

We first would like to thank reviewers for their constructive comments, which led additional useful analyses. Our responses to the formulated remarks are listed below.

Answer to referee #1

- *The authors derived permafrost distributions from climate model output for today's climate and LGM climate conditions. They used different statistical downscaling methods and compared the methods to each other and to observations/reconstructions.*

The kappa statistic is described in the results section 3.2.2 where it is misplaced. It should be either part of the method section or put into an appendix. The whole part of applying the kappa statistic in Sect. 3.2.2 (p. 1661/1662) is very difficult to follow. Around line 16 on p. 1661 I got lost and I was still lost in the beginning of p. 1662. It seems that many complicated measures (based on the Kappa statistic) are needed to show that one method is better than the other. On one hand I think this may be achieved with less or less complicated measures. On the other hand it should be possible to show this in a way, which is easier to understand for a reader who is not familiar with the statistical background.

- We agree with the referee that the paragraph describing the kappa statistic is misplaced. We put it into an appendix (Appendix A). Moreover, we simplified the whole part by applying the kappa statistic in Sect. 3.2.2. Easier statistical indices exist; we may only compute the percentage of good predictions by both methods. The advantage of kappa coefficient (often used with nominal variables) is to take into account the agreement by chance.
- *According to the abstract and general outline, the value of two methods shall be compared, GAM-RV and ML-GAM. This is followed, e.g., in Fig. 3 and 4, where both methods are also compared to the simple bilinear interpolation with RV conditions that is used as a reference. But in the main text this is only partially followed. In sect. 4, suddenly MLR is also introduced and compared to GAM-RV in Fig. 6. But for the latter, no comparison to ML- GAM is done. Also later on, MLR is partially regarded, e.g. in Table 2 and 3. In Fig. 5, three columns are shown (no ML-GAM, but MLR instead), but in the figure caption 4 columns are mentioned in lines 3-4. This is very confusing. Here, the paper is lacking some structure. Either it should be made clear (and followed thoroughly) that three methods are compared to the reference method, or the MLR stuff should be completely removed. In order to avoid an unnecessary lengthening of the paper, it seems that the latter may be the preferable choice.*
- We agree with the reviewer comment. The MLR method was introduced to compare with the non-linear ML-GAM method. The confusion with the figures came from a mistake with old versions. To avoid any misunderstanding and give some structure, we followed the referee advice to completely remove the MLR method.
- *In general the English needs some improvement, as some sentences are somewhat difficult to read (e.g. p. 1650, lines 4-7, p. 1999, lines 11-14, etc.). In addition, the use of 'the' and 'a' may be enhanced. It is 'in the period', not 'at the period' or 'on the period'. The same is valid for 'in the climate'. I recommend proof reading of a native English speaker.*
- We tried to improve English throughout the text.
- *Abstract – Par. 2 - page 1648 - line 14: "...with non-systematic improvements..."*
- Done
- *Abstract – Par. 3 - page 1648 - line 20 It is written: "...we measure a global agreement by kappa statistic of 0.80 with CTRL permafrost data, against 0.68...". This sentence is rather technical and requires that the reader knows about Kappa statistic. Consequently, it is not very suitable for an abstract.*
- We agree with the referee and rewrote the sentence as: "In average for the nine PMIP2 models, we measure a global agreement with CTRL permafrost data that is better when using ML-GAM than when applying the GAM method with air temperature conditions."

- *Abstract – last Par. - page 1649 - line 5 It is written: "...and depend on several other factors deserving further studies". This is a very unspecific statement. You should specify these factors if you mention them in the abstract.*
 - We deleted the end of this sentence.
- *Section 1 – Par. 1 - page 1649 - line 12: "...and is currently..."*
 - Done
- *Section 1 – Par. 5 - page 1650 - line 20: "...(or the inter-model variability), especially..."*
 - Done
- *Section 1 – Par. 6 - page 1651 - line 20 It is written: "...but compels to fix the relationship between temperature and permafrost". I don't understand. Please clarify!*
 - We clarified the text: "GAM is suitable for continuous variable such as temperature. Studying permafrost we are dealing with discrete variable. Hence, we need relationships between temperature and permafrost."
- *Section 3.1 – Par. 1 - page 1654 - line 8-9 It is written: "...and more with preindustrial simulations from climate models". I don't understand. Please clarify!*
 - We deleted the end of this sentence.
- *Section 3.1 – last Par. - page 1655 - line 1: "...regions for the type..."*
 - Done
- *Section 3.2.1 – Par. 2 - page 1657 - line 3-6 It is described that the global mean temperature difference to CRU data over land is added to each model grid box to account for the different time period of the PMIP2 simulations and the CRU data. Given the well-known fact that under the recent global warming, the temperature increase over the high latitudes (that is where permafrost is located) is stronger than in the global mean, this approach does not seem to be valid!*
 - We agree that this approach is probably not the most appropriate. Nevertheless, in our case a local correction corresponds exactly to the action of downscaling. On CTRL period, GAM brings local corrections to climate models according to a calibration on CRU data. This implies that climate models and CRU climatology have approximately the same global mean temperature. Consequently, to account for the different time periods of the PMIP2 simulations and the CRU data, we apply a global mean temperature correction. Moreover whatever the correction this does not change the conclusions about the comparison of downscaling methods and their contributions.
- *Section 3.2.1 – Par. 3 - page 1657 - line 21: "...can be attributed to..."*
 - Done
- *Section 3.2.1 – Par. 3 - page 1657 - line 22 What is the definition of "very remote from any ocean"?*
 - We clarified this: "...being very remote from any ocean corresponding to a purely continental air parcel."
- *Section 3.2.1 – Par. 3 - page 1658 - line 1-5: ACO is only vaguely described. Why do you hide how it is exactly defined? In this way, the reader cannot really follow what has been done.*
 - We do not hide the definitions of the ACO and DCO predictors. They have been used exactly as in Vrac et al. 2007 where they are clearly and completely defined. We completed the

description in the text by adding an appendix (Appendix C) adapted from Vrac et al. 2007 and Martin et al. 2011.

- *Section 3.2.2 – Par. 3 - page 1659 - line 14: “..., we consider their...”*
 - Done
- *Section 3.2.2 – Par. 3 - page 1659 - line 27: “The results for these two climate...”*
 - Done
- *Section 3.2.2 – Par. 4 - page 1660 - line 13 It is written: “...confusion/matching matrix...”. This confuses me. Obviously, too much prior knowledge is required to understand what this kind of matrix is.*
 - We clarified this: “...based on a simple counting of matching and non-matching grid-points in a matrix used to represent errors in assigning classes”.
- *Section 3.2.2 – Par. 5 - page 1661 - line 2: “...“N” correspond to...”*
 - Done
- *Section 3.2.2 – Par. 6 - page 1661 - line 22: “...increases by 14%...”*
 - Done
- *Section 3.2.2 – Par. 6 - page 1662 - line 3 It is written: “...in better agreement...”. Better than what?*
 - Done: “Consequently, the results obtained by GAM-RV are statistically relevant and in better agreement with permafrost data from IPA/FGDC than using a simple interpolation of temperatures.”
- *Section 3.2.2 – Par. 7 - page 1662 - line 4 It is written: “Despite heterogeneous contributions...” What do you mean with heterogeneous contributions?*
 - We rewrote the sentence as: “Despite non-systematic improvement from GAM on permafrost distribution, ...”
- *Section 3.2.2 – Par. 7 - page 1662 - line 6 It is written: “...obtained a percentage of explained variance...”. In which respect?*
 - Done: “All climate models obtained a percentage of explained variance between 97 and 100% with respect to temperature observations.”
- *Section 3.2.2 – Par. 7 - page 1662 - line 7: “...climatology by improving...”*
 - Done
- *Section 4 – title - page 1662 – line 19: “...logistic model”.*
 - Done
- *Section 4 – Par. 1 - page 1662 - line 23: “...more information”.*
 - Done
- *Section 4 – Par. 3 - page 1663 - line 27: “...predictand is estimated...”*
 - Done
- *Section 4 – Par. 5 - page 1664 - line 26: “...clearly appear with...”*

- Done
- *Section 4.1 – Par. 2 - page 1665 - line 28: "... IPA/FGDC to 1.4..."*
 - Done
- *Section 4.1 – Par. 2 - page 1666 - line 2: "In Fig. 5a, ..."*
 - Done
- *Section 4.1 – Par. 4 - page 1666 - line 12-18: With regard to this kappa paragraph: What is the information that should be provided which has not already been transmitted before? This remark relates to my major remark about the kappa application.*
 - This kappa paragraph is related to the ML-GAM method and show that ML-GAM is closer to the CTRL permafrost distribution than with a simple interpolation of temperatures. The previous section deals with the GAM-RV method. For both methods, the kappa coefficient provides global information about the predictions different from the areas indices. We modified the sentence as: "ML-GAM provides more confidence than GAM-RV on the fact that our results are statistically better than chance agreement."
- *Section 4.1 – Par. 5 - page 1666 - line 21: "... (2009) who showed..."*
 - Done
- *Section 4.1 – Par. 5 - page 1666 - line 28: "...to derive a high-resolution permafrost distribution".*
 - Done
- *Section 5 – Par. 1 - page 1667 - line 15: "...with GCM outputs..."*
 - Done
- *Section 5 – Par. 5 - page 1668 - line 28-29: "...whatever SDM is used, the ... more pronounced than in the CTRL period".*
 - Done
- *Section 5 – Par. 5 - page 1669 - line 1: "...still underestimated and..."*
 - Done
- *Section 5 – Par. 5 - page 1669 - line 4: "...than in the CTRL period..."*
 - Done
- *Section 5 – Par. 8 - page 1670 - line 1: "The SDMs include a strong..."*
 - Done
- *Section 6 – Par. 1 - page 1671 - line 23 It is written: "...study at a local-scale needs more physics about permafrost". What do you exactly mean?*
 - We agree that this sentence was not clear. This has been clarified with an example: "... confirm that a study at a local-scale needs more physics about permafrost, such as the hydrological physical processes for example."
- *Figure caption 1 Figure 1 is referred to in the text before abbreviation RV is defined. Thus, abbreviation RV is not defined for Figure 1. Please correct!*
 - Done

- *Figures 3, 4, 5, 6, 7, 8 Panel subtitles, axis descriptions and colour legend descriptions are too small.*
 - Done
- *Figures caption 3, 4, 7, 8 – line 6: “...letters show the...”*
 - Done
- *Figures 6 The figure caption describes a grey area, but I don't see any grey area in the plots, only bluish ones.*
 - It was a mistake. The figure was an old version. This is now corrected.
- *Figures caption 8 – line 4: “...Index by ML-GAM”.*
 - Done

Answer to referee #2

- *The paper compares the agreement between permafrost distributions from different PMIP2 climate models and assessments of permafrost distribution for present-day and LGM conditions. As such, it is clearly suited for publication in Climate of the Past. However, the text is, at times, hard to read and confuses the reader with lots of details. It can be clearly seen that the manuscript was compiled by several authors with different fluency of the English language; a more uniform layout of the text is desirable.*

I suggest to publish the manuscript provided the authors adequately address the following comments.

General remark: There are lots of abbreviations in the text, many of them with nearly identical names. This makes it hard to follow the authors' considerations. It would be helpful to provide a list of abbreviations.

- We agree with the referee. A list of the main abbreviation was added in appendix (Appendix B) and we tried to rewrite the text in a more uniform layout.
- *Page 1649, line 12: Apparently an "is" is missing prior to "currently". But even then, the sentence does not make sense to me.*
 - We deleted the end of the sentence.
- *Page 1649, line 25: There are several publications by Vladimir Romanovsky from UAF and co-authors, which should be mentioned here.*
 - Done
- *Page 1650, line 11: I do not agree that EMICs are computationally expensive (not "intensive"), at least not compared to GCMs. That is the reason EMICs exist.*
 - We agree, we nuanced the sentence accordingly: "These climate models are computationally expensive (in particular GCMs)."
- *Page 1650, line 17: Delete "the".*
 - Done
- *Page 1652, line 18: Replace "on" with "for the".*
 - Done
- *Page 1652, line 18 and following and several other occurrences in the manuscript: It is confusing that the authors deal with two different data sets the model results are compared to (present-day and LGM), but use the word "data" to refer to any of them. It is not always clear from the context what is meant.*
 - We agree with the referee and tried to clarify the referring data (CTRL or LGM) in each case.
- *Page 1653, line 12: 65W, not 65E!*
 - Done
- *Page 1654, line 2: Add "a" after "calibrate".*
 - Done
- *Page 1654, lines 2-6: This is not the original resolution of the CRU data, which hardly can be described as "local".*
 - On the CRU website, the database is clearly downloadable at a 10' resolution. From a

pragmatic point of view, in comparison with the climate models resolution, this high-resolution represents "local-scale" data.

- *Page 1654, line 10: How large is the error of your assumption?*
 - It is difficult to evaluate such an error depending on the inertia of permafrost related to climate change. We agree that we have to keep in mind that this is a strong assumption in our conclusions. We added as a prospect that transient simulations could help us to evaluate how large is the error of this assumption: "In this context, we also have to keep in mind our strong assumption of a near-surface permafrost in equilibrium with climate signal. Downscaling of transient climate simulations could help us to evaluate how large is the difference due to this disequilibrium."
- *Page 1654, line 22: ...but above -8 deg C.*
 - Done
- *Page 1655, line 1: What do you mean by "type of permafrost"?*
 - "Type" means "category", i.e., continuous or discontinuous. We corrected the sentence.
- *Page 1655, line 2: "Criterion".*
 - Done
- *Page 1655, lines 18-20: Unclear what you mean. Also, "has" instead of "have" in line 19.*
 - To run a GAM, we have to specify the statistical distribution family of the explained variable. It is often assumed that temperature has a Gaussian distribution.
- *Page 1656, line 13 and following: This is strongly simplified. What, for example, is the effect of snow cover?*
 - The goal of this article is not to discuss the best predictors for temperature downscaling. Our study is based on the results from Vrac et al. 2007 and Martin et al. 2011. Nevertheless, concerning permafrost, we mentioned several times in the text that other predictors such as snow cover could bring more consistent physics to reconstruct a high-resolution permafrost distribution.
- *Page 1657, line 22: How remote is "remote"?*
 - We clarified this: "...being very remote from any ocean corresponding to a purely continental air parcel."
- *Page 1657, line 25 and following: Why do you need the DCO index at all? All relevant information is in the ACO index.*
 - DCO could be simply seen as the shortest distance to the sea. ACO takes into account the climatological wind intensities and directions and so depends on seasonal-cycle. ACO brings a more physical but different information than DCO. To complete these definitions we added an appendix (Appendix C) adapted from Vrac et al. 2007 and Martin et al. 2011.
- *Page 1658, lines 19/20: Replace "a lot" with "several".*
 - Done
- *Page 1659: The argumentation is hard to follow. Is this a resolution issue?*

- Yes, to conclude we added at the end of the paragraph: “In conclusion, it clearly appears that the resolution plays a significant role in permafrost prediction. GAM-RV provides local information improving the CTRL permafrost distribution.”.
- *Page 1659, line 4: "the Himalayas".*
 - Done
- *Page 1659, line 8: Replace "whose results" by "the results of which".*
 - Done
- *Page 1659, line 10 (and elsewhere): Hard to follow. IPA/FGDC are essentially observations and should for the sake of legibility be called observations. The word "data" is misleading in this context.*
 - Done
- *Page 1659, line 18: Replace "discontinuous permafrost area" with "the area of discontinuous permafrost".*
 - Done
- *Page 1659, line 21: A ratio is always the quotient of something and something else. You cannot talk about a ratio of blue area.*
 - We rewrote the sentence as: “To quantify the proportion of permafrost simulated in right location, %CP (%DP) is the percentage of continuous (discontinuous) permafrost in agreement with permafrost data. %CP (%DP) corresponds to the ratio of continuous (discontinuous) matching area (respectively in blue and turquoise areas on maps 3 and 4) over the continuous (discontinuous) area from IPA/FGDC observations.”.
- *Page 1659, line 23: "summing up".*
 - Done
- *Page 1660, paragraph 1: I have no idea what you are talking about. Page 1660, line 3 and line 6: What does "inter-variation" mean?*
 - The term “inter-variation” (between climate models) is defined in Introduction as “the inter-models variability”. We detailed as follow: “The plots also reveal a weaker inter-variation between climate models (or inter-model variability) with downscaling.”
- *Page 1660, line 8: "extent".*
 - Done
- *Page 1660, line 10: Replace "chance agreement" with "agreement by chance". Delete "achieved". Even then, the whole paragraph is hardly understandable.*
 - We agree with the referee. Changes have been done and for more details we discussed the kappa statistic into an appendix (Appendix A).
- *Page 1660, line 11: "This index can take values between 0 and 1...".*
 - Done
- *Page 1660, line 13: What is a "confusion matrix"?*

- We clarified this: "...based on a simple counting of matching and non-matching grid-points in a matrix used to represent errors in assigning classes".
- *Page 1661, line 7: "ECHAM5 has a kappa of 0.64, while the value is 0.68 for IPSL- CM4."*
 - Done
- *Page 1664, line 12: "As discussed in section 3.1, ..."*
 - Done
- *Page 1665, line 6: I do not understand the argumentation.*
 - We modified the text: "However, the probabilities can take continuous values between 0 and 1 and allows us to obtain for each grid-point three complementary probabilities for the continuous, discontinuous and no permafrost categories. In ML-GAM, the modeled relationship also varies according to the selected predictors and the studied climate model."
- *Page 1665, line 21: "the Himalayas"*
 - Done
- *Page 1665, line 23: "mountains", not "mounts"*
 - Done
- *Page 1666, line 2: "In Fig. 5a..."*
 - Done
- *Page 1666, line 21: "...who showed..."*
 - Done
- *Page 1666, line 29: Probably "model" is missing here.*
 - No, we rewrote the sentence as: "Soil temperature, vegetation type and snow cover could bring more consistent physics to reconstruct a high-resolution permafrost distribution."
- *Page 1667, paragraph 1: What are you talking about?*
 - We clarified the text: "Without temperature downscaling ML-GAM leads to a more precise spatial representation of permafrost in better agreement with observed CTRL data. In conclusion, bypassing temperature downscaling provides an adapted relationship between permafrost and predictors for each climate model."
- *Page 1669, line 1: Confusing text.*
 - We clarified the sentence: "Continuous permafrost derived from downscaled temperature is still underestimated. Moreover, depending on CMs, no or few discontinuous permafrost is predicted at the right place".
- *Page 1669, line 12: Do you mean "present-day data" here?*
 - We corrected the sentence: "With a LGM climate closer to LGM data..."
- *Page 1669, line 26: Which data do you mean here?*

- Done: "...those from LGM data...".
- *Page 1670, line 19: Bad English.*
 - We deleted the interrogative sentence.
- *Page 1671, line 23: What do you mean here?*
 - We clarified the sentence with an example: "... confirm that a study at a local-scale needs more physics about permafrost, such as the hydrological physical processes for example."
- *Page 1671, line 27 and page 1672, line 1: "None..." ... "whatever the method used" means the same.*
 - We rewrote the sentence as: "None of the studied climate models can represent a LGM permafrost extent comparable to observed data. This is true for GAM-RV and ML-GAM."
- *Page 1672, line 3: Which data do you refer to here?*
 - We corrected: "The differences with LGM data..."
- *Page 1679, line 8: The author's name is Bäuml, not Bauml.*
 - Done
- *Figures 3, 4, 7 and 8 are too small.*
 - Done