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Interactive comment on "Is there warming in the pipeline? A multi-model analysis of the zero emission commitment from CO_2" *by* Andrew H. MacDougall et al.

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The study is addressing an important unknown in the climate system as to whether there is continued warming or cooling on a decadal timescale after carbon emissions cease. There is a comprehensive analysis of 18 Earth system models (of either full or intermediate complexity) following a common default experiment of CO2 increasing until 1000 PgC has been emitted and then freely varying.

I am very positive towards the ambition, scope and rigour of the manuscript. A key outcome is the message is that ocean and terrestrial carbon uptake is particularly important in determining the Zero Emissions Commitment (ZEC). I have 2 concerns

with regards the strength of this conclusion.

1. The analysis of the thermal response on a decadal timescale focuses on changes in planetary heat uptake and the efficacy, representing a non-dimensional weighting of planetary heat uptake. The study ignores any explicit discussion of temporal changes in climate feedback parameter (due to their method to diagnose the effective climate sensitivity), particularly associated with clouds. Since the study is focussing on decadal timescales, this omission is likely to be important and should be more fully discussed. Clouds represent one of the biggest uncertainties in climate sensitivity and are known to evolve in time. This potentially important contribution of physical climate feedbacks merits a fuller discussion.

I fully realise that time-variations of the climate feedback parameter may be related to temporal variability in the efficacy. Indeed the authors include a 30% uncertainty in the planetary heat uptake term to take account of this effect, but do not extensively discuss the implications of this uncertainty. In their crucial figure 7, the sign of the ZEC in most model cases is uncertain given the uncertainty arising from the efficacy weighting of the change in the planetary heat uptake. Thus, there needs to be more acknowledgement of the uncertainty in the ZEC due to physical climate feedbacks (or an explanation of why these physical climate feedbacks are less uncertain at the time of zero emission). Whether this uncertainty represents random variability or a systematic trend needs to be addressed.

2. There is a larger inter-model spread in the response of the terrestrial carbon feedback. A key conclusion is that the terrestrial carbon response is of central importance in dictating whether surface temperature continues to rise or fall after emissions ceases. However, this conclusion needs to be seriously caveated by the choice of terrestrial carbon cycle and whether nutrient limitation is included. It might be the case that the terrestrial carbon cycle is becoming over strong if there are no constraining limitations applied. It would be useful to group the analysis of the terrestrial response into those model responses with and without nutrient limitation, and then more clearly contrast

their behaviour.

A further recommendation is in the final conclusion is to recap as to how this work compares with prior studies, particularly for the multi-centennial timescale. This context is set out earlier in the motivation, but it is unclear as to the extent of agreement or not with the inferences in the prior work.

In summary, I think that the study is important and recommend minor edits, particularly to discuss the outcomes of the study in terms of the effect of physical climate feedbacks (via the efficacy) and the controls of nutrient limitation in the terrestrial system, and placing the study in the context of prior work.

Detailed points:

L12 Mention the large uncertainty in the sign of the ZEC from the 30% uncertainty in the efficacy.

L71/72. Both prior studies are addressing the multi-centennial timescale, rather than the previous discussion of a millennial timescale (L30-41). Your study should relate back to these two prior studies and identify what is different to the arguments outlined by Ehlert and Zickfeld (2017) and Williams et al. (2017).

L77 Recommend rephrase to avoid ambiguity so as to make clear to the reader what part of the sentence “only” refers to.

P8-11 Recommend placing the model descriptions in Tables 2 to 5 in the Appendix.

L175. Add Williams et al. (2017) for the multi-centennial case as that study has addressed the different thermal and carbon controls for delayed warming.

P13. In contrast to the model descriptions, I think that the theory in Appendix A could have been placed in the main text, but up to the authors discretion.

L198 include that the change in ocean heat uptake includes a time-dependent weighting from the efficacy.

L209. Include that the Gregory ECS is a time average fit over the time period of interest, while the efficacy is time dependent.

L217 The efficacy values may not simply be representative of internal variability, but may also be associated with systematic shifts in climate feedback, such as systematic changes in cloud types with changing surface temperature.

L223 The authors have acknowledged the importance of the efficacy by including a 30% uncertainty. However, is there a systematic trend to the efficacy or are there random variations in the different models? In diagnostics of ESM2M, there is a progressive increase in the efficacy from close to 1.5 to over 2 in 100 years after emissions cease, which may be equivalently interpreted as a systematic decrease in climate feedback parameter that continues for several centuries; see Williams et al. (2017). If there is a systematic trend, then the implications for the ZEC are different to if there is simply uncertainty in how the efficacy evolves.

L254. Clarify the timescale.

Figure 2. It is difficult to pick out individual model types, particularly those coloured blue and green. Recommend split the panels and show the responses for different types of models to gain more insight.

L333 The response is interpreted in terms of changes in the “deep ocean circulation”. However, the anthropogenic invasion of heat and carbon is being dominated by ventilation of the thermocline, see Sabine et al. (2004) Science or Zanna et al. (2019) PNAS. Schematic figure of Goodwin et al. (2015) Nature Geosciences or model diagnostics in Williams et al. (2017) J. Climate set out this thermocline ventilation view.

L335. The large uncertainty in the efficacy weighting of ocean heat uptake in Figure 7 can change the sign of the ZEC and so this aspect is certainly of comparable importance to the terrestrial carbon sink.

Figure 10. It is striking how low a proportion of the intermodel variability in the ZEC

is explained by any of these metrics. Do these fits improve or alter if different subsets of models are included? The relatively weak fits suggests that the ZEC is being determined by a competition of processes and examining one process in isolation only provides limited insight.

Figure 11 is more encouraging in showing that for the same model type, there is a relationship between the ZEC and the TCRE, with an increasing ZEC with a higher ECS. L368 There is a poor relationship between the ZEC and the TCR and ECS when looking across a range of models, but there is a stronger relationship when looking at the same model.

L399 Mention that over multiple centuries that warming might further increase or decline. Useful to expand upon that statement and compare further with the prior studies examining the multi-centennial response.

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