Climate
of the Past
Discussions

Interactive comment on "LGM permafrost distribution: how well can the latest PMIP multi-model ensembles reconstruct?" *by* K. Saito et al.

Anonymous Referee #1

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General comments

This manuscript provides an assessment of the LGM permafrost distribution in coupled AOGCMs on the basis of simulated soil temperatures (direct method). For this purpose, results from the PMIP3 database were used. The analysis is compared with previous work that categorized permafrost from surface air temperatures (indirect method) taken from PMIP2 simulations of the LGM climate. The results certainly provide useful information on the performance of climate models under LGM conditions. It is shown that the models are generally capable of simulating a reasonable distribution of permafrost in the present-day and LGM climates.

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In my view, the manuscript requires a moderate revision before it can be published. As detailed below, my main points concern the presentation of the results and the need for an evaluation of the inferred LGM permafrost distribution using reconstructions.

Main comments

I) An important part of the manuscript is devoted to a comparison of the direct and indirect methods. It is concluded that both methods have their advantages and disadvantages, and that the direct methods does not necessarily perform better. However, this is mostly based on visual comparison of (small!) maps, making it hard for the reader to assess the performance of the two methods. It would therefore be helpful if Table 2 could be extended by including estimates for different key regions and also include observed modern areas of frozen ground. This would allow a more thorough evaluation of the two methods using the 0k simulations. It would also make clear where the models do well and where they have problems.

II) Page 1569, line 14: '... this is a perfect time for assessing the models' ability to reconstruct LGM frozen ground, as there is an effort from the observational side for an Action Group of the International Permafrost Association (IPA) to compile and publish in 2013 an evidence-based map of maximum permafrost extent during the last glaciations period ...'. Wouldn't it make more sense to wait with the present paper until this evidence-based map is available, so that the model-results can be directly compared with this map? This sounds like a missed opportunity to me. In any case, a map of reconstructed LGM permafrost should be included in the manuscript as a reference to evaluate the LGM simulations. If the IPA-map is not yet available for this purpose, a map should be constructed based on previous work. For instance, Vandenberghe et al. (2012) provides a map with LGM permafrost limits for Eurasia, and similar reconstructions exist for North America. A comparison of the presented LGM permafrost distributions with a map based on reconstructions would certainly have added value. Based on the reconstructed map, also estimates for the LGM could be added to Table 2, similar to what I have suggested for 0k (see my comment I).

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III) Page 1578, line 18: 'These results imply larger differences between simulated subsurface thermal regimes among the models, which may be due to differences in implemented physics regarding freeze-thaw processes among the models. The high diversity found in the PMIP2 0 k map owes partly to differences in boundary conditions among the models, such as ice sheets, land/sea mask and orography distribution'. In my view this formulation('may be due to differences', 'owes partly to') is too vague. Please perform a more detailed analysis of the reasons behind the differences between models.

IV) Most results are presented in global maps. However, in my opinion these maps are not very well suited, as they are too small to see the sometimes subtle differences and regional details discussed in the text. I would suggest to focus the results on the Northern Hemisphere and to provide circumpolar maps with a polar projection.

Minor comments

- Page 1568, line 25: typo, 'uases' should be 'uses'

- Page 1569, lines 8-10: '... these comparisons produced mixed results consistent with evidence in some regions but not in others, including north of the Alps etc'. It is not clear from this sentence if the evidence north the Alps is consistent or not. Please rephrase.

- Page 1569, line 21: 'The issues this study attempts to address are:'. I would suggest to revise into 'The issues addressed in this study are:'.

- Page 1569, line 26: 'How is the information regarding modeled surface and sub-surface temperatures on a grid box associated with and consolidated into the frozen-ground zonation in the area represented by the grid?' For me it is not very clear what is meant here and I had to read this sentence a couple of times. So I suggest to rephrase.

- Page 1570, line 12: 'Summary of the used models, institutes or groups, and simulations is summarized in Table 1.' The summary is summarized? Please rephrase.

- Page 1571, line 12: 'using the last ten years of the simulations.' Why are only these last 10 years used in the analysis? What is the rationale behind this? Why not take at least 30 years as is normally done for climatological analyses?

- Page 1572, line 12: I suggest to make clear that this paragraph is only relevant for the analysis of the PMIP3 results.

- Page 1572, line 21: 'Continuous': the bottom soil layer is frozen (at or below 0C) for the entire period. 'Discontinuous': the bottom soil layer is frozen for more than half of the period. 'Seasonal': the top soil layer is frozen for more than 30 % of the period. The definitions should be redefined so that the categories exclude each other. For instance, in the definitions as presented here, 'Seasonal' can occur at the same time as 'Continuous', since the bottom layer can be perennially frozen and the top soil can be frozen for more than 30% of the time as well. Obviously, 'Seasonal' only makes sense if the bottom soil layer is not frozen. Please clarify. In addition, please make clear what is meant by 'the period'.

- Page 1572, line 28: For the PMIP2 results, the surface air temperatures are used to estimate the distribution of permafrost. Is this the temperature at 2m, or really at the surface? Is the snow pack and its thickness as calculated by the model taken into account? A thick snow pack may isolate the soil from the cold atmosphere above, so if the surface air temperatures are used, this may result in too cold estimates for the ground beneath. Please discuss

- Page 1574, line 15: Do all models used in this study have 365 days per year? Some model use 360 days per year (i.e. equal months of 30 days) for efficiency.

- Page 1576, line 16: 'The LGM permafrost maps reconstructed from observational evidence in the previous studies shows...' It is not clear to me what previous studies are meant here. Saito et al. (2012, 2013)?

- Page 1577, line 20: 'Continuous permafrost increased at 21k relative to 0k in all

cases, though the differences varied among the experiments and methods from 2 to 13 million km2, partly due to coarse horizontal resolution.' How does the coarse horizontal resolution affect the permafrost area? Please elaborate.

- Page 1579, line 29: It would be good to note that there is no 'good correspondence' between the modelled boundaries and field-based evidence for LGM-permafrost in Western Europe. See discussion in Vandenberghe et al. (2012, QSR).

- Page 1582, line 20: 'Larger inter-model diversity of soil temperature based distribution has implied that the subsurface regime is still at the development phase'. This sentence is not clear to me. Please explain more clearly what you mean here.

- Page 1582, line 25: Including snow dynamics is mentioned here as a possible improvement. However, the PMIP3 models already include snow dynamics, implying that in the soil temperature calculation this is already explicitly taken into account.

- The reference list is incomplete. At least three references are missing: Koven et al. (2013), Vandenberghe & Pissart (1993); Vandenberghe et al. (2012).

- Figure 2: Please make the legend bars consistent.

- Supplementary Figures 7-10: What does white shading signify? By the way, I am not convinced that providing the numerous maps in the supplementary figures is necessary.

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