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Non-parametric estimation of subreach solute travel time distribution from multiple tracer breakthrough curves

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Artificial tracer additions have been widely applied to characterize solute transport in streams. A common experimental design is to observe the breakthrough curve (BTC) of a tracer at multiple, successive locations downstream of the injection point. This approach allows comparison of the transport behaviour between individual subreaches or combinations of subreaches. Typically, solute transport is characterized by fitting a parametric transient storage model to match observed BTCs. Interpretation of the resulting model parameters may seem straight forward, however, different parameter sets can provide equally good fits to the observations, limiting the utility of this parametric approach for comparison of different subreaches and different streams.
We propose a deconvolution approach, based on observed, successive BTCs, to estimate the transfer functions that characterize the transport process between observation locations. The estimated transfer functions can be regarded as the BTC that would have been observed if individual tracer injections had been performed for each subreach. This approach enables characterization of subreach transport beyond parameter fitting, such as applying a variety of transient storage metrics or temporal moment analysis.
The underlying assumption of our deconvolution method is that an observed downstream tracer BTC can be described by the convolution of the upstream BTC with a transfer function. The deconvolution is performed in the frequency domain. A direct application of the inverse Fourier transform to compute the transfer function in the time domain would likely result in physically unreasonable negative values and variability at high frequencies as a result of noise in the BTC data. To overcome these difficulties we apply an iterative updating procedure for the estimates of the transfer function.
Our deconvolution method can also be applied to naturally time varying signals such as time series of electrical conductivity. Thus, our method provides a framework for integrating continuously monitored natural tracers and data from artificial tracer injections to derive solute transport characteristics of stream reaches.