Contribution to Hearing on EPA's proposed GHG Standards for New Power Plants
14 Nov 2013

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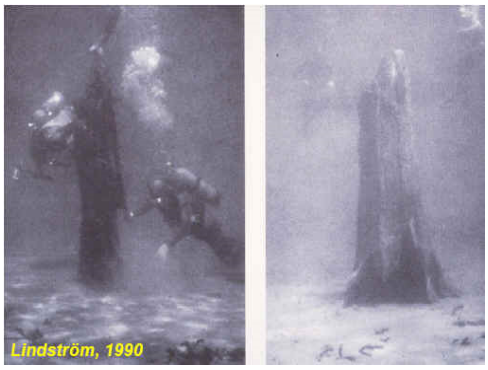
I am John R. Christy, Distinguished Professor of Atmospheric Science, Alabama's State Climatologist and Director of the Earth System Science Center at The University of Alabama in Huntsville. I have served as a Lead Author, Contributing Author and Reviewer of IPCC assessments, have been awarded NASA's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

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

Extremes

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

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



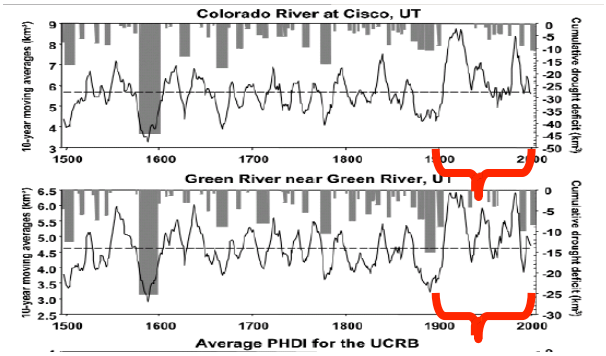
California

At right are photos from Lindstrom (1990) of divers examining trees which grew on dry ground around 900 years ago in what is now a Sierra Nevada alpine lake. This indicates that a drastic

but natural change to a much drier climate must have lasted for at least a century for trees to have grown to these sizes on dry ground.

Rocky Mountains

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



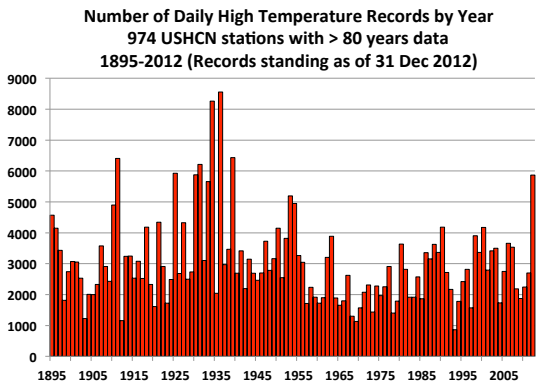
Great Plains

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

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

U.S. Daily High Temperature Records

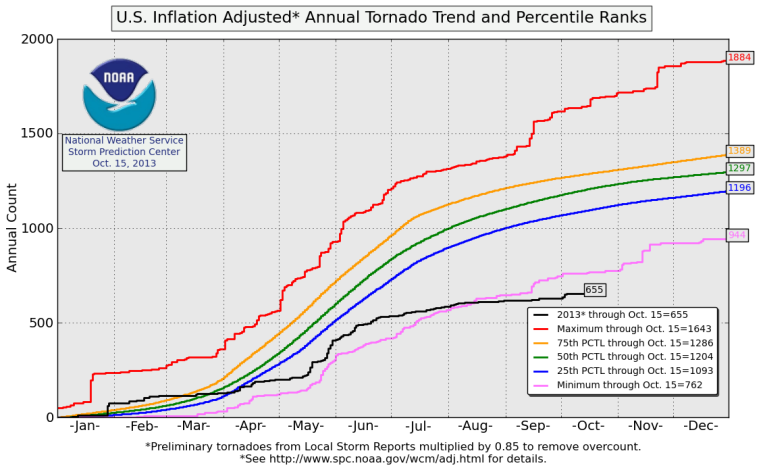
Are daily high temperature extremes becoming more frequent? To answer such a question, one must obviously consider datasets that span an appropriate length of time. If one does the analysis with stations of at least 80 years of data, and determines the number of daily temperature records by year that stand as of 31 Dec 2012, the



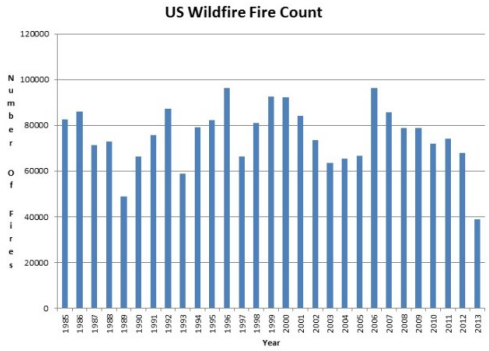
answer to the question is "no." It is true that the number of records in 2012 was quite high, thanks to a very warm March and a hot Mid-Western summer. However in comparison to the heat waves of the 1930s, the summer was not the "worst" for heat. 2012 finished in 8th place on the list, just below 6th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

Recent Tornadoes

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



Recent Wildfires



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

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

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

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

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

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

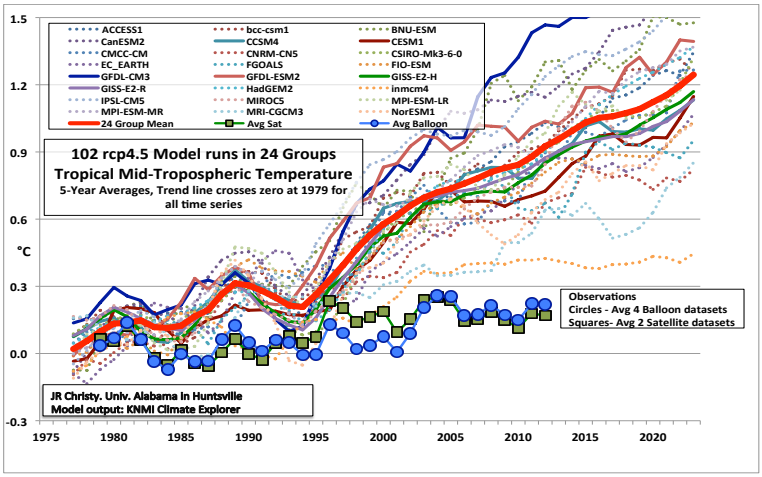
There are innumerable types of events that can be defined as extreme events – so for the enterprising individual (unencumbered by the scientific method), weather statistics can

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

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

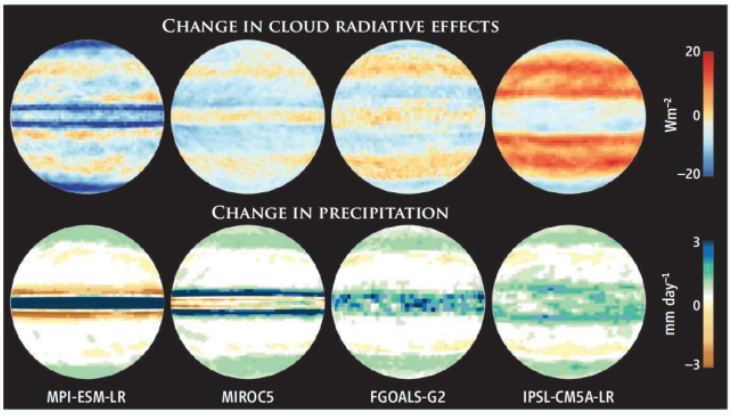
Utility of Climate Models

In the figure below I provide the 35-year record (1979-2013) of atmospheric temperature in the tropics – the key region in which climate models respond to greenhouse gas warming with a large and distinct signal. The focus on the tropics is important because of the consistent and significant warming that climate models indicate should have already occurred as a result of the increasing concentration of greenhouse gases we have put into the atmosphere. It also represents a part of the global atmosphere in which the critical water vapor and cloud feedbacks have major influences. The tropical atmosphere is also a huge and easy target for modeling projects to hit if the physics are well represented. Since this warming should have taken place already, this provides for us a way to test the model simulations. There are 102 model runs represented in the figure, but I have organized them by the 24 types of models. The thick red line is the average of the 24 groups. Thin, solid lines are the six model groupings created by U.S. institutions and the dotted lines by those from outside the U.S. The observations are provided by six independent sources, with "balloons" being the average of the four balloon-borne datasets and "satellites" the average of the two groups which utilize satellite instrumentation.



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

An extremely important paper was published in *Nature Climate Change* this past spring as one of the first studies to actually perform a test of model capabilities in a controlled experiment to understand the impacts on the critical processes that affect the way the temperature will change (Stephens and Bony, 2013). They simply ran four major climate models over an ocean-covered earth (i.e. a very simple earth) with the current ocean temperatures, then again with elevated ocean temperatures. The experiment would then reveal the impact of the extra warmth on the way the climate system operates, especially, clouds and rain because they have significant impacts on the warming processes. So, getting clouds and rain correct is necessary for long-term integrations. To their surprise, the four major models gave quite different results, both in terms of the magnitude *and of the sign* of the change in clouds and rain as shown in the figure. This is exactly the type of fundamental, rigorous evaluation that must be encouraged for other parts of the modeling enterprise. One can only conclude that at least three of the four models fail (if on the odd chance one is correct) to depict some of the fundamental processes of the Earth system. This result supports the comments in the paragraphs above which demonstrate the climate modeling enterprise must go "back to the basics" as stated in Stephens and Bony.



Basing scientific conclusions about climate change (or basing policy decisions about energy) on climate model output is risky given the "disconnect" between model simulations and the observed world.

The IPCC Summary for Policy Makers

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

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

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

First, the IPCC gives climate models the authority to distinguish "natural" from "human" caused climate change because instruments can't. However, as demonstrated, these same models on average fail by a significant amount to reproduce the climate of the past 35 years (the years most directly impacted by rising greenhouse gas emissions.) But in conclusion, the IPCC now has ever more confidence that the models can distinguish "natural" from "human" change (change which the models cannot produce) in correct proportions. It doesn't make sense to me.

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

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

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

Seventeen Years Ago – House Committee on Science

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

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

One of my concluding statements was, and I quote,

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

Now here we are, over 17 years later. It appears the nation has indeed enacted "knee-jerk" remedies to "combat climate change" through regulations on carbon dioxide. I warned the congress in 1996 that these would be "unproductive and economically damaging." I have since provided testimony that demonstrates that these regulations will be "unproductive" regarding their impact on climate. I will leave it to economists to determine whether the regulations are also "economically damaging", especially for the poorest among us.

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

It is enlightening to examine the 35-year comparison of models and observations of atmospheric temperature in the tropics – the key region in which climate models respond to greenhouse gas warming with a large and distinct signal. This is an exceptionally large target for climate models to aim at, and it incorporates the critical water vapor and cloud feedbacks about which we know so little. The current record is now twice as long as was available when I testified in 1996 and the models are more complicated, expensive and numerous, representing an industry unto itself. The comparison shows that the very latest climate models' tropical response to CO2, on average, is still 2 to 4 times greater than reality, just as it was in 1996.

I believe we missed a tremendous opportunity 17 years ago to develop a better understanding of the climate system at the expense of creating a climate modeling industry. To compound the problem, I believe we failed to fund substantial projects to examine the output of climate models in an independent, objective and methodological way, i.e. there were no "red teams" funded to rigorously study the output of models on which the most expensive of regulations now rely.

The observing system which tells us what the climate is doing has suffered some losses in coverage and quality, especially at the surface. Most importantly, the diversion of basic science resources to study the effect of rising greenhouse emissions by modelling at the expense of understanding the ubiquitous variations of the natural system has left us still wondering what portion of the change is natural and what portion is human-caused.

References:

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

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McKitrick, R.R., S. McIntyre and C. Herman, (2010): Panel and multivariate methods for tests of trend equivalence in climate data sets. Atmos. Sci. Lett., 11(4), 270-277. doi: 10.1002/asl.290.

McKitrick, Ross, Stephen McIntyre and Chad Herman (2011) Correction to "Panel and Multivariate Methods for Tests of Trend Equivalence in Climate Data Series" *Atmospheric Science Letters* October 7 2011, DOI: 10.1002/asl.360.

radar screen of the world, there are many NGOs and other groups, even groups of scientists and institutions, that provide climate-change information in various forms and quality, often lacking comprehensiveness and proper recognition of uncertainties. There is a strong pressure to provide 'just-in-time' scientific updates for policy-makers and stakeholders, as was the case in the preparations for the 2009 climate-change conference in Copenhagen. The IPCC must not yield to this pressure.

In this field of different and divergent forces, confusion may arise. An honest broker therefore is an asset. From my perspective, the IPCC has fulfilled this role with remarkable rigour and integrity. This role is now at risk, as the stakes are higher than ever before. The requirement that assessments are policy relevant but never policy prescriptive, as formulated in the *Principles Governing IPCC Work*, is of paramount importance. Our task is to inform the policy-makers and the public strictly in a 'what if' mode. Any other approach must be left to NGOs, negotiators or individuals. Only with strict adherence to procedures and to scientific rigour at all stages will the IPCC continue to provide the best and most robust information that is needed so much.

Produce more reports faster

Jeff Price
Lead author (AR3, AR4), director, climate-change adaptation, WWF United States

The IPCC is accepting nominations (until 12 March 2010) from governments and participating organizations for authors for its Fifth Assessment Report. One recommendation for the IPCC that could be implemented immediately is in how its coordinating lead authors and review editors are selected.

Currently, authors are selected to represent "a range of views, expertise, gender and geographical representation". However, given the importance placed on these assessments, the most senior positions should be filled by the nominees most expert in their field, regardless of balance. These authors should be the most knowledgeable nominee about the range of topics in their chapter, best able to cooperatively work with a team of international scholars. Preferably, they should have previously been involved in an IPCC assessment and be familiar with IPCC standards and methodologies. Geographic and gender balance should then be used in selection of lead authors. The level of work required in preparing an assessment is large. Increasing the number of lead authors would provide better balance and give more scientists the ability to participate in the process.

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

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

Open debate: Wikipedia-style

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

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

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

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

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

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

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

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

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

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

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

IPCC diagnosis – permanent paradigm paralysis

Posted on September 28, 2013 | 577 Comments

by Judith Curry

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

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

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

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

developing climate models, with the expectations that these models will provide actionable information for policy makers.

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

Symptoms of the disease

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

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

And finally:

- after several decades and expenditures in the bazillions, the IPCC still has not provided a convincing argument for how much warming in the 20th century has been caused by humans.
- the politically charged rhetoric has contaminated academic climate research and the institutions that support climate research, so that individuals and institutions have become advocates; scientists with a perspective that is not consistent with the consensus are at best marginalized (difficult to obtain funding and get papers published by 'gatekeeping' journal editors) or at worst ostracized by labels of 'denier' or 'heretic.'

- decision makers needing regionally specific climate change information are being provided by the climate community with either nothing or potentially misleading predictions from climate models.

Diagnosis of the cause of the disease

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

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

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

Paradigm paralysis is the inability or refusal to see beyond the current models of thinking. The vast amount of scientific and political capital invested in the IPCC has become self-reinforcing, so it is not clear how move past this paralysis as long as the IPCC remains in existence. The wickedness of the climate change problem makes if difficult to identify points of irrefutable failure in either the science or the policies,

although the IPCC's insistence that the pause is irrelevant and temporary could provide just such a refutation if the pause continues. In any event, there is a growing realization of that neither the science or policy efforts are making much progress, and particularly in view of the failure climate models to predict the stagnation in warming, and that perhaps it is time to step back and see if we can do a better job of understanding and predicting climate variability and change and reducing societal and ecosystem vulnerabilities.

Broader implications of the disease

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

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

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

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

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

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

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

Conclusion

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