Application of experimental design-based assisted history matching for uncertainty quantification in radioactive waste repositories

Integrity of Nuclear Waste Repository Systems – Cross-Scale System Understanding and Analysis

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EGU | 04.05.2020 | Internet

Bundesministerium für Bildung und Forschung

HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

OpenGeoSys
OPEN-SOURCE MULTI-PHYSICS

Internet – 04.05.2020

Safety of Radioactive Waste Repositories

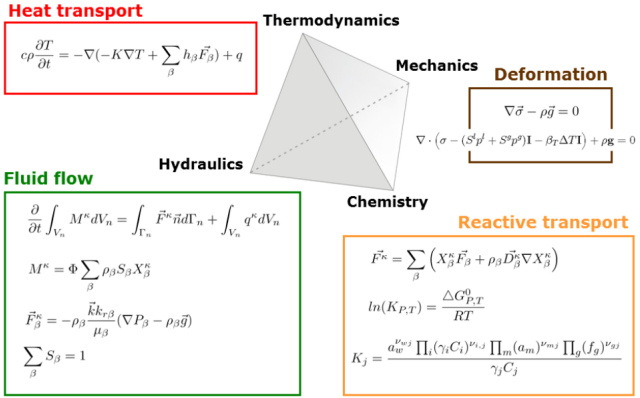
Safety assessment ⇒ Probabilitstic integrity analysis ⇒ UQ/SA

- safety needs to be 'guaranteed' for $\approx 10^6\ \mathrm{a}$
- large spatial extends
- processes on many different scales need to be considered

⇒ large epistemic uncertainties

- host rocks: rock salt, crystalline, clay rock
- in deterministic FE models
- of THM/C(B) processes
- uncertainties: parameter and model

⇒ OpenGeoSys
OPEN-SOURCE MULTI-PHYSICS

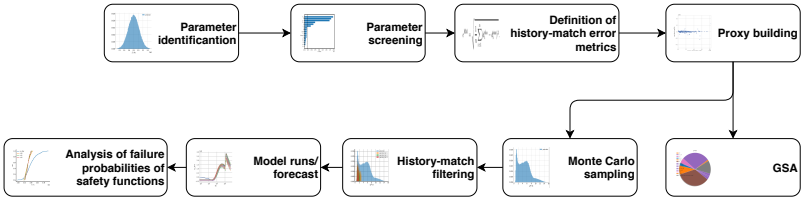


Source: Kolditz, Olaf, et al. "OpenGeoSys: an open-source initiative for numerical simulation of thermo-hydro-mechanical/chemical (THM/C) processes in porous media." Environmental Earth Sciences 67.2 (2012): 589-599.

DoE-based history matching

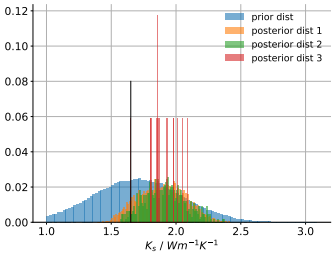
overview

- consideration of parameter and model uncertainties
- incorporates exp. data
- approach general and customizable
- global sensitivity can be studied on proxy model

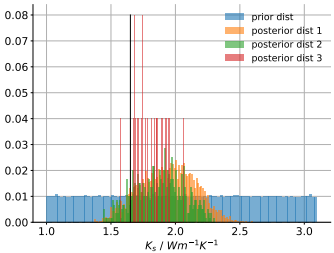


Impact of filter on different priors:

non-uniform prior



uniform prior



- past effort has been mainly on "C"-part (parameter uncertainties in transport of radioactive nuclides)

We want a method that is/can deal with

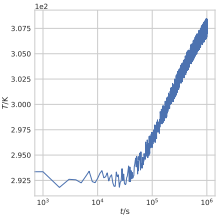
- highly non-linear equations and couplings
- parameter and model uncertainties alike
- computationally feasible

Simplified analytical model of one canister of rad. waste in inf. hom. medium for testing

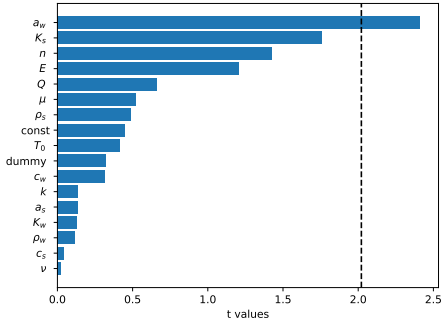
Thermal consolidation around a point heat source in a fluid-saturated porous medium. Original publication: **Booker, J. R.; Savvidou, C. (1985), International Journal for Numerical and Analytical Methods in Geomechanics, 1985, 9. Jg., Nr. 2, S. 173-184.**

Correction: **Chaudhry, A. A.; Buchwald, J.; Kolditz, O. and Nagel, T. (2019), International Journal for Numerical and Analytical Methods in Geomechanics, 2019, https://doi.org/10.1002/nag.2998.**

- includes THM coupling
- model used for synthetic exp. data generation + analysis

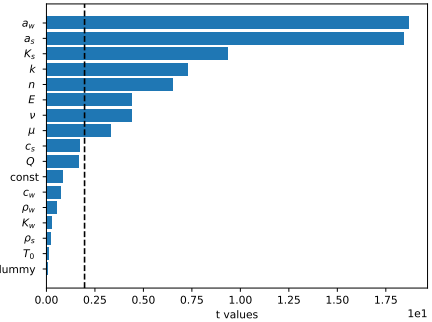


folded Placket-Burman (32 samples):



F-Test: 0-Hypothesis confirmed (prob$\approx$ 0.9)

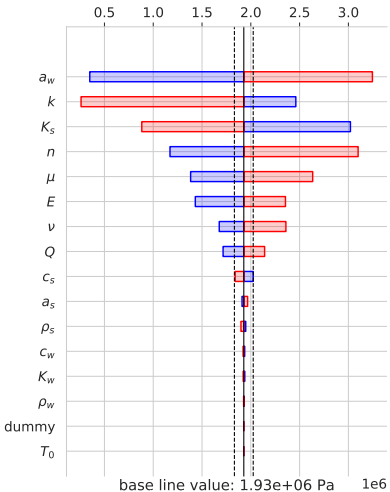
LHS 400 samples



0-Hypothesis rejected (prob $\approx 1.4e-62$)

Sensitivity Screening

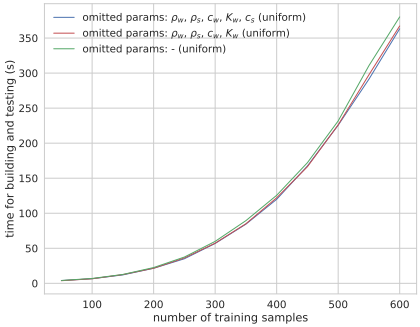
OVAT

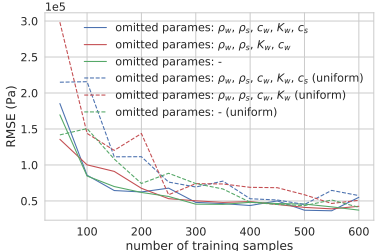


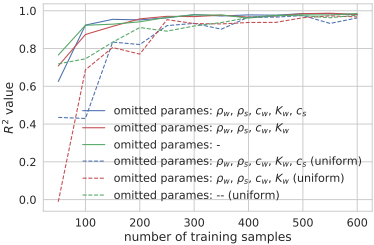
- Insignificant values: ρ_w, ρ_s ,K_w and c_w confirmed by t-test with Latin-hypercube design
- however, idea is to throw away parameters before building design!
- what is the cost/gain of reducing uncertainty space?

Proxy Building

GP regression



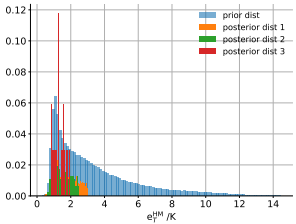




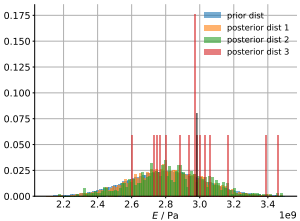
- neglecting parameters has nearly no influence
- proxy quality worse for all uniform sampling

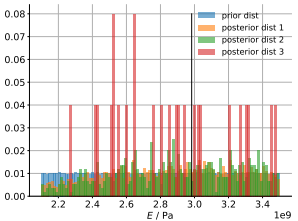
Monte-Carlo Sampling/HM-filtering 1

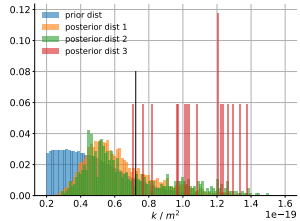
- sampling on proxy
- sample size: 200 000
- HM: filtering with three test filters
- allows also for parameter estimation

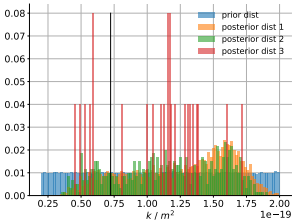


History Match Filtering2: Parameter estimation







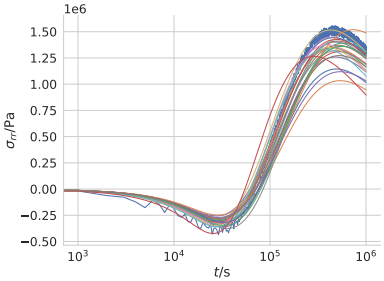


$\Rightarrow$ interactions?

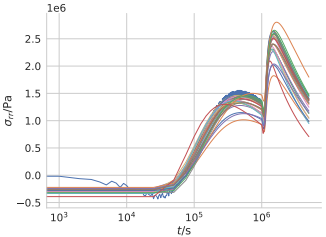
Forecast

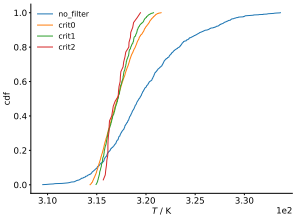
- Real model runs with history match

Ana for HM-match

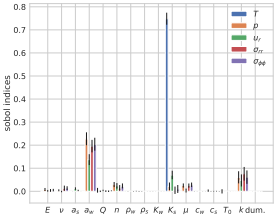


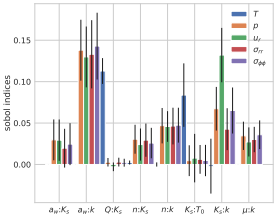
FE-run using OpenGeoSys for forecast with altered BC



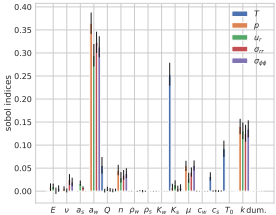


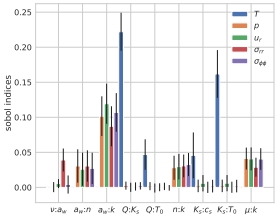
S1/S2 based on prior bounds





S1/S2 based on posterior bounds





Summary/Conclusion

- Application of DoE based history-matching to THM model for purpose of UQ/SA in the field of radioactive waste management
- uncertainty space can be reduced by knowledge of a-priori distributions
- significant epistemic uncertainties in these systems are unavoidable
- however specific parameter distributions have only a minor influence on the output
- filter must be chosen with care
- filter effect is also significant for GSA

Outlook:

- application to real experiments already taking place at Mt. Terri URL site
- investigation of impact cross-scale heterogeneities