

Interactive comment on “Effect of changing ocean circulation on deep ocean temperature in the last millennium” by Jeemijn Scheen and Thomas F. Stocker

Anonymous Referee #1

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The authors compare the contribution of surface temperature and of the ocean circulation changes in response to a moderate radiative perturbation to temperature variations in the deep ocean. This study is welcome as it is often assumed that, in case of a relatively small changes in circulation, the effect of those changes can be neglected and we can consider that the signal at depth can be simply interpreted as the result of the transport of anomalies created at surface by the mean circulation. By doing some well-designed experiments and precise diagnostics, the authors show that this approximation of constant circulation leads to an underestimation of the changes and biases in the timing of warming and cooling at many locations. The manuscript is well-written and provides the adequate information. I have only a few suggestions below on the

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structure of the paper or to improve the clarity of some parts but none is mandatory for me before publication.

General comment

1/ I think Table 2 is hard to follow without reading the sup. mat. Furthermore, the uncertainties are very large (as shown by the residuals) and it does not bring much new information. The diagnostic related to water age could be instructive but, except in one case, the value is very small and very uncertain (see lines 306-307 and line 536). I thus suggest to move it to sup. mat. So, all the information related to those diagnostics is grouped at one location. The results could be mentioned in section 3.4 but without details. It also implies that the values of effect one can be computed as given line 528 and display a lower uncertainty.

Specific comments

1/ Line 25. I guess the sentence refers to the ocean depth at the core location but the majority of the cores record changes in SST or near surface temperature changes.

2/ Line 107. I am not sure I understand what is meant by ‘at every surface grid cell are set to a latitude-longitude field’. Does it mean that a constant spatial field is used and the value is different for each grid cell? Please rephrase.

3/ Line 115. Maybe I missed something in the procedure but is it possible that a drift occurs just because of the shift to fixed ocean velocities in OcFIX. Is this taken into account?

4/ Line 134. The comparison of results of this study with the ones of Collins et al. is made for different conditions and time periods. Would it be possible to compare the results presented here for the 20th century with the trends for the 20th century simulated in other models for a more meaningful comparison ?

5/ Line 141. Isn't it Fig 2a ?

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6/ Line 166. The link with Fig A3 is not straightforward as you did not explain that it corresponds to tracer concentration while the reader could have imagine that it relates directly to 'persistent cold anomaly'.

7/ Line 171. Maybe it would be useful to discuss the ventilation rate in the Southern Ocean in the model and its realism as it may have an impact on the results.

8/ Line 175. What is the 'TRA minimum' ?

9/ Line 212. Is it the southward heat transport?

10/ Line 219. Why is there a difference of one order of magnitude in the results while the difference in the forcing is only a factor 3?

11/ Why is it surprising ?

12/ Line 356. 600 CE is usually not associated with a medieval warm period. The classical 'Medieval Climate Anomaly' is rather around 850-1150 CE.

13/ Line 357 and below (e.g. 364-365). The results of GH19 seems to be well in agreement with the observations. I think this should be mentioned more explicitly and discussed.

14/ Line 369-370. This model bias provides very important information. For me, this has to be explained earlier in order to analyze the implications for all the diagnostics presented.

15/ Figure 11. It is not easy to compare with the Figure 2 of GH2019. Could it be possible to reproduce for instance on figure 11 the anomalies deduced from observations (or the results of GH2019 if publicly available) ?

16/ Line 377. Is it 'already warming' or 'warmer conditions than in 1875' ?

17/ Line 385. As the model is fast, would it be possible to make an additional experiment to prove this hypothesis ?

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18/ Line 413. For me, with the experimental design, SSTs are the same but the heat uptake can be different (as circulation for instance can be different).

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