Travel Time Uncertainty Reduction by Multiobjective Optimisation of Isotope Age Tracer Models

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Quantification of the travel time distribution and transport parameters in fractured aquifers is crucial for understanding contaminant transport in fractured systems. Although knowledge about the travel time distribution is a helpful tool to assess the solute transport, it can't be measured directly. Travel time is typically back-computed from different tracers in groundwater by applying well established analytical methods. However, in fractured aquifers diffusive exchange with the rock matrix, intersection of streamtubes and associated mixing, as well as other processes can cause deviation of the estimated travel time from the mean advective travel time. Direct numerical modelling of the tracer's reactive behavior with the travel time as one of the calibrated parameters can lead to non-uniqueness of the result. These non-unique solutions typically lead to a high level of parametric uncertainty especially on catchment scale. In this work, we address the reduction of uncertainty in mean travel time, shape parameter of travel time distribution, fracture aperture, and porosity by means of multiobjective optimization enhanced by surrogate modelling. For pre-selection of potentially plausible model runs Gaussian Processes Emulation (GPE) was applied within four-parametric space. We use the GPE with multitracer conditioning for pre-selection of plausible parameter combinations. Posterior distributions were employed to estimate the mean groundwater travel times at sampling locations, to distinguish between different rock facies of captured streamlines, and to get an estimate of fracture apertures. We confirm the hypothesis that using tritium and helium isotopes together with radiogenic helium measurements helps to achieve a unimodal posterior distribution and reduces uncertainty significantly.