Stochastic inverse methods for near-surface geophysical problems

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Abstract: Geophysical methods have wide-reaching applications in near-surface environmental and hydrological research because of their ability to provide estimates of spatially distributed subsurface physical properties at a scale and resolution that are often highly relevant to corresponding modeling and prediction needs. Over the past two decades, significant advancements have been made in terms of obtaining hydrologically and/or environmentally relevant information from geophysical data, most notably addressing the challenge that geophysically derived properties (e.g., electrical conductivity, seismic wave velocity) are typically poorly linked with the subsurface properties of direct interest to the problem at hand (e.g., permeability, contaminant concentration). One key area of near-surface geophysical research that is still in its infancy, however, involves uncertainty quantification of the corresponding inverse problems. Knowledge regarding spatially distributed parameter uncertainty is absolutely essential for making predictions based on geophysical data, which in turn serves as the basis for effective decision-making.

Uncertainty quantification (UQ) for geophysical problems is notoriously challenging because of the typically high dimension of the model parameter space combined with the computational complexity of the associated numerical simulation processes. Although a wide variety of UQ approaches have been developed, one methodology that has become increasingly popular in recent years involves stochastic sampling from the Bayesian posterior parameter distribution using Markov-chain-Monte-Carlo (MCMC) methods. In this presentation, I will summarize work that we have conducted in this overall domain of research with applications to vadose and saturated zone hydrological problems. In addition, I will present recent developments with respect to the incorporation of geostatistical information into Bayesian inverse problems through sequential resampling, along with an evaluation of the numerical efficiency of this approach. Finally, the issue of model error in Bayesian-MCMC inverse approaches will be investigated, with a view towards potential strategies for accounting for the bias of simplified, computationally efficient forward models in the calculated posterior statistics.