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Stochastic optimization algorithm selection in hydrological model calibration based on fitness landscape characterization

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The process of hydrological model parameter calibration is routinely performed with the help of stochastic optimization algorithms. Many such algorithms have been created and they sometimes provide varying levels of performance (as measured by an efficiency metric such as Nash-Sutcliffe). This is because each algorithm is better suited for one type of optimization problem rather than another.

This research project's aim was twofold. First, it was sought upon to find various features in the calibration problem fitness landscapes to map the encountered problem types to the best possible optimization algorithm. Second, the optimal number of model evaluations in order to minimize resources usage and maximize overall model quality was investigated.

A total of five stochastic optimization algorithms (SCE-UA, CMAES, DDS, PSO and ASA) were used to calibrate four lumped hydrological models (GR4J, HSAMI, HMETS and MOHYSE) on 421 basins from the US MOPEX database. Each of these combinations was performed using three objective functions (Log(RMSE), NSE, and a metric combining NSE, RMSE and BIAS) to add sufficient diversity to the fitness landscapes. Each run was performed 30 times for statistical analysis. With every parameter set tested during the calibration process, the validation value was taken on a separate period. It was then possible to outline the calibration skill versus the validation skill for the different algorithms.

Fitness landscapes were characterized by various metrics, such as the dispersion metric, the mean distance between random points and their respective local minima (found through simple hill-climbing algorithms) and the mean distance between the local minima and the best local optimum found. These metrics were then compared to the calibration score of the various optimization algorithms.

Preliminary results tend to show that fitness landscapes presenting a globally convergent structure are more prevalent than other types of landscapes in this particular case, which seems to favour the CMAES algorithm. However, when the landscape is very noisy (as indicated by smaller distances between local optima), other algorithms such as DDS and ASA seem better suited to tackle this type of problem. It was also noted that problem dimensionality has a direct impact on the relative performances of the algorithms.

For the validation aspect, it was shown that calibration scores improve continuously, but validation skill is quickly maximized after less than 25% (2500 in this case) of the allowed modelled evaluations. Any improvement to validation skill after attaining this point is purely due to noise fluctuations in the signal.