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Seasonal temperature and precipitation amount recorded in monthly oxygen isotope measurements of meteoric water

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The oxygen isotope composition of meteoric water ($\delta^{18}O_{MW}$) is commonly reconstructed from a wide variety of substrates in order to reconstruct mean annual climate at a given site. These reconstructions are based on robust relationships showing that temperature, latitude, altitude, and precipitation all affect $\delta^{18}O_{MW}$ values. However, a quantitative relationship to assess how seasonal climate affects seasonal changes in $\delta^{18}O_{MW}$ ($\Delta\delta^{18}O_{MW}$) has not been determined. Here we use the International Atomic Energy Agency's Global Network of Isotopes in Precipitation database to produce a global relationship relating seasonal climate (i.e., temperature and precipitation) to $\Delta\delta^{18}O_{MW}$. We include in our analysis 365 stations that reported a complete suite of monthly temperature, precipitation, and $\delta^{18}O_{MW}$ data. From these data, we produced a global relationship between average monthly temperature (T) and average monthly $\delta^{18}O_{MW}$ value ($R = 0.80$, $n = 4312$) and identified a non-linear $\delta^{18}O_{MW}/T$ gradient that decreases with increasing temperature. This relationship was able to explain most of the variability in $\Delta\delta^{18}O_{MW}$ for the sites located >37° from the equator ($R = 0.88$, $n = 219$), but was a poor-predictor of $\Delta\delta^{18}O_{MW}$ at all other sites ($R = 0.30$, $n = 146$). By incorporating the effect of changes in seasonal precipitation amount (which is greatest in the tropics) to our relationship, we hoped to reconcile the poor fit observed within our low latitude sites. Towards this, we calculated a $\delta^{18}O_{MW}$ depletion rate = 0.0082 ‰/mm, that when applied to all 365 sites, allowed us to predict the $\Delta\delta^{18}O_{MW}$ value for all sites through knowledge of seasonal changes in temperature and precipitation amount ($R = 0.83$, $n = 365$). The wide applicability of this relationship to diverse climates and geographic locations makes it particularly relevant towards reconstructing seasonal climate from geologic substrates containing seasonal $\delta^{18}O_{MW}$ information (e.g., tree-rings, teeth, speleothems).