

## ***Interactive comment on “Geologic constraints on earth system sensitivity to CO<sub>2</sub> during the Cretaceous and early Paleogene” by D. L. Royer et al.***

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We thank the reviewer for comments on the manuscript. We also thank the reviewer for commenting on all the other comments and replies posted so far. Most of the reviewer's comments touch on topics raised in the other reviews. Our numbering here follows that of the reviewer.

1. As we have noted in many of our other replies, we will emphasize in the revised version that we are not establishing a firm minimum ESS value for the entire Cretaceous-early Paleogene interval. Our conclusion is that CO<sub>2</sub> and temperature data for \*some\* of the interval is most consistent with a 3 °C or higher ESS. In principle, it would be

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nice to establish confidence intervals for these ESS estimates, but I am not aware of a method for doing this for deliberately-underestimated values (standard confidence-interval methods are based on best-fit estimates). Our goal was to present ESS estimates that are unlikely to be revised downward in the future (so long as new paleo-CO<sub>2</sub> data aren't dramatically higher and new temperature data aren't dramatically lower); we feel we have succeeded in this goal.

We disagree with the reviewer that our treatment of uncertainty in the CO<sub>2</sub> and temperature data was not transparent or sufficiently thorough. We discuss the uncertainties in CO<sub>2</sub> estimation at length, including an alternative ESS calculation based on a constant 2000 ppm concentration. We also discuss in detail the steps for converting tropical and deep-sea temperatures to global surface temperature, and how our procedure results in an underestimation of temperature change. And we spend a full page discussing the uncertainties in paleogeography.

We agree with the reviewer that a constant ESS cannot be firmly excluded. We will revise the appropriate section accordingly.

2. The review by Abbot pointed out the limitations of our approach for handling solar luminosity, and we are adopting his suggestions in the revisions. The radiative forcing of paleogeography is less well-constrained, but our primary conclusions remain unchanged even if the effect is in the 3-5 °C range.

We discuss at length the significance of mixing glacial and non-glacial periods in our ESS estimates (see, for example, orange lines in Figure 1b-c). We also make two provisional ESS estimates from tie-points that are all from non-glacial periods, which circumvents this mixing effect.

3. We cite the work of Hansen et al. (2008), who calculate a 6 °C ESS for the late Pleistocene assuming all radiative factors are climate feedbacks (CO<sub>2</sub>, CH<sub>4</sub>, aerosols, continental ice sheets, etc.).

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