



# CLIMATE SCIENCE

Assumptions, policy implications, and the scientific method

Judith Curry, John Christy, Michael Mann and Roger Pielke Jr

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## **About this report**

This report publishes testimony given by four prominent climate scientists to a hearing of the Committee on Science, Space and Technology of the US House of Representatives on 29 March 2017. Minor stylistic changes have been made to the text as originally presented by the witnesses.

# 1 Testimony of Professor Judith Curry

## Major points

- Scientific progress is driven by the creative tension spurred by disagreement, uncertainty and ignorance.
- Progress in understanding the climate system is being hampered by an institutionalized effort to stifle this creative tension, in the name of a 'consensus' that humans have caused recent climate change.
- Motivated by the mandate from the United Nations Framework Convention on Climate Change (the UNFCCC), the climate community has prematurely elevated a scientific hypothesis on human-caused climate change to a ruling theory through claims of a consensus.
- Premature theories enforced by an explicit consensus-building process harm scientific progress because of the questions that *don't* get asked and the investigations that *aren't* undertaken. As a result, we lack the kinds of information to more broadly understand climate variability and societal vulnerabilities.
- Challenges to climate research have been exacerbated by:
  - unreasonable expectations from policy makers
  - scientists who are playing power politics with their expertise and trying to silence scientific disagreement through denigrating scientists who do not agree with them
  - professional societies that oversee peer review in professional journals writing policy statements endorsing the consensus and advocating for specific policies.
- Policymakers bear the responsibility of the mandate that they give to panels of scientific experts. The UNFCCC framed the climate change problem too narrowly and demanded of the IPCC too much precision – where complexity, chaos, disagreement and the level of current understanding resists such precision.
- A more disciplined logic is needed in the climate change assessment process that identifies the most important uncertainties and introduces a more objective assessment of confidence levels.
- Expert panels with diverse perspectives can handle controversies and uncertainties by assessing what we know, what we don't know, and where the major areas of disagreement and uncertainties lie.

## Introduction

I thank the Chairman and the Committee for the opportunity to offer testimony today on 'Scientific Method as it Relates to Climate Change'. I am Professor Emeritus of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology. I have devoted four decades to conducting research on a variety of topics related to weather and climate. In recent years my focus has been on uncertainty and the interface between climate science and policy. As President of Climate Forecast Applications Network LLC, I have been working with decision makers to use weather and climate information to reduce vulnerability to extreme weather and climate events.

I am increasingly concerned that both the climate change problem and its solution have been vastly oversimplified. The result of this simplified framing of a complex, wicked problem is that we lack the kinds of information to more broadly understand climate variability and societal vulnerabilities.

Motivated by the mandate from the United Nations Framework Convention on Climate Change (UNFCCC) to address dangerous human-caused climate change, the climate community has worked for more than 20 years to establish a scientific consensus on human-caused climate change, which has prematurely elevated a scientific hypothesis to a ruling theory. Premature theories enforced by an explicit consensus-building process harm scientific progress because of the questions that *don't* get asked and the investigations that *aren't* undertaken.

Challenges to climate research have been exacerbated by:

- expectations from policy makers
- scientists who are playing power politics with their expertise and trying to silence scientific disagreement through denigrating scientists who do not agree with them
- professional societies (that oversee the peer review in professional journals) who are writing policy statements endorsing the consensus and advocating for specific policies.

Motivated by these concerns, my testimony focuses on the following issues of central relevance to the issues of climate science and the scientific method:

- the scientific method for complex environmental systems
- how scientists fool themselves
- disagreement and reasoning about climate uncertainty
- the interface between climate science and policy.

## Scientific method for complex environmental systems

My perspective on the scientific method is based on four decades as a scientist and extensive readings on the philosophy and sociology of science. Over the past seven

years, I have been exploring these issues as they relate to climate science in a series of blog posts<sup>1</sup> and several publications.<sup>2</sup> My perspective is summarized below.

Science is a *process* for understanding how nature works. The scientific process can be summarized as: ask a question or pose a hypothesis, set up an objective test or experiment, and make a scientific argument – and then repeat. A scientific argument uses logic to combine assumptions and evidence. Science is often *mis* characterized as the assembly and organization of data and as a collection of facts on which scientists agree. Science is *correctly* characterized as a process in which we keep exploring new ideas and changing our understanding of the world, to find new representations of the world that better explain what is observed. Part of science is to do calculations and to make predictions, but another part of science is to ask deep questions about how nature works.

‘Scientifically proven’ is a contradiction in terms – science does not prove anything. Scientists have a vision of reality that is the best they have found so far, and there may be substantial disagreement among individual scientists. Science works just fine when there is more than one hypothesis to explain something – in fact, disagreement spurs scientific progress through creative tension and efforts to resolve the disagreement. Science is driven by uncertainty, disagreement and ignorance – the best scientists actively cultivate doubt. Scientists do not concentrate on what they know, but rather on what they don’t know. Science is an ongoing process of revision that may be incremental, and occur in fits and starts or through an unexpected breakthrough. Scientists tackle ignorance in formulating their research approach through challenging assumptions and presuppositions, curiosity, imagination, identifying connections with other research, and revisiting apparently settled questions.

How do we evaluate scientific theories, which are collections of hypotheses? All theories are underdetermined by data. Theories are evaluated based on independent corroboration, effectiveness in explaining phenomena and making predictions. Aspects of science that are reasonably settled are reliably used as assumptions for other scientific investigations and often enter into the realm of engineering.

What is the status of climate science as it relates to the nature and causes of variations on timescales from decades to centuries? The foundation of climate science rests on fundamental laws such as Newton’s laws of motion, Planck’s law and the Stefan Boltzmann law, the first and second laws of thermodynamics, ideal gas laws, gravitation, and conservation of mass and energy. There are numerous theories of complex processes (collections of hypotheses) that contribute to our understanding of climate science, including the theory of rotating fluids, the theory of boundary layers, the theory of gaseous infrared spectroscopy and radiative transfer. These theories are widely accepted.

The meta-theory of greenhouse warming of the climate system incorporates many

hypotheses and theories about how components of the climate system work. It is an empirical fact that the Earth's climate has warmed overall for at least the past century. However, we do not know how much humans have contributed to this warming and there is disagreement among scientists as to whether human-caused emissions of greenhouse gases are the dominant cause of recent warming, relative to natural causes.

## **Complexity**

Scientific arguments in physics, chemistry and cell biology are typically based on controlled laboratory experiments, where explanation and prediction can be based on a few variables. There are elements of climate science that can be addressed using these methods, notably in atmospheric chemistry and the physics and chemistry of aerosol and cloud particles.

However, scientific investigations of the dynamics of the entire climate system have more in common with systems biology and economics than with laboratory physics and chemistry, owing to the complexity of the systems under investigation and the inability to conduct controlled experiments. Complexity of the climate system arises from chaotic behavior and the nonlinearity of the equations for motions in the atmosphere and ocean, high dimensionality of the system (many different variables, varying in three dimensions and with time), and the linking of multiple subsystems (e.g. atmosphere, oceans, land surface, glacier ice).

The aggregate properties and changes of complex systems cannot be determined from sum of the individual components, owing to interactions among the components and the different scales of organization within the system. Complex systems are studied using information theory and computer simulation models (e.g. global climate models.) While some of the equations in climate models are based on the laws of physics, many key processes in the model are only approximated and are not directly related to physical laws.

Global climate models are used by scientists to represent aspects of climate that are difficult to observe, experiment with theories in a new way by enabling hitherto infeasible calculations, understand a system of equations that would otherwise be impenetrable, and explore the system to identify unexpected outcomes. As such, global climate models are an important element of climate research. For models of a complex system, the notion of a correct or incorrect model is not well defined. The relevant issue is whether the model 'works' and is fit for its intended purpose.

## **Assessment of climate models**

In a recent report entitled *Climate Models for Laymen*,<sup>3</sup> I described how climate models are useful tools for conducting scientific research to understand the climate system.

However, I argued that current global climate models are not fit for the purpose of attributing the causes of recent warming or for predicting global or regional climate change on timescales of decades to centuries, with any high level of confidence. Concerns about the utility of climate models include:

- Predictions of the impact of increasing CO<sub>2</sub> on climate cannot be rigorously evaluated for order of a century.
- Failure to provide a consistent explanation of the early 20th century warming and the mid-century cooling.
- Inability to simulate the magnitude and phasing of large-scale ocean oscillations on decadal to century timescales
- Insufficient exploration of climate model uncertainties.
- Extremely large number of unconstrained choices in terms of selecting model parameters and parameterizations.
- Evaluation of climate models against the same observations used for model tuning.
- Fundamental lack of predictability in a complex nonlinear system.

## **How scientists fool themselves**

Prior to 2010, I accepted and supported the consensus conclusions from the assessment reports published by the Intergovernmental Panel on Climate Change (IPCC) – I felt that this was the responsible thing to do. However, following the revelations of Climategate,<sup>4</sup> I realized that I had fallen victim to ‘groupthink’ – a pattern of thought characterized by conformity to group values and the manufacture of consensus that results in self-deception. I undertook an investigation into the ways that scientists can fool themselves, by examining deceptions from other fields of science and reading analyses from the perspectives of psychology and the philosophy and sociology of science. Below are my reflections on how climate scientists can fool themselves, and what they can do about it.

### **Cognitive biases**

Because of the complexity of the climate problem, scientists use different mental models for evaluating the interconnected evidence. Biases can abound when reasoning and making judgments about such a complex problem. Bias can occur by excessive reliance on a particular piece of evidence, the presence of cognitive biases in reasoning shortcuts, failure to account for indeterminacy and ignorance, and logical fallacies and errors, including circular reasoning.

Cognitive biases relate to self-deception. Cognitive biases of particular relevance to the science of climate change include:

- *confirmation bias*: the tendency to search for or interpret information in a way that confirms one's preconceptions
- *self-serving bias*: a tendency for people to evaluate information in a way that is beneficial to their interests
- *belief bias*: evaluating the logical strength of an argument based on belief in the truth or falsity of the conclusion
- *framing*: using a narrow approach that pre-ordains the conclusion
- *overconfidence*: unjustified, excessive belief
- *illusory correlations*: false identification of relationships with rare or novel occurrences

A recent article by statistician Regina Nuzzo in *Nature* summarizes the problem:

This is the big problem in science that no one is talking about: even an honest person is a master of self-deception. In today's environment, our talent for jumping to conclusions makes it all too easy to find false patterns in randomness, to ignore alternative explanations for a result or to accept 'reasonable' outcomes without question – that is, to ceaselessly lead ourselves astray without realizing it.<sup>5</sup>

Simply, scientists are human and subject to biases. Further, they have personal and professional stakes in the outcomes of research – their professional reputation and funding is on the line. Assuming that individual scientists have a diversity of perspectives and different biases, then the checks and balances in the scientific process including peer review will eventually see through the biases of individual scientists. However, when biases become entrenched in the institutions that support science – the professional societies, scientific journals, universities and funding agencies – then that subfield of science may be led astray for decades and make little progress.

### **Premature theories and manufactured consensus**

A scientific argument can evolve prematurely into a ruling theory if cultural forces are sufficiently strong and aligned in the same direction. Science policy expert Daniel Sarewitz describes the process:

Like a magnetic field that pulls iron filings into alignment, a powerful cultural belief is aligning multiple sources of scientific bias in the same direction. The belief is that progress in science means the continual production of positive findings. All involved benefit from positive results, and from the appearance of progress. Scientists are rewarded both intellectually and professionally, science administrators are empowered and the public desire for a better world is answered.<sup>6</sup>

I have argued that cognitive biases in the context of the IPCC's consensus-building process surrounding human-caused climate change have resulted in the consensus

becoming increasingly confirmed in a self-reinforcing way, to the detriment of the scientific process.<sup>7</sup> Princeton philosopher Thomas Kelly provides some general insights into the sources of confirmation bias and belief polarization that are relevant to the climate change consensus.<sup>8</sup> Kelly argues that belief held at earlier times can skew the total evidence that is available at later times, via characteristic biasing mechanisms, in a direction that is favorable to the initial belief. All else being equal, individuals tend to be significantly better at detecting fallacies in an argument for a conclusion that they disbelieve, than when the same fallacy occurs in an argument for a conclusion that they believe. Of particular relevance to the IPCC's consensus on human-caused climate change:

As more and more peers weigh in on a given issue, the proportion of the total evidence which consists of higher order psychological evidence [of what other people believe] increases, and the proportion of the total evidence which consists of first order evidence decreases... At some point, when the number of peers grows large enough, the higher order psychological evidence will swamp the first order evidence into virtual insignificance.<sup>9</sup>

So what are the implications of Kelly's arguments for the IPCC's consensus on human-caused climate change? Cognitive biases in the context of an institutionalized consensus building process have arguably resulted in the consensus becoming increasingly confirmed in a self-reinforcing way. An extended group of scientists derive their confidence in the consensus in a second-hand manner from the institutional authority of the IPCC and the emphatic nature in which the consensus is portrayed. This 'invisible hand' marginalizes skeptical perspectives and is operating to the substantial detriment of climate science, as well as biasing policies that are informed by climate science.

Premature theories enforced by an explicit consensus building process harm scientific progress because of the questions that *don't* get asked and the investigations that *aren't* undertaken. Overconfident assertions take away the motivation for scientists to challenge the consensus, particularly when they can expect to be called a 'denier' for their efforts and see their chances diminish for professional recognition and research funding. As a result of the enforced consensus, there is little independent thought that seeks to advance fundamental understanding or develop an independent aggregate understanding of how the climate system works.

When a field of science becomes entangled with politics and public policy debates – such as climate science – the stakes for diverging from the consensus point of view become much higher. Rather than encouraging scientific debate, there are attempts by scientists, the media and politicians to end debate by insisting that a large majority of scientists support a consensus, referring to those that disagree as 'deniers'. Sound theory does not need to demonize its opponents; rather these are the tactics of elevating a premature theory to dogma and enforcing it for political purposes.

## Overcoming bias

A scientist's job is to continually challenge his/her own biases and ask 'How could I be wrong?' Playing 'devil's advocate' helps a scientist examine how their conclusions might be misguided and how they might be wrong. Overcoming one's own biases is difficult; an external devil's advocate can play a useful role in questioning and criticizing the logic of the argument.

T.C. Chamberlain's method of 'multiple working hypotheses'<sup>10</sup> is a strategy that brings into view every rational explanation of the phenomena. The value of multiple working hypotheses lies largely in its suggestiveness of lines of inquiry that might otherwise be overlooked. More formal methods include 'Red team' and 'Team B' approaches that provide competitive analyses to challenge the dominant ones. I have participated in two interesting experiments along these lines for climate science, which are described below.

In 2014, the American Physical Society (APS) held a workshop to consider its statement on climate change. A committee of eminent physicists, each with no particular expertise in climate science or an apparent dog in the public debate, selected six climate scientists with diverse perspectives (Isaac Held, Ben Santer, William Collins, Judith Curry, Richard Lindzen, John Christy) to address specific questions prepared by the committee that were related to the IPCC 5th Assessment Report. The APS produced a complete transcript of the workshop.<sup>11</sup> This transcript is a remarkable document – it provides, in my opinion, the most accurate portrayal of the scientific debates surrounding climate change.

Organized under the auspices of the Dutch Ministry of Infrastructure and the Environment, Climate Dialogue<sup>12</sup> offered a blog platform for discussions between scientists on important climate topics that are of interest to both fellow scientists and the general public. The goal was to explore the full range of views that scientists have on the selected issue. Each discussion was initiated by a short introduction written by the editorial staff, followed by guest essays by two or more invited scientists. The scientists reacted to each other's essays and to questions posed by the editorial staff. The public (including other climate scientists) could comment on a separate thread. After the online discussion, Climate Dialogue editors wrote a summary, describing the areas of agreement and disagreement between the discussants. I participated in the inaugural dialogue on Arctic sea ice, and there were a total of six dialogues before the effort was terminated. Each of these dialogues is a testament to the importance of this kind of scientific dialogue and debate in terms illuminating and clarifying the scientific issues and uncertainties.

Beyond overcoming bias, the dialectical nature of science can play an important role in solving problems of societal relevance. When scientific input is sought on a socially relevant issue, we need to acknowledge that there are competing hypotheses and theories that are of practical consequence. Societal problem solving would

benefit greatly from forums that bring together the proponents of these competing inquiries for debate and joint problem solving.

## **Disagreement and reasoning about climate uncertainty**

During my investigation of arguments and evidence being used to support the IPCC statement on the causes of recent climate change, it became apparent to me that there were rational reasons for disagreement about many aspects of these arguments. I concluded that reasoning about a complex system with many uncertainties is not at all straightforward. My investigations on this topic included reading about argumentation and disagreement from the perspectives of philosophy and law, as well as logical inference and network theory. I published two articles on these topics.<sup>13,14</sup> My reflections on disagreement, uncertainty and reasoning about the complex climate problem are summarized below.

### **Disagreement**

Science proceeds just fine with indefinite conclusions, disagreement and multiple hypotheses. In fact, science works best under the creative tension of competing hypotheses. Disagreement among scientists and support for rival hypotheses can arise from:

- insufficient and inadequate observational evidence
- disagreement about the value of different classes of evidence (e.g. paleoclimate reconstructions, global climate models)
- disagreement about the appropriate logical framework for linking and assessing the evidence
- overconfidence and differing assessments of areas of ambiguity and ignorance
- belief polarization as a result of cultural pressures and the politicization of the science.

In the context of disagreement, it is important to distinguish between disbelief – believing an argument is false – and non-belief – believing that the argument is not true. Disbelief is actually a case of belief, whereas non-belief is a state of suspended judgment of neither believing the argument true nor believing it false. A failure to make this distinction was the recent media coverage of statements made by EPA administrator Scott Pruitt:

I think that measuring with precision human activity on the climate is something very challenging to do and there's tremendous disagreement about the degree of impact, so no, I would not agree that it's a primary contributor to the global warming that we see. But we don't know that yet. We need to continue the debate and continue the review and the analysis.<sup>15</sup>

The media characterized this statement as ‘EPA head Scott Pruitt denies that carbon dioxide causes global warming.’<sup>16</sup> Pruitt’s statement was incorrectly characterized as a statement of disbelief, when it was clearly a statement of non-belief.

### **Reasoning about climate uncertainty**

Reasoning about a complex system with many uncertainties is not at all straightforward. The general reasoning underlying the IPCC’s arguments for human-caused climate change is described by Oreskes as a ‘consilience of evidence’ argument, which consists of independent lines of evidence that are explained by the same theoretical account.<sup>17</sup> Oreskes draws an analogy for the consilience of evidence approach with what happens in a legal case. Continuing with the legal analogy, legal scholar James Johnston<sup>18</sup> characterized the IPCC’s arguments as a legal brief, designed to persuade, in contrast to a legal memo that is intended to objectively assess both sides. Along the lines of a legal memo, the consilience of evidence argument is not convincing unless it includes parallel evidence-based analyses for competing hypotheses. Any evidence-based argument that is more inclined to admit one type of evidence or argument rather than another tends to be biased. Multiple lines of evidence that produce a high confidence level for each of two opposing arguments is referred to as the ‘ambiguity of competing certainties’. If uncertainty and ignorance are acknowledged adequately, then the competing certainties disappear. Disagreement and clarification of uncertainties then become the basis for focusing research in a certain area, and so moves the science forward.

The complexity of the climate system makes the concept of ‘consilience failure’ rather challenging. If one of the lines of evidence turns out to be flawed, then how does this influence the overall argument? The ‘doesn’t matter’ versus ‘death knell’ interpretations can be explained by the use of two different logics represented by the ‘jigsaw puzzle analogy’<sup>19</sup> and the ‘house of cards analogy.’<sup>20</sup> Consider a partially completed jigsaw puzzle, with many pieces in place, some pieces tentatively in place, and some missing pieces. Default reasoning allows you to infer the whole picture from an incomplete puzzle if there is not another picture that is consistent with the puzzle in its current state. Under a monotonic logic, adding new pieces and locking existing pieces into place increases what is known about the picture. For a climate scientist having a complex mental model of interconnected evidence and processes represented by the jigsaw puzzle, the evidence in the North report<sup>21</sup> critical of the paleo-temperature reconstructions (the so-called ‘Hockey Stick’) merely jiggled loose a few puzzle pieces but didn’t change the overall picture. Skeptics, lacking the same puzzle frame but focused on the specific conclusions of the North report, viewed the evidence as collapsing the house of cards and justifying major belief revision on the subject. Which frame is ‘correct’? Well, both are overly simplistic heuristics used in the absence of formal logical arguments.

The ways of combining evidence and the associated uncertainties and logics becomes critical in determining how one would even go about falsifying the theory or inferring anything about the theory from comparison of model predictions and observations. I have found that most disagreement on topics related to climate change is associated with different mental models for assessing and combining evidence to make inferences. A more disciplined logic is needed to assess the relative merits of the different arguments through identifying the most important uncertainties and introducing a more objective assessment of confidence levels.

In 'Reasoning about climate uncertainty',<sup>22</sup> I argued that a useful approach would be the development of hierarchical logical hypothesis models that provide a structure for assembling the evidence and arguments in support of the main hypotheses or propositions. A logical hypothesis hierarchy (or tree) links the root hypothesis to lower level evidence and hypotheses. While developing a logical hypothesis tree is somewhat subjective and involves expert judgments, the evidential judgments are made at a lower level in the logical hierarchy. Essential judgments and opinions relating to the evidence and the arguments linking the evidence are thus made explicit, lending structure and transparency to the assessment. To the extent that the logical hypothesis hierarchy decomposes arguments and evidence to the most elementary propositions, the sources of disagreement are easily illuminated and potentially minimized.

An issue of central importance for the use of scientific research in policy making is uncertainty management and elucidation of the elements of uncertainty. My paper 'Reasoning about climate uncertainty' describes several such approaches that comprehensively describe the pedigree and quality of the relevant data sets and methods and characterize uncertainty in a manner that covers the range from complete numerical formalization of probabilities to ignorance, and includes the possibility of unspecified but surprising events.<sup>23</sup>

### **The interface between climate science and policy**

I first became caught up in the political debate about climate change following publication of our paper in 2005 relating hurricane intensity with global warming.<sup>24</sup> The uncanny timing of publication of this paper was three weeks after Hurricane Katrina devastated New Orleans. While global warming was mentioned only obliquely in the paper, the press focused on the global warming angle and a media and political furore followed. My reflections on this were published in a paper entitled 'Mixing politics and science in testing the hypothesis that greenhouse warming is causing a global increase in hurricane intensity'.<sup>25</sup> In recent years, I have continued to investigate the interface between climate science and policy, and have become increasingly concerned about its dysfunction.

In the 1990s, 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.<sup>26</sup> This objective has led to a focus on identifying human influences on climate, dangerous environmental and socio-economic impacts of climate change, and stabilization of CO<sub>2</sub> concentrations in the atmosphere. The IPCC has become conflicted by its makeup and its mandate from the UN – to focus on a change of climate that is attributed to human activity. If the IPCC found that climate change was *not* being affected by human alteration of the atmosphere or that it is not 'dangerous,' the UNFCCC would not need it to exist. Findings of 'dangerous human-caused climate change' seem inevitable with this framing of the climate change problem and the mandate from policymakers.

In the early 1990s there was belief in the feasibility of reducing uncertainties in climate science and climate models, and a consensus-seeking approach was formalized by the IPCC. Global climate models were elevated to a central role through investigations of climate change impacts and applications. Very substantial investments have been made in further developing climate models, with the expectation that these models will provide actionable information for policy makers.

The hope, and the potential, of climate models for providing actionable information for policymakers have not been realized. With the failure of climate models to reduce uncertainty about the sensitivity of the climate system to CO<sub>2</sub> and the failure to accurately simulate decadal and regional climate variability,<sup>27</sup> 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. The climate modeling community, the funding agencies and policy makers have locked themselves into a single climate modeling framework that has been very expensive in terms of funding and personnel.

An unintended consequence of this strategy is that there have been very few resources left over for true climate model innovations and fundamental research into climate dynamics and theory. Such research would not only support improved 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. With climate science focusing on climate model outputs rather than on climate dynamics and theory, we've lost a generation of climate dynamicists. As a result, we are lacking the intellectual resources to understand important and challenging issues such as: the effects of the sun on climate, the network of natural internal variability on multiple timescales, the mathematics of extreme events, and predictability of a complex system characterized by spatio-temporal chaos.

Decision makers needing regionally-specific climate change information are be-

ing provided with either nothing or potentially misleading predictions from climate models that are not fit for this purpose. Hoping and expecting to rely on information from climate models about projected regional climate change to guide adaptation responses has diverted attention from using observational, historical and paleoclimate data from the region to develop the basis for future scenarios. Further, increased scientific focus on subseasonal (weeks) and seasonal (months) weather/climate forecasts<sup>28</sup> could produce the basis for tactical adaptation practices with substantial societal benefits.

How and why did we land between a rock and a hard place on the issue of climate science? 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 the early 1990s by the UNFCCC, who framed both the problem and the solution as irreducibly global in terms of human-caused global warming. 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 a single course of policy action – radical emissions reductions.

The climate community has worked for more than two decades to establish a scientific consensus on human-caused climate change, prematurely elevating a hypothesis to a ruling theory. The IPCC's consensus-seeking process and its links to the UNFCCC emissions reduction policies have had the unintended consequence of hyper-politicizing the science and introducing bias into both the science and related decision-making processes. The result of this simplified framing of a wicked problem is that we lack the kinds of information to more broadly understand climate variability and societal vulnerabilities.

The politicization of climate science has contaminated academic climate research and the institutions that support climate research, so that individual scientists and institutions have become activists and advocates for emissions reductions policies. 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.'

Policymakers bear the responsibility of the mandate that they give to panels of scientific experts. In the case of climate change, the UNFCCC demanded of the IPCC too much precision where complexity, chaos, disagreement and the level current understanding resists such precision. Asking scientists to provide simple policy-ready answers for complex matters results in an impossible situation for scientists and misleading outcomes for policymakers. Unless policymakers want experts to confirm their preconceived bias, then expert panels should handle controversies and uncertainties by assessing what we know, what we don't know, and where the major uncertainties lie.

Imagine if, circa 1990, the UN had framed the climate change problem in the fol-

lowing way:

There are a number of causes of climate change, including manmade causes. Climate science should work to understand all causes of climate variability change that are relevant on decadal to century timescales, and the impact of climate variability and change on societies and ecosystems.

Such a framing would have arguably led to better understanding of the climate system and a much more rational approach in developing policies related to reducing our vulnerabilities to extreme weather and climate variations.

A better social problem-solving framework is needed for managing risk under conditions of deep uncertainty, which employs a broader systems analysis and explicitly incorporates uncertainty to identify paths to a flexible, robust and economical outcome. Social science research is needed to analyze ways of incorporating scientific understanding with all of its uncertainties into decision making related to complex, wicked problems.

### **The war on science**

I read Chris Mooney's book *The Republican War on Science*<sup>29</sup> shortly after it was published in 2005. It really resonated with me at the time, when I was in the midst of the 'hurricanes and global warming war'. Although the book has 'Republican' in the title, much of the content was really about a bipartisan war on science. The 'war on science' is being fought on two fronts: politicians ignoring science; and using bad science to justify a political agenda. The notion of 'war of science' is also about the naivete of scientists regarding the role of science and evidence in policy making.<sup>30</sup>

With the advent of the Trump administration, concerns about 'war on science' have become elevated, with a planned March for Science on 22 April 2017.<sup>31</sup> Why are scientists marching?<sup>32</sup> The scientists' big concern is 'silencing of facts'. This concern apparently derives from their desire to have their negotiated 'facts' – such as the IPCC consensus on climate change – dictate public policy. These scientists also fear funding cuts and challenges to the academic scientific community and the elite institutions that support it.

The 'war on science' that I am most concerned about is the war from *within* science – scientists and the organizations that support science who are playing power politics with their expertise and passing off their naïve notions of risk and political opinions as science. When the IPCC consensus is challenged or the authority of climate science in determining energy policy is questioned, these activist scientists and organizations call the questioners 'deniers' and claim 'war on science.' These activist scientists seem less concerned with the integrity of the scientific process than they are about their privileged position and influence in the public debate about climate and energy policy. They do not argue or debate the science – rather, they denigrate scientists who disagree with them. These activist scientists and organizations are perverting the po-

litical process and attempting to inoculate climate science from scrutiny – this is the *real* war on science.

## Conclusion

In the midst of disagreement among policy makers about the response to climate change, climate science has been caught in the crossfire. Challenges to climate research have been exacerbated by unreasonable expectations from policymakers, as well as by the behavior of climate scientists and professional societies who are using their professional expertise and preferred political outcomes as the basis for attempting to pervert the political process and inoculate climate science from scrutiny and debate.

My concern is that the integrity and objectivity of climate research is being compromised. As a result, we have oversimplified the climate change problem and its solutions. This oversimplification has:

- biased scientific research through politicization and funding priorities.
- undercut the political process and dialog necessary for real solutions in a highly complex world.

We need to rethink the social contract between scientists and government, and develop a new model for policy-relevant science. This is needed to ensure the integrity of science and to improve the basis for science to inform the policy process. Here are some recommendations:

1. Embrace science as an iterative process, not a collection of 'facts'. Scientists that engage the public across the political spectrum and invite them to engage in the process of science can help build public support for science.
2. New incentive structures for scientists working in fields that are policy relevant can focus on careful management of bias and uncertainty, public engagement, responsible interactions with the media, and participation in the policy process as an honest broker.
3. Scientists interested in engaging with the policy process need a much better understanding of the policy process, the role that science plays, and how complexity, pluralism and uncertainty in science is accommodated in the policy process.
4. Scientists need better guidelines on the ethical implications of using their expertise for political purposes and a code of conduct for communicating uncertainty and responsibilities for making public statements related to their expertise.
5. Bias and advocacy by institutions such as professional societies is a major concern for the integrity of science.

6. For policy-relevant science and regulatory science, more formal methods of uncertainty characterization and management should be used in scientific research and assessments.
7. For policy-relevant and/or regulatory science where there is substantial uncertainty or disagreement about key conclusions, a Red Team or Team B approach for assessments can clarify the strength of the arguments and key areas of disagreement. Avoid consensus-seeking approaches.
8. Narrow framing of research priorities on topics where there are widespread uncertainties and debate can bias the research. Funding for Red Team or Team B approaches would help overcome such systematic biases.
9. Funding priorities in climate research that support observing systems (surface and satellite-based), fundamental climate dynamics research and research to improve short-term climate predictions (sub-seasonal to interannual) would support improved climate models and 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.
10. A better social problem-solving framework that employs a broader systems analysis and explicitly incorporates uncertainty can provide paths to flexible, robust and economical outcomes.

I'm hoping that these recommendations and this hearing will open up a dialogue on how the federal government can better support research into the complex climate system that in turn supports improved policy outcomes in reducing our vulnerability to climate variability.

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## 2 Testimony of Professor John Christy

### Summary

'Science' is not a set of facts but a process or method that sets out a way for us to discover information and which attempts to determine the level of confidence we might have in that information. In the method, a 'claim' or 'hypothesis' is stated such that rigorous tests might be employed to test the claim to determine its credibility. If the claim fails a test, the claim is rejected or modified then tested again. When the 'scientific method' is applied to the output from climate models of the Fifth Assessment of the UN's Intergovernmental Panel on Climate Change (IPCC AR5), specifically the bulk atmospheric temperature trends since 1979 (a key variable with a strong and obvious theoretical response to increasing GHGs in this period), I demonstrate that the consensus of the models fails the test to match the real-world observations by a significant margin. As such, the average of the models is considered to be untruthful in representing the recent decades of climate variation and change, and thus would be inappropriate for use in predicting future changes in the climate or for related policy decisions.

The IPCC inadvertently provided information that supports this conclusion by

- showing that the tropical trends of climate models *with* extra greenhouse gases failed to match actual trends
- showing that climate models *without* extra greenhouse gases agreed with actual trends.

A report of which I was a co-author demonstrates that a statistical model that uses only natural influences on the climate also explains the variations and trends since 1979 without the need of extra greenhouse gases. While such a model (or any climate model) cannot 'prove' the causes of variations, the fact that its result is not rejected by the scientific method indicates it should be considered when trying to understand why the climate does what it does. Deliberate consideration of the major influences by natural variability on the climate has been conspicuously absent in the current explanations of climate change by the well-funded climate science industry.

One way to aid Congress in understanding more of the climate issue than what is produced by biased 'official' panels of the climate establishment is to organize and fund credible 'red teams' that look at issues such as natural variability, the failure of climate models and the huge benefits to society from affordable energy, carbon-based and otherwise. I would expect such a team would offer to Congress some very different conclusions regarding the human impacts on climate.

## **Introduction**

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 lead author, contributing author and reviewer of United Nations IPCC assessments, have been awarded NASA's Medal for Exceptional Scientific Achievement, and in 2002 was elected a fellow of the American Meteorological Society.

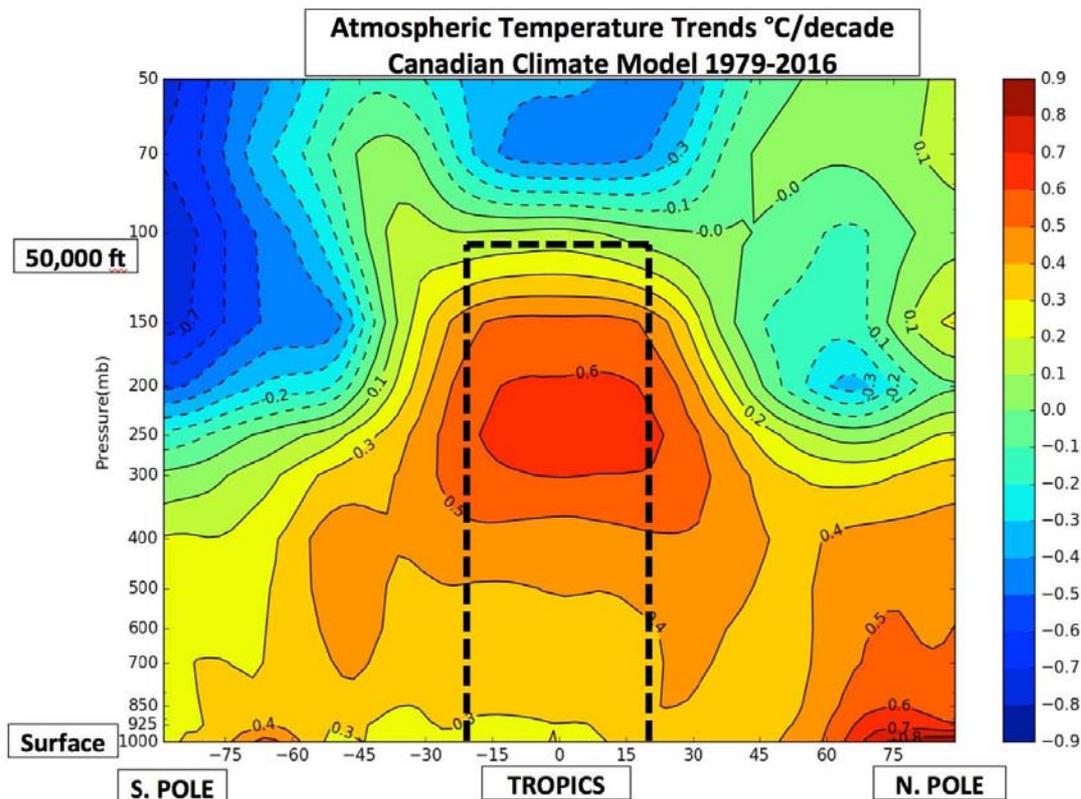
It is a privilege for me to offer my analysis of the current situation regarding atmospheric temperature datasets and whether the traditional scientific method using these datasets has been applied in climate science regarding the pronouncements about climate change used in policy. I addressed other aspects of climate change including extreme events, crop production, impact of regulation (there is none on the climate) and data confidence in my last Senate<sup>1</sup> and House<sup>2</sup> appearances.

My research area might be best described as building datasets from scratch to advance our understanding of what the climate is doing and why – an activity I began as a teenager over 50 years ago. I have used traditional surface observations as well as measurements from balloons and satellites to document the climate story. Many of our UAH datasets, generated by myself and UAH colleagues Drs Roy Spencer and W. Daniel Braswell, are used to test hypotheses of climate variability and change.

## **Applying the scientific method to climate models from the IPCC AR5**

In my last appearance before this committee<sup>3</sup> I addressed the active campaign of negative assertions made against the various sources of data we use to monitor the temperature of the bulk atmosphere. I demonstrated that the main assertions were incorrect and that we can have confidence in the observations and one reason was that we now have several independent sources from around the world providing data with which to inter-compare. In this testimony I shall focus on the temperature of the bulk atmospheric layer from the surface to about 50,000 ft – a layer which is often called by its microwave profile name 'TMT' (temperature of mid-troposphere). This layer is particularly important because it captures the atmospheric region that is anticipated to warm rapidly and unambiguously if greenhouse theory is well-understood. As such, if the impact of extra greenhouse gases (GHGs) is to be detected, it should be detected here. In Figure 1 I show an example from a climate model simulation<sup>4</sup> of the anticipated temperature change for the period 1979–2016.

Figure 1 indicates that, according to theory, the tropical region should have experienced significant warming over the past 38 years due to extra GHGs. (There were 102 model runs to check and they all indicated a warming tropical atmosphere, but to different degrees, as shown later.) To test this result we follow the traditional scientific



**Figure 1:** Temperature trends ( $^{\circ}\text{C}/\text{decade}$ ) for 1979–2016 of the cross-section of the atmosphere as simulated by the Canadian Climate Model.

The tropical band ( $20^{\circ}\text{S}$ – $20^{\circ}\text{N}$ ) is outlined for the bulk layer (surface to 50,000 ft) that represents the microwave TMT measurement (temperature of mid-troposphere). This outlined-layer is the region of prominent warming for the 1979–2016 period as depicted in all models and thus is the region to examine relative to observations.

Figure by Rob Junod, UAH.

method in which a claim (hypothesis) is made and then is tested against independent information to see if the claim can be sustained or whether it is falsified. If the claim is confirmed, then we generally look for another test to confirm the claim again. If many tests are consistent with the claim, then we may have confidence in it. If the claim fails a test, we look for reasons why and modify or reject the original claim and start over. Since the thrust of this hearing is to see how the scientific method was or was not applied in the pronouncements about climate science, this will serve as an excellent example because it deals with a foundational climate metric that should reveal significant change if theory is correct: the temperature of the bulk atmosphere.

## **Observational data used to test climate models**

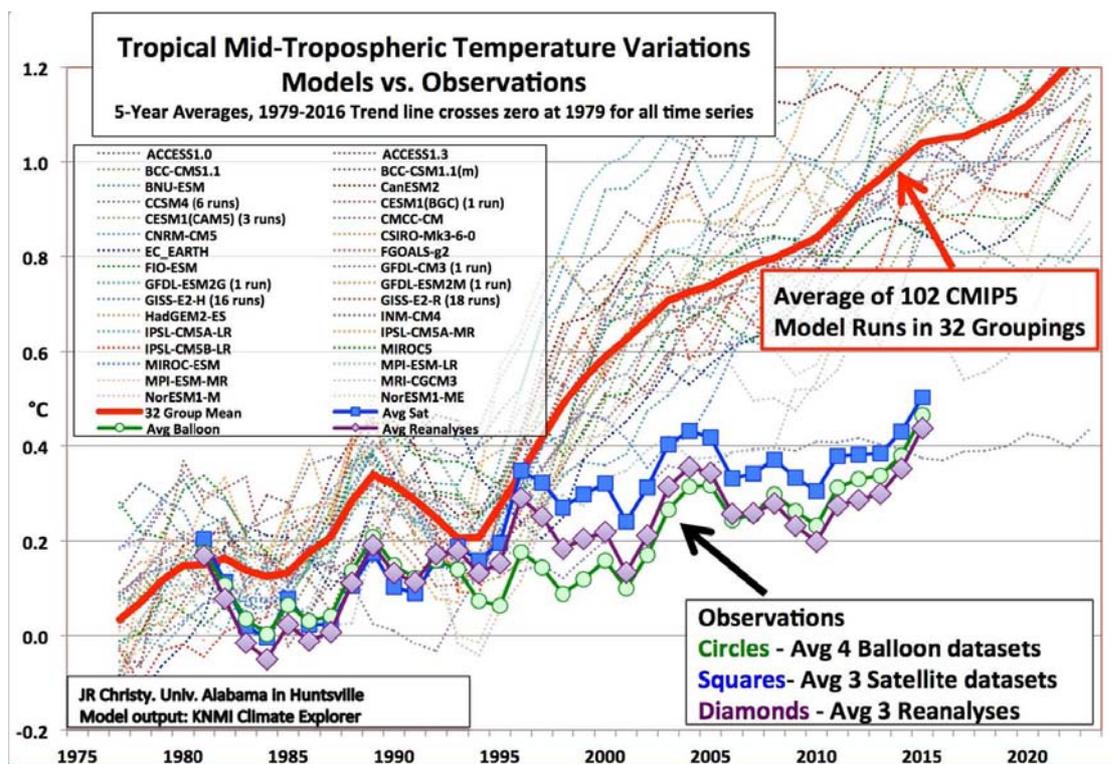
Recall that the results from climate models are simply hypotheses (claims) about how the climate should have evolved in the past. The claim here is: ‘the bulk atmospheric temperature trend since 1979 of the consensus of the IPCC AR5 climate models represents the actual trend since 1979’. (1979 is the beginning of the satellite temperature era.) To test this claim we compare the TMT model trends against TMT from several observational datasets. The first type of observational dataset is built from satellites that directly measure the bulk atmospheric temperature through the intensity of microwave emissions. These data are essentially global in coverage and monitor the Earth everyday. There are three sources, UAH (University of Alabama in Huntsville), RSS (Remote Sensing Systems, San Rafael, CA) and NOAA.

The second type of measurement is produced from the ascent of balloons that carry various instruments including thermistors, which monitor the air temperature as the balloon rises through this layer. From these measurements a value equivalent to the satellite TMT profile is calculated. Balloon stations are not evenly spaced throughout the Earth, but because the upper air is much more horizontally coherent in its features than the surface, a few balloons can represent a very large area in terms of temperature variability. The sources of these balloon datasets are RAOBCORE and RICH (University of Vienna, Austria), NOAA and UNSW (University of New South Wales, Australia).

Finally, major weather centers around the world generate atmospheric conditions, every six hours or so of the entire Earth at many vertical levels, called reanalyses. These products use many sources of data, including satellites and balloons, and merge the observations with a continuously running general circulation model. From the information at the vertical levels the TMT quantity is generated for an apples-to-apples comparison with models, satellites and balloons. The sources of the reanalyses are ERA-I (European Centre for Medium-Range Weather Forecasts (ECMWF) – ReAnalysis-Interim), NASA-MERRA2 and JRA-55 (Japan ReAnalyses). These three types of systems – satellites, balloons and reanalyses – represent very different means of computing the bulk atmospheric temperature and are provided by independent, international entities, giving us confidence in the observational results.

## **Testing the claim: applying the scientific method**

In Figure 2 we show the evolution of the tropical TMT temperature since 1979 for 102 climate model runs grouped in 32 curves by institution. Some institutions contributed a single simulation, others as many as 18. Multiple runs from a single institution’s model category were averaged into a single time series here. The curves show the temperature evolution of the atmosphere in the tropical box shown in Figure 1.



**Figure 2:** Five-year averaged values of annual mean (1979–2016) tropical bulk TMT as depicted by the average of 102 IPCC CMIP5 climate models (red) in 32 institutional groups (dotted lines).

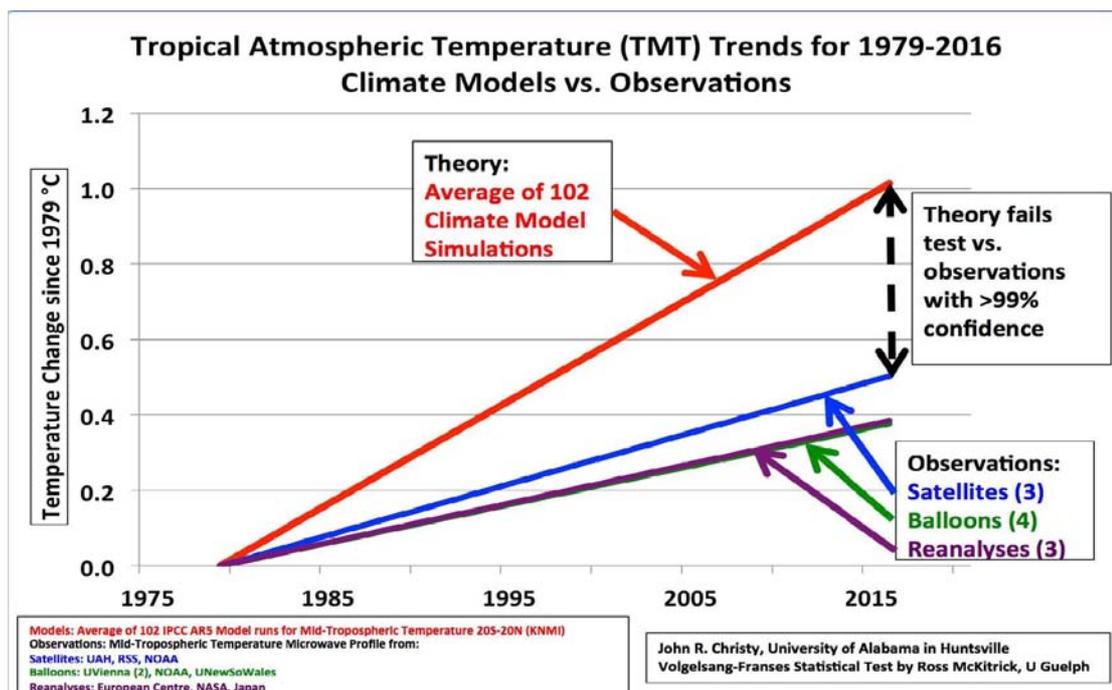
The 1979–2016 linear trend of all time series intersects at zero in 1979. Observations are displayed with symbols: green circles, average of 4 balloon datasets; blue squares, 3 satellite datasets; purple diamonds, 3 reanalyses. See text for observational datasets utilized. The last observational point at 2015 is the average of 2013–2016 only, while all other points are centered 5-year averages.

Here we have climate model results (i.e. ‘claims’ or ‘hypotheses’) to compare with observational datasets in a test to check whether the model average agrees with the observed data. We test the model average because it represents the consensus of the theoretical models and is used to develop policy, and is embodied in policy-related products such as the social cost of carbon, the National Climate Assessment and the EPA Endangerment Finding.

I provided model and observational information as annual temperature anomalies (both tropical and global) to Dr Ross McKittrick (University of Guelph) who has published extensively as an applied econometrician on the application of statistical techniques to the testing of climate hypotheses. He applied the Vogelsang–Franses F-test method to these data.<sup>5</sup> This method is particularly suitable for determining

whether the trends of two time series are equivalent or significantly different. The result found in their 2010 paper indicated model trends were significantly warmer than observations for the earlier datasets available at that time.

What we are really testing here are the rates of warming depicted by the models and the observations for the period 1979–2016. I have simplified a depiction of the test in Figure 3, so that the rate of warming is directly viewed, showing what the test is measuring. The basic test question is, 'Is the red line significantly different from



**Figure 3:** The linear trends of the average of the climate model simulations (red) and the averages of the three types of observational datasets described in the text.

the others?' The results are shown in Table 1; there is no equivalence between the model average trend and the observational datasets whenever the value of the test is greater than 84 at the <1% level. As shown, all test values exceed 84, and thus the mean model trend is highly significantly different from the observations. The scientific conclusion here, if one follows the scientific method, is that the average model trend fails to represent the actual trend of the past 38 years by a highly significant amount. As a result, applying the traditional scientific method, one would accept this failure and not promote the model trends as something truthful about the recent past or the future. Rather, the scientist would return to the project and seek to understand why the failure occurred. The most obvious answer is that the models are

**Table 1:** Test for equivalence between the 1979–2016 trend of the mean of 102 CMIP-5 climate model simulations and the trends of various observational datasets.

|              | Tropics |            | Global |            |
|--------------|---------|------------|--------|------------|
|              | Trend   | Test value | Trend  | Test value |
| Balloons     | +0.102  | 259        | +0.111 | 165        |
| Satellites   | +0.136  | 104        | +0.117 | 149        |
| Reanalyses   | +0.104  | 157        | +0.123 | 87         |
| Average all  | +0.113  | 187        | +0.117 | 158        |
| CMIP5 models | +0.274  |            | +0.216 |            |

Non-equivalence at the 99% confidence level is indicated by test values greater than 84, shown in red.

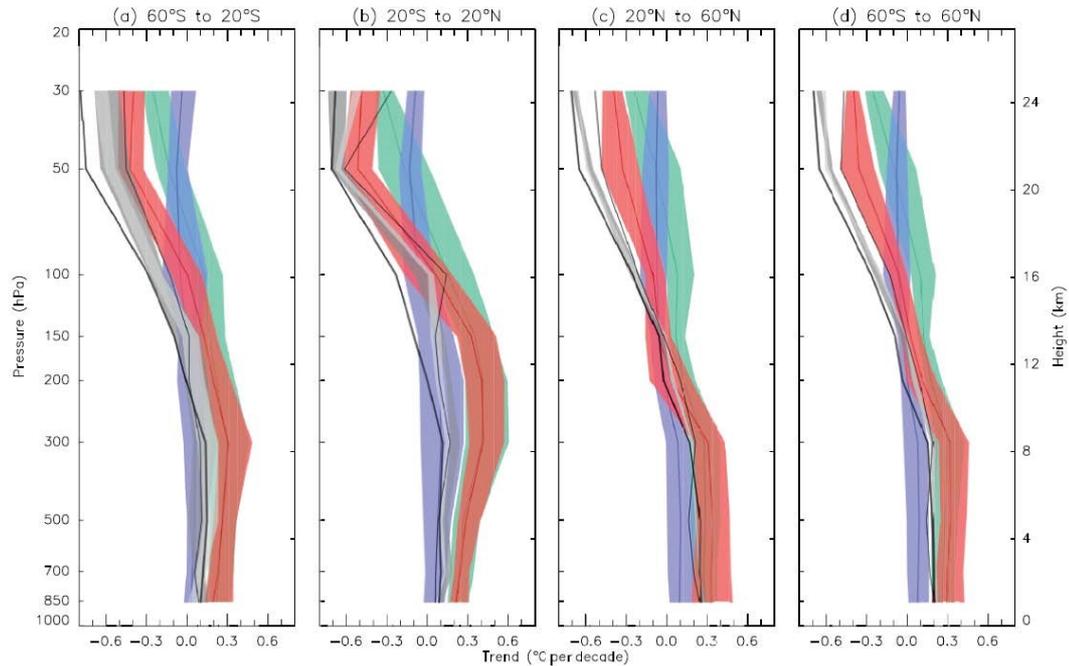
simply too sensitive to the extra GHGs that are being added to both the model and the real world.

We do not use surface temperature as a testable metric because models, to varying degrees, are tuned to agree with the surface temperature observations already – that is, they’ve been given the answer ahead of time – thus a comparison of the surface would not be a valid scientific test.<sup>6</sup>

### **The IPCC AR5 (2013) displayed a similar result: the models failed**

Oddly enough, such an important result (i.e. that models fail the test of representing the real-world bulk temperature trend) was available to see in the most recent IPCC AR5. Unfortunately, it was buried in the Supplementary Material of Chapter 10 without comment. In Figure 4, I present the figure that appeared in this IPCC section. I was a reviewer (a relatively minor position in that report) in the AR5 and had insisted that such a figure be shown in the main text because of its profound importance, but the government-appointed lead authors decided against it. They opted to place it in the Supplementary Material, where little attention would be paid, and to fashion the chart in such a way as to make it difficult to understand and interpret. I have taken the same information in Figure 4 (the IPCC’s AR5 Fig. 10.SM.1) and simplified the presentation so as to be clearer; see Figure 5. The trends here represent trends at different levels of the tropical atmosphere from the surface up to 50,000 ft. The gray lines are the bounds for the range of observations, the blue for the range of IPCC model results *without* extra GHGs and the red for IPCC model results *with* extra GHGs.

What is immediately evident is that the model trends in which extra GHGs are included lie completely outside of the range of the observational trends, indicating again that the models, as hypotheses, failed a simple ‘scientific-method’ test applied to this fundamental climate-change variable. That this information was not clearly and openly presented in the IPCC is evidence of a political process that was not rep-

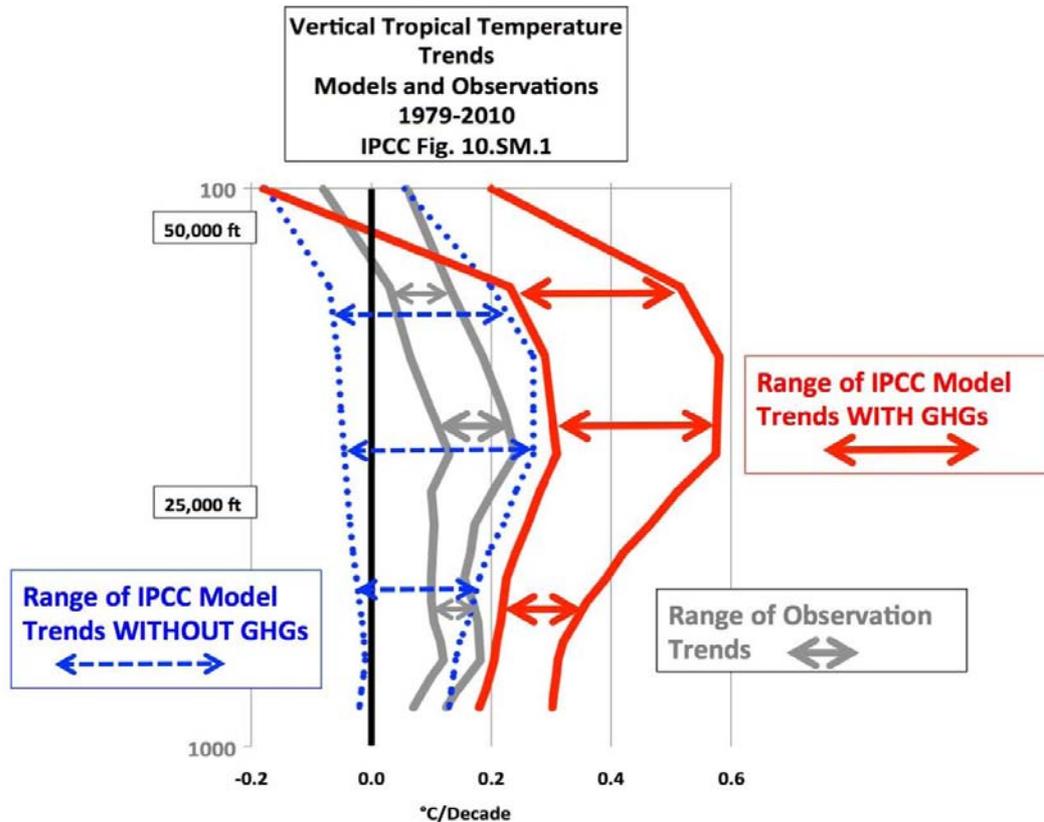


**Figure 10.SM.1** | Observed and simulated zonal mean temperatures trends from 1979 to 2010 for CMIP5 simulations containing both anthropogenic and natural forcings (red), natural forcings only (blue) and greenhouse gas forcing only (green) where the 5th to 95th percentile ranges of the ensembles are shown. Three radiosonde observations are shown (thick black line: Hadley Centre Atmospheric Temperature data set 2 (HadAT2), thin black line: RAdiosone OBservation COrrrection using REAnalyses (RAOBCORE) 1.5, dark grey band: Radiosonde Innovation Composite Homogenization (RICH)-obs 1.5 ensemble and light grey: RICH- $\tau$  1.5 ensemble. (Adapted from Lott et al. (2013) but for the more recent period from 1979 to 2010.)

**Figure 4:** Figure 10.SM.1 of the IPCC AR5 Supplementary Material for Chapter 10.

These are trends (1979–2010) for various vertical levels of the atmosphere from:  
 (a) observations (gray band – difficult to see); (b) models without extra GHGs (blue band); (c) models with extra GHGs and other forcings (red band). The lower portion of the tropical chart (second panel from left) is simplified in Figure 5 and used for the following discussion.

representative of the dispassionate examination of evidence as required by the scientific method. Further, (and this took guts) the IPCC then claimed high confidence in knowing *why* the climate evolved as it did over the past few decades (humans as the main cause) ignoring the fact the models on which that claim was based had failed an obvious and rather easy-to-perform validation test. Incredibly, what Figure 5 shows is that the bulk tropical atmospheric temperature change is modeled best when *no extra* GHGs are included – a direct contradiction to the IPCC conclusion that observed changes could only be modeled *if extra* GHGs were included.



**Figure 5:** Simplification of IPCC AR5 figure shown in Figure 4 above.

The colored lines represent the range of results for the models and observations. The key point displayed is the lack of overlap between the GHG model results (red) and the observations (gray). The non-GHG model runs (blue) overlap the observations almost completely.

## **A simple statistical model that passed the same ‘scientific method’ test**

The IPCC climate models performed best versus observations when they did *not* include extra GHGs, and this result can be demonstrated with a statistical model as well. I was co-author of a report which produced such an analysis.<sup>7</sup> In this report we examine annual estimates from many sources of global and tropical deep-layer temperatures since 1959 and since 1979, utilizing explanatory variables that did not include rising carbon dioxide concentrations. We applied the model to estimates of global and tropical temperature from the satellite and balloon sources, individually, as shown in Figure 2. The explanatory variables are those that have been known for

decades, such as indices of El Niño-Southern Oscillation (ENSO), volcanic activity, and solar activity.<sup>8</sup> One of the ENSO explanatory variables was the accumulated MEI (Multivariate ENSO Index,<sup>9</sup> in which the index was summed through time to provide an indication of its accumulated impact. This 'accumulated-MEI' was shown to be a potential factor in global temperatures by Spencer and Braswell,<sup>10</sup> Interestingly, later work has shown that this 'accumulated-MEI' has virtually the same impact as the accumulated solar index, both of which generally paralleled the rise in temperatures through the 1980s and 1990s and the slowdown in the 21st century. Thus our report would have the same conclusion with or without the 'accumulated-MEI.'

The basic result of this report is that the temperature trend of several datasets since 1979 can be explained by variations in the components that naturally affect the climate, just as the IPCC inadvertently indicated in Figure 5. The advantage of the simple statistical treatment is that the complicated processes, such as clouds, ocean-atmosphere interaction, aerosols, etc., are implicitly incorporated by the statistical relationships discovered from the actual data. Climate models attempt to calculate these highly non-linear processes from imperfect parameterizations (estimates), whereas the statistical model directly accounts for them since the bulk atmospheric temperature is the response-variable these processes impact. It is true that the statistical model does not know what each sub-process is or how each might interact with other processes. But it also must be made clear: it is an understatement to say that no IPCC climate model accurately incorporates all of the non-linear processes that affect the system. I simply point out that because the model is constrained by the ultimate response variable (bulk temperature), these highly complex processes are included.

The fact that this statistical model explains 75–90% of the real annual temperature variability, depending on dataset, using these influences (ENSO, volcanoes, solar) is an indication the statistical model is useful. In addition, the trends produced from this statistical model are not statistically different from the actual data (i.e. passing the 'scientific-method' trend test, which assumes the natural factors are not influenced by increasing GHGs). This result promotes the conclusion that this approach achieves greater scientific (and policy) utility than elaborate climate models, which on average fail to reproduce the real world's global average bulk temperature trend since 1979.

The over-warming of the atmosphere by the IPCC models relates to a problem the IPCC AR5 encountered elsewhere. In trying to determine the climate sensitivity, which is how sensitive the global temperature is relative to increases in GHGs, the IPCC authors chose *not* to give a best estimate. (A high climate sensitivity is a foundational component of the last administration's social cost of carbon.) The reason? Climate models were showing about twice the sensitivity to GHGs of calculations based on real, empirical data. I would encourage this committee, and our government in general, to consider empirical data, not climate model output, when dealing with environmental regulations.

## **Red teams needed because consensus science is not science**

*One way for Congress to receive better (less biased) information about claims of climate science is to organize 'red teams', as is done in other parts of government and industry when critical systems, programs or infrastructure are under consideration. I have discussed this idea in several previous congressional hearings. I include here the section describing red teams from my testimony on 20 September 2012 before the Subcommittee on Energy and Power of the House Committee on Energy and Commerce.*

The term 'consensus science' will often be appealed to regarding arguments about climate change to bolster an assertion. This is a form of 'argument from authority.' Consensus, however, is a political notion, not a scientific notion. As I testified to the Interacademy Council in June 2010, wrote in *Nature* that same year,<sup>11</sup> and documented in my written House Testimony last year,<sup>12</sup> the IPCC and other similar assessments do not represent for me a consensus of much more than the consensus of those selected to agree with a particular consensus. The content of these climate reports is actually under the control of a relatively small number of individuals – I often refer to them as the 'climate establishment' – who through the years, in my opinion, came to act as gatekeepers of scientific opinion and information, rather than brokers. The voices of those of us who object to various statements and emphases in these assessments are, by and large, dismissed rather than accommodated. This establishment includes the same individuals who become the 'experts' called on to promote IPCC claims in government reports, such as the Endangerment Finding by the Environmental Protection Agency. As outlined in my House testimony,<sup>13</sup> these 'experts' become the authors and evaluators of their own research relative to research which challenges their work. But with the luxury of having the 'last word' as 'expert' authors of the reports, alternative views vanish.

I've often stated that climate science is a 'murky' science. We do not have laboratory methods of testing our hypotheses as many other sciences do. As a result, what passes for science includes opinion, arguments-from-authority, dramatic press releases, and fuzzy notions of consensus generated by preselected groups. This is not science.

I noticed the House passed an amendment last year to de-fund the IPCC. We know from the Climategate emails and many other sources that the IPCC has had problems with those who take different positions on climate change than what the IPCC promotes. There is another way to deal with this, however. Since the IPCC activity is funded by US taxpayers, I propose that 5–10% of the funds be allocated to a group of well-credentialed scientists to produce an assessment that expresses legitimate, alternative hypotheses that have been (in their view) marginalized, misrepresented or ignored in previous IPCC reports (and thus EPA and National Climate Assessments). Such activities are often called 'red team' reports and are widely used in government

and industry. Decisions regarding funding for red teams should not be placed in the hands of the current 'establishment' but in panels populated by credentialed scientists who have experience in examining these issues. Some efforts along this line have arisen from the private sector.<sup>14</sup> I believe policymakers, with the public's purse, should actively support the assembling all of the information that is vital to addressing this murky and wicked science, since the public will ultimately pay the cost of any legislation alleged to deal with climate.

Topics to be addressed in this red team assessment, for example, would include:

- evidence for a low climate sensitivity to increasing greenhouse gases
- the role and importance of natural, unforced variability
- a rigorous and independent evaluation of climate model output
- a thorough discussion of uncertainty
- a focus on metrics that most directly relate to the rate of accumulation of heat in the climate system
- analysis of the many consequences, including benefits, that result from CO<sub>2</sub> increases
- the importance that affordable and accessible energy has to human health and welfare.

What this proposal seeks is to provide to Congress and other policymakers a parallel, scientifically-based assessment regarding the state of climate science, which addresses issues that heretofore have been un- or under-represented by previous taxpayer funded, government-directed climate reports. In other words, our policymakers need to see the entire range of findings regarding climate change.

## **In summary**

'Science' is not a set of facts but a process or method that sets out a way for us to discover information and which attempts to determine the level of confidence we might have in that information. In the method, a 'claim' or 'hypothesis' is stated such that rigorous tests might be employed to test the claim to determine its credibility. If the claim fails a test, the claim is rejected or modified then tested again. When the 'scientific method' is applied to the output from climate models of the IPCC AR5, specifically the bulk atmospheric temperature trends since 1979 (a key variable with a strong and obvious theoretical response to increasing GHGs in this period), I demonstrate that the consensus of the models fails the test to match the real-world observations by a significant margin. As such, the average of the models is considered to be untruthful in representing the recent decades of climate variation and change, and thus would be inappropriate for use in predicting future changes in the climate, or for related policy decisions.

The IPCC inadvertently provided information that supports this conclusion by:

- showing that the tropical trends of climate models *with* extra greenhouse gases failed to match actual trends
- showing that climate models *without* extra greenhouse gases agreed with actual trends.

A report of which I was a co-author demonstrates that a statistical model that uses only natural influences on the climate also explains the variations and trends since 1979 without the need of extra greenhouse gases. While such a model (or any climate model) cannot 'prove' the causes of variations, the fact that its result is not rejected by the scientific method indicates it should be considered when trying to understand why the climate does what it does. Deliberate consideration of the major influences by natural variability on the climate has been conspicuously absent in the current explanations of climate change by the well-funded climate science industry.

One way to aid congress in understanding more of the climate issue than what is produced by biased 'official' panels of the climate establishment is to organize and fund credible 'red teams' that look at issues such as natural variability, the failure of climate models and the huge benefits to society from affordable energy, carbon-based and otherwise. I would expect such a team would offer to Congress some very different conclusions regarding the human impacts on climate.

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### 3 Testimony of Professor Michael Mann

Mr Chairman, and members of the Committee. My name is Michael Mann. I am Distinguished Professor of Atmospheric Science at Penn State University, and Director of the Penn State Earth System Science Center. My research involves the use of climate models, the analysis of empirical climate data, and developing methods for comparing observations and model predictions. The primary focus of my research is understanding the long-term behavior of the climate system, and determining the roles of various potential agents of climate change, both natural and human.

I have served as organizing committee chair for the National Academy of Sciences *Frontiers of Science*, and as the co-author or advisor for several National Academy of Sciences reports related to climate change. I have served as editor for the *Journal of Climate* of the American Meteorological Society and have served as a member of numerous other international and US scientific working groups, panels and steering committees. I was awarded the Hans Oeschger Medal of the European Geophysical Union in 2012 and received the Friend of the Planet Award from the National Center for Science Education in 2014. I am a Fellow of the American Geophysical Union, the American Meteorological Society, and the American Association for the Advancement of Science. I have authored more than 200 publications, and several books including *Dire Predictions: Understanding Climate Change*, *The Hockey Stick and the Climate Wars* and *The Madhouse Effect: How Climate Change Denial Is Threatening Our Planet, Destroying Our Politics, and Driving Us Crazy* with Tom Toles, the Pulitzer Prize-winning editorial cartoonist for the *Washington Post*.

Let me first comment about *why* I went into science. I was fascinated by the natural world as a child and wanted to devote my life to understanding it. This led me on a lifelong journey of scientific discovery that is every bit as thrilling to me today as it was as a child. When the science has broader societal importance, that's icing on the cake.

Earlier this week, for example, my colleagues and I published a study in the journal *Scientific Reports* using a combination of observations and climate model simulations to demonstrate a linkage between climate change and jet stream behavior linked to extreme, persistent weather events like the 2011 Texas and Oklahoma drought and the 2015 California wildfires. Continuing to pose questions and to seek to answer them using scientific tools and observations – that's what I truly love doing.

But I'm here today because I'm also passionate about communicating what we know to the public and to policymakers. I have become convinced that no pursuit could be more noble. So about this hearing: It is important to make clear at the outset that there is extremely broad agreement among the world's scientists on the basic facts of human-caused climate change. The US National Academy of Sciences, the Royal Society of the UK, and all of the scientific societies<sup>1</sup> of all of the industrial nations – the more than 30 scientific societies<sup>2</sup> in the US that have weighed in on the matter,

and at least 97%<sup>3</sup> of scientists publishing in the field have all concluded, based on the evidence, that climate change is real, is human-caused, and is already having adverse impacts on us, our economy, and our planet.

Yet we find ourselves at this hearing today, with three individuals who represent that tiny minority that reject this consensus or downplay its significance, and only one – myself – who is in the mainstream. That's 25%, a far cry from the 97–99% figure that actually characterizes where the world's scientists stand on this issue. This creates the illusion of a debate that does not exist. This is not an auspicious start for a hearing that purports to be examining science rather than antiscience, fact rather than fiction.

I coined the term 'Serengeti Strategy' back in 2012 in *The Hockey Stick and the Climate Wars*<sup>4</sup> to describe how industry special interests who feel threatened by scientific findings – be it tobacco and lung cancer, or fossil fuel burning and climate change – single out individual scientists to attack in much the same way lions of the Serengeti single out an individual zebra from the herd. In numbers there is strength, but individuals are far more vulnerable. Science critics will therefore often select a single scientist to ridicule, hector, and intimidate. The presumed purpose is to set an example for other scientists who might consider sticking their neck out by participating in the public discourse over certain matters of policy-relevant science.

I should know. I've found myself<sup>5</sup> at the center of such episodes more than once, as a result of the iconic 'Hockey Stick' that my co-authors and I published in the late 1990s that demonstrates the unprecedented nature of recent warming. While the hockey stick is hardly the basis<sup>6</sup> of the case for human-caused climate change, the visually compelling character of the graphic has made it – and indeed, me – a target of climate change deniers for years.

In October 2003 just days before a critical US Senate resolution to acknowledge the threat of human-caused climate change, an 'article' was published by climate change-denial friendly 'journal' that engaged in dubious attacks on the hockey stick. A fossil fuel industry front group published an op-ed trumpeting the specious criticisms in *USA Today* on the morning of the Senate vote. Senator James Inhofe of 'climate change is the greatest hoax<sup>7</sup> ever perpetrated on the American people' infamy happily trumpeted the article during the Senate floor debate. While the critique on the hockey stick would soon be summarily dismissed,<sup>8</sup> it served the short-term purpose of hijacking the discussion. The bill did not pass.

In 2005, as the House of Representatives was considering energy and climate legislation, Joe Barton (R-TX), Chair of the House Energy and Commerce Committee and a leading recipient of fossil fuel money engaged in what was widely condemned as a 'witch-hunt'<sup>9</sup> against me and my Hockey Stick co-authors. Barton demanded all of my personal emails and correspondence with other scientists, and numerous other materials, in an apparent effort to find something, anything, he could use to try to discredit the iconic Hockey Stick. In the cynical minds of our critics, discrediting our work

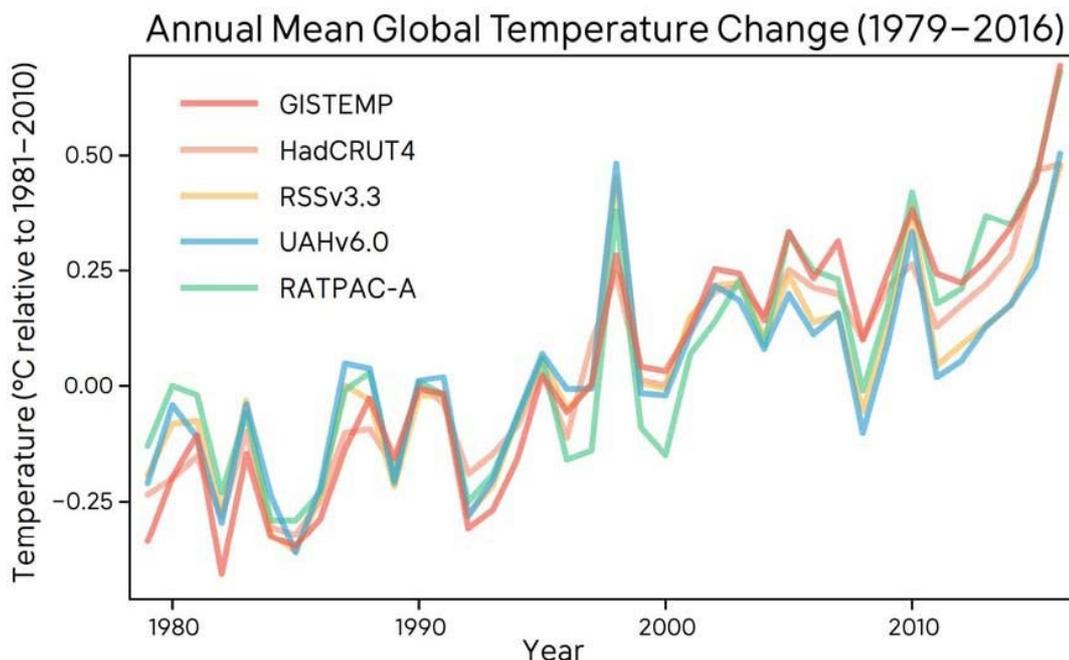
would somehow undermine the entire case for concern over human-caused climate change.

On the eve of the Copenhagen UN climate summit of December 2009 – seen as the greatest opportunity yet for an international agreement to limit greenhouse gas emissions – a trove of emails, including many of my own, had been stolen, and combed through for words and phrases (like ‘trick’ – a completely appropriate term in science for a clever approach) that might seem embarrassing or even damning. The out-of-context snippets were posted on climate change deniers’ websites and then spread through right-wing blogs and news sites. Soon even mainstream news organizations were credulously parroting the denialist narrative that a few stolen emails somehow called into question the fundamental evidence behind human-caused climate change, a result of nearly two centuries<sup>10</sup> of scientific research. I and a small number of other leading climate scientists found ourselves at the very center of the smear campaign.

At least 10 investigations and reviews have established<sup>11</sup> that there was no wrongdoing on the part of the scientists (indeed, the only wrongdoing was the criminal theft of the emails in the first place). The vindications, however, occurred long after fossil fuel interests and those doing their bidding had the opportunity to sabotage efforts to reach an international agreement limiting carbon emissions (Oil-rich Saudi Arabia, for example, insisted<sup>12</sup> in Copenhagen that the stolen emails justified opposition to any agreement to limit carbon emissions; Russia also appears to have played some role in the hacking and/or dissemination of the emails).

We now have the latest in this perpetual series of bad-faith assaults on climate science, and the story is eerily familiar. The attacks, as always, have focused on a particular individual – in this case, Tom Karl,<sup>13</sup> the recently retired Director of NOAA’s National Climatic Data Center and a scientist for whom I have the deepest respect.

For proper context, we must consider the climate denial myth *du jour* that global warming has ‘stopped’. Like most climate denial talking points, the reality is pretty much the opposite of what is being claimed by the contrarians. All surface temperature products, including the controversial UAB satellite temperature record, show a clear long-term warming trend over the past several decades (Figure 1). We have now broken the all-time global temperature record for three consecutive years<sup>14</sup> and a number of published articles have convincingly demonstrated that global warming has continued unabated despite when one properly accounts for the vagaries of natural short-term climate fluctuations. A prominent such study<sup>15</sup> was published by Tom Karl and colleagues in 2015 in the leading journal *Science*. The article was widely viewed as the final nail in the ‘globe has stopped warming’ talking point’s coffin. Last month, opinion writer David Rose of the British tabloid the *Daily Mail* – known for<sup>16</sup> his serial misrepresentations of climate change and his serial attacks on climate scientists – published a commentary<sup>17</sup> online attacking Tom Karl, accusing him of having



**Figure 1:** Comparison of the various surface or lower atmospheric temperature records during past few decades (graph by Peter Jacobs of George Mason University).

‘manipulated global warming data’ in the 2015 Karl et al article. This fake news story was built entirely on an interview with a single disgruntled former NOAA employee, John Bates, who had been demoted from a supervisory position at NOAA for his inability to work well with others.

Bates’ allegations were also published on the blog of climate science denier Judith Curry (I use the term carefully – reserving it for those who deny the most basic findings of the scientific community, which includes the fact that human activity is substantially or entirely responsible for the large-scale warming we have seen over the past century – something Judith Curry<sup>18</sup> disputes<sup>19</sup>). That blog post and the *Daily Mail* story have now been thoroughly debunked by the actual scientific community.<sup>20</sup> The *Daily Mail* claim that data in the Karl et al. *Science* article had been manipulated was not supported by Bates. When the scientific community pushed back on the untenable ‘data manipulation’ claim, noting that other groups of scientists had independently confirmed<sup>21</sup> Karl et al’s findings, Bates clarified that the real problem was that data had not been properly archived and that the paper was rushed to publication. These claims too quickly fell apart.

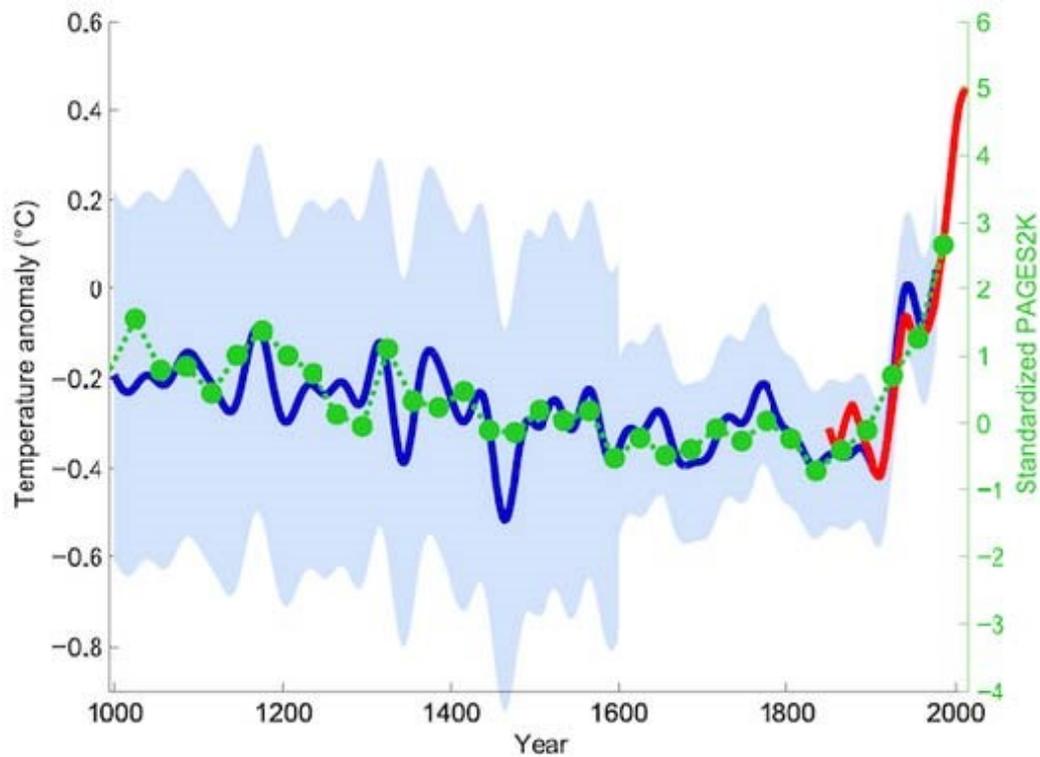
Though Bates claimed that the data from the Karl et al study was ‘not in machine-readable form’, independent scientist Zeke Hausfather, lead author of a study<sup>22</sup> that

accessed the data and confirmed its validity, wrote in a commentary<sup>23</sup> ‘...for the life of me I can’t figure out what that means. My computer can read it fine, and it’s the same format that other groups use to present their data’. As for the claim that the paper was rushed to publication, Editor-in-chief of *Science* Jeremy Berg says, ‘With regard to the “rush” to publish, as of 2013, the median time from submission to online publication by *Science* was 109 days, or less than four months. The article by Karl et al. underwent handling and review for almost six months. Any suggestion that the review of this paper was ‘rushed’ is baseless and without merit. *Science* stands behind its handling of this paper, which underwent particularly rigorous peer review.’

Shortly after the *Daily Mail* article went live, a video attacking Karl (and NOAA and even NASA for good measure) was posted by the *Wall Street Journal*. Within hours, the *Daily Mail* story spread like a virus through the right-wing blogosphere, appearing on numerous right-wing websites and conservative news sites. It didn’t take long for the entire Murdoch media empire in the US, UK and elsewhere to join in, with the execrable *Fox News* for example alleging<sup>24</sup> Tom Karl had ‘cooked’ climate data and, with no sense of irony, for *political reasons*.

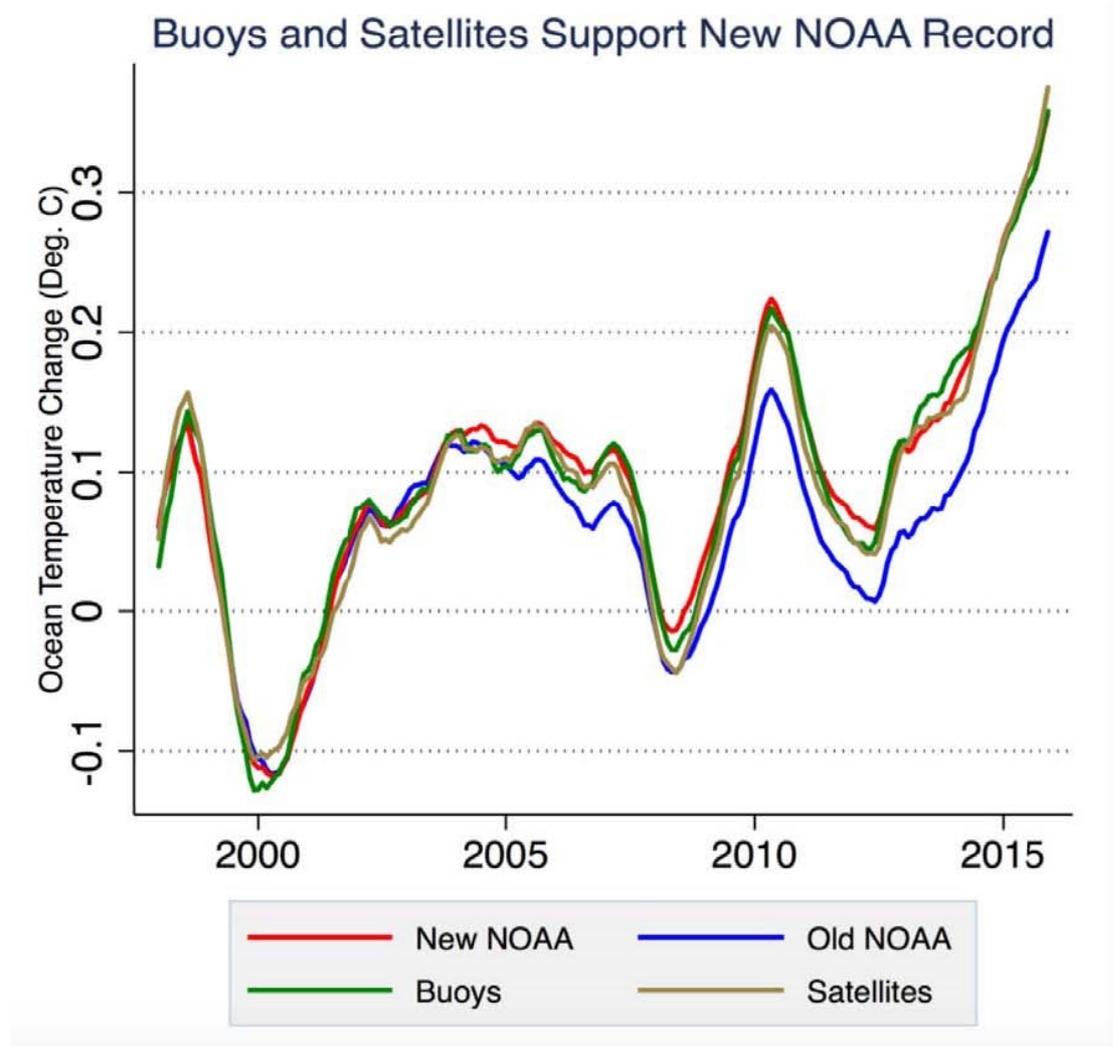
Rep. Lamar Smith (R-TX), chair of this committee has a history<sup>25</sup> of launching attacks on climate science and climate scientists. He quickly posted a press release praising the *Daily Mail* article, placing it on the science committee website, and falsely alleging that government scientists had ‘falsified data’. Smith, it turns out, had been planning a congressional hearing timed to happen just days after this latest dustup, intended to call into question<sup>26</sup> the basis for the EPA regulating carbon emissions. His accusations against Karl and NOAA of tampering with climate data was used in that hearing to claim that the entire case for concern over climate change was now undermined.

Of course, even if the Karl study was completely wrong, it wouldn’t in any way alter what we know about climate change. Just as our critics have intentionally ignored the many independent studies reaffirming<sup>27</sup> the ‘Hockey Stick’ curve in the peer-reviewed scientific literature (see Figure 2), so too have Karl’s critics ignored that his findings have been replicated and confirmed by other research groups publishing in the peer-reviewed literature. That includes the study<sup>28</sup> led by Zeke Hausfather of the ‘Berkeley Earth’ project – a project funded in part by the Koch Brothers and including<sup>29</sup> as one of its original team members, climate change contrarian Judith Curry. The authors showed that the Karl et al. estimates agree with the best available independent estimates of ocean warming (see Figure 3). Lead author Hausfather has stated<sup>30</sup> that ‘The fact that the new NOAA record is effectively identical with records constructed only from higher quality instruments (buoys, satellite radiometers, and Argo floats) strongly suggests that NOAA got it right and that we have been underestimating ocean warming in recent years.’ Let me make some additional observations with regard to this latest episode. Climate contrarians like to accuse scientists



**Figure 2:** PAGES 2k temperature reconstruction published by team of 78 scientists around the world using the most widespread paleoclimate database to date (Ahmed et al., *Nature Geoscience*, 2014) shown (green) along with the original Mann et al 1999 'Hockey Stick' reconstruction (blue), and instrumental (HadCRUT4) temperature record (red). Blue shading indicates uncertainty in the Mann et al temperature reconstruction (graph by Klaus Bitterman of Potsdam Institute for Climate Studies).

of understating uncertainty. Anyone who knows scientists and is familiar with scientific research understands how absurd that accusation is. Scientists embrace the concept of uncertainty, because it guides us – it informs our choices of what additional measurements to make and hypotheses to pursue. I would note that our 1999 'Hockey Stick' article that is so much maligned by climate change deniers, contained the words 'uncertainties' and 'limitations' in the title. Let me also remind you that the implications of scientific 'uncertainty' are rather different from what your contrarian witnesses would like you to believe. Leading economists like Harvard's Marty Weitzman have shown that<sup>31</sup> uncertainty is most likely a reason for even more concerted action to mitigate climate change because of what is known as the 'heavy tail' of the



**Figure 3:** Global sea surface temperatures from the old NOAA record (ERSSTv3b), the new NOAA record (ERSSTv4), and instrumentally homogenous records from buoys and satellites. See Hausfather et al. (2017) for details, as well as comparisons with shorter Argo-based records.

distribution of risk, namely the huge potential costs if the impacts turn out to be even greater than predicted, something that appears to be the case now with the potential rapid collapse<sup>32</sup> of the West Antarctic Ice Sheet and the increased sea level rise that will come with it.

Contrarians also falsely accuse scientists of conspiring to enforce 'dogma'. But the way scientists get articles in leading journals like *Science* or *Nature* is by demonstrat-

ing something novel – something we didn't already know, not by simply reiterating what is known. And herein lies a conundrum for those attacking the Karl et al. study. One of the articles seized upon in a previous hearing by Chairman Smith as a supposed indictment of Karl et al. is a *Nature Climate Change* article<sup>33</sup> (Fyfe et al 2016) on which I was a co-author. As a co-author of this article, I can assure you that it in no way calls into question the integrity of NOAA's data, or the honesty of Tom Karl and his colleagues, whom I hold in the highest esteem. We simply differed with them on the best interpretation of the temperature record, demonstrating that the interpretation of whether or not there was a temporary slowdown in warming during the first decade of the 21st century depends on precisely how the baseline warming trend is defined.

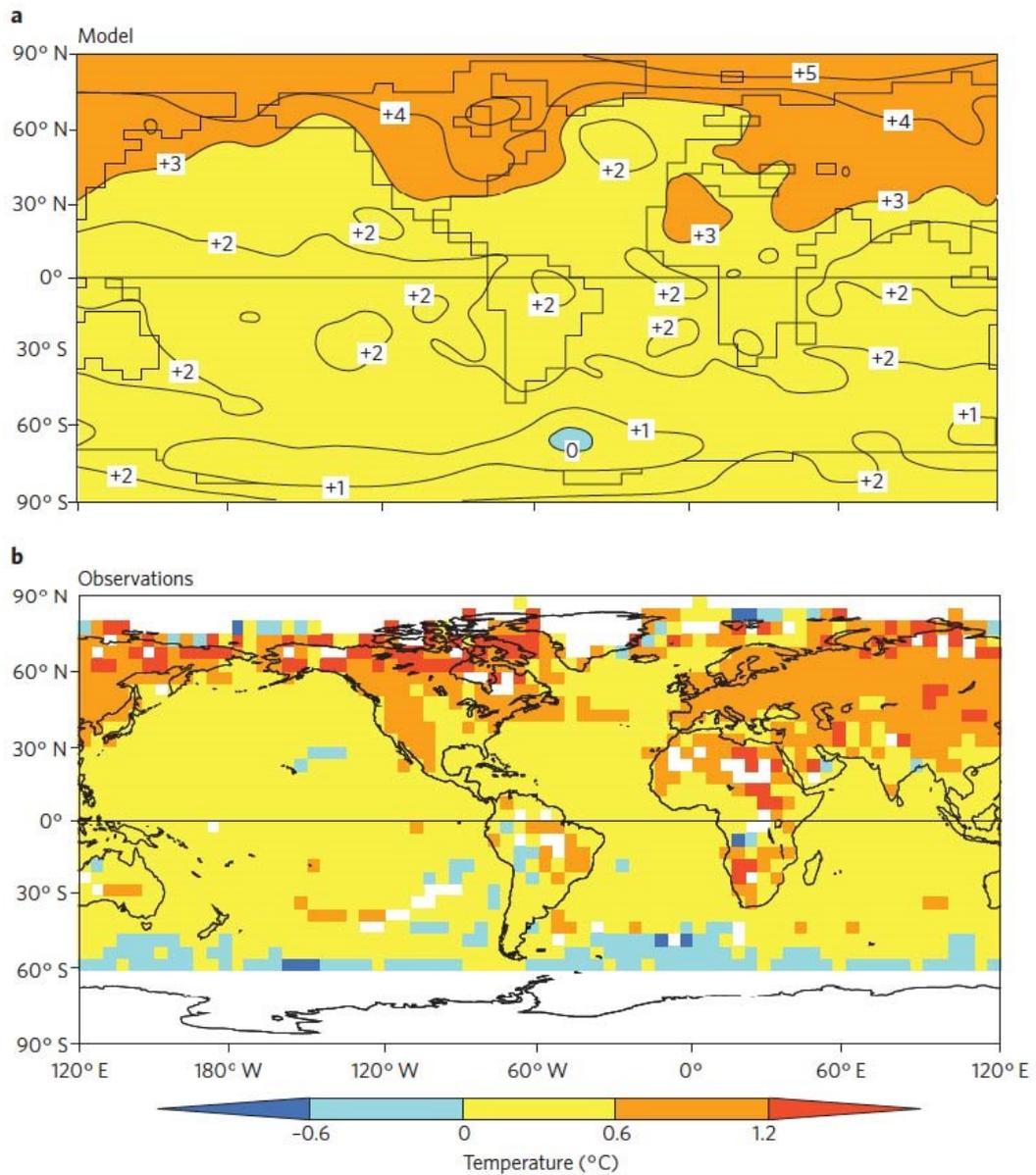
Chairman Smith can't have it both ways. This study can't both be an indictment of Tom Karl and colleagues and at the same time support the Chairman's conspiracy theories about climate scientists colluding with each other and being compromised by 'groupthink'. What our *Nature Climate Change* piece actually demonstrates is that there is indeed a robust, healthy, and respectful debate among scientists when it comes to interpreting data and testing hypotheses. True scientists are skeptics – real skeptics, contesting prevailing paradigms and challenging each other, in the peer-reviewed literature, at scientific meetings, and in seminars – the proper channels for good faith scientific debate. That, of course, is inconvenient to the caricature that Congressman Smith and his contrarians witnesses have sought to paint when it comes to climate science and climate scientists.

While we're at it, let me address another favorite talking point of the critics, the claim that climate models we use to project future climate change are unreliable and untested. The reality is that the models have been tested vigorously and rigorously in numerous ways, and have passed a number of impressive tests in the past, such as James Hansen's famous successful predictions<sup>34</sup> from the 1980s and 1990s. Let me take the opportunity to bring your attention to one particular analysis<sup>35</sup> that appears in the latest issue of *Nature Climate Change*. Back in 1989, legendary climate scientists Ron Stouffer (a graduate of our program at Penn State I'm proud to say) and Suki Manabe made a prediction not just of the average warming of the globe, but of the precise global pattern of that warming. That pattern matches the observed pattern of warming that has ensued remarkably well (see Figure 4).

When I was attacked by Joe Barton<sup>36</sup> a little more than decade ago over the hockey stick, at a time when both houses of Congress and the presidency were in the hands of Republicans, I found support in the hands of both the Bush Administration's Office of Science and Technology Policy, and moderate, pro-science, pro-environment Republicans in the Senate and House such as John McCain (R-AZ) and Sherwood Boehlert (R-NY). Mr. Boehlert was the Republican Chairman of this Committee, the Science Committee, at the time. Where are these good faith conservatives today? Why are

they not speaking out against this latest abuse against science and reason? If they fail to force their concerns, we must worry just how far down the antiscience rabbit hole we'll be going this time.

There is a worthy debate to be had about climate policy. And I am deeply appreciative of the efforts of conservatives like Bob Inglis<sup>37</sup> of South Carolina, former Reagan administration officials James Baker and George Schultz,<sup>38</sup> and Republican-led groups like RepublicEN<sup>39</sup> and the Niskanen Center<sup>40</sup> to promote conservative solutions to solving the climate problem. It is time for other Republicans to put aside the antiscience and engage instead in the worthy debate to be had about how we solve this great challenge to all of humanity.



**Figure 4:** Pattern of warming predicted by climate model simulations performed in 1989 (top) compared with observed pattern (bottom) of warming (from Stouffer and Manabe, *Nature Climate Change*, 2017).

## Biography of Michael E. Mann

Dr Michael E. Mann is Distinguished Professor of Atmospheric Science at Penn State University, with joint appointments in the Department of Geosciences and the Earth and Environmental Systems Institute (EESI). He is also director of the Penn State Earth System Science Center (ESSC). Dr Mann received his undergraduate degrees in physics and Applied Math from the University of California at Berkeley, an M.S. degree in physics from Yale University, and a PhD in Geology and Geophysics from Yale University. His research involves the use of theoretical models and observational data to better understand Earth's climate system. Dr Mann was a Lead Author on the *Observed Climate Variability and Change* chapter of the Intergovernmental Panel on Climate Change (IPCC) Third Scientific Assessment Report in 2001 and was organizing committee chair for the National Academy of Sciences *Frontiers of Science* in 2003. He has received a number of honors and awards including NOAA's outstanding publication award in 2002 and selection by *Scientific American* as one of the fifty leading visionaries in science and technology in 2002. He contributed, with other IPCC authors, to the award of the 2007 Nobel Peace Prize. He was awarded the Hans Oeschger Medal of the European Geosciences Union in 2012 and was awarded the National Conservation Achievement Award for science by the National Wildlife Federation in 2013. He made Bloomberg News' list of fifty most influential people in 2013. In 2014, he was named Highly Cited Researcher by the Institute for Scientific Information (ISI) and received the Friend of the Planet Award from the National Center for Science Education. He is a Fellow of the American Geophysical Union, the American Meteorological Society, and the American Association for the Advancement of Science. He is also a co-founder of the award-winning science website RealClimate.org.

Dr Mann is author of more than 200 peer-reviewed and edited publications, and has published three books including *Dire Predictions: Understanding Climate Change*, *The Hockey Stick and the Climate Wars* and most recently, *The Madhouse Effect* with *Washington Post* editorial cartoonist Tom Toles.

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## 4 Testimony of Professor Roger Pielke Jr

My testimony focuses on how members of Congress can better support scientific integrity in climate research and the steps that members can take to avoid contributing to the pathological politicization of science.

### Take-home points

- Science offers a powerful set of methods, evidence and an orientation to knowledge that can be essential to effective decision making.
- The science and policy communities have together over many decades developed highly credible, legitimate and relevant mechanisms for the assessment of the state of knowledge in any area of relevance to decision making.
- The legislative process is essential to a well-functioning democracy, but it is not well suited to the reliable characterization of the overall state of knowledge on a particular topic.
- How elected officials chose to utilize assessment and legislative processes for characterizing knowledge has great influence over the degree to which science becomes pathologically politicized.
- Ultimately, on complex, political issues like climate policy, reaching agreement on matters of science is neither necessary nor sufficient for policy action to occur.

### My recent experiences where science meets politics

Despite publishing many peer reviewed papers on a wide range of climate-related topics with colleagues around the world and having my research included in the reports of the Intergovernmental Panel for Climate Change (IPCC),<sup>1</sup> I experienced an organized effort of delegitimization by members of Congress and the White House, supported by their political allies in the media and in well-funded advocacy groups. These efforts were successful in that they resulted in me re-orienting my academic career away from climate-related research.

Here are some specifics of my experiences over the past few years:

- Several months after I testified before this committee in December, 2013, the White House posted on its website a six-page essay by the President's Science Advisor, John Holdren, which claimed falsely that my testimony before this committee was 'not representative of mainstream views on this topic in the climate-science community' and was 'seriously misleading.'<sup>2</sup>

- Science advisor Holdren's false claims were put forward even though my testimony was drawn from and consistent with the most recent reports of the IPCC. I have for decades supported the scientific assessment process of the IPCC and did so explicitly in my 2013 Congressional testimony.
- One year later, Congressman Raul Grijalva (D-AZ) opened a formal investigation of me and six other professors (three of us are testifying here today). In his letter to my university's president, Mr. Grijalva justified the investigation of me by relying on the science advisor's false claims: 'John Holdren, director of the White House Office of Science and Technology Policy, has highlighted what he believes were serious misstatements by Prof. Pielke of the scientific consensus on climate change,' and cited Dr. Holdren's essay on the White House website.<sup>3</sup>
- In his letter, Mr. Grijalva introduced another false implication – that I, and the other academics, had 'potential conflicts of interest and failure to disclose corporate funding sources.'<sup>4</sup> Mr. Grijalva's letter cited Exxon Mobil and the Koch Foundation as possible sources of undisclosed funding that I may have received.
- The communications director for the House Natural Resources Committee explained how we seven academics were chosen to be investigated by Mr. Grijalva: 'The way we chose the list of recipients [of Mr. Grijalva's letter] is who has published widely, who has testified in Congress before, who seems to have the most impact on policy in the scientific community.'<sup>5</sup>
- Publishing widely, testifying before Congress when asked and doing work with policy impact are usually held up as virtues among academics who are supported with public funds, but not in this circumstance.
- My university conducted the investigation as requested by Mr. Grijalva, and (no surprise to me) found that I have never received any fossil fuel or Koch Foundation funding. In 2016, the University of Colorado's elected Board of Regents issued a statement of support for me and academic freedom more generally.<sup>6</sup>
- Despite being ultimately vindicated about the integrity my research and my funding sources, as well as receiving the strong support of my university's leadership, the investigation proved extremely harmful to my ability to work in the field of climate.
- I have academic tenure (thankfully) and have chosen to shift the focus of my research to other interesting subjects at the intersection of science, policy and politics.
- Further details of my experiences can be found in an op-ed, included as Appendix A to this testimony.

## **Lessons of my experience**

- Scientific evidence in support of the conclusions I presented to this committee in 2013 is even stronger today. There is little scientific basis in support of claims that extreme weather events – specifically, hurricanes, floods, drought, tornadoes – and their economic damage have increased in recent decades due to the emission of greenhouse gases. In fact, since 2013 the world and the United States have had a remarkable stretch of good fortune with respect to extreme weather, as compared to the past.
- The lack of evidence to support claims of increasing frequency or intensity of hurricanes, floods, drought or tornadoes on climate timescales is also supported by the most recent assessments of the IPCC and the broader peer reviewed literature on which the IPCC is based.
- I have included an update of relevant data and summary conclusions of the IPCC related to trends in extreme weather as Appendix B to this testimony.<sup>†</sup>
- My experience as an inconvenient academic is not unique. Politicians, including elected officials in Congress, and enthusiastic advocates from both sides of the aisle have targeted climate researchers whose peer-reviewed research they do not like – including all four witnesses testifying here today. Such dynamics of delegitimization are not unique to the climate issue.
- Academics – no matter how solid their research may be – are no match for well-funded advocacy groups, activists in the media, the White House or Congress.
- Members of Congress have great power to delegitimize inconvenient experts, even derail their careers, and in the process, contribute to the pathological politicization of science.
- Members of Congress also have the power to defuse the pathological politicization of science, to uphold scientific integrity and put both science and politics in their proper places.
- This is a bipartisan challenge, which can only be addressed with a bipartisan commitment to scientific integrity.

## **Recommendations to improve the state of scientific integrity in climate science**

I have studied and written about science in policy and politics for several decades. I am a part of an international community of scholars and practitioners who focus on

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<sup>†</sup> Appendix B has not been reproduced in this GWPF version of Prof Pielke's testimony. Interested readers can find it in the original version as submitted to the House of Representatives.<sup>7</sup>

the challenges of science advice to governments.<sup>8</sup> There is consequently a deep body of knowledge and evidence on scientific advice – what works, and what does not.

My most well-known contribution to this area of scholarship and practice is *The Honest Broker: Making Sense of Science in Policy and Politics* (Cambridge University Press, 2007). Drawing on my experiences, my research and that of the broader community focused on scientific advice, I offer the following recommendations focused on how members of Congress can help to improve the state of scientific integrity in climate science.

- Policymakers and scientists have developed well-established processes for assessing the state of scientific knowledge on subjects of relevance to policy makers.
- Such processes include federal advisory committees, the National Academies, the assessments of the IPCC and many others nationally and internationally.
- There is also an enormous academic literature on the role of scientific assessments in policy and politics. Google Scholar lists almost a million articles under the key words ‘scientific assessments policy politics’.<sup>9</sup>
- Assessments of scientific knowledge are most effective when they address questions that policymakers have judged to be relevant to decision making and do so in a way that is viewed to be authoritative, unbiased and inclusive.<sup>10</sup>
- Such processes work best when they accurately characterize areas of uncertainty and ignorance, in addition to what is known with greater certainty. Such accurate characterization is facilitated when assessment processes are populated by a diversity of experts, including those who may hold minority or unpopular perspectives.
- Members of Congress have the standing and authority to call for such assessments, to ensure through oversight that they are conducted with integrity and are responsive to their information requests.
- In contrast, while the legislative process can be extremely effective in highlighting partisan differences on policy, it is not well suited to provide an accurate characterization of the state of scientific understandings.
- Sometimes debates over science serves as a proxy for debates about policy preferences or political orientation. When members of Congress participate in such proxy debates, it contributes to the pathological politicization of science.
- Assessments are best conducted outside the spotlight of high stakes political conflict.
- There is of course a risk that such assessments might be captured by interests, fall prey to groupthink or gatekeeping, or fail to accurately represent scientific understandings. In such instances the assessment process may become viewed

as partisan, illegitimate or simply not useful. In my area of expertise this occurred in the Fourth Assessment Report of the IPCC.<sup>11</sup>

- Climate science is a particularly politicized research area, meaning that careful attention should be paid to how assessments are organized and who leads and participates in them.
- Consequently, oversight of the integrity of these assessments is an important and appropriate role for Congressional committees, among others.
- However, the investigation of individual researchers (whether governmental or non-governmental) is not an appropriate role for Congress and is unlikely to contribute positively to the upholding of scientific integrity.
- A bipartisan truce ending such investigations of individual researchers should start immediately.
- Congress should support the role of scientific assessments in providing an accurate perspective on questions asked by policymakers. In climate, the IPCC, if it did not exist, would have to be invented. If members of Congress wish to secure robust answers to questions of climate science, impacts or economics, they might look to the IPCC.
- However, if the IPCC is not viewed to be legitimate, then Congress could easily request the US National Academy of Sciences (or other authoritative body) to empanel a high level, unimpeachable assessment process. Such assessments related to climate have of course been done for decades and the overarching scientific conclusions have remained consistent.
- We have plenty of knowledge and experience about how to arrive at accurate assessments of the state of scientific understandings on any topic. It is a choice whether or not to utilize that knowledge and experience.
- Irrespective of the state of scientific understandings, policy action related to energy policies and improving adaptation to climate variability and change does not require that everyone believe the same things about climate science or that all uncertainties be eliminated.<sup>12</sup>

### **To avoid any confusion: my views on climate science and policy**

Because the climate issue is so deeply politicized, it is necessary to include several statements to clearly present my views. The following conclusions are taken from my book *The Climate Fix* in a section entitled 'Guidelines for a common sense approach to climate policy'.<sup>13</sup> In that book, I call for a low but rising carbon tax to fund energy innovation, focused on cleaner, cheaper and more broadly accessible energy technologies. If the world's economy is to decarbonize, it will be because of advances

in energy technology, and not because everyone comes to hold the same views of climate science.<sup>14</sup>

### **Increasing carbon dioxide influences the climate system, perhaps dramatically and irreversibly**

That human activities have led to changes in the earth system is broadly accepted. So too is the possibility that such changes could lead to undesirable outcomes in the future. For those wanting to know more – much more – about aspects of climate science, the report of Working Group I of the IPCC is an excellent place to start further investigations, even as aspects of that report continue to be contested.

### **The climate system is subject to multiple human influences**

Carbon dioxide...is not the only important human influence. The climate system is complex and is still not fully characterized. Even so, many scientists and policy makers have concluded that dealing with carbon dioxide should be a top policy priority.

### **Our ability to see the future is limited**

There are debates about how the future will play out that simply cannot be resolved on the timescales of decision making. Efforts to gain clarity about the future may in fact have the paradoxical consequence of making that future even cloudier. Decisions about climate change will occur in the context of contestation, uncertainties and ignorance.

### **Certainty is not forthcoming**

As decisions are made about decarbonizing economies and improving adaptation to climate in the coming years, certainties about the long-term climate future are not forthcoming. UK science adviser John Beddington explains, 'There is a fundamental uncertainty about climate change prediction that can't be changed.' As Andy Revkin summarizes his years of covering the climate debate:

What the debate comes down to is not whether changes are coming but when they'll occur – and how severe they'll be. There is serious scientific disagreement about such vital questions as how fast and far temperatures, seas, and storm strength could rise.

Such disagreements will persist for the foreseeable future. Uncertainties are a reality to be lived with and managed. They are not going away.

## **Stabilizing atmospheric concentrations of carbon dioxide does not stop climate change**

Carbon policy is not a comprehensive climate policy. It is possible that the world could successfully address accumulating concentrations of carbon dioxide in the atmosphere and still have to deal with a significant issue of human influences on the climate system. For this reason, among others, Mike Hulme has written that climate change is a problem to be managed, not solved.<sup>15</sup> Our debates about climate change would benefit by distinguishing carbon policies from greenhouse gas policies and broader conceptions of climate policy.

## **Biography of Roger Pielke Jr.**

Roger Pielke, Jr. has been on the faculty of the University of Colorado since 2001. Currently, he serves as the director of the Sports Governance Center, a new initiative on campus, and faculty affiliate of the Center for Science and Technology Policy Research. He is a Professor in the Environmental Studies Program and from 2001–2016 was a Fellow of the Cooperative Institute for Research in Environmental Sciences (CIRES). Roger served several terms as the founding director of the university's Center for Science and Technology Policy Research. Roger's research focuses on science, innovation and politics, which he has explored in many topical areas over recent decades, including: space policy, natural disasters, energy policy, climate policy and more recently, in sports governance.

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 he 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 has held academic appointments at Macquarie University in Sydney, Australia, Oxford University and the London School of Economics.

Roger has hundreds of peer-reviewed publications and, for those who consider such things, he has an H-Index of 51 (Google). He is also author, co-author or co-editor of eight books, including *The Honest Broker: Making Sense of Science in Policy and Politics* published by Cambridge University Press (2007), *The Climate Fix: What Scientists and Politicians Won't Tell you About Global Warming* (2011, Basic Books), and *The Rightful Place of Science: Disasters and Climate Change* (CSPO: ASU, 2014). His most recent book is *The Edge: The War Against Cheating and Corruption in the Cutthroat World of Elite Sports* (Roaring Forties Press, 2016).

## Appendix A: 2016 op-ed on my experiences in climate research

### My Unhappy Life as a Climate Heretic<sup>16</sup>

*My research was attacked by thought police in journalism, activist groups funded by billionaires and even the White House.*

Much to my surprise, I showed up in the WikiLeaks releases before the election. In a 2014 email, a staffer at the Center for American Progress, founded by John Podesta in 2003, took credit for a campaign to have me eliminated as a writer for Nate Silver's FiveThirtyEight website. In the email, the editor of the think tank's climate blog bragged to one of its billionaire donors, Tom Steyer: 'I think it's fair [to] say that, without Climate Progress, Pielke would still be writing on climate change for 538.'

WikiLeaks provides a window into a world I've seen up close for decades: the debate over what to do about climate change, and the role of science in that argument. Although it is too soon to tell how the Trump administration will engage the scientific community, my long experience shows what can happen when politicians and media turn against inconvenient research – which we've seen under Republican and Democratic presidents.

I understand why Mr. Podesta – most recently Hillary Clinton's campaign chairman – wanted to drive me out of the climate-change discussion. When substantively countering an academic's research proves difficult, other techniques are needed to banish it. That is how politics sometimes works, and professors need to understand this if we want to participate in that arena.

More troubling is the degree to which journalists and other academics joined the campaign against me. What sort of responsibility do scientists and the media have to defend the ability to share research, on any subject, that might be inconvenient to political interests – even our own?

I believe climate change is real and that human emissions of greenhouse gases risk justifying action, including a carbon tax. But my research led me to a conclusion that many climate campaigners find unacceptable: There is scant evidence to indicate that hurricanes, floods, tornadoes or drought have become more frequent or intense in the US or globally. In fact we are in an era of good fortune when it comes to extreme weather. This is a topic I've studied and published on as much as anyone over two decades. My conclusion might be wrong, but I think I've earned the right to share this research without risk to my career.

Instead, my research was under constant attack for years by activists, journalists and politicians. In 2011 writers in the journal *Foreign Policy* signaled that some accused me of being a 'climate-change denier.' I earned the title, the authors explained, by 'questioning certain graphs presented in IPCC reports.' That an academic who raised questions about the Intergovernmental Panel on Climate Change in an area of his expertise was tarred as a denier reveals the groupthink at work.

Yet I was right to question the IPCC's 2007 report, which included a graph purporting to show that disaster costs were rising due to global temperature increases. The graph was later revealed to have been based on invented and inaccurate information, as I documented in my book *The Climate Fix*. The insurance industry scientist Robert-Muir Wood of Risk Management Solutions had smuggled the graph into the IPCC report. He explained in a public debate with me in London in 2010 that he had included the graph and misreferenced it because he expected future research to show a relationship between increasing disaster costs and rising temperatures. When his research was eventually published in 2008, well after the IPCC report, it concluded the opposite: 'We find insufficient evidence to claim a statistical relationship between global temperature increase and normalized catastrophe losses.' Whoops.

The IPCC never acknowledged the snafu, but subsequent reports got the science right: there is not a strong basis for connecting weather disasters with human-caused climate change.

Yes, storms and other extremes still occur, with devastating human consequences, but history shows they could be far worse. No Category 3, 4 or 5 hurricane has made landfall in the US since Hurricane Wilma in 2005, by far the longest such period on record. This means that cumulative economic damage from hurricanes over the past decade is some \$70 billion less than the long-term average would lead us to expect, based on my research with colleagues. This is good news, and it should be OK to say so. Yet in today's hyper-partisan climate debate, every instance of extreme weather becomes a political talking point. For a time I called out politicians and reporters who went beyond what science can support, but some journalists won't hear of this. In 2011 and 2012, I pointed out on my blog and social media that the lead climate reporter at the *New York Times*, Justin Gillis, had mischaracterized the relationship of climate change and food shortages, and the relationship of climate change and disasters. His reporting wasn't consistent with most expert views, or the evidence. In response he promptly blocked me from his Twitter feed. Other reporters did the same.

In August this year on Twitter, I criticized poor reporting on the website Mashable about a supposed coming hurricane apocalypse – including a bad misquote of me in the cartoon role of climate skeptic. (The misquote was later removed.) The publication's lead science editor, Andrew Freedman, helpfully explained via Twitter that this sort of behavior 'is why you're on many reporters' "do not call" lists despite your expertise.'

I didn't know reporters had such lists. But I get it. No one likes being told that he misreported scientific research, especially on climate change. Some believe that connecting extreme weather with greenhouse gases helps to advance the cause of climate policy. Plus, bad news gets clicks.

Yet more is going on here than thin-skinned reporters responding petulantly to a vocal professor. In 2015 I was quoted in the *Los Angeles Times*, by Pulitzer prize-

winning reporter Paige St. John, making the rather obvious point that politicians use the weather-of-the-moment to make the case for action on climate change, even if the scientific basis is thin or contested.

Ms. St. John was pilloried by her peers in the media. Shortly thereafter, she emailed me what she had learned: 'You should come with a warning label: quoting Roger Pielke will bring a hailstorm down on your work from the London *Guardian*, *Mother Jones*, and *Media Matters*.'

Or look at the journalists who helped push me out of FiveThirtyEight. My first article there, in 2014, was based on the consensus of the IPCC and peer-reviewed research. I pointed out that the global cost of disasters was increasing at a rate slower than GDP growth, which is very good news. Disasters still occur, but their economic and human effect is smaller than in the past. It's not terribly complicated.

That article prompted an intense media campaign to have me fired. Writers at *Slate*, *Salon*, the *New Republic*, the *New York Times*, the *Guardian* and others piled on. In March of 2014, FiveThirtyEight editor Mike Wilson demoted me from staff writer to freelancer. A few months later I chose to leave the site after it became clear it wouldn't publish me. The mob celebrated. ClimateTruth.org, founded by former Center for American Progress staffer Brad Johnson, and advised by Penn State's Michael Mann, called my departure a 'victory for climate truth.' The Center for American Progress promised its donor Mr. Steyer more of the same.

Yet the climate thought police still weren't done. In 2013 committees in the House and Senate invited me to a several hearings to summarize the science on disasters and climate change. As a professor at a public university, I was happy to do so. My testimony was strong, and it was well aligned with the conclusions of the IPCC and the US government's climate-science program. Those conclusions indicate no overall increasing trend in hurricanes, floods, tornadoes or droughts – in the US or globally.

In early 2014, not long after I appeared before Congress, President Obama's science adviser John Holdren testified before the same Senate Environment and Public Works Committee. He was asked about his public statements that appeared to contradict the scientific consensus on extreme weather events that I had earlier presented. Mr Holdren responded with the all-too-common approach of attacking the messenger, telling the senators incorrectly that my views were 'not representative of the mainstream scientific opinion'. Mr. Holdren followed up by posting a strange essay, of nearly 3000 words, on the White House website under the heading, 'An analysis of statements by Roger Pielke Jr.,' where it remains today.

I suppose it is a distinction of a sort to be singled out in this manner by the president's science adviser. Yet Mr Holdren's screed reads more like a dashed-off blog post from the nutty wings of the online climate debate, chock-full of errors and misstatements.

But when the White House puts a target on your back on its website, people no-

tice. Almost a year later Mr Holdren's missive was the basis for an investigation of me by Arizona Rep. Raul Grijalva, the ranking Democrat on the House Natural Resources Committee. Rep. Grijalva explained in a letter to my university's president that I was being investigated because Mr Holdren had 'highlighted what he believes were serious misstatements by Prof. Pielke of the scientific consensus on climate change'. He made the letter public.

The 'investigation' turned out to be a farce. In the letter, Rep. Grijalva suggested that I – and six other academics with apparently heretical views – might be on the payroll of Exxon Mobil (or perhaps the Illuminati, I forget). He asked for records detailing my research funding, emails and so on. After some well-deserved criticism from the American Meteorological Society and the American Geophysical Union, Rep. Grijalva deleted the letter from his website. The University of Colorado complied with Rep. Grijalva's request and responded that I have never received funding from fossil-fuel companies. My heretical views can be traced to research support from the US government.

But the damage to my reputation had been done, and perhaps that was the point. Studying and engaging on climate change had become decidedly less fun. So I started researching and teaching other topics and have found the change in direction refreshing. Don't worry about me: I have tenure and supportive campus leaders and regents. No one is trying to get me fired for my new scholarly pursuits.

But the lesson is that a lone academic is no match for billionaires, well-funded advocacy groups, the media, Congress and the White House. If academics – in any subject – are to play a meaningful role in public debate, the country will have to do a better job supporting good-faith researchers, even when their results are unwelcome. This goes for Republicans and Democrats alike, and to the administration of President-elect Trump.

Academics and the media in particular should support viewpoint diversity instead of serving as the handmaidens of political expediency by trying to exclude voices or damage reputations and careers. If academics and the media won't support open debate, who will?

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6. I am very proud to be associated with the University of Colorado, whose leadership offered unwavering support throughout my experiences, see: [http://www.dailycamera.com/cu-news/ci\\_30558681/cu-board-shows-support-faculty-students-academic-freedom](http://www.dailycamera.com/cu-news/ci_30558681/cu-board-shows-support-faculty-students-academic-freedom).
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