How well do we know our models?

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In Geosciences, we face the challenge of characterizing uncertainties to provide reliable predictions of the earth surface to allow, for instance, a sustainable and renewable energy management. In order, to address the uncertainties we need a good understanding of our geological models and their associated subsurface processes.

Therefore, the essential pre-step for uncertainty analyses are sensitivity studies. Sensitivity studies aim at determining the most influencing model parameters. Hence, we require them to significantly reduce the parameter space to avoid unfeasibly large compute times.

We distinguish two types of sensitivity analyses: local and global studies. In contrast, to the local sensitivity study, the global one accounts for parameter correlations. That is the reason, why we employ in this work a global sensitivity study. Unfortunately, global sensitivity studies have the disadvantage that they are computationally extremely demanding. Hence, they are prohibitive even for state-of-the-art finite element simulations.

For this reason, we construct a surrogate model by employing the reduced basis method. The reduced basis method is a model order reduction technique that aims at significantly reducing the spatial and temporal degrees of freedom of, for instance, finite element solves. In contrast to other surrogate models, we obtain a surrogate model that preserves the physics and is not restricted to the observation space. As we will show, the reduced basis method leads to a speed-up of five to six orders of magnitude with respect to our original problem while retaining an accuracy higher than the measurement accuracy.

In this work, we elaborate on the advantages of global sensitivity studies in comparison to local ones. We use several case studies, from large-scale European sedimentary basins to demonstrate how the global sensitivity studies are used to learn about the influence of transient, such as paleoclimate effects, and stationary effects. We also demonstrate how the results can be used in further analyses, such as deterministic and stochastic model calibrations. Furthermore, we show how we can use the analyses to learn about the subsurface processes and to identify model short