

Interactive comment on “Stripping back the Modern to reveal Cretaceous climate and temperature gradient underneath” by Marie Laugié et al.

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Overview:

This paper attempts to deconvolve the impact of four different boundary conditions (carbon dioxide, ice sheets, solar luminosity and vegetation/soil parameters) on the climate and temperature gradients of the Late Cretaceous to understand their relative roles. Through the use of the IPSL model a series of simulations are performed with changing the model boundary conditions in a step-wise fashion through introducing each one until a fully Late Cretaceous is simulated from the Pre-industrial.

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They find that CO₂ has the largest impact on the climate signal, but also signify that paleogeography also plays an important role in perturbations in the pole-equator temperature gradient through changes in ocean circulation and feedbacks.

General comments:

This is an interesting study using an updated version of the IPSL model looking at the long standing issue of equitable climates of the past problem. I like the experiment design used within this study, it nicely deconvolves the different boundary conditions being investigated in a somewhat clean manner. Although it is, as I am sure the authors well know, more difficult to identify the direct and indirect influence of the non-linear feedbacks that can also occur without a full suite of simulations looking at each boundary condition individually/in pairs in a matrix style approach.

Although the issue is still present this work does provide some interesting results and what influence each boundary condition investigated has on the general climate and the pole-equator temperature gradient.

I think this study should be published and I look forward to being able to reference it, however I do have some comments that may help improve the manuscript before publication.

â€¢ Why should the Cenomanian-Turonian thermal maximum be of more relevance than that of the PETM, MECO, etc. to the future. Worth while to flesh out why this particular time period is deemed important â€¢ There will also be non-linear feedbacks that cannot be deconvolved with the current methodology. I.e. The proportion of landmass at different latitudes between the pre-industrial and Cretaceous at Preindustrial CO₂ levels (and topographic height differences) will have a dissimilar impact on the vegetation response and in turn the warming response from increased CO₂. â€¢ I did sometimes get a bit confused with the methodology section. It was sometimes hard to see what models were initialised with what initial conditions. How were some of the boundary conditions treated. i.e. what were the actual albedo prescribed? Was the

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vegetation uniformly applied even to mountain regions where it may not grow? Might be worth being a bit more concise in describing them individual boundary conditions and how they were implemented for clarity and reproducibility. → Minor point. Some of the use of English could be improved in places, however this is fairly ancillary and does not in any way detract from the good science being shown. → Page 5 – Line 40. It looks like only the 1X-NOICE is in equilibrium in the deep ocean. The other four still appear to be trending. I think for clarity this should be stated or changed to “near-surface equilibrium”. I certainly sympathise as some of my own simulations can take up to 10,000 model years to reach equilibrium. However, I do not think this will change the overall results, but for clarity it should not be stated as complete equilibrium. Gregory plots may also be another useful diagnostic to see if you have an energy imbalance otherwise. → Ice sheet removal impact. I agree with your assessment of the regional impact, however it might also be that you get a pseudo ice sheet in the 1X-NOICE simulation with perennial snow cover over the soil surface, just a low elevation one. I suspect this is the case as in the 4X-NOICE you get a much large response in the change in surface and planetary albedo. Did you ever run a 4xCO₂ experiment with ice sheets in the pre-industrial to see the relative impact of just the CO₂? → Do you see any change in ocean circulation patterns from removal of the ice sheet and increased CO₂ in the preindustrial?

Minor comments:

→ Page 1 & 2 – Line 17 & 33. ‘period’ not “era” → I think it is worthwhile to define what you mean by ‘high’ and ‘low’ latitudes as you often see different values purported in different studies for clarity. → Throughout – put references in chronological order. → Page 2, Line 60. Define “P.A.L.” here. This is the first instance in the ms rather than on page 6- line 50. → Page 3 – Line 79. Change sentence to “the primary driver of Cretaceous climate has been suggested”. → Page 3 – Line 83. Delete erroneous “s”. → Page 4 – Line 96. Probably more accurate to say “We performed six simulations using both Pre-industrial and Late Cretaceous boundary conditions where we

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incrementally modify the Pre-industrial boundary conditions to that of the Late Cretaceous for.....1,2,3,4". → Page 4. Although stated that IPSL-CM5A2 has been used for contemporary and future climate simulations it would be worth adding a line that states how well the model performs in simulating a modern-day climate. → Page 5 – Line 20. Repetition of "long" in the sentence. Remove one of them. → Page 5 – Line 37. "retreat" to retreat. But I think 'removed' would be more accurate. → Page 6 – Line 53. Is that from the 4X-NOICE simulation? → Page 6 – Line 218-222. Did you look at atmospheric stability arguments in relation to this? → Page 6 – Line 223. Do you mean greater season ice melt or there being less sea ice area in the 4X-NOICE compared to the 1X-NOICE simulation? → Page 12 – Section 3.5.1. The percentage change adds to 99%. Rounding error? → Page 12 –Line 321-324: There does not appear to be any change in the N.Hem SST gradients (0.45/lat). Any idea why? You attribute the Greenland ice sheet/sea ice for less sensitivity in the atmospheric gradient of the N.Hem. Something similar here? → Page 14 – Line 370. Do you mean that you used the Tabor, et al. dataset and adding more data points to it? → Page 14 – Line 388. Only if you suggest there is a seasonal proxy bias. This is mentioned later on, but might be worth a few ref's that show there are seasonal bias in some proxies. → Page 16 – Line 448. Do you mean 'more complex' rather than "large"? → Page 17 – Line 480. "cloud" not "clouds". → Page 17 – Conclusions section. This is a tad bit repetitive of the results/discussion. Perhaps broaden this out with respect to the discussion in your introduction. → Figure 1, 5,6, 8, 9, 11 Captions. Add 'mean annual' to caption. → Figure 2. Is that the model resolution geographies? → Figure 11b. Appears to be some modelling studies missing? E.g. HadCM3L 2xCO₂ data point and others. Or was I interpreting this wrongly? Quite possible!

Best, Alex Farnsworth

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