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An experimentally-validated framework for interpreting active-DTS measurements conducted in fully saturated porous media

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Our ability to characterize aquifers, predict contaminant transport and understand biogeochemical reactions occurring in the subsurface directly depends on our ability of characterizing the distribution of groundwater flow. In this context, recently-developed active-Distributed Temperature Sensing (DTS) experiments are particularly promising, offering the possibility to characterize groundwater flows resulting from heterogeneous flow fields. Here, based on theoretical developments and numerical simulations, we propose a general framework for estimating active-DTS measurements, which can be easily applied and takes into account the spatial distribution of the thermal conductivities of sediments.

Two independent methods for interpreting active-DTS experiments are proposed to estimate both the porous media thermal conductivities and the groundwater fluxes in sediments. These methods rely on the interpretation of the temperature increase measured along a single heated fiber optic (FO) cable and consider heat transfer processes occurring both through the FO cable itself and through the porous media. In order to validate these interpretation methods with independent experimental data, active-DTS measurements were collected under different flow-conditions during laboratory tests in a sandbox. First, the combination of a numerical model with laboratory experiments allowed improving the understanding of the thermal processes controlling the temperature increase. Then, the two complementary and independent interpretation methods providing an estimate of both the thermal conductivity and the groundwater flux were fully validated and the excellent accuracy of groundwater flux estimates (< 5%) was demonstrated.

Our results suggest that active-DTS experiments allow investigating groundwater fluxes over a large range spanning 1×10^{-6} to 5×10^{-2} m/s, depending on the duration of the experiment. The active-DTS method could thus be potentially applied to a very wide range of flow systems since groundwater fluxes can be investigated over more than three orders of magnitude. In the field, the reliable and direct estimation of the distribution of fluxes could replace the measurement of hydraulic conductivity, whose distribution and variability still remains difficult and time consuming to evaluate.