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Comment on esd-2021-78

Anonymous Referee #2

Referee comment on "Earth System Sensitivity: a Feedback perspective" by Peter O. Passenier, Earth Syst. Dynam. Discuss., <https://doi.org/10.5194/esd-2021-78-RC2>, 2022

Review of "Earth System Sensitivity: a Feedback perspective" by Peter O. Passenier.

This manuscript explores the consequences a narrowing of uncertainty in equilibrium climate sensitivity (ECS) has for the Earth system sensitivity (ESS) using a feedback analysis. The analysis compares the ECS range from IPCC AR5 (likely 1.5-4.5 K) to the narrower range taken from Cox et al. 2018 (likely 2.2-3.4 K) which was derived from an emergent constraint based on observed variations in global temperature. It then explores the implications of these two ECS ranges for ESS by assuming several possible values for Earth system feedbacks (ice sheet albedo feedback, methane, etc). It concludes by making the point that even with a narrowed (Cox et al.) ECS range, the resulting ESS values could be larger than the IPCC AR5 ECS range, with possible implications for Paris targets.

The manuscript is well written and interesting to read. The methods are based on a straightforward application of feedback analysis. However, I have several major concerns that need to be addressed before I could recommend publication.

1) Sherwood et al. 2020 and IPCC AR6 WG1 Chapter 7 are two recent community assessments of ECS that narrow the likely range to about 2.5-4 K based on multiple lines of evidence (including emergent constraints). This is the likely ECS range that should be used in the analysis instead of the single study of Cox et al. 2018 (which has been challenged on methodological grounds and may turn out to not be robust, see discussion

in IPCC AR6 Chapter 7).

2) The AR6 definition of ECS includes everything but the feedbacks associated with ice sheet changes and CO₂. That is, it includes methane, vegetation, and many other biogeochemical/physical feedbacks whose values are assessed in AR6 Chapter 7. So, the only feedback of relevance for ESS here would be the ice sheet feedback.

Regarding the ice sheet feedback, AR6 Chapter 7 states the following:

... ice sheet mass loss leads to fresh water fluxes that can modify ocean circulation (Swingedouw et al., 2008; Goelzer et al., 2011; Bronselaer et al., 2018; Golledge et al., 2019). This leads to reduced surface warming... However, model simulations in which the Antarctic ice sheet is removed completely in a paleoclimate context indicate a positive global mean feedback on multi-millennial timescales due primarily to the surface albedo change... This net positive feedback due to ice sheets on long timescales is also supported by model simulations of the mid-Pliocene warm period... As such, overall, on multi-centennial timescales the feedback parameter associated with ice sheets is likely negative (medium confidence), but on multi-millennial timescales by the time the ice sheets reach equilibrium, the feedback parameter is very likely positive (high confidence; see Table 7.10). However, a relative lack of models carrying out simulations with and without interactive ice sheets over centennial to millennial timescales means that there is currently not enough evidence to quantify the magnitude of these feedbacks, or the timescales on which they act.

That is, on timescales of a century (of relevance for the Paris targets) the ice sheet feedback is probably negative, and only on timescales of several centuries and longer does it become positive, but with a value that is not well quantified on either timescale. In light of the AR6 assessment, a positive ice sheet feedback does not seem to be relevant for Paris targets. The ice sheet feedback values chosen in this study need to be well justified. And note that the value derived from the LGM is not suitable for a calculation of ESS relevant for future warming.

3) Given the above, I am not sure that the analysis can add much to the existing literature on ESS. While showing the impact of different hypothetical ice sheet feedback values for ESS (on top of different ECS ranges) would be a fine exercise, I don't see what new information it would provide or how ESS relates to Paris targets which deal with warming this century. It's also possible that I am missing something, but either way the author needs to better explain the relevance and novelty of the feedback calculation

performed here.

References

IPCC AR6 WG1 Chapter 7:

https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_07.pdf

Sherwood et al. (2020). An assessment of Earth's climate sensitivity using multiple lines of evidence. *Reviews of Geophysics*, 58, e2019RG000678.

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