EGU2020-11938
https://doi.org/10.5194/egusphere-egu2020-11938
EGU General Assembly 2020

Calibration of multiple paleotemperature proxies in modern lacustrine carbonate and lipids, Green Lake, New York, USA

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The application of novel paleotemperature proxies such as the carbonate clumped isotope (Δ47) paleothermometer and GDGT-derived TEX_{86} temperature index offer insight into the continental record of ancient temperatures. While standardizing laboratory protocols has enhanced each methodology, the modern calibrations necessary to fully exploit their application in ancient environments lag. As the application of clumped isotopes and GDGTs in ancient lacustrine deposits expands, it is essential to describe the limitations and utility of each technique in modern environments.

This study employs biweekly monitoring and water sampling of a temperate lake, Green Lake, Fayetteville, NY, USA, for water, lipids, and calcite, to explore how isotope- and GDGT-based proxies record seasonal changes in temperature. In addition to monitoring water temperature, we analyzed samples collected at depths between 0.5 and 15 m below the lake surface from May to October 2019 for carbon and oxygen isotopes, clumped isotopes, and GDGTs. Water samples were analyzed for hydrogen, oxygen isotopes, and ionic chemistry. The results allow for a comparison of the water column-derived lacustrine record of the clumped isotope paleothermometer of calcite, oxygen isotope paleothermometer of calcite, and GDGT-derived temperature indices.

Previous work shows the majority of calcite precipitated annually in the water column grows rapidly during summer warming, so we expected proxy temperatures to reflect summer water temperatures at the depth of sampling. Over the May to October sampling period surface water temperatures were 14 to 25 °C, with the highest temperatures measured July 11. At 15 m below the surface water temperature ranged from 10 to 13°C. Temperatures calculated using the fractionation relation from Kim and O'Neil (1997), and preliminary calcite and water $\delta^{18}O$ values from various depths are within uncertainty but 0 to 5°C cooler than measured water column temperatures at the time and depth of sampling. Carbonate Δ47 proxy temperatures, though the majority fall within uncertainty, suggest systemic temperature offset 6 to 19 °C hotter than the water column. It is currently unclear if calcite sampled from a given depth is locally formed or if it settles from higher in the water column, where temperatures are higher. Additional data are needed to test the hypothesis that higher $\delta^{18}O$ and lower Δ47 values for carbonate reflect disequilibrium effects.

Future work will extend the dataset and make proxy temperature comparisons to sediment cores to create an empirical temperature transfer function between seasonal information and recorded core temperatures. A suite of soxhlet extracted lipid samples await HPLC analysis to confirm the existence of GDGTs in these samples. With the ensemble of data, we will clarify: 1) how seasonality of the proxy record relates to mean annual air temperature; 2) the correspondence between T(Δ47) values and observed water column temperatures; and 3) which GDGT-temperature indices, TEX_{86}, TEX_{86}', along with the BIT index, accurately describe temperature within the water column. The results of this study will provide constraints on how to interpret temperature signals recovered from the lacustrine record, and the utility of a multi-proxy approach.