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A Novel 3-OH-FA-based Temperature Calibration in Southeast Asia

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Reconstructing past climate variability is critical for understanding long-term environmental change, particularly in monsoon-dominated regions like Southeast Asia. Organic geochemical proxies, including 3-hydroxy fatty acids (3-OH-FAs) and glycerol dialkyl glycerol tetraethers (GDGTs), provide insights into past temperature and pH conditions. Across a continental scale transect, incorporating 48 lakes and 30 soils, we find robust temperature relationships. In lake sediments, RAN_{13} moderately correlates with mean annual air temperature (MAAT; R^2 = 0.52), supporting its application as a novel palaeotemperature proxy. RIN_{17} insignificantly correlates with MAAT (R^2 = 0.32), in contrast to the previous study in Chinese lakes, limiting its reliability. In addition, RIN_{15} emerges as an additional lake temperature indicator in this region (R^2 = 0.60). In soils, RAN_{17} shows strong correlations with MAAT (R^2 = 0.64), suggesting this proxy captures bacterial lipid adaptation to temperature at broad regional to global scales. Whereas RAN_{15} exhibits a weaker correlation with MAAT (R^2 = 0.20), challenging its applicability in global soil calibrations. Comparisons with GDGT proxies confirm that cyclisation of branched tetraethers (CBT) remains a reliable pH indicator in lake sediments (R^2 = 0.41), while methylation index of 5-methyl branched tetraethers (MBT'_{5ME}) significantly correlates with MAAT in soils (R^2 = 0.34) and lake sediments (R^2 = 0.73). While previous studies demonstrated strong correlations between 3-OH-FA-derived pH proxies (e.g. Branching Ratio, Branched Index, and RIN) and soil pH in China, Europe, and Africa, our study finds no significant correlation in Southeast Asia. This suggests that microbial community composition and hydrological influences may override pH control on 3-OH-FA distributions in this region. These findings highlight key regional differences, where 3-OH-FA-based soil pH proxies fail to capture expected trends, and certain temperature proxies, such as RIN_{17} and RAN_{15}, exhibit weaker performance in Southeast Asia. The results highlight the need for region-specific calibrations and suggest that hydroclimatic influences and microbial ecology may complicate both pH and temperature reconstructions in monsoon-affected environments. This study refines the applicability of 3-OH-FA and GDGT proxies, advancing their use in tropical paleoclimate reconstructions. Our headline result is the continued promise of RAN_{13} as a novel and broadly applicable palaeotemperature for lake sediments.

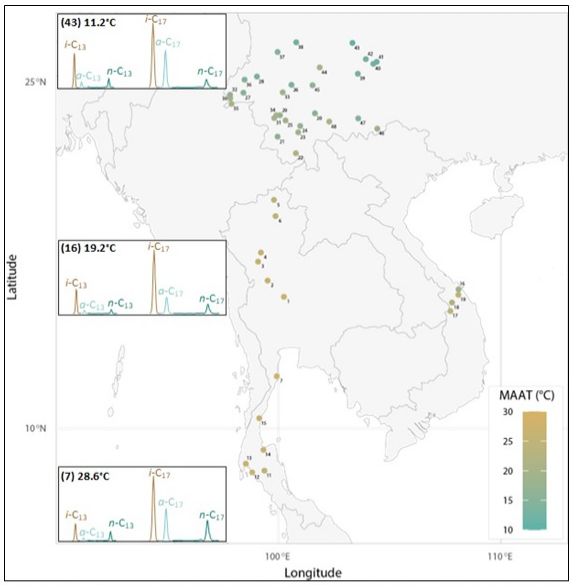

Fig. 1. Locations of the 48 Southeast Asian lakes (30 co-samples of soils) used in this study. The color spectrum of the dots shows the mean annual air temperature (MAAT) of each sampling site. The three inset boxes give examples of the partial distributions of the C_{13} range of study sites, and C_{17} 3-OH-FA homologs from lake sites with the lowest, medium, and highest MAATs (11.2 – 28.6°C).

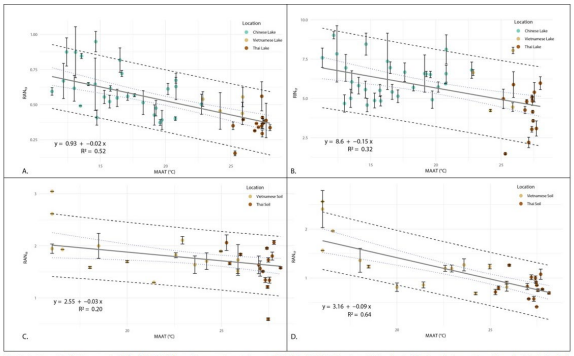

Fig. 2. Scatter plots between established 3-OH-FA-based temperature indices and MAAT with 95% functional (blue dashed line) and observational bounds (black dashed line), representing a 95% probability that: a) a new observation and; b) the true function without observational errors will lie within the respective bounds. (A) RAN_{13}, (B) RIN_{17}, (C) RAN_{15}, and (D) RAN_{17}.