Reply for anonymous reviewer #2 of PMIP4 experiments using MIROC-ES2L Earth System Model

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Thank you, the anonymous reviewer, for the thought-provoking and constructive comments. In the following reply, the reviewer's comments are written in black texts and our responses are in bold and blue texts.

The manuscript documents four PMIP4 experiments setup with MIROC-ES2L Earth system model, and evaluate the model performance by comparing with the published proxy data indication. The authors made efforts to run long spin-up for LGM and presented the spin-up process step by step in detail. The other three experiments setup are relatively easier to setup and needs shorter spin-up time than the LGM experiment. The evaluation of the model results are shown for temperature and precipitation through model-data comparison, which is understandable since only these climate parameters are widely reconstructed. MIROC-ES2L is an earth system model, and most of the components are turned on for the PMIP4 experiments (my guess, the authors should confirm this in the paper), means the model is able to produce more physical parameters than those available from proxy data. It is worthy to present more features such as sea-ice, deep ocean temperature and salinity, carbon cycle, modelled dust etc, to show the advantages of an earth system model. I suggest the authors do a major revision by adding more information to promote the ESM's capability.

Thank you for properly evaluating our work. As you say, there are few analyses that take advantage of the properties of the Earth System Model, so we have compiled additional analyses discussing the biogeochemical cycles of LGM and revised the text accordingly.
The answers to specific comments will be given one by one in the following.

Specific comments:

Line 53-54: Are these models include the interactive dust, or do you mean the prescribed dust emission is not proper and may influence the simulated temperature? It would be interesting to see the dust simulated in MIROC-ES2L and compare with the prescribed dust, especially for LGM.

It was poorly explained and misleading. We added the following in the relevant section.
"The dust deposition was several to tens of times higher at LGM (Lambert et al. 2008, Lamy et al. 2014, Dome Fuji Ice Core Project members 2017), but was difficult to reproduce by LGM

experiments; to reproduce the dust abundance at LGM, we need to assume glaciogenic dust (Mahowald et al. 2006, Ohgaito et al. 2018), or assuming an erodibility map (Albani et al. 2014). And an erodibility map was formally introduced in PMIP4 (Kageyama et al. 2017), in addition to the dust emission that is simulated in non-Paleo simulations. In Ohgaito 2018, they showed that simulated dust affects the temperature around Antarctica."

The simulated dust is shown in Fig. 8 and Supplemental Fig. S3 and explained in Sect. 4.2. We think that the sensitivity experiments that prescribe dust are interesting in assessing the impact of dust changes on climate, but it is beyond the scope of the description paper of PMIP4 experiments. We add discussion on it in Sect .5 as a suggestion for future study.

Line 98: "The ecosystem modules can simulate global carbon and nitrogen cycles explicitly." As listed in table 1 for all the experiments the GHG concentrations are following the PMIP4 protocol. It is not clear if the ecosystem modules are not turned on and how does the model treat the CO2 and N2O in the atmosphere, please clarify.

The model itself calculates carbon and nitrogen fluxes by OECO2 and VISIT-e, but in these experiments, the simulated CO2 and N2O fluxes do not change the atmospheric concentrations and thus their changes do not feedback on climate (i.e., the concentrations are prescribed to the PMIP4 specified values and the fluxes are simulated for the diagnostic purposes). This has been added to Sect 2, end of 1st paragraph.

Line 100: "Dynamics of aerosols are calculated by an online aerosol module". Since most model that does not have an interactive aerosol module use the prescribed PI aerosol for all the past periods, I am curious if the dynamical module in MIROC-ES2L simulated aerosols, such as dust, are different from those prescribed aerosols.

Aerosols are calculated online in the aerosol module SPRINTARS (Fig 1 and details at Takemura et al. 2000, 2002, 2005, and 2009). In the case of dust, the amount of dust generated is determined by the values of wind speed, soil moisture, vegetation type, snow cover, and LAI for each time step.
Figure 8 compares PI and LGM dust deposition to various proxy data archives. An additional comparison of the deposition maps and proxy archives is shown in Supplemental Fig. S3. An explanation of that figure is given in the text, Sect 4.2.

Line 105-106: Are the model configurations (interactive components) and resolutions same in the DECK and PMIP4 experiments?

Yes. These PMIP4 experiments use the same binary as the DECK experiments. That is, they have the same resolution and the same configurations.
The listed input data given in Table 1 are different from PI. The explanations are added in the manuscript at the end of Sect. 2.

Line 138-140: These parameters are listed in the table 1 and no need to repeat in the text.

The sentences have been changed to be more descriptive, such as "The main difference between these periods and the PI period was the change in insolation attributable to Earth's orbit, as shown in Fig. 3(b and c), where seasonality was amplified in the NH and diminished in the Southern Hemisphere."

Page 21, table 2: This table does not provide more information than the description in the text, either remove this table or provide more specific information than only given the reference.

We intended to list up all the experiments with a set of Table 1 and Table 2.
You pointed out that it would be better to have a table of all the experiments to be able to see all the experiments at a glance, so we changed Table 1 to a list of all the experiments by adding LM and HIST.

Line 680, Fig6b: there is a sharp gradient at around 30N, can you explain?

The sharp gradient shown by the contour lines around 32°N would be caused by a strong and deep westerly boundary current and associated strong upwelling (Brady et al., 2013), which can be seen in the previous LGM modelling studies having strong AMOC (Brady et al. 2013, Muglia and Schmittner 2015, Sherriff-Tadano et al. 2018). This is added in the text.

Line 221-225, regarding the HIST part in Fig13, more information about the three ensembles during HIST period are needed. The HIST part in Fig13 is hard to observe and compare. It would be more informative to show another figure only for HIST part, in order to draw the conclusion that the initial conditions for HIST from the end of LM experiment is similar to that from the long PI run, and discuss if this is the case for other models or it might be model dependent.

In Fig. 13(b), we included a figure from 1850 to 2014; Fig. 13(b) includes an additional 30 historical experiments for CMIP6, which are increased ensemble members recently using

MIROC-ES2L.

On the other hand, the historical ensemble experiment was removed from Figure 13(a), making it difficult to identify. The historical ensemble starting from the standard PI had a large positive bias from HadCRUT4 in the late 19th and early 20th century, whereas the post-LM HIST experiment showed a small positive bias. This is shown as a histogram in Figure 13c and is discussed in Section 4.4.

The authors present the four experiments separately, a summary table or figure to compare the four past periods would be helpful to have an overview of the climate change, and differences of modelled glacial and interglacial climate.

We have summarized them in Table 1, as mentioned above.

Minors:

Line 36, “the Pliocene”, should be " mid-Pliocene (3.2 million years before present)”.

changed

Line 181, “by PI”, suggest change to “in PI or at PI”.

changed