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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 aimed at improving the assessment of TTDs by using Fyw as additional information in lumped isotope models. First, we calculated Fyw from monthly δ18O-samples for 24 contrasting sub-catchments in a meso-scale catchment (3300 km^2). Fyw ranged from 0.01 to 0.27 (mean= 0.11) and was not significantly correlated with catchment characteristics (e.g., mean slope, catchment area, and baseflow index) apart from the dominant soil type. Second, assuming gamma-shaped TTDs, we determined time-invariant TTDs for each sub-catchment by optimization of lumped isotope models using the convolution integral method. Whereas multiple optimization runs for the same sub-catchment showed a wide range of TTD parameters, the use of Fyw as additional information allowed constraining this range and thus improving the assessment of MTTs. 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.