Geophysical Research Abstracts
Vol. 21, EGU2019-3042, 2019
EGU General Assembly 2019

Time-variability of the fraction of young water in a small headwater catchment

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The time precipitation needs to travel through a catchment to its outlet is an important descriptor of a catchment's susceptibility to pollutant contamination, nutrient loss and hydrological functioning. The fast component of total water flow can be estimated by the fraction of young water (Fyw) which is the percentage of streamflow younger than three months. Fyw is calculated by comparing the amplitudes of sine waves fitted to seasonal precipitation and streamflow tracer signals. This is usually done for the complete tracer time series available neglecting annual differences in the amplitudes of longer time series. Considering inter-annual amplitude differences, we here employed a moving time window of one-year length in weekly time steps over a 4.5-years [U+F064]18O tracer time series to calculate 189 Fyw results. The results were then tested against the following null hypotheses, defining 2% difference in Fyw as significant based on results of previous studies: (1) Fyw does not deviate more than ±2% from the mean of all Fyw results indicating long-term invariance. Larger deviations would indicate either flow path changes or a change in the relative contribution of different flow paths; (2) for any four-week window Fyw does not change more than ±2% indicating short-term invariance. Larger deviations would indicate a high sensitivity of Fyw to a 1-4 weeks shift in the start of a one-year sampling campaign; (3) for a given calendar month Fyw does not change more than ±2% indicating seasonal invariance of Fyw. In our study, all three null hypotheses were rejected. Thus, the Fyw results were time-variable, showed a high variability in the chosen sampling time and had no pronounced seasonality. Based on high short-term variability of Fyw when the mean adjusted R^2 was below 0.2 we recommend that a low R^2 should be regarded as indicating potentially highly uncertain Fyw results. Furthermore, while investigated individual meteorological factors could not sufficiently explain variations of Fyw, the runoff coefficient showed a moderate negative correlation of r = -0.54 with Fyw. This indicated that when annual runoff exceeded precipitation the catchment received the water deficit from storage which is old water causing a decrease in Fyw. The results of this study suggest that care must be taken when comparing Fyw of catchments that were based on different calculation time periods.