Late Oligocene Seasonal Precipitation Based on δ₁³C Profiles in Fossil Wood: A Proxy System Model Case Study with Monte Carlo Uncertainty

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Current forecasting models disagree on the direction of hydroclimate change in the East Asian Monsoon (EAM) under anthropogenic climate change due to the offsetting effects of anthropogenic aerosols and CO₂-driven warming. Records of monsoon intensity from deep time may inform the modeling community about EAM characteristics in a warmer world absent the influence of humans, yet most proxies produce hydroclimate estimates averaged over large temporal scales. Here we provide the first annually resolved, quantitative estimates of seasonal precipitation from East Asia during the Oligocene, a time of higher CO₂ and global temperature than the Common Era. The precipitation reconstruction is based on intra-annual variation in carbon isotopes (δ₁³C) across growth rings of exquisitely preserved fossil wood from Nanning, southern China. A proxy system model trained on a global data set of modern trees was adapted for local application in East Asia and validated using a local weather station and a replicated, intra-ring δ₁³C record from two living evergreen trees in Nanning (22 rings, 317 δ₁³C samples). We then applied the technique to three late Oligocene fossil wood specimens (20 rings, 518 δ₁³C samples). A clear pattern of consistent, summer-dominated precipitation was found, with ~4.5 times more precipitation in summer (Pₛ) than winter (Pₜ). Seasonal precipitation estimates were calculated using Monte Carlo resampling, resulting in median Pₛ = 1042 (95% C.I. = 628-1517) and Pₜ = 235 (95% C.I. = 50-578), which are indistinguishable from the instrument record at a nearby weather station, where Pₛ = 977 (95% C.I. = 662-1434) and Pₜ = 292 (95% C.I. = 165-515), and from proxy application on the two modern trees near the fossil site, where Pₛ = 1058 (95% C.I. = 617-1558) and Pₜ = 188 (95% C.I. = 31-583). These data demonstrate that by the late Oligocene, precipitation patterns in East Asia had strength and seasonality as least as strong as modern conditions, which suggests the presence of an East Asian Monsoon-style system prior to the Neogene. These findings also imply that the EAM may intensify if future policy decisions lead to a reduction in anthropogenic aerosol emissions in East Asia.