Response to reviewers

For easier reading, we repeat the reviewer's comments in black and answer then in *blue*.

Reviewer 1

First of all, I apologise to the authors for my late review.

We apologise for the late response! The new version of the manuscript will include updated reconstructions as well as the results from 2 new models. This will result in modifications of some of the manuscript's main messages but we felt it was important to keep the results as up to date as possible.

The article presents preliminary results of the new PMIP4-CMIP6 exercise, compare it to the former PMIP3-CMIP5 simulation ensemble, along with new LGM temperature databases for continental and oceanic temperatures. It is an important and interesting update of the LGM experiments, well organized, and provides a state-of the art on recent advances in climate modeling and data compilation. It is very descriptive but I enjoyed very much reading it. Sometimes, figures are not easy to read, but I don't see how it could be improved given all the dimensions the model/data comparison requests. I recommend publication with some minor rectifications that do not, in my opinion, require any further round of review.

We thank the reviewer for his positive comments.

I list these minor remarks below, in order of appearance in the article, and do my best to help the authors dealing (or not dealing) with them as fast and easily as possible.

Introduction:

Lines 74-77: those two sentences imply that a shallower NADW & expanded AABW seen in data are not compatible with an increase in AMOC seen in models. My understanding is that both are not necessarily incompatible. It is e.g. discussed in Sigman et al., 2010, Nature (doi:10.1038/nature09149) in the chapter 'polar ventilation of the deep ocean', please check and verify that using the formulation 'This is at odds' is appropriate here.

We actually meant "deepening of the AMOC", and have corrected the manuscript accordingly. We have also completed the list of references. The corresponding paragraph now reads:

"The LGM boundary conditions also had a strong impact on ocean circulation, as documented via multiple tracers (e.g. Lynch-Stieglitz et al., 2007, Jaccard and Galbraith, 2011, Böhm et al., 2015) which suggest a shallower North Atlantic Deep Water cell and expanded Antarctic Bottom Water (AABW). Besides, Gebbie (2014) uses a combination of synthesis of multiple tracers measured in sediment cores for the LGM and a global tracer transport model to show that these tracers are compatible with a vertical distribution of NADW and AABW similar to today, but that the core of the NADW water mass shoals by 1000m. None of these proposed reconstructions of glacial circulation is consistent with the PMIP3-CMIP5 model results (Muglia and Schmittner, 2015) which all show a deepening of the Atlantic Meridional Overturning Circulation (AMOC), with NADW reaching the ocean floor in the northern North Atlantic for some models."

3.3. Hydrological cycle:

Figure 6 indicates a large zonal changes btw PMIP4 & PMIP3 in the equatorial zone with increased (decreased) precip in PMIP4 wrt PMIP3 around Indonesia and Atlantic sectors (equatorial Pacific and western Indian ocean). It is complex, I agree, but I find this pattern very interesting, could you discuss a little bit more such pattern?

Sentence lines 282-284: again this feature is very interesting. Do you have any idea about what could cause that at first order? (shifts in ITCZ patterns, Sunda-Sahul shelf shelf exposure, ice sheet geometry?)

Yes, these patterns are standing out from the maps showing PMIP4 – PMIP3 differences in precipitation and in precipitation minus evaporation. The patterm is actually similar for PI (cf Fig. 1), suggesting that it is the PMIP4 models which perform differently from the PMIP3 ones, and not so much a difference in the responses to LGM forcings and boundary conditions.

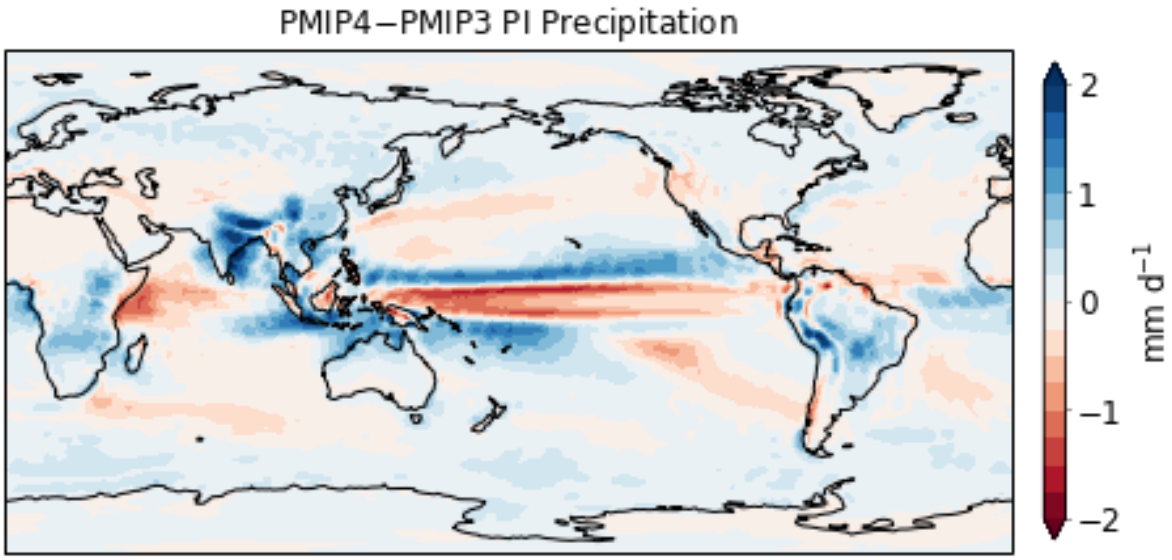

Figure 1 : Differences in mean annual precipitation simulated by the PMIP4 models (ensemble mean), compared to the PMIP3 models (ensemble mean).

4 Data-model comparison:

I think you should immediately start by emphasizing that the new data reconstruction overall agree better with model outputs than the Bartlein and MARGO ones.

With updated reconstructions compared to the first submission of this manuscript, this is not quite true anymore. But we keep the idea to give an overall assessment from the figures showing large-scale averages first.

Lines 294-295: it seems that summer temperatures at high latitudes as estimated in the old and new datasets have nothing in common, please point it out.

We disagree that summer temperatures at high latitudes are substantially different in the two data sets. There is more scatter in the MTWA reconstructions from Bartlein and this is what causes the apparent shift from the 1:1 line at the cool end. However, there are certainly points where there is congruence between the two sets of reconstructions. Furthermore, there is no significant difference in GDD, an alternative measure of summer warmth, between the two data sets. We have made a systematic comparison of the datasets by latitude, shown below (Figure 2), which indicates that there is overlap in the reconstructions, though as we state Cleator tends to reconstruct less extreme cold temperatures and be less noisy - which is a consequence of the reconstruction technique.

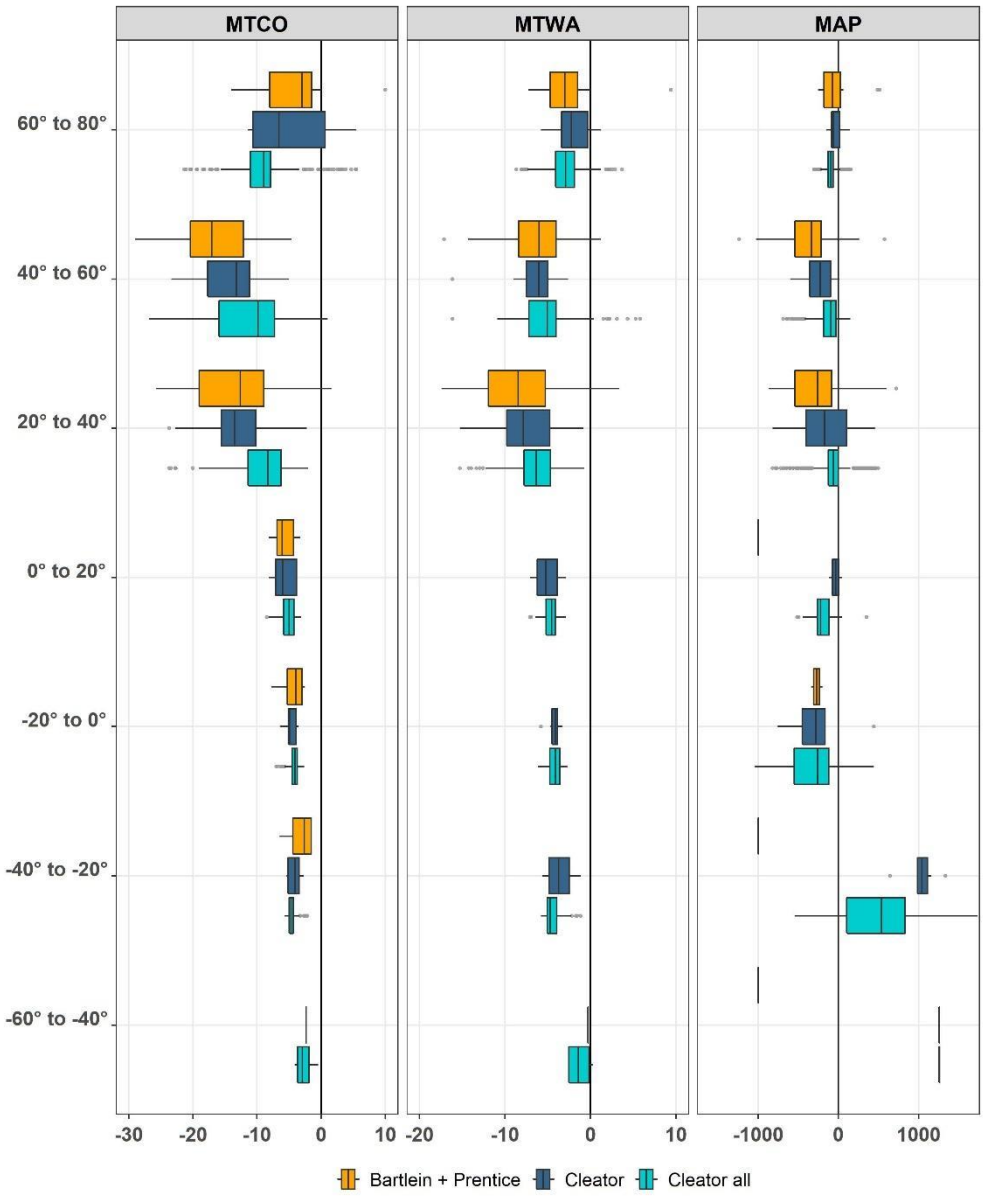

Figure 2 : comparison of the reconstructed anomalies for MTCO, MTWA and MAP, averaged by latitudinal bands. Bartlein et al. (2011) reconstructions in orange, Cleator et al. (2019) reconstructions, only at points where there is a value for the Bartlein et al. (2011) reconstruction In dark blue, full Cleator et al. (2019) reconstruction in green.

Lines 318-319 (whereas the currently available PMIP4-CMIP6 simulations tend to be warmer than the reconstructions.): I don't really see that

Right. This sentence should have been "whereas the currently available PMIP4-PMIP6 simulations tend to stand closer to the reconstructions or on their warm side. " However, with the inclusion of the results from two new models (CESM1.2 and IPSLCM5A2) this sentence might have to modified.

Line 323: iLOVECLIM, did you mean AWIESM?

Indeed, we meant AWIESM2.

Lines 328-329 (However, the simulated change in winter temperature is smaller than indicated by the reconstructions (Fig. 12, top line).): not everywhere when the new datasets are considered
This is actually strictly right only for western Europe. We will modify the sentence.

Lines 365-373 & Figure 13: Why such a figure? To me, it only shows improvement of Tierney in how the SST database might be representative if models get it right. I am not sure this last figure and paragraph is really helpful here.
Conclusion (The MARGO (2009) data set does not provide a strong constraint on the upper limit of the cooling because no model simulates warmer temperature anomalies than these reconstructions.): even if I completely agree with you, you could not say that the MARGO data are wrong because models can't reproduce it. Please reformulate.
This figure is an attempt to constrain the global mean surface temperature change based on the different data sets. We will reformulate the paragraph to make this clearer in the new manuscript.

'Volodin 2018' in Table 1 is missing in the references.
This reference will be added in the next version of the manuscript.

Figure 3: correct the caption 'same as Figure 1' (not 2).
This has been corrected, thank you.
Also, is there something going on in the Walker circulation?
It is difficult to draw strong conclusions on the Walker circulation from this figure only. This topic is left for further study.

Figure 7, top left: please add the zero horizontal line, this will help
OK, this will be done for the new version, for figures 2 and 7.

Figure 9: please add the 1:1 line and indicate which axis corresponds to which dataset
OK, this will be done for the new version.

Figure 12: I wonder if is it technically manageable (and useful to the reader) to make a clear figure with the same Y axis for the same regions (and/or seasons), so we could appreciate the magnitude of the differences btw them?
Yes, this can be done. We will try to modify the figure accordingly in the next version of the manuscript.