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Using transient travel time distributions to understand and model catchment dynamic states

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Recent trends in hydrology have focused on transient catchment dynamics, with particular emphasis on, among others, the dynamic connectivity of streamflow source areas and the use of space and time variant travel time distributions. The understanding of such processes is coupled with increased knowledge of transport dynamics, whose reliability can be tested on new high-frequency hydrochemical datasets. Here, we propose methods derived from the time-variant theory of travel time distributions to investigate and model catchment functioning under different hydrologic conditions. We present extensive applications to highly monitored watersheds that show how the transition to different catchment states is mirrored by changes in the mixing of ages stored and released by the catchment, causing the chemical composition in the discharge to vary accordingly. The mixing of ages is modelled through special age functions, that summarize large-scale mixing in complex heterogeneous media and drive the shape of the travel time distributions. Such functions can vary significantly if studied e.g. before, during or after storm events. Our results suggest that these mixing function are able to properly summarize the catchment state and its attitude to store and release solutes. Additionally, we study the ensemble behaviour of travel time distributions corresponding to different catchment states, thereby addressing the issue of the critical timescale within which temporal integration can be performed without losing the essence of the underlying transport processes.