Geophysical Research Abstracts
Vol. 20, EGU2018-6933, 2018
EGU General Assembly 2018


# Effective predictive uncertainty analysis using reduced order models

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The size and complexity of many physically-based groundwater models make model calibration and uncertainty analysis computationally demanding. This also applies to scenario simulations and predictive uncertainty assessment for water resource management. Reduced order models (ROMs) alleviate the computational burden but introduce new challenges. While ROMs are faster, they are often limited in their parameterization and process representation, which can lead to predictive bias and an underestimation of uncertainty. A method to combine the strengths of both complex and simple models is model reduction and uncertainty scaling via a paired model approach (Doherty & Christensen, 2011).

For this method, we generate random parameter sets for a complex model and simulated the corresponding model outputs. These outputs are used as calibration targets for two different ROMs. We construct scatter plots of calibrated simplified model outputs (x-axis) versus random complex model outputs (y-axis) for different model predictions and estimate uncertainty scaling factors from these plots. This leads to a more realistic uncertainty estimate of the ROMs.

We applied the method for a transient numerical Modflow model of the Wairau aquifer in the Marlborough Region on the South Island of New Zealand. This aquifer, fed by the Wairau River, is used for drinking water supply and agricultural irrigation in the Blenheim region.

Two different ROMs were created in this study. The first model is a numerical Modflow model, based on the complex model, with a coarsened computational grid and drastically simplified parameterization. The second type of surrogate models is artificial neural networks (ANNs). We chose and optimized a separate network structure for each point in the dataset (i.e. for each groundwater well). Both ROMs are compared to the complex model with regard to their predictive performance and uncertainty estimates for different predictions.

While the simplified Modflow model is three times faster than the complex model, the ANNs run up to factor 1000 times quicker. The ANNs also reproduce the real-world datasets quite well, while the simplified Modflow model is less accurate for some of the observations. However, both ROMs appear to be suitable for the uncertainty assessment of groundwater head predictions.

Literature:

Doherty, J., Christensen, S., 2011. Use of paired simple and complex models to reduce predictive bias and quantify uncertainty. Water Resour. Res. 47 (12), W12534. http://dx.doi.org/10.1029/2011WR010763