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A new perspective on catchment storage gained from a nested catchment experiment in Luxembourg (Europe)

Laurent Pfister (1), Julian Klaus (1), Christophe Hissler (1), Jean François Iffly (1), Laurent Gourdol (1), Nuria Martinez-Carreras (1), and Jeffrey J. McDonnell (2)

(1) CRP-Gabriel Lippmann, EVA, Belvaux, Luxembourg (pfister@lippmann.lu), (2) Global Institute for Water Security, University of Saskatchewan, Saskatoon SK S7N 3H5

Recent hydrological process research focussed on how much water a catchment can store and how these catchments store and release water. Storage can be a valuable metric for catchment description, inter-comparison, and classification. Further storage controls catchment mixing, non-linearities in rainfall-runoff transformation and eco-hydrological processes. Various methods exist to determine catchment storage (e.g. natural tracer, soil moisture and groundwater data, hydrological models). Today it remains unclear what parts of the catchment storage are measured with the different models. Here we present a new hydrometric approach to answer the question how much water a catchment can store.

We tested our approach in a dense hydro-climatological monitoring network that encompasses 16 recording stream-gauges and 21 pluviographs in the Alzette River basin in Luxembourg (Europe). Catchment scales are ranging from 0.47 to 285 km^2 and they have clean- and mixed combinations of distinct geologies ranging from schists to marls, sandstone, dolomite and limestone.

Previous investigations in the area of interest have shown that geology largely controls winter runoff coefficients. Here, we focus at how catchment geology is ultimately affecting catchment storage.

We used the approach of Sayama et al. (2011) to compute catchment dynamic storage changes for each winter season over the period 2002-2012 (based on precipitation as input; discharge and evapotranspiration as output). We determined dynamic storage changes for each winter semester (October to March) in all 16 catchments over the period 2002-2012. At the beginning of each hydrological winter season, all catchments showed similar trends in storage change. A few weeks into the winter season, catchments with lowest permeability (e.g. marls) started to plateau. The highest storage values were reached several months later in the season in catchments dominated by permeable substrate (e.g. sandstone).

For most catchments, we found strong correlations between baseflow prior to the recharge period (i.e. at initiation of the total storage calculations) and the seasonal maximum value of the total storage change calculations. In order to determine the maximum storage potential for each catchment, we fitted a trendline through the annual 'initial baseflow - maximum storage' populations. By extrapolating these trendlines to zero flow conditions, we obtained the maximum storage potential.

Our results show that these maximum storage values clearly tend to be larger in catchments dominated by permeable substrate, compared to areas underlain by impermeable bedrock. In the latter, average filling ratios were found to be substantially higher (exceeding 80%) than in catchments dominated by permeable substrate (approximately 40%). These findings were confirmed by average seasonal winter runoff coefficients that are substantially higher in catchments dominated by impermeable bedrock (Pfister et al., in prep.). Our new approach allows a fast assessment of storage potential in catchments based on discharge, precipitation and evapotranspiration data.

Pfister L. et al. 2014: Catchment storage, baseflow isotope signatures and basin geology: Is there a connection? In preparation.

Sayama, T., McDonnell, J.J., Dhakal, A., Sullivan, K., 2011. How much water can a watershed store ? Hydrological Processes 25, 3899-3908.