CO₂ Storage Optimization under Geomechanical Risk and Prediction Uncertainty Using Coupled-Physics Models

The team developed a novel framework for optimization of geologic CO₂ storage under geomechanical risks, where coupled flow-geomechanics simulations are used to quantify the risks of injection-induced ground surface deformation and rock failure in reservoir and caprock layers. A multi-objective optimization problem was formulated and solved to maximize CO₂ storage while minimizing the two forms of geomechanical risks: ground surface uplift and induced seismicity due to rock failure. The optimization decision variables include the design parameters, mainly locations of injection wells. In general, the injection rates or pressure can also be added to further enhance the optimization results. Multiple numerical experiments with increasing complexity were presented to demonstrate the performance of the proposed framework, and multiple well scenarios were studied for investigating the storage limit related to the geomechanical risks.

Reservoir Grid
Accomplishments:
The team presented a new optimization framework for CO₂ storage under geomechanical risks, including ground surface uplift and rock failure that can lead to induced seismicity. Specifically, optimization strategies are sought for maximizing the amount of CO₂ that is stored in a geologic formation, while minimizing geomechanical risk measures. Rigorous coupled flow and geomechanical simulation is adopted to quantify the amount of CO₂ storage and the risks associated with ground surface uplift and rock plastic strain. The CO₂ storage and the two geomechanical risk measures constitute the three objective functions that are included in the multi-objective optimization framework. Several numerical experiments were conducted to demonstrate the application of the developed multi-objective optimization framework to CO₂ storage problem for a different number of wells. The results indicate that different well configurations can be selected with and without including geomechanical risks in the optimization problem.

NETL Collaboration:
The researchers received input from NETL researchers regarding modeling, simulation, and risk assessment aspects of geologic CO₂ storage. Their collaboration was primarily focused on discussing their approach and assumptions in developing the coupled physics modeling and risk assessment aspects of the project. They received information about the activities of the NRAP team and discussed the possibility of benchmarking their framework using models used by this team. Discussions led to making reasonable assumptions in constructing the models, including model dimensions, boundary conditions, and modeling rock property distributions. Based on results and discussion with NETL research personnel, the team identified important parameters, with appropriate description of their heterogeneity, which they included in their micro-seismic data integration formulation. They received the field model for Farnsworth, which is related to a CO₂-EOR project, to test their developed methods. They adapted the model into a coupled flow and geomechanical simulation model and used it for testing their algorithms.

Relevant Presentation:

https://sites.psu.edu/ucfer