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Exploring controls on transit times and storage properties in mesoscale catchments in Switzerland

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Dynamic and total storage of water in catchments are fundamental controls of catchments' responses to precipitation input. The dynamic storage is related to the storage-discharge relationship and to mean hydrological response times (MRT), whereas the total storage of water in a catchment can only be determined by transit time analysis using for example stable water isotopes and is related to the mean tracer transit times (MTT). It has been hypothesized that a relationship exists between the total and dynamic storage in catchments, however, experimental data from a larger number of catchments is still lacking to provide empirical support for these relationships and to test whether storage depends on other catchment characteristics. In this study mean transit times (MTT) and mean response times (MRT) of 24 catchments in Switzerland with differing geology and altitudes, ranging from the Swiss Jura to the Swiss Alps have been determined. MTTs and MRTs were obtained through the calibration of lumped parameter convolution models and have been used to determine total and dynamic storages, respectively, for each of the 24 catchments. The simulation performance for catchments with snow-dominated runoff regimes could greatly be improved by including an elevation dependent un-calibrated energy-balance snow model predicting melt water input. The stable water isotope data as input for the tracer concentration convolution model was obtained by fortnightly runoff sampling over two years and a new spatial interpolation scheme based on the Swiss ISOT-measurement network. MTTs have been estimated and compared for three different transfer functions: the exponential model, the gamma distribution and the two parallel reservoir (TPLR) model. For the 24 studied catchments, total storage varied considerably between 380 mm and 18000 mm, whereas dynamic storage varied only between 25 and 370 mm. Systematic differences in MTT estimates were found for the three different transfer functions. The results indicate no systematic relation between MTTs and MRTs. MTTs appear to be primarily controlled by underlying geology, whilst they are only weakly correlated with topographic catchment indices. The study thus revealed an interesting pattern of controls on dynamic and total storage that is relevant to the estimation of catchment responses of water quality and quantity.