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Cross-scale insights into flow and nutrient dynamics through coupled tracer-aided ecohydrological and biogeochemical modeling

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Stable isotope tracers in water (e.g., ^{2}H and ^{18}O) have recently been widely used in soil-plant-atmosphere-continuum studies to quantify storage-flux-age interactions, mixing processes and the partitioning of precipitation into evaporation and plant transpiration, as well as groundwater recharge and runoff generation. Tracer-aided ecohydrological modeling can explicitly capture the role of vegetation dynamics in these processes, and constraining models using tracers can provide more realistic representation of water flow paths and ages. Such constraints are of particular importance in the context of catchment nutrient modeling, which integrates conservative hydrological mixing and reactive ecological and biogeochemical processes. Therefore, coupled tracer-aided modeling of ecohydrology and water quality has the potential to improve our understanding of catchment functioning and provide an evidence base for managing environmental trends under changing anthropogenic pressures. Moreover, in the domain of process-based modeling, fully distributed models have been shown to be advantageous in terms of efficiently capturing the high heterogeneity of natural and anthropogenic controls, and linking the modeling efforts with multiple data sources at different scales.

In this project, we apply advanced isotope-based modeling concepts to the intensively monitored TERENO - Bode catchment (ca. 3300 km^2), which exhibits high gradients of hydroclimate, geology and landscape characteristics, and has associated anthropogenic impact gradients. We firstly focused on a well-studied, agricultural sub-catchment (Schäfertal, 1.44 km^2). Rich data sets of long-term, high-frequency hydrometeorological conditions, vegetation dynamics, isotopes and agricultural management practices were integrated into the new tracer-aided ecohydrological model EcH$_2$O-iso, which here is further coupled with the nitrate turnover and transport routines from the new mHM-Nitrate model. The flexible, fully distributed structure of the coupled model allows in-deep, extensive investigation of flow, tracer and nitrate dynamics across scales. Measurements at different spatial scales and under contrasting flow conditions (from lysimeter plots to the catchment monitoring network) were integrated for multi-criteria calibration in order to test and improve the model. The initial modeling in the small headwater catchment opens new

opportunities for future upscaling investigations based on the hierarchical monitoring settings in the Bode catchment (from plots to headwaters, and to nested catchments (from ca. 100 to 3000 km^2)).