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Differences between fully Bayesian and pragmatic methods to assess predictive uncertainty and optimal monitoring designs

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Data acquisition for monitoring the state in different compartments of complex, coupled environmental systems is often time consuming and expensive. Therefore, experimental monitoring strategies are ideally designed such that most can be learned about the system at minimal costs.

Bayesian methods for uncertainty quantification and optimal design (OD) of monitoring strategies are well suited to handle the non-linearity exhibited by most coupled environmental systems. However, their high computational demand restricts their applicability to models with comparatively low run-times. Therefore, pragmatic approaches have been used predominantly in the past where data worth and OD analyses have been restricted to linear or linearised problems and methods. Bayesian (nonlinear) and pragmatic (linear) OD approaches are founded on different assumptions and typically follow different steps in the modelling chain of 1) model calibration, 2) uncertainty quantification, and 3) optimal design analysis.

The goal of this study is to follow through these steps for a Bayesian and a pragmatic approach and to discuss the impact of different assumptions (prior uncertainty), calibration strategies, and OD analysis methods on the proposed monitoring designs and their reliability to reduce predictive uncertainty. The OD framework PreDIA (Leube et al. 2012) is used for the nonlinear assessment with a conditional model ensemble obtained with Markov-chain Monte Carlo simulation representing the initial predictive uncertainty. PreDIA can consider any kind of uncertainties and non-linear (statistical) dependencies in data, models, parameters and system drivers during the OD process. In the pragmatic OD approach, the parameter calibration was performed with a non-linear global search and the initial predictive uncertainty was estimated using the PREDUNC utility (Moore and Doherty 2005) of PEST. PREDUNC was also used for the linear OD analysis.

We applied PreDIA and PREDUNC for uncertainty quantification of groundwater exchange fluxes and optimal design analysis using a steady-state model for a section of the river Steinlach (South Germany). The model involves a Pilot Point parameterization scheme for hydraulic conductivity and six zones with uncertain river bed conductivities.

Preliminary results show that optimal designs are highly sensitive to how the current knowledge is quantified or modelled. For the case analysed here it seems to be of particular importance how prior predictive uncertainty is perceived and implemented.