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Determination of kinetic isotopic fractionation of water during bare soil evaporation

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A process-based understanding of the water cycle in the atmosphere is important for improving meteorological and hydrological forecasting models. Usually only net fluxes of evapotranspiration – ET are measured, while land-surface models compute their raw components evaporation –E and transpiration –T.

Isotopologues can be used as tracers to partition ET, but this requires knowledge of the isotopic kinetic fractionation factor (α_K) which impacts the stable isotopic composition of water pools (e.g., soil and plant waters) during phase change and vapor transport by soil evaporation and plant transpiration. It is defined as a function of the ratio of the transport resistances in air of the less to the most abundant isotopologue. Previous studies determined α_K for free evaporating water (Merlivat, 1978) or bare soil evaporation (Braud et al. 2009) at only low temporal resolution. The goal of this study is to provide estimates at higher temporal resolution.

We performed a soil evaporation laboratory experiment to determine the α_K by applying the Craig and Gordon (1965) model. A 0.7 m high column (0.48 m i.d.) was filled with silt loam (20.1 % sand, 14.9 % loam, 65 % silt) and saturated with water of known isotopic composition. Soil volumetric water content, temperature and the isotopic composition (δ) of the soil water vapor were measured at six different depths. At each depth microporous polypropylene tubing allowed the sampling of soil water vapor and the measurement of its δ in a non-destructive manner with high precision and accuracy as detailed in Rothfuss et al. (2013). In addition, atmospheric water vapor was sampled at seven different heights up to one meter above the surface for isotopic analysis.

Results showed that soil and atmospheric δ profiles could be monitored at high temporal and vertical resolutions during the course of the experiment. α_K could be calculated by using an inverse modeling approach and the Keeling (1958) plot method at high temporal resolution over a long period. We observed an increasing δ in the evaporating water vapor due to more enriched surface water. This leads to a higher transport resistances and an increasing α_K.

References

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