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Spatial evolution of warming across the Chinese Loess Plateau over the last deglaciation

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Background

The Chinese Loess Plateau (CLP) is one of the best continuous paleoclimate archives on land, and its sediments host a long record of East Asian Monsoon (EAM) climate variability. Some studies suggest that the onset of atmospheric warming over the last deglaciation leads the gradual northwestward migration of the East Asian Summer Monsoon (EASM). However, spatial variations in the length of the offset and amplitude of warming is limited by the lack of quantitative temperature records.

Here, we generate quantitative temperature records over the past 40 kyr based on soil bacterial membrane lipids stored in seven loess-paleosol profiles along a Northwest (NW) to Southeast (SE) transect across the CLP.

Temperature *vs.* MagSus

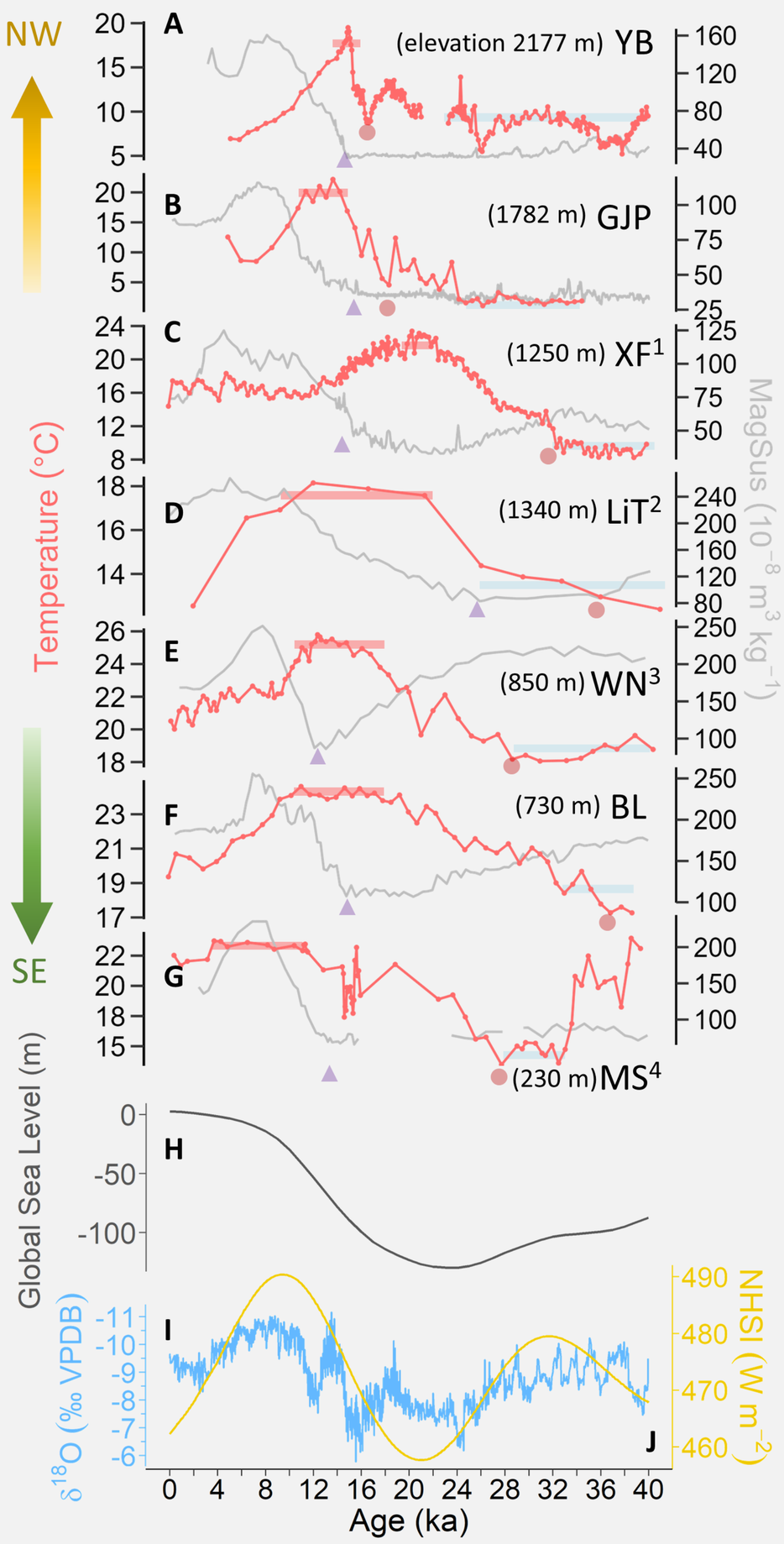


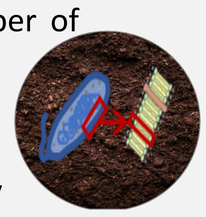
Fig. 1 (A-G) BrGDGT-based temperature (red line) and magnetic susceptibility (MagSus, gray line) at sections from Northwest to Southeast (top to bottom) across the CLP[1-4], red circles and purple triangles indicate the onset of warming and MagSus, respectively. All records are based on the original age model. **(H)** Global sea level[6]. **(I)** $\delta^{18}O$ of stacked speleothem records from Hulu/Sanbao/ Dongge caves[7]. **(J)** North Hemisphere Summer Insolation (NHSI, JJA, 35°N).

Method

Biomarkers: Branched glycerol dialkyl glycerol tetraethers (**brGDGTs**) are membrane lipids synthesized by heterotrophic soil bacteria. The molecular structure of these lipids responds to temperature, where brGDGTs contain an increasing number of methylations with decreasing temperature[5].

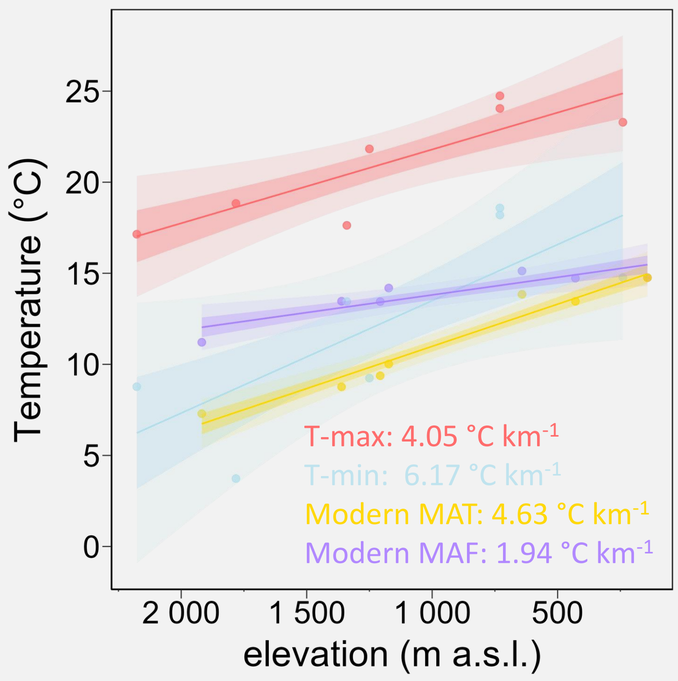
Loess *vs.* paleosol

Magnetic susceptibility (MagSus): MagSus is generally high in paleosol layers affected by the soil pedogenesis representing warm and wet climate and is regarded as an indirect indicator of EASM strength.



brGDGTs

Elevation dependent warming?



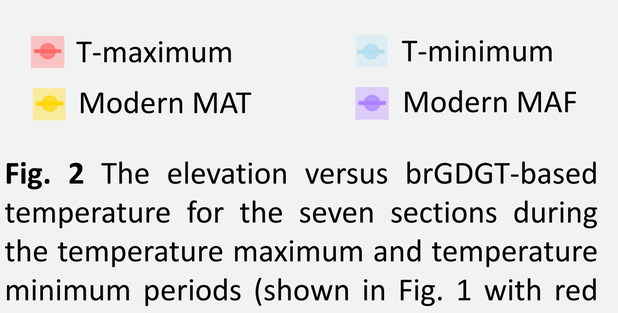


Fig. 2 The elevation versus brGDGT-based temperature for the seven sections during the temperature maximum and temperature minimum periods (shown in Fig. 1 with red and blue bars in section panels, respectively). The modern mean annual temperature (MAT) and mean air temperature for months above freezing (MAF) are plotted for reference. The linear regression line with 68% CI and 95% CI is shown with shading.

EASM intensity?

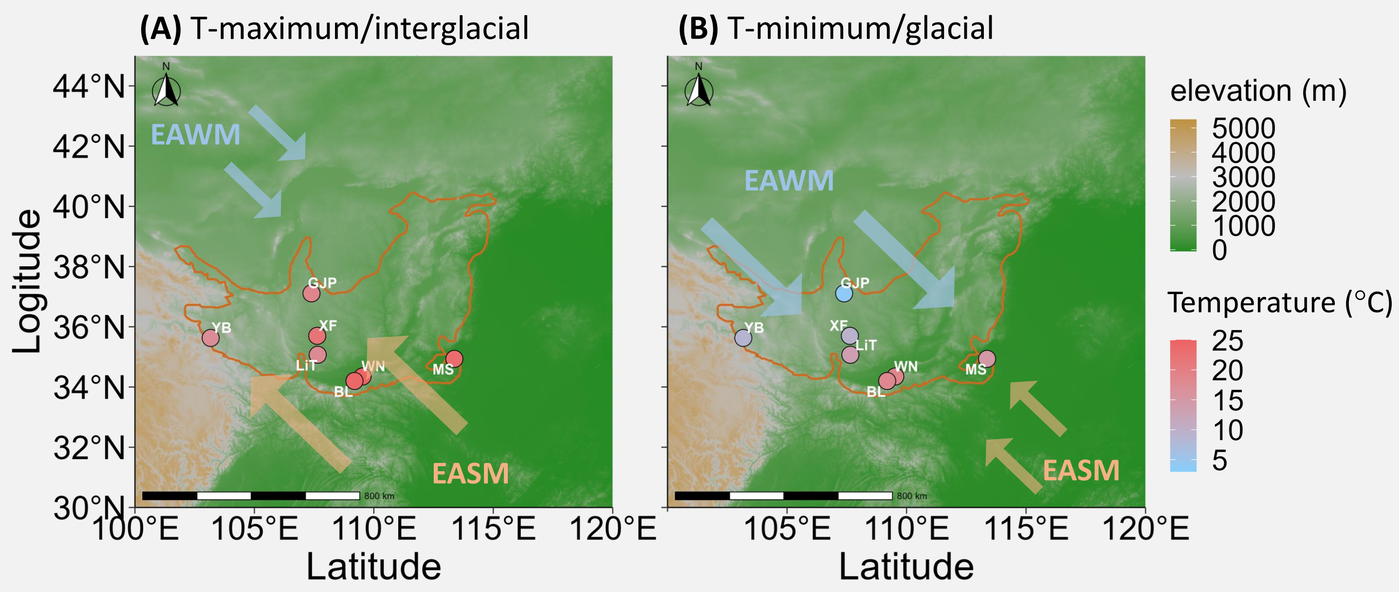


Fig. 3 Spatial difference in brGDGT-based temperature during **(A)** the temperature maximum period and **(B)** the temperature minimum period. The orange and blue arrows indicate East Asian Summer Monsoon (EASM) and East Asian Winter Monsoon (EAWM), respectively.

Key points

- The **absolute temperature** decreases from the SE to NW of the CLP (Fig. 1), that follows the adiabatic cooling trend with increasing elevation (Fig. 3B).
- The **amplitude of deglacial warming** increases from ~5 °C in the SE to ~15 °C in the NW CLP (Fig. 1). This indicates that high elevation sites are sensitive to temperature change.
- The **onset of deglacial warming** (●) in the NW lags that in the SE by up to 15 ka (Fig. 1). This is likely due to the gradual waning of Northern Hemisphere ice sheets that blocks the penetration of the EASM to the NW CLP (Fig. 1H). The **increase of MagSus** (▲) **consistently lags that of atmospheric warming** across the CLP (Fig. 1).
- The change in slope between minimum and maximum temperatures suggests that **warming will be amplified in high elevation areas**, including the Tibetan Plateau, the Earth's third Pole.

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