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Parameter dimension reduction using the active subspace method for a lumped karst aquifer model

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Lumped hydrological models are tools commonly used to simulate the discharge of karst springs. Lumped model parameters are often not measurable and they need to be estimated during model calibration. While a low-dimensional parameter space is beneficial to avoid model equifinality and to reduce model output uncertainties, a large number of parameters is required when implementing a hydrological model that can reproduce the effect of land use changes. To overcome this issue, methods to reduce the parameter-space dimension are needed.
In our research study, we applied the recently proposed active subspace method to the LuKARS model (i.e. a hydrotope-based lumped karst aquifer model) with an initial 21-dimensional parameter space implemented for the Kerschbaum spring recharge area in Waidhofen a.d. Ybbs (Austria). The active subspace method searches for orthogonal directions in the parameter space which are relevant to update a defined prior to a well-constrained posterior parameter distribution. The identified relevant directions, in the best case, create a lower dimensional subspace that can be used to approach the higher dimensional problem as well as to compute global sensitivity metrics for each model parameter.
Using the active subspace method, we were able to reduce the original 21-dimensional parameter space to a 4-dimensional one and to investigate the related model parameter uncertainties. By applying the active subspace method to three different model scenarios of our case study, we could show which properties of the hydrotope-based model structure are decisive to reproduce the hydrological variability of the measured karst spring discharge. These are the respective space covered by a regarded hydrotope as well its specific discharge variability. We conclude that the active subspace method is a promising tool to reduce parameter and structural uncertainties of lumped karst aquifer models with a high dimensional parameter space.