Lindberg and co-authors report on the well-known and unique Lake E sediment record from the Russian Arctic. Their analysis of brGDGT and n-alkane biomarkers allow new and revised interpretations of past environmental change in terms of precipitation and vegetation across the mid-Pleistocene transition (MPT), a global and enigmatic period of climate change. Overall, the paper is very well written with clear accompanying figures that allow the reader to visualize the text appropriately. Although the authors do explore the utility of the brGDGT proxy using various calibrations and statistical analyses, I offer some suggestions for further data interrogation that I hope will benefit the paper. The fact that this paper provides a rare and continuous terrestrial Arctic paleoclimate record across the MPT naturally amplifies its impact. Collectively, with some revisions, this manuscript will be a highly valuable contribution to both the paleoclimate and brGDGT proxy community. I congratulate the authors on a very nice manuscript – it was a pleasure to read.

Specific Comments

L11: Please be consistent with ka or kyr throughout the paper. Same applies for Ma and Myr.

L34-35: Maybe I'm just not familiar with ecology well enough, but it sounds oxymoronic to have cool forests indicative of a warm climate?

L40: Might be worth briefly mentioning what proxies these T and P reconstructions are based on.

L72: You say that MPT lake records are particularly rare. Are there any others? If so, would be worth adding some references, otherwise clarify that Lake E is the only known one!

L84: Can you provide a sentence or two on how the age model is constructed (i.e., what geochronological tools/proxies)? Do you have a sense of how the age model uncertainty (good/bad) effects the timing on your biomarker records? This seems particularly relevant for the spectral analyses.

L95: Please clarify which months you include in summer…JJA?

L96: When do shallower regions reach 5-6 degC...summer? Please specify.

L100: Thermodynamics of the lake? Please specify.

L106: It seems like these 41 re-analyzed samples are a sub-set of the original (de Wet et al., 2016). Was there a strategy for why these ones were chosen rather than re-analyzing the entire dataset?

L109: This sentence is a little misleading because I do not believe de Wet et al. (2016) analyzed n-alkanes. Please rephrase. In addition, and similar to my prior comment, these do not represent all samples de Wet et al. (2016) analyzed. Was there reason behind how many and which samples were re-analyzed for brGDGTs and n-alkanes from the original sample set of de Wet et al. (2016)?

L141: I do not agree with the decision to only use 5-methyl indices. Micro/mesocosm experiments for lake brGDGTs (Martínez-Sosa and Tierney, 2019) in addition to the environmental samples from East Africa (Russell et al., 2018) demonstrate a positive correlation between the abundance of total 6-methyl brGDGT isomers and temperature. A lake record from Iceland also shows some 6-methyl isomers strongly correlated with T inferred from alkenones (Harning et al., 2020). Since we do not have culture experiments to better test which brGDGTs are produced across which environmental gradients, I think it is best to explore the full gamut rather than a subset.

L145: Like my previous comment, I suggest, especially since we do not yet have culture studies for brGDGTs and that there are not that many existing empirical lake calibrations that separate the 5 and 6-methyl isomers, all calibrations be tested. These would include:
Feng et al. (2019)
Harning et al. (2020)
Raberg et al. (2021)

Since they are all also from or include high latitude/altitude locations, they should be just as applicable as the East African and Greenland calibrations and may offer some interesting insights (see later comments).

L158: Is 211 the number of samples you analyzed (127) and those from de Wet (85)? If so, should this number read 212?

L164: CPI should be defined in the methods.

L166: Would it be possible to conduct a change point type analysis here? Otherwise, it seems rather arbitrary to select 900 ka as the boundary. I agree it looks like 900 ka reflects a regime shift, but our eyes can do weird things and I find that statistics help us be more objective.

L224: Other Arctic sites not mentioned suggest this assumption may be less robust (e.g., Dion-Kirschner et al., 2020), where the data show that terrestrial plants also produce a substantial amount of mid-chain plant waxes. I also skimmed the Wilkie paper, and it looks like they only reported on alkanoic acids, which do not necessarily correlate with alkanes as implied here. Might be worth briefly expanding on some of these limitations for your ACL interpretation.

L229: How do these previous studies link ACL and aridity? Modern instrumental calibrations or downcore proxy correlations? I'm not as familiar with using alkanes as a precipitation proxy, so it may help other readers in a similar boat. Is there a physiological mechanism that causes this response to precipitation variability?

L233-234: Same comment as above. What proxies is this aridity condition based on? Please briefly mention.

L249: In re to the visual correlation between ACL and landscape openness index, are there any statistical regression techniques that could be used to support your observation?

L251-252: Since you mention at the end of the previous paragraph that you refine the ACL interpretation for Lake E, does your interpretation differ from the prior studies you discussed? If so, in what way?

L257-259: I don't agree with the argument that dominance of 5-methyls suggests MBT'5Me is most suitable. Transfer functions for other non-biomarker proxies (e.g., foraminifera, chironomids, etc.) can include non-dominant taxa that are important for interpreting changes in T, or whatever the variable of interest is. Therefore, I'd suggest exploring all the available calibrations that separate the isomers, even those that may include 6-methyls, and those that include other calibration approaches, such as stepwise forward selection, as I suggest earlier. I'll also note that Russell et al. (2018) present a SFS calibration that does feature a lower RMSE than their MBT'5Me index calibration's.

L261: Fair to exclude Dang et al. (2018). And if the other calibrations I suggest are also not optimal is some similar way, it could be mentioned here, but each should be systematically evaluated.

L265: Raberg et al. (2021) provide a number of Arctic sites in their modern lake brGDGT calibration.

L270: Yes, naturally because they are all use the same index. I think this is also one reason why it will be interesting to try some other non-MBT-index calibrations to test if these patterns are consistent or not and explore what brGDGTs are key drivers in the indices. In this sense, it may also be interesting to conduct a Pearson correlation matrix as Feng et al. (2019) did to explore the relationship between individual brGDGTs. You may find similarities between other calibration Pearson matrices that could support use (or not) of a certain calibration.

L276-293: This paragraph seems to imply that the pollen-inferred T record is more reliable. Both pollen and brGDGT T proxies have various assumptions and therefore only reflect approximations of past events. I think this paragraph could be rephrased to exclude statements such as "unreasonably large, L280" and "more realistic, L284" and perhaps more objectively compare the 2 T proxy records (pollen and brGDGTs). One of the motivations for this study seems to be producing a rare continuous T record through the MPT. However, if we already have that through pollen, what's the value of brGDGTs here, especially if you think that are not realistic? There are many brGDGT studies that link different distributions to various environmental parameters (e.g., pH, salinity, DO, etc.), which may be a more valuable, or at least supplemental, discussion topic to include.

L286: In Figure S5, it would be interesting to plot up some additional environments as well. Just eyeballing, there appear to be some similarities between brGDGT distributions in Lake E and Svalbard fjord sediments (Dearing Crampton-Flood et al., 2019) and marine sediments (see plots in Xiao et al., 2020), as examples.

L318: Do other qualitative or quantitative climate records from Lake E show a long-term cooling trend that could be compared here?

L321-322: Yes, a lack of MPT cooling at Lake E may be odd, but in addition to climate-driven hypotheses, our still growing knowledge of the brGDGT proxy may also limit or obscure these observations.

L413: Or there is another environmental or microbial factor that contributes to brGDGT distribution changes (e.g., Weber et al., 2018; De Jonge et al., 2019, 2021) and Facies C is still indicative of T.

L440: You explain ACL earlier as a proxy for aridity, so might be better to limit your interpretations of ACL to that here as well. Why would trees expand under increased aridity?

L492: Clarify that this is increased "oceanic" stratification. It took me a few reads to realize you weren't referring to Lake E.

L449: Can you specify which SST proxies? This makes it easier for the reader to independently compare different proxies, as each have different assumptions and interpretations.

Figure 1: Panel B shows 2 yellow dots but only one is mentioned in the caption. Please clarify.

Figure 3: Please clarify in the caption what the bold line is for n-alkane ACL…also a 5-point moving average?

Figure S5: Would be good to include all the lake sediment samples I mention from the other calibration studies in the ternary diagram.

Technical Comments

L22: Change "exhibits" to "exhibit". Data are plural

L46: Comma after "ka"

L60: Insert "may have" or something similar before "worked". Otherwise, it sounds like this *is* what happened

L75: Capitalize "arctic", and check if needed elsewhere throughout the ms

L106: I suggest phrasing as "46.77 to 31.06 m" so that it is consistent with the ages you mention just before (i.e., older/deeper to younger/shallower).

L161: Change "they" to "the peaks" or something. It's always easier to follow if pronouns are not used.

L167: Extra and/or missing words around “samples characterized”. Please clarify.

L362: Journal should not be referenced in in-text citations.

L389: Does it need to be mentioned or clarified that the LR stack is annual rather than summer biased as you argue the brGDGTs are?

L393-394: Are there any statistical regression analyses that can be used to support this observed alignment between brGDGTs and obliquity?

L412: There are some missing words in the latter half of this sentence.

L539: A little wordy/awkward phrasing…perhaps just “Spectral analysis of the brGDGT record, in comparison with marine records, suggests…”

L506: Add “Sea” after “Bering”

References (Not included in original text)

Dearing Crampton-Flood, E., Peterse, F., Sinninghe Damste, J.S., 2019. Production of branched tetraethers in the marine realm: Svalbard fjord sediments revisited. Org. Geochem. 138, 103907.

De Jonge, C., Radujkovic, R., 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. Org. Geochem., 137, 103897.

De Jonge, C., Kuramae, E.E., Radujkovic, D., Weedon, J.T., Janssens, I.A., Peterse, F., 2021. The influence of soil chemistry on branched tetraether lipids in mid- and high latitude soils: Implications for brGDGT-based paleothermometry. Geochim. Cosmochim. Ac. 310, 92-112.

Dion-Kirschner, H., McFarlin, J.M., Masterson, A.L., Axford, Y., Osburn, M.R., 2020. Modern constraints on the sources and climate signals recorded by sedimentary plant waxes in west Greenland. Geochim. Cosmochim. Ac. 286, 336-354.

Feng, X., Zhao, C., D'Andrea, W.J., Liang, J., Zhou, A., Shen, J., 2019. Temperature fluctuations during the Common Era in subtropical southwestern China inferred from brGDGTs in a remote alpine lake. Earth Planet. Sci. Lett. 510, 26–36.

Harning, D.J., Curtin, L., Geirsdóttir, Á., D’Andrea, W.J., Miller, G.H., and Sepúlveda, J., 2020. Lipid biomarkers quantify Holocene summer temperature and ice cap sensitivity in Icelandic lakes. Geophys. Res. Lett. 47, 1–11.

Martínez-Sosa, P., Tierney, J., 2019. Lacustrine brGDGT response to microcosm and mesocosm incubations. Org. Geochem. 127, 12–22.

Weber, Y., Sinninghe Damste, J.S., Zopfi, J., De Jonge, C., Gilli, A., Schubert, C.J., et al., 2018. Redox-dependent niche differentiation provides evidence for multiple bacterial sources of glycerol tetraether lipids in lakes. Proc. Natl Acad. Sci. 115, 10926–10931.

Xiao, W., Wang, Y., Liu, Y., Zhang, X., Shi, L., Xu, Y., 2020. Predominance of hexamethylated 6-methyl branched glycerol dialkyl glycerol tetraethers in the Mariana Trench: source and environmental implication. Biogeosci. 17, 2135-2148.