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Simulator-based Bayesian inference of enhanced geothermal reservoir properties

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Estimates of in-situ geothermal reservoir properties are essential for many scientific, operational, and regulatory purposes, including the controlling and managing of the potentially induced seismicity. We present first results of our research that combines results from a forward 3D viscoelastic damage rheology model (DRM) with a Bayesian Optimization with Likelihood-Free Inference (BOLFI) algorithm. We demonstrate the efficiency of this tool to invert for a wide range of structural and seismo-hydro-mechanical parameters supported by the DRM solver. The comparatively expensive forward calculations done with the Hydro-PED Finite-Element solver simulate hydro-mechanical interactions including the evolution of deformation, stress, rock damage, permeability, and fluid flow in response to the ambient conditions and the engineered overpressurization. Estimating the distributions of selected key parameters by comparing the results of the Hydro-PED model with observed, or here, synthetic, quantities is feasible because the machine learning BOLFI tool is a sample-efficient algorithm that minimizes the required iterations. In this work we set up a synthetic proof-of-concept case and infer the posterior distribution of the ambient stress conditions. We show that an arbitrarily chosen potency target function which encodes the spatial distribution of energy release within the reservoir produces more accurate results of the ambient principal stress values compared to a simpler event count target function. In our discussion we emphasize that the employed misfit function can be tailored to couple phenomena across multiple spatial and temporal scales observed during an hydraulic stimulation experiment. We discuss potential solutions to the computational challenges including GPU architectures and intermediate emulator stages that are advantageous to increase the resolution of the reservoir feedback processes. We conclude with an outlook on how simulator-based inference can be used to test and refine hypotheses on reservoir behavior before, during, and after stimulation for more effective EGS implementations.

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