the largest producers of oysters in the US. Oregon is the largest supplier of oyster seed to independent growers throughout the US West Coast. The annual economic impact (gate value) of the US West Coast Shellfish industry is estimated at approximately $270 million, and directly employees 3200 people in coastal areas where other employment opportunities are limited. This industry and these jobs are critical to the economic well-being of these coastal communities, and oysters make up the bulk of the shellfish production in the Pacific Northwest. The oyster seed crisis, as it has been called in the Pacific Northwest, resulted in a 22% decline in oyster annual production from 2005 to 2009, and a 13% annual decline in gross sales. The industry, prior to the seed crisis used to produce nearly 95 million pounds of oysters per year, this was reduced to less than 75 million pounds annually, by 2009. The economic impact over the seed crisis period has been estimated at $110 million in gate value, and this does not include economic multipliers or costs included to adapt to changing water chemistry

Starting in about 2005-2006, Whiskey Creek Shellfish Hatchery (Netarts Bay, OR) and Taylor Shellfish Hatchery (Dabob Bay, WA) began having significant production failures of Pacific Oyster seed. Both hatcheries are owned and operated by multi-generational shellfish growers, and both reported they had never previously encountered persistent failures of this scale and scope. The initial concern was a pathogen called *Vibrio tubiashii* that infects larvae in hatchery settings, and samples from the hatcheries indicated that the pathogen was present. At the Whiskey Creek Hatchery, a comprehensive water filtration system was installed in 2007; in 2008 failures continued but no *Vibrio* was found in the hatchery or in the incoming waters. Production failures in 2008 included month-long failures of larvae that generally occurred in the mid to late summer.

At the end of 2008, personnel began to link the failures to the upwelling of deep oceanic water, which led to the possibility that seawater with high levels of dissolved CO_2 (pCO_2) was to blame. In 2009, Oregon State University scientists began working with the Whiskey Creek Hatchery on the issue and were able to confirm that in fact elevated pCO_2 (low pH) seawater was the culprit. In fact, what was found was quite striking; exposure to elevated pCO_2 water during the first 48 hours of larval life could predict just over half of the variability in how much oyster seed the hatchery produced. And the waters did not have to be "corrosive" or even that high in pCO_2 for these effects to manifest.



The figure left shows the relationship between larval production and a measure of corrosiveness to the calcium carbonate mineral that larvae use to make their shell. Importantly, these are not experiments, this is real production and chemistry data from the hatchery. Values of saturation state below 1 are considered corrosive; however, even at values above 1, there are still sub-lethal losses of larvae. Each point on the graph represents one cohort of larvae in 2009, and a "relative production" value of 1 indicates that the cohort ended up with roughly the same biomass they started with. In other words, it would be akin to planting a cornfield, and having the same mass of corn at harvest that you started with as seed.

Through the installation of a real-time pCO_2 monitor, hatchery personnel noted they could take advantage of the daily inhale and exhale of Netarts Bay; by filling their culture tanks in the afternoon (after the seagrasses and phytoplankton in the bay have sucked up pCO_2), instead of morning, they were able to avoid the worst of the high pCO_2 water. This monitoring equipment prevented Whiskey Creek Hatchery, a hatchery that had historically supported roughly 70% of independent oyster growers on the US West Coast, from going out of business. The Washington Blue Ribbon Panel on Ocean Acidification estimated the total loss to the industry in gate value of $110 million.

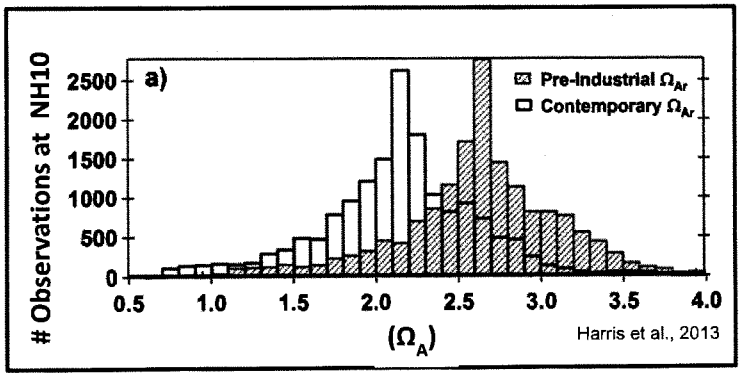
Subsequent work on monitoring and adaptation has allowed the hatcheries to rebound, and restore a major production of their annual loss. Two of the three large commercial hatcheries in the US PNW are now taking the "Tums" approach, in which they are buffering all of the water coming into the hatchery. This coupled with a shift to a much earlier production season, has provided resiliency on the short-term to the oyster industry. One side effect of this buffering has been improved production of other shellfish, previously believed to be robust to OA. In the Taylor's hatchery, since the installation of their buffering system they have seen much improved survival of geoduck seed, as their shells are thicker and more able to withstand the outplanting than previously. Although they had not previously seen massive mortality, this is a classic example of a shifting baseline, where conditions change slowly enough that human perception generally does not notice the change.

The effects of ocean acidification are happening today, and can be seen in the following electron micrograph of Pacific oyster larvae raised in water at the Taylor's Hatchery (end of document). It has now been documented that under elevated pCO_2, larvae are unable to properly make their shells; they have a limited amount of energy to do so until they complete their first shell (and can begin feeding). In fact, for many of the failures that have occurred, larvae do actually appear for about a week, then they stop swimming, as they have run out of energy and cannot recover. Think neonatal nutrition. This is expensive for hatcheries, given that the larvae are essentially marked in the first 48 hours, then the actual response manifests seven days later. In that time the hatcheries are feeding cultured food to the larvae and heating seawater to support their growth.

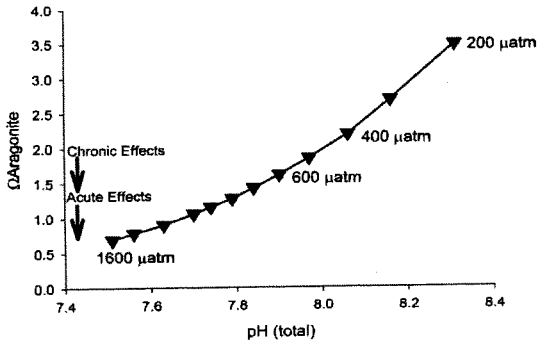
The question should arise of how come all of a sudden, in this region, did high pCO_2 impact oyster larvae? The Pacific Northwest has naturally elevated pCO_2 to begin with due to the upwelling of old, deep oceanic water. The best estimates indicate that this water last contacted the atmosphere 30-50

years ago, setting the current baseline CO_2 levels. Each year, as source water sinks, that baseline increases a little bit more, pushing conditions closer to important thresholds for oyster larvae and other sensitive species including other bivalves and pteropods (important food for salmon). In fact, estimates of the near-shore chemistry with the anthropogenic fossil fuel CO_2 removed indicate there has been a nearly 0.5 decrease in saturation state (that important measure of how easy it is to make shell material).

The graph below shows the distribution of observations just off shore Newport, OR, and what it would have been before the addition of fossil fuel. Importantly, the average conditions are quickly approaching the thresholds we now know are important for bivalve larvae, and Pacific Oysters in particular. A survey of the literature indicates that chronic, sub-lethal effects on bivalve larvae appear to begin when this measure of how easy it is to make shell material hits about 2.0. At about 1.5 we begin to see acute impacts on bivalve larvae.

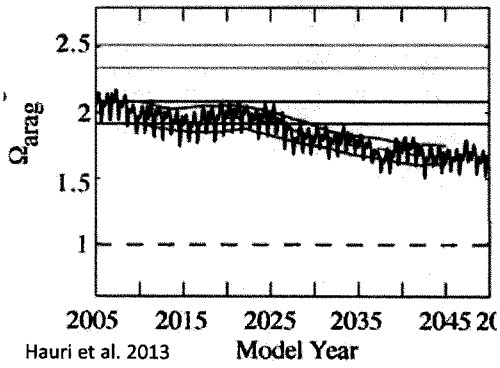


It is very important to note that these changes in saturation state do not translate into large changes in pH. The figure below is from a manuscript in preparation by Waldbusser *et al.* This shows the change in saturation state and pH relative to CO_2 for oceanic water typical of upwelling along the Oregon coast. The important point is that not much additional CO_2 results in decreases in saturation state that are critical to bivalve larvae, while pH hasn't changed in nearly as significant a way. The best current models suggest these levels will be outside of the present range in conditions within 20 years in the highly productive California Current Ecosystem. See below.



So where are we now? Shellfish hatcheries are being equipped with monitoring equipment, but need continued technical support staff to help ensure proper instrument operation. Buffering of water and timing of oyster seed production has shored up the seed production side, but significant questions remain regarding the timing of seed planting and fate of seed. Several growers have noted increasing mortality of seed planted mid to late summer. In fact, one major grower no longer plants seed after June in Willapa Bay, WA, as the seed almost always die. Although this corresponds to the major upwelling period in the PNW, we are just starting to get sensors in the water in these locations.

Many growers are planting oyster seed much earlier in the year, months before upwelling begins; however, food for oysters is also much more limited this time of year. We do not yet know if this is an issue, or if oysters can simply catch up when food becomes more available. If this is a problem, then there is a shrinking window of time when conditions will support planting of seed.



Hauri et al. 2013

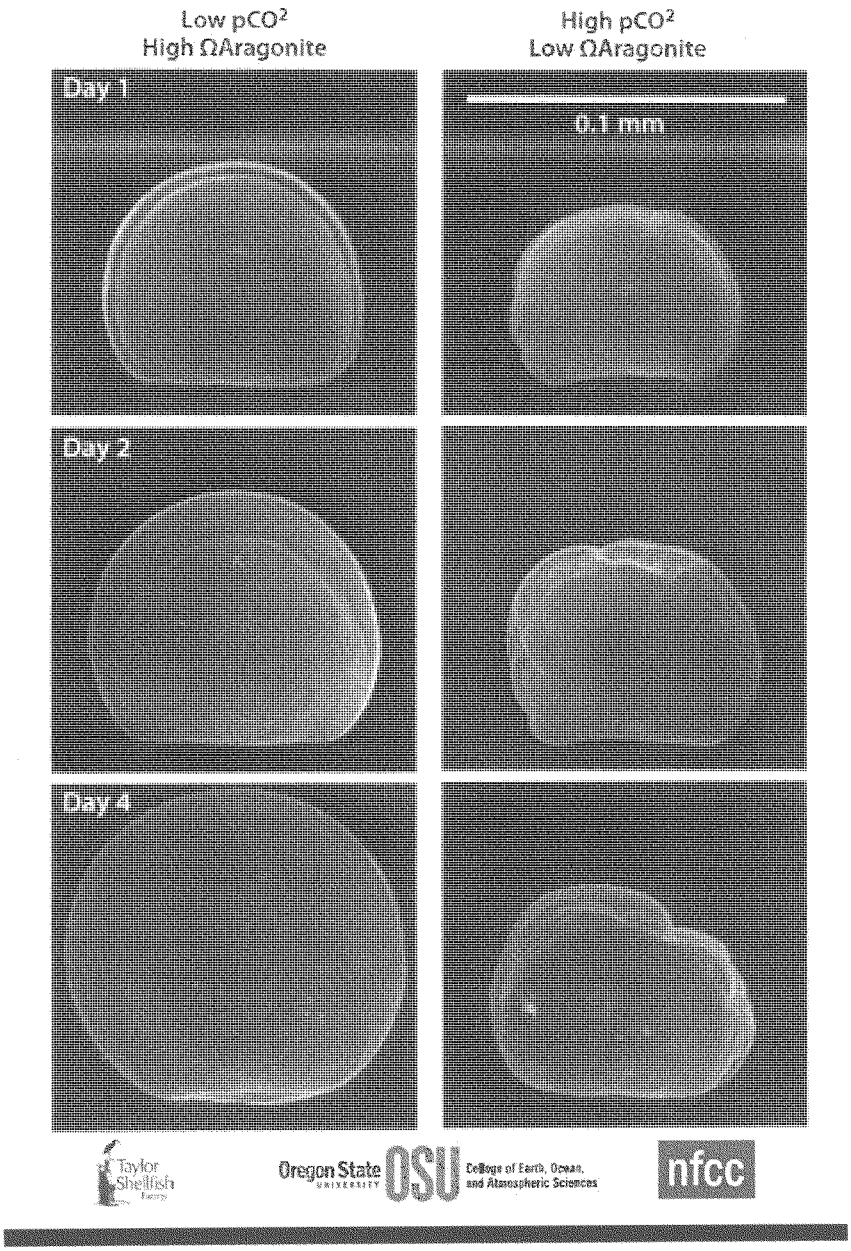
In summary, ocean acidification is happening now; the ocean has become 30% more acidic in the span of only a few years. There are significant economic impacts of ocean acidification on the shellfish industry, and although there is some capacity to adapt and alter chemistry in hatcheries, seawater chemistry cannot be effectively altered across entire water bodies at the moment. There is not much more capacity for waters in the Pacific Northwest to absorb much more CO_2 without leading to increasingly persistent problems for commercially and ecologically important species. Although in some locations it may be possible to take regional actions to stem off some more immediate impacts, such as habitat restoration, without a global carbon policy that significantly reduces CO_2 emissions, conditions will continue to deteriorate in the world's oceans and threaten food production and livelihood.

For more information:
http://coenv.washington.edu/research/major-initiatives/ocean-acidification/ocean-acidification-in-the-pacific-northwest/

Videos on the problem (WA and OR)-

http://www.youtube.com/watch?v=5IJl-INsVYE

http://www.youtube.com/watch?v=qPhgyB8o_U4


Low pCO2
High ΩAragonite
High pCO2
Low ΩAragonite
Day 1
0.1 mm
Day 2
Day 4
Taylor Shellfish
Oregon State University
OSU
College of Earth, Ocean, and Atmospheric Sciences
nfcc

SHELLFISH IN DISTRESS
The Collaborative Research Effort is Needed to Secure
Survival of the Shellfish Industry in British Columbia
Island
Scallops
OCEAN
SMART

Shellfish Farming in British Columbia

The Problem: Ocean Acidification

* The shellfish industry is in crisis due to unprecedented changes in the ocean environment: OCEAN ACIDIFICATION
* Both wild and hatchery-produced shellfish have already been negatively impacted
* At risk are over decades of research and development and millions of dollars of investment by, BC Shellfish growers, governments, First Nations, and Foundations

Shellfish Farming in British Columbia

The Solution: A Collaborative Approach

* Shellfish that can thrive in an increasingly acidic ocean must be selected to secure the future viability of the industry

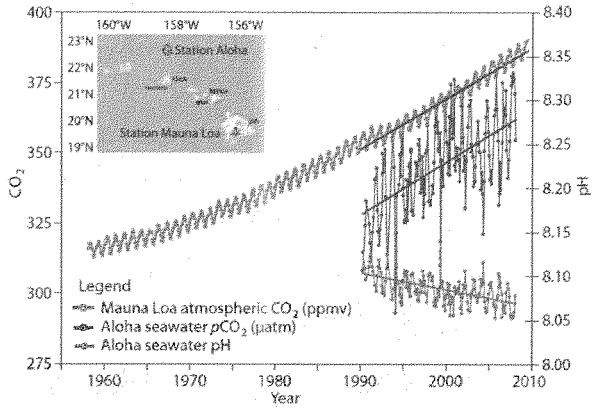
* Solving the problem requires a coordinated effort, combining the resources and expertise of:
  - BC Shellfish Growers
  - First Nations
  - Government (e.g. Fisheries and Oceans Canada) and academic scientists
  - Funding sources

Shellfish Farming

The Challenge Facing the Shellfish Industry in BC

Ocean Acidification

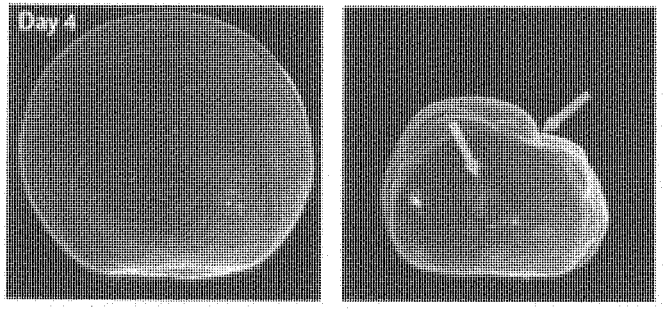
- Greatest threat to survival of the BC shellfish industry today
- Caused by increasing levels of CO_2 in the ocean
- Affects the ability of calcified organisms to form shell
- Shellfish larvae and juveniles are particularly susceptible



Increase in atmospheric and oceanic CO_2 in Hawaii over recent years. (Source: NOAA)

Shellfish Farming

Mitigation of Ocean Acidification



Scanning electron micrograph of (left) healthy four-day old shellfish larva and (right) larva grown in seawater with high levels of CO_2. (Source: Oregon State University and Taylor Shellfish Farms)

AT THE HATCHERY:

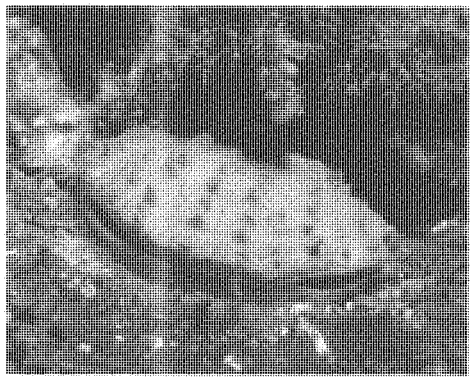
* Ocean acidification caused significant mortality of oyster and scallop larvae in 2009 and 2010 at ISL
* The problem was successfully mitigated in 2011 and 2012 by buffering the seawater. NaOH, NaCO

Scallop Farming

Mitigation of Ocean Acidification

AT THE FARMS:

- In 2013, 90% mortality was experienced in all three year classes (2010, 2011, 2012)
- This was attributed to a weakening of the animals by ocean acidification
- The ocean cannot be buffered, so scallops able to thrive in an increasingly acidic environment must be selected
- Alternate scallop species that may be more tolerant must also be investigated



The local Giant Rock Scallop may be an alternate culture species in BC. (Source: SIMoN / MBNMS)

Ocean Acidification
CO_2 (atm)
88% of carbon in the ocean exists in the carbonate ion (at pH=8)
CO_2 (aq) + H_2O ⟺ H_2CO_3 ⟺ HCO_3^- + H^+ ⟺ CO_3^{2-} + $2H^+$
CO_3^{2-} + Ca^{2+} ⟹ $CaCO_3$
Marine calcifiers (ex. dissolved ions into solid calcium carbonate, these structures dissolve if the concentration of dissolved ions is too

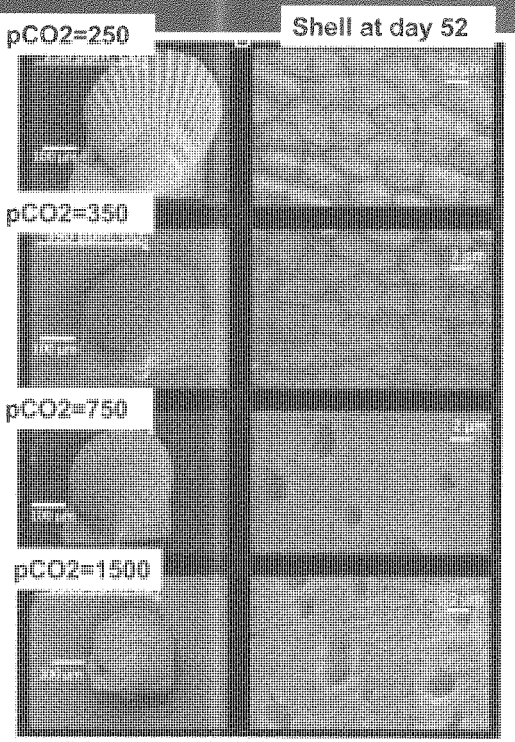
Ocean Acidification
Coast-Puget Sound: August 2008
Coast
Juan de Fuca
Admiralty Inlet
Main Basin
South Sound
Coast-Hood Canal: August 2008
Coast
Juan de Fuca
Admiralty Inlet
Hood Canal
0
100
200
300
8.0
7.8
7.6
7.4
7.2
7.0
Feely et al 2010 Est Coast Shelf Sci 88:442-449

800,000 years of atmospheric CO2
Ice-core data before 1958. Mauna Loa data after 1958.
CO2 Concentration (ppm)
400
350
300
250
200
150
800
700
600
500
400
300
200
100
0
Thousands of Years Ago

Shellfish Response to Acidification: bay scallop example

- Decreased fertilization rates
- Decreased hatching success
- Decreased larval growth
- Impacts on acid-base metabolic physiology
- Shell deformities
- Problems with deposition of calcium carbonate and weakening of shell

(Kurihara et al 2008 MEPS 373:275-284; Fabry et al 2008 ICES 65: 414-432)



Talmage *et al* 2010 PNAS 107: 17246-17251

Functional Genomics ACRDP project for oysters and scallops

Environment One

i.e. atm. pCO2 (~350μatm)

- Organism responds to environment
- gene expression (RNA production) changes
- Some genes are up-regulated (produce more mRNA) and others are down-regulated

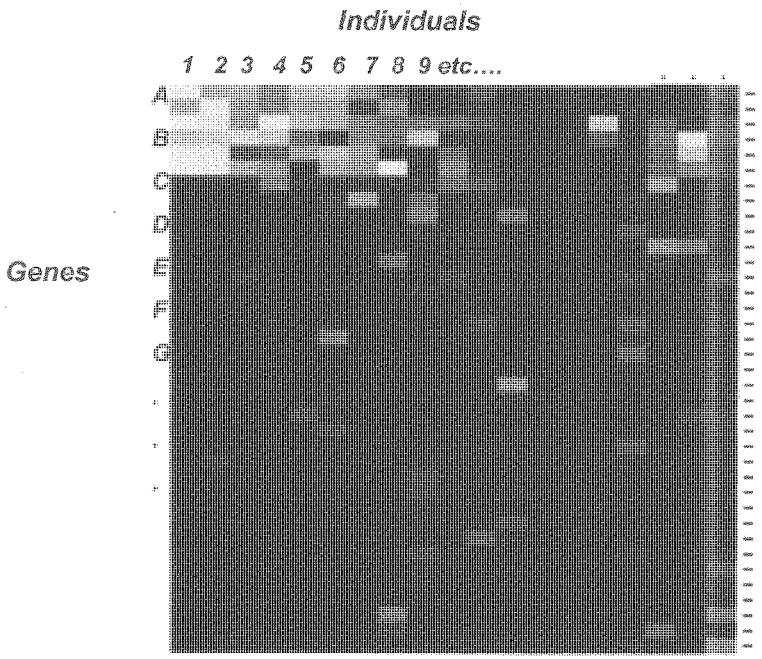
Environment Two

i.e. high pCO2 (~550μatm)

- Organism responds to environment with different response than environment 1
- gene expression (RNA production) changes
- Some genes are up-regulated (produce more mRNA) and others are down-regulated

- RNA isolated from organisms
- Visualized on a microarray slide
- Compare organisms from environment 1 to those from environment 2 and identify differences in gene expression
- Determine which physiological pathways differentially expressed genes are part of

Functional Genomics: microarray



Scallop Microarray

- Based on ESTs from *Patinopecten yessoensis* and *C. gigas*
- 24505 unique expressed sequence tag probes
  - 91 probes for pathogenic marine bacteria
  - 24414 probes for scallop sequences
  - 33% of scallop probes are annotated (putative gene function known)
  - Annotated genes include those for the following pathways (among others):
    - Protein metabolism
    - Immune function
    - Growth and development
    - Cell signalling
    - Reproduction

Functional Genomics: biomarkers

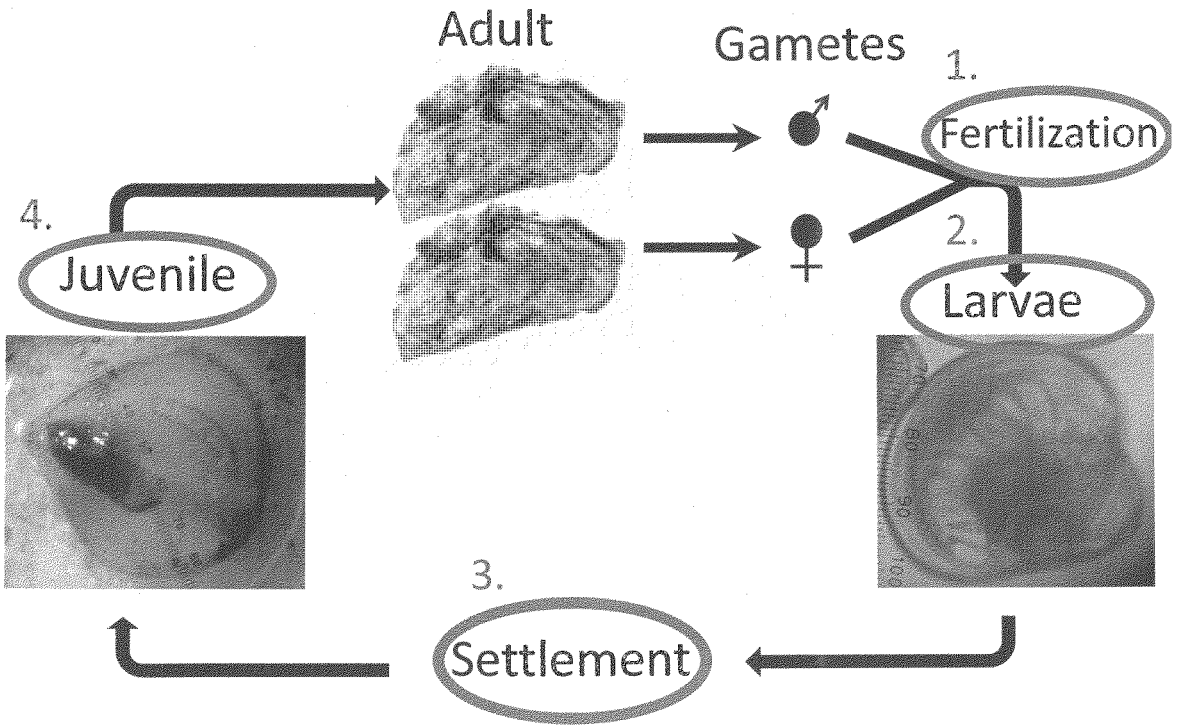
Goal:

to discover genes which, when up- or down-regulated, indicate whether scallops and oysters are being negatively impacted by ocean acidification

Applications:

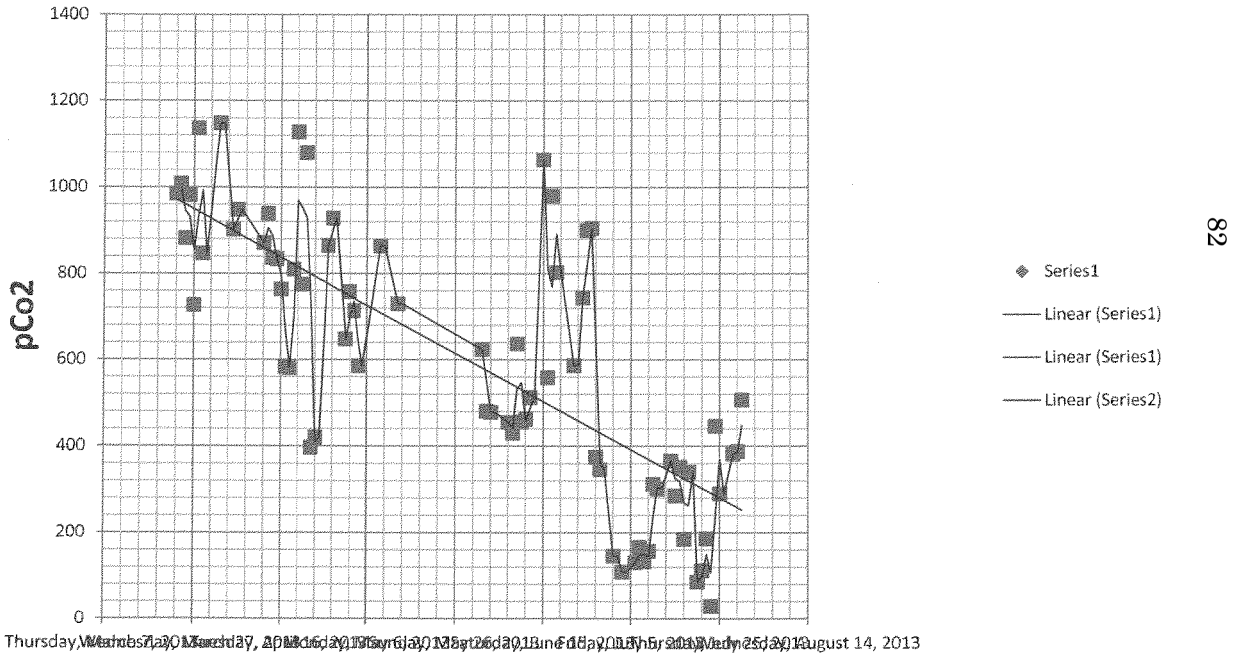
- more efficient selective breeding and ability to target desired traits such as tolerance to high pCO_2
- early (sub-clinical) indicators of poor health
- measurable markers for determining if environmental manipulations are having the desired affect

How does increased pCO_2 affect...

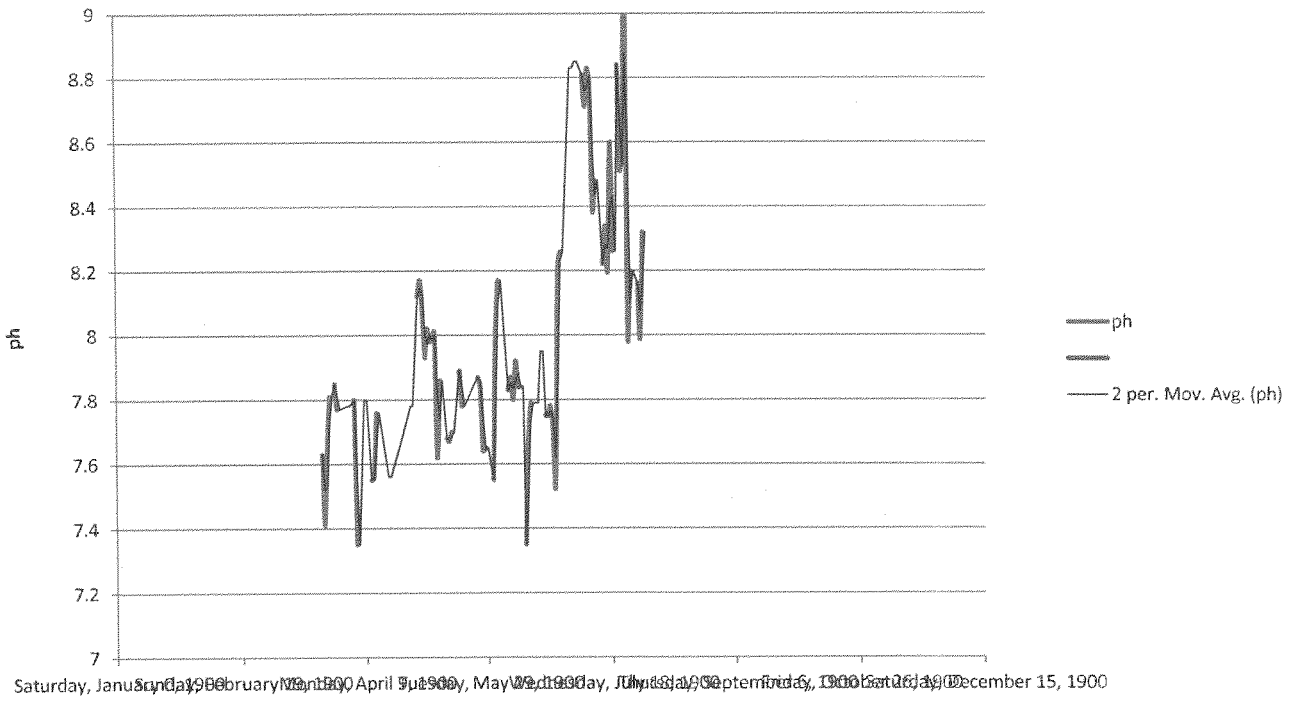


Flask experiment

Partial pressure of CO2 in seawater at Qualicum Beach



Ph of seawater in Qualicum Beach



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- ODYSSEY SHELLFISH
- LIMBERIS SEAFOODS
- ISLAND SEAFARMS INC
- RKS LABS LTD.
- ISLAND SCALLOPS
- DFO, GENOMICS
- KYUQUOT SEAFOODS LTD
- WE WAI KAI SEAFOOD CORP
- POST DOC ERIN McCELLAND
- MASTER STUDENT MANON PICARD

Acknowledgments

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ADVANCE COPY FOR PUBLICATION -- SUBJECT TO CHANGE

Summer flounder stirs north-south climate change battle.

An uncivil war is brewing over "fluke," one of the most popular fish of U.S. East Coast, as its habitat drifts north in warming waters.

By Marianne Lavelle

The Daily Climate

http://www.dailyclimate.org

The summer flounder – one of the most sought-after catches on the U.S. East Coast – is stirring up a climate change battle as it glides through the sand and grasses at the bottom of a warming North Atlantic.

Also known as "fluke," the flat, toothy fish is remarkable for its ability to change color to adapt to its surroundings, rendering it almost invisible to predators and prey.

Some scientists say in recent years the species has begun adapting in another way. As the Atlantic Ocean has warmed, they say, the fish have headed north.

The center of summer flounder population, recorded as far south as Virginia around 1970, is now off the New Jersey coast. Its migration has set the stage for battle between northern and southern East Coast states on how to share the business of harvesting this tasty, lean fish—valued at $30 million per year commercially and untold millions more for the recreational fishing industry.

Battle lines have been drawn over a fish that has staged a remarkable come-back from overfishing, but has returned to a dramatically changed environment in the sea and on land. On one side are southern states, most importantly, North Carolina, with a commercial fishing fleet that has been pummeled in recent years by competition from cheap foreign seafood imports. It is eager to hold onto its summer flounder quota, based on its historic leading role in East Coast fluke fishing, even if that now means motoring closer to New Jersey to find the fish. On the other side are northern states, particularly New York, where recreational sports fishing has become an important business and economic engine that is chafing under what it views as outdated quotas.

Sen. Charles Schumer, D-N.Y., has pledged to bring "fluke fairness" to Long Island by introducing legislation to do away with the long-standing state-by-state summer flounder management quotas that he says short-change New York's fishermen. But North Carolina is not likely to surrender its quota quietly.

"This is an opportunistic reason for using climate change or whatever the heck reason they want to use—the northern states would like to get some of our quota," said Jerry Schill, president of the North Carolina Fisheries Association. He maintains it would be an unfair way to repay Tar Heel State commercial fishers for sacrifices they've made that have helped rebuild the summer flounder stock so that it's robust enough to head into cooler waters.

The regional authorities that manage East Coast fishing under U.S. law made tweaks in their summer flounder plans this year in an attempt to address concerns about inequity and allow more flexibility for recreational anglers. But unhappiness persists, and work is underway on a longer-term solution.

A team of scientists from four mid-Atlantic universities, working with the fishery managers and with funding from the U.S. National Oceanic and Atmospheric Administration (NOAA) Sea Grant program, this spring launched a project aimed at better understanding what is happening with the summer flounder, *Paralichthys dentatus*. The researchers hope that their close examination of this one species will serve as a prototype approach for addressing similar conflicts and quandaries over fisheries that are bound to arise as climate change's impact becomes more evident.

A study published earlier this month by NOAA researchers suggests that more fluke are now found north primarily because fishing pressure has been reduced, not because of climate change. But co-author Jon Hare, NOAA's Northeast Fisheries Science Center in Narragansett, Rhode Island, says the team plans to publish follow-up research showing warming is, in fact, causing a northward shift for two other northeastern species that have been grouped together with summer flounder in the same federal management: scup and black sea bass.

"Much of our management assumes that conditions in the future will be the same as they have been in the past," said Hare. "Now have observational data to show the conditions have been changing through time, so assumptions about the future are being brought into question."

Previous research has shown that changes in local temperatures can explain recent geographical shifts of more than 300 different fish species: They've migrated toward the north or south poles, and even east or west into deeper waters, depending on their original locations. "We do think that climate is playing an important role for a wide range of species," said Malin Pinsky, a Rutgers University ecologist who led that research and who now is leading the NOAA Sea Grant study on summer flounder's changes.

Subhead

While scientists try to sort how much of fluke's northward shift is climate-change related and how much is not, pressure is building on authorities charged with divvying up the fishery among East Coast states.

"Fish have very strong thermal preferences, and they also have tails," said Richard Robins, chairman of the Mid-Atlantic Fishery Management Council, one of eight regional fishery management councils tasked with meeting demand while preventing overfishing in U.S. waters. "They don't wait to be convinced."

The council, which by law recommends species management plans that are then approved and enforced by the U.S. Department of Commerce's National Marine Fisheries Service, has had to cope with northward shifts by several species, including the Atlantic mackerel, he said.

But perhaps no fish is causing as much consternation as the summer flounder, which is not only highly prized by commercial fishing operations. It is among the top ten most popular fish caught in U.S. waters by recreational anglers, who relish pursuit of "flatties," or "doormats," as the largest fluke are sometimes called. Summer flounder are known for grabbing bait aggressively with well-developed teeth. "They offer a particular challenge to the angler bold enough to use light tackle," notes one web site on northeastern fishing.

Fluke were so heavily overfished in the 1980s that commercial landings plummeted from 38 million pounds to a low of 9 million pounds by 1990. The haul by recreational fishers dropped from around 30 million pounds to about 3 million pounds.

Only after the contentious and much-litigated process of putting quotas, size, and catch limits into place in the early 1990s did the species recover. By 2010, NOAA declared the summer flounder stock rebuilt. Total annual harvest recently has been about 20 million pounds of fluke per year, split 60-40 percent between commercial and recreational fishers.

Subhead

With flaky, white meat, easily broiled, poached, or fried, summer flounder is considered by many to be a sustainable seafood choice, since it is caught wild by U.S. fishers in the carefully managed program. And it is popular for East Coast diners looking for fresh catch, a stand-out local choice at a time when 91 percent of seafood on U.S. plates is imported, mostly from farming operations in Asia.

"In many ways, it has been a success story," says Pinsky.

But as fluke stocks have rebuilt, the North Atlantic has been warming, at 0.41° F (0.23°C) per decade from 1982 to 2006, or close to twice the global average for marine ecosystems, according to one widely cited study. And the bottom trawl surveys conducted by the U.S. NMFS since the 1960s show that the center of the summer flounder population has moved northward at roughly 19 miles (30 kilometers) per decade for the past 40 years.

That poses a problem, because the commercial summer flounder quotas are based on where fish were brought into port—"landings," in industry parlance—as they stood during the 1980s. As a result, in the commercial fishery, nearly 28 percent of the quota is allocated to North Carolina, followed by Virginia, with 21 percent, and New Jersey, with 16 percent. New York's share is just under 8 percent.

The fact that fewer summer flounder are found off just off North Carolina's coast hasn't been a major impediment for that state's commercial boats, which have been willing to travel long distances for catch. "North Carolina boats have always been very, very mobile," says Schill, who knows stories of N.C. boats in the 1950s going as far as Alabama to find shrimp. "They do what they have to do to put bread on the table."

So North Carolina vessels travel north, if necessary, to catch summer flounder, then motor home so the fish are landed in state, counting against its high quota.

But for recreational anglers, who typically cast bait close to their home state ports, summer flounder's northward migration is starkly evident. Under the rules in place last year, New York anglers could only bring in fish at least 19 inches in length, with a possession limit of four fish. Even so, New Yorkers landed more than 500,000 fluke in 2013, about 13 percent over the target regulators set for the state. Meanwhile, North Carolina's rules were far looser; recreational fishers could reel in fluke as small as 15 inches, with a possession limit of six fish. Nevertheless, N.C. recreational summer flounder landings totaled just 45,240 fish, some 67 percent below the state's target. New Jersey anglers, meanwhile, caught 1.2 million fish, about 22 percent over target, especially rankling to boats in neighboring Long Island waters.

At the end of last summer, New York Governor Andrew Cuomo threatened to sue federal authorities to overturn the summer flounder management rules, which he said "stifle the New York fishing industry." His office estimated that New York's fishing industry is losing about $6 million per year in revenue because its allocation falls below that of neighboring states.

"All of this is set against the backdrop of demographic change in the Northeast, and a huge boom in recreational fishing," points out Chris Kennedy, environmental economics professor at Virginia's George Mason University, one of the team of researchers working on the NOAA Sea Grant project on summer flounder. The change that is happening in the water is only one part of the equation that the team is tackling, he said. They are trying to understand the changes occurring on land as well, in both commercial and recreational fishing communities.

For both New York and New Jersey's fishing industries, still recovering from 2012 superstorm Sandy damage, it has been painful to forego the readily available fluke just offshore. "Due to economic losses sustained due to Hurricane Sandy, many marinas and tackle stores in the northeast were relying on the summer flounder fishery to finance rebuilding and repair costs," noted the Mid-Atlantic Fishery Management Council's fishery performance report completed at the end of last summer.

Subhead

New York's recreational summer flounder restrictions were eased somewhat this season, and are now in line with those in both New Jersey and Connecticut. But the Mid-Atlantic Council, and its partner agency, the Atlantic States Marine Fisheries Commission, which regulates fishing with three miles of shore, are reopening their summer flounder management plans, with the hope of arriving at a longer-term solution.

"We're going to revisit what is the appropriate management response to the emerging idea that the fluke biomass have shifted north and east," explains council member Jeff Kaelin.

Kaelin, who heads up government affairs for Lund's Fisheries, a commercial operation based in Cape May, N.J., says that the unintended consequences of the current system are readily apparent to his own company's operations. Although most of the vessels Lund's owns or works with call Cape May home port, some have North Carolina permits. They may catch summer flounder right off the Jersey shore, but need to head south "and burn hundreds of gallons of fuel to land 100 boxes of fluke against their [North Carolina] quota," says Kaelin. "That's with fuel at $3 to $4 a gallon, and very contrary to the issues of climate change and carbon footprint."

Kaelin says that with the help of electronic monitoring and reporting, it might be possible to address the problem with greater flexibility—allowing commercial boats to bring fish into port in New Jersey, but tally their catch against North Carolina's quota. That idea will not sit well, however, with the N.C. coastal fish processing industry, which is relying on fresh catch. "As an industry organization, we want the biggest bang for the buck for our state," says Schill.

He maintains the problem is that authorities have not figured out how to manage a species that has rebuilt as strongly as the summer flounder. Schill says he hopes the fishing community across the Middle Atlantic can reach agreement on fluke without regulatory intervention.

Kennedy says that few relish the prospect of reallocation of the fluke quota, even if the fish has swum far from its historic habitat. "Whenever you change the allocation, it's never good for everyone," he says. "There are always winners and losers."

Even more daunting is the prospect of what will happen in the years ahead, when projections call for the North Atlantic to warm even more dramatically. Summer flounder's northward journey may not yet be at an end.

It's not surprising that the system set up long ago to manage the fishery, involving two separate regional stakeholder councils and seven states with differing interests, has difficulty addressing the fluke's geographic shift, says Kennedy. "It illustrates well the difficulties facing local authorities and stakeholder groups, representing a spectrum of priorities, when attempting to respond to large-scale environmental change."

</tail>Marianne Lavelle is a science reporter for the Daily Climate, a nonprofit news service covering energy, the environment and climate change. Follow her on Twitter @mlavelles (http://twitter.com/mlavelles).

On the web:

U.S. NOAA animation of shifting summer flounder distribution:

http://www.nefsc.noaa.gov/ecosys/climate_change/movie5-17.html

Senator MERKLEY. Thank you, Mr. Cohen.
Dr. South.

STATEMENT OF DAVID SOUTH, Ph.D., EMERITUS PROFESSOR, SCHOOL OF FORESTRY AND WILDLIFE SCIENCES, AUBURN UNIVERSITY

Mr. SOUTH. It is a privilege to provide you with my views of forest and wildfires. Foresters know that there are many examples of how human activity affects both the total number and size of wildfires. Policymakers who halt active forest management and kill green harvesting jobs really end up contributing to the build up of fuels in the forest. This eventually increases the risk of catastrophic wildfires.

To attribute this human caused increase to the fire risk, to carbon dioxide emissions is simply unscientific. In today's world of climate alarmism, accuracy really doesn't seem to matter. I am therefore not surprised to see many journalists spreading the idea that carbon emissions cause large wildfires. There is a well known point called the serenity prayer and it states: God, grant me the serenity to accept the things I cannot change, the courage to change the things I can, and the wisdom to know the difference. Now that I am 65, I realize that I can't change the behavior of the media, and I can't change the weather.

Early in my career, I gave up trying to change the media and make them correct their mistakes about forest management. Now I just concentrate on my colleagues, trying to get them to do a better job of sticking to the facts. I will leave the guesses of the future to others. Untrue claims about the underlying causes of wildfires can spread like wildfire. The false statement that wildfires in 2012 burned a record 9.2 million acres in the U.S. is cited in numerous articles and is found in more than 2,000 Web sites. But you can see by the looking at the graph that wildfires in the 1930s burned about four times that rate.

Wildfires in 2012 were certainly an issue of concern, but those who push an agenda really need to exaggerate the claims in order to fool the public. This graph shows carbon emission rising since 1926. If we cherry pick data from 1926 to 1970, we get a negative relationship between carbon dioxide and fire size. However, if we cherry pick data from 1985 to the current year, we get a positive relationship. Neither of these relationships proves anything about the effects of carbon dioxide on wildfires, since during dry season, human activity is the overwhelming factor that determines both the number and size of wildfires.

In the 48 States there have been about 10 extreme mega-fires. Eight of these fires occurred during cool decades. These data suggest that extremely large mega-fires were four times more common before 1940, back when carbon dioxide concentrations were less than 310 parts per million. It looks to me like we cannot reasonably say that man-made global warming causes extremely large wildfires.

Seven years ago, this committee conducted a hearing about climate change, and wildfires weren't even mentioned in that meeting, but hurricanes, droughts, were mentioned a number of times. I am pleased to provide you with my forestry views because unlike

hurricanes, droughts, and the polar vortex, we can actually promote forestry practices that will reduce the risk of wildfires. Unfortunately, some of our national forest management policies have in my view contributed to increasing the risk of wildfires.

I am certain that attempts to legislate a change in the concentration of carbon dioxide in the atmosphere will have no effect on reducing the size of wildfires or on the frequency of droughts. In contrast, allowing forest management practices to create economically lasting forestry jobs in the private sector might reduce the fuel loads of dense forests. In years when demand or renewable resources are high and increasing the number of thinnings and harvesting jobs might actually have a real impact on reducing wildfires.

Thank you for this opportunity to address the subcommittee.

[The prepared statement of Mr. South follows:]

Testimony of David B. South
Retired Emeritus Professor, Auburn University
Subcommittee on Green Jobs and the New Economy
3 June 2014

Human Activity, more so than Climate Change, Affects the Number and Size of Wildfires

I am David B. South, Emeritus Professor of Forestry, Auburn University. In 1999 I was awarded the Society of American Foresters' Barrington Moore Award for research in the area of biological science and the following year I was selected as Auburn University's "Distinguished Graduate Lecturer." In 1993 I received a Fulbright award to conduct tree seedling research at the University of Stellenbosch in South Africa and in 2002 I was a Canterbury Fellow at the University of Canterbury in New Zealand. My international travels have allowed me the opportunity to plant trees on six continents.

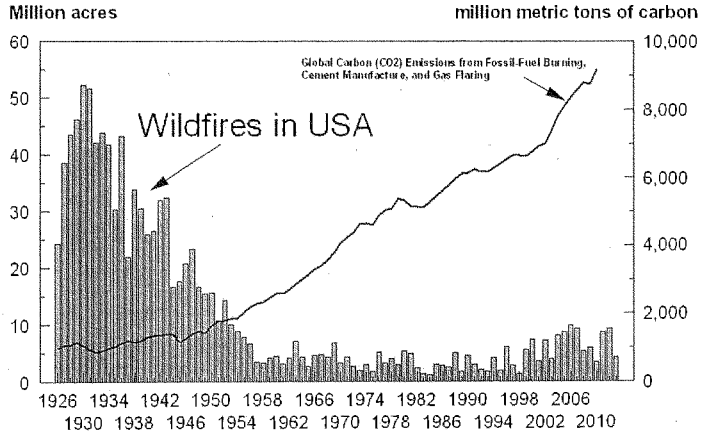
It is a privilege for me to provide some data and views on factors that affect forests and wildfires. Foresters know there are many examples of where human activity affects both the total number and size of wildfires. Policy makers who halt active forest management and kill "green" harvesting jobs in favor of a "hands-off" approach contribute to the buildup of fuels in the forest. This eventually increases the risk of catastrophic wildfires. To attribute this human-caused increase in fire risk to carbon dioxide emissions is simply unscientific. However, in today's world of climate alarmism, where accuracy doesn't matter, I am not at all surprised to see many journalists spreading the idea that carbon emissions cause large wildfires.

There is a well-known poem called the "Serenity prayer." It states "God, grant me the serenity to accept the things I cannot change, the courage to change the things I can, and wisdom to know the difference." Now that I am 63, I realize I can't change the behavior of the media and I can't change the weather. Early in my career I gave up trying to get the media to correct mistakes about forest management and to avoid exaggerations. I now concentrate on trying to get my colleagues to do a better job of sticking to facts; I leave guesses about the future to others.

Untrue claims about the underlying cause of wildfires can spread like "wildfire." For example, the false idea that "Wildfires in 2012 burned a record 9.2 million acres in the U.S." is cited in numerous articles and is found on more than 2,000 web sites across the internet. In truth, many foresters know that in 1930, wildfires burned more than 4 times that amount. Wildfire in 2012 was certainly an issue of concern, but did those who push an agenda really need to make exaggerated claims to fool the public?

Here is a graph showing a decreasing trend in wildfires from 1930 to 1970 and an increasing trend in global carbon emissions. If we "cherry pick" data from 1926 to 1970 we get a negative relationship between area burned and carbon dioxide. However, if we "cherry pick" data from 1985 to 2013 we get a positive relationship. Neither relationship proves anything about the effects of carbon dioxide on wildfires since, during dry seasons, human activity is the overwhelming factor that determines both the number and size of wildfires.

Figure 1.



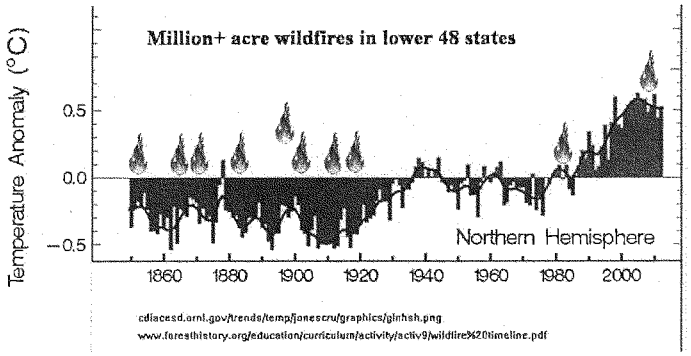
Source: 1960-2013 National Interagency Coordination Center
1926-1960; Dr. Stephen Pyne Bureau of the Census, Historical Statistics of the United States

http://cdiac.ornl.gov/ftp/ndp030/global.1751_2010.ems

In the lower 48 states there have been about ten "extreme megafires," which I define as burning more than 1 million acres. Eight of these occurred during cooler than average decades. These data suggest that extremely large megafires were 4-times more common before 1940 (back when carbon dioxide concentrations were lower than 310 ppmv). What these graphs suggest is that we cannot reasonably say that anthropogenic global warming causes extremely large wildfires.

Figure 2.

A 180-year history of wildfires in the USA (lower 48 states) indicates that eight "extreme megafires" (1million+ acres) occurred during decades that were cooler than average.



Seven years ago, this Committee conducted a hearing about "Examining climate change and the media" [Senate Hearing 109-1077]. During that hearing, concern was expressed over the weather, which was mentioned 17 times, hurricanes, which were mentioned 13 times, and droughts, which were mentioned 4 times. In the 41,000 word text of that hearing, wildfires (that occur every year) were not mentioned at all. I am pleased to discuss forestry practices because, unlike hurricanes, droughts, and the polar vortex, we can actually promote forestry practices that will reduce the risk of wildfires. Unfortunately, some of our national forest management policies have, in my view, contributed to increasing the risk of catastrophic wildfires.

In conclusion, I am certain that attempts to legislate a change in the concentration of carbon dioxide in the atmosphere will have no effect on reducing the size of wildfires or the frequency of droughts. In contrast, allowing active forest management to create economically-lasting forestry jobs in the private sector might reduce the fuel load of dense forests. In years when demand for renewable resources is high, increasing the number of thinning and harvesting jobs might have a real impact in reducing wildfires.

Thank you for this opportunity to address the Subcommittee.

Additional thoughts and data

A list of names and locations of 13 megafires in North America.

Year	Fire Name	Location	Lives lost	Acres burned
1825	Miramichi	New Brunswick- Maine	> 160	3 million
1845	Great Fire	Oregon	-	1.5 million
1868	Silverton	Oregon	-	1 million
1871	Peshtigo	Wisconsin-Michigan	>1,500	3.78 million
1881	Thumb	Michigan	>280	>2.4 million
1889	Feb-15-16	South Carolina	14	3 million
1902	Yacoult	Washington and Oregon	-	> 1 million
1910	Big Blowup	Idaho Montana	85	>3 million
1918	Cloquet-Moose Lake	Minnesota	450	1.2 million
1950	Chinchaga	British Columbia Alberta	-	3.5 million
1988	Yellowstone	Montana Idaho	-	1.58 million
2004	Taylor Complex	Alaska	-	1.3 million
2008	Lightning series	California	23	>1.5 million

Figure 3 is another timeline that was constructed by examining fire scars on trees from the Southwest (Swetnam and Baisan 1996). Fire suppression/prevention activities started having an effect at the end of the 19th century and this apparently reduced the wide-scale occurrence of wildfires in the Southwest. Both of these graphs show a decline in megafires after 1920. This tells me that humans affect both the size and cycle of wildfires to a much greater extent than does increasing levels of carbon dioxide in the atmosphere.

Figure 3.

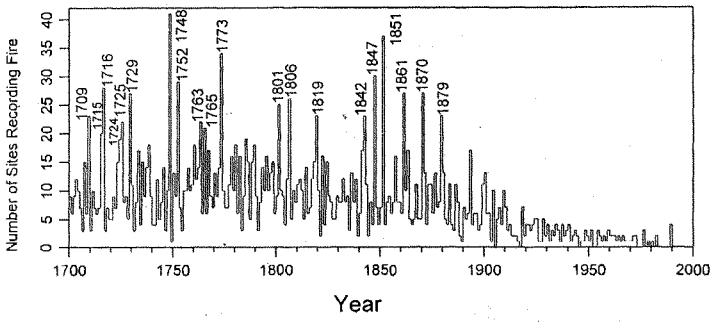


Figure 5. Regional fire occurrence time series from a network of 63 fire history sites in the Southwestern U.S. The largest 20 fire years are listed, based on the maximum numbers of sites recording these years.

http://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1085&context=barkbeetles

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The "most destructive fire" in history?

I must comment on the term "most destructive" when used in the context of wildfires. When I ask what "most destructive" actually means, I get several answers. In some articles, the number used (when there actually is a number) is calculated using nominal dollar amounts. Therefore, the rate of inflation is one factor (possibly the deciding factor) that causes fires to become more "destructive" over time. In other cases, the ranking just involves counting the number of structures burned. This takes inflation out of the equation, but it inserts urban sprawl into the equation. For example, "the number of housing units within half a mile of a national forest grew from 484,000 in 1940 to 1.8 million in 2000." Therefore, the increasing wealth of our nation (more building in fire-prone areas) can easily explain why wildfires have become "more destructive" over time. These facts are rarely mentioned by journalists who use the "most destructive" term when attributing the damage to "climate change." Scientifically, I say the term "most destructive" holds little meaning. For example, was the 1871 fire that killed over 1,500 people (possibly 2,400) and burned over 3.75 million acres the "most destructive" in US history? If not, why not?

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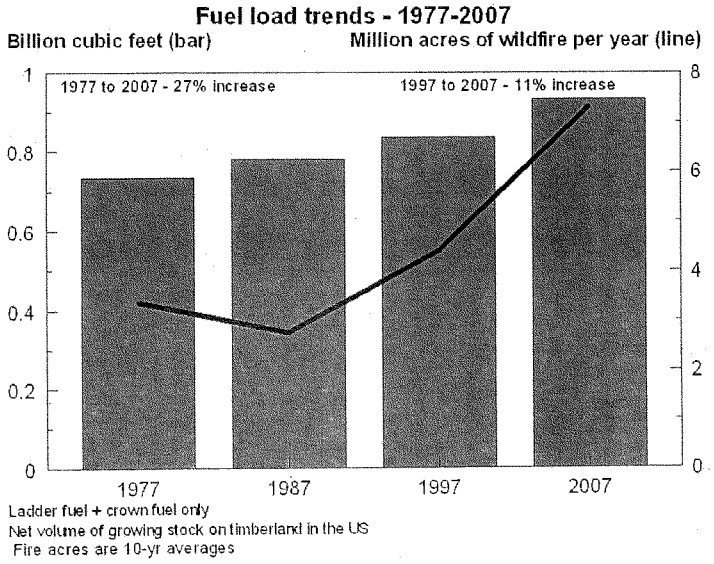
High fuel load = high wildfire danger?

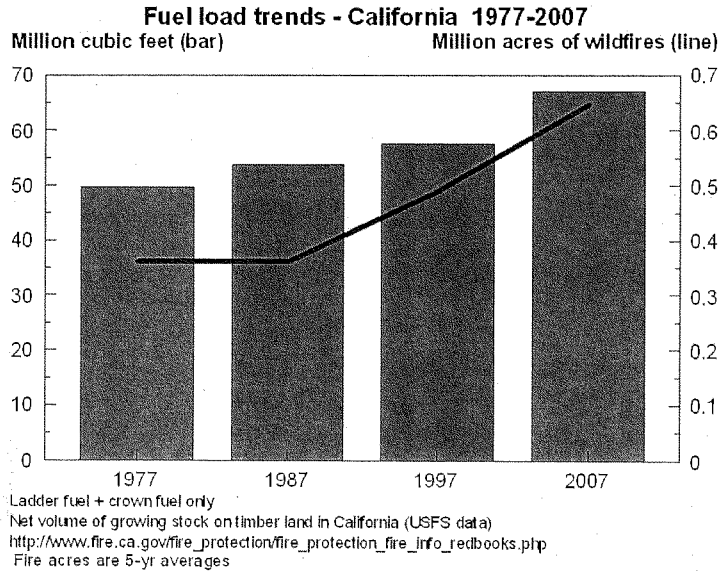
Fuel loading (or fuel volume) is reported as the amount of fuel available per acre. The higher the fuel loading, the more heat produced during a wildfire. Intense wildfires occur during dry seasons when winds are high and there is high fuel loading. The classification of fuels includes (1) surface, (2) ladder, and (3) crown fuels. The risk of wildfires since 1977 has increased on federal lands, in part, because of an increase in the "fuel load." This increase is due to tree growth plus a reduction in harvesting logs for wood products (see Figure 6). The evidence in the figure below indicates that as fuel loads on timberland increase, the area of wildfire increases.

Figure 4.



The theory that higher fuel loads cause an increase in wildfires (during dry seasons) is also supported by data from California. In just a decade, fuel loads increased on timber land by 16 percent while average wildfire size increased by 32 percent.

Figure 5.



In cases where policy allows, foresters can reduce the risk of destructive wildfires by reducing fuel loads. They can reduce ladder and crown fuels by harvesting trees and transporting the logs to a mill. This can be accomplished as final harvests, economic thinnings, firebreak thinnings and biomass thinnings (e.g. to make pellets). Surface fuels can be reduced by conducting prescribed burns (a.k.a. controlled burns). However, in the past policy has been determined by concerns expressed by journalists and activists who are against the cutting of trees. Many "preserve the forest" and "anti-forest management" policies end up increasing the risk of intense wildfires. For example, a number of climate experts recently (24 April 2014) signed a letter hoping to reduce the number of "green jobs" in North Carolina. These experts are apparently against the cutting of trees to produce wood pellets for export to the UK. They say that "a growing body of evidence suggests that trees rather than wood waste are the primary source of the wood pellets exported to the UK from the Southern US."

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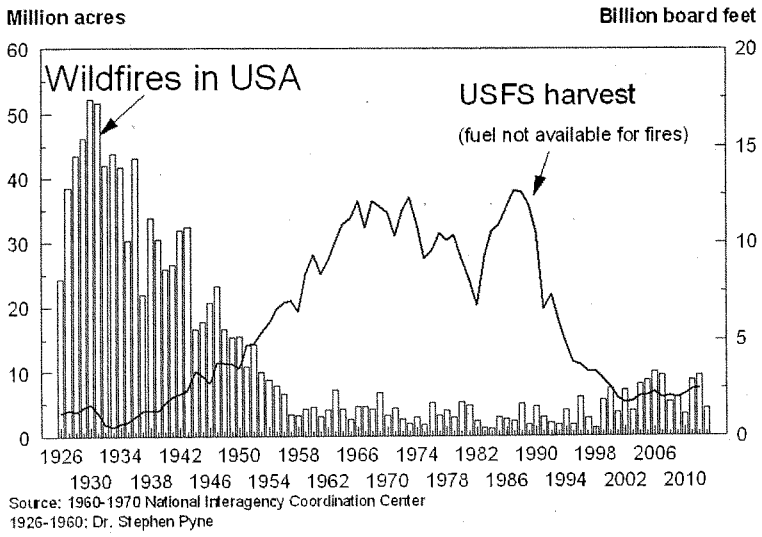
Would a return to harvesting 12 billion board feet per year reduce fuel loads on National Forests?

From about 1965 to 1990, the US Forest Service harvested about 12 billion board feet per year on National Forests. Removing this wood reduced the rate of increase in fuel loads on our National Forests. As a result, the wood volume on timber land in the West changed very little between 1977 (346.7 billion cubic feet) and 1987 (347 billion cubic feet). In contrast, wood volume over the next 10-years increased by 5 percent. Obviously stopping the harvesting of trees has increased wildfire risk in National Forests (due to increasing average wood biomass and fuel loads).

Figure 6.



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Correlation does not prove causation

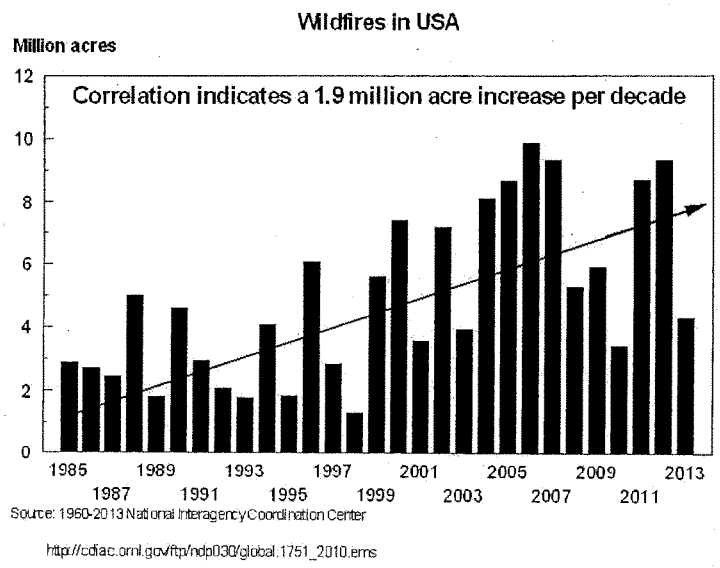
I assume most Senators (and even some journalists) know that finding a "significant" trend does not prove causation (http://www.latimes.com/business/hiltzik/la-fi-mh-see-correlation-is-not-causation-20140512-column.html). In fact, a low occurrence of large megafires over the past 90

years does not prove that droughts were more common before 1950. Actual weather records or analysis of tree-rings can be used to document drought events.

Those committed to the scientific process know that the cause behind the decline in megafires is not proved by a simple correlation. Although Figure 2 (above) indicates large megafires were more common in decades with cooler temperatures, this is certainly not proof of a relationship with temperature. In reality, human activity (e.g. effective fire suppression) is the real causation for a decline in million-acre wildfires.

Figure 7 is a graph of a short-term (i.e. 28 year) trend for wildfire size in the USA. When using data from 1985 to 2013, the trend suggests the total area burned increased by 1.9 million acres per decade. This type of correlation has been the driving force behind the current media frenzy.

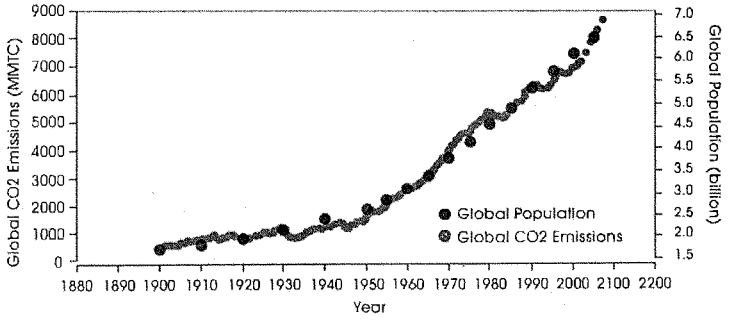
Figure 7.



Regarding a trend line similar to that in Figure 7, here is what one journalist wrote: "US wildfires have gotten much bigger over the past three decades. There's some variation from year to year, but the overall trend is upward. One recent study in *Geophysical Research Letters* found that wildfires in the western United States grew at a rate of 90,000 acres per year between 1984 and 2011. What's more, the authors found, the increase was statistically unlikely to be due to random chance."

In contrast, Figure 1 illustrates that, for the lower 48 states, the amount of wildfires ***declined*** at a rate of 400,000 acres per year between 1926 and 2013. This decline was also statistically "unlikely to be due to random chance" (i.e. 1 chance out of 10,000). [Note: The rate of decline from 1926 to 1956 was about 1.3 million acres per year]. I have never seen the print media publish a graph like Figure 1, even though similar ones are easy to find on the internet (http://www.fao.org/docrep/010/ai412e/ai412e09.jpg). They are either reluctant to inform the public about the history of wildfires, or they simply don't know the information is available. Either way, they might not realize a "statistically significant" relationship reported in their article does not mean the relationship has any real meaning.

Figure 8.



(Source: World Climate Report, 2008)

Here is an example of how the wrong conclusion can be made even with a "significant correlation." Let's assume that people cause wildfires and that more people cause more wildfires. We know that people cause carbon emissions and more people cause more carbon emissions (Figure 8). Journalists might assume that carbon emissions are causing more wildfires (due to a significant trend), but the driving force behind more wildfires is likely due to people causing more wildfires. Good scientists point out to the public all the various factors that might explain an increase in wildfires. In contrast, those with an agenda will tell the public only about the factors that support their agenda (or beliefs). They ignore scientists who warn readers that: "Due to complex interacting influences on fire regimes across the western U.S. and the relatively short period analyzed by this study, care must be exercised in directly attributing increases in fire activity to anthropogenic climate change."

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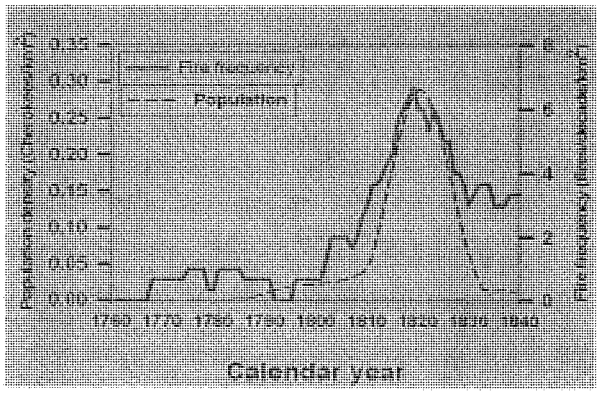
In reality, people affect both the size and number of wildfires

Unlike hurricanes, droughts and tornadoes, humans cause many wildfires. During the 19th century, Native Americans and European immigrants increased the number of wildfires. The following graph suggests the fires in the Boston Mountains of Arkansas were related to the population of Cherokee Indians (Guyette, Spetich and Stambaugh 2006).

Figure 9.



Guyette, Spetich and Stambaugh, 2006

In most places in the US, humans are the major cause of wildfires. In 2012, only about 5 percent of fires in California were caused by lightning. The Rim Fire (100 miles east of San Francisco) was ignited by a campfire in 2013 and was perhaps the third largest fire in California. Even so, some (who might be against cutting of trees to lower fuel levels) contend severe fire seasons are the result of prolonged drought combined with lightning. If this human-caused wildfire had not occurred, the amount of wildfires in California that year would have been reduced by 44%. Since one human fire can increase acres burned by over 250,000 acres, I say it is unscientific to attribute trends in wildfires to carbon dioxide levels without accounting for the various ways humans actually affect wildfires (e.g. arson, smoking, target practice, accidents, etc.).

Figure 10.

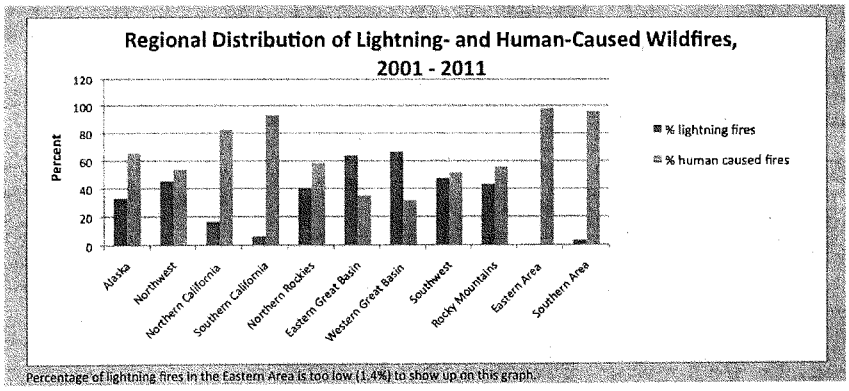
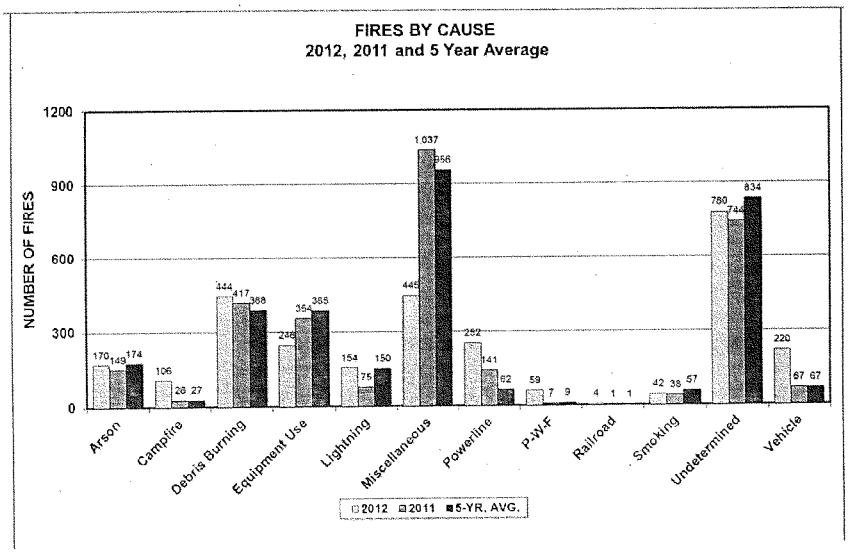


Figure 11.



In areas that are unpopulated, fire fighters can concentrate their limited resources on suppressing the fire. However, in areas where population growth has increased the density of houses, some crews are diverted to protecting property instead of attacking the fire. As a result, the relative size of the fire increases. The policy of allowing more homes to be built in fire-prone areas likely has increase the size of future fires (if more resources are devoted to protecting the homes). Randy Eardley (a spokesperson for the Bureau of Land Management) said that in the past, "it was rare that you would have to deal with fire and structures," "Nowadays, it's the opposite. It's rare to have a fire that doesn't involve structures." In fact, I was recently told that one of the primary reasons for increased burned acres is that - in the interest of firefighter safety, cost, and biotic benefits, "fire officers are more willing to back off" and let the wildfire burn out.

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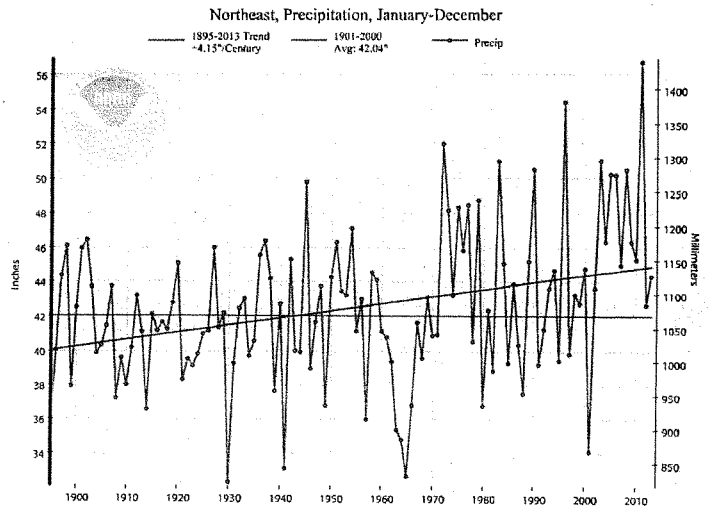
Some forests receive more rainfall now than 100 years ago

Examining historical weather data shows that some forests now receive more rainfall on average, than occurred a century ago. For example, precipitation in the Northeast has increased about 10%. Of course rainfall pattern is very important in the cycle of droughts, but one advantage of an increase in rainfall might be an increase in growth of trees. The following are trends in precipitation for various regions in the lower 48 states: Northeast +4.1" per century; Upper Midwest +2.8"; South +2.5"; Southeast +0.6"; Southwest -0.2"; West no change; Northern Rockies and Plains +0.5"; Northwest +0.7".

Figure 12.



In some places the extra rainfall might have resulted in a reduction in wildfires. For example, summer precipitation in British Columbia increased from 1920 to 2000. In one region the increase may have been over 45%. Authors of the study (Meyn et al. 2013) observed a

"significant decrease in province-wide area burned" and they said this decrease was "strongly related to increasing precipitation, more so than to changing temperature or drought severity." In some areas, a benefit of an increase in precipitation could be fewer wildfires.

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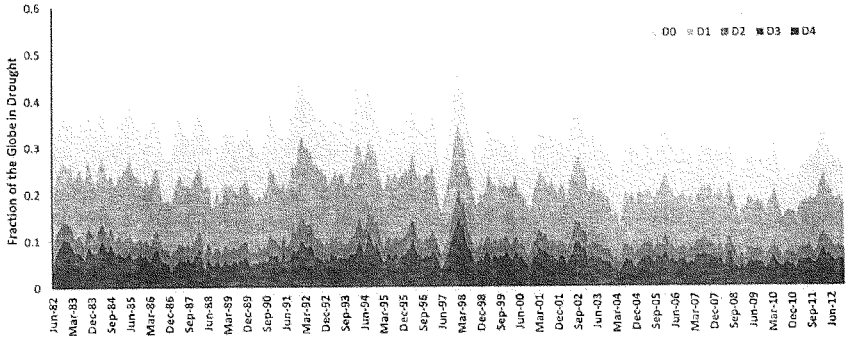
Some forests receive less rainfall now than 40 years ago

Drought increases the risk of wildfire. The extent of wildfires for any given year will depend on if a drought occurs that year. One should expect some variability in the occurrence of droughts, and we can document various drought cycles by using the NOAA web site "Climate at a Glance." We might also expect a single, large wildfire to burn more acres in a drought year than in a rainy year. Therefore, it is not surprising that total area burned is higher in drought years than in non-drought years.

As previously mentioned, some journalists are spreading the idea that carbon dioxide is causing more droughts. But if it were true, we should see droughts increasing globally (not just in one drought-prone region of the US). The following figure illustrates the global pattern of drought since 1982 and it clearly suggests that droughts globally have not gotten worse over the two decade timeframe (Hao et al. 2014). It appears that some journalists are not aware of this global pattern. Of course some might be aware of this pattern but it does not fit their narrative. As a result, they report that droughts for a specific location inereased during a decade.

Figure 13.



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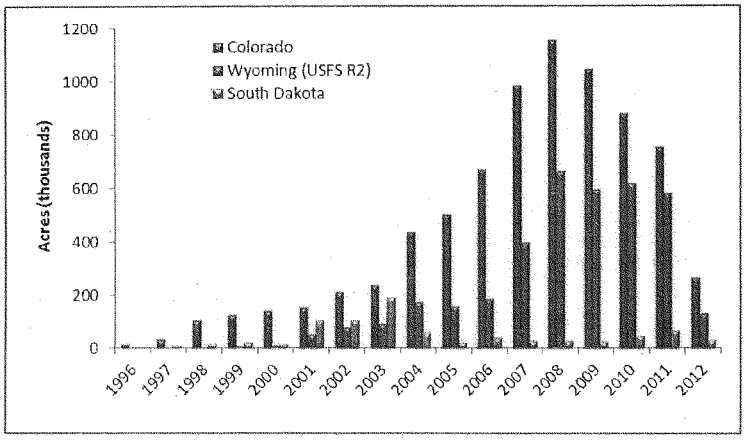
Risk of pine beetles increase on forests with no thinning

Pine beetles have killed millions of trees in Canada and in the United States. Foresters and entomologists know that pine beetle outbreaks are cyclical in nature. When pine trees are under stress, they attract pine beetles. Trees undergo stress when they are too close together (i.e. too dense) and things get worse when there is a drought. Once conditions are right, the beetles thrive in stressed trees and the progeny attack more trees and the domino effect begins. Foresters and ecologists know that pine beetle cycles have occurred naturally over thousands of years.

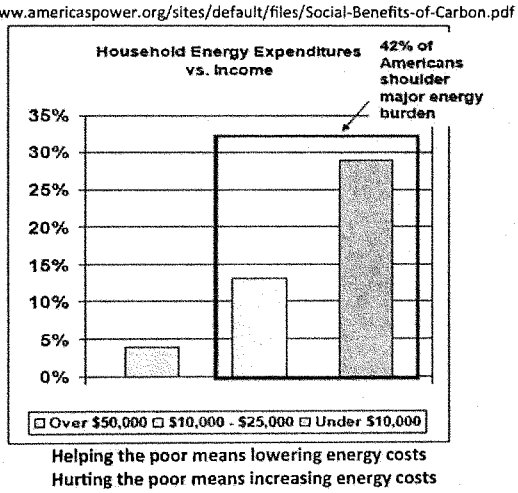
Figure 14.



One factor that increases the risk of a beetle outbreak are policies that do not permit the thinning of trees. State and national forestry organizations know the risk of a beetle outbreak is higher in counties occupied by National Forests. For example, in Texas, the US Forest Service says that "Very little suppression took place during the last outbreak. A majority of those treatments were designed to protect RCW habitat as mandated by the Endangered Species act. SPB were left alone in most of the wilderness and killed large acreages." In contrast, some "environmental" groups object to beetle suppression methods that involve cutting trees in wilderness areas. As a result, thinning operations are delayed, beetle attack stressed trees, and then large populations of beetles spread to adjacent privately-owned forests. After the trees die, the risk of wildfire increases. Wildfires start (due to carelessness or accidents or arson) and large expenditures are made to put the fire out. Journalists then report that carbon dioxide caused the inferno. The public concern over wildfires might cause some in Washington to want to increase the cost of energy. For example, this month my electrical cooperative sent me an e-mail suggesting that new EPA regulations could increase my bill by 50%. Of course we know that increasing the cost of energy will hurt the poor more than the wealthy.

Figure 15.

http://www.americaspower.org/sites/default/files/Social-Benefits-of-Carbon.pdf



Source: American Association of Blacks in Energy

Foresters tell the public that the best way to prevent a beetle outbreak is to thin the forest to will increase tree health. We also know that planting too many seedlings per acre will also increase the risk of beetles.
http://www.forestry.state.al.us/Publications/TREASURED_Forest_Magazine/2005%20Summer/How%20to%20Grow%20Beetle%20Bait%20-%20Revisited.pdfly-owned forests.

In contrast, the public also tells foresters how to manage beetle risks in wilderness areas. The following is just two pages of a seven-page document illustrating how much time and man-hours are wasted before operations to reduce the risk of pine beetles can precede in wilderness areas.

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Dr. South offers a bet on sea level rise for year 2024

In the past, I have had the good fortune to make a few bets with professors (http://www.aaes.auburn.edu/comm/pubs/highlightsonline/summer99/south.html). For example, I won a bet on the future price of oil and was successful in betting against Dr. Julian Simon on the price of sawtimber (i.e. he sent me a check a year after making the bet). Five years ago, I offered to bet on an "ice free" Arctic by the summer of 2013, but a BBC journalist [who wrote a 2007 article entitled "Arctic summers ice-free 'by 2013' "] and several ice experts declined my offer. To date, the number of bets I have made has been limited since I have a hard time finding individuals who are confident enough to make a wager on their predictions.

I would like to take this opportunity to offer another "global warming" bet. This time the outcome will be based on sea level data for Charleston, SC. Recently I was told that "If we do nothing to stop climate change, scientific models project that there is a real possibility of sea level increasing by as much as 4 feet by the end of this century."

At Charleston, the rate of increase in sea level has been about 3.15 mm per year. A four foot increase (over the next 86 years) could be achieved by rate of 14 mm per year. I am willing to bet $1,000 that the mean value (e.g. the 3.10 number for year 2012 in Figure 16) will not be greater than 7.0 mm/yr for the year 2024. I wonder, is anyone really convinced the sea will rise by four feet, and if so, will they take me up on my offer? Dr. Julian Simon said making bets was a good way to see who was serious about their beliefs and who is just "talking the talk."

Figure 16.

Annual change in sea level at Charleston, SC.

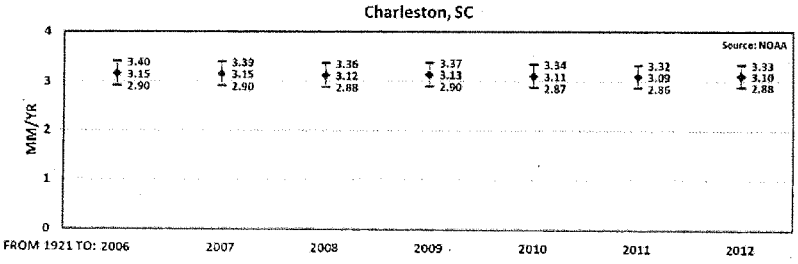
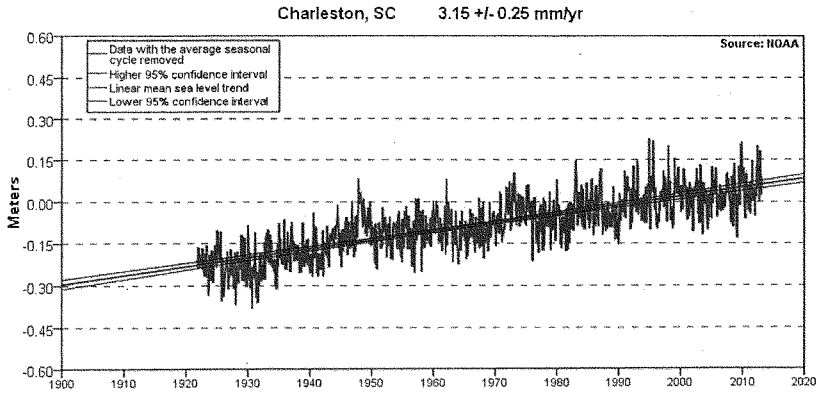


Figure 17.



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LETTERS

What If Our Guesses Are Wrong?

This old professor would like to comment on four "climate change" articles. A 1973 article entitled "Brace yourself for another ice age" (*Science Digest* 57:57–61) contained the following quote: "Man is doing these things... such as industrial pollution and deforestation that have effects on the environment." A 1975 article about "Weather and world food" (*Bulletin of the American Meteorological Society* 56:1078–1083) indicated the return of an ice age would decrease food production. The author said "there is an urgent need for a better understanding and utilization of information on weather variability and climate change..." Soon afterwards, Earle Layser wrote a paper about "Forests and climate" (*Journal of Forestry* 78:678–682). The following is an excerpt from his 1980 paper: "One degree [F] may hardly seem significant, but this small change has reduced the growing season in middle latitudes by two weeks, created severe ice conditions in the Arctic, caused midsummer frosts to return to the upper midwestern United States, altered rainfall patterns, and in the winter of 1971–1972 suddenly increased the snow and ice cover of the northern hemisphere by about 13 percent, to levels where it has since remained" (Bryson 1974). Spurr (1953) attributed significant changes in the forest composition in New England to mean temperature changes of as little as 2 degrees. Generally, the immediate effects of climatic change are the most striking near the edge of the Arctic (Sutcliffe 1969, p. 167) where such things as the period of time ports are ice-free are readily apparent. However, other examples cited in this article show that subtle but important effects occur over broad areas, particularly in ecotonal situations such as the northern and southern limits of the boreal forest or along the periphery of a species' range.

Among these papers, Layser's paper has been cited more often (> 20 times), but for some reason, it has been ignored by several authors (e.g., it has not been cited in any *Journal of Forestry* papers). Perhaps it is fortunate that extension personnel did not choose to believe the guesses about a coming ice age. If they had chosen this "opportunity for outreach," landowners might have been advised to plant locally adapted genotypes further South (to lessen the impending threat to healthy forests). Since the cooling trend ended, such a recommendation would have likely reduced economic returns for the landowner.

A fourth article was about "state service foresters' attitudes toward using climate and weather information" (*Journal of Forestry* 112:9–14). The authors refer to guesses about the future as "climate information" and, in just a few cases, they confuse the reader by mixing the terms "climate" and "weather." For example, a forecast that next winter will be colder than the 30-year average is not an example of a "seasonal climate forecast." Such a guess is actually a "weather forecast" (like the ones available from www.almanac.com/weather/longrange). Everyone should know that the World Meteorological Organization defines a "climate normal" as an average of 30 years of weather data (e.g., 1961–1990). A 3-month or 10-year guess about future rainfall patterns is too short a period to qualify as a "future climate condition." Therefore, young foresters (<50 years old) are not able to answer the question "have you noticed a change in the climate" since they have only experienced one climate cycle. They can answer the question "have you noticed a change in the weather over your lifetime?" However, 70-year-olds can answer the question since they can compare two 30-year periods (assuming they still have a good memory).

Flawed computer models have overestimated (1) the moon's average temperature, (2) the rate of global warming since the turn of the century, (3) the rate of melting of Arctic sea ice, (4) the number of major Atlantic hurricanes for 2013, (5) the average February 2014 temperature in Wisconsin (−13.6° C), etc. Therefore, some state service foresters may be skeptical of modelers who predict an increase in trapped heat and then, a few years later, attempt to explain away the "missing heat." Overestimations might explain why only 34 out of 69 surveyed foresters said they were interested in "long-range climate outlooks." Some of us retired foresters remember that cooling predictions made during the 1970s were wrong. Even "intermediate-term" forecasts for atmospheric methane (made a few years ago with the aid of superfast computers) were wrong. Therefore, I am willing to bet money that the "long-range outlooks of climate suitability" for red oak will not decline by the amount predicted (i.e., tinyurl.com/kykschq). I do wonder why 37 foresters (out of 69 surveyed) would desire such guesses if outreach professionals are not willing to bet money on these predictions.

I know several dedicated outreach personnel who strive to provide the public with facts regarding silviculture (e.g., on most sites, loblolly pine seedlings should be planted in a deep hole with the root collar 13–15 cm belowground). However, if "right-thinking" outreach personnel try to convince landowners to alter their forest management based on flawed climate models, then I fear public support for forestry extension might decline. I wonder, will the public trust us if we don't know the difference between "climate" and "weather," won't distinguish between facts and guesses, and won't bet money on species suitability predictions for the year 2050?

David B. South
Pickens, SC

Unsafe Practices

On the cover of the January 2014 issue, I see at least a baker's dozen foresters and loggers standing in the woods and not a single hardhat is in sight.

We often hear how we should be mentoring young people and new foresters. I don't believe unsafe practices should be championed on the cover of American forestry's principal publication.

Douglas G. Turner
Newtown, PA

Professional paper

Some basic questions about climate models

David B. South, Peter Brown and Bill Dyck[1]

Some foresters are concerned about increasing CO_2 levels in the atmosphere while others doubt that CO_2 has been the main driver of climate change over the past million years or over the past two centuries (Brown *et al.* 2008). We three admit that (1) we do not know what the future climate will be in the year 2100, (2) we do not pretend to know the strength of individual feedback factors, (3) we do not know how much 600 ppm of CO_2 will warm the Earth and (4) we do not know how the climate will affect the price of pine sawlogs in the year 2050 (in either relative or absolute terms). The climate is not a simple system and therefore we believe it is important to ask questions. The following 15 questions deal mainly with global climate models (GCM).

A LIST OF QUESTIONS

1: Have any of the climate models been verified?

Relying on an unverified computer model can be costly. NASA relies on computer models when sending rockets to Mars and the model is verified when the landing is successful. However, when using one unverified computer model, a $125 million Mars Climate Orbiter crashed on September 23, 1999. The model was developed by one team of researchers using English units while another used metric units. This crash demonstrates how costly an unverified computer model can be to taxpayers. At the time, Edward Weiler, NASA's Associate Administrator for Space Science said "People sometimes make errors".

Is it possible that people sometimes make errors when developing complex models that simulate the Earth's climate? Is it possible that some models might have "cause and effect" wrong in the case of feedback from clouds? Is it possible to construct models that produce precise (but inaccurate) estimates of temperature in the future? Do some researchers believe in computer predictions more than real data?

A report by the International Panel on Climate Change (IPCC) shows a predicted "hot zone" in the troposphere about 10 km above the surface of the equator (IPCC 2007b; Figure 9.1f). Why has this "hot zone" not been observed? We do not know of any paper that reports the presence of this, theoretical, hot spot. Is the absence of this hot zone (Douglass *et al.* 2007) sufficient to invalidate the climate models? If not, why not?

IPCC figure TS.26 includes computer projections of four CO_2 emission scenarios for the years 2000 to 2025 (IPCC 2007a). Figure 1 is an updated version with extra data points. The mean of the projections for global temperatures are jagged, suggesting that for some years the temperature is predicted to increase (e.g. 2007) while in others the temperature is predicted to decline slightly (e.g. 2008). However, observed data for 2006, 2007 and 2008 all fall below the projections. Although several models suggest the temperature for 2008 should be about 0.59 °C above the 1961-1990 mean, the value in 2008 was 0.328°C (are all three digits past the decimal point significant?). Although we should not expect any given year to lie on the line, this value is outside the range of "uncertainty" listed for green, red and blue lines and is almost outside the uncertainty range for the orange line. If the observed data falls outside the range of uncertainty for eight years into the future, why should foresters be "believe" the models will be accurate (ie. lie within the uncertainty bar) 100 years into the future? At what point do we admit the Earth's climate is not tracking with the "virtual" climate inside a computer? Is the theoretical "hot spot" above the equator a result of programming error? More importantly, how much money are foresters willing to spend on the output of unverified computer models?

2: Is it possible to validate climate models?

"Verification and validation of numerical models of natural systems is impossible. This is because natural systems are never closed and because model results are always non-unique. Models can be confirmed by the demonstration of agreement between observation and prediction, but confirmation is inherently partial. Complete confirmation is logically precluded by the fallacy of affirming the consequent and by incomplete access to natural phenomena. Models can only be evaluated in relative terms, and their predictive value is always open to question. The primary value of models is heuristic". (Oreskes *et al.* 1994).

3: How accurate are the predictions of climate models?

Australian Bureau of Meteorology uses computer models to project weather outlook for three months into the future. The Bureau's web page states that "These outlooks should be used as a tool in risk management and decision making. The benefits accrue from long-term use, say over ten years. At any given time, the probabilities may seem inaccurate, but taken over several years, the advantages of taking

[1]*David South is a Forestry Professor at Auburn University, Bill Dyck is a Science and Technology Broker who has worked for the plantation forest industry and Peter Brown is a Registered Forestry Consultant. The authors' statements should not be taken as representing views of their employers or the NZIF. Full citations may be found at: https://fp.auburn.edu/sfws/south/citations.html*

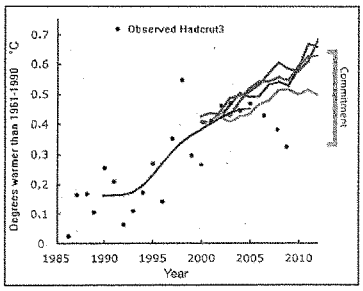

Figure 1. A comparison of observed surface temperature means (Hadcrut3) with model projections of Hadcrut3 global averages (adapted from Figure TS.26 in IPCC technical summary - page 69). Observed annual mean temperatures are shown (black dots) along with decadal averages (1990-2005 line). Multi-model mean projections (2000-2013 lines) from the IPCC (2007a) report for the SRES B1, A1B and A2 scenarios (top three lines) and a "commitment" scenario. The orange "commitment" curve shows means of 16 model projections of warming if greenhouse gas and aerosol concentrations were held constant from the year 2000. The uncertainty range indicated against the right-hand axis is for the "commitment" scenario only. Observed values for 2006, 2007 and 2008 are all below the "commitment" line and the observed value for 2008 might lie below the uncertainty range.

account of the risks should outweigh the disadvantages." Is this statement simply a hope or is it supportable by data? These computer model predictions can be compared with actual temperature data over a ten year period. The results could illustrate if farmers (who invest money based on the predictions) have benefited from the models or have they suffered from use of the models. The difference can provide evidence to illustrate if the 3-month forecasts are any better than flipping a coin. One reason why many farmers do not use these 3-month forecasts is because in some areas, the models are no better than a random guess.

Some claim it is more difficult to predict weather three months into the future than it is to predict the climate 100 years into the future. We question this belief system. What is the record of predicting climate 100 years into the future? Which of the 23 climate models is the most accurate when predicting past events? Is a complex computer program that predicts the average temperature for NZ in the past more accurate than one that predicts the average temperature for the Earth 100 years from now? Which prediction would be more accurate (determined by predicted minus actual °C)? Which set of comparisons has the greater standard deviation?

We know that climate models can vary widely in their guesses about how much rain a specific region on Earth might receive (Singer 2008). So how accurate are climate models when predicting the past? When models predict precipitation for a given location, we can compare the prediction with actual records. For example, Lim and Roderick (2009) provided predictions of annual precipitation for the last three decades of the 20th Century. Examination of the output from 39 computer scenarios reveals that predictions of NZ annual precipitation (Figure 2) ranged from 936 mm to 1851mm/yr (mean of 1293 mm; standard deviation was 226 mm). The recorded mean rainfall/precipitation of 29 AWIS stations (located mostly at towns or cities) for the years 1971-2000 was 1419 mm, but the mean of 27 AWIS stations (not including Milford Sound and Mount Cook) was 1115 mm. Neither value represents the actual mean precipitation value for NZ, in fact we do not know of an accurate estimate. One cannot take 268,680 km² and multiply it by some number (say 1.3 m) to determine the mass of water that fell on NZ in 1999. Of the 39 computer estimates of past NZ precipitation, how can we identify the one that is closest to the actual value for NZ if we cannot even determine the actual value?

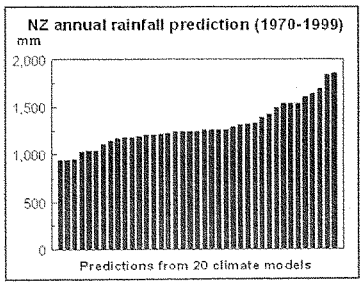

Figure 2. A comparison of predicted rainfall from 20 climate models (adapted from Lim and Roderick 2009). There are 39 output scenarios (bars) with some climate models producing seven estimates and some with only one estimate. Nobody knows the mass of precipitation that fell on NZ during the 30 year period and therefore we do not know which computer simulation is closest to the actual value for average rainfall in NZ.

4: Most climate models have clouds as a positive feedback mechanism. If clouds actually produce a negative feedback, then CO_2 caused global warming is a non-issue (i.e. warming over then next 100 years might be 0.5 °C). Do climate models have clouds modelled correctly?

"All 23 IPCC climate models now exhibit positive cloud and water vapour feedback" (Roy Spencer, personal

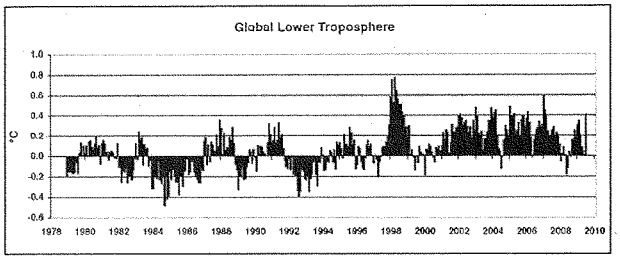

Figure 4. Globally averaged satellite-based temperature of the lower atmosphere (where zero = 20 year average from 1979 to 1998). February, 1998 was 0.76 °C above the 20-year average. Data provided by Professors John Christy and Roy Spencer, University of Alabama, Huntsville.

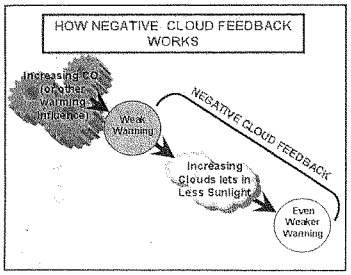

Figure 3 A negative cloud feedback would increase the Earth's albedo (figure provided by Dr. Roy Spencer).

communication). Most climate modellers assume that weak warming will decrease the amount of clouds which reduces the albedo of the Earth. A lower albedo (ie. less cloud cover) results in more warming.

In contrast, Spencer and Braswell (2008) suggest that clouds likely produce a negative feedback. Weak warming seems to increase the amount of clouds which increases the albedo of the Earth (Figure 3). If increases in CO_2 results in more clouds, this will invalidate most climate models. Roy Spencer said that "if feedbacks are indeed negative, then manmade global warming becomes, for all practical purposes, a non-issue." What real-world data prove that increasing CO_2 will result in fewer clouds?

In 1988 Steven Schneider said "Clouds are an important factor about which little is known" (Revkin 1988). "When I first started looking at this in 1972, we didn't know much about the feedback from clouds. We don't know any more now than we did then."

Did climate models have the feedback from clouds correct in 1988? Is the feedback from clouds any different now than it was three decades ago? Does the magnetic activity of the sun affect cosmic rays and the formation of clouds (Svensmark and Calder 2007)? Do climate modellers include cosmic rays in their models? Do climate modellers really believe their 2009 models have the formation of clouds correct in their models?

5: Can we estimate how much of the +0.76°C temperature departure recorded in February 1998 (Figure 4) can be attributed to El Niño and how much can be attributed to the CO_2 that originates from burning of fossil fuels?

Steven Schneider (Revkin 1988) said "To begin with, the magnitude of the various perturbations (to use the scientists' delicate word) of the environment are difficult to predict. And estimates of even the immediate effects of those perturbations are unreliable. Still harder to predict are the ground-level consequences of these effects - for example, the number of feet by which sea level will rise given a particular rise in the temperature of the globe, or the effects on phytoplankton of a particular increase in ultraviolet radiation caused by a particular reduction in the ozone layer. Harder yet to predict - lying, really, entirely in the realm of speculation - are the synergistic consequences of all or some of these effects. And lying completely beyond prediction are any effects that have not yet been anticipated."

"For all these reasons, the margin for error is immense. And that, of course, is the real lesson to be learned from the world's earlier attempts at predicting global perils. What the mistakes show is that in these questions even the most disinterested and professional predictions are filled with uncertainty. Uncertainty in such forecasts is not a detail, soon to be cleared up; it is part and parcel of the new situation - as inextricably bound up with it as mounting levels of carbon dioxide or declining levels of ozone. For

the scientists' difficulties do not stem merely from some imperfections in their instruments or a few distortions in their computer models; they stem from the fundamental fact that at this particular moment in history mankind has gained the power to intervene in drastic and fateful ways in a mechanism - the ecosphere - whose overall structure and workings we have barely begun to grasp."

6: How did the IPCC determine that it is extremely unlikely that warming in the past 50 years was caused by natural fluctuations?

Table 9.4 in WG1 (page 792; IPCC 2007b) provides a synthesis of "climate change detection results." Regarding surface temperature, the authors state that it is extremely likely (>95%) that "warming during the past half century cannot be explained without external radiative forcing." We wonder, exactly what does this statement mean? Are the authors simply predicting that researchers (e.g. Svensmark and Calder 2007; Spencer and Braswell 2008; Klotzbach *et al.* 2009) will never publish papers to suggest that natural variation in clouds could explain the warming?

We agree that humans have altered surface temperatures by construction of roads and cities, afforestation, producing black carbon (i.e. soot), burning of fuel (which releases heat and water vapour). We have no doubt that temperatures records are biased upwards because of "heat islands" and because thermometers are often located in improper locations (Klotzbach *et al.* 2009). However, it is not clear how the ">95% likelihood" value was obtained. Was it obtained from "an elicitation of expert views" (IPCC 2005) or from a quantitative analysis of output from climate models (Tett *et al.* 1999)?

7: What system was sampled when declaring an anthropogenic change has been detected with less than 1% probability?

In 2001, the IPCC panel concluded that "most of the observed warming over the last 50 years is likely due to increases in greenhouse gas concentrations due to human activities." In 2007, the IPCC authors go on to say that "Anthropogenic change has been detected in surface temperature with very high significance levels (less than 1% error probability)"(IPCC 2007b). We wonder how the authors went about calculating a p-value of <1% if there is confounding between CO_2 increases and natural changes in clouds? We asked a few IPCC experts, they said the p-value was obtained by generating a data set from a computer model. In other words, you create a virtual world without people, generate hypothetical temperatures from the virtual world, compare the two sets (virtual world with people and virtual world without people) and then generate a p-value.

In 2007, Dr. Bob Carter (Adjunct Professorial Research Fellow - James Cook University) wrote "In the present state of knowledge, no scientist can justify the statement: 'Most of the observed increase in globally averaged temperature since the mid-20th century is very likely due [90 per cent probable] to the observed increase in anthropogenic greenhouse gas concentrations,' as stated in the IPCC's 2007 Summary for Policy Makers." We agree with Dr. Carter. We assume that virtual worlds were sampled to determine the 1% probability. We claim that the 1% probability was applied to output from climate models and not to replications made from the real world.

8. One climate model suggests that increasing the albedo of the Earth's surface from deforestation is stronger than the CO_2 effect from deforestation. Would harvesting native forests in temperate and boreal zones (plus making wood furniture and lumber from the harvested logs) and converting the land to pastureland cool the Earth?

After examining a virtual Earth, Bala *et al.* (2007) said "We find that global-scale deforestation has a net cooling influence on Earth's climate, because the warming carbon-cycle effects of deforestation are overwhelmed by the net cooling associated with changes in albedo and evapotranspiration." Has this climate model been verified? If an increase the albedo (from deforestation) is more powerful than the CO_2 effect (South 2008a), why are albedo credits (South and Laband 2008) not included in Climate Trading Schemes?

9. IPCC authors predict an increase in the number of record hot temperatures and that this will often cause a decline in the number of record cold temperatures. Are there data to support this claim? Is it true that an increase in record high temperatures will result in a decline in record low temperatures?

Solomon and others (IPCC 2007a) say that "linking a particular extreme event to a single, specific cause is problematic" and we concur. However, the authors go on to say that "An increase in the frequency of one extreme (e.g., the number of hot days) will often be accompanied by a decline in the opposite extreme (in this case the number of cold days such as frosts)." We do not know of a reference to support this claim. We question the claim that the probability of a record cold event in January or July is less now than it was in the 19th century. In fact, in 2009, six U.S. states set cold temperature records (115 year data) for the month of July (IA, IL, IN, OH, PA, WV). Why did these records occur if the probability of a cold July is less now than it was in 1893?

We also question the claim that "In some cases, it may be possible to estimate the anthropogenic contribution to such changes in the probability of occurrence of extremes." How is this possible? Other than simply guessing, we fail to see how a scientist could estimate an anthropogenic contribution to an increase in frequency of record cold/high

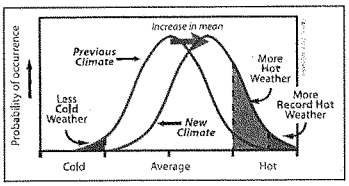

Figure 5. Schematic showing the IPCC view that little or no skew and kurtosis occurs when the mode shifts by +0.7 °C. The authors suggest the probability of extreme low temperatures decrease in proportion to the probability of high temperature (Figure 1, Box TS.5 from IPCC 2007a).

temperatures. Rare events do occur in nature. Researchers can certainly show a correlation, but how would they determine how much of the 0.76 °C departure in Figure 4 is anthropogenic? We "estimate" that 99% of this value is due to El Niño but we admit this estimate can not be verified.

Solomon, Qin, Manning and others suggest temperatures for a given region or for the Earth follow a "familiar 'bell' curve" and when the climate warms (for whatever reason), the entire distribution is shifted to the right (Figure 5). They suggest that a histogram of the pattern of temperature occurrences is similar for both the "previous climate"

Table 1. Dates of record high and low temperatures for some southern hemisphere locations (as of December 2008). Note that in these cases, the record low temperature occurred after the record high temperature. Although these records do not prove anything, they are not hypothetical. Note that no record high temperature occurred after 1975 and all record low temperatures but one occur after 1970.

Country/location	Record	°C	Date
Antarctica	High	14.6	5 January, 1974
	Low	-89.2	21 July, 1983
Argentina	High	48.9	11 December, 1905
	Low	-33	1 June, 1907
Australia	High	50.7	2 January, 1960
	Low	-23	29 June, 1994
New Zealand	High	42.4	7 February, 1973
	Low	-21.6	3 July, 1995
South Africa	High	50	3 November, 1918
	Low	-18.6	28 June, 1996
South America	High	49.1	2 January, 1920
	Low	-39	17 July, 1972

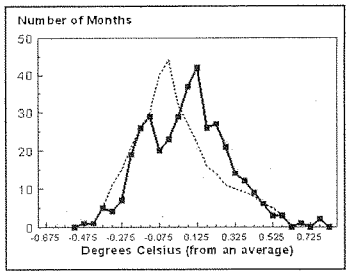

Figure 6. Histogram showing actual data (N = 367) from satellites over the period (December 1978 to June 2009). Each solid square represents the number of months that the temperature of the troposphere (above the southern hemisphere oceans) varied from an arbitrary mean value. Data (ie. solid squares) obtained from the Climate Center University of Alabama at Huntsville (http://www.ncdc.noaa.gov/oa/climate/research/uahncdc.lt). The dashed line represents a hypothetical distribution from a cooler period in the past. In this graph, the tails from both curves are deliberately identical. The hypothetical line was drawn so that the probability of extreme events is not changed.

and the "new" warmer climate. We propose an alternate hypothesis (Figure 6). The distribution is negatively skewed with the tails about the same as before. A third hypothesis suggests that the warmed distribution becomes negatively skewed and flatter (i.e. platykurkic). This hypothesis is supported by predictions of ocean temperatures by the Max Planck Institute (National Assessment Synthesis Team 2000; page 83). Are there any actual data to support the IPCC hypothesis that assumes no change in kurtosis or skewness?

In Table 1, we provide some extreme high and low temperatures for selected land based locations in the Southern Hemisphere. Note that for these locations, no record high temperature occurred after 1975 and all but one record low temperature occurred after 1970. The occurrence of extreme low temperatures following record high temperatures in the southern hemisphere is interesting, especially since this is counter to the "no change in skew or kurtosis" hypothesis. The theory presented in Figure 5 suggests a 0% probability of a record extreme cold event occurring after global warming.

We predict that one or more of the records in Table 1 will be broken by the year 2100. If Antarctica drops below -90 °C, someone might claim it was caused by humans (perhaps due to chemicals depleting the ozone layer). Likewise, if a record high temperature occurs in Australia or New Zealand, we will likely read that it was caused by humans. The experts

quoted might even take an unscientific approach and provide a probability in an attempt to prove the event was anthropogenic.

10. Solar irradiance that reaches the Earth's surface has declined since 1950. How much of reduction in irradiance is due to an increase in clouds and how much is due to an increase in pollution (i.e. soot and aerosols)?

"As the average global temperature increases, it is generally expected that the air will become drier and that evaporation from terrestrial water bodies will increase. Paradoxically, terrestrial observations over the past 50 years show the reverse" (Roderick and Farquhar 2002). How much of the "global dimming" (Stanhill 2005) is due to humans caused air pollution and how much is due to a negative feedback from clouds?

11. Why do some forest researchers use statistical downscaling approaches when the scenarios have largely been regarded as unreliable and too difficult to interpret?

Wilby and others (2004) have pointed out that some modellers combine coarse-scale (i.e. hundreds of kilometres), global climate models with higher spatial resolution, regional models sometimes having a resolution as fine as tens of kilometres. Most of the statistical downscaling approaches "are practiced by climatologists rather than by impact analysts undertaking fully fledged, policy oriented impact assessments. This is because the scenarios have largely been regarded as unreliable, too difficult to interpret, or do not embrace the range of uncertainties in GCM projections in the same way that simpler interpolation methods do. This means that downscaled scenarios based on single GCMs or emission scenarios, when translated into an impact study, can give the misleading impression of increased resolution equating to increased confidence in the projections" (Wilby *et al.* 2004).

12. When comparing similar locations and the same number of weather stations in NZ, has the average temperature changed much since 1860?

We agree that natural events affect the Earth's temperature (e.g. McLean *et al.* 2009). We also agree that human activities such as deforestation, afforestation, irrigation, road construction, city construction, etc. can alter the albedo of the Earth's surface. However, we are uncertain that average temperatures experienced in NZ during 1971 to 2000 are that much different than the temperatures experienced from 1861 to 1866 (Table 2). Why do temperatures records from Hokitika, NZ (since 1866) show no increase in temperature (Gray 2000)?

Predicted annual temperature changes (in °C) relative to 1980-1999 have been predicted for 12 climate models (Table A2.1 Ministry for the Environment. 2008). All 12 models predict an increase in temperature for NZ (for the period 2030 to 2049). A German model predicts only a 0.33 °C increase while a Japanese model predicts a 2 °C increase. In contrast, an older model (of unknown origin), predicts that NZ will be cooler in July 2029 than it was in July of 1987 (Revkin 1988). There are only about two decades to go before the year 2030, so it will be interesting to see which of the 13 models is closest to the observed data. When compared to 1987, will NZ be cooler in the winter of 2028 than most other locations in the world (Revkin 1988) or will it be about 2 °C warmer (e.g. miroc32 hires)?

13. Do outputs from climate models allow some researchers to selectively ignore real-world observations?

Farman *et al.* (1985) were the first to report a reduction

Table 2: A comparison of temperature data from five locations in New Zealand with predicted temperature in 2040. Pre-1868 data are from New Zealand Institute Transactions and Proceedings 1868 (http://tinyurl.com/7ycpl6) and post-1970 data are from National Institute of Water and Air Research (http://tinyurl.com/a5nj3c). Guesses for annual mean temperature for the year 2040 are in brackets (from Table 2.2 Ministry for the Environment. 2008). Table adapted from Vincent Gray.

Station	Years of data	Before 1867	Years of data	1971-2000	2040
		°C		°C	°C
Auckland	15	15.7	25	15.1	[16.0]
Taranaki - New Plymouth	12	13.7	20	13.6	[14.5]
Nelson	16	12.8	25	12.6	[13.5]
Christchurch	11	12.8	26	12.1	[13.0]
Dunedin	15	10.4	26	11.0	[11.9]
Mean		13.1		12.9	

in the Antarctic ozone hole. Some experts at first dismissed the observations of the British scientist since Farman's findings differed with predictions generated using NASA computer models (Schell 1989). This is not the only case where output from an unverified computer model was initially given more credence than actual observations. Recently, Svensmark and Calder (2007) provide data to propose a new theory of global warming. Have researchers relied on an unverified computer model to disprove a new theory of climate change (Pierce and Adams 2009)?

14. Do foresters rely on predicted timber prices that are generated from combining three complex computer models?

A climate model, a biogeochemistry model and an economics model were used to predict standing timber prices for the United States (Joyce *et al.* 2001). Prices were predicted to increase by 5 to 7% from 2000 to 2010 but no error bars were included the graph. In contrast, actual prices for standing sawlogs in 2009 are generally lower than they were in 2000 (in some cases 40% lower). Would any forestry consultant rely on 10-year price forecasts generated by combining three complex computer models? Do researchers actually believe they can determine what the price of standing timber would be in the year 2050 if CO_2 levels in the atmosphere were kept at 355 ppmv (Ireland *et al.* 2001)?

15. To capture the public imagination, should foresters offer up scary scenarios?

Stephen Schneider (Schell 1989) said "as scientists, we are ethically bound to the scientific method, in effect promising to tell the truth, the whole truth, and nothing but - which means that we must include all the doubts, the caveats, the ifs, ands, and buts. On the other hand, we are not just scientists but human beings as well. And like most people we'd like to see the world a better place, which in this context translates into our working to reduce the risk of potentially disastrous climatic change. To do that we need to get some broad-based support, to capture the public's imagination. That, of course, entails getting loads of media coverage. So we have to offer up scary scenarios, make simplified, dramatic statements, and make little mention of any doubts we might have. This 'double ethical bind' we frequently find ourselves in cannot be solved by any formula. Each of us has to decide what the right balance is between being effective and being honest. I hope that means being both."

Conclusions

We are concerned the scientific method is being downplayed in today's world. Hypothesis testing is an irreplaceable tool in science, but some no longer test hypothesis and others do not declare their doubts. Now, all that is needed to set policy is an unverified computer model, some warnings about the future, some name calling, and a good marketing program. Debate is essential to scientific progress, but it seems it is no longer in vogue. Sometimes, those who ask questions (like the 15 above) are ignored, suppressed, or attacked with name calling (e.g. see Witze 2006; Seymour and Gainor 2008; South 2008b).

Our profession should be a place where questions about computer models (either process based forestry models or three-dimensional climate models) are welcomed. Debate should be encouraged and hypotheses should be tested (not simply proposed). However, it now seems a number of researchers and foresters have accepted the hypothesis that CO_2 is the primary driver of a changing climate. Some ignore factors such as changes in cloud cover, changes in surface albedo (Gibbard *et al.* 2005), changes in cosmic rays, increases in soot (in air and on ice), and the Pacific Decadal Oscillation. Ignoring these factors appears to be driven by the idea that the Earth's complex climate system is relatively easy to control by planting more trees on temperate and boreal grasslands.

We hope our profession will rise above soothsaying and will encourage debate on topics and policies that affect our forests. As NZIF members, if we choose not to question authority, we might be accused of violating our code of ethics.

What if Climate Models are wrong?

People who trust IPCC climate projections (e.g. Figure 1) also believe that Earth's atmospheric Greenhouse Effect is a radiative phenomenon and that it is responsible for raising the average surface temperature by 33°C compared to an airless environment. According to IPCC Third Assessment Report (2001): "*For the Earth to radiate 235 watts per square meter, it should radiate at an effective emission temperature of -19°C with typical wavelengths in the infrared part of the spectrum. This is 33°C lower than the average temperature of 14°C at the Earth's surface.*" Mainstream climate science relies on a simple formula based on Stefan-Boltzmann (S-B) radiation law to calculate Earth's average temperature without an atmosphere (i.e. -19°C). This formula is also employed to predict Moon's average temperature at -20 C (253K) (e.g. NASA Planetary Fact Sheet). But is the magnitude of the atmospheric greenhouse effect really 33 C? What if the surface temperature of Earth without an atmosphere were much colder? What if the popular mean temperature estimate for the Moon were off by more than 50 C?

Although we cannot experimentally verify the -19 C temperature prediction for a hypothetical airless Earth, we could check if the predicted -20 C average temperature for the Moon is correct. After all, the Moon can be viewed as a natural grey-body equivalent of Earth, since it orbits at the same distance from the Sun and has virtually no atmosphere (the gas pressure at the lunar surface is only about 3×10^{-10} Pa). Recent data from the Diviner instrument aboard NASA's Lunar Reconnaissance Orbiter as well as results from detailed thermo-physical models (e.g. Vasavada et al. 1999, 2012) indicate that the Moon average surface temperature is actually -76 C (197.3K). Diviner measurements discussed by Vasavada et al. (2012) show that, even at the lunar equator (the warmest latitude on the Moon), the mean annual temperature is -60 C (213K) or 40 C *cooler* than the above theoretical global estimate. Why such a large discrepancy between observed and calculated lunar temperatures?

According to a new analysis by Volokin & ReLlez (2014), climate scientists have grossly overestimated Moon's average temperature and Earth's black body temperature for decades due to a mathematically incorrect application of the S-B law to a sphere. The current approach adopted by climate science equates the mean physical temperature of an airless planet (T_{gb}, K) with its effective emission temperature (T_e, K) calculated from the equation:

$$T_e = \left[\frac{S_o(1-\alpha_p)}{4\epsilon\sigma}\right]^{0.25} \qquad (1)$$

where S_o is the solar irradiance (W m^{-2}), i.e. the shortwave flux incident on a plane perpendicular to solar rays above the planet's atmosphere, α_p is the planet average shortwave albedo, ϵ is the surface thermal emissivity ($0.95 \leq \epsilon \leq 0.99$), and $\sigma = 5.6704\times10^{-8}$ W m^{-2} K^{-4} is the

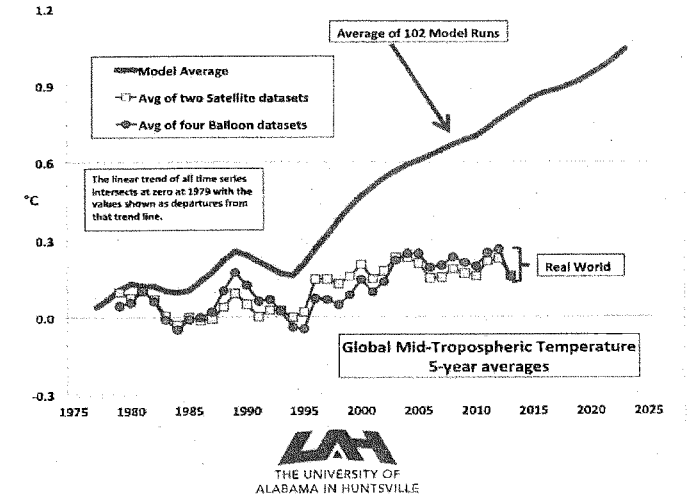

Figure 1. Model projections of global mid-tropospheric temperature (red line) compared to observed temperatures (blue and green lines). Figure courtesy of Dr. John Christy

S-B constant. The factor ¼ serves to re-distribute the solar flux from a flat surface to a sphere. It arises from the fact that the surface area of a sphere ($4\pi R^2$) is 4 times larger than the surface area of a flat disk (πR^2) with the same radius R. Inserting appropriate parameter values for Earth in Eq. (1), i.e. $S_o = 1361.7$ W m^{-2}, $\alpha_p = 0.305$, and $\epsilon = 1.0$, produces $T_e = 254.2$K (-19 C), which is the basis for the above IPCC statement. We note that the -20 C (253K) temperature estimate for the Moon is obtained from Eq. (1) using $\alpha_p = 0.305$, which is Earth's albedo that includes the effect of clouds and water vapor on shortwave reflectivity. However, the correct albedo value is the Moon 0.12 - 0.13, which yields ~270 K (- 3 C) for the Moon average temperature according to Eq. (1).

Equation (1) employs a spatially averaged absorbed solar flux to calculate a mean surface temperature. This implies a uniform distribution of the absorbed solar energy across the planet surface and a homogeneous temperature field. However, these assumptions are grossly inaccurate, because sunlight absorption on a spherical surface varies greatly with latitude and time of day resulting in a highly non-uniform distribution of surface temperatures. This fact along with the non-linear (4^{th} root) dependence of temperature on radiative flux according to S-B law creates a relationship known in mathematics as Hölder's inequality between integrals (e.g. Abualrub and Sulaiman 2009; Wikipedia: Hölder's inequality). Hölder's inequality applies to certain types of non-linear functions and states that, in such functions, the use of an arithmetic average for the independent distributed variable will *not* produce a physically

correct mean value for the dependent variable. In our case, due to a non-linear relationship between temperature and radiative flux and a strong dependence of the absorbed solar flux on latitude, one cannot correctly calculate the true mean temperature of a uni-directionally illuminated planet from the spatially averaged radiative flux as attempted in Eq. (1). Due to Hölder's inequality, the effective emission temperature produced by Eq. (1) will always be significantly higher than the physical mean temperature of an airless planet, i.e. $T_e \gg T_{gb}$.

Volokin & ReLlez (2014) showed that, in order to derive a correct formula for the mean physical temperature of a spherical body, one must *first* take the 4th root of the absorbed radiation at every point on the planet surface, and *then* average (integrate) the resulting temperature field rather than calculate a temperature from the spatially averaged solar flux as done in Eq. (1). Using proper spherical integration and accounting for the effect of regolith heat storage on nighttime temperatures, Volokin & ReLlez (2012) derived a new analytical formula for the mean surface temperature of airless planets, i.e.:

$$T_{gb} = \frac{2}{5}\left[\frac{S_o\,(1-\alpha_e)}{\epsilon\sigma}\right]^{0.25} \Phi(\eta_e) \qquad (2)$$

where $\Phi(\eta_e)$ is given by:

$$\Phi(\eta_e) = (1-\eta_e)^{0.25} + 0.931\,\eta_e{}^{0.25} \qquad (3)$$

Here, α_e is the effective shortwave albedo of the planet surface, η_e (eta) is the effective fraction of absorbed solar flux stored as heat in the regolith through conduction, and $\Phi(\eta_e) \geq 1.0$ is a dimensionless scaling factor that boosts the average global temperature above the level expected from a planet with zero thermal inertia, i.e. if the surface were completely non-conductive to heat. Thanks to $\eta_e > 0$ (non-zero storage of solar energy in the regolith), the night side of airless celestial bodies remains at a significantly higher temperature than expected from the cosmic microwave background radiation (CMBR) alone. This increases the mean global planetary temperature. The fraction of solar flux stored in regolith can theoretically vary in the range $0.0 \leq \eta_e \leq 1.0$. In reality, however, due to physical constrains imposed by the regolith thermal conductivity, this range is much narrower, i.e. $0.005 < \eta_e < 0.015$, which limits the temperature enhancement factor to $1.25 < \Phi(\eta_e) < 1.32$. According to Eq. (3), $\Phi(\eta_e)$ has a non-linear dependence on η_e - it increases for $0.0 \leq \eta_e \leq 0.5$ and decreases when $0.5 \leq \eta_e \leq 1.0$ reaching a maximum value of 1.627 at $\eta_e = 0.5$. However, since it is physically impossible for a planet's regolith to store on average as much as 50% of the absorbed solar flux as heat, $\Phi(\eta_e)$ cannot practically ever reach its theoretical maximum.

Independent thermo-physical calculations along lunar latitudes yielded $\eta_e = 0.00971$ for the Moon, hence $\Phi(\eta_e) = 1.29$ according to Eq. (3). Due to the lack of moisture and convective heat transport between soil particles in an airless environment, the apparent thermal conductivity of the regolith of celestial bodies without atmosphere is much lower than that on Erath resulting in values for η_e close to 0.01. Volokin & ReLlez (2014) showed that Eq. (2) quite accurately predicts Moon's true average surface temperature of 197.3 K (within 0.25 K) using observed and independently derived values for $S_o = 1361.7$ W m^{-2}, $\alpha_e = 0.13$, and

$\epsilon = 0.98$, and η_e. In general, Formula (2) is expected to be valid for any airless spherical body provided $S_o \geq 0.15$ W m^{-2}. If solar irradiance is lower than 0.15 W m^{-2}, then the relative contribution of CMBR to planet's temperature becomes significant and another, more elaborate formula for T_{gb} needs be used (see Volokin & ReLlez 2014).

Equation (2) demonstrates that T_{gb} is physically incompatible with T_e via the following comparison. Using $S_o = 1{,}361.7$, $\alpha_e = 0.13$ and $\epsilon = 0.98$ in Eq. (1) yields $T_e = 270.2$K for the Moon. This estimate is 21.5K *higher* than the *maximum* theoretically possible temperature $T_{gb} = 248.7$K produced by Eq. (2) using the same input parameters and a physically *unreachable* peak value of $\Phi(\eta) = 1.627$ corresponding to $\eta_e = 0.5$. Therefore, it is principally impossible for an airless planet to reach an average global temperature as high as its effective emission temperature! This renders T_e a pure mathematical construct rather than a measurable physical quantity implying that T_e is principally different from T_{gb} and should not be confused it.

Earth's atmospheric greenhouse effect (AGE) can be measured as a difference between the actual average global surface temperature (T_s) and the mean temperature of an equivalent grey body with no atmosphere orbiting at the same distance from the Sun such as the Moon. Adopting T_e as the grey-body's mean temperature, however, produces a meaningless result for AGE because a non-physical (immeasurable) temperature (T_e) is being compared to an actual physical temperature (T_s). Hence, the correct approach to estimating the magnitude of AGE is to take the difference between T_s and T_{gb}, i.e. two physical palatable temperatures. Using the current observed average global surface temperature of 14.4°C (287.6K) (NOAA National Climate Data Center: Global Surface Temperature Anomalies) and the above estimate of Earth's true gray-body mean temperature (i.e. Moon's actual temperature), we obtain AGE = 287.6 K – 197.3 K = 90.3 K. In other words, the greenhouse effect of our atmosphere is nearly 3 times larger than presently assumed! This raises the question: can so-called greenhouse gases, which collectively amount to less than 0.4% of the total atmospheric mass, trap enough radiant heat to boost Earth's average near-surface temperature by more than 90 K? Or is there another mechanism responsible for this sizable atmospheric thermal effect in the lower troposphere? Observations show that the lower troposphere emits on average 343 W m^{-2} of long-wave radiation towards the surface (e.g. Gupta et al. 1999; Pavlakis et al. 2003; Trenberth et al. 2009). Such a thermal flux is 44% *larger* than the global averaged solar flux absorbed by the *entire* Earth-atmosphere system (i.e. 238-239 W m^{-2}) (Lin et al. 2008; Trenberth et al. 2009). This fact implies that the lower troposphere contains more kinetic energy than can be accounted for by the solar input alone. Considering the negligible heat storage capacity of air, these measurements suggest the plausibility of an alternative non-radiative AGE mechanism. Consequently, if another major AGE mechanism existed that is not considered by the current climate science, what would this imply for the reliability and accuracy of climate-model projections based on the present radiative Greenhouse paradigm?

In closing, we concur with physicist and Nobel Prize laureate Richard Feynman, who said: "*It does not make any difference how beautiful your guess is, it does not make any difference how smart you are, who made the guess, or what his name is - if it disagrees with experiment, it is wrong! That is all there is to it.*" (1964 lecture at Cornell University).

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Questions from: Senator David Vitter

1. Needless to say I found your testimony pretty compelling. Recently, Majority Leader Harry Reid claimed that global warming was the cause of increased wildfires. In reviewing your testimony, not only was Majority Leader Reid wrong about wildfires increasing, he was also wrong about trying to make the insinuation that human caused C02 somehow contributes to wildfires. Can you share additional information about the inaccuracies of such claims? As well, can you share about how failures like this to speak precisely on the facts and what the science says undermines the public's understanding of the earth's climate?

Majority Leader Harry Reid and I are both concerned about the intensity of wildfires. We both agree that humans are responsible for most of the wildfires in the USA. I say that intensity is directly related to fuel loads (see my testimony). In contrast, Senator Reid apparently believes those who claim that the number and size of wildfires (from 1926 to 2013) is related to atmospheric carbon dioxide. I say to make such a claim is unscientific and detracts from discussing policies that could be helpful in reducing the severity of wildfires.

NUMBER OF WILDFIRES PER YEAR

In regards to the frequency of wildfires (since 1983, I agree with EPA. They say "The data do not show an obvious trend during this time."
http://www.epa.gov/climatechange/pdfs/print_wildfires-2014.pdf

I want to point out that counting the number of wildfires is not an exact science. The total number for a given year can vary by more than 40,000 (see EPA figure 1 in above pdf). The average size of wildfires also likely depends on if the number for a given year was 120,000 (USFS) or 70,000 (NIFC). If we can't agree on the number of wildfires, how can anyone say how many (of the extra 50,000 estimated by the USFS in the year 2011) were caused by extra carbon dioxide? I expect scientists will not attempt to answer this question since (1) the variability in the estimate for the number varies so widely; so many human-caused factors are confounded with year.

This year, 100 percent of the wildfires in Southwest Oregon were caused by humans (see table below). When compared to the previous 10-yrs, the number of wildfires started by smokers has increased by 43%, and the number caused by debris burning has increased by 71%. I would not at all be surprised if some lobby group says the increase in wildfires in Oregon is due to increases in carbon dioxide. By ignoring the facts, these groups lose credibility.

Southwest Oregon District

"STEWARDSHIP IN FORESTRY"

Statistical Fires For: Monday, June 30, 2014
Week Number: 26

	WEEKLY NUMBER OF FIRES BY SIZE CLASS							WEEKLY		YEAR TO-DATE					
								FIRES	ACRES	FIRES			ACRES BURNED		
CAUSE	A	B	C	D	E	F	G			2014	HISTORIC 2004-2013	%	2014	HISTORIC 2004-2013	%
Acres	<.26	.26-9.9	10-99.9	100-299.9	300-999.9	1000-4999.9	5000+								
01 LIGHTNING	0	0	0	0	0	0	0	0	0	0	22	0%	0	17	0%
02 RAILROAD	0	0	0	0	0	0	0	0	0	0	0		0	1	0%
03 EQUIPMENT USE	1	0	0	0	0	0	0	1	0.1	16	18	90%	25.61	124	21%
04 RECREATIONIST	1	0	0	0	0	0	0	1	0.25	8	8	100%	16.98	17	97%
05 SMOKER	0	0	0	0	0	0	0	0	0	5	4	143%	0.23	1	43%
06 DEBRIS BURNING	1	0	0	0	0	0	0	1	0.01	32	19	171%	159.58	31	511%
07 ARSON	0	0	0	0	0	0	0	0	0	2	2	87%	0.51	3	19%
08 JUVENILES	0	0	0	0	0	0	0	0	0	0	3	0%	0	2	0%
09 MISCELLANEOUS	1	0	0	0	0	0	0	1	0.1	13	10	127%	2.22	13	17%
Under Investigation	1	0	0	0	0	0	0	1	0.01	6			46.87		
TOTAL LIGHTNING	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*22*	*0%*	*0*	*17*	*0%*
TOTAL MAN CAUSED	*5*	*0*	*0*	*0*	*0*	*0*	*0*	*5*	*0.47*	*82*	*64*	*128%*	*252*	*192*	*131%*
GRAND TOTAL	*5*	*0*	*0*	*0*	*0*	*0*	*0*	*5*	*0.47*	*82*	*86*	*96%*	*252*	*209*	*120%*

NON STAT # OF FIRES	
WEEK	SEASON
0	8

% of fires 10 acres or less	95.1%

WEEK:	Total NFCA's =33
SEASON:	Total NFCA's = 130

Produced By:
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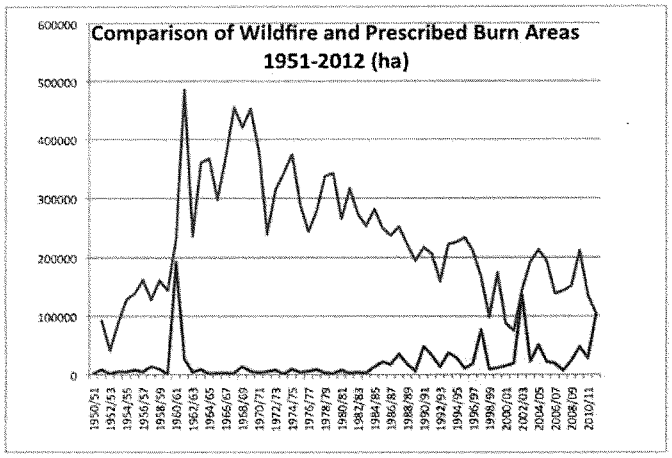
AREA OF WILDFIRES PER YEAR

In the USA, a majority (5.4 million acres) of wildfires in 2011 were caused by humans. The remaining 3.3 million acres were caused by lightning (and lava). The total for 2011 was 8.7 million acres which is about one-fifth to one-sixth the amount burned annually from 1930 to 1935 (see my testimony for a graph showing area burned from 1926 to 2013).

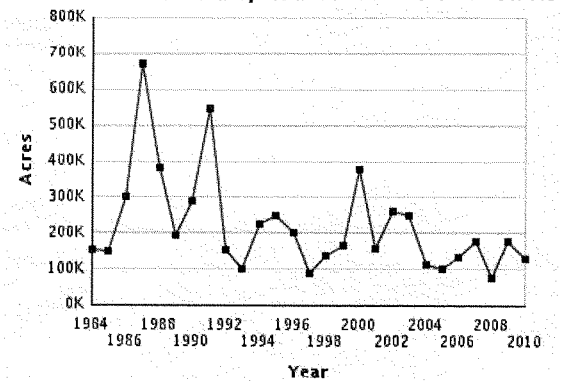
Here are three additional graphs, one from Australia, one from the Northern US and one for the state of Wisconsin. In these locations, the amount of area burned by wildfires has declined over time. For Australia, there was a rapid increase from 1951 to 1961 followed by a gradual decline. These graphs illustrate a decline in wildfires over time. The decrease in area burned coincides with an increase in global temperatures. They do not support a universal claim that carbon dioxide causes more wildfires. There is a reason why the public may not be generally aware of these graphs.

The green line shows the area of wildfires in Australia while the red line indicates the amount of prescribed burns.

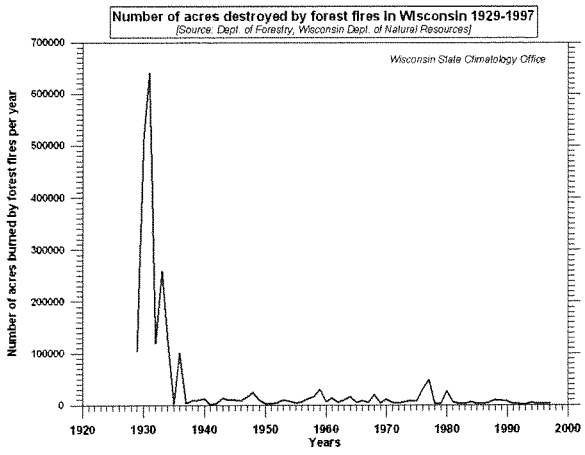


http://apps.fs.fed.us/fsiis/data.fetchContents.do?iId=7&mId=7.2

Amount of land burned by wildfire in 20 Northern States



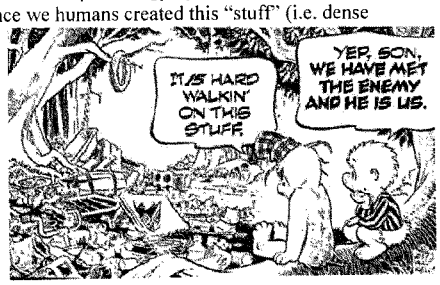
http://apps.fs.fed.us/fsiis/data.fetchContents.do?iId=7&mId=7.2



FAILURE TO SPEAK PRECISELY ON THE FACTS ABOUT HUMAN CAUSES OF WILDFIRES UNDERMINES THE PUBLIC'S UNDERSTANDING OF HOW TO REDUCE THE OCCURANCE AND SEVREITY OF WILDFIRES

I agree with Congressman Doc Hastings (WA-04) who said *"There will always be drought, there will always be heat spells, and there will always be fire that is out of our control". "While our hearts are with the families and communities affected by wildfire and those who put themselves in harm's way to protect us from it, an ounce of prevention is worth a pound of cure, and what must be cured are the overgrown and unhealthy forests that are in many cases providing the fuel for these fires."*

The primary reason why we are experiencing severe wildfires is because we have adopted national forest policies that allow the buildup of fuel loads (see this link for more testimony on a House hearing on "wildfire and forest management" -- http://www.gpo.gov/fdsys/pkg/CHRG-113hhrg81897/pdf/CHRG-113hhrg81897.pdf). Since we humans created this "stuff" (i.e. dense forests with high fuel loads), I wonder if blaming wildfire severity on "climate change" is just a way to avoid admitting that *WE* are the ones who created overstocked, dense, fire-prone forest stands. In regards more destructive wildfires, "we have met the enemy and he is us."



2. We now know that the vast majority of climate model predictions have been wrong. We've now gone 15+ years without any warming to speak of, and researchers are beginning to take a serious look at how to rectify the observational data versus the models. Can you summarize some of your concerns with the models pursuant to your 2009 article in the New Zealand Journal of Forestry and if any of your thoughts have changed since that time?

Since my 2009 article, I have learned some additional facts about climate models and predictions. As a result, I have become more critical of flawed climate models.

(1) First, even a basic climate model will give a wrong answer when the math is performed incorrectly. Some (who use a basic temperature model) say the moon's average temperature is -20° C but measurements indicate the mean value is much colder (see my testimony for more details). Several researchers are aware of this difference, but so far the error has been ignored by non-scientists.

(2) In my 2009 article, I presented a graph that compared model projections of global temperature with surface observations. We now have five more years of temperature data which have been included in the updated figure below. All five mean values (including means from three previous years) are below the orange "commitment" curve (see figure below). The orange "commitment" curve represents the mean of 16 model projections of warming IF greenhouse gas and aerosol concentrations were held constant from the year 2000. From these observations, I reject the null hypothesis that there is no difference between modeled and observed values.

(3) I have noticed that a number of authors who write AGW papers do not follow the scientific method. In fact, some do not cite evidence that contradicts their conclusions. Some even delete graphs when they show how wrong projections have been in previous reports (e.g. see methane graph below).

(4) Several modelers are willing to bet their own money on the stock market but it seems (to me) that most won't make even a small wager on their own climate predictions/scenarios. Why should I believe in their scenarios, and alter my lifestyle, if they have no confidence in their models?

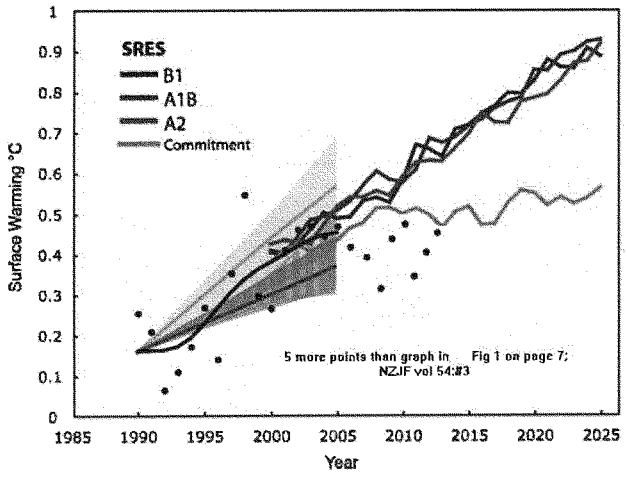
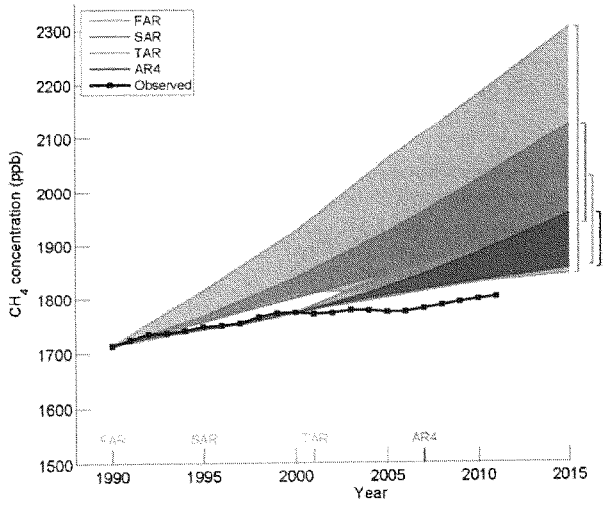


Figure 1. Model projections of global temperature change compared to observed (HadCRUT3) surface temperature means (Solid dots). Observations since 2005 have been lower than projected. Adapted from Figure TS.26 in IPCC technical summary http://tinyurl.com/7gjkvzf .



Climate scenarios (repeatedly) overestimate the increase in methane in the atmosphere.

3. In your testimony you say "correlation does not prove causation". Such a statement reminds me of a famous quote by French mathematician and theoretical physicist Jules Henri Poincare "Science is built up of facts, as a house is built of stones; but an accumulation of facts is no more science than a heap of stones a house." Can you share with me your thoughts on the problems with using correlation to assume causation and the notion of consensus in science and how scientific theories are really tried and tested?

IT IS UNSCIENTIFIC TO ASSUME CAUSATION FROM A CORRELATION

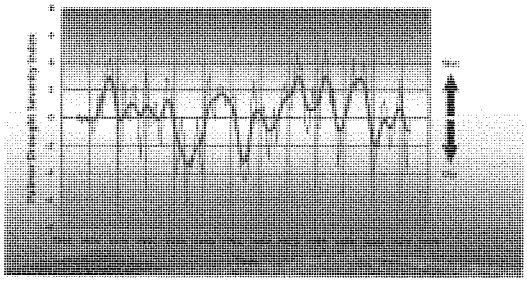
"Causality is the area of statistics that is most commonly misused, and misinterpreted, by non-specialists. Media sources, politicians and lobby groups often leap upon a perceived correlation, and use it to 'prove' their own beliefs. They fail to understand that, just because results show a correlation, there is no proof of an underlying causality." Martyn Shuttleworth

Assuming causation from a correlation is potentially deadly. For example, some (e.g. Dr. Andrew Wakefield) have assumed that vaccinations cause autism in children. The belief in causation is strong, despite studies to the contrary.
http://www.sciencedirect.com/science/article/pii/S0264410X14006367%20

From 1890 to 2014, the carbon dioxide in the atmosphere has increased. Some might claim CO_2 increases are the cause of droughts (figure below), especially when they "cherry-pick" limited time-periods that show an increasing trend in drought over time. In contrast, objective scientists look at the entire period and see no such trend.

Some regions have experienced increased precipitation while other areas (located far from storm tracks) are likely to experience less precipitation and increased risk of drought. Since the 1950s, some regions of the world have experienced longer and more intense droughts, particularly in southern Europe and West Africa, while other regions have seen droughts become less frequent, less intense, or shorter (for example, in the USA). Some advocates are willing to scare the public by "cherry picking" regions that have seen an increase in drought over time. They might plot CO_2 in the atmosphere along with a trend of increasing drought (e.g. 1905 to 1935). Claiming droughts during this period were caused by carbon dioxide increases (due to a cherry-picked correlation) is both unscientific and unethical. Many advocates fail to understand that, just because results show a correlation, there is no proof of an underlying causality."

Figure 1. Average Drought Conditions in the Contiguous 48 States, 1895–2013



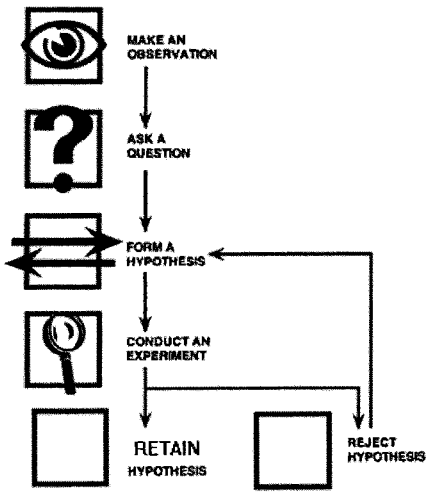
CONSENSUS HOLDS NO WEIGHT IN REJECTING A THEORY

"Let's be clear: the work of science has nothing whatever to do with consensus. Consensus is the business of politics. Science, on the contrary, requires only one investigator who happens to be right, which means that he or she has results that are verifiable by reference to the real world. In science consensus is irrelevant. What is relevant is reproducible results. The greatest scientists in history are great precisely because they broke with the consensus."

"There is no such thing as consensus science. If it's consensus, it isn't science. If it's science, it isn't consensus. Period." Michael Crichton

THE SCIENTIFIC METHOD

This is a simple flow chart for the scientific method.



And here is an example.

Observation: Climate model simulations predict trends in upper air warming that are 39% greater than simulated trends in surface temperatures. The jargon term for this is "hot spot."

Question: Does the "hot spot" exist? Is there really a difference between real-world upper air temperatures trends and the trends in surface temperatures?

Form a null hypothesis: There is no difference in trends (C/decade) between measured upper air temperatures and measured surface temperatures

Conduct an experiment: Measure trends in surface temperatures (20°S – 20°N) using data from weather stations. Measure lower troposphere trends (20°S – 20°N) using data from balloons. Compare both trends (1979-2011).

Retain hypothesis or reject null hypothesis: The data suggest temperature trends are similar. No evidence of a "hot spot." The null hypothesis remains.

Publish the results: Santer B. and 26 others (2012). Identifying human influence on atmospheric temperatures. Proceeding of the National Academy of Sciences. doi:10.1073/pnas.1210514109

Repeat the process: Douglass, D.H. & Christy, J.R. (2013). Reconciling observations of global temperature change: 2013. Energy & Environment, 24(3), 415-420.

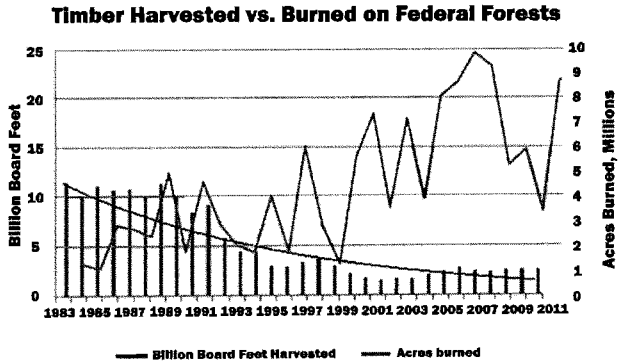
Finally: Inspect climate models to determine why they produce a spurious "hot spot."

Note: Non-scientists do not test hypotheses and some continue to claim the "hot spot" exists in both the real world and in the virtual world of climate models.

Questions from: Senator Jeff Sessions

1. All else being equal, would increasing the number of board-feet harvested from U.S. National Forests each year, over the long-run, reduce the severity of wildfires?

Yes. Reducing the amount of wood in a forest by commercial thinning reduces the energy released in a wildfire. This reduces the severity since heat emitted is directly related to the amount of standing and dead timber. As an example, the heat given off from a bundle of 10 matches is half that from 20 matches. A fire occurs in both cases, but the severity is doubled for the 20 match bundle.



"National forests are in an unhealthy and dangerous state resulting in larger and more intense wildfires. In 2012, wildfires burned 9.3 million acres, while the U.S. Forest Service only harvested approximately 200,000 acres." House Committee on Natural Resources (July 11, 2013) http://naturalresources.house.gov/news/documentsingle.aspx?DocumentID=342124

Some National Forests now have about 70% more stored energy per acre than 6 decades ago. Firefighters know it is much harder to put out a wildfire when the amount of energy released per acre is increased by 70%. This extra energy increases the effort needed to extinguish the fire and the intensity results in additional burned acreage. The following graph illustrates how quickly fuel loads have increased in the Intermountain region (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah and Wyoming). A forest policy that allows harvesting only a fraction of annual growth is equivalent to a policy that promotes an increase in the severity of future wildfires (i.e. it increases the fuel load of forest). National forest policies that limit commercially viable logging have increased the fuel load and thus have increased the risk of catastrophic wildfires.

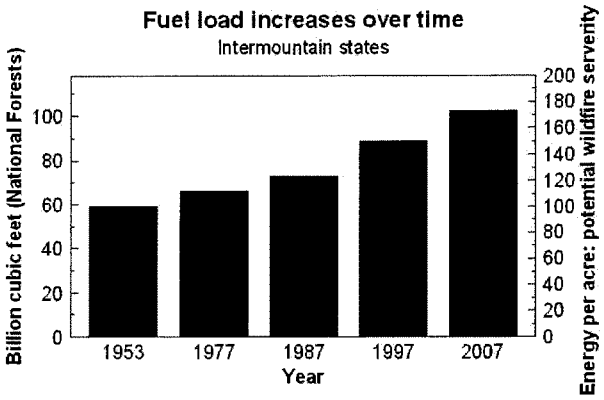


Figure 1. Increases in volume and energy (stored in wood) on USFS forests in the Intermountain states over time. Wood energy is expressed in relative units with 1953 set at 100.

The following text is from a 2003 web site at Northern Arizona University.

A century of general fire absence in western ponderosa pine forests has led to large accumulations of highly flammable fuels. The problem is exacerbated in the drier Southwestern climate by very slow decomposition rates (Kallander 1969). Sapling thickets generate particularly large amounts of woody fuels, creating ideal conditions for laddering and thereby increasing the probability for crown fires.

Under the former regime of frequent, low-intensity fire, rapid buildups of highly flammable fuel in the form of resprouting grasses and needle cast were regularly consumed. Large woody fuels rarely accumulated over extensive areas. Mortality of large trees from surface fires was unlikely, and crown fires exceptionally rare (Biswell et al. 1973).

By 1979, Sackett reported average fuel loads at 22 tons per acre (ranging from 8 to 48 tons per acre) for 62 Southwestern pine stands. Harrington (1982) verified the heavy fuel loading, finding an average of 34 tons per acre in southeastern Arizona. Formerly uncommon large, woody fuels averaged about 8 tons per acre.

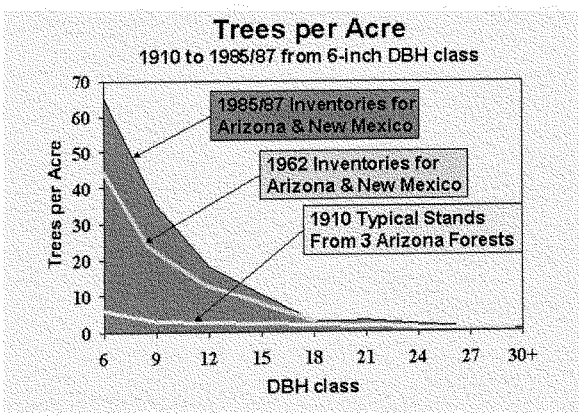
Extreme fuel loads make prescribed burning not only risky in terms of potential for escape, but often unintentionally destructive. Consumption of large amounts of fuel generates large amounts of heat. As thick mats of duff smolder for up to 72 hours, ash is formed from the top down, creating an insulating cover. The insulation prevents heat from escaping causing it to penetrate the mineral soil. Burning for long time periods can result in temperatures exceeding 140 degrees F causing instant cambium or root death. Lower temperatures for longer periods can also kill plant tissues.

Studies at Fort Valley and Long Valley Experiment Forests in Arizona measured lethal temperatures deeper than 8 inches in mineral soil on some sites. The first burn in 100 years at the Chimney Spring Prescribed Fire Research Area at Fort Valley killed almost 40 percent of the old-growth ponderosa pines that had survived numerous pre-settlement fires. Mortality did not appear until several years after the burns and continued to be greater than on unburned sites (Sackett and Haase 1992).

Costly and labor intensive removal of duff, woody material, and ladder fuels decreases potential fire intensity, total heat release, and resistance to control. However, the fuel hazard is only temporarily reduced as up to 2 tons per acre of fine fuels are normally cast annually. Even more can accumulate from fire-injured trees. Repeated burning is essential to remove these fire-created fuels and generally maintain a low fuel hazard.

[references are found at http://forestfire.nau.edu/fuelloads.htm]

The following graph illustrates a rapid increase in the number of trees in Arizona and New Mexico. Reducing tree stocking by commercial thinnings would reduce fuel loads without relying on an unsustainable and or inadequate supply of public money.



http://forestfire.nau.edu/densities.htm

2. What are the principal reasons why timber harvests have decreased from national forests in recent years?

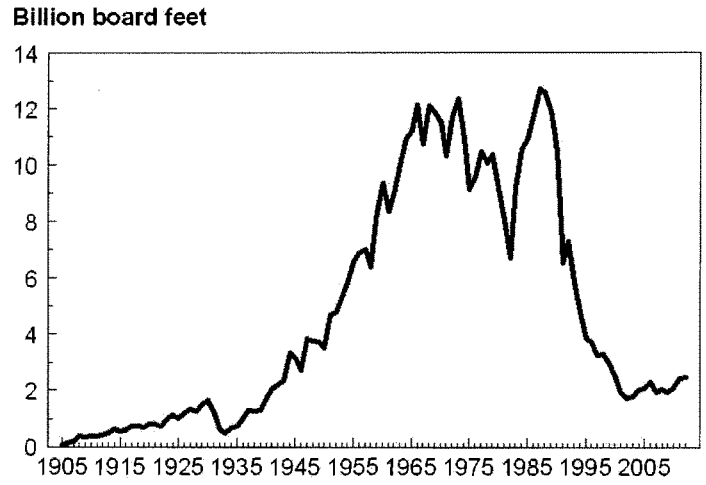


Figure 2. Annual harvest rates of timber from National Forests

The primary reason why timber harvests have declined by more than 80% is due to a desire by the public and environmental groups to "preserve" national forests by keeping logging to a minimum. It seems to me that many environmental groups want the Natural Forests to be managed the same way as National Parks are managed.

During the post-World War II housing boom, national forests were viewed as a ready supply of building material. A common economic, harvesting method used involved clearcutting. Even with this rate of harvesting, the amount of standing timber on National Forests increased by 59% (from 1953 to 1977). This level of harvest was not sufficient to keep the risk of wildfire from increasing (due to an increase in fuel load). Due to public concerns over the environment, Congress passes several laws to protect forests. Additional laws formalized the concept of "multiple-use," whereby the uses of timber, forage, and water shared equal footing with wildlife conservation and recreation opportunities. As the above graph illustrates, timber sales on national forests increased to the 12 billion board foot mark during this period. As James Walls pointed out to the sub-committee (on June 1, 2014), there were five mills in operation at this time in Lake County, Oregon, but now only one remains in operation. As harvests decreased, we began importing more wood to help meet increasing demand. The country continues to import more wood than it exports.

In the 1970's, concerns about environmental impacts and conflicting uses escalated, leading to increased Federal lawsuits against logging. This resulted in Congress enacting additional environmental protection measures. As a result, the Forest Service now operates federal timber sales under some of the most paper-work intensive environmental protection policies in the world. In response to the public and in hopes of reducing lawsuits, today's USFS timber harvest has dropped by 81 percent (back to a 1941 level of about 2 billion board feet per year) when compared to harvest rates in the 1970's. In addition clearcut harvests have been reduced by 80 percent over the last decade.

The following newspaper article is just one example of many that shows why logging and timber harvests on US Forest Service land have declined while risk of wildfire has increased. USFS foresters no longer decide where, when and how much timber to harvest; lawyers and federal judges decide.

Suit seeks to stop timber project intended to protect Helena's water supply

June 26, 2014 11:20 am By TOM KUGLIN Independent Record

Two conservation groups have filed a lawsuit in an attempt to stop the Red Mountain Flume Chessman Reservoir timber project that officials say is necessary to protect Helena's water supply.

The Montana Ecosystems Defense Council and the Native Ecosystems Council filed the suit in Federal District Court in Missoula on Thursday. The groups cited threats to wildlife, other timber harvest in the area and a slim chance of catastrophic wildfire as the reasons for the suit. The groups also said the project needed more environmental analysis.

"The reason the city and Forest Service give for the timber sale is to protect the watershed from wildfire," said Steve Kelly, director of the Montana Ecosystems Council. "But there is no scientific evidence that indicates forest conditions in the Ten Mile watershed are abnormal. Pine beetles and fire are not an indication of poor health in lodgepole pine forests."

http://helenair.com/news/suit-seeks-to-stop-timber-project-intended-to-protect-helena/article_31756e02-fd56-11e3-b08c-0019bb2963f4.html

3. Does the US have more or less forest cover now than we had 100 years ago?

The US now has about 3% more forest cover than a century ago. The amount of forest land in 1907 (what would become the 50 states) is estimated at 740.87 million acres. We now have about 25.367 million more acres in forests (2012 estimates). This increase is due largely to natural regeneration on abandoned farmland along with tree planting on former cropland and pastures. The Northeastern States now have over 30 million acres more than in 1907 and the North Central States have over 10 million more acres of forests.

Senator MERKLEY. Thank you very much, Dr. South.
Dr. Legates.

STATEMENT OF DAVID R. LEGATES, Ph.D., CCM, PROFESSOR, DEPARTMENT OF GEOGRAPHY, UNIVERSITY OF DELAWARE

Mr. LEGATES. Thank you, Mr. Chairman, Senators.

Carbon dioxide is plant food, and more of it can be a positive. If global temperatures rise for any reason, the length of the growing season will be increased, the amount and diversity of crops will be enhanced, and more areas of the planet will be farmed. The big problem, however, is a limiting factor for agriculture in much of the world, water availability. Soil moisture in a normal world depends on a complicated interaction of changes in precipitation and increases in water demand. Globally, we have seen drought frequencies have not changed over the past 60 years.

The percentage of the United States in moderate or extreme drought has not changed in 112 years, a pattern that has been noted by the climate change science program and the IPCC. Recently, droughts have not become more intense or of longer duration. Thus, the historical record does not warrant claiming that global warming will negatively impact agriculture.

Dire forecasts of extreme drought arise, however, from climate model simulations which are only as good as their ability to simulate precipitation. Most models overestimate the frequency of rainfall but underestimate its intensity. Thus, while models may appear correct in the aggregate, they don't get the process correct. How can models make accurate estimates of precipitation changes when they cannot simulate correctly the mechanisms that drive precipitation?

Evaporative demand is driven by air temperature. But models have overestimated the air temperature rise since 1979 by almost 1 degree Fahrenheit. If precipitation and air temperature are not modeled properly, how then can modeled soil moisture be relied upon to prepare farmers for an uncertain future?

Climate changes because climate has always changed, and droughts have happened in the past and are likely to occur again with similar frequencies and intensities. Thus, I believe preparation for their return is a better strategy than trying in vain to mitigate them through draconian carbon dioxide emission control policies, such as those proposed only yesterday.

However, I have become increasingly concerned as to how this scientific debate is being corrupted. In my 2003 Senate testimony regarding the hockey stick, I lamented that a healthy scientific debate was being compromised. An attack had been made on the scientific process. Editors at two journals have been harassed; one of the journals was threatened with an organized boycott by scientists over a paper it had published. The senior editor moved to bar two scientists from future publication in the journal solely because of their position on climate change, without a hearing, and without even accusation of fraud or plagiarism.

I would like to report that things have become better. They haven't. In 2009, ClimateGate shed light on how the scientific process was being subverted. In my case, I learned I had been denied publication of an important paper due to solely a conclusion be-

tween another scientist and an editor. Over the years I have applied for several Federal grants, including NASA and U.S. Department of Agriculture, the latter having nothing to do with climate change. It is not that I received bad reviews; indeed I received no reviews at all. Program officers refused to respond by e-mail or telephone. Their behavior appears related to an article that appeared in the National Academies of Science which is often used as a blacklist to target "researchers unconvinced of anthropogenic global warming."

Several years ago, I and two colleagues in Delaware received FOIAs for material related to climate change. My story is documented in my written testimony. The university general counsel informed me that he would review my documents regardless of how or where they were produced. The other faculty members that participated in the IPCC indicated FOIA did not apply to them. I was told that although the law may not require him to turn over anything; it does not preclude him from doing so. In essence, I will be treated differently simply because he can treat me that way.

So I sought legal counsel. The dean informed me I could not hire my own lawyer and the college would no longer support me. I was removed as the Delaware State climatologist, as co-director of an environmental network I has spent nearly a decade to develop, as faculty advisor to a student group and from all departmental responsibilities. Legal counsel finally agreed to treat all of us equally. This never occurred. He never went through materials for anyone else; I alone was targeted, then lied to. Even the faculty union that supported Dr. Mann at the University of Virginia told me that FOIA matters did not fall within their bailiwick.

According to the CBO of the University, none of my research material or e-mails fall under the FOIA law. The actions of the university violate the terms of a Federal arbitration case. There is nothing in my records of which I am embarrassed. I tell you this story not because I seek sympathy, but because of many other cases for which the victims cannot speak out. This so-called war on science is nothing but a diversion. The real war is being waged within the halls of academia and within our Federal granting agencies.

As with lysenkoism in the Soviet Union, a healthy scientific discussion is being subverted for political and personal gain. Scientists who deviate from the anthropogenic global warming playbook are harassed, have articles, grants, and proposals rejected without review, are treated more harshly than their peers, and are removed from positions of power and influence. Young scientists quickly learn to toe the party line or at least remain silent. Thus, they lose their career before it begins.

I leave you with this thought: when scientific views come under political attack from within academia, the loser is independent thinking and good policymaking because all require rational thought to be effective. Thank you.

[The prepared statement of Mr. Legates follows:]

STATEMENT TO THE ENVIRONMENT AND PUBLIC WORKS COMMITTEE OF THE UNITED STATES SENATE

David R. Legates, Ph.D., C.C.M.
University of Delaware

3 June 2014

I am a Professor of Climatology at the University of Delaware and I served as the Delaware State Climatologist from 2005 to 2011. I also am an adjunct faculty member in the Department of Agricultural Economics & Statistics and the Physical Ocean Science and Engineering Program. I received a B.A. in Mathematics and Geography, a M.S. in Geography, and a Ph.D. in Climatology, all from the University of Delaware. I served on the faculty of the University of Oklahoma and Louisiana State University before returning to the University of Delaware in 1999. I was part of the US delegation that negotiated a protocol for the first climate data exchange program with the Soviet Union in 1990. I am recognized as a Certified Consulting Meteorologist by the American Meteorological Society and was the recipient of the *2002 Boeing Autometric Award* in Image Analysis and Interpretation by the American Society of Photogrammetry and Remote Sensing.

I would like to thank the Chair and the Committee for the privilege to offer my views and my thirty years of experience on climate change from the perspective of a climatologist. My expertise lies in statistical methods in climatology, particularly as it relates to the hydrologic cycle – precipitation and soil moisture. For my dissertation, I developed the first digital and gridded global precipitation and air temperature dataset that specifically incorporates biases arising from the precipitation gage measurement process. This database is still used today in climatology as a standard against which climate model-derived fields and regional assessments are compared. I also have published several important articles that discuss the impact of precipitation variability on soil moisture in regional and global studies. In the following discussion, I will address the potential impact of climate change on agriculture and relay some of my pressing concerns that are related to the treatment of climate scientists who do not agree with the anthropogenic global warming disaster scenarios.

1. Global Warming and Agricultural Impacts

One of the important questions raised by the response of increasing atmospheric carbon dioxide concentrations is the possible impacts on agriculture, aquaculture, and commercial/recreational fishing. Considering that CO_2 is food for plants and animals, this is seen as a positive and any potential negative effects are minimal. But if global surface air temperatures do rise for any reason, this will undoubtedly increase the length of the growing season which, in turn, will enhance the amount and diversity of crops that can be grown. Moreover, it will allow for more areas of the planet to be farmed, primarily in the Northern Hemisphere, thereby increasing crop productivity. Billions of acres of land in northern Canada and Russia could become cultivable. The limiting factor, however, is the moisture availability to plants as agriculture in much of the world is restricted by water availability both from precipitation and surface/groundwater reserves.

A discussion of the possible results of soil moisture availability in a warmer world depends on a complicated interaction of two factors – changes in the precipitation climatology and increases in evapotranspiration (the combined effect of soil evaporation and plant transpiration). The impacts of these two factors are opposite in sign; precipitation, when it occurs, is likely to increase but the potential for evapotranspiration also is likely to increase, both due to the increase in the saturation vapor pressure as a function of increasing air temperature. The question then is which dominates – does the increase in precipitation compensate for the increase in the evapotranspiration demand or does the increase in air temperature reduce soil moisture reserves such that droughts will become more likely? Complicating this discussion is the fact that atmospheric circulation changes may affect the patterns of precipitation so that some areas may become more drought-prone while others may become less so. **Pinpointing the exact geographical areas for which drought/increased rainfall are likely to occur lie far beyond our technology for the foreseeable future.**

To answer the questions, climatologists employ two methods. In one, historical patterns and trends over the last century are extrapolated to provide a forecast of what might happen in the future. From the demise of the Little Ice Age – a relatively cold period between about 1300 and 1850 A.D. (Soon *et al.* 2003) that is concomitant with decreased solar output – to the late 1990s,

air temperatures increased about 0.6°C (~1.1°F). We can use this rising trend in air temperature to make prognostications as to what we might expect from a warming world in the future. The second method involves climate models – mathematical/statistical representations of the climate system. These models are used to simulate future climate scenarios from which patterns of climate change are inferred. We will examine the results using both of these methods.

1.1 Historical Patterns and Trends in Drought

Several analyses have focused on patterns and trends associated with drought. Hao *et al.* (2014) used satellite analysis to examine global patterns of drought from June 1982 through December 2012 (Figure 1). Only a slight decrease in abnormally dry and moderate drought conditions has occurred, though it is not statistically significant. Note particularly the increase in global drought

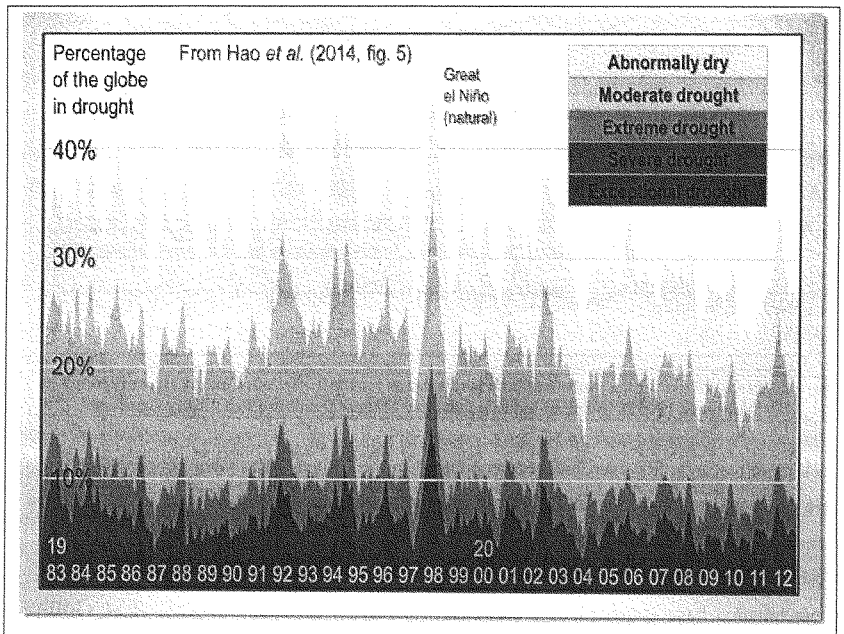


Figure 1: Fraction of the global land in D0 (abnormally dry), D1 (moderate), D2 (severe), D3 (extreme), and D4 (exceptional) drought condition (adapted from Figure 5 of Hao *et al.* (2014).

in 1998 resulting from the rather strong naturally-occurring El Niño of that year. Patterns in precipitation for the Twentieth Century show no observable trend over the entire period of record for either the globe or for either hemisphere (New *et al.* 2001 – Figure 2). Regionally, the only statistically significant pattern occurs for the upper latitudes of the Northern Hemisphere (where snowfall is better measured in the latter portion of the record due to better snow-gage instruments) and for the lower latitudes of the Northern Hemisphere (dominated by the Sahel region in Africa, where overgrazing has substantially changed the landscape and, consequently, the precipitation climate of the region). Sheffield *et al.* (2012) concur with the results of Hao *et al.* (2014): "more realistic calculations…suggest there has been little change in drought over the past 60 years."

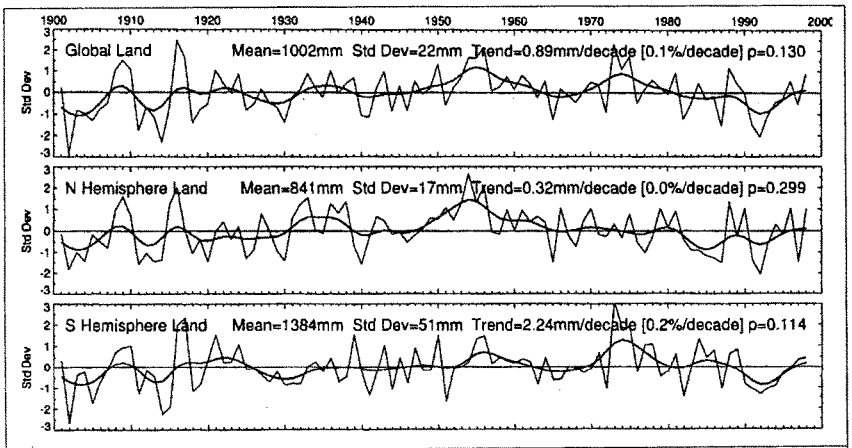


Figure 2: Precipitation for the globe and both hemispheres for the Twentieth Century (from Figure 3 of New *et al.* (2001). *p*-values indicate that none of these trends are statistically significant.

Much more research, however, has been conducted in the United States where observations are more dense and reliable. Generally, precipitation tended to increase over much of the United States between 1895 to 2012, although with much lower certainty in the record prior to 1950 (Vose *et al.* 2014). Groisman and Knight (2008), however, argued that "prolonged dry episodes" of precipitation have increased over the southwestern United States. McCabe *et al.* (2010) addressed this issue by examining a more complete dataset and concluded that there is "little

evidence of long-term positive trends in dry event length in the southwestern United States." We concluded that El Niño and La Niña events and the Pacific Decadal Oscillation are largely responsible for the variability in trends in dry event length in the southwestern United States. Station network limitations and the treatment of missing data adversely affected the results of Groisman and Knight (2008).

Again, however, the main concern focuses on the change in precipitation relative to the change in evapotranspirative demand. Senate testimony by John Christy of the University of Alabama in Huntsville (Christy 2012) has shown that the daily all-time record high temperatures from 970 weather stations with at least eighty years of record peaked in the 1930s and the numbers since 1955 have not increased (Figure 3). This trend also is consistent for a subset of stations in the central United States and along the US West Coast (Christy 2012).

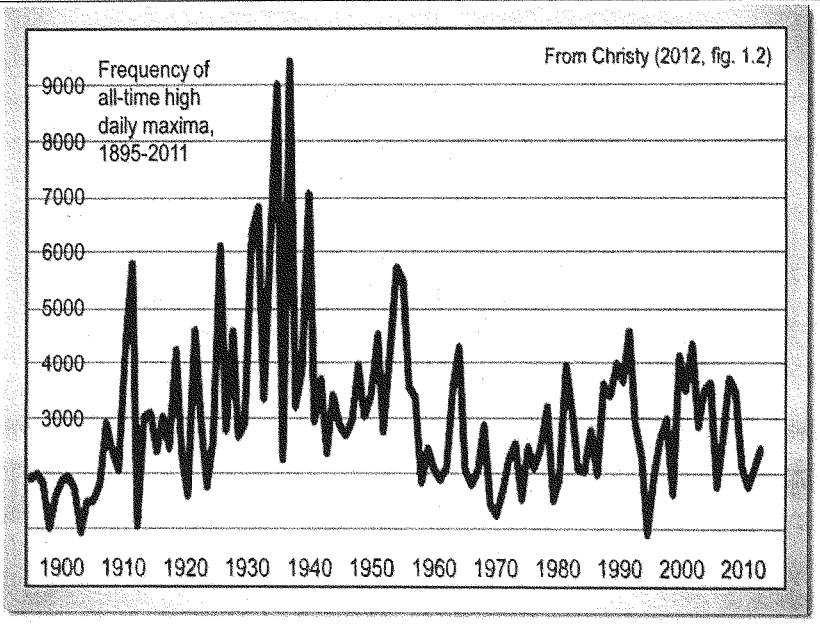


Figure 3: Frequency of all-time high maximum daily air temperatures, 1895 to 2011, at 970 USHCN stations with at least eighty years of observations (from Figure 1.2 of Christy 2012).

However, our primary concern in agriculture is the statistics of drought – changes in its intensity, frequency, and duration. Woodhouse and Overpeck (1998), comparing drought variability in the Central United States over the last two millennia concluded, "The droughts of the 20th century have been characterized by moderate severity and comparatively short duration, relative to the full range of past drought variability." A plot of the Palmer Drought Severity Index, averaged for the contiguous United States, shows considerable variability from 1900 to 2012 with the droughts of the 1930s standing out, but without any long-term trend. This pattern has also been noted by the US Climate Change Science Program (2008) – "When averaged across the entire United States, there is no clear tendency for a trend…long-term trends (1925-2003)…show that droughts have, for the most part, become shorter, less frequent, and cover a smaller portion of the United States over the last century."

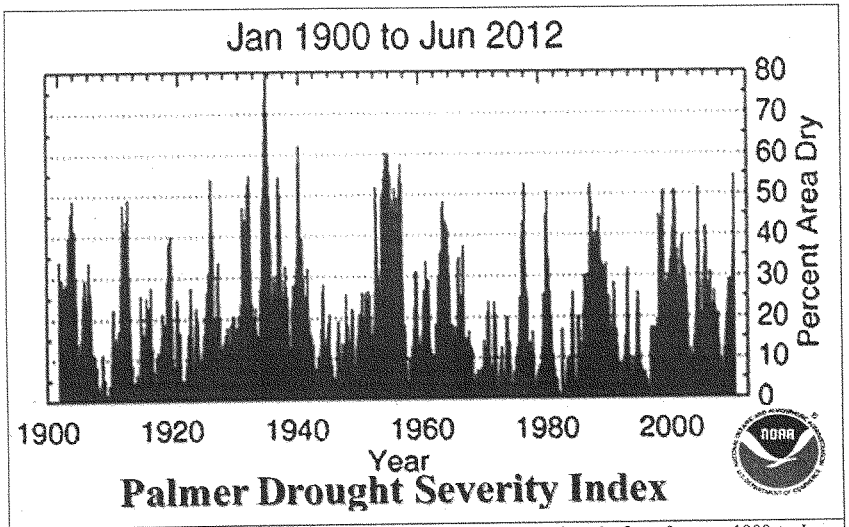


Figure 4: Percentage of the United States in moderate or extreme drought from January 1900 to June 2012 (from the National Climate Data Center, Asheville NC).

Regionally, there have been numerous studies and their results have been similar. For example, Bekker *et al.* (2014), using a 576-year reconstruction of flood conditions, concluded that droughts of greater magnitude, duration, and intensity have occurred previously in Utah. Knapp *et al.* (2002) found that the period since 1950 was "anomalous in the context of this [500-year]

record for having no notable multiyear drought events." For the Idaho, Montana, and Wyoming region, Wise (2010) argued that "the instrumental record (*i.e.*, since the late 1800s) does not contain a drought of the extent seen in the mid-1600s." Gray *et al.* (2004) found that dry conditions in the Sixteenth Century (*i.e.*, during the Little Ice Age) were greater in magnitude and duration than anything seen in the Twentieth Century for the same region.

Andreadis and Lettenmaier (2006) concluded that Midwestern droughts "have, for the most part, become shorter, less frequent, less severe, and cover a smaller portion of the country over the last century." Even the Special Report of the IPCC (IPCC 2012) concluded "...In some regions droughts have become less frequent, less intense, or shorter, for example, in Central North America." Indeed, NOAA scientists (NOAA 2013) concluded that the 2012 Central Great Plains drought "resulted mostly from natural variations in weather."

In the Eastern United States, Pederson *et al.* (2012) concluded that recent droughts are not unprecedented over the last 346 years, with more frequent droughts occurring between 1696 and 1820 A.D. during the colder conditions of the Little Ice Age. Indeed, Quiring (2004) concurred that "...the recent growing-season moisture anomalies that occurred during 2002 and 2003 can only be considered rare events if they are evaluated with respect to the relatively short instrumental record (1895-2003)" and that condition during the 16th Century were longer and more severe.

My overall conclusion is that droughts in the United States are more frequent and more intense during colder periods. Thus, the historical record does not warrant a claim that global warming is likely to negatively impact agricultural activities.

1.2 Model-derived Trends and Patterns of Drought

Global climate models (or General Circulation Models – GCMs) are only as good as their ability to simulate precipitation. They are descriptions of the full three-dimensional structure of the Earth's climate and often are used in a variety of applications, including the investigation of the possible role of various climate forcing mechanisms and the simulation of past and future climates. There are, however, several important issues to remember with GCMs. First, they are

limited by our incomplete understanding of the climate system and how the various atmospheric, land surface, oceanic, and ice components interact with one another. They are further limited by our ability to transform this incomplete understanding into mathematical representations. We may have a general feel for the complex interrelationships between the atmosphere and the oceans, for example, but expressing this understanding in a set of mathematical equations is much more difficult. Second, GCMs are limited by their own spatial and temporal resolutions. Computational complexity and finite restrictions on computing power reduce GCM simulations to coarse generalities. As a result, many small-scale features, which may have significant impact on the local, regional, or even global climate, are not represented. Thus, we must recognize that GCMs, at best, can only present a gross thumbnail sketch. Regional assessments over areas encompassing many GCM grid cells are the finest scale resolution that can be expected. It is inappropriate, and grossly misleading, to select results from a single grid cell and apply it locally. It cannot be over emphasized that GCM representations of the climate can be evaluated at a spatial resolution no finer than large regional areas, seldom smaller than a region defined by a square several hundred miles (at least several GCM grid cells) on a side. Even the use of "nested grid models" (models which take GCM output and resolve it to finer scale resolutions) does not overcome this limitation, since results from the GCM simulation drives such models and no mechanism is available to feedback the results of such finer-scale models to the GCM.

Another limitation in GCMs is that given the restrictions in our understanding of the climate system and its computational complexity, some known phenomena are simply not reproduced in climate models. Hurricanes and most other forms of severe weather (*e.g.*, nor'easters, thunderstorms, and tornadoes) simply cannot be represented in a GCM owing to the coarse spatial resolution. Other more complex phenomena resulting from interactions among the elements that drive the climate system may be limited or even not simulated at all. Such indicators should be flags that something fundamental is lacking in the GCM. These phenomena should be produced in the model as a result of our specification of climate interactions and driving mechanisms; their absence indicates a fundamental flaw in our understanding of the climate system, our mathematical representation of the process, the spatial and temporal limitations imposed by finite computational power, or a combination of the above.

An assessment of the efficacy of any climate model, therefore, must focus on the ability of the model to simulate present climate conditions. If a model cannot simulate what we know to be true, then it is unlikely that model prognostications of climate change are believable. However, a word of caution is warranted. It is common practice to "tune" climate models so that they better resemble present conditions. This is widely acceptable, because many parameters in GCMs cannot be specified directly and their values must be determined through empirical trial-and-error. However, this raises the concern that a GCM may adequately simulate the present climate, not because the model correctly represents the processes that drive the climate; but rather, because it has been tuned to do so. Thus, the model may appear to provide a good simulation of the climate, when in fact the model may poorly simulate climate change mechanisms. **In other words, a GCM may provide an adequate simulation of the present-day climate conditions, but it does so for the wrong reasons.** Model efficacy in simulating present-day conditions, therefore, is not a guarantee that model-derived climate change scenarios will be reasonable. To address this question, modelers often employ simulations of past climates, such as the Holocene or the Pleistocene, to see if the model provides the kind of climate that we can infer existed during such epochs. Of course, our knowledge of pre-historical climate conditions is tenuous and extremely crude, which limits the utility of such evaluations.

A final limitation in climate modeling is that in the climate system, everything is interconnected. In short, anything you do wrong in a climate model will adversely affect the simulation of every other variable. The most problematic variable is precipitation. Precipitation requires moisture in the atmosphere and a mechanism to cause it to condense (causing the air to rise over mountains, by surface heating, as a result of weather fronts, or by cyclonic rotation). Any errors in representing the atmospheric moisture content or precipitation-causing mechanisms will result in errors in the simulation of precipitation. Thus, GCM simulations of precipitation will be affected by limitations in the representation and simulation of topography, since mountains force air to rise and condense to produce orographic (mountain-induced) precipitation (*e.g.*, the coastal mountain ranges of Washington and Oregon). Incorrect simulations of air temperature also will adversely affect the simulation of precipitation since the ability of the atmosphere to store moisture is directly related to its temperature. If winds, air pressure, and atmospheric circulation are inadequately represented, then precipitation will be adversely affected since the atmospheric

flow of moisture that may condense into precipitation will be incorrect. Plant transpiration and soil evaporation also provide moisture for precipitation; therefore, errors in the simulation of soil moisture conditions will adversely affect the simulation of precipitation. Simulation of clouds solar energy reaching the ground will affect estimates of surface heating which adversely affects the simulation of precipitation. Even problems in simulating oceanic circulation or sea ice concentrations will affect weather patterns, which affect precipitation simulations.

Equally important is the fact that inaccuracies in simulating precipitation, in turn, will adversely affect the simulation of virtually every other climate variable. Condensation releases heat to the atmosphere and forms clouds, which reflect energy from the sun and trap heat from the Earth's surface – both of which affect the simulation of air temperature. As a result, this can affect the simulation of winds, air pressure, and atmospheric circulation. Since winds drive the circulation of the upper layers of the ocean, the simulation of ocean circulation also is affected. Air temperature conditions also contribute to the model simulation of sea ice formation, which would be adversely affected. Precipitation is the only source of soil moisture; hence, inadequate simulations of precipitation will adversely affect soil moisture conditions and land surface hydrology. Vegetation also responds to precipitation availability so that the entire representation of the biosphere can be adversely affected. Clearly, the interrelationships among the various components that comprise the climate system make climate modeling difficult. Keep in mind, however, that it is not just the long-term average and seasonal variations that are of interest. Demonstrating that precipitation is highest over the tropical rainforests and lowest in the subtropical deserts is not enough. Climate change is likely to manifest itself in small regional fluctuations. Moreover, we also are interested in intra-annual (year-to-year) variability. Much of the character of the earth's climate is in how it varies over time. A GCM that simulates essentially the same conditions year after year clearly is missing an important component of the earth's climate. Thus, the evaluation of climate change prognostications using GCMs must be made in light of the model's ability to represent the holistic nature of the climate and its variability. **In sum, the simulation of precipitation, and subsequently soil moisture, is adversely affected by inaccuracies in the simulation of virtually every other climate variable while, in turn, inaccuracies in simulating precipitation adversely affect virtually every other variable in the model.**

It should be noted that GCMs are not weather prediction models. Their utility is not in predicting, for example, whether it will rain in southern England on the morning of July 14, 2087. Rather, we are interested in determining whether the probability of precipitation will be substantially different from what it is today – in both the frequency and intensity of precipitation events. In general, we want to know whether the summer of 2087 is likely to be wetter or drier than present conditions, and by how much. As such, GCMs are only used appropriately to address the likelihood of changes over large spatial and temporal scales -- assessing changes for specific dates or locations are beyond the scope of GCM utility.

But this is my biggest concern. If a climate model simulates an increase in precipitation for the near or distant future, I want to know why. In particular, I want to verify that it is because a specific precipitation-producing mechanism has changed. Are there more tropical storms or nor'easters simulated? More frontal precipitation? Is there more convective activity from surface heating that leads to more rising air? Or has the atmospheric circulation changed such that orographic precipitation is enhanced?

Unfortunately, this is where over-reliance on GCMs forecasts can betray us. In these models, precipitation is produced almost exclusively from a single mechanism – surface convection – and is often termed "popcorn precipitation" since it occurs over large regions and relatively frequently (see Zolina 2014)). When models are averaged over seasons, the classic pattern of global precipitation emerges with a moist equatorial region, decreased precipitation in the Subtropics, and increased precipitation in mid-latitudes that tapers off with colder temperatures toward the poles. While this may *appear* correct in the aggregate, it has achieved its apparent success without properly simulating the mechanisms that create precipitation in the real world. How possibly, therefore, can the models make accurate prognostications of precipitation when they do not simulate correctly the mechanisms that drive precipitation? And if precipitation is not modeled properly, how then can soil moisture estimates be used to prepare farmers for an uncertain future?

Stephens *et al.* (2010) identifies this problem with three state-of-the-art climate models and numerical weather prediction models. Using high resolution CloudSat observations over the oceans (where precipitation is more uniform spatially), they demonstrate that the differences between the models and the observations are much greater than observational and averaging errors. They conclude "the general tendency is for models to produce precipitation that is far too frequent, especially in midlatitudes" (*i.e.*, the United States). Note that tropical precipitation is largely convective (although some stratiform precipitation does occur – Janowiak *et al.* 1995) but that in midlatitudes, precipitation arises from a variety of mechanisms. Instead of simulating frontal passages and organized weather systems, the models exhibit "popcorn precipitation" where it rains far too often. As a consequence of having it rain too frequently, the intensity of modeled precipitation is that when it occurs, its intensity is much lower than observed. Thus, the total precipitation is reasonable but its distribution (frequency and intensity) is grossly in error. Even models that have spatial resolutions as fine as 7-14 km (4.4-8.8 mi) exhibit these problems. When averaged to seasonal averages for the globe, the models do remarkably well. However, they achieve this level of success for the wrong reasons. Regionally, the GCMs "tend to produce too much precipitation over the tropical oceans and too little in midlatitudes". Moreover, this is where soil moisture is greatly affected – models that rain too frequently with lighter amounts will necessarily overestimate soil moisture conditions because soil moisture responds not just to the amount of precipitation but is very dependent on its timing.

As Dr. John Christy demonstrated in his Senate Testimony (Christy 2012), the March-to-July precipitation, as simulated by most climate models, exhibits considerable variability between the models but does not exhibit a long-term trend. For the Southeastern United States (Figure 5, top), the models vary from an average of less than 15 inches to more than 25 inches and most models tend to underestimate the observed precipitation from 1890 to 2012. Similarly, the models also vary from below 15 inches to more than 24 inches for the Midwestern United States (Figure 5, bottom) although the models tend to be wetter than observations.

If models indicate that precipitation is not forecast to change over this century, how do models suggest an adverse impact on agriculture will occur? Models suggest that air temperatures will increase substantially over the next century, rising by as much as 6°C (10.8°F). This indicates

that the evapotranspirative demand will increase substantially and result in lower soil moisture conditions and hence more droughts. However, these models have significantly overestimated the warming of the last fifteen years (Figure 6) such that they command little confidence.

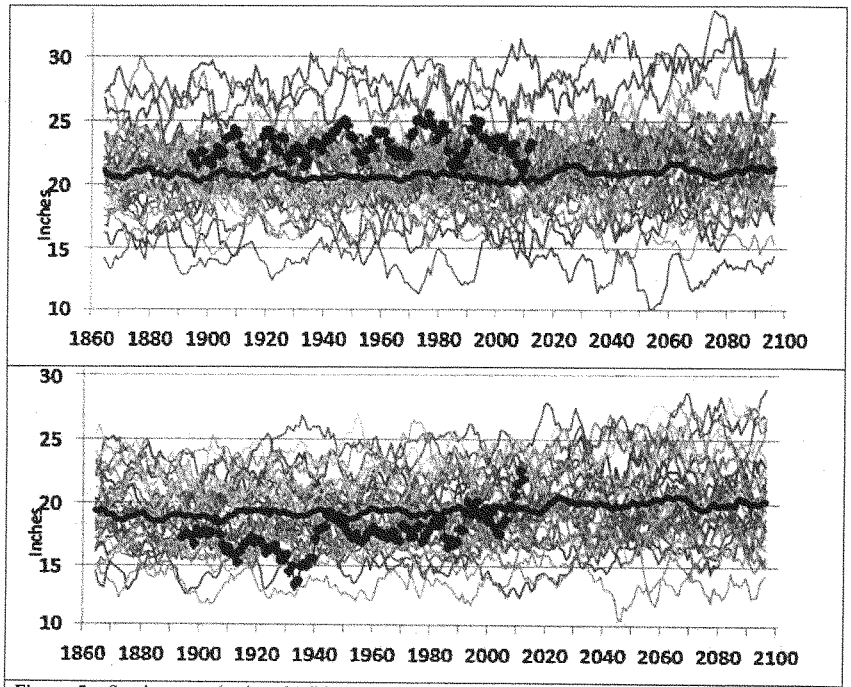


Figure 5: Southeastern (top) and Midwestern (bottom) United States precipitation as measured from observations (black dots) and models (colored lines; median in solid black) for 1860 to 2100 (from Figures 2.2 and 2.3 in Christy 2012).

The consistent and substantial over-predictions of the general-circulation climate models are reflected in those of the Intergovernmental Panel on Climate Change, which, in 1990, predicted that near-term warming would occur at a rate exactly double what has actually occurred. Furthermore, none of the models predicted that for 17 years 9 months, or more than half the entire satellite temperature record, there would be no global warming at all (Figure 7).

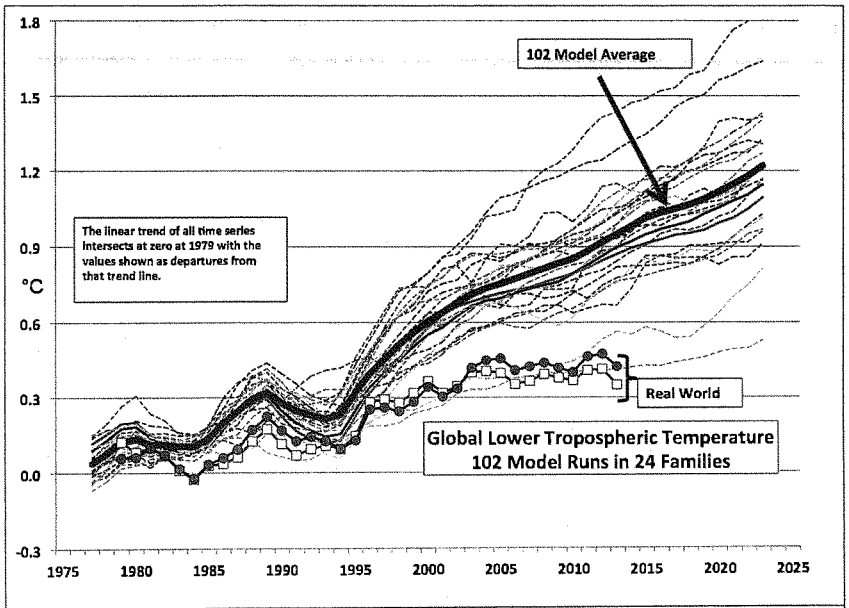


Figure 6: Global surface air temperature (in °C) as simulated by 102 climate models runs (colored, dashed lines). The solid red line is the model average, the circles are the balloon observations, and the squares are the satellite measurements (from Pielke Sr. 2014).

As Dirmeyer (2014) argues, "The problem is that coupled land-atmosphere models used for weather and climate forecasting and research have never been thoroughly validated in terms of their simulation of the coupled processes that provide predictability." Even if the land surface model was perfect, it will provide bad simulations if forced by "an atmospheric model with serious systematic biases or inadequately represented physical processes" (see also Steinhaeuser and Tsonis 2014). Given the limitations of the models not only in predicting global air temperatures but also in estimating precipitation and soil moisture conditions, it seems that a more reasonable approach is not to rely on the model prognostications; but rather, to focus on policies that allow for adaptation to the observed variability in precipitation and soil moisture. **Droughts that have happened in the past are likely to occur again, and with likely similar frequencies and intensities; thus, preparation for their return is a better strategy than trying to mitigate them through draconian CO_2 emission control policies.**

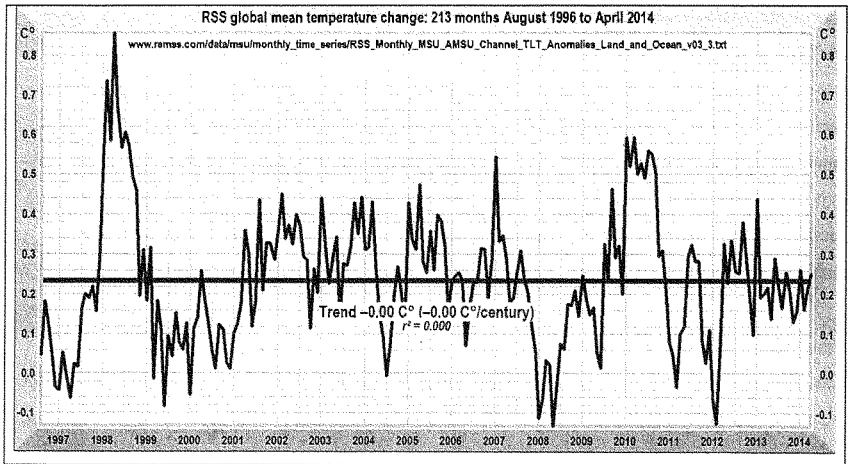


Figure 7: Monthly global mean surface air temperature anomalies monitored by satellite (RSS), August 1996 to April 2014. For 213 months, or more than half the entire satellite record, the least-squares linear-regression (thick bright blue line) has been zero.

1.3 The Scientific Method versus Post-Normal Science

The scientific method has long been the 'gold standard' among scientists. It is the empirical evidence that separates science from mythology and is the key to finding scientific truth (Legates *et al.* 2013). Indeed, it is the evaluation of theories with observations that have trumped appeals to authority or consensus or the longevity of a theory (Legates *et al.* 2014). As Legates *et al.* (2013) argued, "results from climate models are often erroneously posited as observations themselves or even data and even when they diverge considerably from the real observations, they are used to drive theory construction…results from climate models should be used with extreme care and not be taught as scientific fact."

As a response to policy-making when a 'solution' is demanded immediately and the facts are obscured by error, widely divergent views exist, models are inherently uncertain, Post-Normal Science emerges where 'science by consensus' reigns. It has been strongly argued that even in its early days, the Intergovernmental Panel on Climate Change abandoned the scientific method in favor of this new paradigm (Saloranta 2001, Legates *et al.* 2013). This inherently morphs the role of the scientist from an impartial observer and seeker of the truth to one who dons the hat of

an advocate. This is where the so-called 'consensus arguments' arise where an appeal to some very large percentage of scientists appears to give credibility to a particular viewpoint. Most of these consensuses are contrived (see Legates *et al.* 2014) and serve to push an agenda that diverges widely from truth-seeking. The scientific method has been abandoned by many in the climate change discussion with an appeal to the masses through an imaginary consensus of scientists. This has greatly undermined both the quest for truth in this debate and the respect the general public has for scientists who advocate for anthropogenic global warming disaster scenarios.

2. The Silencing of the Dissenters

In my Senate Testimony in 2003 regarding the so-called "Hockey Stick" graph of global air temperature (Legates 2003), I concluded with the statement

> I'm sorry that a discussion that is best conducted among scientists has made its way to a United States Senate committee. But hopefully it has become evident that a healthy scientific debate is being compromised and that only by bringing this discussion into the light can it be properly addressed.

At that time, an attack had been made on the scientific process. Editors at two journals were harassed to the extent that an abrogation of their commitment to reviewer confidentiality had been demanded of them. One of the journals, *Climate Research,* was threatened with an organized boycott and the Director of its parent organization, who first evaluated the situation and exonerated the managing editor, recanted in the face of this boycott. The newly appointed Senior Editor had moved to bar two scientists from future publication in *Climate Research* – without a hearing and without even an accusation of fraud or plagiarism.

I would like to provide you with an update on how the state of science has progressed in the intervening eleven years as it regards climate change. In 2009, a release of documents from the University of East Anglia in the United Kingdom (known colloquially as 'ClimateGate') shed light on how the scientific process was being subverted. With respect to me personally, I learned that in 2001, I had been denied publication of an important rebuttal due to collusion between an author and an editor. In the Second Assessment Report (SAR) of the IPCC, the phrase "balance

of evidence suggests a discernible human influence on global climate" had been inserted, and that five separate statements to the contrary had been removed by a single author. Dr. Robert E. Davis and I examined the citations given in support by Dr. Ben Santer, Dr. Thomas Wigley, and their colleagues. We had found that the statistic they used to make their conclusions was seriously flawed and published our results. Wigley and his colleagues published a rebuttal and we were denied a response since "we did not add anything significant to the discussion." I assumed we had not done enough to sway an impartial editor.

But in an e-mail, Dr. Wigley explained how he had engineered his rebuttal and suggested it be used as a template for others. He indicated he had contacted the editor, complained that any such publication criticizing his research should have been cleared by him first, and the two agreed that his rebuttal would be treated as a new submission and any response Davis and I made were to be squelched by the editor. We had always suspected such events might have occurred but it took the ClimateGate documents to provide the proof.

But these issues were to pale in comparison to what was about to happen. On December 16, 2009, I received a letter that, due to the ClimateGate revelations and pursuant to the Delaware Freedom of Information Act (FOIA), Greenpeace requested my "email correspondence and financial and conflict-of-interest disclosures" that were "in the possession of or generated by the Office of the Delaware State Climatologist" from January 1, 2000 regarding 'global climate change' and containing any of 22 additional keywords.

The Delaware FOIA statute is fairly terse with respect to the University. It simply states that the University of Delaware is exempt from State FOIA except for the conduct of the Board of Trustees of the University and documents relating to the expenditure of public funds. Although during my tenure as the State Climatologist, the Office obtained no funds from either the State or the University – I provided goodwill climate services to the State on behalf of the University – and I had conducted no business that could be construed as climate change related. Technically, nothing should have been produced.

Shortly after receiving the request from Greenpeace, I met with the University Vice President and General Counsel, Mr. Lawrence White. He summarily informed me that I was required to turn over not just documents related to the State Climate Office and what Greenpeace requested, but ALL documents that I had in my possession relating to 'global climate change' – whether or not they were produced through the State Climate Office. I was told that as a faculty member, I must comply with the request of a senior University official.

On January 26, 2010, Mr. White received a letter from the Competitive Enterprise Institute (CEI) making a nearly identical request of three other faculty members who had contributed to the Intergovernmental Panel on Climate Change. One of those faculty members was from my own department (Dr. Frederick E. Nelson) and had an office down the hall from me. Mr. White sent me an e-mail containing this FOIA request and indicated "this one will probably be answered with a short 'no'." After a follow-up letter by CEI on February 3, Mr. White finally responded that "because the information you seek does not relate to the expenditure of public funds, the University respectfully declines your records request."

I subsequently met with Mr. White to obtain an explanation as to why I was being treated differently. He explained to me that I did not understand the law. As he sees it, even though the law may not require the University to produce e-mails and documents, the law does not prohibit him from requiring me to produce them for his perusal and potential release to Greenpeace. As such, I was again instructed to turn over all the documentation he requested to him ASAP.

At that point, I sought outside legal counsel. On February 9, 2010 and after questions raised by my lawyer, Mr. White agreed to a 'do-over'. After further review, Mr. White indicated in a letter to CEI that he wished to retract his email to them and "reconsider the substance of your FOIA request" because his initial response "did not take sufficient account of the legal analysis required under the Act." Mr. White indicated to CEI and to my lawyer that their FOIA would be handled in a manner identical to my Greenpeace FOIA.

In a telephone conversation between me and the Dean of the College of Earth, Ocean, and Environment, I subsequently was told that as a University faculty member, Mr. White

represented both me and the University. She insisted that he worked for me, was indeed working in my best interest in this instance, and that I must follow all of his instructions. I objected and indicated that I felt I was being treated differently from other faculty members and that treatment was simply unfair. Finally, she concluded that because I had hired my own lawyer, the College would no longer support me and she ceased communicating with me on this matter.

Shortly after our discussion, the Deputy Dean informed me that the Dean had decided that she wanted me to resign as the Delaware State Climatologist so he could take over that role. Subsequently, I was removed as the State Climatologist. I also was removed as co-Director of the Delaware Environmental Observing System (an observational network I had spent nearly a decade to develop), as faculty advisor to the Student Chapter of the American Meteorological Society, and from all my committee assignments within my department. The Chair of the Department attempted to remove me from several grants that I had obtained. I have since been restricted from serving on any departmental committees.

In a discussion with my colleague, Dr. Frederick Nelson, I learned that he had met with one of Mr. White's assistants'. Dr. Nelson related to me that she shared all she could about my FOIA discussions but then left the meeting without providing instructions regarding his FOIA. He subsequently sent a follow-up email to both her and Mr. White asking for specifics of what he was to produce. As of July 2012, he had yet to hear back from either of them. He has since retired from the University.

On June 20, 2011 – 472 days or exactly 1 year and 3.5 months – I again heard from Mr. White. He had now hired a 3rd year law student to go through the materials I had provided to him over a year earlier. But why the delay and now the sudden flurry of activity? Less than a month earlier, on May 25, 2011, the Virginia Supreme Court had ruled on the case between Attorney General Ken Cuccinelli and the University of Virginia that emails by former professor Dr. Michael Mann and in the University of Virginia's possession must be turned over to the Attorney General's Office. Interestingly, all this began as a result of a CEI FOIA of Dr. Mann that followed a similar Greenpeace FOIA on Dr. Patrick Michaels – a former faculty member at the University of Virginia. The American Association of University Professors (AAUP) and several

professional organizations including the American Meteorological Society and the American Geophysical Union (of which both Dr. Michaels and I are members) vehemently protested the FOIA request. The AAUP stressed to the University of Virginia that "we urge you to use every legal avenue at your disposal to resist providing the information demanded in the [civil investigative demand]" arguing that "documents and e-mail communications that were part of an ongoing scientific discussion might be taken out of that context, and used to create an impression of wrongdoing." They concluded that "it is the University's obligation to protect academic freedom by seeing that legal tools such as this...are not used to intimidate scientists whose methods or conclusions are controversial."

Interestingly, Dr. Joan DelFattore, president of the AAUP Chapter at the University of Delaware had recently published an article on academic freedom at the University of Delaware. Citing her appreciation for having a general council (*i.e.*, Mr. White) who understands the importance of academic freedom, she wrote:

> "It is also useful to consider that once an administration silences any speech, it may be assumed that the university is endorsing whatever speech it fails to suppress. A university's real interest lies in fostering the exchange of divergent views on the understanding that the university itself does not necessarily endorse any of them and certainly does not endorse all of them."

I therefore decided to elicit her assistance through the AAUP. While her comments sounded laudable, her response to me was that FOIA matters "would not fall within the scope of the AAUP". This, of course, is in direct contrast to the stance taken by the AAUP in the Cuccinelli vs. University of Virginia where the AAUP President, Cary Nelson, wrote:

> "We are urging the University of Virginia to...publicly [resist] the threat to scholarly communication and academic freedom represented by the concerted effort to obtain faculty emails...Whatever people may think of climate research, the climate for academic freedom must not be allowed to deteriorate. If scientists think every email they send may be subject to a politically motivated attack, it will create a chilling effect on their discourse and hurt scientific research.'"

Indeed, the AAUP defended Dr. Mann at the University of Virginia but refused to become involved in my similar case at the University of Delaware, citing that they stood firmly behind Mr. White's actions.

Finally, on July 22, 2011, I was provided a list of what Mr. White had decided to release to Greenpeace – pending my permission. Mr. White further reiterated that he was indeed treating the subjects of the CEI FOIA in an identical manner. Communication I had with Dr. Nelson and the response by the 3rd year law student to my query – she indicated I was the only faculty member whose documents were being examined – suggests otherwise. If I am being singled out for my views – punish the 'skeptics' while protecting the 'believers' as happened by the disparate treatment at the University of Virginia regarding Drs. Mann and Michaels – then doesn't that make the entire discussion of academic freedom at the University of Delaware by Dr. DelFattore into a lie? Again, Dr. DelFattore wrote that "once an administration silences any speech, it may be assumed that the university is endorsing whatever speech it fails to suppress." On this topic I cannot agree more.

Mr. White wrote "if you object to the release on any of these documents, then I would inform the groups requesting this information that there are some documents in Dr. Legates' custody that we have not produced and that they should direct further questions about the documents to you." I am puzzled as to why I have the right to object to the release of any documents. If Mr. White's interpretation of FOIA as it pertains to the university is correct, then why should I or any other faculty member be allowed to object to their release? Doesn't the law trump my protests? But if he has decided to release documents outside of the FOIA just because he can, as he explained to me at the outset, then the University has unfairly targeted me. On this there can be no middle ground.

Through my attorney, I subsequently requested several questions be answered by Mr. White. Until my letter, I had not indicated to Mr. White that I had been in contact with Dr. Nelson regarding his FOIA case. At this point, I informed Mr. White that I knew he had not asked Dr. Nelson to produce any documents, despite the fact that on three occasions, Mr. White had asserted he would treat all of us equally.

The next day, February 2, 2012, Mr. White responded to questions posed to him – not to the ones contained in my letters but to questions he had already answered on August 2, 2011. Most interesting is Mr. White's response to question 1 of that exchange which explicitly addressed the equal treatment of me and those targeted by the CEI FOIA request:

> "Attached is a .pdf of an email exchange we had on February 10, 2010, memorializing our agreement on how this matter would proceed. Term 5 provides: "Dr. Legates and the University of Delaware professors who are the subject of the Competitive Enterprise Institute's FOIA request (dated Feb. 3, 2010) will be subject to the same process—that is, they too will be required to produce documents for your review—and they will be subject to the same legal standard for determining whether and to what extent FOIA applies."

On August 2, 2011, Mr. White had provided a short, one word response to that question – "Confirmed." But on February 2, 2012, his reply to the same question indicates he had not been truthful:

> "I have not yet dealt with FOIA requests directed at faculty members other than Dr. Legates. I reiterate that, if and when additional documents are gathered relating to other FOIA requests on this subject matter, you will be allowed to review those documents before they are produced."

In February of 2010, Mr. White had agreed that all parties would be subject to the same procedures and insisted that he was proceeding in exactly the same manner with them. Now, he asserts that "if and when additional documents are gathered" I will be allowed to review those documents. Why should I have the right to look at the documents of others? More importantly, two years had passed since CEI submitted its FOIA request and Mr. White indicated that "I have not yet dealt with FOIA requests directed at faculty members other than Dr. Legates." This clearly indicates that he had no intent to honor his 'do-over' request on February 9, 2010 – in essence, I *will* be treated differently than other faculty because he has every right to treat me that way.

I have since become aware of a case that involved the University of Delaware in 1991. In the Gottfredson/Blits federal arbitration case of 1991, the University of Delaware explicitly

conceded (and it was upheld by the arbiter) that the University's review of research and teaching notes would violate a faculty member's academic freedom. The University's Faculty Senate Committee on Research that had investigated Professor Linda Gottfredson stated that, "the Committee has never directed its attention to the content or method of any faculty member's research or teaching, and would oppose any attempt to restrict a colleague's rights in these protected areas" (*i.e.*, areas of academic freedom and contract rights). In a meeting with the Chief Budget Officer of the University, I learned that my faculty salary only includes my teaching workload since FY2009 when that was transferred to state support. Thus, the *only* item that could be covered by State funds (and hence covered under the State FOIA) was my teaching materials since September 2008. No e-mails, no unfunded research, no service assignments were covered. Mr. White's actions violate a federal ruling to which the University has agreed to abide by.

Thus, there were no documents that fell under the Greenpeace FOIA – nothing I did as Delaware State Climatologist related to global climate change and none of my teaching duties were accomplished as the Delaware State Climatologist. On April 8, 2014, my documents were finally returned to me.

Thus, it appears that Mr. White arbitrarily decided to gather, examine, and potentially release files to Greenpeace simply because he, acting as an officer of the University has chosen to harass and try to silence me for deviating from 'University-approved' scientific views. I chose to resist the release of these materials – not because I have anything to hide – but to protect my academic freedom and the freedom of others and to reject the University's attempts "to intimidate scientists whose methods or conclusions are controversial," as the AAUP argued at the University of Virginia. If one faculty member can be bullied by a heavy-handed administration, then certainly other faculty will be under attack in the future.

Over the years, I have applied for several federal grants. Two in particular, submitted to NASA and the USDA (the latter involved using precipitation estimates by weather radar to enhance agricultural planning which had nothing to do with climate change), were never reviewed. It is not that I have received bad reviews; indeed, I have received no reviews at all. Program officers

refuse to provide reviews and even to respond by e-mail or telephone. My understanding is that this is related to Anderegg *et al.* (2010) which often is used as a type of 'black list' to identify "researchers unconvinced of anthropogenic global warming," to use their terminology.

As existed in the case of Lysenkoism in the Soviet Union, a healthy scientific discussion is being subverted for political and personal gain. With the recent case of Professor Lennart Bengtsson and the story I have told here, scientists who deviate from the anthropogenic global warming playbook are likely to be harassed, have grants and proposals rejected without review, be treated more harshly than their peers, and be removed from positions of power and influence. I would have hoped that in the past decade, the discussion has become more civil. Indeed, a civil discussion can be had with some scientists that believe in the extreme scenarios of anthropogenic global warming. But too many in places of prominence and with loud voices have made this a war zone. Scientists like Bengtsson and myself have tenure or its equivalent and are somewhat insulated from the extreme attacks. But young scientists quickly learn to 'do what is expected of them' or at least remain quiet, lest they lose their career before it begins.

I leave you with this thought: When scientific views come under political attack, so too does independent thinking and good policy-making because all require rational thought to be effective.

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Environment and Public Works Committee Hearing
June 3, 2014
Follow-Up Questions for Written Submission

Questions for Legates

Questions from: Senator David Vitter

1. *In reading your testimony you have a pretty compelling story about the disparate treatment of researchers in the academic community. As an observer I can't imagine that is good for science and the scientific process what you went through and how one-sided it was. On the issue of science generally, can you tell me if good science works by consensus, or if it is a process of critically thinking and why it is so important that scientists not be afraid of retribution as they work to resolve a lot of the failed models and predictions that have made their way into the public discourse?*

Science often relies on a consensus to define 'mainstream' thought. That is not to say that a consensus is necessarily correct nor does it imply that a majority of scientists agree with that consensus. Indeed, a true consensus is determined only by extensive critical thinking and evaluation of the theory. Consensus, therefore, should result from a 'trial by fire' where a theory has been extensively tested and evaluated. The scientific method can be considered as an iterative algorithm by which scientists advance new theories that are modified and corrected by surviving error-detection and elimination by other scientists in a theoretically never ending process. A consensus is built, therefore, not because more scientists warm to the theory but because scientists become convinced by the fact that it has not yet been demonstrated to be incorrect. Indeed, the quest for the truth is a never-ending process and even long-held theories are sometimes overturned by new revelations. As Albert Einstein famously stated, "No amount of experimentation can ever prove me right; a single experiment can prove me wrong." Science is not a belief system; it requires proof and lack of contrarian evidence to discern the truth. In reality, scientists agree on very little except those ideas which are now relatively obvious – in the grey areas where science is developing, research is focused on the cutting edge, ideas are new, and processes are not well understood, disagreements are bound to exist in spades. This is at the heart of the scientific method since complex problems require much time and energy to flesh out the truth from the fiction, with the result that often a consensus is never really achieved.

The problem policy makers often have with this process is that it works too slowly. Policy must be made now and it is not possible to wait until all the facts are in – a consensus must be built now using expert assessments, particularly in highly important areas where uncertainty and a lack of knowledge exist but where immediate decisions are needed. The apparent successor to the traditional scientific method is *post-normal science* where an *extended peer community* weighs in on the topic and generates a body of knowledge through consensus. Through this radical departure from the scientific method, development of a consensus is dictated not by the 'trial by fire' process that characterizes the scientific method; but rather, it is the prescribed result – the 'end' itself. Thus, it is in this context that this new 'consensus-driven' paradigm must be produced that agrees with a prescribed set of facts and coordinates the response strategy accordingly.

Unfortunately, consensus-building is not a simple process. Scientists agree to the basic tenets of any discussion that experiments and measurements have established. For example, that greenhouse gases are active in the thermal infrared portion of the electromagnetic spectrum and that climates are moderated by the presence of large bodies of water. Important areas, however, are still in doubt, such as the overall effect of clouds and the sensitivity of the climate to carbon dioxide. This is why there is so much effort being placed on a so-called 'consensus of climate scientists' by anthropogenic global warming believers. As we discussed in Legates *et al.* (2014), the question "Do you believe in global warming?" can be answered in numerous ways, since "global warming" is not properly defined. Does it refer to "anthropogenic global warming" or to a warming of the globe at some unspecified time-scale? Thus, scientists who disagree strongly on the anthropogenic contribution of climate change may answer 'Yes' to the imprecise question "Do you believe in global warming?".

Since critical evaluation of even widely-held tenets is the 'fire' that identifies truth and ultimately builds a consensus, it must be protected as a vital component of the scientific method. George Bernard Shaw once said that "All great truths begin as blasphemies." 'Settled science' has been overturned many times in past history. The geocentric universe was widely believed and many heliocentric-believing scientists were ridiculed until it was proven incorrect by the work of Johannes Kepler in 1609 through the writings of Copernicus and the observational data of Brahe. Semmelweis suggested in 1848 that hand washing would greatly decrease infant mortality, much to the scorn and ridicule of his peers. It was not until much later that Pasteur and an understanding of germs confirmed that Semmelweis' argument was valid. Continental drift was dismissed as fancy until plate tectonics were better understood in the 1960s, despite the fact that it had been first suggested by Ortelius in 1596 and developed by Wegener in 1912. Even recently, the long-held consensus that eating fat killed people has now been shown to be false.

Science is constantly evolving; many times scientists get it right while sometimes hypotheses are overturned through further knowledge and understanding. But historically, science has reticent to change paradigms or overthrow existing ideas even when they become demonstrably invalid. Today, funding plays a key role in the professional life of most scientists and funding agencies are unlikely to fund science that challenges existing beliefs, especially if it is likely to cause a major shakeup in the scientific discipline. That is largely because program officers and scientists were once students and students tend to believe what they were taught.

To protect the ability of a faculty member to pursue controversial topics, the concept of academic tenure was created. It goes hand-in-hand with academic freedom as it allows tenured faculty to dissent from the 'consensus', disagree with authorities, and pursue controversial topics without fear of reprisal. Without such protection, a consensus could perpetuate itself as skeptical inquiry might be met with retaliation or punishment. Tenure, however, only protects a faculty member from being terminated without just cause; it is why groups like the National Association of Scholars so fiercely defends academic freedom since retaliation is often more subtle than job termination.

2. *Albert Einstein once said "When the number of factors coming into play in a phenomenological complex is too large, the scientific method in most cases fails. One need*

only think of the weather, in which case the prediction even for a few days ahead is impossible." Dr. Judith Curry, head of the earth sciences department at Georgia Tech, recently testified that the real problem on why the models and predictions have been so wrong is because the science was oversimplified, indicating that CO_2 may not be quite the driver of climate that was originally thought. Can you talk some about how the rush to attack CO_2 created a lot of the failed models and predictions, as well as speak to how truly complex our climate is and all the factors that influence our climate?

Historically, the definition of 'climate' as 'average weather' has given the impression to many that climate is not dynamic and is little more than a statistical summary. This has led to the erroneous belief that climate should not change and that any change in climate is bad. Climate itself has been oversimplified by arguments such as "the Earth's atmosphere acts like a blanket" or that "carbon dioxide causes the Earth to heat like the windows of a car on a hot afternoon". Both reduce the atmosphere to only its radiative properties and ignore the effect of atmospheric motions (both horizontally and vertically) and the evaporation of water on the climate.

I believe that in the early days of modeling, much of the focus was based largely on the radiation budget. Simple 0-dimensional (Earth as a point in space) or 1-dimensional (Earth has only Pole-to-Equator variations) models could either ignore the horizontal and vertical patterns or simply parameterize them with a simple latitudinal diffusion coefficient. Even as 2-dimensional Radiative-Convective models were being developed, our understanding of the radiation budget was more complete than other processes such as large-scale cloud formation and spatial gradients. Thus, radiation and the temporal changes in 'simple' atmospheric molecules such as carbon dioxide and methane were given more attention and impact than the more complex interrelationships with climate inferred by the most important greenhouse gas, water vapor. Because water exists on Earth in all three phases – solid, liquid, and gas – and because it transitions through these three phases relatively easily, transferring energy through the movement of evaporated water, it is the most important gas in the atmosphere and, since its phase change involves the creation and dissipation of clouds, ice sheets, and sea ice, it is the most difficult to model correctly. Most telling was the comment of Dr. Michael Mann at my Senate Testimony in 2005 when asked why we were not more interested in water vapor, he responded "...because it cannot be regulated."

I cannot begin to explain how utterly complex our climate system is. Processes occur on a variety of space and time scales, many of which are far below the spatial and temporal resolution of most climate models. Water changes phase and passes from ice sheets and sea ice, to liquid water in the oceans, lakes, streams, and groundwater, and to water vapor in the atmosphere. Condensed moisture in the atmosphere can be either solid or liquid and creates clouds that affect both the incoming solar radiation and trap outgoing heat energy. As I wrote in an article (Legates, 2014 – attached), precipitation is the Achilles' Heel of climate modeling: "...anything that is modeled incorrectly in a climate model will adversely affect the simulation of every other variable...[and] incorrect simulations of the precipitation/condensation process necessarily will adversely affect the simulation of other aspects of the energy balance [of the model]." Currently, precipitation is badly simulated by climate models since they generate rain too frequently with too little moisture (*e.g.*, light showers every day over most of the planet) do not exhibit the full range of precipitation-forming mechanisms that occur. I demonstrated that these impacts are not

trivial – an error of only 0.1 inch in simulating liquid rainfall is equivalent to the energy required to heat the entire troposphere by 1.4°F and models exhibit differences between the simulated and observed precipitation that can exceed 0.1 inch per day.

3. *One of the things that I think is largely missed in the discussion is that there are benefits of CO_2. Can you discuss some of the research that has been done on the benefits of CO_2 to plant and animal life?*

In an article entitled "The Many Benefits of Atmospheric CO_2 Enrichment" (attached), Drs. Craig and Sherwood Idso describe fifty-five benefits arising from increased atmospheric carbon dioxide concentrations. They note that plants grow faster, their photosynthetic rate is increased, and plants significantly increase their biomass under higher atmospheric carbon dioxide concentrations (see Figure 1) and that because their stomates can be closed longer, they have decreased water demands and suffer less air pollution stress. In particular, this decreases soil erosion by expanding plant cover. Biodiversity too is enhanced because it increases the niche security of many different forms of plants and with more biodiversity, net primary productivity, and biomass comes a greater ability to remove that carbon from the atmosphere, creating a natural negative feedback on CO_2. This, in turn, enhances the plant resistance to disease and increases the positive effects of earthworms and microbes in the soil as well as the response of nitrogen-fixing soil bacteria. Production of the protein Glomalin is increased, which enhances the soil and decreases the risk of potentially toxic soil elements, as well as other beneficial substances such as phosphorus and other nutrients as well as vitamin C and other antioxidants. Tropospheric ozone is enhanced by isoprene which will be significantly reduced under increased

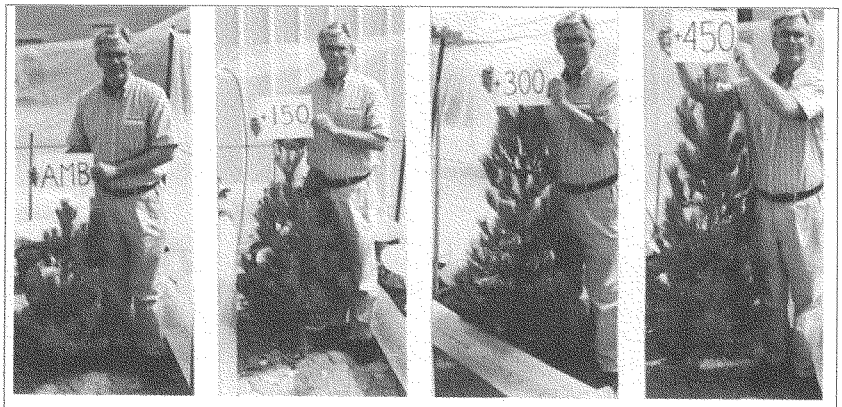

Figure 1: Dr. Sherwood Idso showing the effect of carbon dioxide on spruce trees under different atmospheric carbon dioxide concentrations.

CO_2 concentrations. Humans too will be benefit. Longevity has increased through increased agricultural productivity as well as a decrease in human mortality due to slightly increased temperatures, decreased cardiovascular diseases, and a positive impact on respiratory health.

The other big concern is oceanic acidification. Although the oceans will remain alkaline (or basic), upwelling zones are the most productive where nutrients and phytoplankton are more prevalent. Ironically, these areas are where the oceans are the least alkaline. When Dr. Jane Lubchenco, Under Secretary of Commerce for Oceans and Atmosphere, testified on December 2, 2009 on "The Administration's View on the State of Climate Science", she said: "So who in the ocean is affected by this [acidification]? Any plant or animal that has a shell or skeleton made of calcium carbonate…the hard parts of many familiar animals such as oysters, clams, corals, lobsters, crabs, … are made of calcium carbonate." Her figures show shells dying in low pH (acidic) conditions. But as recent research has noted, "most of these experiments used semi-continuous cultures, in which the carbonate system was modified by the addition of acid and/or base to control pH" (Iglesias-Rodriguez *et al.*, 2008) and "…previous lab studies…used hydrochloric acid, not carbon dioxide [carbonic acid], to lower the pH of the water in the calcification studies (Pennisi, 2009). Research by Dr. Justin Ries has shown that for the Maine lobster (Figure 2) and the blue crab (Figure 3) higher concentrations of carbon dioxide enhance

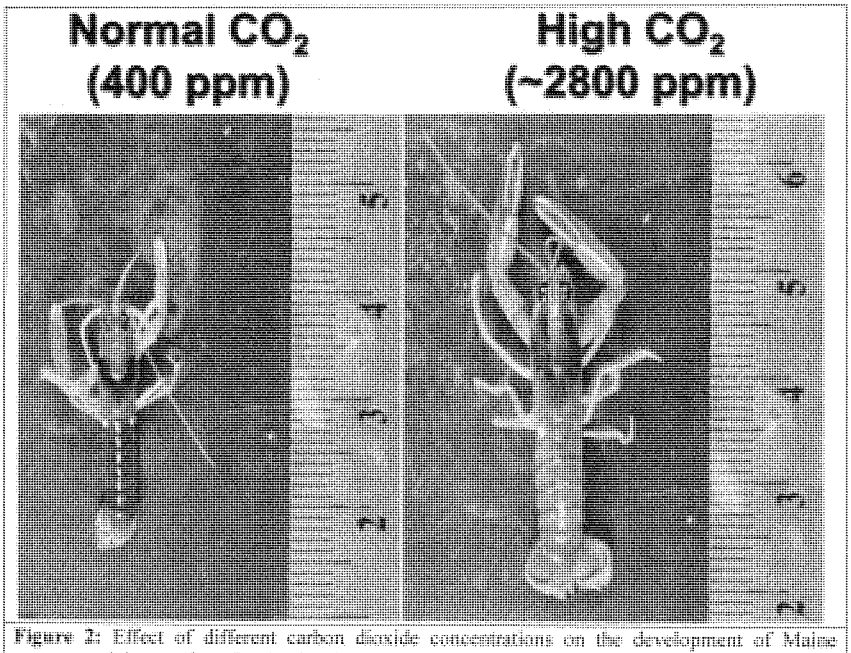

Figure 2: Effect of different carbon dioxide concentrations on the development of Maine lobsters (from Dr. Justin Ries, University of North Carolina-Chapel Hill).

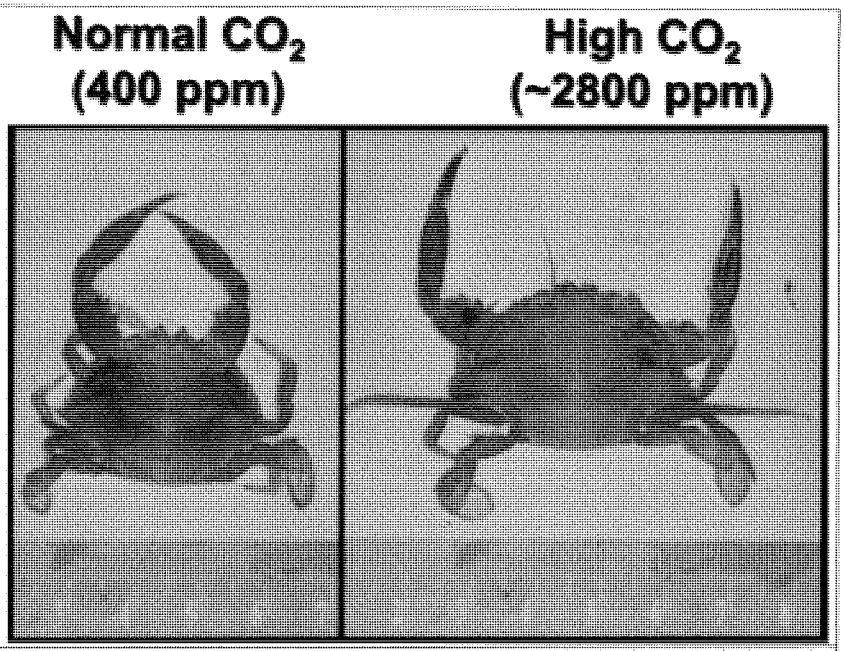

Figure 3: Effect of different carbon dioxide concentrations on the development of Blue Crabs (from Dr. Justin Ries, University of North Carolina-Chapel Hill).

growth rather than stunt it. This is because the chemistry is different for water acidified by hydrochloric acid (HCl) than carbonic acid (H_2CO_3). Iglesias-Rodriguez *et al.* (2008) concludes, "increased atmospheric CO_2 also enhances marine life, in contradiction to previous claims where lower pH in the ocean was said to be dissolving calcium material (*i.e.*, $CaCO_3$) and therefore causing harm to marine life."

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Environment and Public Works Committee Hearing
June 3, 2014
Follow-Up Questions for Written Submission

Questions for Legates

Questions from: Senator Jeff Sessions

1. *Many of those that urge policy action to drastically reduce US greenhouse gas emissions frequently cite a statistic that goes something like "97% of scientists agree that global warming is man-made." Can you comment on that figure?*

The "97%" figure has appeared in several seemingly authoritarian articles over the years. One early source is the infamous "Oreskes Consensus" (Oreskes, 2004). Oreskes searched the ISI database looking for articles between 1993 and 2003 with the keyword "Global Climate Change" (see 2005 Erratum where 'global' was added). She found 928 abstracts which she divided into six categories, ranging from "explicit endorsement of the consensus position, evaluation of impacts, mitigation proposals, methods, paleoclimate analysis, and rejection of the consensus position". She concluded that the first three categories included 75% of the abstracts (accepting the consensus view) while the other 25% dealt with methods or paleoclimate. None disagreed with the consensus position. Numerous problems were raised with the results in that the keyword used did not necessarily cover all possible papers on the topic, to an inability to replicate the analysis, to identification of papers that should have been placed into the last category. The problem many had was that the published literature could not possibly exhibit a 100% agreement (it is easy to find a single paper that disagrees with the consensus), the use of a single keyword lacked diversity, and the lack of reproducibility in the study rendered it suspicious.

Doran and Zimmerman (2009) sought to overcome these obstacles by using a nine question survey that was sent to 10,257 Earth scientists. They focused primarily on two questions: (1) Over the last two centuries, have mean global temperatures risen, fallen, or remained constant, and (2) Is human activity a significant contributing factor in changing mean global temperature? The survey received responses from 3146 individuals (30.7%) of which only 5% (~157) classified themselves as 'climate scientists'. Of these climate scientists, 96.2% answered "risen" to question (1) and 97.4% answered "Yes" to question (2). They concluded that "the debate on the authenticity of global warming and the role played by human activity is largely nonexistent among those who understand the nuances and scientific basis of long-term climate processes". Of course, the problem here is that while the sample may not necessarily be representative, responses to the questions do not prove their conclusions. Most climatologists would be expected to answer "risen" to the first question due to (at least) the demise of the Little Ice Age in the 1800s and "Yes" to the second question due to (at least) the impact of the Urban Heat Island.

Anderegg *et al.* (2010) ranked 908 climate scientists (minimum of twenty climate publications) on the "total number of climate publications authored" and their citation rate by counting "the number of citations for each of the researcher's four highest-cited papers (defined here as

prominence) using Google Scholar." Each researcher was then classified into those who are either convinced or unconvinced by the evidence as determined by whether they had signed statements strongly dissenting from the views of the IPCC. Anderegg *et al.* (2010) found that about 97% of the 200 most prolific writers on climate change believe "it is 'very likely' that anthropogenic greenhouse gases have been responsible for 'most' of the 'unequivocal' warming of the Earth's average global temperature in the second half of the 20th century" (single quotes in the original). Apparently, their view was that unless a scientist openly signed statements that disagreed with the IPCC, s/he was "convinced by the evidence". Limiting their analysis to the 200 most prolific writers provides an odd and relatively convenient way to limit the field from which a consensus is drawn.

Most recently, Cook *et al.* (2013) examined 11,944 climate abstracts from 1991 to 2011 matching two keywords – 'global climate change' or 'global warming'. Although they noted that 66.4% of abstracts did not take a stand on anthropogenic global warming, 97.1% of the abstracts that did "endorsed the consensus position that humans are causing global warming." Incredibly, this figure has been translated to mean 97% of climate scientists agree with the consensus position. The analysis used by Cook *et al.* (2013) is shoddy at best and several authors have pointed out the extensive errors. We did so in Legates *et al.* (2014) which was submitted with my original testimony; it is again included here. Legates *et al.* (2014) reviewed the same papers and concluded that "only 41 papers – 0.3 percent of all 11,944 abstracts or 1.0 percent of the 4,014 expressing an opinion, and not 97.1 percent" agreed with the argument that human activity is primarily responsible for the 20th Century warming. Numerous other researchers, whose research questions the supposed consensus, have come forward to protest that their paper was grossly misrepresented by the categorization of their work by Cook *et al.* (2013).

A major issue with these as well as other such compendia is the black-white dichotomy that is constructed. Scientists do not either believe that all climate change is human-induced (by CO_2) or that humans have no impact on the climate whatsoever. Often a question is raised as to whether humans influence the climate with a "yes" answer being recorded as human-induced climate change will be significant and extreme. Thus, the consensus is made, not because everyone agrees with the concept in principle, but because the question is so framed that any deviation from the extreme view that 'humans have no impact on the climate of the Earth' is tacitly included with the consensus – which then is rewritten to say a much stronger statement than was asked by the question. Indeed, scientists skeptical of the global warming gloom-and-doom scenarios would likely be included as agreeing with the consensus in the Oreskes (2004), Doran and Zimmerman (2009), Anderegg *et al.* (2010), and Cook *et al.* (2013) studies. Thus, most of these 'consensus-building' efforts are largely intellectually fraudulent.

The quest for consensus is, in my view, an attempt to replace the scientific method with a new paradigm – post-normal science. In my answer to Senator Vitter's first question, I discussed in detail the idea of a scientific consensus and that it comes about not by a poll but as a result from a 'trial by fire' where a theory has been extensively tested and evaluated. I urge you to read what I wrote in that answer because it strongly pertains to this discussion.

2. *The Southwestern US is experiencing a 3-year drought. How does this dry spell compare with past droughts over the last 1000 years before influence from extra CO_2?*

The current drought is small compared to the range of droughts over the last millennium.

We first have to remember that the Southwestern United States is a desert and as such, rainfall is naturally low. Where you have high water demand that is growing over time in an area that has low rainfall totals, you have the potential for increasing *hydrologic droughts*; that is, where water demand exceeds water supply. *Meteorological drought* is based solely on precipitation and their changes while *agricultural drought* considers the influence on crops and vegetation. As the demand for water increases, there is no doubt that hydrologic drought has concomitantly increased. Climatologists examine meteorological and agricultural droughts to distinguish changes in water demand from a change in water supply.

For the Southwestern United States, Groisman and Knight (2008) argued that "prolonged dry episodes" of precipitation have increased over the southwestern United States. They concluded that episodes of daily precipitation below 1 mm for a month or longer had increased nationwide over the last four decades, particularly in the summer months and for the Southwestern United States (especially California and Nevada). Noting that Groisman and Knight (2008) used the Cooperative Station Network which often has missing days in the record and are taken by volunteers, McCabe, Legates, and Lins (2010) examined the First-Order Station Network from 1951 to 2006, which has near complete record and are professional observations made by the National Weather Service. We concluded that there is "little evidence of long-term positive trends in dry event length in the southwestern United States." We further found that El Niño/La Niña events and the Pacific Decadal Oscillation are largely responsible for the variability in trends in dry event length. We wrote (italics added):

> "Little evidence of long-term positive trends in dry event length in the southwestern United States is apparent in the analysis of daily [NWS First Order] precipitation data. However, *a number of sites indicate negative trends in dry event characteristics*, particularly for water years and cool seasons. Most of the variability in dry event characteristics in the southwestern United States is attributable to [El Niño/La Niña] and [Pacific Decadal Oscillation] variability...*It is most likely, therefore, that the results of Groisman and Knight (2008) may be biased by the limitations in their data network and the treatment of missing data.*

A number of other forensic studies have attempted to put the current frequency of drought in the Southwestern United States in a longer-term, historical context. For example, Benson *et al.* (2002) and Mensing *et al.* (2004) used sediment cores from Pyramid Lake NV to construct a 7600-year chronology of drought. They found that over the last three millennia, drought intervals have ranged from 80 to 230 years with drought durations on average of 20 to 100 years. Droughts more than a century in length last occurred more than 450 years ago – more recent drought durations were less than a decade.

Using tree-ring chronologies, Ni *et al.* (2002) estimated cool season precipitation (November to April) for Arizona and New Mexico over the last millennium. Although "sustained dry periods

comparable to the 1950s drought" occurred several times before, the 1950s drought lasted only about seven years while other droughts lasted longer – such as the mega-drought of the 1500s which lasted for almost thirty years. In New Mexico, Rasmussen *et al.* (2006) developed a drought chronology from stalagmites in caves of the Guadalupe Mountains and concluded that the data "suggest periods of dramatic precipitation variability over the last 3000 years, exhibiting large shifts unlike anything seen in the modern record." Woodhouse (2004) further noted that the 16th Century Megadrought (1580-1600) and three 13th Century droughts were far more severe than any of the droughts of the 20th Century. Other researchers have concurred; for example, Cook *et al.* (2010) wrote "while severe, this turn of the century drought has not yet clearly exceeded the severity of two exceptional droughts in the 20th Century."

There also has been much work on the effect of ocean oscillations (*e.g.*, El Niño/La Niña and the Pacific Decadal Oscillation) on drought in the Western United States. Seager (2007) compared five great droughts – the Civil War drought, the 1870s drought, 1890s drought, the Dust Bowl drought, and the 1950s drought – with the recent drought from 1998 to 2002 and concluded it "was most likely caused by multiyear variability of the tropical Pacific Ocean" which involved "a persistent La Niña-like state in the tropical Pacific." Seager (2007) goes on to state that "although the Indian Ocean has steadily warmed over the last half century, this is not implicated as a cause of the [recent] drought because the five prior droughts were associated with cool Indian Ocean sea surface temperatures" and colder global climate conditions.

3. *If the U.S. stopped all CO_2 emissions today, with no cars, no electricity from fossil fuels, and net zero emissions from biomass, would there be any noticeable impact on either global CO_2 emissions or climate?*

While the impact would be large for global CO2 emissions, the net impact on climate would be very small. Here is why.

Using data from the Netherlands Environmental Assessment Agency (2013), the United States since 1990 produces about 5 billion tons of CO_2 annually from fossil fuels and cement production; that figure has risen slightly until 2008 and has dropped slightly since. In 2013, global emissions were about 35 billion tons which puts the United States contribution currently at about 1/7 of the world's total (~15% by their calculations). A sudden decrease of 15% in the production of global CO_2 would certainly have a noticeable impact on global CO_2 emissions. However, China's increase has been steady since 2002 and it would only take about a decade for them to increase their output by an amount equal to what we would have removed. Given that India is ramping up their emissions as well – like many others in the developing world – it would not take long for our production to be eclipsed.

The question is whether it would have a noticeable impact on the climate. My assessment is that it would be negligible since CO_2 is a small player in climate change. We would still experience hurricanes and tornadoes, heat waves and cold spells, floods and droughts and all other types of weather extremes. Without energy, however, the problem is that we would not be able to prepare and guard against these weather extremes. Both rich and poor would suffer and the United States would fall into a third world state that was technologically backward. We would pay heavy costs for virtually no measurable gain.

4. *From geologic records, scientists tell us that corals appeared and multiplied during the Mesozoic period from 250 to 63 million years ago.*
   a. *What was the atmospheric concentration of CO_2 at that time?*
   b. *Can you tell me if the ocean is more or less acidic today than it was at that time?*

The best reconstruction of CO_2 concentrations for 250 to 60 million years ago is from the Vostok ice core (Petit *et al.*, 1999). The carbon dioxide concentration ranged from a high of about 285 ppmv at about 245 kyr BP and about 125 kyr BP to a low of approximately 190 ppmv at approximately 60 kyr BP and between 135 and 165 kyr BP. Given that ocean circulation was much different than it is today due to the different land distribution, it is not hard to imagine that ocean pH varies broadly with the atmospheric carbon dioxide concentrations.

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Precipitation: The *Achilles' Heel* of Climate Models?

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ABSTRACT

Current state-of-the-art General Circulation Models (GCMs) do not simulate precipitation well owing to models which rain too frequently with too little moisture and that do not exhibit the full range of precipitation-forming mechanisms that occur in the real world. It is demonstrated here that the impact of these errors are not trivial – an error of only 1 mm in simulating liquid rainfall is equivalent to the energy required to heat the entire troposphere by 0.3°C. Given that models exhibit differences between the observed and modeled precipitation that often exceed 1 mm day^{-1}, this lost energy is not trivial. Thus, models and their prognostications are largely unreliable.

1. INTRODUCTION

One of the legacies of Dr. Frederick Singer will be his early and pointed criticism of climate models. He has written extensively on the differences between model simulations of the present-day climate and observations, particularly as the discussion relates to air temperature and the global energy balance (*e.g.*, Douglas *et al.*, 2004a; 2004b; 2008; Singer, 1982; 2001a; 2001b; 2011; 2013). Such research has prompted other model-observation intercomparisons, the most

telling of which is the evaluation of precipitation. Admittedly, precipitation is quite difficult to simulate in a GCM because, in part, it depends many other processes.

This paper will show that the biases associated with the simulation of precipitation in climate models adversely affects air temperature simulations which, in turn, feedbacks positively to undermine the simulation of air temperature and other components of the energy balance as well as global and regional circulation patterns. While models are 'tuned' to appear correct in the aggregate, they do not properly simulate the entire spectrum of precipitation-causing *processes*.

2. General Circulation Models (GCMs)

When someone refers to a 'model', one usually thinks of a replica of an actual object. The main distinction between a model and a 'toy' is the attention to detail and functionality. Models are more detailed and often have similar functionality to their original counterparts but are often smaller (or sometimes larger) to allow someone to better grasp the full concept of the real object.

Scientific models convey a similar, but broader, meaning. A scientific model can be physical reproduction of reality; for example, a scale model of the solar system that is laid out on some college campuses (such as the University of Delaware). A model can also be a simplification of a more complex concept, such a model of the atom, which can be used to convey a difficult theory to the general public. Often, a model is a set of mathematical equations arising from fundamental physics and empirical relationships that mimics the actions and response of the real world. These models are solved on computers which lends the title "computer models" to models of this genre.

General circulation models (or GCMs) are a good example of a computer model. They are mathematical representations of the physical laws and processes that drive the Earth's climate. Their purpose is to simulate the climate by providing fields of air temperature, humidity, winds, precipitation, and other variables and their variability resulting from a variety of forcing mechanisms (*i.e.*, internal and external changes to parameters that affect the climate). GCMs are limited, however, by both our understanding of what drives, shapes, and affects the climate as well as how the climate responds to these forcing mechanisms – as well as the speed and capabilities of modern-day computers.

How GCMs treat the complex interaction between the atmosphere and the Earth's surface is a critical component. Large bodies of water – oceans, lakes, rivers, *etc.* – provide substantial amounts of moisture and energy to the atmosphere and since they cover nearly three quarters of the Earth's surface, they are highly important. Moreover, these components of the *hydrosphere* are always in constant motion so that the energy and moisture they contain is an important mechanism for the redistribution of energy and moisture around the globe. Thus, this circulation must be adequately modeled and the transfer of energy and moisture between the ocean and the atmosphere must be appropriately described. Modeling these process within a GCM is extremely difficult.

But the hydrologic cycle is more than just interactions between bodies of water and the atmosphere – the most complicated connection lies between the atmosphere and the land surface. Most terrestrial environments are extremely heterogeneous with a high degree of spatial

variability in vegetation and human-created structures. GCMs, by contrast, must assume that the landscape and atmospheric processes are either constant over large areas up to a hundred miles across (for Cartesian or grid-based GCMs) or that they exhibit a very high degree of smoothness spatially (for spectral-based GCMs). Thus, the sheer nature of surface heterogeneity makes it very difficult to model land-surface processes within a GCM. Interactions between this heterogeneous land surface and the atmosphere also are extremely complex as plants vary not only in their size and shape but also in their ability to access soil moisture reserves and to utilize this soil water.

Based on this complexity and that GCMs must necessarily simplify these processes, several important limitations arise. GCMs are limited by our incomplete understanding of the climate system and the various interactions between the atmosphere, hydrosphere, and the land surface and by how this incomplete knowledge is transformed into mathematical equations. GCMs also are limited by their spatial and temporal resolutions. Representing this spatial and temporal heterogeneity is severely restricted by computing power which reduces the ability of GCM simulations to coarse generalities. As a result, many small- and regional-scale features, which may have significant impact on the local, regional, or even global climate, are not represented. It cannot be over emphasized that GCM representations of the climate can be evaluated at a spatial resolution no finer than large regional areas, seldom smaller than a region defined by a square several hundred miles (at least several GCM grid cells) on a side. Even the use of 'nested grid models' (models which take GCM output and resolve it to finer scale resolutions) does not overcome this limitation since results from the GCM simulation drives such models and no mechanism is available to feedback the results of such finer-scale models to the GCM.

A further limitation is that given the restrictions in our understanding of the climate system and its computational complexity, GCMs simply cannot reproduce some very important phenomena. For example, hurricanes and most other forms of severe weather (*e.g.*, nor'easters, tornadoes, and thunderstorms) simply cannot be represented in a GCM owing to the coarse spatial resolution. Other more complex phenomena resulting from interactions among the elements that drive the climate system may be limited or even not simulated at all. Phenomena such as the Pacific Decadal Oscillation, the Atlantic Multidecadal Oscillation, and other complex interrelationships between the ocean and the atmosphere, for example, are inadequately reproduced or often completely absent in climate model simulations. Their absence indicates a fundamental flaw exists in either our understanding of the climate system, the mathematical parameterization of the process, the spatial and temporal limitations imposed by finite computational power, or a combination of all three.

3. Precipitation in a GCM

A further limitation of GCMs is that the climate itself is highly complex, with numerous feedbacks and interactions. Thus, simulations of climate variables do not occur independently of the other variables in the models – everything is interconnected. Air temperature and its variability, by virtue of its importance, is often considered as the most important climate variable. Thus, climate modelers pay close attention to the surface air temperature field since it comes under the highest scrutiny and is the most often used and cited variable. But the interconnected nature of the climatic system results in a strong propagation of errors. In short, anything that is modeled incorrectly in a climate model will adversely affect the simulation of every other variable. Modelers may 'tune' the air temperature field so it appears reasonable but

the key question is "Does the model properly simulate the important features that comprise our climate system?" One may arrive at a reasonable result but for all the wrong reasons. In that case, model prognostications are likely to be worthless at best or even misleading since if the process is not accurately modeled, how can we be assured that the changes resulting from various forcing mechanisms are valid?

Consider precipitation. At the macro-scale, the precipitation-forming process requires moisture in the atmosphere (humidity) and a mechanism to cause it to condense. All mechanisms require the air to cool below the dew point temperature – almost always through forcing the air to rise and cool adiabatically – and include causing the air to rise over topography (orographic), surface heating (convective), interaction with air masses (weather fronts), or by cyclonic rotation. Thus, at the macro-scale, any errors in simulating the atmospheric moisture content or the location and magnitude of these precipitation-causing mechanisms will directly undermine the accurate simulation of precipitation.

Thus, GCM simulations of precipitation will be affected by limitations in the representation and simulation of topography since mountains force air to rise. Incorrect simulations of air temperature also will adversely affect the simulation of precipitation since the moisture content of the atmosphere is directly related to its temperature. If winds, air pressure, and atmospheric circulation are inadequately represented, precipitation will be adversely affected since the atmospheric flow of moisture that may condense into precipitation will be incorrect. Plant transpiration and soil evaporation also provide moisture for precipitation; therefore, errors in the simulation of soil moisture conditions will adversely affect the simulation of precipitation.

Simulation of clouds alter the solar energy reaching the ground, which affects estimates of surface heating and subsequently convective precipitation. Even problems in specifying oceanic circulation or sea ice concentrations will affect weather patterns, which affect precipitation simulations. In sum, the simulation of precipitation is adversely affected by inaccuracies in the simulation of virtually every other climate variable.

The issue is that inaccuracies in simulating precipitation, in turn, will adversely affect the simulation of virtually every other climate variable. Condensation of moisture releases heat to the atmosphere and forms clouds, which reflect energy from the sun and trap heat from the Earth's surface – all of which affects the simulation of air temperature. Inaccuracies in the three-dimensional structure of air temperature subsequently can affect the simulation of winds, air pressure, atmospheric circulation, and even the formation and distribution of sea ice. Since winds drive the circulation of the upper layers of the ocean, the simulation of ocean circulation also is affected. As soil moisture is a direct response to the precipitation input, inadequate simulations of precipitation will adversely affect soil moisture conditions and land surface hydrology. Vegetation also responds to moisture availability so that the entire representation of the biosphere can be adversely affected. Clearly, the interrelationships among the various components that comprise the climate system make climate modeling difficult.

It must be noted, however, that GCMs simulations are far more than just the long-term average conditions and traditional seasonal variations that we observe. Demonstrating that precipitation is highest over the tropical rainforests and lowest in the subtropical deserts is not enough as climate change often manifests itself in small regional-scale fluctuations. It also is extremely

important to simulate properly the intra-annual variability as much of the character of the Earth's climate is in how it varies over time. A GCM that exhibits little year-to-year variability is clearly missing an important component of the Earth's climate. Thus, any evaluation of climate change prognostications using GCMs must be made in light of the model's ability to represent the holistic nature of the climate and its variability.

And that is where GCMs are severely lacking. Assume a climate model simulates a change in precipitation for the near or distant future. It is important to know *why* the precipitation is forecast to change – what specific precipitation producing mechanism(s) has changed due to the forcing placed on the model. Are more or fewer tropical storms or nor'easters simulated to occur? Will frontal precipitation be altered due to changes in air mass formation and/or their movement? Will there be more or less convective activity from surface heating that leads to a change in the rising air? Or has atmospheric circulation been altered such that orographic precipitation is affected?

While precipitation in the real world arises from several mechanisms (*i.e.*, orographic, convective, frontal, or cyclonic rotation), precipitation in a GCM is produced almost exclusively from a single cause – surface convection. The term 'popcorn precipitation' is often used to explain precipitation in a GCM since it resembles the popping of popcorn kernels with rainfall occurring over large regions and relatively frequently (Zolina, 2014). When these models are averaged over seasons, the classic pattern of global precipitation emerges with a moist equatorial region, decreased precipitation in the subtropics, and increased precipitation in mid-latitudes that tapers off with the colder temperatures toward the poles (Figure 1). While this may *appear*

correct in the aggregate, the GCM has achieved its apparent success without properly simulating the mechanisms that create real-world precipitation. How possibly, therefore, can the models make accurate prognostications of precipitation when they do not simulate correctly the mechanisms that drive precipitation?

Stephens *et al.* (2010) identifies this problem from three state-of-the-art climate models and numerical weather prediction models. Using high resolution CloudSat observations over the oceans (where precipitation is more uniform spatially), they demonstrate that the differences between the models and the observations are much greater than observational and averaging errors. They conclude "the general tendency is for models to produce precipitation that is far too frequent, especially in midlatitudes" (Stephens *et al.*, 2010:8). Note that tropical precipitation is largely convective (although some stratiform precipitation does occur – Janowiak *et al.*, 1995) but that in midlatitudes, precipitation arises from a variety of mechanisms. Instead of simulating frontal passages and organized weather systems, the models exhibit 'popcorn precipitation' where rainfall occurs far too often. As a consequence of having it rain too frequently, the intensity of modeled precipitation is that when it occurs, its intensity is much lower than observed. Thus, precipitation totals appear reasonable but its distribution (frequency and intensity) is grossly in error. Even models that have spatial resolutions as fine as 7-14 km (4.4-8.8 mi) exhibit these problems. When averaged to seasonal averages for the globe, the models appear to do remarkably well. However, they achieve this level of success for the wrong reasons. Regionally, the GCMs "tend to produce too much precipitation over the tropical oceans and too little in midlatitudes" (Stephens *et al.*, 2010:11).

Christy (2012) demonstrated that the March-to-July precipitation, as simulated by most climate models, exhibits considerable variability between the models but does not exhibit a long-term trend. For both the Southeastern and Midwestern regions of the United States (Figure 2), model-simulated precipitation varies by a factor of two and most models tend to underestimate precipitation in the Southeast and overestimate precipitation in the Midwest (and Southwest – see Langford *et al.*, 2014). Spatially, regional estimates of precipitation can vary widely from model to model (see Dai, 2006; IPCC, 2013; Stephens *et al.*, 2010).

Soden (2000) highlights another problem associated with the simulation of precipitation by GCMs. Concomitant with the model's ability to simulate the *processes* that drive precipitation is the model's ability to simulate year-to-year variability in precipitation. Although GCMs are not weather prediction models and their utility is not in predicting, for example, whether it will rain in Southern England on the morning of July 14, 2087, it nevertheless is important that they also exhibit the observed intra-annual variability. Part of climate change prognostications is in determining whether the probability of precipitation will be substantially different from what it is today – in both the frequency and intensity of precipitation events. In general, we want to know whether the summer of 2087 is likely to be wetter or drier than present conditions and by how much.

Soden (2000:541) demonstrates that there is a "substantial difference between the observed and GCM-simulated variation in tropical-mean precipitation...the magnitude of the observed variations in $<\delta P>$ [precipitation variability] is substantially larger than that predicted by current GCMs and clearly lies outside the range of intermodal variability" (Figure 3). He goes on to

suggest that "not only do the GCMs differ with respect to the observations, but the models also lack coherence among themselves...even the extreme models exhibit markedly less precipitation variability than observed. Kang *et al.* (2002) agrees that models underestimate intra-annual precipitation variability in the western Pacific but notes that models tend to exaggerate the intra-annual variability of precipitation associated with the Indian summer monsoon. Indeed, Soden (2000:542) concludes, "if the GCMs are in error, this deficiency would presumably reflect a *more fundamental flaw common to all models*" (emphasis added). Although newer models do show an improvement, they continue to underestimate the observed inter-annual variability (Song and Zhou, 2014; Wang *et al.*, 2011).

Another fundamental problem that affects GCM simulations of precipitation is the representation of topography, particularly in spectrally-based GCMs (*i.e.*, models where fields are represented as a series of spherical harmonics rather than specific grid boxes). Biasutti *et al.* (2003) demonstrates the representation of topography in a GCM using a T42 (triangular truncation at wavenumber 42) spectral resolution (Figure 4). The Andes are represented as a single 'bump' without individual mountains and reaching an altitude of only 3000 meters. In Eastern Africa, the mountains are represented by a large plateau while the Himalayas appear as simply a gradual rise over a large area. But an additional problem focuses on how the models represent the oceans. Rather than being at or near sea-level, spectral models require all fields to be smooth mathematical functions such that waveforms arising from these mountains propagate out into the world's oceans. Lindberg and Broccoli (1996) demonstrate that using a GCM with R30 (rectangular truncation at wavenumber 30), the oceans exhibit topographical variations on the order of several hundreds of meters (Figure 5). For example, the effect of the Andes is to create

a wave train across the entire Pacific Ocean; the remnants can still be seen near the coast of Australia. In the model, orographic effects are generated because the model 'sees' a mountain range – and the rising and descending motions both enhance and diminish precipitation.

3. Precipitation and the Energy Budget

If precipitation were an esoteric variable that had little further impact on the rest of the climate simulation, these problems could be noted and largely ignored. But the moisture converted from water vapor to liquid or solid form (through condensation and/or deposition) exchanges energy with the environment. Thus, getting the cloud cover amount incorrect – and by implication, the amount of moisture in precipitation – has a profound effect on the energy balance. Condensation of moisture from latent heat is transformed into other components of the energy balance, including sensible heat (change in temperature), kinetic energy (change in atmospheric motion), and potential energy (change in vertical positioning). Since the First Law of Thermodynamics states, among other things, that energy can neither be created nor destroyed, incorrect simulations of the precipitation/condensation process necessarily will adversely affect the simulation of other aspects of the energy balance – including air temperature.

To show the relative effects of moisture condensation and to put errors in precipitation simulations into focus, consider the energy produced by the condensation of 1 mm of moisture. Although precipitation is usually considered as a depth of water, it can be written as a volume of water per unit area – 0.001 $m^3\ m^{-2}$. The density of water changes with its temperature but for simplicity, consider a temperature of 15°C. Considering only the transformation of water vapor to liquid water (*i.e.*, the Latent Heat of Vaporization), we can write

$$(0.001\ m^3m^{-2})\ x\ (999.1026\ kg\ m^{-3})\ x\ (2.4656\ x\ 10^6\ J\ kg^{-1}) = 2.4634\ x\ 10^6 J\ m^{-2}. \quad (1)$$

Thus, the condensation of 1 mm of precipitable water releases $2.4634\ x\ 10^6$ Joules of energy per unit area.

If this energy were distributed over the entire troposphere (the lower 80% of the atmosphere), weighted by density (since atmospheric density decreases with increasing height), how much of a temperature increase would occur? The mass of the atmosphere is approximately $5.136\ x\ 10^{18} kg$ (Lide, 1996) while the surface area of the Earth is approximately $5.1\ x\ 10^8 km^2$. This yields an average mass per unit area for the troposphere of

$$(5.136\ x\ 10^{18}\ kg)\ x\ (5.1\ x\ 10^8\ km^2)^{-1}\ x\ \left(\frac{1\ km}{1000\ m}\right)^2\ x\ 0.8 = 8.0565\ x\ 10^3\ kg\ m^2. \quad (2)$$

Warming this $8.0565\ x\ 10^3\ kg\ m^2$ of air by $2.4634\ x\ 10^6\ J\ m^{-2}$ and using a value for the specific heat of air of $1.005\ x\ 10^3\ J\ kg^{-1}K^{-1}$, yields

$$(2.4634\ x\ 10^6\ J\ m^{-2})\ x\ (1.005\ x\ 10^3\ J\ kg^{-1}K^{-1})^{-1}\ x\ (8.0565\ x\ 10^3\ kg\ m^2\ )^{-1} = 0.3042\ K \quad (3)$$

Thus, the energy released by condensing a simple 1 mm of rainfall is sufficient to warm the entire troposphere by approximately 0.3°C! When we recognize that the errors in simulating precipitation can be off by considerably more than a millimeter per day (IPCC, 2013) and are not

consistent in their timing in that precipitation occurs far too frequently (Stephens *et al.* 2010), it becomes clear that the bias in modeled precipitation is a major problem for not just model simulations of the current conditions, but especially for model prognostications of the future.

CONCLUSIONS

One of the fundamental problems with GCMs lies in their simulation of precipitation. Virtually every error that is made within a climate model adversely affects the precipitation estimates which, in turn, adversely affects virtually every other aspect of the climate model. While much of the focus of climate models lies in their simulation of surface air temperature and how it is likely to change in the future, it is the precipitation field that exposes the most glaring discrepancies between the real world and the model representation of it. As a result, the surface air temperature field must be tuned to adjust for the inadequacies in the simulation of precipitation since, as demonstrated here, a simple error of 1 mm of condensed moisture represents enough energy to warm the column of air through the entire depth of the troposphere by 0.3°C. Given that errors in precipitation simulation are significantly larger than 1 mm – both in magnitude as well as timing since models tend to produce too little rain that occurs too frequently – these errors are often greater than the climate change signal that is sought. Thus, GCMs must be used with caution; and their prognostications taken largely with a grain of salt.

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FIGURE CAPTIONS

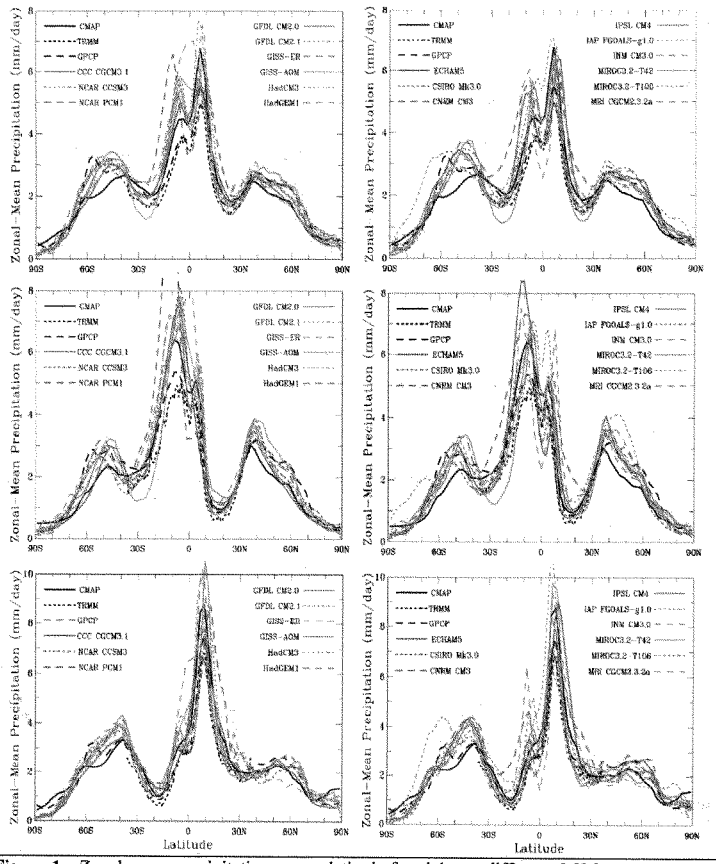
Figure 1: Zonal-mean precipitation versus latitude for eighteen different GCMs compared with three different climatologies (CMAP, TRMM, and GPCP) for the globe (top), January (middle), and July (bottom). Left and right panes display different climate models (from Dai, 2006).

Figure 2: Southeastern (top) and Midwestern (bottom) United States precipitation as measured from observations (black dots) and models (colored lines; median in solid black) for 1860 to 2100 (from Figures 2.2 and 2.3 in Christy, 2012).

Figure 3: Change in precipitation over time. The heavy dark line is the observed precipitation, the thin line is the model ensemble average for the given year, and one 'model' standard deviation is shown by the vertical lines around the model ensemble average (from Soden, 2000).

Figure 4: Representation of topography using a standard T42 truncation scheme in a spectrally-based climate model. The contour interval is 400 m. Negative altitudes of below -200 m occur west of the Andes while the highest peaks are only 3000 m high. Note also the inaccuracies of the representation of topography in Africa (from Biasutti *et al.*, 2003).

Figure 5: Surface elevation (in meters) represented by a spectrally-based climate model using an R30 truncation scheme (approximately 2.25° of latitude by 3.75° of longitude spatial resolution). Note the 'mountains' over the oceans (from Lindberg and Broccoli, 1996).



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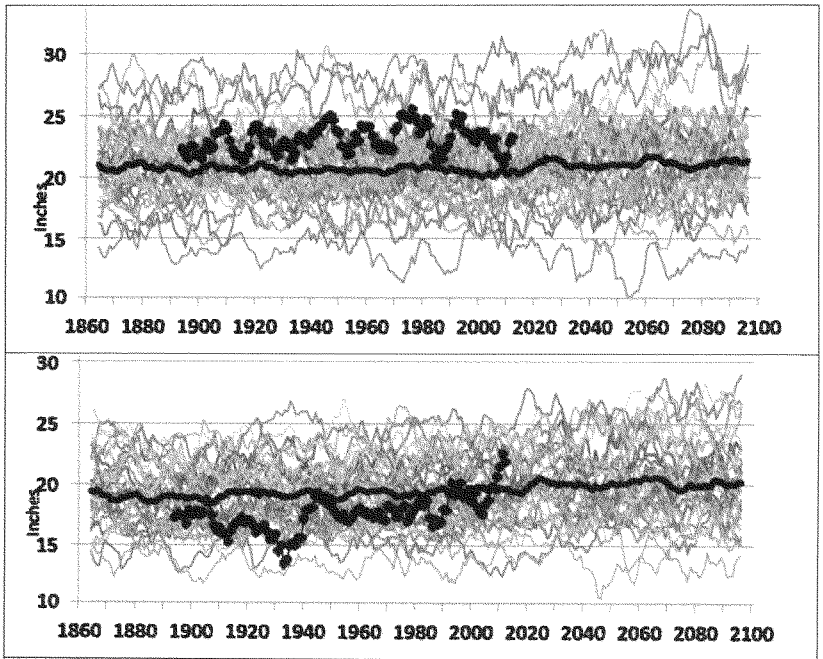

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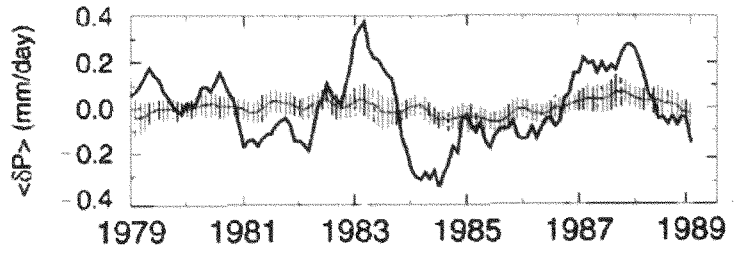

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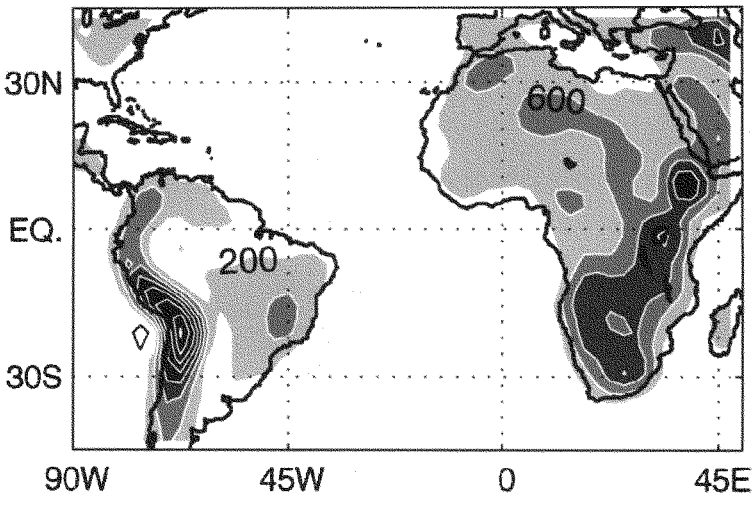

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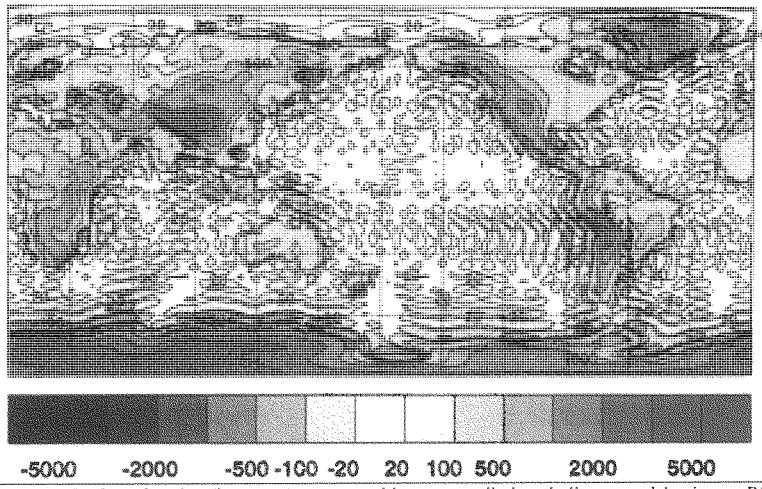

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Climate Consensus and 'Misinformation': A Rejoinder to *Agnotology, Scientific Consensus, and the Teaching and Learning of Climate Change*

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Abstract Agnotology is the study of how ignorance arises via circulation of misinformation calculated to mislead. Legates et al. (Sci Educ 22:2007–2017, 2013) had questioned the applicability of agnotology to politically-charged debates. In their reply, Bedford and Cook (Sci Educ 22:2019–2030, 2013), seeking to apply agnotology to climate science, asserted that fossil-fuel interests had promoted doubt about a climate consensus. Their definition of climate 'misinformation' was contingent upon the post-modernist assumptions that scientific truth is discernible by measuring a consensus among experts, and that a near unanimous consensus exists. However, inspection of a claim by Cook et al. (Environ Res Lett 8:024024, 2013) of 97.1 % consensus, heavily relied upon by Bedford and Cook, shows just 0.3 % endorsement of the standard definition of consensus: that most warming since 1950 is anthropogenic. Agnotology, then, is a two-edged sword since either side in a debate may claim that general ignorance arises from misinformation allegedly circulated by the other. Significant questions about anthropogenic influences on climate remain. Therefore, Legates et al. appropriately asserted that partisan presentations of controversies stifle debate and have no place in education.

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Science is the belief in the ignorance of experts.
Feynman (1969)

1 Introduction

Agnotology is the study of general or even systemic ignorance and its cultural production arising from a basic lack of knowledge, from selective choice, and from an intentional attempt to deceive (Proctor 2008). In the context of this paper, the focus will be on misinformation said to have arisen not through inadvertence, nor through any limitation in the state of knowledge, nor through any defect in teaching or learning, but through the self-interested determination of some sufficiently influential faction to circulate misinformation calculated to sow doubt, to conceal a truth, or to promote falsehoods.

Bedford (2010), seeking to apply agnotology to climate science education, asserted that vested interests had promoted doubt and ignorance about what he maintained was a consensus about the implicit effect that anthropogenic influences on the climate were potentially so damaging as to require urgent implementation of policies to abate them. Legates et al. (2013) added to that discussion with a paper raising questions about the legitimacy of attempting to apply agnotology to the politically-charged climate debate. In the rejoinder by Bedford and Cook (2013), it is evident that the claim of "misinformation" that the fossil-fuel industry is said to be circulating is contingent upon the post-modernist assumption that the truths that are the end and object of scientific inquiry are discernible by reference to the existence of a consensus among climate scientists, and upon the further assumption that such a consensus exists.

Bedford and Cook (2013), in agreement with Bedford (2010), outline their position as follows:

(1) There is an overwhelming consensus within the scientific community [that] ...the Earth's global average temperature is increasing, and human emissions of greenhouse gases, especially carbon dioxide, are the main cause (p. 2020),
(2) Despite this very strong consensus, the general public, especially in the United States of America, perceives substantial disagreement among scientists on these fundamentals (p. 2020),
(3) A campaign of obfuscation regarding climate change science has been undertaken since the late 1980s, funded in part by the fossil fuels industry (p. 2020), and
(4) A careful examination of the claims made in popular literature or films regarding human-induced climate change could be a useful critical thinking exercise and test of content knowledge for students (pp. 2020–2021).

The climate consensus in (1) is the standard definition—which, significantly, does not explicitly encompass the notion that any policy action should be taken to mitigate our influence on the climate. However, the literature does not evidence a "very strong" consensus as defined by (2). There is, however, general agreement among scientists that there is a greenhouse effect; that our emissions of carbon dioxide and other greenhouse gases enhance it; and that some consequent warming may be expected. The general public correctly perceives these basic climatological tenets, which are tenets not because there is a consensus about them but because they have been demonstrated by measurement and experiment.

If the definition of agnotology is accepted, then a priori either faction in a polarized scientific debate may be guilty of circulating misinformation calculated to obfuscate or to mislead. Just as the fossil fuel industry has a vested interest in questioning whether

consensus stands part of the scientific method, whether there is a consensus, and whether—even if there were a consensus—there are more cost-effective methods to mitigate global warming today than to adapt to any net-adverse consequences tomorrow, so too do the environmental lobby and large sections of the academic community have a vested interest in maintaining that argument from consensus is scientific, that there is an overwhelming consensus, and that we must act to mitigate climate change regardless of the cost. These considerations underpin the original concern of Legates et al. (2013) that agnotology has the strong potential for misuse whereby a 'manufactured' consensus view can be used to stifle discussion, debate, and critical thinking.

Though we are grateful to Bedford and Cook for their commentary, and though we agree with them on points such as (4) above, a substantive rebuttal of points (1)–(3) follows. These significant areas of disagreement require further discussion.

2 Climate or Climate Change?

Climatology is the study of the climate of the Earth—its causes, interactions, variability, and feedbacks. It is subdivided into a number of major areas of study (Landsberg and Oliver (2005) including physical climatology (mass or energy exchanges at the Earth's surface), dynamic and synoptic climatology (atmospheric motion and its concomitant thermodynamics), regional climatology (why climate varies over space), and applied climatology (use of climate science to solve agricultural, transportation, and design issues, for example). Climate change transcends all four of these subdivisions in that virtually all climatologists agree that climate is never stationary; but rather, is in a constant state of change on time-scales ranging from hours to eons.

Unfortunately, more time is spent in teaching about climate change than about the Earth's climate. Students are taught as early as the first grade that carbon dioxide causes temperatures to rise; so much emphasis is put on the transfer of energy by electromagnetic radiation that students are often unaware that more energy is transferred to the atmosphere by latent heat than by longwave radiation. The effect of failing to teach climate science is that climate merely becomes *average weather* and climate change is the dynamics of how carbon dioxide will change this average or *normal* condition. Moreover, it also leads to a misunderstanding—whether innocent or intentional—of how questions are viewed by scientists and other respondents. The question "Do you believe in climate change?" for example, can yield a biased picture if the scientist uses the strict scientific definition of climate change while the questioner often views 'climate change' as being synonymous with 'anthropogenic global warming.'

3 A Scientific Basis for an Uncertain Science

The first tenet posited by Bedford and Cook (2013, p. 2021) is that the

> ...basic science is defined as the findings that greenhouse gas concentrations have been rising since the Industrial Revolution; this has occurred largely, though not exclusively, due to the burning of fossil fuels; and this increase in greenhouse gas concentrations is the main cause of an observed increase in Earth's global average temperature over the period of instrumental record (generally since the mid-late nineteenth Century).

Note that Bedford and Cook have mixed the 'basic science' of climatology with their definition of climate change. The authors go on to question our belief in what they call 'basic science':

> Legates et al.'s (2013, p. 9) statement that 'The science is indeed uncertain owing to incomplete and complicated observational evidence' is therefore too imprecise to be helpful. To which aspects of the science of human-induced climate change are they referring? Are they proposing that it is unclear whether carbon dioxide is a greenhouse gas? Or that the concentration of carbon dioxide in the atmosphere has increased since direct measurements began in 1958? Or that global average temperatures in 2012 are greater than they were in 1900? If so, it would be intriguing to discover the basis for these claims of uncertainty. While some measure of uncertainty applies to any scientific finding, Legates et al. (2013) appear to be arguing that even these basic points are too uncertain to be taught in a science classroom without some alternative viewpoint to provide 'balance'. An overwhelming body of evidence indicates that this is not the case. (p. 2023)

This remark conflates the discussion of climate science with climate change and illuminates an errant linear thought process. The logical *fallacy of false cause* here arises from the premises (1) that carbon dioxide is a greenhouse gas, (2) that atmospheric concentrations of it have been increasing since 1958, and (3) that global average temperatures have increased since 1900. But the conclusion that rising global temperatures must be chiefly attributable to increasing carbon dioxide concentrations does not necessarily follow. The issues have always been whether and to what extent changes in the climate are caused by changes in greenhouse gas concentrations and whether there is a causal, not simply correlative, link. For mere correlation (to the extent that it exists) does not necessarily entail causation. Thus, Legates et al.'s (2013) assertion that the science [of climate change] is indeed uncertain owing to incomplete and complicated observational evidence is true.

Given that Bedford and Cook (2013) confuse climate science with anthropogenic climate change arguments, it is useful here to discuss three broad themes that underlie scientific skepticism about anthropogenic global warming, so as to provide a proper scientific context for our subsequent discussion. First, scientific skepticism arises because of the continued failure of direct evidence for detailed spectral studies of electromagnetic radiation related to the greenhouse effects of atmospheric carbon dioxide (Huang et al. 2007; Huang and Ramaswamy 2008). This is related to an inaccurate representation of the effects and impacts of enhanced greenhouse warming from increased atmospheric carbon dioxide in simulations which often disagree with observations. Even where there might be some apparent agreements, the results are known to derive from large compensating errors in different spectral bands and regions (see e.g., Brindley and Allan 2003; Huang et al. 2007; Huang and Ramaswamy 2008).

A second reason is the extensive empirical evidence from paleoclimatic and geologic perspectives that casts doubt on whether atmospheric carbon dioxide has a predominant role as the driver of weather and climate (e.g., Soon et al. 2003; Kukla and Gavin 2004, 2005; Soon 2007; Akasofu 2010). Paleoclimatic data show that over time, climate varies naturally on local, regional, and global spatial scales with a very large range of warming-cooling, wetting–drying, and glacial-interglacial cycle amplitudes. Yet at no point in the >11,000 years since the abrupt termination of the Younger Dryas cooling event brought the last Ice Age to an end has absolute global mean surface temperature departed from the mean by much more than 3 °C. Higher-resolution paleoclimatic temperature and hydrological proxies demonstrate that variations on the pertinent timescales of decades to centuries are entirely plausible even in the absence of any apparent influence by changing levels of atmospheric carbon dioxide. This point may come as a surprise,[1] but it has

[1] This point is highlighted to stress the difficulties in ascertaining the actual causal role and impact of changing atmospheric carbon dioxide content on weather statistics and climate change over long time scales. We are aware of an opposing conclusion reached by Alley (2007), for example, where atmospheric carbon dioxide content is said to be quintessential for the presence of climate change on all timescales. Dr. Alley's presentation is at http://agu.org/meetings/fm09/lectures/lecture_videos/A23A.shtml.

recently been noted that even during the dramatic 100 kyr glacial-interglacial cycles of the last 800,000 years or so, the role of atmospheric carbon dioxide can hardly be qualified as a primary driver (e.g., Soon 2007). Furthermore, the sensitivity and dependence of the regional climates of the Arctic and of China on solar radiation at multi-decadal to centennial timescales has been emphasized by Soon (2009) and Soon et al. (2011). Alternate hypotheses such as unforced variations from internal oscillations of the coupled ocean–atmosphere system must be comprehensively examined and quantified before any firm conclusion can be reached as to the magnitude of anthropogenic influences on global temperature.

Our third reason for scientific skepticism about whether atmospheric carbon dioxide is the primary driver of climate change is related to the over-reliance on climate model outputs which exhibit a strong exaggeration in their results even when narrowly adopting atmospheric carbon dioxide as the sole driver of climate responses. Lindzen and Choi (2011) and Choi (2011) recently documented that general circulation models, such as those cited in the *Assessment Reports* of the United Nations Intergovernmental Panel on Climate Change (IPCC), have consistently overestimated the climate sensitivity to rising atmospheric carbon dioxide. The current generation of models is still unable to represent properly the real-world oceanic and atmospheric processes.

The existence of these and many other well-evidenced scientific uncertainties demonstrates that teaching students about the climate *must* include discussions of how complicated the Earth's climate system is and of why we cannot possibly have all the answers to every question about how and why climate changes. In particular, fundamental problems related to the parameterization of climate components with complex and potentially unknown interactions—notably forcings and feedbacks, especially those concerning clouds and the oceans—remain unsolved and are likely to remain so for the foreseeable future (Essex 1986, 1991; Soon et al. 2001; Lindzen 2007; Koutsoyiannis et al. 2009). Owing to difficulties in simulating Arctic clouds (Walsh et al. 2009), climate models also have failed to simulate the surface shortwave and longwave radiation budgets in the Arctic by a very large margin when compared to the relatively minor effect of rising carbon dioxide in the scenarios posited. For example, Zhu et al. (2007) discussed the important biases in simulating low marine clouds in the tropics and emphasized that a correct determination of sea surface temperatures and above-inversion atmospheric stability remains two serious hurdles for any climate model.

Understanding the oceans too is essential to understanding the causes of climate change because they interact dynamically with the atmosphere and pose problems that simplistic modeling of ocean mass flows and wind-assisted circulation cannot address (Ghil et al. 2008; Wunsch 2002, 2010). Specifically, Wunsch (2002, 242–243) said:

> The history of oceanography is littered with appealing, simplifying ideas, that had ultimately, to be painfully dislodged. The problem is further compounded by the fact that models have become so sophisticated and interesting, it is tempting to assume they must be skillful. This is a very dangerous belief! ... It is not uncommon to see published calculations of future climate states obtained using ocean models with a spatial resolution as coarse as 4° [in longitude and latitude]. Although the writers of such papers would undoubtedly deny that they are producing "forecasts", the reader is usually given little or no guidance as to the actual expected skill of such models. Is it plausible that a 4° or even 1° ocean model can be integrated with skill for 1000 years? If there is real skill, then the modeling community has solved one of the most difficult of all problems in turbulence: that of a rotating, stratified fluid in a complex geometry. What is the evidence for its truth?

The poor fit of current climate models results to the historical and recent air temperature records (e.g., Soon et al. 2003; Koutsoyiannis et al. 2008; Akasofu 2010; Anagnostopoulos et al. 2010) shows that while they may be of heuristic value (e.g., Soon et al. 2001), they

simply cannot predict future climates (Green et al. 2009). For example, climate models cannot model historical climate fluctuations where atmospheric carbon dioxide lags air temperature because model prognostications of regional surface temperatures, or even of global mean surface air temperature, are inherently dependent on carbon dioxide levels under the current paradigm of climate forcings and feedbacks. Pielke et al. (2009) raise important criticisms of models' treatment of atmospheric carbon dioxide as if it were the only (or at least the dominant) climate forcing. An objective analysis must consider not only all other anthropogenic climate forcings but also naturally-caused climate changes as well as the limits to predictability of the climate system (Essex et al. 2007; Ghil et al. 2008; Koutsoyiannis 2010).

Notwithstanding the dominance of uncertainty in climate change science, Bedford and Cook (2013) argue for a strong scientific consensus on climate change. While they, and Bedford (2010), do admit there is ample room for disagreement, they assert that the "basic science of human-induced climate change" (p. 2021)—that since carbon dioxide is a greenhouse gas and its atmospheric concentration has been increasing since 1958 concomitant with a rise in global average air temperature, there must be a causal link—defines a scientific consensus. Despite their basic assertion, global air temperatures have not been rising at all since the dawn of this Millennium (since January 2001) and, in fact, for several years before that (Fig. 1). This raises the question of what natural or anthropogenic influences have offset any global warming since 2001 caused by carbon dioxide. Many suggestions have been posited, but the absence of global warming for more than 16 years indicates that influences with a signal at least as strong as the impact of increasing concentrations of atmospheric carbon dioxide have also affected the global air temperature record. This is why uncertainty still remains and cannot be dismissed.

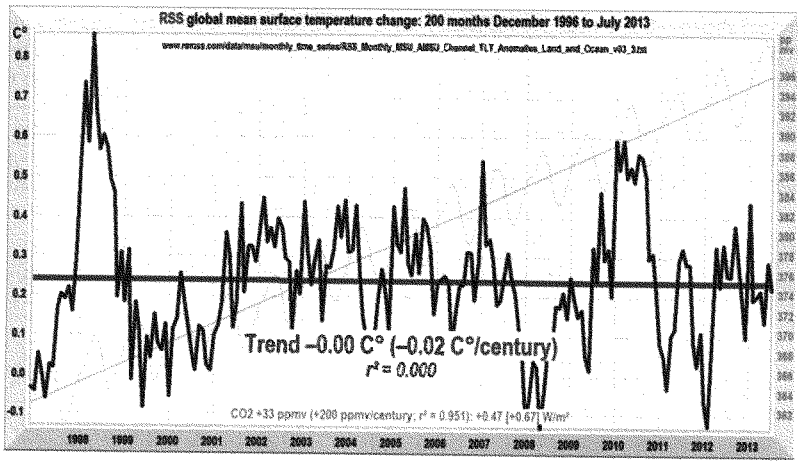

Fig. 1 Monthly global mean surface air temperature anomalies, December 1996 to July 2013 (Remote Sensing Systems, Inc.), showing no trend over 16 years and 8 months (200 months), notwithstanding a rising trend in carbon dioxide concentrations at a rate equivalent to 200 μatm century^{-1} (NOAA 2013), implying a radiative forcing of 0.47 W m^{-2} from carbon dioxide alone or 0.67 W m^{-2} over the period once the additional forcing from all other anthropogenic influences is taken into account

4 Whither Scientific Consensus?

The crux of the argument in Bedford and Cook (2013) for an overwhelming scientific consensus is that several surveys examining the peer-reviewed literature "demonstrate that [while] it is possible to find peer-reviewed publications that explicitly reject the scientific consensus on human-induced climate change, ...such publications represent a vanishingly small minority of the scientific community's output on the subject" (pp. 2021–2022). Several articles are cited (Oreskes 2004; Doran and Zimmerman 2009; Anderegg et al. 2010) but the article that the authors define as "the most thorough assessment of the peer-reviewed literature on human-induced climate change to date" (p. 2021) is Cook et al. (2013). Since Bedford and Cook (2013) assign considerable importance to this article, who lead author is also an author of Bedford and Cook (2013), a more thorough discussion of it is warranted.

As Legates et al. (2013) had argued, the philosophy of science allows no role for head-count statistics. Aristotle's *Sophistical Refutations*, (circa 350 B.C.), codified the argument from consensus, later labeled by the medieval schoolmen as the *argumentum ad populum* or head-count fallacy, as one of the dozen commonest logical fallacies in human discourse. Al-Haytham, the eleventh-century philosopher of science who is credited as the father of the scientific method, wrote that "the seeker after truth" (i.e., the scientist) places no faith in mere consensus, however venerable. The English biologist Thomas Henry Huxley (1866) wrote "The improver of natural knowledge absolutely refuses to acknowledge authority, as such...For him, skepticism is the highest of duties, blind faith the one unpardonable sin."

Popper (1934) formalized the scientific method as an iterative algorithm by which scientists advance new tentative theories to address a general problem, which is modified to the extent that these new hypotheses survive error-elimination by other scientists. The most likely outcome, especially in the physical sciences, is that error elimination will fail either to demonstrate or to disprove the hypothesis, in which case it gains credibility not because a consensus supports it but because it has not (yet) been demonstrated to be false. By this process, which may continue *ad infinitum*, science iteratively converges upon the truth. In Popper's definition, consensus plays no role. Science is not a belief system.

A new scientific paradigm, however, seeks to replace the scientific method with *expert* assessments, particularly in highly important areas where uncertainty and a lack of knowledge exist but where immediate decisions are needed. *Post-normal science* (see Funtowicz and Ravetz 1993) seeks, therefore, to create an *extended peer community* that weighs in on the topic and generates a body of knowledge through consensus. Thus, the quest to produce a *scientific consensus* that agrees with a prescribed set of facts and coordinates a response strategy is essential in post-normal science, a radical departure from the classical scientific method. Thus, Bedford and Cook (2013) have tacitly replaced the scientific method with this new consensus-driven paradigm (see also Saloranta 2001).

The problem, of course, is that consensus-building is difficult. Scientists will agree to the basic facts that experiment and measurement have established (e.g., carbon dioxide absorbs energy in the thermal infrared portion of the electromagnetic spectrum, and more energy is transferred from the surface to the atmosphere through latent heat than long-wave radiation). However, many of the important areas are still in doubt (e.g., the overall effect of clouds and their feedbacks, and the climate sensitivity to radiatively-active gases). It is of immense importance, therefore, that the proper question be asked and its answer interpreted correctly. The question "Do you believe in global warming?" can be answered in numerous ways, since "global warming" is not properly defined. Does it refer to

"anthropogenic global warming" or to a warming of the globe at some unspecified time-scale? Thus, scientists who disagree strongly on the anthropogenic contribution of climate change may answer 'Yes' to the imprecise question "Do you believe in global warming?".

It is essential that rigorously precise terms be used in defining the consensus, if a consensus truly exists. These terms must be quantitatively expressed and must be sufficiently rigorous to be testable. Yet Cook et al. (2013) do not restrict their questions to a single definition of the hypothesis to which their consensus is said to adhere. They deploy three definitions of consensus interchangeably:

> *The unquantified definition:* "The consensus position that humans are causing global warming" (p. 1),
> *The standard definition:* As stated in their introduction, that "human activity is very likely causing most of the current warming (anthropogenic global warming, or AGW)" (p. 2), and
> *The catastrophist definition:* That our enhancement of the greenhouse effect will be dangerous enough to be 'catastrophic' (i.e., "explicit rejection" of the consensus view "provides little support for the catastrophic view of the greenhouse effect", p. 3).

Note that in *the unquantified definition*, it is asserted that humans cause global warming, whereas in *the standard definition*, the level of agreement is only "very likely." Moreover, *the catastrophist definition* extends the warming to *catastrophic* consequences not encompassed in *the unquantified or standard definitions*; *the catastrophist definition* is also implicit in the Introduction of Bedford and Cook (2013, p. 1):

> An accurate perception of the degree of scientific consensus is an essential element to public support for climate policy (Ding et al. 2011). Communicating the scientific consensus also increases people's acceptance that climate change (CC) is happening (Lewandowsky et al. 2012).

The catastrophist definition is implicit in this passage because it demands that people accept that 'climate change is happening', implying that a climate policy response resulting from catastrophic consequences of anthropogenic global warming will be essential.

None of these three definitions is precise enough to be Popper-falsifiable. Worse, the three definitions are mutually exclusive. Not only do Cook et al. (2013) adopt them interchangeably, so that it is not clear which definition their survey is really testing, but each definition is imprecise and insufficiently quantified to allow rigorous falsification.[2] Moreover, none of these definitions specifies the period to which it applies, or how much global warming was observed over that period, or whether the warming is continuing, or at what rate, or whether that or any rate (and, if so, what rate) is considered dangerous.

The standard definition, though it is quantitative in that it holds that at least 50 % of all global warming since 1950 is anthropogenic, assigns no quantitative value to 'very likely'. *The unquantified and catastrophist definitions* do not specify what fraction of warming is considered anthropogenic. A hypothesis to the effect that humans cause some warming, or even that most current global warming is very likely to be anthropogenic, is not—and does not necessarily imply—a hypothesis to the effect that current warming, if continued over some unspecified period, might prove sufficiently damaging to justify any climate policy to address climate change, still less any public support for it. The implication of the cited

[2] Note that Cook et al. (2013) have apparently missed the key conclusions from three independent studies. First, Knight et al. (2009) have suggested that "The simulations rule out (at the 95 % level) zero trends for intervals of 15 years or more, suggesting that an observed absence of warming of this duration is needed to create a discrepancy with expected present-day warming rate" (p. S23). Santer et al. (2011), in adopting a slightly different metric, offered the conclusion: "Our results show that temperature records of at least 17 years in length are required for identifying human effects on global-mean tropospheric temperature" (p. 1). Finally, Huang (2013) provided an even more definitive detection and diagnostic of the carbon dioxide-global warming hypothesis by suggesting that "the most detectable secular trend signals appear in the CO_2 band and the time it takes to see these radiance changes is much less than 12 years" (p. 1711).

remark in the Introduction of Cook et al. (2013) is that the authors of all abstracts expressing an explicit or implicit endorsement of *the unquantified and standard definitions,* which do not encompass catastrophism, also endorse *the catastrophist definition.*

Cook et al. (2013) also cite other papers whose authors adopt multiple imprecise and ill-quantified definitions of consensus. For example, Doran and Zimmerman (2009) sent a 2-min online survey to 10,257 Earth scientists at universities and government research agencies. Of the 3,146 respondents (a 31 % return rate), only 5 % identified themselves as climate scientists and only a mere 79 (2.5 %) listed 'climate science' as their area of expertise, having published more than half their recent peer-reviewed papers on climate change. Of these 79 respondents, 98 % believed human activity was a significant contributing factor in changing mean global temperatures. Furthermore, respondents were not asked whether they believed the anthropogenic contribution to global warming was or might become sufficient to warrant concern or the adoption of a 'climate policy'. The survey demonstrates nothing more than that 77 of 79 respondents believed the anthropogenic effect is non-zero. Moreover, no distinction was drawn between different human impacts; most notably, anthropogenic greenhouse gases versus anthropogenic changes in land use and land cover (see Mahmood et al. 2010).

From publication and citation data, Anderegg et al. (2010) selected 908 of 1,372 climate researchers, defined as scientists who had published at least twenty climate papers and had either signed petitions opposing or supporting the IPCC's positions or had co-authored IPCC reports. Of these, 97–98 % endorsed the standard definition that "anthropogenic greenhouse gases have been responsible for 'most' of the 'unequivocal' warming of the Earth's average global temperature over the second half of the twentieth century" (p. 12107). The standard definition of the consensus in Anderegg et al. (2010) is less imprecise than that of Cook et al. (2013). Yet, like Cook et al. (2013), Anderegg et al. (2010) did not seek to determine how many researchers considered this global warming to be actually or potentially damaging enough to require a climate policy.

Such surveys are often cited as demonstrating a near-unanimous scientific consensus in favor of a climate policy, when they never ask any question about whether and to what extent the anthropogenic component in recent warming might be dangerous or about whether a "climate policy" should be adopted in attempted mitigation of future warming. Nevertheless, Cook et al. (2013), after a subjective review of only the abstracts of 11,944 papers on climate change which "matched the topics 'global climate change' or 'global warming'" (p. 1), conclude that 97.1 % of those that expressed an opinion endorsed the hypothesis as defined in their introduction (i.e., *the standard definition*). However, 66.4 % percent of the abstracts had expressed no position. Thus, 32.6 % of the entire sample, or 97.1 % of the 33.6 % who had expressed an opinion, were said to be in agreement with *the standard definition.* However, inspection of the authors' own data file showed that they had themselves categorized only 64 abstracts, just 0.5 % of the sample, as endorsing *the standard definition.* Inspection shows only 41 of the 64 papers, or 0.3 % of the sample of 11,944 papers, actually endorsed that definition.

It is not possible to discern either from the paper or from the supplementary information what percentage of all abstracts the authors considered to have endorsed *the standard definition.* However, a file of raw data was supplied some weeks after publication. From this file, the abstracts allocated by Cook et al. (2013) to each level of endorsement were counted. No attempt was made to verify whether the allocation of each abstract to one of the specified levels of endorsement was appropriate. The results are given in Table 1. Of the 11,944 abstracts, 3896 (32.6 %) were marked as explicitly or implicitly endorsing at least *the unquantified definition* that humans cause some warming. It was only by

arbitrarily excluding those 7930 abstracts that expressed no opinion (but retaining forty abstracts expressing uncertainty) that Cook et al. (2013) were able to conclude that 97.1 % endorsed 'consensus'. However, the authors' data file shows that they had marked only 64 abstracts (0.5 % of the entire sample) as endorsing *the standard definition* of consensus. Inspection shows that 23 of these 64 do not, in fact, endorse that definition. Only 41 papers (0.3 % of the sample) do so.

The conclusion of Cook et al. (2013, p. 1) as expressed in their Abstract, is "Among [4014] abstracts expressing a position on AGW [Anthropogenic Global Warming], 97.1 % endorsed the consensus position that humans are causing global warming." A 97 % consensus is also asserted in the closing words of the paper: "Among [4014] papers expressing a position on AGW, an overwhelming percentage (97.2 % based on self-ratings, 97.1 % based on abstract ratings) endorses the scientific consensus on AGW" (p. 6). In the introduction to Cook et al. (2013), anthropogenic global warming is defined as the [standard] "scientific consensus that human activity is very likely causing most of the current GW (anthropogenic global warming, or AGW)" (p. 1). However, the authors' own analysis shows that only 0.5 % of all 11,944 abstracts, and 1.6 % of the 4014 abstracts expressing a position, endorsed anthropogenic global warming as they had defined it. But by taking into account that more than one-third of the 64 abstracts do not, in fact, endorse the quantitative hypothesis in Cook et al. (2013), the true percentages endorsing that hypothesis are 0.3 % and 1.0 %, respectively. Accordingly, their stated conclusion is incorrect.

Defects identified in the surveys of climate consensus by Cook et al. (2013) and by the authors of some of the papers they cite follow a recognizable and questionable pattern. Often a simple and limited question is posed (e.g., "Do you believe in global warming?") but it is assumed, on no evidence, that anyone who endorses *the unquantified definition* of consensus also endorses *the catastrophist* (or at least *the standard*) *definition.* In such surveys, whether deliberately or y inadvertence, it is not made clear which hypothesis is under test. Any head-count survey that is unclear about which definition is under test is scientifically valueless. *A fortiori,* a supposed consensus that exhibits multiple definitions

Table 1 Data showing the breakdown of the abstracts reviewed by Cook et al. (2013) by level of endorsement of the climate consensus

Endorsement level		Abstracts	% of all abstracts	% of all abstracts expressing an opinion
1	Explicit, quantified endorsement (standard definition of consensus)	64	0.54	1.59
	Actually endorsing the standard definition upon inspection	41	0.34	1.02
2	Explicit, unquantified endorsement	922	7.72	22.97
3	Implicit endorsement	2,910	24.36	72.50
4a	No position	7,930	66.39	
4b	Expression of uncertainty	40	0.33	1.00
5	Implicit rejection	54	0.45	1.35
6	Explicit, unquantified rejection	15	0.13	0.37
7	Explicit, quantified rejection	9	0.08	0.22
	Total	11,944	100	100

of the consensus hypothesis and fails to state clearly the identity and definition of the hypothesis on the basis of which the survey was actually conducted must be rejected.

Furthermore, consensus hypotheses must be expressed quantitatively. Bias is sure to affect the results when qualitative definitions of a scientific hypothesis give the appearance of being more political than scientific. Most papers that attempt to define a climate change consensus are inherently political by nature.

The conclusion is that the quest for defining a climate change consensus is fraught with bias which is not often apparent. The non-disclosure in Cook et al. (2013) of the number of abstracts supporting each specified level of endorsement had the effect of not making available the fact that only 41 papers—0.3 % of all 11,944 abstracts or 1.0 % of the 4014 expressing an opinion, and not 97.1 %—had been found to endorse the standard or quantitative hypothesis, stated in the introduction to Cook et al. (2013) and akin to similar definitions in the literature, that "human activity is very likely causing most of the current GW (anthropogenic global warming, or AGW)" (p. 2).

Further demonstrating the flaws in Cook et al.'s (2013) assessment of a climate change consensus are the endorsement levels they incorrectly assigned to some of the learned papers whose abstracts they reviewed. Consider as an example the articles cited by two of the authors of this paper—DR Legates and W Soon. The inventory of abstracts surveyed by Cook et al. (2013) cited only three papers by DR Legates and only two by W Soon. Yet these two authors have written many more papers in the more than 20 years (January 1991 to May 2012) covered by Cook et al. (2013). All five selected papers, save one, are labeled as 'taking no position' or 'being uncertain.' Liu et al. (2009) is categorized as giving 'explicit endorsement to the anthropogenic global warming position without quantification' even though the paper suggests a Medieval Warm Period and a Little Ice Age exist and that variability in solar radiation due to solar forcing was evident even in the Industrial Age. Armstrong et al. (2008), of which W Soon was a co-author, was listed by Cook et al. (2013) as 'being uncertain'. Armstrong et al. (2008) discuss articles on polar bear populations by Amstrup et al. (2007) and Hunter et al. (2007), both of whom link increases in greenhouse gases to decreases in polar bear populations. Far from being uncertain, however, Armstrong et al. (2008, p. 390) conclude, "However, the inconsistent long-term trends in the polar bear population suggest that it is best to assume no trend in the long-term", thereby undermining the anthropogenic climate change impact of diminished sea ice on polar bear populations suggested by Amstrup et al. (2007) and Hunter et al. (2007).

The restriction to the key words 'global warming' or 'global climate change' arbitrarily eliminates many relevant papers. Oreskes (2004) used only the search phrase 'global climate change'. DR Legates and W Soon have written numerous papers on the topic of climate change and its possible anthropogenic origins but these were not considered, apparently because the arbitrarily-chosen search phrases did not appear in those papers. A bias, therefore, arises in that those studies which demonstrate a natural cause for climate variability are far less likely to use the search phrases adopted by Oreskes (2004) and Cook et al. (2013). Accordingly, surveys that arbitrarily select some non-randomized subset of the available papers on climate change have little evidential value.

A better approach to determining an appropriate methodology to identify and quantify a consensus can be found in the work of Lefsrud and Meyer (2012). They argue that building a consensus "fundamentally depends upon expertise, ensconced in professional opinion" (p. 1478). Even here, a Classical purist might legitimately argue that appealing to the authority of experts, however well qualified, is the Aristotelian logical fallacy later labeled by the medieval schoolmen as the *argumentum ad verecundiam*—the argument from reputation. Experts can be unanimously wrong, as the case of the 100 German authors who

opposed Einstein's theory of relativity in the years leading to World War II. They were wrong because the regime demanded them to make scientific objectivity subservient to the racial politics of the regime.

Mutatis mutandis, another prejudice (though without the racial bias) appears to have exercised undue influence upon significant segments of the academic and scientific communities today. As a first step towards identifying any such prejudice, Lefsrud and Mayer, rather than asking open-ended questions to which the answers can be interpreted in a myriad of ways, deploy *frames* to identify not only the world views but also social identities of expert survey participants. The authors (p. 1484) define these frames as containing a problem demanding attention, a prognosis for a particular solution, and a rationale for action. Diagnosis, prognosis, or rationale may overlap, yielding frames with some similar and some diverse characteristics. On the question of climate consensus, they surveyed opinion among the Association of Professional Engineers and Geoscientists of Alberta, Canada, and concluded that five frames exist (with the extent of anthropogenic contribution in parentheses): (1) "Comply with Kyoto" (human impact, not normal), (2) "Regulation-Activists" (natural and human-caused, problem is complex), (3) "Fatalists" (natural with little human impact, problem is complex), (4) "Economic Responsibility" (natural and human-caused, no significant impact), and (5) "Nature is Overwhelming" (natural with little human impact). A sixth group did not provide enough information to be categorized. Only the "Comply with Kyoto" group felt that the debate was settled.

The results are surprising. While 99.4 % of all experts felt that the climate is changing, only 36.3 % felt the debate was settled ("Comply with Kyoto" group) while 41.4 % felt that human impacts were small or insignificant (the "Fatalist" and "Nature is Overwhelming" groups). These results, though specific to the engineers and geoscientists of Alberta, indicate that when questions are appropriately directed toward grouping individuals into specific categories based on their true beliefs, a different picture of the consensus can emerge.

5 Public Perception and the Contrived Consensus

It has been demonstrated that the attempt by Bedford and Cook (2013) to apply agnotology to climate science is based on an imagined-scientific consensus. Yet the authors lament that the public does not buy into the consensus story they have contrived. They blame "a deliberate effort to foster this [skeptical] view among the public" (pp. 2023–2024). In pursuit of the argument for a well-funded and well-organized disinformation campaign by 'climate deniers', they cite articles from the New York Times and from activist groups (e.g., Informed Citizens for the Environment) to support their claims.

However, the balance of opinion in the mainstream news media has tended to endorse the catastrophist position, and the funding by governments and environmental groups for that position is very likely to outweigh greatly the funding for skeptical groups. The United States Government alone had spent almost US$80 billion on climate-related policies in the 20 years from 1989 to 2008; carbon trading worldwide reached US$180 billion in 2011, though it is now declining; yet Exxon Mobil was criticized for having spent a total of US$23 million on skeptical groups. Through public pressure brought about by environmental groups, it now spends nothing on them.

The real reason why the public do not endorse catastrophism is that they are not convinced that every extreme event is linked, somehow, to anthropogenic climate change—a link that even serious scientific journals have attempted, on no evidence, to

make. For instance, the Editor-in-Chief of the journal *Science* made a similar accusation in a 2005 editorial:

> As Katrina and two other hurricanes crossed the warm Gulf of Mexico, we watched them gain dramatically in strength. Papers by Kerry Emanuel in *Nature* and by Peter Webster in [*Science*] during the past year have shown that the average intensity of hurricanes has increased during the past 30 years as the oceans have gained heat from global warming...We know with confidence what has made the Gulf and other oceans warmer than they had been before: the emission of carbon dioxide and other greenhouse gases from human industrial activity, to which the United States has been a major contributor. That's a worldwide event, affecting all oceans...Not only is the New Orleans damage not an act of God; it shouldn't even be called a 'natural' disaster. These terms are excuses we use to let ourselves off the hook. (Kennedy 2006; p. 303)

Yet tropical cyclone activity as measured by the Accumulated Cyclone Energy index[3] (Maue 2009, 2011) is at a 35-year low and in three recent years (2006, 2009, and 2010), there were no hurricane landfalls in the United States.[4] In 2006, ten prominent hurricane scientists, including Emanuel and Webster, issued a statement[5] which said, in part, "The possibility that greenhouse gas induced global warming may have already caused a substantial increase in some tropical cyclone indices has been raised, but no consensus has been reached on this issue." And on the existence of trends in storm intensity, the scientists' statement indicates, "This is still a hotly debated area for which we can provide no definitive conclusion." Seven years have passed since then, but there is still no definitive conclusion.

Recent research on climate extremes accentuates the debate that exists. Many of the arguments that are made regarding climate change focus on the likely increase in variability from a warmer world. This translates into more extreme events—floods, droughts, heat waves, snowfall, hurricanes, etc.—that have the most impact on human loss of life and property. Greenland ice cores suggest that temperature variability is greater during cold periods (Steffensen et al. 2008). But recent research by Huntingford et al. (2013, p. 1) demonstrates

> The time-evolving standard deviation of globally averaged temperature anomalies has been stable. A feature of the changes has been a tendency for many regions of low variability to experience increases, which might contribute to the perception of increased climate volatility...Many climate models predict that total variability will ultimately decrease under high greenhouse gas concentrations, possibly associated with reductions in sea-ice cover. Our findings contradict the view that a warming world will automatically be one of more overall climatic variation.

Here, the concern is that if agnotology labels as misinformation that research which is still under debate, the public may be presented with false information which would twist public perception in that direction.

> Bedford and Cook (2013, p. 2024) assert that
> The rhetorical techniques employed by some works of misinformation extend to misquoting and gross distortions of source material, and such works have the appearance of attempting to persuade readers, viewers or listeners by fair means or foul. Thus, an awareness that some works are written with a view not to providing accurate reportage but to skewing public perception through misrepresentation becomes important background information.

Their tacit suggestion is that virtually everything that disagrees with their contrived consensus view is a misinformation campaign. The possibility that the opposite may be the case has not received their consideration (except possibly for the movie *The Day After*

[3] See http://policlimate.com/tropical/.

[4] Only five such years exist since 1950–2000, 2001, 2006, 2009, and 2010.

[5] http://wind.mit.edu/~emanuel/Hurricane_threat.htm.

Tomorrow). Yet the authors concede they are in limited agreement with us when we wrote, "To the extent that such assertions [of misrepresentation] are true, they apply in spades to the presentations and writings of many scientists who support the IPCC's alarmist view of the situation" (Legates et al. 2013, p. 2010–2011).

Consider arguably the most-seen film on climate change, the movie that has done the most to proselytize for extreme anthropogenic climate change—*An Inconvenient Truth*. Al Gore won the Nobel Peace Prize (along with the IPCC) for this film. It is still shown to school children in science classes, social studies classes, and classes in the humanities even today. The film was, and continues to be, heralded by environmental activists and scientists alike for its apocalyptic view of a future climate thrown out of balance owing to increasing anthropogenic carbon dioxide concentrations. A High Court judge in the United Kingdom[6] ruled that the movie contained nine key scientific errors and could only be distributed to schools in England if it were accompanied by 77 pages of corrective guidance notes to prevent 'political indoctrination'. Despite these factual errors and numerous other mistakes (see Legates 2007), scientists who applauded the film argued that the mistakes "were relatively small and did not detract from the film's central message." The judge disagreed and concluded, particularly in connection with Gore's claim that sea level would imminently rise by 20 feet, that the "Armageddon scenario that he [Gore] depicts is not based on any scientific view."

Or consider the book for children and used in schools to teach about global warming—*The Down-to-Earth Guide to Global Warming* (David and Gordon 2007). On page 18, the book declares "The more carbon dioxide in the atmosphere, the higher the temperature climbed. The less carbon dioxide in the atmosphere, the lower the temperature fell." Students are encouraged to raise a flap labeled, "Lift to see how well CO_2 and temperature go together." The chart shows a remarkable relationship where temperature follows carbon dioxide, except that the curves are mislabeled. The curve labeled "Climate Temperature" is really "CO_2 Concentration in the Atmosphere" and vice versa. In fact, the curve was taken from Fischer et al. (1999, p. 1712) who wrote, "high-resolution records from Antarctic ice cores show that carbon dioxide concentrations increased by 80–100 parts per million by volume 600 ± 400 years *after* the warming of the last three deglaciations" (emphasis added). But when confronted with this error and the fallacy that it spread—namely, that historically air temperature has been largely driven by carbon dioxide concentrations—Michael Oppenheimer noted

> I have reviewed the figure on page 18 of The Down-to-Earth Guide to Global Warming. It appears that the labeling of the axes has been reversed. As a result, the curve labeled 'carbon dioxide concentration' should be labeled 'climate temperature', and vice versa. However, the description of the figure in the accompanying text is accurate, and it fairly represents the current state of scientific knowledge, in terms that would be comprehensible to children 8 years of age or older.

So misinformation is allowed to spread simply because it agrees with the contrived consensus story.

These are but two examples of places where misinformation worthy of study by agnotologists exists in the classroom and there is little effort to set the record straight. Numerous other examples of extreme claims made by proponents of extreme anthropogenic global warming exist. This is one of the fundamental problems with agnotology in climate change as defined by Bedford (2010) and Bedford and Cook (2013)—that misinformation is always couched as a disagreement with the consensus view that the authors

[6] See http://www.telegraph.co.uk/earth/earthnews/3310137/Al-Gores-nine-Inconvenient-Untruths.html and http://www.guardian.co.uk/environment/2007/oct/11/climatechange.

and others like them have contrived. But agnotology, though invented and near-exclusively deployed by a single narrow academic faction, is a two-edged sword. Misinformation has no place in our classroom, regardless of whether the misinformation is peddled by that narrow faction or by its opponents. Rather than spend valuable class time demonizing the opposition, academics would spend their own and their students' time more usefully on making sure that students are presented with factual material that is science-based, eradicating all advocacy science, particularly from the fabricators of the non-existent consensus.

For example, Lenzer (2013), discussing the idea of a contrived consensus in the medical profession, showed that a very high percentage of clinical policy committee chairs and co-chairs had financial conflicts. Unfortunately, such is the case with climate change. Climate change research translates into big money. Researchers buy into the climate change bandwagon and get large grants because it represents a way to appease the administration (with overhead rates sometimes exceeding 100 %!). Those who comply garner an easier path to promotion and tenure. There is a strong impetus to fall in line with the contrived consensus to keep promotion, tenure, and the money lines flowing. Even professional societies feel the need to publish statements on climate change, often without consulting the membership, so as to keep the money flowing to their constituents. As Lenzer (2013, p. 3) concludes, "despite concerns about bias...'we like to stick within the standard of care, because when the shit hits the fan we all want to be able to say we were just doing what everyone else is doing—even if what everyone else is doing isn't very good'." Indeed, one of us (Legates) attended a meeting at the University of Oklahoma in 1990 where a prominent climate scientist lamented that solid Earth geophysics and extragalactic astrophysics garnered the lion's share of the research money while atmospheric science was woefully underfunded. The then-new concern over anthropogenic climate change looked to change that dynamic. The scientist concluded to the effect that "We had better not kill the goose that will lay the golden egg."

6 Agnotology: Teaching Tool or Instrument of Indoctrination?

What is lost on both Bedford (2010) and Bedford and Cook (2013) is that the use of agnotology as a teaching tool is based on the definition of 'misinformation'. They cite non-political and non-controversial areas in physics and psychology classes where preconceived notions and simple misinformation (e.g., 'old wives tales') can be used to make a specific point. One of us (Legates) has used that concept in seventh-grade hydrology lessons to teach that the intuitive idea that 'water flows downhill' is false. Gravity is indeed a strong force, but it is the gradient force (from Fick's First Law of Diffusion) that drives hydrologic flow. Does the water that transpires from plant leaves come from canopy interception? No, it comes from plant roots. But that requires water to flow uphill or upwards in the tree, doesn't it? And through osmotic pressure, indeed it does. See also the discussion of "carbon dioxide causes the Earth to warm like a greenhouse" and "carbon dioxide causes the Earth to warm like a blanket covering your bed" arguments from Legates et al. (2013) for examples where agnotology would be useful to dispel myths that are central to the anthropogenic global warming argument.

The problem arises when the use of agnotology is extended into politically-contentious areas. Whoever defines the consensus also defines what is 'misinformation'. That is why Bedford and Cook (2013) focus extensively on the importance of establishing the scientific consensus. Yet if strong disagreement exists, then it behooves us to present all sides of the

issue. But Bedford and Cook (2013) argue for their contrived consensus, where viewpoints which substantially diverge from this view become *misinformation*.

Totalitarian regimes spread misinformation while demonizing their opposition. How is it different here? *Haud secus isti*. If it is as Michael Oppenheimer argued earlier—though the figure is wrong, the discussion is useful because it agrees with the consensus—then misinformation is being used as *information* to support the consensus. In that instance, agnotology takes on an added connotation—it includes the study of how misinformation is spread as information by those espousing a contrived consensus to support one's cause. With politically-charged issues, those who spread misinformation are usually defined as those who disagree with the advocate. Thus, where there is not an appropriately defined 'consensus' view in politically-charged areas, let us be frank: we are all advocates of a given position. Thus, as Legates et al. (2013, p. 2011) posited as their main point, the use of agnotology in politically-charged contexts such as climate change "can be used to stifle debate and to require acceptance of a single scientific viewpoint."

Bedford (2010) and Bedford and Cook (2013) suggest the explicit use of non-peer reviewed sources—newspaper articles and books such as Michael Crichton's *State of Fear*—to show examples of misinformation on climate change. The problem with this approach is that many who write on climate change in the popular media have no scientific background or training. This includes the many authors who support varieties of catastrophism. The implication is that if one pundit makes a clearly erroneous statement, the pundit speaks for the group; and demonstration that this person spouts misinformation is tantamount to demonstrating that all people who disagree with the position we espouse are equally biased. The easy solution is to bisect the group into a polarized dichotomy of the 'environmentally conscious' and the 'climate change deniers' and thus debunking several of the extreme statements will suffice to undermine all of the opposition arguments. This, unfortunately, teaches our students to polarize all arguments and look on with disdain at the views spoken by those with whom we disagree. As Legates et al. (2013) wrote, this is *not* what our classrooms should become.

One wonders if Bedford and Cook would welcome discussions about agnotology leveled against those who follow the consensus. For example, the United Nations Environment Programme issued a statement in 2005[7] proclaiming 'fifty million climate refugees by 2010'. Those numbers, of course, never materialized. But in 2011, the UN was back[8] with another forecast: '60 million environmental refugees by 2020'. Examples like this are legion, largely because the popular press is overrun by articles which agree with the contrived consensus. Advocacy groups on all sides live in the non-peer reviewed world where scientific rules do not necessarily apply. Thus, advocacy materials must be introduced into the classroom only with extreme caution. Legates et al. (2013) cautioned about the use of newspaper accounts as sources of both information and misinformation in the classroom.

That is not to say that peer review guarantees factual presentations; far from it. While it is assumed that reviewers will be impartial, bias and other tendencies (both positive and negative) undermine the process, especially when hotly-debated subjects like climate change are considered. Hollander (2013) laments that the biggest threat to peer review lies in the prevailing orthodoxies (i.e., imagined consensus) that determine what gets published: "Deviating from the prevailing, apparent consensus or orthodoxies could be a major

[7] From Norman Myers, "Environmental refugees. An emergent security issue". 13 Economic Forum, Prague, OSCE, May 2005; Millennium Ecosystem Assessment, 2005.

[8] http://phys.org/news/2011-02-million-environmental-refugees-experts.html.

roadblock to publishing" (p. 149). Although Hollander argues that such biases have more influence in social sciences and humanities than on the physical sciences, the climate change issue has shown that such biases can impinge upon even scientific debate. Establishment of a consensus, no matter how badly contrived, is essential in defining misinformation which deviates from it. Editors, then, are predisposed, and even pressured, to select reviewers that will perpetuate the consensus. Even the reviewers themselves "are likely to have internalized the prevalent, conventional, politically correct wisdom, and will be reluctant to approve of writings that appear to deviate from it" (Hollander 2013, p. 149).

Furthermore, the peer review process is manipulated when aided by complicit editors who can change the tenor of a given publication and can arbitrarily decide what viewpoints are published and which are not. Often, editors know which reviewers are likely to provide a positive review and which are likely to reject a submission. As Weissberg (2013, p. 158, emphasis in original) notes,

> An editor can *honestly* therefore kill a piece that he dislikes for whatever reason, including ideological aversion, simply by forwarding it to an excessively demanding reviewer. A death sentence can also be given by facilitating an ideological mismatch: sending a submission that reaches a *conservative* conclusion to a referee famous for strident liberalism.

Though anonymity of referees should lead to a frank appraisal, often it invites irresponsibility (Weissberg 2013). Anonymity often allows reviewers to be make unsubstantiated claims or even to be openly hostile; the cloak of secrecy will prevent discovery or retaliation. Real science invites debate and discussion; pseudo-science attempts to silence dissent.

7 Conclusion: The Lack of a Scientific Consensus and Its Impact on Agnotology

Legates et al. (2013), far from being an "aggressive critique" of Bedford (2010), focused not on that paper per se but on the issue of using misinformation (e.g., agnotology) to further the so-called *consensus* view of climate change. We thank the two authors for their discussion, which serves to show areas where we both agree and, in particular, to highlight areas where we strongly disagree.

The position taken by Bedford and Cook (2013) is not new. The authors argue that an "overwhelming consensus" exists among scientists but is not perceived by the public owing to "a campaign of obfuscation" by the fossil fuel industry and its allies. Agnotology, the authors write, can be used in the classroom to identify this alleged campaign of misinformation and to teach students how to detect and learn from this misinformation (p. 2020). It has been demonstrated that the so-called consensus view is a fabrication, contrived by asking ill-defined questions, deploying multiple definitions of the consensus hypothesis interchangeably, or perusing abstracts identified by selective search terms and not necessarily interpreted with a clear and impartial eye. It is no less legitimate to argue that the environmental lobby and its many friends in academe have circulated misinformation, including misinformation about the existence and extent of a supposed scientific "consensus", as it is to argue—as Bedford and Cook argue—that the fossil fuel lobby has circulated misinformation calculated to minimize the anthropogenic influence on the evolution of the climate object. It is very likely that governments, the environmental lobby, academe and the news media have spent far more on information (and perhaps on misinformation) than the fossil fuel lobby.

Those who are financially dependent upon acquiescence in whatever governments may require have found it expedient, in the absence of definitive or even of adequate scientific data and results, to manufacture a *scientific consensus*, at all costs, so that the "misinformation" that is the focus of agnotological studies can be improperly defined as that which deviates from this consensus. Bedford and Cook (2013) make the need for the consensus very clear: for, without it, it is difficult—and perhaps impossible—to argue convincingly that those who question the magnitude and cost of the anthropogenic influences on the climate are guilty of purveying misinformation. In fact, however, there is a decided lack of consensus among scientists, and especially among those who are trained in climate science or have studied it extensively. The 97.1 % consensus claimed by Cook et al. (2013) turns out upon inspection to be not 97.1 % but 0.3 %. Their claim of 97.1 % consensus, therefore, is arguably one of the greatest items of misinformation that has been circulated on either side of the climate debate.

Whilst agnotology can be useful in many situations where 'old wives tales,' myths, and other incorrect ideas exist, the value of using agnotology in politically-charged discussions such as climate change is questionable. Since the definition of *misinformation* lies in the eye of the advocate of a particular viewpoint, there is a danger that agnotology may serve not to enhance discussion or learning but rather to stifle debate and silence critics. Thus, the conclusion of Legates et al. (2013, p. 2007) that demonizing any position that is at odds with a not necessarily soundly-derived conclusion in politically-charged discussions has no place in education (see also Weiss 2012) remains valid.

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Variability and trends in dry day frequency and dry event length in the southwestern United States

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[1] Daily precipitation from 22 National Weather Service first-order weather stations in the southwestern United States for water years 1951 through 2006 are used to examine variability and trends in the frequency of dry days and dry event length. Dry events with minimum thresholds of 10 and 20 consecutive days of precipitation with less than 2.54 mm are analyzed. For water years and cool seasons (October through March), most sites indicate negative trends in dry event length (i.e., dry event durations are becoming shorter). For the warm season (April through September), most sites also indicate negative trends; however, more sites indicate positive trends in dry event length for the warm season than for water years or cool seasons. The larger number of sites indicating positive trends in dry event length during the warm season is due to a series of dry warm seasons near the end of the 20th century and the beginning of the 21st century. Overall, a large portion of the variability in dry event length is attributable to variability of the El Niño–Southern Oscillation, especially for water years and cool seasons. Our results are consistent with analyses of trends in discharge for sites in the southwestern United States, an increased frequency in El Niño events, and positive trends in precipitation in the southwestern United States.

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1. Introduction

[2] Dry events are an important natural process that, by definition, affects large areas for extended periods of time. Climate model simulations have been interpreted as indicating that global warming will substantially change the magnitude and variability of precipitation and, subsequently, dry event occurrence [*Intergovernmental Panel on Climate Change*, 2007]. Although a number of studies have examined trends in temperature [*Karl and Riebsame*, 1984; *Intergovernmental Panel on Climate Change*, 2007], precipitation [*Karl and Riebsame*, 1984; *Groisman and Easterling*, 1994; *Karl and Knight*, 1998; *New et al.*, 2001], and other hydrologically important variables such as streamflow [e.g., *Lettenmaier et al.*, 1994; *Lins and Slack*, 1999, 2005; *Groisman et al.*, 2001; *McCabe and Wolock*, 2002; *Milly et al.*, 2002, 2005] and the Palmer Drought Severity Index [*Dai et al.*, 2004], few studies have examined trends in dry event frequency and duration [e.g., *Groisman and Knight*, 2008].

[3] *Andreadis and Lettenmaier* [2006] examined streamflow to determine the temporal variability of the frequency, duration, and severity of dry events (measured by low streamflows) in the conterminous United States for 1925 through 2003. They found that dry events decreased for most of the United States during this period, except for the southwestern states where dry event duration and severity increased. *Andreadis and Lettenmaier* [2006] further reported that in the southwestern states, dry event trends were positive even in areas with positive trends in precipitation because of increases in air temperature, subsequent increases in evapotranspiration, and resultant decreases in streamflow.

[4] In a recent study of trends in dry event duration using precipitation data for the warm season months (defined as a period when mean daily temperature remains persistently above 5°C) in the conterminous United States, *Groisman and Knight* [2008] concluded that the mean duration of prolonged dry episodes (based on daily precipitation below 1 mm for 1 month or longer in the eastern United States and 2 months or longer in the southwestern United States) has significantly increased. *Groisman and Knight* [2008] found that during the past four decades, dry event duration during the warm season increased significantly nationwide, with notable increases in the southwestern United States. The largest increases in warm season dry event duration were found for California and Nevada.

[5] Since the mid-1970s, the frequency of El Niño events has been higher than the long-term average [*Ebbesmeyer et al.*, 1991; *Miller et al.*, 1994]. Precipitation in the southwestern United States generally is greater during El Niño years than during normal and La Niña years [*Redmond and*

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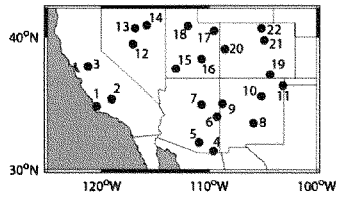

Figure 1. Locations of weather stations used in the analysis. Site numbers refer to numbers listed in Table 1.

Koch, 1991]. Increased precipitation in the southwestern United States associated with the higher frequency of El Niño events since the mid-1970s should result in decreased drought length; this is contrary to the results of *Groisman and Knight* [2008]. In addition, from the mid-1970s until recently, the Pacific Decadal Oscillation was in a positive regime that may have enhanced the effects of El Niño events on precipitation in the southwestern United States [*Gershunov and Barnett*, 1998; *Gershunov et al.*, 1999].

[6] The objective of this study is to examine in detail the variability and trends in the frequency of dry days and the length of dry events in the southwestern United States. The southwestern United States was chosen for analysis because (1) it has the highest consumptive use of water as a percentage of renewable supply in the United States [*Lins and Stakhiv*, 1998] and (2) dry event conditions in this region during the early 21st century have increased awareness of its vulnerability to water shortages. In addition, the studies of *Andreadis and Lettenmaier* [2006] and *Groisman and Knight* [2008] both identified significant increases in dry event length in this region.

2. Data and Methods

[7] Daily precipitation data from Weather Bureau-Army-Navy (WBAN) stations located in the southwestern United States were used to assess the frequency of dry days (days with precipitation below 2.54 mm (0.1 inches)) and dry event length (number of consecutive dry days). *Groisman and Knight* [2008] used a threshold value of 1 mm (0.04 inches). It should be noted that analyses using both of these thresholds produced similar results.

[8] Data were selected for water years (October through September) 1951 through 2006 (Figure 1 and Table 1). During this period, 22 sites have nearly complete (99% complete) daily precipitation data. WBAN stations were selected because of the completeness of data record and the relative consistency of observational procedures. The National Weather Service Cooperative Station Network [used by *Groisman and Knight*, 2008] contains many missing observations and changes in observers and practices [*Pielke et al.*, 2007] that create some inconsistencies in data time series.

[9] Two analyses were performed. The first analysis involved computing the 5 year moving frequency of dry days, computed as the fraction of days for each site with daily precipitation below 2.54 mm (dry days) for each water year, cool season (October through March), and warm season (April through September). Trends in the 5 year moving fractions of dry days were computed and analyzed. Five year moving periods were used to increase the number of possible dry days during each period (which helps avoid periods with small numbers of dry days). Trends were identified using Kendall's tau [*Press et al.*, 1986]. Kendall's tau is a nonparametric correlation statistic that is less sensitive to outliers than are parametric statistics such as Pearson's correlation coefficient. Kendall's tau was used to evaluate trends in the frequency of dry days (and other drought measures (i.e., dry event length)) by examining correlations between time and drought measures.

[10] The second analysis involved computing the mean dry event length at each site for each water year, cool season, and warm season. Dry events were identified as periods during a water year, or cool or warm season, with 10 or more (or 20 or more) consecutive days of daily precipitation below 2.54 mm. The minimum lengths of 10 and 20 days were chosen for this study to have a length that was long enough to be hydrologically important, but not too long so that a number of dry events could not be identified within a water year or season. *Groisman and Knight* [2008] used minimum lengths of 20, 30, and 60 days, but these periods make it difficult to identify more than a few dry events each water year or season. The mean length of dry events was computed for 5 year moving periods using the two thresholds of 10 and 20 days with daily precipitation below 2.54 mm. Linear trends in 5 year moving average dry event length for each site were computed for the water year, the cool season, and the warm season (computed as a correlation with time).

[11] To be consistent with the research presented by previous hydroclimatic studies [e.g., *Andreadis and Lettenmaier*, 2006; *Groisman and Knight*, 2008] we use significance testing in the analyses presented in this study. However, we

Table 1. List of Sites Used in the Study[a]

Site	Name	State	Latitude	Longitude
1	Santa Maria Public AP[b]	California	34.900°N	120.450°W
2	Bakersfield AP	California	35.433°N	119.050°W
3	Stockton Metro AP	California	37.883°N	121.233°W
4	Douglas Bisbee Intl	Arizona	31.467°N	109.600°W
5	Tucson Intl AP	Arizona	32.133°N	110.950°W
6	Springerville	Arizona	34.133°N	109.283°W
7	Winslow Muni AP	Arizona	35.033°N	110.717°W
8	Carrizozo	New Mexico	33.633°N	105.900°W
9	Zuni	New Mexico	35.100°N	108.783°W
10	Las Vegas Mnni AP	New Mexico	35.650°N	105.150°W
11	Clayton Muni AP	New Mexico	36.450°N	103.150°W
12	Austin #2	Nevada	39.500°N	117.067°W
13	Battle Mountain AP	Nevada	40.617°N	116.867°W
14	Elko Regional AP	Nevada	40.833°N	115.783°W
15	Cedar City	Utah	37.717°N	113.100°W
16	Hanksville	Utah	38.417°N	110.700°W
17	Vernal Muni AP	Utah	40.433°N	109.550°W
18	Salt Lake City	Utah	40.783°N	111.967°W
19	Trinidad Perry Stokes AP	Colorado	37.267°N	104.333°W
20	Grand Junction Walker Fire Department	Colorado	39.133°N	108.533°W
21	Denver Stapleton	Colorado	39.767°N	104.867°W
22	Fort Collins	Colorado	40.617°N	105.133°W

[a]Site numbers (column 1) refer to sites illustrated in Figure 1.
[b]AP, Airport; Metro, Metropolitan; Intl, International; Muni, Municipal.

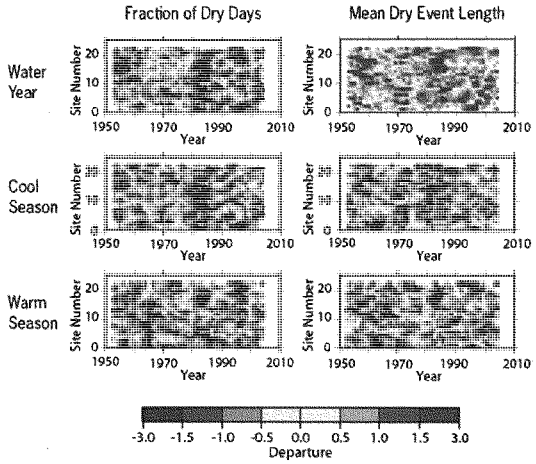

Figure 2. Time series of standardized departures of the fraction of dry days and dry event length for each site and for water years, cool seasons, and warm seasons. Site numbers correspond to the site numbers in Figure 1 and Table 1.

recognize that a number of recent studies have challenged the concept of statistical significance when applied to hydroclimatic time series [*Cohn and Lins*, 2005].

3. Results and Discussion

[12] The time series of the fraction of dry days and dry event length for each site and for water years, cool seasons, and warm seasons were converted to standardized departures by subtracting the respective long-term mean and dividing by the respective long-term standard deviation. This resulted in time series with means of 0 and variances of 1. The conversion to time series of standardized departures allows easy comparison among the sites. Examination of the time series of standardized departures (Figure 2) indicates similar temporal patterns of departures for most sites. For the time series of the fraction of dry days, the temporal patterns of departures are similar for many sites, especially for water years and cool seasons. For the time series of dry event length, the temporal patterns in departures for water years and cool seasons indicate similarity in temporal patterns among most of the sites. In addition, the temporal patterns of departures for both the fraction of dry days and dry event length do not appear to indicate any long-term trends.

[13] Maps of trends in the fraction of dry days for water years, cool seasons, and warm seasons indicate that most trends are negative (Figure 3 and Table 2). For water years, 18 sites exhibit negative trends in the fraction of dry days, and eight of these trends are statistically significant at a 95% confidence level ($p = 0.05$). In contrast, only four sites indicate positive trends in the fraction of dry days for water years, and none of these trends is statistically significant at $p = 0.05$. For the cool season, 19 sites exhibit negative trends (12 are statistically significant at $p = 0.05$), and only 3 sites indicate positive trends (none are statistically significant). For the warm season, 14 sites exhibit nega-

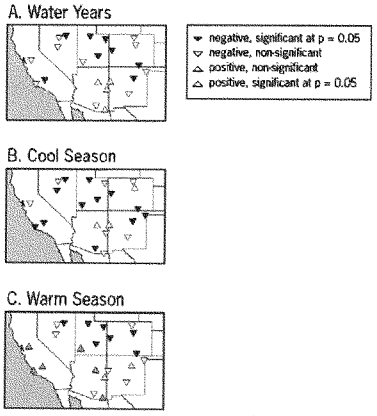

Figure 3. Trends in 5 year moving fraction of days with daily precipitation below 2.54 mm, from 1951 to 2006. The statistical significance of trends (at a 95% confidence level ($p = 0.05$)) was determined using Kendall's tau.

Table 2. Number of Sites for Which Negative and Positive Trends Were Observed for 5 Year Moving Fraction of Days With Daily Precipitation <2.54 mm and 5 Year Moving Average Length of Dry Events[a]

	Water Year		Cool Season		Warm Season	
	Negative	Positive	Negative	Positive	Negative	Positive
Fraction of days with precipitation <2.54 mm	18 (8)	4 (0)	19 (12)	3 (0)	14 (7)	8 (6)
Dry event length						
Minimum length of 10 days	18 (11)	4 (1)	18 (8)	4 (0)	13 (5)	9 (4)
Minimum length of 20 days	15 (9)	7 (1)	20 (6)	2 (0)	12 (5)	10 (5)

[a]Negative and positive trends were identified using Kendall's tau. Statistically significant trends at a 95% confidence level are indicated in parentheses.

tive trends (seven are statistically significant), and 8 sites exhibit positive trends (six are statistically significant).

[14] A comparison of mean 5 year moving average time series of the fraction of dry days indicates a large amount of agreement between all three time series (i.e., water year, cool season, and warm season) (Figure 4). Trends in mean 5 year moving average time series of the fraction of dry days are statistically significant (at $p = 0.05$) for water years and cool seasons but not for the warm season (Table 3).

[15] Trends in 5 year moving average dry event length for both the 10 and 20 day thresholds indicate a mix of positive and negative trends (Figure 5 and Table 2). For the 10 day threshold during the warm season, there were rather small differences between the number of positive trends and negative trends in dry event length: 13 negative trends (five are statistically significant at $p = 0.05$) and 9 positive trends (four are statistically significant). However, for the water year, there were relatively large differences between the numbers of positive and negative trends: 18 negative trends (11 are statistically significant) and 4 positive trends (only one is statistically significant). Similarly, for the cool season, there were relatively large differences between the number of negative and positive trends: 18 negative trends (eight are statistically significant) and 4 positive trends (none are statistically significant). In all cases examined (water year or specific season, minimum event length of 10 or 20 days, and counts of all trends or only trends deemed to be statistically significant at $p = 0.05$), the number of negative trends exceeded the number of positive trends.

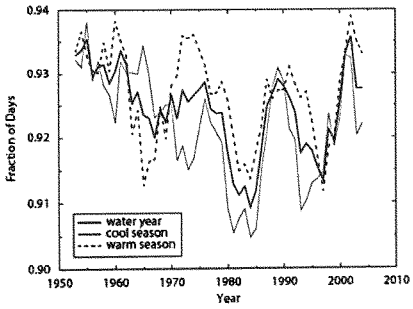

Figure 4. Five year moving time series of the mean fraction of days with daily precipitation below 2.54 mm for water years (October through September), cool seasons (October through March), and warm seasons (April through September).

[16] Figure 6 illustrates mean 5 year moving average time series of dry event length for water years, cool seasons, and warm seasons and for the 10 and 20 day thresholds. The time series indicate a large amount of temporal variability. Linear trends in these time series indicate that the only statistically significant (at $p = 0.05$) trends are negative trends in dry event length for water years and cool seasons (Table 3). However, for the warm season time series, an increase in dry event length during the last part of the period analyzed indicates a sharp increase in dry event length. This increase is a result of the late 20th century and early 21st century drought in the western United States [*McCabe et al.*, 2004]. These dry years at the end of the record result in the positive trends in dry event length during the warm season for some sites (Figure 5).

[17] Because some sites indicated positive trends in dry event length during the warm season, an analysis was performed to evaluate the changes in dry event length during the warm season for the same dry event lengths used by *Groisman and Knight* [2008]. Figure 7 illustrates time series of mean 5 year moving average dry event lengths for minimum dry event thresholds of 10, 20, 30, and 60 days. All of the time series indicate a similar temporal pattern. None of the trends is large enough to be labeled as statistically significant at $p = 0.05$. In addition, it is noteworthy that the trend for the largest threshold (60 days) is negative, indicating a decrease in dry event lengths for a 60 day threshold.

[18] Because trend tests are influenced by the magnitude of values at the beginning and end of a period analyzed, multiple trend tests were computed for all sites by varying the beginning date and ending date of the time series analyzed. The 5 year moving average time series of mean dry event lengths (10 days or longer) for each site were used for

Table 3. Trends in 5 Year Moving Average Time Series of the Mean Fraction of Days With Daily Precipitation <2.54 mm and 5 Year Moving Average Mean Length of Dry Events[a]

	Water Year	Cool Season	Warm Season
Fraction of days with precipitation <2.54 mm	−0.28[b]	−0.33[b]	−0.15
Dry event length			
Minimum length of 10 days	−0.32[b]	−0.36[b]	0.08
Minimum length of 20 days	−0.18	−0.21[c]	0.03

[a]Trends were identified using Kendall's tau.
[b]Statistical significance at a 99% confidence level.
[c]Statistical significance at a 95% confidence level.

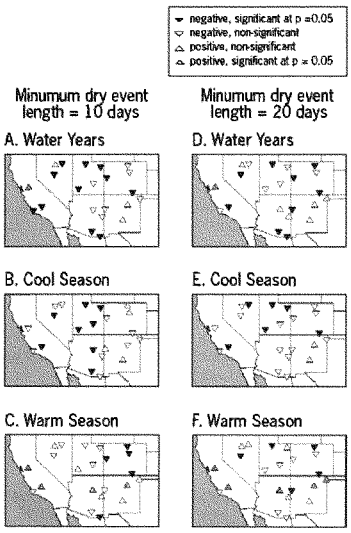

Figure 5. Trends in the 5 year moving mean length of dry events (computed using a minimum dry event length of 10 and 20 days) for water years (October through September), cool seasons (October through March), and warm seasons (April through September). The statistical significance of trends (at a 95% confidence level ($p = 0.05$)) was determined using Kendall's tau.

this analysis. The multiple trend tests were computed for all possible periods of at least 10 five year moving average periods in length during the 1951–2006 period. The number of sites with statistically significant ($p < 0.05$) positive or negative trends for each time period was counted. The statistical significance of the trends was computed using Kendall's tau. The counts of sites with statistically significant positive and negative trends for each period then were plotted against the beginning and ending dates (the dates indicate the center year of 5 year moving periods) of each period analyzed (Figure 8).

[19] Examination of the counts of statistically significant trends in dry event length indicates small numbers of sites with significant positive trends for any period (Figure 8). The time periods with the largest number of sites with significant positive trends are found for the water year and cool season and are for periods with a beginning date near 1980 and an ending date near 2004 (the center year of the last 5 year moving period). Significant positive trends occur for this period because of the drought that occurred in the southwestern U.S. beginning in the 1990s.

[20] Relative to the number of significant positive trends, the number of sites with significant negative trends is larger for many time periods, particularly for the water year and cool season. For the water year, the largest number of sites with significant negative trends in dry event length was found for beginning dates near 1950 and ending dates near the mid-1990s. For the cool season, the largest number of sites with significant negative trends in dry event length was found for periods beginning near 1950 and ending just before 1990.

[21] The results of the multiple trend tests across all sites confirm that there are few sites with significant positive trends in dry event length for most periods of time, except for the period beginning near 1980 because of the drought conditions in the southwestern U.S. that began in the 1990s. In contrast, there are several sites with significant negative trends in dry event length for several different periods of time.

[22] Because the El Niño–Southern Oscillation (ENSO) is an important driver of climate variability in the southwestern United States, an analysis was performed to determine whether the temporal variability in dry events was related to ENSO variability [*Redmond and Koch*, 1991]. For this analysis, time series of 5 year moving average NINO3.4 sea surface temperatures (SSTs) (an index of ENSO) averaged for water years, cool seasons, and warm seasons were correlated with the respective water year or season mean 5 year

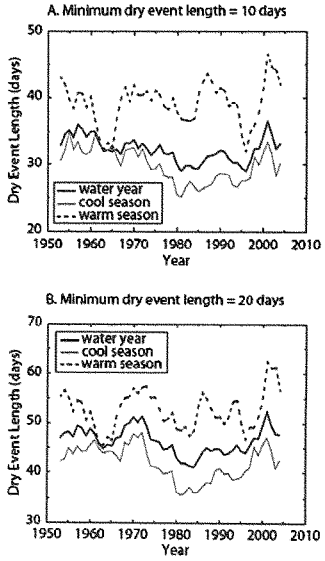

Figure 6. Five year moving average time series of mean dry event length (computed using minimum dry event lengths of 10 and 20 days) for water years (October through September), cool seasons (October through March), and warm seasons (April through September).

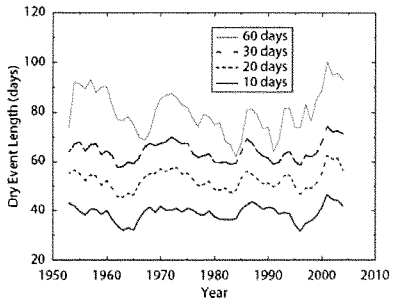

Figure 7. Five year moving average time series of mean dry event length (computed using minimum dry event lengths of 10, 20, 30, and 60 days) for warm seasons (April through September).

moving average time series of the fraction of dry days and the length of dry events (Table 4). Results indicate substantial rank correlations between NINO3.4 SSTs and the variability of the number of dry days and dry event length in the southwestern United States. The rank correlations are negative and are strongest for water years and cool seasons. The negative correlations indicate that when NINO3.4 SSTs are warm (cool), the fraction of dry days and the length of dry events decrease (increase) in the southwestern United States. These results are consistent with the effects of ENSO in the southwestern United States [*Redmond and Koch*, 1991].

[23] To identify dominant modes (i.e., frequencies) of variability in the fraction of dry days and dry event length that are jointly shared in both time and space among the 22 sites, a nonparametric spectral domain technique called the Multi Taper Method–Singular Value Decomposition (MTM-SVD) is applied to the data for the water year and the cool and warm seasons [*Mann and Park*, 1996]. This method is data driven and is unaffected by trends and other aliasing problems that commonly constrain the traditional time and frequency domain techniques.

[24] For each frequency, the localized fractional variance (LFV) is computed. The LFV provides a measure of the distribution of variance by frequency. Confidence levels (e.g., 95% and 99%) are computed based on the locally white noise assumption and are constant outside the secular band. *Mann and Park* [1996] described a bootstrap method used to obtain the confidence bands for this study. The MTM-SVD technique has been effectively applied to the analysis of global SSTs and sea level pressures [*Mann and Park*, 1994, 1996], global SSTs and Palmer Drought Severity Index values [*Apipattanavis et al.*, 2009], identification of dominant modes of variability in the Atlantic basin [*Tourre et al.*, 1999], and also for forecasting [*Rajagopalan et al.*, 1998].

[25] The MTM-SVD analysis of the fraction of dry days for all 22 sites indicated statistically significant (above $p = 0.05$) spectral peaks, which are common among water years and cool and warm seasons, at bidecadal, ENSO, and biannual frequencies (Figure 9). For dry event length, the significant spectral peaks common across all time periods are at bidecadal and ENSO frequencies (Figure 10).

[26] The significant spectral peaks at bidecadal frequencies can be seen in Figure 2 by the alternating persistent periods of positive and negative departures of the fraction of dry days and dry event length. This spectral frequency may be related to the influence of the Pacific Decadal Oscillation on precipitation in the southwestern United States [*Nigam et al.*, 1999].

[27] The significant spectral peaks at ENSO frequencies support the correlations between NINO3.4 SSTs and the fraction of dry days and dry event length (Table 3). The spectral analysis provides additional evidence that ENSO accounts for a substantial portion of the variability in the fraction of dry days and dry event length in the southwestern United States.

[28] Another interesting result of the spectral analysis is that, except for the cool season, there are no statistically significant spectral peaks that suggest long-term trends in the fraction of dry days or dry event frequencies (Figures 9

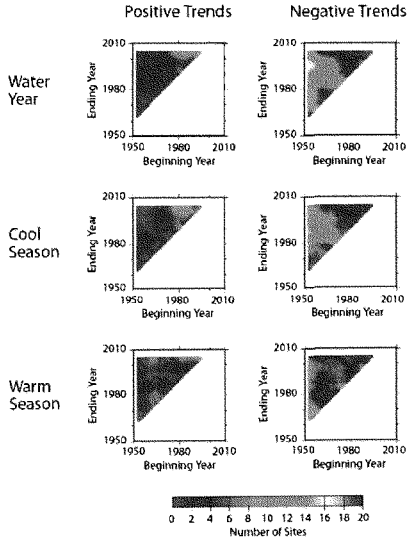

Figure 8. Number of sites with statistically significant (at a 95% confidence level ($p = 0.05$)) positive and negative trends in 5 year moving average time series of mean dry event length (using dry events with a minimum length of 10 days) for water years and cool and warm seasons. The beginning and ending dates refer to the center year of the 5 year moving period. The statistical significance of trends was determined using Kendall's tau.

Table 4. Rank Correlations Among 5 Year Moving Average NINO3.4 Sea Surface Temperatures, 5 Year Moving Average Time Series of Mean Fraction of Days With Daily Precipitation <2.54 mm, and 5 Year Moving Average Mean Length of Dry Events[a]

	Water Year	Cool Season	Warm Season
Fraction of days with precipitation <2.54 mm	−0.73	−0.69	−0.52
Dry event length			
Minimum length of 10 days	−0.74	−0.71	−0.41
Minimum length of 20 days	−0.68	−0.58	−0.51

[a]NINO3.4 sea surface temperatures were averaged for water years, cool seasons, and warm seasons.

and 10). The significant spectral peaks at the lowest frequencies for the cool season suggest significant long-term trends and are likely related to long-term negative trends in the fraction of dry days and dry event length (Table 2).

[29] Results of these analyses are consistent with analyses of trends in discharge for sites in the southwestern United States [*Lins and Slack*, 1999, 2005], a shift to an increased frequency in El Niño events [*Ebbesmeyer et al.*, 1991] that results in a wetter southwestern United States, and positive trends in precipitation in the southwestern United States. These results, however, contradict those of *Andreadis and Lettenmaier* [2006] and *Groisman and Knight* [2008], who found an increase in dry event duration in the southwestern United States.

[30] Differences between the results of this study and those presented by *Andreadis and Lettenmaier* [2006] can be explained, in part, by the differences in periods analyzed. *Andreadis and Lettenmaier* [2006] examined trends for 1925 through 2003, whereas this study examined trends for 1951 through 2003; thus, much of the trend may have occurred prior to 1951. In addition, *Andreadis and Lettenmaier* [2006] examined trends in dry event duration defined using modeled streamflow that includes the effects of temperature, whereas in this study, dry events were defined only using precipitation.

[31] In contrast, the differences between the results of this study and those of *Groisman and Knight* [2008] are more difficult to explain. Our analysis relied solely on WBAN stations, because of their completeness of record and consistency of observational practices. The cooperative station network often is adversely affected by missing data, differing starting and ending dates, and changes in observers and methodology [*Groisman and Legates*, 1994, 1995; *Daly et al.*, 2007]. Missing observations are more prevalent and spatial interpolation is problematic during drier conditions because precipitation, particularly in the southwestern United States, is highly localized. We would contend that the completeness and quality of the data set used in our study is likely to yield results that are more indicative of the actual pattern of change in dry day events in the southwestern United States than results obtained using data from the cooperative station network.

4. Conclusions

[32] Little evidence of long-term positive trends in dry event length in the southwestern United States is apparent in the analysis of daily WBAN precipitation data. During the mid-1990s to late 1990s, drought conditions began in the

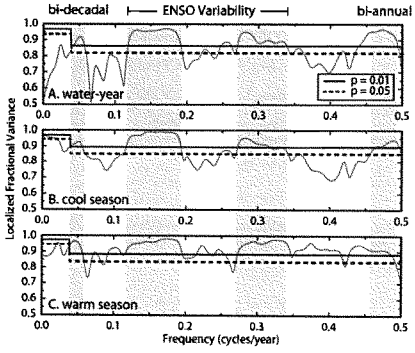

Figure 9. Localized fractional variance spectrum from a spectral analysis of 5 year moving average fraction of dry days for 22 sites in the southwestern United States for the period 1951 through 2006 (gray line). The horizontal lines indicate the 95% ($p = 0.05$) and 99% ($p = 0.01$) confidence levels. The gray shaded bars indicate statistically significant frequencies (at $p < 0.05$) that are common among water years and cool and warm seasons.

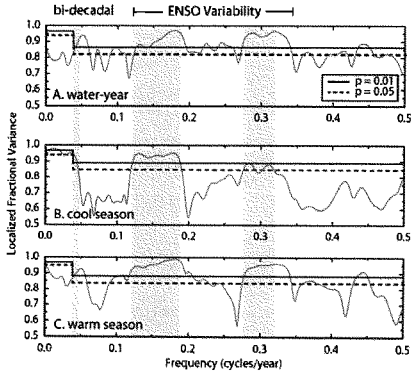

Figure 10. Localized fractional variance spectrum from a spectral analysis of 5 year moving average dry event lengths for 22 sites in the southwestern United States for the period 1951 through 2006 (gray line). The horizontal lines indicate the 95% ($p = 0.05$) and 99% ($p = 0.01$) confidence levels. The gray shaded bars indicate statistically significant frequencies (at $p < 0.05$) that are common among water years and cool and warm seasons.

southwestern United States and persisted in the 21st century. This drought has resulted in positive trends in dry event length for some sites in the southwestern United States. However, most of the statistically significant trends in the number of dry days and dry event length are negative trends for water years and cool seasons.

[33] In addition, correlation and spectral analyses indicate that a substantial portion of the variability in dry event characteristics in the southwestern United States is attributable to ENSO variability, particularly for water years and cool seasons. Since the mid-1970s, El Niño events have been more frequent, and this has resulted in increased precipitation in the southwestern United States, particularly during the cool season. The increased precipitation is associated with a decrease in the number of dry days and a decrease in dry event length.

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Learning and Teaching Climate Science: The Perils of Consensus Knowledge Using Agnotology

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Abstract Agnotology has been defined in a variety of ways including "the study of ignorance and its cultural production" and "the study of how and why ignorance or misunderstanding exists." More recently, however, it has been posited that agnotology should be used in the teaching of climate change science. But rather than use agnotology to enhance an understanding of the complicated nature of the complex Earth's climate, the particular aim is to dispel alternative viewpoints to the so-called *consensus* science. One-sided presentations of controversial topics have little place in the classroom as they serve only to stifle debate and do not further knowledge and enhance critical thinking. Students must understand not just what is known and why it is known to be true but also what remains unknown and where the limitations on scientific understanding lie. Fact recitation coupled with demonizing any position or person who disagrees with a singularly-derived conclusion has no place in education. Instead, all sides must be covered in highly debatable and important topics such as climate change, because authoritarian science never will have all the answers to such complex problems.

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"All great truths begin as blasphemies."
George Bernard Shaw, *Annajanska* (1919)

1 Introduction

Agnotology[1] has been defined by Proctor (2008) as the study of ignorance and its cultural production. Proctor sees the study of ignorance as having three facets which result from a basic lack of knowledge (presumably to be ultimately known, if possible), from selective choice (i.e., choosing to remain ignorant), and from an intentional attempt to deceive. With respect to education, all three components are important when studying difficult and/or controversial topics. Science educators must teach what is known and how it has come to be known to be true. But educators must also strive to convey areas where and why scientific knowledge is lacking. Many topics, such as the influence of gravitational fields on stars and orbiting objects or the interaction of particles at subatomic scales are filled with uncertainties because of the very nature of the process involved. Indeed, any complex study will involve ignorance to some degree which must be properly conveyed to students or the general public. But that ignorance resides in an incomplete understanding of the scientific matter at hand, which is different from deliberately and culturally directed ignorance.

How the three facets of agnotological ignorance are treated is therefore of considerable importance. Regarding these three facets, Proctor claims that

> Ignorance has many interesting surrogates and overlaps in myriad ways with—as it is generated by—secrecy, stupidity, apathy, censorship, disinformation, faith, and forgetfulness, all of which are science-twitched...Ignorance is most commonly seen...as something in need of correction, a kind of natural absence or void where knowledge has not yet spread. Educators, of course, are committed to spreading knowledge. But ignorance is more than a void—and not even always a bad thing...A founding principle of liberal states is that omniscience can be dangerous...liberal governments are (supposed to be) barred from knowing everything...juries also are supposed to be kept ignorant, since knowledge can be a form of bias (Proctor 2008, p. 2).

While Proctor sees ignorance as stemming from his list of bad or subversive activities, he also feels it can ultimately be used for good since too much knowledge can create an authoritarian system (i.e., *anti-liberal* in the classic sense of the word) or lead to biases by jumping to erroneous conclusions (e.g., the man who has cried 'wolf' too many times in the past may, in fact, be telling the truth this time around—although ignorance of the past may ultimately lead to an unjustified trust in this individual).

Agnotology also has been defined as "the study of how and why ignorance or misunderstanding exists" (Bedford 2010, p. 159). In this context, agnotology is not limited just to things that are not known but includes those ideas of which we are certain are true but, in reality, are not. Ignorance, or a lack of knowledge, can be used to describe what is not known (i.e., Proctor's First Facet) but the second describes a "willful ignorance" or a condition of "in denial" (i.e., Proctor's Second Facet). The degree that a scientist is certain about something (certainty that is never actually achieved) is because that conclusion is based upon scientific evidence. Unless and until the evidence changes or is supplemented, the scientist has no way of knowing that the conclusion *in reality* is not true, for it is not scientific to reach a conclusion in the absence of evidence. Agnotology is further rooted deeply within a cultural context with humans being the dominant agents of knowledge

[1] "Without knowledge" in Greek would be *agnostos*, so agnostology would be a more accurate term which is related etymologically to *gnosis* and *agnostic*. Here, however, the term "agnotology" will be used to be consistent with Proctor and Schiebinger (2008).

dissemination and concomitant information loss (Schiebinger 2005). Ignorance, in Schiebinger's view, is not simply the product of inexact or uninformed science but arises from cultural, historical, and political biases, both consciously and unconsciously. These three views come together to provide a useful working definition since ignorance arises from both commission[2] and omission and, in its most basic definition, ignorance is simply a lack of knowledge of the truth. This definition of agnotology considers reasons for a lack of understanding or incorrect knowledge and is consistent with that of Proctor (2008) where ignorance arises from such undesirable and likely malicious sources. For the purpose of academic discourse, the word *ignorance* can be used therefore in a vastly expanded manner. Restating and expanding upon Proctor's Three Facets, *Type I Ignorance* represents true ignorance (i.e., a basic lack of knowledge), *Type II Ignorance* represents selective ignorance (i.e., representing an assertion that something is true either without evidence or against existing evidence), and *Type III Ignorance* represents deceptive ignorance (i.e., the willful exercise of cultural bias).

Expanding upon this definition, a focus on *Type I Ignorance* would appear to be a useful teaching tool. It is important to stress what is not known and why just as much as it is to teach what is known and why. McComas et al. (1998) argued that students learn the *what* of science but not the *how* which leads to misunderstandings about how science actually works. Providing an educated discussion of the uncertainties in scientific knowledge is far better than simply proclaiming that "the science is settled" or implying that science provides all the answers. For example, the climate system is exceedingly complex and components of the hydrologic cycle operate on such a large spectrum of spatial and temporal scales that a complete understanding of many processes has not yet been unlocked. Having students comprehend both the depths of scientific knowledge and where and why that knowledge is lacking builds the potential for inquisitive minds that might someday be capable of unlocking these stubborn secrets. At the very least, it provides a true appreciation for the exceedingly complex nature of the world.

It should be noted that agnotology is not the first attempt to classify how human thought goes awry. Philosopher David Stove, for example, attempted to construct a nosology (i.e., a classification of disease) of human thought in 1991. In his essay on *What's Wrong With Our Thoughts?*, Stove argued that

> Defects of empirical knowledge have less to do with the ways we go wrong in philosophy than defects of *character* do: such things as the simple inability to shut up; determination to be thought deep; hunger for power; fear, especially the fear of an indifferent universe...these are among the obvious emotional sources of bad philosophy (Stove 1991, p. 188, italics in original).

Scientists cannot know *why* something is not known or often even that it is not known. Of course, how can something be discussed when scientists do not know that they are ignorant of it! What is important, however, is that scientists be honest and ever-searching for the truth—and on that everyone has to be taken on face-value, assuming there is no hidden agenda or axe to grind.

2 Agnotology and Climate Change

Anthropogenic climate change is one of the most controversial and politically-charged topics of recent time. Simply put, the discussion arises from the assertion (hypothesis) that

[2] Indeed, almost every discussion of agnotology and the intent to deceive refers to the 1969 tobacco company memo declaring "Doubt is our product".

dangerous global warming is, or will be, caused by continuing human emissions of greenhouse gases, especially carbon dioxide. This is, in fact, a testable scientific hypothesis. This issue has been viewed as having such significant importance that a special branch of the United Nations, the Intergovernmental Panel on Climate Change (IPCC), has been established to advise governments on the matter.

Consequently, the science of the Earth's climate is a subject that is appropriately broached even in elementary school curricula. But unfortunately, it is one which is very complex. Simplifications must be used to explain topics far more complex than could be breached for the students' level of comprehension. For example, educational materials on climate change are filled with simplistic statements such as "the atmosphere acts like a blanket covering the Earth" or "the Earth's atmosphere functions like a greenhouse, allowing light to enter but inhibiting heat from escaping." These myths pervade because they are simple and students seem to grasp the concept even if they are really being misled. It is well-known that the atmosphere stimulates the transport of energy by convection whereas a blanket warms by inhibiting air motions. Greenhouses warm because the energy exchange by latent and sensible heat is reduced, not because the glass is transparent to light and opaque to infrared (i.e., heat) energy (see Lindzen 2007). Indeed, an experiment was conducted by Wood (1909) where sunlight was passed through both glass (transparent to light but opaque to heat) and rock salt (transparent to both light and heat) with equal warming conditions (see also Jones and Henderson-Sellers 1990).[3] Even in the very use of the word 'heat' there is much confusion (Romer 2001).

But such simplifications teach bad concepts and provide students with a false confidence in their understanding of science that should be, but most often is not, unlearned as they progress to higher levels of study. Although few have heeded his warnings, Essex (1991) proffered an early criticism of such simplistic representations of 'global warming', 'heat radiation', and 'the greenhouse effect' even from a pedagogical sense. Essex concludes that

> The only real certainty is that the definitive questions of prediction (if, how much, when, and where climate change will take place) are fundamental scientific questions that models cannot answer alone. We are *not* faced with a problem that can be treated by mere *applications* of theory imported from *more basic* fields. The problem of long-term prediction is a significant fundamental scientific obstacle even for those other fields that might be appealed to (Essex 1991, p. 132, emphasis in the original).

Overcoming these 'ignorance by commission' statements is a necessary goal to further scientific knowledge; indeed, this goal addresses *Type II Ignorance* (and, in some cases, maybe *Type III Ignorance* issues) and, therefore, should be a desirable goal of true agnotology.

Recently, agnotology has been posited as a viable tool for exploring controversial topics such as global climate change (Oreskes and Conway 2008). But rather than use agnotology to enhance understanding of the complicated nature of a complex system, it has been suggested that agnotology should be used to reinforce one side of the debate. Using anthropogenic climate change as the ideal example, Bedford (2010, p. 161) presents his case as to how the study of misinformation (unintentional) and disinformation (intentional) spread by *skeptic* scientists can be used to teach students the science of global warming and separate it from the "global warming agnogenesis [ignorance] literature." To the degree

[3] We are not arguing here that the 'Greenhouse Effect' does not exist; rather, the Earth's surface is indeed warmer than it would be in the absence of an atmosphere. What Wood's example suggests is that a greenhouse on the Earth's surface warms not because light gets in more easily than heat gets out but because the processes of latent and sensible heat exchange are removed as possible pathways for energy transmission with the outside atmosphere. In the atmosphere, latent and sensible heat fluxes are much more efficient in transmitting heat from the surface to the atmosphere than electromagnetic radiation which is why the greenhouse warms.

that such assertions are true, they apply in spades to the presentations and writings of many scientists who support the IPCC's alarmist view of the situation.

Bedford (2010) concludes that geographic education can be enhanced by an explicit study of agnotology so that critical thinking can be developed, knowledge and comprehension of scientific details can be furthered, and students can better understand scientific literature from newspaper accounts. Indeed, if the study of agnotology can be beneficial to further knowledge and enhance critical thinking, then by all means it should become a part of any educator's toolkit. But our views strongly disagree with Bedford's in that newspaper reports are invariably based on highly-spun press releases and interviews given by those who support the alarmist view and dissenting views, if presented at all, are ridiculed. Thus, as defined by Bedford (2010), agnotology can be used to stifle debate and to require acceptance of a single scientific viewpoint.

Unfortunately, Bedford's view of agnotology in teaching climate change is profoundly misplaced and potentially dangerous. It is based on the notion that dissenting views should not be presented if there is a scientific consensus, even if such a consensus is contrived. Most arguments in support of anthropogenic climate change alarmism assert that climate change has a singular dominant cause—human activities—which has been widely proven and accepted. In such a context, dissention from the supposed consensus is not just ignorant (in the misinformation sense of *Type II Ignorance*) but is also judged to be malicious (i.e., disinformation in the context of *Type III Ignorance*). Indeed, agnotology then becomes little more than an appeal to *attack the opposition*. It is not simply acceptable to teach such a one-sided view of climate change science (nor any other science, for that matter) that amounts to nothing more than the belittlement of opposing viewpoints. This is not how science works, nor what science classrooms should become.

The science is settled is a mantra that is often repeated by anthropogenic global warming believers to preclude any further discussion of the science. While an extensive evaluation of the intricacies of climate change science is not provided here, it is important to mention that climate change is an important scientific debate that is far from being well-understood. The interested reader is urged to consult Betz (2009) and Pielke et al. (2009) for a further examination of the true extent of the climate change discussion and the unknowns in climate science; and to the reports of the Non-governmental Panel on Climate Change (NIPCC) for compendious examples of alternative scientific views on global warming to those of the IPCC.[4] The existence of such diverse viewpoints is important for agnotology, since teaching students about the climate *must* include discussions of how complicated the Earth's climate system is and why science cannot possibly, already or ever, have all the answers to every question about climate and its variability and change.

Concomitant with this *attack the opposition* view of agnotology are *ad hominem* attacks on individual scientists as well as a selective appeal to authority and training. The usual mantra of the *consensus* view is to assert that those espousing the consensus are *real* climate scientists whereas *skeptics* are simply commenting on topics out of their field of expertise. It is seldom noted that some of the stalwarts of the *consensus* view were not trained in related fields either or that some of the independent scientists who disagree with the IPCC's alarmist view are highly distinguished. Nevertheless, an appeal to credentials is irrelevant for true scientific discourse. It matters not who funds or conducts the science; what matters is whether the message can withstand scientific scrutiny. Discussion and debate are essential in all areas of scientific discourse, to separate the wheat from the chaff and assertions and hearsay from scientific evidence. At the end of the day, *one plus one*

[4] http://www.nipccreport.org/reports/reports.html.

equals three will always be shown to be false, but only if we are willing to listen to a contrasting view that *one plus one only equals two*. It is surely hoped that classroom pedagogy would assert that scientific arguments should be won or lost on the merits of the evidence, not by the pedigree of the people doing the research—and that holds for scientists on all sides of every argument.

Bedford (2010) suggests several outcomes that are to be achieved through the use of agnotology in the global warming debate. The first is to address what is known and why it is known. But put bluntly, this fails to admit that there is any other valid viewpoint except that presented by the 'consensus' authorities, and simply reiterates to students that the science is settled and that science has all the answers. The second outcome stresses the importance of peer review and, in particular, the scientific method. However, it is the third outcome—"Strengthened Critical Thinking Skills"—with which there could not be more disagreement. Bedford states

> A third [outcome] exploits the concept that certain aspects of a multi-faceted problem become less contentious with further research, while new difficulties arise and need to be addressed. It is therefore possible, indeed common, to achieve a scientific consensus on some aspects of a problem, but not others. Thus, for example, there are certainly areas of global warming research that are legitimately contested in the peer-reviewed literature, such as the extent to which hurricanes have already strengthened due to anthropogenic climate change...however, the basics of global warming—that greenhouse gases cause warming, and human emissions of those gases are enhancing the greenhouse effect and causing Earth to warm further—are essentially uncontested. By blurring the distinctions between the generally agreed-upon basics and the still-contested areas at the margins, the agnogenesis campaign is once again able to suggest that there is no consensus on global warming (Bedford 2010, p. 161).

Regarding scientific matters, claims of consensus as an argument for validity are simply noxious. After all the very motto of the Royal Society of London itself is *Nullius in verba*, meaning roughly "Take no one's word for it." Any suggestion that critical thinking is achieved by distinguishing the 'consensus' from other viewpoints is no more than the indoctrination of a single viewpoint. The process of critical thinking requires investigating *all* perspectives analytically, examining their internal consistency, reproducibility (a hallmark of science and scientific inquiry), and coherency from previously-defined set of climate principles. Having a student understand why they should not believe a certain viewpoint can only be achieved by having them analyze that particular viewpoint from all perspectives, not by indoctrinating them that all opposing views are intentional or unintentional misrepresentations of fact. A strengthened understanding of the basic science of weather and climate is truly required because the academic community often substitutes *climate change science* for *climate science*. Indeed, few scientists and educators appreciate how much of climate science is really not known.

3 A View of Agnotology and the Classroom

A better approach exists for the use of agnotology in the classroom to foster critical thinking in a healthy atmosphere. First, it has to be noted that students must be provided with a presentation of the basic facts regarding climate science at a level appropriate to their comprehension, before launching into any discussions of mechanisms that might or might not lead to its change and variability. They can only understand climate change if they are first well-grounded in the science of climate, not simply considering it as *average weather*, which is often the way it is presented. Differing viewpoints on this topic must be faithfully and respectfully presented, including a discussion of what is not known or cannot

be known. It also is imperative to dispel myths about basic principles that pervade the classroom because of the need for a simplified explanation to a highly complex problem (e.g., the aforementioned "the atmosphere acts like a blanket" example). Students benefit more from open scientific discussions than from a mere insistence to regurgitate facts and figures or even the blind adoption of apparently popular and authoritative claims. Science depends on observational analysis, experimental evidence, rational arguments, and skepticism (McComas et al. 1998). However, McComas et al. (1998, p. 527) are correct when they conclude "it is vital that the science education community provide an accurate view of how science operates."

In 1944, George Bernard Shaw quipped that "the average man can advance not a single reason for thinking that the Earth is round"—the Earth is round simply because scientists say it is. Today, satellites and space flight provide an advantage to demonstrate that the oblate ellipsoid model of the Earth is most plausible. But a student gains far more understanding about the nature of the Earth by asking them to prove to Shaw's "average man of 1944" that the Earth is not flat (i.e., without using pictures from space). Navigation, lunar eclipses, and astronomy all are viable reasons and they provide the student with a better understanding of why we believe what we believe. Thus, learning must include proof of ideas to be truly active learning rather than simply bowing to authority by proclaiming *consensus science*.

This paper begins with an earlier quote from George Bernard Shaw that "All great truths begin as blasphemies." It must be noted that the science has been *settled* many times in past history only to find that the authorities were wrong. The Earth was at the center of the Universe until it was ultimately proven by Johannes Kepler in 1609 that the gravitational model of a heliocentric solar system was correct, in accordance to the suggestions of Nicolaus Copernicus and the observational data of Tycho Brahe. Ignaz Semmelweis suggested in 1848 that hand washing would greatly decrease infant mortality, much to the scorn and ridicule of his peers. It was not until much later that Louis Pasteur and an understanding of germs confirmed that Semmelweis' argument was indeed valid. Continental drift was dismissed as fancy until plate tectonics were better understood in the 1960s, despite the fact that it had been first suggested by Abraham Ortelius in 1596 and developed by Alfred Wegener in 1912.

That is not to say that all of science will one day be demonstrated to be false or that every alternative theory or hypothesis should be considered. Science is constantly evolving; many times scientists get it right, but at the same time many hypotheses are also in time overturned through further knowledge and understanding. Alternative theories also have their merits. Historically, science has been reticent to change paradigms or overthrow existing ideas even when they become demonstrably invalid. Today, funding plays a key role in the professional life of most scientists and funding agencies are unlikely to fund science that challenges existing beliefs, especially if it is likely to cause a politically unwelcome outcome. That is largely because program officers and scientists were once students, and students tend to believe what they were taught.

An example of this was presented in the NOVA program entitled "Do Scientists Cheat?" (NOVA 1988). Amidst the discussion of several prominent university faculty who had committed fraud to garner more funds and to enhance their reputations is the story of Scott McGee who taught biology and the scientific method to seventh graders in Brookline MA (USA). McGee was quoted as saying, "many of us refuse to consider that failure or the discovery that you lack an important piece of information is also valuable information." One of the projects McGee had his students undertake was to fill a large jar with water, algae, microorganisms, mud, and sediments from a nearby pond and observe it for 3 months. The students were then required to write a paper describing what they observed

and how it related to the concepts they were learning. Given that ecosystems are exceedingly complex, it is impossible to expect that a jar-sized sample will exhibit all or even any of the basic principles that had been discussed in class. But McGee's seventh graders believed that results are important and reporting that their observations are at odds with the expected theory, developed by authority figures, is not likely to yield a good grade. McGee indicated that all of the eighth graders who had taken his class the previous year admitted they had falsified data to fit the population models they had been taught.

It is uncommon, and not always healthy, for a student to question every fact or theory presented to them. That is why it is imperative that students be taught what is known and why we think it is known to be true, as well as what is not known and why—call that agnotology, if you will. It is further imperative that for controversial topics, such as anthropogenic climate change, other views be presented and discussed. In particular, theories are seldom black-and-white; indeed, the anthropogenic climate change discussion is not polarized into those who believe humans are the only agents of climate change and those who believe humans can have no impact on their environment. Teachers who present only a single viewpoint without a proper discussion of climatic processes, regardless of what that viewpoint is, are only encouraging a generation of students to believe only what they are taught, to portray those with whom they disagree as uninformed or ignorant or biased or deceitful, and to blindly follow authoritarian leadership. Lysenkoism in the Soviet Union from the 1930s through the mid-1960s is a classic example of the isolational utopia that develops when opposing ideas are squelched.

4 The Uncertain Nature of Science

Unfortunately, the boundary between what should and should not be questioned in science is fuzzy. It should not be critically presented, for example, that the Earth is flat or that the NASA Moon missions were conducted on a sound stage in the Nevada desert just because someone says it is so. Thus, the need exists to determine guidelines for which scientific topics demand a discussion of multiple interpretations and which ones should be taught as fact—pending credible evidence which may later call them into question. From a strictly scientific point of view, all topics are subject to continuing scientific criticism. Even Newtonian physics has been questioned as to whether it applies at certain space and time scales. But on the education side, it is not useful to present all science as being potentially incorrect, although it is imperative to stress the importance of the scientific method in guiding scientists to know what they believe to be true. So where is the line to be drawn?

Even what is meant by the *scientific method* has changed over the years. Kuhn notes:

> The more carefully [historians] study, say, Aristotelian dynamics, phlogistic chemistry, or caloric thermodynamics, the more certain they feel that those once current views of nature were, as a whole, neither less scientific nor more the product of human idiosyncrasy than those current today. If these out-of-date beliefs are to be called myths, then myths can be produced by the same sorts of methods and held for the same sorts of reasons that now lead to scientific knowledge. If, on the other hand, they are to be called science, then science has included bodies of belief quite incompatible with ones we hold today. Given these alternatives, the historian must choose the latter. Out-of-date theories are not in principle unscientific because they have been discarded. That choice, however, makes it difficult to see scientific development as a process of accretion (Kuhn 2012, pp. 2–3).

Indeed, the common bond that has separated the scientific method (as it has evolved over the years) from mythology has been the empirical evidence. The final arbiter has not been an appeal to authority or consensus or even an argument for the longevity of the theory, hypothesis, etc.; scientific observations have always held the final say. Observational

evidence is the key to finding scientific truth. However, results from climate models are often erroneously posited as observations themselves or even data and even when they diverge considerably from the real observations, they are used to drive theory construction. Results from climate models should be used with extreme care and not be taught as scientific fact.

Saloranta (2001) describes the dilemma of policy makers struggling with anthropogenic climate change science. What is the rational approach to policy-making when facts yield an incomplete picture, views of numerous climatologists diverge, and models are inherently uncertain while decision-making, policy makers argue, is critical and urgently pushed by polarized interests? Enter *Post-Normal Science* where stakes are high and conflicting views exist amidst a process filled with a high-degree of uncertainty accompanied by a strong ethics component. Rather than focusing on observational evidence, which may be conflicting and fuzzy, all *stakeholders* (from scientists to lay-people to special interests) contribute to the ultimate decision of what is to be taken as *truth* and subsequently, what should be done with this *knowledge*. It is viewed by adherents as assisting the normal scientific process in areas where the scientific method has failed. Saloranta (2001) makes a strong case as to how the Intergovernmental Panel on Climate Change may have abandoned the traditional, observation-refereed, scientific method in favor of the Post-Normal Science paradigm. However, this new framework places the scientist in the role of an advocate—someone who argues for a particular outcome rather than searching for truth with an unbiased eye. This is anathema to the original definition of the scientific method.

Lackey (2013) highlights this observation by noting that too often scientists have become policy advocates. Rather than being objective, *normative science*—where an assumed and usually unstated policy bias is used to sway the normal scientific process—is a corruption of traditional scientific principles and is rapidly becoming the norm in climate change science. Lackey argues that normative science is stealthy because the advocacy bias is often neither evident nor revealed but usually normative science is filled with qualitative terms that are designed specifically to affect policy, not convey scientific knowledge. Lackey concludes his article by cautioning scientists to play their appropriate role: provide facts, probabilities, and analysis but avoid normative science.

This illustrates precisely why the discussion of anthropogenic climate change must be presented in the classroom as an ongoing scientific debate rather than an authoritative- or consensus-driven fact. The science is indeed uncertain owing to incomplete and complicated observational evidence. Allowing Post-Normal Science to substitute for an observation-based scientific method results in circular reasoning—what a group wishes to be true becomes truth simply because they have deemed it to be. However, students must begin their educational journey by assuming that what they are taught is fact—and that the teacher and/or the textbook are the ultimate authorities. But educators must use this authority with the greatest of care so that students learn about science and so that their scientific knowledge is not undermined by biased presentations from advocates posing as scientists.

5 Conclusion

Students are cheated and cannot learn critical thinking if they are only presented with one-sided facts. Presentation of only a consensus viewpoint and the demonization of anyone holding an opposing view in such a complex and unsettled topic as climate change are clearly dangerous to a proper understanding of the science. The limited view of agnotology

held by some has represented little more than an effort to stifle debate and to "attack the (presumed) ignorant" through *ad hominem* statements and presentations. One-sided presentations of controversial topics have little place in any academic setting and do nothing to further knowledge and enhance critical thinking. Thus, Chamberlin's (1890) admonishment to circumvent "the dangers of parental affection for a favorite theory" is as valid today as it was in the late 19th Century.

Science education must be such that students can, in fact, argue successfully why they believe what they believe. Understanding what is not known and why must be an essential component of that education. Simple recitation of facts coupled with the demonization of any position or person who disagrees with a singularly-derived conclusion does not develop critical thinking and has no place in education. Students cannot learn the scientific method or critical thinking, nor will they benefit until they have learned to examine all scientific evidence without fear or prejudice. By contrast, a more useful approach is to cover all sides of this scientific debate, recognize that multiple viewpoints (more than two) exist, and stress what is not known and why it is not (call that agnotology, if you will) rather than teaching students that "the science is settled" because authoritarian science has all the answers.

Thus, Weiss (2012, p. 100), who argued that agnotology should "encompass the much more typical realm of genuine uncertainties," is quite correct. Agnotology should not be allowed to devolve into *ad hominem* attacks and motive speculation to further one side of the argument. Science deals with uncertainties—from where they originate, how they affect the results, and how they are considered in reaching the conclusions—and it is imperative that students understand early on that science does not always have all the answers. To truly engage students and make them active learners, a teacher has to present all sides of controversial issues and then teach students how to ascertain consistency, reproducibility, and coherency in their arguments. This is the only way students can actually learn and expand their secure knowledge in scientific subjects. An open mind is the key to true knowledge.

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Subcommittee on Green Jobs and the New Economy
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One Page Summary

1. If global surface air temperatures rise for any reason, this will undoubtedly increase the length of the growing season which, in turn, will enhance the amount and diversity of crops that can be grown. Moreover, it will allow for more areas of the planet to be farmed, primarily in the Northern Hemisphere, thereby increasing crop productivity.

2. The limiting factor, however, is the moisture availability to plants as agriculture in much of the world is restricted by water availability both from precipitation and surface/groundwater reserves. Pinpointing the exact geographical areas for which drought/increased rainfall are likely to occur lie far beyond our technology for the foreseeable future.

3. My overall conclusion is that droughts in the United States are more frequent and more intense during colder periods. Thus, the historical record does not warrant a claim that global warming is likely to negatively impact agricultural activities.

4. A General Circulation Model may appear to provide a good simulation of the climate, when in fact the model may poorly simulate climate change mechanisms. In other words, a GCM may provide an adequate simulation of the present-day climate conditions, but it does so for the wrong reasons.

5. The simulation of precipitation, and similarly soil moisture, is adversely affected by inaccuracies in the simulation of virtually every other climate variable while inaccuracies in simulating precipitation adversely affect virtually every other variable in the model.

6. Droughts that have happened in the past are likely to occur again, and with likely similar frequencies and intensities; thus, preparation for their return is a better strategy than trying to mitigate them through draconian CO_2 emission control policies.

7. I have provided you also with my observations of how climatologists who dissent from the anthropogenic global warming disaster scenarios have been treated. I leave you with this thought – When scientific views come under political attack, so too does independent thinking and good policy-making because all require rational thought to be effective.

Senator MERKLEY. Thank you all very much for your testimony, we will now have 5-minute periods. I believe the order after I ask my questions, we will go to Senator Sessions and then to Senator Vitter. Senator Wicker has said he'll defer to his colleagues. And I didn't see you come in, Senator Whitehouse. So, let me check on the order. We will go back and forth between Ds and Rs. Thank you.

So, I wanted to start, Mr. Walls, in Lake County, I have been very struck when I visit there, it is obviously a rural economy, a rural part of the State of Oregon and a lot of emphasis on renewable energy, and I believe a stated goal of the county is to try to replace virtually all of the fossil fuels burned with renewable sources. Is part of the factor driving that conversation in Lake County general observations by folks about the impact of carbon dioxide on, as you were putting it, on the forests?

Mr. WALLS. In the beginning, which would have been about 10 years ago, when we started working on this, it became clear afterwards when we started analyzing and we did a paper on it, we could offset 93 percent. My board just approved this past week that we will go public with all our findings and try and develop a plan to use renewables to offset all carbon emissions.

So we grew into that as we learned more and more of the benefits of the economic benefits of renewable energy, how it would impact us and we just said, well, what is that going to do to climate change? What is that going to do to carbon dioxide emissions? And like I said in my testimony, what we have on the drawing table today would offset 93 and to get to 100 is not that difficult from there. We are well on that road. I think we can be 100 percent offset within 10 years.

Senator MERKLEY. Great. Thank you. I was looking at the National Climate Assessment and Summary. It notes that climate change is exacerbating major factors that lead to wildfire, heat, drought, and dead trees, that it outweighed other factors in determining the burned area in the western U.S. from 1916 to 2003, including the exacerbation of bark beetle outbreaks, which normally die in cold weather, more wildfires, as change continues. Then I saw that there is a 2011 report that estimates that if you increase the temperature 1.8 degrees Fahrenheit, which is approximately 1 degree Celsius, that you would quadruple the amount of acreage burned. But as you look at the forest issues, if I understand your testimony correctly, you are seeing both the impacts of human management of the forest as a factor, but also the overlay of these climate factors.

Mr. WALLS. Exactly, and as I mentioned it has impacted our snowpack dramatically. If you look in the Klamath Forest just to the south of us, this year they had six snow cell sites that were zero percent snowpack.

Senator MERKLEY. And with that, drier conditions.

Mr. WALLS. Yes, and then the beetle kill. We have never seen, well, beetle kill gets into lodgepole pine naturally. But it has never been the size that it is today. And that is because we don't have the cold temperatures and they get to live year after year because of the warmer temperatures and they are not being killed. And 350,000 acres is abnormal, nobody has ever seen that. And then I

think throughout the whole west, into Canada was over 4 million acres of beetle kill, somewhere in that neighborhood.

Senator MERKLEY. Thank you very much.

Mr. Pope, turning to the farming side, one of the things you mentioned were changes in the wheat farming, and are you arguing that the changes in wheat are being impacted by changing temperatures?

Mr. POPE. Yes, and when you look at the situation in the southern plains right now, clearly the drought over the last few years has had a huge impact. I think too, that when you look at the situation as far as precipitation, and clearly, with wheat, wheat's a really resilient crop, it depends on when you get the rain and what time the rains come. The challenge is the rain patterns that we have been seeing, the way that things are changing, you put into that the effects, late season freezes, the droughts; clearly, we are seeing an impact on the wheat crops from the changes in the climate that we are experiencing right now.

I think there are some things that we can do to help adapt to that situation, I hope we can do some things to move forward a little bit as are as improving the soil health, try to do things to help make our farms more resilient to droughts, to freezes, to sudden flooding event, heavy rain events. I think that is a challenge we have got far in front of us is to try to make sure that we got those tools to do that job.

Senator MERKLEY. Thank you, and in the 45 seconds I have left, I read a recent report about oysters in the Chesapeake declining in part because of acidity, but that also has a secondary impact because oysters filter the water in the Chesapeake, possibly offsetting many of the efforts to clean up the Chesapeake Bay. Is that consistent with what you are seeing?

Mr. COHEN. So first, oysters are specifically a great benefit for the environment because they are filter feeders, and they do clean. One of the things why in the Chesapeake Bay they are trying to bring them back Is because they need to clean the Bay up. But in the Chesapeake, very similar to what is happening in the Pacific Northwest, is that we have rising levels of pCO_2 the partial pressure of CO_2 in the ocean, and therefore, rising acidity. In the Pacific Northwest, we have been able to document it because it is mostly hatchery based. And there as hatchery based, you can control what is happening and identify.

It is a little harder in the wild environment to determine what is happening to see really whether or not this spawning that has taken place, again with the it is not really spawning; it is a little baby larvae have a hard time setting up their shell. They can't accept the calcium into their shell because of the acidity. If you use Tums, in your stomach, it is really calcium, you are buffering. Does that answer your question?

Senator MERKLEY. Thank you, and I would ask a lot more, but my time is expired. I will ask everyone to keep their question within the 5 minutes. Maybe an answer we will go over, since we have a number of folks who certainly want to jump into this, and I believe, Senator Sessions, you are next.

Senator SESSIONS. Thank you, Mr. Chairman.

Dr. Legates, the time that we can intimidate people who present scientific papers that disagree with the current idea that is in fashion needs to be over. And we need to challenge that. I am not going to rest easy about it myself. I know the President, and I have challenged this twice, he said the temperature around the globe is increasing faster than was predicted even 10 years ago. He said that twice. Do any of you gentlemen support that statement? Have any science that would back that up?

Well, Mr. Ashe doesn't because I have asked him about it. So we do not need to tolerate the President of the United States falsely asserting the status of climate in America. We need to be able to allow scientists to present contrary views without being intimidated by the politically correct crowd. I feel strongly about it, and we are going to keep working on that. The U.S. Climate Change science program said "In May 2008 a tendency toward a decrease in severity and duration of drought over the latter half of the 20th century, a decline. And a decrease in the severity and duration of drought."

So I think about that Kingston trio song, Mr. Pope, Texas you could substitute Oklahoma for Texas, they are riding in Africa, they are starving in Spain, the whole world is full of strife, and Texas needs rain. So we got a lot of drought in the 1930s, did we not in Oklahoma? More than you have today? In the Dust Bowl times?

Mr. POPE. Actually, if I could answer, it is actually drier now that it was in the 1930s, and actually the drought in the 1950s is the drought of record in Oklahoma. The drought of the 1930s is actually the third worst, the one that we are in right now is actually worse than the one we had in the 1950s and the one we had in the 1930s.

Senator SESSIONS. So you think it is more severe than the 1930s?

Mr. POPE. Yes, it is. If it hadn't been for the conservation practices on the land right now, I feel very confident in telling you we would be experiencing the challenges that we say in the 1930s as far as wind erosion.

Senator SESSIONS. That is not the trend across the country, apparently. Dr. South, thank you for your statement and the data you submitted with it. You have a chart here that indicates that rainfall in forest lands in different regions of the country have increased over 100 years ago. Is that the way I read that?

Mr. SOUTH. In the northeast.

Senator SESSIONS. It indicates that others areas have increases also?

Mr. SOUTH. Yes.

Senator SESSIONS. Matter of fact, every one of the regions seem to show, you indicate other regions have had reductions.

Mr. SOUTH. There's no change in the west, there is a slight decrease in the southwest.

Senator SESSIONS. Where the droughts are severe now. But you have a 4 percent increase in the northeast?

Mr. SOUTH. Minus two-tenths of an inch in 100 years.

Senator SESSIONS. OK, in the southwest?

Mr. SOUTH. In the southwest.

Senator SESSIONS. Overall, we are not seeing a decline in rainfall that appears to me, throughout the country as a whole. Dr. South, isn't it true that we have had a resurgence of game in Alabama?

Mr. SOUTH. Certain species, that is correct.

Senator SESSIONS. Isn't it true that many forests are being managed far better than in the past?

Mr. SOUTH. Better is a value term, but from a forestry perspective, I would say yes.

Senator SESSIONS. Land that were once row cropped and broken up every year, marginal lands, highly erodible lands, are now in timber, are they not?

Mr. SOUTH. Yes.

Senator SESSIONS. And from an environmental and CO_2 point of view, is that increase in timberlands in the southeast, that I know about, that is positive, would you not say for CO_2 and the environment?

Mr. SOUTH. From a mathematics perspective, yes.

Senator SESSIONS. So the way we manage timber would be you would plant an open field that is being harvested every year, trees grow for 15 years, they are thinned, the trees then grow faster because there's a thinning, and then they are harvested 15 years 30 years 50 years, and replanted. I would say that is a renewable resource, would you not?

Mr. SOUTH. Definitely.

Senator SESSIONS. Would you oppose the idea that we shouldn't treat wood as a renewable resource like we do corn? Would you oppose the idea that some are raising that we shouldn't use wood for renewable energy or other resources like pellets?

Mr. SOUTH. Yes.

Senator SESSIONS. Thank you, Mr. Chairman.

Senator MERKLEY. Thank you very much.

Senator Whitehouse.

Senator WHITEHOUSE. I appreciate that planting trees helps reduce carbon, but it hardly offsets the coal plant next door that is putting out tens of thousands of tons of carbon dioxide. The 50 worst carbon plants in the country put out more carbon than Korea, and Korea is a pretty industrialized country. We are seeing these effects in New England.

Senator Sessions was pleased to bring up that there was actually additional rain falling in the Northeast, not only is there additional rainfall in the Northeast just as the climate projections expect, but it is falling in more powerful rain bursts, just as the climate experts predicted, and those more powerful rain bursts are causing repeated damaging flooding. We have had year after year of hundred-year floods in Rhode Island, we had one that hit the 500-year level, in Cranston, Rhode Island, and it just keeps coming.

Like Senator Merkley, we are an ocean State, and we are seeing dramatic changes in our oceans. And people can quibble and quarrel at the far, remote fringes of the scientific debate, but tell that to our fishermen. We had a very nice guy, Chris Brown, head of the Rhode Island Commercial Fisherman's Association, Mr. Cohen, you spoke about this, I will echo what you said, Chris is a fisherman. He grew up on the ocean. His dad and his granddad were fishermen. This is his life, and here's what he said when he came

to testify for us: "I fish on a much different ocean today than when I first started fishing with my grandfather as a boy in the mid-1960s." Not that long ago. "When I started out catching haddock, in to the water around point Judith, it was commonplace. The last year, I caught only two. Regularly caught in Rhode Island now is the species of croaker, grouper, cobia, drum, and tarpon. My grandfather never saw a single one of these in his entire life as a fisherman."

As another fisherman said to me, Sheldon, it is getting weird out there. And it is not just Rhode Island waters, I traveled through the South Atlantic over the break, and they told me that off Charleston, they are catching snook. Snook is a fish you used to have to go down to Fort Lauderdale to catch. Now they are catching snook off of Charleston, and it is working its way up. Red fish are being caught as far north as Cape Cod.

And in case the warming oceans and the moving around of the fisheries and all of that upheaval in the natural order isn't enough, against Rhode Island shores, the oceans are 10 inches higher than in the 1930s. Sooner or later another hurricane like the Hurricane of 1938 is going to come and give us a punch.

I ask my colleagues if you are genuinely interested in this issue, spend 10 minutes for my sake on Google looking at the images of what happened to my State in the hurricane of 1938. Then imagine what happens when that 10 inches that is there now and wasn't then of additional sea level gets stacked up further by storm surge and thrown against our shores. It is a potential catastrophe. The idea that I am supposed to overlook this is preposterous, and the idea that my side of the ledger doesn't count and the only side of the ledger that counts is jobs in the coal industry or jobs in the oil and gas industry is equally preposterous.

The science out there has become spectacularly clear, even though there remains a fringe. But it is not a fringe that any rational person would put a bet on in their real lives in any other circumstance.

So I want to conclude by thanking Senator Merkley for this program, I want to thank Mr. Cohen for his testimony about these fisheries. We are way past a debate on whether this is real. This is happening in people's lives now in ways that are unprecedented, and we have got to get responsible about doing something about it.

I thank the Chairman.

[The prepared statement of Senator Whitehouse follows:]

STATEMENT OF HON. SHELDON WHITEHOUSE,
U.S. SENATOR FROM THE STATE OF RHODE ISLAND

Today the Committee will discuss how American jobs that depend on our natural resources are being affected by climate change. I want to thank Chairman Merkley for drawing attention to this issue.

From Rhode Island's Narragansett Bay to the national forests of Oregon, nature's bounty provides us with life's essentials: clean air and water that sustain us; crops and timber that support industries like food production, manufacturing, and textiles; and the healthy, diverse wildlife that has always been part of outdoor recreation and tourism in this country. Climate change threatens to rob us of that.

Yesterday, EPA proposed rules to limit the climate altering greenhouse gas pollution spewed from existing power plants. And already we've heard the same tired arguments from the big polluters and their Republican allies: The polluters are calling this part of a "war on coal" that will kill jobs and impose unfair costs on industry. Don't believe them. Their claims are exaggerated at best, and flat-out false at

worst—and they always look at only one side of the ledger, ignoring the effects of carbon pollution on the rest of us.

On the other side of the ledger are real, measurable costs for American citizens: damage to coastal homes, businesses, and infrastructure from rising seas and erosion; missed work days due to respiratory ailments triggered by smog; forests dying from beetle infestations and swept by unprecedented wildfire seasons; farms ravaged by worsened drought and flooding. This side of the ledger counts, too, and damage to hunting and fishing is on it.

I want to particularly mention the toll climate change is already taking on the fishing industry, both commercial and recreational. Our oceans are ground zero for damage from carbon pollution. The oceans are warming. That's a measurement, not a theory. Sea level is rising. That's another measurement. Oceans are becoming more acidic. Again, a measurement, not a theory or projection.

These changes are putting the natural order into upheaval. Some species are moving toward the colder water of the North and South Poles, shifting as quickly as 10 to 45 miles per decade. Events timed for spring and summer, like egg laying or migration, are happening earlier—about 4 days per decade.

Rhode Island Commercial Fishermen's Association President Chris Brown testified at an EPW subcommittee hearing recently. Chris's livelihood depends on the oceans. He put it like this: "I fish on a much different ocean today than when I first started fishing with my grandfather as a boy in the mid-1960s. When I started out, catching haddock in the waters around Point Judith was commonplace. . . . Last year I caught only two. . . . Regularly caught now in Rhode Island are the species of croaker, grouper, cobia, drum, and tarpon. My grandfather never saw a single one of these in his entire life as a fisherman."

He continued: "The wild caught fisheries of the Northeast may ultimately prove to be the 'coal miner's canary' for this Nation as we grapple with the issue of climate change. A reconsideration of strategy is called for given the enormous chasm between what we have endured and what we have gained."

On a recent trip through the Southeast, I met with fishermen in South Carolina who told me that snook are now being caught off the coast of Charleston. And I've heard that redfish are being caught as far north as Cape Cod. This is new in these fishermen's lifetime. As another Rhode Island fisherman told me, "It's getting weird out there."

On the West Coast, as Senator Merkley knows, acidified ocean waters wiped out three-quarters of the oyster larvae at a hatchery in Oregon and crashed wild stocks in Washington State.

Recent research led by NOAA scientists found that ocean acidification off our West Coast is hitting the pteropod especially hard. Pteropods are tiny marine snails that are food for salmon, mackerel, and herring. They are the base of the food chain. No pteropods means crashed salmon, mackerel, and herring fisheries. Dr. William Peterson, an oceanographer at NOAA's Northwest Fisheries Science Center and coauthor of the study said, "We did not expect to see pteropods being affected to this extent in our coastal region for several decades." For several decades.

Without a doubt, these drastic changes put the jobs and livelihoods of fishermen at risk. And if you want to look at mammals, look at New Hampshire moose, dying with 50,000–100,000 ticks on them, because of less snow. Do not talk to me about the coal jobs at risk unless you're willing to talk to me about what carbon pollution is doing to us, on the other side of the ledger.

I look forward to today's discussion.

Senator MERKLEY. Thank you very much, Senator Whitehouse.

Senator Vitter.

Senator VITTER. Thank you, Mr. Chairman, and thanks to our witnesses.

First of all, I am sorry I came too late for the first panel featuring Director Ashe. On February 25th, when he was last before the committee, I had asked him questions, some important questions, I think, regarding the consultation under the Endangered Species Act with regard to EPA's new proposals regarding existing power plants. His job is about endangered and threatened species and understanding impacts on that. Clearly, these new regulations have the potential for major impacts on that.

I asked him if he and EPA were consulting under the law because of that. He didn't know, he didn't have answers; I asked him

to follow up. He has not followed up. I sent a letter to him and Administrator McCarthy regarding this mandated consultation on March 6th. I have gotten no response. So I will continue following up, but that is his job, this is a major set or regulations, and we do expect answers about their responsibility for consultation.

Now in terms of questions, Dr. South, I share your concern that every weather item in the news it seems is sort of held up as the newest example of the impact of climate change with no real science behind that asserting, and this is also true of wildfires. Just recently, for instance, the Democratic Majority Leader Harry Reid claimed that global warming was the cause of increased wildfires, pure and simple. You testified about that. If you can go back and underscore, what do you think the science, the historical records lays out in terms of any trends over time regarding wildfires, No. 1, and No. 2, what do you think are the leading causes of any trends that do exist?

Mr. SOUTH. Those who claim that CO_2 causes additional wildfires are not making scientific statements. Instead, they are being easily fooled by journalists. Wildfires have typically been associated with droughts and with forest conditions that make wildfires more probable. The chart that I showed showing a lot of wildfires in the 1930s before we started having really active wildfire fighting forces gives you an idea of how cyclic it can be. The downward trend that you see is caused by humans. Our activity is trying to fight the fires. The urban sprawl that has resulted in people building houses in the forest has my view and others taking manpower away from fighting fires and into protecting homes. And this can increase the size of the wildfire that they happen to be working on.

So, spending more time on preventing houses from catching fire and taking the time away from attacking the front causes the size of the fire to be larger.

Senator VITTER. Also in this area, what are your thoughts about current management of our forests and that factor regarding wildfires?

Mr. SOUTH. Well, we have the general view of the public. We are starting to let the public manage our forests instead of letting foresters, and when the public causes litigation, delays, thinning practices, delays, fuel wood reductions, activities, we get a buildup of fuels and an increased risk of wildfires. So by enacting polices that lock up wilderness areas decreases harvesting rates. We used to harvest about 12 billion board feet per year off of a national forest and that has dropped down to nothing now. So our national forests are getting bigger, and this is all causing for more catastrophic wildfires when they do occur.

Senator VITTER. OK, thank you.

Senator MERKLEY. Thank you very much, Senator Vitter.

Senator Wicker.

Senator WICKER. Thank you, Mr. Chairman. I have to say this: I have not today nor have I ever in a committee hearing insulted the integrity of witnesses on the other side of an issue, and we have come perilously close to that in this committee today. It has been suggested by my friend from Rhode Island that Dr. South and Dr. Legates are part of a fringe. To me, this is the very kind of public intimidation and insulting rhetoric that Professor Legates

has talked about in having experienced at the University of Delaware, and I take exception to it.

Now, Dr. Legates, you are a signatory of the Oregon petition, are you not?

Mr. LEGATES. Yes, sir.

Senator WICKER. That Oregon petition says there is no convincing scientific evidence that human release of carbon dioxide and methane or other greenhouse gases is causing or will in the foreseeable future catastrophic heating of the Earth's atmosphere and disruption of the Earth's climate. I assume this is some petition that you and some fringe scientists from Oregon got together and signed. Is that correct?

Mr. LEGATES. No, I believe there are thirty-some thousand people who signed that petition.

Senator WICKER. Thirty-some thousand people. Would you describe these people?

Mr. LEGATES. Many of them are scientists, Ph.D.s in other disciplines, or people who are connected with climate change and doing research in various areas associated with it.

Senator WICKER. Well, I just have to say that I appreciate someone standing up and challenging the conventional wisdom. Martin Luther did that. Martin Luther King did that. I appreciate some people who are willing to hold up their hand and say, wait a minute, I have some data here, and I would like to suggest a contrary position.

Mr. LEGATES. Well, I would not put myself quite in that category.

Senator WICKER. Well, but it is an important issue, and I have to say I admire you for standing up, and Dr. South also, for standing up, and saying you have a right to be heard and a right to be listened to and a right not to be insulted by being called part of a lunatic fringe. Now, you have concluded that droughts in the United States are more frequent and more intense during colder periods. Is that correct?

Mr. LEGATES. Yes, that is what the data indicates. When we look at droughts over the last 2,000 years, they tend to become more intense and more frequent when the temperatures have become colder.

Senator WICKER. Dr. South, you have offered a couple of bets to your fellow scientists over time. Is that correct?

Mr. SOUTH. Yes, sir.

Senator WICKER. I believe, 5 years ago, you offered a bet on an ice-free Arctic in the summer of 2013, when a BBC journalist wrote a 2007 article entitled Arctic Summers Ice-Free by 2013. And several ice experts declined to bet with you. Is that correct?

Mr. SOUTH. That is correct.

Senator WICKER. If they had bet with you, they would have lost that bet. Is that correct?

Mr. SOUTH. That is correct.

Senator WICKER. You currently are offering a bet on sea-level rise. Would you tell the committee about that?

Mr. SOUTH. Yes. I am looking for someone who would be willing to bet $1,000 on the sea-level increase for the year 2024 in Charleston, South Carolina. The rate currently is around 3.15 millimeters, I do not know how they do that to the nearest hundredth of a milli-

meter, but you can do it mathematically; I do not know how you can do it scientifically. I will bet that the rate 10 years from now is not over 7 millimeters. If a 7-millimeter rate starts now and goes to the year 2100, it would equal about a 2-foot increase. Many people are talking about a 14-millimeter rate being equivalent to a 4-foot increase. So I am essentially betting that for the next 10 years, it will be not increasing at a rate that would equal a 2-foot increase by the year 2100, but I am not going to be living that long, so I cannot win that bet.

Senator WICKER. Would this bet apply to your heirs and assigns?

[Laughter.]

Mr. SOUTH. Yes, it would.

Senator WICKER. Thank you very much. We have had a good hearing, and there are people watching this, and there will be people late at night, Mr. Chairman, watching this hearing, that are suffering from insomnia, and perhaps someone will take Dr. South up on his bet.

Senator MERKLEY. Thank you very much to all of our witnesses. I appreciate you bringing your expertise to bear. We have heard today that climate change is having impacts on the ground right now; that it is not an abstract theory; it is not about models, decades, or multiple decades into the future; that the changes on the ground right now are real and measurable, and they are affecting American's livelihoods, and farming, and hunting, and fishing, and forestry. These are real jobs and real impacts on this generation and the next.

We have heard about bark beetle infestations; we have heard about migrations of fish; we have heard about the impact of intensifying wildfires, the impact of magnified droughts, the impact of more acidic oceans in the Pacific and their impact on oyster reproduction. I just have to wonder, if baby oysters are having trouble forming a shell, how many other shellfish impacts are there that are going to be problematic for the food chain in our oceans and our fisheries? These things are real at this moment, and they confront us with evidence that must not be ignored.

Certainly, this is in the context of a debate at this moment about specific measures that we might take to limit carbon dioxide, including that from coal fire to power plants. The cost of ignoring climate change will continue to increase. The costs are real; the costs are tangible; they will affect jobs, and they affect our rural resources. With this challenge in mind, I really appreciate the testimony before this committee today. Members of the committee will have 2 weeks from today to submit additional written questions to the witnesses, and I would certainly ask if you receive such questions that you respond, and we will make sure the answers are circulated.

With that, the meeting is adjourned.

[Whereupon, at 12:08 p.m., the committee was adjourned.]

[Additional material submitted for the record follows:]

MINDING THE CAMPUS
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SHORT TAKES

MAY 19, 2014

Climate-Change Shenanigans at the U. of Delaware

Posted by Jan Blits

May a public university manipulate a Freedom of Information (FOIA) request of a faculty member in an effort to squelch the politically incorrect side in the on-going climate wars? The University of Delaware, which has a long, sorry history of political correctness, seems to think that it may--even if its actions violate the faculty member's academic freedom, Delaware's FOIA law, and the University's own FOIA policy.

In December, 2009, David Legates, a University of Delaware professor who was the Delaware State Climatologist from 2005 to 2011, received a FOIA request from Greenpeace. It sought Legates' "e-mail correspondence and financial and conflict of interest disclosures" "in the possession of or generated by the Office of the Delaware State Climatologist" from January 1, 2000, concerning "global climate change." Legates is an outspoken critic of the evidence used to show the human effect on climate.

Under Delaware state law, FOIA requests to the University for a faculty member's academic materials are limited to activities supported by state funding. During Legates' tenure, the Stete Climate Office received no state (or University) funding. Nor did Legates receive any state funds for his work as State Climatologist, and the State Climate Office never undertook activities concerning "global climate change." In short, *none* of Legates' work fell within the scope of the FOIA request.

Nevertheless, UD Vice President and General Counsel, Lawrence White, decided that Legates must provide *more* than Greenpeace had requested, not only all State Climate Office documents, but all documents he had on global climate change, whether or not Greenpeace had requested them. White's expansive list, covering all of Legates' teaching, research and service materials going back to 2000, included work unrelated to the State Climate Office, whether conducted on Legates' own time or on University time, through his personal e-mail or his University e-mail, on his personal computer or a University computer, both in hard files and on computer disks. According to White, Legates had no choice. As a faculty member, White instructed him, Legates had to comply with the request of "a senior University official." It seemed not to matter to White that the Delaware FOIA law limits requests to state-funded activity and UD's own policy limits it further to research that is state-funded.

The Virginia Supreme Court recently ruled that, despite Virginia's FOIA law, the University of Virginia was correct in refusing to comply with a FOIA request for the records and e-mails of a former faculty member, Michael Mann, famous (or infamous) for his alarmist "hockey stick" image of the recent rise in global air temperature. The Virginia law had made all UVA faculty members subject to FOIA requests. The Delaware law, in contrast, restricts requests to faculty who are state-funded and to the work they carry out with state funds. (State money accounts for only a small portion of UD's revenue.) For many years, the University administration has designated some faculty as doing state-funded work, but kept or removed faculty members from the list if administrators believed that they were likely to receive an unwanted FOIA request. For reasons administrators have declined to explain, a small portion of Legates' teaching salary was, curiously, placed *on* the list of state-funded activity shortly before Greenpeace filed its FOIA request in 2009.

A month after Greenpeace's request to Legates, the Competitive Enterprise Institute, an opponent of Greenpeace, filed a nearly identical FOIA request with UD for information on three other Delaware faculty members. These three had contributed to the Intergovernmental Panel on Climate Change, a United Nations group often (and recently) warning of the catastrophic effects of global warning. White said no, "because the information you seek does not relate to the expenditure of public funds." When asked to explain the disparate treatment, White told Legates that he (Legetes) did not understand the law. Muddling his own argument, White said that while the law did not *require* him to give Greenpeace all the documents he had requested from Legates, the law did not *prohibit* him from requiring Legates to produce them. His authority as a "senior University official" evidently trumped Delaware law and University policy. Under pressure, Legates submitted all the demanded materials in March, 2010.

Under Delaware law, FOIA requests must be answered within ten days (unless there is need to consult with an agency counsel), but White did nothing with Legates' materials for more than 15 months. In June, 2011, he hired a third-year law student to sort through them. "We have interpreted that language [of the Delaware FOIA law] to mean that we are obliged to produce records, otherwise non-privileged, that pertain to work by Dr. Legates that is supported through grants from state agencies," White wrote. The law-student's trolling came up short. The resulting file contained, in its entirety, 1) two e-mail exchanges about federal, not state, funding sources, 2) an invitation from a state agency to give a talk on climate change, for which Legates was not paid, and 3) a report to the Governor and General Assembly on the Delaware Water Supply Coordinating Council, which Legates had no hand in writing and in which he is not mentioned, but which he was simply given when he joined the Council.

White had listed a second category of documents, however, which he said the University was also "obliged" to produce. "[A]nd class-room related work such as syllabi, instructional materials, and class postings, (because a small portion of his salary was paid out of state-appropriated funds)." The file of these teaching documents contained 1) materials from Legates' introductory course on "Climatic Processes," 2) two e-mail exchanges with two off-campus professors about climate change and the classroom, and a third about his speaking in a graduate course, 3) his 2010 CV, and 4) his Climatologist agreement and related correspondence with the

Governor's Chief of Staff. Again, contrary to White's false claim, the University has no obligation to produce teaching materials. Its own FOIA policy excludes requests for such materials. Teaching has always enjoyed the full protection of academic freedom. Administrators may not examine it except for cause. Despite claiming that he was "obliged" to produce the materials, White, unable to square his action with official policy, state law or rules of academic freedom, tried to trivialize it as harmless: "[T]hese materials strike me as innocuous in the extreme, and I propose to turn them over all over the Greenpeace."

That was not all. White also decided "to produce copies of speeches, papers, presentations and other materials that were created by Professor Legates and subsequently published, delivered in lecture form, or otherwise made public." Many of these public items were gathered from the internet by the law student. While conceding that the state FOIA does not require the disclosure of public materials and Greenpeace had not requested them, White said that he would "turn them over [to Greenpeace] only because it seems potentially provocative to me NOT to surrender documents that are already in the public domain" (his caps). Never at a loss for a pretext to trample faculty rights, White, having claimed that it was harmless to violate Legates' rights, now claimed that it would be harmful NOT to violate his rights.

This is not the first time the University of Delaware has violated a faculty member's academic freedom and tried to silence controversial research. Twenty-five years ago, the University banned receiving grants from the foundation supporting the research of a faculty member, Linda Gottfredson. In banning the funding, the University granted that for it to "direct...its attention to the content or method of any faculty member's research or teaching" would violate the faculty member's academic freedom. Gottfredson won at federal arbitration when she showed that the University did precisely what it stipulated it must not do (full disclosure: I was her co-plaintiff). When reminded of this precedent and the University's own stipulation, White, reaching for still another excuse to violate Legates' rights, said that academic freedom does not impede FOIA requests. State law trumps University policy, he said. When reminded that Legates' materials included nothing that was subject to the Delaware FOIA law, White dismissed the objection out of hand, without answering it. As he disdainfully declared yet again, the faculty member did not adequately understand the intricacies of the law.

It would be bad enough had White properly applied the FOIA law and UD policy to Legates, but only Legates, and exempted the three politically correct faculty from the burden he levied on Legates. But, much worse, in the guise of asserting his administrative authority and his superior understanding of the law, White repeatedly misrepresented and ignored the established policy and law. Again and again, he fabricated his own policy and law, and justified his actions against Legates on specious grounds. He used his position as Vice President and General Counsel to transform faculty protections against political interference into a cudgel to silence one side in the current climate debate.

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WALL STREET JOURNAL

The Myth of the Climate Change '97%'

What is the origin of the false belief—constantly repeated—that almost all scientists agree about global warming?

By
JOSEPH BAST And
ROY SPENCER
May 26, 2014 7:19 p.m. ET

Last week Secretary of State John Kerry warned graduating students at Boston College of the "crippling consequences" of climate change. "Ninety-seven percent of the world's scientists," he added, "tell us this is urgent."

Where did Mr. Kerry get the 97% figure? Perhaps from his boss, President Obama, who tweeted on May 16 that "Ninety-seven percent of scientists agree: #climate change is real, man-made and dangerous." Or maybe from NASA, which posted (in more measured language) on its website, "Ninety-seven percent of climate scientists agree that climate-warming trends over the past century are very likely due to human activities."

Yet the assertion that 97% of scientists believe that climate change is a man-made, urgent problem is a fiction. The so-called consensus comes from a handful of surveys and abstract-counting exercises that have been contradicted by more reliable research.

One frequently cited source for the consensus is a 2004 opinion essay published in Science magazine by Naomi Oreskes, a science historian now at Harvard. She claimed to have examined abstracts of 928 articles published in scientific journals between 1993 and 2003, and found that 75% supported the view that human activities are responsible for most of the observed warming over the previous 50 years while none directly dissented.

Ms. Oreskes's definition of consensus covered "man-made" but left out "dangerous"—and scores of articles by prominent scientists such as Richard Lindzen, John Christy, Sherwood Idso and Patrick Michaels, who question the consensus, were excluded. The methodology is also flawed. A study published earlier this year in Nature noted that abstracts of academic papers often contain claims that aren't substantiated in the papers.

Another widely cited source for the consensus view is a 2009 article in "Eos, Transactions American Geophysical Union" by Maggie Kendall Zimmerman, a student at the University of Illinois, and her master's thesis adviser Peter Doran. It reported the results of a two-question online survey of selected scientists. Mr. Doran and Ms. Zimmerman claimed "97

percent of climate scientists agree" that global temperatures have risen and that humans are a significant contributing factor.

The survey's questions don't reveal much of interest. Most scientists who are skeptical of catastrophic global warming nevertheless would answer "yes" to both questions. The survey was silent on whether the human impact is large enough to constitute a problem. Nor did it include solar scientists, space scientists, cosmologists, physicists, meteorologists or astronomers, who are the scientists most likely to be aware of natural causes of climate change.

The "97 percent" figure in the Zimmerman/Doran survey represents the views of only 79 respondents who listed climate science as an area of expertise and said they published more than half of their recent peer-reviewed papers on climate change. Seventy-nine scientists—of the 3,146 who responded to the survey—does not a consensus make.

In 2010, William R. Love Anderegg, then a student at Stanford University, used Google Scholar to identify the views of the most prolific writers on climate change. His findingswere published in Proceedings of the National Academies of Sciences. Mr. Love Anderegg found that 97% to 98% of the 200 most prolific writers on climate change believe "anthropogenic greenhouse gases have been responsible for 'most' of the 'unequivocal' warming." There was no mention of how dangerous this climate change might be; and, of course, 200 researchers out of the thousands who have contributed to the climate science debate is not evidence of consensus.

In 2013, John Cook, an Australia-based blogger, and some of his friends reviewed abstracts of peer-reviewed papers published from 1991 to 2011. Mr. Cook reported that 97% of those who stated a position explicitly or implicitly suggest that human activity is responsible for some warming. His findings were published in Environmental Research Letters.

Mr. Cook's work was quickly debunked. In Science and Education in August 2013, for example, David R. Legates (a professor of geography at the University of Delaware and former director of its Center for Climatic Research) and three coauthors reviewed the same papers as did Mr. Cook and found "only 41 papers—0.3 percent of all 11,944 abstracts or 1.0 percent of the 4,014 expressing an opinion, and not 97.1 percent—had been found to endorse" the claim that human activity is causing most of the current warming. Elsewhere, climate scientists including Craig Idso, Nicola Scafetta, Nir J. Shaviv and Nils- Axel Morner, whose research questions the alleged consensus, protested that Mr. Cook ignored or misrepresented their work.

Rigorous international surveys conducted by German scientists Dennis Bray and Hans von Storch —most recently published in Environmental Science & Policy in 2010—have found that most climate scientists disagree with the consensus on key issues such as the reliability of climate data and computer models. They do not believe that climate processes

such as cloud formation and precipitation are sufficiently understood to predict future climate change.

Surveys of meteorologists repeatedly find a majority oppose the alleged consensus. Only 39.5% of 1,854 American Meteorological Society members who responded to a survey in 2012 said man-made global warming is dangerous.

Finally, the U.N.'s Intergovernmental Panel on Climate Change—which claims to speak for more than 2,500 scientists—is probably the most frequently cited source for the consensus. Its latest report claims that "human interference with the climate system is occurring, and climate change poses risks for human and natural systems." Yet relatively few have either written on or reviewed research having to do with the key question: How much of the temperature increase and other climate changes observed in the 20th century was caused by man-made greenhouse-gas emissions? The IPCC lists only 41 authors and editors of the relevant chapter of the Fifth Assessment Report addressing "anthropogenic and natural radiative forcing."

Of the various petitions on global warming circulated for signatures by scientists, the one by the Petition Project, a group of physicists and physical chemists based in La Jolla, Calif., has by far the most signatures—more than 31,000 (more than 9,000 with a Ph.D.). It was most recently published in 2009, and most signers were added or reaffirmed since 2007. The petition states that "there is no convincing scientific evidence that human release of . . . carbon dioxide, methane, or other greenhouse gases is causing or will, in the foreseeable future, cause catastrophic heating of the Earth's atmosphere and disruption of the Earth's climate."

We could go on, but the larger point is plain. There is no basis for the claim that 97% of scientists believe that man-made climate change is a dangerous problem.

Mr. Bast is president of the Heartland Institute. Dr. Spencer is a principal research scientist for the University of Alabama in Huntsville and the U.S. Science Team Leader for the Advanced Microwave Scanning Radiometer on NASA's Aqua satellite.

Testimony by
Dr Richard S.J. Tol
to the hearing entitled
Examining the UN Intergovernmental Panel on Climate Change Process for the Fifth Assessment Report
Committee on Science, Space and Technology
US House of Representatives
Thursday, May 29, 2014

It is an honour and pleasure to be here. My name is Richard Tol. I am a professor of economics at the University of Sussex and the Vrije Universiteit Amsterdam. I am a research fellow at the Tinbergen Institute and CESifo. **I am ranked among the Top 100 economists in the world by IDEAS/RePEc[1] and among the 25 most cited climate researchers according to Google Scholar[2].** I am an editor of Energy Economics, a top field journal. I was one of the first to statistically show that the observed global warming over the last one and a half century is caused by the accumulation of greenhouse gases in the atmosphere.[3] I used to advocate tradable permits, but having observed the EU ETS I now favour a carbon tax. I helped the UK government set its levy on methane from landfills, the Irish government design and set its carbon tax, and the US government set its carbon price. **I have been involved in the Intergovernmental Panel on Climate Change since 1994, serving in various roles in all three working groups, most recently as a Convening Lead Author in** the economics chapter of **Working Group II.**

An appropriate solution to any problem requires a good understanding of its mechanisms, its consequences, and the consequences of any countermeasure. The climate problem is so complex that at the moment only the USA can mount sufficient expertise to cover the entire issue. The EU cannot. Maybe China can in 20 years' time. **Other countries** than the USA **need international collaboration** on scientific and policy advice **through a body like the Intergovernmental Panel on Climate Change. A common understanding of the issues is probably also helpful for the international climate negotiations** although shared knowledge does not imply agreement on desirable outcomes. **I therefore favour reform of the IPCC rather than its abolition.**

I will focus my remarks on Working Group II of the IPCC because I know that one best. Working Group II is on the impacts of climate change, on vulnerability and adaptation. **Researchers tend to study those impacts because they are concerned about climate change.**

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[1] http://ideas.repec.org/top/top.person.all.html#pto90

[2] http://scholar.google.co.uk/citations?view_op=search_authors&hl=en&mauthors=label:climate_change&after_author=pOsLADa6__8J&astart=20

[3] Tol and de Vos (1993), *Theoretical and Applied Climatology*, **48**, 63-74.

Academics who research climate change out of curiosity but find less than alarming things are ignored, unless they rise to prominence in which case they are harassed and smeared. The hounding of Lennart Bengtsson is a recent example. Bengtsson is a gentle 79 year old. He has won many awards in a long and distinguished career in meteorology and climatology. He recently joined the advisory board of an educational charity and felt forced to resign two weeks later. As an advisor, he was never responsible for anything this charity did, let alone for the things it had done before he joined. For this, he was insulted by his peers. A Texas A&M professor even suggested he is senile.[4] Strangely, the climate "community" did not speak out when one of its own was elected for the Green Party[5]; nor does it protest against close ties between IPCC authors and the Environmental Defence Fund[6], Friends of the Earth[7], Greenpeace[8] or the World Wide Fund for Nature[9]. Other eminent meteorologists have been treated like Bengtsson was – Curry, Lindzen, Pielke Sr. Pielke Jr has been mistreated too, merely for sticking to the academic literature, as reflected by the IPCC, that there is no statistical evidence that the impact of natural disaster has increased because of climate change. I have had my share of abuse too. Staff of the London School of Economics[10] and the Guardian[11] now routinely tell lies about me and my work.

People volunteer to work for the IPCC because they worry about climate change. An old friend was an author for an IPCC special report. He was surprised that his co-authors were there for political reasons. In turn, they were surprised because he was there out of intellectual curiosity how electricity systems could possible function with a high penetration of non-dispatchable renewables.

Governments nominate academics to the IPCC – but we should be clear that it is often the environment agencies that do the nominating. Different countries have different arrangements, but it is rare that a government agency with a purely scientific agenda takes the lead on IPCC matters. As a result, certain researchers are promoted at the expense of more qualified colleagues. Other competent people are excluded because their views do not match those of their government. Some authors do not have the right skills or expertise, and are nominated on the strength of their connections only.

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[4] https://twitter.com/AndrewDessler/statuses/467100118844321792

[5] http://www.greenparty.bc.ca/elected_mla; http://www.europarl.europa.eu/meps/en/96725/BAS_EICKHOUT_home.html

[6] http://www.princeton.edu/step/people/faculty/michael-oppenheimer/

[7] http://www.up.ethz.ch/people/former/mmalte

[8] http://www.pik-potsdam.de/news/public-events/archiv/greencyclesii/programme/16.5.2011/hare/hare-cv

[9] http://www.biology.uq.edu.au/staff/hoegh-guldberg

[10] http://www.lse.ac.uk/GranthamInstitute/Media/Commentary/2014/April/A-flawed-conversation-about-the-Stern-Review.aspx; http://www.lse.ac.uk/GranthamInstitute/Media/Commentary/2014/March/Errors-in-estimates-of-the-aggregate-economic-impacts-of-climate-change.aspx

[11] http://www.theguardian.com/environment/climate-consensus-97-per-cent/2014/apr/30/economics-clear-need-climate-action; http://www.theguardian.com/sustainable-business/blog/environment-climate-change-denier-global-warming; http://www.theguardian.com/environment/earth-insight/2014/may/15/ipcc-un-climate-reports-diluted-protect-fossil-fuel-interests; http://www.theguardian.com/environment/planet-oz/2014/may/23/climate-mccarthyism-confected-outrage-checking-record-global-warming-policy-foundation

All this makes that the authors of the IPCC are selected on concern as well as competence. In the wake of the Fourth Assessment Report, the InterAcademy Council recommended that the IPCC be more transparent on the characteristics of the authors.[12] Putting their CVs online would be a small effort. It would be useful to systematically compare the academic performance of those selected, those nominated and those who volunteered.

This selection bias **shows in the Fifth Assessment Report of Working Group II. The Summary for Policy Makers** (SPM) **talks about trends in crop yields, but omits the most important of them all – technological change** – which has pushed up crop yields since times immemorial.[13] **It shows the impacts of climate change on agriculture assuming that farmers will not adjust their practices in the face of changed circumstances** – the far less dramatic impacts after adaptation are hidden in the main report. **It shows that the most vulnerable country would pay some ten percent of its annual income towards coastal protection, but omits that the average country would pay less than one-tenth of a percent**[14] – again, the lower, more relevant number is buried in the report. **It emphasizes the health impacts of increased heat stress but downplays the health impacts of decreased cold stress** – although the latter may well be numerically more important.[15]

This alarmist bias made me take my name of the Summary for Policy Makers in September 2013. My views on the impacts of climate change are well known. I liked the first draft of the Summary, which had as one of its key findings that the worst impacts of climate change really are symptoms of mismanagement and underdevelopment. It was just not credible that I would put my name to the final draft of the Summary, which its overemphasis on risk. Unfortunately, news of me stepping down made headlines in March 2014, giving the press an excuse to focus on the people involved rather than on the structural deficits of the IPCC.

Problems are not limited to the Summary for Policy Makers. There is a large body of work in the peace research literature that agrees that climate change is a minor, contributory factor in violent conflict, if at all.[16] There is a small body of work in the environmental science literature that argues that climate change is a major cause of violent conflict.[17] The IPCC grants the two literatures parity of esteem.[18]

The SPM worries that climate change may trap more people in poverty. One chapter[19] argues that this cannot be supported by the literature: There are a few weak papers

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[12] http://reviewipcc.interacademycouncil.net/
[13] Ruttan (2002), *Journal of Economic Perspectives*, **16**, 161-184.
[14] Nicholls and Tol (2006), *Philosophical Transactions of the Royal Society*, **A361**, 1073-1095.
[15] McGeehin and Mirabelli (2002), *Environmental Health Perspectives*, **109**, 185-189. Ye et al. (2012), *Environmental Health Perspectives*, **120**, 19-28.
[16] Gleditsch (2012), *Journal of Peace Research*, **49**, 3-9.
[17] Hsiang et al. (2013), *Science*, **341**, 6151.
[18] IPCC WG2 AR5 Chapters 12 and 19.
[19] IPCC WG2 AR5 Chapter 10

reaching opposite conclusions. Another chapter[20] cites two papers[21] – neither of which is on poverty traps – and the SPM echoes its language on climate change and poverty traps.

There is section on emerging risks. The first paper on an issue is always dramatic. That is the only way to get something onto the scientific agenda. Follow-up papers then pooh-pooh the initial drama. This has been repeated pattern in the climate change impacts literature from the 1980s onwards. The first papers on sea level rise, agriculture, health, ocean currents, and ice caps were sharply at odds with later, much better informed research.[22] But the IPCC chose not to wait for those follow-up papers.

Working Group III is not without fault either. A little bit of emission reduction costs little. But as targets get more stringent, costs escalate. Not so according to WG3: The tables in the SPM and the underlying chapter suggest that very ambitious targets are only slightly more expensive than ambitious targets, even though ambitious targets are far more expensive than lenient targets. This surprising finding is a statistical fluke. Emission reduction is easy according to some studies, which duly explore very ambitious targets. Emission reduction is hard according to other studies; very ambitious targets are prohibitively expensive and results not reported. The surprisingly low cost of meeting very stringent emission reduction targets is the result of selection bias: as targets get more stringent, an increasing number of expensive models are excluded. Oddly, the IPCC made the same mistake in the Fourth Assessment Report, and was alerted to the error.[23]

I think that these mishaps reflect bias in the authors. **The IPCC should** therefore **investigate the attitudes of its authors and their academic performance and make sure that, in the future, they are more representative of their peers.**

If similar-minded people come together, they often reinforce each others' prejudices.

The IPCC should deploy the methods developed in business management[24] and social psychology[25] to guard against group think. These include a balanced composition of peer groups, changing the compositing of groups, appointing devil's advocates, and inviting outside challengers. This requires active support from the IPCC leadership. To the best of my knowledge, outside challengers are rare. Indeed, I know of only one occasion. Peter Dixon, an Australian economist, told a group of IPCC authors they got it all wrong: The cost savings due to induced technological change as reported by the IPCC[26] are an artefact of misspecified models. Sjak Smulders, a Dutch economist,

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[20] IPCC WG2 AR5 Chapter 13
[21] Ahmed et al. (2009), *Environmental Research Letters*, **3**, 034004; Hertel et al. (2010), *Global Environmental Change*, **20**, 577-585.
[22] Tol (2008), *Environmental Values*, **17**. 437-470.
[23] Tavoni and Tol (2010), *Climatic Change*, **100**, 769-778.
[24] Eisenhardt et al. (2001), *Harvard Business Review*, **75**, 77-85.
[25] Postmes et al. (2001), *Journal of Personality and Social Psychology*, **80**, 918-930.
[26] IPCC WG3 AR4 Chapter 11

said much the same at an IPCC workshop.[27] Their advice was ignored and one of the authors duly promoted to working group chair.

Not all IPCC authors are equal. Some hold positions of power in key chapters, others subordinate positions in irrelevant chapters. The IPCC leadership has in the past been very adept at putting troublesome authors in positions where they cannot harm the cause.

That practice must end. This is best done by making sure that the leaders of the IPCC –chairs, vice-chairs, heads of technical support units – are balanced and open-minded.

The funding model of the IPCC is partly at fault. Multilateral organizations depend on their sponsors, but most have their own budget. The IPCC relies mostly on contributions in kind, and this hampers the IPCC's ability to control the quality of the contributions.

The leaders of the IPCC steer its assessment reports, and dictate its media presence. Working Group I conclude, in its latest assessment report, that the climate sensitivity – the eventual warming for a given change in the atmospheric concentration of greenhouse gases – is lower than previously thought. This is great news for all those who worry about climate change, but it somehow did not make it into the press release.

The IPCC releases a major report every six years or so. That is not frequent enough to keep abreast of a fast-moving literature.

When preparations started for the Fifth Assessment Report, the world hadn't warmed for 13 years. That is a bit odd, if the climate models are correct, but does not warrant a lot of attention. By the time the report was finished, it hadn't warmed for 17 years. That is decidedly odd[28], but hard to accommodate in a near-final draft that has been through three rounds of review. After the report was finalized, but before it was published, a number of papers appeared with hypotheses about the pause in warming.[29] The Fifth Assessment Report of Working Group I was out of date before it was released.

A report that is rare should make a big splash – and an ambitious team wants to make a bigger splash than last time. It's worse than we thought. We're all gonna die an even more horrible death than we thought six years ago.

Launching a big report in one go also means that IPCC authors will compete with one another on whose chapter foresees the most terrible things. IPCC reports are often two to three thousand pages long, but there are two or three main findings only. Authors who want to see their long IPCC hours recognized should thus present their impact as worse than the next one.

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[27] https://www.ipcc.ch/pdf/supporting-material/expert-meeting-2005-01.pdf
[28] Fyfe et al. (2013), *Nature Climate Change*, **3**, 767-769.
[29] http://www.economist.com/news/science-and-technology/21598610-slowdown-rising-temperatures-over-past-15-years-goes-being

The IPCC should abandon its big reports and convert to journal-style assessments instead. That would reduce the pressure for media attention. It would allow the IPCC to update its assessment as frequently as needed. It would also be easier to invite second opinions and minority reports.

In learned journals, the editor guarantees that every paper is reviewed by experts. IPCC editors do not approach referees. Rather, they hope that the right reviewers will show up. Large parts of the IPCC reports are, therefore, not reviewed at all, or not reviewed by field experts. In a journal, papers that are not good enough, are rejected. In a journal, a promising paper is sent back for further revision – regardless of deadlines. IPCC chapters are never turned down, and always finished on time. **The IPCC should move to journal style reviews and editors.**

The IPCC is best seen as a natural monopoly.[30] The IPCC cannot suppress supply to raise prices – as the typical monopolist would – but it reveals other signs of monopolistic behaviour. There is a lack of innovation – the First and Fifth Assessment Reports were prepared in much the same way, and cover similar ground. There is little regard for clients – the IPCC response to the scandals in the Third and Fourth Assessment Report was haughty. And the IPCC uses its monopoly power to muscle into other fields – most recently scholarships. **Monopolies should be broken up, but natural monopolies – where the costs of duplication are greater than the benefits of competition – should be tightly regulated.**

The clients of the IPCC, the environment agencies of the world, are often also its regulators. It is time to end that cosy relationship. Let the IPCC be run by the National Science Foundation and its counterparts in other countries and be overseen by the National Academy and its counterparts. These organizations are not without their faults, but at least their core mission is to do good science. **The climate problem is serious enough to deserve a serious international body to assess the state of knowledge.**

After the Fourth Assessment Report, the InterAcademy Council suggested useful reforms: More transparency in author selection, a registry of conflicts of interests, stronger review editors, open peer review.[31] Others suggested that the Bureau, which both runs and oversees the IPCC, should be split.[32] **These** recommendations **were by and large ignored because the recommendations came after preparations for the Fifth Assessment Report had started; and because few countries supported IPCC reform.** `Conflicts of interests are now registered, but neither verified nor disclosed. **It should be said, though, that the Fifth Assessment Report of IPCC Working Group II is a lot better than the Fourth Assessment Report.** The IPCC should continue in this direction.

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[30] Tol (2011), *Climatic Change*, **108**, 827-839.
[31] http://reviewipcc.interacademycouncil.net/
[32] Tol (2011), *Climatic Change*, **108**, 827-839.

The IPCC does useful things. The Fifth Assessment Report shows that the Stern Review[33] overestimated the impacts of climate change[34] and underestimated the impacts of climate policy[35]. This undermines the justification of the two degree target of the EU, UN and the current administration of the USA. The Fifth Assessment Report shows that double regulation – say subsidies next to tradable permits – increases costs without further reducing emissions.[36] This conclusion was inadvertently dropped from the German translation[37], which is unfortunate as double regulation is widespread in Germany.

We need an organization that is not beholden to any government or any party to anchor climate policy in reality as we understand it. A reformed IPCC can play that role.

[33] http://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/sternreview_index.htm
[34] IPCC WG2 AR5 Chapter 10
[35] IPCC WG2 AR5 Chapter 6
[36] IPCC WG3 AR5 Chapter 15
[37] http://www.welt.de/wirtschaft/article128124861/Die-dreiste-Berichtsfaelschung-der-Klimatrickser.html

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