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Evaluating the added value of young water fractions for determining water transit times in diverse catchments

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Water transit time distributions (TTDs) are important descriptors of hydrological functioning and solute mobilization in catchments. The use of transport models based on StorAge Selection (SAS) functions is promising for characterizing non-stationary TTDs. Model parameters are typically calibrated using tracer concentration in inflow (e.g., precipitation) and outflow (e.g., streamflow) in order to obtain suitable values of SAS function parameters and, thereby, simulate TTDs at catchment-scale. However, due to uncertainties in tracer data and equifinality problems in SAS modelling, modeled TTDs can be subject to considerable uncertainty. Therefore, we need alternative and independent methods that can help constrain model parameters. An example is the young water fraction (F_{yw}), which quantifies the proportion of catchment outflow younger than approximately 2–3 months. Our work attempts to explore the robustness of F_{yw} in constraining SAS model parameter values and, in turn, reducing predictive uncertainty of TTDs in multiple contrasting sub-catchments in the Central European Bode River Basin. We simulated TTDs using sparse (i.e., monthly) stable water isotope data ($\delta^{18}O$) in streamflow for calibration in an experimental SAS modelling framework. In a subsequent step, we directly compared the model estimates of long-term average (marginal) TTDs with F_{yw} derived from the seasonal cycles of $\delta^{18}O$ measured in precipitation and streamflow. Our results showcase if and to what extent F_{yw} is a valuable additional constraint to infer SAS parametrizations as well as improve TTD predictions and the characterization of water age selection dynamics, and identify potentials and gaps in isotope-based TTD models. Our results also show how the effectiveness of F_{yw} in reducing the predictive uncertainty of TTDs may depend on the water use by plants and land use change across physiographically different sub-catchments. Overall, as the relevance of F_{yw} in TTD modeling is not yet well established, our aim is to investigate whether additional indicators such as F_{yw} are useful for TTD modeling and thus allow improving the description of flow and transport in catchment areas, especially in situations where a high-resolution tracer data are lacking.