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A Fast Simulation Method for Uncertainty Quantification of Subsurface Flow and Transport

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The spreading of contaminants, or tracers, in groundwater aquifers is mainly driven by flow velocity variations caused by the spatially heterogeneous hydraulic conductivity. The conductivity correlation structures are often complex and the variance levels can be high, but only few conductivity measurements are usually available. As a result, contaminant transport predictions in large subsurface systems involve high uncertainties. To quantify these uncertainties, we propose a new simulation method with a computational cost that is about three orders of magnitude lower than the cost of conventional Monte Carlo simulation (MCS). In MCS, a large number of equi-probable hydraulic-conductivity realizations is generated. For each realization, flow and transport computations are performed. Then, the ensemble of simulation results is post-processed to obtain the transport statistics of interest. The new method is based on parameterized Markov processes for the Lagrangian velocity of fluid particles, which allow for the presence of an arbitrary number of conductivity measurements. We demonstrate the applicability of the new method for different dispersion scenarios involving highly heterogeneous, multi-Gaussian, log-conductivity fields.