Geophysical Research Abstracts
Vol. 17, EGU2015-7186, 2015
EGU General Assembly 2015

Seasonal tracer cycles, mean travel time, and young water in heterogeneous and nonstationary catchments

James Kirchner
ETH Zurich, Dept. of Environmental Systems Science, Zurich, Switzerland (kirchner@ethz.ch)

Many environmental systems are nonstationary and heterogeneous, but we often analyze them using theoretical frameworks that assume stationarity and homogeneity, resulting in aggregation errors that are rarely explored and almost never quantified. Here I explore this general problem in one specific context: the use of seasonal cycles in chemical or isotopic tracers, such as Cl^{-}, $\delta^{18}O$, or $\delta^{18}H$ to estimate catchment mean travel times.

Seasonal tracer cycles are widely used to quantify time scales of transport and mixing in catchments. Any system that transports and mixes fluids will damp sinusoidal cycles of tracers that those fluids carry. If the system is homogeneous and stationary, one can compare the amplitudes of the input and output cycles, using simple algebraic formulas, to calculate the tracer's (and thus the fluid's) mean travel time.

Here I show that these calculations will often be wrong by several hundred percent, when applied to catchments with realistic degrees of heterogeneity and nonstationarity. This aggregation error arises from the strong nonlinearity in the relationship between tracer cycle amplitude and mean travel time.

One can show, however, that seasonal tracer cycles reliably estimate the "young water fraction" in stream flow, defined as the fraction of runoff with travel times of less than roughly 0.2 years. Numerical experiments show that this young water fraction (not to be confused with the event-based "new water" in hydrograph separations) is predicted by seasonal tracer cycle amplitudes within a precision of a few percent, across the entire range of mean travel times from nearly zero to near infinity. Most importantly, this relationship is virtually free of aggregation error; that is, the same relationship also holds (again within a few percent) for runoff from highly heterogeneous mixtures of strongly contrasting subcatchments, and for runoff from catchments exhibiting strong nonstationarity. Some implications of these results will be discussed.