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Interactive comment on "Constraints on long term warming in a climate mitigation scenario" *by* Benjamin Sanderson

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Summary: This study explores the long-term warming of climate for heavily mitigated scenarios, discussing the reasons behind changes in the sensitivity of warming to cumulative carbon emitted over time. An efficient model ensemble is generated and integrated with both prescribed concentration pathways (e.g. Figure 1), and an adaptive pathway algorithm to generate warming scenarios that restore towards the desired warming targets (e.g. Figure 2).

The study discusses how the required mitigation efforts are affected by changes in the sensitivity of surface warming to cumulative carbon emitted over time (the TCRE), and how a constant TCRE framework may not be able to account for such effects.

I found the study, as currently written, difficult to place in the context of existing literature. In particular, this study is missing comparisons to existing literature using

observationally-constrained ensembles to explore the future carbon budget, adaptive mitigation pathways, and the time evolutions of effective climate sensitivity and transient climate response to emission.

Before such comparisons are made, it is difficult to say what in this study is new, and how it fits within existing knowledge.

Major points: Significant areas of existing literature missing from discussion.

1. Observation-constrained ensembles exploring the future carbon budget

The study as currently written is missing comparisons to existing literature on observation-constrained calculations of future carbon budget for this century (Goodwin et al., 2018a) and out to year 2300 (Goodwin et al., 2018b) generated using the WASP model.

More details are required for the method used here for generating an observationally-constrained ensemble. A full methodology needs to be presented containing prior assumptions, observational constraints and how the observational constraints are applied. This method used here should then be compared to the Monte Carlo plus history-matching method presented in Goodwin et al. (2018a).

Note that both Goodwin et al. (2018a) and (2018b) studies adopt an efficacy on the ocean heat uptake, which is equivalent to allowing the effective climate sensitivity to change over time (where the ocean heat uptake efficacy is greater than 1 the effective climate sensitivity in the present day is less than the equilibrium climate sensitivity on multi-century timescales, and where the efficacy is less than 1 the effective climate sensitivity for the present day is greater than the equilibrium value). As such, both studies allow the effective climate sensitivity to vary implicitly over time, and do not assume a relationship between TCR and ECS like the FaIR model studies (an approach which this study critiques). The fact that no relationship is assumed between TCR and ECS in this study is currently discussed, but to assess whether the method is novel is needs to be compared to the WASP model methodology, for which this is also true.

2. Comparison to adaptive mitigation pathway algorithms in the literature: The Goodwin et al (2018b) study in Earth's Future presents and uses an adaptive mitigation pathway approach to restore a large ensemble of observation-constrained efficient model simulations to 1.5 and 2.0 °C targets – in a very similar manor to the results presented in this study in Figure 2. Given the similarity of the method, the results in this study should be compared to this existing Goodwin et al (2018b) study in the literature.

The 'Adaptive scenario design' used here (Figure 2, Appendix A1.2) should be compared to the 'Adaptive Mitigation Pathway' algorithm presented in Goodwin et al (2018b) and used in Brown et al. (2018) and Nicholls et al (2018). The resulting model output in this study, for compatible carbon emission pathways, should then be compared to the similar output generated in these previous studies in the literature.

3. Comparisons to existing literature on the reasons behind continued warming after emissions cease and the non-constancy of the TCRE

This study is missing comparisons to existing literature, both on the reasons behind continued surface warming after emissions cease (e.g. Frölicher et al., 2014; Williams et al., 2017a) and on the reasons behind near-constancy (or otherwise) of the TCRE (e.g. Goodwin et al., 2015; Williams et al., 2017b). One of the potential reasons that TCRE is non-constant is a change in effective climate sensitivity. However, other possible reasons are discussed in the studies mentioned here. The reasons behind non-constancy of the TCRE in the model simulations presented here should be quantified in a way that relates to previous studies in the literature such as these.

4. Constraints on the time-evolution of effective climate sensitivity in the literature One effect leading to a change in TCRE over different response timescales is that the effective climate sensitivity also evolves over different response timescales. Again, here the discussion is missing sections of the literature. For example, Goodwin (2018) generates a large ensemble of model simulations with explicitly time-evolving

effective climate sensitivity, and then uses historic observations to constrain how effective climate sensitivity evolves on different response timescales. This reveals an increase in effective climate sensitivity over time (Goodwin, 2018) that will, crucially for this study, affect future mitigation requirements for a given warming target. Rohling et al. (2018) presents a similar account of time-evolving effective climate sensitivity from a paleo-perspective. These studies should be discussed and the results of this study compared to these previous findings.

It should also be noted that unlike the FaIR model methodology that is currently discussed for comparison (e.g. section 2, Lines 170-185), the WASP model methodology in Goodwin et al. (2018a; 2018b) and Goodwin (2018) does not assume a prior relationship between TCR and ECS or a near-constant TCRE. Therefore, comparisons to the WASP methodology deserve a separate discussion in section 2.

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