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Tracking water fluxes in distributed models to quantify variability of water transit time distributions with climate and topography

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The WATET (Water Age and Tracer Efficient Tracking) hydrological model is introduced to quantify the main controls of variability in water transit time distributions (TTDs) at catchment scale. In the model hydrological and conservative transport simulations are coupled to follow multiple water parcels in space and time through small to mid-size catchments. The model is first tested and benchmarked on a catchment in UK where extensive data of discharge and a conservative environmental tracer, chloride, are available. Discharge and chloride concentration are satisfactory reproduced by the model, which generates confidence on the simulated TTDs both forward and backward in time. Results show that TTDs conditional on a given rainfall time are mostly correlated to the season in which the rain event occurs, whereas TTDs conditional on a given exit time are mostly affected by catchment wetness. To further shed light on TTD dynamics, the model is subsequently applied to five catchments in different climatic regions. Virtual scenarios combining the five climates and two topographies are developed to infer and compare the influences of climatic and topographic catchment characteristics on transit time distribution and fraction of young water. Results reveal that for wet climates we can mostly define a curve describing water transit distributions as a function of cumulative discharge that only depends on topographic properties. On the contrary, in dry climates the variability of transit time and young water fraction is much larger even when time is rescaled with cumulative discharge, therefore a synthesis of climatic effects on transit times remains elusive.