Geophysical Research Abstracts
Vol. 20, EGU2018-13442, 2018
EGU General Assembly 2018

Age contrasts of stored and flowing waters under stationary and non-stationary conditions

Wouter Berghuijs (1) and James Kirchner (1,2,3)

(1) Department of Environmental Systems Science, ETH Zurich, Zürich, Switzerland , (2) Swiss Federal Research Institute WSL, Birmensdorf, Switzerland, (3) Department of Earth and Planetary Science, University of California, Berkeley, California, USA

Waters flowing out of systems are often unlike the waters stored in those same systems. For example, waters in aquifers are often much older than the stream waters that drain them. Simple physically based reasoning suggests that these age contrasts should be expected wherever catchments are heterogeneous (which is to say: everywhere). However, a general quantitative explanation of these age contrasts remains elusive.

We show that under stationary conditions conservation of mass and age dictate that the age distribution of water stored in a system can be directly estimated from the age distribution of its outflows, and vice versa. This in turn implies that the system's preference for the release or retention of waters of different ages can be estimated directly from the age distribution of outflow under stationary conditions.

Catchments are generally non-stationary, limiting the usefulness of the established relationship between ages of groundwater and streamflow. However, modeling experiments using Storage Selection Functions indicate that the relationship remains accurate under a wide range of non-stationary conditions.

Using simple models of transit times, we show that the mean age of stored water can range from half as old as the mean age of streamflow (for plug flow conditions) to almost infinitely older (for strongly preferential flow). Streamflow age distributions reported in the literature often have long upper tails, consistent with preferential flow and implying that storage ages are substantially older than streamflow ages. Mean streamflow ages reported in the literature imply that most streamflow originates from a thin veneer of total groundwater storage. This preferential release of young streamflow implies that most groundwater is exchanged only slowly with the surface, and consequently must be very old.

Where information is available for both storage ages and streamflow ages, our analysis establishes consistency relationships through which each could be used to better constrain the other. By quantifying the relationship between groundwater and streamflow ages, our analysis provides tools to jointly assess both of these important catchment properties.