

A Response to the “Data or Dogma?” hearing

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On December 8, 2015, Senator Ted Cruz – the chairman of the Senate subcommittee on Space, Science, and Competitiveness – convened a hearing entitled “Data or Dogma?” The stated purpose of this event was to promote “...open inquiry in the debate over the magnitude of human impact on Earth’s climate” (1). In the course of the hearing, the chairman and several expert witnesses claimed that satellite temperature data falsify both “apocalyptic models” and findings of human effects on climate by “alarmist” scientists. Such accusations are serious but baseless. The hearing was more political theatrics than a deep dive into climate science.

Satellite-derived temperature data were a key item of evidence at the hearing. One of the witnesses^a for the majority side of the Senate subcommittee showed the changes (over roughly the last 35 years) in satellite- and weather balloon-based measurements of the temperature of the mid-troposphere (TMT), a layer of the atmosphere extending from the Earth’s surface to roughly 18 km (2). Satellite TMT measurements are available from late 1978 to present. Observed TMT data were compared with TMT estimates from a large number of model simulations. This comparison was ‘Exhibit A’ for the majority side of the subcommittee.

Senator Cruz used Exhibit A as the underpinning for the following chain of arguments: 1) Satellite TMT data do not show any significant warming over the last 18 years, and are more reliable than temperature measurements at Earth’s surface; 2) The apparent “pause” in tropospheric warming is independently corroborated by weather balloon temperatures; 3) Climate models show pronounced TMT increases over the “pause” period; and 4) The mismatch between modeled and observed tropospheric warming in the early

^aProf. John Christy from the University of Alabama at Huntsville.

33 21st century has only one possible explanation – computer models
34 are a factor of three too sensitive to human-caused changes in
35 greenhouse gases (GHGs). Based on this chain of reasoning,
36 Senator Cruz concluded that satellite data falsify all climate models,
37 that the planet is not warming, and that humans do not impact
38 climate.

39 This logic is wrong. First, satellites do not provide direct
40 measurements of atmospheric temperature: they are not
41 thermometers in space. The satellite TMT data plotted in Exhibit A
42 were obtained from so-called Microwave Sounding Units (MSUs),
43 which measure the microwave emissions of oxygen molecules from
44 broad atmospheric layers (2-4).^b Converting this information to
45 estimates of temperature trends has substantial uncertainties.^c The
46 major uncertainties arise because the satellite TMT record is based
47 on measurements made by over 10 different satellites, most of which
48 experience orbital decay (5) and orbital drift (6-8) over their lifetimes.
49 These orbital changes affect the measurements of microwave
50 emissions, primarily due to gradual shifts in the time of day at which
51 measurements are made. As the scientific literature clearly
52 documents, the adjustments for such shifts in measurement time are
53 large,^d and involve many subjective decisions (2-4, 6-8). Further
54 adjustments to the raw data are necessary for drifts in the on-board
55 calibration of the microwave measurements (9, 10), and for the

^bMSU estimates of the temperature of tropospheric layers also receive a small contribution from the temperature at Earth's surface.

^cThis conversion process relies on an atmospheric radiation model to invert the observations of outgoing, temperature-dependent microwave emissions from oxygen molecules. Since oxygen molecules are present at all altitudes, the microwave flux that reaches the satellite is an integral of emissions from thick layers of the atmosphere.

^dAt the end of the hearing, Senator Cruz questioned the reliability of thermometer measurements of land and ocean surface temperature, and highlighted the large adjustments to "raw" surface temperature measurements (adjustments which are necessary because of such factors as changes over time in thermometers and measurement practices). He did not mention that the surface temperature adjustments are typically much smaller than the adjustments to "raw" MSU data (2, 3, 8).

56 transition between earlier and more sophisticated versions of the
57 MSUs.^e

58 In navigating through this large labyrinth of necessary adjustments to
59 the raw data, different plausible adjustment choices lead to a wide
60 range of satellite TMT trends (2-10). This uncertainty has been
61 extensively studied in the scientific literature, but was completely
62 ignored in the discussion of Exhibit A by Senator Cruz and by
63 witnesses for the majority side of the subcommittee (2-15). The
64 majority side was also silent on the history of satellite temperature
65 datasets. For example, there was no mention of the fact that one
66 group's analysis of satellite temperature data – an analysis indicating
67 cooling of the global troposphere – was repeatedly found to be
68 incorrect by other research groups (2, 3, 5-10).

69 Such corrective work is ongoing. Satellite estimates of atmospheric
70 temperature change are still a work in progress (2, 3, 8), and the
71 range of estimates produced by different groups remains large.^f The
72 same is true of weather balloon atmospheric temperature
73 measurements (2, 11-13, 15-17).^g Surface thermometer records also
74 have well-studied uncertainties (2, 19, 20), but the estimated surface
75 warming of roughly 0.9°C since 1880 has been independently
76 confirmed by multiple research groups (2, 15, 19, 20).

77 The hearing also failed to do justice to the complex issue of how to
78 interpret differences between observed and model-simulated
79 tropospheric warming over the last 18 years. Senator Cruz offered
80 only one possible interpretation of these differences – the existence
81 of large, fundamental errors in model physics (2, 21). In addition to
82 this possibility, there are at least three other plausible explanations

^eThis transition occurred in 1998, at the beginning of the 18-year “no significant warming” period highlighted by Senator Cruz.

^fFor example, over the longer 1979 to 2014 analysis period, tropospheric warming is a robust feature in all observational TMT datasets. For shorter, noisier periods (such as 1996 to 2014), the sign of the TMT trend is sensitive to dataset construction uncertainties.

^gDisappointingly, Exhibit A neglects to show at least one weather balloon temperature dataset with substantial tropospheric warming over the last 18 years (18).

83 for the warming rate differences shown in Exhibit A: errors in the
84 human (22-25), volcanic (26-30), and solar influences (24, 31) used
85 as input to the model simulations; errors in the observations
86 (discussed above) (2-20); and different sequences of internal climate
87 variability in the simulations and observations (23, 24, 30, 32-36). We
88 refer to these four explanations as “model physics errors”, “model
89 input errors”, “observational errors”, and “different variability
90 sequences”. They are not mutually exclusive. There is hard scientific
91 evidence that all four of these factors are in play (2-20, 22-36).

92 “Model input errors” and “different variability sequences” require a
93 little further explanation. Let’s assume that some higher
94 extraterrestrial intelligence provided humanity with two valuable gifts:
95 a perfect climate model, which captured all of the important physics in
96 the real-world climate system, and a perfect observing system, which
97 reliably measured atmospheric temperature changes over the last 18
98 years. Even with such benign alien intervention, temperature trends
99 in the perfect model and perfect observations would diverge if there
100 were errors in the inputs to the model simulations,^h or if the purely
101 random sequences of internal climate oscillations did not “line up” in
102 the simulations and in reality (23, 24, 30, 32-36).

103 In short, “all models are too sensitive to CO₂” is not the only valid
104 explanationⁱ for the model-data differences in Exhibit A (2, 11, 13, 18,
105 22-24, 26, 30, 32-38). Dozens of peer-reviewed scientific studies
106 show that the other three explanations presented here (“model input
107 errors”, “observational errors”, and “different variability sequences”)

^hSuch as leaving out volcanic cooling influences that the real world experienced (23, 24, 26-30).

ⁱThe model results shown in Exhibit A are from so-called “historical climate change” simulations. These simulations involve changes in a number of different human and natural influences (e.g., human-caused changes in GHG levels and particulate pollution, and natural changes in solar and volcanic activity). They are not simulations with changes in GHG levels only, so it is incorrect to interpret the model-versus-observed differences in Exhibit A solely in terms of model sensitivity to GHG increases.

108 are the primary reasons for most or all of the warming rate
109 differences in Exhibit A.^j

110 But what if climate models really were a factor of three or more too
111 sensitive to human-caused GHG increases, as claimed by the
112 majority side of the subcommittee? The telltale signatures of such a
113 serious climate sensitivity error would be evident in many different
114 comparisons with observations, and not just over the last 18 years.
115 We'd expect to see the imprint of this large error in comparisons with
116 observed surface temperature changes over the 20th century (37-42),
117 and in comparisons with the observed cooling after large volcanic
118 eruptions (30, 43, 44). We don't. There are many cases where
119 observed changes are actually larger than the model expectations
120 (41, 42), not smaller.

121 In assessing climate change and its causes, examining one individual
122 18-year period is poor statistical practice, and of limited usefulness.
123 Analysts would not look at the record of stock trading on a particular
124 day to gain reliable insights into long-term structural changes in the
125 Dow Jones index. Looking at behavior over decades – or at the
126 statistics of trading on all individual days – provides far greater
127 diagnostic power. In the same way, climate scientists study changes
128 over decades or longer (39-42, 45), or examine all possible trends of
129 a particular length (23, 38, 46-48). Both strategies reduce the impact
130 of large, year-to-year natural climate variability^k on trend estimates.
131 The message from this body of work? Don't cherry-pick; look at all
132 the evidence, not just the carefully selected evidence that supports a
133 particular point of view.

^jAnother incorrect claim made at the hearing was that the mainstream scientific community had failed to show the kind of comparisons model-data comparisons presented in Exhibit A. Results similar to those in Exhibit A have been presented in many other peer-reviewed publications (2, 13, 18, 23, 24, 30, 32, 35, 38, 46, 48).

^kSuch as the variability associated with unusually large El Niño and La Niña events, which yield unusually warm or cool global-mean temperatures (respectively). The El Niño event during the winter of 1997 and spring of 1998 was likely the largest of the 20th century, and produced a large warming “spike” in surface and tropospheric temperatures.

134 In summary, the finding that human activities have had a discernible
135 influence on global climate is not falsified by the supposedly “hard
136 data” in Senator Cruz’s Exhibit A. The satellite data and weather
137 balloon temperatures are not nearly as “hard” as they were portrayed
138 in the hearing. Nor is a very large model error in the climate
139 sensitivity to human-caused GHG increases the only or the most
140 plausible explanation for the warming rate differences in Exhibit A.
141 Indeed, when the observational temperature datasets in Exhibit A are
142 examined over their full record lengths – and not just over the last 18
143 years – they provide strong, consistent scientific evidence of human
144 effects on climate (41, 42, 48). So do many other independent
145 observations of changes in temperature, the hydrological cycle,
146 atmospheric circulation, and the cryosphere (41, 42).

147 Climate policy should be formulated on the basis of both the best-
148 available scientific information and the best-possible analysis and
149 interpretation. Sadly, neither was on display at the Senate hearing on
150 “Data or Dogma?” There was no attempt to provide an accurate
151 assessment of uncertainties in satellite data, or to give a complete
152 and balanced analysis of the reasons for short-term differences
153 between modeled and observed warming rates. Political theater
154 trumped true “open inquiry”.

155 Climate change is a serious issue, demanding serious attention from
156 our elected representatives in Washington. The American public
157 deserves no less.

158

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168 **References**

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171 [open-inquiry-in-the-debate-over-the-magnitude-of-human-impact-on-earth-s-climate.](https://www.commerce.senate.gov/public/index.cfm/2015/12/data-or-dogma-promoting-open-inquiry-in-the-debate-over-the-magnitude-of-human-impact-on-earth-s-climate)
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