ASSESSMENT OF AQUIFER UNCERTAINTY USING MRF-BASED STOCHASTIC JOINT INVERSION OF GEOPHYSICAL AND HYDROLOGICAL MEASUREMENTS

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Hydrogeophysical assessment of aquifer properties typically involves limited noisy measurements coupled with an incomplete understanding of the target process. Obtaining a deterministic solution is, therefore, unrealistic given the largely uncertain inputs. Stochastic imaging (SI), in contrast, provides multiple, equally likely estimations that enable probabilistic assessment of aquifer properties in a realistic fashion. Generating geologically realistic prior features in SI requires higher-order statistics, which are usually borrowed from training images (TIs). The borrowed statistics may, however, produce undesirable outcomes if the TIs are unrepresentative of the target structures.

We present a data-driven alternative to the TI-based SI algorithms based on Markov random field (MRF) modeling. In MRF modeling, the simulation of spatial features is guided by Gibbs energy (GE) minimization. Local configurations with smaller GEs have a higher likelihood of occurrence and vice versa. Here, the parameters of the Gibbs distribution for computing the GE are estimated from the joint hydrogeophysical data via a Bayesian learning procedure, thereby enabling the generation of site-specific structures in the absence of reliable TIs. The inferred parameters of the Gibbs distribution are then utilized to generate site-specific structures for stochastic reconstruction of the target. The reconstruction proceeds in two-steps with the simulation of the lithological structure of the aquifer followed by the estimation of the hydraulic attributes within the identified lithologies. This two-step modeling approach permits the delineation of physically realistic, sharp lithological boundaries. We demonstrate the performance of the algorithm with a joint inversion of time-lapse concentration and electrical resistivity measurements, in a hypothetical trinary hydrofacies aquifer characterization problem.