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Towards Improved Interpretation of Multi-Tracer Experiments in Subsurface Media

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Interpretation of field tracer experiments is notoriously difficult due to a lack of detailed information on subsurface flow paths and mixing between pathways, incomplete knowledge about subsurface heterogeneity, and problems with parameter estimation. Multiple tracer with different transport properties hold great promise for recovering detailed information on transport processes and parameters, but only if robust methods for modeling the results are developed. In a recent GRL paper (32, L18408, doi:10.1029/2005GL023940, 2005) we have presented a combined parameter and state estimation method, called SODA for improved prediction of subsurface flow and transport, and demonstrated its utility for modeling the breakthrough curve of a single tracer. In this paper, we extend the methodology to transport modeling problems involving multiple tracers, coping with the issue of potentially conflicting information about the underlying transport system based on the behavior of the different tracers. The extended SODA method operates by defining different objective functions for fitting the measured breakthrough curves of different tracers and uses recursive state estimation to explicitly account for conceptual model error. The parameter estimation problem is formulated in a multi-objective context and solved using a parallel computing implementation of the computerized Multi-Objective Shuffled Complex Evolution (MOSCEM-UA) global optimization algorithm. The conceptual transport model employed is an extension of the mixing model approach developed previously to include diffusion into the rock matrix. We illustrate the effectiveness of this approach by modeling a multi-tracer experiment conducted in fractured volcanic tuff in the saturated zone near Yucca Mountain, Nevada