Geophysical Research Abstracts
Vol. 14, EGU2012-7389-2, 2012
EGU General Assembly 2012

Tracking variations of catchment storage with stable water isotopes

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The hydrologic response function (HRF) describes how fast a catchment responds to a precipitation event. The transit time distribution (TTD) determines how long water from an event spends in a catchment. We know that the HRF and the TTD are different from each other if catchment storage varies in time. We can use this knowledge, reverse the logic and track storage in a catchment by determining how the HRF and the TTD vary over a period of time.
The HRF can be determined by comparing water fluxes into and out of the catchment. The TTD is most easily measured by using stable water isotopes as tracers and keeping track of them in both inflow and outflow.
The difference in the shape of the two functions informs us whether water is being released from storage or whether water is added to storage. If a catchment reacts very fast to a precipitation event (short HRF) but the TTD of the event is skewed towards longer transit times, it means that a large fraction of the outflowing water will be released from storage (pre-event water). If a catchment reacts more slowly, then the shapes of the HRF and the TTD are more similar and a higher fraction of outflow will be event water.
We used isotope and water flux data from a small mountainous semi-arid catchment with high variability in total catchment storage to demonstrate that the method yields reasonable results. We also ran an infiltration model (HYDRUS) to test our hypothesis for different scenarios (antecedent moisture conditions and precipitation event properties).