

Interactive comment on “Climate reconstructions based on GDGTs and pollen surface datasets from Mongolia and Siberia: Calibrations and applicability to extremely dry and cold environments” by Lucas Dugerdil et al.

Anonymous Referee #1

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I have finished a review on the manuscript “Climate reconstructions based on GDGTs and pollen surface datasets from Mongolia and Siberia: Calibrations and applicability to extremely dry and cold environments”, submitted to biogeosciences discussions by Lucas Dugerdil and co-authors.

The paper represents an interesting dataset, and great care is taken to develop models based on two different independent paleoclimate data: pollen and brGDGT lipids. I have few comments to make that will hopefully make the manuscript even more relevant for readers interested in using pollen and GDGTs in cold areas. Investigating

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Mongolian brGDGT lipid and pollen distributions illustrates local dependencies that are different from global dependencies.

To frame the impact of this observation, the authors need to be more transparent whether and why current global and regional calibrations fail in Mongolia. I would suggest the authors to move the section 5.4. “Issues in Modelling Mongolian Extreme Bioclimate” forward, as this section highlights why dry and cold areas represent challenging conditions for current proxy calibrations. It also allows to present some of the limitations of this study (existing error on climate parameters) before diving into technical model selection steps. For brGDGTs I would recommend to include a figure that shows the variation of MBT'5ME and MAT of soils on a global scale, with the Mongolian soils plotted in this dataset. If the Mongolian soils plot within the global variation of soils, the observed environmental dependencies might be extrapolated to other cold areas. The calibration between currently used brGDGT based proxy values and MAT is mentioned to be plotted in Supp Fig. 3, but this Fig. was not available online.

I am however skeptical of using a heterogeneous brGDGT dataset (including soils, lake sediment data, moss) for developing a new model to predict temperature. Generally, brGDGT from lake sediments are distinct from the surrounding soils, and their different environmental dependency has resulted in the development of lake-specific and soil-specific calibrations. However, in this dataset lake and soil samples are treated as having the same environmental dependency. The MAP is expected to have the same impact on lake-derived brGDGTs as on soils, which makes little sense as there is no link between MAP and aridity in lakes. If the authors have the opinion that the brGDGTs in the lake surface samples are soil-derived and represent an average catchment signal, the authors should elaborate on that. Also, the moss samples are generally not used for brGDGT calibration. Do we expect the brGDGTs to be produced by bacteria within the moss, or to represent an average of soil-derived particles delivered by wind?

The authors mention the effect of aridity on brGDGTs (Dang et al., 2016), but don't include in the discussion whether they see the same brGDGT response in the Mongolian

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datasets. The authors have not attempted to make a model to predict MAT, that uses the MAP values as a confounding factor. Why not? The authors state that MAP and MAT correlate in this dataset (this is not plotted anywhere?), but the impact on the models is not discussed. Along the same line: can a partial RDA be used to illustrate the environmental dependencies (MAT or MAP) of brGDGTs in the absence of variation in the second driving factor?

The authors present several models for brGDGT calibration. I agree that caution should be used when using multiple variables (as discussed in section 5.1 and 5.2). Would an adjusted r^2 value be useful in this case? I would consider moving the models that are not selected to the supplementary material, so it is clear which model has the best predictive value according to the requirements that the authors have set. Please also see my comment below on selecting a model that makes 'biological sense'.

Comments on content: The introduction introduces several concepts and biomarker lipid groups that are not included in the discussion. Please remove this information (e.g. the impact of human populations on pollen-based climate reconstructions, or the existence of H-shaped or OH-GDGTs). Removing this will open up space to explain those concepts that are used better, and make the relevant part of the introduction more specific.

I also have several minor and 'editorial' comments to make. I indicated 'vague' phrasing where it was difficult for the reader to follow the interpretation:

L 13. Rephrase "derived to the low range of climate parameters encompassed in the study area".

L 19. Rephrase "input proxies" and be more specific. Use f_i estimates of climate parameters values. Why does the calibration of the climate proxies matter for the understanding of the interaction between climate model outputs and input? It's a bit arm-wavy, be specific.

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L 20. Current climate changes.

L 22. What is meant with 'degradation'?

L25. It is not clear why Mongolia is a hinge area. A hinge area would be influenced by two different climatic drivers, but here the authors state only which climatic drivers do not influence Mongolia. It contradicts L 23-24?

L 29. Perhaps use 'environmental systems' rather than 'climate systems'?

L 31. Please add references here that are an example of the use of pollen and geochemical proxies in lake sediments, or let the sentence reflect the references better.

L 34. Add 'in the absence of human influences'.

L 35. Do you mean specifically the transport mechanism of pollen? 'Pollen rain' is not self-explanatory to me.

L 52-55. This part is too vague. Mention that brGDGTs distributions have been correlated with MAT and pH in soils and in lakes. Please add the reference to Russell et al. (2018) [recent lake calibration that includes temperature and pH]. Refer to Dearing-Crampton Flood as the most recent brGDGT-temperature calibration.

Russell, J.M., Hopmans, E.C., Loomis, S.E., Liang, J., Sinninghe Damsté, J.S., 2018. Distributions of 5- and 6-methyl branched glycerol dialkyl glycerol tetraethers (brGDGTs) in East African lake sediment: Effects of temperature, pH, and new lacustrine paleotemperature calibrations. *Organic Geochemistry* 117, 56–69.

Dearing Crampton-Flood, E., Tierney, J.E., Peterse, F., Kirkels, F.M.S.A., Sinninghe Damsté, J.S., 2020. BayMBT: A Bayesian calibration model for branched glycerol dialkyl glycerol tetraethers in soils and peats. *Geochimica et Cosmochimica Acta* 268, 142–159.

L 59. What do the BIT index and the IIIa/IIa index reconstruct? It is not clear what is meant with 'the source'. L 61. Use bacterial producers instead of 'organisms'.

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L 63. Better phrase as: 'composition of bacterial community' and refer to De Jonge et al. (2019).

De Jonge, C., Radujković, D., Sigurdsson, B.D., Weedon, J.T., Janssens, I., Peterse, F., 2019. Lipid biomarker temperature proxy responds to abrupt shift in the bacterial community composition in geothermally heated soils. Organic Geochemistry S0146638019301275.

L 64. Please be specific 'climate and soil parameters' could mean many different things!

L 67-68. Are these ratios going to be used in the discussion? If not, consider emitting them.

L 69. Please add what the Ri/b index is (isoprenoid versus branched GDGTs?). How is aridity expected to influence brGDGT distributions?

L 70. Climatic features: please specify which ones.

L 71. The sentence that describes what will be done in this study seems to come too early, perhaps it can be moved to L 79 or removed?

L 73. Rephrase, is there a verb missing here? Based on pollen for instance?

L 77. Help the reader situate this, how many kilometers is there between your site and the other studies?

L 79, multi-proxy calibration comparison study. I.e., you will make a calibration based on more than 1 proxy? Which ones? Perhaps 76-79 can be removed as the following paragraph explains what will happen in this study?

L 84. Please include whether these 'surface samples' are soils, sediments?

L 85. Here you use 'biomarker', next line 'GDGTs'. Please use the same term throughout and be as specific as possible.

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L 95. There is no need to add 'in latitude' and 'in longitude'.

L 104. What do the authors mean with "actual GDGT analysis following the calibration approaches presented in De Jonge et al. (2014a), Davtian et al. (2016) 105 and Naafs et al. (2017, 2018)." Do they mean concentrations, fractional abundances, or climate proxy ratios?

L 110. Can the authors add the location of the Darkhad basin to the map?

L 115-125. Can the authors add a map with the expanse of the vegetation types? There is an extensive description, but this information can be conveyed much better with a map. The same goes for the extension of the different biomes (L 130-141).

L 139. Reconsider 'stocked onto', is this a common phrase to describe the orographic effect?

L 155. Please mention again what MAT and WAPLS means here? Reconsider 'Among', for instance: a selection was made from?

L 178. Type: head group.

L 184. Does Davtian et al. (2018) present a modification of the Hopmans et al. (2016) method? Please summarise shortly. If not, remove the reference to Davtian et al. (2018).

L 186. Please rephrase, "compounds were gathered" does not convey how the CBT and MBT proxies are calculated. Please add a formula [I found the formula's below in a Table, refer to this Table in the text] and change the name (De Jonge et al., 2014 uses the MBT'5ME ratio, not the MBT ratio). The formula presented for the fractional abundance is not clear (what is $\frac{\text{brGDGT}}{\text{GDGT}}$?). The authors can simply state that the fractional abundance of brGDGTs is the % brGDGTs compared to the total of brGDGTs. The same is valid for iGDGTs ($\frac{\text{iGDGT}}{\text{sum(iGDGTs)}}$).

L 192. Say "SIG Bioclimatic Data" instead of "climate parameters", otherwise it is

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necessary to specify which climate parameters are meant here.

L 195. Rephrase “gathered some”.

L 218. Please explain “AP” and “NAP”.

L 245. Specify “geographic scales”.

L 249. Rephrase. What is meant with “in case the highest R2 and the lowest RMSE were not applied for the same number of analogues?”

L 251. What do the authors mean with “the method fits well”.

L 253. What is meant with DB? Database?

L 260. To simplify the comparison.

L 267. Replace X. Please add more reference on iGDGTs in soils, it is too simplistic to say that they are only produced in the water column (as they are obviously also present in soils).

L 274: Are consistent between sample types. But are they, Fig. 4B seems to show some differences between samples types? This is also what we would expect from previous studies where a different distribution between soils and lakes was observed?

L 275. Check phrasing.

L 275. If the PCA only explains 37% of the variance within the brGDGTs, is it still useful to show it?

L 289. Which climate parameters? All of the ones mentioned in methods section on SIG Bioclimatic Data?

L 290. I am worried that including surface sediment, soil and moss samples might be introducing variation in the brGDGT dataset, that results in the absence of a correlation between the MBT'5Me and the MAAT. The way forward here would be to split the dataset between lake and soil samples, rather than to go forward and make a new

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model. In the PCA I can't see which samples are soils, moss or lake sediment, so it is not clear which impact the different sample types can have on the calibration.

L 294. Were 7-Me brGDGTs encountered in soils? I have not seen any reports of this, are the authors sure this was not a heavy isomer of a brGDGT IIIb that can be seen in the m/z of 1050?

L 305. The authors discuss a statistical approach to select the best model. However, what is neglected is the 'biomechanical logic' behind a model. If the authors follow the reasoning in the introduction, you would expect an increase in branched compounds with decreasing temperature (this is also seen in the global temperature dependencies). Is this reflected by the environmental dependencies in this study? Is this reflected by the models selected?

L 323. How different are these models with different parameters? Can the authors define a requirement and select the best model according to this requirements? And move the rest of the models to Supp. Information?

L 328. (Fig. 7A1).

L 331. Please rephrase, a wide dataset extension is not something that I know of. Also, what are "alleviated extreme values"?

L 342. Is the 2019 paper still in press?

L 349. It would be good to have these results in a figure. Does this concern only soils (for which the soil calibration dataset was developed) or also other sample types?

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