Geophysical Research Abstracts
Vol. 21, EGU2019-3321, 2019
EGU General Assembly 2019

Catchment travel times from composite StorAge Selection functions: superposition of streamflow generation processes

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Catchment travel times integrate the variety of hydrological flow processes and give additional insights into catchment functioning beyond the hydrograph. StorAge Selection (SAS) functions describe how residence times of water in storage are related to travel times of water in catchment outflows. As such, SAS functions can completely summarize transport processes in catchments and are ideal to simulate catchment outflows and their concentrations in various solutes and tracers. Previous studies using SAS functions suggested that single analytical shapes commonly used for SAS functions may not be sufficient to fully describe transport processes in various hydrological systems. In this study we define composite SAS functions as a weighted sum of several components. The parameterization of these SAS functions uses not only catchment storage as a state variable and thus goes beyond recent studies in other catchments. Composite SAS functions allowed realistic simulations of the complex high resolution (sub-daily) streamflow deuterium (δ2H) dynamics measured for 2 years in the Weierbach, a forested headwater catchment in Luxembourg, whereas a single SAS functions of variable shapes failed. The three components of the SAS functions could furthermore be related to the existence of streamflow generation mechanisms with contrasting travel times that are superimposed in this catchment. Composite SAS functions therefore describe accurately the transport processes in the catchment. Our work suggests that future studies should also consider more components in the SAS functions to correspond to the increase in tracer sampling frequency allowing more inferences on catchment transport processes.