Geophysical Research Abstracts
Vol. 20, EGU2018-8301, 2018
EGU General Assembly 2018

Using young water fractions to identify streamflow generation mechanisms across 22 Swiss catchments

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Comparing catchments' hydrologic responses to their physiographic properties and climatic forcing helps to identify dominant controls on water storage and streamflow generation mechanisms. Here, we used the young water fraction (F_{yw}), i.e. the fraction of streamflow younger than roughly 3 months, for a catchment inter-comparison study across 22 sites in Switzerland. We leveraged an extensive data set of δ^{18}O in precipitation and streamwater and calculated F_{yw} from the seasonal cycle amplitudes – a more robust method for characterizing catchment storage ages than a tracer-based determination of travel time distributions. We then explored how F_{yw} varies with the catchments' physiographic properties and climatic forcing. The analysis revealed strong positive correlations between F_{yw} and catchment characteristics that control wetness conditions (e.g., mean monthly precipitation and mean precipitation intensity) and near-surface flow routing (e.g., drainage density and areal fractions of saturated soils). We further found that young water fractions generally increase with discharge, and that this sensitivity of F_{yw} to discharge varies from site to site. In order to quantify the discharge (Q) sensitivity of F_{yw} we developed a method to calculate the linear slope of the $Q - F_{yw}$ relationship. The discharge sensitivity expresses how F_{yw} responds to changes in river discharge, which is used here as a proxy for catchment wetness and hydro-climatic forcing. Interestingly, the young water fraction and its discharge sensitivity were not correlated with each other, suggesting that these metrics represent different diagnostic indicators of catchment hydrologic behaviour. From site-to-site variations in discharge sensitivities and from correlations with catchments' physiographic properties and climatic forcing, we conclude that low discharge sensitivities imply greater persistence in the relative contributions of fast and slow flowpaths to streamflow during both high and low flows. High discharge sensitivities, on the other hand, imply shifts in flowpath dominance during higher flows, such as when subsurface water tables rise into more permeable layers or the river network expands further into the landscape.