

TOWARDS RELIABLE RECONSTRUCTIONS OF PLIOCENE TERRESTRIAL TEMPERATURES USING BRANCHED TETRAETHER MEMBRANE LIPIDS

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The Mid-Piacenzian Warm Period (mPWP, *ca.* 3.3-3.0 Ma) is a frequently targeted interval for model simulations because it is considered to be an analogue for the climate of the mid-21st century. CO₂ levels, continental configurations, land elevations, and ocean bathymetry during the mPWP were comparable to present. However, global temperatures were warmer by 2-4 °C, indicating that current climate may not have reached equilibrium. While sea surface temperature (SST) reconstructions for the mPWP are abundant, temperatures in the terrestrial realm remain poorly constrained due to the scarcity of stratigraphically complete terrestrial sedimentary archives and a lack of quantitative proxies for mean air temperature (MAT).

Branched glycerol dialkyl glycerol tetraethers (brGDGTs) have emerged as a promising proxy for terrestrial MAT reconstruction, as the relative distribution of these bacterial membrane lipids in soils correlates with MAT (Weijers et al., 2007). Upon mobilization and subsequent transport from land to sea by rivers, these soil-derived brGDGTs are buried in the coastal marine sedimentary archive, where they should represent an integrated climate signal of the catchment area. Despite their presumed soil-origin, recent studies indicate that brGDGTs can also be produced in the coastal marine environment, which may alter the initial soil signature. Thus, brGDGTs should only be used as paleothermometer at sites where a substantial terrestrial input is expected.

Here, we aim to produce continental air temperature records for the Pliocene using brGDGTs in continental margin and continental shelf sediments. We target three sites that are all located relatively close to the mouth of a major river that was active during the Pliocene: ocean drilling program (ODP) Site 925 on the Ceará Rise (Amazon outflow), ODP Site 625 in the Gulf of Mexico (GoM, Mississippi outflow), and the Hank borehole in the Netherlands (Rhine-Meuse outflow).

Although brGDGTs were present in the GoM sediments, extremely low (0.002-1) branched to isoprenoid tetraether (BIT) index values, a ratio of soil-derived to marine-derived tetraethers, indicates that this site did not receive a substantial amount of terrestrial organic matter in the Pliocene. This is confirmed by the low amounts of pollen and plant leaf waxes in this core. Moreover, the high (0.5-0.7) weighted average of the number rings in the tetramethylated brGDGTs (#rings_{tetra}; Sinninghe Damsté, 2016) indicates that most of the brGDGTs have a marine origin, which disqualifies this site for continental paleotemperature reconstruction. In contrast, both the high BIT and the low #rings_{tetra} for the Ceará Rise sediments are more promising for brGDGT paleothermometry. However, the trends in



brGDGT-derived temperatures seem inconsistent, particularly the absence of any cooling trend over the Plio-Pleistocene transition. Strikingly, the brGDGTs in the Ceará rise sediments are dominated by 6-methyl isomers, resulting in high values (~0.8) for the isomer ratio (IR), whereas the generally acidic soils in the Amazon catchment mostly contain 5-methyl brGDGTs and are characterised by low IR values. Subsequent comparison of the brGDGT composition in the Ceará rise sediments with that in modern suspended particulate matter (SPM) from the Amazon River demonstrated that the majority of the brGDGTs in the Ceará Rise sediments must have been produced in situ in the river itself. Thus, the Ceará Rise site is also deemed unsuitable for brGDGT paleothermometry.

Finally, the brGDGTs in the Hank borehole seem more promising for paleotemperature reconstruction. Using the #rings_{tetra} index, a mixing model, and a newly developed coastal marine transfer function, we could correct the brGDGT record for a marine overprint. This resulted in the first reliable terrestrial MAT record for Pliocene North Western Europe (Dearing Crampton-Flood et al., 2018). To further increase the value of this record for climate modelling, we constructed a high-resolution age model for the Pliocene North Sea basin. This is challenging as coastal settings represent dynamic sedimentary systems with potential lowstand hiatuses, varying freshwater input, and re-transportation, that hampers the straightforward age model construction technique using the stable oxygen isotope (δ^{18} O) signature of benthic foraminifera for tuning to a global δ^{18} O reference curve (eg. Lisiecki and Raymo, 2005). We circumvent these issues by an integrated seismo-stratigraphic approach in which we use δ^{18} O of endobenthic foraminifera that are less sensitive to freshwater input and re-transportation, resulting in detailed age model for the period *ca.* 3.2-2.8 Ma. This allows us to place our brGDGT-based temperature record within the mPWP. A marine and terrestrial palynological dataset for the same borehole supports the trends of the MAT record.

Hence, we present the first continuous, well-dated temperature record for continental NW Europe during the Pliocene. Our final record shows that terrestrial temperatures during the mPWP were relatively stable and ranged from 10-12 °C. This is 1-3 °C warmer than the present MAT of the Netherlands. The outcomes of this study also stress the importance of understanding sources of brGDGTs in sedimentary archives prior to applying the brGDGT paleothermometer.

References

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