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Triple oxygen isotopes reveal large, orbitally-paced swings in South American monsoon strength and regional water balance

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Monsoons are central to the planet's water and energy cycles, however, details about how water balance responds to global climate change remains poorly understood. Sediment records at Lake Junín (11°S, 76°W) provide an opportunity to explore these connections in the South American monsoon domain over the last 650 ka. Here, we focus on two interglacials, the Holocene (12.7–0 ka) and MIS 15 (621–563 ka), when sediment proxies suggest rapid regional hydroclimate fluctuations occurred. Using clumped isotope distributions of lake carbonates, we find that water temperatures during both interglacials were similar to present, however, methodological uncertainties (~5°C) are large compared to the interglacial temperature variability expected in the tropics (<2°C). From the clumped isotope water temperatures and oxygen isotope ($\delta^{18}O$) values of these carbonates, we reconstruct lake water $\delta^{18}O$ values over MIS 15 and the Holocene. We then use triple oxygen isotopes to evaluate the influence of evaporation on lake water $\delta^{18}O$ values and reconstruct estimates of unevaporated precipitation $\delta^{18}O$ values. We find that the degree of lake water evaporation and reconstructed precipitation $\delta^{18}O$ values are highly correlated both to each other and to precession-paced changes in summer insolation during both MIS 15 and the Holocene. Lake water $\delta^{18}O$ values follow changes in the monsoon and are up to +9‰ higher than corresponding precipitation $\delta^{18}O$ values during MIS 15 and ca. +4 to +9‰ higher during the Holocene, indicating the strong, but variable, role of evaporation on lake water balance. This striking connection indicates regional climate and local water balance are linked to global climate forcings. Orbital solutions suggest that precession-paced changes in summer insolation (~23 ka cycles) control both monsoon strength and local water balance within each interglacial. However, wetter end-member conditions during MIS 15 compared to the Holocene (i.e., lower minima for reconstructed precipitation $\delta^{18}O$ values and evaporative water loss), are likely explained by differences in eccentricity (100 ka cycles), as high eccentricity during MIS 15 results in larger seasonal interhemispheric insolation differences which drives stronger monsoons. Together, these data provide new evidence of the connections between global climate, monsoon strength, and regional water balance.