MPITOUGH2-EMGEO – A MASSIVELY PARALLEL DATA INVERSION FRAMEWORK FOR JOINT HYDROGEOPHYSICAL REAL-WORLD APPLICATIONS

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iTOUGH2 (inverse TOUGH2) is an inversion framework that provides inverse modeling capabilities for TOUGH2, a general-purpose hydrogeological simulator for multiphase, multicomponent, non-isothermal flows in multidimensional fractured-porous media. TOUGH2 employs integral finite differences for the spatial discretisation, while time is discretised in a fully implicit way using first-order finite differences. We have developed a massively parallel version, MPiTOUGH2, which realizes a hierarchically parallel architecture by distributing both the model domain and the data domain among a large number of parallel processes. Distributing the data domain involves distributing multiple inversion realizations, as carried out in stochastic analysis. This scheme maximizes scalability, particularly important for merging the hydrological simulator with a geophysical simulator for the purpose of large-scale hydrogeophysical inverse problems. EMGeo is a 3D finite-difference modeling/inversion framework for geophysical data types, currently including controlled-source electromagnetic, magnetotelluric, electrical resistivity tomography, (spectral) induced polarization, and gravity. It has been applied extensively by industry and academia to large-scale hydrocarbon exploration, geothermal and environmental studies. We have developed a combined inversion framework MPiTOUGH2-EMGeo that allows for investigation of coupled hydrogeophysical processes with high-fidelity, typically occurring in the context of geologic CO2 storage, geothermal system characterization, and environmental remediation and monitoring applications. We investigate two coupling approaches. In the first approach, a direct coupling through a petrophysical model is used in order to merge hydrological tracer borehole measurements with field-scale geophysical data. The suite of methods provided by EMGeo can be exploited to incorporate multiple geophysical data types in the hydrogeophysical inverse problem. The second approach involves a looser coupling of hydrological and geophysical attributes through common-structure constraints, also referred to as cross-gradient constraints. The methods are demonstrated by carrying out realistic feasibility studies based on DOE's Integrated Field Research Challenge Site at Rifle, Colorado, for the purpose of monitoring remediation efforts in a shallow unconfined aquifer.