Review of Dugerdil *et al.* for *Biogeosciences*

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Summary

Dugerdil *et al.* present an analysis of soil and lacustrine brGDGT samples from Central Asia that considers new and published data from the region. The analysis focuses on the role of salinity, pH, and sample type in obscuring the relationship between the degree of brGDGT methylation and temperature. The analysis indicates that the generally weak relationship between the MBT'_{5Me} index and mean annual air temperature can be attributed to these variables, to different degrees. The work presented here is an important step forward for understanding the systematics of brGDGTs in Central Asia and I look forward to the publication of this work once my concerns are addressed.

Please find my specific concerns about the manuscript below.

Warm regards,

- Joseph Novak

Major Comments

Abstract (L4–6): This study does not introduce the Arid Central Asian brGDGT database, as this same dataset was analyzed in a recent publication by this group in *Paleoceanography and Paleoclimatology* (https://doi.org/10.1029/2025PA005214). Same applies for the statement in **Lines 93–94**. I think it would be more appropriate to discuss this work as a further exploration of the Arid Central Asian brGDGT database.

"confounding factors": Throughout the text, the phrase "confounding factors" is used to refer to any variable other than temperature. I think a slight reframing of the text would be useful to clarify what is of interest here. Specifically, salinity and pH as they relate to brGDGT distributions and aridity. Discussing these factors as independent variables of interest rather than confounding factors may be a useful way to highlight the importance of the work presented here.

Figure 1 and database composition: There are some inconsistencies in the Figure that make me question whether database is entirely composed of sediment/soil samples. Firstly, there are purple stars plotted on the map, but these are not shown in the Figure legend. In the case of the Lake Baikal basin (where I work), these mark the locations of moss polster brGDGT samples reported in previous work by Dugerdil et al. (2021). Similarly, the blue stars within Lake Baikal appear to mark suspended particulate matter samples reported by (De Jonge et al., 2015; note that this paper is not cited by the authors). Neither of these data types are soil / sediment. Based on these observations in the region I am familiar with, I question whether the rest of the database was constructed carefully and ask that the authors carefully screen the data or more clearly distinguish between sample types in this figure and in their analysis, particularly if different types of lacustrine (sediment vs. suspended particulate matter) and terrestrial (soil vs. plant tissues) samples are being considered in combined datasets. This is especially important to distinguish since the text discussing the new data presented in this study communicates a much stricter definition of a lacustrine or soil sample than what appears to be the rule in the portion of the database composed of previously published data.

On a related note to the comment above, I am doubtful that Lake Baikal is a useful point of comparison to the other samples in the ACA database for generating a regional calibration since this lake is remarkably different from the much smaller / ephemeral lakes in the rest of the dataset. This may merit a bit of text to talk about if you want to include data from Lake Baikal in this analysis.

L119–132: This section would benefit from some supplementary figures showing the environmental variables you are discussing, either as maps or histograms. As it stands, this is a pretty dense wall of text to get through without any visualization to help the reader understand what is being communicated.

L142–143: "The chemical characteristics of the ACA surface samples include pH and Electro-Conductivity (EC, Fig. 2, step 2), both measured *ex-situ* in the laboratory, even for lacustrine samples." Was there anything done to make sure that microbial respiration post sample collection did not cause the samples to become more acidic during transport? For the lacustrine samples, what is the logic that the pH or salinity of the pore water in the sediments is equivalent to the properties of the lake water? This is particularly concerning for pH, since the pH of sediment pore waters can change substantially (and therefore become different from the overlying water column) in even the upper few cm of the sediments (e.g., Bachmann et al., 2001; https://doi.org/10.1016/S0375-6742(01)00189-3).

3.1.1 brGDGT concentrations (L262–269): Comparing concentration measurements across studies is really tricky because there is no authentic brGDGT standard. The C_{46} internal standard (Huguet et al., 2006) is useful for considering relative differences in concentration between samples run at the same time, but this method does not control for instrument drift (see Figure 4 of Huguet et al., 2006). Some work needs to be done to show whether the uncertainties introduced by this shortcoming of the C_{46} method pose a problem for the analysis here. Or, at the very least, some text needs to be added to acknowledge this shortcoming of the concentration data. The discussion of the concentration data here feels somewhat random since they do not appear to be discussed later in the text. If they are going to be brought up, it would be interesting to understand if concentration is related to any of the indices that describe the brGDGT distributions. For example, we found a relationship between brGDGT concentration and IR_{6Me} in lacustrine sediment samples from Lake Baikal (Novak et al., 2025).

4.2.4 Toward a scale of confounding factor strength (L582–609): This section does not present any sort of quantitation of the strength of the confounding factors in the temperature-methylation relationship, so the name of this subsection is not appropriate. Rather, this text is a discussion of previous work on the topic. Is there maybe a way to tie this discussion in with the previous sections a bit more coherently? As it stands, I struggled to understand what the takeaway message of these two paragraphs is.

4.3.3 Confounding factors effect on temperature calibrations (L646–660): Text needs to be added to the methods that explains how lakes were classified into the different "salinity classes." Specifically, the cutoff values for the different classes need to be given and, if they are not taken from another publication, justification for these cutoffs should also be provided.

Figure 10: This figure design is really confusing to me. What is going on with the z-scores at the top of the figure? What do the boxes with lines represent?

Equation 6: This should probably be broken up into sub-equations (i.e., 6.1, 6.2, etc.) since there are multiple equations listed here. Also, five regressions are shown in Figure 10, but only three equations are given here. Why? This should be justified in the text or the other two equations provided.

Minor Comments

L26: I do not think we can really call brGDGTs a "new" proxy anymore.

L29: "…well preserved ***in lake sediments***…" current wording is not grammatical.

L30–33: This sentence is written in a confusing way that is not understandable to someone who is not familiar with the brGDGT proxy.

L33: "The relationship is clear and linear." I think there are missing words here. It is not clear what relationship you are talking about.

L34: This sentence would benefit from consolidation.

L35: "***acidic*** lakes"

L38: This statement could use a citation or two as an example.

L55: "pentamethyls" is a bit informal. Here and elsewhere this language should be replaced with "pentamethylated brGDGTs," adapted as appropriate for the molecules discussed in each instance.

L60: "This leads to a ***different*** temperature relationship between brGDGTs ***in soils*** and MAAT…"

L68–69: "…low organic matter **content**…"

L85: "Salinity is ***thought*** to influence…" is probably more appropriate since there is not (at least to my knowledge) a biochemical explanation for why the salinity would cause preferential synthesis of different brGDGTs.

L89: isn't MLR the typical abbreviation for multiple linear regression?

L95: "…totaling 761 ***samples***."

L97: What specific temperature variable(s) are you correlating to?

L112: What does "the data location was randomly selected" mean?

L138: ***core tops*** rather than "top cores"

L193–197: The justification for not looking at DC or DC' does not make a lot of sense to me. Should not all of the indices be considered?

L256: "the size of the data is high" this reads a bit awkwardly. How about, "since ***the number of samples is large***."

2.5 Database compilations: If you are going to include Lake Baikal data, the database is missing recently published surface sediment samples from Lake Baikal (Novak et al., 2025).

Figure 3: Some text is needed in the figure caption discussing how the bounds of the box and whisker plots are defined.

3.1.2 brGDGT fractional abundances: More figure callouts are needed in this section. Figure 3 is rather complicated, so it would be helpful to guide the reader through each of the panels.

L276: "The 7-methyl isomers ***are more abundant*** in lacustrine…"

L277: If you are talking about Figure 3, these are box and whisker plots, not histograms.

L256–282: The language here needs to be tightened up. When talking about the data, "trends" would imply some sort of regression exercise that generated an estimate of slope. Here, it is more important to talk about differences in the median values in the sample sets separated by aridity class (which is what the box and whisker plots are showing). This could be coupled with significance tests in differences of the mean.

L292–293: What do you mean by the aridity effect? This is not clear from the text.

L304: I would not say this is a "clear aridity gradient" since there is substantial overlap between the distributions plotted on the upper axes of the plots in Figure 5. This result is, perhaps, suggestive of an aridity gradient.

3.2.1: Some text explaining why this analysis was done and what the VIF value means would be really useful to guide the reader through this dense section of the text.

L341–345: Figure callouts are needed here.

L364: The meaning of the "*" needs to be explained, or the p-value can just be written as $p << 0.001$ or however else is appropriate for each relationship.

L361–372: Is there a figure associated with these tests and statements (presumably Figure 6)? Callouts are needed.

L372: Is there a figure or statistical test (preferably both) you can point to that indicates that "hyper-arid samples often have extreme values" ?

L384–386: I think you mean "…there is a strong ***correlation*** between…"

L428–429: The confounding factor in relation to what? Estimating MAAT from one of the methylation indices?

L454: "attenuation" is not the right word to use. ***Weakening*** is probably what you mean.

L475: typo here.

L500: Again, a confounding factor for what?

L512–514: "These thresholds of salinity classes are attenuated…" I do not really understand what you mean here. What thresholds do you mean? I do not see any in the Figure that is referenced. I understand that you are talking about the difference in the correlation strength to salinity of IR_{6Me} vs. IR_{6+7Me}, but the language here is hard to follow.

L526–527: What is a "correlation disruption"?

L528: "global Chinese soils" seems self-contradictory.

L562: What is a "not recalibrated temperature reconstruction" ?

L564: "*over-representation*" Also, not really sure what you mean here.

L615: “constrained” is not the correct word to use here. I think you mean “***led****”* but you should make sure of that.

L643: What is a “locally recalibrated global calibration” ?

L644-645: Could some of this not be because of the typically different seasonality of brGDGT and pollen temperatures? As in, brGDGTs typically are a proxy of MAAT or MAF while pollen is typically mean temperature of the warmest month or mean temperature of the coldest month? Temperature change is expected to have a different magnitude across different seasons from climate model simulations and modern observations (Feldl and Merlis, 2021, is an example from the high latitudes).

L684–685: I do not think “lead” is communicating your intended meaning in this sentence, but I cannot figure out what you are trying to say so I cannot suggest a better word.

L695: Rather than “mitigated” I think you mean “***limited***.”