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A rainfall amount weighted meteoric water line for use in hydrological applications

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Use of stable isotope data in precipitation from GNIP or other sources commonly involves determining a local meteoric water line (LMWL) based on a least squares regression (LSR) of monthly rainfall data. Local meteoric water lines are used in a variety or hydrological applications, commonly to determine the relationship of surface or groundwaters to a potential precipitation source or to determine the degree of evaporative enrichment of the water. The intersection between the LMWL and a local evaporation line is commonly used as a start point for calculating evaporative enrichment.

The equations widely used to determine the LMWL give equal weighting to all data points regardless of the rainfall amount they represent. In reality smaller rainfall amounts are more likely to have a lower d-excess due to re-evaporation of raindrops or biases in the sampling method. Larger rainfall events tend to be more depleted in the heavier isotopes. By allowing small rainfall amounts, which may have experienced evaporative enrichment, to have equal influence on the slope of the LMWL, a bias towards the less hydrologically significant rainfall is introduced. For applications of the LMWL relating to groundwater recharge, dam storage and major flow events it is the higher rainfall events that are most important, so it is appropriate to use a LMWL that is weighted towards those events so as not to overestimate the d-excess of hydrologically important depleted rainfall.

We propose the use of a rainfall amount weighted LMWL (δ^2H = $a \cdot \delta^{18}$O + b) for hydrological applications, where the parameters a and b in the line of best fit, $y_i = ax_i + b$, are obtained by minimising the least squares equation:

$$LS = \frac{\sum_{i=1}^{n} p_i \left(y_i - ax_i - b\right)}{\sum_{i=1}^{n} p_i}$$

where p_i is the rainfall (or precipitation) amount, n is the number of measurements and y and x represent δ^2H and δ^{18}O, respectively.

Using the GNIP we test the hypothesis that the rainfall weighted LSR will have larger slopes for most sites, with the impact most pronounced in arid and semi-arid areas. For Alice Springs in arid central Australia the ordinary LSR gave a LMWL of δ^2H = 6.86$\cdot\delta^{18}$O + 4.48, whereas the rainfall weighted LSR was δ^2H = 7.52$\cdot\delta^{18}$O + 9.3. In contrast relatively small increases in the slope of the LMWL were observed at Australian coastal sites.