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Reconstructing seasonal climate from high-resolution carbon and oxygen isotope measurements across tree rings

Brian A. Schubert[1] and A. Hope Jahren[2]

[1]University of Louisiana at Lafayette, School of Geosciences, Lafayette, LA 70504, USA
[2]University of Hawaii, SOEST, Honolulu, HI 96822, USA

Intra-annual records of carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotope measurements across tree rings reveal significant changes in $\delta^{13}C$ and $\delta^{18}O$ value across each growing season. We previously found that across a broad range of climate regimes, the seasonal change in $\delta^{13}C$ measured within tree rings reflects changes in seasonal precipitation amount, and demonstrated its utility for quantifying seasonal paleo-precipitation from non-permineralized, fossil wood. Here we produce an equation relating intra-ring changes in $\delta^{18}O$ to seasonal changes in temperature and precipitation amount, but the equation yields for unknowns (summer and winter precipitation amounts, and cold and warm month mean temperatures). By combining high-resolution $\delta^{13}C$ and $\delta^{18}O$ records with independent estimates of mean annual temperature and mean annual precipitation, we show how our general, global relationships could be used to quantify seasonal climate information from fossil sites. We validate our approach using high-resolution $\delta^{13}C$ and $\delta^{18}O$ data from trees growing at five modern sites (Hawaii, Alaska, Norway, Guyana, and Kenya). The reconstructed estimates of seasonal precipitation and temperature showed excellent agreement with the known climate data for each site (precipitation: $R^2 = 0.98$; temperature: $R^2 = 0.91$). These results confirm that across diverse sites and tree species, seasonal climate information can be accurately quantified using a combination of carbon and oxygen intra-ring isotope profiles.