

Interactive comment on “The early Eocene equable climate problem revisited” by M. Huber and R. Caballero

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We are happy to have further text on the likely variability during the time interval considered. We have some text already, but we can expand on that—the dynamic range of climate variability in the Eocene, even just the early Eocene, is quite large and worth highlighting. We explicitly aren't trying to model the brief hyperthermals themselves (it's the early Eocene, absent the hyperthermals that ideally we are trying to gauge as you have surmised), but extensive evidence (for example the early Eocene "cool interval") exists to support a varying climate and we have attempted to represent this (where possible) by including max and min "error bars" that include all the information from time series where such exist. Our high latitude temperatures vary from ~ 18 to ~ 8 and it is difficult to tell whether this represents a real signal or just the various biases,

sampling errors, and other issues that paleoclimate proxies interpretation is err to. Almost certainly it represents both. The modelling results at 4480 ppm are if anything still too cold in a couple of the highest latitude sites, although they are much better fit with an additional doubling (not shown). There are no terrestrial tropical data to refute or support the model within that even warmer regime, so we are comfortable restricting ourselves here to the very warm, but not hottest Eocene end-members.

The modelling results at 2240 ppm have already been published and compared with data in Liu et al., 2009 and Eldrett et al., 2009. At 2240 the model does a reasonable job at reproducing the SSTs (and high latitude terrestrial temperature record) for the mid-to-late Eocene.

So to answer the specific questions: "This seems pretty important to me because the background variance in temperature across the early Eocene, even excluding the PETM and other hyperthermals, may be more than the difference between the results of the 4480 and 2240 runs. Is this correct, and if so, how should it be interpreted?"

It would require further CO₂ (another doubling) or alternatively another radiative forcing agent, such as methane, to reproduce the warmer envelope of early Eocene or hyperthermal temperatures. The 2240 ppm case produces results much more comparable to middle Eocene conditions. This is described in the text.

"There was at least a variance of 2x forcing across the early Eocene independent of the hyperthermals?" Yes, or alternatively "sensitivity" (whether fast or "earth system") was high, or variable in the early Eocene.

"In the end, it comes down to a query as to how much can we slide the modeling curve up and down, especially at high latitudes, and/or compress the data across the early Eocene because of temporal differences (and presumably greenhouse gas forcing?). What do things look like when you add blue dots = 2240 to Figure 4?"

As shown in Figure 3, a reduced CO₂ level would simply decrease temperatures by

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3-5 C in a straightforward way. Adding more points to figure 4 would clutter it.

"And by how much does this affect various interpretations? Does it make things worse or better by lumping all the data and comparing to a single model? Are the discrepancies reduced or amplified by changing the baseline conditions x2 and comparing things in the time domain?"

We have tried, over the four years it took to compile the data, to both slice time more thinly and to course-grain the view more to see if it affected the interpretation. We established this particular time slice as a happy medium between having enough data to reduce the sampling error and having a narrow enough time slice that the data are "representative" of a given climate state. In reality, when one looks at any time series through these intervals one sees a temperature time series that appears qualitatively self-similar, with fluctuations of noticeable magnitude across all sampling intervals (consistent with the presence of a red-noise like distribution).

The results we are showing are the end product of that analysis and represent our best attempt to characterize the general aspects of the early Eocene climate, with the error bars as characterization of the likely range of spread around these values in various parts of the interval. At the moment, we think this is the best that can be done for the broad interval in which equable climates have been noted. Although for individual hyperthermals perhaps a better job can be done and it is hard to know if these intervals are representative of the climate system in any sort of equilibrium during the early Eocene.

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