Reconciliation of Competing Climate Science and Policy Paradigms

Extended Abstract # CC-38

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Introduction

"Equilibrium climate sensitivity" (ECS) is a metric that encapsulates the magnitude and temporal progression of global warming induced by anthropogenerated changes in Earth's atmosphere. It is expressed as a warming of surface average air temperature over the preindustrial background caused by a doubling of atmospheric carbon dioxide. It is *not* the same as a prospective observed warming, which may be somewhat higher, as one period of warming in the instrumental record, 1910-45, was too early to be caused by enhanced carbon dioxide. The warming that was re-established in 1976 is likely to have a significant anthropogenerated component. It is reasonable to assume that approximately 0.5°C of a total warming of approximately 0.9°C is likely related to greenhouse-gas (GHG) emissions.

With regard to the Paris Agreement's aspirational target of 2.0°C of warming by 2100, this should obviously apply only to the GHG component. That leaves an additional 1.5°C as "permissible".

This presentation will show that it is plausible that the world will meet this target.

Main Text

Three recent developments harmonize policy and global warming science. They are

- The growing disparity between predicted bulk tropospheric temperatures and observed values, especially at altitude in the tropics, casts overall doubt on the utility of general circulation models (GCMs) with regard to 21st century temperatures. The current model suite has an average ECS of 3.2°C (IPCC, 2013)[1]. The problem probably arises as a consequence of the recently acknowledged significant tuning of the GCMs in order for them to simply simulate the evolution of 20th century surface temperatures.

- Alternatively, estimates of ECS made beginning in 2011 and based upon observations have a mean of 2.0°C. Those based upon a refined analysis of the effects of sulfate aerosols (Stevens, 2015; followed by Lewis (2015))[2,3] give an ECS as low as 1.4°C. The systematic problems with the more traditional GCMs promote reliance on this alternative suite.

- The substitution of abundant and inexpensive natural gas for coal in electrical generation is the United States is likely to continue in other countries with advanced economies. Because modern natural gas-fired generation facilities are cost less to build and operate than coal facilities, new coal-based capacity is likely to be more limited to developing countries with substantial supplies of domestic coal. Taken together, this argues against the use of RCP 8.5 for future projections, despite it being the "business-as-usual" scenario in the 2015 Paris climate agreement

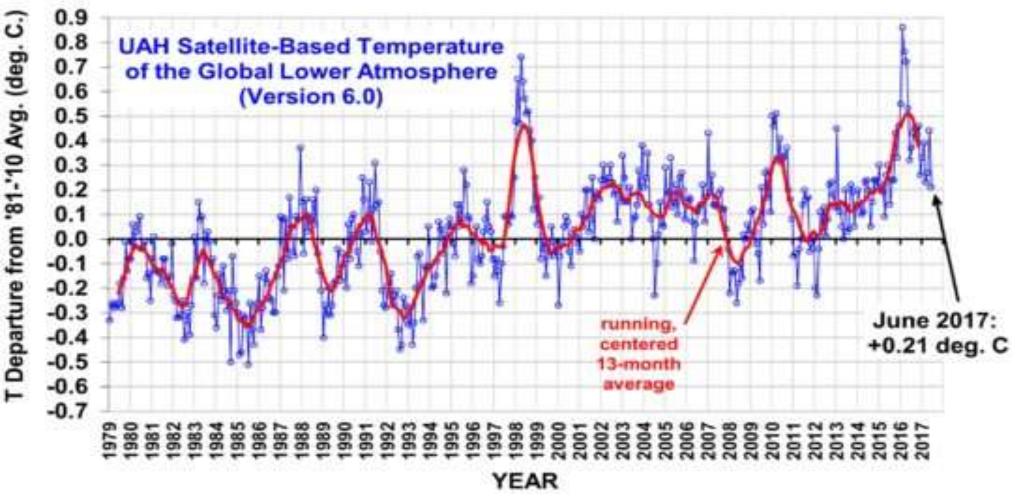
Surface temperature evolution after 1997 remains controversial. The Hadley Center (HadCRU3, and the 2012 revision, HadCRU4)[4] surface history clearly show a "pause" in warming until the 2015-6 El Niño. Karl et al. (2015), using a revised sea-surface temperature record, had more post-1998 warming than predecessor records, but (at the time of publication), the early 21st century trend was not significant by normative scientific standards (p. le .05).[5] The latest revisions of the two satellite-sensed lower tropospheric temperatures from University of Alabama-Huntsville (UAH) and Remote Sensing Systems (RSS) both showed a "pause", but along with the surface temperature histories, acquired significant post-2000 trends with the 2015-6 El Niño.[6,7]

As the El Niño faded, both the UAH lower tropospheric (Figure 1) and 2-meter reanalysis records (Figure 2) indicate that temperatures have returned to near their pre-El Niño levels.

Santer et al. (2017) noted that the pause indeed was not captured in the ensemble behavior of the recent generation of climate models,[8] another reason to embrace the more historically-based calculations. The two periods of "pause" (the first of which, from 1945-75, is actually a slight decline (Figures 3 and 4) and the period of warming beginning in the late 1970s, are currently associated with the Interdecadal Pacific Oscillation (IPO; Meehl et al. (2016)).[9] Meehl et al. (2016) have forecast an imminent acceleration in the rate of surface warming tied to a hindcast of a change of the Interdecadal Pacific Oscillation (IPO) from negative to positive beginning in 2013.[10] The recent post-El Niño temperatures in Figures 1 and 2 (beginning in 2017) do not support that forecast, at least at this time.

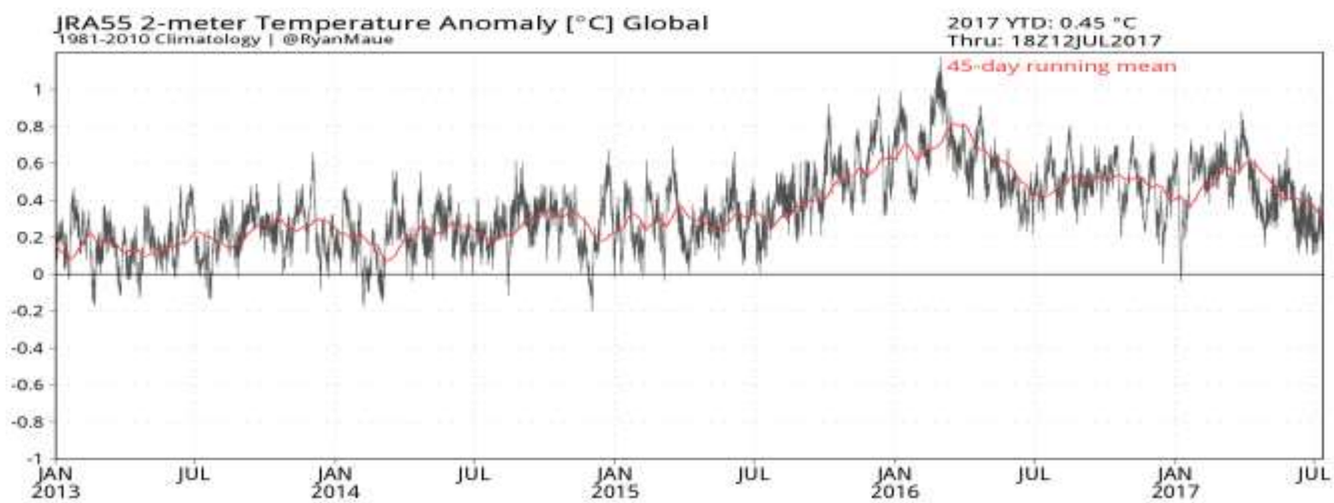
If an IPO switch results in a warming at a similar rate as the 1976-late 1990s value, the overall decadal surface trend value will not depart very far from the 0.18°C/decade surface warming established since the initiation of warming in the 1970s (0.16° ending prior to the 2015-16 El Niño spike) 0.11° in the UAH satellite record). The observed trend in this case would remain significantly below the approximately 0.4°/decade characteristic for the current and next decades in the current model suite.[10]

Figure 1: UAH Lower Tropospheric Temperatures (Spencer, 2017)[6]



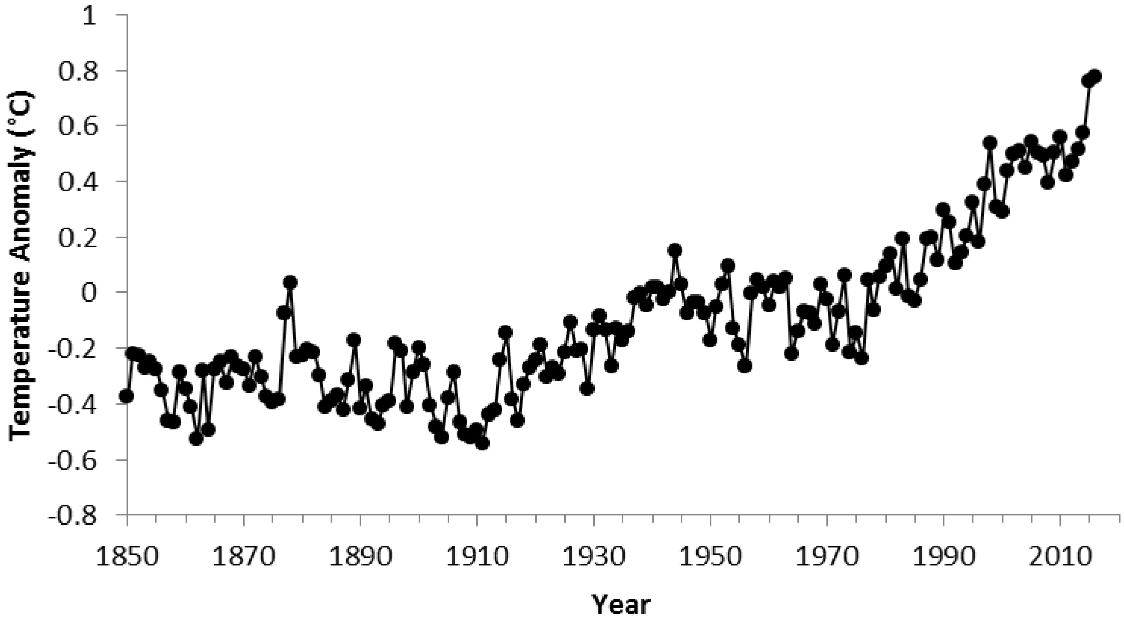
(Source: Dr. Roy Spencer[6]

Figure 2: JRA 55 2-meter reanalysis temperature, 1/1/13 to 7/12/17



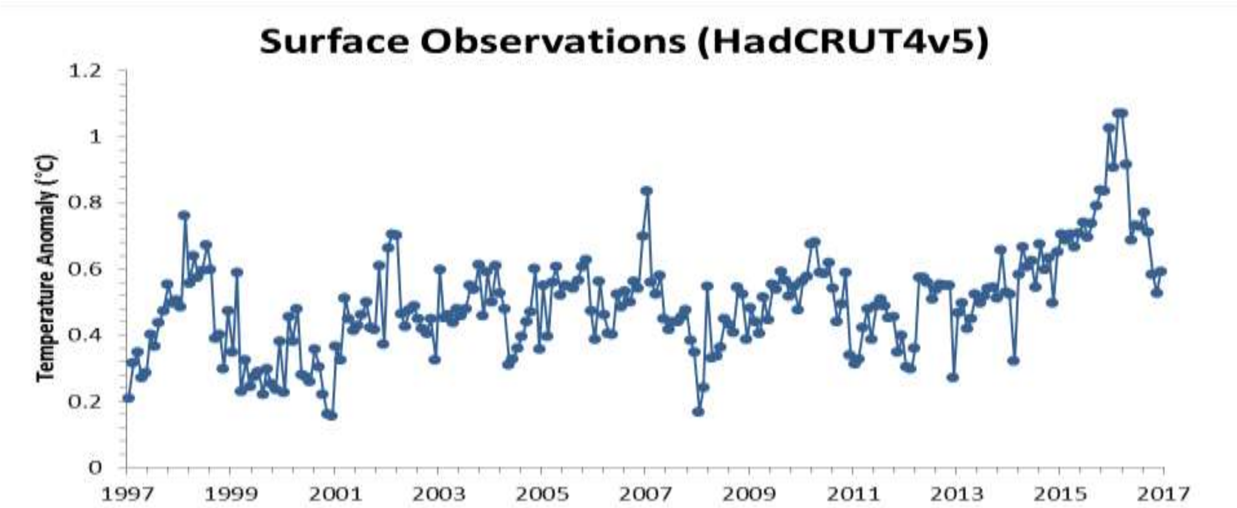
(Source: http://icdc.cen.uni-hamburg.de/1/daten/reanalysis-atmosphere/jra55.html, analysis by Dr. Ryan Maue, Cato Institute)

Figure 3: Global Surface Temperature Anomalies, 1850-2016



(Source: Climate Research Unit, University of East Anglia)[4]

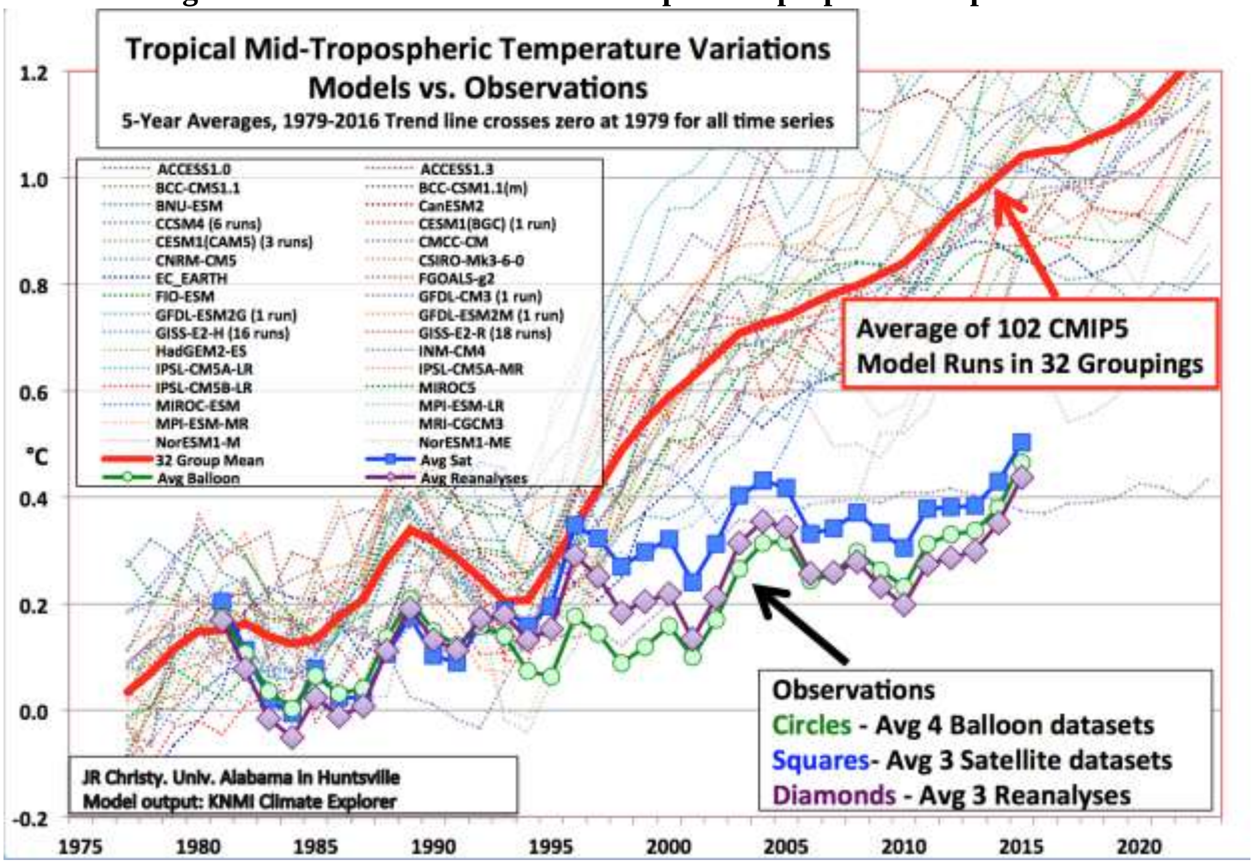
Figure 4: Monthly temperature anomalies 1997-2017



(Source: Climate Research Unit, University of East Anglia)[4]

The ECS in Meehl et al. (2016) is 3.2°C, which is typical for the IPCC Fifth Assessment Report (2013) model ensemble. However, as shown in Figure 5, there is emerging evidence that this suite of models is not able to predict recent temperatures, with major implications for their forecasts of future weather regimes. The problem is evident in the entire tropical mid troposphere (20ºN-20ºS), through which the majority of earth's atmospheric moisture is transported above the shallow trade wind inversion. This zone covers 35.5 per cent of the surface. Figure 3 begins in January, 1979, which is the starting point for the satellite data.

Figure 5: Modelled and observed tropical tropospheric temperatures.

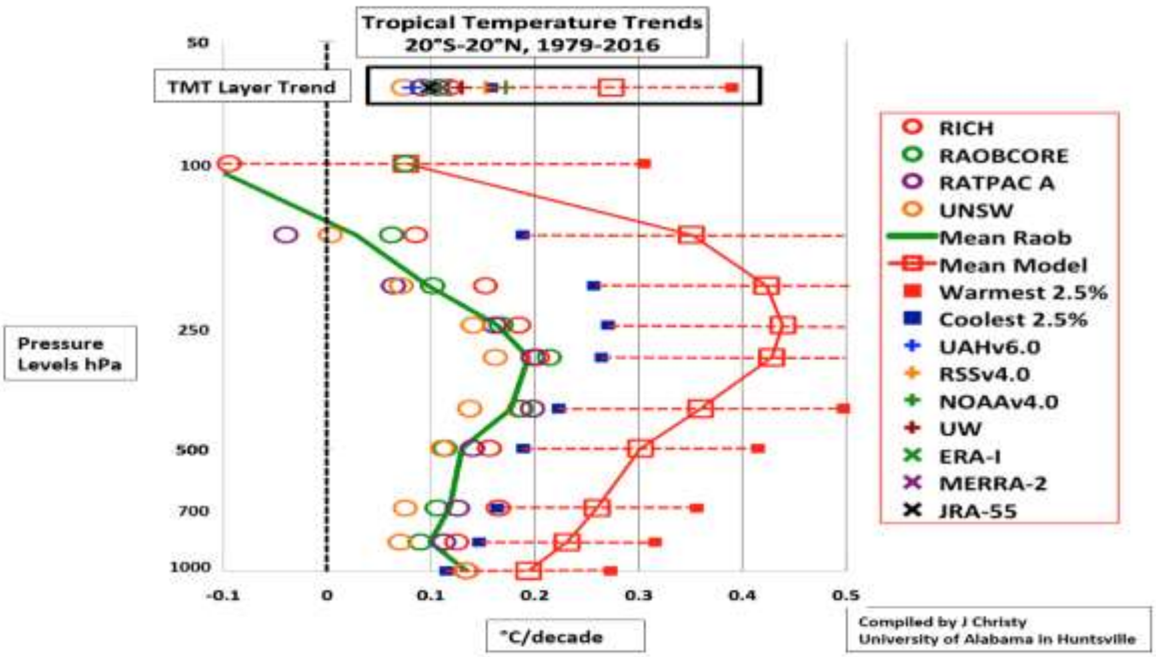


(From 2017 congressional testimony of John Christy to the House Committee on Science, Space, and Technology, March 29, 2017.)[11]

If their mid-troposphere is systematically mis-specified, that brings into question the models as useful estimators for future climate. Indeed, as shown in Figure 3, the model suite (with one exception, which is the current Russian climate model) dramatically overpredicts mid-tropospheric warming.

Ten of the 32 model families in figure 5 are earth system models, which interact climate with the biosphere. While these are relatively new, the parent climate models are general circulation models resident at the particular laboratory, and the ESMs are clearly having the same problem that the GCMs have with temperatures measured in the satellite era.

Figure 6. Observed (green, circles) and predicted (red, squares)tropical temperatures versus height.



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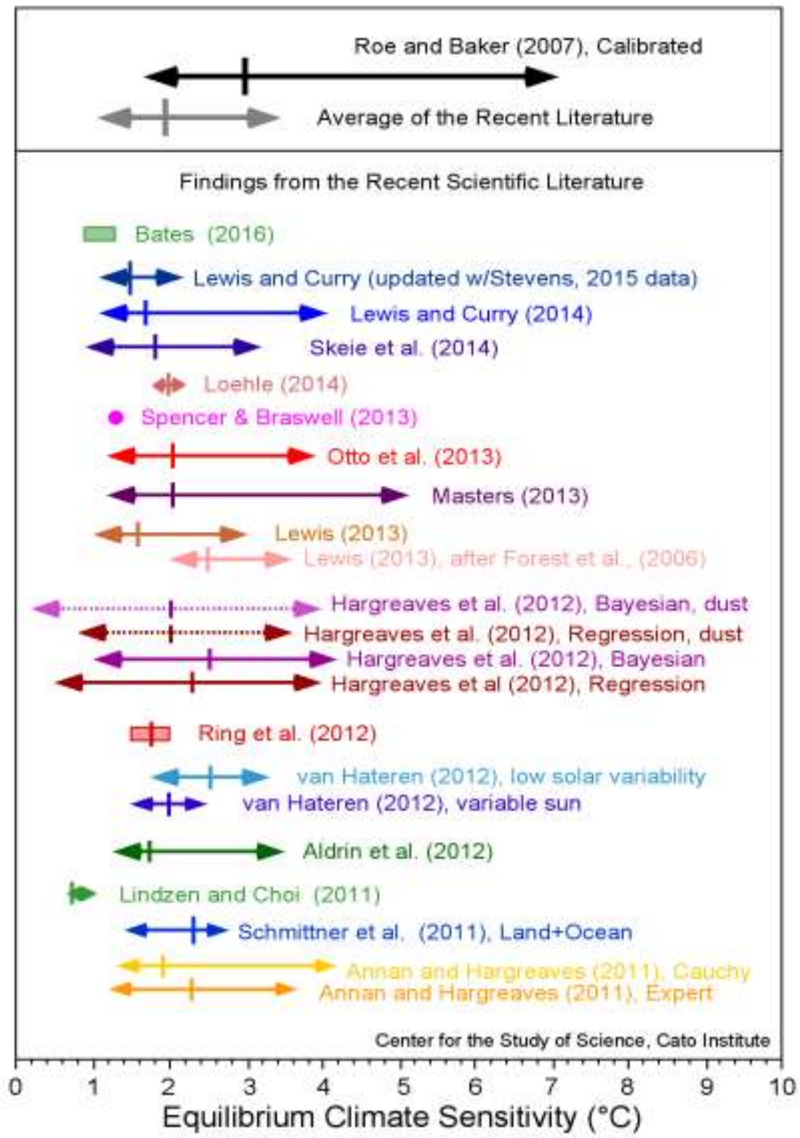
(Source: Christy, J. R., 2017. Figure S10 in *State of the Climate 2016*, Bulletin of the American Meteorological Society)[12]

The models have predicted several *times* more warming than is being observed in the upper half of the tropical troposphere (above 500 hPa).

The implication is that vertical motion in the tropical troposphere is substantially and systematically nderestimated in most of the climate models, which means in reality there is a stronger Hadley circulation, stronger subtropical subsidence, and stronger trade winds. It is important to understand that the weather regime implications of these errors, which are large, have not been quantified. In general, it is the vertical stratification of temperature that determines tropical precipitation and cloudiness. The models must be systematically predicting a less cloudy and precipitating atmosphere than is being observed, an enormously important error, and vital to calculating any water vapor feedback, which is the major reason that these models produce more than the approximately 1°C of warming resulting from doubling atmospheric carbon dioxide.

Absent the immediate appearance of a much greater warming trend than has been observed since the mid-1970s, it becomes more reasonable to rely on observationally-based sensitivity calculations, as the observations are clearly departing from previous model output, making subsequent model output increasingly untrustworthy. In recent years, observationally-based calculations tend to show a lower sensitivity, as detailed in Figure 7.

Figure 7: Recent low-sensitivity ECS estimates.



(Source: Michaels and Knappenberger (2016)[13])

These all postdate the initial publication of the models used in the IPCC's Fifth Assessment Report. The top line is the ECS probability function (0.90 total) used in calculations of the "social cost of carbon" through 2016, for comparison with these largely observationally-based estimates.

It has long been known that GCMs with only increases in carbon dioxide predict too much warming; this was "officially" recognized as early as the Second Assessment Report of the IPCC (1996)[14], which noted that either the warming was being attenuated by sulfate aerosol, or the sensitivity was simply overestimated. It is logical that the modelling community would gravitate towards the former, for reasons detailed elsewhere,[13] but the work of Stevens (2015)[2] on the actual radiative effects of sulfates prompts a re-examination of the sensitivity itself.

Stevens (2015) noted the dilemma that "tuning" models to simulate the warming of the early 20th century forces them to produce far too much warming beginning in the late 20th century, which, as can be seen in Figures 3 and 4, has obviously happened.

Using Stevens' sulfate estimates, Lewis (2015) concluded that sulfates exert less than half of the cooling effect in the real world than they do in the IPCC models.[3] Building on that, he calculated a most likely mean ECS of around 1.4°C with a transient sensitivity (temperature change at time of doubling) of around 1.2°C. In Michaels and Knappenberger (2016) the mean ECS in the observation-based literature is 2.0°C[13], versus the IPCC (2013) value of 3.2°C.

As shown in Voosen (2016), all models are tuned to the 20th century temperature history, but only recently has the extent of tuning required begun to be revealed.[15] It should be noted that each tuning step, be it for cloud entrainment, albedo, or oceanic heat flux, predisposes a model to instability and inaccuracy when placed in true forecast mode. That's because known physics can often be at least slightly departed from in order to get the proper fit. That same inaccuracy then propagates through the future like one of Lorenz's butterflies, which may be the ultimate reason for the disparities in Figures 5 and 6.

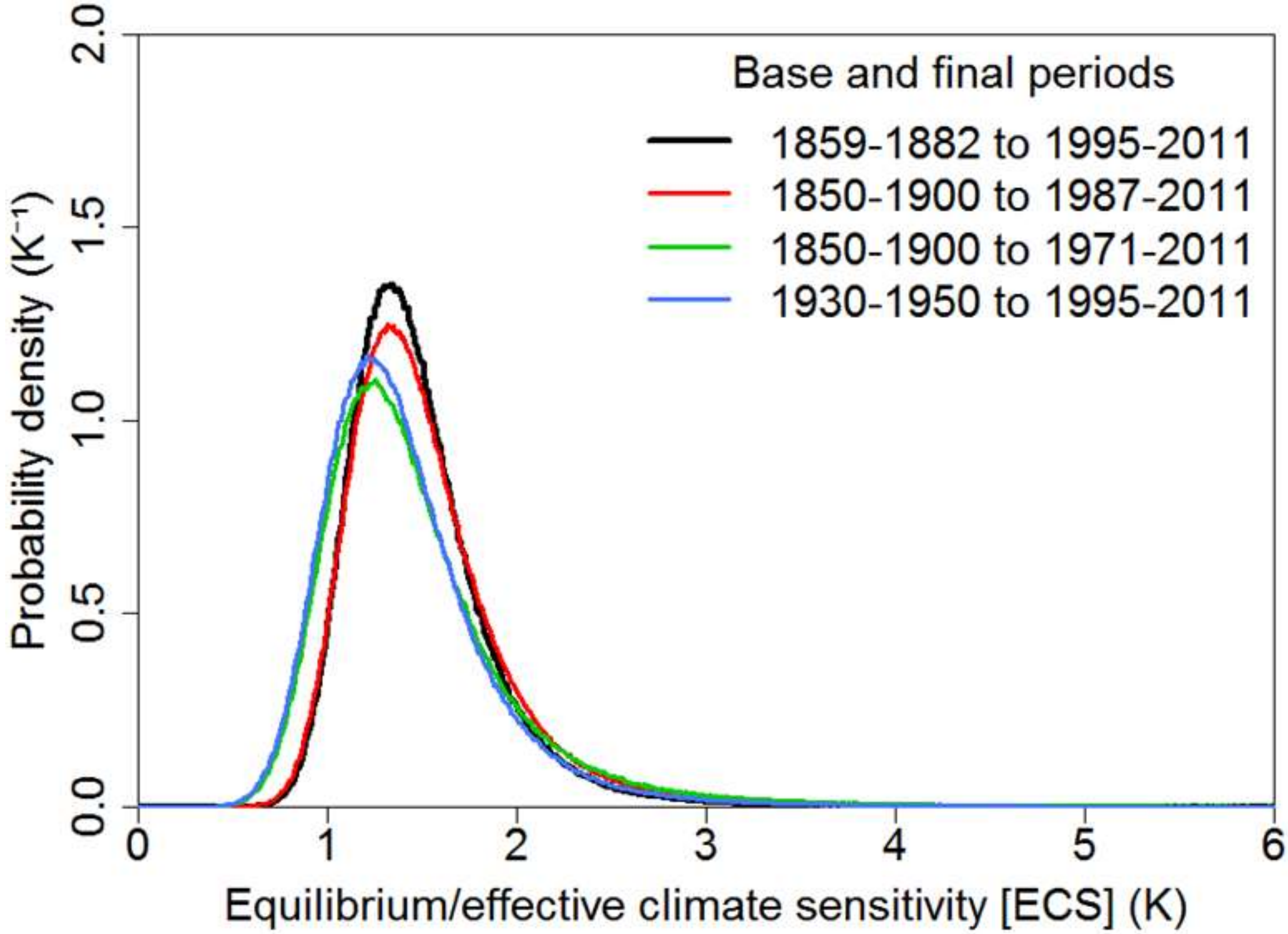
It is well-known that the response of temperature to increasing concentration of carbon dioxide is logarithmic while the increase itself is a low-order exponent. In most model solutions this results in a constant (not an increasing) rate of warming, once it is established. (This is also evident in the behavior of the models shown in Figure 5, if the prescribed "volcanoes" of 1983 and 2011 are removed.) Despite their obvious flaws with regard warming rates and vertical stratification, the remarkable observed linearity of warming since it resumed in the 1970s (Figure 9) is quite encouraging, in that at least the functional form of warming (linear versus exponential) has been correctly specified. A continuation from the present through 2100 yields 1.5°C, for a total of 2.0°C due to GHGs, in keeping with the Paris Agreement.

Summary

Three developments, taken together, have important implications.

- The current family of models is too hot throughout the tropical troposphere, which covers over 35 per cent of the surface, and that this is possibly a result of over-tuning to match the surface record. The vertical stratification of temperature, which controls upward motion (and therefore precipitation) is very far off in the upper troposphere. The result is that they are useless for reliable projections of future weather regimes, as almost all atmospheric moisture above the trade wind inversion originates in tropical convection that is controlled by the temperature stratification.

Figure 8. ECS probability distributions using different base and final periods for sulfate aerosol forcing.



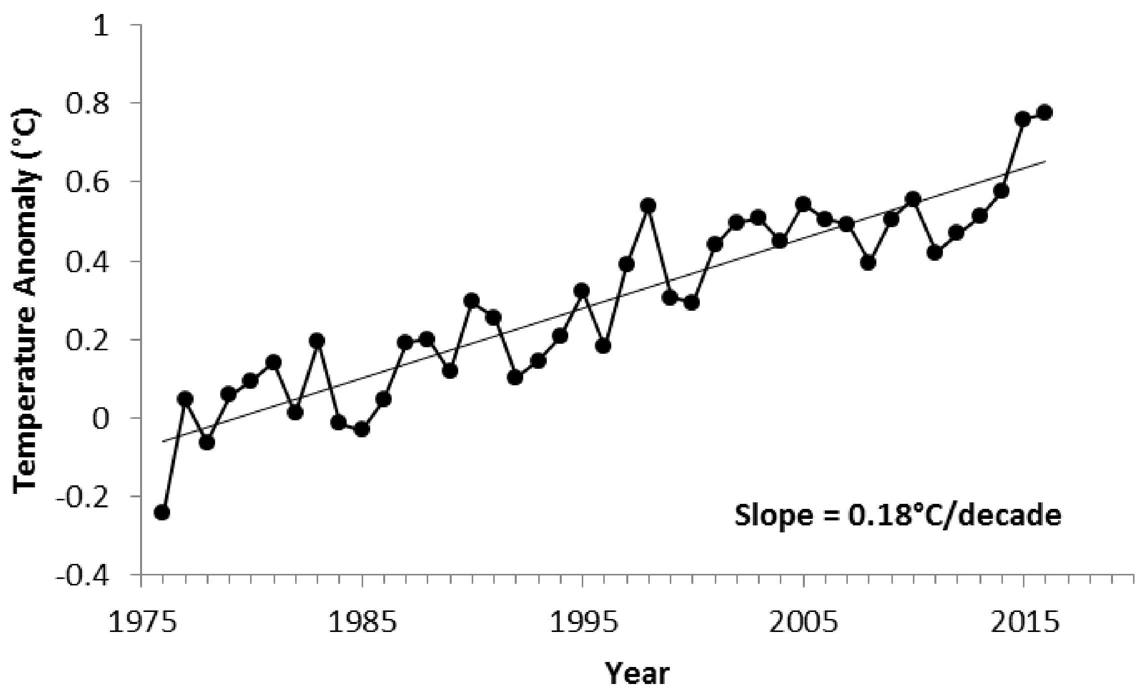
From Lewis and Curry (2015)[3]

- Observationally-derived models more realistically simulate observed climate change and a lower prospective equilibrium climate sensitivity.
- Cost-effective substitution of natural gas for coal, first in the United States, and then spreading throughout the world (with the exceptions noted above) will make the Paris 2.0° target attainable with relative ease, therefore harmonizing global warming science and policy.

The natural gas revolution pretty much guarantees that most developed countries that use coal for electrical generation will gradually phase it out. (This includes coal-intensive China, where, as it becomes more affluent, the citizenry will surely demand cleaner air).

Coupled with a lower sensitivity and the predicted linearity of future warming, this limits GHG-related warming to 2.0ᴼC by 2100. Note that the real GHG-related warming to date is not the figure used in the Paris calculations (is in Climate Action Tracker, 2015)[16], which assumes *all* warming since the industrial revolution is a result of GHGs. A lower sensitivity and large scale substation of natural gas for coal for electrical generation, and eventually for long-distance transport (BNSF railway is already experimenting with natural gas tenders) will constrain the warming of the remaining 82 years of this century to 1.5°C, yielding a total GHG-related warming of 2.0ᴼC, and fulfilling the Paris agreement.

Figure 9: Linear warming since 1976



(Source: Climate Research Unit, University of East Anglia)[4]

REFERENCES

1. Intergovernmental Panel on Climate Change, *Climate Change 2013, The Scientific Basis.* Cambridge University Press, 2013, 1552 pages.

2. Stevens, B. *J. Clim*, **2015**, *28*, 4794-819.

3. Lewis, N, 2015. The implications for climate sensitivity of Bjorn Stevens' new aerosol forcing paper. https://niclewis.files.wordpress.com/2015/10/ar5_ebstudy_stevens15faer1e.pdf, 5pp.

4. Morice, C. P., et al. "Quantifying uncertainties in global and regional temperature change using an ensemble of observational estimates: The HadCRUT4 data set", *J. Geophys Res: Atm*, **2012**, DOI: 10.1029/2011JD017187. Datafile at https://crudata.uea.ac.uk/cru/data/temperature/

5. Karl, T.R., et al. "CLIMATE CHANGE. Possible artifacts of data biases in recent global surface warming hiatus", *Science*, **2015**, DOI: 10.1126/**science**.aaa5632.

6. Spencer, R. W., http://www.drroyspencer.com/2017/07/uah-global-temperature-update-for-june-2017-0-21-deg-c/.

7. http://www.remss.com/node/5206

8. Santer, B.D., et al. "Causes of differences in model and Satellite tropospheric warming rates", *Nature Geosci*, **2017**, *10*, 478-85.

9. Meehl, G. A.; Hu, A.; Teng, H. *Nature Comm*, **2016** doi:10.1038/ncomms11718.

10. http://climexp.knmi.nl/plot_atlas_form.py

11. Christy, J. R., "U.S. House Committee on Science, Space & Technology, 29 Mar 2017", https://science.house.gov/sites/republicans.science.house.gov/files/documents/HHRG-115-SY-WState-JChristy-20170329.pdf

12. Christy, J. R., 2017. State of the Climate in 2017. Special supplement to *Bulletin of the American Meteorological Society* **98**, Figure S10.

13. Michaels, P. J., Knappenberger, P.C., *Lukewarming: The New Climate Science that Changes Everything*, Cato Books, Washington DC, 2016, 248pp.

14. Intergovernmental Panel on Climate Change, *Climate Change 1995, The Science of Climate Change*, Cambridge University Press, 2013, 588 pages.

15. Voosen, P., "Climate scientists open up0 their black boxes to scrutiny", *Science*, **2016**, *354*, 401-02, 28 October 2016.

16. http://www.climateactiontracker.org

KEY WORDS

Paris Agreement, Climate Sensitivity, Global Warming