STATEMENT TO THE
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
OF THE UNITED STATES HOUSE OF REPRESENTATIVES

Hearing on
"The President's U.N. Climate Pledge"

15 April 2015

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Major points:

Recent data and research supports the importance of natural climate variability and calls into question the conclusion that humans are the dominant cause of recent climate change:

- The hiatus in global warming since 1998
- Reduced estimates of the sensitivity of climate to carbon dioxide
- Climate models predict much more warming than has been observed in the early 21st century

We have made some questionable choices in defining the problem of climate change and its solution:

- The definition of 'dangerous' climate change is ambiguous, and hypothesized catastrophic tipping points are regarded as very or extremely unlikely in the 21st century.
- Efforts to link dangerous impacts of extreme weather events to human-caused warming are misleading and unsupported by evidence.
- Climate change is a 'wicked problem' and ill-suited to a 'command and control' solution
- It has been estimated that the U.S. INDC of 28% emissions reduction will prevent 0.03°C in warming by 2100.

The inadequacies of current policies based on the Precautionary Principle are leaving the real societal consequences of climate change and extreme weather events (whether caused by humans or natural variability) largely unaddressed:

- We should expand the frameworks for thinking about climate policy and provide policy makers with a wider choice of options in addressing the risks from climate change.
- Pragmatic solutions based on efforts to accelerate energy innovation, build resilience to extreme weather, and pursue no regrets pollution reduction measures have justifications independent of their benefits for climate mitigation and adaptation.

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I thank the Chairman and the Committee for the opportunity to offer testimony today on 'The President's U.N. Climate Pledge.' I am Professor and former Chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology. As a climate scientist, I have devoted 30 years to conducting research on a variety of topics including climate feedback processes in the Arctic, the role of clouds and aerosols in the climate system, and the impact of climate change on the characteristics of tropical cyclones. As president of Climate Forecast Applications Network LLC, I have been working with decision makers on climate impact assessments, assessing and developing climate adaptation strategies, and developing subseasonal climate forecasting strategies to support adaptive management and tactical adaptation.

I am increasingly concerned that both the climate change problem and its solution have been vastly oversimplified.[1] My research on understanding the dynamics of uncertainty at the climate science-policy interface has led me to question whether these dynamics are operating in a manner that is healthy for either the science or the policy process.[2] As a result, I am concerned that the U.S. Intended Nationally Determined Contribution (INDC) to the United Nations Framework Convention on Climate Change (UNFCCC) will do essentially nothing to change the climate, and the U.S. and other nations will remain vulnerable to climate surprises and extreme weather events.

My testimony focuses on the following issues of central relevance to the U.S. INDP:

- Weakening case for dangerous human-caused climate change
- The climate change response challenge
- Expanding the policy options for responding to climate change

A weakening case for dangerous anthropogenic climate change

Scientists agree that surface temperatures have increased since 1880, humans are adding carbon dioxide to the atmosphere, and carbon dioxide and other greenhouse gases have a warming effect on the planet. However there is considerable disagreement about the most consequential issues:

- Whether the warming since 1950 has been dominated by human causes
- How much the planet will warm in the 21st century
- Whether warming is 'dangerous'

The central issue in the climate change debate is the extent to which the recent (and future) warming is caused by human-caused greenhouse gas emissions versus natural climate variability – variations from

[1] Curry, JA and Webster PJ 2011: Climate science and the uncertainty monster. *Bull Amer Meteorol. Soc.,* 92, 1667-1682. http://journals.ametsoc.org/doi/pdf/10.1175/2011BAMS3139.1

[2] Judith Curry, Statement to the Subcommittee on Environment of the U.S. House of Representatives Hearing on Policy Relevant Climate Science in Context, 25 April 2013. https://curryja.files.wordpress.com/2013/04/curry-testimony-2013-il.pdf

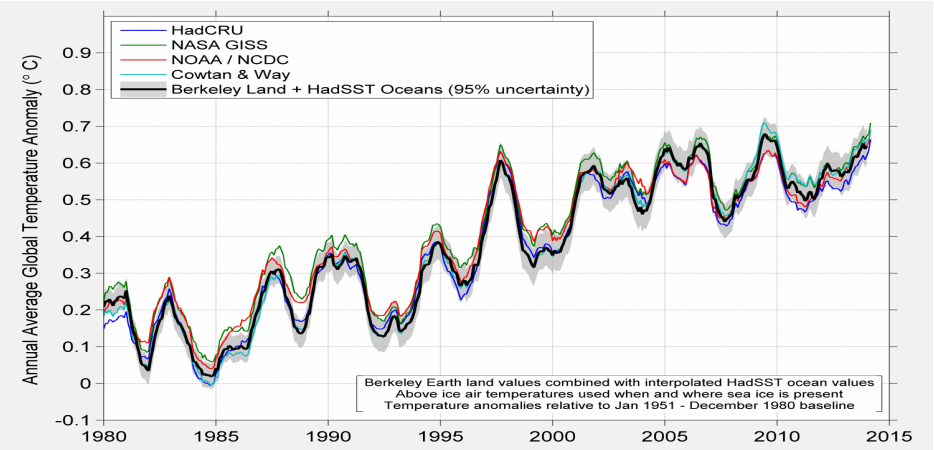
the sun, volcanic eruptions, and large-scale ocean circulations. My 2014 testimony before the Senate Environmental and Public Works Committee[3] argued that the 2013 report from the Intergovermental Panel on Climate Change (IPCC AR5 WG I)[4] weakened the case for dangerous anthropogenic climate change relative to the IPCC AR4 published in 2007. A summary is presented here of recent data and research that supports the importance of natural climate variability and calls into question the IPCC's conclusion that humans are the dominant cause of recent climate change. The policy relevance of this issue is that if humans are not the dominant cause of climate change, then attempts to modify the climate through reducing greenhouse gas emissions will have little impact on future climate change.

Hiatus in global warming

The IPCC AR5 notes a slowdown in surface warming since 1998:

> "[T]he rate of warming over the past 15 years (1998–2012) [is] 0.05 [–0.05 to +0.15] °C per decade which is smaller than the rate calculated since 1951 [of] 0.12 [0.08 to 0.14] °C per decade."

This figure shows the recent global temperatures through 2014 from several different global data sets[5]:



The media touted 2014 as the 'warmest year' in the historical record; however, given the uncertainties in the analyses, 2014 was in a statistical tie with 2010 and 2005. The UK dataset HadCRU, with perhaps a more realistic assessment of uncertainties, found 2014 to rank among the top 10 warmest years, all of which are since 1998. While the recent decade is the warmest in history, the ties for warmest year further reflect a plateau in the warming.

So we have no significant temperature increase since 1998, which has been a period with 25% of the total human CO2 emissions. This hiatus in warming is at odds with the 2007 IPCC AR4 report, which expected warming to increase at a rate of 0.2 °C per decade in the early 21st century.

Numerous recent research papers have highlighted the importance of natural variability associated with circulations in the Atlantic and Pacific Oceans, which is now believed to be the dominant cause of the hiatus. If the recent warming hiatus is caused by natural variability, then this raises the question as to what extent the warming between 1975 and 1998 can also be explained by natural climate variability.

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[3] Judith Curry, Statement to the Senate Committee on Environment and Public Works 25 April 2014 http://www.epw.senate.gov/public/index.cfm?FuseAction=Files.View&FileStore_id=07472bb4-3eeb-42da-a49d-964165860275

[4] IPCC reports can be obtained at http://www.ipcc.ch

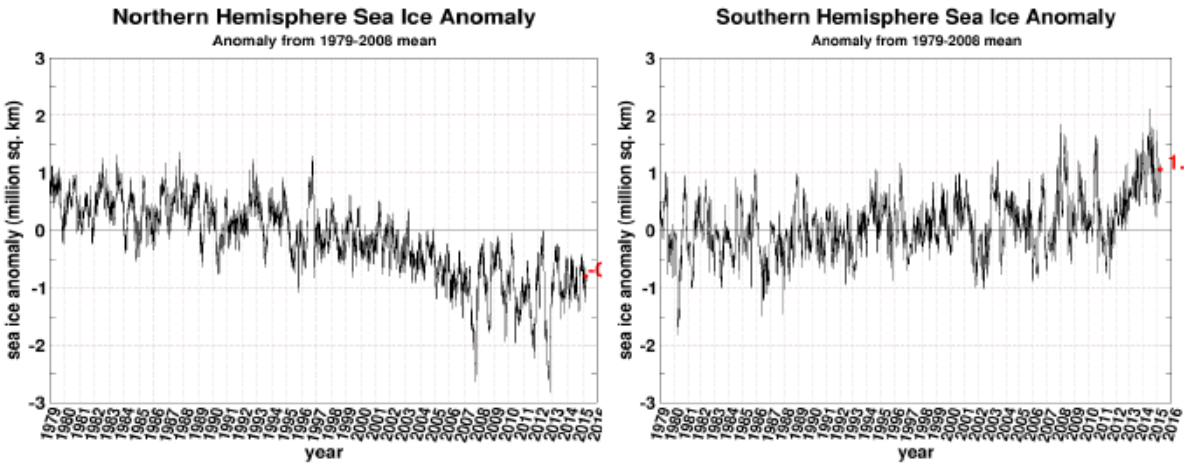
[5] Figure courtesy of Robert Rohde of the Berkeley Earth Surface Temperature team

Sea ice

The IPCC AR5 acknowledges the strong role of natural variability in determining sea ice variability and change on multidecadal time scales. Nevertheless, the IPCC AR5 concluded:

- "[I]t is *very likely* that the Arctic sea ice cover will continue to shrink and thin all year round during the 21st century. It is also *likely* that the Arctic Ocean will become nearly ice-free in September before the middle of the century (*medium confidence*)."

Below are satellite observations of sea ice variability through 2014.[6]



In 2013 and 2014, Arctic sea ice recovered from its summertime minima during the period 2007-2012. Notably, Arctic sea ice volume (a metric that combines both horizontal extent and ice thickness) shows a continuing increase since 2012[7]. During 2014, Antarctic sea ice set a wintertime maximum record.

A recent paper by Swart et al.[8] emphasized that internal climate variability can mask or enhance human-induced sea-ice loss on timescales ranging from years to decades or even a century. A new paper by Zhang[9] clarifies the natural fluctuations that influence Arctic sea ice loss – heat transported by the Atlantic and Pacific, and wind patterns over the Arctic that drive sea ice out from the central Arctic, where it melts in the North Atlantic. In particular, the recent cooling in the high latitudes of the North Atlantic is associated with the current recovery of the sea ice in the Atlantic sector.

Clearly, there is a lot going on with respect to variability in Arctic and Antarctic sea ice that cannot be explained directly or even indirectly by warming from human-caused greenhouse gases. Climate models do not simulate correctly the ocean heat transport and its variations. Scientists do not agree on the explanation for the increasing Antarctic sea ice extent, and the key issue as to whether human-caused warming is the dominant cause of the recent Arctic sea ice loss remains unresolved.

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[6] http://arctic.atmos.uiuc.edu/cryosphere/IMAGES/seaice.anomaly.arctic.png
http://arctic.atmos.uiuc.edu/cryosphere/IMAGES/seaice.anomaly.antarctic.png

[7] http://psc.apl.washington.edu/wordpress/wpcontent/uploads/schweiger/ice_volume/BPIOMASIceVolumeAnomalyCurrentV2.1.png

[8] Swart et al 2015 Influence of internal variability on Arctic sea-ice trends, *Nature climate Change*, 5, Pages: 86–89 DOI: doi:10.1038/nclimate2483

[9] Zhang, R. 2015. Mechanisms for low-frequency variability of summer Arctic sea ice extent, *Proceedings of the National Academy of Sciences,* doi:10.1073/pnas.1422296112

Sensitivity

Human-caused warming depends not only on increases in greenhouse gases but also on how 'sensitive' the climate is to these increases. Climate sensitivity is defined as the global surface warming that occurs when the concentration of carbon dioxide in the atmosphere doubles. If climate sensitivity is high, then we can expect substantial warming in the coming century as emissions continue to increase. If climate sensitivity is low, then future warming will be substantially lower.

The most relevant definition of climate sensitivity is the actual change of surface temperature in 70 years if carbon-dioxide concentrations double, called the 'transient climate response'. The IPCC AR4 (2007) concluded that the transient climate response is *very likely* larger than 1°C and *very unlikely* greater than 3°C. The IPCC AR5 (2013) concluded that the transient climate response is *likely* [17-83%] in the range of 1 to 2.5°C.

Last year, Nicholas Lewis and I published a paper[10] that found transient climate response to have a *likely* range of 1.05-1.80°C. Using an observation-based energy balance approach, our calculations used the same data for the effects on the Earth's energy balance of changes in greenhouse gases, aerosols and other drivers of climate change given by the IPCC AR5. Our range for the transient climate response is much narrower, with far lower upper limits, than reported by the IPCC AR5.

Recent research suggests even lower values of the transient climate response. The greatest uncertainty in these estimates is accounting for the effects of small aerosol particles in the atmosphere, which have a cooling effect on the climate (partially counteracting the greenhouse warming). A new paper by Stevens[11] constrains the impact of aerosols on climate to be significantly smaller than assumed in the AR5. Nicholas Lewis has re-run the calculations using aerosol impact estimates in line with this paper. The *likely* range for the transient climate response is 1.05 to 1.45°C. By contrast, most climate model estimates of transient climate response are higher than 1.8°C. Research continues to assess the methods used to estimate climate sensitivity. However, the reduced estimates of aerosol cooling lead inescapably to reductions in the estimated upper bound of climate sensitivity.

Are climate models running too 'hot'?

These new climate sensitivity estimates, combined with the slowdown or 'hiatus' in global warming since 1998, add to the growing evidence that climate models are running too 'hot.'

The near-term temperature projections of the climate models are shown below, compared with observations of global temperatures through 2014.[12] The observed global temperatures, particularly since 2011, are below or just at the bottom bound of the 5-95% envelope of the CMIP5 climate model simulations. Overall, the trend in the model simulations is substantially larger than the observed trend over the past 15 years.

Note the hatched red area, this seems to be a concession to the hiatus. The IPCC cites 'expert judgment' as the rationale for lowering the projections (indicated by the red hatching), to account for the apparent oversensitivity of the models.

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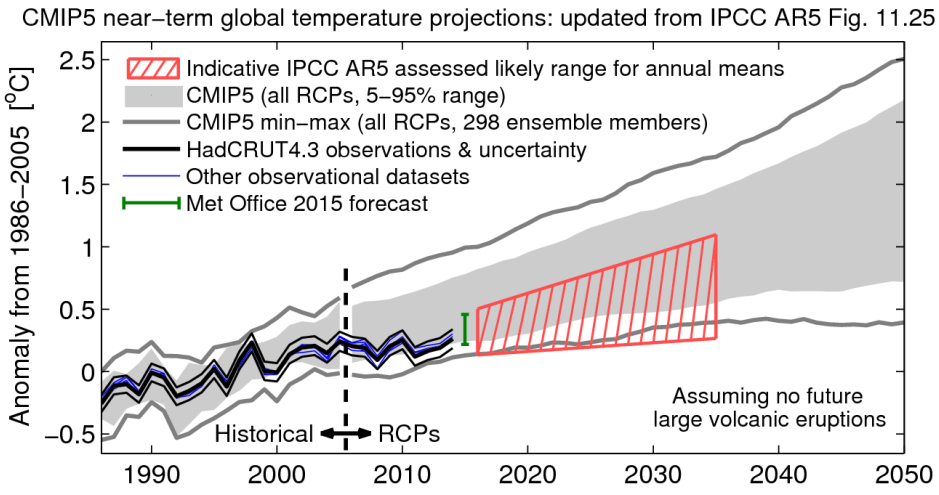
[10] Lewis, N. and J.A. Curry, (2014) The implications for climate sensitivity of AR5 forcing and heat uptake. *Climate Dynamics* http://link.springer.com/article/10.1007%2Fs00382-014-2342-y#page-1

[11] Stevens, B (2015) Rethinking the lower bound on aerosol forcing. *J. Climate*, http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-14-00656.1

[12] A revised version of Figure 11.25 from the AR5 WG1 Report is given by Ed Hawkins at http://www.climate-lab-book.ac.uk/comparing-cmip5-observations/



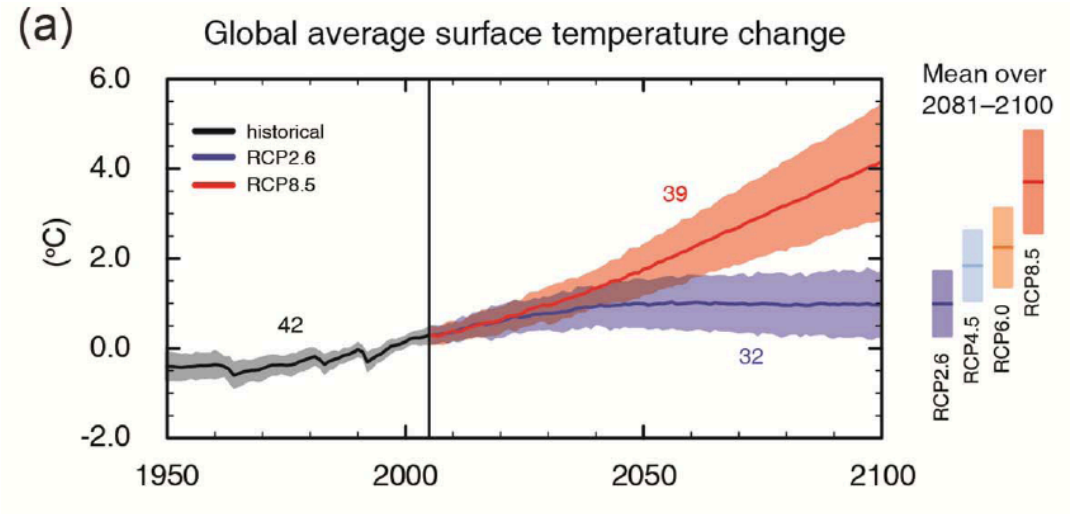
Based upon climate model projections, the probability of the hiatus extending beyond 20 years is vanishing small. The warming hiatus, combined with assessments that the climate-model sensitivities are too high, raises serious questions as to whether the climate-model projections of 21st century temperatures are fit for supporting public policy decisions:

- Are climate models too sensitive to greenhouse forcing?
- Is modeled treatment of natural climate variability inadequate?
- Are model projections of 21st century warming too high?

Whither the 21st century climate?

The issue of greatest concern is how the climate will evolve during the 21st century. There are two different views on this.

The first perspective is that of the IPCC, which projects continued warming through the 21st century, and is expected to surpass the 'dangerous' threshold of 2°C warming as early as 2040. The figure below, from the IPCC AR5 Summary for Policy Makers, shows climate model projections of 21st century warming, with RCP8.5 reflecting 'business as usual' emissions of greenhouse gases.



The other perspective emphasizes natural variability:

- Our understanding of circulation regimes in the Atlantic and Pacific Oceans (stadium wave hypothesis)[13] suggests that the 'hiatus' will continue at least another decade, perhaps into the 2030's. Arctic sea ice will recover over the next two decades.
- Climate models are too sensitive to human forcing; 21st century warming will be on the low end of IPCC projections (or even below).
- Solar variations and volcanic eruptions are a wild card. Russian scientists[14] argue that there was a Grand Solar Maximum that peaked in the late 20th century, and that we can expect a Grand Solar Minima (contributing to cooling) to peak around 2060.
- And finally, we can't rule out unforeseen surprises. The hiatus in warming in the early 21st century was an unforeseen surprise.

Time will tell which of these two perspectives is correct.

Summary

Anthropogenic climate change is a theory in which the basic mechanism is well understood, but the potential magnitude is highly uncertain. We know that the climate changes naturally on decadal to century time scales, but we do not have explanations for a number of observed historical and paleo- climate variations, including the warming from 1910-1940, the mid-20th century cooling and the 21st century hiatus in warming. Disagreement regarding climate change arises from our recognized uncertainty regarding natural climate variability.

Climate model projections of the 21st century climate are losing credibility because of:

- Failure to predict the early 21st century hiatus in surface warming
- Inability to simulate the patterns and timing on multidecadal ocean oscillations
- Lack of account for future solar variations and solar indirect effects on climate
- Apparent oversensitivity to increases in greenhouse gases

So, how will the 21st century climate evolve? Apart from lack of confidence in climate model projections that focus primarily on the impact of increases in greenhouse gases, we don't have sufficient understanding to project solar variations, future volcanic eruptions and decadal to century variations in deep ocean circulations. We can't rule out a continuation of the warming hiatus, or even cooling during parts of the 21st century. How solar variations, volcanic eruptions, ocean circulations and human influences will interact to determine the evolution of the 21st century climate is not known with any confidence, and scientists disagree as to which of these factors will dominate.

The climate change response challenge

Claims that the earth has been warming, that there is a greenhouse effect, and that man's activities have contributed to warming, are trivially true, but they are essentially meaningless by themselves in terms of alarm. These truths also do not mandate a specific policy response.

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[13] Wyatt, MG and JA Curry, 2013: Role for Eurasian Arctic shelf sea ice in a secularly varying hemispheric climate signal during the 20th century. *Climate Dynamics*, http://curryja.files.wordpress.com/2013/10/stadium-wave1.pdf

[14] Abdussamatov, H 2013: Current long-term negative energy balance of the earth leads to the new little ice age. *Journal of Geology and Geophysics* http://omicsgroup.org/journals/grand-minimum-of-the-total-solar-irradiance-leads-to-the-little-ice-age-2329-6755.1000113.pdf

Is climate change dangerous?

Central to responding to climate change is this question: Is warming 'dangerous'? The UN Framework Convention on Climate Change (UNFCCC) international environmental treaty (1992) states as its objective:[15] "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent ***dangerous*** anthropogenic interference with the climate system."

The IPCC 3rd and 4th Assessment reports refer to 'reasons for concern.' It wasn't until 2010 that some clarification of 'dangerous' was provided by UN international negotiators:[16] "In 2010, governments agreed that emissions need to be reduced so that global temperature increases are limited to below 2 degrees Celsius." The target of 2^{o}C remains the focal point of international agreements and negotiations, although this definition remains controversial and is being challenged.

The original rationale for the 2^{o}C target is the idea that 'tipping points' - abrupt or nonlinear transition to a different state - become likely to occur once this threshold has been crossed, with consequences that are largely uncontrollable and beyond our management. The IPCC AR5 considered a number of potential tipping points, including ice sheet collapse, collapse of the Atlantic overturning circulation, and permafrost carbon release. Every single catastrophic scenario considered by the IPCC (Table 12.4) has a rating of *very unlikely* or *exceptionally unlikely* and/or has *low confidence*. The only tipping point that the IPCC considers *likely* in the 21st century is disappearance of Arctic summer sea ice (which reforms each winter, in any event).

In the absence of tipping points on the timescale of the 21st century, the 2^{o}C limit is more usefully considered by analogy to a highway speed limit:[17] driving at 10 mph under the speed limit is not automatically safe, and exceeding the limit by 10 mph is not automatically dangerous, although the faster one travels the greater the danger from an accident. Analogously, the 2^{o}C limit should not be taken literally as a real danger threshold.

Nevertheless, the 2^{o}C limit is used politically to motivate the urgency of action to reduce CO_2 emissions. At a recent UN Climate Summit, Secretary-General Ban Ki-moon warned that: "Without significant cuts in emissions by all countries, and in key sectors, the window of opportunity to stay within less than 2 degrees [of warming] will soon close forever."[18] Actually, this window of opportunity may remain open for quite some time. The implications of the lower values of climate sensitivity found by Lewis and Curry and other recent studies is that human-caused warming is not expected to exceed the 2^{o}C 'danger' level in the 21st century. A slower rate of warming means there is less urgency to phase out greenhouse gas emissions now, and more time to find ways to decarbonize the economy affordably. It also allows us the flexibility to revise our policies as further information becomes available.

Is it possible that something really dangerous and unforeseen could happen to Earth's climate during the 21st century? Yes it is possible, but natural climate variability (perhaps in conjunction with human-caused climate change) may be a more likely source of possible undesirable change than human causes. In any event, attempting to avoid such a dangerous and unforeseen climate by reducing fossil fuel emissions will be futile if natural climate is a dominant factor.

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[15] http://unfccc.int/essential_background/convention/items/6036.php
[16] http://unfccc.int/essential_background/items/6031.php
[17] http://www.carbonbrief.org/blog/2014/12/two-degrees-a-selected-history-of-climate-change-speed-limit/
[18] http://newsroom.unfccc.int/unfccc-newsroom/un-climate-summit-ban-ki-moon-final-summary/

Biased information cascades

Climate change may exacerbate environmental problems that are caused by overpopulation, poorly planned land-use and over-exploitation of natural resources. However, it is very difficult to separate out the impacts of human caused climate change from natural climate change and from other societal impacts. Nevertheless, climate change has become a grand narrative in which human-caused climate change has become a dominant cause of societal problems.[19] Everything that goes wrong, and even pre-existing concerns, reinforces the conviction that that there is only one thing we can do prevent societal problems – stop burning fossil fuels. This grand narrative misleads us to think that if we solve the problem of climate change, then these other problems would be ameliorated.

Politicians, activists and journalists have stimulated a biased information cascade of alarm about human-caused climate change to support a political agenda of reducing fossil fuel emissions. An information cascade is a self-reinforcing process of collective belief formation that triggers a self-perpetuating chain reaction as a band wagon or snowballing process: the more attention a danger gets, the more worried people become, leading to more news coverage and greater alarm. Because slowly increasing temperatures don't seem alarming, the cascade facilitators push extreme weather events and public health impacts as being caused by human-caused climate change, more of which is in store if we don't quickly act to cool the planet by reducing fossil fuel emissions.

A deconstruction of this information cascade is needed to avoid bias in our thinking and to better understand the true risks of human caused climate change:

- The basis for this cascade originates from the 1992 UNFCCC treaty, to avoid dangerous human caused climate change through stabilization of CO2 emissions. Note, it was not until 1995 that the IPCC 2nd Assessment Report identified a 'discernible' human influence on global climate. The policy 'cart' was clearly leading the scientific 'horse.'
- Then, the UNFCCC changed the definition of climate change to refer to a change of climate that is attributed directly or indirectly to human activity. This leads to the perception that all climate change is caused by humans.
- Sea level rise and extreme weather events such as hurricanes, drought and heat waves are attributed to climate change, which is assumed *de facto* to be caused by humans.
- Human health impacts, national security risks, etc. that are exacerbated by extreme weather events are then fallaciously inferred to be caused by human-caused climate change.

A critical link in this cascade is the link between human-caused climate change and extreme weather. In 2012, the IPCC published a *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (SREX).[20] The Report found low to medium confidence of a trend in droughts in some regions and the frequency of heavy rains in some regions, and high confidence of a trend in heat waves in Australia. There is no trend in hurricanes or wild fires. Attribution of any trend in extreme weather events to human caused climate change cannot be done with any confidence. With regards to the perception (and damage statistics) that severe weather events seem more frequent and more severe over the past decade, there are several factors in play. The first is the increasing vulnerability and exposure associated with increasing concentration of wealth in coastal and other disaster-prone regions. The second factor is natural climate variability. Many extreme weather events have documented relationships with natural climate variability; in the U.S., extreme weather events (e.g. droughts, heat waves and hurricanes) were significantly worse in the 1930's and 1950's.[21]

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[19] Korhola, E-R 2015 Climate change as a political process https://helda.helsinki.fi/bitstream/handle/10138/136507/Therisea.pdf?sequence=1

[20] IPCC SREX http://www.ipcc-wg2.gov/SREX/

[21] Curry, JA 2014 Senate EPW testimony http://judithcurry.com/2014/01/16/senate-epw-hearing-on-the-presidents-climate-action-plan/

The information cascade of climate change as apocalypse is impeding our ability to think rationally about how we should respond to climate change, and acts to narrow the viewpoints and policy options that we are willing to consider in dealing with complex issues such as public health, weather disasters and national security. Should we be surprised when reducing CO_2 emissions does not ameliorate any of these problems?

Wrong trousers: climate change as a wicked problem

In the decades since the UNFCCC Treaty and the Kyoto Protocol, global emissions have continued to increase, especially in developing countries. UN Climate Conferences have not produced a new treaty in this framework. Opposition to a new treaty arises from concerns over economic costs and the need to ameliorate energy poverty in less developed countries. A key issue in the climate policy debate is whether the proposed 'cure' (i.e. CO_2 emissions reduction and associated economic hardships) is worse than the 'disease' (i.e. warmer temperatures).

In their Wrong Trousers essay,[22] Prins and Rayner argue that we have made the wrong cognitive choices in our attempts to define the problem of climate change and its solution, by relying on strategies that worked previously for 'tame' problems. A tame problem is well defined, well understood, and the appropriate solutions are agreed upon. Cost-benefit analyses and mitigation techniques are appropriate for tame problems, and the potential harm from miscalculation is bounded.

By contrast, climate change is better characterized as a 'wicked' problem, which is a complex tangle characterized by multiple problem definitions, the methods of understanding are open to contention, and 'unknown unknowns' suggest chronic conditions of ignorance and lack of capacity to imagine future eventualities of both the problem and the proposed solutions. The complex web of causality may result in surprising unintended consequences to attempted solutions that generate new vulnerabilities or exacerbate the original harm. Further, the wickedness of the climate change problem makes if difficult to identify points of irrefutable failure in either the science or the policies.

As another pair of 'wrong trousers,' the enshrinement of the Precautionary Principle into the UNFCCC Treaty represents a mismatch between the problem and the proposed solution. The Precautionary Principle works fine for tame problems, but introduces many potentially undesirable consequences when applied to a wicked problem. The Precautionary Principle enjoins us to do our utmost to avoid the possibility of catastrophe or ruin, and is arguably a decisive consideration for ruin problems.[23] However, arguments that we face the possibility of ruin in the 21st century from climate change are very weak and not supported by the evidence that we have.

Overreaction to a possible catastrophic threat may cause more harm than benefits and introduce new systemic risks, which are difficult to foresee for a wicked problem. The known risks to human well-being associated with constraining fossil fuels may be worse than the eventual risks from climate change, and there are undoubtedly some risks that we currently don't foresee.

The wickedness of the climate change problem is further manifested in the regional variability of the risks. Balancing the risks of climate change and the policy response is very difficult across different regions and countries that face varying risks from climate change, energy poverty and threats to economic development. Some regions may actually benefit from a warmer climate. Regional perceptions of a preferred climate or 'dangerous' climate change depend on societal values and vulnerability/resilience, which vary regionally and culturally. Climate has always changed, independently of human activity, so

[22] Prins and Rayner, 2007. The wrong trousers: radically rethinking climate policy http://eureka.bodleian.ox.ac.uk/66/
[23] Taleb, N et al. 2014: The precautionary principle. Extreme Risk Initiative NYU http://arxiv.org/pdf/1410.5787.pdf

climate change is nothing new; there is no *prima facie* reason for thinking the climate of the past or present is better than the future. Further, our current preferences for avoiding a particular climate of the future fail to account for human creativity and ingenuity in creating new technologies and social and political structures that will condition our perceptions and the consequences of climate change.

Expanding the policy options for responding to climate change

There is reason to be concerned about climate change, and humans are influencing climate in the direction of warming. However, effectively responding to the possible threats from a warmer climate is made very difficult by the deep uncertainties surrounding the risks both from the problem and the proposed solutions. The climate change problem is characterized by deep uncertainties in the trajectory of 21st century climate change, long timescales of the risk over which there is much uncertainty about societal vulnerabilities and capacities to respond, and disagreement among experts regarding the efficacy of different strategies and the value of alternative outcomes.

The complexity and wickedness of the climate change problem argues against a 'command and control' solution based on some guessed-at optimal policy. Attempting to deal with a wicked problem using strategies designed for tame problems can result in a 'cure' that is worse than the original 'disease.' Arguably the biggest problem with climate policy has been an overly narrow set of narratives and policy options. Expanding the frameworks for thinking about climate policy and its relation to other societal problems can lead to developing a range of more tractable policy options that would provide policy makers with a wider choice of options in addressing the risks from climate change.

Precautionary Principle – more sorry than safe?

The UNFCCC has formulated the climate change problem and solution as irreducibly global in context of the Precautionary Principle, with the solution focused on global reductions of greenhouse gas emissions.

Individual countries are submitting to the UNFCCC their INDCs. The U.S. INDC has a goal of reducing emissions by 28% below 2005 levels by 2025. Apart from considerations of feasibility and cost, it has been estimated[24] using the EPA MAGICC model that this commitment will prevent 0.03°C in warming by 2100. When combined with commitments from other nations, only a small fraction of the projected future warming will be ameliorated by these commitments. If climate models are indeed running too hot, then the amount of warming prevented would be even smaller. Even if emissions immediately went to zero and the projections of climate models are to be believed, the impact on the climate would not be noticeable until the 2nd half of the 21st century. It is not clear exactly what the INDC commitments are expected to accomplish.

The UNFCCC policies and the Precautionary Principle have brought us to a point between a rock and hard place, whereby the proposed policy with its extensive costs and questions of feasibility are inadequate for making a meaningful dent in slowing down the expected warming. And the real societal consequences of climate change and extreme weather events (whether caused by humans or natural variability) remain largely unaddressed.

Given that the policies proposed under the imprimatur of the Precautionary Principe are very costly, politically contentious and would not change the climate in any meaningful way, we should consider other decision making frameworks and risk management approaches for addressing climate change.

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[24] http://www.cato.org/blog/002degc-temperature-rise-averted-vital-number-missing-epas-numbers-fact-sheet

Decision making strategies under deep uncertainty

Rather than negotiating an optimal policy based on a negotiated scientific consensus, robust and flexible policy strategies can be designed that account for uncertainty, ignorance and dissent. Robust strategies formally consider uncertainty, whereby decision makers seek to reduce the range of possible scenarios over which the strategy performs poorly. Flexible strategies are adaptive, and can be quickly adjusted to advancing scientific insights and new conditions that arise.

Under conditions of deep uncertainty, the following options are available to frame decision making:[25]

- Do nothing, or delay in order to gather more information
- Enlarge the knowledge base for decisions through broader perspectives
- Invoke the Precautionary Principle
- Adaptive management
- Build a resilient and anti-fragile society

Each of these strategies incorporates information about uncertainty into the decision making process, albeit in different ways. The politics surrounding the climate policy debate is framed as a choice between delaying a policy response until uncertainties are reduced versus invoking the Precautionary Principle aimed at emission stabilization targets determined largely by climate models.

The other decision framework options are receiving increasing attention, and justification for addressing the climate change problem are transitioning away from precaution to a risk management approach justified by the economics of preventing losses from climate change. The World Bank has a recent paper entitled *Investment decision making under deep uncertainty – application to climate change*[26] that summarizes existing decision-making methodologies that are able to deal with the deep uncertainty associated with climate change: cost-benefit analysis under uncertainty, cost-benefit analysis with real options, robust decision making, and Climate Informed Decision Analysis.

As an alternative to the Precautionary Principle, The Breakthrough Institute has proposed Climate Pragmatism,[27] a pluralistic approach based on innovation, resilience and no regrets. This pragmatic strategy centers on efforts to accelerate energy innovation, build resilience to extreme weather, and pursue no regrets pollution reduction measures. Each of these three efforts has justifications independent of their benefits for climate mitigation and adaptation. Further, this framework does not depend on any agreement about climate science or the risks posed by uncontrolled greenhouse gases.

Resilience and anti-fragility

The threats from climate change (whether natural or human caused) are fundamentally regional, associated not only with regional changes to the weather/climate, but with local vulnerabilities and cultural values and perceptions. In the least developed countries, energy poverty and survivability is of overwhelming concern, where there are severe challenges to meeting basic needs and their idea of clean green energy is something other than burning dung inside their dwelling for cooking and heating. In many less developed countries, particularly in South Asia, an overwhelming concern is vulnerability to extreme weather events such as floods and hurricanes that can set back the local economies for a generation. In the developed world, countries are less vulnerable to climate change and extreme weather events and have the

[25] Bammer, G and M Smithson 2008: *Uncertainty and Risk: Multidisciplinary Perspectives.* Taylor & Francis, 382 pp.
[26] http://elibrary.worldbank.org/content/workingpaper/10.1596/1813-9450-6193
[27] http://thebreakthrough.org/blog/Climate_Pragmatism_web.pdf

luxury of experimenting with new ideas: entrepreneurs want not only to make money but also to strive for greatness and transform the infrastructure for society.

Resilience is the ability to 'bounce back' from unexpected shocks. The difference in impact and recovery from Hurricane Sandy striking New York City in 2012 versus the impact of Tropical Cyclone Nargis striking Myanmar in 2008[28] reflects very different vulnerabilities and capacities for bouncing back. Nassim Taleb's concept of antifragility,[29] whereby you learn and grow from adversity. suggests strategies of economic development, reducing the downside from volatility, developing a range of options, tinkering with small experiments, and developing and testing transformative ideas.

A regional focus on addressing the risks of climate change allows for a range of bottom-up strategies to be integrated with other societal challenges, including overpopulation, environmental degradation, poorly planned land-use and over-exploitation of natural resources. Some of these problems can be carved out as tame problems, where everyone can agree on both the problem and the solution, in the context of traditional risk management approaches. And near-term benefits to the region can be realized in terms of reduced vulnerability to a broad range of threats, improved resource management, and improved environmental quality.

A focus on policies that support resilience and anti-fragility avoids the uncertainties of attributing climate change to humans versus nature and avoids the hubris of thinking we know what the future climate holds. The questions then become 'How much resilience can we afford?' and 'How can we best promote the development of transformative ideas and technologies?'

Conclusion

There is reason to be concerned about climate change. However, effectively responding to the possible threats from a warmer climate is made very difficult by the deep uncertainties surrounding the risks both from the problem and the proposed solutions. Uncertainty is a two edged sword; future climate outcomes might be better or worse than currently believed. However, recent research has sharpened the blade of the sword in the direction of less impact from human-caused climate change and greater political and economic infeasibility of meaningful reductions in CO_2 emissions.

Therefore, I am concerned that the proposed U.S. INDC to address the perceived problems of climate change will do essentially nothing to change the climate, and the U.S. and other nations will remain vulnerable to climate surprises and extreme weather events.

The framing of the climate change problem by the UNFCCC/IPCC and the early articulation of a preferred policy option has marginalized research on broader issues surrounding climate variability and change and stifled the development of a broader range of policy options.

The wickedness of the climate change problem provides much scope for disagreement among reasonable and intelligent people. Arguably the biggest problem with climate policy has been an overly narrow set of narratives and policy options. Expanding the frameworks for thinking about climate policy and its relation to other societal problems can lead to developing a range of more tractable policy options that would provide policy makers with a wider choice of options in addressing the risks from climate change.

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[28] Webster, PJ 2008 Myanmar's Deadly Daffodil. *Nature Geoscience*, http://webster.eas.gatech.edu/Papers/Webster2008c.pdf

[29] Taleb, N 2012 *Antifragile: Things That Gain From Disorder*. Random House.

Short Biography

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Dr. Judith Curry is Professor and former Chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology and President of Climate Forecast Applications Network (CFAN). Dr. Curry received a Ph.D. in atmospheric science from the University of Chicago in 1982. Prior to joining the faculty at Georgia Tech, she held faculty positions at the University of Colorado, Penn State University and Purdue University. Dr. Curry's research interests span a variety of topics in climate; current interests include air/sea interactions, climate feedback processes associated with clouds and sea ice, and the climate dynamics of hurricanes. She is a prominent public spokesperson on issues associated with the integrity of climate science, and is proprietor the weblog Climate Etc. judithcurry.com. Dr. Curry has recently served on the NASA Advisory Council Earth Science Subcommittee, the DOE Biological and Environmental Research Advisory Committee, and the National Academies Climate Research Committee and the Space Studies Board and the NOAA Climate Working Group. Dr. Curry is a Fellow of the American Meteorological Society, the American Association for the Advancement of Science, and the American Geophysical Union.

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Funding sources for Curry's research have included NSF, NASA, NOAA, DOD and DOE. Recent contracts for CFAN include a DOE contract to develop extended range regional wind power forecasts and a DOD contract to predict extreme events associated with climate variability/change having implications for regional stability. CFAN contracts with private sector and other non-governmental organizations include energy and power companies, reinsurance companies, other weather service providers, the Natural Resource Defense Council and the World Bank. Specifically with regards to the energy and power companies, these contracts are for medium-range (days to weeks) forecasts of hurricane activity and landfall impacts. CFAN has one contract with an energy company that also includes medium-range forecasts of energy demand (temperature), hydropower generation, and wind power generation. CFAN has not received any funds from energy companies related to climate change or any topic related to this testimony.

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For more information:

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