

Interactive comment on “The effect of low ancient greenhouse climate temperature gradients on the ocean’s overturning circulation” by W. P. Sijp and M. H. England

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Received and published: 4 February 2016

Author note: one figure (Fig. 4) has been altered in response to this review, and has been uploaded to the site. The caption is at the end of this response.

Review of the manuscript “The effect of low ancient greenhouse climate temperature gradients on the ocean’s overturning circulation”, by W. P. Sijp and M. H. England

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I miss a short discussion of possible caveats arising from a certain choice of parameters (i.e. diapycnal diffusivities) or of model numerics (i. e. accuracy of underlying transport schemes) likely to affect the simulated MOC response. It makes a difference whether the models MOC is predominantly driven by winds or by diffusion. (see T. Kuhlbrodt, A. Griesel, M. Montoya, A. Levermann, M. Hofmann, and S. Rahmstorf (2007) Reviews of Geophysics 45, RG2001, doi:10.1029/2004RG000166.)

We agree that a short discussion based on Kuhlbrodt et al. 2007 is beneficial, and include the following text:

There are two proposed driving mechanisms of the present Atlantic Meridional Overturning circulation (Kuhlbrodt 2007), involving a balance between deep sinking and low-latitude diapycnal upwelling driven by downward turbulent diffusion of heat, or wind-driven upwelling in the Southern Ocean associated with the absence of a Drake Passage gap (Toggweiler and Samuels 1995). The choice of numerical model parameters could influence the relative importance of each mechanism, and potentially the overturning response to temperature gradients. However, Schewe and Levermann (2009) show that meridional density differences set the overturning strength in both scenarios. Density gradients remain relatively constant in our experiments, suggesting robustness of our results. The absence of a deep Drake Passage gap in our experiments suggests the importance of diapycnal upwelling as a deep water removal mechanism.

As the authors point out, it is known from former studies using present day boundary conditions that the MOC correlates linearly to deep (or mid-depth) ocean meridional density gradients (Rahmstorf, 1996; Griesel and Maqueda, 2006). In Figure 4 (d) and (f) the SST's and surface densities are shown. It would be nice to add two further panels showing the same quantities at depth at around 500 to 1000 meters.

We have now included these panels: one for density at 500m depth and one for 1000m

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depth. We have adjusted the figure caption. To discuss these panels, we add to page 4798, line 17, after (Fig. 6c):

“ and Figure 4 (g) and (h).”

Regarding figure 4 (a): Is the atmospheric albedo kept identical in all the three experiments?

Yes. We now state this in the model experiment and design section when referring to Fig. 4a.

I do not really understand the sentence in the abstract (page 4788, starting at line 10) “Ocean poleward heat transport is significantly reduced only in the Northern Hemisphere, as now the circulation operates across a reduced temperature gradient, suggesting the overturning circulation dominates heat transport in greenhouse climates.” so: A significantly reduced ocean poleward heat suggests a dominance in overturning mediated heat transport ??? Please rephrase!

We see how this could be unclear, and now rephrase this sentence of the Abstract to:

“Ocean poleward heat transport is significantly reduced only in the Northern Hemisphere, as now the circulation operates across a reduced temperature gradient, suggesting a sensitivity of northern hemisphere heat transport in greenhouse climates to the overturning circulation.”

Page 4788 line 24: “. . . redistributes heat across the global, ...” Did you mean “. . . across the globe, . . . ” ?

Yes, we have now changed “global” to “globe” here.

Page 4791 line 11: What is an “enhanced extratropical radiative balance” ?

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We mean an enhanced greenhouse effect in the extratropical regions. We now rephrase this to:

“...involve an enhanced greenhouse effect in the extratropical regions.”

Page 4810: Figure 6: What is the meaning of the three labels at the base of the figures (y – axis) ?

These labels indicate the units of the quantities shown. We now indicate this in the figure caption.

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