Timescale and the amount effect: Monsoon intensity proxy problems at annual to decadal scales

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Terrestrial stable isotope records, such as those derived from speleothems, often serve as a guide to past changes in the isotopic compositon of local meteoric waters. The interpretation of these records is frequently directly or indirectly based on the amount effect in rainfall, where more negative $\delta^{18}O$ values are associated with greater amounts of rainfall at low latitudes. Although the original observation of the amount effect was based on monthly data, the idea is often applied to much longer records, annual to millenial. Oxygen isotope variability in these records has also been attributed to variation in monsoon intensity across a broad region through an amount effect mechanism.

In order to test this concept in the modern rainfall record and at time scales that are appropriate to meteoric water in the vadose zone, we analyzed three monsoon-region long records of stable isotopes in modern rainfall. Weighted mean $\delta^{18}O$ values show no or low correlation to rainfall at the total seasonal, annual, or decadal scales for New Delhi, Hong Kong, and Tucson, Arizona, USA. Even when a correlation exists, the noise present in the relationship prevents the identification of wetter or drier years or decades.

We also compared mean $\delta^{18}O$ values to broad regional indicies of monsoon intensity. For intervals of stronger than average monsoon rainfall the $\delta^{18}O$ value of rain tended to be close to the long term mean at that location. It is only in weaker than average monsoons where the most negative and most positive $\delta^{18}O$ values are observed. This unexpected result is supported by Rayleigh fractionation modeling, where weaker monsoon systems carry less atmospheric moisture and are driven to more negative $\delta^{18}O$ values with modest rainfall amounts.

To test the Rayleigh fractionation model as applied to monsoon systems we extracted rainfall oxygen isotope ratios and amounts from an isotope enabled global climate model, GISS ModelE, and an isotope reanalysis simulation, IsoGSM. Model results generally conform to the observations above, annual weighted mean $\delta^{18}O$ values of precipitation have high or low values in weaker than average monsoon years; $\delta^{18}O$ values in strongest monsoon years approach long term means.