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Identifying flow processes in catchments with porewater isotope profiles

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Detecting the movement of water in the vadose and saturated zone in catchments is still a challenging task in understanding hydrological processes. Little is known about the interaction between spatial patterns and the subsurface processes to driving forces like precipitation or radiation. Therefore, our study was aimed to gain new insights into the spatial patterns of subsurface processes using porewater stable isotopes profiles. First, we drilled holes to the depth of the soil-bedrock interface at 36 sites and took soil samples of each drill core in 5 cm intervals. The sample locations are situated in the schistous part of the Attert catchment in the Grand Duchy of Luxembourg and can be differentiated according to their topography and vegetation cover into forested hillslopes and grasslands at plateaus and in the riparian zones. The pore water of these soil samples was analyzed for the isotopic composition (δ^2H and δ^{18}O) with the equilibration method to derive δD and δ^{18}O values as a function of soil depth. In the next step, we simulated these isotope profiles with a physically based one-dimensional water flow model, where rainfall amount, its isotopic composition, evapotranspiration with the Penman-Monteith equation, and site specific soil physical parameters served as input parameters. Finally, to test interactions between topographical descriptors and the patterns in the isotope profiles, a generalized linear mixed model (GLMM) was applied. The slope, topographic wetness index, elevation, aspect, distance to stream, soil cover, and land use served as physically based variables. A comparison between the observed and modeled isotope profiles allowed for detecting anomalies. The differences between the variation of the measured isotopes on the one hand and the simulated ones on the other hand could be attributed to the following processes: i) mixing of water in the vadose zone due to both, temporally rising groundwater table and input from percolating rainfall water, ii) evaporation processes in the top soil, and iii) subsurface flow along the soil-bedrock interface. Which one of these processes dominated at each site depended on the respective physiographic characteristics. The results of the GLMM supported the hypothesis of an interplay between structural and functional traits. The results suggests that information about the porewater stable isotopic composition across the soil profiles seem to be a promising tool to differentiate between the functional responses and flow pathways in catchments.