Earth Syst. Dynam. Discuss., referee comment RC2
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Comment on esd-2021-86

Anonymous Referee #2

Referee comment on "Does feedback temperature dependence influence the slow mode of the climate response?" by Tim Rohrschneider et al., Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2021-86-RC2, 2022

Summary:

This paper presents interesting and useful new results on the timescales of the climate response to CO2 forcing, exploiting 1000-year long step forcing AOGCM experiments. While the results are novel, I found the presentation rather complex and hard to follow, so I am requesting major revisions to make the paper more accessible.

Main comments:

1) Presentation

Overall I found the text difficult to read, despite it being well polished and free of typos – to the point that I didn't understand everything despite a careful read. I ended up becoming frustrated and skipped most of section 5. The issues start with the abstract, where things should be kept simpler in my opinion. In particular, I struggled with the sentence L11–13, which I'm still not sure I fully understand after reading the paper. Can this be explained more simply, or perhaps omitted?

The introduction begins rather abruptly, and assumes a fairly high level of background knowledge – for example, that it is commonly understood that the response to CO2 forcing can be decomposed into fast and slow components. The notion that climate feedbacks are temperature dependent is also assumed. I think these concepts should be introduced more slowly, with references to the relevant prior literature:

- What do we know about feedback temperature dependence? Is this commonly simulated by GCMs?
- Do we know the sign of this dependence, or is this still a subject of ongoing research? The text asserts that feedbacks become more amplifying with warming (L25), yet this is inconsistent with two out of four GCMs used in this study (Table 1).

Another confusing aspect for me was the introduction of the two conceptual models (Eqs. 4–6):

- What physics underlie the 1st model (based on two regions, Eqs. 4–5)? Presumably this is meant to reflect the SST pattern effect, but I don't think this was explained.
- It would help to discuss the commonalities and differences between the two models. My understanding would be that using an efficacy term (epsilon) in the 2nd model could be mathematically equivalent to using spatially-varying feedbacks in the 1st model – is this correct? The 2nd model additionally includes a heat transport efficiency term – what physics does this involve and does it make the 2nd model different from the first?
- The authors ultimately choose to focus on the two-region model (Eqs. 4–5), as stated L182. Why this choice, and how does it affect the interpretation of the results? Do we even need both models in the paper?

I feel like it might help to use an appendix to discuss some of the more technical aspects of the two conceptual models and/or the methodological choices, so as to keep the main text simpler and more focused on the key results and their interpretation.

2) Definition of feedback temperature dependence

I would like the authors to clarify and make explicit their definition of temperature-dependent feedbacks. It seems to me that there are two quite distinct types of temperature dependence: (a) a temperature-dependent SST pattern effect, versus (b) temperature-dependent feedback processes (independent of the SST pattern). The latter could be quantified for example using uniform SST warming or cooling experiments. My understanding is that the temperature dependence discussed in the present paper includes both processes (a) and (b), but it would be good to clarify this. Do the authors know which type of temperature dependence is more important for their findings? If we want to understand and perhaps observationally constrain the temperature dependence of climate feedbacks, it seems to me that different approaches would be needed for (a) versus (b).

Specific comments:

- L24: “As a result” – of what?
- L112: Should clarify that this isn’t the formulation used by Held et al. and Winton et al. (who didn’t consider feedback temperature-dependence, as far as I’m aware?)
- L185: Shouldn’t it be N_F(t=0)?
- L186–188: I wasn’t able to follow this, can you explain in more detail or illustrate this graphically? (After further reading, I see this is explained more clearly L225–227. This needs to be reorganised.)
- L193–196: Again I wasn’t able to fully follow. I’d recommend explaining this in more detail in an appendix.
- L248: remove extra “between”
- L283–284: I didn’t follow this reasoning.
- L441: “publicly *available* experiments”
- L443: The reference to year 2100 is odd, considering that the results are based on idealised step forcing experiments, rather than realistic RCP-style scenarios.