



How young water fractions can delineate travel time distributions in contrasting catchments

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Travel time distributions (TTDs) are crucial descriptors of flow and transport processes in catchments. Tracking fluxes of environmental tracers such as stable water isotopes offers a practicable method to determine TTDs. The mean transit time (MTT) is the most commonly reported statistic of TTDs; however, MTT assessments are prone to large aggregation biases resulting from spatial heterogeneity and non-stationarity in real-world catchments. Recently, the young water fraction (Fyw) has been introduced as a more robust statistic that can be derived from seasonal tracer cycles. In this study, we determined Fyw and TTDs in 24 contrasting sub-catchments in a meso-scale catchment (3300 km²) in Germany. In particular, we aimed at improving the assessment of TTDs by using Fyw as additional information in lumped isotope models. Fyw derived from seasonal tracer cycles ranged from 0.01 to 0.27 (mean=0.11) and was mainly correlated with the dominant soil type. Assuming gamma-shaped TTDs, we determined time-invariant TTDs for each sub-catchment from isotope models using the convolution integral method. Multiple optimization runs for the same sub-catchment showed a wide range of TTD parameters due to model equifinality. This implies that a large number of calibration runs might be required to obtain the global optimum of such isotope models. In contrast, the use of Fyw as additional information allowed constraining this range and thus improving the assessment of MTTs (with smallest deviations from Fyw mostly at MTTs of between one and seven years). Hence, the best model fit to observed isotope data might not be the desired solution, as the resulting TTD might define a young water fraction non-consistent with the tracer-cycle based Fyw. Given that the latter is a robust descriptor of fast-flow contribution, isotope models should instead aim at accurately describing both Fyw and the isotope time series in order to improve our understanding of flow and transport in catchments.