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Earth System Dynamics Discussions

ESDD

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Interactive Comment

Interactive comment on "Geologic constraints on earth system sensitivity to CO_2 during the Cretaceous and early Paleogene" *by* D. L. Royer et al.

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The reviewer criticizes our use of Charney sensitivity as a baseline for comparison with Earth system sensitivity (ESS). The reviewer is not surprised that climate sensitivity is different when the timescale of integration is millions of years instead of hundreds of years. We consider the discussion of Charney sensitivity important for two reasons. First, Charney sensitivity is the most commonly-used climate sensitivity concept. It makes sense, then, that a differently-defined concept of climate sensitivity (such as ESS) is compared against it. Charney sensitivity is a standard reference point and offers a well-established framework for discussing why ESS may or may not differ from it (section 4 in our paper). Other papers on ESS use Charney sensitivity in a similar way. Second, the geological community is one of the target audiences of our paper, and many in this community are familiar most with Charney sensitivity. While it may be obvious to the reviewer that Charney sensitivity will deviate from ESS, we suspect that this conclusion is not as well known among geologists.

The other general concern raised by the reviewer is the robustness of the CO2 and temperature reconstructions that underlie our ESS estimates. This is a legitimate concern, and it is the principal reason why we chose to calculate minimum estimates of ESS (maximum CO2 change, minimum temperature change), not best-fit estimates of ESS. By following this approach, we minimize the potential influence of these uncertainties. As such, we consider it beyond the scope of our paper to rigorously review all CO2 and temperature data. We do discuss the potential warm-bias of TEX86 estimates, and conclude that the benthic-based temperature estimates (Figure 1c-d) should be trusted over the tropical-based ones (Figure 1b). For CO2, we determine that even if levels were consistently very high (2000 ppm, above almost all of the errors of individual estimates), our fundamental conclusions about ESS remain unchanged (dashed lines in Figure 1b-c). The reviewer also lists several assumptions that we make that he/she thinks may undermine our ESS estimates. These assumptions likely have little-to-no impact on our ESS interpretations:

-no ice: many decades of work firmly establish no significant accumulations of ice during the Cretaceous and early Paleogene;

-no benthic temperature gradient: we do not assume a lack of gradient, we take the deep-water data at face value (see Figure 1C);

-a constant ESS value: we do not assume a constant ESS value, we assume a constant ESS between tie-points; we discuss this extensively in section 3;

-a “known” shift in solar luminosity: the modeling of solar evolution is well established and used extensively by geologists;

-no vegetation feedbacks and no continental displacements: we discuss the potential impact on temperature by continental motion and associated vegetation changes (see section 2). We conclude that quantifying these effects is presently difficult, but they are likely of a magnitude small enough to not significantly affect our main conclusions.

To help clarify our methodology, we will add a paragraph at the end of section 2 that summarizes which processes we treat as separate forcings and which processes we consider as part of the response when calculating ESS. This will also help set-up our discussion of the 'missing feedbacks' in section 4.1, because the missing feedbacks must come from the list of processes that we considered part of the response (clouds, aerosols, other greenhouse gases, etc.). We consider the discussion of missing feedbacks fundamentally important. Without it, the paper would be considerably weaker because no insight would be provided for why ESS is different than Charney sensitivity. Ultimately, the identity of these missing processes is far more important for understanding the Earth system than knowing the value of ESS.

Interactive comment on Earth Syst. Dynam. Discuss., 2, 211, 2011.

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