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

Hearing on
"Review of the President's Climate Action Plan"

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I am Chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology. I have devoted 30 years to conducting research on topics including climate of the Arctic, the role of clouds and aerosols in the climate system, and the climate dynamics of extreme weather events. As President of Climate Forecast Applications Network (CFAN) LLC, I have worked with decision makers on climate impact assessments, assessing and developing meteorological hazard and climate adaptation strategies, and developing subseasonal climate forecasting strategies to support adaptive management.

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] I see a growing gap between what science is currently providing in terms of information about climate variability and change, and the information needed to understand and manage associated risks.

My testimony focuses on the following issues of central relevance to the President's Climate Change Program:

- Evidence reported by the IPCC AR5 weakens the case for human factors dominating climate change in the 20th and early 21st centuries.
- Climate change in the U.S. and the importance of natural variability on understanding the causes of extreme events
- Sound science to manage climate impacts requires improved understanding of natural climate variability and its impact on extreme weather events

The IPCC AR5 WGI Report – a weaker case for anthropogenic global warming

Last September, the Intergovernmental Panel on Climate Change (IPCC) released the 5th Assessment Report (AR5) from Working Group I (WGI) – The Physical Science Basis. Over the past two decades, the IPCC's reports have expressed increasingly confident consensus views of the importance of anthropogenic influence on the global climate, as reflected by these statements from the Summary for Policy Makers (SPM):

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[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.

- AR4 (2007): "*Most of the observed increase in global average temperatures since the mid-20th century is **very likely** (>90% confidence) due to the observed increase in anthropogenic greenhouse gases.*" (SPM AR4)

- AR5 (2013): "*It **is extremely likely** (>95% confidence) that human influence has been the dominant cause of the observed warming since the mid-20th century.*" (SPM AR5)

The AR5 statement of 'extremely likely' implies that the overall arguments have strengthened. However, several key elements of the AR5 WGI report point to a weakening of the case for attributing most of the warming to human influences, relative to the previous assessment AR4 (2007):

- Lack of warming since 1998 and the growing discrepancies between observations and climate model projections
- Evidence of decreased climate sensitivity to increases in atmospheric CO_2 concentrations
- Evidence that sea level rise during 1920-1950 is of the same magnitude as in 1993-2012
- Increasing Antarctic sea ice extent

The following summarizes the key points, using the figures and text from the IPCC AR5 WG1 Report and comparing them with the AR4.

Recent hiatus in surface warming and discrepancies with climate models

The IPCC AR5 notes the lack of 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 (1951–2012) [of] 0.12 [0.08 to 0.14] °C per decade."* (AR5 SPM)

The significance of this hiatus in warming since 1998 arises from comparison with climate model projections. The IPCC AR4 stated:

> *"For the next two decades, a warming of about 0.2°C per decade is projected for a range of SRES emission scenarios."* (AR4 SPM)

The fifth phase of the Coupled Model Intercomparison Project (CMIP5)[3] has produced a multi-model dataset that includes long-term simulations of twentieth-century climate and projections for the twenty-first century and beyond. CMIP5 provides the climate model simulations used in the AR5. Figure 1 summarizes the near-term projections from CMIP5 of global mean surface temperature anomalies. The observed global temperature record, particularly since 2005, are on the low end of the model envelope that contains 90% of the climate model simulations, and observations in 2011-2012 are below the 5-95% envelope of the CMIP5 simulations. Overall, the trend in the model simulations is substantially larger than the observed trend over the past 15 years.[4]

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[3] Taylor, Karl E., Ronald J. Stouffer, Gerald A. Meehl, 2012: An Overview of CMIP5 and the Experiment Design. *Bull. Amer. Meteor. Soc.*, **93**, 485–498. http://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-11-00094.1

[4] A revised version of Figure 11.25 from the AR5 WG1 Report is given by Ed Hawkins http://www.climate-lab-book.ac.uk/2013/updates-to-comparison-of-cmip5-models-observations/, which also includes the new surface temperature climatology by Cowtan and Way (2013) *Roy. Meteorol. Soc.* http://onlinelibrary.wiley.com/doi/10.1002/qj.2297/abstract. It is seen that this new climatology is slightly warmer, but does not significantly change the climate model discrepancies with observations

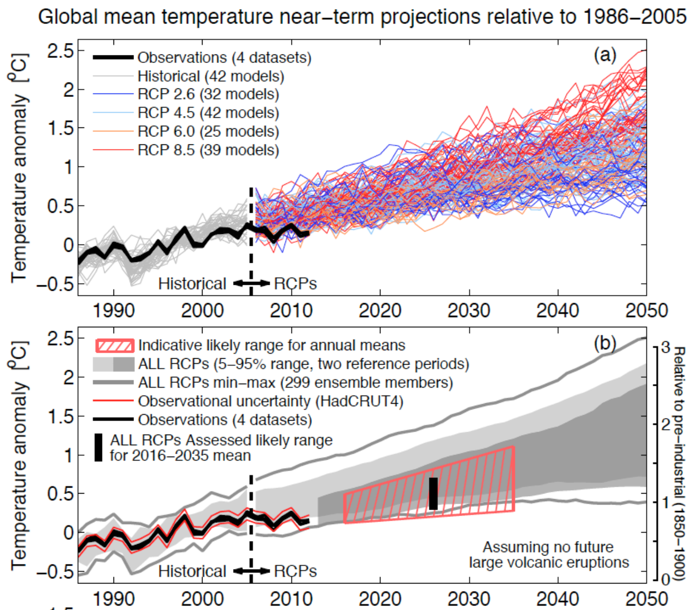

Figure 1. Comparison the global average surface temperatures from the surface temperature data sets with the CMIP5 simulations. The red-hatched region shows the likely range for annual mean global surface teperature during the period 2016–2035 based on expert judgment. From Figure 11.25 (IPCC AR5 WG1).

Regarding projections for the period 2012-2035, the CMIP5 5-95% trend range is 0.11°C–0.41°C per decade. The IPCC then cites 'expert judgment' as the rationale for lowering the projections (indicated by the red hatching):

"However, the implied rates of warming over the period from 1986–2005 to 2016–2035 are lower as a result of the hiatus: 0.10°C–0.23°C per decade, suggesting the AR4 assessment was near the upper end of current expectations for this specific time interval." (AR5 Chapter 11)

This lowering of the projections (and decreasing the trend) relative to the results from the raw CMIP5 model simulations was done based on expert judgment that some models are too sensitive to anthropogenic forcing.

While the near term projections were lowered relative to the CMIP5 simulations, the AR5 states with regards to extended-range warming:

"Increase of global mean surface temperatures for 2081–2100 relative to 1986–2005 is projected to likely be in the ranges derived from the concentration driven CMIP5 model simulations." (AR5 Chapter 12)

In Table SPM.2, which provides a summary of the CMIP5 simulations for the different emission scenarios for the periods 2046-2065 and 2081-2100, a note in the caption states:

"The likely ranges for 2046−2065 do not take into account the possible influence of factors that lead to the assessed range for near-term (2016−2035) global mean surface temperature change that is lower than the 5−95% model range, because the influence of these factors on longer term projections has not been quantified due to insufficient scientific understanding." (AR5 SPM)

This statement acknowledges that there is an uncertainty and possible bias leading to high values that has not been taken into account due to lack of understanding. Although this statement is made explicitly only for the period 2046-2065, the issue is also not accounted for in the later period. This kind of *insufficient scientific understanding* is not a good basis for high confidence in the climate model simulations and projections.

Regarding the current hiatus, the IPCC concludes that:

> *". . . the hiatus is attributable, in roughly equal measure, to a decline in the rate of increase in effective radiative forcing (ERF) and a cooling contribution from internal variability (expert judgment, medium confidence). The decline in the rate of increase in ERF is primarily attributed to natural (solar and volcanic) forcing but there is low confidence in quantifying the role of forcing trend in causing the hiatus, because of uncertainty in the magnitude of the volcanic forcing trend and low confidence in the aerosol forcing trend."* (AR5 Chapter 11)

In summary:

- After expecting a global mean surface temperature increase of 0.2°C per decade in the early decades of the 21st century based on climate model simulations and statements in the AR4, the warming over the past 15 years is only ~0.05°C.
- The IPCC AR5 bases its surface temperature projection of 0.10 to 0.23°C per decade for the period 2016-2036 on expert judgment, which is lowered relative to the climate model results that predict substantially greater warming
- The IPCC does not have a convincing or confident explanation for the current hiatus in warming.

Sensitivity of climate to doubled CO2 concentrations

The equilibrium climate sensitivity (ECS) is defined as the change in global mean surface temperature at equilibrium that is caused by a doubling of the atmospheric CO_2 concentration. The IPCC AR4 conclusion on climate sensitivity is stated as:

> *"The equilibrium climate sensitivity. . . is likely to be in the range 2°C to 4.5°C with a best estimate of about 3°C and is very unlikely to be less than 1.5°C. Values higher than 4.5°C cannot be excluded."* (AR4 SPM)

The IPCC AR5 conclusion on climate sensitivity is stated as:

> *Equilibrium climate sensitivity is likely in the range 1.5°C to 4.5°C (high confidence), extremely unlikely less than 1°C (high confidence), and very unlikely greater than 6°C (medium confidence)* (AR5 SPM)

The bottom of the 'likely' range has been lowered from 2 to 1.5°C in the AR5, whereas the AR4 stated that ECS is very unlikely to be less than 1.5°C. It is also significant that the AR5 does not cite a best estimate, whereas the AR4 cites a best estimate of 3°C. Further the AR5 finds values of ECS exceeding 6°C to be very unlikely, whereas the AR4 did not have sufficient confidence to identify an upper bound at this confidence level. The stated reason for not citing a best estimate in the AR5 is the substantial discrepancy between observation-based estimates of ECS (lower), versus estimates from climate models (higher). Figure 1 of Box 12.2 in the AR5 WG1 report shows that 11 out of 19 observational-based studies of ECS have values below 1.5°C in the range of their ECS probability distribution.

Hence the AR5 reflects greater uncertainty and a tendency towards lower values of the ECS than the AR4. The discrepancy between observational and climate model-based estimates of climate sensitivity is substantial and of significant importance to policymakers -- sensitivity, and the level of uncertainty in its value, is a key input into the economic models that drive cost-benefit analyses and estimates of the social cost of carbon.

Sea level rise

In the AR5 SPM, the following statements are made regarding sea level rise:

> *"It is very likely that the mean rate of global averaged sea level rise was 1.7 [1.5 to 1.9] mm yr^{-1} between 1901 and 2010, 2.0 [1.7 to 2.3] mm yr^{-1} between 1971 and 2010 and 3.2 [2.8 to 3.6] mm yr^{-1} between 1993 and 2010.* ***It is likely that similarly high rates occurred between 1920 and 1950."*** (AR5 SPM)

> *"It is* ***very likely*** *that there is a substantial contribution from anthropogenic forcings to the global mean sea level rise since the 1970s."* (AR5 SPM)

The rate of global mean sea level as portrayed in AR5 is shown in Figure 2 below.

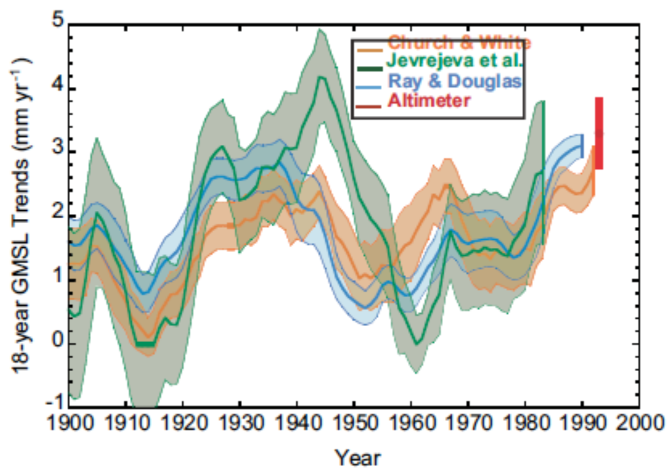

Figure 2. 18-year trends of global mean sea level rise estimated at 1-year intervals. The time is the start date of the 18-year period, and the shading represents the 90% confidence. The estimate from satellite altimetry is also given, with the 90% confidence given as an error bar. [AR5 WGI Figure 3.14]

In AR5 SPM there are significant changes relative to the AR4 WG1 SPM concerning the estimated contributions to sea level rise from different sources:

Table 1: Contributions to sea level rise from different sources (mm per year)

	AR4 (1993-2003)	AR5 (1993-2010)
Thermal expansion	1.6	1.1
Glaciers and ice caps	0.77	0.76
Greenland ice sheet	0.21	0.33
Antarctic ice sheet	0.21	0.27
Land water storage	---	0.38
Sum	0.28	0.28
Observed sea level rise	3.1	3.2

Thermal expansion is one third smaller in AR5 and land water storage with a substantial amount is completely new in AR5, while the sum of these sources remained constant. With regards to land water storage, a recent paper[5] estimated that the human impacts, particularly unsustainable ground water use, have contributed a sea-level rise of about 0.77 mm yr^{-1} between 1961 and 2003, which is twice as large as the estimate used in the AR5.

Global sea level has been rising for the past several thousand years. The key issue is whether the rate of sea level rise is accelerating owing to anthropogenic global warming. It is seen that the rate of rise during 1930-1950 was comparable to, if not larger than, the value in recent years. Hence the data does not seem to support the IPCC's conclusion of a substantial contribution from anthropogenic forcings to the global mean sea level rise since the 1970s. Further, the growing realization of the importance of land water storage to sea level rise is diminishing the percentage of sea level rise that is associated with warming. Better understanding of natural versus anthropogenic components of sea level rise and the impacts of land use (especially groundwater depletion) on sea level rise is needed to effectively evaluate policy responses to sea level rise.

Sea ice

The IPCC AR5 reports the following trends in sea ice:

> *"Continuing the trends reported in AR4, the annual Arctic sea ice extent* ***decreased*** *over the period 1979–2012: the rate of this decrease was very likely between 3.5 and 4.1% per decade* (AR5 SPM)
>
> *"It is very likely that the annual Antarctic sea ice extent* ***increased*** *at a rate of between 1.2 and 1.8% per decade between 1979 and 2012.* (AR5 SPM)

AR5 Chapter 10 states:

> *"Anthropogenic forcings are very likely to have contributed to Arctic sea ice loss since 1979. There is low confidence in the scientific understanding of the observed increase in Antarctic sea ice extent since 1979, due to the incomplete and competing scientific explanations for the causes of change and low confidence in estimates of internal variability."* (AR5 Chapter 10)
>
> *"Arctic temperature anomalies in the 1930s were apparently as large as those in the 1990s and 2000s. There is still considerable discussion of the ultimate causes of the warm temperature anomalies that occurred in the Arctic in the 1920s and 1930s."* (AR5 Chapter 10)

The increase in Antarctic sea ice is not understood and is not simulated correctly by climate models. Further, Arctic surface temperature anomalies in the 1930's were as large as the recent temperature anomalies. Notwithstanding the simulations by climate models that reproduce the decline in Arctic sea ice, more convincing arguments regarding causes of sea ice variations requires understanding and ability to simulate sea ice variations in *both* hemispheres.

A key issue in understanding the recent decline in Arctic sea ice extent is to understand to what extent the decline is caused by anthropogenic warming versus natural climate variability.

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[5] Pokhrel et al. 2013: Model estimates of sea-level change due to anthropogenic impacts on terrestrial water storage. *Nature Geoscience.* http://www.nature.com/ngeo/journal/v5/n6/full/ngeo1476.html

Analysis[6] of the CMIP3 and CMIP5 simulations found that about 41% of the recent sea ice decline could be attributed to anthropogenic warming from the CMIP3 models, and about 60% from the CMIP5 models. A recent paper seeks to interpret the multi-decadal natural variability component of the Arctic sea ice in context of a 'stadium wave'.[7] This paper suggests that a transition to recovery of the natural variability component of the sea ice extent has begun in the Eurasian Arctic sector, and that the recovery will reach its maximum extent circa 2040.

Summary

Multiple lines of evidence presented in the IPCC AR5 WG1 report suggest that the case for anthropogenic warming is weaker than the previous assessment AR4 in 2007. Anthropogenic global warming is a proposed theory whose basic mechanism is well understood, but whose magnitude is highly uncertain. The growing evidence that climate models are too sensitive to CO_2 has implications for the attribution of late 20th century warming and projections of 21st century climate.

If the recent warming hiatus is caused by natural variability, then this raises the question as to what extent the warming between 1975 and 2000 can also be explained by natural climate variability.

The stadium wave hypothesis[8] predicts that the warming hiatus could extend to the 2030's. Based upon climate model projections, the probability of the hiatus extending beyond 20 years is vanishing small. If the hiatus does extend beyond 20 years, then a very substantial reconsideration will be needed of the 20th century attribution and the 21st century projections of climate change.

Climate change in the U.S.

The prospect of increased frequency and severity of extreme weather in a warmer climate is proposed as potentially the most serious near term impact of climate change. Metaphors such as climate change 'loading the dice' for severe weather or causing 'weather on steroids' are frequently used to communicate an elevated probability of extreme weather events as a result of human-caused climate change. Because of their large socioeconomic impacts, weather catastrophes act as focusing events for the public in the politics surrounding the climate change debate. The perception that humans are causing an increase in extreme weather events is a primary motivation for the President's Climate Change Plan:

> *". . . climate change is no longer a distant threat – we are already feeling its impacts across the country and the world. Last year was the warmest year ever in the contiguous United States and about one-third of all Americans experienced 10 days or more of 100-degree heat. The 12 hottest years on record have all come in the last 15 years. . . And increasing floods, heat waves, and droughts have put farmers out of business, which is already raising food prices dramatically."*

In 2012, the IPCC published a *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (SREX)[8]. The following draws from the SREX, the IPCC AR5 WG1 report, and climatic data for the U.S. provided by NOAA and the Berkeley Earth Surface Temperature project.

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[6] Stroeve, J. et al. 2012: Trends in Arctic sea ice extent from CMIP3, CMIP5 and observations. Geophys. Res. Lett., 39, L16502

[7] 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

[8] https://ipcc-wg2.gov/SREX/

U.S. surface temperatures

Figure 3 shows the latest analysis of annual surface temperature anomalies for the continental U.S. since 1850, from Berkeley Earth Surface Temperature Project. The year 2012 was the warmest year on record for the U.S., followed by 2006, 1998, and 1934. Globally, 2012 ranked as the 8th or 9th warmest year, with Argentina also recording its warmest year. It is seen that the annual average temperature for 2013 was relatively cool, and ranked only as the 42nd warmest year for the continental U.S.

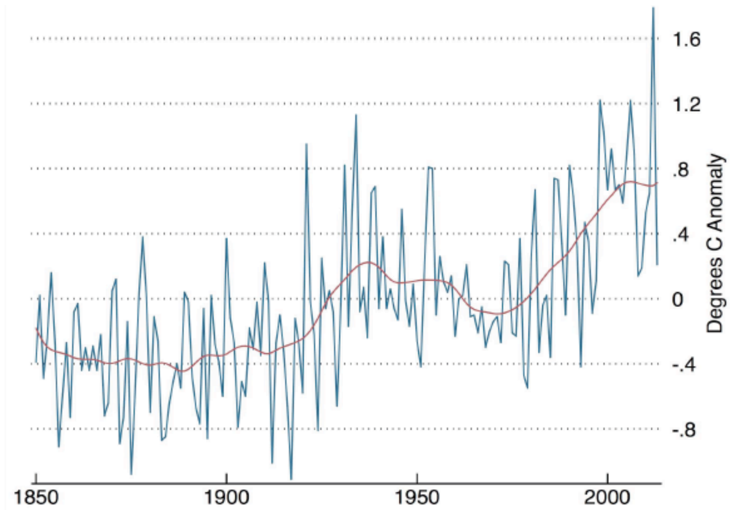

Figure 3. Annual average surface temperature anomalies for the continental U.S. since 1850. Data and plot from the Berkeley Earth Surface Temperature Project.

Summer heat extremes

Figure 4 shows the number of daily record high summertime daily maximum temperatures (T_{max}) and minimum temperatures (T_{min}) for the continental U.S. since 1895. The number of daily record T_{max} shows no trend, with a strong maximum during the 1930's. The number of daily record T_{min} also shows a maximum in the 1930's, but also shows an overall increasing trend since the 1970's.

The EPA also cites evidence that summertime heat waves were frequent and widespread in the 1930s, and these remain the most severe heat waves in the U.S. historical record.[9] Overall, any evidence of an anthropogenic effect (greenhouse gases, aerosols, land use) on summertime record high temperatures is more likely to be seen in T_{min} than in T_{max}.

[9] http://www.epa.gov/climatechange/images/indicator_figures/high-low-temp-figure1-2013.gif

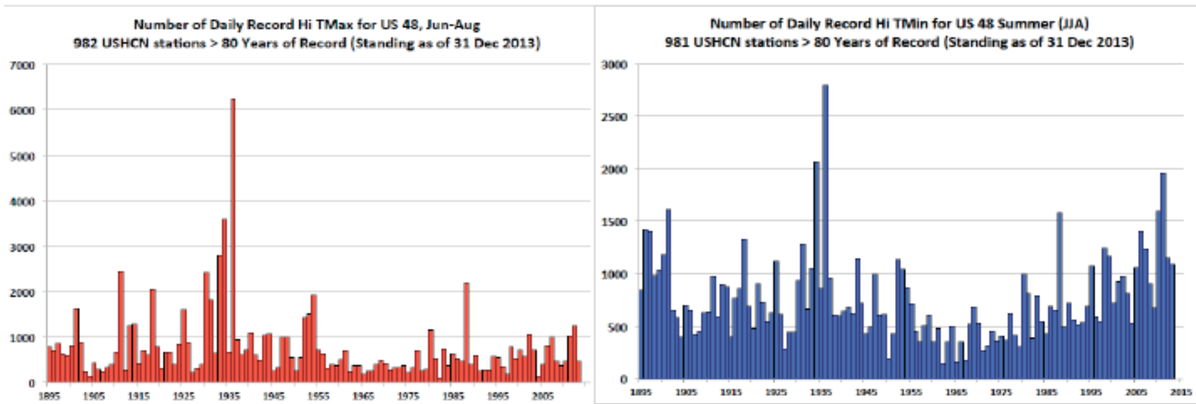

Figure 4. Number of daily record high T_{max} (red; left) and T_{min} (blue; right) for the summer season (Jun-Aug) for the continental U.S. Data obtained from 981 USHCN stations with surface temperature records exceeding 80 years and standing as of 12/31/13. Figure courtesy of John Christy, University of Alabama Huntsville.

Winter cold extremes

Figure 5 shows the number of daily record wintertime maximum (T_{max}) and minimum (T_{min}) temperatures for the continental U.S. since 1895. A declining trend in wintertime T_{min} records is seen, with very few records for the period 1997-2013. The wintertime T_{max} records do not show any particular trend, with a cluster of records during the 1930's and the 1980's standing out years with the largest number of wintertime T_{max} records.

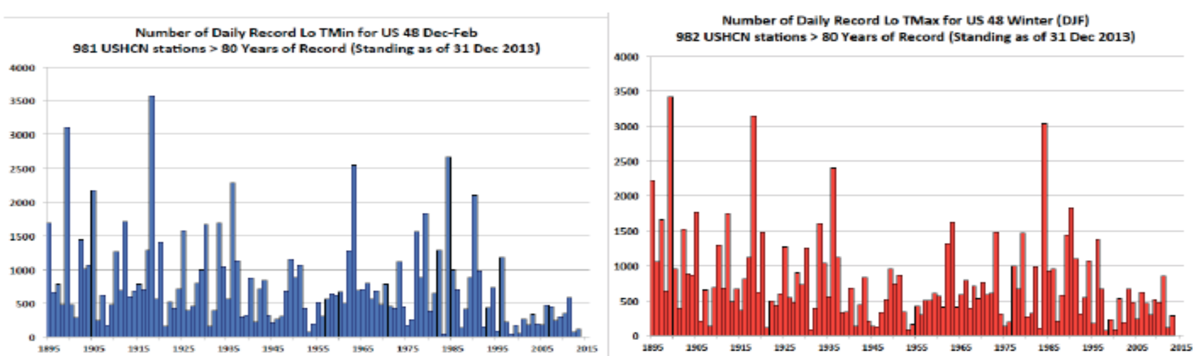

Figure 5. Number of daily record low T_{min} (top) and T_{max} (bottom) for the winter season (Dec-Feb) for the continental U.S. Data obtained from 981 USHCN stations with surface temperature records exceeding 80 years, and standing as of 12/31/13. Figure courtesy of John Christy, University of Alabama Huntsville.

Last week, the central and eastern U.S. was in the midst of a major cold wave, with large regions dropping below 0^oF and wind chills reaching below -30^oF. On one hand, some have stated that such cold is clear evidence that global warming is nonsense. On the other, some have argued that the cold wave is another example of extreme weather forced by increased greenhouse gases. Neither statement is supported by the evidence. There is nothing in Figure 5 to suggest that extreme cold air outbreaks (as reflected in record temperatures) are becoming more frequent in the U.S. With regards to the polar vortex, such circulation patterns are not uncommon. Analogues for a similar pattern and associated major wintertime cold air outbreak occurred in 1977, 1978, 1985, 1993 and 1994.[10]

[10] personal communication, Joe Bastardi of WeatherBell

Precipitation

Extremes in precipitation (drought and heavy rainfall events) are shown in Figure 6. These data reflect NOAA's Climate Extreme Index, which is calculated as the percentage of the U.S. being falling in the upper or lower tenth percentile of the local period of record. Drought is represented by the Palmer Drought Severity Index (PDSI) and heavy rainfall events are characterized from extremes in 1-day precipitation.

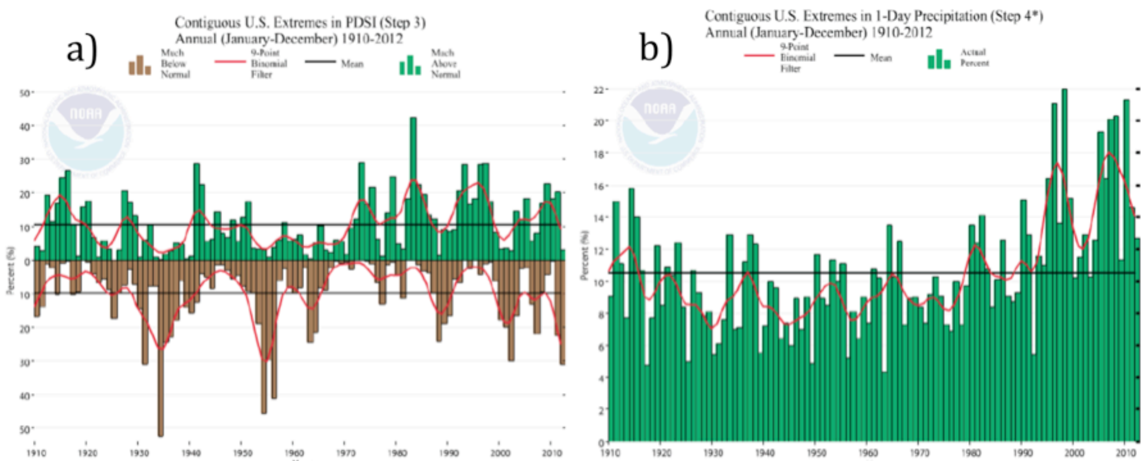

Figure 6. Annual frequency (%) of extremes in a) the Palmer Drought Severity Index; and b) extremes in 1-day precipitation. Figures obtained from the NOAA NCDC Climate Extremes Index
a) http://www.ncdc.noaa.gov/extremes/cei/graph/3/01-12 b) http://www.ncdc.noaa.gov/extremes/cei/graph/4/01-12

Figure 6a shows that the most extreme droughts were observed in the 1930's and 1950's. The largest positive extremes (wet) are seen since the 1980's. Figure 6b shows the historical distribution of extremes in 1-day rainfall rates. The highest values are clustered in the period since the 1990. It is unclear whether an increase in flooding can be attributed to the increase in extreme rainfall rates owing to the confounding factors of land use change and urbanization. Combined, Figures 6a and 6b present a picture of increasing precipitation and decreasing frequency of extreme drought.

Sea level rise

As cited above, the IPCC AR5 finds a mean global sea level rise of 3.2 [2.8 to 3.6] mm yr^{-1} between 1993 and 2010, and states that there is very likely a substantial contribution from anthropogenic forcings since the 1970s. In many locations, local factors dominate the sea level variations: rising or subsidence from geologic processes, coastal engineering projects, and human impacts on terrestrial water storage including reservoir operation, ground water use and irrigation.

Figure 7 shows local trends in sea level for the U.S. coast. The predominant arrow color is green (0-3 mm/yr), which is nominally below mean global sea level rise. In Florida, sea level is rising at a rate of only 0.75 to 2.4 mm/yr. By contrast, Louisiana sea level rise exceeds 9 mm/yr. The Mid Atlantic coast has sea level rises ranging from 2.5 to 6 mm/yr. Along the coast of the Gulf of Alaska, sea level is *decreasing* at rates exceeding -10 mm/yr.

Many locations have a rate of sea level rise that differs significantly from the global average value. This occurs owing to the dominance of local factors (geologic and/or land use) on sea level rise. Projected rates of sea level rise for the period 2081-2100 depend on emission scenarios, and range from 3 to 15 mm/yr, with most scenarios projecting a substantial acceleration over the current rate. Sea level rise projections using climate models may be too high owing to biases in sensitivity to greenhouse gases, and projections based on semi-empirical models may be too high owing to insufficient consideration given to land water storage. Assessing vulnerability of individual locations to anthropogenically-induced sea level rise also needs to account for local factors (e.g. geologic and land use) driving sea level rise as well as natural variability in sea level rise.

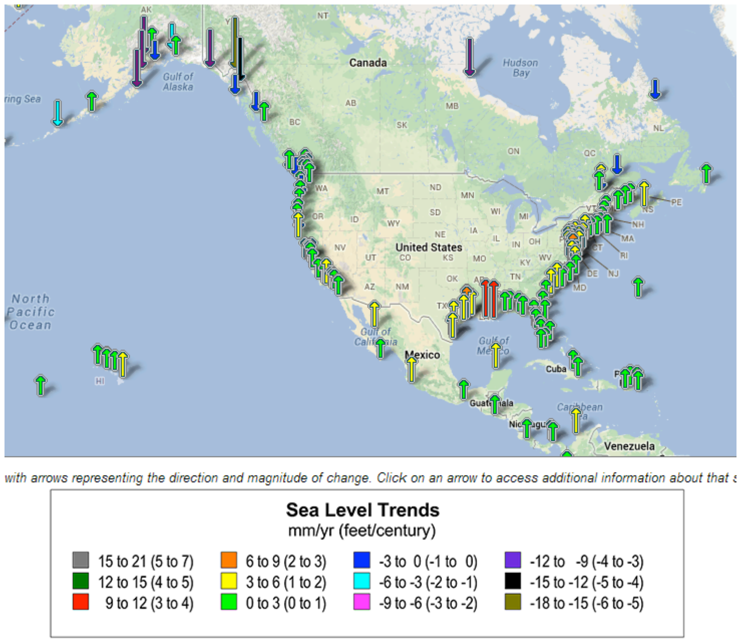

Figure 7. Local trends in sea level determined from tide stations, with arrows representing the direction and magnitude of the change. http://tidesandcurrents.noaa.gov/sltrends/

Summary

With regards to the impacts of climate change on the continental U.S., the following trends are seen over the past century are seen:

- declining frequency of wintertime cold extremes
- declining frequency of drought
- increasing frequency of heavy rain events
- increasing sea level rise that is dominated by local factors in many locations

There is a large component of natural variability seen in the 100+ year data record particularly for drought and heat waves, each of which had maximum extremes during the 1930's. Sea level rise also shows a maxima during the 1930's to 1940's.

There is a widespread perception that extreme weather events are worsening, as reflected by this statement from President Obama's State of the Union address:

> *"Heat waves, droughts, wildfires, and floods – all are now more frequent and intense. We can choose to believe that Superstorm Sandy, and the most severe drought in decades, and the worst wildfires some states have ever seen were all just a freak coincidence. Or we can choose to believe in the overwhelming judgment of science – and act before it's too late."*[11]

In the U.S., most types of weather extremes were worse in the 1930's and even in the 1950's than in the current climate, while the weather was overall more benign in the 1970's. This sense that extreme weather events are now more frequent and intense is symptomatic of 'weather amnesia' prior to 1970. The extremes of the 1930's and 1950's are not attributable to greenhouse warming and are associated with natural climate variability (and in the case of the dustbowl drought and heat waves, also to land use practices).

There is no *a priori* scientific reason to prefer the climate of the 1930's, the 1970's, the current climate, or a climate that is 1-2^{o}C warmer than present. Which climate is preferable from a socioeconomic perspective:

- the current warmer climate with fewer extreme cold air outbreaks versus the climate of the 1970's with fewer heat waves?
- the current climate with fewer severe droughts and more frequent heavier rainfall, versus prior periods with overall less rainfall?
- the present climate, or a future climate that is 1-2^{o}C warmer with overall more rainfall and less frequent drought, fewer extreme cold events but more frequent heat waves?

The preference undoubtedly varies regionally. The key issues are the adaptive capacity of societies, and the unresolved moral dilemma of how to balance obligations towards future generations against obligations to the current generation, which underlies economic debates around the discount rate.

Sound science in support of good judgment

The premise of President Obama's Climate Action Plan is that there is an overwhelming judgment of science that anthropogenic global warming is already producing devastating impacts, which is summarized by this statement from the President's Second Inaugural Address:

> *Some may still deny the overwhelming judgment of science, but none can avoid the devastating impact of raging fires and crippling drought and more powerful storms.*

This premise is not strongly supported by the scientific evidence:

- the science of climate change is not settled, and evidence reported by the IPCC AR5 weakens the case for human factors dominating climate change in the 20th and early 21st centuries
- with the 15+ year hiatus in global warming, there is growing appreciation for the importance of natural climate variability
- the IPCC AR5 and SREX find little evidence that supports an increase in most extreme weather events that can be attributed to humans, and weather extremes in the U.S. were generally worse in the 1930's and 1950's than in recent decades.

Not only is more research needed to clarify the sensitivity of climate to carbon dioxide and understand the limitations of climate models, but more research is needed on solar variability, sun-climate connections, natural internal climate variability and the climate dynamics of extreme weather events. Improved understanding of these aspects of climate variability and change is needed to help

[11] http://www.whitehouse.gov/state-of-the-union-2013

government officials, communities, and businesses better understand and manage the risks associated with climate change.

Nevertheless, the premise of dangerous anthropogenic climate change is the foundation for a far-reaching plan to reduce greenhouse gas emissions and reduce vulnerability to extreme weather events. Elements of this Plan may be argued as important for associated energy policy reasons, economics, and/or public health and safety. However, claiming an overwhelming scientific justification for the Plan based upon anthropogenic global warming does a disservice both to climate science and to the policy process.

Motivated by the precautionary principle to avoid dangerous anthropogenic climate change, attempts to modify the climate through reducing CO_2 emissions may turn out to be futile. The stagnation in greenhouse warming observed over the past 15+ years demonstrates that CO_2 is not a control knob on climate variability on decadal time scales. Even if CO_2 mitigation strategies are successful and climate model projections are correct, an impact on the climate would not be expected for a number of decades owing to the long lifetime of CO_2 in the atmosphere and thermal inertia driven by the ocean (AR5 WG1 FAQ 12.3); solar variability, volcanic eruptions and natural internal climate variability will continue to be sources of unpredictable climate surprises.

Specifically with regards to most extreme weather events, their frequency and intensity is heavily influenced by natural internal variability. Whether or not anthropogenic climate change is exacerbating extreme weather events, vulnerability to extreme weather events will continue owing to increasing population and wealth in vulnerable regions. Climate change (regardless of whether the primary cause is natural or anthropogenic) may be less important in driving vulnerability in most regions than increasing population, land use practices, and ecosystem degradation. Regions that find solutions to current problems of climate variability and extreme weather events and address challenges associated with an increasing population are likely to be well prepared to cope with any additional stresses from climate change.

Short Biography

Judith Curry
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Dr. Judith Curry is Professor and 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 has published over 190 journal articles and is author of the books *Thermodynamics of Atmospheres and Oceans* and *Thermodynamics*, *Kinetics and Microphysics of Clouds.* She is also Editor of the *Encyclopedia of Atmospheric Sciences*. She is a prominent public spokesperson on issues associated with the integrity of climate research, and is proprietor of the weblog Climate Etc. judithcurry.com. Dr. Curry currently serves on the DOE Biological and Environmental Research Advisory Committee, and has recently served on the NASA Advisory Council Earth Science Subcommittee, 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.

Financial declaration

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, NGOs and development banks. 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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