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Climate of the Past Discussions

Interactive comment on "Global mean surface temperature and climate sensitivity of the EECO, PETM and latest Paleocene" *by* Gordon N. Inglis et al.

Anonymous Referee #1

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In the study, the authors estimated the global mean surface temperature (GMST) of the EECO, PETM, and LP. They used the latest compilations of sea-surface temperature (SST), land air temperature (LAT), and ocean bottom water temperature (BWT). They tested multiple methods including simple mathematical model, statistical model, and a combination of them with general climate model simulations. The authors further combined estimates from multiple methods into a "best estimate", which is 13.3±0.5°C, 18.7±0.8°C, and 11.7±0.6°C for EECO, PETM, and LP, respectively. They then calculated a gross estimate of the average climate sensitivity using their GMST and CO2-forcing estimates, which is around 2.8–4.8°C.

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Discussion paper

This study is a step forward in the estimation of the early Eocene GMSTs in its usage of the latest temperature compilations, its exploration of multiple methods, and its quantification of uncertainty from potential biases in proxies. I recommend the publication of this manuscript in Climate of the Past after the comments listed below are addressed.

Major comments: 1. For multiple occasions, corrections or inferences are based on a single climate model. For example, the correction offset in Dsurf-1 and the inference in Dsurf-2. I suggest that the authors explore potential difference in GMST estimates if other models are used, as they are available in the DeepMIP archive (Lunt et al., 2020).

2. Assumptions of some methods should be better explored. For example, Dsurf-2 assumes that GMST scales linearly with local temperature. Does this assumption hold in model simulations? This could be tested in DeepMIP simulations, as there are several modeling groups providing more than two simulations with different CO2 levels (Lunt et al., 2020).

3. Related to 2, the authors should also verify the assumptions made in Dcomb-1, i.e. GMST = 0.5 * (tropical SST + BWT). This is especially necessary when results from this method are consistently lower than other methods. That Dcomb-1 can estimate the modern GMST within an error of $\sim$1°C does not guarantee its consistent performance for a hothouse climate. I suggest the authors test this method in model simulations. I understand that most of the current Eocene simulations are short in length and bottom water temperature has substantial trend, but there are longer runs that are worth exploring (e.g., GFDL runs in Hutchinson et al. (2018); HadCM3 runs; and CESM1 runs in Cramwinckel et al. (2018)). Also, Dcomb-1 is incompatible with Ddeep-1. Dcomb-1 assumes ΔGMST = 0.5 * (Δtropical SST + ΔBWT), while Ddeep-1 assumes ΔGMST = ΔBWT. It is better to keep only one method that has smaller biases.

4. The reported uncertainty of the “best estimate” is meaningless. An estimation uncertainty of 0.5–0.8°C is impossible for Eocene GMST, given the large uncertainty of

individual reconstructions, data scarcity, and the uneven spatial distribution of records. I suggest that a more appropriate method is used to better quantify the uncertainty, e.g., a Monte Carlo bootstrapping method.

5. In addition to the "gross ECS estimate", it would be interesting to calculate an ECS using the GMST and CO2 increases from the LP to PETM (e.g., Shaffer et al., 2016).

Minor comments: Line 69: If we take the modern climate as a baseline, Eocene climate forcings are more than just proxy CO2. For example, several climate forcing agents are discussed in Lunt et al. (2017). Please consider changing "CO2 proxy data" to "knowledge of climate forcing".

Line 84: Please define BWT.

Line 140: Please provide more details of the "modern values". Which dataset is used? What time period is used as modern reference?

Line 172: "temperature gradients are roughly half modern values or less". Please list references for this.

Line 190: Delete one "utilize two"

Line 202: 4x CO2?

Line 532–541: Please add a discussion of a caveat of this ECS estimate, as ECS depends on the background climate, e.g., it might increase with warming (Caballero and Huber, 2013; Zhu et al., 2019).

Figure and Table captions: Please specify what the uncertainty range in tables/figures represent (e.g., 1 sd).

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