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Hamiltonian Monte Carlo algorithm for the characterization of hydraulic conductivity from the heat tracing data

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Estimating spatial distributions of the hydraulic conductivity in heterogeneous aquifers has always been an important and challenging task in hydrology. Generally, the hydraulic conductivity field is determined from hydraulic head or pressure measurements. In the present study, we propose to use temperature data as source of information for characterizing the spatial distributions of the hydraulic conductivity field. In this way, we performed a laboratory sandbox experiment with the aim of imaging the heterogeneities of the hydraulic conductivity field from thermal monitoring. During the laboratory experiment, we injected a hot water pulse, which induces a heat plume motion into the sandbox. The induced plume was followed by a set of thermocouples placed in the sandbox. After the temperature data acquisition, we performed a hydraulic tomography using the stochastic Hybrid Monte Carlo approach, also called the Hamiltonian Monte Carlo (HMC) algorithm to invert the temperature data. This algorithm is based on a combination of the Metropolis Monte Carlo method and the Hamiltonian dynamics approach. The parameterization of the inverse problem was done with the Karhunen-Loève (KL) expansion to reduce the dimensionality of the unknown parameters. Our approach has provided successful reconstruction of the hydraulic conductivity field with low computational effort.