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Climate of the Past Discussions

Interactive comment on "Data-constrained assessment of ocean circulation changes since the middle Miocene in an Earth system model" *by* Katherine A. Crichton et al.

Anonymous Referee #2

Received and published: 17 February 2020

The authors use model simulations and proxy records to better understand ocean temperature and circulation change since 15 Ma. To do so, they perform a series of cGENIE simulations using data from previously run HadCM3 simulations with period appropriate topography and 400 ppm CO2. The cGENIE experiments specifically explore the impacts of CO2 concentrations and amounts of freshwater flux from the Atlantic to the Pacific. Equilibrium cGENIE outputs of temperature and d13C are compared with surface temperature and benthic d18O and d13C records. The best model-proxy agreements provide insight into the causes of long term climate change.

This study is interesting. I believe it should be published in Climate of the Past after

revision. The paper is well written and generally well structured. Although there are many limitations of the model setup, these caveats are mostly addressed. Here are some comments that should be addressed before publication -

1) I wonder how important paleogeography is to the response. The discussion contains speculation about the importance of gateways but I think this topic can easily be explored in greater detail. It would be interesting to compare the proxies from all time periods using only the Holocene configurations. Does paleogeography actually improve the model-proxy agreement? The authors already have all the results necessary for this comparison.

2) I would like to see how the biases in HadCM3 are translated into cGENIE (muffingen) either by a comparison of the Holocene (HadCM3 forcing) and default cGENIE (observation forcing) simulations or by a comparison of the Holocene ocean circulation in cGENIE and HadCM3. This would help determine if the biases come from HadCM3 or cGENIE. A few sentences on the biases in cGENIE's ocean circulation would also be helpful.

3) In the paper, the FwF changes are usually discussed with respect to changes in North Atlantic deep water. However, do most of the benthic proxy sites record a North Atlantic signal or an Antarctic signal? I realize that the changes are related, but talking about the Antarctic response might be more direct in some instances.

Other comments –

Line 21 – What is the "present-day" climate sensitivity? This is mentioned several times in the text without citation. Is it based on the transient climate sensitivity?

Line 34 – Doesn't Bell et al. (2015) suggest that the closure did not impact AMOC? Please include additional details about ongoing debate within the community here.

Line 50 – Here there are a lot of citations on the importance of vegetation. Are there specific citations to support the roles of bathymetry, topography, and CO2 as well?

Line 85 – List what types of proxies make up the surface reconstructions.

Line 111 – Are the reconstructions on paleolocations.org the same as the reconstructions used to make the maps in the HadCM3 experiments?

Line 133 – Please briefly mention the potential limitations of excluding iron cycling.

Line 165 – How many HadCM3 years are used as inputs?

Line 183 – The argument for a zonal average albedo is not strong because there is no comparison of results with default GENIE simulations.

Line 188 – Why was this CO2 coefficient chosen?

Line 193 – Over how many years are the proxies averaged? I assumed the proxy averaging interval was long enough that orbital variability does not matter much, but based on the supplemental, it seems I was incorrect. I recommend averaging proxy records over 100 kyr or more to reduce the likelihood of capturing high frequency variability that is not simulated with the model. Also, might the use of present-day boreal summer near aphelion skew the results towards particular solutions?

Line 210 – Ha! Hopefully “which does not exist” is not necessary.

Line 219 – “modal”->”model” and “in prep” cannot be cited. Either discuss or remove.

Line 233 – The variability is so small that there is no benefit to averaging? I find this surprising.

Line 239 – I agree this is extremely interesting. Please list the simulations that show this behavior.

Line 243 – For oscillations that are longer ($\sim$4 kyr), how do you know they are persistent with only a 10 kyr long simulation? Please plot an example of these oscillations in the supplement? If you have to average over 4 kyr, are you in equilibrium over these 4 kyr?

What are the initial ocean conditions for these simulations?

Line 266 – Again, what is the present-day climate sensitivity?

Line 269 – Some of this information sounds like a better fit in the methods or figure caption.

Line 277 – Again, you might be able to quantify these things a bit by comparing the proxies against only the Holocene simulation.

Line 299 – Can you modify these assumptions within uncertainty to improve model-proxy agreement?

Line 315 – Not necessary to perform, but I wonder if you might get a better agreement for the Holocene with a lower CO2.

Line 326 – How do you determine the best fit value here?

Line 333 – “again supports”

Line 377 – Interesting!

Line 391 – Given the other parameterizations, how robust is this backed out d13CO2?

Line 413 – Similar result were also found in Carrapa et al., 2019 (Ecological and hydroclimate responses to strengthening of the Hadley circulation in South America during the Late Miocene cooling; PNAS)

Line 427 – “greenhouse”

Line 438 – This paragraph and parts of the following paragraphs do not fit very well with the findings of the simulations and seems a bit unnecessary.

Line 450 – “do”

Line 456 – What about the higher climate sensitivity of the CMIP6 models?

Line 484 – How much flux do you have through the CAS?

Line 487 – Again, you should be able to test the role of the CAS.

Line 495 – The precipitation response to warming is not this simple.

Line 562 – Why is the fit so poor >70°?

Figure 8 – It would be helpful to plot CO2 compilations against your best estimate (e.g. Foster et al., 2017; Berner and Kothavala, 2001).

Figure 11 – Use a single color contour bar.

Figure 14 - Similar cross section plots of d13C and temperature would be very helpful.

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