Soil Temperature Calibration and Paleoaltimetry of the Tibetan Plateau

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Motivation

How and when did the Tibetan Plateau become so high and flat?

- Has the mean elevation of some parts of the Plateau subsided, perhaps 1000 m, since ~15-10 Ma?
- Are there regions of Tibet, like the Lhunpola and Nyima basins, that rose abruptly 1000-2000 m near 15 Ma?

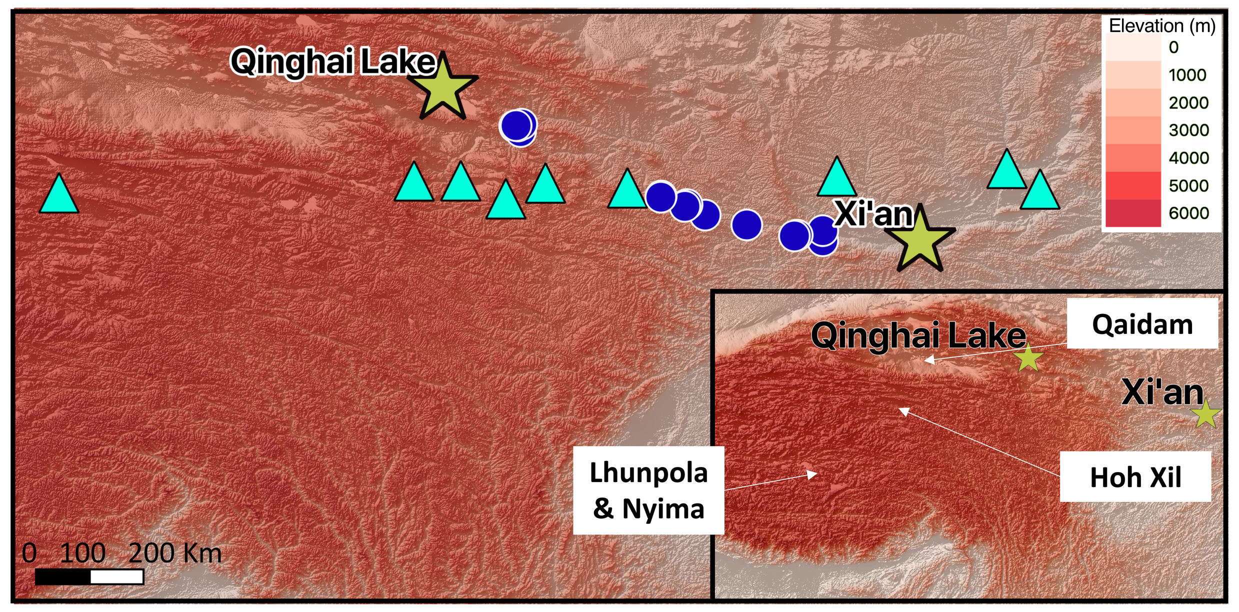


Figure 1. Map of the region between NE Tibet and Xi'an showing locations of temperature loggers deployed in 2019 (dark blue circles) and climate stations of the Chinese meteorological station network (light blue triangles). Lower right figure shows the Tibetan Plateau and the location of four basins.

Field work

- We measured air and soil temperatures from an altitudinal transect (from ~400 m to ~4000 m) on the northeastern margin of the Tibetan Plateau (Fig. 1).
- These measurements were taken from July 2019 to July of 2020 in soils at 10 cm and 50 cm below the surface and at ~1.5 m in the air at 18 sites (Fig. 4).
- We sampled soil from 10 cm and 50 cm depth at the same sites where we measured temperatures, and we analyzed brGDGTs in these soils.

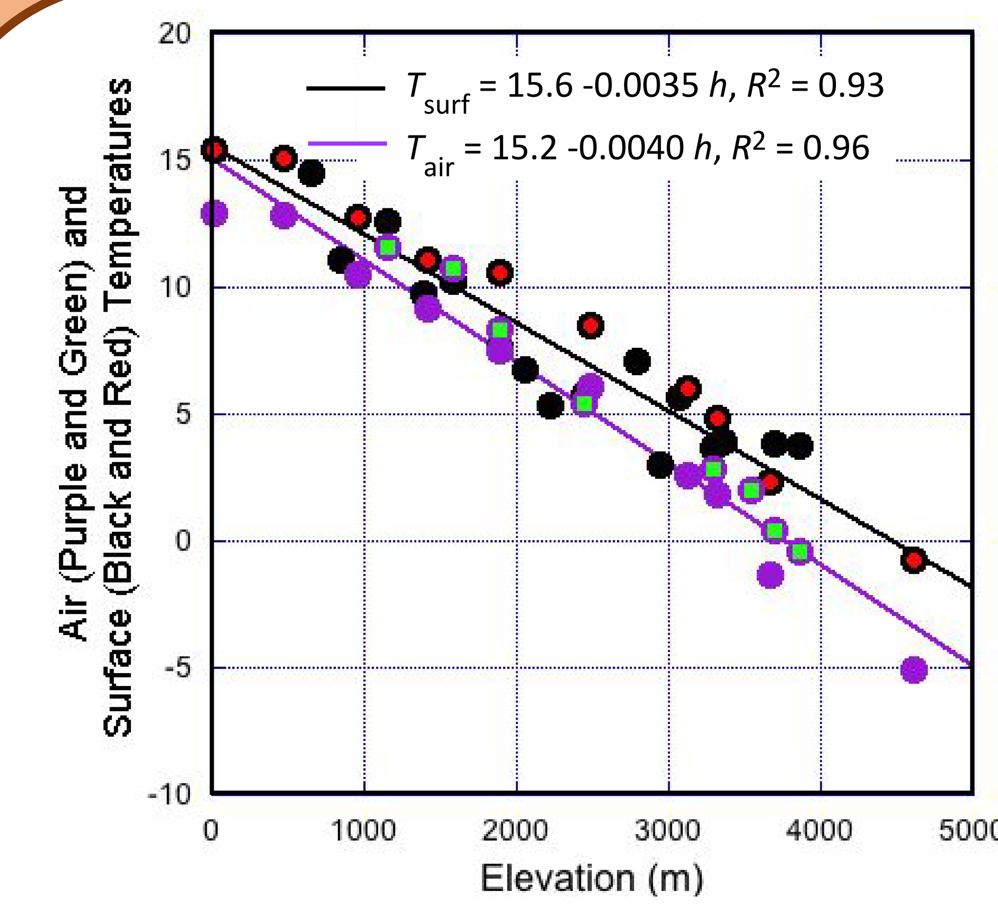


Figure 4. Mean annual soil (black and red) and surface air (purple and green) temperatures versus elevation from sites in Figure 1. Purple and red are from the Chinese Meteorological network, and red and green are from sties that we installed.

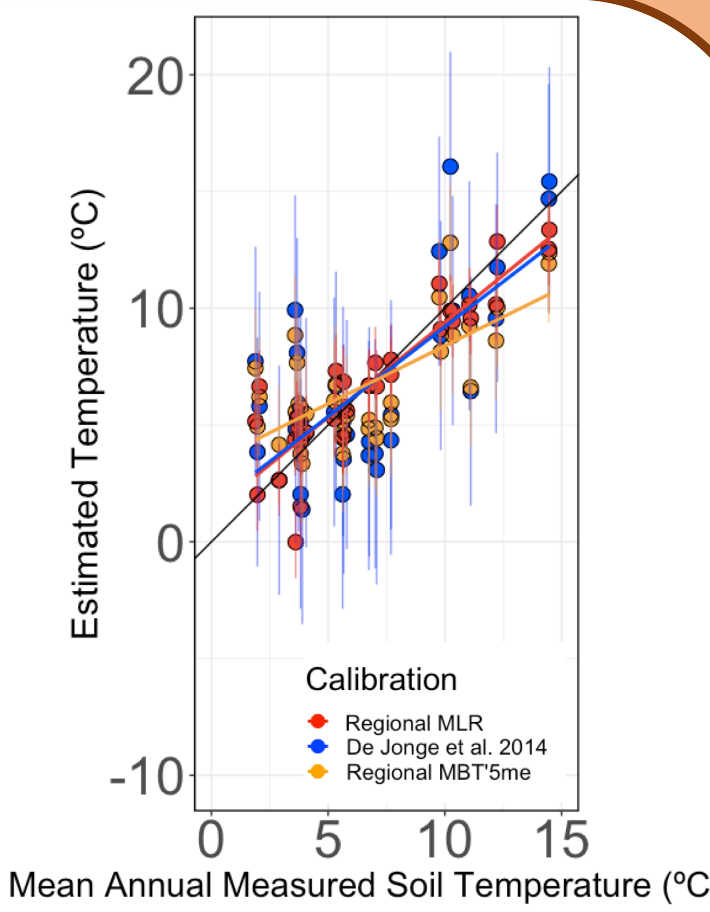
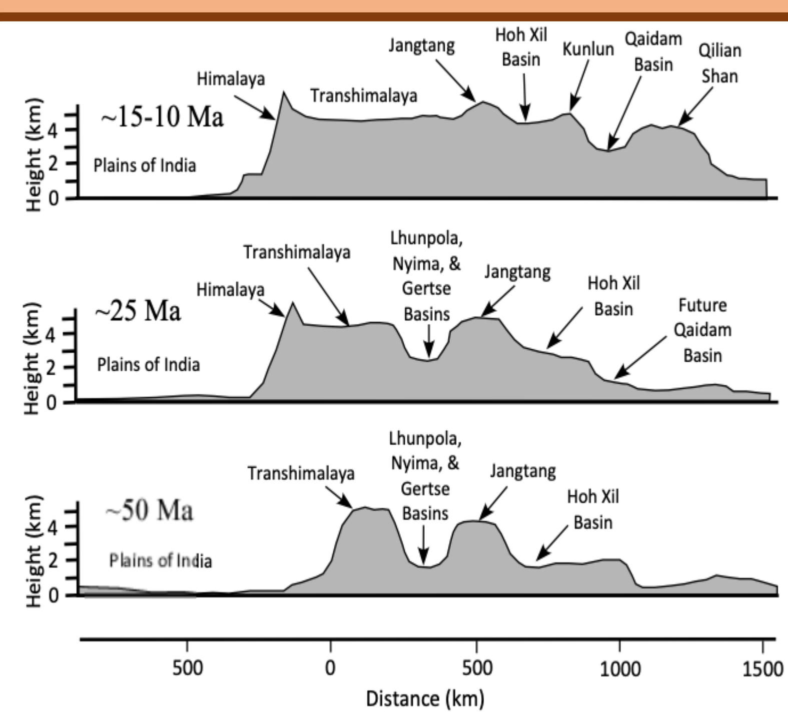


Figure 5. Calibrations of mean annual soil temperature applied to our brGDGT soil dataset: (red) our regional calibration and (orange) our fit of the MBT'5me index, and those using (blue) De Jong et al. (2014).

Objective



We seek to determine past surface-air temperatures from the Tibetan Plateau to constrain its surface-elevation history.

Figure 2. Hypothesized topographic profiles across Tibet, modified from Spicer (2017).

Results

- Our temperatures combined with surface and air temperatures from Chinese meteorological stations in the same latitude band show dTs/dz = –4.0°C/km, where Ts = soil temperature and z = elevation, and dTa/dz = –3.5°C/km, where Ta = air temperature (Fig. 4).
- We obtained a regional calibration with RMSE = 1.5°C based on the abundances of Ia, IIa, and IIc brGDGTs (Fig. 5).
- Application of different calibrations to samples obtained by our Chinese colleagues from the Miocene Yaxicuo Formation suggest paleotemperatures from ~5°C to 12 °C using our Regional Soil MLR calibration for fluvio-lacustrine and fluvial sediment and Martínez-Sosa et a. 2020 for lacustrine sediment (Fig. 6).

brGDGTs background

- Bacterial lipid biomarkers known as branched Glycerol Dialkyl Glycerol Tetraethers (brGDGTs) are cell membrane lipids produced by unknown bacteria in ubiquitous environments.
- Empirical correlation with modern temperature, allow estimates of past temperatures of these lipid biomarkers preserved in sedimentary archives.
- Global calibrations have root-mean-squared errors (RMSE) of ~4°C.
- For paleoaltimetry, the method is still in development, because of uncertainties both in inferred temperatures and in the conversion of temperature to elevation.

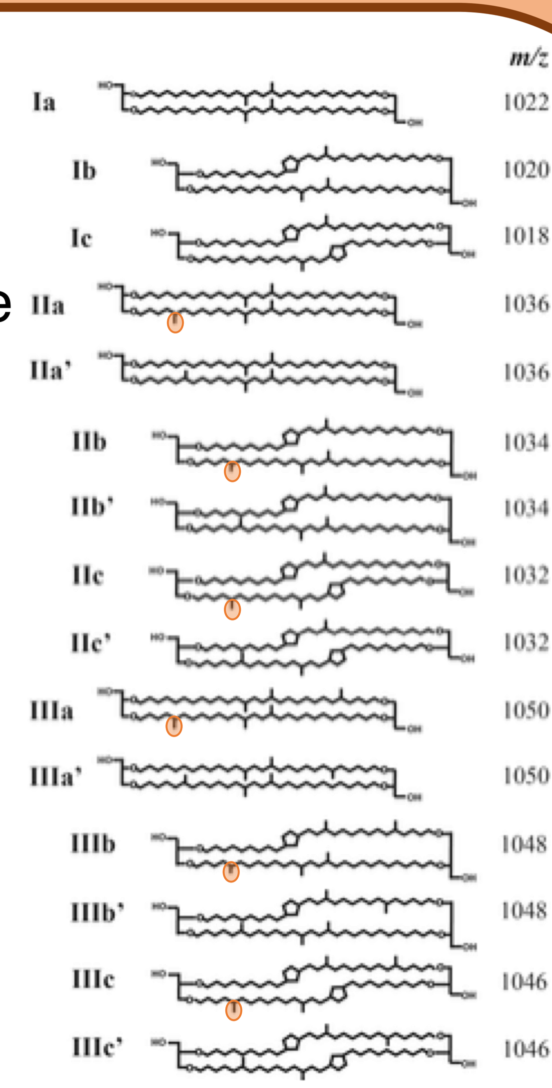


Figure 3. Chemical structures of brGDGTs. Numbers I, II, and III denote brGDGTs with 4, 5, and 6 methyl branches and/or cyclopentyl moieties, and letters correspond to different numbers of cyclopentyl moieties: 'a' – 0, 'b' – 1, and 'c' – 2; m/z means mass to charge ratio. Prime symbols indicate C6-methylation, and C5-methylations are highlighted in orange. Figure modified from Hanna et al. (2016).

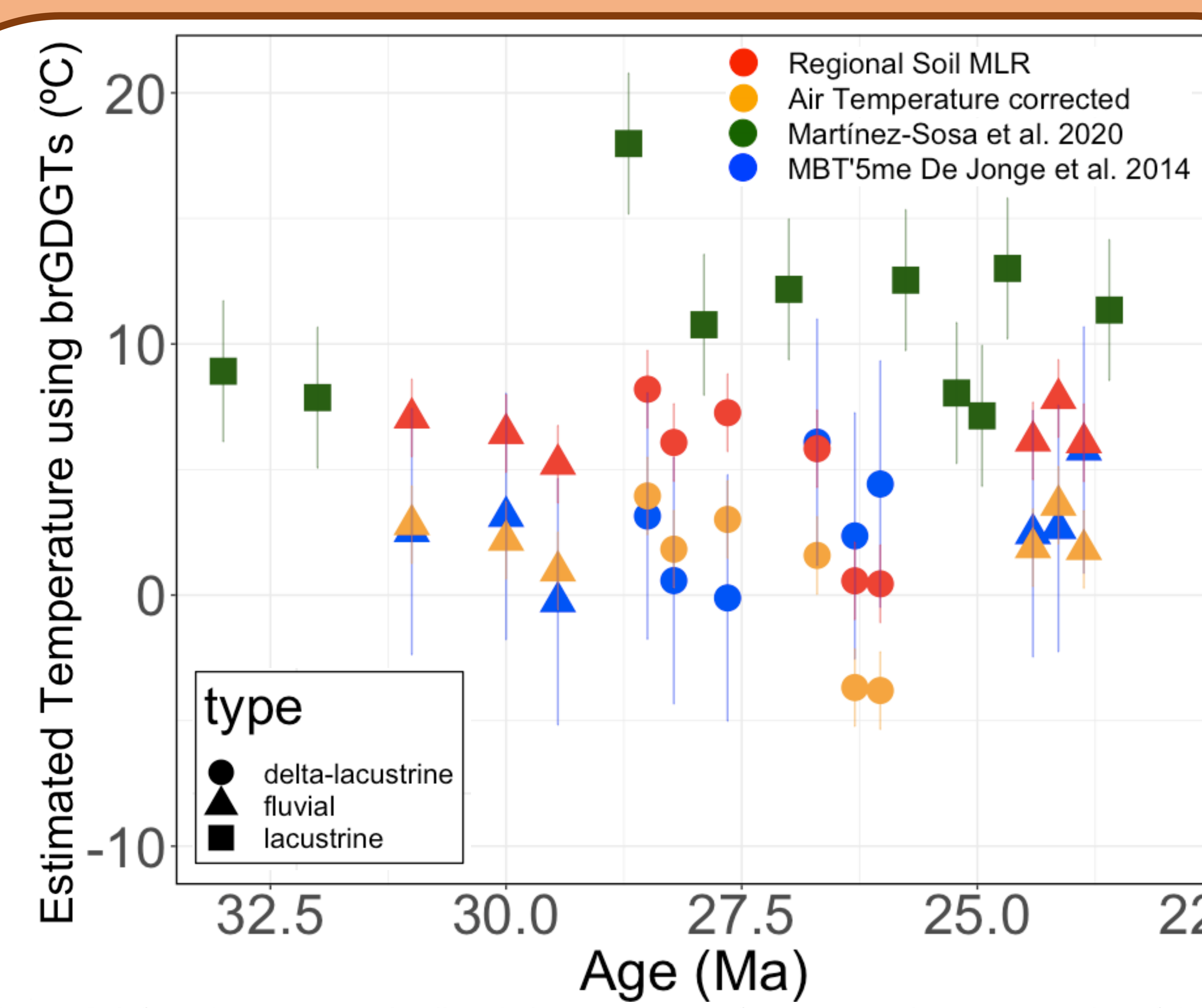


Figure 6. Inferred mean annual soil and air temperatures from reconnaissance samples of the Yaxicuo Group using different calibrations.

Conclusions

- With our new calibration and refinements of it, we should be able to estimate paleotemperatures from Tibet with uncertainties of < 2°C.
- With a decrease at 4°C/km and an estimate of sea level temperature in past time, likely uncertain by < 3°C, we should be able to estimate paleo-elevations with uncertainties no greater than ~1 km, and this should allow determination of when different parts of Tibet rose to current elevations of 4.5-5 km.