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Embracing parameter correlation in hydrological models: explicitly accounting for it improves identifiability

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Correlation between parameters is a problem even in the calibration of very simple hydrological models. A common way to deal with parameter correlation is to keep one of the model parameters fixed at a prespecified value. However, fixing one of them might make us overconfident about our ability to constrain the other parameters which the fixed one may interact with. If we want to make inferences about catchment functioning from a calibrated hydrological model we should recognize how uncertain we are about its parameters, i.e., all model parameters should be part of the inference especially if we know that potential interactions may occur. Since correlation between parameters may turn the parameter inference a difficult task, we should seek to eliminate it as much as possible.

In this study, we analysed the correlation between parameters of the nonlinear reservoir, a building block of many conceptual hydrological models. In this type of reservoir, the outflow is a power function of storage with exponent α and drainage coefficient k. Even in this two-parameter problem equifinality is inevitable. The parameters k and α are strongly related with one another, in that the dimension of k varies according to the value of α. Therefore, a first attempt to deal with this interaction could be to eliminate k from model equations.

We applied the parameterisation of the nonlinear reservoir proposed by Kirchner (2016) and evaluated its implementation in four conceptual hydrological models built using the SUPERFLEX framework. In Kirchner's approach, the drainage function is formulated by using a reference storage parameter, S_{ref}, and the exponent α. However, these two parameters remain strongly correlated. Therefore, we investigated how the non-identifiability problem caused by parameter correlation can be mitigated by using transformations of the parameter space. The nonlinear reservoir model was applied to a synthetic data set as to eliminate the influence of the many sources of error intrinsic to every modelling problem. The other four conceptual models were calibrated using data from a real catchment. All parameter inferences were performed using the DREAM algorithm. We found that: (i) parameterising the nonlinear reservoir using S_{ref} and α instead of the problematic drainage coefficient k and α improved search efficiency; (ii) parameter correlation is reduced (but not entirely) when a parameter space composed of S_{ref} and S_{ref}/α is considered, as proposed by Kirchner (2016); and (iii) a simple transformation based on a linear regression can be used to remove the correlation between two parameters, but further investigation is needed for situations in which many parameters interact at the same time.

Reference

Kirchner, J. W.: Aggregation in environmental systems – Part 2: Catchment mean transit times and young water fractions under hydrologic nonstationarity, Hydrol. Earth Syst. Sci., 20, 299-328, https://doi.org/10.5194/hess-20-299-2016, 2016.