Predicting Optimal Borehole Locations for Parameter Estimation in Geothermal Reservoirs Using Optimal Experimental Design

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Parameter estimation with inverse methods is a crucial step in geothermal reservoir modeling. Often, pethrophysical parameters such as permeability or thermal conductivity have to be estimated from sparse borehole observation data such as temperature or pressure. Here, the spatial location of the borehole (i.e. the observation data) within the model domain plays an important role for the quality of the inversion result (e.g. Rath et al. 2006). Previous studies explained the formulation and implementation of this mathematical optimization problem and demonstrated its feasibility for finding borehole locations in two- and three-dimensional reservoir models that minimize the uncertainty of estimating hydraulic permeability of a model unit from temperature measurements by deterministic inversion (Padalkina et al. 2013, Seidler et al. 2016). Various OED techniques are implemented in the Environment for Combining Optimization and Simulation Software (EFCOSS) (Seidler et al. 2014, Rasch & Bücker 2010). To address problems arising from geothermal modeling, this software framework links mathematical optimization software with SHEMAT-Suite, a geothermal simulation code for fluid flow and heat transport through porous media.

The aim of this master project is to study the sensitivity of this OED approach to factors such as measurement errors and a priori data density on a set of synthetic reservoir models. The models should differ in complexity, main heat transport processes or boundary conditions. This will additionally allow for investigating the effect of the geothermal reservoir type on OED simulations.

References:

Padalkina K, Bücker HM, Herty M, Rath V, Seidler R, 2013. Model identification for flow simulations in geothermal reservoirs: towards optimally drilling boreholes, Proc. Appl. Math. Mech., 13(1):345.

Rasch A, Bücker HM, 2010. EFCOSS: An Interactive Environment Facilitating Optimal Experimental Design, ACM Transactions on Mathematical Software, 37(2).

Rath V, Wolf A, Bücker HM, 2006. Joint three-dimensional inversion of coupled groundwater flow and heat transfer based on automatic differentiation: sensitivity calculation, verification, and synthetic examples, Geophys. J. Int., 167:453-466.

Seidler R, PadalkinaK, Bücker HM, Ebigbo A, HertyM, Marquart G, Niederau N ,2016. Optimal experimental design for reservoir property estimates in geothermal exploration. Comput Geosci, 20:375-383.

Seidler R, Bücker H, Rostami M, Neuhäuser D, 2014. On the Design of the EFCOSS Software Architecture When Using Parallel and Distributed Computing, In: Proceedings of the 9th International Conference on Software Engineering and Applications (ICSOFT-EA-2014), pp 445-454.

Skill

Programming 3/5 (Python, Fortran, Bash)

Fieldwork 0/5

Laboratory work 0/5

Theory 4/5 (Inversion, OED)

Processing 5/5 (e.g. with Pyhon or Matlab)

Interpretation 5/5

Geology 3/5 (Geothermal reservoir types and parameters)

Opportunity

Approved Further Education / Training	No
Training with particular software	Yes (SHEMAT-Suite, EFCOSS)
Training with particular hardware	Yes (RWTH Compute Cluster)
Temporary relocation at a research partner	No
Temporary relocation for fieldwork	No
Coverage of costs relocation/accommodation/expenses	No
Local assistance (e.g. housing) provided	No
Publication possible	Yes

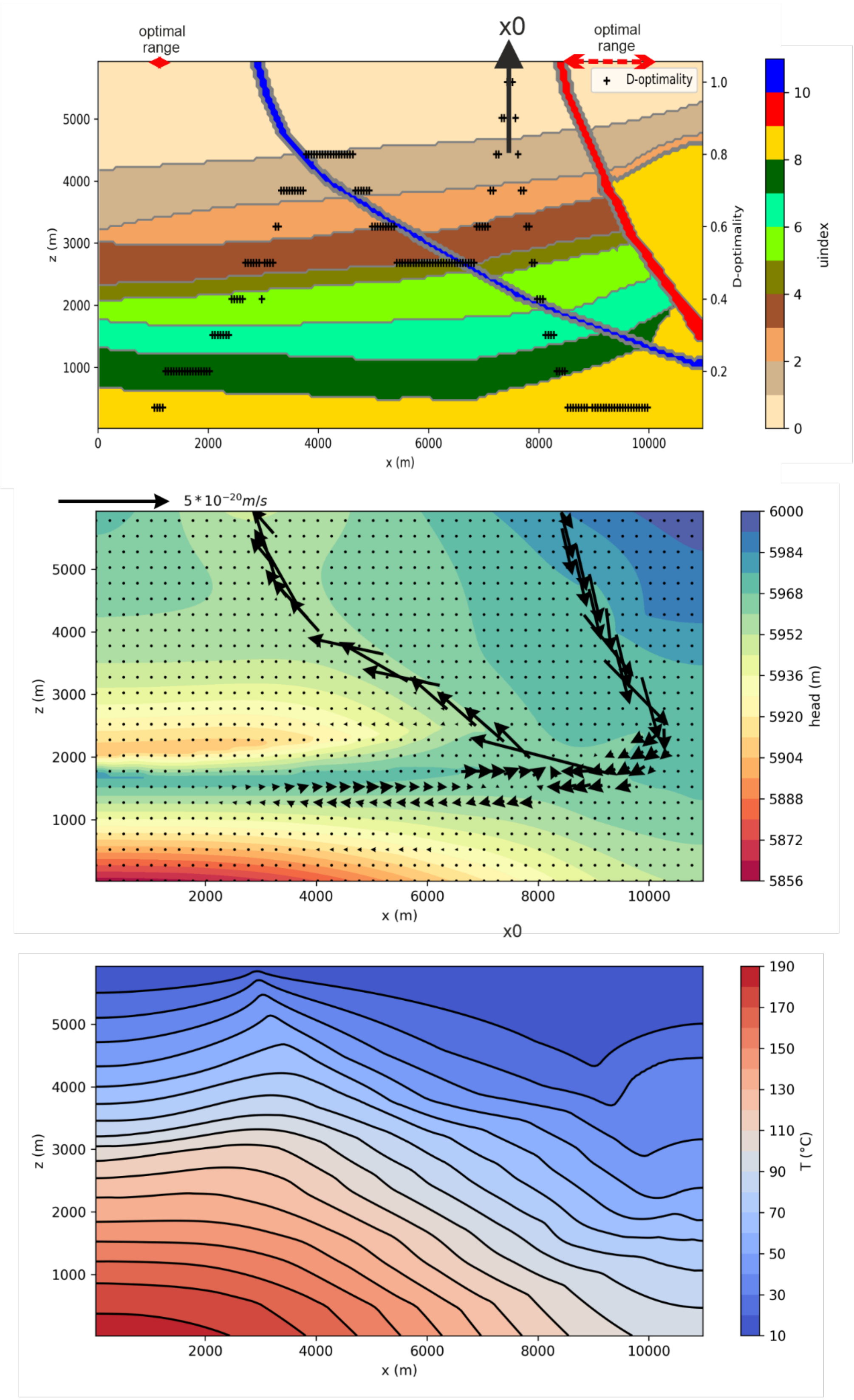

Fig. 1: Numerical forward model of a synthetic geothermal reservoir above a salt diapir computed with SHEMAT-Suite Top: Reservoir structure in terms of geological model units, unit 9 in yellow is the salt and units 10 and 11 in red and blue are permeable faults. The remaining units are various sedimentary layers. X0 marks the location of the existing borehole and the black crosses depict the OED result in terms of normalized and binned D-optimality. Red arrows display two optimal ranges for an additional borehole. Middle: Darcy flow in terms of hydraulic reference head and darcy velocity (arrows) for the true reservoir properties. Bottom: Steady state temperature distribution for the true reservoir properties.