Universität Basel

Research Project

Validation and application of a novel, terrestrial biomarker-based paleo thermometer to Holocene Swiss lake sediments and soils

Third-party funded project

Project title Validation and application of a novel, terrestrial biomarker-based paleo thermometer to Holocene Swiss lake sediments and soils
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Of paramount importance for our comprehension and simulation of recent and future climate change is the precognition of climate variations in Earth's history, yet instrumental and reliable historical data are only available for the last few centuries. For times scales beyond this very recent past, climate variations can be reconstructed with the aid of proxy-indicators in climate archives such as ice sheets, spelotherms, as well as aquatic sediments. Albeit the importance of the terrestrial realm in the global climate, paleoclimatological research traditionally focused on marine sediments. Typically, these span very long time periods, but they are rarely suitable to resolve sub-millennial time scales. Where they exist, the continental temperature (T) reconstructions are often limited to relative T fluctuations. A promising approach to go beyond the qualitative assessment of T variability in the past is to use aă temperature-proxy, which is based on the analysis of (presumably) soil-bacterial lipids preserved in sedimentary archives, and which allows for absolute T reconstructions. This paleothermometer relies on the relative abundance of methyl-branched and cyclic dialkyl glycerol tetraethers (GDGTs) (i.e., MBT/CBT-indices), which changes linearily with the mean annual air temperature (MAAT) (Weijers et al. 2007a). In addition to information on MAAT, MBT/CBT-measurements allow for the reliable assessment of soil-pH, which can be a qualitative indicator of climate wetness.

Similar to marine sediments, lake sediments are important geological archives, which may span time intervals from thousand to hundred thousands of years, and, hence, have a high potential for portraying long-term terrestrial climate variations. While MBT/CBT-ratios were successfully used to reconstruct mean annual air temperature (MAAT) from soils, the applicability of this paleothermometer to lacustrine sediments needs substantial testing. To date, for example, most of the existing MBT/CBT-measurements from modern lake sediments seem to consistently underestimate observational T-data, yet the mechanisms behind the observed discrepancies remain unresolved. It has been suggested that in situ production of the relevant bacterial GDGTs (within the lake's water column or after burial in sediments) and/or diagenetic effects are likely to alter soil-derived GDGT-patterns in lake sediments. However, in a pilot study to this proposal (Niemann et al., 2011), we could show that specific environmental conditions (e.g., as encountered in the euxinic Lake Cadagno, Switzerland) may be particularly conducive to the preservation of original bacterial GDGT signatures, so that the MBT/CBT paleothermometer can precisely resolve subtle temperature changes of <1 řC.

Here, we propose to test and calibrate the MBT/CBT-paleothermometer in lacustrine settings, with the particular goal to elucidate the processes that may perturb the direct reflection of primary soil signa-

tures within the lake's sedimentary archive. We plan i) to conduct GDGT measurements in catchment soils, sediment trap material, surface sediments and sediment cores from various Swiss lakes ii) to set up incubation experiments with soil and sediment samples under controlled laboratory conditions to study mechanisms of secondary GDGT alteration, and iii) to apply the calibrated MBT/CBT thermometer to the Holocene sediments from central Switzerland. In the first stage of the project, we will compare GDGT-patterns in recent lake sediments with those in soils from the respective lake catchments. MBT/CBT -based T and pH estimates will be compared to instrumental data, which will permit us to determine the sensitivity and accuracy of the lacustrine MBT/CBT-paleothermometer under the given sedimentation/preservation conditions. The GDGT analysis of the sinking flux collected in sediment traps - representing the transient stage between soil organic matter genesis and burial in the lake basin - will allow further insight into the potential role of in situ production and secondary alteration of MBT/CBT-signatures. In the second part of the project, bacterial GDGTs will be studied in experimental setups where soils and sediments are exposed to different regimes of oxia and temperature. Here, we also plan to measure the relevant GDGTs not only as core-lipids but also as intact polar lipids (IPLs), which will allow us to discern dead (fossil) and viable sources of the target lipids. Results from the calibration study will finally provide the basis for GDGT measurements in a long sediment core from Lake Soppensee. The Holocene and Late Glacial record of T-variations from Lake Soppensee will be compared to other proxy-based T-records (e.g., from Lake Cadagno), and will allow constraints on the effect of large-scale climate perturbations on geographically adjacent regions, which are separated by a meteorological divide (i.e. the Alps).

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