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Calculations of evaporative losses using stable water isotope composition in dry climates

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Evaporative loss from surface waters is a major component of the hydrological cycle in arid zones, restricting recharge to aquifers and limiting the persistence of surface water bodies. Calculation of evaporative loss is founded on the so-called Craig-Gordon model (C-G), and the stable hydrogen and oxygen isotope composition of water can be successfully used to estimate progressive evaporation. The advantage of this approach is that it does not require monitoring of water levels, inflow and outflow rates. However, the precision and reliability of calculations in very hot and dry climates can be compromised by variable isotope composition of air moisture, which thus needs to be calibrated for C-G model calculations.

In this study, we tested the range of uncertainty in the estimation of evaporative losses by cross-validating a simplified stable isotope model with field pan evaporation experiments. The use of standardized pans (1.2 m diameter, max volume 300 dm^3) allowed simulation of fast evaporation from shallow water bodies in hot and dry climates (mean daily temperature 29°C and relative humidity between 19 and 26% RH during an 11 day experiment). The stable isotope composition of water in pans changed from -8.23‰ (δ^{18}O) and -56‰ (δ^2H) to approximately +6.0‰ (δ^{18}O) and +2.4‰ (δ^2H), reflecting evaporative losses of 56% in sun and 53% in shade. The maximum difference between observed (measured in the field) and calculated evaporative losses was $<$3.0%.

Several factors may contribute to the uncertainty in the evaporative loss calculations. The analytical uncertainty in the determination of the stable isotope composition of water may contribute to $\sim$0.6% (δ^{18}O) and $\sim$1.4% (δ^2H). The model is less sensitive to uncertainty in climatic variables and an uncertainty of 1°C in air temperature will result only in the uncertainty of $\sim$0.1% (δ^{18}O and δ^2H); uncertainty in relative humidity of 10% will result in an uncertainty in the final outcome of 0.4% (δ^{18}O) and 1.0% (δ^2H). Significantly higher uncertainty in evaporative loss estimation is associated with uncertainty in ambient air moisture estimation or analysis. An error of 20‰ in δ^2H and 5.0‰ in δ^{18}O will result in a maximum difference of 2.4% (δ^2H) and 1.7% (δ^{18}O) in the final calculations.

Our experiments form the basis of software (Hydrocalculator), which provides quick and accurate estimation of evaporative losses based on isotopic composition and an understanding of what uncertainties can be associated with this simplified approach.