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Streamflow components beyond binary quick-/baseflow separation

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Understanding streamflow components is important to assess ecological functioning of rivers. Streamflow components can be separated based on tracers or solutes, but also with hydrograph separation. Binary or two-component hydrograph separation of the total streamflow into a quick- and baseflow component and the associated baseflow index (BFI) have been frequently criticized for the arbitrary choice of separation parameters and for merging different delayed components into one baseflow component. Several studies have found that during regionalization of delayed streamflow contributions the BFI is often outperformed by simple catchment characteristics such as elevation. This suggests that a two-component BFI is not reliable across different streamflow regimes (e.g. rainfall, snowmelt, glaciermelt). To overcome this limitation, we employed the delayed flow index (DFI), we recently developed. Considering the dynamics of multiple delayed contributions to streamflow the DFI is based on characteristic delay curves with breakpoint estimates to avoid arbitrary separation parameters allowing to distinguish four types of delayed streamflow contributions. The method has been applied to streamflow records from 60 headwater catchments in Germany and Switzerland along a pronounced elevational gradient of roughly 3000 m. We found that the quickflow signal generally diminishes often earlier compared to the two-component BFI-analysis. With the DFI snowmelt and groundwater signals in snow-dominated catchments can be distinguished. In general, flow contributions with delays shorter than 60 days control the seasonal streamflow dynamics. Exploring the DFI in combination with a low flow stability index to better understand the controls of seasonal low flow regimes across different regime classes we found that typical low flow seasons in different regimes are dominated by different short and long delayed streamflow components. Comparing our results with a study that employed tracer and modelling methods the application of the DFI accordingly reveals that subsurface storage in high alpine catchments is larger than previously thought and overall not smaller than in lowland catchments.