Reconstructing Late Pleistocene Air Temperature Variability based on Branched GDGTs in the Sedimentary Record of Llangorse Lake (Wales)

David J. Maas[1,2,*], Wim Z. Hoek[2], Francien Peterse[1], Keechy Akkerman[1], John J. Lowe[3], Alison MacLeod[3], Ian Matthews[3], Adrian Palmer[3], Jaap S. Sinninghe-Damsté[1,4] and Mike J.C. Walker[5]

1) Department of Earth Sciences, Utrecht University, The Netherlands 2) Department of Physical Geography, Utrecht University, The Netherlands 3) Centre for Quaternary Research, Department of Geography, Royal Holloway, University of London, UK
4) NIOZ Royal Netherlands Institute for Sea Research, Department of Marine Organic Biogeochemistry, The Netherlands
5) Department of Archaeology, University of Wales, Wales, UK *) Corresponding author : d.j.maas@students.uu.nl

Universiteit Utrecht

Location Llangorse Lake in Wales
(2015 data SIO, NOAA, U.S. Navy, NGA, GEBCO, Landsat, IBCAO)

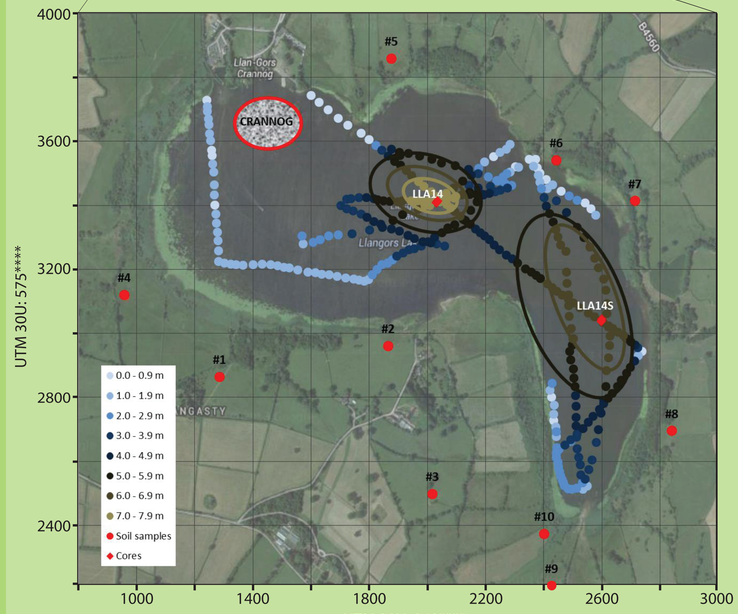

Figure 1: Bathymetry measurements, soil sample - and sediment core locations: collected between Aug 26 - Sept 9, 2014 Crannog cored by Palmer et al. 2008

Introduction

Llangorse Lake is situated in a glacial depression at the boundary of the River Wye catchment, in the Afon Llynfi valley and lies at 153 m+OD. The (banded) organic silts of sedimentary unit 3 (see figs. 2 and 3) are thought to represent Lateglacial Interstadial sediments (Jones et al., 1985 and the coring at the Crannog by Palmer et al., 2008). Branched Glycerol Dialkyl Glycerol Tetraethers (brGDGTs) are bacterial membrane-spanning lipids which can be used to reconstruct mean (annual) air temperature (MAT). Lacustrine brGDGT temperature reconstructions are often affected by production of lipids ***in situ*** in the water column, resulting in a "cold bias" (e.g. Tyler et al., 2010).

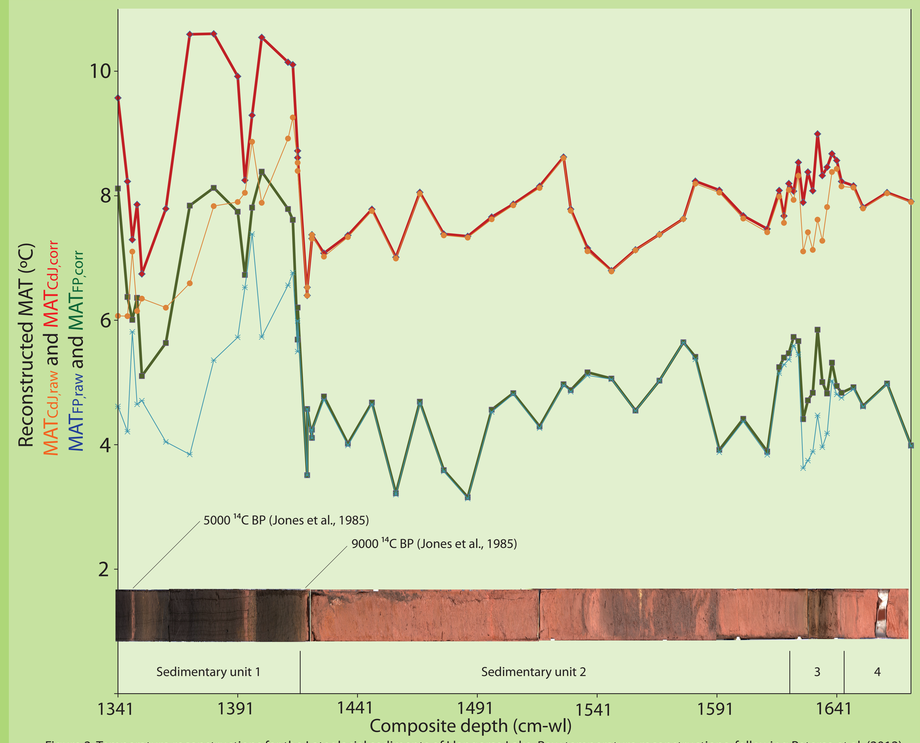

Figure 2: Temperature reconstructions for the Lateglacial sediments of Llangorse Lake. Raw temperature reconstructions, following Peterse et al. (2012) and de Jonge et al. (2014) and corrected temperature reconstructions using a linear end member mixing model to account for in situ production

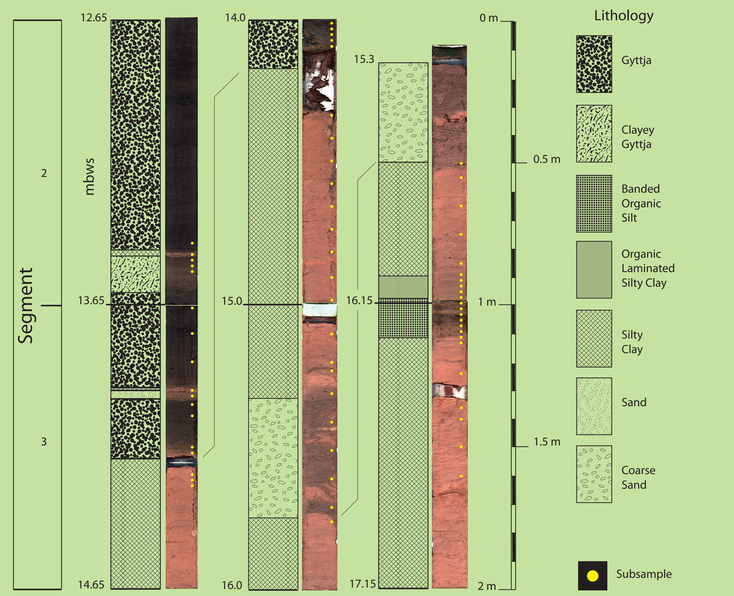

Figure 3: Core segments and lithology from overlapping cores from the southern basin of Llangorse Lake

$$MAT_{FP12} = 0.81 - 5.67 * CBT + 31.0 * MBT' \quad (n = 176, r^2 = 0.59; RMSE = 5.0℃)$$

$$MAT_{CdJ14} = 7.17 + 17.1 * [Ia] + 25.9 * [Ib] + 34.4 * [Ic] - 28.6 * [IIa] \quad (n = 222, r^2 = 0.68; RMSE = 4.6℃)$$

(Peterse et al., 2012 and de Jonge et al. 2014, respectively)

$$MAT_{SSS} = \gamma MAT_{SPM} + (1-\gamma) MAT_{CSS} \quad \text{with} \quad MAT_{SPM} = MAT_{CSS} - \delta \quad \text{and}$$

$$MAT_{SSS} = MAT_{CSS} - (\gamma\delta) \quad \text{yields} \quad \boldsymbol{MAT_{corr}} = MAT_{SSS} + (\gamma\delta) \quad \text{with} \quad \delta = 4℃$$

$$\gamma = \frac{\sum [brGDGT]_{sample}}{\sum [brGDGT]_{max}} = \frac{[Ia]_{sample} + [Ib]_{sample} + [Ic]_{sample} + [IIa]_{sample}}{[Ia]_{max} + [Ib]_{max} + [Ic]_{max} + [IIa]_{max}}$$

Linear end member model defining the relative contribution of catchment soil brGDGT (CSS) and in situ produced brGDGTs (SPM) contribution to the surface sediment brGDGT accumulation (SSS).

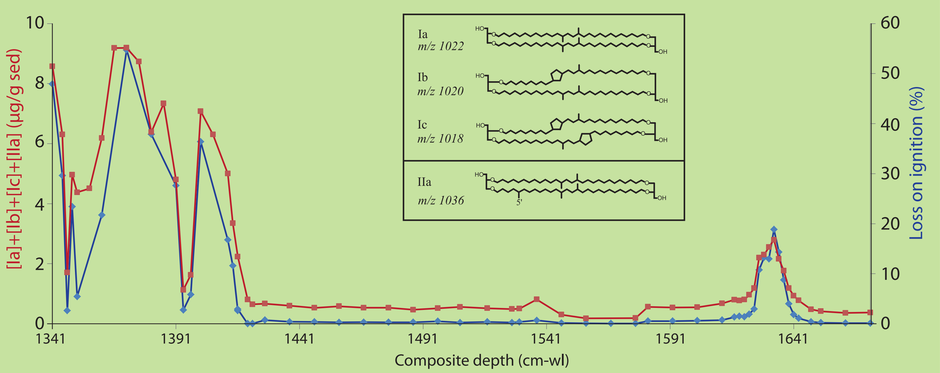

Figure 4: Comparison between the summed concentration of the lipid compounds used in determining the in situ production and loss on ignition analysis (main figure). Branched Glycerol Dialkyl Glycerol Tetraether (brGDGT) membrane molecules represented in γ and used in MATCdJ (figure inset: modified after de Jonge et al., 2014)

Methods

Subsamples from the composite core of the southern basin of Llangorse Lake are analyzed using Liquid Chromatography and Mass Spectrometry (LC-MS). Mean annual air temperatures (MAT) can be calculated from the ratio between different membrane lipids (see above and fig. 2, also: de Jonge et al., 2014).

A simple end member mixing model is defined to account for the variation in in situ production of brGDGTs. The offset derived from in situ produced lipids is converted via surface sediment calibration with meteorological data (δ=4°C). The amount of in situ production is quantified using the lipid concentration in the subsamples (see fig. 4)

Results

The reconstructed MAT is corrected for in situ production to remove potential "cold bias" in the individual samples (see fig. 2). This is especially apparent in sedimentary unit 1, as is expected from the generally higher LOI values derived from higher organic matter content (see fig. 4). A reconstructed temperature difference of ~5 °C at the Lateglacial - Interglacial Transition is in accordance with that found in other records using different methods (e.g. Whitrig bog, Chironomids: Brooks and Birks, 2000).

The two phases of cooling in the gyttja deposits coincide with an increased amount of clastic sediment input (see figs 3 and 4). The reconstructed temperatures are in these phases mainly based on catchment soil brGDGT input, which supports the idea that these are in fact periods of locally cooler conditions.

Conclusion

Branched GDGTs can be used as an additional proxy for use in paleoclimate reconstructions from lacustrine sediments. There is need to quantify the relative contribution of catchment soil - and in situ end members to the sediment. Lake specific calibrations must me made, using local meteorological data and sediment surface samples to account for the local offset (the δ parameter in the end member mixing model).

References: Brooks and Birks (2000) JQS, **15**, 759 - 764 | Jones et al. (1985) E. Sur. Proc. Landf., **10**, 227 - 235 | de Jonge et al. (2014) GCA, **141**, 97 - 112 | Louchouarn et al. (1999) Org. Geochem., **30**, 675 - 699 | Peterse et al. (2012) GCA, **96**, 215 - 229 | Tyler et al. (2010) JQR, **115**, 1 - 11

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Uwitec coring raft used during fieldwork