Drought and Global Climate Change: An Analysis of Statements by Roger Pielke Jr
John P. Holdren, 28 February 2014

Introduction

In the question and answer period following my February 25 testimony on the Administration's Climate Action Plan before the Oversight Subcommittee of the U.S. Senate's Committee on Environment and Public Works, Senator Jeff Sessions (R-AL) suggested that I had misled the American people with comments I made to reporters on February 13, linking recent severe droughts in the American West to global climate change. To support this proposition, Senator Sessions quoted from testimony before the Environment and Public Works Committee the previous July by Dr. Roger Pielke, Jr., a University of Colorado political scientist. Specifically, the Senator read the following passages from Dr. Pielke's written testimony:

> *It is misleading, and just plain incorrect, to claim that disasters associated with hurricanes, tornadoes, floods or droughts have increased on climate timescales either in the United States or globally.*
>
> *Drought has "for the most part, become shorter, less, frequent, and cover a smaller portion of the U.S. over the last century". Globally, "there has been little change in drought over the past 60 years."*

Footnotes in the testimony attribute the two statements in quotation marks within the second passage to the US Climate Change Science Program's 2008 report on extremes in North America and a 2012 paper by Sheffield *et al*. in the journal Nature, respectively.

I replied that the indicated comments by Dr. Pielke, and similar ones attributed by Senator Sessions to Dr. Roy Spencer of the University of Alabama, were not representative of main-stream views on this topic in the climate-science community; and I promised to provide for the record a more complete response with relevant scientific references.

Dr. Pielke also commented directly, in a number of tweets on February 14 and thereafter, on my February 13 statements to reporters about the California drought, and he elaborated on the tweets for a blog post on The Daily Caller site (also on February 14). In what follows, I will address the relevant statements in those venues, as well. He argued there, specifically, that my statements on drought "directly contradicted scientific reports", and in support of that assertion, he offered the same statements from his July testimony that were quoted by Senator Sessions (see above). He also added this:

> *The United Nations Intergovernmental Panel on Climate Change found that there is "not enough evidence at present to suggest more than low confidence in a global-scale observed trend in drought."*

In the rest of this response, I will show, first, that the indicated quote from the US Climate Change Science Program (CCSP) about U.S. droughts is missing a crucial adjacent sentence in the CCSP report, which supports my position about drought in the American West. I will also show that Dr. Pielke's statements about global drought trends, while irrelevant to my comments about drought in California and the Colorado River Basin, are seriously misleading, as well, concerning what is actually in the UN Panel's latest report and what is in the current scientific literature.

Drought trends in the American West

My comments to reporters on February 13, to which Dr. Pielke referred in his February 14 tweet and to which Senator Sessions referred in the February 25 hearing, were provided just ahead of President Obama's visit to the drought-stricken California Central Valley and were explicitly about the drought situation in California and elsewhere in the West.

That being so, any reference to the CCSP 2008 report in this context should include not just the sentence highlighted in Dr. Pielke's testimony but also the sentence that follows immediately in the relevant passage from that document and which relates specifically to the American West. Here are the two sentences in their entirety (http://downloads.globalchange.gov/sap/sap3-3/Brochure-CCSP-3-3.pdf):

> *Similarly, long-term trends (1925-2003) of hydrologic droughts based on model derived soil moisture and runoff show that droughts have, for the most part, become shorter, less frequent, and cover a smaller portion of the U.S. over the last century (Andreadis and Lettenmaier, 2006). The main exception is the Southwest and parts of the interior of the West, where increased temperature has led to rising drought trends (Groisman et al., 2004; Andreadis and Lettenmaier, 2006).*

Linking Drought to Climate Change

In my recent comments about observed and projected increases in drought in the American West, I mentioned four relatively well understood mechanisms by which climate change can play a role in drought. (I have always been careful to note that, scientifically, we cannot say that climate change caused a particular drought, but only that it is expected to increase the frequency, intensity, and duration of drought in some regions—and that such changes are being observed.)

The four mechanisms are:

1. In a warming world, a larger fraction of total precipitation falls in downpours, which means a larger fraction is lost to storm runoff (as opposed to being absorbed in soil).
2. In mountain regions that are warming, as most are, a larger fraction of precipitation falls as rain rather than as snow, which means lower stream flows in spring and summer.
3. What snowpack there is melts earlier in a warming world, further reducing flows later in the year.
4. Where temperatures are higher, losses of water from soil and reservoirs due to evaporation are likewise higher than they would otherwise be.

Regarding the first mechanism, the 2013 report of the IPCC's Working Group I, *The Science Basis* (http://www.climatechange2013.org/images/report/WG1AR5_TS_FINAL.pdf, p 110), deems it "likely" (probability greater than 66%) that an increase in heavy precipitation events is already detectable in observational records since 1950 for more land areas than not, and that further changes in this direction are "likely over many land areas" in the early 21st century and "very likely over most of the mid-latitude land masses" by the late 21st century The second, third, and fourth mechanisms reflect elementary physics and are hardly subject to dispute (but see also additional references provided at the end of this comment).

As I have also noted in recent public comments, additional mechanisms have been identified by which changes in atmospheric circulation patterns that may be a result of global warming could be affecting droughts in the American West. There are some measurements and some analyses

suggesting that these mechanisms are operating, but the evidence is less than conclusive, and some respectable analysts attribute the indicated circulation changes to natural variability. The uncertainty about these mechanisms should not be allowed to become a distraction obscuring the more robust understandings about climate change and regional drought summarized above.

Global Drought Patterns

Drought is by nature a regional phenomenon. In a world that is warming on the average, there will be more evaporation and therefore more precipitation; that is, a warming world will also get wetter, on the average. In speaking of global trends in drought, then, the meaningful questions are (a) whether the frequency, intensity, and duration of droughts are changing in most or all of the regions historically prone to drought and (b) whether the total area prone to drought is changing.

Any careful reading of the 2013 IPCC report and other recent scientific literature about on the subject reveals that droughts have been worsening in some regions in recent decades while lessening in other regions, and that the IPCC's "low confidence" about a global trend relates mainly to the question of total area prone to drought and a lack of sufficient measurements to settle it. Here is the key passage from the Technical Summary from IPCC WGI's 2013 report (http://www.climatechange2013.org/images/report/WG1AR5_TS_FINAL.pdf, p 112):

> *Compelling arguments both for and against significant increases in the land area affected by drought and/or dryness since the mid-20th century have resulted in a low confidence assessment of observed and attributable large-scale trends. This is due primarily to a lack and quality of direct observations, dependencies of inferred trends on the index choice, geographical inconsistencies in the trends and difficulties in distinguishing decadal scale variability from long term trends.*

The table that accompanies the above passage from the IPCC's report—captioned "Extreme weather and climate events: global-scale assessment of recent observed changes, human contribution to the changes, and projected further changes for the early (2016-2035) and late (2081-2100) 21st century"—has the following entries for "Increases in intensity and/or duration of drought": under changes observed since 1950, "low confidence on a global scale, likely changes in some regions" [emphasis added]; and under projected changes for the late 21st century, "likely (medium confidence) on a regional to global scale".

Dr. Pielke's citation of a 2012 paper from Nature by Sheffield *et al*., entitled "Little change in global drought over the past 60 years", is likewise misleading. That paper's abstract begins as follows:

> *Drought is expected to increase in frequency and severity in the future as a result of climate change, mainly as a consequence of decreases in regional precipitation but also because of increasing evaporation driven by global warming[1-3]. Previous assessments of historic changes in drought over the late twentieth and early twenty-first centuries indicate that this may already be happening globally. In particular, calculations of the Palmer Drought Severity Index (PDSI) show a decrease in moisture globally since the 1970s with a commensurate increase in the area of drought that is attributed, in part, to global warming[4-5].*

The paper goes on to argue that the PDSI, which has been relied upon for drought characterization since the 1960s, is too simple a measure and may (the authors' word) have led to overestimation of global drought trends in previous climate-change assessments—including the IPCC's previous (2007) assessment, which found that "More intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics."

The authors argue for use of a more complex index of drought, which, however, requires more data and more sophisticated models to apply. Their application of it with the available data shows a smaller global drought trend than calculated using the usual PDSI, but they conclude that better data are needed. The conclusion of the Sheffield *et al*. paper has proven controversial, with some critics pointing to the inadequacy of existing observations to support the more complex index and others arguing that a more rigorous application of the new approach leads to results similar to those previously obtained using the PDSI.

A measure of the differences of view on the topic is available in a paper entitled "Increasing drought under global warming in observations and models", published in Nature Climate Change at about the same time as Sheffield et al. by a leading drought expert at the National Center for Climate Research, Dr. Aiguo Dai. Dr. Dai's abstract begins and ends as follows:

> *Historical records of precipitation, streamflow, and drought indices all show increased aridity since 1950 over many land areas[1,2]. Analyses of model-simulated soil moisture[3,4], drought indices[1,5,6], and precipitation minus evaporation[7] suggest increased risk of drought in the twenty-first century. … I conclude that the observed global aridity changes up to 2010 are consistent with model predictions, which suggest severe and widespread droughts in the next 30-90 years over many land areas resulting from either decreased precipitation and/or increased evaporation.*

The disagreement between the Sheffield et al. and Dai camps appears to have been responsible for the IPCC's downgrading to "low confidence", in its 2013 report, the assessment of an upward trend in global drought in its 2007 Fourth Assessment and its 2012 Special Report on Extreme Events (http://www.ipcc-wg2.gov/SREX/) .

Interestingly, a number of senior parties to the debate—including Drs. Sheffield and Dai—have recently collaborated on a co-authored paper, published in the January 2014 issue of Nature Climate Change, entitled "Global warming and changes in drought". In this new paper, the authors identify the reasons for their previous disagreements; agree on the need for additional data to better separate natural variability from human-caused trends; and agree on the following closing paragraph (quoted here in full):

> *Changes in the global water cycle in response to the warming over the twenty-first century will not be uniform. The contrast in precipitation between wet and dry regions and between wet and dry seasons will probably increase, although there may be regional exceptions. Climate change is adding heat to the climate system and on land much of that heat goes into drying. A natural drought should therefore set in quicker, become more intense, and may last longer. Droughts may be more extensive as a result. Indeed, human-induced warming effects accumulate on land during periods of drought because the 'air conditioning effects' of water are absent. Climate change may not manufacture droughts, but it could exacerbate them and it will probably expand their domain in the subtropical dry zone.*

Additional References (with particularly relevant direct quotes in italics)

Christopher R. Schwalm *et al.*, Reduction of carbon uptake during turn of the century drought in western North America, Nature Geoscience, vol. 5, August 2012, pp 551-556.

> *The severity and incidence of climatic extremes, including drought, have increased as a result of climate warming. … The turn of the century drought in western North America was the most severe drought over the past 800 years, significantly reducing the modest carbon sink normally present in this region. Projections indicate that drought events of this length and severity will be commonplace through the end of the twenty-first century.*

Gregory T. Pederson *et al.*, The unusual nature of recent snowpack declines in the North American Cordillera, Science, vol. 333, 15 July 2011, pp 332-335.

> *Over the past millennium, late 20th century snowpack reductions are almost unprecedented in magnitude across the northern Rocky Mountains and in their north-south synchrony across the cordillera. Both the snowpack declines and their synchrony result from unparalleled springtime warming that is due to positive reinforcement of the anthropogenic warming by decadal variability. The increasing role of warming on large-scale snowpack variability and trends foreshadows fundamental impacts on streamflow and water supplies across the western United States.*

Gregory T. Pederson et al., Regional patterns and proximal causes of the recent snowpack decline in the Rocky Mountains, US, Geophysical Research Letters, vol. 40, 16 May 2013, pp 1811-1816.

> *The post-1980 synchronous snow decline reduced snow cover at low to middle elevations by ~20% and partly explains earlier and reduced streamflow and both longer and more active fire seasons. Climatologies of Rocky Mountain snowpack are shown to be seasonally and regionally complex, with Pacific decadal variability positively reinforcing the anthropogenic warming trend.*

Michael Wehner et al., Projections of future drought in the continental United States and Mexico, Journal of Hydrometeorology, vol. 12, December 2011, pp 1359-1377.

> *All models, regardless of their ability to simulate the base-period drought statistics, project significant future increases in drought frequency, severity, and extent over the course of the 21st century under the SRES A1B emissions scenario. Using all 19 models, the average state in the last decade of the twenty-first century is projected under the SRES A1B forcing scenario to be conditions currently considered severe drought (PDSI<-3) over much of the continental United States and extreme drought (PDSI<-4) over much of Mexico.*

D. R. Cayan *et al*., Future dryness in the southwest US and the hydrology of the early 21st century drought, Proceedings of the National Academy of Sciences, vol. 107, December 14, 2010, pp 21271-21276.

> *Although the recent drought may have significant contributions from natural variability, it is notable that hydrological changes in the region over the last 50 years cannot be fully explained by natural variability, and instead show the signature of anthropogenic climate change.*

E. P. Maurer *et al.*, Detection, attribution, and sensitivity of trends toward earlier streamflow in the Sierra Nevada, Journal of Geophysical Research, vol. 112, 2007, doi:10.1029/2006JD08088.

> *The warming experienced in recent decades has caused measurable shifts toward earlier streamflow timing in California. Under future warming, further shifts in streamflow timing are projected for the rivers draining the western Sierra Nevada, including the four considered in this study. These shifts and their projected increases through the end of the 21st century will have dramatic impacts on California's managed water system.*

H. G. Hidalgo *et al*., Detection and attribution of streamflow timing changes to climate change in the western United States, Journal of Climate, vol. 22, issue 13, 2009, pp 3838-3855, doi: 10.1175/2009JCLI2740.1.

> *The advance in streamflow timing in the western United States appears to arise, to some measure, from anthropogenic warming. Thus the observed changes appear to be the early phase of changes expected under climate change. This finding presages grave consequences for the water supply, water management, and ecology of the region. In particular, more winter and spring flooding and drier summers are expected as well as less winter snow (more rain) and earlier snowmelt.*