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Interpreting biosignatures from high latitudinal plant fossils: the influence of light regimes on ancient CO_2 reconstruction

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Reconstructing life, climate, and environments in high latitudes plays a critical role in understanding Earth system evolution in the past and holds a key in predicting the dynamic change of future climate. The lush forests dominated by deciduous conifers such as *Metasequoia*, *Taxodium*, and *Larix* once occupied Earth's high latitudes left rich fossil records thus provide important materials for paleoenvironmental reconstruction during Earth's warming periods. Our previous work showed that leaves developed under simulated Arctic lights yielded relatively depleted stable carbon isotope values ($\delta^{13}C$) but more positive stable hydrogen values (δD), the latter of which results in a smaller apparent hydrogen fractionation factor between lipids and environmental water ($\varepsilon_{lipid-water}$).

We performed further quantitative tests on how Artic lights impact on key plant epidermal traits and $\delta^{13}C$ values that contribute to the reconstruction of ancient CO_2 using the Franks model, an increasingly popular leaf-gas exchange approach. We analyzed the whole leaf stomatal density (WL-SD), plant guard cell length (GCL) and width (CGW), as well as $\delta^{13}C$ values from sun and shade leaves sampled from *Metasequoia*, *Taxodium*, and *Larix* growing in greenhouse mimicking the Arctic light conditions. We also tested leaf bulk $\delta^{13}C$ values of genetically homogenous *Metasequoia* leaves grown along a latitudinal gradient spanning 30 degrees in the Northern Hemisphere.

Our results confirmed that the Arctic continuous light affects key Franks model parameters, including WL-SD and $\delta^{13}C$ values, while GCL and GCW show no statistically significant difference, although the degree of influence may vary among different plant taxa. The $\delta^{13}C$ offsets between *Metasequoia* sun and shade leaves systematically increased along with the increase of latitudinal gradient. These influences led to an over estimation of reconstructed CO_2 level using leaves growing under continuous light, suggesting that further work to quantitatively correct the reconstruction is needed. Given that the Franks model relies on the computation of both photosynthetic rate (A) via stomatal geometry and $\delta^{13}C$ values, which impacted by both the intensity and duration of high latitudinal light, reconstructed CO_2 using plant fossils from high latitudes need to take the influence of light conditions into consideration.