

## **Review to the revised manuscript by Hunter et al., in review for publication in *Climate of the Past***

I would like to thank the authors for their great work in revising the manuscript. I am grateful that my review has been appreciated. If my comments, although numerous, were helpful to improve the manuscript, then I consider the time, invested in the review, to have been well spent. At the same time I apologize if I was picky, and highlighted also small details like punctuation. Yet, I believe that it is better to fix these details now than to have another extensive revision phase before the final typesetting – or even worse, to miss such details before final publication.

My review of the revised manuscript is based on the authors' replies to comments and suggestions made by anonymous referee #1 and a final reading of the updated manuscript. With regard to the latter I focused on the version with highlighted changes (Cp-2018-180\_AuthorResponse\_R1.pdf) rather than the typeset version in *Climate of the Past* format (Cp-2018-180\_SJH\_R1.pdf) – the latter I have only consulted in a limited number of cases when the version with highlighted changes was not clear or incomplete (e.g. in the case of Table 1). Hence, I need to point out that my review is based on the assumption that both versions are compatible. As suggested by the editor I have not referred to the manuscript document available via the official route, but rather used the updated documents Cp-2018-180\_SJH\_R1.pdf and Cp-2018-180\_AuthorResponse\_R1.pdf. These updated documents have been provided by the authors via a weblink to the editor, who then conveyed this information to me.

I will start my review by an overall evaluation of the manuscript, followed by answers to authors' responses to comments by anonymous reviewer #1. My review will be concluded by a list of smaller changes that I suggest to apply to the revised manuscript before publication.

### Overall evaluation of the manuscript

My personal impression is that the manuscript has matured significantly, and I tip my hat again to the authors' impressive amount of work that is presented in their manuscript. Comments by reviewer #1 to the previous version of the manuscript have been taken into account by the authors. The respective requests for changes sufficiently reflect, with very few exceptions (see my list of minor changes below, that I suggest to implement), in the updated text. This includes: a) clarification of technical details and processes of the model (e.g. impact of wind stress on sea ice transport, resolution of the model, representation of bathymetry on full grid cells and the impact that this model characteristic may have on fine details of modern and Mid-Pliocene bathymetry in the model); b) updates to the terminology in the manuscript, making it more easy for the reader to follow statements by the authors (e.g. pointing out that simulations with increased CO<sub>2</sub> are based on a pre-industrial orography, rather than lumping all such simulations together into a group called "pre-industrial experiments", which was misleading in the previous version of the manuscript).

The manuscript experienced significant improvements since the first review and I suggest acceptance for publication in *Climate of the Past* with minor revisions (see my list of suggestions below).

## Remarks to authors' responses to comments by anonymous reviewer #1

Thank you for improving the detail with which the MOSES2 scheme is described. I think that the readers of the manuscript will be grateful for the additional information. Thanks also for clarifying a) the levels to which the freshwater is distributed; b) the clarification regarding the modification of bathymetry, that is necessary in order to cater for full ocean grid cells; c) additional information that illustrates the horizontal grid resolution. I am in particular fond of the additional text with regard to treatment of modern iceberg trajectories, river routing, treatment of freshwater correction for past or future warmer climate states, procedure to create the Mid-Pliocene model setup, as well as the method employed for model spinup. I completely agree with the authors that sensitivity tests regarding the impact of the global redistribution of the freshwater correction are beyond the scope of this manuscript. Still, I believe that the additional information provided by the authors in the revised version of the manuscript will enable the reader to better understand the correction method, and to assess in which respect this procedure may, or may not, impact on the simulations' results.

I would like to point out that the presentation of the results has been greatly improved. Adjustment of manuscript text by adding further references to figures, as well as revising the text with regard to the simulated Mid-Pliocene climate patterns that are shown in the various illustrations, is sufficient to clarify questions that reviewer #1 had with regard to the first version of the manuscript.

Regarding my remark to P18L5 of the original manuscript and the authors' answer: This is interesting. In the objected reference one author's surname is misspelled in the original publication, which explains why Hunter et al. (2019) also have this spelling error in their list of references. To my knowledge the name of the author in question is spelled Jean-Yves Peterschmitt, note the s in the surname. Yet, as the typo is also present in the original publication, I assume it is correct and consistent to also misspell the author's surname here.

## Minor changes to the revised manuscript before publication

There are a number of minor things that the authors may want to adjust before proceeding with final publication of the manuscript. Page and line numbers refer to the version with highlighted changes that is located in the second part of document Cp-2018-180\_AuthorResponse\_R1.pdf. I would like to thank the authors for providing a revised manuscript document that very clearly identifies changes with respect to the last version of the text. On the one hand this simplified my work significantly. On the other hand, there are some bugs in the numbering that caused me some problems. An offset of page numbers between the end of the bibliography (P36) and the start of the Figures (P28), as well as non-sensible page numbering on many pages, caused me some headache when trying to provide "coordinates" to locations where I suggest further changes to be implemented. I did my best to provide meaningful page and line numbers below, but the authors need to make sure that I did not get lost in recounting, which is very possible. Furthermore, apparently not all changes promised by the authors in the replies to comments by reviewer #1 made it into the final manuscript, see my comment to P8L12 below. Based on this finding I would like to ask the authors to once more carefully check that all changes announced in their replies to reviewer comments have actually been implemented into the revised manuscript. I have no capacities to check this for each and every promised change myself again.

P1,L8: Capitalize “southern hemisphere”.

P2,L11: Should the text “(Pliocene Research Interpretation and Synoptic Mapping)” be directly following the term “PRISM4”, and the reference to Dowsett et al. (2016) follow at the end of the sentence?

**Note: From here on there is something wrong with the line numbers in the manuscript version with highlighted changes. Some line numbers are missing (e.g. the occurrence of line number 20 on page 9), counting is restarted after line 15 or 20 on following pages, so that line number 5 may occur more than once per page, or the counting does not start at the uppermost line of a page. Hence, I provide line numbers based on my own counting, in that I strictly increase the line number by one for every non-empty line, the start value being the last sensible line number of any given page (or the first line if there is no sensible line number on a page).**

P3,L6 (my counting): I think the text should read “[...] the atmosphere model layers drape [...]”.

P3,L15 (my counting): Consider replacing “for a suite” by “for an ensemble”, to avoid the text “[...] well suited for a suite [...]”.

P4,L9 (my counting): I would consider to cite Haywood et al. (2010,2011) as references for PlioMIP1 at the end of the sentence, that is also the end of the line.

P4,L14 (my counting): Move the definition of the abbreviation of PMIP2 to line 9, i.e. following its first occurrence. I assume LSCE (2007) and Braconnot et al. (2007) should then both be cited in line 9?

P4,L16 (my counting): A word is missing, maybe the text should read “[...] with previous work, but we acknowledge [...]”.

P5,L6 (my counting): Check the term “Pliocene communities”; I think it either should read “Pliocene community’s” or “Pliocene communities”, depending on whether the authors refer to one, or more than one, community. Plus: Would it make sense to specify what exactly the authors mean when referring to “Pliocene community”? I assume that this term refers to “Pliocene modeling groups”, but I may be wrong.

P5,L22/23 (my counting): Consider replacing: “uppermost layer of ocean” by “uppermost ocean layer”; “Internally-draining basins” by “Internal drainage basins” or, alternatively, “endoreic basins”.

P6,L4 (my counting): I think the “a” at “Cox, 1984a” should be removed, as there is only one publication of Cox (1984) cited in this manuscript.

P6,L8/9 (my counting): Consider to clarify the structure of the sentence by changing “[...] is 1 hour and horizontal [...]” to “[...] is 1 hour, horizontal [...]”.

P6,L17/18 (my counting): The sentence should be changed to “[...] between the Eastern Atlantic and the Western Mediterranean [...]”.

P7,L3 (my counting): Replace “to provided” by “to provide”.

P8,L9 (my counting): Consider to replace “comma separated” by “comma-separated”; furthermore, the clarification of the use of hyphens, that the authors promised to add to this sentence (see their reply to change request P5,L25 of reviewer #1) has not been added to the updated manuscript. This must be fixed to avoid continued confusion on the readers’ side by the double terminology of comma-separated and hyphenated lists of model simulations, the latter of which so far is not defined in the text.

P8,L10 (my counting): Replace “of of” by “of”.

P9,L14 (my counting): Based on the list of simulations in Table 1, mentioning simulations  $_{orb}Eoi^{280-450}$  in subsection heading 3.2 is wrong. There is only one orbit sensitivity study for Pliocene geography, i.e.  $_{orb}Eoi^{400}$ , right? Please confirm and fix the text accordingly.

P9,L18/19 (my counting): I would rephrase the sentence to: “The modern geography is provided to facilitate the anomaly method of boundary condition generation.”

P9,L19 (my counting): Based on what follows in the lines of the next page I would assume that the phrase “is first regridded” is not correct here. Should this rather read: “is created”? The regridding is specified later on, and what follows in this sentence explains more than just the regridding.

P10L2 (my counting): Add a possessive apostrophe to change “to the models” to “to the model’s”.

P10,L17 (my counting): Change “regions when” to “regions where”.

P10,L18 (my counting): I think somewhere here or in the following lines the authors should give an explicit statement that highlights that vegetation is prescribed rather than simulated. Such a statement was removed further up, in response to a reviewer remark arguing that the previous location of the statement was not suitable. Yet, it seems that this important information is now completely missing from the manuscript, with the exception of Table 1. Without an explicit statement in the text, that vegetation is prescribed rather than computed, I fear that the information regarding regridding of the PRISM4 vegetation could be misinterpreted, leading to the possible assumption that PRISM4 vegetation may act as an initialization for a vegetation model, rather than as a time-invariant boundary condition in a simulation.

P11,L2 (my counting): Add a comma at the end of the line after “the modern lake distribution”, to clarify the meaning of the sentence in presence of many occurrences of “as”.

P11,L14 (my counting): I think the comma after “island specification” should be replaced by a full stop.

P12,L10/13 (my counting): Replace some occurrence of “and” with comma to improve readability of the rather long sentence, e.g.: “The atmosphere model (AGCM) was initialized in a 50 year run with PRISM4 LSM, basic surface scheme (lakes, ice, shrubs and orography), pre-industrial CO2 (280 ppm), as well as zonal hemispheric-symmetric monthly Sea Surface Temperature (SST) and sea ice distribution derived from the initial 2500 model year pre-industrial HadCM3 simulation from Section 3.1.”

P12,L17 (my counting): Change “is continued run” to “is continued”.

P12,L20 (my counting): Change “the set of island line integrals are” to “the set of island line integrals is”, or alternatively remove “set of”.

P13,L8 (my counting): I think the statement, that CO<sub>2</sub> is held fixed at 400 ppm, is not needed here, as this was already stated under item 5, and this fact did not change in item 6, correct?

P14,L1 (my counting): I think the height, at which surface temperature is defined, should be put into brackets: “[...] surface (1.5 m) air temperature [...]”.

P14,L12 (my counting): Is the word “imbalance” missing after “TOA”?

P15,L7-9 (my counting): I would add a reference (or several) that justifies the authors claim that 400 ppm is indeed in the middle of the anticipated CO<sub>2</sub> range for the relevant time period.

P15,L14 (my counting): Change “Tables 3” to “Table 3”.

P16,L5 (my counting): Order of referenced values and references could be improved. I propose to change the text to: “[...] also lies between values derived in the PlioMIP2 studies by Kamae et al. (2016) (2.4°C) and Chandan and Peltier (2017) (3.8°C), [...]”.

P16,L8/9 (my counting): I think in the context of the region chosen by the authors for analysis of polar amplification, it is more appropriate to refer here to Northern and Southern Hemisphere, rather than to North and South Pole.

P16,L11 (my counting): Add a comma after “Baltic Sea regions”.

P16,L21 (my counting): Based on the information in Table 3, I believe the authors mixed up the values for the anomalies Eoi400-E400 (which should be 2.9-1.8=1.1°C) and E400-E280 (which should be 1.8-0=1.8°C). Please confirm and correct if necessary.

P17,L3 and L6 (my counting): If I am not mistaken you need to refer to Haywood et al. (2013b), rather than to Haywood et al. (2013a). Please verify and fix if necessary.

P18,L2 (my counting): I would add commas before and after “e.g. North Africa and the East Antarctic Ice Sheet”.

P18,L11 (my counting): I suggest to add a comma after “South Central Pacific”.

P19,L1 (my counting): Remove the full stop at the end of subsection heading 4.1.3.

P19,L15 (my counting): Remove the comma after “of daily data.”

P20,L6 (my counting): Add a comma after “jet stream axis”. Furthermore, do you talk about one axis (then add a “an” or “the” before “axis”) or about multiple axes (then change “axis” to “axes”) accordingly.

P20,L8: Do not capitalize “Ocean” in the subsection heading 4.2.

P20,L15-17: The cooling during DJF and MAM is not shown in any figure or table, right? Please add a respective remark to the text.

P21,L9 (my counting): Could the authors please explain in the main text the meaning of their statement “but this effect diminishes with increased CO<sub>2</sub>”? Based on the values shown in Table 6 this statement is unclear to me. According to my interpretation of the values, paleogeography indeed increases the warm pool area by about 12.4x10<sup>6</sup> km<sup>2</sup> GWP; yet, also for increased CO<sub>2</sub> the area further increases. The change Eoi400 vs. E400 is 8.2x10<sup>6</sup> km<sup>2</sup> GWP, right? I might be wrong, but if I consider the appreciable variability around the given mean values, then the term “diminish” appears at least to me a bit strong here.

P23,L6 (my counting): According to Table 7 the difference in maximum AMOC between Eoi400 and E280 is rather 3.9 Sv than the mentioned 4.2 Sv. Please confirm and correct. There are some other slight inconsistencies between numerical values mentioned in the text and derived from tables, e.g. for the standard deviation for E280 AMOC maximum (1.1 in the table vs. 1.2 in the text). I would once more carefully check that values in text and tables are consistent.

P23,L9 (my counting): The weakening of AMOC at 40°N in Eoi280 vs. E280 is really difficult to see based on Fig. 12. By eye I would say that the strength of the AMOC at this latitude is actually stronger in Eoi280, but I may be wrong. While in general this may be a minor observation, due to the potentially causal link to sea surface temperature changes suggested by the authors, it may still be significant with respect to the conclusions drawn from the AMOC change. Could the authors kindly confirm their statement and/or provide a clarification in the text – or maybe highlight the regions of interest, for example with boxes, in Fig. 12?

P27,L8 (my counting): I would rephrase “[...] appear sensitive to TSI value [...]”. Maybe just delete “value”?

P28,L3 and L5 (my counting): Again, the reference should likely be to Haywood et al. (2013b), not to Haywood et al. (2013a).

P28,L10 (my counting): Consider to connect “model dependent” with a hyphen.

P28,L18 (my counting): I would split the long sentence in two: “[...] uses an annually-derived correction (Section 2.2). In theory, [...]”.

P29,L19 (my counting): Add a comma to the text: “[...] diffusive pipes to represent, otherwise unrepresented, narrow straits.”

P29/30: The text spreading over both pages could be improved, e.g.: “An example is the subaerial extension of Ireland and Scotland within PRISM4, posing the question how this region should be represented within the model, and how the model-representation may influence the simulation of the Norwegian Current.”

P30, L6/7 (my counting): Small improvements of the text could lead to the following formulation: “Paleogeography-induced changes in the mean state, for example the path of the Antarctic Coastal Current around the Peninsula island (Section 4.2.5), represent non-analogous [...]”.

P30,L11 (my counting): Add a comma after “Hill (2015)”.

P30,L12 (my counting): Change “within North American” to “within North America”, and add a comma after the closing bracket.

P30,L13 (my counting): Avoid close proximity of the very similar words “considered” and “considering”.

P30,L18 (my counting): Could the authors kindly check the website address to the USGS PlioMIP2 website? I have trouble accessing it via the provided link.

P32/33: Maybe the order of references Dowsett et al. (2016) and Dowsett et al. (2013) should be swapped?

**Note: After the references section, ending on page P36, there is an offset in page numbering. Page numbers provided by the authors are not unique across the manuscript. I have recounted the pages from P37 on (which is P28 according to the authors page numbers) and give my page numbers for the comments below.**

P38 (my counting): Consider to not capitalize the “Y” in the time unit.

P39,40,41,42,45, and potentially 51 if you consider to mention the confidence criterion is also there, like done for other relevant figure captions, but not yet on page 51 (my counting): Consider to replace all occurrences of “criteria” by “criterion”, which to my knowledge is the correct singular form of this word. Maybe also consider to replace the formulation “at a” by “based on a”.

P43 (my counting), Fig. 7: I have to admit that the color scale of the color bar, where intervals of  $10 \times 10^9 \text{kg/s}$  intervals are split into two subintervals, albeit having same color, is causing difficulty when trying to interpret the statements by the authors with regard to strength of Hadley Cells in the model vs. observational and reanalysis data. If there is no good reason for having subdivisions of same color, I would just merge them. Furthermore, remove the superfluous space in  $E^{280}$ . There is an inconsistency between simulations as listed in the overall figure caption and the subfigure caption (E400 vs. Eoi400) – this needs to be fixed.

P44 (my counting), Figure 8: Remove the superfluous space in  $E^{280}$ . Furthermore, there is an apparent inconsistency between the captions of subfigures, that state that data for simulations E280, Eoi280, and Eoi400 is shown, while the caption of the whole figure states that rather values for E280, Eoi280, and E400 are shown. This inconsistency needs to be fixed, also with regard to references to the figure in the text (P19/P20). As in the light of this inconsistency it is difficult to impossible for me to follow the conclusions drawn by the authors on said text pages, the authors may want to carefully check their statements on the behavior of StJ and PJ once more. Furthermore, I would add an “a” after “within”, and an “is” after “speed”. Due to the chosen color for the minimum and maximum of the index, it is often difficult to differentiate between extremes of the data and the land sea mask. Maybe the authors find colors that provide a better contrast between data extremes and land sea mask.

P46 (my counting), Figure 10: Consider to capitalize “hemisphere”.

P47 (my counting), Figure 11: Fix multiple typos in “climatological meaning”, where I assume rather “climatological averaging” is meant.

P51 (my counting), Figure 15: Resolve the inconsistent terminology (MASST vs. SST) in figure caption vs. subfigure caption.

P52 (my counting), Table 1, (P38 in the typeset version); simulation no. 5: Fix the typo in “vegeation”; simulation no. 8: consider to remove the “of”.

P54 (my counting), Table 5: Add an “is” in the caption after “reported as it”.

P55 (my counting), Table 6: See reviewer #1’s comments regarding Page 37, Table 6 for the first review. There are some suggested reformulations for the text below the table that have not yet been implemented. Yet, doing so would make lots of sense in my humble opinion.

Page 56 (my counting), Table 8: I suggest the following reformulation: “From the barotropic streamfunction we derive the mean ACC latitude (the Polar front) from the centroid of the zonal transport, and the core width from the  $\pm 50\%$  boundary.”

## References

Haywood, A.M., H.J. Dowsett, B. Otto-Bliesner, M.A. Chandler, A.M. Dolan, D.J. Hill, D.J. Lunt, M.M. Robinson, N. Rosenbloom, U. Salzmann, and L.E. Sohl, 2010: Pliocene Model Intercomparison Project (PlioMIP): Experimental design and boundary conditions (Experiment 1). *Geosci. Model Dev.*, 3, 227-242, doi:10.5194/gmd-3-227-2010.

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