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The Honorable Lamar Smith
Chairman
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, D.C. 20515

Cc: Honorable Eddie Bernice Johnson
Ranking Member
Committee on Science, Space, and Technology

March 28, 2017

Dear Mr. Smith,

We are coauthors of the Fyfe *et al.* paper published in 2016 in *Nature Climate Change*.[1] You recently referenced this paper at a Subcommittee hearing on March 16, 2016.[2] We are writing to clarify what the Fyfe *et al*. paper actually finds and claims. We also want to ensure that the conclusions of the Fyfe *et al*. paper are not misconstrued as a criticism of Thomas Karl, of the Karl *et al.* paper published in *Science* in 2015,[3] or of the valuable research that Dr. Karl and his team have performed over many years.

Thomas Karl is a first-rate climate scientist. He served NOAA with distinction for decades. Dr. Karl and his colleagues at the National Center for Environmental Information (NCEI) developed rigorous scientific methods for estimating global changes in land and ocean surface temperatures. This is a critically important area of climate science.

NCEI made its surface temperature data sets freely available to the climate science community. This helped scientists around the world to conduct research on the size, rate, and causes of long-term temperature change, and helped to improve our knowledge of natural climate variability. NCEI temperature data are also key yardsticks for evaluating the performance of computer models of the climate system.

Science is dynamic, not static. All surface temperature data sets have evolved over time, as scientists found better ways of accounting for the effects of changes in measurement systems, measuring practices, and the geographical coverage of observations. Similar improvements have occurred in measurements of the heat content of the world's oceans, and in satellite estimates[4,5,6] of temperature change in Earth's atmosphere. The evolution of observed temperature data sets is a normal, on-going scientific process. It is not evidence of questionable behavior.

In their 2015 *Science* paper, Karl *et al*. identified changes in three different aspects of surface temperature measurement systems. These observing system changes must be addressed in order to reliably estimate the true, climate-related temperature signals in the data. After accounting for

the evolution of the measuring system, Karl *et al*. concluded that the rate of surface warming in the first 15 years of the 21st century was "at least as great as (in) the last half of the 20th century".

Fyfe *et al*. acknowledged the "high scientific value" of the work performed by Dr. Thomas Karl and his colleagues. We stand by our statement. It is of great benefit to understand how observational temperature data are affected by changing measurement systems. Karl *et al*. deserve credit for focusing attention on this issue, and for inspiring important research on the further improvement of surface temperature datasets.[7]

While Karl *et al*. focused on developing a better understanding of temperature observations, Fyfe *et al*. summarized and synthesized scientific understanding of decadal changes in warming arising from natural variability of the climate system. The emphasis in the Fyfe *et al*. paper was on studying internal variability (caused by phenomena like El Niños, La Niñas,[8] and the Interdecadal Pacific Oscillation[9,10,11,12]) and on assessing the effects of natural external changes in volcanic aerosols[13] and the Sun's energy output.[14]

Fyfe *et al*. found that the rate of temperature increase in the early 21st century was slower than during the latter part of the 20th century. Reduced warming was apparent in both surface observations and in satellite measurements of the temperature of Earth's lower atmosphere (the troposphere).

The bottom line is that Karl *et al*. and Fyfe *et al*. reached different conclusions regarding the warming rate in the early 21st century. This was largely due to different justifiable choices the two sets of authors made about the timescales and periods of interest. The Karl *et al*. finding – that the recent rate of surface warming is larger than in previous data sets – is supported by an independent study of surface temperature measurements.[7] Other sources of information support the Fyfe *et al*. finding of a reduced rate of surface warming in the early 21st century. These sources include independent satellite estimates of tropospheric temperature change, physical understanding of the waxing and waning of different "modes" of internal variability, and measurements of the changes over time in volcanic aerosols and the Sun.

All of the factors studied by Karl *et al*. and Fyfe *et al*. (changing observing systems, internal variability, and natural variations in the Sun and volcanoes) affect temperature records, and affect our interpretation of the size and significance of decade-to-decade changes in warming rate. The scientific challenge is to reliably quantify the contribution of each factor to short-term changes in warming rate.[15]

Finally, we would like to emphasize that Karl *et al*. and Fyfe *et al*. agree on the most important scientific points. We agree that human influence on climate is real, is large, and is ongoing. We agree that this influence is primarily due to fossil fuel burning, and to the resulting human-caused changes in atmospheric levels of heat-trapping greenhouse gases.[16] We agree that human-caused changes in greenhouse gases should lead – and do lead – to global-scale warming of Earth's atmosphere, oceans, and land surface.[17] We agree that we have identified large global warming signals in the observed surface temperature changes from the late 19th century to the present,[18] in the satellite atmospheric temperature data that have featured prominently in recent Congressional hearings,[19,20] and in ocean heat content measurements.[21]

And we agree with Karl *et al*. that on top of the underlying global-scale warming trend over the past 150 years, we should see – and do see – natural, decade-to-decade ups and downs caused by internal variability, volcanic activity, and changes in the Sun's energy output. These decade-to-decade fluctuations in warming are not a scientific surprise. They have been discussed at length in every national and international assessment of climate science. Sometimes the "ups" act in the same direction as human influences, leading to accelerated warming. Sometimes the "downs" lead to a short-term decrease in warming. Our disagreement with Karl *et al*. about the size of the most recent short-term fluctuation does not call into question the reality of long-term human-caused warming.

Sincerely,

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P.S.: We are also submitting a letter from our colleagues at the Canadian Centre for Climate Modelling and Analysis: Dr. John Fyfe, Dr. Greg Flato, Dr. Nathan Gillett, and Dr. Neil Swart. Dr. Fyfe was the lead author of the 2016 Fyfe *et al*. *Nature Climate Change* paper, and Drs. Flato, Gillett, and Swart are co-authors of the Fyfe *et al*. paper. All four of our colleagues affirm their scientific support for the statements we have made in our letter.

[1]Fyfe, J.C., G.A. Meehl, M.H. England, M.E. Mann, B.D. Santer, G.M. Flato, E. Hawkins, N.P. Gillett, S.-P. Xie, Y. Kosaka, and N.C. Swart, 2016: Making sense of the early 2000s global warming slowdown. *Nature Climate Change*, **6**, 224-228.

[2]https://science.house.gov/sites/republicans.science.house.gov/files/documents/HHRG-114-SY18-WState-S000583-20160316.pdf

[3]Karl, T.R., A. Arguez, B. Huang, J.H. Lawrimore, J.R. McMahon, M.J. Menne, T.C. Peterson, R.S. Vose, and H.-M. Zhang, 2015: Possible artifacts of data biases in the recent global surface warming hiatus. *Science*, **348**, 1469-1472.

[4]Santer, B.D., T.M.L. Wigley, and K.E. Taylor, 2011: The reproducibility of observational estimates of surface and atmospheric temperature change. *Science*, **334**, 1232-1233.

[5]Wentz, F.J., and M. Schabel, 1998: Effects of orbital decay on satellite-derived lower tropospheric temperature trends. *Nature*, **394**, 661-664.

[6]Mears, C. A., and F.J. Wentz, 2005: The effect of diurnal correction on satellite-derived lower tropospheric temperature. *Science*, **309**, 1548-1551.

[7]Hausfather, Z., K. Cowtan, D.C. Clarke, P. Jacobs, M. Richardson, and R. Rohde, 2017: Assessing recent warming using instrumentally homogeneous sea surface temperature records. *Sci. Adv.*, **3**, e1601207.

[8]Kosaka, Y., and S.-P. Xie, 2013: Recent global-warming hiatus tied to equatorial Pacific surface cooling. *Nature*, **501**, 403-407.

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[10]England, M.H., et al., 2014: Recent intensification of wind-driven circulation in the Pacific and the ongoing warming hiatus. *Nature Climate Change*, **4**, 222-227.

[11]Trenberth, K.E., 2015: Has there been a hiatus? *Science*, **349**, 791-792.

[12]Steinman, B.A., M.E. Mann, and S.K. Miller, 2015: Atlantic and Pacific multidecadal oscillations and Northern Hemisphere temperatures. *Science*, **347**, 988-991.

[13]Solomon, S., J.S. Daniel, R.R. Neely, J.-P. Vernier, E.G. Dutton, and L.W. Thomason, 2011: The persistently variable "background" stratospheric aerosol layer and global climate change. *Science*, **333**, 866-870.

[14]Kopp, G., and J.L. Lean, 2011: A new, lower value of total solar irradiance: Evidence and climate significance. *Geophysical Research Letters*, **38**, L01706, http://dx.doi.org/10.1029/2010GL045777.

[15]Flato, G.M., et al., 2013: Evaluation of climate models. In: *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Stocker, T.F., et al. (eds.), Cambridge University Press, pp. 741-866.

[16]The basis for our understanding of human-induced changes in climate stretches back to the 1850s, when carbon dioxide was first identified as a greenhouse gas. It is not a new development. Similarly, our observational understanding of large-scale temperature change dates back to the 1930s, when it was first shown that global land areas were warming (see ref. 17).

[17]Hawkins, E., and P.D. Jones, 2013: On increasing global temperatures: 75 years after Callendar. *Quarterly Journal of the Royal Meteorological Society*, **139**, 1961-1963.

[18]Bindoff, N. *et al*. Detection and attribution of climate change: from global to regional. In: *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Stocker, T.F., et al. (eds.), Cambridge University Press, 867-952.

[19]Santer, B.D., et al., 2013a: Identifying human influences on atmospheric temperature. *Proceedings of the National Academy of Sciences*, **110**, 26-33.

[20]Santer, B.D., et al., 2013b: Human and natural influences on the changing thermal structure of the atmosphere. *Proceedings of the National Academy of Sciences*, **110**, 17235-17240.

[21]Gleckler, P.J., et al., 2012: Robust evidence of human-induced global ocean warming on multi-decadal time scales. *Nature Climate Change*, **2**, 524-529.