



EGUsphere, referee comment RC1
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Comment on "Potential bias in effective climate sensitivity from state-dependent energetic balance"

Anonymous Referee #1

Referee comment on "Potential for bias in effective climate sensitivity from state-dependent energetic imbalance" by Benjamin M. Sanderson and Maria Rugenstein, EGU Sphere, <https://doi.org/10.5194/egusphere-2022-167-RC1>, 2022

General Comments:

Sanderson et al. use a simple climate model composed of several exponential decay terms to model the output of pre-industrial control and abrupt-4×CO₂ simulations from CMIP5, CMIP6, and LongRunMIP. The authors use this simple climate model to estimate potential biases in effective climate sensitivity (EffCS) estimates. This approach is novel and provides an interesting framework to analyze EffCS; however, there are several points that the authors should address in order for me to recommend this manuscript for publication.

Specific Comments:

1) The new framework the authors developed is interesting; however, I am having a hard time deciphering why this paper is important. I am not sure what the main point of the paper is. Is the main point to answer the question the authors stated at the end of the introduction: "How plausible are the higher sensitivity [CMIP6] models"? Is the main point to say that ECS is actually higher than suggested by EffCS given by CMIP6 or IPCC AR6? The authors state "Our results highlight the potential for error in estimates of effective climate sensitivity through the assumptions on the asymptotic radiative balance of climate models (page 9 line 9)". The authors need to go a step further and provide an indication of what their suggestion for the value of EffCS would be based on their new framework. The authors should discuss their results in the context of recent literature that examines estimates of EffCS. Recent studies have provided estimates of EffCS, such as Zelinka et al. (2020), Tokarska et al. (2020), McBride et al. (2021), Sherwood et al. (2020), and the new comprehensive evaluation conducted by IPCC AR6. Do the authors have a new range

of EffCS using their approach compared to these other analyses? Could the authors suggest a way to constrain the estimate of EffCS based on the model's radiative imbalance between the PICTRL and ABRUPT4X simulation? The authors should add comparisons to recent literature in their results section. In the conclusions section, the authors should expand upon the importance of their results to indicate a revision or addition to current estimates of EffCS, or suggestions on how to revise the current estimate of EffCS using their approach.

2) How did the authors determine the minimum and maximum values of τ for the short timescale, intermediate time scale, and long-time scale given in Table 1? Are these values supported by literature?

3) The authors should explain how assessing the radiative imbalance in the control simulation, R_0^{CTRL} , impacts the parameters in Eq. 1a or Eq. 1b. As currently written, it is unclear how this assessment is incorporated into Eq. 1a and 1b.

4) Equilibrium climate sensitivity and effective climate sensitivity are the response of the climate system to a doubling of CO_2 relative to preindustrial. The authors use the ABRUPT4X scenario, which is for a quadrupling of CO_2 . In other methods, such as Gregory et al. (2004), the temperature response to the quadrupling of CO_2 needs to be divided by 2 to achieve an estimate of the temperature response to the doubling of CO_2 . The authors do not discuss how their method accounts for the fact they are using an ABRUPT4X scenario to assess the temperature response to a doubling of CO_2 . The authors should elaborate in the methods section how they account for this discrepancy.

5) There is no mention of IPCC AR6 in this paper. How does this analysis compare to the best estimate (3°C) and range of ($2 - 5^\circ\text{C}$) of ECS given by AR6? Does the new framework in this paper support a lower or higher value of EffCS than provided by IPCC?

6) Figures 1 and 2 are barely discussed. The authors should add more discussion of these figures to the results section, especially highlighting any important interpretations of the figures, or move these two figures to the Appendix.

7) In the results section, the authors jump back and forth between discussing Figure 3 or Figure 4 (Page 6 lines 1 – 19), making it difficult to follow the points the authors are trying to make. The authors should consider editing this section by first discussing and interpreting Figure 3, then discussing and interpreting Figure 4.

8) The authors need to verify that the figure captions match the figures. Colors and types of lines described in the figure captions do not match what was plotted in the figure, making it difficult to interpret the figures (see the Technical Corrections related to each figure below).

9) Table A2 is an important table, displaying the difference between EffCS computed using various methods for the LongRunMIP simulations. The authors should consider moving Table A2 into the main part of the text. They can add a discussion of the table to the results section, highlighting why the estimates for $\Delta T_{\text{best-est}}$ and ΔT_{extrap} are similar for some models yet different for others.

Technical Corrections:

Equation 1b: Constant is written as R^{4x} , but referred to as R_0^{4x} in the text (page 3 line 1)

Table 1: R_n scaling factors are not listed in Table 1, but S_n scaling factors are listed. Is there a reason why the R_n scaling factors are omitted?

Table 1: R_0 is included in the table, but this variable does not appear in either Eq. 1a or Eq. 1b. How does this variable relate to these two equations?

Why are the lines in figures 1 and 2 labeled as S_{LR} , S_{eff} , and S_{extrap} . In Eq. 1a, 1b, 2, and 3, S refers to a scaling factor. Why are the authors using this variable (S) to label the different lines?

Figure 1 Caption:

- Authors state solid yellow lines are linear regressions used to estimate effective climate sensitivity for the first 150 years of data. This should be the dotted yellow lines.
- Authors state solid pink lines are linear regressions used to estimate effective climate sensitivity for the last 15% of warming. This should be the dotted pink lines.
- Authors state vertical dotted pink and yellow lines show corresponding values of effective climate sensitivity. Should be vertical solid pink and yellow lines.
- Authors state solid yellow horizontal line shows the PICTRL net energy imbalance averaged over the final 100 years of the simulation. There are no solid yellow horizontal lines. There are green horizontal lines, which are not included in the caption or legend. Are the green lines supposed to be the PICTRL net energy imbalance? If not, make sure to label what the green lines are showing.
- Solid blue line is not described in the caption
- I am not sure that the dashed blue line is described correctly in the figure caption. Authors say the dashed blue line shows an exponential model fit, but the lines in all of the subplots in Figure 1 are horizontal. Is the solid blue line actually showing the exponential model fit? If so, what do the dashed blue lines represent?
- Green dots are not described in the caption

Figure 1 General Comments:

- Green and blue dots in the legend representing PICTRL and ABRUPT4X are very faint, almost impossible to see. Make them more legible in legend.
- I cannot distinguish the difference between the blue dots representing ABRUPT4X and the light blue ellipse showing the 5-95 CI for ΔT_{extrap} . It looks like only the light blue ellipse is plotted.
- What does n_{yr} show? I assume it is the number of years in the LongRunMIP simulation, but the authors should include a description of the parameter in the figure caption for clarity.
- Make sure the lines plotted on the figure do not go through the text (i.e., CNRMCM61 panel has solid blue and dotted yellow lines going through $n_{yr} = 1850$)

Figure 2 Caption:

- There is a description of black points, but there are no black points in the figure or legend
- Which dashed horizontal line illustrates ΔT_{extrap} ? Blue? Green?
- A description of the green dashed line does not appear in the figure caption, and the green dashed line is not included in the legend.
- A description of the green dots does not appear in the figure caption
- Authors state the dashed purple line is $\Delta T_{\text{best-est}}$. I do not see a purple line. There is solid pink line. Is this pink line supposed to be $\Delta T_{\text{best-est}}$?

Figure 2 General Comments:

- Missing "of" in the sentence: "Shaded regions and thin dotted lines show the 10th and 90th percentiles **of** the fitted ensemble projections"
- The 4xCO₂ and pictrl is written differently from PICTRL and ABRUPT4X in the first figure caption and the main text. These scenarios should be referred to in a consistent manner
- There are no lines or symbols next to 4xCO₂ and pictrl in the legend

Figure 3 General Comments:

- It is difficult to distinguish the blue dots and the blue shaded region, specially towards the right side of each panel. Making the shaded region a different color, or different shade of blue could help distinguish the points from the shaded region.
- Why do some of the models have visible 10th and 90th percentiles at the beginning and ending of the blue line, but others do not? What is different in the models with very small ranges of uncertainty from those with larger ranges?
- 4xCO₂ in the legend does not match ABRUPT4X labeling in figure caption and the main text
- Missing "of" in the sentence: "Shaded regions and thin lines show the 10th and 90th percentiles **of** the fitted ensemble projections"

Figure 4 Caption:

- Left hand column:
 - Caption says there are whiskers in the left-hand column on the light blue diamond symbols. There are no whiskers plotted showing the 10th & 90th percentiles of ΔT_{extrap}

- Central Column:
 - Caption says there are cyan error bars plotted, but they are not on the figure. Only show blue diamonds
 - Solid and dashed yellow lines are not described in the figure caption

Figure 4 General Comments:

- Is there any range of uncertainty for the values of $\Delta T_{\text{best-est}}$ shown by the red diamonds? If so, then this uncertainty should be indicated on the figure
- There is no legend included with this figure, whereas the other 3 figures included legends. Consider adding a legend to this figure.

Page 3 Line 31: What does "this estimate" refer to? ΔT_{extrap} , R_{extrap}^{4x} , or both?

Page 3 Line 35: Some other models should be included as described as behaving as expected. GISSER2R and GFDLESM2M show near zero equilibrium TOA balance in both PICTRL and ABRUPT4X simulation in Figure 3. Why were these models excluded from this sentence?

Why are the values in the brackets for ΔT_{extrap} and ζ_{extratp} the same in Tables A2, A3, and A4? The table caption explains that the numbers in the brackets represent the 5th and 95th percentiles. I find it highly unlikely that the 5th and 95th percentiles are the same, especially since the median value is larger than the values in the brackets.

Page 9 Line 21: Missing closing parentheses after Table A1

References:

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Tokarska, K. B., Hegerl, G. C., Schurer, A. P., Forster, P. M., and Marvel, K.: Observational constraints on the effective climate sensitivity from the historical period, *Environ. Res. Lett.*, 15, 1–12, <https://doi.org/10.1088/1748-9326/ab738f>, 2020.

Zelinka, M. D., Myers, T. A., McCoy, D. T., Po-Chedley, S., Caldwell, P. M., Ceppi, P., et al.: Causes of higher climate sensitivity in CMIP6 models. *Geophysical Research Letters*, 47, e2019GL085782. <https://doi.org/10.1029/2019GL085782>, 2020.