Sources of Variation in Climate Sensitivity Estimates

**Misdefinition**

**PROBLEM** Lack of CO2 data constraining TCR’s PDF

The bulk of the interest in climate sensitivity is arguably for its applicability to centennial climate forecasts. Equilibrium climate sensitivity is clearly out of the question for that application, which leaves transient climate response, TCR, as the IPCC’s only applicable definition of climate sensitivity. (The IPCC also defines TCRE, transient climate response to a tetradecane increase in carbon emissions, but climate sensitivity is customarily understood in terms of response to radiative forcing rather than emissions.)

TCR is hard to estimate because it is defined for a behavior of CO2 for which we have no prior experience, namely a compound annual growth rate (CAGR) of 3% per annum. Models estimate their parameters as probability density functions (PDFs) calculated iteratively from other PDFs using Bayes’ theorem, starting from priors constrained by empirically obtained relations between geophysical variables. The difficulty for TCR is that the only relations we’ve seen between CO2 and climate are for much lower CAGRs, and these seem to be an universally accepted way to bridge that data gap.

**SOLUTION** A simple modification to TCR’s definition

We propose a simple modification of TCR, which we call Preventing Climate Response. We replace the 1% CAGR of CO2 with a 2% CAGR for anthropogenic CO2 defined as the excess CO2 over the natural background of 280 ppm. This is essentially a simplification of D. Hofmann’s law of 2010 [1].

**ADVANTAGES**

Three justifications for this modification

(i) TCR is a far better fit than TCRs with CAGRs 3.5 to 5.0, one of the scenarios we are very interested in, as Figure 1 makes clear. (The abrupt climate change forecast by RCP8.5 for 2070 is very interesting.)

(ii) We have excellent data constraining PCR from past centuries, as illustrated by Figure 2.

(iii) The extreme straightness of log(DO2CO2–280) as seen in Figure 3 makes it likely that estimates of PCR will remain good until that curve starts to bend down, about whose timing we know nothing whatsoever.

**Mistakes**

**PROBLEM** PCR seems no better than TCR in practice

Some authors have understood climate sensitivity to mean simply the response of climate to a doubling of CO2 without the ECS requirement of waiting until the response equilibrates (and so implicitly assuming effective real time climate sensitivity), and without the TCR requirement that CO2 rise at 1% a year during the warming (and so implicitly assuming the prevailing behavior of CO2 on which to base the response). Figures 1–3 show this to be equivalent to PCR. Lohle and Scalfati [2011] (2012) obtained a warming induced by CO2 of 0.66 °C/century, based on fitting CO2 rising at the TCR CAGR of 1% to an extrapolation of the TCR curve through 2100. Since it takes 0.7 of a century for CO2 to double at that rate, this would be a PCR of 0.69/7 = 0.046°C/doubling. Fig. 4 duplicates their method exactly in MATLAB.

One might infer from this wide range that PCR does no better than TCR as a notion of climate sensitivity that can be reliably estimated.

**SOLUTION** Simple mistakes that are easily fixed

Both estimates make elementary mistakes in estimating PCR as respectively too low and too high.

(a) L&K’s mistake is to relate warming during 1943–2010 to the TCR 1% CAGR for CO2 instead of that for CO2 during that period. (We obtained 2.32 when we duplicated it in MATLAB as per Fig. 5.)

(b) Lovejoy makes two mistakes. First is his assumption that global warming is entirely attributable to CO2 when in fact total solar irradiance TSI increased during 1900–1950, a period in which CO2 increased relatively little. Second, when the CO2 data is uniformly distributed in time its logarithm concentrates more of those data points in the left half of the plot, exaggerating the Sun’s contribution.

When the appropriate corrections are made, the respective estimates of L&K and Lovejoy converge to the neighborhood of 1.8 Celsius doubling. The correction for L&K is simply to use the correct CO2 data. For Lovejoy it suffices to detrend GISTEMP by the likely influence of solar irradiance and then resample GISTEMP to create data points radiatively even along the radiative forcing x-axis, easily done with MATLAB’s interp1 function.

**Mistrust**

**PROBLEM** Climate is too noisy to estimate PCR accurately

We see this already with Lovejoy’s method, which not only attributed the 1900–1950 rise in TSI to CO2 but then dismissed that error by concentrating much of the data into where the CO2 was not changing much. We infer that fitting linear regression fitter both CO2 and TSI is HadCRUT4 is to avoid Lovejoy’s overestimation of PCR. The blue curve in Figure 6 shows the residual after this fitting.

This residual is quite noisy, with a standard deviation σ of 165 millikelvin (mK). This gives a quantitative sense in which “climate is always changing”, and also rates doubts as to the quality of the fit: the noise could be masking considerable uncertainty.

Applying a 65-year moving average filter to this residual yields the red curve, whose σ of 8.4 mK is dramatically lower. The significance of this huge decrease is that, with the exception of changes due to CO2 and TSI, we can now say “climate is always changing σ”, namely with all event durations and oscillation periods shorter than 65 years.

While some decrease is to be expected, such a large decrease is remarkable. We can get insight into how filtering the residual benefits its use in a filter of 16 by comparing (i) what we would have obtained if we had omitted TSI from the above fit, and (ii) TSI itself, after smoothing both with a 65-year moving average. (This is recent TSI reconstructed from group numbers, [2] and positive.)

Both turn out to have a σ of 26 mK. This is more typical of what is obtained when modeling data with one signal when other signals are present: they naturally fit the signal, even where the noise is uncorrelated.

The next plot shows that we still haven’t fully solved our attribution problem.

What we infer in this case is that TSI is essentially the only other signal present! All other contributors to climate varied too rapidly to survive the 65-year filter. That plot shows that we still haven’t fully solved our attribution problem.

**Mitigation**

**PROBLEM** What if we fall off the straight line in Fig. 3?

There is no apparent geophysical reason why climate sensitivity would be well-defined. The concept is at best an article of faith of both climate science and climate denial, the latter because it provides teleological-teleological goals for debating climate change authoritatively.

What we have shown here is that the concept of climate sensitivity defined as exponentially rising temperature rise requires CO2 to increase exponentially rising CO2 has shown remarkable stability between 1850 and now and we provide estimates of 280–630 ppm.

It seems very likely to us that this would hold also of exponentially rising CO2. The difference is that we hypothesize two common sources contributing together (this PCR) for this TCR. We have no experience to date of CO2 rising at a 3% a year, or that rate even until past 1900. What we have measured is that rate of increase over such a short period.

We proposed PCR as a modification of TCR much better suited by its regularity to estimate a good PDF for TCR.

With 1850 years of data in hand and only 2 or more years in this century, if all significant climate factors continue along their trajectories to date, “business as usual”, allowing Figures 3 and 6 to be projected forward 50 or perhaps even 100 years, we would expect ACO2 to increase from today’s 410 ppm to 1300 ppm by 2100. The rate 260 ppm to 900 ppm, confining log2(960/410) = 1.25 doublings of CO2. With PCR in the range 1.7–2.0, that entails a further rise during this century by 1.272 = 1.7–2.1 degrees and 1.52 = 2.5 degrees.

This however does not refer to the year 2100 itself but only to the likely over 65 years in window that in view. The right side, about half of those years are likely to be colder. More ominously the other half are likely to be hotter. What we can’t say right now is which years will be which, we only know their average with any confidence, as a sort of uncertainty principle for climate.

All this is predicated on AGW continuing to rise with a CAGR of about 2%. If some more Earth’s inhabitants are able to reduce that CAGR significantly, the business as usual assumption is no longer satisfied.

**Conclusions**

We traced the wide variations in TCR to a paucity of available climate data that is not obvious how to fix. We proposed PCR as a modification of TCR much better supported by extrinsic climate data. We traced the wide variations in previous estimates of PCR to easily fixed elementary mistakes. We identified confounding of solar irradiance and radiative forcing as an obstacle to further improvements in PCR. And we showed that mitigation benefits to the planetary could however be detrimental to climate change policies, namely the possibility that the vegetable kingdom could violate Le Chatelier’s principle. Where we can’t rule out that plants could pull us back into an ice age, though how soon would some critical biology?

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**References**


**Abstract**

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