Point to point response to reviewers' comments

The comments are in blue, and our responses are in black.

Response to Reviewer 2:

Comment from reviewer 2

This manuscript presents initial results from the Nor-ESM modeling group for two simulations of the mid-Pliocene Warm Period experiment (Eoi400 of Haywood et al., 2016b), the core paleoclimate experiment of the Pliocene Model Intercomparison Project (PlioMIP) Phase 2, as a contribution to CMIP6. The simulations were run with the older NorESM-L (also used in PlioMIP1) and the more recent NorESM1-F. Six key diagnostic variables were examined, and the NorESM-L PlioMIP2 run was also compared to the group's earlier efforts for PlioMIP Phase 1. This is a solid contribution to the PlioMIP2 effort, and I recommend publication of this paper, subject to minor modifications to address the comments raised here.

We thank the reviewer for the positive assessment and constructive comments on our manuscript. We respond to the reviewer's comments below.

General comments:

Of note is the authors' finding that the NorESM1-F mid-Pliocene simulation actually warms less (+1.7 degC global mean SAT, +1.2 degC global mean annual SST compared to PI control) than the equivalent simulation with the older NorESM-L model (+2.1degC global mean SAT, +1.5 degC global mean annual SST). This relative cooling of higher resolution model compared to the lower resolution model is not entirely expected, nor is both model versions' relative cooling of the Pliocene simulation compared to PI control; it is also not consistent with some of the other PlioMIP2 experiments already reported (MRI-CGCM2.3, CCSM4, IPSL-CM5A). Furthermore, the NorESM1-F Eoi400 simulation is itself cooler than the equivalent PlioMIP1 simulation (-1.1 degC global mean SAT). The authors attribute this primarily to the change in paleogeographic boundary conditions from PlioMIP1 to PlioMIP2. While this is certainly possible for NorESM-L, paleogeography alone cannot address why the newer NorESM1-F is generally not as warm as the older NorESM-L under PlioMIP2 boundary conditions.

It would be helpful to know how the equilibrium climate sensitivity differs between the two model versions. It would also be useful to know whether the authors have previously documented any differences in run results owing the horizontal grid resolution differences between the coarser grid NorESM-L and finer grid NorESM1-F.

NorESM-L is the low resolution version of the NorESM1-M (the CMIP5 version of the NorESM) and is designed for simulations of past climates (Zhang et al., 2012;

Bents et al., 2013). NorESM1-F is different from NorESM1-M with new implementations and code developments, including some updates to the ocean physics and modification in the atmosphere component, and aiming to have a similar performance with adequate resolution, process representations, and improved integration efficiency (Guo et al., 2019).

The estimated equilibrium climate sensitivity of NorESM1-F is 2.29 ℃ (Guo et al., 2019), which is lower than that of NorESM-L (3.1 ℃, Haywood et al., 2013). Compared to NorESM-L, the estimated lower equilibrium climate sensitivity of NorESM1-F may, at least partly, explain its simulated lower warming in the Pliocene.

NorESM-L is the low resolution version of NorESM1-M, and the latter has the same resolution as NorESM1-F. With the same resolution, the estimated equilibrium climate sensitivity of NorESM1-F is still lower than NorESM1-M (2.29 ℃ *vs*. 2.9 ℃) (Iversen et al., 2013; Guo et al., 2019). Therefore, the resolution difference between the two versions seems not to be the most important reason for the simulated lower warming in Pliocene with NorESM1-F as compared to NorESM-L. It is difficult to make a 'clean' comparison in terms of resolution only, as there are also significant code changes in the physics between the two models.

Specific comments:

Page 3, lines 17-19 – Can the authors be more specific about the additional improvements to the MICOM ocean component of NorESM? Also, the authors note that NorESM1-F was run without the CAM4-Oslo advanced scheme for interactions between aerosols and clouds. Is there a CMIP6 PI control run available for NorESM1-F with the CAM4-Oslo scheme enabled, to compare with the NorESM1-F described here? I wonder whether the absence of this scheme with the newer model might also contribute to the lower magnitude of warming in the mid-Pliocene run described here.

Revised. We added more details about NorESM1-F in Section 2.2 in the revised manuscript.

Compared to NorESM1-M, there are some updates in the ocean physics in NorESM1-F. NorESM1-F employs a method to reduce sea ice thickness biases in shelf regions and modifies the methods of parameterization of oceanic mesoscale eddies and the vertical mixing (Guo et al., 2019). With those updates to the ocean physics, NorESM1-F provides reasonable simulations of sea ice and AMOC (Guo et al., 2019).

There is no CMIP6 PI run available for NorESM1-F with the CAM4-Oslo scheme enabled. To limit model complexity and speed up model integration, both NorESM-L and NorESM1-F use the standard, prescribed aerosol chemistry of CAM4 rather than that of CAM4-Oslo. We have clarified this point in Section 2 of model descriptions.

Page 4, lines 10-15 – It is unclear why NorESM-L was run with different PI greenhouse gas values (280 ppmv, 270 ppbv, 760 ppbv of CO2, N2O and CH4 respectively) compared to NorESM1-F (284.7 ppmv, 275.68 ppbv, 791.6 ppbv of CO2, N2O and CH4 respectively) for the PI control run. If this was done so that the only key difference between PlioMIP1 and PlioMIP2 simulations with NorESM-L was the new paleogeographic reconstruction for PlioMIP2, it would be helpful to **clarify that**. If, however, the code for NorESM-L has been updated since 2012, it would be necessary to provide more detail on what has changed.

There is no change in the code of NorESM-L since 2012.

The choice of PI greenhouse gas vales with NorESM-L is based on the guideline of PMIP. However, the choice of PI greenhouse gas vales with NorESM1-F is based on the CMIP5 guideline.

Section 4.5 Sea Ice, pages 6-7 – The sea ice differences between NorESM-L and NorESM1-F merit some additional discussion, especially for the Southern Ocean around Antarctica. Can the authors elaborate on why NorESM1-F is producing so much more ice in this region?

We re-organized some sentences in Section 5.1 to give some explanation. Simulated Pliocene southward ocean heat transport to the Southern Ocean is reduced according to NorESM1-F, but increased according to NorESM-L (Fig. 7), which partly explains the reduction in the Southern Ocean sea ice extent being more pronounced for NorESM-L than it is according to NorESM1-F (Fig. 5) (Page 9, Line 8–11 in the manuscript with the revisions marked).

The divergent responses in sea ice are more likely to be associated with the Southern Ocean stratification in Pliocene simulated between the two versions. NorESM-L simulates increased ventilation in the Southern Ocean, while NorESM1-F does not. The Pliocene sea ice reduction is larger in NorESM-L than in NorESM1-F. However, it remains difficult to fully explain the divergent responses. We pointed out the possible reason in the discussion: "Such divergent responses in Southern Ocean stratifications also appeared in the PlioMIP1 simulations (Zhang, Z. et al., 2013a). It remains difficult to fully explain the divergent responses. The explanation is likely related to the updated ocean physics and/or higher resolution in NorESM1-F, when compared to NorESM-L" (Page 9, Line 25–28 in the manuscript with the revisions marked).

Technical comments:

Page 2, line 21 – There is a reference here to Zhang, R. et al 2013. Elsewhere, there are cites for Zhang, R. et al 2013a and Zhang, R. et al 2013b, but there are a total of three Zhang, R. et al 2013 references in the reference list. These should be renumbered to avoid confusion.

In the manuscript, there is only one reference to Zhang, R. et al 2013. And the other two references are to Zhang, Z. et al. 2013a and Zhang, Z. et al. 2013b.

Page 4, line 4 – How many ocean layers for NorESM1-F?

There are 53 vertical layers in the ocean component of NorESM1-F.

We added this information in Section 2.2. Please see Page 4, Line 13 in the manuscript with the revisions marked.

Page 5, lines 15-17 – The description of the regional temperature highs is not consistent with Table 3 – perhaps because Table 3 lists regions from SH pole to NH pole, which is a little non-intuitive.

Revised.

In both tables 3 and 5, the order of the region list was not right in the manuscript. After we corrected this in the revised version, the listing regions start from the NH and are consistent with the description in the context.

Please see tables 3 and 5.

Page 5, line 21 – Should read "circum-Arctic" rather than "circus-Arctic"

Revised.

Page 9, lines 6-7 – Perhaps say "In contrast," rather than "On the contrary,"

Revised.

Table 3 and Table 5 – listing regions starting with the NH polar region at the top would be a more intuitive way to present this information

Revised.

Referrences

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