A FACTUAL LOOK AT THE RELATIONSHIP BETWEEN CLIMATE AND WEATHER

HEARING

BEFORE THE

SUBCOMMITTEE ON ENVIRONMENT

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED THIRTEENTH CONGRESS

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December 11, 2013

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A FACTUAL LOOK AT THE RELATIONSHIP BETWEEN CLIMATE AND WEATHER

WEDNESDAY, DECEMBER 11, 2013

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENVIRONMENT
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to call, at 10:08 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Lamar Smith [Chairman of the Committee] presiding.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States

House of Representatives

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Subcommittee on Environment

A Factual Look at the Relationship between Climate and Weather

Wednesday. December 11, 2013
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Witnesses

Dr. John R. Christy, Professor and Director, Earth System Science Center, NSSTC, University of Alabama in Huntsville

Dr. David Titley, Director, Center for Solutions to Weather and Climate Risk, Pennsylvania State University

Dr. Roger Pielke Jr., Professor and Director, Center for Science and Technology Policy Research, University of Colorado

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON ENVIRONMENT

HEARING CHARTER

A Factual Look at the Relationship Between Climate and Weather

Wednesday, December 11, 2013
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

PURPOSE

The Subcommittee on Environment will hold a hearing entitled *A Factual Look at the Relationship Between Climate and Weather* on Wednesday, December 11, 2013 in Room 2318 of the Rayburn House Office Building. The purpose of the hearing is to examine the links between climate change and extreme weather events such as hurricanes, tornadoes, droughts, and floods.

WITNESS LIST

- **Dr. John Christy**, Professor and State Climatologist, University of Alabama in Huntsville.
- **Dr. David Titley**, Director, Center for Solutions to Weather and Climate Risk, Pennsylvania State University.
- **Dr. Roger Pielke Jr.**, Professor, Center for Science and Technology Policy Research, University of Colorado.

BACKGROUND

Extreme weather events are often characterized as being severe in nature. In the United States, tornadoes, hurricanes, and droughts are examples of weather events that most often have the potential to become extreme. Definitions also note that the term "extreme weather" is based on expected distribution of events, for example occurring less than 5% of the time.[1] Even though extreme weather events are rare, their impacts to the United States are calculable in terms of loss of life and damage to the economy.

Links between extreme weather events and climate change are often cited after such weather events occur. In order to examine climate change and the Earth's atmosphere, the Intergovernmental Panel on Climate Change (IPCC) was created in 1998 by the World Meteorological Organization and the United Nation's Environment Program. The IPCC was

[1] http://www.emc.ncep.noaa.gov/gmb/ens/target/ens/albapr/albapr.html

originally tasked with preparing reports on all aspects of climate change and its impacts.[2] Since then, the IPCC has evolved to "assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation."[3]

In 1990, the IPCC released its first Assessment Report, which expressed the importance of climate change and the need for international cooperation.[4] In general, the subsequent reports of the IPCC are used globally to guide policy and provide support for climate change research. Last September, the IPCC released the Summary for Policymakers of Working Group 1's contributions to the Fifth Assessment Report (AR5).[5] Working Group 1 re-characterized the links between extreme weather events and climate change in its Summary for Policy Makers (see Appendix).

In 2012, the IPCC released a Special Report on "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation." Within the IPCC's Summary for Policymakers, they explained that:

> There is evidence from observations gathered since 1950 of change in some extremes. Confidence in observed changes in extremes depends on the quality and quantity of data and the availability of studies analyzing these data, which vary across regions and for different extremes.... Extreme events are rare, which means there are few data available to make assessments regarding changes in their frequency or intensity. The more rare the event the more difficult it is to identify long-term changes. Global-scale trends in a specific extreme may be either more reliable (e.g., for temperature extremes) or less reliable (e.g., for droughts) than some regional-scale trends, depending on the geographical uniformity of the trends in the specific extreme.... Attribution of single extreme events to anthropogenic climate change is challenging.[6]

The difficulty in attributing specific severe weather events to climate change was further described in a September 2012 editorial in Nature:

> Attribution is the attempt to deconstruct the causes of observable weather and to understand the physics of why extremes such as floods and heatwaves occur. This is important basic research. Extreme weather and changing weather patterns — the obvious manifestations of global climate change — do not simply reflect easily identifiable changes in Earth's energy balance such as a rise in atmospheric temperature. They usually have complex causes, involving anomalies in atmospheric circulation, levels of soil moisture and the like. Solid understanding of these factors is crucial if researchers are to improve the performance of, and confidence in, the climate models on which event attribution and longer-term climate projections depend.[7]

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[2] http://www.ipcc.ch/organization/organization_history.shtml#.UkXN6RBxPm4
[3] http://www.ipcc.ch/pdf/ipcc-principles/ipcc-principles.pdf
[4] http://www.ipcc.ch/ipccreports/far/wg_I/ipcc_far_wg_I_full_report.pdf
[5] http://www.climatechange2013.org/images/uploads/WGIAR5-SPM_Approved27Sep2013.pdf
[6] http://ipcc-wg2.gov/SREX/images/uploads/SREX-SPMbrochure_FINAL.pdf
[7] http://www.nature.com/news/extreme-weather-1.11428.

ADDITIONAL READING

- IPCC Special Report on Extreme Weather: http://ipcc-wg2.gov/SREX/images/uploads/SREX-SPMbrochure_FINAL.pdf
- IPCC Assessment Report 5. Working Group 1. Summary for Policy Makers: http://www.climatechange2013.org/images/uploads/WGI_AR5_SPM_brochure.pdf

Appendix

Table SPM.1 | Extreme weather and climate events: Global-scale assessment of recent observed changes, human contribution to the changes, and projected further changes for the early (2016–2035) and late (2081–2100) 21st century. Bold indicates where the AR5 (black) provides a revised* global-scale assessment from the SREX (blue) or AR4 (red). Projections for early 21st century were not provided in previous assessment reports. Projections in the AR5 are relative to the reference period of 1986–2005, and use the new Representative Concentration Pathway (RCP) scenarios (see Box SPM.1) unless otherwise specified. See the Glossary for definitions of extreme weather and climate events.

Phenomenon and direction of trend	Assessment that changes occurred (typically since 1950 unless otherwise indicated)	Assessment of a human contribution to observed changes	Likelihood of further changes: Early 21st century	Likelihood of further changes: Late 21st century
Warmer and/or fewer cold days and nights over most land areas	*Very likely* {2.6} *Very likely* *Very likely*	***Very likely*** {10.6} *Likely* *Likely*	*Likely* {11.3}	*Virtually certain* {12.4} *Virtually certain* *Virtually certain*
Warmer and/or more frequent hot days and nights over most land areas	*Very likely* {2.6} *Very likely* *Very likely*	***Very likely*** {10.6} *Likely* *Likely* (nights only)	*Likely* {11.3}	*Virtually certain* {12.4} *Virtually certain* *Virtually certain*
Warm spells/heat waves. Frequency and/or duration increases over most land areas	***Medium confidence*** **on a global scale** ***Likely*** **in large parts of Europe, Asia and Australia** {2.6} *Medium confidence* in many (but not all) regions *Likely*	***Likely***[a] {10.6} Not formally assessed *More likely than not*	Not formally assessed[b] {11.3}	*Very likely* {12.4} *Very likely* *Very likely*
Heavy precipitation events. Increase in the frequency, intensity, and/or amount of heavy precipitation	*Likely* more land areas with increases than decreases[c] {2.6} *Likely* more land areas with increases than decreases *Likely* over most land areas	***Medium confidence*** {7.6, 10.6} *Medium confidence* *More likely than not*	*Likely* over many land areas {11.3}	***Very likely*** **over most of the mid-latitude land masses and over wet tropical regions** {12.4} *Likely* over many areas *Very likely* over most land areas
Increases in intensity and/or duration of drought	***Low confidence*** **on a global scale** ***Likely*** **changes in some regions**[d] {2.6} *Medium confidence* in some regions *Likely* in many regions, since 1970[e]	***Low confidence*** {10.6} *Medium confidence*[f] *More likely than not*	*Low confidence*[g] {11.3}	***Likely*** **(*****medium confidence*****) on a regional to global scale**[h] {12.4} *Medium confidence* in some regions *Likely*[e]
Increases in intense tropical cyclone activity	***Low confidence*** **in long term (centennial) changes** ***Virtually certain*** **in North Atlantic since 1970** {2.6} *Low confidence* *Likely* in some regions, since 1970	***Low confidence***[i] {10.6} *Low confidence* *More likely than not*	*Low confidence* {11.3}	***More likely than not*** **in the Western North Pacific and North Atlantic**[j] {14.6} *More likely than not* in some basins *Likely*
Increased incidence and/or magnitude of extreme high sea level	*Likely* (since 1970) {3.7} *Likely* (late 20th century) *Likely*	***Likely***[k] {3.7} *Likely*[k] *More likely than not*[k]	*Likely*[l] {13.7}	***Very likely***[l] {13.7} *Very likely*[m] *Likely*

* The direct comparison of assessment findings between reports is difficult. For some climate variables, different aspects have been assessed, and the revised guidance note on uncertainties has been used for the SREX and AR5. The availability of new information, improved scientific understanding, continued analyses of data and models, and specific differences in methodologies applied in the assessed studies, all contribute to revised assessment findings.

Notes:

[a] Attribution is based on available case studies. It is *likely* that human influence has more than doubled the probability of occurrence of some observed heat waves in some locations.

[b] Models project near-term increases in the duration, intensity and spatial extent of heat waves and warm spells.

[c] In most continents, *confidence* in trends is not higher than *medium* except in North America and Europe where there have been *likely* increases in either the frequency or intensity of heavy precipitation with some seasonal and/or regional variation. It is *very likely* that there have been increases in central North America.

[d] The frequency and intensity of drought has *likely* increased in the Mediterranean and West Africa, and *likely* decreased in central North America and north-west Australia.

[e] AR4 assessed the area affected by drought.

[f] SREX assessed *medium confidence* that anthropogenic influence had contributed to some changes in the drought patterns observed in the second half of the 20th century, based on its attributed impact on precipitation and temperature changes. SREX assessed *low confidence* in the attribution of changes in droughts at the level of single regions.

[g] There is *low confidence* in projected changes in soil moisture.

[h] Regional to global-scale projected decreases in soil moisture and increased agricultural drought are *likely* (*medium confidence*) in presently dry regions by the end of this century under the RCP8.5 scenario. Soil moisture drying in the Mediterranean, Southwest US and southern African regions is consistent with projected changes in Hadley circulation and increased surface temperatures, so there is *high confidence* in *likely* surface drying in these regions by the end of this century under the RCP8.5 scenario.

[i] There is *medium confidence* that a reduction in aerosol forcing over the North Atlantic has contributed at least in part to the observed increase in tropical cyclone activity since the 1970s in this region.

[j] Based on expert judgment and assessment of projections which use an SRES A1B (or similar) scenario.

[k] Attribution is based on the close relationship between observed changes in extreme and mean sea level.

[l] There is *high confidence* that this increase in extreme high sea level will primarily be the result of an increase in mean sea level. There is *low confidence* in region-specific projections of storminess and associated storm surges.

[m] SREX assessed it to be *very likely* that mean sea level rise will contribute to future upward trends in extreme coastal high water levels.

Chairman SMITH. The Subcommittee on the Environment will come to order.

Welcome, everyone, to today's hearing titled "A Factual Look at the Relationship between Climate and Weather," and let me also say that we have a little bit of a sparse attendance today for two reasons. One, there are Members of the Republican Caucus who are still hearing what the budget deal is all about. I expect them to trickle in shortly, and we have lost both Republican and Democrat Members to a Nelson Mandela memorial service, so we are down in numbers a little bit but not down in interest or in making a record, thanks to the expertise from our witnesses today. I am going to recognize myself for an opening statement, then the Ranking Member.

Administration officials and the national media regularly use the impacts from hurricanes, tornados, droughts, and floods to justify the need for costly climate change regulations. President Obama stated in his 2013 State of the Union Address that, "We can choose to believe that Superstorm Sandy, and the most severe drought in decades, and the worst wildfires some states have ever seen were all just a freak coincidence. Or we can choose to believe in the overwhelming judgment of science and act before it is too late."

However, the "overwhelming judgment of science" does not support the President's claims. According to the Intergovernmental Panel on Climate Change (IPCC), there is high agreement among leading experts that long-term trends in weather disasters are not due to human-caused climate change.

The story is the same when we look at each type of extreme weather event. Hurricanes have not increased in the United States in frequency, intensity or normalized damage since at least 1900. It has been seven years since a Category 3 or stronger hurricane made landfall in the United States.

Government data also indicates no association between climate change and tornado activity. Whether measured by the number of strong tornados, tornado-related fatalities or economic losses associated with tornados, the latter half of the 20th century shows no climate-related trend.

The data on droughts yields similar results. For example, the National Oceanic and Atmospheric Administration concluded that climate change was not a significant part of the recent drought in Texas. And the IPCC found that "in some regions droughts have become less frequent, less intense, or shorter. IPCC's latest report also states there is low confidence in any climate-related trends for flood magnitude or frequency on a global scale.

The science is clear and overwhelming but not in the way the President said. The fact is, there is little evidence that climate change causes extreme weather events. Instead of trying to scare the American people and promote a political agenda, the Administration should try to protect the lives and property of our Nation's residents from extreme weather by better weather forecasting.

This Committee last week passed bipartisan legislation to do just that. The Weather Forecasting Improvement Act of 2013 strengthens our Nation's ability to save lives and property through advanced research and implementation of next-generation weather forecasting abilities.

I hope this hearing will make clear that the impact of climate change is often exaggerated. Politicians and others should rely on good science, not science fiction, when they discuss extreme weather. Otherwise, they will lack credibility when advocating new policy changes.

[The prepared statement of Mr. Smith follows:]

PREPARED STATEMENT OF FULL COMMITTEE CHAIRMAN LAMAR S. SMITH

Administration officials and the national media regularly use the impacts from hurricanes, tornadoes, droughts, and floods to justify the need for costly climate change regulations. President Obama stated in his 2013 State of the Union Address that, "We can choose to believe that Superstorm Sandy, and the most severe drought in decades, and the worst wildfires some states have ever seen were all just a freak coincidence. Or we can choose to believe in the overwhelming judgment of science and act before it's too late."

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The IPCC's latest report also states there is "low confidence" in any climate-related trends for flood magnitude or frequency on a global scale. The science is clear and "overwhelming," but not in the way the president said. The fact is there is little evidence that climate change causes extreme weather events.

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Chairman SMITH. That concludes my opening statement, and the gentlewoman from Oregon, Ms. Bonamici, is recognized for her statement.

Ms. BONAMICI. Thank you, Mr. Chairman.

Today we continue what has been a popular topic for this Subcommittee and indeed the Committee at large: what impacts, if any, the changing climate is having on our daily life and the lives of our constituents. It is not likely that the Committee will reach consensus on this question anytime soon, but nonetheless I welcome and appreciate the witnesses who are here today.

Dr. Titley, I am interested not just in your experiences at NOAA, but also in your work for the Navy, where you rose to the rank of Rear Admiral. And I know I speak for the entire Subcommittee when I say that we are very grateful to you for your service to the Nation.

Dr. Titley's work has been at the interface of weather and climate through his long career with the U.S. Navy and now, at the Pennsylvania State University. There is a long list of good scientists who would be capable of appearing before us to shed light on the facts of the relationship between climate and weather. Actually I would like to see more of them come before this Subcommittee and the Committee in the whole because whatever our diverse views on climate change, there is absolutely no disagreement that severe weather events can devastate our constituents, deprive them of their livelihoods, and sometimes even take their lives. Ruling out research into a potential link between climate change and severe weather events would be burying our heads in the sand.

Recently, I worked with Members of the Subcommittee on what is now bipartisan legislation to address the Federal weather enterprise and how it might be improved to provide our constituents with better warning of severe weather events. I know my constituents on the coast of Oregon rely on weather forecasting information that can tell them when it is safe to go out fishing, and my constituents in Yamhill County need information on weather patterns to help make decisions about the grapes they grow to make world-famous Oregon pinot noir, and if we are here to learn that it is erroneous to associate any given day's weather or any particular storm with climate change, then that is fine. However, climate change challenges us to think in terms of decades of accumulated change. Making comments on today's weather is easy. Learning what factors might influence long-term climate patterns is significantly more difficult. Our constituents should be able to count on their elected leaders to take a difficult look at a complicated subject. The lesson of this hearing cannot be that a potential link between climate change and severe weather is too difficult to determine or understand, and therefore we should stop trying.

It should not be controversial to examine if the weather will change as a consequence of global warming. Scientific projections from the IPCC make it apparent that we will live in a hotter world. We already have a warmer world than that of our grandparents. In many of our districts, residents will experience drier environments with more drought. Those of us who represent particularly wet areas may find that precipitation arrives in more intense storms. The oceans will be warmer and that may well produce stronger or more frequent tropical storms. To focus only on the question of whether there will be more extreme events misses the point that by the end of this century much of the world as we know it, in our districts and in the States and across the world will be considerably altered by the weather effects of climate change.

We need to face up to the risks of global warming and do more to reduce carbon emissions. Americans have always boldly faced risks and challenges. Our own armed services have already begun taking climate change seriously. The Navy, as Rear Admiral Dave Titley could attest, has been struggling with the strategic implication of year-round open seas in the Arctic.

In summary: anthropogenic climate change is real. There is a strong consensus that we are already seeing climactic consequences from warming. The continued warming of the globe will have pro-

found effects on our country and the world. This situation creates an opportunity for the United States to show leadership in reducing carbon emissions, as well as in adapting and mitigating the effects of climate change.

Finally, I want to join the chairman in noting that I do not want the absence of more Members on my side of the aisle to be perceived as a lack of interest in this important topic. As the Chairman noted, this morning there is a memorial service for Nelson Mandela at the National Cathedral, and many Members are attending that service.

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

[The prepared statement of Ms. Bonamici follows:]

PREPARED STATEMENT OF SUBCOMMITTEE ON ENVIRONMENT RANKING MINORITY MEMBER SUZANNE BONAMICI

Mr. Chairman, today we continue what has been a popular topic for this Subcommittee and indeed the Committee at large: what impacts, if any, the changing climate is having on our daily life and the lives of our constituents. It is not likely that the Committee will reach consensus on this question anytime soon, but nonetheless I welcome and appreciate the witnesses who are here today. Dr. Titley, I am interested not just in your experiences at NOAA, but in your work for the Navy, where you rose to the rank of Rear Admiral. And I know I speak for the entire Subcommittee when I say that we are very grateful to you for your service to the nation.

Dr. Titley's work has been at the interface of weather and climate through his long career with the U.S. Navy and, now, at Pennsylvania State University. There is a long list of good scientists who would be capable of appearing before us to shed light on the "facts" of the relationship between climate and weather. Actually I would like to see more of them come before this committee, because whatever our diverse views on climate change, there is absolutely no disagreement that severe weather events can devastate our constituents, deprive them of their livelihoods, and sometimes even take their lives. Ruling out research into a potential link between climate change and severe weather events would be burying our heads in the sand.

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If we are here to learn that it is erroneous to associate any given day's weather or any particular storm with climate change, then that is fine. However, climate change challenges us to think in terms of decades of accumulated change. Making comments on today's weather is easy. Learning what factors might influence long-term climate patterns is significantly more difficult. Our constituents should be able to count on their elected leaders to take a difficult look at a complicated subject. The lesson of this hearing cannot be that a potential link between climate change and severe weather is too difficult to determine or understand, and therefore we should stop trying.

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We need to face up to the risks of global warming and do more to reduce carbon emissions. Americans have always boldly faced risks and challenges. Our own Armed Services have already begun taking climate change seriously. The Navy, as

retired Rear Admiral Dave Titley could attest, has been struggling with the strategic implication of year-round open seas in the Arctic.

In summary: anthropogenic climate change is real; there is a strong consensus that we are already seeing climactic consequences from warming; the continued warming of the globe will have profound effects on our country and the world. This situation creates an opportunity for the United States to show leadership in reducing carbon emissions, as well as in adapting and mitigating the effects of climate change.

Finally I would like to note that I do not want the absence of Members on my side of the aisle to be perceived as a lack of interest in this important topic. This morning there is a memorial service for Nelson Mandela at the National Cathedral, and many Members are attending that service.

Thank you, I yield back.

Chairman SMITH. Thank you, Ms. Bonamici.

And let me introduce our witnesses. Our first witness today is Dr. John Christy, Professor and Director of the Earth System Science Center at the University of Alabama in Huntsville. Since November 2000, he has been Alabama's State Climatologist. Dr. Christy has served as a lead author, contributor and expert reviewer for the UN reports by the Intergovernmental Panel on Climate Change, which included satellite temperatures as well as other climate data sets he constructed. Dr. Christy is also a Fellow of the American Meteorological Society. He has served on five National Research Council panels or committees and has performed research funded by NASA, NOAA, DOE, DOT and the State of Alabama. Dr. Christy received his master's and doctoral degrees in atmospheric sciences from the University of Illinois.

Our next witness is Dr. David Titley, Director of the Center for Solutions to Weather and Climate Risk at Pennsylvania State University. Dr. Titley served as a Naval Office for 32 years and rose to the rank of Rear Admiral. Dr. Titley's career included duties as Commander, Naval Meteorology and Oceanography Command, Oceanographer and Navigator of the Navy, and Deputy Assistant Chief of Naval Operations for Information Dominance. After retiring from the Navy, Dr. Titley served as the Deputy Under Secretary of Commerce for Operations, the Chief Operating Officer position at the National Oceanic and Atmospheric Administration. Dr. Titley holds a master's degree in science and meteorology and physical oceanography, and a Ph.D. in meteorology from the Naval Post Graduate School.

Our third witness today is Dr. Richard Pielke, Professor of Environmental Studies and Director for the Center for Science and Technology Policy Research at the University of Colorado. Before joining the faculty of the University of Colorado from 1993 to 2001, Dr. Pielke was a Scientist at the National Center for Atmospheric Research. Over the past 20 years, Dr. Pielke has collaborated with researchers around the world to publish dozens of peer-reviewed papers on extreme weather events and climate change. He is also a Senior Fellow of the Breakthrough Institute and holds academic appointments at Macquarie University in Sydney, Australia, and the London School of Economics. Dr. Pielke holds degrees in mathematics, public policy and political science, all from the University of Colorado.

We welcome you all and look forward to your testimony, and Dr. Christy, we will begin with you.

TESTIMONY OF DR. JOHN R. CHRISTY,
PROFESSOR AND DIRECTOR,
EARTH SYSTEM SCIENCE CENTER, NSSTC,
UNIVERSITY OF ALABAMA IN HUNTSVILLE

Dr. CHRISTY. Thank you, Chairman Smith and Ranking Member Bonamici, for the privilege it is to offer my views on climate change. I am John Christy, Professor of Atmospheric Science at the University of Alabama in Huntsville and Alabama State Climatologist. I served as a lead author of the IPCC years ago. My research might best be described as building data sets from scratch to advance our understanding of what the climate is doing and why.

Have climate extremes of the past 50 years been unprecedented? To answer that question statistically, one needs 1,500 to 2,000 years of data with which to compare. Only then can one determine if the characteristic is unusual. For a few extremes such as drought, we have long data sets. In the 12th century, there were megadroughts, far worse than any we have seen in the past century. As noted in more detail in my written testimony, when the comparison is done properly, to label today's events as extreme usually fails the test of time.

Now to the IPCC climate models. On the screen, the figure you will see, a 35-year record of atmospheric temperature in the tropics, the key region in which climate models respond to greenhouse gas warming with a large and distinct signal and was used by the EPA as a fingerprint of climate change. This shows that the very latest climate model simulations are on average warming the tropics two to five times greater than the real world, as shown by the symbols. In other words, the models cannot tell us why the temperature did what it did in the past 35 years.

Now, regarding the IPCC now, please note that the IPCC was written by IPCC select scientists and that the document represents their opinions. Many of the conclusions are fine but some of the key ones do not represent the views of the broader climate science community. For example, the headline statement from the summary for policymakers baffles me. It reads: "It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century."

First, the IPCC relies on climate models to distinguish natural from human caused climate change. However, as demonstrated in the chart, these same models fail to represent the climate of the past 35 years by a significant amount. But in its conclusion, the IPCC now claims more confidence that the models can distinguish natural from human change in correct proportions over a period of time during which the models fail. So if the models can't tell us what has happened, how can they tell us why it happened? It just doesn't make sense to me.

I see two things here. One, we need to go back to the drawing board on climate modeling with a rigorously independent validation program or red-team approach, and two, the world community needs to be exposed to the real debates of climate science rather than the statements of a carefully selected few.

Seventeen years ago in March 1996, I testified before this Committee about climate change and new data sets my colleague, Roy Spencer, and I pioneered. Using these data, Richard McKnight,

also at UA Huntsville, and I wrote a paper in Nature magazine that indicated climate model simulations were warming the planet about four times too fast. Now over 17 years later, we still see the latest climate models warming the key region of the tropical atmosphere about four times too fast. In a paper published last week, Swanson demonstrated that these latest models are actually getting worse.

It was clear at that time and agreed to by nearly everyone that our understanding of how the climate system works was poor and we needed more observations to better understand natural variability. One of my concluding statements 17 years ago was, and I quote: "Without a continuing program of research that places climate variations in proper perspective and reports with improving confidence on their causes, we will be vulnerable to calls for kneejerk remedies to combat climate change which likely will be unproductive and economically damaging."

Regulations have been put forward based upon those climate model projections. I have shown in previous testimony that these regulations will be unproductive in terms of climate effects, and I will let economists answer the question about whether the economic effects of higher energy prices will be damaging, especially for the poorest among us.

In summary, we have a lot of work to do to understand why the climate is not changing according to proper projections, projections that unfortunately have been used to create policy.

Thank you very much.

[The prepared statement of Dr. Christy follows:]

A Factual Look at the Relationship Between Climate and Weather
Subcommittee on Environment
Committee on Science, Space and Technology
11 December 2013

Testimony of John R. Christy
University of Alabama in Huntsville.

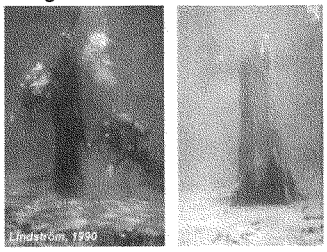
I am John R. Christy, Distinguished Professor of Atmospheric Science, Alabama's State Climatologist and Director of the Earth System Science Center at The University of Alabama in Huntsville. I have served as a Lead Author, Contributing Author and Reviewer of IPCC assessments, have been awarded NASA's Medal for Exceptional Scientific Achievement, and in 2002 was elected a Fellow of the American Meteorological Society.

It is a privilege for me to offer my views on the relationship between climate and weather based on my experience as a climate scientist. My research area might be best described as building datasets from scratch to advance our understanding of what the climate is doing and why. I have used traditional surface observations as well as measurements from balloons and satellites to document the climate story. Many of my datasets are used to test hypotheses of climate variability and change.

Extreme Events

As the global temperature failed to warm over the past 15 years, it became popular to draw attention to the occurrence of extreme weather events as worrisome consequences of postulated climate change due to increasing concentrations of greenhouse gases. For example, many claims have been made that weather events of the past 50 years are "unprecedented", therefore must be caused by human influences. However, one can only establish such events as statistically unusual, a lower standard than "unprecedented," if a minimum of 30 or more such periods with consistent data are available. This means we need 1500 to 2000 years of information with which to compare our recent 50-years of history to determine whether any characteristic is truly unusual.

For a few parameters we have such data. Severe drought leaves a clear mark on the landscape so that we know our nation experienced droughts in the 12th century, the so-called mega-droughts, which were much worse than any we've seen in the past century. Thus, droughts of the past 50 years are not unusual and obviously not "unprecedented" as shown next.

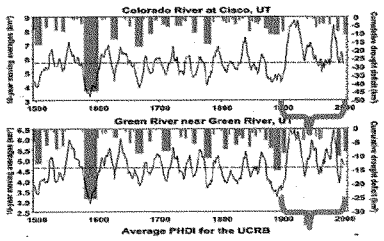


California
At right are photos from Lindstrom (1990) of divers examining trees which grew on dry ground

around 900 years ago in what is now a Sierra Nevada alpine lake. This indicates that a drastic but natural change to a much drier climate occurred and must have lasted for at least 50 years for trees to have grown to these sizes on dry ground.

Rocky Mountains

A 500-year history of moisture in the upper Colorado River basin (below) indicates the past century was quite moist while major multi-decadal droughts occurred in all four prior centuries (Piechota et al. 2004.) Indeed, the conclusion of Piechota et al. states that after examining the paleo-record, the present-day droughts "could be worse." These and other evidences point to the real probability that water supply in the West will see declines simply as a matter of the natural variability of climate.



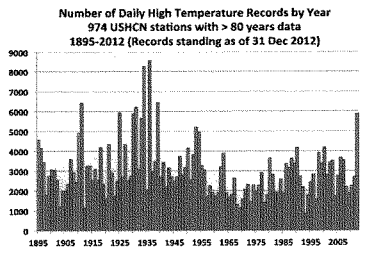
Great Plains

In the Great Plains, the period from 3000 to 1500 years ago saw a drier and warmer climate during which a significant parabolic sand dune ecosystem developed, especially in western Nebraska and NE Colorado (Muhs 1985). In other words, parts of the Great Plains resembled a desert. Many of these areas experienced dune "reactivation" during Medieval times (900-1300 AD). Then, the climate moistened and cooled beginning around 1300 AD to support the short-grass prairie seen today, though "reactivation" is possible at any time (Schmeisser, 2009). Indeed, Muhs and Holliday (1995) found that dune reactivation can occur within decadal time scales from extended drought by examining the Great Plains environment of only the past 150 years.

With the massive use of ground water for irrigation, the High Plains Aquifer has declined an average of 12.8 ft, with some areas in the Texas panhandle down over 150 ft. The key point here is that the Plains is subject to natural (and sobering) long-term droughts that would very likely tax the current water management system (ground-water withdrawals) while not replenishing the aquifer, producing a situation of reduced agricultural productivity, especially in its southern reaches.

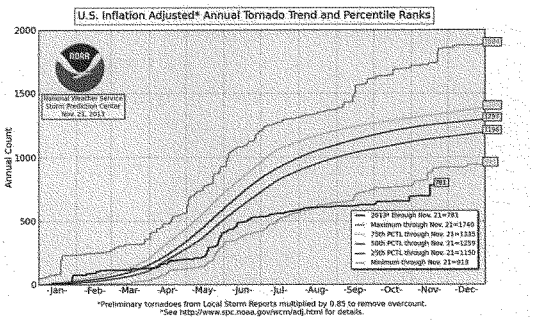
U.S. Daily High Temperature Records

Are daily high temperature extremes becoming more frequent? To answer such a question, one must obviously consider datasets that span an appropriate length of time. If one does the analysis with stations of at least 80 years of data, and determines the number of daily temperature records by



year that stand as of 31 Dec 2012, the answer to the question is "no." It is true that the number of records in 2012 was quite high, thanks to a very warm March and a hot Mid-Western summer. However in comparison to the heat waves of the 1930s, the summer was not the "worst" for heat. 2012 finished in 8th place on the list, just below 6th and 7th places by a few days. Imagine what this diagram would show if we had 1000 years of climate data in which it would be certainly likely that many years experienced more record warmth than even the 1930s.

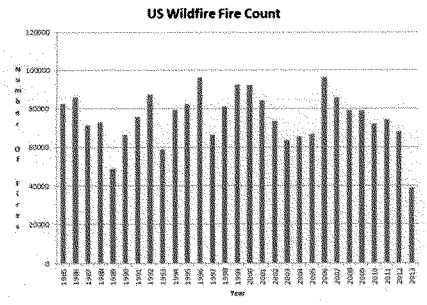
Recent Tornadoes



The image to the right from NOAA indicates we are in a very low tornado period in our country – in fact the current year (right, black line) is the lowest year-to-date (Nov.) value in the 60-year history. This of course is not a prediction that tornadoes will decline in the future nor that there will be few tornadoes the rest of this year. It is simply a recognition that the number of tornadoes can vary significantly from year to year and there is no long term trend (http://www.spc.noaa.gov/wcm/adj.html)

Recent Wildfires

Wildfires are a natural consequence of the U.S. climate variability and a feature to which many components of the natural ecosystem have found ways for advantage-taking. Nowadays however, our fire suppression activities that allow excessive buildup of fuel combined with the careless or premeditated human character of some folks, gives greater opportunity for wildfires to be started and to destroy. The current year has included the huge Rim Fire in the central Sierra Nevada of California, but, on the whole, the year is well below average as shown in the graphic to the above (data from the National Interagency Fire Center http://www.nifc.gov/fireInfo/fireInfo_stats_totalFires.html). A related metric is total snowfall in the Sierra of California which has also shown no trend since the Southern Pacific Railroad Company began measuring snowfall in 1878 (Christy 2012).



West Antarctica Coastal Temperatures

Temperatures over the vast expanse of the Antarctic continent have not shown significant warming in the past several decades. Indeed satellite-based observations of the atmospheric temperature above Antarctica show a slight decline since 1979. However, measurements along the coast of West Antarctic and its Peninsula have warmed in recent years. Thomas et al. (2013) have reconstructed 308 years of temperature variations (1702-2009) through stable isotopes and confirmed the recent warming. They found that,

> *... this warming trend is not unique. More dramatic isotopic warming (and cooling) trends occurred in the mid-nineteenth and eighteenth centuries suggesting that at present, the effect of anthropogenic climate drivers at this location has not exceeded the natural range of climate variability in the context of the past ~300 years.*

Here we have another example that indicates we must have hundreds of years of climate records before trying to assess whether recent changes are unusual. In this case, the temperatures of West Antarctica have experienced similar and likely greater changes than recently observed in merely the last 300 years, a period before which humans could have affected the climate.

What does Extreme Weather really tell us?

The point about our lack of understanding of the causes of extreme weather was summed up in an article in *Nature* magazine with the title "Extreme Weather – Better models are needed before exceptional events can be reliably linked to global warming" (*Nature*, 20 September 2012, vol 489, pg 335-6.) The emphasis in the article agrees with my statement that our level of understanding about the climate system is so low that we cannot predict nor attribute unusual events to human emissions of greenhouse gases using models and/or limited data records. The article discusses the problem that current climate models are not "fit to inform legal and societal decisions" without further "enormous research" because at present they are not ready for such tasks.

The article notes that extreme events "have complex causes, involving anomalies in atmospheric circulation, levels of soil moisture and the like." The comments of one scientist at a recent workshop on the topic indicated "the coarse and mathematically far-from-perfect climate models used to generate attribution claims ... are unjustifiably speculative, basically unverifiable and better not made at all." Not all participants felt this way, however *Nature* reported that, "None of the industry and government experts at the workshop could think of any concrete example in which an attribution might inform business or political decision-making." In other words, industry and government would prefer an accurate forecast over the notion of attributing that forecast to a particular cause. Unfortunately, the ability to make accurate long-range forecasts is not here yet.

In the examples above, we don't see increases in extreme events (which is also true for tornadoes, hurricanes, floods, etc. - see my House testimony of 31 March 2011) but we must certainly be ready for more to come as part of nature's variability.

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

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

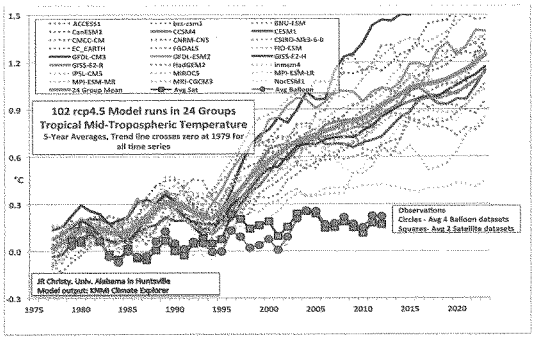
There are innumerable types of events that can be defined as extreme events – so for the enterprising individual (unencumbered by the scientific method), weather statistics can supply an unlimited, target-rich environment in which to discover a "useful" extreme event. Thus, when the enterprising individual observes an unusual weather event, it may be tempting to define it as a once-for-all extreme metric to "prove" a point about climate change – even if the event was measured at a station with only 30 years of record. Extreme events happen, and their causes are intricately tied to the semi-unstable dynamical situations that can occur out of an environment of natural, unforced variability. In other words, Mother Nature has within her all the necessary tools to generate extreme events that exceed what we've seen in the past 50 years.

Science checks hypotheses (assertions) by testing specific, falsifiable predictions implied by those hypotheses. The predictions are to be made in a manner that, as much as possible, is blind to the data against which they are evaluated. It is the testable predictions from a specific set of hypotheses, otherwise known as climate model simulations, that run into trouble as shown below. Before going on to that test, the main point here is that extreme events do not lend themselves as being rigorous metrics for *convicting* human CO2 emissions of being guilty of causing them.

Utility of Climate Models

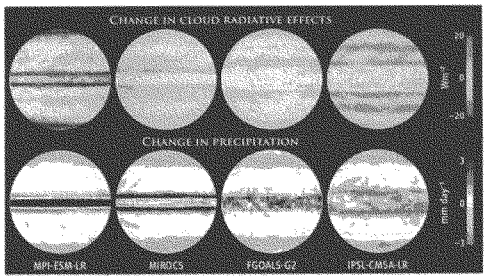
In the figure below I provide the 35-year record (1979-2013) of atmospheric temperature in the tropics – the key region in which climate models respond to greenhouse gas warming with a large and distinct signal. The focus on the tropics is important because

of the consistent and significant warming that climate models indicate should have already occurred as a result of the increasing concentration of greenhouse gases we have put into the atmosphere. It also represents a part of the global atmosphere in which the critical water vapor and cloud feedbacks have major influences. In addition, changes in this region were determined by the EPA to be a key line of evidence of greenhouse-gas caused climate change. Finally, the tropical atmosphere is also a huge and easy target for modeling projects to hit if the physics are well represented. Since this warming should have taken place already, this provides for us a way to test the model simulations. There are 102 model runs represented in the figure, but I have organized them by the 24 types of models. The thick red line is the average of the 24 groups. Thin, solid lines are the six model groupings created by U.S. institutions and the dotted lines by those from outside the U.S. The observations are provided by six independent sources, with "balloons" being the average of the four balloon-borne datasets and "satellites" the average of the two groups which utilize satellite instrumentation.



The comparison shows that the very latest climate model simulations used in the IPCC Assessment released two months ago indicate that their response to CO2 on average is 2 to 5 times greater than reality. In strict statistical testing, we can say that the models on average failed a simple hypothesis test to check whether they could represent the path the real world took on tropical atmospheric temperatures (see Douglass et al. 2007, McKitrick et al. 2010, 2011, Douglass and Christy 2013).

An extremely important paper was published in *Nature Climate Change* this past spring as one of the first studies to actually perform a test of model capabilities in a controlled experiment to understand the impacts on the critical processes that affect the way the temperature will change (Stephens and Bony, 2013). They simply ran four major climate models over an ocean-covered earth (i.e. a very simple earth) with the current



ocean temperatures, then again with elevated ocean temperatures. The experiment would then reveal the impact of the extra warmth on the way the climate system operates, especially, clouds and rain because they have significant impacts on the warming processes. So, getting clouds and rain correct is necessary for long-term integrations. To their surprise, the four major models gave quite different results (figure above), both in terms of the magnitude *and of the sign* of the change in clouds and rain as shown in the figure. This is exactly the type of fundamental, rigorous evaluation that must be encouraged for other parts of the modeling enterprise. One can only conclude that at least three of the four models fail (if on the odd chance one is correct) to depict the fundamental processes of the Earth system. This result supports the comments in the paragraphs above which demonstrate the climate modeling enterprise must go "back to the basics" as stated in Stephens and Bony.

In a paper published last week, Swanson (2013) examined the previous generation of climate models used in the IPCC AR4 (2007, known as CMIP3) in comparison with the latest generation of models employed in the current IPCC AR5 (known as CMIP5 models as I used earlier). Swanson found that the newer CMIP5 models were worse at depicting actual climate variations than the older CMIP3 versions. He suggests that the modelers have a "selection bias based on warming rate" that attempts to replicate the rapid warming of the Arctic (a small region) while becoming worse (too warm) in the much more vast tropics and southern hemisphere. He argues for a "healthy dose of diversity" to be reintroduced into the climate simulation enterprise.

Basing scientific conclusions about climate change (or basing policy decisions about energy) on climate model output is risky given the inability of model simulations to reproduce the real world – and their results are not getting better.

The IPCC Summary for Policy Makers

Regarding the IPCC, please note that the IPCC was written by IPCC-selected scientists and that the document represents their opinions. Many of the conclusions are fine but some of the key ones do not represent the views of many in the broader climate community.

The headline statement from the 2013 *Summary for Policy Makers* baffles me. It reads,

> *It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century.*

First, the IPCC relies on climate models to distinguish "natural" from "human" caused climate change because instruments can't. However, as demonstrated, these same models on average fail by a significant amount to reproduce the climate of the past 35 years (the years most directly impacted by rising greenhouse gas emissions.) But in conclusion, the IPCC now has even more confidence that the models can distinguish "natural" from "human" change over a period the models clearly fail to simulate well. It doesn't make sense to me.

Now, it is true that *in the models*, most of the warming in the past 50 years is due to greenhouse gases, but since the model-based warming did not occur in reality (by a significant amount), how can one claim that reality was driven by greenhouse gas warming?

I see two things here, (1) the need to go back to the drawing board on climate modeling with special attention to the causes of natural variations and with a rigorously independent validation program (i.e. a set of relatively inexpensive but true "**Red Teams**"), and (2) the world community needs to be exposed to the real debates in climate science rather than statements amounting to a consensus of those who already agree with a certain consensus. These are sentiments I have been advocating for years in congressional testimony and which appear in an article published in *Nature* magazine (Christy, 2010 see after references).

In addition, I direct the reader to a supplement attached to this written testimony by Professor Judith Curry of Georgia Tech entitled, "IPCC Diagnosis – Permanent Paradigm Paralysis." The title is an apt description of where the IPCC process has gone.

Seventeen Years Ago – House Committee on Science

Seventeen years ago, in March 1996, I testified before this committee regarding climate change. In that testimony I reported on the development of the deep layer atmospheric temperature datasets from satellites that Roy Spencer, then of NASA now of UAHuntsville, and I had pioneered. Using these data, Richard McNider, also of UAHuntsville, and I wrote a paper in *Nature* magazine that indicated climate model simulations were warming the planet about 4 times faster than in reality (Christy and McNider 1994). Further analysis confirmed a rate in models 2 to 4 times faster than the real world.

It was clear at the time, and agreed to by nearly everyone, that our understanding of how the climate system worked was poor and much more research was needed on observing the climate and on understanding its natural variations. I also noted that we should expect weather extremes to continue because that has been the nature of climate from the beginning.

One of my concluding statements was, and I quote,

> *Without a continuing program of research that places climate variations in proper perspective* [i.e. natural climate variations] *and reports with improving confidence on their causes, we will be vulnerable to calls for knee-jerk remedies to combat "climate change," which likely will be unproductive and economically damaging.*

Now here we are, over 17 years later. It appears the nation has indeed enacted "knee-jerk" remedies to "combat climate change" through regulations on carbon dioxide. I

warned this committee in 1996 that these would be "unproductive and economically damaging." I have since provided testimony that demonstrates that these regulations will be "unproductive" regarding their impact on climate. I will leave it to economists to determine whether the regulations which result in higher energy prices are also "economically damaging", especially for the poorest among us.

The nation did indeed support some efforts to improve the climate observing system, especially from space, to help in determining *what* was happening with the climate, and then begin to understand *why* changes are taking place. Other efforts seem to be falling by the wayside, including attention to the network of high quality surface monitoring stations such as NOAA's Regional Climate Reference Network. Simply put, we need to know *what* the climate is doing before claiming to know *why* it is doing what it is doing. Without accurate observations we can not know *what* the climate is doing.

It is enlightening to examine the 35-year comparison of models and observations of atmospheric temperature in the tropics – the key region in which climate models respond to greenhouse gas warming with a large and distinct signal and a region promoted by the EPA as a fingerprint of human-induced climate change. This is an exceptionally large target for climate models to aim at, and it incorporates the critical water vapor and cloud feedbacks about which we know so little. The current record is now twice as long as was available when I testified in 1996 and the models are more complicated, expensive and numerous, representing an industry unto itself. The comparison shows that the very latest climate models' tropical response to CO2, on average, is still 2 to 5 times greater than reality, just as it was in 1996.

I believe we missed a tremendous opportunity 17 years ago to develop a better understanding of the climate system because research dollars were directed to establish a climate modeling industry. To compound the problem as it developed, I believe we failed to fund substantial projects to examine the output of climate models in an independent, objective and methodological way, i.e. we did not establish "red teams" to rigorously study the output of models on which the most expensive of regulations now rely. This has left us 17 years later still wondering what portion of the recent modest change is natural and what portion might be human-caused.

Conclusion

In this testimony, evidence is presented to demonstrate that recent weather events are not outside the extremes that have occurred in the past when human influences were negligible. Therefore in my view one cannot attribute these recent events with any confidence to something beyond nature. Climate models are promoted as tools that are able to discriminate natural climate events versus those that might happen as a result of the increases in greenhouse gases due to human activities and have been used by EPA for regulatory action. Unfortunately, as demonstrated here and discussed in the literature, climate models have not demonstrated acceptable skill in terms of depicting even very fundamental, large-scale climate variations, and thus are unable to identify natural versus human-influenced events on regional scales. Indeed, the lack of modeling skill regarding

very basic processes such as tropical tropospheric variations, indicates that the modeling enterprise has not been subject to rigorous, independent "Red Team" oversight during its expensive growth period. In addition, significant advancements are needed in observing and understanding the natural processes of climate before reliable, though basic, forecasts are forthcoming. It is unfortunate, in my opinion, that recent policy has been made based on the projections of these faulty models. Climate science has a long way to go.

References:

Christy, J.R. and R.T. McNider, 1994: Satellite greenhouse signal. *Nature*, 376, p. 325. Relevant quote, "Curve "e" reveals an upward trend of +0.09 °C per decade, or about one-quarter of the magnitude of climate model results."

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be used in selection of lead authors. The level of work required in preparing an assessment is large. Increasing the number of lead authors would provide better balance and give more scientists the ability to participate in the process.

A new class of short, rapidly prepared, peer-reviewed reports is also needed. At present, publication options include supplemental material (no peer review required), technical papers (based on existing assessments) or assessments and special reports that undergo two reviews (expert and government/expert, usually taking more than two years to complete). For topics of emerging importance or uncertainty, we need reports based on expert meetings and literature synthesis that undergo only a single round of extensive peer review with review-editor oversight before publication. The IPCC should also expand the number of specialist task forces, task groups and hold more expert meetings to provide additional scientific review and oversight for the broadening array of models (including model comparisons and validation) and methodologies used in emissions reporting, estimating and monitoring impacts, and in developing assessments and adaptation plans.

Finally, the current period between assessments is too long. One option would be for the IPCC, or another body, to produce an annual review, assessment and synthesis of the literature for policy-makers (for example, three annual review volumes with a synthesis chapter in each volume) prepared by experts in the field. Although the editors of the volumes should ideally be drawn from past IPCC authors and editors, the review articles could be submitted by any author, as they would for a journal, with appropriate peer review and assessment for publication.

Open debate: Wikipedia-style

John R. Christy
Lead author (AR3), University of Alabama in Huntsville, USA

Since 1992 I have served as an IPCC contributor and in 2001, as a lead author. My experience has left me of the firm conviction that the IPCC should be removed from UN oversight.

The IPCC selects lead authors from the pool of those nominated by individual governments. Over time, many governments nominated only authors who were aligned with stated policy. Indeed, the selections for the IPCC Fourth Assessment Report represented a disturbing homogeneity of thought regarding humans and climate.

Selected lead authors have the last word in the review cycle and so control the message, often ignoring or marginalizing dissenting comments. 'Consensus' and manufactured-confidence ensued. The recent leaking of e-mails from the Climatic Research Unit at the University of East Anglia in Norwich, UK, put on display the unsavoury cycle of marginalizing different viewpoints. Now several errors of overstatement, such as that of the melting rate of the Himalayan glaciers, have been exposed.

Unfortunately, prestigious media, including *Nature*, became cheerleaders for these official reports, followed then by governments trying to enact policies that drastically reduced emissions to 'stop global warming' while increasing energy costs.

I recommended last year that the next IPCC report invites published authors to write about the evidence for low climate sensitivity and other issues. The IPCC then would be a true reflection of the heterogeneity of scientific views, an 'honest broker', rather than an echo chamber. My recommendation assumed a business-as-usual IPCC process.

However, voluminous printed reports, issued every six years by government-nominated authors, cannot accommodate the rapid and chaotic development of scientific information today. An idea we pitched a few years ago that is now worth reviving was to establish a living, 'Wikipedia-IPCC'. Groups of four to eight lead authors, chosen by learned societies, would serve in rotating, overlapping three-year terms to manage sections organized by science and policy questions (similar to the Fourth Assessment Report). The authors would strike a balance between the free-for-all of true science and the need for summary statements.

Controversies would be refereed by the lead authors, but with input from all sides in the text, with links to original documents and data. The result would be more useful than occasional big books and would be a more honest representation of what our fledgling science can offer. Defining and following rules for this idea would be agonizing, but would provide greater openness.

The truth, and this is frustrating for policy-makers, is that scientists' ignorance of the climate system is enormous. There is still much messy, contentious, snail-paced and now, hopefully, transparent work to do. ■

See also Perspectives, page 747.
Have your say on the future of the IPCC at go.nature.com/orzWau.

http://judithcurry.com/2013/09/28/ipcc-diagnosis-permanent-paradigm-paralysis/

IPCC diagnosis – permanent paradigm paralysis

Posted on September 28, 2013 | 577 Comments

by Judith Curry

Diagnosis: paradigm paralysis, caused by motivated reasoning, oversimplification, and consensus seeking; worsened and made permanent by a vicious positive feedback effect at the climate science-policy interface.

In a previous post, I discussed the IPCC's diagnosis of a planetary fever and their prescription for planet Earth. In this post, I provide a diagnosis and prescription for the IPCC.

In the 1990's, the world's nations embarked on a path to prevent dangerous anthropogenic climate change by stabilization of the concentrations of atmospheric greenhouse gases, which was codified by the 1992 UN Framework Convention on Climate Change (UNFCCC) treaty. The IPCC scientific assessments play a primary role in legitimizing national and international policies aimed at reducing greenhouse gas emissions. This objective has led to the IPCC assessments being framed around identifying anthropogenic influences on climate, dangerous environmental and socio-economic impacts of climate change, and stabilization of CO_2 concentrations in the atmosphere.

At the time of establishment of the UNFCCC, there was as yet no clear signal of anthropogenic warming in the observations, as per the IPCC First Assessment Report (FAR) in 1990. It wasn't until the IPCC's Second Assessment Report in 1995 that a *'discernible'* human influence on global climate was identified. The scientific support for the UNFCCC treaty was not based on observations, but rather on our theoretical understanding of the greenhouse effect and simulations from global climate models. In the early 1990's there was the belief in the feasibility of reducing uncertainties in climate science and climate models, and a consensus seeking approach was formalized by the IPCC. General circulation climate models became elevated to the central role by policy actors and scientists from other fields investigating climate change impacts and applications – this has in turn has elevated the role and position of these climate models in climate change research. Very substantial investments have been made in further developing climate models, with the expectations that these models will provide actionable information for policy makers.

In 2006/2007, climate change had soared to the top of the international political agenda, as a result of Hurricane Katrina, Al Gore's *An Inconvenient Truth*, publication of the IPCC AR4 in 2007, and award of the Nobel Peace Prize to Al Gore and the IPCC. It was claimed that the science was settled, and that it clearly demanded radical policy and governmental action to substantially cut CO2 emissions.

Symptoms of the disease

Seven years later, with the release of the IPCC AR5, we find ourselves between the metaphorical rock and a hard place with regards to climate science and policy:

- as temperatures have declined and climate models have failed to predict this decline, the IPCC has gained confidence in catastrophic warming and dismisses the pause as unpredictable climate variability
- substantial criticisms are already being made of the IPCC AR5 Reports as well as of the IPCC process itself; IPCC insiders are bemoaning their loss of their scientific and political influence; the mainstream media seems not to be paying much attention to the AR5 SPM; and even IPCC insiders are realizing the need for a radical change
- global CO2 emissions continue to increase at higher than expected rates and a growing realization of the infeasibility of meeting emissions targets
- failure of the UNFCCC Conference of Parties to accomplish much since 2009 beyond agreeing to establish future meetings
- Growing realization that you can't control climate by emissions reductions
- European countries and Australia are backing away from their emission reductions policies as they realize their economic cost and political unpopularity
- increasing levels of shrillness on both sides of the political debate, with the 'warm side' steeped in moral panic and hyperbole

And finally:

- after several decades and expenditures in the bazillions, the IPCC still has not provided a convincing argument for how much warming in the 20th century has been caused by humans.
- the politically charged rhetoric has contaminated academic climate research and the institutions that support climate research, so that individuals and institutions have become advocates; scientists with a perspective that is not consistent with the consensus are at best marginalized (difficult to obtain funding and get papers published by 'gatekeeping' journal editors) or at worst ostracized by labels of 'denier' or 'heretic.'
- decision makers needing regionally specific climate change information are being provided by the climate community with either nothing or potentially misleading predictions from climate models.

Diagnosis of the cause of the disease

How and why did we land between a rock and a hard place on the climate change issue? There are probably many contributing reasons, but the most fundamental and profound reason is arguably that both the problem and solution were vastly oversimplified back in 1990 by the UNFCCC/IPCC, where the framed both the problem and the solution as irreducibly global. This framing was locked in by a self-reinforcing consensus-seeking approach to the science and a 'speaking consensus to power' approach for decision making that pointed to only one possible course of policy action – radical emissions reductions. The climate community has worked for more than 20 years to establish a scientific consensus on anthropogenic climate change. The IPCC consensus building process played a useful role in the early synthesis of the scientific knowledge. However, the ongoing scientific consensus seeking process has had the unintended consequence of oversimplifying both the problem and its solution and hyper-politicizing both, introducing biases into the both the science and related decision making processes.

In their Wrong Trousers essay, Prins and Rayner argue that we have made the wrong cognitive choices in our attempts to define the problem of climate change, by relying on strategies that worked previously with ozone, sulphur emissions and nuclear bombs. While these issues may share some superficial similarities with the climate change problems, they are 'tame' problems (complicated, but with defined and achievable end-states), whereas climate change is 'wicked' (comprising open, complex and imperfectly understood systems). For wicked problems, effective policy requires profound integration of technical knowledge with understanding of social and natural systems. In a wicked problem, there is no end to causal chains in interacting open systems, and every wicked problem can be considered as a symptom of another problem; if we attempt to simplify the problem, we become risk becoming prisoners of our own assumptions.

The framing of the climate change problem by the UNFCCC/IPCC and the early articulation of a preferred policy option by the UNFCCC has arguably marginalized research on broader issues surrounding climate variability and change, resulting in an overconfident assessment of the importance of greenhouse gases in future climate change and stifling the development of a broader range of policy options. The result of this simplified framing of a wicked problem is that we lack the kinds of information to more broadly understand climate change and societal vulnerability.

Paradigm paralysis is the inability or refusal to see beyond the current models of thinking. The vast amount of scientific and political capital invested in the IPCC has become self-reinforcing, so it is not clear how move past this paralysis as long as the IPCC remains in existence. The wickedness of the climate change problem makes if difficult to identify points of irrefutable failure in either the science or the policies, although the IPCC's insistence that the pause is irrelevant and temporary could provide just such a refutation if the pause continues. In any event, there is a growing realization of that neither the science or policy efforts are making much progress, and particularly in view of the failure climate models to predict the stagnation in warming, and that perhaps it is time to step back and see if we can do a better job of understanding and predicting climate variability and change and reducing societal and ecosystem vulnerabilities.

Broader implications of the disease

Specifically with regards to climate research, for the past decade most of the resources have been expended on providing projections of future climate change using complex Earth system models, assessing and interpreting the output of climate models, and application of the output of climate models by the climate impacts community.

The large investment in climate modeling, both in the U.S. and internationally, has been made with the expectation that climate models will support decision making on both mitigation and adaptation responses to climate change. So, are these complex global climate models especially useful for decision makers? The hope, and the potential, of climate models for providing credible regional climate change scenarios have not been realized.

With the failure of climate models to simulate the pause and regional climate variability, we have arguably reached the point of diminishing returns from this particular path of climate modeling – not just for decision support but also for scientific understanding of the climate system. In pursuit of this climate modeling path, the climate modeling community — and the funding agencies and the policy makers — have locked themselves into a single climate modeling framework with a focus on production runs for the IPCC, which has been very expensive in terms of funding and personnel. An unintended consequence of this strategy is that there has been very little left over for true climate modeling innovations and fundamental research into climate dynamics and theory — such research would not only support amelioration of deficiencies and failures in the current climate modeling systems, but would also lay the foundations for disruptive advances in our understanding of the climate system and our ability to predict emergent phenomena such as abrupt climate change.

As a result, we've lost a generation of climate dynamicists, who have been focused on climate models rather than on climate dynamics and theory that is needed to understand the effects of the sun on climate, the network of natural internal variability on multiple time scales, the mathematics of extreme events, and predictability of a complex system characterized by spatio-temporal chaos. New structural forms are needed for climate models that are capable of simulating the natural internal variability of the coupled ocean-atmosphere system on timescales from days to millennia and that can accurately account for the fast thermodynamic feedback processes associated with clouds and water vapor.

Hoping and expecting to rely on information from climate models about projected regional climate change to guide adaptation response has diverted attention from using observational, historical and paleoclimate data from the region to more usefully develop the basis for future scenarios. Further, increased scientific focus on subseasonal (weeks) and seasonal (months) weather/climate forecasts could produce the basis for tactical adaptation practices with substantial societal benefits.

Securing the common interest on local and regional scales (referred to by Brunner and Lynch as "adaptive governance") provides the rationale for effective climate adaptation strategies. This requires abandoning the irreducibly global consensus seeking approach in favor of open debate and discussion of a broad range of policy options that stimulate local and regional solutions to the multifaceted and interrelated issues surrounding climate change.

The IPCC needs to get out of the way so that scientists and policy makers can better do their jobs.

Conclusion

The diagnosis of paradigm paralysis seems fatal in the case of the IPCC, given the widespread nature of the infection and intrinsic motivated reasoning. We need to put down the IPCC as soon as possible – not to protect the patient who seems to be thriving in its own little cocoon, but for the sake of the rest of us whom it is trying to infect with its disease. Fortunately much of the population seems to be immune, but some governments seem highly susceptible to the disease. However, the precautionary principle demands that we not take any risks here, and hence the IPCC should be put down.

John R. Christy

Dr. John R. Christy is the Distinguished Professor of Atmospheric Science and Director of the Earth System Science Center at the University of Alabama in Huntsville where he began studying global climate issues in 1987. Since November 2000 he has been Alabama's State Climatologist. In 1989 Dr. Roy W. Spencer (then a NASA/Marshall scientist and now a Principle Research Scientist at UAH) and Christy developed a global temperature data set from microwave data observed from satellites. For this achievement, the Spencer-Christy team was awarded NASA's Medal for Exceptional Scientific Achievement in 1991. In 1996, they were selected to receive a Special Award by the American Meteorological Society "for developing a global, precise record of earth's temperature from operational polar-orbiting satellites, fundamentally advancing our ability to monitor climate." In January 2002 Christy was inducted as a Fellow of the American Meteorological Society.

Dr. Christy has served as a Lead Author, Contributor and Expert Reviewer for the U.N. reports by the Intergovernmental Panel on Climate Change in which the satellite temperatures as well as other climate datasets he constructed were included. He has served on five National Research Council panels or committees and has performed research funded by NASA, NOAA, DOE, DOT and the State of Alabama and has published many articles including studies appearing in Science, Nature, Journal of Climate and The Journal of Geophysical Research. Dr. Christy has provided testimony to several congressional committees.

Dr. Christy received the M.S. and Ph.D. degrees in Atmospheric Sciences from the University of Illinois (1984, 1987). Prior to this career path he had graduated from the California State University in Fresno (B.A. Mathematics, 1973, Distinguished Alumnus 2007) and taught Physics and Chemistry as a missionary teacher in Nyeri, Kenya for two years. After earning a Master of Divinity degree from Golden Gate Baptist Seminary (1978) he served four years as a bivocational mission-pastor in Vermillion, South Dakota where he also taught college math.

Dr. Christy is married to the former Babs Joslin, a fellow missionary whom he met in Kenya. They have two married children, Mrs. Alison Fields, an Applied Math graduate of Auburn University and Brian, a Physics/Math graduate of Auburn and PhD graduate from University of Maryland. He is now a Post-Doc Physicist at Franklin and Marshall University. Garet and Alison Fields are parents of three of their grandchildren and Brian and Kristen Christy of their fourth. Dr. Christy also runs, completing races from 2 to 31.1 miles over rugged terrain.

Chairman SMITH. Thank you, Dr. Christy.
Dr. Titley.

TESTIMONY OF DR. DAVID TITLEY, DIRECTOR, CENTER FOR SOLUTIONS TO WEATHER AND CLIMATE RISK, PENNSYLVANIA STATE UNIVERSITY

Admiral TITLEY. Thank you, Chairman Smith and Ranking Member Bonamici, distinguished Members for the opportunity and privilege to present to you today on this very, very important topic.

As mentioned, I am Dave Titley and I currently am a Professor of Practice at Meteorology at the Pennsylvania State University and the Founding Director of the Center for Solutions to Weather and Climate Risk. I am here in my personal capacity today, and the views that I represent are mine.

When—in the Navy, we have—I am just going to talk. It is much, much easier.

In the Navy, we have a saying called the "bottom line up front," and it is like just tell me what I really, really need to know. So here, sir, is the way that I see the salient points for today's hearing.

The first is, is that the climate change is very real. I was very, very encouraged, sir, to hear from your opening statement your numerous quotes from the IPCC. The IPCC shows that the climate is in fact warming. We see that in the temperature record in both the air and the ocean, and as you I am sure know, 90 percent of the heat is in fact in the ocean. It is kind of the Willie Sutton theory. Why do we study it? It is where the heat is.

The ice is collapsing. We see the ecosystems moving. We see the sea level rising. If you look at any one of these individually, you can sometimes try to figure out well, what is going on here, but when you put it all together, it gets pretty hard to come up with something other than that the climate is changing, and we know the basics. We certainly still have questions on the details like tornados, like typhoons, but we kind of understand the basics. I mean, this is cutting-edge 19th-century science. Fourier, Tyndall, Arnhus all figured this stuff out in the 19th century.

If you take a look at Jim Hanson's model that he—climate model he published in Nature magazine in 1980, it showed the rise in temperature. In fact, he was too conservative. The temperature, the global temperature, has actually risen more than what Hanson projected. And some models are going to be too slow, some are going to be too aggressive. I think there is a saying called "all models are wrong but some are useful."

So what can we actually tell out of these models? So, I mean it is—hopefully we are doing more than just like looking at individual models because, you know, frankly, you don't need a brain to do that, but we understand the science, we understand the physics, we understand then what the models can help us in, and we kind of look at this in a risk framework. I mean, again, I am a—we are all sort of victims of our past circumstance, and mine is national security. I spent 32 years in the Navy. So I kind of look at this as the way that we looked at security issues in the national defense realm. We did not necessarily wait for that extreme event.

I mean, imagine if this was a terrorism hearing in the summer of 2000. What would we say? Well, we would say we have had a few events, you know, some people in Africa, we had a bombing in the World Trade Center in the 1990s but we really haven't see a big signal. Is that where we want to be on climate? Do we want to wait for that catastrophic signal to then say oh, my, God, now we need to do things. So I kind of see the system blinking red here. And why do I say that? Warmer oceans, moister atmosphere, warmer air temperatures, does it mean that we have seen that catastrophic signal? No. But the absence of evidence is not the evidence of absence. So we don't know, and there is a big, big difference between not knowing versus saying well, since we haven't seen anything, therefore it is not going to happen.

So I kind of would look for a risk management strategy. I was very happy, sir, to hear about the Weather Forecasting Improvement Act. As you may know, the Department of Defense and Department of Navy have funded, starting with President's budget FY13, a program called Earth System Prediction Capability. It is interagency. NOAA is participating. I would strongly encourage and hope that the Committee can help NOAA further participate in that along with NASA, Department of Energy and Department of Defense. The idea is to get better at everything from zero hours or today's forecast to about 30 years because this is where in the real world we make our budgets, we make our decisions. It is sort of, you know, our infrastructure decisions. If you are a city planner, if you are an emergency manager, you know, seasons, years, that is where we need to get better, that intersection of weather and climate.

As Dr. Christy said, there is a lot to learn there, and I hope we can help out.

Thank you very much, sir.

[The prepared statement of Admiral Titley follows:]

A Factual Look at the Relationship between Weather and Climate

David W Titley, Rear Admiral USN (Ret.), Ph.D.

Professor of Practice and Director, Center for Solutions to Weather and Climate Risk

The Pennsylvania State University

Briefing to the United State House of Representatives Committee on Science, Space and Technology, Subcommittee on the Environment

Thank you Chairman Stewart, Ranking Member Bonamici, distinguished members of the Committee on Science, Space and Technology for the opportunity to present today. This is a privilege to come before you today and discuss this very important topic.

I am David Titley and currently serve as the Founding Director of the Center for Solutions to Weather and Climate Risk at the Pennsylvania State University. I had the honor of serving in the United States Navy for 32 years and retired last year as a Rear Admiral and Assistant Deputy Chief of Naval Operations for Information Dominance. When I retired, I was also the Oceanographer and Navigator of the Navy, and Director of U.S. Navy Task Force Climate Change. Subsequent to my time in the Navy, I served as Deputy Undersecretary of Commerce for Operations, sometimes known as the Chief Operating Officer position of the National Oceanic and Atmospheric Administration (NOAA). My Center at Penn State currently receives no Federal Funding; my views today are my own. I am here today because I believe a factual discussion of climate change, its links to weather, what we do and do not know, and some possible ways to deal with this challenge of an uncertain future is a very important discussion for our nation's leadership to have. Thank you for holding this hearing.

In the Navy we have a saying, to just give me the 'Bottom Line Up Front' or BLUF. So here's my BLUF for today's hearing:

- **The Change is Real:** The change in the climate, and therefore the change in the weather, is real. Multiple independent sources of data show a rise in temperatures and rise in the ratio of record high temperatures to record low temperatures; an increase in the intensity of precipitation events – that is, the hardest rains are getting harder; the continued collapse in the area and amount of summer-time sea ice in the Arctic Ocean;

an acceleration of sea level rise; acidifying oceans; and ecosystems moving poleward and up in elevation where possible.

- **The Absence of Evidence is not the Evidence of Absence:** Although we know a lot, we don't know everything. Specifically, there is still much to discover about how the changing climate will impact rainfall in specific areas, the number, distribution and intensity of severe storms, and the impact on hurricane and typhoon frequency, size, and strength. How the changes in Arctic Sea Ice and the opening of the Arctic Ocean will impact the weather we experience here in the mid-latitudes is still being debated and explored within the weather and climate communities. But I cannot over-emphasize that not knowing is very different than knowing that there not an impact. As Dr. Jeffrey Marquess and I stated in a recent Op-Ed: "to ignore the possibility of change is the same as assuming we have high confidence there will be no change - and that is simply not true."[1]
- **We know how to succeed even when the future is unknown:** Traditional risk planning takes the chance or probability of an event and multiplies it by the impact. But even when it is difficult to assess the likelihood of a specific event, there are still available methods by which risk planning and mitigation can be accomplished. Our national security teams frequently have to account for these "deep uncertainties" and they have a variety of tools to assist them. Rich scenario planning, assumptions-based planning and similar methods can be used with the goal of identifying all plausible vulnerabilities and their subsequent impacts. National Security and strategic military planners have used these tools successfully for decades – we can apply these methods and adapt them to the climate change challenge.

The earth's climate has naturally varied for millions of years (Figure 1 – From John Englander "High Tide on Main Street"; it will continue to do so for millions more (e.g., . However, humans, through the release of greenhouse gases, also have the capability to modify the earth's climate in a way that previously could occur only by nature. If the climate has always changed in the past and will do so in the future, then why do we care? We care because we are forcing a change to a system that has been remarkably stable in the past 8-12 thousand years (Figure 2 -- From John Englander "High Tide on Main Street"); the time when humans developed agriculture, civilization and our modern way of life. It's not that the climate of the past few thousand years is optimal *per se*, but its stability allowed us to base a civilization on an overall predictability of where our coasts would be, when the rains would come, and the length of the growing seasons. Later on we would construct our buildings, towns, and cities all based on a historical understanding of the averages and extremes of our historical climate. And must

[1] http://hamptonroads.com/2013/11/marqusee-and-titley-did-we-learn-hurricane-sandy

importantly, we made a foundational assumption that past climate predicted our future. Those assumptions no longer hold.

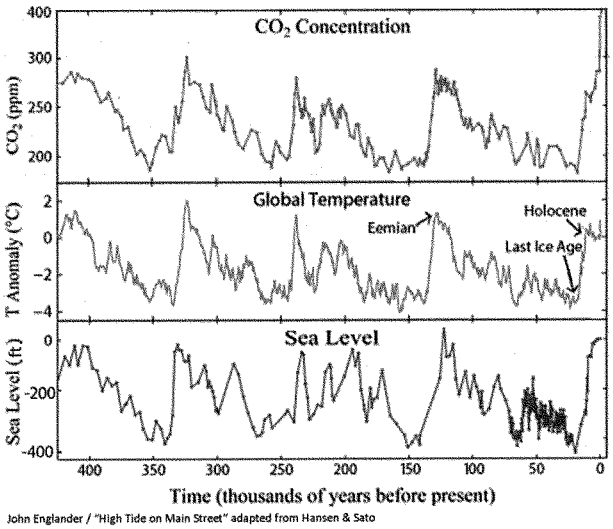

Figure 1 – From John Englander "High Tide on Main Street"

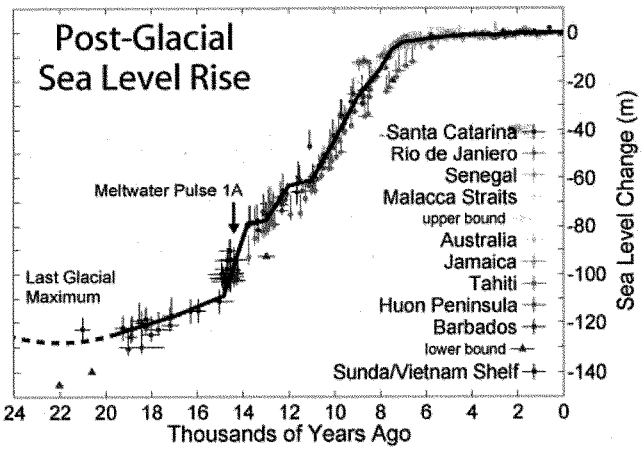

Figure 2 -- From John Englander "High Tide on Main Street"

While we certainly don't know everything about climate change and how it will impact the weather, we do know quite a lot. Doctors Heidi Cullen and Marshall Shepherd both testified earlier this year before the U.S. Senate Committee on the Environment and Public Works. Both witnesses eloquently and factually addressed what we know about rising temperatures and changing rain and snowfall patterns. To quote Dr. Cullen: "Across the globe, we are observing things we would not expect to observe in a climate controlled purely by natural variability. According to NOAA, 2012 was the 10th warmest year since climate records began in 1880." Dr. Cullen goes on to state that "this marks the 36th consecutive year (since 1976, when Gerald R. Ford was President) that the yearly global temperature was above average."[2] A record like that is equivalent to flipping a coin and getting 'heads' 36 consecutive times. The chances of that happening with an un-weighted coin: 1 in 68 billion. Put another way, you are almost 400 more times more likely to win the Powerball jackpot than you are to see this temperature record if the climate was not changing. Dr. Cullen goes on to state that the first 12 years of the 21st century rank in the top 14 warmest of all years recorded (again, since 1880), and that last year was warmer than every year in the 20th century except for 1998.

The United States is participating fully in this trend. As noted by Dr. Marshall in his testimony, "NOAA confirms that average temperature in the United States for 2012 was ... 3.2 degrees Fahrenheit above the 20th century average, and 1.0 degree above 1998, the previous warmest year in the United States"[3] (Figure 3).

[2] http://www.epw.senate.gov/public/index.cfm?FuseAction=Files.View&FileStore_id=c88f09be-da24-4501-8a69-c53f6b730c81

[3] http://www.epw.senate.gov/public/index.cfm?FuseAction=Files.View&FileStore_id=1f670e51-ddc9-4ef0-a3a7-b8d4afb8effc

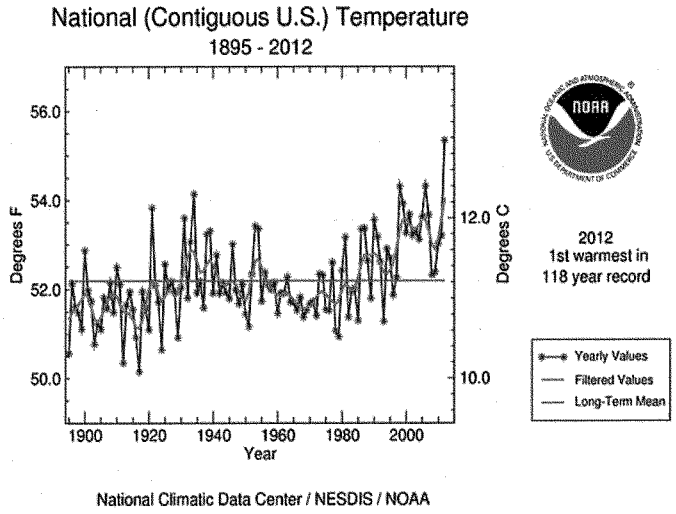

Figure 3

Another way to look at the change in temperature is to examine and compare the ratio between record high temperatures and record low temperatures (Figure 4 -- Meehl et. al. The Relative Increase of Record High Maximum Temperatures Compared to Record Low Minimum Temperatures in the U.S., Geophysical Research Letters, 2009). While there is much season-to-season and year-to-year variability, when we step back and examine the data some overall trends become clear. If the climate were not changing, we would expect to see fewer record highs and record lows, and a roughly equal ratio between highs and lows. Instead, the data show a distinct upward bias in the ratio. What is particularly interesting is a slight increase in the number of record highs, but a dramatic decrease in the number of record lows being set; on average, nights are warming faster than days. An example of this phenomenon can be seen in the temperature record for Washington DC (Figure 5 – Grieser http://www.washingtonpost.com/blogs/capital-weather-gang/wp/2013/06/26/warm-temperature-records-dramatically-outpacing-cold-records-in-washington-d-c/).

With respect to heavier amounts of rain, or increased downpours, I again quote Dr. Cullen: "Heavy downpours are increasing nationally, especially over the past three to five decades. According to the draft National Climate Assessment, those events in the top 1 percentile of intensity have increased in every region of the contiguous United States since 1958 – with the

largest increases occurring in the Midwest and Northeast (Figure 6 -- Percent increase from 1958 - 2011 in the amount of precipitation falling in very heavy events. Draft National Climate Assessment, Chapter 2, 2013). The reason for these heavier rain events is relatively simple: in a world warmed by heat-trapping greenhouse gasses, there's more evaporation, the atmosphere can hold more water vapor, and when that water vapor condenses as rain or snow, there's more of it available to fall." However, just as noted with the temperature record, there is still much seasonal, annual, and inter-seasonal variability in the precipitation. Human-forced climate change has not replaced either natural climate variability nor the day-to-day changes in weather we are all familiar with. Rather, the human-induced changes in climate are in addition to those produced by nature.

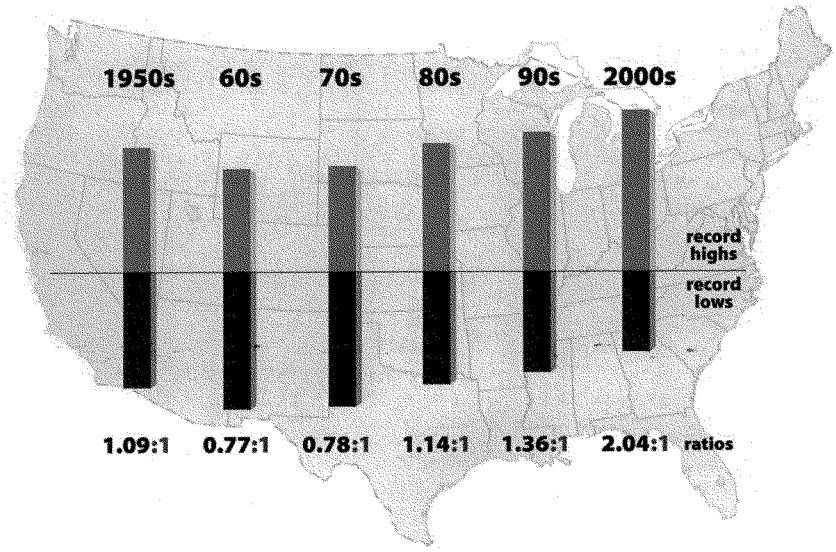

Figure 4 -- Meehl et. al. The Relative Increase of Record High Maximum Temperatures Compared to Record Low Minimum Temperatures in the U.S., Geophysical Research Letters, 2009

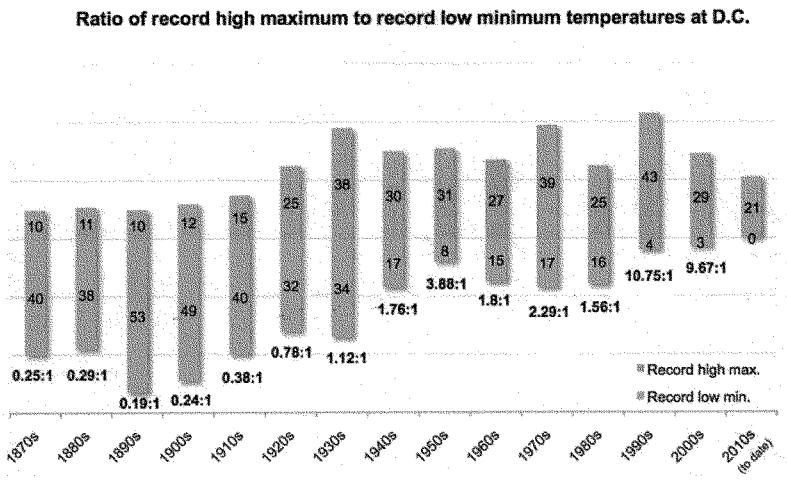

Figure 5 – Grieser http://www.washingtonpost.com/blogs/capital-weather-gang/wp/2013/06/26/warm-temperature-records-dramatically-outpacing-cold-records-in-washington-d-c/

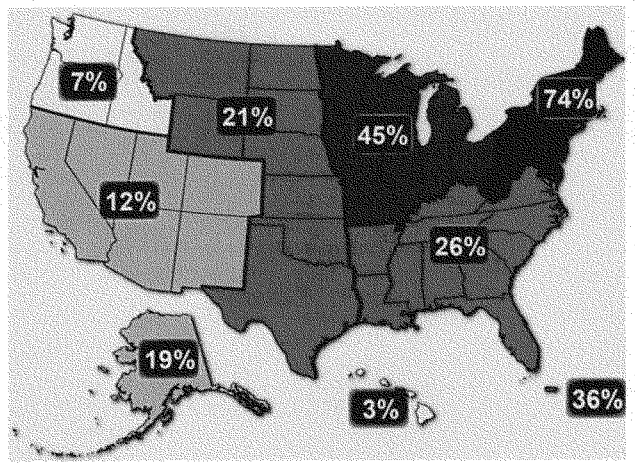

Figure 6 – Percent increase from 1958 - 2011 in the amount of precipitation falling in very heavy events. Draft National Climate Assessment, Chapter 2, 2013

Nowhere in the world are the changes to today's climate more dramatic than in the Arctic. In less than a generation, the Arctic has transitioned from an Ocean that remained mostly frozen year round with extensive thick, multi-year ice to an environment with greatly reduced ice area and thickness. In 2009 I told Navy leadership that I expect to see several weeks of ice-free conditions in the arctic by the mid-to-late 2030's. When I made that forecast, many people thought I was way too aggressive in expecting the ice to disappear. Now, less than five years later, people believe I may have been too conservative on my forecast. Figure 7 -- PIOMAS Mean monthly Arctic Sea Ice Volume for April and September. Dashed lines parallel to linear fit represents one and two standard deviations from the trend. Error bars are estimated based on thickness observations and model sensitivity studies. Adapted from Schweiger et. al, Uncertainty in modeled Arctic sea-ice volume. Journal Geophysical Research, 2009from the University of Washington's Polar Science Center, shows the decline in both winter (April) and summer (September) ice volume (or the average extent multiplied by the average thickness). Note the lack of recovery in volume between 2012 and 2013.

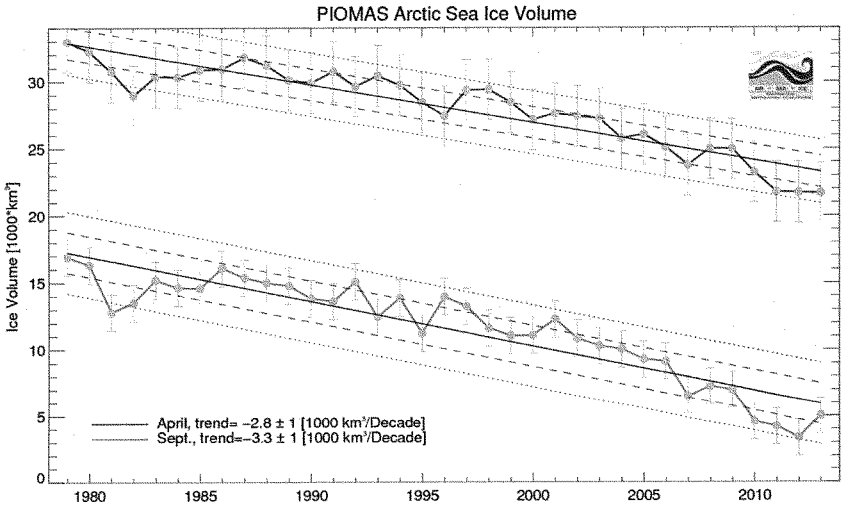

Figure 7 -- PIOMAS Mean monthly Arctic Sea Ice Volume for April and September. Dashed lines parallel to linear fit represents one and two standard deviations from the trend. Error bars are estimated based on thickness observations and model sensitivity studies. Adapted from Schweiger et. al, Uncertainty in modeled Arctic sea-ice volume. Journal Geophysical Research, 2009

Another component of climate change that is increasing well known is Sea Level Rise. Caused by the warming of the ocean (e.g., thermal expansion), melting glaciers and increasingly the flow of both the Greenland and West Antarctic ice sheets into the ocean; sea level rise is one of the most serious implications of climate change. A rise in the global sea level provides a higher

"launching point" for any storm surge. Figure 8 -- *Past and future sea-level rise. For the past, proxy data are shown in light purple and tide gauge data in blue. For the future, the IPCC projections for very high emissions (red, RCP8.5 scenario) and very low emissions (blue, RCP2.6 scenario) are shown. Source: IPCC AR5 Fig. 13.27.* shows the latest IPCC projections for average global sea level rise. The Panel now expects a rise between 60 cm and a meter (or about 2-3 feet) by 2100. This is a substantial increase over the 2007 IPCC report. The rise in average sea level is one of the reasons that coastal flooding is expected to worsen, even without assuming any change in the frequency or intensity of the storms themselves. Higher sea levels also increase the risk of salt-water intrusion on fresh water aquifers and impede the drainage of storm sewers. In fact today in Miami Beach at high tide storm sewers routinely back up and flood seawater onto the streets they are supposed to be draining.[4] Figure 9 -- "Recurrent Flooding Study for Tidewater Virginia (2013). Data courtesy of L. Atkinson, Old Dominion Universityshows the number of hours a neighborhood in Norfolk Virginia is now flooding each year. Like all weather and climate data, there is much short-term variability, but the accelerating trend is clear – and worrisome.

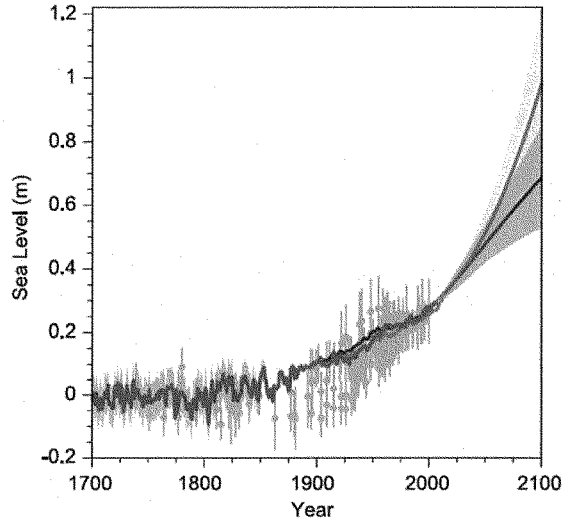

Figure 8 -- *Past and future sea-level rise. For the past, proxy data are shown in light purple and tide gauge data in blue. For the future, the IPCC projections for very high emissions (red,*

[4] http://miami.cbslocal.com/2013/10/17/blame-the-moon-for-south-floridas-tidal-flooding/

RCP8.5 scenario) and very low emissions (blue, RCP2.6 scenario) are shown. Source: IPCC AR5 Fig. 13.27.

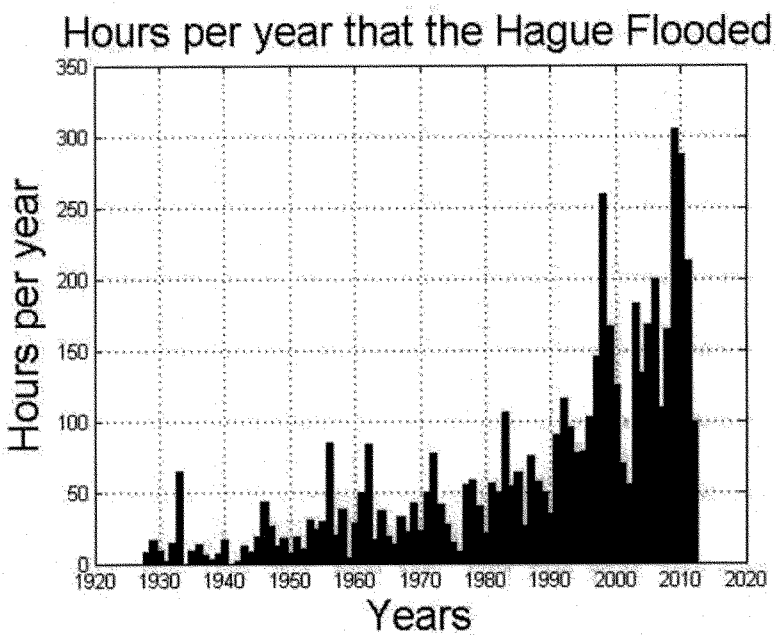

Figure 9 -- "Recurrent Flooding Study for Tidewater Virginia (2013). Data courtesy of L. Atkinson, Old Dominion University

In addition to these observed physical changes (temperature, rainfall intensity, Arctic sea ice, sea level rise) observed, there are equally dramatic changes in the ecosystems. Flora and fauna have been moving polewards and upwards at a rate of 10.5 miles and 36 ft respectively, per decade[5]. These changes are most apparent at the boundary of an ecosystem. Species are stressed when, for whatever reason, they can no longer migrate as quickly as the climate is changing. The climate change is exacerbating changes and existing stresses in the ecosystem, with the unfortunate consequence of increasing risk to pests and invasive species. As an example, the Greater Yellowstone Ecosystem now hosts a bark beetle population "outside the historic range of

[5] National Climate Assessment, Chapter 8 (2013)

variability"[6]. Warmer winters have allowed more beetles to survive winter, complete two lifecycles in a year rather than the tradition one, and move further north and up in elevation.

In summary, a combination of multiple, independent sources of data provide the basis to the latest conclusion from the Intergovernmental Panel on Climate Change: "Warming of the climate system is unequivocal, and since the 1950's, many of the observed changes are unprecedented over decades to millennia… Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system[7]." We should not be surprise; these conclusions rest on science discovered in the 19th century by Fourier, Tyndall, Arrhenius and their colleagues.[8]

A graphical summary (Figure 10 -- Source: http://www.munichre.com/app_pages/www/@res/pdf/media_relations/press_dossiers/durban_2011/press_folder_durban_2011_en.pdf) from Munich Re shows the increasing number of storm, hydrologic and climatological events over the past 30 years. Note how the number of geophysical events (e.g., earthquakes, tsunamis, volcanic eruptions) remains relatively constant, while the trend for weather, water and climate events is on the rise.

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[6] *Ibid*

[7] Summary for Policy Makers of the Working Group I contribution to the IPCC Fifth Assessment Report (2013)

[8] http://www.aip.org/history/climate/co2.htm

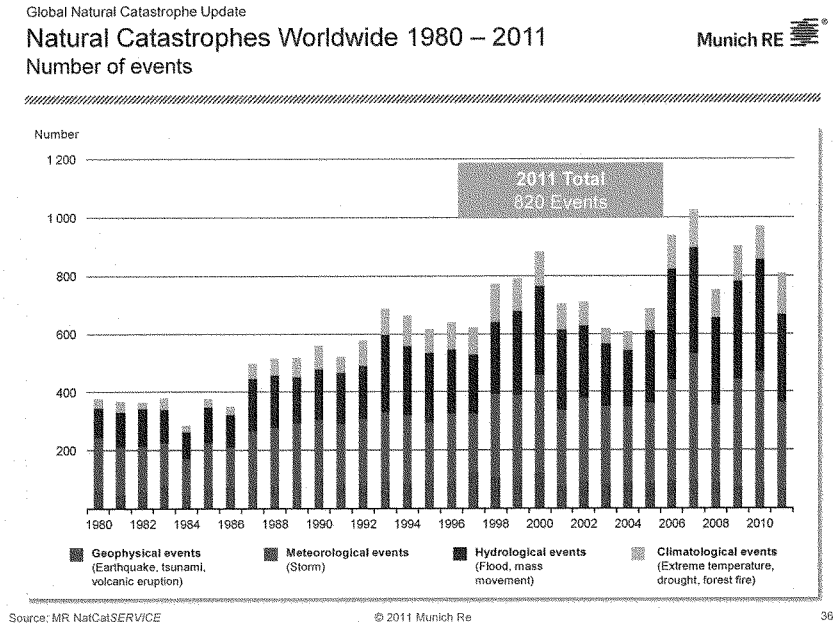


Figure 10 – Source: http://www.munichre.com/app_pages/www/@res/pdf/media_relations/press_dossiers/durban_2011/press_folder_durban_2011_en.pdf

But, while the 'big picture' is well understood, there are still important details yet to be discovered. Many of these details involve severe thunderstorms and tornados, as well as tropical cyclones, commonly known as hurricanes or typhoons. There are varied reasons for no clear links: the natural variability may overwhelm any climate signal, especially if the historical record contains changes in observational methods or instruments; a changed climate may simultaneously enhance and suppress a specific type of weather phenomena; or there simply may not be a link between the changed climate and the specific weather type in question.

Tornados are a good example of high-impact weather where we do not yet know if there is a climate link. A casual glance at the record of destructive tornados, shown in Figure 11, would at first glance seem to indicate either no link between climate change and the number of violent (F3+) tornados – or perhaps even a slight decrease with time. However, as described by Dr. Paul Markowski and colleagues' excellent recent article[9] the U.S. record of violent tornados is far

[9] http://www.livescience.com/41632-the-truth-about-tornadoes.html

from consistent in its assessment, with over-rating tornado strength common prior to the 1970's and frequently under-rating intensity in the 2000's.

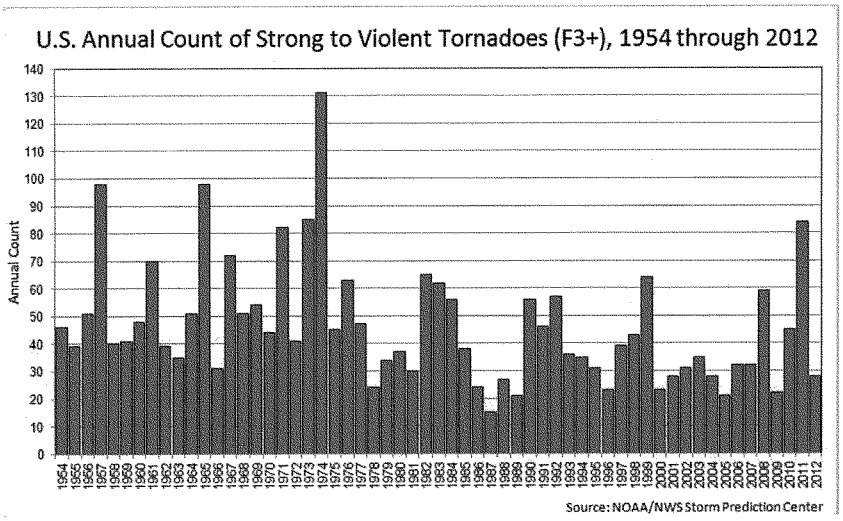


Figure 11

The link between hurricanes and typhoons and climate change is still not yet known. Large annual and regional variation and many competing, and conflicting, factors come together when trying to explain the past and predict the future of hurricane intensity. Hurricanes require a deep layer of warm water to reach their maximum intensity. The average water temperature of the top few hundred feet of ocean determines the storm's maximum potential strength. And we know the upper layers of the ocean have been warming. But hurricanes are not only creatures of the ocean – they cannot exist unless the atmosphere is also favorable. 'Favorable' for a hurricane means consistent winds with increasing height, high moisture content and a general rising of the atmosphere. If these conditions are not met, the hurricane either will not form, or it will be much weaker than its potential. The just-concluded 2013 northern hemisphere hurricane and typhoon season saw examples of a unfavorable and favorable atmospheres: In the North Atlantic, dry, sinking air and hostile winds produced one of the quietest hurricane seasons in recent memory. By contrast, favorable atmospheric conditions and very warm, deep waters spawned five 'super-typhoons' with sustained winds greater than 150 mph, including Super-Typhoon Haiyan that made landfall in the Philippines with maximum sustained winds estimated at 195 mph.

What does all this mean? The absence of evidence is not the evidence of absence. Or stated another way, saying we don't know today the impact of climate change on these phenomena is very different than stating that climate change has no impact on typhoons and hurricanes. What we do know is that these storms are forming in a warmer, moister environment and above a warmer ocean. We also know that current research indicates our future may include more intense, and possibly more frequent, storms[10]. That is a risk not to be summarily discounted.

I am frequently asked if a specific or extreme event (for example, typhoon, Sandy, drought, snowstorm) is or is not "caused" by climate change. Frankly, that is the wrong question. It's like asking someone if their childhood upbringing "caused" him or her to attend a specific college. It's more useful to think of climate as the deck of cards from which our daily, specific weather events are dealt. And as the climate changes, so does our deck of cards. For every degree of warming, we add an extra Ace into the deck. So, over time, the unusual hands, like a Full House with Aces high, become more plausible – and more common – with time.

A useful way to think about how to deal with this uncertain, but not completely unknown, future is through a risk management framework. Rather than wait for a series of extreme, or disruptive, events to occur and then react, an alternate way to approach our changing climate may be to adopt some proven tenets from the security community. Figure 12 Source: http://online.wsj.com/news/articles/SB10001424053111904106704576583203589408180# shows the number of war-related deaths on the battlefield over the past 70 years.

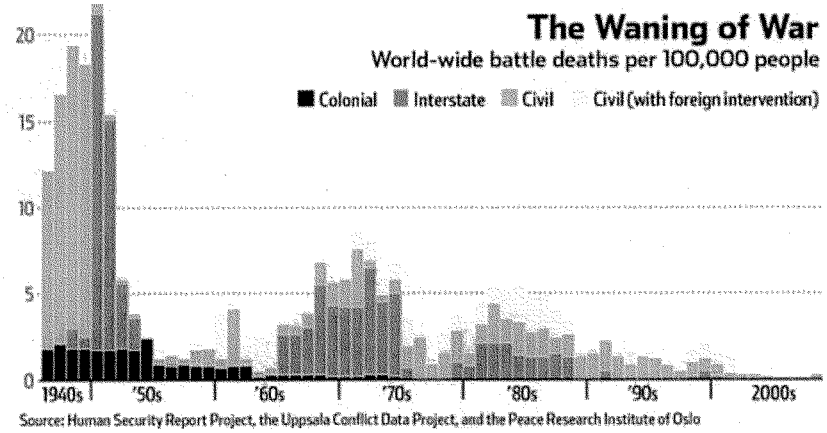


Figure 12 Source: http://online.wsj.com/news/articles/SB10001424053111904106704576583203589408180#

[10] Emanuel, K., Downscaling CMIP5 Climate Models Shows Increased Tropical Cyclone Activity over the 21st Century. *Proceedings National Academy of Sciences*, 2013

If these statistics are the climate-equivalent of extreme events, one might be tempted to say we no longer have a need to invest in our military or domestic security programs. That would of course be ridiculous; we rightly invest in our security and defense as one component of hedging against unknown or unlikely security risks. Likewise with a changing climate: it matters less which specific event was or was not directly related to climate change or how many specific events occur in any given year. Climate risks and security risks share another trait in common: "The worst matters much more than the bad"[11]. In other words: What are the near-term and future risks to our way of life – and what policies and structures should we put in place to manage and mitigate those risks?

So how might we go about such a challenge? One way might be to start with this six-step process, consistent in broad goals with the President's Climate Action Plan[12]:

- Develop better understanding of the factors and primary drivers behind the loss numbers. The first step to solving a problem is making sure you are working on the right issues.
- Set up a monitoring system. Assign specific responsibilities. Many National Academy Society (NAS) reports have called for such a monitoring system. The NAS 'Abrupt Climate Changes' report released last week is the latest to call for such a monitoring system.
- Adjust policies today for what we know – and for what we might reasonably expect in the coming decades. Hope should not be the strategy.
- Invest in better understanding – and ultimately prediction – at the boundary between weather and climate. While scientifically this is very challenging, it is also very important for people and a myriad of decisions. From a security, economic, agricultural, infrastructure and policy perspective, greater climate knowledge of the next few seasons to the next decade or two would be extremely useful. While we should not use today's uncertainty as an excuse to defer action, better understanding of the climate over the next 2-20 years would be very useful in allocating scarce resources. The Department of the Navy is funding today the 'Earth System Prediction Capability' or ESPC – an interagency program designed to provide our country the next-generation of integrated air-ocean-ice-land prediction system[13]. Navy is working with other components of the DoD, as well as NOAA, NASA and the Department of Energy to ensure our nation has

[11] Burroughs, William "Climate Change in Prehistory: The End of the Reign of Chaos", Cambridge University Press, 2005

[12] http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf

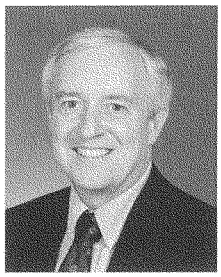
[13] http://espc.oar.noaa.gov/

the world's best operational weather and climate prediction tools at our disposal. This National Imperative must be a National Priority.

- As we work on adapting to our changing climate we should not lose sight of the big picture: how to move the world's energy system to a predominantly non-carbon based energy source to power the world. How can we unleash the innovation and energy that makes our country great to solve one of the grand challenges of the 21st Century? We are the country that is developing a self-driving car and whose private companies can send satellites to geosynchronous orbit. With the right policies I am sure our private sector can develop – and profit from – energy solutions that will power the world in a sustainable fashion into the future.

In closing, our country is dealing with a significant change in the world's climate; it is a large challenge. But our country has met challenges of this magnitude before and succeeded – and we will do so again. We do not need the "4-D's": Doom, Denial, Despair and Delay. They are not helpful. We don't know everything but we know enough to act now. By focusing our efforts in a risk-based framework on meeting the climate challenge, we can prepare for the short-term while shaping our longer-term future. We can provide the policies, stability and guidance our country needs to unleash our country's energy, creativity and initiative. I am convinced we will be proud and amazed at what we can accomplish. Thank you very much for your time and attention; I look forward to taking your questions.

Dr. Titley is a Professor of Practice in the Department of Meteorology at the Pennsylvania State University. He is also the founding Director of Penn State's Center for Solutions to Weather and Climate Risk.



Dr. Titley is a nationally known expert in the field of climate, the Arctic, and National Security. He served as a naval officer for 32 years and rose to the rank of Rear Admiral. Dr. Titley's career included duties as Commander, Naval Meteorology and Oceanography Command, Oceanographer and Navigator of the Navy, and Deputy Assistant Chief of Naval Operations for Information Dominance. While serving in the Pentagon, Dr. Titley initiated and led the US Navy's Task Force on Climate Change. After retiring from the Navy, Dr. Titley served as the Deputy Undersecretary of Commerce for Operations, the Chief Operating Officer position at the National Oceanic and Atmospheric Administration.

Dr. Titley has spoken across the country and throughout the world on the importance of climate change as it relates to National Security. The Department of Defense requested he present on their behalf at both Congressional Hearings and the Intergovernmental Panel on Climate Change (IPCC) meetings from 2009 to 2011.

Dr. Titley is a member of the Hoover Institution's Arctic Security Initiative, and serves on the Advisory Boards of the Applied Research Laboratory at Penn State, the Center for Climate and Security, Columbia University's Center for Research on Environmental Decisions, and the Association of Climate Change Officers. He is a member of the National Academies of Science committee on Geoengineering and the Center for Naval Analysis' Military Advisory Board and co-chairs the National Research Council's "A Decadal Survey of Ocean Sciences" committee.

In 2009 Dr. Titley was elected a Fellow of the American Meteorological Society and in 2011 was awarded an honorary Doctorate from the University of Alaska, Fairbanks.

Chairman SMITH. Thank you, Dr. Titley.
Dr. Pielke.

**TESTIMONY OF DR. ROGER PIELKE JR.,
PROFESSOR AND DIRECTOR,
CENTER FOR SCIENCE AND
TECHNOLOGY POLICY RESEARCH,
UNIVERSITY OF COLORADO**

Dr. PIELKE. Chairman Smith, Ranking Member Bonamici, thank you for hearing my testimony today. I am a Professor of Environmental Studies at the University of Colorado. Before I jump into my substance, I do want to say I was an intern on this Committee in 1991 under George Brown, and I have a lot of respect for the work of the Members and the staff, and it is always great to come back.

I have three take-home points, and then underneath that I will have a few more specifics. Number one, there exists exceedingly little scientific support for claims found in the media and political debate that hurricanes, tornados, floods and drought have increased in frequency or intensity on climate time scales either in the United States or globally. Two, similarly, on climate time scales, it is incorrect to link the increasing cost of disasters with the emissions of greenhouse gases. Three, these conclusions that I have just reported are part of a broad scientific consensus including that recently reported by the Intergovernmental Panel on Climate Change in its 5th assessment report as well as a special report it did last year on extreme events.

So here are a few more specifics. Globally, weather-related losses measured in dollars have not increased since 1990 when the data starts being good as a proportion of GDP. Insured catastrophic losses have not increased as a proportion of GDP since 1960. Hurricane landfalls have not increased in the United States in frequency, intensity or normalized damage since at least 1990. The same holds true for tropical cyclones globally since at least 1970, again when the data is good.

Now, people in New York and New Jersey might not agree with this, but the United States is actually in an extended period of relatively good luck with respect to hurricane landfalls. We haven't seen a category 3 landfall for the longest time period since 1900, at least. If rates return to the historical average, we will see much more hurricane damage than we have in recent years.

Floods have not increased in the United States in frequency or intensity since at least 1950. Flood losses as a percentage of U.S. GDP have actually dropped by 75 percent since 1940.

Tornados in the United States have not increased in frequency, intensity or normalized damage since 1950, and based on research that we have done, there is some evidence in fact that they have actually declined, the strongest tornados.

Drought has, and I quote from a U.S. government science assessment report, "for the most part become shorter, less frequent and cover a smaller portion of the United States over the last century." Globally, and I quote from a paper in Nature, there has been little change in drought over the past 60 years."

Now, that being the case, it is also true that the absolute cost of disasters will undoubtedly increase significantly in coming years due to greater wealth and population and locations exposed to extreme. So disasters will be an important focus of policy irrespective of the future course of climate change.

Now, to avoid any confusion, because this issue is so politicized, I thought I would make a few further statements to put my testimony into context.

Humans influence the climate system in profound ways including through the emission of carbon dioxide via the combustion of fossil fuels, and again, I point you to the IPCC, which has been mentioned as the authoritative basis for that statement. Researchers have detected and in some cases attributed a human influence in other measures of climate extremes beyond those that I discuss in my testimony including surface temperatures, specifically, heat waves, and some measures of precipitation extremes. The inability to detect and attribute increasing trends and the incidents of hurricanes, floods, tornados and drought does not mean that human-caused climate change is not real or of concern. It does mean, however, that some activists, politicians, journalists, corporate and government agency representatives, even scientists who should know better have made claims that are unsupportable based on evidence and research. Such claims when they are made could undermine the credibility of arguments for action on climate change, and to the extent that such false claims confuse those who make decisions related to extreme events, they could lead to poor decision-making.

A considerable body of research projects that various extremes may in fact become more frequent and/or intense in the future as a direct consequence of the human emission of carbon dioxide.

Our research and that of others suggests that even assuming that these projections are true, it will be many decades, perhaps longer before that signal of human-caused climate change can be detected in the statistics of hurricanes, and the same holds for other phenomena that have the same statistical properties. If you are looking for evidence of climate change, don't look at extreme events. Our decisions related to climate change will take place long before we have certainty on that topic.

Thank you for the opportunity to provide this testimony, and I look forward to your questions.

[The prepared statement of Dr. Pielke follows:]

STATEMENT OF DR. ROGER PIELKE, JR.
to the SUBCOMMITTEE ON ENVIRONMENT
of the COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
of the UNITED STATES HOUSE OF REPRESENTATIVES

HEARING on
A FACTUAL LOOK AT THE RELATIONSHIP OF CLIMATE AND WEATHER
11 December 2013

Short Biographical Note

My academic degrees are in mathematics, public policy and political science. I began studying extreme weather and climate in 1993 at the National Center for Atmospheric Research in Boulder, CO. Over the past 20 years I have collaborated with researchers around the world to publish dozens of peer-reviewed papers on hurricanes, floods, tornadoes, Australian bushfires, earthquakes and other subjects related to extreme events. Since 2001, I have been a professor of environmental studies at the University of Colorado. A longer bio can be found as an appendix to this testimony. My views on climate policy and politics, not discussed in this testimony, can be found in my recent book, *The Climate Fix* (Basic Books, 2011).

Take-Home Points

- There exists exceedingly little scientific support for claims found in the media and political debate that hurricanes, tornadoes, floods and drought have increased in frequency or intensity on climate timescales either in the United States or globally.[1]
- Similarly, on climate timescales it is incorrect to link the increasing costs of disasters with the emission of greenhouse gases.
- These conclusions are supported by a broad scientific consensus, including that recently reported by the Intergovernmental Panel on Climate Change (IPCC) in its fifth assessment report (2013) as well as in its recent special report on extreme events (2012).

Here are some specific conclusions, with further details provided below:

- Globally, weather-related losses ($) have not increased since 1990 as a proportion of GDP (they have actually decreased by about 25%) and insured catastrophe losses have not increased as a proportion of GDP since 1960.
- Hurricane landfalls have not increased in the US in frequency, intensity or normalized damage since at least 1900. The same holds for tropical cyclones globally since at least 1970 (when data allows for a global perspective).
- Floods have not increased in the US in frequency or intensity since at least 1950. Flood losses as a percentage of US GDP have dropped by about 75% since 1940.
- Tornadoes in the US have not increased in frequency, intensity or normalized damage since 1950, and there is some evidence to suggest that they have actually declined.
- Drought has "for the most part, become shorter, less frequent, and cover a smaller portion of the U. S. over the last century."[2] Globally, "there has been little change in drought over the past 60 years."[3]

[1] The IPCC defines climate timescales to be 30-50 years and longer.
[2] This quote comes from the US Climate Change Science Program's 2008 report on extremes in North America.
[3] Sheffield et al. in Nature, http://www.nature.com/nature/journal/v491/n7424/full/nature11575.html

- The absolute costs of disasters will increase significantly in coming years due to greater wealth and populations in locations exposed to extremes. Consequent, disasters will continue to be an important focus of policy, irrespective of the exact future course of climate change.

To avoid any confusion

Because the climate issue is so deeply politicized, it is necessary to include several statements beyond those reported above.

- Humans influence the climate system in profound ways, including through the emission of carbon dioxide via the combustion of fossil fuels.[4]
- Researchers have detected and (in some cases) attributed a human influence in other measures of climate extremes beyond those discussed in this testimony, including surface temperatures (heat waves) and in some measures of precipitation.[5]
- The inability to detect and attribute increasing trends in the incidence of hurricanes, floods, tornadoes and drought does not mean that human-caused climate change is not real or of concern.
- It does mean however that some activists, politicians, journalists, corporate and government agency representatives and even scientists who should know better have made claims that are unsupportable based on evidence and research.
- Such claims could undermine the credibility of arguments for action on climate change, and to the extent that such false claims confuse those who make decisions related to extreme events, they could lead to poor decision making.
- A considerable body of research projects that various extremes may become more frequent and/or intense in the future as a direct consequence of the human emission of carbon dioxide.[6]
- Our research, and that of others, suggests that assuming that these projections are accurate, it will be many decades, perhaps longer, before the signal of human-caused climate change can be detected in the statistics of hurricanes (and to the extent that statistical properties are similar, in floods, tornadoes, drought).[7]

The remainder of this written testimony provides data and references to support the claims made in the "take-home points" above. The "take-home points" are broadly supported by peer-reviewed research, US governmental assessments of climate science and the recent reports of the Intergovernmental Panel on Climate Change, specifically its Special Report on Extreme Events (IPCC SREX 2012) and its recently-released Working Group I report of its fifth assessment.[8]

[4] See, e.g., Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 2013, http://www.ipcc.ch

[5] The IPCC AR5 (2013) summarizes at the global scale, "Overall, the most robust global changes in climate extremes are seen in measures of daily temperature, including to some extent, heat waves. Precipitation extremes also appear to be increasing, but there is large spatial variability…There is limited evidence of changes in extremes associated with other climate variables since the mid-20th century."

[6] There are exceptions, for instance, the IPCC SREX (2012) concludes of winter storms, "There is medium confidence that there will be a reduction in the number of extratropical cyclones averaged over each hemisphere." However, the IPCC AR5 (2013) concludes of observations to date, "In summary, confidence in large scale changes in the intensity of extreme extratropical cyclones since 1900 is low."

[7] Crompton, RP, RA Pielke and KJ McAneney (2011), Emergence timescales for detection of anthropogenic climate change in US tropical cyclone loss data. *Environ. Res. Lett.* **6** (1) doi: 10.1088/1748-9326/6/1/014003

[8] IPCC SREX (2012) refers to IPCC, 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi,

Global Weather-Related Disaster Loss ($) Trends

What the IPCC SREX (2012) says:

- "There is high confidence, based on high agreement and medium evidence, that economic losses from weather- and climate-related disasters have increased"
- "There is medium evidence and high agreement that long-term trends in normalized losses have not been attributed to natural or anthropogenic climate change"
- "The statement about the absence of trends in impacts attributable to natural or anthropogenic climate change holds for tropical and extratropical [winter] storms and tornadoes"
- "The absence of an attributable climate change signal in losses also holds for flood losses."

What the data says:

1. **Globally, weather-related losses have not increased since 1990 as a proportion of GDP (they have actually decreased by about 25%).**

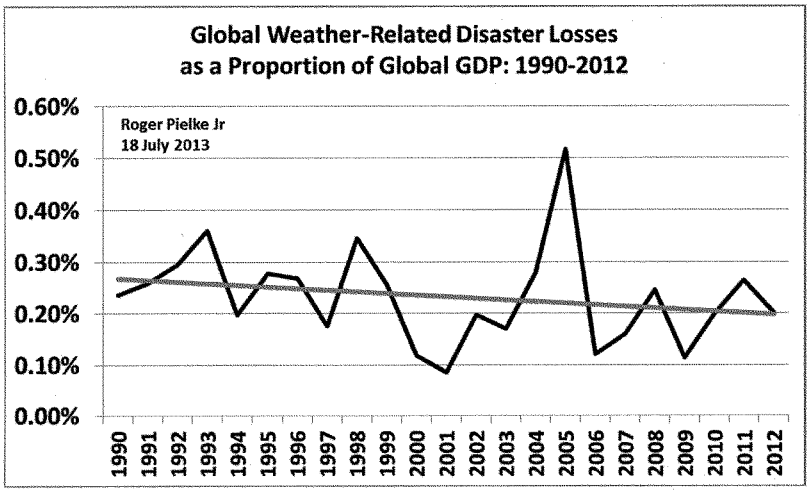


Figure 1. Global weather-related disasters as a proportion of global GDP, 1990-2012. Source of loss data: Munich Re.[9] Source of GDP data: United Nations.[10]

M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (Eds.) Cambridge University Press.

[9] http://www.munichre.com/en/reinsurance/business/non-life/georisks/natcatservice/great_natural_catastrophes.aspx

[10] http://unstats.un.org/unsd/snaama/dnllist.asp

2. Insured catastrophe losses have not increased as a proportion of GDP since 1960.

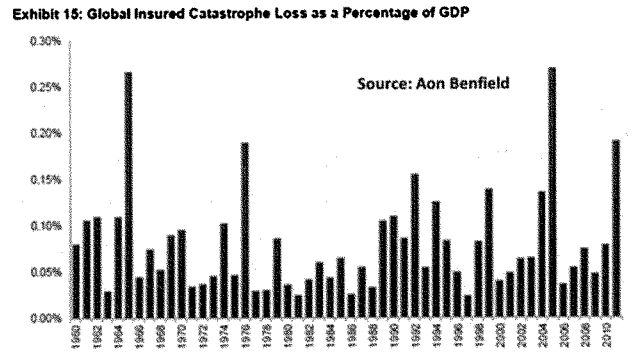


Figure 2. Global insured catastrophe loss as a percentage of global GDP. Source: Aon Benfield.[11]

Note: The peer-reviewed literature on this subject is extensive and robust. Neumayer and Barthel (2011), in a study conducted at the London School of Economics and supported financially by Munich Reinsurance conclude:

> "[B]ased on historical data, there is no evidence so far that climate change has increased the normalized economic loss from natural disasters."[12]

Hurricanes

What the IPCC AR5 (2013) says:

- "Current datasets indicate no significant observed trends in global tropical cyclone frequency over the past century … No robust trends in annual numbers of tropical storms, hurricanes and major hurricanes counts have been identified over the past 100 years in the North Atlantic basin"

What the IPCC SREX (2102) says:

- "Low confidence in attribution of any detectable changes in tropical cyclone activity to anthropogenic influences."

What the data says:

3. Hurricanes have not increased in the US in frequency, intensity or normalized damage since at least 1900.

[11] http://thoughtleadership.aonbenfield.com/Documents/20130103_reinsurance_market_outlook_external.pdf

[12] Neumayer, E. and F. Barthel. 2011. Normalizing Economic Loss from Natural Disasters: A Global Analysis, *Global Environmental Change*, **21**:13-24

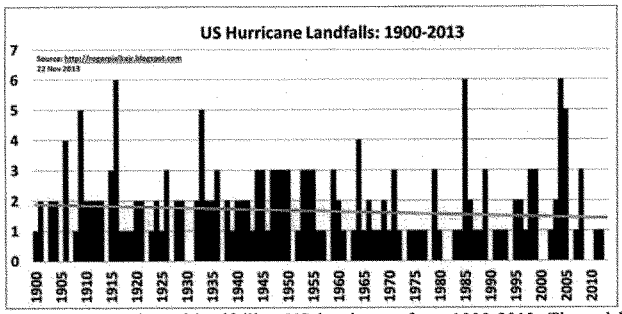


Figure 3a. Number of landfalling US hurricanes from 1900-2013. The red line shows the linear trend, exhibiting a decrease from about 2 to 1.5 landfalls per year since 1900. Source: NOAA.[13]

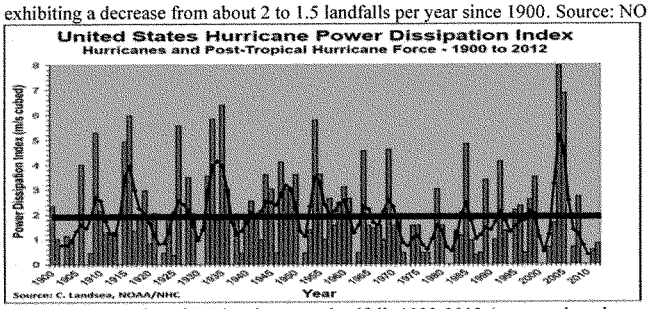


Figure 3b. Intensity of US hurricanes at landfall, 1900-2012 (measured as the summed power dissipation for each year). The heavy black line shows the linear trend. Source NOAA, figure courtesy Chris Landsea, NOAA/NHC.

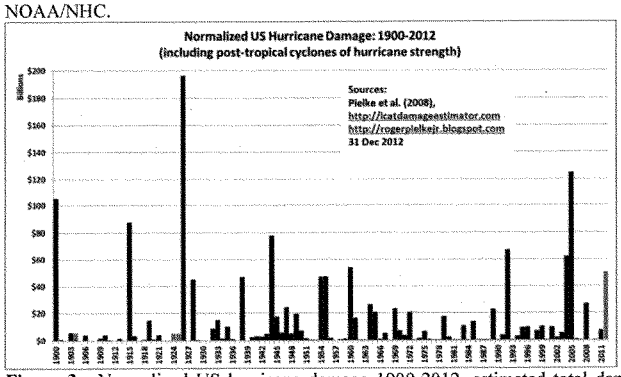


Figure 3c. Normalized US hurricane damage 1900-2012, estimated total damage if each past hurricane season occurred with 2012 levels of development. After Pielke et al. 2008.[14] Note that the figure includes Superstorm Sandy (2012) in gray and placeholders for the three other "post-tropical cyclones of hurricane strength" which made landfall in 1904, 1924 and 1925.

[13] http://www.aoml.noaa.gov/hrd/hurdat/All_U.S._Hurricanes.html

[14] Pielke, Jr., R.A., J. Gratz, C.W. Landsea, D. Collins, M. Saunders, and R. Musulin (2008), Normalized Hurricane Damages in the United States: 1900-2005. *Natural Hazards Review* **9**:29-42. Data updated to 2012 values using the ICAT Damage Estimator: http://www.icatdamageestimator.com

4. **There are no significant trends (up or down) in global tropical cyclone landfalls since 1970 (when data allows for a comprehensive perspective), or in the overall number of tropical cyclones.**

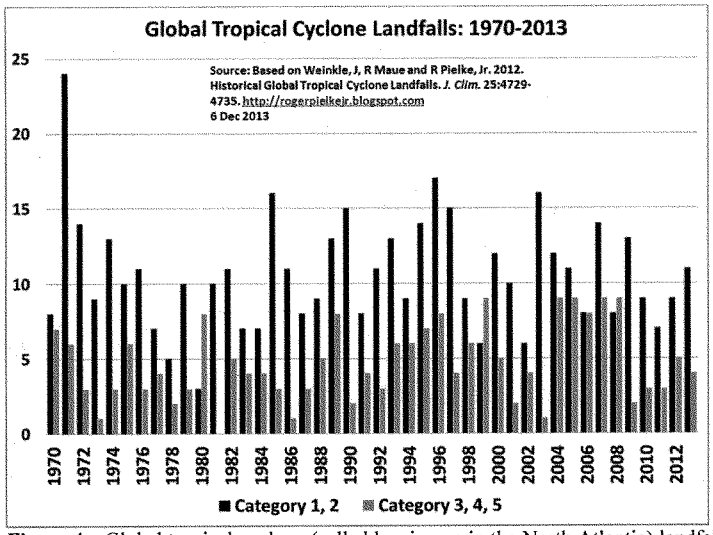


Figure 4a. Global tropical cyclone (called hurricanes in the North Atlantic) landfalls, 1970-2013, after Weinkle et al. 2012.[15] Note: 2013 is preliminary, thanks to R. Maue.

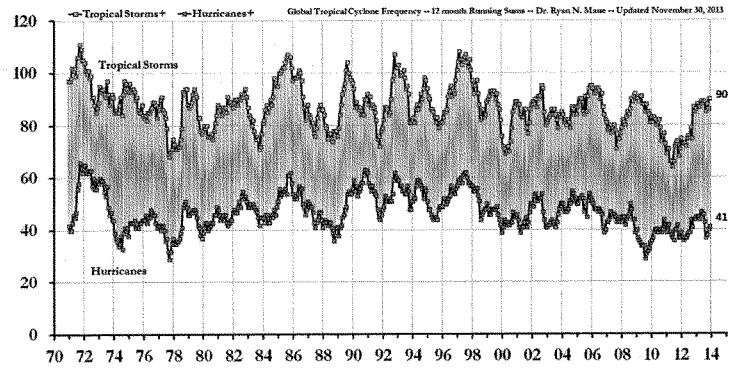


Figure 4b. Total count of tropical cyclones of tropical storm (top curve) and hurricane strength, 12-month running sums 1970 through November 30, 2013. Figure courtesy Ryan Maue.[16]

[15] Weinkle, J, R Maue and R Pielke (2012), Historical Global Tropical Cyclone Landfalls. Journal of Climate, **25**:4729-4735

A Note on US Hurricanes

The United States is currently in a remarkable stretch with no major hurricane (Category 3+) landfalls, as shown in the figure below. The five-year period ending 2013 has seen 2 total hurricane (Cat 1+) landfalls. That is a record low for any five-year period since 1900. Two other five-year periods have seen 3 landfalls (years ending in 1984 and 1994). Prior to 1970 the fewest landfalls over a five-year period was 6. From 1940 to 1957, every 5-year period had more than 10 hurricane landfalls (1904-1920 was almost as active).

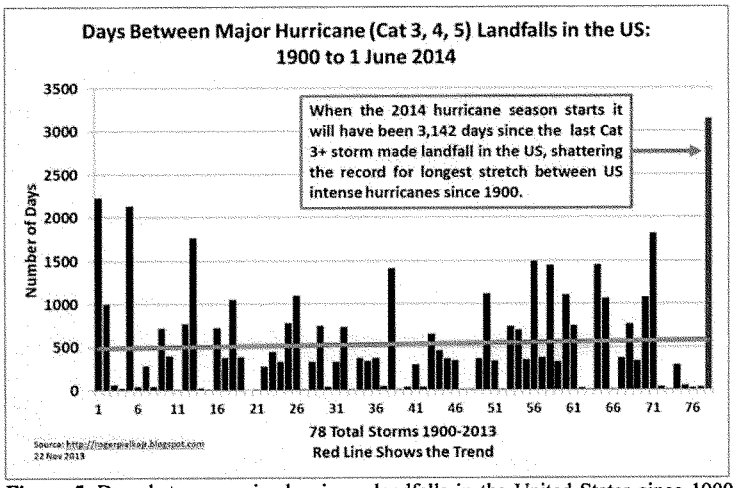


Figure 5. Days between major hurricane landfalls in the United States since 1900. There have been 78 major hurricane landfalls in the US from 1900 to 2013. Source: NOAA.

Floods

What the IPCC AR5 (2103) says:

- "In summary, there continues to be a lack of evidence and thus low confidence regarding the sign of trend in the magnitude and/or frequency of floods on a global scale."

What the IPCC SREX (2012) says:

- "There is limited to medium evidence available to assess climate-driven observed changes in the magnitude and frequency of floods at regional scales"
- "there is low agreement in this evidence, and thus overall low confidence at the global scale regarding even the sign of these changes.."

[16] After Maue, R. N. (2011), Recent historically low global tropical cyclone activity. , *Geophys. Res. Letts.* **38**:L14803, doi:10.1029/2011GL047711.

What the data says[17]:

5. Floods have not increased in the US in frequency or intensity since at least 1950.

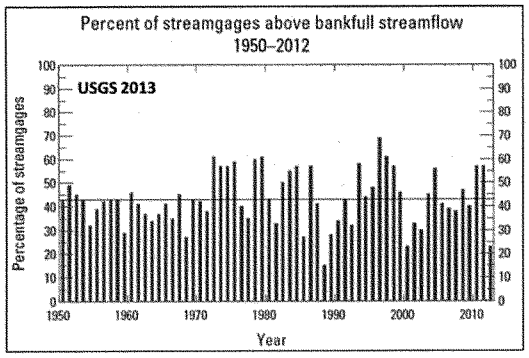


Figure 5. One measure of flood frequency from the USGS, percent of US stream gauges above "bankfull streamflow." The USGS explains: "The bankfull streamflow is defined as the highest daily mean streamflow value expected to occur, on average, once in every 2.3 years."[18]

6. Flood losses as a percentage of US GDP have dropped by about 75% since 1940.

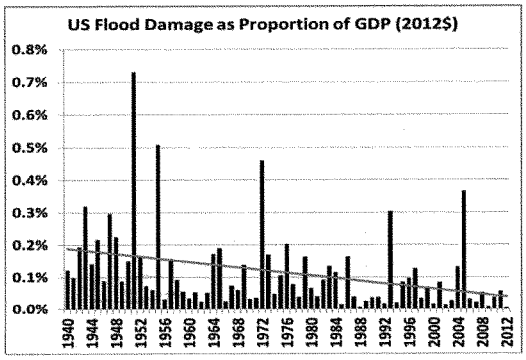


Figure 6. US flood losses as a percentage of US GDP. [19] Annual flood losses have decreased from about 0.20% of US GDP to <0.05% since 1940. Flood loss data from NOAA HIC[20], GDP data from OMB.[21]

[17] Note: A 2005 peer-reviewed paper examined flood trends around the world and concluded: "observations to date provide no conclusive and general proof as to how climate change affects flood behaviour." Source: Kundzewicz, Z.W., D. Graczyk, T. Maurer, I. Przymusińska, M. Radziejewski, C. Svensson and M. Szwed, 2005. Trend detection in river flow time-series: 1. annual maximum flow. *Hydrol. Sci. Journal*, **50**:797-810.

[18] Xiaodong Jian, David M. Wolock, Harry F. Lins, and Steve Brady, Streamflow of 2012—Water Year Summary, U.S. Geological Survey, Reston, Virginia, May 2013.

[19] After Downton, M., J.Z.B. Miller, and R. A. Pielke, Jr. (2005), Reanalysis of the U.S. National Flood Loss Database. *Natural Hazards Review* **6**:13-22

[20] http://www.nws.noaa.gov/hic/

[21] http://www.whitehouse.gov/sites/default/files/omb/budget/fy2014/assets/hist10z1.xls

Tornadoes (and small scale weather extremes, such as hail)

What the IPCC AR5 (2013) says:

- "In summary, there is low confidence in observed trends in small-scale severe weather phenomena such as hail and thunderstorms because of historical data inhomogeneities and inadequacies in monitoring systems."

What the IPCC SREX (2012) says:

- "There is low confidence in observed trends in small spatial-scale phenomena such as tornadoes and hail"

What the data says:

7. **Tornadoes have not increased in frequency, intensity or normalized damage since 1950, and there is some evidence to suggest that they have actually declined.**[22]

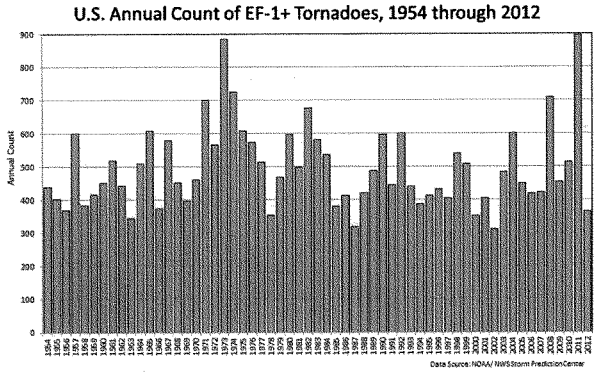


Figure 7a. Count of US tornadoes of at least EF1 strength, 1954-2012. For a discussion of challenges in interpreting trends in tornado data, see Simmons et al. 2013 and references therein.

Source: NOAA, http://www.ncdc.noaa.gov/oa/climate/severeweather/tornadoes.html

[22] Simmons, KM, D Sutter and R Pielke (2013), Normalized tornado damage in the United States: 1950-2011. *Environ. Hazards* **12**:132-14.

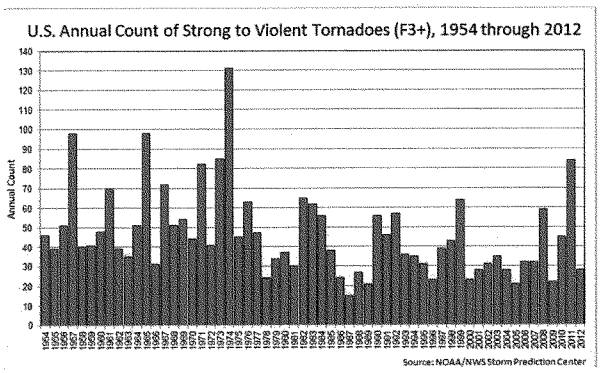


Figure 7b. Count of US tornadoes of at least EF3 strength, 1954-2012. For a discussion of challenges in interpreting trends in tornado data, see Simmons et al. 2013 and references therein.

Source: NOAA, http://www.ncdc.noaa.gov/oa/climate/severeweather/tornadoes.html

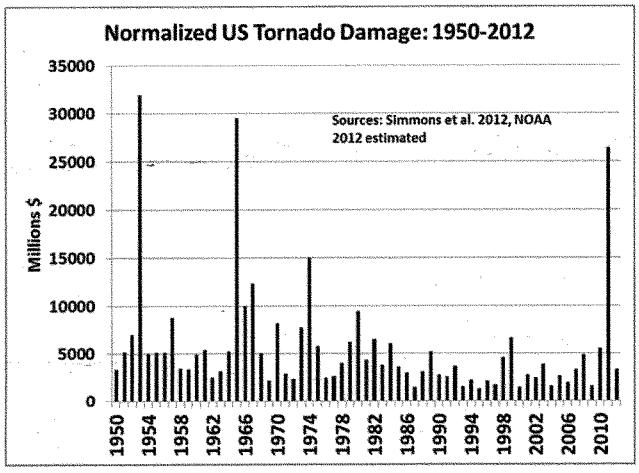


Figure 7c. Normalized US tornado damage, estimated total damage if tornadoes of past years occurred with 2012 levels of development. After Simmons et al. 2013. Note 2012 is estimated.[23]

Here is what Simmons et al. (2013) concluded with respect to long-term trends in tornado incidence and normalized losses:

[23] Simmons, KM, D Sutter and R Pielke (2013), Normalized tornado damage in the United States: 1950-2011. *Environ. Hazards* **12**:132-14. Preliminary estimates show that 2013 damage will be comparable to 2012.

> "The analysis presented in this paper indicates that normalized tornado damage in the US from 1950 to 2011 declined in all three normalization methods applied (two are statistically significant one is not). The degree to which this decrease is the result of an actual decrease in the incidence of strong tornadoes is difficult to assess due to inconsistencies in reporting practices over time. However, an examination of trends within sub-periods of the dataset is suggestive that some part of the long-term decrease in losses may have a component related to actual changes in tornado behaviour. Further research is clearly needed to assess this suggestion. However, we can definitively state that there is no evidence of increasing normalized tornado damage or incidence on climatic time scales."

In addition, earlier this month six leading US tornado experts wrote that claims for the existence of trends in tornado incidence (up or down) was not supported by evidence: "no one knows what effect global warming is having on tornado intensity. Tornado records are not accurate enough to tell whether tornado intensity has changed over time."[24] Our recent work finds no evidence for increasing incidence of the strongest tornadoes, and is suggestive that some part of an observed decline may be due to actual changes in incidence, rather than fully explained by changes in reporting (Simmons et al. 2013).

Drought

What the IPCC AR5 (2013) says:

- "In summary, the current assessment concludes that there is not enough evidence at present to suggest more than low confidence in a global-scale observed trend in drought or dryness (lack of rainfall) since the middle of the 20th century"[25]

What the IPCC SREX (2012) says:

- "There is medium confidence that since the 1950s some regions of the world have experienced a trend to more intense and longer droughts, in particular in southern Europe and West Africa, but in some regions droughts have become less frequent, less intense, or shorter, for example, in central North America and northwestern Australia."
- For the US the CCSP (2008)[26] says: "droughts have, for the most part, become shorter, less frequent, and cover a smaller portion of the U. S. over the last century."[27]

What the data says:

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[24] http://news.yahoo.com/real-truth-tornadoes-op-ed-180014832.html

[25] The AR5 explains that its low confidence on drought trends is, "due to lack of direct observations, geographical inconsistencies in the trends, and dependencies of inferred trends on the index choice. Based on updated studies, AR4 conclusions regarding global increasing trends in drought since the 1970s were probably overstated. However, it is likely that the frequency and intensity of drought has increased in the Mediterranean and West Africa and decreased in central North America and north-west Australia since 1950."

[26] CCSP, 2008: Weather and Climate Extremes in a Changing Climate. Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [Thomas R. Karl, Gerald A. Meehl, Christopher D. Miller, Susan J. Hassol, Anne M. Waple, and William L. Murray (eds.)]. Department of Commerce, NOAA's National Climatic Data Center, Washington, D.C., USA, 164 pp.

[27] CCSP (2008) notes that "the main exception is the Southwest and parts of the interior of the West, where increased temperature has led to rising drought trends."

8. Drought has "for the most part, become shorter, less frequent, and cover a smaller portion of the U. S. over the last century."[28]

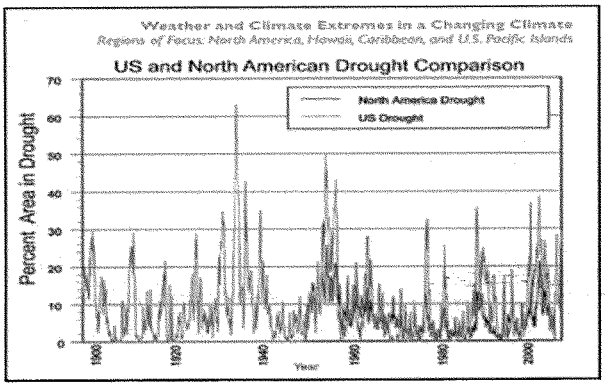

Figure 8. Figure 2.6 from CCSP (2008) has this caption: "The area (in percent) of area in severe to extreme drought as measured by the Palmer Drought Severity Index for the United States (red) from 1900 to present and for North America (blue) from 1950 to present."[29]

[28] This quote comes from the US Climate Change Science Program's 2008 report on extremes in North America.

[29] Note: Writing in Nature Senevirnate (2012) argues with respect to global trends that, "there is no necessary correlation between temperature changes and long-term drought variations, which should warn us against using any simplifications regarding their relationship."
http://www.nature.com/nature/journal/v491/n7424/full/491338a.html

Biography of Roger Pielke Jr.

Roger Pielke, Jr. has been on the faculty of the University of Colorado since 2001. He is a Professor in the Environmental Studies Program and a Fellow of the Cooperative Institute for Research in Environmental Sciences (CIRES), where he serves as Director of the Center for Science and Technology Policy Research. Roger's research focuses on science, innovation and politics and in 2011 began also to write and research on the governance of sports organizations. Roger holds degrees in mathematics, public policy and political science, all from the University of Colorado. In 2012 Roger was awarded an honorary doctorate from Linköping University in Sweden and was also awarded the Public Service Award of the Geological Society of America. Roger also received the Eduard Brückner Prize in Munich, Germany in 2006 for outstanding achievement in interdisciplinary climate research. Before joining the faculty of the University of Colorado, from 1993-2001 Roger was a Scientist at the National Center for Atmospheric Research. Roger is a Senior Fellow of the Breakthrough Institute, and holds academic appointments at Macquarie University in Sydney, Australia and the London School of Economics. He is also author, co-author or co-editor of seven books, including **The Honest Broker: Making Sense of Science in Policy and Politics** published by Cambridge University Press (2007). His most recent book is **The Climate Fix: What Scientists and Politicians Won't Tell you About Global Warming** (2011, Basic Books). He is currently working on a book on technology, innovation and economic growth.

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Chairman SMITH. Thank you, Dr. Pielke, and let me recognize for questions and then the Ranking Member.

Dr. Christy, let me address my first couple of questions to you, and the first is this: that some people like the President and the EPA Administrator, Gina McCarthy, have made this assertion: "97 percent of climate scientists think climate change is real, human activities are contributing to it, and that it presents a big threat to our planet." Is that an accurate statement?

Dr. CHRISTY. No, not at all. That statement came from a question that was relatively benign about, do humans have some effect on the climate, and it only used 77 respondents out of several thousand, so it was highly selective. And the American Meteorological Society, by the way, did do a survey of its professional members and found only 52 percent said that climate change of the past 50 years was due mostly to humankind. So a 52 percent amount is quite small, I think, in terms of confidence.

Chairman SMITH. You think the 52 percent is much more credible than the 97 percent?

Dr. CHRISTY. Oh, yeah. It included over a thousand respondents.

Chairman SMITH. Okay. Fifty-two percent I don't think by anybody's definition is a consensus, by the way, so I would say that there is not necessarily a consensus.

My second question is this: Some scientists have claimed that the recent 15-year pause in global warming has been caused by the additional heat being absorbed by our oceans. Is that true?

Dr. CHRISTY. Well, that is a speculation at this point because the data are very imprecise when you go down below 700 meters in the ocean, and so not having real good data, it is hard to make conclusions about that. However, even if it is true, what it indicates is that our models cannot express accurately what is actually happening in the climate system.

Chairman SMITH. Okay. Thank you, Dr. Christy.

Dr. Pielke, a couple questions for you. The first is, over the last half century—and I think you testified to this as well—the scientific community has not been able to detect any increased frequency or intensity of hurricanes, tornados, droughts or floods. So there has been no scientific, I think, proof that any of these types of extreme weather have increased over the last number of years. That has been confirmed by the IPCC, which I quoted in my opening statement. That being the case, what does that say about any projections as to the future number of extreme weather events?

Dr. PIELKE. We did a study where we asked the question, let us look at climate model output, assume that it is true, and then look back and say when would we have detected those changes, and we looked in the statistics of hurricanes. It is a little bit like saying you are playing blackjack with a shady dealer and he puts an extra ace into the deck and you say how many hands would we have to play before we have some statistical evidence that there is a change in the composition of the deck, and the answer is that it is the better part of a century or longer before we would be able to detect the changes that are currently projected. So there is no physical basis actually for expecting that we would be able to detect those signals today, even assuming that those signals are there but will emerge deep into the future.

Chairman SMITH. Okay. Thank you, Dr. Pielke. One more question. Recently there was a national TV ad run by the Natural Resources Defense Council that indicated that "taking action against climate change" would "reduce extreme weather events like Hurricanes Katrina, Irene and Sandy." Is there evidence that these storms have been driven by human-caused climate change?

Dr. PIELKE. There is not presently that evidence, and further, there is not evidence that we have a discernible impact on the future rates or intensities of those forms. There is a lot of good policies that can be put in place to deal with the threats of extreme events including hurricanes, and there is also a lot of good reasons to discuss energy policy changes including greenhouse gases but modulating the future rate of extreme events is probably not high on that list.

Chairman SMITH. And particularly with Hurricane Sandy, just to go back to that hurricane, there was a great deal of damage in part because it hit highly populated areas, not because the storm was severely or unusually strong, as we pointed out today. It is Hurricane Sandy that has been embraced by a lot of people as an indication of climate change causing extreme weather like that hurricane but you don't think there is any truth to that?

Dr. PIELKE. Well, actually, Hurricane Sandy was not even a hurricane-strength storm. It was incredibly intense, had massive damage, but the main reason it had massive damage was because it hit one of the most populated, wealthy parts of our coastline. Had it actually taken that left turn in Nova Scotia, it would have much less impacts and been much less severe.

Chairman SMITH. But again, no correlation between weather change and Hurricane Sandy as such?

Dr. PIELKE. Right.

Chairman SMITH. Okay. Thank you, Dr. Pielke.

That concludes my questions. I will recognize the gentlewoman form Oregon, Ms. Bonamici, for hers.

Ms. BONAMICI. Thank you very much, Mr. Chairman, and thank you to all the witnesses.

Dr. Titley, some people assert, and I have heard this, that there has been no warming in the global climate temperature since 1998. Did global warming end in 1998?

Admiral TITLEY. If only. That would have made everything so much easier. As we have already heard, the temperatures have not stopped warming since 1998, and in fact, NOAA's data show that for the United States, 2012, not 1998, was the warmest year for the continental United States.

As has already been mentioned, the oceans continue to warm, and while we would always want better data, and I think I agree with Dr. Christy, we do agree on that, that a monitoring system is in all of our interests. Having said that, the Argo floats and the altimetry data for the ocean unequivocally show that this is where the heat is going. Now, why it is going there is an open question but it is going there, and 90 percent of the heat is in the ocean system. So the Earth continues to warm and there is some very recent research that shows it might be warming even faster now. So yes, ma'am, it is warming.

Ms. BONAMICI. Thank you. And I have a couple more questions. Dr. Titley, you have used the term "all systems are flashing or blinking red" in the climate, and could you expand on that? What do you mean by that? In terms of weather, what could we anticipate in the coming decades as a result of climate change?

Admiral TITLEY. With respect to whether we can tell this to a, let us say, a 95 percent confidence level, the normal statistical way, you know, Dr. Pielke is right; it is going to take a long time. However, do we wait for like hundreds of terrorist attacks to say you know, there is a statistical change that something may be going on here. So for the system to be blinking red simply looking at the amount of additional moisture and amount of additional heat in the ocean and the atmosphere, we know hurricanes are basically heat engines. One of their main factors is how warm and how much heat do you have in the upper ocean. We know that is increasing.

So it is a little bit like playing with a loaded gun here. Now, is it going to go off? Well, maybe yes, maybe no. But you look at the typhoon that went into the Philippines, strongest winds ever recorded on landfalling, is that climate change? I don't know but the atmosphere lined up with the ocean to create one of the most strongest storms we have ever seen.

Ms. BONAMICI. Thank you. And Dr. Titley, you previously served in the Navy as a Rear Admiral and you manage both weather and climate programs, so people sometimes have a hard time seeing how changes in climate and changes in weather, how that matters in their lives. So can you talk a little bit about the Arctic? Because I think that is a place where you can really illustrate how these changes have real-world consequences for the United States, and I know there is something about that in your written testimony, but could you expand on that briefly, please?

Admiral TITLEY. Yes, ma'am. I sometimes tell people that we plan for climate but we live in weather, and that is really what it is. It is, you know, climate is the card deck from which the weather hands are being dealt. So we see that card deck changing faster in the Arctic than in any other place. So for the Navy, we see the climate is changing, so from a security perspective, we need to—the Navy needs to be ready—one of Chief of Naval Operations three tenets—be ready for a changing environment, and it is really not a political issue because we would make sure we have plans for changes in economics, demographics, political situations, so why wouldn't we plan for changes in the physical situations?

So one of the things we need is better weather forecasts. If we are going to work up there, and that is what the Earth System Prediction Capability is to help us with, ma'am.

Ms. BONAMICI. Right. Well, thank you. And I have a follow-up on that, and I again want to thank the Members of the Subcommittee for working on the weather forecasting bill with all of us.

Dr. Titley, from an economic perspective—and you touched on this briefly when you talked about the analogy to security. From an economic perspective, isn't it wise to prepare for severe weather events and save property and perhaps lives rather than simply responding to them after they happen? I want to note that the Reinsurance Association of America has begun to adjust its business

model to reflect a rising number of catastrophic events. They recently sent a letter with recommendations for policymakers along those same lines. I would like to include that for the record, and we will submit a copy.

Chairman SMITH. Without objection, that will be made a part of the record.

[The information appears in Appendix II]

Ms. BONAMICI. Thank you.

So from an economic perspective, isn't it wise to prepare for these events rather than just responding?

Admiral TITLEY. Yes, ma'am. Very briefly, as you mentioned, the insurance industry, the reinsurance industry, sees a number of weather catastrophes, by their definition, significantly increasing. The part I find interesting is, they also look at geophysical like earthquake, tsunami; those aren't going up. So you can't just say well, there is more people, more wealth, living by the ocean. The weather part is going up. And of course, preparation is always better than reaction.

Ms. BONAMICI. Thank you very much. My time is expired. I yield back. Thank you.

Chairman SMITH. Thank you, Ms. Bonamici. The gentleman from Texas, Mr. Neugebauer, is recognized.

Mr. NEUGEBAUER. Thank you, Mr. Chairman, and thank you for calling this important hearing.

Dr. Pielke, you know, when we talk about a lot of these extreme weather conditions, we tend to talk to them in the context of cost: what did this event cost, what did that event cost. And so some have even suggested that when you start to talk about climate trends that you somehow associate the cost of these disasters with the cost of these climate changes, climate trends. Is there a relationship between these financial damages and extreme weather events and long-term climate trends?

Dr. PIELKE. A lot of care has to be taken in looking at cost damage because like anything else in the economy, it changes quickly over time. We have more wealth, which is a good thing, generally, but that means more property, more exposure to losses, and so it is—you are setting yourself for errors by taking, say, the raw Munich Reinsurance data and coming to some conclusions about the climate system.

There has been a number of studies that have tried to normalize those economic records to try to say something about the climate data, and there are several dozen of them now, and they come to a remarkable consensus, that there is in fact no signal of human-caused climate change in the economic loss record really globally but also in individual locations around the world.

Mr. NEUGEBAUER. You know, Dr. Titley showed a figure in his testimony that displayed the number of natural catastrophes worldwide by, I believe, Munich Reinsurance. Is there any basis for claiming that any part of the increases in disaster losses can be attributed to human-caused change?

Dr. PIELKE. Munich Reinsurance, which is one of the world's largest reinsurance companies, had that exact same question several years ago. So they funded a big study at the London School of Economics to actually go into their data and look at that, and

you will see that is cited in my testimony. They found that no part of that increase in global disaster losses could be attributed to human-caused climate change. So that was their own research submitted to peer-review outlets, which I think is pretty consistent with what the research community has concluded. So I think there is a pretty strong answer to that question.

Mr. NEUGEBAUER. The warning coordination meteorologist at NOAA Storm Prediction Center in Norman, Oklahoma, Greg Carbon, I believe, stated that "There really is no scientific consensus on connection between global warming and tornadic activity, jumping from a large-scale event like global warming to relatively small-scale events like tornados, a huge leap across the varieties of scales."

Dr. Christy, Dr. Pielke, do you agree with that statement?

Dr. CHRISTY. Yes, that sounds reasonable.

Dr. PIELKE. I will say that yes, that statement sounds reasonable, and we have actually looked at the tornado record, which is complicated by the fact that there were different ways to measure tornados that the Weather Service has used over time, and one of the most interesting features of the tornado record is that if you look at the damage that has been caused, which is an independent record from the tornados themselves, there has actually been a decline over many decades. So that gives us some reason to think that the evidence that you see, there is certainly no evidence of an increase in tornadic activity, especially the most damaging ones, but there is a slight hint that perhaps even there may be a decrease in recent decades. I wouldn't put too much weight on that but it is much stronger on the lack of increase side.

Mr. NEUGEBAUER. And the last question, what is the danger that we begin to try to tie these two together in the debate and the discussion that we are having on climate change?

Dr. PIELKE. I guess I would say that these are really two important issues. Climate change, the effect that we have on the planet is an important issue. Extreme events both nationally and internationally, as we saw in the Philippines, are also an important issue. And if we begin using extreme events as kind of a poster child for energy policy, we are doing a disservice to both debates. So I think it is important to understand what the science says, and if the science says there is no linkage, then, you know, let us not force that. Let us take these issues apart and have a reasonable policy discussion rather than a proxy debate through the science.

Mr. NEUGEBAUER. Dr. Christy, do you have a reaction on that?

Dr. CHRISTY. Dr. Roger Pielke said it correctly, that preparing for extreme events is something we should always be doing. I like the idea of the Weather Service being given extra resources to do that for forecasting but also in preparation of our infrastructure and responses and so on. That is good no matter what the climate might do in the future.

Mr. NEUGEBAUER. But those who try to tie the cost of those two to kind of impute that into the cost of climate change, are they doing the debate a disservice?

Dr. CHRISTY. Yes, and I yield to Dr. Pielke on that. He has done quite a bit of work, and he is exactly right, that that linkage needs to be broken right there.

Mr. NEUGEBAUER. Thank you, Mr. Chairman.

Chairman SMITH. Thank you, Mr. Neugebauer. The gentleman from California, Mr. Takano, is recognized.

Mr. TAKANO. Dr. Titley, I am interested in this question about reinsurance. It has been stated here at this hearing that no costs heretofore can be demonstrated to have been attributed to climate change, but can you tell me— you know about reinsurance models going forward—whether climate change science has affected their modeling and their understanding of risk.

Admiral TITLEY. Just very briefly, sir, what I can tell you is, the reinsurance industry is intensely interested in how the climate is changing because it is a business issue for them. It is not a politics issue; it is business. And when they see the number of weather catastrophes increasing and increasing significantly, they have got to wonder how is that impacting their business. They may or may not be statistically related to climate but I will tell you, I lived on the Gulf Coast, and when I watched my hurricane premiums go from about $600 a year to $6,000 a year, there is real impact. And they are not coming back down and we don't see them coming back down. So I think there is a real impact in both the insurance and reinsurance industry as we price the risk of extreme weather.

Mr. TAKANO. Do you agree with some of the claims made that there is no association between climate change and tornadic activity?

Admiral TITLEY. Thank you certainly for that question. Words matter, and you know, I was almost going to start nodding my head up and down with the other witnesses until I heard that there was no linkage. There is a tremendous difference between no linkage and a linkage that is not known. It is only a subtle word change but there is a really big difference. I think the scientific consensus is not that there is no linkage. The scientific consensus is, we don't know. And that is a very, very important definition, sir, but we do know, we have a warmer and more moister world and that means that we need to really be careful because we know both with severe weather, with big thunderstorms and with hurricanes, those are one of, not the only, but those are primary important ingredients to creating big storms.

Mr. TAKANO. Also, could you comment on the claim that there have been no increase in extreme weather events?

Admiral TITLEY. Yes, sir. I think it really matters again, how do you define extreme weather events. I looked up the definition of "extreme" since I thought we were going to be talking about that today, and one of the main definitions is away from the center. Again, just take the basic data. We have had for the last 36 years since President Ford was in office above-normal temperatures. That is away from the center. And they are getting further and further away. Now, if you take each year as kind of its own thing, imagine like flipping a coin 36 times and getting heads. I mean, if that is a fair coin, I want to go to Vegas with you because the odds of that are about one in 68 billion. To put it another way, there is a 400 times chance, greater chance that you are going to win the Powerball, which is $400 million, by the way, this week than getting 36 coins to flip heads in a row. So I would say that is extreme,

and the ice and the Arctic, that is extreme. We have seen geologic changes in less than ten years. That is pretty extreme, sir.

Mr. TAKANO. Moving from the independent assessment of businesspeople and reinsurance, you come from a military background, how has climate change science affected the hard-hatted decisions about what the Navy or other armed forces or having to do to adjust? Is climate change science having an impact on those sort of decisions?

Admiral TITLEY. Yes, sir. It is in the most—the highest-level strategies of the Department of Defense. It is in what the DOD calls the Quadrennial Defense Review. Climate change is talked about there. I could go through very, very quickly just about three places. The Arctic, it is opening up a whole new theater of operations. That is being driven by climate.

Infrastructure and sea-level rise, we haven't talked much about sea-level rise but it is a huge issue, probably up 2, 3, 4 feet. We were just in Norfolk. I have a graph in my testimony that shows exponentially rising hours of flooding in some Norfolk neighborhoods. The Department of Defense is worried about that. The Navy is, and people ask why is the Navy concerned? It is like it is kind of a ship thing. We have to put our bases at sea level so it is going to be a big deal.

And then finally, how does climate change potentially exacerbate conflicts, and there has been a number of peer-reviewed studies that show both the Arab Spring and Syria probably have some climate linkages. Thanks.

Mr. TAKANO. Thank you. Thank you, Mr. Chairman.

Chairman SMITH. Thank you, Mr. Takano. The gentleman from California, Mr. Rohrabacher, is recognized for his questions.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman. I have been running back and forth. There is a hearing in Afghanistan going on, and I am sort of involved in that issue as well.

Just some of the statements that Doctor—pronounce your name for me. Is it Titley?

Admiral TITLEY. Yes, sir, Titley.

Mr. ROHRABACHER. Okay. Doctor, is there any time period in the last 100 years when there has been a similar de-icing in the Arctic area?

Admiral TITLEY. No, sir, not in the last 100 years.

Mr. ROHRABACHER. So in the last 100 years, there hasn't been a thawing out?

Admiral TITLEY. Not to the degree that we are seeing now.

Mr. ROHRABACHER. The degree. Okay. And in the past, of course, before the 1300s, there was much less ice up there. Is that correct?

Admiral TITLEY. As best the paleoclimatologists can tell, the world today is warmer than it has been probably for about the last 44,000 years, sir. I think you and I had this discussion actually at a previous hearing, I remember, and I quoted the Native Americans, the Inuit, who are riding the Coast Guard cutter Healey, nothing in their oral history showed the kind of changes that are happening in the Arctic today.

Mr. ROHRABACHER. So Greenland wasn't green, and it was always icy, and Iceland was always Iceland, and from what I understand at times that there is lots of evidence to suggest that there

was large communities in Greenland and Iceland that actually because it got colder disappeared.

Admiral TITLEY. Yes, sir. We may be talking past each other slightly. I am talking about sea ice, the Arctic sea ice.

Mr. ROHRABACHER. Well, I understand that the sea ice had a lot to do with the Iceland community disappearing because they lost their transportation for supplies from Europe.

Admiral TITLEY. Yes. When you take a look at the Arctic as a whole, we have not seen the diminishing or the lessening of the sea ice in thousands and thousands of years. This is unprecedented.

Mr. ROHRABACHER. Do the other two witnesses agree with that assessment?

Dr. CHRISTY. Not at all. I think he might have misspoke on the 44,000 number but the globe, especially the Arctic, has been much warmer in the past than it is today and there is plenty of evidence to support that. As well as the sea ice, that is a bit more murky on how much sea ice was there in any particular year but it does look like it had receded much further, especially in the mid-Holocene period, five, six, seven thousand years ago when Greenland was much warmer than it is today.

Mr. ROHRABACHER. Okay.

Admiral TITLEY. The globe, sir, has been warmer in the past. It has warmed and it has cooled. Climate has changed for millions of years. It will change for millions of more. The difference is, is in about the last eight to twelve thousand years, we have had very stable climate relative to what climate normally is, and that is when we built human civilization. It is why we put our cities where we did, it is why the agriculture is where it is. So if we start changing that for whatever reason, that becomes a huge issue that humanity as a whole will have to deal with. So yes, the climate does change. That is not the issue.

Mr. ROHRABACHER. But just in terms of we were talking about the Arctic, you agree that it has never been warmer in the Arctic?

Admiral TITLEY. Overall, it has not been warmer for thousands of years in the Arctic.

Mr. ROHRABACHER. We have one disagreement. Dr. Pielke?

Dr. PIELKE. It is not my expertise so I am happy to let those guys fight.

Mr. ROHRABACHER. All right. Thank you very much.

Let me just ask, I sat through Hurricane Hazel when I lived in North Carolina at the time. I remember the trees. That was a pretty strong hurricane back in the 1950s. Was that stronger than Sandy or weaker than Sandy?

Admiral TITLEY. It depends how you measure the strength. If you measure by the winds—and I think it has already been brought up that two of our most destructive hurricanes have actually been pretty—by the Saffir-Simpson scale, pretty weak storms. Katrina, not many people realize this, was actually a category 2 when it made landfall. Sandy was not even technically a hurricane——

Mr. ROHRABACHER. Now, a lot of the damage that we are talking about is——

Admiral TITLEY. —is storm surge.

Mr. ROHRABACHER. —not based on the climate or the strength of the wind but instead where the people have built and what kind of houses.

Admiral TITLEY. And it is storm surge, sir. And it is the storm surge with a rising overall——

Mr. ROHRABACHER. You mentioned that the sea rates have gone up, the ocean levels 4, 5 feet. Do our other witnesses agree with that?

Dr. CHRISTY. I don't think—it was someone's projection, I think. It has not—and it has not accelerated either. The sea level has not been accelerating in terms of its rising level.

Mr. ROHRABACHER. So over the centuries, you are suggesting sea levels are rising and you are suggesting that they are not. Is that correct?

Admiral TITLEY. The data do show——

Dr. CHRISTY. The sea level is rising. It is just at a rate that is not accelerating.

Mr. ROHRABACHER. I see.

Admiral TITLEY. It is accelerating. It is right now 3.2 millimeters per year and it is accelerating, and are going to deal with 2 to 3 feet by the end of this century, at least.

Mr. ROHRABACHER. And accelerating from what time period? Was it accelerating—you know, we see the pictures of the continents and everything changing. If the continents can change and the sea level rises and changes then before mankind is ever around—see, most every time when you are suggesting that this is due to climate change, we are not really talking about climate change. We are talking about manmade climate change because what you are saying is then being used as an excuse to control the activities of mankind, correct?

Admiral TITLEY. Okay. Congressman, I don't get into the politics. When I did this in the Navy, the reason we looked at this is because the battle space was changing. Now, why the battle space is changing was not our core interest but we saw the battle space was changing. But when you then walk back the physics, if you put in greenhouse gases, it is changing it, so from a policy perspective, how do we deal with the greenhouse gases. You can regulate it, you can use market forces, you can do a number of different things but, you know, again, this is cutting-edge 19th-century science so whether we are going to deal with that or not but that is kind of the crux of the matter. So the sea level——

Mr. ROHRABACHER. You are right. It is the crux of the matter, and if we try to suggest that we know the climate is always changing, but if we are suggesting that the greenhouse gases that mankind puts into the air—of course, 90 percent of the greenhouse gases come from natural sources—but if you are suggesting then we have an excuse to control human activity, and quite frankly, controlling human activity is not necessarily consistent with the founders of this country, who believed that human beings have rights to control their own actions.

Thank you very much, Mr. Chairman.

Chairman SMITH. Thank you, Mr. Rohrabacher.

I would like to follow up on a subject that Mr. Rohrabacher brought up and ask Dr. Titley and Dr. Christy this question. As I

understand it, some people point to the decrease in Arctic sea ice as an indication of a calamity or a red flag. Arctic sea ice went down for a number of years, actually went up last year. The Antarctic sea ice has gone up, increased for the last 30 years, and when you combine the two, the amount of sea ice, Antarctic and Arctic is actually above the average over the last number of years. So why should we be concerned about some diminution of Arctic sea ice when the total sea ice is above average and when Antarctica has been going up? Dr. Titley and Dr. Christy.

Admiral TITLEY. Thanks, sir. Just very briefly, when the Arctic sea ice goes down, it goes down in the summer. That allows a lot more heat to get into the atmosphere because it is summertime. The winter ice in the Antarctic is increasing. There is already no sun down there, so, one, it doesn't matter. I tell people the difference between the Arctic and the Antarctic, it is people, not penguins, so the difference in what is going on in the Arctic profoundly affects human civilization. The difference going on with the winter sea ice in the Antarctic really doesn't affect anyone. So it is a matter of changing the global balance. The Arctic is kind of the northern hemisphere's refrigerator, and we are kind of getting rid of the refrigerators.

Chairman SMITH. Okay. Thank you, Dr. Titley.

Dr. Christy?

Dr. CHRISTY. Yes, the Arctic is different because it is a confined space. The Arctic ice cannot grow really much more than what it is because of the land area. And it is not correct to say that the Antarctic sea ice doesn't have an effect. In fact, because it grows without bound to lower latitudes, it actually increases the albedo of the Earth and so it does have a profound effect, even more so than the albedo change of the Arctic ice because of the angles of solar inclination.

So yeah, the global sea ice is above average right now, and that is something. You know, we really don't—we can't predict. You can't find a single model that is able to show that result.

Chairman SMITH. Okay. I thank you both for answering that follow-up question. I think we have no other individuals to ask questions, so thank you all very much for your expertise today, for the information you have provided us. We very much appreciate it, and we stand adjourned.

[Whereupon, at 11:05 a.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. John R. Christy

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Subcommittee on Environment

Hearing Questions for the Record
The Honorable Lamar Smith

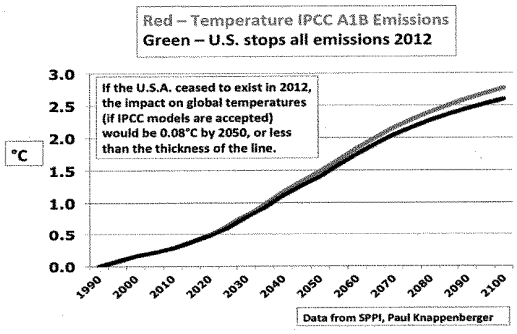
A Factual Look at the Relationship between Climate and Weather

Dr. Christy

1. During his State of the Union Address, President Obama warned that, "for the sake of our children and our future, we must do more to combat climate change." He went on to say that we must "choose to believe in the overwhelming judgment of science—and act before it's too late."

    a. Is there an overwhelming judgment of science—or any science—that the President's regulatory actions will address the threat that he is so concerned about?

The evidence is clear that the regulatory actions recommended by the Administration will not have a discernable impact on the climate system no matter how sensitive one believes the climate is to carbon emissions. For example, even if the United States had disappeared from the face of the Earth in 2012 (i.e. reducing its emissions to zero) the net impact on global temperatures would be 0.08 °C by 2050, an amount that global temperatures vary by from day to day. However, this figure utilizes one of the higher sensitivity values from models, so that a more realistic sensitivity would imply a change of less than 0.05 °C by 2050. Therefore, regulations that reduce U.S. emissions by fractional values of the total current emissions will see impacts on the order of 0.01 °C or less – an amount too small to measure and that will not affect weather events at all.



    b. Is there even an overwhelming judgment of science on the relative contributions of human and natural factors in causing climate change?

John R. Christy
University of Alabama in Huntsville

The simple answer is no for the following reason. We do not have a magic thermometer that can separate temperature changes due only to nature and changes due only to humans. The thermometer only tells us *what* the change in temperature has been, not *why*. To answer the "why" question, scientists create climate models that are supposed to accurately reflect the processes of the climate system so they can determine the role of natural and human influences. Unfortunately, as demonstrated in my testimony, the models fail significantly to provide the answer to *what* has happened. Since determining *what* the temperature has done is the prerequisite before stating *why* the temperature has varied, the models cannot be relied on to distinguish natural and human contributions. As stated in my testimony, "If the models can't tell us WHAT happened, how can they tell us WHY it happened?"

The IPCC-selected authors, by accepting the models as accurate, made the claim that they were 95 percent confident that humans were causing most of the warming in the last several decades. A very similar question was asked of the professional members of the American Meteorological Society and only 52 percent agreed at some level with the IPCC authors. This is clearly not "overwhelming." However, even in that 52 percent, one must take into account the fact many of the respondents were funded by the federal government who itself is a cheerleader for claims of human induced climate change. The conflict-of-interest should be obvious. Thus the "52 percent" may be an overly biased value. In any case, there is not an "overwhelming judgment" about the relative contributions of human and natural factors because *these quantities cannot be directly measured* and have clearly not been accurately represented in models.

2. There has been no significant change in mean global temperature now for 15 or more years— despite that atmospheric carbon dioxide levels have risen from about 365 parts per million to 400 parts per million over that period. Even the UN's Intergovernmental Panel on Climate Change has admitted that global warming has stopped in its most recent report on the science.

    a. What do you think this says about the sensitivity of global temperature to carbon dioxide levels? Hasn't the IPCC retreated from its previous position on carbon dioxide sensitivity?

There are two components of concern here. The first is climate sensitivity. With the minimal warming over the last 35 years during which greenhouse gases have increased the most, new studies of climate sensitivity estimates are less than that assumed in the past, though the IPCC tried to minimize those studies.

The second component is natural variability. When compared with nature, the models are fairly "stiff" and don't reveal the large swings of climate that are common in its natural state. So not only is climate sensitivity very likely overstated in models, the role of natural variability is very likely understated. As a result, the models are unable to depict and ascribe-to-a-cause the true state of the climate systems variations.

The IPCC is struggling with Climate Sensitivity – generally adhering to the long-held and very broad range of 1.5 to 4.5°C per doubling of CO2. This indicates the state of science had provided no improvement in precision in over 25 years of expensive research (see Box 12.2 of AR5 WG1). Elsewhere the IPCC indicates that some of the latest CMIP5 models "have a higher sensitivity ... than the real world" (AR5 11-23, 11-51). Another IPCC development was that the "likely" lower end of climate sensitivity was reduced from 2° in AR4 to 1.5° in AR5 and that "best fit to the observed surface and ocean warming for ECS [Equilibrium Climate Sensitivity] values [is] in the lower part of the range" (AR5 12-74). Thus, the IPCC has lowered its range for climate sensitivity.

3. In light of the last decade and a half of global temperatures not rising, have we learned anything new about the relationship between temperature and extreme weather events?

The evidence indicates extreme events are not increasing in intensity or severity and thus have little relationship to the global average temperature. Thus, despite whatever the global average temperature might be, extreme events will continue to occur.

   a. In light of this "pause," how can the President and others continue to project with medium and high confidence that certain extremes may get worse?

The evidence does not support such claims, so one would need to ask the Administration how they came to such a conclusion. I recall in another Hearing that the witnesses for the Democrats/Administration did not speak up when asked directly if they agreed with the President's statement on extremes.

4. If we were to pretend the President is correct, and droughts, floods, hurricanes, and other events are getting worse due to man-made climate change, do you believe unilateral steps by the U.S. – like taxing energy or carbon dioxide – would have any meaningful impact on this alleged climate change impact?

As I have testified in previous hearings and in Federal Court, the climate impact of the currently-enacted and proposed regulations will have such a minuscule effect on the climate system that it will not be confidently assessable (see answer to 1.a above.) The U.S. emission total as a fraction of the global emissions is falling and is now around only 17 percent. These regulations seek to diminish this 17 percent while other countries, i.e. China, India, Germany, etc., are increasing their carbon emissions. Simple arithmetic indicates these U.S. measures will not have a discernable impact on the climate system, no matter what one believes about how sensitive the climate is to emissions.

5. Satellite measurements are the only truly global temperature measurements, unaffected by artifacts such as the urban heat island effect. You have been monitoring the lower troposphere since 1979. Can you describe for the Committee how the reality of these global temperature measurements compares with the predictions of the 73 climate models that you have compared them to?

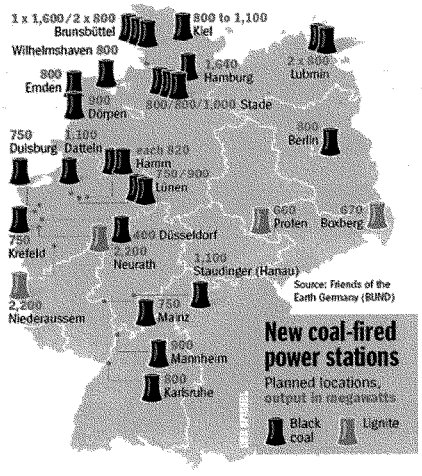
The stunning result of my comparisons, which in this Hearing actually included 102 climate model simulations (not 73), was that all 102 simulations anticipated more warming than actually occurred, with most being too warm not by mere percentages but by factors of 3 to 6. This to me is a colossal failure of the climate modeling industry. The implications are: (1) climate modeling is immature, (2) climate model output is inappropriate for use as evidence to separate human and natural influences on the climate, (3) climate model output is inappropriate for policymaking, (4) the expenditure over the past two decades of hundreds of millions of dollars must be questioned, and (5) the climate modeling industry needs to be subject to objective and independent oversight and evaluation.

6. During the hearing you spoke to the differences between Arctic sea ice and Antarctic sea ice extent. Please elaborate on the state of Earth's sea ice over the last few years.

It is well known that the Arctic Sea Ice Extent has declined in the past 35 years while that of the Antarctic has increased. These measurements are based on satellite observations which can easily distinguish open water from ice. On the date of the hearing, when summed together, the total global sea ice extent was 600,000 km^2 above the long-term average. The Earth continues to have sea ice.

7. Were there any aspects of testimony received during the hearing regarding extreme weather events and climate change that you would like to elaborate on further?

It should be noted how the rest of the world views the claim that carbon emissions are having a negative impact on climate and weather extremes. The largest emitter is China, a country that has just announced planned increases in coal-fired electricity by increasing coal production by 100 million tons annually (http://www.smh.com.au/environment/climate-change/china-steps-up-coal-capacity-even-as-pollution-mounts-20140109-30ipe.html.) Indeed China consumes almost half of the world's coal at present (3.8 of 8.1 billion tons – EIA.) Therefore it is clear China places a priority on electrification of its economy as a better investment for its people than fear of weather extremes. On the other end of the political spectrum is Germany, long thought to be a "green" country, that has recently finished five new coal-fired power plants with 24 more in various phases of construction (Figure). The German CO2 emissions will rise as a result, despite "climate disruption" concerns of the "Greens." By their action, Germany does not apparently fear any negative impact of weather extremes.

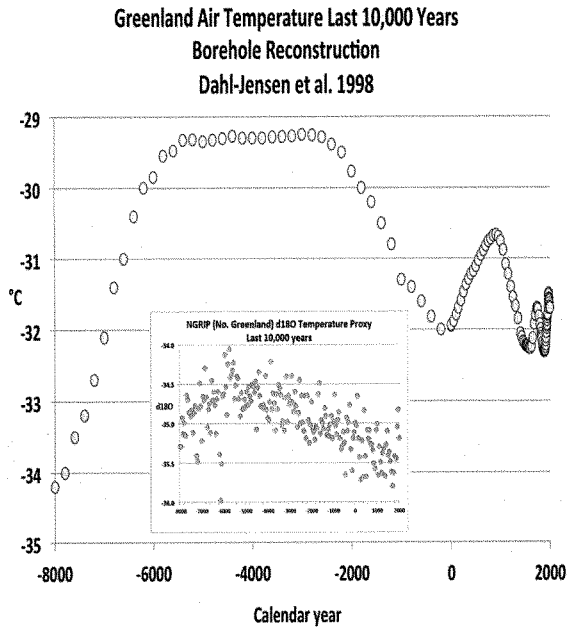


John R. Christy
University of Alabama in Huntsville

8. Were there any aspects of testimony received during the hearing regarding extreme weather and climate change that you disagree with? If so, please elaborate.

One witness claimed that Katrina was a category 2 hurricane when it hit the Gulf Coast in 2005. It was a category 5 out over the water, diminished to category 4 just before hitting land, then slightly diminished again to a strong category 3 at landfall (125 mph). Katrina had 50 percent more cyclone energy than a category 2 storm. The witness was in error.

The same witness also claimed the Arctic is warmer now than it has been in 44,000 years. The evidence against such a statement is overwhelming with the mid-Holocene (about 5 to 9 thousand years ago) clearly warmer than today. At left is a figure of the Arctic temperatures represented by Greenland from two completely independent sources showing the warm period from 2000 to 6000 BCE. It is clear that the mid-Holocene was warmer than today by a substantial amount.



John R. Christy
University of Alabama in Huntsville

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Subcommittee on Environment

Hearing Questions for the Record
The Honorable Suzanne Bonamici

A Factual Look at the Relationship between Climate and Weather

Dr. Christy

1. You cite the recent AMS survey of meteorologists for the proposition that there is not a consensus among scientists that there is anthropogenic climate change. Several other studies and surveys have concluded that there is such a scientific consensus among climate scientists. Given that, why do you cite the AMS study and not acknowledge the others? What do you say to the assertion that the population surveyed by AMS is not reliably expert in the field of climate science?

Thank you for this question as claims about the views of scientists from various surveys have caused considerable misunderstanding among policymakers and the general public. While opinion polls (i.e. surveys) are very important in a democratically-accountable political system, and "majority rule" is the very foundation of our democracy, such is not the case in the scientific realm. Thus, this issue of surveys is, in fact, a red herring since surveys do not produce scientific truth about the physical climate system. What further convolutes the utility of surveys is the fact that on the issue of climate change they have often involved fairly ambiguous questions directed at groups selected in biased ways.

I cited the AMS survey because it posed the question most closely related to the claim made by the IPCC (i.e. that it is "extremely likely [95 percent certainty] that human influence has been the dominant cause of the observed warming since the mid-20th century." The professional membership of the AMS agreed with a similar statement "is global warming happening and is it mostly human?" at a rate of only 52 percent. This can hardly be thought of as a consensus, and the professional membership of the AMS in my opinion is one of the few groups which follows the issue of climate change very closely. In addition, most of the membership is not funded by the climate establishment and thus is better able to provide objective, expert opinions apart from the influence of federal dollars – dollars which too often are provided to confirm the biases commonly held about climate change. The conclusion here is that in a survey of the professional membership of the AMS essentially half do not support the IPCC claim of such high confidence.

Your statement above about change is very different "...consensus among scientists that there is anthropogenic climate change." There is no quantification or alarm at all in this statement, hence as long as there is some tiny, even irrelevant change, one should answer yes (as I would) to the statement. I would suspect the agreement of scientists here would be near 100 percent because humans affect the climate in many ways, including through the development of the surface (i.e. farming, urbanization, etc.) Thus the "consensus" of "anthropogenic climate change" is at once vague, unquantified and obvious. It is important to know what question is being considered.

The main problem here is the extrapolation of a statement such as yours by global warming enthusiasts to a claim completely uncalled for, i.e. to something like this "... consensus that human-caused climate change is dangerous and policies to reduce carbon emissions by directly or indirectly increasing energy costs are required." This alarm and policy prescription is not part of the relatively benign statement that climate is changing (as it always has) and that humans have some role in that.

Regarding other surveys which purport to claim a "97 percent" consensus, one can quickly find deficiencies in those in follow up studies (see Legates et al. 2013). Key points to note are that some of the surveys did not sample the respondents in an unbiased way while others asked fairly ambiguous questions, i.e. "Do you believe humans have had a [significant] influence on the climate?" This latter question would be answered positively by scientists like me because we have detected in various climate variables the impact of some type of human influence (most notably that due to development of the land surface). Then again, the "significant influence" may be only 5 percent of the change and thus very small, but if detectable, then one must answer the question in the affirmative. However, this says nothing about whether the climate change was related to greenhouse gases or whether this climate change was "dangerous" or that policies which increase the cost of energy would have any effect at all on the human-caused part of climate change.

The fundamental issue I raised regarding the IPCC is that the opinion of the IPCC scientists rests on the performance of the AR5 climate models. I demonstrated in the Hearing that the models were not trustworthy to answer the question of human influence on climate because they could not even reproduce the current climate. Those are numbers, not opinions. History is replete with examples where the majority of "experts" were wrong in the face of inconvenient evidence.

I understand that in the political system, decisions are mostly based on opinions of constituents. I am here to offer some illuminating *numbers of science* (not *opinions of scientists*) that the committee members have likely not seen before and which I hope they would take into account regarding the immaturity and murkiness of climate science. I do not support the notion of making decisions based upon climate model simulations because

they show such poor performance relative to the real world. Nor do I support opinions of those who "believe" in climate model output.

2. You pointed to ice expansion in the Antarctic as a variable in the global climate system that would offset the loss of ice in the Arctic through the albedo effect. Can you explain how winter ice expansion in Antarctica produces an offsetting effect to the loss of ice in the Arctic?

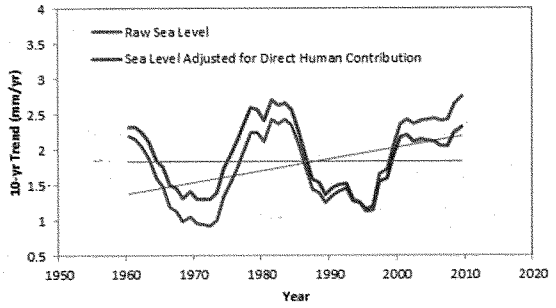
The area of the Arctic sea ice is essentially confined to the Arctic Ocean which is mostly bounded by the northern hemisphere continents. This configuration obviously inhibits equatorward expansion and therefore inhibits a means for the Arctic to have a larger albedo impact. The situation is almost the opposite in the southern hemisphere where the Antarctic continent sits near the South Pole so that sea ice, which grows around it, may expand unbounded to lower latitudes. As the SH sea ice has expanded in the past few decades the expansion to lower latitudes means the albedo (reflectivity) will increase non-linearly as more ice is exposed to solar radiation at ever-increasing inclination angles (thus reflecting more and more sunlight). This effect was discussed in Pielke et al. 2004, as a so-called isolation-weighted albedo. The sunlight at Arctic Ocean latitudes (>70°) is always (if at all) at very low angles which means absorption is less (even for open water) compared with lower latitudes (as low as 55°S) where the Antarctic sea ice can be found and where sunlight falls on any day of the year. The largest albedo effect in the SH occurs as the sun's inclination increases in their Spring (Sep-Nov) while the sea ice lags behind in melting.

I would point out that the NH snow cover is a major albedo factor too and that during the winter of 2012-13, the extent reached its maximum of the past few decades.

3. In the hearing there was some debate about sea level trends. In particular there was disagreement about whether sea levels have been rising and the rate of change in sea levels. Please describe your understanding of sea level trends, particularly over the last 150 years, and provide citations to the work you find to be the most authoritative.

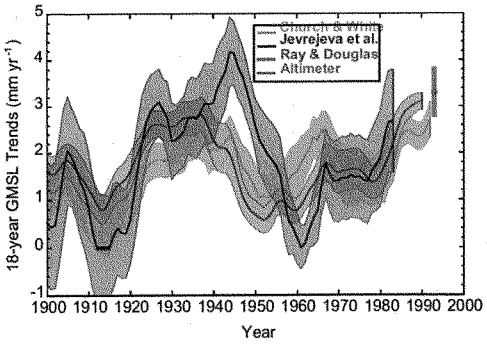
That sea level has been rising over the past 150 years was not questioned. Sea level has been rising since the last glacial maximum around 20,000 years ago through the current interglacial period known as the Holocene. During the main sea level rise, from 15,000 to 7,000 years ago, the rate was about 12mm/year because there were large volumes of ice at relatively low latitudes, such as the upper Midwest and Canada, which were available for melting. Sea level has been higher in previous interglacial periods, the most recent being about 125,000 years ago during which sea level was 5 to 6 m higher than today. This evidence from previous interglacial periods indicates there is more land-ice to melt in the

current interglacial (with or without human influence) and thus continued sea level rise is to be expected.



Sea level is a complex quantity to monitor due to numerous factors which must be taken into account. The standard measurements by tide gages world-wide indicate the rate of sea level rise has not changed in the past 100 years (Holgate 2007, Jevrejeva et al. 2008, Wada et al. 2010, Church and White 2011, Wada et al. 2012) with current rates (near 2.5 mm/year) seen in the 1950s as well. The figure above shows the 10-yr moving linear trend through the raw sea level values (red) to produce rates-of-rise, and (blue) the sea level after removing the contribution from impoundments and continental dewatering, 1960-2009 (data from Church and White, 2011; Wada et al., 2012). (for figure, see http://www.cato.org/publications/commentary/current-wisdom-no-climaterelated-acceleration-sea-level-rise.) What is interesting in the figure above is that the changes shown are produced by direct human action (i.e. (a) reservoir building which holds water back, or (b) dewatering wetlands which sends extra water to the ocean) and not climate change. [Note: I prefer the tide-gage measurements as these are consistent through the time period examined. Satellite measurements are only recent and require considerable adjustment for use.]

Chapter 3 IPCC WGI



The IPCC AR5 (Fig. 3-14, left) also indicates that the estimate of the current rate of sea level rise is similar to rates of previous decades (again using primarily tide gage measurements).

It should be clear, as noted above, that the sea level should continue to rise in the current interglacial just as it has in previous interglacial periods until the next ice age.

John R. Christy
University of Alabama in Huntsville

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Responses by Admiral David Titley
Dr. David Titley

Q1. What is the level of consensus among climate scientists that there is climate change? Please list the sources that support your views.

The question as to the level of consensus that: (1) there is climate change; and (2) that humans are the primary cause of that change, has been studied several times over the past decade. At least three papers on this subject have been published in the peer-reviewed literature.

Oreskes (2004) searched peer-reviewed abstracts published between 1993 – 2003 on the subject of 'global climate change'. Of the 928 papers that contained the term ('global climate change') "Remarkably, none of the papers disagreed with the consensus position." (Orsekes, 2004)

Doran and Zimmerman (2009) surveyed over 10,000 Earth scientists. Their response rate was 30.7%, typical for web-based surveys. Their survey encompassed scientists who identified their primary expertise in geochemistry, geophysics, oceanography, geology, hydrology and paleontology. About 5% of the respondents identified themselves as climate scientists, and over 8% stated that the majority of their peer-reviewed publications over the past five years addressed the issue of climate change.

Doran and Zimmerman's results showed that over 90% of their respondents stated that mean global temperatures have risen compared to the pre-1800's level, and that 82% of the participants stated that human activity "is a significant contributing factor in changing mean global temperatures." However, the number of scientists who stated that human activity is a significant contributing factor rose as correlated with their expertise and active research and specialization in climate science. Specifically, 97.4% of climate scientists who were actively publishing in the peer-reviewed literature about climate change stated that human activity was a significant contributing factor.

Finally, the following paragraph from the web site 'Skepticalscience.com' http://www.skepticalscience.com/global-warming-scientific-consensus-intermediate.htm summarizes the findings of Cooke et. al. (2013):

> "Scientists need to back up their opinions with research and data that survive the peer-review process. A Skeptical Science peer-reviewed survey of all (over 12,000) peer-reviewed abstracts on the subject 'global climate change' and 'global warming' published between 1991 and 2011 (Cook et al. 2013) found that over 97% of the papers taking a position on the subject agreed with the consensus position that humans are causing global warming. In a second phase of the project, the scientist authors were emailed and rated over 2,000 of their own papers. Once again, over 97% of the papers taking a position on the cause of global warming agreed that humans are causing it."

Q2: An American Meteorological Society (AMS) survey was cited by one witness at the hearing as evidence for the proposition that there is not a scientific consensus regarding anthropogenic climate change. Is this a reliable study for this claim? In your opinion, on balance, are there studies that are more reliable and, if so, why?

The witness was extremely selective in quoting numbers from this AMS survey. This peer-reviewed study by Stenhouse et. al. (2013) sought to replicate and extend the previously referenced work of Dornan and Zimmerman (2009). The AMS survey asked members to characterize their area of expertise (climate science, other science, other) and publication focus (climate, other, or non-publishers).

The **key finding: 93% of actively publishing climate scientists responded that humans have contributed to global warming**, conforming closely to Doran and Zimmerman's (2009) finding of 97%. Furthermore, for the entire sample size of 1821 respondents, only 4% stated that global warming was not happening, and only 5% are convinced that global warming over the past 150 years is due solely or mostly to natural causes.

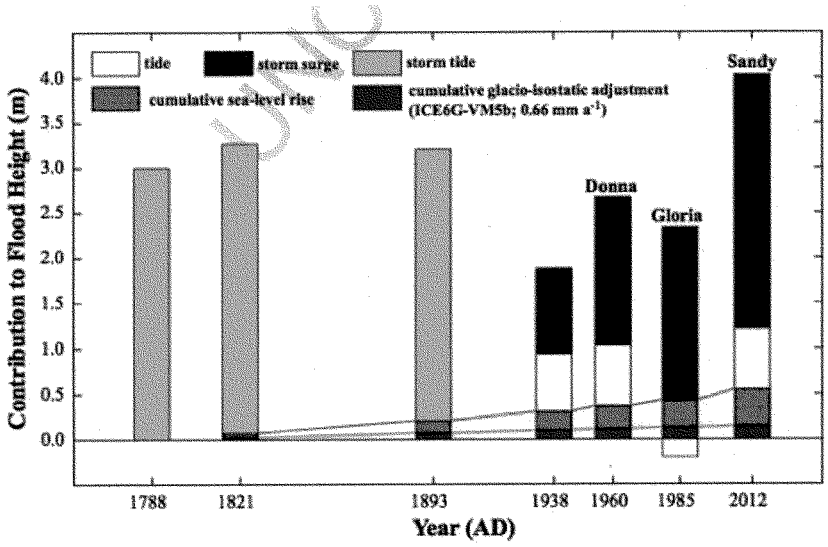
Finally, the authors believe the number of AMS member who would have responded in the affirmative to the question of anthropogenic global warming would have been even higher if the question had been confined to the past 50 (vice 150) years. This belief is based on a number of written comments from survey participants.

Q3: There have been claims that Sandy was not a particularly powerful storm and that the media focus was largely because the storm hit New York City. Can you access this claim and clarify what, if any, physical or other characteristics (size, strength, etc.) made Sandy so damaging? Is there a potential link between rising sea levels and the damage caused by Sandy?

Sandy was a unique storm in many ways, Quoting from the National Oceanic and Atmospheric Administration (NOAA) Hurricane / Post-Tropical Sandy Service Assessment released in May 2013, (http://www.nws.noaa.gov/os/assessments/pdfs/Sandy13.pdf) "Its historically unprecedented track approached New Jersey and New York from the east; storms typically approach from the south. Sandy also made an atypical transition to post-tropical status. The storm evolved when a tropical cyclone merged with an intense low pressure system and dramatically increased in size before landfall."

In other words, Sandy was the first time we had seen a hurricane wrapped inside a nor'easter cyclone, it was really large in size, and its track from east to west, making a direct hit on the coast of New Jersey, had not been previously observed. Sandy was a unique event. The size and strength of Sandy, combined with its movement, allowed waves and storm surge to build dramatically along the northern New Jersey, Long Island, New York and southern New England.

In addition to the storm surge, the rise in sea levels contributed to the overall destructiveness of the surge and inundation. The relative contribution of the various components of surge, and their comparison with previous historic storms in the New York City area since 1788 can be seen in the graphic below, from Kemp and Horton (2013)[1]



While tides and the storm surge were the major components of Sandy's destructiveness, this graph shows the ever-increasing contribution to inundation from a rising sea level.

Q4: How does a rising sea level affect the impact of extreme storms on coastal communities and what does that suggest for the future?

Rising sea levels will make existing storms and Hurricane more destructive, even if the individual storms themselves are no more intense than observed historically. The surge and inundation will be starting from a higher baseline than was seen in the 20th century. My expectation is that global sea levels will rise around three feet in the 21st century. Unfortunately, some locations of great value to the U.S., like the Gulf Coast and Hampton Roads region in Virginia will likely see increased values of apparent sea level rise, due to an unfortunate confluence of local and global effects.

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[1] Kemp, A.C. and Horton, B.P., 2013. Contribution of relative sea-level rise to historical hurricane flooding in New York City. Journal of Quaternary Science, 28, 537-541.

Therefore, in future decades, even routine and otherwise unremarkable storms will have serious impact on local infrastructure, and the big storms, without adaptation, will have unprecedented impacts on our coastal communities.

Q5: Can you explain the albedo effect? Is it likely that the expansion of Antarctic ice impacts the albedo of the earth? How does this compare to the effects of ice loss in the Arctic?

The albedo effect, in the context of climate, is a measure of how much of the Sun's energy is reflected back into space. The more light and white-colored surface (e.g., clouds, snow, ice) compared to dark matter (e.g., water, forests, pavement), the higher the albedo effect and the more energy is reflect away, rather than absorbed by the earth's system.

The sea ice systems of the Antarctic and Arctic are very different, due to Antarctica being a continent surrounded by ocean and the Arctic being an ocean that is basically surrounded by landmasses. The Antarctic sea-ice system has, for centuries if not millennia, experienced very large changes between the winter-time growth of ice and the melt-back to summer conditions. During the entire year, the vast majority of the Antarctic continent remains covered by snow and ice (and thus has a high albedo). While the Antarctic sea-ice expands dramatically in the southern hemisphere winter (and its growth rate has increased in recent years), the impact on global albedo is small. That is because the ice reaches it maximum extent in winter, when the sun is at a low angle and contributes little to the earth's total heat budget. In the southern hemisphere summer, the sea-ice retreats rapidly back to near the continent's edge, resulting in the same snow and ice coverage (primarily the continent itself) as has been observed historically.

In the Arctic Ocean, the difference is there is a dramatic loss of sea-ice in the summer time compared to earlier decades in the 20th century. This difference in the summer time changes the albedo in the Arctic from very high values (60-90%) because of the snow and ice, to the very low values (10-20%) of ocean water. The energy of the summer sun is absorbed by the open waters of Arctic Ocean, further warming the waters and resulting in additional sea-ice melt. This is the 'arctic amplification process.

In summary: the key to impacting the albedo and Earth's energy budget is the difference in snow and ice cover in the summer seasons, compared to the historical averages. The Antarctic system has yet to have a significant decrease in its albedo in the summer with a snow-covered continent surrounded by a small ring of sea-ice. In contrast, the loss of summer sea-ice in the Arctic Ocean has impacted the Arctic's albedo effect and accelerated the warming in the Arctic, consistent with both global warming theory and computer simulations.

Q6: When was the Arctic as warm as it is now? Please feel free to comment on global temperatures overall as well as the issue of an ice-free Arctic. Please point the Committee to citations for work that supports your position.

Reliable satellite measurements of the Arctic only started in 1979, and there are very few meteorological observing stations older than 100 years in the Arctic. Scientists therefore must use proxies in the ice, biological, cultural, and geologic records to determine the last time the Arctic was as warm as today.

The information provided by the National Snow and Ice Data Center (NSIDC) sums up the answer to this question as well as anyone:

> *We know for sure that at least in the distant past, the Arctic was ice-free. Fossils from the age of the dinosaurs, 65 million years ago, indicate a temperate climate with ferns and other lush vegetation.*
>
> *Based on the paleoclimate record from ice and ocean cores, the last warm period in the Arctic peaked about 8,000 years ago, during the so-called Holocene Thermal Maximum. Some studies suggest that as recent as 5,500 years ago, the Arctic had less summertime sea ice than today. However, it is not clear that the Arctic was completely free of summertime sea ice during this time.*
>
> *The next earliest era when the Arctic was quite possibly free of summertime ice was 125,000 years ago, during the height of the last major interglacial period, known as the Eemian. Temperatures in the Arctic were higher than now and sea level was also 4 to 6 meters (13 to 20 feet) higher than it is today because the Greenland and Antarctic ice sheets had partly melted. Because of the burning of fossil fuels, global averaged temperatures today are getting close to the maximum warmth seen during the Eemian. Carbon dioxide levels now are far above the highest levels during the Eemian, indicating there is still warming to come.*
>
> *According to analyses at NASA and NOAA, the past decade has been the warmest in the observational record dating back to the 19th century and the Arctic has been substantially higher than the global average.*

Recent research by Miller et. al. (2013)[2] sampled 145 radiocarbon dates on rooted tundra plants in the eastern Canadian Arctic. The data show that the average summer temperatures of the last ~100 years are higher now than during any century in more than at least 44,000 years, including the peak warmth of the early Holocene. Further research will be required to see if this result is replicated in different regions in the Arctic.

Q7: Although there have certainly been times in the past when the earth was as warm or warmer than it is now or is likely to be by the end of this century, how does

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[2] Miller, G. H., S. J. Lehman, K. A. Refsnider, J. R. Southon, and Y. Zhong (2013), Unprecedented recent summer warmth in Arctic Canada, *Geophys. Res. Lett.*, 40, 5745–5751

the pace of contemporary climate change impact societies and biological systems and their ability to adapt to change?

It is really outside my scope of expertise to comment on how biological systems may or may not adapt to that change. My professional judgment as a retired Navy Admiral is that the security risk, or risk o instability, to any society goes up when confronted by rapid change, no matter the source. Samuel Huntington makes a similar argument in his 1986 book "*Political Order in Changing Societies*".

As to the rate of climate change, a 2013 study by Stanford scientists Noah Diffenbaugh and Chris Field state that the rate of climate change is occurring 10 times faster than any climate change on Earth in the past 65 million years. http://news.stanford.edu/news/2013/august/climate-change-speed-080113.html This rate of change, perhaps even more than the absolute change itself, when combined with a population of over 7 billion people, their need for adequate and assured food, energy, and water, and globalized, mutually aware and inter-connected societies, pose a challenge not seen to civilization at least since the Black Death in the 14th century,

Q8: In the hearing there was some debate about sea level trends. In particular there was disagreement about whether sea levels have been rising and the rate of change in sea levels. Please describe your understanding of sea level trends, particularly over the last 150 years, and provide citations to the work you find to be the most authoritative.

I believe the conclusions of the Fifth Assessment report (AR5) of the IPCC (2013)[3] are reasonable. In Chapter 3 of AR5, the IPCC states that is it 'virtually certain' (99-100% probability) that the sea level rose in the 20th century. There is at least a 90% likelihood that the mean (or average) rate of sea level rise was 1.5 mm / year from 1901 – 1990. From 1993 – 2010, that rate of sea level rise increased to an average of 3.2 mm / year. The IPCC report stresses the need for long (e.g., multi-decadal observations of sea level rise to account for long-term natural variations in global sea level resulting from natural variations to include El Nino, La Nina, the Pacific Decadal Oscillation, the Atlantic Multi-decadal Oscillation.

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[3] Rhein, M., S.R. Rintoul, S. Aoki, E. Campos, D. Chambers, R.A. Feely, S. Gulev, G.C. Johnson, S.A. Josey, A. Kostianoy, C. Mauritzen, D. Roemmich, L.D. Talley and F. Wang, 2013: Observations: Ocean. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental
Panel on Climate Chang [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V.
Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

A recent paper[4] further emphasized the importance of accounting for these natural variations. Cazenave and her colleagues analyzed recent sea level trends since1993 using both satellite altimetry-based data and observations from the Gravity Recovery and Climate Experiment (GRACE) data set (these data have been available since 2003). They found that the 'La Nina' events of the early 21st century explain virtually all of the apparent slowdown in global sea level rise. During 'La Nina' (El Nino) events, more rain falls on the land (ocean) than on the ocean (land) and results in a short-term decrease (increase) in global sea level rise until the water flows through the hydrologic cycle and back into the ocean. After correcting for the La Nina trend, Cazenave et. al. found the rate of sea level rise has been constant at 3.3 mm / year (+/- 0.1 mm / year) since 1993.

[4] Cazenave, A., Dieng, H. B., Meyssignac, B., von Schuckmann, K., Decharme, B., and Berthier, E., The Rate of Sea-level Rise, *Nature Climate Change.* (2014)

Responses by Dr. Roger Pielke Jr

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Subcommittee on Environment

RESPONSES OF ROGER PIELKE, JR. TO
Hearing Questions for the Record
The Honorable Lamar Smith

A Factual Look at the Relationship between Climate and Weather

Dr. Pielke

1. Everyone from the UN Intergovernmental Panel on Climate Change to the President to the journal Nature have admitted it is very difficult to attribute specific weather events to climate change. However, Dr. Titley and Dr. James Hansen have argued that man-made climate has resulted in the deck being stacked toward more extreme weather events generally.

    a. Is this characterization correct? Is there a detectable signal that these events have been made more likely over the scale of decades?

PIELKE RESPONSE: Debate over the influence of human-caused climate change on extreme events often conflates expectations for the future with observations of the past. The scientific literature, as assessed by the Intergovernmental Panel on Climate Change, does include projections for some types of extreme events to become more frequent and/or more intense. At the same time, as I summarized in my testimony, there is very limited evidence to support claims that such increases in frequency and/or intensity have been observed in most types of extremes – notably, the incidence and impacts of tropical cyclones (hurricanes), floods, drought, tornadoes and winter storms. Given a set of projections for changes in frequency/intensity of particular extreme events, it is a mathematical exercise to calculate when such changes might be detected in the observational record. As I detailed in my testimony, such detection may lie in the distant future. Consequently, that no such signal is detected today is consistent with long-term projections. That is, we should not expect to see changes in most types of extreme at the present time and this is indeed what the data shows.

2. In light of the last decade and a half of global temperatures not rising, have we learned anything new about the relationship between temperature and extreme weather events?

    a. In light of this "pause," how can the President and others continue to project with medium and high confidence that certain extremes may get worse?

PIELKE RESPONSE: While the issue of the so-called "pause" in global temperature increases has attracted considerable attention, it is not of direct relevance to understanding either the historical patterns of most extreme events or long-term projections for their future evolution.

3. Dr. Titley's testimony cites a single study regarding one climate model about tropical cyclone activity in the 21st century when making that claim that "our future may include more intense, and possibly more frequent storms."

    a. How is this claim consistent with the IPCC's recently-revised projection that there is "low confidence" in any increase in intense tropical cyclone activity through 2050?

PIELKE RESPONSE: Dr. Titley is correct to say that "our future may include more intense, and possibly more frequent storms." However, it would also be correct to say that "our future may include less intense, and possibly less frequent storms." Looking across studies, rather than at any single study, the IPCC concludes, "there is low confidence in region-specific projections of frequency and intensity."

4. Has man-made climate change contributed to increased intensity or frequency of wildfires is the U.S., as the President has indicated?

PIELKE RESPONSE: The IPCC AR5 does not detect or attribute a linkage between human-caused climate change and wildfire intensity or frequency. However, there is ample literature to suggest that such a connection is plausible. The many factors which influence wildfire incidence, many of which are related to human activities, make the detection and attribution of signals difficult.

5. Were the recent floods in Colorado driven by man-made climate change?

PIELKE RESPONSE: Attribution of causality to human-caused climate change for single-events remains a much debated topic and of questionable scientific value. Flooding in the US Southwest, including Colorado has decreased on climate time-scales (Hirsch and Ryberg 2012).

6. Is there evidence that recent historic droughts in Texas have been driven by man-made climate change?

PIELKE RESPONSE: You will find conflicting claims on Texas drought in the literature. A NOAA report does not find strong evidence for such a linkage.[1] Another recent study is suggestive of a linkage.[2] Attribution of causality to human-caused climate change for single-events remains a much debated topic and of questionable scientific value. Drought in the US, as I documented in my testimony, has not increased nation-wide or globally on climate timescales.

7. Were there any aspects of testimony received during the hearing regarding extreme weather events and climate change that you would like to elaborate on further?

[1] http://drought.gov/drought/content/drought-task-force-report-page
[2] http://www1.ncdc.noaa.gov/pub/data/cmb/bams-sotc/extreme-events/Rupp-et-al.pdf

PIELKE RESPONSE: No. I am quite satisfied with the breath of information that I shared in my testimony.

8. Were there any aspects of testimony received during the hearing regarding extreme weather and climate change that you disagree with? If so, please elaborate.

PIELKE RESPONSE: No.

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Subcommittee on Environment

RESPONSES OF ROGER PIELKE, JR. TO
Hearing Questions for the Record
The Honorable Suzanne Bonamici

A Factual Look at the Relationship between Climate and Weather

Dr. Pielke

1. In your testimony you acknowledge that anthropogenic climate change is a real phenomenon with real consequences for the climate. You also condemn "activists, politicians, journalists, corporate and government agency representatives and even scientists" for making claims about climate change being a contributing factor to extreme weather events for which there is not strong evidence. You said that "such claims could undermine the credibility of arguments for action on climate change..." There is nothing in your testimony that similarly condemns "activists, politicians, journalists, corporate and government agency representatives and even scientists" who deny that climate change is happening at all or that there are anthropogenic causes for climate change. Could their claims also be undermining the credibility of arguments for action on climate change? Why or why not?

PIELKE RESPONSE: There are at least three reasons why those who "deny that climate change is happening at all or that there are anthropogenic causes for climate change" are largely irrelevant and thus a distraction. First, while there are people who "deny that climate change is happening at all or that there are anthropogenic causes for climate change" most of those who identify themselves as opposed to action on climate change admit the reality of climate change and even a human role, but take issue with its significance in the context of the actions that are often proposed in response. Second, as I document in my book **The Climate Fix** (2010) public opinion on the reality of climate change, a human role in it and the importance of action has been remarkably strong for many decades. Public opinion varies, often with the weather, but there is nothing unique about public opinion on climate change that would suggest it as an obstacle to action. History shows many important issues with much less public support for which action was taken. Third, those calling for action on climate change often ground their arguments in claims of scientific authority. To the extent that such claims are shown to be overstated or just wrong – as often the case with respect to extreme events – then the resulting loss of credibility will be disproportionately larger than to those who start from a minority position or on the fringes of science. I elaborated on these arguments in a recent essay for *The Guardian*.[3]

[3] http://www.theguardian.com/science/political-science/2013/may/24/climate-sceptics-winning-science-policy

2. You make a second claim regarding the pernicious results of overstated connections between extreme weather events and climate change: that such "false claims confuse those who make decisions related to extreme events, and could lead to poor decision-making." Please provide an example of where this has happened as well as the resulting consequences.

PIELKE RESPONSE: In 2007, Working Group II of the Intergovernmental Panel on Climate Change included a graph in its report which showed an apparent correlation between increasing global temperatures and the global costs of disasters. This graph was included in violation of the IPCC's guidelines, as it had never appeared in any scientific study. It was created by an IPCC author, an employee of a catastrophe modeling firm called RMS, because he expected that it would show up in a future study. In order to get the graph into the report the author intentionally mis-cited it to a separate non-peer reviewed white paper that he had co-authored (ironically, as a contribution to a workshop that I organized.) However, that graph did not ever appear in that future study and the IPCC author later admitted that its inclusion was a mistake (This episode is detailed in **The Climate Fix**).

At the same time, the company that employed this IPCC author had made a dramatic change to its estimates of hurricane incidence in the United States. In 2011 the Sarasota Herald-Tribune was awarded a Pulitzer Prize for its investigative reporting of what came next. Here is an excerpt from that prize-winning reporting:[4]

> RMS, a multimillion-dollar company that helps insurers estimate hurricane losses and other risks, brought four hand-picked scientists together in a Bermuda hotel room.
>
> There, on a Saturday in October 2005, the company gathered the justification it needed to rewrite hurricane risk. Instead of using 120 years of history to calculate the average number of storms each year, RMS used the scientists' work as the basis for a new crystal ball, a computer model that would estimate storms for the next five years.
>
> The change created an $82 billion gap between the money insurers had and what they needed, a hole they spent the next five years trying to fill with rate increases and policy cancellations.
>
> RMS said the change that drove Florida property insurance bills to record highs was based on "scientific consensus."
>
> The reality was quite different.
>
> Today, two of the four scientists present that day no longer support the hurricane estimates they helped generate. Neither do two other scientists involved in later revisions. One says that monkeys could do as well.
>
> In the rush to deploy a new, higher number, they say, the industry skipped the rigors of scientific method. It ignored contradictory evidence and dissent, and created penalties for

[4] http://www.pulitzer.org/archives/9195

> those who did not do likewise. The industry flouted regulators who called the work biased, the methods ungrounded and the new computer model illegal.
>
> Florida homeowners would have paid more even without RMS' new model. Katrina convinced the industry that hurricanes were getting bigger and more frequent. But it was RMS that first put a number to the increased danger and came up with a model to justify it.
>
> As a result of RMS' changes, the cost to insure a home in parts of Florida hit world-record levels.

It turns out, since RMS issued its forecast of enhanced hurricane activity, the United States has not been struck by a Category 3 or stronger hurricane, marking the longest such stretch going back to at least 1900. The new estimates proved wildly overstated.

For its part, RMS today views the science of hurricanes quite differently, "warmer atmospheric conditions may act to reduce the likelihood of hurricane landfalls along the Atlantic Coast due to stronger atmospheric winds blowing west to east during hurricane season, effectively pushing storms away from the U.S.".[5]

Meanwhile, overblown claims of a sudden change in US hurricane risk led to dramatic increases in insurance costs for Florida residents. The Sarasota Herald Tribune Explains:

> For most of the past two decades, risk models have relied on actual hurricane activity recorded over more than 100 years to produce averages and other estimates of storm formation.
>
> But even before Katrina, RMS was under pressure to disband the long-term outlook. Insurance insiders wanted something they believed would be more accurate. And they wanted it to forecast hurricane activity for next few years based on current conditions, not simply assume history would repeat itself.
>
> The pressure came from several places. Some reinsurers sought validation that global warming was increasing the threat of hurricanes. Others in the industry wanted a short-term model to encourage investors, who wanted odds on their returns in the near term.
>
> RMS CEO Hemant] Shah says he had an obligation to pursue the short-term model because of the belief that hurricanes had gotten more dangerous.

The overstatement of the connection between climate change and extreme events can sometimes just be a bit of political hyperbole intended to add intensity to support for climate policies. But such overstatement can also have consequences. In this well-documented case the overstatement

[5] http://www.rms.com/blog/2013/09/15/2013-atlantic-hurricane-season/

resulted in the transfer of tens of billions of dollars from Florida citizens to reinsurance companies based on flawed estimates of hurricane risk.[6]

3. As I understand it, rather than trying to control carbon emissions, you advocate an expansion of alternative energy sources to serve both economic demands and environmental needs. What policies and programs would you advocate in order to expand alternative energy sources? What level of funding in the U.S. would be needed to carry this forward? How would you recommend structuring this approach to obtain the broadest support from energy sectors and to minimize opposition from fossil fuel industries? Would this approach be adequate to slow the release of carbon emissions and reduce the inevitable changes that result from those releases?

PIELKE RESPONSE: Thanks for this question. Just about everyone recognizes that developing the energy resources for the future will require innovation. The conventional view has been that putting a price on carbon – via a substantial tax or cap-and-trade program – would provide businesses and consumers with incentives to invest more in energy innovation. However, the fatal flaw in this perspective is that efforts to raise the costs of energy have their political limits, such as observed in Europe just this week, as the EU has stepped back from aggressive and costly energy policies in order to shore up the continent's competitiveness. I, along with many colleagues, have argued that instead of focusing primarily on making dirty energy expensive, we should focus to a greater degree on making clean energy cheap.

A great commitment to public sector innovation might be supported with a low carbon tax (How low? At whatever level is politically acceptable). Consider that a $5 per ton tax on carbon dioxide would add about $0.04 to the price of a gallon of gas and raise about $30 billion per year in the US (Pielke 2010). To put this into context, the Department of Energy will spend $2.4 billion on energy R&D programs in FY 2014.[7]

As the United States has learned from its experiences with shale gas and shale oil, innovation which leads to lower priced energy costs confer substantial economic and competitiveness benefits. Such innovation requires partnerships of the public and private sectors, and often a very long lead time -- the key innovations underpinning shale gas and oil technologies were decades in the making.

The world will continue to demand more and more energy. Whatever one thinks about climate change it is in the interests of the United States to be at the forefront of energy innovation for decades to come. We should think hard about how we might bring greater resources to meeting the challenges and opportunities posed by energy demands of a growing world. Building a bridge

[6] This experience is not unique. A just-released scientific paper written by an all-star team of researchers (involved with the IPCC: concludes: "There is such a furore of concern about the linkage between greenhouse forcing and floods that it causes society to lose focus on the things we already know for certain about floods and how to mitigate and adapt to them." http://www.tandfonline.com/doi/full/10.1080/02626667.2013.857411

[7] http://www.aaas.org/news/rd-fy-2014-omnibus-department-energy

to that energy future by placing a small tax or fee on today's energy makes good sense. These ideas are discussed in greater depth in *The Hartwell Paper* and elsewhere.[8]

4. In your "Truth in Testimony" statement, you acknowledge receiving more than $12.7 million in grant support from NSF—all but $39,435 of that came from social and behavioral/economic accounts. What projects and publications resulted from this funding? Did any of that funding contribute to work that you testified about in this hearing?

PIELKE RESPONSE: The total reported in the "Truth in Testimony" statement is actually $2.8 million. Most of that funding supported a project called "Science Policy Assessment and Research on Climate" (SPARC) which was funded under the NSF competition on Decision Making Under Uncertainty (the other two listed projects were science policy-related and did not focus in any way on climate). SPARC "conducts research and assessments, outreach, and education aimed at helping climate science policies better support climate-related decision making in the face of fundamental and often irreducible uncertainties." That project, now completed, resulted in hundreds of publications several of which were cited in my testimony.[9] A comprehensive account of that project and the work which it did can be found at: http://cstpr.colorado.edu/sparc/.

[8] http://www.lse.ac.uk/researchAndExpertise/units/mackinder/theHartwellPaper/Home.aspx

[9] http://cstpr.colorado.edu/sparc/library/sparc_library_search.html?showAllRecords=true&searchString=&action=Search&goInto=&toClose=

Appendix II

Additional Material for the Record

SUBMITTED BY REPRESENTATIVE SUZANNE BONAMICI

RAA
REINSURANCE ASSOCIATION OF AMERICA
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Facsimile: (202) 638-0936
http://www.reinsurance.org

December 9, 2013

The Honorable Suzanne Bonamici
Ranking Member
Subcommittee on Environment
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Congresswoman Bonamici:

I am writing to you on behalf of the Reinsurance Association of America, a national trade association representing reinsurance companies doing business in the United States, to address the RAA's perspective on weather and climate-related weather impacts in the United States in advance of the Environment Subcommittee's hearing on December 11, 2013.

Our industry is science based. Blending the actuarial sciences with the natural sciences is critical in order to provide the public with resources to recover from natural events. As the scientific community's knowledge of changes in our climate and the resulting weather continue to develop, it is important for our communities to incorporate that information into the exposure and risk assessment process, and that it be conveyed to stakeholders, policyholders, the public and public officials that can, or should, address adaptation and mitigation alternatives. Developing an understanding about climate and its impact on droughts, heat waves, the frequency and intensity of tropical hurricanes, thunderstorms and convective events, rising sea levels and storm surge, more extreme precipitation events and flooding is critical to our role in translating the interdependencies of weather, climate risk assessment and pricing.

Insurers see climate primarily through the prism of extreme natural events. Research by Munich Reinsurance Company (Munich Re) reflects a rising number of natural catastrophes globally and in the U.S.[1] In the 1980's, the average number of natural catastrophes globally was 400 events per year. In recent years, the average is 1000. Munich Re's analysis suggests the increase is driven almost entirely by weather-related events. North America has seen a fivefold increase in the number of such events since 1980.[2] In comparison, Europe has seen a twofold increase.

In this regard, it is indisputable that the recent rise in damages, insured, economic and uninsured, is heavily influenced by the concentration of people and property in geographically vulnerable areas.[3,4,5] Urbanization, increased development and population shifts have placed more people with destructible assets in areas most impacted by extreme weather. NOAA's recent State of the Coast report observes that in a U.S. population of 313 million (based on the 2010 census), coastal shoreline counties comprise 39% or 123 million people; watershed counties comprise 52% of the

[1] MR NatCat SERVICE, Natural Catastrophes Worldwide 1980-2013
[2] Munich Re Natural Catastrophes in the USA, 1980-2012
[3] NOAA U.S. Population Living in Coastal Watershed Counties
[4] Total Value of Insured Coastal Exposure in 2012
[5] Total Potential Home Value Exposure to Storm Surge Risk in 2013

U.S. population. In coastal shoreline counties, NOAA reports there are 49 million housing units with an expected increase in population of 10 million people before the next census in 2020. The NOAA report notes that an average of 1355 building permits are issued per day in these shoreline counties.

Together with changes in weather patterns, intensity, and number of events, the result, of course, is an inevitable rise in insured and uninsured damages globally and in the U.S.

However, other climate/weather related perils also cause major damage. Tornado losses in the U.S. exceeded $1 billion only once prior to 1998. Since then, there have been 29 such events. Severe wind is not the only peril reflecting this pattern. Goldman Sachs Global Economics reports the 2012 U.S. drought alone cut crop yields, reducing 3rd quarter 2012 GDP by .4%—the equivalent of another Superstorm Sandy. Droughts are now the third most costly category of natural catastrophe loss with crop losses dominant. Recent wildfire major events have destroyed homes and threatened communities.[6]

But what if the past is not prologue and, in a changing climate, weather, economic and social trends exacerbate the impact? In a study on Climate Change Impacts conducted for FEMA by AECOM, the firm concluded that the typical 100 year floodplain nationally would grow by 45% and by 55% in coastal areas (with significant regional variations and assuming a fixed shoreline). Notably the report attributed 70 percent of the projected growth in 100 year floodplains to climate change and 30 percent to expected population growth (the analysis assumes 4 feet of sea level rise by the year 2100). The study recommends immediate attention to the implications for the Federal government's National Flood Insurance Program, which is already $26 billion in debt.

Disaster assistance is already a major expense to the Federal government and has set records in recent years.[7] Dr. David Cummins of Temple University's School of Risk Management estimates the subsidization of disaster-prone areas embedded in Federal disaster assistance practices has encouraged development and increased Federal exposure. He estimates the expected average annual bill for Federal disaster assistance related to natural catastrophes at $20 billion. Current funding for FEMA's Disaster Relief Fund is $1 billion. Dr. Cummins estimates this unfunded liability over the next 75 years at $1.2 to $5.7 trillion, at the high end, essentially the unfunded obligations for Social Security.

As an enabler of change, the financial services industry can help guide society towards an effective response. As Congress considers the impact of climate change, the RAA suggests the following legislative principles or actions to consider:

- Provide tax credits to individuals for specified mitigation and resiliency actions associated with extreme weather and climate change.
- Incent communities to develop and implement mitigation and resiliency initiatives.
- Reform the National Flood Insurance Program to reflect extreme weather and climate risk in its rates.
- Apply Federal standards to state/local building codes and incorporate climate and extreme weather risk into these standards.
- Purchase or relocate properties near coastal or river areas at repeat risk.
- Use nature to mitigate risk before and after extreme events.
- Transfer development rights from coastal and river properties to areas inland (Strengthen the Coastal Barrier Resources Act)

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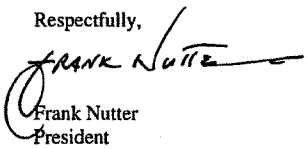
[6] National Interagency Fire Center Number of Acres Burned in Wildfires
[7] Number of Federal Disaster Declarations 1953-2013

- Fund adequate remote sensing for NOAA and NASA.
- Require the Army Corps of Engineers to assess climate risk for all projects.
- The Federal government should lead by example: GSA should assess its buildings and critical facilities in light of climate and extreme weather information.
- Fund climate and weather research through the National Science Foundation, NOAA and other Federal agencies at priority levels.
- Use disaster assistance as an incentive for local communities for climate and extreme weather sensitive, forward looking recovery.

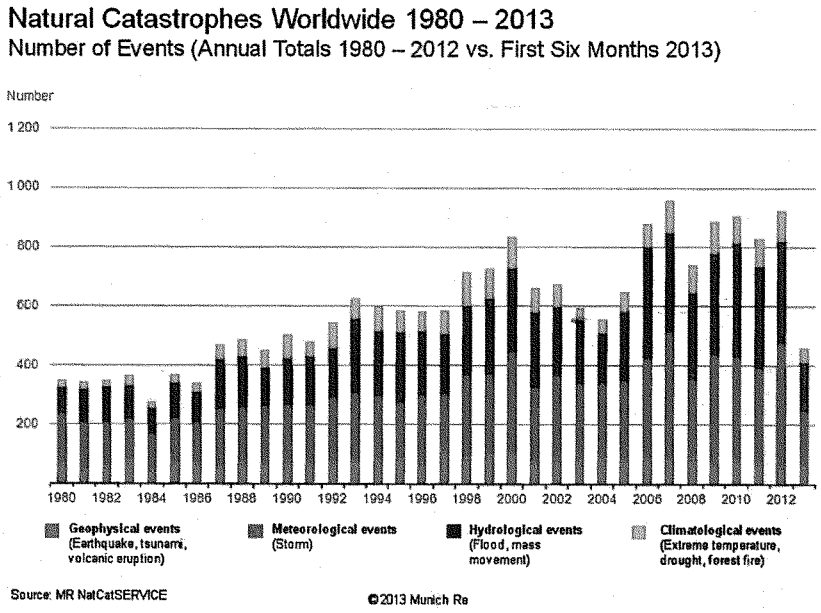
The Reinsurance Association and its member companies welcome the attention of Congress to the critical issues of extreme weather and climate. We are committed to work with you to address the exposure of citizens and their property to extreme weather risk and to seek ways to improve the resilience of our communities.

Respectfully,

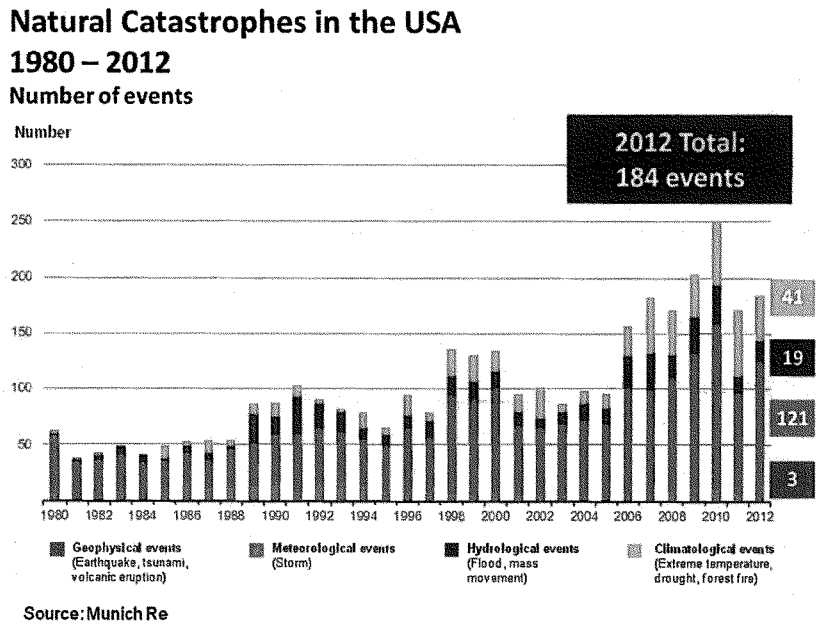


Frank Nutter
President
Reinsurance Association of America
1445 New York Avenue, N.W., 7th Floor
Washington, D.C. 20005

Footnote 1


Natural Catastrophes Worldwide 1980 – 2013
Number of Events (Annual Totals 1980 – 2012 vs. First Six Months 2013)
Number
1 200
1 000
800
600
400
200
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Geophysical events (Earthquake, tsunami, volcanic eruption)
Meteorological events (Storm)
Hydrological events (Flood, mass movement)
Climatological events (Extreme temperature, drought, forest fire)
Source: MR NatCatSERVICE
©2013 Munich Re

Footnote 2


Natural Catastrophes in the USA
1980 – 2012
Number of events
Number
2012 Total:
184 events
300
250
200
150
100
50
41
19
121
3
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Geophysical events (Earthquake, tsunami, volcanic eruption)
Meteorological events (Storm)
Hydrological events (Flood, mass movement)
Climatological events (Extreme temperature, drought, forest fire)
Source: Munich Re

Footnote 3

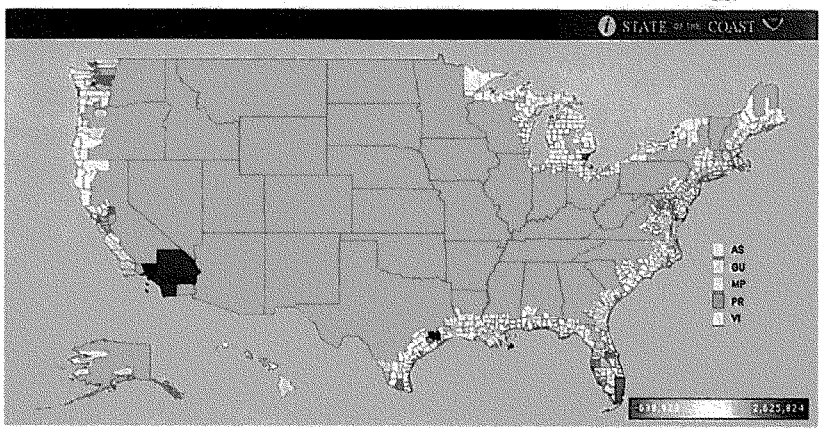
U.S. Population Living in Coastal Watershed Counties

52%
Percent of the nation's total population that lived in coastal watershed counties in 2010 (less than 20% of the total land area excluding Alaska).
Source: U.S. Census Bureau, 2011

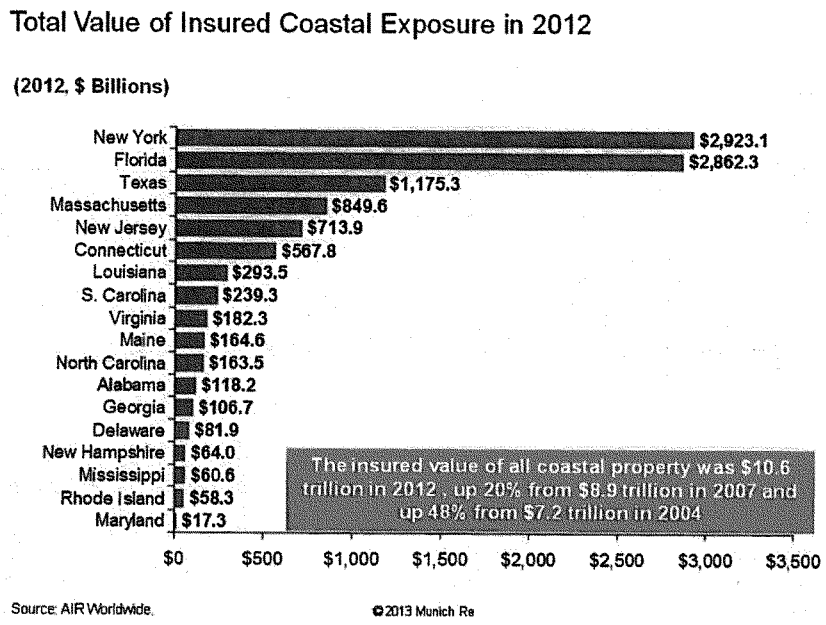
50.9 million
Increase in U.S. coastal watershed county population from 1970 to 2010 (or a 45% increase).
Source: U.S. Census Bureau, 2011

319
Average population density of the coastal watershed counties (excluding Alaska). Inland density averages 61 persons per square mile.
Source: U.S. Census Bureau, 2011

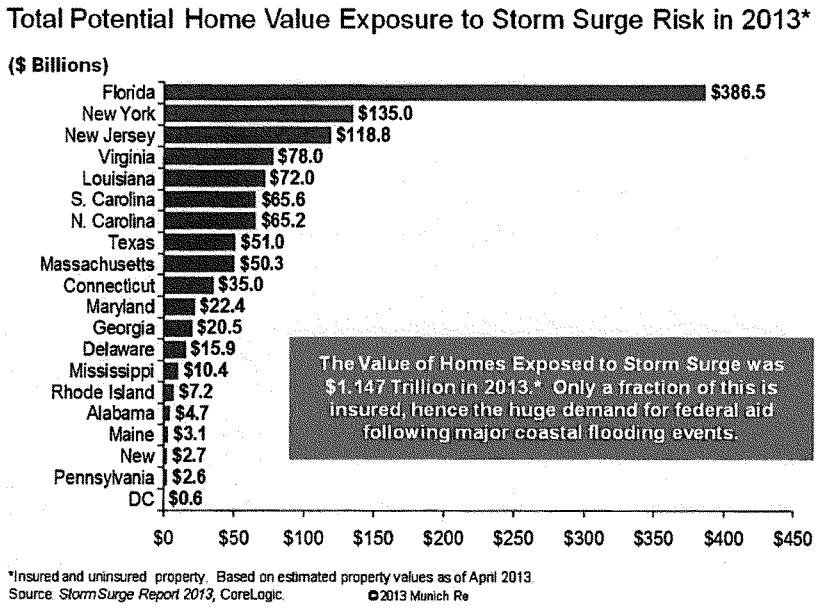
14.9 million
Expected increase in U.S. coastal watershed county population by 2020 (or a 9% increase, excluding Alaska).
Source: Woods & Poole, 2011; NOAA, 2011; U.S. Census Bureau, 2011



Footnote 4

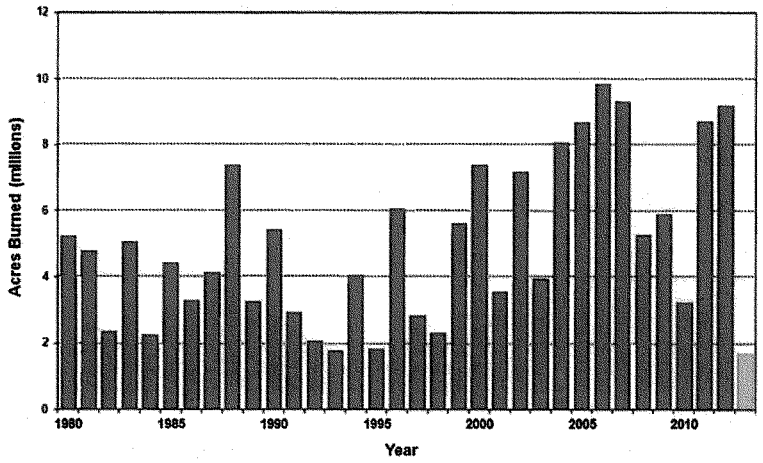

Total Value of Insured Coastal Exposure in 2012
(2012, $ Billions)
New York $2,923.1
Florida $2,862.3
Texas $1,175.3
Massachusetts $849.6
New Jersey $713.9
Connecticut $567.8
Louisiana $293.5
S. Carolina $239.3
Virginia $182.3
Maine $164.6
North Carolina $163.5
Alabama $118.2
Georgia $106.7
Delaware $81.9
New Hampshire $64.0
Mississippi $60.6
Rhode Island $58.3
Maryland $17.3
The insured value of all coastal property was $10.6 trillion in 2012 , up 20% from $8.9 trillion in 2007 and up 48% from $7.2 trillion in 2004
$0
$500
$1,000
$1,500
$2,000
$2,500
$3,000
$3,500
Source: AIR Worldwide.
©2013 Munich Re

Footnote 5


Total Potential Home Value Exposure to Storm Surge Risk in 2013*
($ Billions)
Florida $386.5
New York $135.0
New Jersey $118.8
Virginia $78.0
Louisiana $72.0
S. Carolina $65.6
N. Carolina $65.2
Texas $51.0
Massachusetts $50.3
Connecticut $35.0
Maryland $22.4
Georgia $20.5
Delaware $15.9
Mississippi $10.4
Rhode Island $7.2
Alabama $4.7
Maine $3.1
New $2.7
Pennsylvania $2.6
DC $0.6
$0 $50 $100 $150 $200 $250 $300 $350 $400 $450
The Value of Homes Exposed to Storm Surge was $1.147 Trillion in 2013.* Only a fraction of this is insured, hence the huge demand for federal aid following major coastal flooding events.
*Insured and uninsured property. Based on estimated property values as of April 2013.
Source: Storm Surge Report 2013, CoreLogic.
©2013 Munich Re

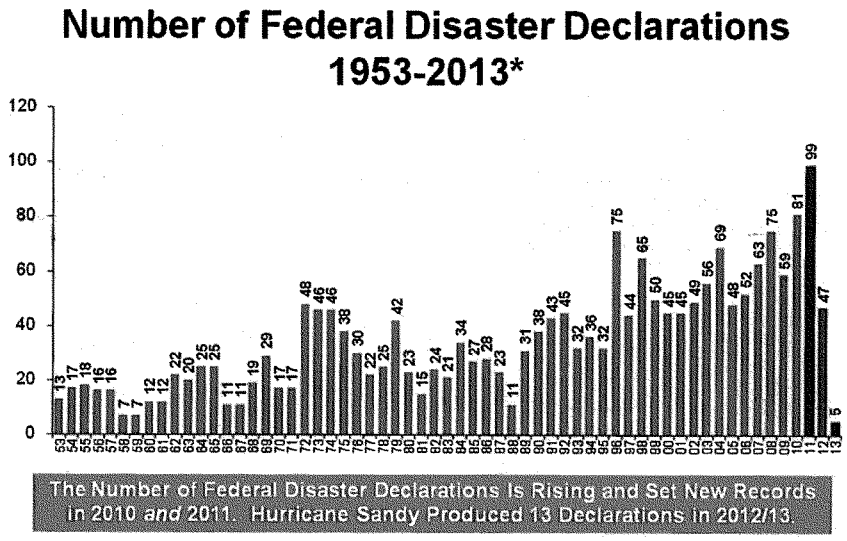
Footnote 6

Number of Acres Burned in Wildfires,
1980 – 2013 YTD



Source: National Interagency Fire Center

Footnote 7



*Through Feb. 24, 2013.
Source: Federal Emergency Management Administration, http://www.fema.gov/disasters, Insurance Information Institute.

Resources

- Core Logic: Storm Surge Report: Residential Storm Surge Exposure Estimate for the US Coastal Areas (2012)
- Federal Financial Exposure to Natural Catastrophe Risk, David Cummins, Michael Suher and George Zanjani (2010)
- Goldman Sachs, Global Economics, Commodities and Strategy Research
- ClimateWise, Summary of the IPCC Special Report on Managing the Risks of Extreme Events and Disasters
- Applied Insurance Research Coastline at Risk: Update to the Estimated Insured Value of US Coastal Property (2013)
- NOAA State of the Coast National Coastal Population Report (March 2013)
- Geneva Association (International Association for the Study of Insurance Economics): The Insurance Industry and Climate Change (July 2009)
- Munich Reinsurance, Climate Variability and Climate Change
- AECOM: The Impact of Climate Change and Population Growth on the national Flood Insurance Program through 2100 (June 2013)

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