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To whom it may concern,

Re: Response letter to Reviewer 2, after submission of manuscript "*Simulation of the mid-Pliocene Warm Period using HadGEM3: Experimental design and results from model-model and model-data comparison*" by CJR Williams *et al*. to Climate of the Past.

I extend my sincere appreciation to Reviewer 2 for their thorough examination of my manuscript, and their detailed and highly constructive comments. I propose to address all of your concerns.

Here, I address the your suggestions, comment-by-comment. In the following, your comments are blue and in a smaller font, and my corresponding response follows in a standard font.

I very much hope that my responses will satisfy you and meet your expectations.

Yours faithfully,

Dr Charles JR Williams, and co-authors

REVIEWER 2

Williams et al describe a HadGEM3 simulation run using the PlioMIP2 protocol. They document many technical details associated with this simulation that may be important for subsequent researchers. They provide some headline results from the simulation and place it in context within the literature. This is a manuscript that is certainly worthy of publication in Climate of the Past. Naturally, I have some comments about the manuscript and propose some edits that would make the manuscript more appealing to readers. However, I see them as potential improvements rather than obstacles.

Content-related comments

- I was surprised that there was no mention of "hydrological sensitivity" within this manuscript. Given the focus on both the global mean precipitation change and the global mean temperature changes, this seems like an oversight. This approach in effect normalizes precip changes by the warming, resulting in units of %/oC. Eat It is the most common metric to intercompare global mean precipitation changes.

Thank you for this comment, this was indeed an oversight. Therefore a new figure, in the form of a scatterplot showing normalised precipitation changes versus temperature changes, will be added to the main manuscript, with appropriate accompanying discussion.

- At no point is there any discussion as to whether the climate of modified control simulation is the same as the standard control run. This is potentially important for future researchers, as the manuscript only describes changes w.r.t. piControl_mod, whilst the data available on the ESFG only allows a calculation of changes w.r.t. piControl.

We agree with this comment so thank the reviewer - the impact of the model input parameter change is discussed very briefly in Section 2.3.3, where it is stated that "… *testing of those changes for GC4 has found that they have no detectable impact on model climatology*", but indeed we do not provide a comparison of the *piControl* and *piControl_mod*, other than including both of them in the timeseries in Figure 6. We will therefore add some discussion about these just after Figure 6, and we will also include a new figure in the Supplementary Material in the form of spatial maps showing temperature and precipitation climatologies from both simulations.

- The discussion of the sea ice changes does not explain to the reader some key features – such as the fact that the model is seasonally ice-free in both hemispheres. Replacing Fig. 8 with something more pertinent would go a long way to improve the discussion. Please consider polar stereographic plots (perhaps without the annual mean), along with some time-series of sea ice area/extent in both simulations.

Thank you for pointing out this omission. We will replace Figure 8 with seasonal polar stereographic plots, as well as a timeseries of sea ice area, and appropriate discussion.

- Remove the table which is masquerading as a panel in Fig. 14

This will be done, with the RMSE values instead being included inside brackets next to each model name.

- L761. "excess warming". You have not provided any evidence that the warming in HadGEM3 is excessive. Your focus solely on RMSE during your data-model comparison does not provide a direction. If you want to make this kind of statement (which would enhance the overall reach of the publication), then you need to look at other metrics as well.

This phrase will be changed.

Technical comments

- Sect 2.3.2.2: please include some text about how you are specifying vegetation over West Antarctica. Some stuff about this emerges in later sections, but I was expecting something here. Is there a reason you didn't specify it all as lake?

That this will be changed, to add some text about how vegetation over West Antarctica was specified.

- L306. Here we reach something about Antarctica, but it was unclear at this point whether you meant dominant vegetation in the piControl or mPWP. how had you determined the vegetation in mPWP?

This will be clarified.

- Sect 2.3.2.4 seems to only discuss the initial conditions for the land model. I presume that the initial conditions for the atmosphere and sea ice models don't really matter. However, the initial conditions for the ocean must play a large role in the distance from equilibrium discussed later. Please be explicit in what initial conditions are being used.

This section will be clarified.

- Sect 3.1.2 I feel that there are criteria specified for equilibria in either the CMIP or PMIP protocols (and possibly both). It would be better to refer to those, than solely compare with a single preindustrial control simulation value.

The authors are not aware of any specific criteria listed within either the CMIP or PMIP websites, nor in any of the PMIP GMD papers; the only exception is Otto-Bliesner *et al*. (2017), where it says the simulation "… should be long enough to minimize at least surface climate trends". Likewise the Pliocene experimental design paper (Haywood *et al*. 2016) only says "integration length is to be set to at least 500 years…". To the authors knowledge, the only PMIP-related paper that specifically gives equilibrium criteria is the Eocene experimental design paper (Lunt *et al*. 2017). This is why the preindustrial control simulation value from Menary *et al*. (2018) was used. We request that this remains the same in the revised version, although we have modified this sentence to make it clearer.

- L447. Why are only the extratropical temperatures considered to make assessments about the whole hemisphere?

A sentence will be inserted into the manuscript to explain that these metrics were used to be consistent with Alan Haywood's paper, which we discuss in section 4.2.

- L611 What are the "warmest PI anomalies"? The manuscript shows no assessment of the piControl_mod simulation.

The word PI will be removed, to make this clearer.

- L766. Do you really mean 'climate sensitivity' here – or should it be Earth System sensitivity?

This sentence will be rewritten, for clarity.

- L770. "such as" is inappropriate as only the 3 named variables are available.

This will be removed.

- L775. I get "authors of the appropriate publication" for the models in section 4.1. However, it is not clear who readers should be contacting for output from models included in section 4.2. If this is Alan Haywood (because of H20) then please state explicitly.

This will be changed so that the readers are pointed to Alan's paper, where the appropriate references are given.

Text/presentation comments

- Remove section headers 2.2.1 and 2.2.2. Just add the single sentence about other models to the end of the previous paragraph

These will be removed.

- L232. replace comma before JULES with a bracket.

This will be done.

- L257. preindustrial

This will be corrected.

- Fig. 4. It is hard to read the text in this image, or in fact really grasp the details of the upper 5 panels. Is there a way to condense this down, so it is more visible? Consider only showing a single PFT and increasing the panel size.

This will be done, replacing this figure with example PFT.

- L315/316. such as is repeated.

This error will be amended.

- Fig. 5. It is nigh-on-impossible to read the text in this figure when it is printed out. Please consider whether all panels are necessary. I believe the snow depth at least should be removed as the values shown may not have much physical meaning (1000 snow-water-equivalent in kgm-2 is roughly equal to 3m depth of fresh-ish snow).

This will be changed, removing the snow depth and making the others (especially the colour bars) larger and easier to read.

- L359. "the thousands of years ideally needed" -> "thousands of years". Let the reader judge whether this is appropriate.

This sentence will be changed.

- L361/362. Please confirm that there is no typo here with the number of years. They both contain the same digits, but in a different order.

There is no typo here with the number of years: 576 is the total number, with 50 years being the final climatology therefore leaving 526 years as the spin-up.

- Table 1. Some, if not all, the units stated in this table are incorrect. They should include "/century".

This error will be corrected.

- Table 1. Please revise the caption of this table. Firstly, it does not show "trends in … measures of climate equilibrium". Secondly, please write your TOA statement as a full sentence, and be more explicit about its relation to warming. For example, "A positive TOA imbalance indicates a net loss of energy from the Earth System".

This will be corrected and the suggested statement will be used.

- L425. Little is gained by abbreviating OceTemp and OceSal? Please remove.

These abbreviations will be removed.

- L439-468. This paragraph is both long and dense. Consider splitting the sea ice discussion into its paragraph.

This paragraph will be separated.

- L444-449. This sentence is rather long. Consider subdividing.

This sentence will be divided.

- L477-482. This sentence is rather long with many subclauses. Consider subdividing.

This sentence will be divided.

- L480. The sudden reappearance of H20 confused me (in part as it looks like the chemical symbol for water). I suggest removing the abbreviation.

This abbreviation will be removed.

- L517. Can you move "for comparative purposes" to the end of the sentence to improve readability?

This will be moved.

- L522. Remove hanging data availability sentence.

This will be removed.

- Fig. 11 Do you mean "annual mean" instead of "climatology"?

This will be corrected.

- L548 and onwards. Consider replacing your PA abbreviation with just "amplification" if polar amplification is really too long.

This change will be made throughout the manuscript.

- L550. "from" seems the wrong preposition

This will be changed.

- Table 4. Can you put the ECS into this table as well, please?

ECS values will be added into this table.

- Fig 12. Label all the panels, not just over half them.

All the panels here will be labelled.

- L608. Clause about being at top-end of range felt overly repetitive.

This sentence will be changed.

- L627. Be consistent in your terminology. In the previous sentence "wettest" related to absolute rainfall. Here it appears to relate to a change in rainfall.

This sentence will be changed.

- L653-4. Please rephrase this sentence.

This sentence will be changed.

- L663-671. This additional discussion got actually me more confused. Is it possible to rephrase it?

This paragraph will be rewritten.

- L676. The RMSE is given in Table 3, please cite it.

The table will be cited here.

- L676-686. Personally, I would chop everything after "halfway amongst them". The subsequent description provides list insight into the reason.

This latter half of the sentence will be removed.