We thank the reviewer for their comments. In this document, we detail our responses.

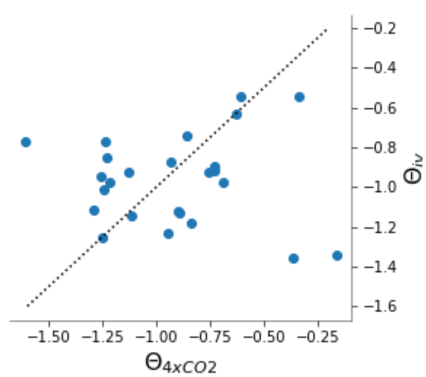
1) It would be helpful to provide a little more physical motivation for the choice of tropical 500 hPa temperature. I see some good reasons why mid-tropospheric temperature should work better (e.g., it should scale better with LR, WV and LW cloud feedbacks), but I don't think this was discussed anywhere. Why use tropical temperature rather than global-mean? Is there a physical rationale, or did this simply work better in MPI-ESM?

Also, although mid-tropospheric temperature clearly works better for the overall feedback, I expect the scaling with Ta might actually be a worse choice for some individual feedback processes (e.g. surface albedo, marine low cloud). This might be worth discussing briefly.

A: To address this, we have added a paragraph to the paper: "There are several plausible reasons why T_A may control R better than T_S. It seems likely that several of the feedbacks — e.g., lapse rate, water vapor, longwave cloud — should be strongly influenced by atmospheric temperatures rather than ΔT_S. More recently, it has been shown that atmospheric temperatures play a key role in regulating low clouds [Zhou et al., 2016, 2017], thereby influencing the shortwave cloud feedback. The net result is a clear dependence of ECS on atmospheric stability [Ceppi and Gregory, 2017]. We have not further investigated this — ultimately, our use of ΔT_A in Eq. 4 is based on empirical observations [Murphy, 2010; Spencer and Braswell, 2010; Trenberth et al., 2015] that it correlates well with ΔR. Other metrics, such as global average atmospheric temperature work almost as well. Clearly, further investigations on how to best describe the Earth's energy balance are warranted."

2) A key result is that the revised feedback parameter theta more accurately estimates the "true" feedback strength under CO2 forcing. This is shown to be the case in MPI-ESM (L172-176). However, does this hold for CMIP5 models in general? I.e., do the values of theta estimated in control runs correlate well with those in 4xCO2?

A: This is not a claim we make in the paper, although one might infer it from the MPI model. Indeed, there is *some* correlation between short-term and long-term theta in the CMIP5 ensemble, as seen here:



Caption: Scatter plot of Θ_{4xCO2} vs. $\Theta_{control}$ from the CMIP5 ensemble. Each point represents values from model.

However, because of the outlier models, the relation is hard to interpret and we have not pursued this "emergent constraint" approach in our estimate of ECS using our revised framework [Dessler and Forster (2018, February 6). An estimate of equilibrium climate sensitivity from interannual variability. Retrieved from eartharxiv.org/4et67].

We have added a short statement to the paper to reflect this: "It may also be possible to use the relation between short-term and long-term Θ as an emergent constraint to convert short-term observations to the long-term response. There is some scatter in the relation in the CMIP5 ensemble, however, so more analysis of how these relate is likely required before ECS can be constrained in this way."

Relatedly, I would also suggest adding the correlation between R and Ta in CMIP5 piControl to Fig. 4, as additional bars in a different color.

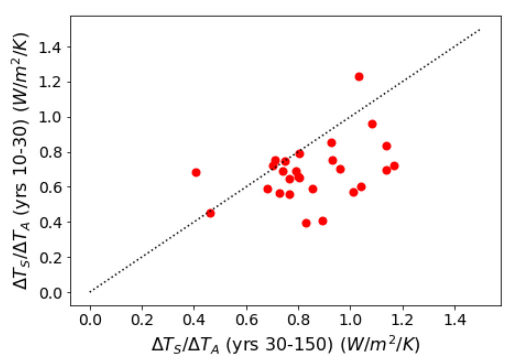
A: We have done that.

3) One important issue that isn't discussed in the paper is that the "pattern effect" doesn't simply go away with the improved relationship; rather, it shifts from the feedback parameter to the Ts/Ta term. This isn't a problem, but the way the paper is currently written, some readers might get that impression.

A: We have added a sentence discussing this: "This means that the pattern effect's impact on ECS calculations shifts from λ in Eq. 2 to the $\Delta T_S/\Delta T_A$ term in Eq. 4."

So if most of the curvature in the relationship between radiative response and temperature goes away with the revised framework (Fig. 6), I expect there must be some curvature in the Ta versus Ts relationship in 4xCO2 runs. Can the authors confirm this?

Confirmed.



Caption. Scatterplot of slope of ΔT_S vs. ΔT_A in CMIP5 abrupt4xCO2 runs. Each point represents one model. The dotted line is the 1:1 line. The subscripts (10-30, 30-150) indicate the years of the run from which the slopes are calculated.

We've added a sentence to the paper mentioning that there is curvature in T_A vs T_S relation: "One can conclude from this that there is curvature in the relation between T_A and T_S in the models, emphasizing the need to improve our understanding of the factors that control $\Delta T_S/\Delta T_A$, including how future patterns of surface warming will evolve."

4) I expect the Ts/Ta ratio cannot be reliably estimated from historical runs in the presence of large variability (for the same reason that lambda cannot be reliably estimated - because of the pattern effect). So we must rely on models to estimate this ratio under future global warming, meaning that it will be important to understand how future patterns of surface warming will develop. I suggest the authors discuss this briefly, for example in the conclusions.

We have added a sentence to the paper mentioning this point: "One can conclude from this that there is curvature in the relation between T_A and T_S in the models, emphasizing the need to improve our understanding of the factors that control $\Delta T_S/\Delta T_A$, including how future patterns of surface warming will evolve."

Other minor comments:

I suggest using colors in Fig. 6, rather than dark grey and black.

Done

L223: Cite Andrews and Webb 2018 - For future reference, it would be useful to mention the value of theta estimated from observations (horizontal dashed bar in Fig. 7a).

Done.