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Interactive comment on "Deep Ocean Temperatures through Time" *by* Paul J. Valdes et al.

Anonymous Referee #2

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This paper explores the relationships between surface air temperature, polar temperature, and benthic temperature through geologic time using a series of HadCM3 simulations. Paleogeographies come from Scotese and Wright (2018), CO_2 concentrations come from either Foster et al. (2017) or a new "smoothed" interpretation of CO_2 records, solar evolution comes from Gough (1981), and orbital configuration is set to present-day. The number of simulations is very impressive. These data will be a valuable resource for the paleoclimate community. Regarding the manuscript, it is well written and easy to follow, but I have some recommendations before publication.

1) It would be useful to compare the proxy data with model data at the proxy collection sites instead of global averages. This could provide additional information about how well the current benthic records can reconstruct deep ocean temperature through time

and how well the benthic records reflect surface temperature.

2) Because the analyses largely focus on benthic temperature, I think benthic temperature is a better metric for determining equilibrium than global ocean temperature. Related, there is unexpected variability in some of the long-term temperature responses in figure 3. Can you rule out this type of response in the simulations that you only ran for 2000 years?

3) Additional details above how the "smoothed" CO_2 curve was derived are necessary. It sounds like it is based on temperature reconstructions, which makes its better agreement with the benthic records unsurprising. The information on lines 174-177 is not sufficient.

4) Why use a linear relationship for reconstructing surface temperature from deep ocean temperature? The relationship in figure 9 is non-linear. Might a non-linear fit improve the model based reconstructions?

5) How well does HadCM3 simulate present-day benthic temperature? If there are significant biases, maybe anomaly maps would make more sense. Also, a sentence about the dynamic vegetation would be nice.

Line 54 – Consider efforts using different models? (e.g. Donnadieu et al. (2016); Ladant et al. (2020))

Line 155 – Can we assume ocean salinity was constant through time?

Line 222 – What were the initial ocean conditions for the original simulation(s)?

Line 226 – All simulations were run in sequence? If not, please provide additional details about your spin up procedure.

Line 229 – Citation for the lack of multiple equilibria?

Line 230 – Impress number of simulations in near-equilibrium, but the values that define equilibrium seem a bit arbitrary.

Line 265 – Why only below 1000 m? Uncertainty in shelf reconstructions? Also, there is a discrepancy with a figure text stating below 300 m.

Line 266 – I don't fully understand the reasoning behind using 2000 m temperatures. Please explain further. Is it to suggest that other records from 2000 m can tell us about the global benthic temperature? Is it to suggest that the model does not need to reach deep ocean equilibrium?

Line 282 – You say paleosols and stomata underestimate CO_2. Please provide citations. What CO_2 reconstructions does this leave for deep time?

Line 291 – Many other citations for model-proxy discrepancy in the Miocene (e.g. Goldner et al., 2014)

Line 303 – Again, why use 2000 m temperature for comparison here?

Lines 309-313 – The proxy community would be very interested in a few more details on the evolution of deep water formation through time. Maybe a few plots of mixed layer depth would help show this?

Line 322 – Again, comparison at proxy locations would be more informative.

Line 352 – Sluggish circulation can also modify salinity and ocean d18O (e.g. Zhou et al., 2008)

Line 355 – Upchurch et al. (2015) also tested cloud microphysics.

Line 372 – I'm surprised that the mixed layer depth compared worse than polar temperature with benthic temperature.

Line 377 – Please show the response with just Cenozoic data

Line 395 – What happens to the high latitude temperature response when deep water forms primarily at the low latitudes?

Line 409 – Is HadCM3 underestimating the temperature gradient response or just un-

derestimating sensitivity to CO2?

Line 434 – Can you speculate about what this means for proxy interpretation?

Line 440 – Isn't the albedo feedback somewhat offset by the fact that SSTs cannot get below 2°C?

Figures –

Need lettering on all panels. What each panel illustrates is not always clear.

Figure 1 – Land fraction is very low before 250 Ma! How does this impact your results?

Figure 2 – I think this may work better as a supplement figure with more time periods.

Figure 3 – What do the colors represent? Maybe easier to see with thinner lines.

Figure 4 – Should be "less than 1000 m". What is the Bemis latitudinal correction? Why not use a salinity based correction? Any correction for Mg/Ca?

Figure 5 – Some bias in the present-day simulation at 2000 m, which should be mentioned in the text.

Figure 6 – Are SSTs calculated below the sea ice? Might help to plot regressions for Foster and Smoothed separately.

Figure 7 – Reason for the large change in average ocean depth at ~240 Ma?

Figure 10 – Dashed lines are a bit difficult to distinguish.

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