Predicting Long-Term Thermal Performance in Enhanced Geothermal Systems from Short-Term Tracer Tests

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Predicting the thermal performance of an enhanced geothermal system (EGS) requires a comprehensive characterization of the underlying fracture flow patterns from practically available data such as tracer data. However, due to the inherent complexities of subsurface fractures and the generally insufficient geological/geophysical data, interpreting tracer data for fracture flow characterization and thermal prediction remains a challenging task. The present study aims to tackle the challenge by leveraging a data assimilation method to maximize the utilization of information inherently contained in tracer data, and meanwhile maintain the flexibility to handle various uncertainties. A tracer data interpretation framework was proposed with the following three components integrated: (a) We use principal component analysis (PCA) to reduce the dimensionality of model parameter space. (b) We use ES-MDA (ensemble smoother with multiple data assimilation) to invert for fracture aperture/flow fields and obtain posterior model ensembles for uncertainty quantification. Various data types are assimilated jointly to improve the predictive ability of the posterior ensemble. (c) The inverted fracture aperture fields are then incorporated into reservoir models to predict thermal performance. We developed a field-scale EGS model to verify the ability of the framework to characterize highly heterogeneous fracture aperture/flow fields and predicting thermal performance. We also applied the framework to a mesoscale field experiment to demonstrate its potential application in real-world geothermal reservoirs. The results indicate that the proposed framework can effectively retrieve fracture flow information from tracer data for thermal prediction and uncertainty quantification, and thus provide informative guidance for EGS optimization and risk management.

10 Aug 2023

3:30 p.m.

Conference Room, 3/F, Mong Man Wai Building

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