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Estimation of effective parameters for unsaturated flow in heterogeneous porous media

Daniel Erdal and Insa Neuweiler
Institute of Fluid Mechanics, Leibniz Universität Hannover, Hannover, Germany (erdal@hydromech.uni-hannover.de)

The unsaturated zone is an important part of the hydrologic cycle and in modeling of large systems it provides the important link between the land surfaces and groundwater systems. One of the problems when modeling water fluxes in the unsaturated zone is to estimate the model parameters from observations. Due to heterogeneities of the soil, these parameters depend on length scale. Especially for flow models with large domain sizes it is often required to represent soil structure as simple as possible. This means that heterogeneous structures with strong effects on the flow behavior may become incorporated in larger homogeneous grids, requiring that a model is set up in such a way that the impact of the structure on averaged variables is still represented.

When parameterizing a flow model for the unsaturated zone it is therefore important that the resulting effective parameters are independent of where and when measurements are taken. Many approaches to deal with these problems have been suggested, including upscaling theory and geostatistics. This study looks at the use of explicit error models to guide a Markov Chain Monte Carlo (MCMC) calibration process towards effective parameter sets that are consistent, independent of where and how the measurements are taken.

To illustrate the problem of parameter estimation three virtual reality multi step outflow experiments are created using three sand columns with different strongly heterogeneous soil structures. A homogeneous model is then used to model the water flow in the columns. In the first part of the contribution it is shown how inconsistent a MCMC calibration can be if measurements used for the calibration do not cover a representative volume of the structure. In the second part, three different external error models for the observations that allow for a calibration that acknowledge soil structure is implemented and tested. The three error models used are all variable in space but constant in time and the difference between them is the amount of prior information required about the soil structure, ranging from only an idea about percentages of materials to a fairly good idea of the full subsurface structure.

The results indicate that the use of an error model can increase the consistency of the resulting model parameters. If a fair estimate of the soil structure is available, the result is at its best, with fairly short calibration times and consistent result independent of where the measurements are taken. If no additional information is available the result is still improving compared to the cases without error model, but the cost is a large increase in calibration time to reach a convergence of the MCMC algorithm. The result could be useful when calibrating large scale models where only local data is available.