Authors Response to review comments for:

Deep Ocean Temperatures through Time

We thank the reviewer for their additional comments, and have responded to all points. Grey text are the referee comments, black text is our response, and red text is the text added to manuscript.

"We have also examined the temperatures timeseries at 2731m (the deepest layer for which we have time series data) and it shows the same trends (see supplementary figures)."
The supplemental figures are very helpful for understand the responses. I agree that global and 2731m ocean temperatures generally show the same trends. However, global and 2731m ocean temperature do not have a consistent offset between time periods, which is very interesting and important for comparing models with proxies. Hopefully these differences will be explored in great detail in future works.

Yes. We will almost certainly will do. The changes in vertical gradients in the ocean are intriguing.

By the way, there are some formatting issues and inconsistencies in the supplemental figures. Please fix before publication.

Done.

"Except for the very coldest temperatures, the residuals of the linear fit are near Gaussian suggesting that there is no systematic evidence for non-linear variations. Moreover when studies use deep ocean temperatures to estimate global surface temperatures, they always assume linearity."
That's my point. You would not expect a linear relationship at low temperatures. I thought previous works distinguished between warm and cold climates.

In some recent papers, they may have done this but in the original papers by Hansen etc. they used a simple linear fit. We have added a further sentence to emphasis this.

This suggests that using a simple linear relationship (as in (Hansen et al., 2008)) could be improved upon.

The ocean initial conditions are still not clear. "we initialized the ocean temperatures and salinity with the values from previous model simulations from similar time periods" does not say much. From the supplemental, some simulations start cold, and some simulations start warm. Is initial salinity the same for all simulations? Are the initial conditions to blame for the unusual jumps in ocean temperature in some simulations (e.g. preindustrial)?

We have added further sentences explaining the initial conditions. We have also added a new table (2) which shows the length of all simulations, and the initial conditions. The unusual jumps at the start of the simulation were an attempt to speed-up convergence by linearly interpolating the trends. We have also explained this.

To speed up the convergence of the model, we initialized the ocean temperatures and salinity with the values from previous model simulations from similar time periods using the commercial in confidence paleogeographies. Specifically, we had a set of 17 simulations covering the last 440Ma. We selected the nearest simulation to the time period. For instance, the 10.5 Ma, 14.9 Ma, and the

19.5Ma simulations were initialised from the 13Ma simulation performed using the alternative paleogeographies. Table 2 summarises the simulations performed in this study and shows the initialisation of the model. The Foster CO_2 simulations were initialised from the end point of the smooth CO_2 simulations. In the first set of simulations (smooth CO_2) we also attempted to accelerate the spin up by using the ocean temperature trends at year 500 to linearly extrapolate the bottom 10 level temperatures for a further 1000 years. This had limited success and was not repeated. The atmosphere variables were also initialized from the previous model simulations but the spin-up of the atmosphere is much more rapid and did not require further intervention.

I thought HadCM3 requires a piece of land at the poles, is this not the case? It does not appear in the supplemental land mask figures.

HadCM3 has to have a polar island in the ocean model but the atmosphere model can handle the correct surface type. For instance, in the present day model there is land at the singularity at the N.Pole but in the atmosphere model it "sees" seaice. Therefore the principle issue is that the ocean model does not allow flow across the pole. The polar stereographic plots in the supplementary is showing the atmosphere grid (because it is showing whether there is landice). The other plots are Mollweide and the ocean plots do have land at the poles. However, because Mollweide is an area conserving projection, it is impossible to see the polar islands. We have added text to explain this.

To avoid singularity at the poles, the ocean model always has to have land at the poles (90N and 90S), but the atmosphere model can represent the poles correctly (i.e. in the pre-industrial geography, the atmosphere considers there is sea ice covered ocean at the N.Pole but the ocean model has land and hence there is no ocean flow across the pole).

We also took the opportunity to correct some spelling errors and improve the grammar.