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OGS#PETSc approach for robust and efficient simulations of strongly coupled hydrothermal processes in EGS reservoirs

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A robust and computationally efficient solution is important for 3D modelling of EGS reservoirs. This is particularly the case when the reservoir model includes hydraulic conduits such as induced or natural fractures, fault zones, and wellbore open-hole sections. The existence of such hydraulic conduits results in heterogeneous flow fields and in a strengthened coupling between fluid flow and heat transport processes via temperature dependent fluid properties (e.g. density and viscosity). A commonly employed partitioned solution (or operator-splitting solution) may not robustly work for such strongly coupled problems its applicability being limited by small time step sizes (e.g. 5-10 days) whereas the processes have to be simulated for 10-100 years. To overcome this limitation, an alternative approach is desired which can guarantee a robust solution of the coupled problem with minor constraints on time step sizes.

In this work, we present a Newton-Raphson based monolithic coupling approach implemented in the OpenGeoSys simulator (OGS) combined with the Portable, Extensible Toolkit for Scientific Computation (PETSc) library. The PETSc library is used for both linear and nonlinear solvers as well as MPI-based parallel computations. The suggested method has been tested by application to the 3D reservoir site of Groß Schönebeck, in northern Germany. Results show that the exact Newton-Raphson approach can also be limited to small time step sizes (e.g. one day) due to slight oscillations in the temperature field. The usage of a line search technique and modification of the Jacobian matrix were necessary to achieve robust convergence of the nonlinear solution. For the studied example, the proposed monolithic approach worked even with a very large time step size of 3.5 years.