We would like to thank the reviewer for re-reviewing our manuscript and for providing detailed and constructive feedback and suggestions. Their feedback and suggestions have significantly improved our manuscript, and we appreciate that. Below, we have addressed each comment individually, with the original comments in the back text and our responses in blue.

Some key suggestions include:

- The authors should review and revise the abstract. Although the authors have significantly changed the text, they have not really updated the abstract to reflect these changes, including reconsidering the broad statement that cald/cren is decoupled from their temperature reconstructions (see e.g. Table S4).

Reply: We revised the abstract as:

“The Holocene Thermal Maximum (HTM), a period during the Early and Middle Holocene when Greenland experienced a warmer climate than pre-industrial times, provides an ideal opportunity to test the sensitivity of the Greenland Ice Sheet to prolonged warmth. However, available climate reconstructions from the Greenland and surrounding regions provide a contrasting picture of the HTM—several reconstructions show an earlier HTM between the Early- to Middle-Holocene, while others show a delayed HTM between the Middle- to Late-Holocene. This discrepancy may be due to either seasonal sensitivity of the proxies or to spatio-temporal climate variations. Here we generate five new Holocene timeseries of branched glycerol dialkyl glycerol tetraether (brGDGT)-inferred mean air temperature for months above freezing from lakes along a latitudinal transect in southwestern Greenland, yielding a total of seven Holocene brGDGT-inferred time series in this region. Lake model sensitivity tests indicate minimal intra-lake variation in both the seasonal production window of brGDGT and the sensitivity to air temperature changes. Moreover, higher caldarchaeol-to-crenarchaeol ratios during the Early Holocene indicate anoxic or suboxic conditions in all lakes; however, these conditions do not show a consistent relationship with reconstructed temperatures, indicating that regional climate is the primary driver of the reconstructed temperature time series. Six of the brGDGT time series suggest a temperature maximum between approx. 7.5 and 5 ka, following peak summer insolation and in agreement with many regional reconstructions. A site far from both the coast and the Greenland Ice Sheet suggests peak warmth in the Early Holocene. These results, based on a single proxy, suggest that southwestern Greenland experienced similar Holocene summer temperature trends, with local temperature variations caused by proximity to the ice sheet and the ocean. Further investigations quantifying seasonal sensitivity between proxies and local effects (e.g., site-specific systematics and proximity to the ice sheet and the ocean) may help reconcile the differences and refine Holocene climate reconstructions.

- It seems pertinent to include Lake Gus in Figure 5 and given that the data for the lake was produced by the same research group is likely to be available to them. They present Lake Gus as an outlier in temperature trends in terms of timing but do not give the GDGTs the same depth of examination that the other lakes receive.

Reply: We include both Lake Gus and Lake 578 in Figure 5. A detailed discussion of the GDGT data from Lake Gus is presented in Cluett et al. (2023); therefore, we do not discuss it in detail here. However, we elaborated the discussion in Section 3.3.4 to include GDGT data from Lake Gus as:

"In Lake Gus, reconstructed temperatures were significantly correlated with Cald/Cren values (Table S4). However, samples with elevated Cald/Cren ratios also contained less than 30% hexa-methylated brGDGTs, which was interpreted as indicating a shift in brGDGT sources rather than a direct redox effect on temperature calibration (Cluett et al., 2023). These samples were therefore excluded from the temperature reconstructions (Cluett et al., 2023)."

• I request that the authors make a point in the main text recognizing that the temperature data from N3 indicate that it is likely summer-stratified today and the model supports this stratification persists for most of the IFS. This is somewhat buried in the supplemental (Figure S9) but would be appropriate to include in section 3.3.4. The muted extension of the stratification period in the model may be explained by the observation that there aren't that many additional days in the IFS during which N3 isn't already stratified. It is a little hard to consolidate e.g., lines 365-375 which insinuates these lakes should all be well-mixed during most of the IFS with Figures S8, S9 which show the only lakes they have observational data from both have extended periods of summer-stratification during the IFS today under what I think of as relatively weak summer forcing, relative to the early-middle Holocene.

Reply: We added texts in the MS as:

"Aquatically produced brGDGTs in the study lakes may be influenced by anoxic or suboxic conditions, potentially biasing temperature reconstructions (Acharya et al., 2023; Harning et al., 2025; Raberg et al., 2025). Modern observations from Lake N3 indicate that the lake stratifies early in the ice-free season, a pattern also supported by model simulations (Fig. S9). Consequently, changes in stratification dynamics throughout the Holocene may have affected brGDGT production and distribution in the study lakes. To assess this potential impact, we used the caldarchaeol-to-crenarchaeal ratio (Cald/Cren), a proxy for suboxic conditions in the water column and/or lake sediments where caldarchaeol is produced (Baxter et al., 2021; Blaga et al., 2009; Sinninghe Damsté et al., 2022)."

• The authors appear to have removed the temperature calibration uncertainty from the temperature estimates in figures—please add this back into the figures. I do think that the error on these measurements deserves a bit more recognition throughout the text as well but recognize that it likely wouldn't fundamentally change the interpretation.

Reply: Thank you for highlighting this. We use the calibration from Otiniano et al. (2024) to reconstruct the mean air temperaure above for the months above freezing, which has a root mean square error (RMSE) of 1.0 °C, and introduces a similar level of uncertainty across all lakes and samples. In contrast, age uncertainty is likely more variable across lakes and samples (Fig. S1-S5), and we therefore prioritise including it in the figures over calibration uncertainty. But we have now included the calibration uncertainty in the text and figure captions.

• Correlation coefficients being low/non-significant between cald/cren and temperature reconstructions doesn't necessarily indicate no influence on brGDGT distributions and thus temperature estimates, as outlined in section 3.3.4. That the 0/cren ratios are persistently (very) high overall through periods of the records, especially in the early-middle Holocene at N3 and Pluto, still provides evidence of conditions that can and likely do affect the temperature reconstruction. These are complex and intertwined gradients, and it reads as 'missing the forest for the trees' in the treatment.

Reply: Thank you for highlighting this. We revised our text in the MS to include that as:

"Correlations between Cald/Cren and reconstructed temperatures were weak or non-significant in Lakes N3 and Marshall throughout the Holocene (Table S4), indicating climate as a primary mechanism controlling reconstructed temperature patterns."

• Are there no brGDGT-inferred temperature estimates from surface sediments at these sites to compare against modern climatologic data? That seems like a first-order test of whether site-specific parameters compete with the regional geographic temperature trends driven by elevation and coastal/inland positioning.

Reply: We agree that analysis of brGDGTs in the surface sediments from the study lakes would be valuable for comparison with modern climatic data. Unfortunately, surface sediments are not available from the study lakes, and GDGT analysis on these sediments is beyond the scope of this study.

• Line 13: Refers to 'from the region' without stating what the region is first

Reply: We revised the sentence as:

"However, available climate reconstructions from Greenland and surrounding regions provide a contrasting picture of the HTM—several reconstructions show an earlier HTM between the Early- to Middle-Holocene, while others show a delayed HTM between the Middle- to Late-Holocene".

• Line 46: is it really accurate to say "patterns of Holocene climate change in Greenland are still poorly resolved" at this point? There are two reviews on this topic and dozens of reconstructions from the island

Reply: We revised the sentence as: "However, there is no consensus regarding the patterns of Holocene climate change in Greenland."

• Line 50: I recommend checking this regional definition against other sources. This broad area is elsewhere considered to be multiple sectors of Greenland (see Danish meteorological institute technical reports on Greenland, for e.g.)

Reply: Thank you for the recommendation. According to the most recent report from the Danish Meteorological Institute (Jensen et al., 2025), Greenland south of Ilulissat is defined as Southern

Greenland. In this study, we therefore retain the classification of the region extending from Nuussuaq to Cape Farewell as Southwestern Greenland.

• Lines 124-133: meteorological observations should be attributed to primary sources that contain the original observations like precipitation amounts

Reply: We added the primary citations in the sentence as:

"Temperature generally declines northward along the coast and with increasing elevation, where snow cover and radiative cooling are more pronounced (Jensen et al., 2025; Karami et al., 2017)."

• Line 164: I am guessing you used BEH HILIC columns and suggest including the phase information details here.

Reply: we revised the text as:

"GDGTs were analyzed on an Agilent 1260 Ultra High-Performance Liquid Chromatograph (UHPLC, Agilent 1260) coupled to an Agilent 6120 Mass Selective Detector (MSD) in selected ion monitoring (SIM) mode in the Biogeochemistry Laboratory at the University of Massachusetts Amherst. Two Waters BEH HILIC columns (2.1 mm × 150 mm, 1.7 µm) were used in series. Chromatography was performed applying a three-phase isocratic solvent gradient using 100% hexane (solvent A) and hexane:isopropanol (9:1, v:v, solvent B): i) 18% B, 25 min; ii) ramp to 35% B, 25 min; iii) ramp to 100% B, 30 min, and system rinse. We followed the procedure described by Hopmans et al. (2016). Peak integration was done using the "chromatoPy" package in Python (Otiniano et al., 2025). We determined the GDGT concentrations in relation to the C46 internal standard."

• Line 167: Suggest elaborating on what it means here to determine GDGT concentrations relative to the C46 internal standard. Were peaks normalized to this somehow? Was a linearity dilution series performed?

Reply: No, we did not normalize peak areas to the C46 internal standard. Instead, GDGT concentrations were quantified by calculating their response relative to the known amount of C46 internal standard added to each sample. This approach allows absolute quantification based on the instrument response factor of the internal standard. We revised the text as:

"We quantified the GDGTs concentration by calculating their response relative to the known amount of C46 internal standard added to each sample."

• Line 211: Figure S9 appears to have a sizeable mismatch between modelled bottom water temps and observed bottom water temps starting ~10ish m water depth, despite the text here stating 'all agree well'. Can you provide somewhere, perhaps here, the range of offset between estimate and model temps?

Reply: We added the following texts in the manuscript:

“There are minimal differences among parameter sets, and all agree well with observed lake temperatures, with root-mean-square error (RMSE) values of 0.7 °C at the surface, 1.0 °C at 5 m depth, and 3.5 °C at 10 m depth (Fig. S9).”

• Line 232: concentrations peak in the early Holocene, but maximum temperatures occur later? Consider adding a discussion point on why peak microbial productivity precedes peak temperature estimates.

Reply: We revised the sentence as:

“Although the reconstructed temperatures indicate peak warmth from 7.5 to 5 ka, GDGT concentrations were high during the Early Holocene in lakes Pluto, Rosaea, Marshall and Bullet and gradually decreased over the Holocene, suggesting that microbial activity was highest prior to peak temperaure (Fig. 2; Figs. S10-S14). High microbial activity in the Early Holocene is likely due to enhanced nutrient inputs associated with recently deglaciated catchments, which declined as vegetation expanded and catchments stabilised.”

• Line 256: Which Otiniano et al. 2024 calibration equation is used? Are decimals on temp estimates meaningful given an uncertainty of +/- 1 degree?

Reply: We used Equation 9 from Otiniano et al. (2024) to reconstruct temperature. We removed decimal places from temperaure estimates.

• Line 265: In earlier review, these points were requested to be included in the figures of temperature reconstructions but 'flagged' and identified as being excluded from consideration as temperature in the discussion for the reasons provided.

Reply: Thank you for this suggestion. All flagged samples are shown in Figures S10, S14, and S17. However, because samples with >0.4 $IR_{6ME}$ are not interpreted in terms of temperature due to non-thermal effects, including them in the main-text figures could confuse readers. We therefore refrain from including them in the main-text figures.

• Lines 324-340: The authors state above the parameterization is somewhat homogenized to reduce computational intensity. How much similarity across the lakes in the model is owed to this?

Reply: Thank you for highlighting this point. While we acknowledge that using a consistent parameter set for the lake thermodynamic balance across the study lakes may introduce minor uncertainties in the absolute temperature estimates, for sensitivity testing, these shared assumptions have negligible effects on the simulated inter-lake temperature differences (Fig. S21–S23). Therefore, the similarity in modelled lake temperatures is not an artefact of parameter homogenisation but instead primarily reflects the imposed regional climate forcing.

• Line 557: where does 0.2 as the uncertainty on this estimate derive from? The calibration error is stated above as 1.0 deg C.

Reply: The value 0.2 in L557 refers to the intra-lake standard deviation of reconstructed temperatures. We now include the calibration error when inferring the magnitude of reconstructed temperatures. We revised our text as:

"BrGDGT-inferred MAF-T timeseries from lakes Pluto, N3, and 578 each show on average 1.4 ± 1.0 °C higher temperatures during the peak warmth (from 7.5 to 5 ka) relative to 1994–2024."

Ultimately, I fundamentally disagree with aspects of the interpretation and find some of the reasoning circular, but the authors have certainly addressed the major problems in earlier drafts and are in their right to present this interpretation as a plausible hypothesis and let the reader/community decide. In my opinion, a stronger manuscript would have acknowledged that geochemical sources of noise (e.g., anoxia imperfectly and non-linearly recorded by cald/cren) in addition to regional climate factors and lake attributes could explain the site-to-site differences. However, the authors clearly are eager to make the case these data are explained entirely by regional differences in air temperature and thus climate and so they should.

Reply: We thank the reviewer for this thoughtful comment. We agree that higher caldarchaeol-to-crenarchaeol ratios, indicative of anoxic or suboxic conditions during the Early Holocene, may have influenced the magnitude of reconstructed temperatures across all study lakes. However, the occurrence of anoxia across all lakes during the Early Holocene cannot account for the observed spatio-temporal differences in reconstructed temperatures. In addition, other site-specific factors, including the seasonal production window of brGDGTs and their sensitivity to air temperature changes, do not provide strong evidence for explaining the intra-lake variability. Therefore, we interpret spatial variation in air temperature, driven by differences in proximity to the ocean, the ice sheet, and topography, as the primary control on temperature variability across the study sites, with other local site-specific effects acting as secondary modifiers. We revised texts in the manuscript as:

"Aquatically produced brGDGTs in the study lakes may be influenced by anoxic or suboxic conditions, potentially biasing temperature reconstructions (Acharya et al., 2023; Harning et al., 2025; Raberg et al., 2025). Modern observations from Lake N3 indicate that stratification occurs early in the ice-free season, a pattern also supported by model simulations (Fig. S9). Consequently, changes in stratification dynamics throughout the Holocene may have affected brGDGT production and distribution in the study lakes. To assess this potential impact, we used the caldarchaeol-to-crenarchaeal ratio (Cald/Cren), a proxy for suboxic conditions in the water column and/or lake sediments where caldarchaeol is produced (Baxter et al., 2021; Blaga et al., 2009; Sinninghe Damsté et al., 2022). The Cald/Cren ratio ranged from 1 to 857 in all study lakes, with generally low values in lakes Marshall, and Rosaea and high values in lakes Bullet, N3 and Pluto (Fig. 5). The ratio was higher from 10 to 7 ka in lakes Rosaea, Bullet, Marshall, and Pluto suggesting reduced oxygen availability, while afterwards, it was lower, indicating higher oxygen availability. Similarly, the Cald/Cren ratio was higher in Lake N3 from 8 to 5 ka, suggesting lower oxygen availability before decreasing to low levels. While anoxic or sub-oxic conditions are suggested by Cald/Cren, the lake model sensitivity tests under Holocene climate conditions (±5 °C) indicate that stratification occurs early in the ice-free season in all study lakes but does not persist throughout the entire ice-free period, meaning that oxygenated water is mixed to the lake bottom in late summer under all climate scenarios (Fig. 3 and Fig. S18). This indicates that low-oxygen conditions are most likely to occur during the winter, when stratification lasts for ~7-8 months in the warmest model scenarios, but could also occur during the early ice-free season stratification, which lasts up-to ~3 months in the warmest simulations. Further, as the ice-free season duration increases, the duration of isothermal mixing increases, while the duration of stratification remains constant in relatively shallower (Pluto, Gus, Rosaea, Marshall, and Bullet) and increases in deeper study lakes (N3 and 578). This is due to the relatively shallow depths and low dissolved-solids concentrations in these lakes, which make them prone to mixing by solar heating and wind. Such mixing during summer is observed today in Arctic lakes with similar size and chemical composition (Antoniades et al., 2024; Y. Klanten et al., 2023; Yohanna Klanten et al., 2024; Lindborg et al., 2016).

Correlations between Cald/Cren and reconstructed temperatures were weak or non-significant in Lakes N3 and Marshall throughout the Holocene (Table S4), indicating climate as a primary mechanism controlling reconstructed temperature patterns. In contrast, significant negative correlations were present in Lakes Rosaea, Bullet, and Pluto (Table S4), suggesting potential redox-related effects on reconstructed temperatures during periods of inferred suboxia (10–7 ka). In Lake Gus, reconstructed temperatures were significantly correlated with Cald/Cren values (Table S4). However, samples with elevated Cald/Cren ratios also contained less than 30% hexa-methylated brGDGTs, which was interpreted as indicating a shift in brGDGT sources rather than a direct redox effect on temperature calibration (Cluett et al., 2023). These samples were therefore excluded from the temperature reconstructions (Cluett et al., 2023). Similar to our study sites, Lake 578 exhibits high Cald/Cren values during the Early Holocene, and Cald/Cren values show a significant negative correlation with reconstructed temperature over the Holocene (Table S4) (Schneider et al., 2024). These high cald/cren values were interpreted to indicate anoxia during the ice-covered period and/or early in the ice-free season, and likely did not influence the brGDGT-inferred temperatures due to mixing during the ice-free season (Schneider et al., 2024). Observations show that Lake 578 experiences isothermal mixing, which carries oxygenated water to the lake bottom, for at least half of the ice-free season. Lake 578 is similar to or deeper than lakes in this study, which therefore likely experience longer periods of ice-free season isothermal mixing. Moreover, lake-model sensitivity tests suggest that all study lakes experience ≥1 month of ice-free season isothermal mixing even under the warmest conditions. While we cannot completely rule out the effects of anoxia/suboxia and possible cold-bias on MAF-T in our study lakes during the period of high Cald/Cren from 10 to 7 ka, the fact that these lakes experience the most prolonged stratification in winter and significant isothermal mixing during the ice-free season suggests that the impact of anoxia/suboxia on brGDGT-inferred MAF-T is minimal."

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