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Bayesian Geostatistical Inversion Framework for Probabilistic Risk Assessments of Groundwater Contamination

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Probabilistic risk assessment approach has become increasingly popular for evaluating an impact of groundwater contamination. It is based on stochastic modeling of flow and transport processes, commonly using the Monte Carlo approach. For the assessment, it is important not only to obtain the best estimates of the parameters, but also to quantify uncertainty associated with measurement errors and sparseness of the measurements. In conventional approaches, however, the field data tend to be analyzed separately from modeling so that the uncertainty information may not be transferred correctly to the final results.

Here we introduce a Bayesian geostatistical method to integrate the field data directly into the stochastic modeling framework as well as assimilate a various types of the data for characterizing spatially variable hydrological properties. It quantifies the parameter uncertainty as a posterior distribution conditioned the data. This distribution can be directly used for the Monte-Carlo simulations to generate random fields of hydraulic properties and compute possible outcomes of the flow and transport processes. It enables us to remove a discontinuity between data analysis and transport predictions. In addition, due to flexibility of the framework, we can sequentially assimilate different types of datasets, such as pumping tests, tracer tests and geophysical measurements, in a consistent manner as they become available.

We demonstrate our approach in a hypothetical setting of the probabilistic risk assessment. In addition, we show an application to the real data for subsurface characterization in a field-scale experiment for uranium transport at the Hanford 300 Area.

Keywords: groundwater, probabilistic risk assessment, stochastic hydrogeology, geostatistics, Bayesian inversion