Geophysical Research Abstracts
Vol. 21, EGU2019-6149, 2019
EGU General Assembly 2019

Quantifying timescales of catchment storage, transport and hydrological response using ensemble hydrograph separation and ensemble unit hydrographs

James Kirchner (1,2)

(1) ETH Zurich, Dept. of Environmental Systems Science, Zurich, Switzerland (kirchner@ethz.ch), (2) Swiss Federal Research Institute WSL, Birmensdorf, Switzerland

Catchment processes are nonlinear and nonstationary. Thus each mm of rain that falls on a catchment will affect streamflow differently, depending on how that individual parcel of precipitation fits into the sequence of past and future rainfall. Generalizing about a catchment's hydrologic behavior – as distinct from describing the particulars of individual precipitation scenarios and their consequences for runoff – requires tools for abstracting general patterns from this complex rainfall-runoff relationship.

Decades of hydrograph separation studies have estimated the proportions of recent precipitation in streamflow using end-member mixing of chemical or isotopic tracers. Here I show that one can use regressions between tracer fluctuations in precipitation and discharge to estimate the average fraction of new water (e.g., same-day or same-week precipitation) in streamflow across an ensemble of time steps. The points comprising this ensemble can be selected to isolate conditions of particular interest, making it possible to study how the new water fraction varies as a function of catchment and storm characteristics. Even when new water fractions are highly variable over time, one can show mathematically (and confirm with benchmark tests) that ensemble hydrograph separation will accurately estimate their average. Because ensemble hydrograph separation is based on correlations between tracer fluctuations rather than on tracer mass balances, it does not require that the end-member signatures are constant over time, or that all the end-members are sampled or even known, and it is relatively unaffected by evaporative isotopic fractionation.

Ensemble hydrograph separation can also be extended to a multiple regression that estimates both "backward" transit time distributions (the fraction of streamflow that originated as rainfall at different lag times) and "forward" transit time distributions (the fraction of rainfall that will become future streamflow at different lag times), with and without volume-weighting, up to a user-determined maximum time lag. The approach makes no assumption about the shapes of the transit time distributions, nor does it assume that they are time-invariant, and it does not require continuous time series of tracer measurements.

A similar regression-based approach can be used to quantify the ensemble average of a catchment's hydrologic responses to individual precipitation inputs. This "ensemble unit hydrograph" is thematically related to a conventional unit hydrograph, but with key conceptual and mathematical differences. Employing both techniques jointly allows one to quantify both the velocity and celerity of transport and runoff generation at the catchment scale. These approaches will be illustrated with observational data from several experimental catchments.