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Importance sampling algorithms for water resources management

Claudius Bürger (1), Peter Bayer (2), Michael De Paly (3), and Niels Schuetze (4)

(1) Center of Applied Geosciences, University of Tübingen, Germany (claudius.buerger@uni-tuebingen.de), (2) Engineering Geology, Geological Institute, ETH Zurich, Switzerland (bayer@erdw.ethz.ch), (3) University of Tübingen, Wilhelm-Schickard-Institute for Computer Science, Tübingen, Germany (michael.depaly@uni-tuebingen.de), (4) Institute of Hydrology and Meteorology, Dresden University of Technology, Germany (ns1@rcs.urz.tu-dresden.de)

Water resources optimization tasks based on numerical models typically cannot be approached without some assessment of uncertainty. Be it the uncertain meteoric input and/or the unknown subsurface structure and/or parameter distribution – objective function formulations in this context need to contain some extra measure of reliability. Apart from subjective safety-factors a more rigorous reliability analysis will typically contain Monte-Carlo type simulations. E.g. subsurface hydraulic conductivity is modeled as a conditioned, spatially-correlated random field, which is sampled for a large number of realizations. By evaluating a management candidate solution for all of those hydraulic conductivity fields, a probability distribution for the reliability of this particular solution is constructed. For realistic site model layouts, however, such a repetitive numerical model evaluation for the calculation of a single objective function value is easily computationally prohibitive.

In this study we explore a number of heuristic importance sampling algorithms which approximate objective function values during the optimum search and thereby save computation time. The fundamental assumption to all of these algorithms is that in water resources management tasks like well layout and extraction/infiltration rate adaptation a small number of so-called critical realizations exist, which completely determine high-reliability solutions to the management problem. The applied heuristic algorithms learn the importance of particular realizations for the management problem, while the search for the solution progresses. We evaluate several variants of these importance sampling algorithms for a hypothetical, yet typical groundwater management case that is non-linear, non-convex and further defined by a given number of hydraulic conductivity realizations. The in-depth analysis of these importance sampling algorithms shows that the best variants do achieve enormous savings in computation time, can accommodate to different optimization algorithms and that their performance is nearly independent of the non-stationarity of the conditioned fields.