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Comparison of parameter estimation algorithms in hydrological modelling

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While much attention during the past decades has been given to develop automatic optimization procedures for parameter estimation of lumped, conceptual watershed models and groundwater models, very limited attention has so far been devoted to the use of automatic calibration in connection with distributed and integrated hydrological models. The number of potential parameters in distributed hydrological models is huge, since these models are structured to enable the spatial variations in catchment characteristics to be represented by specific parameters in each grid point. Moreover, for distributed prediction, multi-site and multi-variable calibration and validation are normally required, thus requiring a proper methodology to deal with multi-objective measures.

Local search methods have been applied successfully in calibration of groundwater models and have proved to be effective and efficient tools in locating and finding the optimum solution. In lumped, conceptual models the increased non-linearity in the parameter-model response turns the response surface into a more complex shape and local search procedures can be trapped in local optima, thus being unable to reach the global optimum. Global search algorithms have demonstrated to perform well for these types of models, although at a more expensive computational cost.

In this study we investigate the relationship between model complexity and efficiency of search algorithm. In particular, two different search algorithms, a local and a global procedure, are applied to hydrological models of increasing complexity, ranging from a simple recharge steady state groundwater model to a fully integrated hydrological model.

The two algorithms applied in this study are the global search Shuffled Complex Evolution Algorithm, SCE, and the local gradient-based Gauss-Marquardt-Levenberg non-linear scheme, as implemented in the PEST software. The hydrological model used in this work is the MIKE SHE model, which allows to easily change the model formulation. The study site is the Karup catchment in Denmark, that has been already extensively investigated and for which comprehensive hydrological data are available.

Three models of different complexity are investigated:

- A steady-state groundwater model with a simple net-rainfall recharge in which the net rainfall fraction is included as a calibration parameter.
- A transient groundwater model where the recharge is computed using a simple, empirical root zone model.
- A fully integrated model where the unsaturated zone and the evapotranspiration processes are also included in the model and some of their parameters are subject to calibration.

The calibration is conducted in a multi-objective context, where the error measurements related to groundwater levels and streamflow are aggregated and simultaneously minimized. The presence of several, distinct optimal parameter sets (multiobjective equivalent parameter sets) is then dealt with by evaluating the solutions according to the Pareto dominance criterion.

The study aims at defining the level of model complexity where the local search algorithm fails to reach the global optimum and a global strategy has to be applied.