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A novel modeling framework to obtain new insights into the controls of catchment mixing processes

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Understanding the dominant controls and time-invariant behavior of travel times of water and solutes at the scale of catchments is of great scientific interest as it can provide means to quantify catchment-scale solute fluxes. Recent studies, such as, van der Velde et al. (2012) and Botter et al. (2011) have proposed conceptual frameworks for catchment-scale mixing processes by relating travel time distributions for evapotranspiration, discharge and storage to each other in order to derive the Storage Outflow Probability (STOP) functions and the Age functions of water leaving the catchment. However, there is a lack of methodology to directly measure or derive time-variant travel time distributions in the discharge as well as in the evapotranspiration flux. As an alternative, numerical models of water flow are can be used to study major controls of catchment mixing and water age within storage, evapotranspiration and discharge. We propose a novel modeling framework, which is capable of obtaining transient travel time distributions based on a coupled three dimensional surface-subsurface numerical model, external particle tracking routines and subsequent statistical evaluation. We tested our approach on the hydrological well-studied Schäfertal catchment in Central Germany as a base case scenario. Additionally, we aimed to systematically study the shift of the travel time distributions in discharge, evapotranspiration and storage by varying the potential controls, such as: bedrock morphology, catchment slopes, soil properties and temporal dynamics of climatic input in numerical experiments. Furthermore, the travel time distribution results, obtained by our particle tracking approach, were used to calculate the STOP and Age functions for each modeled scenario. Our results provide new insights into the controls of catchment mixing processes, and the transient behavior of age distributions in response to time-variant precipitation and evapotranspiration.

References

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