Calibration of a transient variably-saturated groundwater flow model by iterative ensemble smoothering: Application to the artificially induced flow at the Andra's Meuse/Haute-Marne site

Dan-Thuy Lam, University of Neuchâtel, Centre for Hydrogeology and Geothermics (CHYN), Switzerland
Jaouher Kerrou, University of Neuchâtel, Centre for Hydrogeology and Geothermics (CHYN), Switzerland
Hakim Benabderrahmane, French National Agency for Radioactive Waste Management (ANDRA), France
Pierre Perrochet, University of Neuchâtel, Centre for Hydrogeology and Geothermics (CHYN), Switzerland

The calibration of groundwater flow models in transient state can be motivated by the expected improved characterization of the aquifer hydraulic properties, especially when supported by informative time series data. Within the framework of the Andra's (French National Agency for Radioactive Waste Management) project for a deep geological repository in a low permeable formation in northeastern France, a three-dimensional high-resolution numerical model of variably-saturated flow was developed in order to understand the local flow behavior and to improve the characterization of lithologic structures and heterogeneities of the Oxfordian aquifer system at the Meuse/Haute-Marne site. In order to infer the heterogeneity of the hydraulic parameters of the multi-layered model, notably both hydraulic conductivity and specific storage fields, it is intended to make use of the 12-year hydraulic head and flowrate time series recorded since the hydraulic perturbation created by the excavation of the access shafts and the operation of the Underground Research Laboratory in the Callovo-Oxfordian host formation [1]. Considering the high-dimensional nonlinear problem, we are currently leaning towards iterative forms of the ensemble smoother method [2,3] which large-scale applicability has been illustrated more extensively in the field of petroleum engineering. By assimilating the calibration data in one single step, the algorithms correct iteratively an ensemble of stochastic realizations of parameters generated beforehand on the basis of some prior geological information. In the case of the ensemble-based Kalman methods more generally, this correction computed from the approximation of covariance matrices is particularly effective when the realizations are multi-Gaussian. When applied to more complex non-Gaussian distributions however, these methods have proven to be not so optimal [4]. As also shown on our simplified synthetic case, the ensemble smoother fails to preserve the multimodal distribution and connectivity of facies realizations generated by multiple-point statistics methods, although the data mismatch is being reduced. Given the discrete geological structures described in the Andra's geological model however, a major goal is to investigate how to still best leverage the performance of the iterative ensemble smoother while keeping an ensemble of updated realizations as conceptually acceptable as possible. The performance of selected algorithms combined with additional steps to help mitigate the effects of non-Gaussian patterns, such as Gaussian anamorphosis, or facies resampling from the training image based on updated local probability constraints in the case of multipoint realizations, will be assessed in terms of the model plausibility, quality of history match and uncertainty quantification achieved.

References

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