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Development and application of a paleoclimate proxy for spring temperatures in central North America: did low temperatures limit tree physiological function during the Younger-Dryas?

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Paleoclimate proxies based on wood anatomical measurements have rarely been developed across the temperature range of a species or applied to wood that pre-dates the most recent millennium. From wood anatomical measurements we here describe a novel set of proxies for spring temperature for central North America and present temperature estimates across a critical period within of the Pleistocene-Holocene transition. The proxies we developed use vessel measurements of modern bur oaks (*Quercus macrocarpa* Michx.) from trees at three sites that currently typify the central range, the northern wet edge and the northern dry edge of the species. Spring temperatures were correlated with earlywood (EW) vessel lumen diameter (r=0.58, P=.011), EW hydraulic diameter (r=0.69, P= 0.001) and wood porosity (r=0.68, P=0.002). These signals showed strong coherence across years at each site and among sites across the species range, supporting their use as robust indicators of spring temperatures across thousands of years of climatic change. Paleo temperatures were estimated from 71 sub-fossil tree cross-sections ^{14}C-dated to 10.03-13.84 ka. The use of sub-fossil wood required standardizations for variation in tree age, growth rate and differing degrees of wood collapse incurred during long-term burial.

Spring temperatures during the Pleistocene-Holocene transition were inferred to be about 3.5° C less than modern temperatures, an equivalent or lower temperature than those incurred at the northern edge of the modern species range. Compared to modern oaks, sub-fossil oaks had greater EW vessel frequencies for a given vessel size ($P<0.001$) which partially compensated for vessel size being limited by low temperatures. However, xylem conductivity of sub-fossil oaks was calculated to be less than 50% of the modern values. Under conditions of low atmospheric [CO_2] that promote greater plant water loss for each unit of carbon gain, these reductions in conductivity could potentially induce greater drought stress.

A strong correlation was found between δ^{18}O from the GRIP ice core and the frequency of ^{14}C-dated oaks recovered thus far (r= 0.68, $P<0.001$, 50-year bins). The largest gap between ^{14}C-dated samples (11.98-12.75 ka) corresponds to the peak of the Younger-Dryas cold period. Given our sampling intensity during this period, a gap of this length has a very low probability of occurrence by chance alone ($P<0.001$). Together these lines of evidence point toward further reductions in spring temperatures that hindered the development of adequate vasculature during the Younger-Dryas and the promotion of a regional recession in the northward range expansion of oaks that occurred during the Pleistocene-Holocene transition.