the ENERGY lab

PROJECT FACTS

Carbon Storage – GSRA

Training and Research on Probabilistic Hydro-Thermo-Mechanical Modeling of Carbon Dioxide Geological Sequestration in Fractured Porous Rocks

Background

Fundamental and applied research on carbon capture, utilization and storage (CCUS) technologies is necessary in preparation for future commercial deployment. These technologies offer great potential for mitigating carbon dioxide (CO_2) emissions into the atmosphere without adversely influencing energy use or hindering economic growth.

Deploying these technologies in commercial-scale applications requires a significantly expanded workforce trained in various CCUS technical and non-technical disciplines that are currently under-represented in the United States. Education and training activities are needed to develop a future generation of geologists, scientists, and engineers who possess the skills required for implementing and deploying CCUS technologies.

The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL), through funding provided by the American Recovery and Reinvestment Act (ARRA) of 2009, manages 43 projects that received more than $12.7 million in funding. The focus of these projects has been to conduct geologic storage training and support fundamental research projects for graduate and undergraduate students throughout the United States. These projects include such critical topics as simulation and risk assessment; monitoring, verification, and accounting (MVA); geological related analytical tools; methods to interpret geophysical models; well completion and integrity for long-term CO_2 storage; and CO_2 capture.

Project Description

NETL has partnered with the Colorado School of Mines to conduct research and training to develop and validate an advanced CCUS three-dimensional (3-D) probabilistic simulation and risk assessment model. CCUS simulation and risk assessment is used to develop advanced numerical simulation models of the subsurface to forecast CO_2 behavior and transport; optimize site operational practices; ensure site safety; and refine site monitoring, verification, and accounting efforts. As simulation models are refined with new data, the uncertainty surrounding the identified risks decrease, thereby providing more accurate risk assessment. The 3-D models take into account the full coupling of multiple physical processes (geomechanical, thermal, and fluid flow) and describe the effects of stochastic hydro-thermo-mechanical (HTM) parameters on the modeling of CO_2 flow and transport in fractured porous rocks. Graduate students are involved in the development and validation of the 3-D model that can be used to predict the fate, movement, and storage of CO_2 in subsurface formations, and to evaluate the risk of potential leakage to the atmosphere and underground reservoirs.

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PROJECT DURATION

Start Date
12/01/2009

End Date
5/31/2013

COST

Total Project Value
$297,505

DOE/Non-DOE Share
$297,505 / $0

Government funding for this project is provided in whole or in part through the American Recovery and Reinvestment Act.

U.S. DEPARTMENT OF ENERGY

The scope of the project includes:

- Formulating a rigorous procedure to couple the 3-D hydraulic, thermal, and mechanical modeling of CO_2 storage reservoirs using Biot's theory for fluid flow in deformable porous media.
- Implementing a model for 3-D hydro-mechanical behavior of fractured porous rocks with random fracture geometries based on Oda's crack tensor formulation.
- Developing a Monte Carlo-based risk assessment procedure (Figure 1) for assessing the effects of uncertainties in the predictions of the fate and movement of CO_2 in storage reservoirs and the risks associated with the potential leakage of CO_2 to the atmosphere and underground reservoirs.
- Testing and validating models using available data and case histories of geological storage of CO_2.

Goals/Objectives

The primary objective of the DOE's Carbon Storage Program is to develop technologies to safely and permanently store CO_2 and reduce Greenhouse Gas (GHG) emissions without adversely affecting energy use or hindering economic growth. The Programmatic goals of Carbon Storage research are: (1) estimating CO_2 storage capacity in geologic formations; (2) demonstrating that 99 percent of injected CO_2 remains in the injection zone(s); (3) improving efficiency of storage operations; and (4) developing Best Practices Manuals (BPMs). This project seeks to evaluate the storage permanence of CO_2 in fractured, porous rock. Specific project goals include:

- To use research projects as a means to educate and train students in the science and technology of CCUS, with a focus on geologic storage.
- To investigate an advanced CCUS 3-D simulation and risk assessment model that can be used to predict the fate, movement, and storage of CO_2 in underground formations.
- To evaluate the risk of potential CO_2 leakage to the atmosphere and underground aquifers.

Accomplishments

- As of March 2012, two students had accumulated 1,040 training-related hours under the program.
- Work has started on the coupled simulation of fluid flow and geomechanics of CO_2 geologic storage in fractured porous rocks though the use of the TOUGH2 and FLAC codes.
- Work has continued on the implementation and validation of a stress-strain model for fractured porous rock masses based on the Oda crack tensor. The mathematical formulation of the elasto-plastic model implemented in the finite difference code FLAC (Fast Lagrangian Analysis of Continua) for geomechanical modeling. The implemented model is being validated against problems on the stress-strain response of fractured rocks with known analytical solutions.
- Research continues on the study of the effects of statistical representations of fracture geometry using different Probability Distribution Functions (PDFs) on the anisotropically elasto-plastic behavior of fractured rock masses.
- Work was completed on the two-dimensional stochastic fluid modeling of the flow and transport of CO_2 in saline reservoirs using the multiphase fluid flow computer code TOUGH2. Pre-and post-processing computer codes were written to implement Monte Carlo Simulations (MCS) techniques to simulate the effects of stochastic or random aquifer properties on the transport of CO_2 in saline reservoirs. Initial results were obtained for both the short term and long term response of CO_2 injection in saline reservoirs. The two-phase fluid flow models were also validated against experimental data on injection of supercritical CO_2 in rock core samples under deep aquifer conditions.

Benefits

The overall result of the project will make a vital contribution to the scientific, technical, and institutional knowledge necessary to establish frameworks for the development of commercial-scale CCUS. Further, it will provide an improved understanding of the behavior of CO_2 in storage reservoirs which will supply the basis for developing a better model that can reliably and accurately predict the different hydraulic, thermal, and geomechanical process involved in the permanent geologic storage of CO_2. It is envisioned that the project's proposed simulation and risk assessment model will become an important tool in the planning, design, and management of future CCUS projects. Additionally, the project will offer research opportunities to graduate students who will be well-trained in the skills and competencies required to implement CCUS technologies on a commercial-scale.

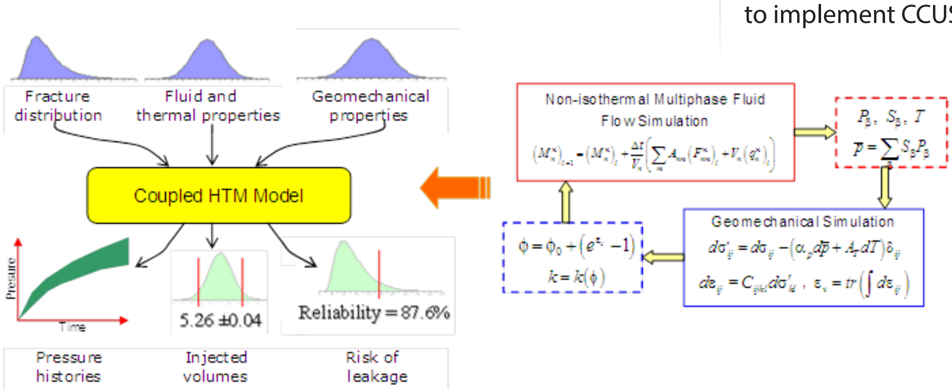

Figure 1. Monte-Carlo Based Probabilistic Hydro-Thermo-Mechanical Modeling of Carbon Dioxide Geological Carbon Storage in Fractured Porous Rocks.