A Holocene temperature, hydrology and ENSO reconstruction from Sumatra using GDGTs, δD_{wax} and XRF



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Introduction

The Indo-Pacific Warm Pool (IPWP) region has a large influence on the Asian-Australian monsoon systems and the El Niño Southern Oscillation (ENSO), the most important driver of global interannual climate variability. However, the region's past changes in temperature, hydrology and ENSO variability are poorly constrained, in particular in terms of terrestrial records.

We reconstruct past hydroclimate using two Holocene peat cores from Sumatra, focusing on hydrology, temperature and ENSO variability.

Main findings

Gradual warming over the Holocene in this low-seasonality setting, offering a new piece of the puzzle to the 'Holocene temperature conundrum'

Rapid drying and intense erosion due to ENSO during the late Holocene following stable and wet conditions during the mid-Holocene

Methods

Leaf wax hydrogen isotopes (δD_{wax}) and **n-alkane distributions** were used to reconstruct precipitation and vegetation.

Microbial membrane lipids, **Glycerol Dialkyl Glycerol Tetraethers** (**GDGTs**), were used to reconstruct temperature and hydrological conditions.

Geochemical composition using **XRF** core scanning were used to infer changes in lithogenic input.

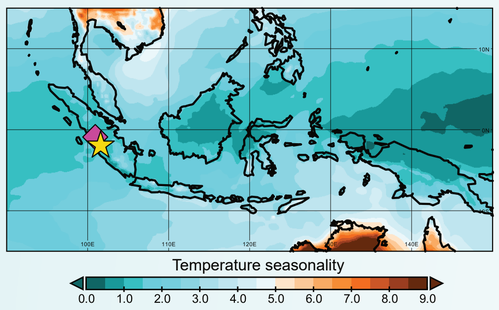


Figure 1. Study area. The diamond and star indicate Site 1 and 2.

ENSO reconstruction

The geochemical analysis shows increased abundance of elements associated with coarse lithogenic minerals (Ti, Al, Zr) during the late Holocene. This is interpreted as intensified erosion during drying, which is indicated by δD_{wax} and the hydrological proxies. The increased erosion is likely a result of the reintensification of ENSO variability in the late Holocene[3].

The mechanistic explanation for erosion during ENSO intensification is that increased droughts (during El Niño events) affected the vegetation and reduced soil stabilization. The soils were then eroded and transported into the peatland during La Niña flooding events.

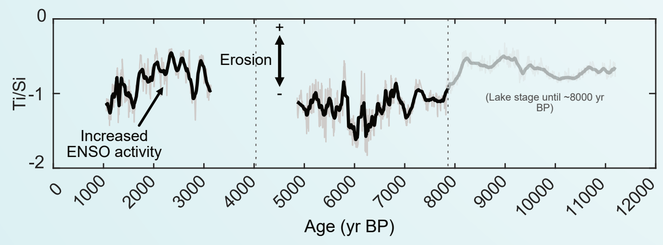


Figure 2. Erosion strenght for the past ~8000 years on Sumatra inferred from the log ratio of Ti/Si from Site 1, indicating grain size.

Hydrology proxies

Our hydrological proxies reflect both large spatial scale convection (δD_{wax}) and local peat conditions (*n*-alkanes and GDGTs). The proxies all suggest a humid mid-Holocene, in agreement with a nearby speleothem record[9], but also show much stronger and faster drying during the late Holocene.

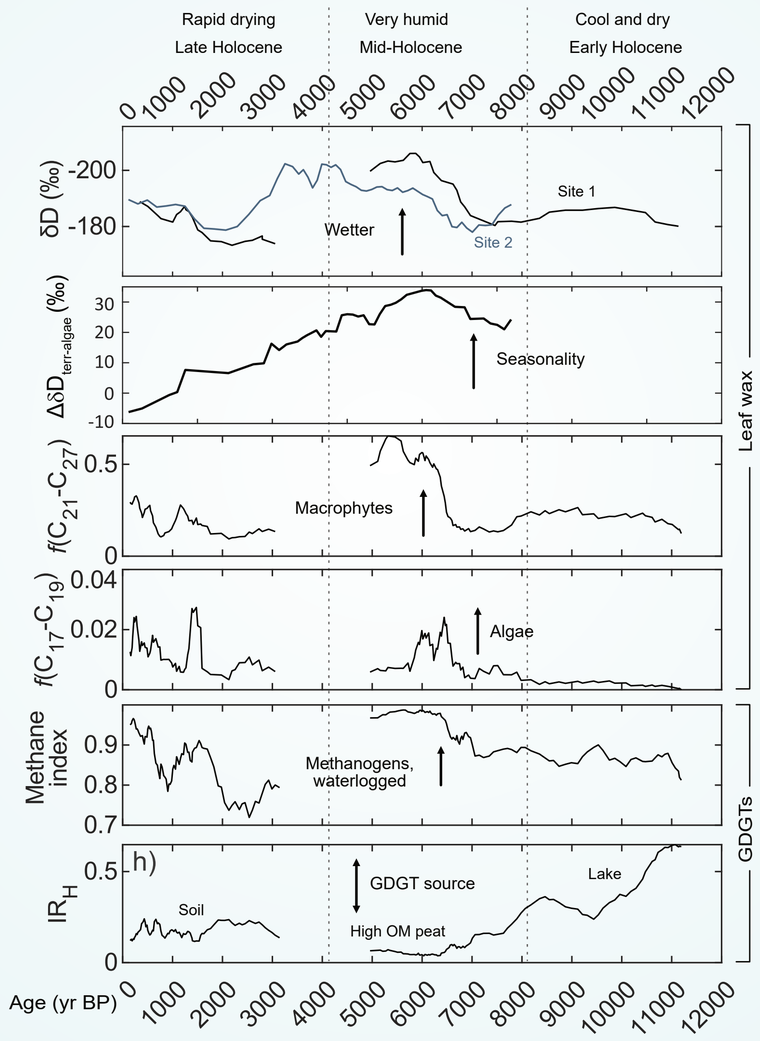


Figure 3. Reconstructed hydrology using GDGTs, δD_{wax} and leaf wax n-alkane distributions (see calculations below).

Temparature reconstruction

Our brGDGT temperature reconstruction shows **gradual warming over the past 8 000 years** (black in Fig. 3). This is in agreement with climate model simulations and nearby SST reconstructions off West Sumatra, but at odds with Eastern IPWP SST reconstructions and global proxy compilations.

This disparity between models and proxies is termed the 'Holocene Temperature conundrum'[1]. A possible explanation for why our reconstruction agrees with models unlike most other reconstructions is that Sumatra experiences among the world's lowest climate seasonality (~1 °C over the year), which removes a bias which may affect other records[2].

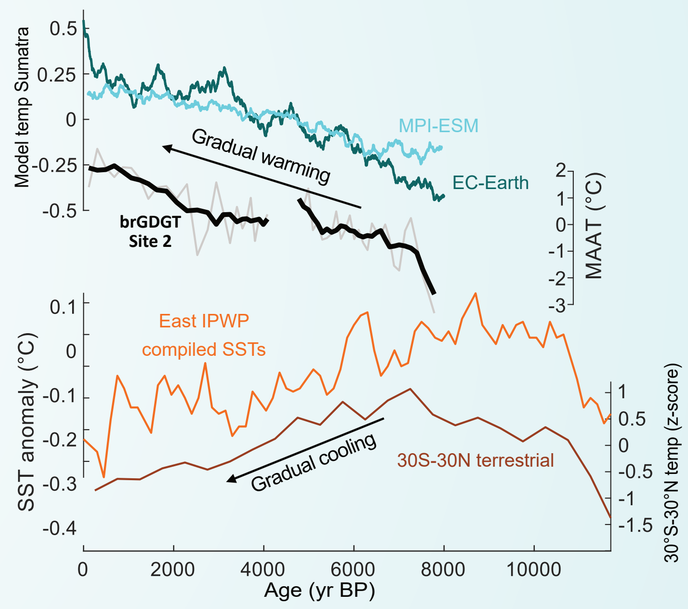


Figure 4. Temperature reconstruction from our brGDGT data, transient climate models simulations (MPI-ESM[7] and EC-Earth[8]), East IPWP SST compilation[5], and low latitude temperature compilation[6].

Figure 5. Site 1 topographic profile and core location in the landscape.

Calculations

n-alkane distribtions:

$f(C_{21}\text{-}C_{27})$: $C_{21}+C_{23}+C_{25}+C_{27}/\Sigma$odd alkanes $C_{17}\text{-}C_{33}$

$f(C_{17}\text{-}C_{19})$: $C_{17}+C_{19}/\Sigma$odd alkanes $C_{17}\text{-}C_{33}$

GDGT indexes:

Methane index (GDGT I+II+III)/(GDGT I+II+III+cren+cren_isomer)

IR_H based on H-shaped brGDGTs:
H1020a+H1020b+H1034a+H1034b/
H1020a+H1020b+H1020c H1034a+H1034b+H1034c

brGDGT mean annual air temperature is derived from BayMBT0[4]

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