KÖPKE Corinna (2017): Identification and characterization of model error arising from simplified forward solvers in hydrogeophysical inverse problems

Abstract

The field of hydrogeophysics concerns the application of geophysical methods to hydrolog- ical problems. To estimate hydrologically relevant subsurface properties and their corre- sponding uncertainties from geophysical data, the subsurface must be parameterized and a forward solver must be chosen to represent the physics of the underlying measurement process. In this regard, several forward solvers often exist having different levels of ac- curacy. Employing simplified forward solvers can reduce the computational costs of the inverse problem but leads to model error. If this model error is not accounted for, pa- rameter estimates can become strongly biased and overconfident. Existing approaches to deal with model error are mainly limited to low-dimensional problems or based on strong assumptions about the statistical distribution of the model error.

In this thesis I develop an alternative method to account for model error in Bayesian inversion, and I apply it to a number of hydrologically relevant example problems. In contrast to traditional approaches aimed towards characterizing the model error through parametric statistical distributions or construction of an error model, my method focuses on identification of the model-error component of the residual through orthogonal projec- tion. Specifically, the residual is projected onto an orthonormal model-error basis that is constructed through the analysis of stochastic realizations of the difference between the simplified and detailed forward solvers. The approach is based on the assumption that the model error lies orthogonal to the other components of the residual and is therefore separable.

In the thesis, my proposed method is first applied to the inversion of synthetic ground- penetrating-radar- (GPR-) derived water content data, acquired during a forced infiltration experiment, for unsaturated soil hydraulic properties. In this case, a single global basis is constructed for the model error. Next, the method is used to invert synthetic crosshole GPR travel-time data for the distribution of the radar wave speed between the boreholes, where a modification was necessary to allow for the development of a local model error basis. This basis is developed during the inversion procedure and is constructed using the K-nearest-neighboring model-error realizations to current location in the parameter space. Finally, the proposed approach is applied to synthetic crosshole GPR travel-time inversion performed with an iterative ensemble smoothing technique. The proposed model-error approach can be applied to large scale parameter-estimation problems without assumptions regarding the model-error statistics. The results in the thesis motivate the application to other examples and real-world inverse problems.