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Soil water storage, mixing dynamics and resulting travel times through the critical zone in northern latitudes

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Water partitioning in the unsaturated zone into groundwater recharge, plant transpiration, and evaporation is fundamental for estimating storages and travel times. How water is mixed and routed through the soil is of broad interest to understand plant available water, contamination transport and weathering rates in the critical zone. Earlier work has shown how seasonal changes in hydroclimate influence the time variant character of travel times. A strong seasonality characterizes the northern latitudes which are particularly sensitive to climate and land use changes. It is crucial to understand how variation and change in hydroclimate and vegetation phenology impact time variant storage dynamics and flow path partitioning in the unsaturated zone.

To better understand the influence of these ecohydrological processes on travel times of evaporative, transpiration and recharge fluxes in northern latitudes, we characterized soil physical properties, hydrometric conditions and soil water isotopic composition in the upper soil profile in two different land scape units in the long term experimental catchment, Bruntland Burn in the Scottish Highlands. Our two sampling locations are characterized by podzol soils with high organic matter content but they differ with regard to their vegetation cover with either Scots Pine (*Pinus sylvestris*) or heather (*Calluna sp.* and *Erica Sp*). To assess storage and mixing dynamics in the vadose zone, we parameterized a numerical 1-D flow model using the soil textural information along with soil moisture and soil water stable isotopes (δ^2H and δ^{18}O). The water flow and transport were simulated based on the Richards and the advection dispersion equation. Differences between water flows of mobile and tightly bound soil waters and the mixing between the two pore spaces were considered. Isotopic fractionation due to evaporation from soil and interception storage was taken into account, while plant water uptake did not alter the isotopic composition of the soil water.

The soil physical model was then used for each sampling location to calculate travel times in a forward mode by introducing a virtual tracer with the precipitation and tracking the fate of this input signal through the unsaturated zone. This allowed us to derive location-specific time variant travel times for groundwater recharge, plant transpiration, and soil evaporation on a daily basis. We especially aimed to assess the influence of plants on the dynamics in the unsaturated zone. With the analysis ongoing, we expect to find length of vegetation dormancy and rooting depth relevant for the travel times of the plant water uptake. We further expect that the rainfall pattern and seasonal evapotranspiration dynamics will govern the temporal dynamics of the recharge travel times. Our results emphasize the importance of the vadose zone catchment storage on the non-linear catchment response resulting from the sensitivity of the soil water dynamics in the upper soil profile to seasonally variable hydroclimatic forcing and ecohydrological interactions.