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Reconciliation of catchment travel times derived from tritium and deuterium

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Catchment travel time distributions (TTDs) are an integrative measure of time-varying flow paths and hydrological processes, commonly derived from tracer data (e.g. 2-H, 3-H). Recently, it has been argued that the use of stable isotopes of O and H compared to tritium neglects the long tails of TTDs and thus truncates our vision on streamflow age. However, the reasons for the truncation of the TTD remain obscured by methodological and data limitations, including different mathematical models and sampling strategies. In this study, we apply composite SAS functions to a forested headwater catchment in Luxembourg, where the complexity of streamflow generation leads to flow paths with highly different TTDs. We calibrate the model with high-frequency (sub-daily) deuterium measurements, as well as nearly 30 tritium stream samples collected over a two-year period. We simulated TTDs based on each tracer individually and jointly. We found that, when using the two tracers in a coherent methodological framework, both tracers result in similar TTD and storage for the studied catchment. We found small differences in the TTDs that might be explained by calculation uncertainties, as well as by the limited sampling frequency for tritium. Using both stable and radioactive isotopes of H as tracers reduced uncertainties in the water age and storage calculations. While tritium and stable isotopes delivered redundant information about younger water, the use of both tracers leveraged the more specific information content of tritium on longer ages in the system. The two tracers had overall different information contents. We found that 30 tritium samples contained more bits of information than approximately 1000 deuterium samples, underlying the importance of complementing stable isotopes studies with tritium data.