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Estimation of hydrological and thermal parameters in the hyporheic zone using a novel Bayesian inverse modeling approach

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Hydrothermal properties of the stream-aquifer interface are key information for modeling water and heat transfers in hydrological basins. Our study introduces an algorithm to estimate hydrological and thermal parameters of the hyporheic zone (HZ), as well as their associated uncertainties.

Properties of the HZ are inferred from a combination of head differential time series and vertically-distributed temperature time series measured continually in a HZ vertical profile. Head differential and two temperature time series are used as boundary conditions for the vertical profile; the other temperature time series are used as conditioning measurements.

Following the Bayesian framework, model parameters are treated as random variables and we seek to characterize their probability density function (PDF) conditional on the temperature time series. Our algorithm follows the Method of Anchored Distributions (MAD) implemented in the MAD# software. In order to cut down the number of simulations needed, we develop a hybrid discrete-continuous inversion approach. We first identify the most sensitive parameters in a sensitivity analysis, these parameters are characterized with continuous PDFs. Less sensitive parameters are represented with a discrete PDFs using a finite number of discrete outcomes. We use a non-parametric likelihood function and time series dimension reduction techniques in order to calculate posterior PDFs of HZ parameters.

We demonstrate the approach on a synthetic study using an analytical solution and then apply it to field measurements gathered in the Avenelles basin, France. We present one application of this approach, the uncertainty-quantified time series of localized stream-aquifer exchanges.