BEFORE THE OFFICE OF ADMINISTRATIVE HEARINGS
FOR THE MINNESOTA PUBLIC UTILITIES COMMISSION
STATE OF MINNESOTA

In the Matter of the Further Investigation in to
Environmental and Socioeconomic Costs
Under Minnesota Statute 216B.2422, Subdivision 3

OAH Docket No. 80-2500-31888

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Sur-Rebuttal Testimony

Professor Richard Lindzen

September 10, 2015

PROFESSOR RICHARD LINDZEN

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Lindzen Sur-Rebuttal

Q: Are you the same Richard Lindzen who testified previously in this proceeding?

A: Yes I am.

Q: How do you plan to organize your testimony?

A: I plan to touch upon the following issues:

- Climate models run hotter than observations
- Climate science, and specifically:
  - the "Iris" feedback mechanism
  - equilibrium climate sensitivity ("ECS")
  - the hiatus in warming and the Karl/NOAA paper
  - the connection between CO_2 emissions and concentrations
- The severity and frequency of extreme events are not increasing, for example:
  - loss of sea ice
  - rise in sea level
  - drought and heat wave
- Peer review and "consensus" based science

I. Climate Models Run Hot

Q: Dr. Dessler disputes your testimony that climate models have been shown to be inaccurate. Is there recent peer-reviewed literature to substantiate the proposition that models show warming in excess of what is observed?

A: Yes. Recent peer-reviewed publications reveal manifold problems with climate modeling, often resulting in a warm bias. Learned members of the scientific community have—

at cost to their personal reputations—gone public with criticism of the supposed "consensus" generated by climate modeling:

1. Prof. Michael Kelly, a member of the Royal Society and the Prince Philip Professor of Technology at Cambridge University, criticized climate models on March 14, 2015: "This flies in the face of the confident predictions made by nearly all the climate computer models that the temperature would continue to rise as it did from 1975 to 1998. More than 60 different explanations have been proposed to explain why this 'pause' or 'hiatus' has happened, and their sheer number is the clearest evidence that the system that climate scientists are seeking to model is irreducibly complex. Human-sourced carbon dioxide is at best one of many factors in causing climate change, and humility in front of this complexity is the appropriate stance."[1]

   A recent paper has changed the thinking about the role of suspended particles (aerosols), which have been thought to have a large impact on external forcing. Stevens (2015) shows, however, that the actual forcing aerosols cause is substantially lower than models assume.[2] Thus, a "fudge factor" which previously allowed models to appear to accurately track past temperatures has now been sufficiently constrained that models with sensitivity greater than 2 °C are highly improbable.

2. A report from a team of scientists from the Chinese Academy of Sciences shows that the most widely used climate models miscalculate the solar zenith, thereby overestimating

[1] Michael Kelly, *Why my own Royal Society is wrong on climate change: A devastating critique of world's leading scientific organisation by one of its Fellows*, The Mail On Sunday (Mar. 14, 2015), *available at* http://www.dailymail.co.uk/news/article-2995239/Why-Royal-Society-wrong-climate-change-devastating-critique-world-s-leading-scientific-organisation-one-Fellows.html.

[2] Bjorn Stevens, *Rethinking the Lower Bound on Aerosol Radiative Forcing*, 28 J. Climate 4794 (2015), available at http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-14-00656.1.

the effects of solar radiation and adding "spurious variation" that is 18 times greater than the total effects of CO_2 on temperature since 1750.[3] In short, a mathematical mistake in the climate models has produced a greater anthropogenic effect on warming than CO_2 emissions.

3. A researcher at the Copernicus Institute for Sustainable Development strongly criticized the approach (used by the IWG in measuring the SCC) of linking models together. Linking models together "unavoidably involves the making of model assumptions that can hardly be validated, such as those needed to bridge the mismatches in spatial and temporal scales."[4]

4. Chapman University Researchers have shown that a key ocean current in the Atlantic correlates more with weather in the Southwestern United States much more than the Pacific currents normally thought to influence weather there, thereby undermining assumptions of climate models.[5]

5. Scientists from the Imperial College in London found that climate models have been omitting the massive stocks of carbon in dead trees, resulting in greater carbon sequestration than models assume.[6]

[3] L. Zhou, *et al.*, *On The Incident Solar Radiation In CMIP5 Models*, 42 Geophys. Res. Lett., 1930 (2015), available at http://onlinelibrary.wiley.com/doi/10.1002/2015GL063239/abstract.

[4] Jeroen P. van der Sluijs & J. Arjan Wardekker, *Critical Appraisal Of Assumptions In Chains Of Model Calculations Used To Project Local Climate Impacts For Adaptation Decision Support—The Case Of Baakse Beek*, 10 Envt'l Ressearch Letters 1 (2015), available at http://iopscience.iop.org/1748-9326/10/4/045005/.

[5] Boksoon Myoung, *et al.*, *On The Relationship Between The North Atlantic Oscillation And Early Warm Season Temperatures In The Southwestern US*, __ Am. Meteorological Soc'y __ (ahead of print) (2015), available at http://journals.ametsoc.org/doi/pdf/10.1175/JCLI-D-14-00521.1.

[6] M. Pfeifer, *et al.*, Deadwood biomass: an underestimated carbon stock in degraded tropical forests?, 10 Environmental Research Letters (2015), available at http://iopscience.iop.org/1748-9326/10/4/044019/.

6. A team from the Centre National des Recherches Météorologiques in France adjusted a model in a manner that reflected recent climate evolutions more faithfully, and found that existing models overestimated warming not only from 1998 to 2012 but in previous decades as well.[7]

7. After resolving internal discrepancies in the IPCC's own methodology, researchers from the Science and Public Policy Institute and the Harvard-Smithsonian Center for Astrophysics found that the IPCC's own data, correctly applied, show a much lower rate of warming.[8]

8. A team of researchers from institutions including NASA's Jet Propulsion Laboratory, the University of Reading, and the Georgia Institute of Technology demonstrated that the Earth's albedo (reflectivity) is an inherently stabilizing feedback mechanism that general climate models do not account for properly.[9]

9. Researchers found that current climate models have failed to account for large climate variations in monsoons which leads to "a strong equatorial easterly bias accompanied by a physically consistent bias in the precipitation dipole."[10]

[7] H. Douville, *et al.*, *The Recent Global Warming Hiatus: What Is The Role Of Pacific Variability?*, 42 Geophys. Research Letters 880-88 (2015), available at http://onlinelibrary.wiley.com/wol1/doi/10.1002/2014GL062775/full.

[8] Christopher Monckton, *et al.*, *Why Climate Models Run Hot: Results from an Irreducibly Simple Climate Model*, 60 Sci. Bull. 122 (2015), available at http://wmbriggs.com/public/Monckton.et.al.pdf.

[9] Graeme L. Stephens, *et al.*, *The Albedo of Earth*, 53 Rev. Geophys. (2015), available at http://webster.eas.gatech.edu/Papers/albedo2015.pdf.

[10] Li, G., Xie, S.-P. and Du, Y. 2015. Climate model errors over the South Indian Ocean thermocline dome and their effect on the basin mode of interannual variability. Journal of Climate 28: 3093-3098.

10. Researchers found that climate models have failed to produce correct results in temperature data or prediction data, because "most models fail to produce the sign of the relationship between [the] shortwave cloud radiative effect and temperature advection."[11]

11. Researchers analyzed whether climate prediction models have improved over time, but found that "the results have not been encouraging," and condemned as irredeemable the fact that "the constraint of the coupled ocean-atmosphere variability will still be a basic limitation on prediction skill."[12]

12. Researchers analyzing CAM5 found that the data hold significant bias that "may result from excessive shallow convection behavior in CAM5," proving that the model errors and deficiencies lead to incorrect results.[13]

13. Climate models are still unable to resolve fundamental obstacles. "[T]he poor ability of climate models in simulating the coupling between the winter atmosphere and preceding summer SST remains an obstacle in predicting the climate variability over the North Atlantic." The researchers went further to condemn climate modeling sciences, finding that "it remains a great challenge to improve model ability in simulating and predicting the North Atlantic climate variability."[14]

[11] Myers, T.A. and Norris, J.R. 2015. On the relationships between subtropical clouds and meteorology in observations and CMIP3 and CMIP5 models. Journal of Climate 28: 2945-2967.

[12] Kumar, A. and Wang, H. 2015. On the potential of extratropical SST anomalies for improving climate predictions. Climate Dynamics 44: 2557-2569.

[13] Wang, C.-C., Lee, W.-L., Chen, Y.-L. and Hsu, H.-H. 2015. Processes leading to Double Intertropical Convergence Zone bias in CESM1/CAM5. Journal of Climate 28: 2900-2915.

[14] Yang, Y. and Wu, L. 2015. Changes of air-sea coupling in the North Atlantic over the 20th century. Advances in Atmospheric Sciences 32: 445-456.

14. Researchers added to the uncertainty of climate models by finding that in Arctic climate projections, "most of the CMIP3/5 models have negative biases" which would mean climate projections are not assuming the cold temperature variables added by the Arctic.[15]

15. Researchers analyzed the CMIP5 models compared to CMIP3 results and found that current model features "lead to unrealistic climatic impacts," demonstrating that there is a significant "common bias in coupled general circulation models."[16]

16. Researchers studying new "bias correction methods" to determine if the new models had corrected previous biases found that "the typical 10 to 20% projected precipitation change in many impact studies ... is possibly of the same magnitude as the uncertainty error brought in by the assumption of bias stationarity." In other words, the bias corrections fall prey to the same bias problems as the models they are attempting to correct.[17]

17. A study of most current models used to analyze climate change (CMPI5), found that "the double intertropical convergence zone (ITCZ) bias still affects all the models that participate in CMIP5." This means "overestimated ascending regimes suggest that

[15] Nishii, K., Nakamura, H. and Orsolini, Y.V. 2015. Arctic summer storm track in IP3/5 climate models. Climate Dynamics 44: 1311-1327.

[16] Gong, H., Wang, L., Chen, W., Nath, D., Huang, G. and Tao, W. 2015. Diverse influences of ENSO on the East Asian-Western Pacific winter climate tied to different ENSO properties in CMIP5 models. Journal of Climate 28: 2187-2202.

[17] Chen, J., Brissette, F.P. and Lucas-Picher, P. 2015. Assessing the limits of bias-correcting climate model outputs for climate change impact studies. Journal of Geophysical Research Atmospheres 120: 1123-1136.

processes inhibiting deep convection (e.g. convective entrainment, downdrafts and large-scale subsidence) are still poorly represented in CMIP5 models."[18]

18. Climate models are not taking into account the major component of the rainfall and monsoon effects, which proves that "further diagnostic work on the relationship between snow and SASM [South Asian Summer Monsoon] in CMIP5 is clearly required."[19]

19. Researchers concluded that "most climate models fail to reproduce the observed seasonal cycle," which demonstrates that there is a "warm SST bias" significantly overestimating climate impacts.[20]

20. Researchers assessed the Asia Pacific Economic Cooperation Climate Center global climate models and found that "atmospheric chaotic dynamics uncertainties in the representation of unresolved sub-grid scales in the models may cause large bias in the models" and even worse they found that "these spreads were as large as the spread of ensemble means of different models."[21]

[18] Oueslati, B. and Bellon, G. 2015. The double ITCZ bias in CMIP5 models: interaction between SST, large-scale circulation and precipitation. Climate Dynamics 44: 585-607.

[19] Li, R., Lu, S., Han, B. and Gao, Y. 2015. Connections between the South Asian Summer Monsoon and the tropical sea surface temperature in CMIP5. Journal of Meteorological Research 29: 106-118.

[20] Zhang, L., Wang, C., Song, Z. and Lee, S.-K. 2014. Remote effect of the model cold bias in the tropical North Atlantic on the warm bias in the tropical southeastern Pacific. Journal of Advances in Modeling Earth Systems 6: 1016-1026.

[21] Singh, U.K., Singh, G.P. and Singh, V. 2015. Simulation skill of APCC set of global climate models for Asian summer monsoon rainfall variability. Theoretical and Applied Climatology 130: 109-122.

21. After conducting a "detailed comparison" of CMIP5 models, an international research team found that "there was considerable spread among the models" and "the models were found to have excessive seasonal variability relative to the observations."[22]

22. Models are unable to accurately simulate major ocean currents that are central to climate mechanisms:

- Atlantic Meridional Overturning[23]
- Pacific Decadal Oscillation[24]
- El Niño Southern Oscillation[25]

Q: Dr. Dessler argues that your critique of climate models as running 2-3 times faster than observations is without support. How do you respond?

A: He is factually incorrect. Even the graph cited by Dr. Dessler (Rebuttal at 24 (Fig. 6)) fails to prove his point. A close look at the right-hand edge of the graph shows observed data running substantially lower than models from about 2000 onward.

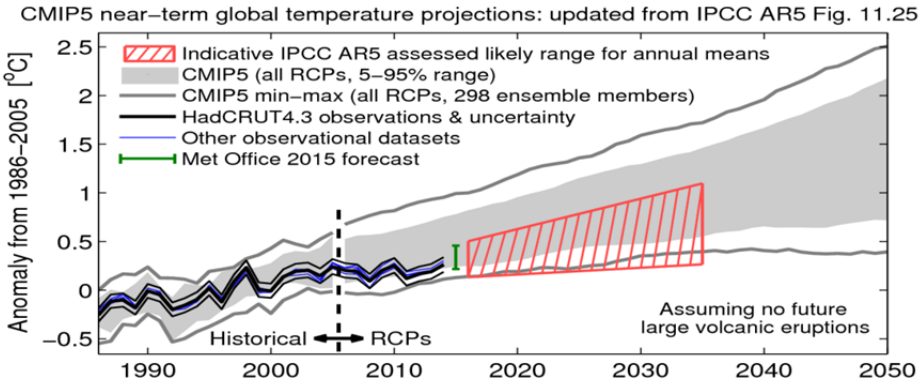
The IPCC Fifth Assessment Report compares climate model simulations with the recent historical temperature record. An updated version of that figure (with more recent observations) is provided by IPCC author Ed Hawkins (http://www.climate-lab-book.ac.uk/comparing-cmip5-observations/):

[22] Ao, C.O., Jiang, J.H., Mannucci, A.J., Su, H., Verkhoglyadova, O., Zhai, C., Cole, J., Donner, L., Iversen, T., Morcrette, C., Rotstayn, L., Watanabe, M. and Yukimoto, S. 2015. Evaluation of CMIP5 upper troposphere and lower stratosphere geopotential height with GPS radio occultation observations. Journal of Geophysical Research: Atmospheres 120: 1678-1689.

[23] Keenlyside, N.S., M. Latif et al (2008) Advancing decadal-scale climate prediction in the North Atlantic sector. Nature, 453, doi:10.1038/nature06921.

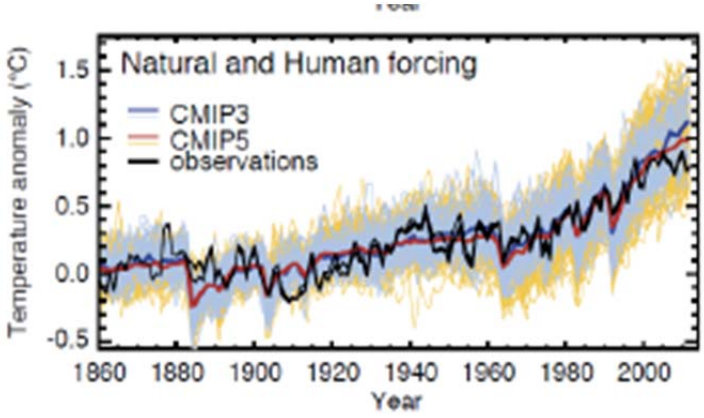
[24] Furtado, J.C., E. DiLorenzo et al (2011) North Pacific Decadal Variability and Climate Change in the IPCC AR4 Models. J. Clim., 24, 3049-3067, DOI: 10.1175/2010JCLI3584.1.

[25] Jin, Emilia K., J. L. Kinter III et al (2008) Current status of ENSO prediction skill in coupled ocean–atmosphere models. Clim Dyn (2008) 31:647–664, DOI 10.1007/s00382-008-0397-3.



The observed global temperatures, particularly since 2011, are below or just at the bottom bound of the 5-95% envelope of the CMIP5 climate model simulations. Overall, the trend in the model simulations is substantially larger than the observed trend over the past 15 years. Note the hatched red area: the IPCC cites "expert judgment" as the rationale for lowering the projections (indicated by the red hatching), to account for the apparent oversensitivity of the models.

Nor have the models been able to simulate the 20th century historical record. Figure FAQ10.1 from the IPCC AR5 (also included in Dessler's testimony as Figure 6) shows:



The climate model simulations (CMIP3, CMIP5) do not reproduce the strong warming trend from 1910-1945, nor do the climate models reproduce the cooling from 1945- 1970, nor do

climate models reproduce the flat temperature trend in the 21st century. The only feature that the climate models accurately simulate is the warming in the last quarter of the 20th century — and as the edge of the graph shows that accord is falling apart.

Dr. Dessler remarks on the importance of short-term variability in comparing climate models with observations. Dr. Dessler argues that adjusting the model simulations to match short-term variability is needed for a robust comparison. (Dessler Rebuttal at 25:5-15). This argument serves to highlight the fact that the models do not reproduce natural variability. Indeed, I note that Dr. Dessler states that "the models assumed incorrect 'forcing' over the last decade," which "causes the models to run 'hot.'" (*Id.* at 25:16-18.) That is an admission that they have over-predicted warming.

Dr. Dessler also raises the issue of accuracy in external forcing. However, the greatest uncertainty in external forcing is aerosol forcing (IPCC AR5 Chapter 3); recent research by Stevens (2015) argues that aerosol forcing is substantially smaller than that used in CMIP5 simulations. Because of the cooling effect of aerosols, reducing aerosol forcing will increase further the discrepancy between models and observations during the hiatus period.[26]

II. Climate Science

A. The "Iris" Effect

Q: What is the "Iris effect"?

A: As described in my opening testimony (at 5:18-22), the "Iris effect" is a natural negative feedback: increased warming leads to reduced cirrus cloud coverage, which in turn

[26] Stevens, B 2015: Rethinking the lower bound on aerosol radiative forcing. J. Climate, 48, 4794-4819 http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-14-00656.1.

allows more infrared radiation (heat) to escape back out into space. This escaped heat, in turn, reduces the rate of temperature increases on Earth.

Q: Has the "Iris effect" been the subject of scholarly debate?

A: Yes it has.

Q: Has the "Iris effect" been disproven or discredited?

A: No. Dr. Abraham's recitation of papers disagreeing with it is based on not a full review of the literature but on his own paper (cited as "Abraham 2014b," seemingly itself from the non-peer-reviewed journal *Cosmopolis*) that simply narrates the succession of papers—it does not grapple with the content of those papers or assess the actual arguments. The fact that it was co-authored with members of advocacy groups indicates that it may have been selective in the papers it discusses.

Dr. Abraham's article does not note the following:

- Responses to articles are normally published as letters, permitting rapid response from the original author. These responses were published as articles, preventing timely response. Abraham failed to cite responses by me and my co-authors – primarily Ming-Da Chou, one of the leaders in radiative transfer theory for both models and satellite retrievals. These responses include:
    - Chou, M.-D. and R.S. Lindzen (2002) Comments on "Tropical convection and the energy balance of the top of the atmosphere." J. Climate, 15, 2566-2570.
    - Chou, M.-D. and R.S. Lindzen (2005) Comments on "Examination of the Decadal Tropical Mean ERBS Nonscanner Radiation Data for the Iris Hypothesis". J. Clim. 18, 2123-2127.

- Chou, M.-D., R.S. Lindzen, and A.Y. Hou (2002a) Impact of Albedo Contrast between Cirrus and Boundary-Layer Clouds on Climate Sensitivity. Atmospheric Chemistry and Physics, 2, 99-101.
- Chou, M.-D., R.S. Lindzen, and A.Y. Hou (2002b) Comments on "The Iris hypothesis: A negative or positive cloud feedback?" J. Climate, 15, 2713-2715.
- Lindzen, R.S., M.-D. Chou, and A.Y. Hou (2002) Comments on "No evidence for iris." Bull. Amer. Met. Soc., 83, 1345–134.

- I responded to the Hartmann and Michelsen (2002) paper in peer-reviewed literature.[27] That paper and others mischaracterized our method, claiming a process that we showed did not apply.
- Once normalized to distinguish between cloud cover from cloud cover per unit cumulus, the DelGenio and Kovari (2002) paper actually finds a *stronger* Iris effect than originally expected.[28]
- Trenberth and Fasullo (2009) was not actually a critique, as Dr. Abraham asserts. The paper mentions that *other* articles critique the Iris effect, but the paper's findings are actually consistent with the Iris effect.[29]

The literature shows no disproof of the Iris effect, only unsupported claims that it has been disproven.

[27] Lindzen, R.S., M.-D. Chou, and A.Y. Hou (2002) Comments on "No evidence for iris." *Bull. Amer. Met. Soc.*, **83**, 1345–1348.

[28] Rondanelli, R.F. and R.S. Lindzen (2008) Observed variations in convective precipitation fraction and stratiform area with SST. *J. Geophys. Res.***113**, D16119, doi:10.1029/2008JD010064; Del Genio, A.D., and W. Kovari, 2002 Climatic properties of tropical precipitating convection under varying environmental conditions. *J. Climate*, **15**, 2597-2615.

[29] Kevin E. Trenberth and John T. Fasullo, *Global Warming Due to Increasing Absorbed Solar* Radiation, 36 Geophys. Rsch. Letters 1, 4 (2009).

Contrary to Abraham's assertions, the most recent science confirms that he is wrong to dismiss the Iris effect. Research from the Max Planck Institute for Meteorology continues to imply the existence of the Iris effect. Taking account of the Iris effect moves climate models closer to observed temperatures and suggests that a low-end climate sensitivity value of 1.5 °C is likely correct.[30] The Iris effect was even a topic of discussion at the recent Ringberg15 conference, hosted by the Max Planck Institut für Meteorologie as part of the World Climate Research Programmes "Grand Challenge" Workshops, which Dr. Dessler attended.

Q: What was on the program at Ringberg 15?

A: The description of the workshop itself notes "contradictory lines of evidence."[31] Prof. Dessler is listed as an attendee, so should be well aware of these "contradictory lines of evidence." One of the papers published on the conference website (and supposedly presented there) explicitly reconsidered my "Iris" theory as a potential negative feedback reducing ECS.[32] Even one of the papers supporting a higher ECS said unequivocally: there is "[o]bservational evidence for an Iris effect"[33] but disagreed over whether it had a negative feedback effect.

B. Climate Sensitivity ("ECS")

[30] Thorsten Mauritsen & Bjorn Stevens, *Missing Iris Effect As A Possible Cause Of Muted Hydrological Change And High Climate Sensitivity In Models*, 8 Nature Geosci. 346 (April 20, 2015), available at http://www.nature.com/ngeo/journal/v8/n5/full/ngeo2414.html.

[31] Max Planck Institut für Meteorologie, "Ringberg 2015," available at http://www.mpimet.mpg.de/en/science/the-atmosphere-in-the-earth-system/ringberg-workshop/ringberg-2014.html.

[32] Bjorn Stevens, *et al.*, "Report from a Workshop Held on 23-27 March 2015, Schloss Ringberg, Germany," 15 (Appendix B (Thorsten Mauritsen, "What if Earth Had an Adaptive Iris?")) (May 19, 2015), available at http://www.mpimet.mpg.de/fileadmin/atmosphaere/WCRP_Grand_Challenge_Workshop/Ringberg_2015/Ringberg2015_Final_WEB.pdf.

[33] Sandrine Bony, Presentation, "Do Climate Models Over-Estimate Cloud Feedbacks?," at 9 (Mar. 23-27, 2015), available at http://www.mpimet.mpg.de/fileadmin/atmosphaere/WCRP_Grand_Challenge_Workshop/Ringberg_2015/Talks/Bony_26032016.pdf.

Q: Dr. Abraham states that you and Dr. Spencer "rely heavily upon [your] own research which has been found to be faulty by [your] peers and in the peer-reviewed literature." Do you cite to other sources?

A: I do. Dr. Abraham fails to assess the quality of much of the evidence I cited, both peer-reviewed and non-peer-reviewed, cherrypicking only a few to criticize. My opening testimony cited to:

- Lewis, N. 2013. An objective Bayesian, improved approach for applying optimal fingerprint techniques to estimate climate sensitivity. *Journal of Climate*, doi:10.1175/JCLID1200473.1.
- Lewis, N. and M. Crok, 2014, *A Sensitive Matter: How The IPCC Buried Evidence Showing Good News About Global Warming*, Global Warming Policy Foundation Report No. 13, 65 pp. http://www.thegwpf.org/content/uploads/2014/02/A-Sensitive-Matter-Foreword-inc.pdf.
- Lewis, N. and J.A. Curry, C., 2014. The implications for climate sensitivity of AR5 forcing and heat uptake estimates. *Climate Dynamics*, 10.1007/s003820142342y.
- Annan, J.D., and J.C Hargreaves, 2011. On the generation and interpretation of probabilistic estimates of climate sensitivity. *Climatic Change*, 104, 324436.
- Ring, M.J., et al., 2012. Causes of the global warming observed since the 19th century. *Atmospheric and Climate Sciences*, 2, 401415, doi: 10.4236/acs.2012.24035.
- Aldrin, M., et al., 2012. Bayesian estimation of climate sensitivity based on a simple climate model fitted to observations of hemispheric temperature and global ocean heat content. *Environmetrics*, doi: 10.1002/env.2140.

- Stevens, B.J., 2015, Rethinking the lower bound on aerosol radiative forcing, *Journal of Climate*, doi: 10.1175/JCLI-D-14-00656.1.

In my discovery responses included with my rebuttal, omitting the list above and my own publications, I cite to:

- J. C. Fyfe, N. P. Gillett, F. W. Zwiers, Overestimated Global Warming over the Past 20 Years, 3 Nature Climate Change 767 (2013).
- Nicholas Lewis, "The implications for climate sensitivity of Bjorn Stevens' new aerosol forcing paper," Mar. 15, 2015, http://climateaudit.org/2015/03/19/the-implications-for-climatesensitivity-of-bjorn-stevens-new-aerosol-forcing-paper/.
- Thorsten Mauritsen & Bjorn Stevens, "Missing Iris Effect as a Possible Cause of Muted Hydrological Change and High Climate Sensitivity in Models," __ Nature Geosci. __ (Apr. 20, 2015) (advance online publication), available at http://www.nature.com/ngeo/journal/vaop/ncurrent/full/ngeo2414.html.
- Peter Stott, *et al.*, The Upper End of Climate Model Temperature Projections is Inconsistent with Past Warming, 8 Envir. Res. Letters (pub. online, Feb. 19, 2013), available at http://iopscience.iop.org/1748-9326/8/1/014024/pdf/1748-9326_8_1_014024.pdf.

Q: Is there a reason a scientist should not cite to his or her own work?

A: No. Part of scientific progress is building on the work one has already accomplished.

Q: How recent is the science the IWG relies on?

A: It is hopelessly out of date. The IWG is still relying on climate sensitivity values from IPCC's AR4 (2007). Even on Dessler's own terms, the IWG's SCC is fatally out-of-date.

The 2010 TSD explicitly drew its ECS figures from AR4, drafted in 2007 (2°C to 4.5°C, with a "best estimate" of 3.0°C).[34] The 2013 TSD declined to revisit the ECS question in any of the three revisions (May 2013, November 2013, and July 2015).[35]

In the meantime, *even the IPCC* has lowered its numbers *and its confidence*. AR4 stated that the ECS was "very unlikely" to be less than 1.5 °C,[36] but AR5 gave 1.5 °C as the low end of the "likely" range[37] with "high confidence."[38] AR5 also declined to determine a "best estimate," while AR4 gave 3 °C,[39] which is the exact value assumed by the IWG's 2010 TSD.[40] The stated reason for not citing a best estimate in the AR5 was the substantial discrepancy between observation-based estimates of ECS (lower), versus estimates from climate models (higher). Hence the AR5 reflects a tendency towards lower values of the ECS than the AR4. 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. Nevertheless, despite the fact that this science had been known for months before its July 2015 revision, the IWG refused to revisit ECS.

[34] Interagency Working Group on the Social Cost of Carbon, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866* at 12-13 (February 2010) [hereafter, "2010 TSD"]. The 2010 TSD was updated in May 2013 and then revised in November 2013 based on two corrections. Interagency Working Group on the Social Cost of Carbon, *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866* App. B at 22 (May 2013, rev. Nov. 2013, 2d rev. Jul. 2015) [hereafter, "2013 TSD"]. Unless specifically noted, citations are to the July revision, the most recent.

[35] 2013 TSD at 2. The statement is the same in all three revisions.

[36] Intergovernmental Panel on Climate Change, *AR4 Synthesis Report* at 38 (2008) [hereafter, "AR4"].

[37] Intergovernmental Panel on Climate Change, *AR5 Synthesis Report* at 62 (2014) [hereafter, "AR5"].

[38] Intergovernmental Panel on Climate Change, Working Group I, *Climate Change 2013: The Physical Science Basis* at 83 (Box 12.2) [hereafter, "AR5/WG 1"].

[39] AR4 at 38.

[40] 2010 TSD at 12-13.

Q: Is there any other evidence the IWG should have taken into account?

A: Yes. Beyond the IPCC, 14 studies and 20 experiments validated a lower, tighter range for ECS between the 2010 TSD and the 2013 update to the TSD. The 2013 TSD ignored all of those studies, and the July 2015 revision reaffirmed the decision to ignore the most recent peer-reviewed science, including:

- Updated data from Nicholas Lewis, who has published papers (both as sole author and jointly with IPCC contributors) cited by the IPCC in its latest report, validate his and Judith Curry's finding of climate sensitivity value of 1.64.[41] (This assumes IPCC figures for ocean heat accumulation are correct. If those figures are an overestimate, then the proper climate sensitivity value could be even lower.)
- Researchers from Chalmers University of Technology found that recalculating the equilibrium climate sensitivity after taking full account of the hiatus in warming resulted in a 90% probability that the correct value was 2°C.[42]
- A March 2015 report by 13 esteemed scientists (including the Assistant Director of Programs, Science and Technology Policy at the United States Department of the Interior) explained that "[t]he temperature is virtually unchanged from that at the beginning of the century. . . . [T]he question is not about warming per se but about how much warming there will be compared to natural variability. The available evidence is

[41] Nicholas Lewis, *Implications Of Recent Multimodel Attribution Studies For Climate Sensitivity*, 44 Climate Dynamics (May 28, 2015), available at DOI: 10.1007/s00382-015-2653-7.

[42] Daniel J.A. Johansson, *et al.*, *Equilibrium Climate Sensitivity In Light Of Observations Over The Warming Hiatus*, 5 Nature Climate Change 449-453 (2015), available at http://www.nature.com/nclimate/journal/v5/n5/full/nclimate2573.html.

entirely consistent with the answer 'not much."[43] "The relation of other observations such as sea-level rise, Artic sea ice extent and ocean heat content all depend on more factors than global mean temperature, and are hardly incontrovertible evidence of warming."[44]

In addition, these publications since the May 2013 revision of the TSD validate a lower ECS:

- Skeie, R. B., T. Berntsen, M. Aldrin, M. Holden, and G. Myhre, 2014. A lower and more constrained estimate of climate sensitivity using updated observations and detailed radiative forcing time series. Earth System Dynamics, 5, 139–175.
- Masters, T., 2013. Observational estimates of climate sensitivity from changes in the rate of ocean heat uptake and comparison to CMIP5 models. Climate Dynamics, doi:101007/s00382-013-1770-4.
    - Dr, Masters also published a prior paper[45] which showed important errors in Dr. Dessler's work attempting to determine cloud radiative forcing.[46]
- Alexander Otto, et al., Energy Budget Constraints on Climate Response, __ Nat. Geosci. __ (advance online publication, May 19, 2013), available at http://www.iac.ethz.ch/people/knuttir/papers/otto13nat.pdf.

[43] Prof. Robert Carter, Prof. Ross McKitrick, Prof. Vincent Courtillot, Prof. Ian Plimer, Prof. Freeman Dyson, Dr. Matt Ridley, Prof. Christopher Essex, Sir Alan Rudge, Dr. Indur Goklany, Prof. Nir Shaviv, Prof. Will Happer, Prof. Fritz Vahrenholt, Prof. Richard Lindzen, "The Small Print: What The Royal Society Left Out" 1, 8 (Global Warming Policy Foundation March 2015) [hereafter, "What the Royal Society Left Out"].

[44] *Id.* at 1.

[45] Masters, T, On the determination of the global cloud feedback from satellite measurements. Earth Syst. Dynam. Discuss., 3, 73–90, 2012.

[46] *Id.* at 77-78 (noting that "there are significant issues with this approach," including "questionable modeling" and "several problems with the snow analysis that regulates interannual surface albedo changes").

- Magne Aldrin, et al., Bayesian Estimation of Climate Sensitivity Based on a Simple Climate Model Fitted to Observations of Hemispheric Temperatures and Global Ocean Heat Content, 23 Envirometrics 253 (May 2012), available at http://www.researchgate.net/publication/260740743_Bayesian_estimation_of_climate_sensitivity_based_on_a_simple_climate_model_fitted_to_observations_of_hemispheric_temperatures_and_global_ocean_heat_content.
- Steven E. Schwartz, et al., Earth's Climate Sensitivity: Apparent Inconsistencies in Recent Assessments, 2 Earth's Future 601 (Dec. 8, 2014).

Q: Is the argument for a low ECS value outside the mainstream of science, as Drs. Dessler and Abraham imply?

A: No. The argument for low ECS is hardly outside of the mainstream. Indeed, in the IPCC's own report, 11 out of 19 observational studies of ECS had ranges that included 1.5 °C.[47] ECS was the chief subject at the Ringberg15 Conference, hosted by the Max Planck Institute.

C. <u>Warming Hiatus and Karl et al./NOAA Data</u>

Q: Drs. Dessler and Abraham suggest that you believe that the climate stopped changing over the past two decades. Is that true?

A: That is a straw man. Nowhere have I suggested that climate has stopped changing. To the contrary, one constant on Earth is an ever-changing climate. Rather, I have stated that there has been no statistically significant atmospheric temperature increase for the past 18 years.

On that score, Dr. Dessler concedes that "Dr. Spencer is correct: beginning around 2000, the uncertainty in the trend expands and begins to encompass zero. Thus, it is correct to say that there has been no statistically significant warming since 2000." (Dessler Rebuttal Testimony at

[47] AR5/WG1 at 83 (Box. 12.2 (Fig. 1)).

15:5-7.) Even the IPCC has accepted a "hiatus" in warming, which reflects a substantial slowdown in the rate of warming relative to the last quarter of the 20th century. The hiatus in global warming is discussed in the IPCC AR5 report: "[T]he rate of warming over the past 15 years (1998–2012) [is] 0.05 [–0.05 to 0.15] °C per decade, which begins with a strong El Niño, is smaller than the rate calculated since 1951 (1951–2012) [of] 0.12 [0.08 to 0.14] °C per decade."[48]

Q: What about ocean heat content? Drs. Dessler and Abraham claim that there is evidence that the oceans are warming. How do you respond?

A: Regarding upper ocean heat content, Abraham cherry picks a single analysis (NODC) and Dessler uses a model of ocean heat content (Balmaseda et al. 2013) from the European Centre for Medium-Range Weather Forecasts (ECMWF) ocean data assimilation model experiment. The IPCC AR5 Working Group I analysis of upper ocean heat content (Figure 3.2, p. 262) shows that some datasets show a hiatus in warming in the upper 700 m of the ocean since 2003, whereas others show continued warming. An updated summary of upper ocean heat content changes is provided in papers by Durack et al. (2014),[49] Llovel et al. (2014),[50] Lyman (2014),[51] Nieves et al. (2015)[52] and Wunsch and Heimbach (2014).[53] A summary conclusion

[48] AR5 at 40.

[49] Quantifying underestimates of long-term upper-ocean warming. Paul J. Durack, Peter J. Gleckler, Felix W. Landerer and Karl E. Taylor Nature Climate Change DOI: 10.1038/NCLIMATE2389.

[50] Deep-ocean contribution to sea level and energy budget not detectable over the past decade W. Llovel, J. K. Willis, F. W. Landerer & I. Fukumori Nature Climate Change 4, 1031–1035 (2014) doi:10.1038/nclimate2387.

[51] John M. Lyman and Gregory C. Johnson, 2014: Estimating Global Ocean Heat Content Changes in the Upper 1800 m since 1950 and the Influence of Climatology Choice*. *J. Climate*, **27**, 1945–1957. doi: http://dx.doi.org/10.1175/JCLI-D-12-00752.1.

[52] Recent hiatus caused by decadal shift in Indo-Pacific heating (http://www.nature.com/nclimate/journal/v5/n5/full/nclimate2573.html).

[53] Bidecadal thermal changes in the abyssal ocean, available at http://ocean.mit.edu/~cwunsch/papersonline/heatcontentchange_26dec2013_ph.pdf.

from these recent analyses is that there has been a flattening or slight cooling of the upper 100 meters since 2004, and temperatures in the upper 300 meters have flattened or cooled since 2003. Analyses of heat content for the upper 700 m continue to disagree, and there are substantial regional variations in the vertical distribution of upper ocean heating/cooling. Changes in the heat content of the upper 700 m could just as well be due to ocean circulations coupling this layer with deeper layers.

Dr. Dessler raises the issue of deep ocean heat content (below 700 m), particularly in Figure 3 from his testimony, which illustrates a model data assimilation experiment using the ECMWF ocean analysis system showing striking ocean warming particularly below 2000 m. This analysis is not an observational data set, but rather a model simulation that has incorporated data. Note that there is virtually no data below 700 m for most of the period, and there is a meaningful amount of data down to 2000 m only since 2005; hence the simulation reflects the model physics.

Dr. Dessler's projection is inconsistent with observational evidence for deep ocean *cooling* since 2005, as presented in recent papers: Llovel et al. (2014), Wunsch and Heimbach (2014), and Nieves et al. (2015). In brief, the new Argo data is providing important new information regarding ocean heat content since 2005; these sensors are continuing to be calibrated and new analyses continue to emerge. Prior to 2005, it is not possible to determine which (if any) of the competing analyses of upper 700 m heat content is correct. Prior to 2005, there is insufficient data to make any credible statements about deep ocean heating; since 2005 the data shows deep ocean cooling.

Q. Dr. Dessler says that a smaller trend over a decade or so does not tell us much about the long-term trajectory of the climate. How do you respond?

A. Dr. Dessler's statement misses the real implication of decadal and multi-decadal variability. Globally, temperatures have increased for the past three centuries. It is only the warming since 1950 that is attributed by the IPCC to humans, and the post-1950 warming didn't begin until 1976 (the period from 1945 to 1975 was a period of slight cooling). Hence the observed warming period from 1976 to 1998 is only slightly longer than the recent hiatus period since 1998. Further, as discussed in my direct testimony, the warming from 1905-1940 is of the same magnitude of the warming since 1976. This evidence provides little basis for concluding that climate variability on multidecadal time scales is caused by humans as opposed to natural variability.

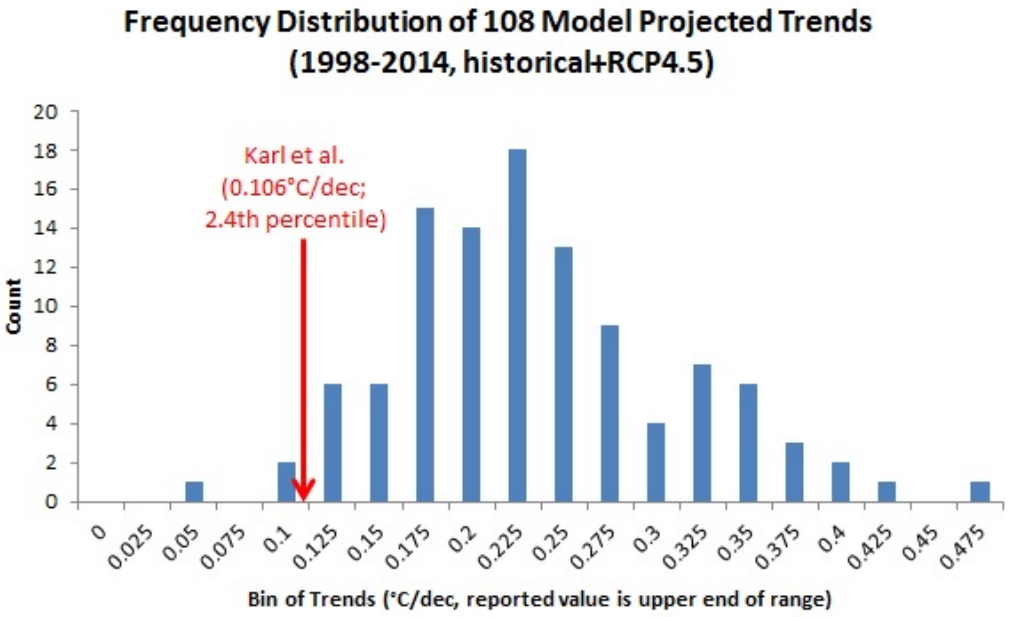
Q: Dr. Abraham points to very recent studies proving there has been warming, such as Karl el al. 2015. Do you agree with those studies?

A: No. I have already explained why the Karl et al. paper[54] is faulty. My rebuttal report (Lindzen Rebuttal, Ex. 1 (Report) at 3:33-5:71) describes how Karl had to "adjust" the data in order to eliminate the hiatus, such as boosting accurate surface buoy readings to homogenize them with temperatures taken from engine intake channels, which are known to be too hot. Karl also cherry-picks start and end dates in order to create his trends. I expand on those criticisms below.

Q: Does the Karl et al. paper show warming consistent with climate models?

[54] Thomas R. Karl, *et al.*, *Possible Artifacts Of Data Biases In The Recent Global Surface Warming Hiatus*, 348 Science 1469 (June 26, 2015), DOI: 10.1126/science.aaa5632, available at http://www.sciencemag.org/content/early/2015/06/05/science.aaa5632.abstract.

A: No. Even at face value, the Karl paper does not salvage the predictions of climate models. Climate models consistently run much hotter than the slight warming trend purportedly identified in the Karl paper, as the following chart shows:[55]



In other words, the vast majority of climate models predict substantially more warming than the relatively tiny amount supposedly identified by the Karl paper. The models on which the SCC relies would still be significantly inaccurate and flawed, even assuming the conclusions of the Karl paper were valid.

Q: Is the Karl et al. paper methodologically consistent with climate models?

A: No. One of the effects of the paper's adjustments is to raise the reported global temperatures in the late 19th and early 20th centuries, making the warming of the 20th century smaller and reducing the rate of change at precisely time when man-made CO_2 emissions were increasing the fastest. Russell Vose, a co-author of the Karl paper, explained that "[o]ur

[55] Richard Lindzen, Patrick J. Michaels, and Paul C. Knappenberger, Is There No "Hiatus" in Global Warming After All?, Cato Institute Blog, June 4, 2015, available at http://www.cato.org/blog/there-no-hiatus-global-warming-after-all.

corrections lower the rate of warming on a global scale."[56] The models on which the SCC rests point in precisely the opposite direction. The Karl et al. paper relies on shifts to the basic understanding of climate that the climate models presume is true.

Q: Did the Karl et al. paper rely on strong data?

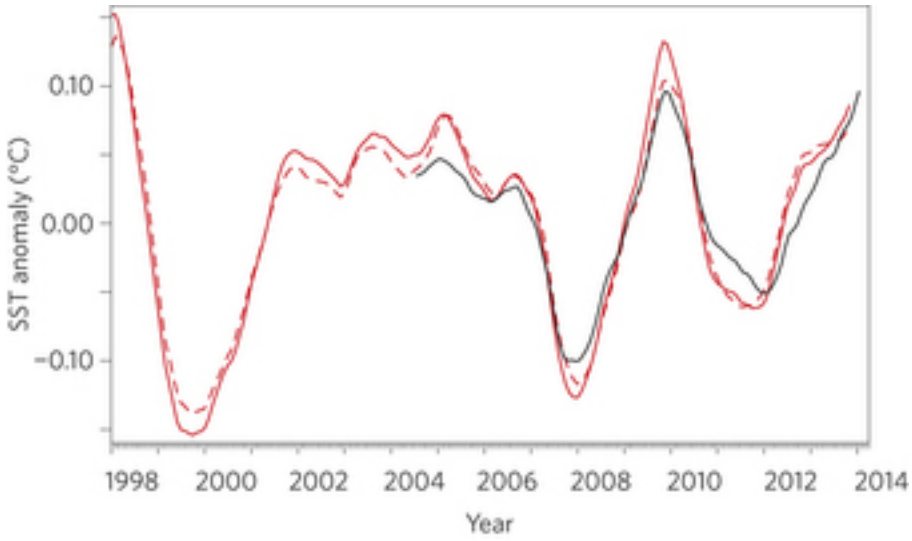
A: No. It uses a suboptimal dataset for sea surface temperatures. It chose not to use the "gold standard" for global ocean surface temperatures, which is a UK dataset known as "HadSST3." As Judith Curry commented, "I personally see no reason to the use the NOAA ERSST dataset, I do not see any evidence that the NOAA group has done anywhere near as careful a job as the UK group in processing the ocean temperatures."[57]

The Karl paper also declined to use data from Argo, a system of more than 3,000 free-drifting buoys that measure the temperature and salinity of the upper 2000 meters of the ocean. The Karl paper justified its disregard of Argo temperature data on the ground that it is not sea-surface data. But the Karl paper did consider ship-derived temperatures (which can be from as much as 15 meters below the surface), and the Argo array measures temperatures from as little as 5 meters below the surface. The refusal to use Argo data is thus hard to justify, and Argo results likely would have altered the Karl paper's conclusions. From 2004 to 2013, Argo shows temperature fluctuations of 1-2 tenths of a degree but little trend:[58]

[56] "Global Warming 'Hiatus,' Long a Puzzle, Is Challenged by a New Study," N.Y. Times, June 5, 2015, A10.

[57] Judith Curry, "Has NOAA 'busted' the pause in global warming?" June 4, 2015, available at http://judithcurry.com/2015/06/04/has-noaa-busted-the-pause-in-global-warming/.

[58] "Unabated planetary warming and its ocean structure since 2006" Nature Climate Change, 2 February 2015. Black line: 5 m optimally interpolated (OI) ARGO; red lines: NOAA OI SST v2.



An October 2014 NASA study using Argo data found "[t]he cold waters of Earth's deep ocean have not warmed measurably since 2005, … leaving unsolved the mystery of why global warming appears to have slowed in recent years."[59] NASA found that, "[i]n the 21st century, greenhouse gases have continued to accumulate in the atmosphere, just as they did in the 20th century, but global average surface air temperatures have stopped rising in tandem with the gases."[60]

The Karl paper's inconsistency with the most reliable data is striking. As Judith Curry commented, "[t]he greatest changes in the new NOAA surface temperature analysis is to the ocean temperatures since 1998. This seems rather ironic, since this is the period where there is the greatest coverage of data with the highest quality of measurements – ARGO buoys and satellites don't show a warming trend."[61]

Q: Can you explain how Karl et al. adjusted the data it used?

[59] "Study Finds Earth's Ocean Abyss Has Not Warmed," Oct. 6, 2014, available at http://science.nasa.gov/science-news/science-at-nasa/2014/06oct_abyss/

[60] *Id.*

[61] Judith Curry, "Has NOAA 'busted' the pause in global warming?" June 4, 2015, available at http://judithcurry.com/2015/06/04/has-noaa-busted-the-pause-in-global-warming/.

A: Karl et al. made 11 adjustments to an existing NOAA set of SST data. Many changes were questionable and effectively guaranteed a statistical warming trend. For example, the paper made an upward adjustment of 0.12 °C in measurements from surface buoys, supposedly to make them "homogeneous" with the longer-running temperature records taken from engine intake channels in marine vessels.[62] This "adjustment" process was arbitrary and biased in favor of warming. Further, it was theoretically unsound. Temperature readings from engine intakes are clearly contaminated by heat conduction from the engine itself and are therefore inappropriate for scientific use.[63] On the other hand, the specific purpose of buoys is environmental monitoring. Adjusting good data (from buoys) upward to match bad data (from engine intakes) seems highly questionable.[64] Moreover, the buoy network has become increasingly dense in the last two decades, and the combination of an increase in the number of buoy measurements and a uniform upward adjustment of 0.12 °C in such measurements effectively manufactures a warming trend in the data.[65]

Q: Buoys can only measure temperatures at discrete points, correct?

A: Yes.

Q: How did Karl et al. fill in the gaps between buoys in order to give a full picture of the surface temperature?

A: Researchers use various methods for interpolation. Karl et al. used temperature readings from Arctic land sources to fill gaps in Arctic Ocean temperature data. Judith Curry observed: "Gap filling in the Arctic is complicated by the presence of land, open water and

[62] Patrick J. Michaels, Richard Lindzen, and Paul C. Knappenberger, Is There No "Hiatus" in Global Warming After All?, Cato Institute Blog, June 4, 2015, available at http://www.cato.org/blog/there-no-hiatus-global-warming-after-all.
[63] *Id.*
[64] *Id.*
[65] *Id.*

temporally varying sea ice extent, because each surface type has a distinctly different amplitude and phasing of the annual cycle of surface temperature. Notably, the surface temperature of sea ice remains flat during the sea ice melt period roughly between June and September, whereas land surface warming peaks around July 1. Hence using land temperatures to infer ocean or sea ice temperatures can incur significant biases."[66] As I and other researchers have noted, "[m]uch of the Arctic Ocean is ice-covered even in high summer, meaning the surface temperature must remain near freezing. Extending land data out into the ocean will obviously induce substantially exaggerated temperatures."[67]

Q: Did the Karl et al. paper use objectively justifiable start and end dates for its analysis?

A: No, the Karl paper cherry-picked start and end dates. The paper starts its trend estimates in 1998 and 2000, which produces a distortion because 1998 was a very strong El Niño year and 1999-2000 was a much cooler La Niña period. Using 2014, which was a warm year for surface temperatures, aggravates the effect. Indeed, including 2013 and 2014 makes the warming trend appear to be 38% larger than previous studies that did not include those two years. The supposed "elimination" of the hiatus, in other words, is largely a product of the selection of certain start and end points to arrive at a particular conclusion.

Q: Does the Karl et al. study invalidate the hiatus?

A: No. It's a flawed study, and other researchers agree that it does not invalidate the hiatus:

[66] "Has NOAA 'busted' the pause in global warming?" June 4, 2015, available at http://judithcurry.com/2015/06/04/has-noaa-busted-the-pause-in-global-warming/.

[67] Richard Lindzen, Patrick J. Michaels, and Paul C. Knappenberger, Is There No "Hiatus" in Global Warming After All?, Cato Institute Blog, June 4, 2015, available at http://www.cato.org/blog/there-no-hiatus-global-warming-after-all.

- Gerald Meehl, a climate researcher at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, explained that, even under the Karl paper's data, there is still a lower warming trend from 1998 to 2012 compared to the previous base period of 1950 to 1999, and thus "there is still a hiatus defined in that way."[68] Meehl stated that "[m]y conclusion is that even with the new data adjustments, there still was a nominal hiatus period that lasted until 2013 with a lower rate of global warming than the warming rate of the last 50 years of the 20th century, and a factor of two slower warming than the previous 20 years from the 1970s to 1990s."[69]
- Dr. Piers Forster, professor of climate change at the University of Leeds, pointed out that "[e]ven with the corrections in this study, the observed warming has not been as large as predicted by models. Other global datasets, even when corrected for missing Arctic data, still show a decreased trend since 1998."[70]
- Lisa Goddard, director of the International Research Institute for Climate and Society (IRI) at Columbia University, commented that Karl and his team "go too far when they conclude that there was no decadal-scale slowdown in the rate of warming globally. This argument seems to rely on choosing the right period — such as including the recent record breaking 2014."[71]

Q: At what level of significance does the Karl et al. paper reports its results?

A: The Karl et al. paper reports its results at a 0.10 significance level.[72]

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[68] Quoted in http://mashable.com/2015/06/04/global-warming-hiatus-study/.
[69] *Id.*
[70] http://phys.org/news/2015-06-global.html
[71] *Id.*
[72] Richard Lindzen, Patrick J. Michaels, and Paul C. Knappenberger, Is There No "Hiatus" in Global Warming After All?, Cato Institute Blog, June 4, 2015, available at http://www.cato.org/blog/there-no-hiatus-global-warming-after-all.

Q: Is that standard?

A: No. Scientific results are usually presented at a 0.05 significance level.

D. The Connection Between Emissions and Concentrations (the Suess Formula)

Q: Dr. Gurney claims to rebut your argument about the relationship between fossil fuel emissions and atmospheric CO_2 levels. Can you explain what the disagreement is about?

A: My testimony questions the connection of fossil fuel emissions to atmospheric CO_2. It is well-known that the fraction of human induced CO_2 is small compared to the total CO_2 in the atmosphere, and natural emission and sink rates are about 20 times greater than anthropogenic emissions. Further, as the accumulation rises, the sink rate is increasing. The CO_2 sinks are not static – they respond systematically to the level of forcing. Dynamic systems analysis versus a simple mass-balance argument accounts for this effect. The sinks respond dynamically to the overall CO_2 concentration in the atmosphere, whether it is due to anthropogenic or natural input. As a result, the simple mass-balance arguments supporting the IPCC conclusions are based on circular reasoning starting with the premise that the increased CO_2 is caused by humans.

Q: Dr. Gurney asserts that the connection between emissions and concentrations of CO_2 are "conclusively established" by measuring the ratio of $^{14}CO_2$, a specific variety of CO_2 with a slightly heavier carbon atom, which could not have been emitted by fossil fuel combustion. Can you explain how that would work?

A: Yes. A variety of CO_2 has a particular isotope of carbon, carbon-14 or ^{14}C, that is not found in fossil fuels because it has a known half-life: by the time a tree has become coal, the

carbon-14 in it is gone. The known half-life and behavior of carbon-14 is the basis for carbon dating.

Q: How is the amount of fossil-fuel-derived CO_2 in the atmosphere measured?

A: There is a well-known amount of $^{14}CO_2$ in the atmosphere. Because fossil fuels do not contain ^{14}C, CO_2 from burning fossil fuels would dilute that known amount of $^{14}CO_2$ with stable CO_2. The ratio between the two forms of CO_2 is known as the Suess Formula (please note the spelling, which Dr. Gurney incorrectly gave as "Seuss").

Q: What did Tans (1979) determine about that ratio?

A: Dr. Gurney questions my statements about the connection between CO_2 emissions and CO_2 concentrations, citing to Tans, et al. (1979).[73] Tans et al. actually found that during an 11-year period (1936-1950), there was an *almost constant level* of ^{14}C despite "a total of 16.6 G ton of carbon from fossil fuels" which was released and "should have resulted in a 4-6% decrease of the atmospheric $^{14}C/C$ ratio during this decade."[74] At best, they argue that "a regional fossil fuel contamination exceeding the global effect *cannot be fully excluded.*"[75]

Tans et al. further find that "Comparing a number of recent [tree] growth rings with direct atmospheric ^{14}C measurements *also does not lead to a definite quantitative conclusion.*"[76] Although Tans, et al., suspected the problem might be local contamination, they concluded: "our

[73] P.P. Tans, *Natural Atmospheric 14C Variation and the Suess Effect*, 280 Nature 826, 827 (Aug. 30, 1979) [hereafter, "Atmospheric Variation"].

[74] *Id.* at 827.

[75] *Id.*

[76] *Id.*

observations of the short term variability of the natural ^{14}C level, however, remain equally valid regardless of the existence of a regional contamination effect."[77]

Moreover, Tans et al. could not find a preindustrial baseline. "Furthermore it is not clear from the measurements which ^{14}C concentration should be chosen as the preindustrial level."[78] Without a known preindustrial baseline, the ratio of CO_2 arising from fossil fuel combustion is hardly "well established."

Q: Is Dr. Gurney correct that the relation of emissions to concentrations is "conclusively established"?

A: No. Dr. Gurney simply asserts, without evidence, that the relationship between emissions and concentrations "is not the outcome of a model but an observed quantity with decades of instrumental support. This instrumental support precludes the notion that something other than fossil fuel CO_2 emissions are driving the secular trend in atmospheric CO_2 levels." (Gurney Testimony 9:11-14.) The only instrumental support he gives – the measurements by Tans et al. (1979) – affirmatively asserts that the measurements do not actually change in the manner theorized, and cannot support a theory by which the percentage of emissions attributable to human fossil fuel combustion could be measured because no baseline could be established.

Q: Do other scientists question the IPCC view?

A: Yes. Numerous recent publications question the IPCC's interpretation of the connection between fossil fuel emissions and atmospheric CO2 content, some of which introduce dynamical systems analysis to address this issue. For example:

[77] *Id.*

[78] *Id.*

- One recent study found that only a very small residual fraction of anthropogenic CO_2 emissions is not captured by carbon sinks and remains in the atmosphere, and further that the anthropogenic CO_2 additional warming extrapolated to the year 2100 was lower than 0.1°C in the absence of feedbacks.[79]
- Another study found that the present anthropogenic CO_2 fraction in the atmosphere is 7.7%, which is substantially smaller than the IPCC's estimate. The study noted: "The IPCC's latest value for the anthropogenic CO_2-percentage in the atmosphere is 28%. This huge gap with the other research results originates from the long residence time calculation method of IPCC."[80]
- Another study found that CO_2 always lags changes in surface temperatures and that changes in atmospheric CO_2 are not tracking changes in human emissions.[81]
- A team of researchers in the U.S. found that "climate models used to predict the rise in CO_2 concentrations in the atmosphere are approximately 17 percent too high because they incorrectly approximate how much CO_2 plants pull from the atmosphere."[82]

[79] Francois Gervais, Tiny warming of residual anthropogenic CO_2. Int J. Mod Phys B, 18, 145095, available at http://www.worldscientific.com/doi/abs/10.1142/S0217979214500957.

[80] Olilla (2015): Anthropogenic CO2 amounts and fluxes between the atmosphere, the ocean and the biosphere. Physical Science International Journal 8(1): 1-17, 2015, Article no.PSIJ.18625, available at http://www.sciencedomain.org/media/journals/PSIJ_33/2015/Jul/Ollila812015PSIJ18625.pdf.

[81] Humlum et al. 2013: The phase relation between atmospheric carbon dioxide and global temperature. Global and Planetary Change, 100, 51-69), available at http://www.sciencedirect.com/science/article/pii/S0921818112001658.

[82] "Study shows increase of CO_2 in the atmosphere is lower than predicted because of plants," http://phys.org/news/2014-10-co2-atmosphere.html. See also Sun et al. 2014: Impact of mesophyll diffusion on estimated global land CO2 diffusion. PNAS, http://www.pnas.org/content/111/44/15774.abstract; High CO_2 spurs wetlands to absorb more carbon: http://phys.org/news/2013-07-high-co2-spurs-wetlands-absorb.html#nRlv; Erickson et al. 2013: Direct and indirect effects of elevated atmospheric CO_2 on net ecosystem production in a Chesapeake Bay tidal wetland. Global Change Biology http://onlinelibrary.wiley.com/doi/10.1111/gcb.12316/abstract.

- Another study found a reverse relationship between atmospheric CO_2 and global temperature: "The primary ingredient of the Anthropogenic Global Warming hypothesis, namely, the assumption that additional atmospheric carbon dioxide substantially raises the global temperature, is studied. This is done by looking at the data of temperature and CO_2, both in the time domain and in the phase domain of periodic data. … These results indicate a reverse function of cause and effect, with temperature being the cause for atmospheric CO_2 changes, rather than their effect. These two hypotheses are discussed on basis of literature, where it was also reported that CO_2 variations are lagging behind temperature variations."[83]
- Another study noted the complex relationship between atmospheric CO_2 and global temperature: "During 1986-2008, the atmospheric CO_2 changed in anti-phase with the global temperature. The phase relationship reversed in 1979 and after 2010. The atmospheric CO_2 was in-phase with the global temperature on the El Niño time scale (2.3 -7 years) except during very strong El Niño years in 1991-1999 when CO_2 led the global temperature."[84]

III. Incidence and Severity of Extreme Events

Q: In general, Drs. Abraham and Dessler show evidence of an increasing number and severity of extreme events (such as forest fires, melting sea ice, storms) that are the

[83] Stallinga and Khmelinskii, 2014: Application of signal analysis to the climate. International Scholarly Research Article ID 161530, available at http://dx.doi.org/10.1155/2014/161530.

[84] Rumzmalkin and Byalko (2015) On the Relationship between Atmospheric Carbon Dioxide and Global Temperature. American Journal of Climate Change, 2015, 4, 181-186. http://www.scirp.org/journal/PaperInformation.aspx?paperID=56384. A similar study is Beenstock, M, Reingewertz, Y, and N Paldor (2012), Polynomial cointegration tests of anthropogenic impact on global warming. Earth Syst Dynam, 3, 173-188, available at http://www.earth-syst-dynam.net/3/173/2012/esd-3-173-2012.html, which found that "greenhouse gas forcing, aerosols, solar irradiance and global temperature are not polynomially cointegrated, and the perceived relationship between these variables is a spurious regression phenomenon."

result of anthropogenic global warming, and suggest that you have selectively chosen data or only examined parts of trends. Do their criticisms have merit?

A: No. Not only are those events not increasing in severity or number, but the evidence tying them to anthropogenic global warming is not credible.

A. Loss of Sea Ice

Q: What does the IPCC say about the loss of sea ice?

A: The IPCC AR5 uses the weasel-word "contributed" when describing the effects of anthropogenic forcings on sea ice. The reason is simple: "Arctic temperature anomalies in the 1930s were apparently as large as those in the 1990s and 2000s."[85] It is important to note, however, that the temperature anomalies in the 1930s would predate the period when warming is supposed to have become anthropogenic.

Q: Is sea ice currently increasing or decreasing?

A: That depends on which part of the trend one examines. When looking at longer cycles, it is more likely increasing. A recent report found that Arctic ice is increasing, not decreasing.[86] Researchers from University College London and the University of Leeds found: "we observe 33% and 25% more ice in autumn 2013 and 2014, respectively, relative to the 2010–2012 seasonal mean, which offset earlier losses. This increase was caused by the retention of thick sea ice northwest of Greenland during 2013 which, in turn, was associated with a 5% drop in the number of days on which melting occurred—conditions more typical of the late 1990s. In contrast, springtime Arctic sea ice volume has remained stable. The sharp increase in sea ice

[85] AR5 WG1, at 907.

[86] Rachel L. Tilling, Andy Ridout, Andrew Shepherd & Duncan J. Wingham, *Increased Arctic Sea Ice Volume After Anomalously Low Melting In 2013*, Nature Geoscience (July 20, 2015), available at http://www.nature.com/ngeo/journal/vaop/ncurrent/full/ngeo2489.html.

volume after just one cool summer suggests that Arctic sea ice may be more resilient than has been previously considered."

Q: Dr. Dessler argued that such a short-term change cannot define a long-term trend. How do you know this is not just an upward blip on a downward graph?

A: A short-term change coupled with a mechanism explaining why it will continue is more likely to turn into a long-term trend. That is what we face when it comes to Arctic ice. A 2014 article by Marcia Wyatt and Judith Curry provides a mechanism for understanding why it is the beginning of a long-term increase that will peak around 2040: a "stadium wave"-shaped oscillation propagates across the Northern Hemisphere, organizing the Atlantic Multidecadal Oscillation and the sea ice in the Eurasian Arctic.[87] This mechanism has been anecdotally corroborated by a very recent paper that finds movements of sea ice as predicted by Wyatt and Curry (2014), increasing as a matter of natural internal variability.[88] When coupled with a plausible mechanism, it is reasonable to take a short-term trend and argue that it is the beginning of a long-term reversal.

B. Sea Level Rise

Q: Dr. Dessler argues that rising sea levels made Hurricane Sandy more destructive than it otherwise would have been. Was that due to global warming?

[87] Marcia Glaze Wyatt and Judith A. Curry, *Role for Eurasian Arctic Shelf Sea Ice in a Secularly Varying Hemispheric Climate Signal During the 20th Century*, 42 Climate Dynamics 2763 (May 2014).

[88] M.H. Halvorsen, *et al.*, *Fram Strait Spring Ice Export and September Arctic Sea Ice*, 9 The Cryosphere Discuss. 4205 (Aug. , 2015).

A: Almost certainly not. The amount of change we are talking about is on the level of 1-2 mm per year (10-20 cm in a century), not 1 meter in a century—a ridiculous figure Dr. Dessler gives with no evidentiary support.

Q: Is that sea level rise due to global warming?

A: Most likely not. The inconvenient truth is that seal levels have been rising for several thousand years now because the glaciers from the ice age are still melting. Ice melting is a natural process. The key question is whether human intervention has *increased* that rate. The IPCC's own graph shows that sea level increases from 1930 to 1950 are as large or larger than the increases documented since 1979:[89]

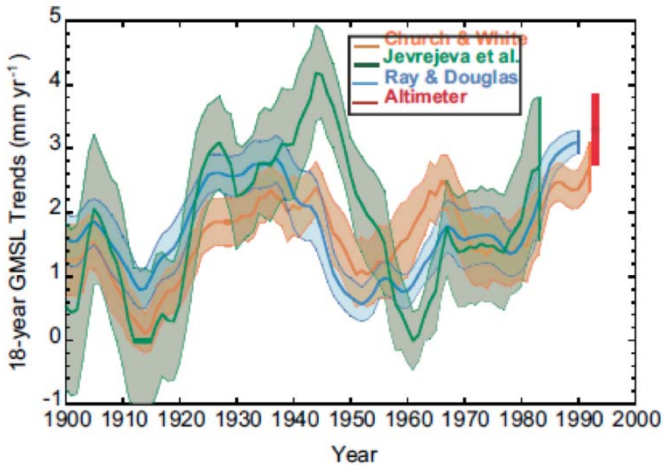


Figure 3.14 18-year trends of global mean sea level rise estimated at 1-year intervals. The time is the start date of the 18-year period, and the shading represents the 90% confidence. The estimate from satellite altimetry is also given, with the 90% confidence given as an error bar. [AR5 WGI Figure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

[89] AR5 WG1, at 289 (Fig. 3.14).

A recent paper explained the difficulty of measuring sea level rise with accuracy, finding that "the rate of [global mean sea level] rise increased (accelerated) continuously from 1.13 mm/yr in 1880 AD to 1.92 mm/yr in 2009 AD."[90] The evidence that sea level rise has accelerated *because of human intervention* is sparse and equivocal.

C. Extreme Weather

Q: Dr. Dessler argues that "humans are playing an increasingly important role in extreme temperature and precipitation events." Do you agree?

A: No. The literature here is at best equivocal when all of it is taken into account. Not even the IPCC shares Dr. Dessler's conviction that extreme weather events are caused by anthropogenic warming. In 2012, the IPCC published a Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX).[91] Key findings from the SREX Summary for Policy Makers include:

> "In many (but not all) regions over the globe with sufficient data, there is *medium confidence* that the length or number of warm spells or heat waves has increased. There have been statistically significant trends in the number of heavy precipitation events in some regions. It is likely that more of these regions have experienced increases than decreases, although there are strong regional and subregional variations in these trends. There is *low confidence* in any observed long-term (i.e., 40 years or more) increases in tropical cyclone activity (i.e., intensity, frequency, duration), after accounting for past changes in observing

[90] Cahill et al., *Modeling Sea-Level Change Using Errors-in-Variable Integrated Gaussian Processes*, 9 Annals of Applied Statistics 547 (2015).

[91] IPCC, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Summary for Policymakers* 6-7 (2012). *Id.* at 19 (Box SPM.2) describes the confidence and probability term usages.

capabilities. There is *low confidence* in observed trends in small spatial-scale phenomena such as tornadoes and hail because of data inhomogeneities and inadequacies in monitoring systems. There is *medium confidence* that some regions of the world have experienced more intense and longer droughts, in particular in southern Europe and West Africa, but in some regions droughts have become less frequent, less intense, or shorter, for example, in central North America and northwestern Australia. There is limited to medium evidence available to assess climate-driven observed changes in the magnitude and frequency of floods at regional scales . . . there is low agreement in this evidence, and thus overall low confidence at the global scale regarding even the sign of these changes."

The IPCC pointed to increased population and wealth as causes of increasing economic losses from extreme events:

> "Increasing exposure of people and economic assets has been the major cause of the longterm increases in economic losses from weather- and climate-related disasters (high confidence). Long-term trends in economic disaster losses adjusted for wealth and population increases have not been attributed to climate change, but a role for climate change has not been excluded (medium evidence, high agreement)."

In 2013, the IPCC released a Summary for Policymakers (SPM), which provided an update on its views on extreme weather. The SPM made only general statements such as "since

about 1950 … the number of cold days and nights has decreased … and the frequency of heat waves has increased in large parts of Europe, Asia and Australia."[92]

Chapter 2 of the Working Group I (AR5) report makes more specific statements, such as the "since about 1950 the number of heavy precipitation events over land has increased"[93] (high confidence), while assessment of observed trend in drought (on global scale) has "low confidence."[94] Also, long-term change in tropical cyclone activity is now assessed with only "low confidence."[95] This latest assessment on extreme weather is a significant departure from its previous (AR4) assessment where higher confidence was attributed to an increasing trend in tropical cyclone activity and global drought.[96]

Climate models do a poor job of simulating the variability and intensity of rainfall even in the present climate, and also do not resolve tropical cyclones adequately. *Nature* recently reported:

> At a workshop last week in Oxford, UK, convened by the Attribution of Climate-related Events group — a loose coalition of scientists from both sides of the Atlantic — some speakers questioned whether event attribution was possible at all. It currently rests on a comparison of the probability of an observed weather event in the real world with that of the "same" event in a hypothetical world without global warming. One critic argued that, given the insufficient observational data and the coarse and mathematically far-from-perfect climate models used to generate attribution claims, they are unjustifiably speculative,

[92] IPCC, Working Group I, *Climate Change 2013: The Physical Science Basis: Summary for Policymakers* 3 (2013), available at https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WGIAR5_SPM_brochure_en.pdf.

[93] AR5/WG1 at 46.

[94] *Id.* at 50.

[95] *Id.*

[96] AR4 WG1 at 239.

basically unverifiable and better not made at all . . . Better models are needed before exceptional events can be reliably linked to global warming.[97]

Q: Is the literature Dr. Dessler cites relevant?

A: No. Two of the studies cited by Dr. Dessler for his contention that "humans are playing an increasingly important role in extreme temperatures and precipitation events" (Dessler Testimony 26:20-27:1) rely on *models* of anthropogenic forcing, not observations. Notably, the observed (actual) trends run cooler than the modeled trends.[98] (Christidis 2011 and Min 2013.) Dr. Dessler is assuming his own conclusion.

Q: Are droughts increasing due to anthropogenic global warming?

A: Most likely not. We are still within ordinary natural patterns of extreme drought. A study denies the claim that increased CO_2 is causing droughts and warming, finding that "the recent drought events from late 1990 to the present are not unusual in the context of the past several centuries."[99] By reconstructing drought cycles in the earlier 1900s, the researchers found that more significant droughts occurred before industrial civilization.[100] This is specifically true of the American West: Evidence from tree rings shows that drought was historically much more extreme in the American West during medieval times with drought periods lasting close to 200 years, while the 20th century is wetter than normal.[101] Indeed, a recent paper found a common cause in the

[97] Nature editorial: Extreme Weather http://www.nature.com/news/extreme-weather-1.11428

[98] See Nikolaos Christidis, *The Role of Human Activity in the Recent Warming of Extremely Warm Daytime Temperatures*, 24 J. Climate 1922, 1925 (Apr. 1, 2011).

[99] Bao, G., Liu, Y., Liu, N. and Linderholm, H.W. 2015. Drought variability in eastern Mongolian Plateau and its linkages to the large-scale climate forcing. Climate Dynamics 44: 717-8733.

[100] *Id.*

[101] McDonald 2007: Severe and sustained drought in southern California and the West: Present conditions and insights from the past on causes. Quaternary International, 173-174, 87-100.

hiatus in warming and the drought in California: circulation patterns in the Pacific.[102] A study examining the causes of the droughts in California from 2012 to 2014 find that natural variability is the dominant cause, and anthropogenic warming only accounts for about 20% of the conditions.[103]

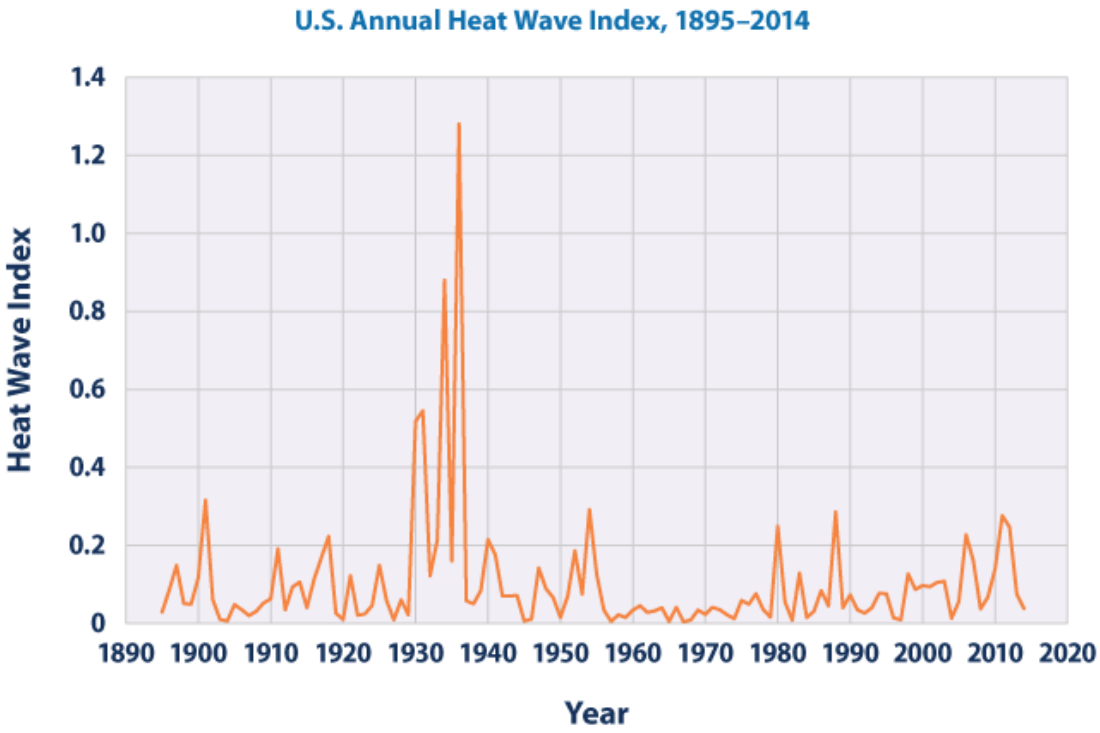
Q: Is the number of heat waves rising as a result of anthropogenic global warming?

A: No. Dr. Dessler's assertion that heat waves are increasing in intensity is belied by the EPA:[104]

[102] Thomas L. Delworth, *et al.*, *A Link between the Hiatus in Global Warming and North American Drought*, 28 J. Climate 3834 (2015).

[103] A. Park Williams, *et al.*, *Contribution of Anthropogenic Warming to California Drought During 2012-2014*, __ Geophys. Rsch. Letters __ (published online Aug. 20, 2015).

[104] EPA, "U.S. Annual Heat Wave Index, 1895-2014," *Climate Change Indicators in the United States* (June 2015), available at http://www.epa.gov/climatechange/science/indicators/weather-climate/high-low-temps.html.



Data source: Kunkel, K. 2015. Updated version of Figure 2.3 in: CCSP (U.S. Climate Change Science Program). 2008. Synthesis and Assessment Product 3.3: Weather and climate extremes in a changing climate. www.globalchange.gov/browse/reports/sap-33-weather-and-climate-extremes-changing-climate.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climatechange/indicators.

Recent heat waves do not compare to the Dust Bowl years in the 1930s. The figure below shows that the decade of the 1930s was the hottest on record in the U.S. and that subsequent decades, especially the 1990s and the 2000s, have been rather mild in comparison.

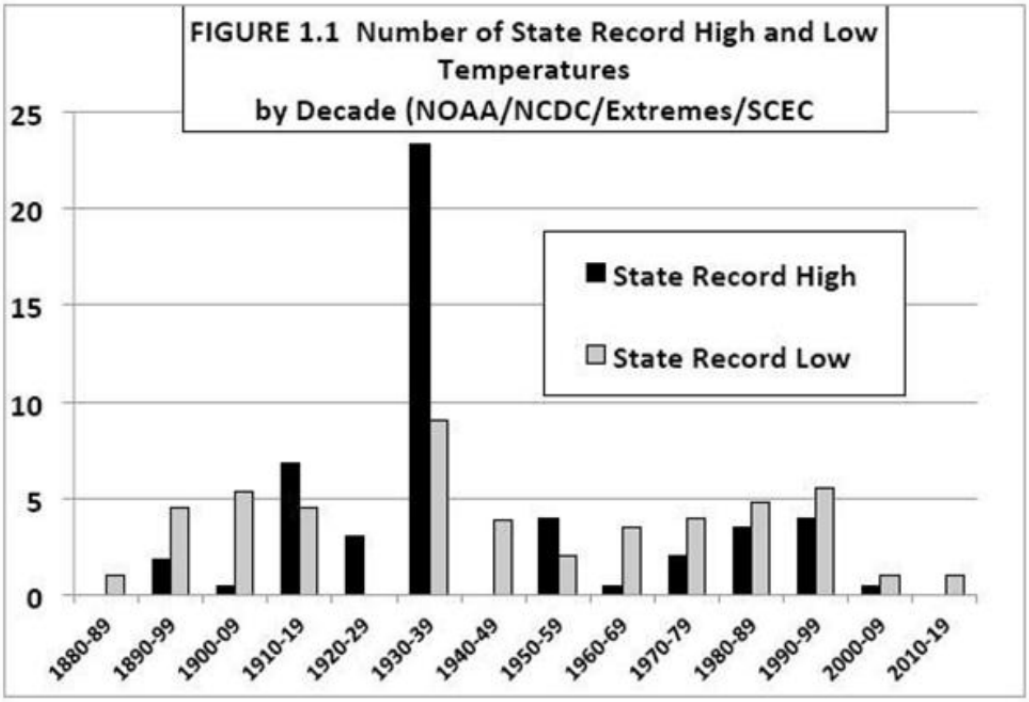


Figure 1. Highest and lowest decadal temperature records for various states in the coterminous USA. The 1930s was the hottest decade. (Data from NOAA)

Q: Dr. Dessler cites to a graph showing warmer mean temperatures (Dessler Rebuttal at 20 (Fig. 4)). Does that graph show an increasing incidence of warmer temperatures?

A: The graph in Figure 4 of Dr. Dessler's rebuttal begins at 1980. By cherry-picking a later start date, he can hide the fact that the 1930s were hotter, and hotter more frequently, than averages now. The full historical record goes even farther back. If Dr. Dessler is concerned about avoiding predictions based on short-term trends, then the *full* cycle of temperature trends—going back to the Medieval Warm Period—would need to be explained.

Q: What about hurricanes?

A: In recent years, worldwide hurricane and tropical cyclone numbers have decreased and fewer landfalls have occurred. For the U.S. east coast, there has not been a single landfall of a hurricane of category 3 or higher since Katrina in August 2005. Sandy, which caused extensive damage to New York and New Jersey on 29–30 October 2012, was actually only a category 1 storm when it made landfall. A study by Maue (2011)[105] shows that tropical cyclone activity as measured by the accumulated cyclone energy has not increased and is at a low value at present. Another study by Chan (2008)[106] documents decadal variations of intense typhoons in the western North Pacific. Chan's study discounts the possibility of rising surface or ocean temperatures affecting the intensity of typhoons. Moreover, an earlier study by Landsea et al. (2006)[107] had questioned whether it is possible to detect trends in extreme tropical cyclones at all.

Q: What about tornadoes?

A: According to Balling and Cervany (2003),[108] the tornado count for severe tornadoes (F3–F5 on the Fujita scale) has declined in recent years. A paper by Simmons et al. (2012)[109] concludes that "when normalized for inflation, GDP (gross domestic product) and societal changes, the tornado damage in the US has actually decreased in recent years."

[105] Maue RN (2011). Recent historically low global tropical cyclone activity. Geophysical Research Letters 38 L14803 doi:10.1029/2011GL047711.

[106] Chan JCL (2008). Decadal variations of intense typhoon occurrences in the western North Pacific. Proc R Soc Series A; 464: 249–272.

[107] Landsea CW et al. (2006). Can we detect trends in extreme tropical cyclones? Science; 313: 452–454.

[108] Balling RG and RS Cerveny (2003). Compilation and discussion of trends in severe storms in the United States: popular perception vs climate reality. Natural Hazards; 29: 103–112.

[109] Simmons KM, D Sutter and R Pielke Jr (2012). Normalized tornado damage in the United States: 1951–2011. Environmental Hazards.

In the U.S., tornadoes are closely linked to severe thunderstorms. Many studies on thunderstorm climatology (e.g., Changnon 2001)[110] have used over 100 years of data to document that "thunderstorms and related activity in the US peaked during the 1920s and 1930s and since then have declined in the late 1990s." Another painstaking study extracts useful data from several thousand prairie-farm newsletters and reconstructs windstorm activity from 1880 to 1995 for the Canadian prairies (Hage 2003).[111] The study (by Hage) concluded that "severe windstorms and associated thunderstorm activity peaked during the early part of the 20th century and has since then declined steadily."

Q: Is there other evidence that extreme weather is not worsening?

A: Yes. Other research supports the conclusion that extreme weather isn't worsening. A group of researchers from the Biodiversity and Climate Research Centre in Frankfurt-am-Main, Germany, "could not identify a general drying trend or an increase in extreme drought events in forests globally."[112] Settlement patterns have a greater effect on wildfires than climate change does. Researchers focusing specifically on the link between climate change and wildfires found that "while climatic warming had little effect on the wildfire regime, and thus on longleaf pine dynamics, urban growth led to an 8% reduction in annual wildfire area."[113]

[110] Changnon SA (2001). Thunderstorms Across the Nation: An Atlas of Storms, Hail and their Damages in the 20th Century. Diane Pub Co.

[111] Hage KD (2003).; On destructive Canadian prairie windstorms and severe winters. Natural Hazards; 29: 207–228.

[112] Steinkamp, J. and Hickler, T. 2015. Is drought-induced forest dieback globally increasing? Journal of Ecology 103: 31-43.

[113] Costanza, J.K., Terando, A.J., McKerrow, A.J. and Collazo, J.A. 2015. Modeling climate change, urbanization, and fire effects on Pinus palustris ecosystems of the southeastern U.S. Journal of Environmental Management 151: 186-199.

IV. Peer Review and the "Consensus"

Q: Dr. Abraham asserts that "97 percent of the world's climate scientists agree that humans are causing climate change." (Abraham Rebuttal 20:6-7.) Is this accurate?

A: No. It comes from an article by Cook, et al. (2013), *Quantifying the Cosensus on Anthropogenic Global Warming in the Scientific Literature*, published in Environmental Research Letters, vol. 8, and has been thoroughly debunked.

A much more credible study undertaken by Strenger, et al. (2015) polled climate scientists (rather than only reviewing papers as Cook did) as to the degree to which they agreed with the keynote statements of the IPCC AR4 and AR5.[114] For AR5, the statement was: "It is extremely likely [95 to 100% probability] that human activities caused more than half of the observed increase in global average surface temperature from 1951 to 2010."[115] The number of respondents agreeing with the "human activities caused more than half of the observed increase" statement was merely 65.9%.[116] Note that this was a survey directly put to scientists themselves, not activists reading paper abstracts, and it found nowhere near 97% agreement with the IPCC's linchpin statement. Of those scientists who agreed that human activities caused more than half of the observed increase, only 65.2% agreed with the IPCC that it was "extremely likely" or

[114] Bart Strengers, *et al.*, PBL Netherlands Envir. Assessment Agency, *Climate Science Survey: Questions and Responses* (Apr. 10, 2015), available at http://www.pbl.nl/sites/default/files/cms/publicaties/pbl-2015-climate-science-survey-questions-and-responses_01731.pdf [hereafter, "Questions and Responses"]; Bart Verheggan, *et al.*, *Scientists' Views about Attribution of Global Warming*, 48 Envt'l Sci. & Tech. 8963 (Aug. 11, 2014), available at http://pubs.acs.org/doi/pdf/10.1021/es501998e [hereafter, "Views about Attribution"]. The survey was designed based on the comparable statement in AR4. The only differences noted were that the confidence level rose in the AR5 statement ("very likely" to "extremely likely") and the wording of AR5 was clearer. My analysis focuses on the AR5 confidence level as the more recent, but there is no material change to the significance of the results.

[115] AR5 WG1, at 60.

[116] Strengers, Questions and Responses, at 8 (Fig. 1a.1).

"virtually certain."[117] Thus, only 43.0% of climate scientists—*not even a majority*—agree with both halves of the IPCC's statement (that it is "extremely likely" that human activities have caused "more than half" of the observed warming).

Not only is there not a consensus, but 57% of climate scientists *do not agree with the IPCC's key statement on anthropogenic global warming*. Notably, Abraham's paper does not even mention this study—the most recent of several scientific studies of opinions—which further substantiates the argument that it is fundamentally a piece of advocacy, not science.

Other published research on this topic includes:

- Farnsworth, S. J., & Lichter, S. R. (2012). The structure of scientific opinion on climate change. *International Journal of Public Opinion Research*, *24*(1), 93-103.
- Bray and von Storch. "A survey of the perceptions of climate scientists 2013." *Helmholtz-Zentrum Geesthacht, Geesthacht.* (2014).
- Stenhouse, Neil, et al. "Meteorologists' Views About Global Warming: A Survey of American Meteorological Society Professional Members." *Bulletin of the American Meteorological Society* 95.7 (2014): 1029-1040.

These studies found ranges of 47 to 90% for the so-called 97% consensus. Of these studies, Abraham cited only to Farnsworth and Lichter (2012) in support of the argument that 97% agreed that warming had occurred, but only 84% agreed that it was human-induced. This discrepancy demonstrates the weakness of not specifying the object of the so-called consensus. When a specific consensus statement is offered—as Strengers and Verheggan did—not even a majority agree in full with the statements the IPCC has issued.

[117] *Id.* at 9 (Fig. 1b).

Notably, even Verheggan (2014) and Strengers (2015) were criticized for having an upward bias. Jose Duarte noted a "structural bias" in the way they selected the people to interview: searching for "global warming" and "global climate change" on Web of Science and sending the survey to the authors of all of the articles that came up.[118] Thus, surveys were sent to the authors of articles on eco-Marxism, philosophy, and commentators on the newspaper industry.[119] More importantly, even when limited to scientific papers, it still included papers on mitigation and impacts that assumed the truth of global warming as a premise to their own arguments. This creates a systematic structural bias "because these categories have no symmetric disconfirming counterparts."[120] "[T]hese researchers have simply imported a consensus in global warming. They then proceed to their area of expertise …. [These papers] do not carry any data or epistemic information about climate change or its causes, and the authors are unlikely to be experts on the subject, since it is not their field."[121]

Q: Dr. Dessler recounts allegations you raised in 2012 regarding the integrity of NASA GISS data, stating that "[t]his episode is deeply revealing about climate skeptics in general and Dr. Lindzen in particular" and that it "speaks volumes about the quality of [your] skepticism." He concludes that "[your] testimony in this case shows the same level of scholarship and due diligence" as that episode. How do you respond to his allegations?

A: Scientists are trained to weigh the quality of a theory according to the evidence for and against it, not by sound-bites about the person putting it forth. In logic such an allegation is

[118] Jose Duarte, *Comment on "Scientists' Views about Attribution of Global Warming,"* 48 Envt'l Sci. & Tech. 14,057 (Nov. 18, 2014), available at http://pubs.acs.org/doi/abs/10.1021/es504574v.

[119] *Id.* at 14,057.

[120] *Id.*

[121] *Id.*

known as an *ad hominem* attack and it proves nothing. The dispute has no bearing *whatsoever* on the current dispute—the integrity of NASA GISS data has not been raised as even a tangential issue—yet Dr. Dessler felt compelled to introduce it as evidence of a lack of academic rigor on my part. I will let my work stand or fall on its own. Not only is Dr. Dessler's substantive argument specious, as Dr. Spencer discusses in his testimony regarding the temperature record, but such a blatant attempt to use irrelevant *ad hominem* attacks as a substitute for reasoned scientific discourse both degrades the quality of that discourse and opens the door to diminishing the respectability of the profession.

Q: How is the quality of discourse affected by allegations such as these?

A: *Ad hominem* attacks substituting for scientific analysis threatens to turn science into a racket. Politics and playground antics have begun to infect reasoned scientific discourse. The ClimateGate emails demonstrate—straight from the horse's mouth—how this issue has turned peer review on its head. It is possible to question catastrophism without denying climate change, yet far too many people—politicians, advocacy groups, even scientists hoping for grants—have a vested interest in ensuring the two are conflated because it allows them to demonize people who disagree with them.[122] Dr. Dessler incorrectly refers to the House of Lords. The talk was given in the House of Commons in one of their discussion rooms. The nature of the error Dr. Dessler describes was due to the fact that GISS used the same URL for slightly different data. The error was generally reckoned to be inconsequential to the discussion but indicative of the adjustments that are possible when data is uncertain to a couple of tenths of a degree.

[122] *See* Richard S. Lindzen, Presentation at the 48th Session, Int'l Seminars on Planetary Emergencies, *The Language of Alarm and the Irrelevance of Science* 13 (Aug. 20, 2015) (listing "the number of special interests that opportunistically have strong interests in believing in the claims of catastrophe despite the lack of evidence").

Ultimately diversions such as these cheapen science and distract from the importance of proceedings such as these. "[S]cience has much at stake. Its hard-earned raison d'être as our most effective tool for objective assessment is being squandered, and with it, the basis for public trust and support. If we do nothing to stop this insanity, science will rightly be regarded as just another racket, and that too is a planetary emergency."[123]

Q: Dr. Gurney described the process of peer review. Do you agree with his characterization of the peer-review process?

A: Peer review, especially in the climate area, is often distorted by publication bias. Papers that exaggerate and promote the risks of global warming are much easier to publish than those that correctly assess it. Further, Dr. Gurney does not accurately describe how the IPCC uses and affects the peer review process.

Q: Is there a publication bias in peer-reviewed sources?

A: Yes, with the result that papers arguing for lower values for the SCC are left out while those reporting higher values are favored. A recent (August 2015) study shows a demonstrable and quantifiable publication bias in favor of higher values of the SCC.[124] Controlling for many variables such as the journal rank and method of calculation, the study found that small estimates of the SCC—especially those that acknowledged the possibility of a negative value—"might be selectively omitted from the literature."[125] "[S]tudies published in peer-reviewed journals tend to suffer more from selective reporting than unpublished papers."[126] These results are robust across

[123] *Id.* at 27.

[124] Tomas Havranek, *et al.*, *Selective Reporting and the Social Cost of Carbon*, __ Energy Economics __ (accepted paper, Aug. 14, 2015), available at http://www.sciencedirect.com/science/article/pii/S0140988 3 15002327.

[125] *Id.* at 31.

[126] *Id.* at 26.

multiple other potential factors.[127] Peer-reviewed sources, whether intentionally or as a matter of unconscious confirmation bias,[128] are biased toward higher SCC values.

To make matters worse, the authors conclude that "some of the parameters used for the calibration of integrated assessment models, such as climate sensitivity or the elasticity of intertemporal substitution in consumption, are likely to be exaggerated themselves because of selective reporting …, which might further contribute to the exaggeration of the SCC reported in individual studies—including the results of the Interagency Working Group."[129] In other words, separate publication biases in climate science fields slant the parameters going into the SCC, resulting in a further artificial inflation of the computed value.

Q: Does the IPCC use only peer-reviewed literature, as Dr. Gurney claims?

A: No. He is flatly wrong, contradicted by the IPCC itself. Dr. Gurney places nearly uncritical faith in the IPCC, yielding the remarkable statement that "the reports only synthesize peer-reviewed research. Hence, opinions are not included." (Gurney Testimony 27:1-2.)

The IPCC itself disagrees. According to a review of its own internal records: "An analysis of the 14,000 references cited in the Third Assessment Report found that peer-reviewed journal articles comprised 84 percent of references in Working Group I, but comprised only 59 percent of references in Working Group II and 36 percent of references in Working Group III (Bjurström and Polk, 2010)."[130] At best, then, the IPCC's Third Assessment Report was still

[127] *Id.* at 25-30

[128] *Id.* at 31.

[129] *Id.* at 33 (citations omitted).

[130] InterAcademy Council, Committee to Review the Intergovernmental Panel on Climate Change, *Climate Change Assessments: Review of the Processes and Procedures of the IPCC* 16 (Oct. 2010) [hereafter, "IPCC Review"], *citing* Bjurström, A., and M. Polk, 2010, Physical and economic bias in climate change research: A scientometric study of IPCC Third Assessment Report, *Climatic Change*, in press. The bibliometric data are also

comprised of 16% "opinions" Gurney believes are completely excluded; at worst, a majority of the references are to such literature. In response to criticism on this score, the IPCC did not ban grey literature but explicitly embraced it: "Although some respondents to the Committee's questionnaire have recommended that only peer-reviewed literature be used in IPCC assessments, this would require the IPCC to ignore some valuable information."[131]

Even with specific procedures in place after the Third Assessment Report for flagging non-peer-reviewed literature, the IPCC still failed to abide by its own guidelines. "Some of the errors discovered in the Fourth Assessment Report had been attributed to poor handling of unpublished or non-peer-reviewed sources …. Moreover, a search through the Working Group reports of the fourth assessment found few instances of information flagged as unpublished or non-peer-reviewed."[132] Thus, not only does the IPCC use grey literature extensively—disagreeing with Dr. Gurney's insistence on solely peer-reviewed literature—it fails to do so with integrity. This is hardly the "gold standard" Drs. Gurney, Dessler, and Abraham are seeking. If peer review is "an expected standard when assessing what is known scientifically" (Gurney Testimony at 25:9-10), they cannot credibly rely on the IPCC's data without further support from genuinely peer-reviewed sources.

Q: Does the IPCC use non-peer-reviewed literature?

A: The IPCC has to rely on non-peer-reviewed literature. A survey of IPCC authors and editors confirms what the IPCC publicly recognizes: it requires such literature in order to stay on

available at http://rogerpielkejr.blogspot.com/2010/03/gray-literature-inipcc-tar-guest-post.html. (Notably, the IPCC itself refers the reader to a blog post.)

[131] IPCC Review at 16.

[132] *Id.* at 17.

the forefront of relevant science. A collection of those survey responses reveals very clear feelings about the role of non-peer-reviewed literature:[133]

- Non-peer-reviewed literature should obviously be minimized but cannot be totally avoided. (page 2)
- …the length of the [IPCC report] was constrained, so the number of citations was constrained. Hence, reviews (including those in the "grey" literature) were strongly favored if those reviews cited the primary literature. (p. 7)
- In some fields non-peer reviewed is the way the science is done. It just has to be carefully used and identified clearly. (p. 22)
- There cannot be any assessment of impacts and possible response strategies to climate change on peer-reviewed literature only. (p. 48)
- My WG III chapter depended heavily on non-peer reviewed literature and I have yet to hear a complaint about its quality. (p. 52)
- Governments want the chapter to cover questions of current relevance for which there [is] often "grey literature" but little peer reviewed literature. (p. 68)
- …to address some of the policy topics it is necessary to use non-peer-reviewed literature. (p. 69)
- Working Groups 2 and 3 make more reference to non-peer reviewed literature…The IPCC assessments are very inclusive and include a comprehensive analysis of all existing literature… (p. 74)

[133] https://sites.google.com/site/globalwarmingquestions/ipcc

- Some of the most policy relevant information does not appear in peer reviewed literature. Without it the IPCC could become irrelevant. (p. 119)
- If I take it that the role of IPCC is to sift available knowledge on climate-related to help policymakers then the use of grey literature is unavoidable as, especially in the [Working Group 2 and 3] domains, there is a great deal of relevant insight outside the peer-reviewed academic literature. It would be a ducking of responsibility to omit this literature… (p. 123)
- Some grey literature is essential as there is nothing else… (p. 128)
- Adaptation is increasingly occurring on the ground and being reported in non-journal-based literature. If [Working Group 2] cannot assess this broad range of literature, its assessment will not be at the cutting-edge. (p. 148)
- I agree that references to non-journal materials are necessary. Especially for regional impacts and adaptation most of useful materials are in technical reports issued by national research institutes…Without using those materials it is difficult to produce a useful report. (p. 219)
- Considering the evolving nature of the science, the assessments would be lacking if alternative sources to peer-reviewed literature were not considered. (p. 225)
- …it is necessary to draw on the grey literature, to capture (for example) engineering knowledge, or information from regions for which there is little journal-published literature. (p. 229)
- …there are vast amounts of information and data that are not published in scientific papers, some of which is also reviewed as strongly as peer-review papers, and without which the assessments of the IPCC would not be possible. Adaptation, much of which is

done autonomously, or by agencies of all sorts, may never be published, and yet it is critical for a correct assessment. (p. 241)

- The issue of non-peer reviewed literature has been a point of ongoing debate in IPCC. For a number of areas of IPCC work non-peer reviewed literature is absolutely essential, because the peer reviewed literature does not cover enough relevant information. (p. 257)
- Academic work is not enough to cover all places and all sectors, which inevitably needs "non-peer-reviewed (Grey) literature". (p. 264)
- As to the [Working Group 2], those Grey literature play a huge role to cover local findings. (p. 264)
- I think the inclusion of grey literature should continue… (p. 284)
- I think there is a need to consider more non-peer reviewed literature (sometimes called grey literature), as this often reflects recent developments… (p. 293)
- Particularly for [Working Groups 2 and 3], it is important to go beyond the peer-reviewed journal literature. This is the case for several reasons…Even in [Working Group 1], much of the actual data on observations appears in tables and reports rather than in the peer-reviewed literature… (p. 313)
- Thus, I think IPCC has to continue to be open to using information and ideas from outside the peer-reviewed journals… (p. 314)
- Grey literature is unavoidable in some areas… (p. 378)
- In my area, policy, non-peer-reviewed literature is essential for latest information and comprehensive review of state of the art. (p. 405)
- The use of non-peer-reviewed literature is necessary… (p. 408)

- Many emerging topics eg. on technologies require extensive use of reports and non-peer-reviewed literature. (p. 423)
- Non peer reviewed literature must be taken into account, in particular where local impacts are evaluated. (p. 458)
- Non-peer-reviewed literature should be avoided whenever possible. But there [are] many cases where such literature has to be taken into account. (p. 469)
- Some chapters rely heavily on gray literature while ignoring peer-reviewed literature on the same matter (e.g., Ch 7 WG2). (p. 543)
- The pressure from [developing countries] to use publications in [developing countries] and/or grey literature is high and effective. This lowers the scientific quality of the report. (p. 555)
- The use of grey literature is unavoidable…Authors should not be plagued by unnecessary rules on the use or non-use of literature… (p. 622)
- [G]rey literature is of absolute importance, given e.g. the fast development of some technologies. (p. 632)
- The use of gray literature cannot be avoided in [Working Groups 2 and 3], as many of the sources are not peer-reviewed, but still high quality (e.g. reports of EEA). (p.643)
- …especially for the policy literature reviewed in [Working Group 3], there is a substantial body of research papers and government-sponsored reports that are not represented in the journal literature. (p. 664)

- In [Working Group 3, for the 2001 and 2007 reports], the procedure was to leave the selection of relevant gray literature to the writing team…No particular precedence was accorded to peer-reviewed and gray literature… (p. 664)
- The preponderance of important so-called "grey literature" simply cannot be ignored by the IPCC. The information it holds is more current than that in journals and it captures non-English knowledge more effectively. (p. 671)

Q: Dr. Abraham insists that "[i]t is also important not to rely upon non-reviewed information submitted by advocacy organizations." Does the IPCC ever rely on advocacy groups?

A: Yes. The IPCC is no stranger to relying on advocacy groups, most frequently the World Wildlife Fund (WWF) and Greenpeace:

- In one celebrated instance, the IPCC had to *retract* a statement about Himalayan glaciers that was based on a faulty WWF report.[134]
- In Section 8.4.2.5, AR4 cited a WWF report for the statement that climate change is affecting mountain glaciers, causing rapid glacier retreat in the Himalayas, Greenland, the European Alps, the Andes Cordillera and East Africa (WWF, 2005: An overview of glaciers, glacier retreat, and subsequent impacts in Nepal, India and China. World Wildlife Fund Nepal Program, 79 pp.);
- In Section 10.2.4.2, AR4 cited a WWF report for the conclusion that rapid glacial melting and runoff are causing more frequent mudflows and landslides (WWF, 2005: An

[134] IPCC, *IPCC Statement on the Melting of Himalayan Glaciers* (Jan. 20, 2010), available at http://www.ipcc. ch/pdf/presentations/himalaya-statement-20january2010.pdf.

overview of glaciers, glacier retreat, and subsequent impacts in Nepal, India and China. WorldWildlife Fund, Nepal Program, 79 pp.);

- In Section 12.4.7.2, AR4 cited a WWF workshop project report to support the statement that climate change will produce significant impacts on selected marine fish and shellfish in the north-east Atlantic marine ecoregion (Baker, T., 2005: Vulnerability Assessment of the North-East Atlantic Shelf Marine Ecoregion to Climate Change, Workshop Project Report, WWF, Godalming, Surrey, 79 pp.);
- In Section 12.7, AR4 cited a WWF report for the global baseline "ecological footprint" against which to compare the footprint of persons living in various global regions (WWF, 2004: Living Planet Report 2004. WWF-World Wide Fund for Nature, Gland, Switzerland, 44 pp.);
- In Section 13.2.3, AR4 cited a WWF report as support for statements about damage to the environment in Latin America caused by the growth of the tourism industry and harbor dredging (WWF, 2004: Deforestation threatens the cradle of reef diversity. World Wide Fund for Nature, 2 December 2004.);
- In Section 13.2.4, AR4 cited the same WWF report for the statement that destruction of mangrove forests substantially reduces fish population on nearby reefs (WWF, 2004: Deforestation threatens the cradle of reef diversity. WorldWide Fund for Nature, 2 December 2004.).
- In Section 6.4.2.6, the Working Group II report referred to a Greenpeace sponsored article for an opaque statement related to climate change, tourism and coral reefs: Hoegh-Guldberg, O., H. Hoegh-Guldberg, H. Cesar and A. Timmerman, 2000: Pacific in peril:

biological, economic and social impacts of climate change on Pacific coral reefs. Greenpeace, 72 pp.

- In Section 3.1.2, the Working Group III report cited a Greenpeace publication regarding sustainable development pathways: Lazarus, M., L. Greber, J. Hall, C. Bartels, S. Bernow, E. Hansen, P. Raskin, and D. Von Hippel, 1993: Towards a fossil free energy future: the next energy transition. Stockholm Environment Institute, Boston Center, Boston. Greenpeace International, Amsterdam;
- In Section 4.3.3.2, the Working Group III report referenced a Greenpeace document for the nations or regions having the most investment in wind-energy: Wind Force 12, 2005: Global Wind Energy Council and Greenpeace;
- In Section 4.3.3.5, the Working Group III report cited a Greenpeace sponsored paper for estimates of potential global concentrated solar power: Aringhoff, R., C. Aubrey, G. Brakmann, and S. Teske, 2003: Solar thermal power 2020, Greenpeace International/European Solar Thermal Power Industry Association, Netherlands;
- In Section 4.3.3.5, the Working Group III report cited a Greenpeace publication for solar energy projects under construction: ESTIA, 2004: Exploiting the heat from the sun to combat climate change. European Solar Thermal Industry Association and Greenpeace, Solar Thermal Power 2020, UK.
- In Section 4.3.3.6, the Working Group III report cited two Greenpeace documents for estimates of current global installed peak solar energy storage capacity: http://www.greenpeace.org.ar/ cop10ing/SolarGeneration.pdf, and Greenpeace, 2006: Solar generation. K. McDonald (ed.), Greenpeace International, Amsterdam;

- In Section 4.4.3.3, the Working Group III report referred to a Greenpeace publication for estimates of potential future wind energy generation: Global wind energy outlook. Global Wind Energy Council, Bruxelles and Greenpeace, Amsterdam, September, 56 pp.

If, as Drs. Abraham, Dessler, Gurney, Kunkle, Martin, and Rumery repeatedly contend, it is inappropriate to rely on literature published by advocacy groups, then they should not be relying on the IPCC. Further, they should not be relying on advocacy sources. The advocacy sources they have relied on include, for example:

1. American Wind Energy Association
2. Interagency Working Group
3. GE Energy Consulting
4. Union of Concerned Scientists
5. Solar Foundation
6. Pew
7. Harvard Project on Climate Agreements
8. EPA
9. National Resource Defense Council
10. Peterson Institute
11. Solar Energy Industries Association
12. Think Progress
13. Utility Dive
14. Cost of Carbon Project
15. Global Wind Energy Council
16. First Solar

17. Resources for the Future
18. Ceres
19. Wind on the Wires
20. Center for American Progress
21. Regulatory Assistance Project
22. National Renewable Energy Laboratory
23. Greentechmedia
24. General Electric International
25. SEIA/GTM Research

Q: Dr. Gurney describes the IPCC's process as "two stringent layers of peer review." Do you agree with his characterization?

A: No. Not only does the IPCC extensively use the "grey literature" Drs. Gurney and Abraham complain about, it has dramatically distorted the peer-review process. Emails among IPCC authors released from the Climate Research Unit at the University of East Anglia demonstrate how deeply ordinary scientific inquiry has been distorted by the IPCC.

While the IPCC does use a "review editor" for each chapter, as a practical matter the authors of chapters themselves determine whether or not to accept or reject critical reviews. This results in a closed ecosystem of self-reinforcing voices, as shown by Chapter 9 of the Working Group I contribution to the Fourth Assessment Report, "Understanding and Attributing Climate Change," the crucial chapter attributing climate change to human causes.[135] In that chapter:

[135] IPCC Working Group I, *Climate Change 2007: The Physical Science Basis* 663-745 (2007) [hereafter, "AR4 WG1"].

- Out of 534 documents cited, 213 had at least one author who was also an author of the chapter (39.9%)
- While there were 44 contributing authors, more than half had co-authored papers with the Lead Author or Coordinating Lead Author
- 94 had been authored by two or more of the chapter's authors
- 50 had been authored by two chapter authors (including 10 written only by chapter authors)
- 26 had been authored by three chapter authors (including 6 that were written only by chapter authors)
- 5 had been authored by five chapter authors
- 1 had been authored by six of the chapter's authors[136]

This assessment does not represent a broad spectrum of views, but rather a tight clique of scientists. There is no impartial mediating editor present to prevent these authors from citing their own work and discounting work critical of it. One of the emails released shows a chapter author acknowledging that peer-reviewed studies disagree with him and not only discounting the opposing data but *refusing even to publish the citation to the opposing view*.[137]

A major concern about the IPCC assessment reports is that they lack transparency and are potentially biased, through the selection of lead authors and review editors as well as selection of which publications to consider. The InterAcademy Council Review of the IPCC found:[138]

[136] Joseph D'Aleo, Comment on EPA's April 24, 2009 Proposed Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, Dkt. No. EPA-HQ-OAR-2009-0171-3187, at 6 (Jun 24, 2009), available at http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2009-0171-3187.

[137] CRU email 1154353922.txt (Jul. 31, 2006).

[138] IPCC Review at xvi.

> Most important are the absence of criteria for selecting key participants in the assessment process and the lack of documentation for selecting what scientific and technical information is assessed. The Committee recommends that the IPCC establish criteria for selecting participants for the scoping meeting, where preliminary decisions about the scope and outline of the assessment reports are made; for selecting the IPCC Chair, the Working Group Co-chairs, and other members of the Bureau; and for selecting the authors of the assessment reports. The Committee also recommends that Lead Authors document that they have considered the full range of thoughtful views, even if these views do not appear in the assessment report.

As a case in point, consider the 2012 synthesis report by Craig Idso entitled *State of the Earth's Terrestrial Biosphere*.[139] In his testimony, Gurney stated that he regarded a previous 2009 report by Idso and Springer as "unreliable." Yet Idso's 2012 report cites approximately 500 publications supporting the argument that the Earth's terrestrial biosphere has been greening – and many of these publications are not included in the IPCC AR5 WG1 Chapter 6.3.2 assessment of the global carbon budget. It is inferred that the IPCC Chapter 6 authors did not consider the full range of thoughtful views on this topic.

[139] http://www.co2science.org/education/reports/greening/TheStateofEarthsTerrestrialBiosphere.pdf.