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Soil tension mediates isotope fractionation during soil water evaporation

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Isotope tracing of the water cycle is increasing in its use and usefulness. Many new studies are extracting soil waters and relating these to streamflow, groundwater recharge and plant transpiration. Nevertheless, unlike isotope fractionation factors from open water bodies, soil water fractionation factors are poorly understood and until now, only empirically derived. In contrast to open water evaporation where temperature, humidity and vapor pressure gradient define fractionation (as codified in the well-known Craig and Gordon model), soil water evaporation includes additionally, fractionation by matrix effects. There is yet no physical explanation of kinetic and equilibrium fraction from soil water within the soil profile.

Here we present a simple laboratory experiment with four admixtures of soil grain size (from sand to silt to clay). Oven-dried samples were spiked with water of known isotopic composition at different soil water contents. Soils were then stored in sealed bags and the headspace filled with dry air and allowed to equilibrate for 24hours. Isotopic analysis of the headspace vapor was done with a Los Gatos Inc. water vapor isotope analyzer. Soil water potential of subsamples were measured with a water potential meter.

We show for the first time that soil tension controls isotope fractionation in the resident soil water. Below a Pf 3.5 the δ-values of 18O and 2H of the headspace vapor is more positive and increases with increasing soil water potential. Surprisingly, we find that the relationship between soil tension and equilibrium fractionation is independent of soil type. However, δ-values of each soil type plot along a distinct evaporation line.

These results indicate that equilibrium fractionation is affected by soil tension in addition to temperature. Therefore, at high soil water tension (under dry conditions) equilibrium fractionation is not consistent with current empirical formulations that ignore these effects. These findings may have implications for plant water uptake studies since plant root water uptake imparts tension to extract water from the soil matrix. Since this is the same physical force as soil water potential, root water uptake at high soil water potential might cause fractionation of soil water. Our work is ongoing to examine these knock-on effects.