the ENERGY lab

PROJECT FACTS

Carbon Storage – ARRA - GSRA

Web-based CO_2 Subsurface Modeling

Background

The overall goal of the Department of Energy's (DOE) Carbon Storage Program is to develop and advance technologies that will significantly improve the effectiveness of geologic carbon storage, reduce the cost of implementation, and prepare for widespread commercial deployment between 2020 and 2030. Research conducted to develop these technologies will ensure safe and permanent storage of carbon dioxide (CO_2) to reduce greenhouse gas (GHG) emissions without adversely affecting energy use or hindering economic growth.

Geologic carbon storage involves the injection of CO_2 into underground formations that have the ability to securely contain the CO_2 permanently. Technologies being developed for geologic carbon storage are focused on five storage types: oil and gas reservoirs, saline formations, unmineable coal seams, basalts, and organic-rich shales. Technologies being developed will work towards meeting carbon storage programmatic goals of (1) estimating CO_2 storage capacity +/- 30 percent in geologic formations; (2) ensuring 99 percent storage permanence; (3) improving efficiency of storage operations; and (4) developing Best Practices Manuals. Developing and deploying these technologies on a large scale will require a significantly expanded workforce trained in various carbon capture and storage (CCS) 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 CCS technologies.

The 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 that focus on conducting geologic storage training and support fundamental research projects for graduate and undergraduate students throughout the United States. The training and projects can be categorized under one or more of the DOE Carbon Storage Program's five Technology Areas: (1) Geologic Storage and Simulation and Risk Assessment (GSRA), (2) Monitoring, Verification, Accounting (MVA) and Assessment, (3) CO_2 Use and Re-Use, (4) Regional Carbon Sequestration Partnerships (RCSP), and (5) Focus Area for Sequestration Science. This training effort is conducting research and training to develop a web-based technology that runs geologic simulations on a network cluster.

Project Description

NETL partnered with San Diego State University (SDSU) to develop a user-friendly Rich Internet Application (RIA) using cutting-edge Asynchronous JavaScript and XML (AJAX) Web technologies to run existing geologic storage simulation software modules on a network-accessible cluster of machines. This online simulation application includes comprehensive chemical and physical processes relevant for modeling geologic CO_2 storage systems. The modeling includes capabilities to simulate diffusive, advective, tortuous, and dispersive mass-transfer, and includes a comprehensive database of solid-phase and aqueous species properties with support for both kinetic and equilibrium reactions. The interface allows users to graphically define a computational domain, specify boundary conditions, specify relevant reaction mechanisms, define mineral properties, and investigate the long term fate of stored CO_2 in geologic formations. The

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PARTNERS

Sienna Geodynamics and Consulting, Inc.

PROJECT DURATION

Start Date	End Date
12/01/2009	11/30/2012

COST

Total Project Value
$299,993

DOE/Non-DOE Share
$299,993 / $0

PROJECT NUMBER

DE-FE0002069

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

Web-based simulator uses existing codes donated by Sienna Geodynamics. SDSU developed a graduate-level course based around learning and implementing the codes. The overall project effort to develop the Internet-capable interface included:

- Creating a Graphical User Interface (GUI) with Web-Service capabilities for simulator input to existing codes that model water/rock chemical reactions in a fractured CO_2 geologic storage environment.
- Developing a cross-disciplinary class available over the Internet that uses data from existing and proposed sites as model inputs.
- Investigating a way of adapting other codes (finite difference and finite element) to examine geomechanical and potential surface deformation effects of injected 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 GHG emissions without adversely affecting energy use or hindering economic growth. This project helped to reach this Programmatic goal through research and modeling of geochemical, geomechanical, and surface deformation effects that result from CO_2 injection. These effects play a key role in tracking CO_2 in the subsurface and understanding its behavior to ensure efficient and permanent CO_2 storage. Specific objectives of the project included:

- Creation of an AJAX Web application and associated Simple Object Access Protocol (SOAP)-based Web Services that provides users an ability to model and numerically simulate water-rock chemical reactions using only a standard Web browser (Figure 1).
- Development of a cross-disciplinary graduate course on CCS that includes having the students using the Web application to simulate the advection and diffusion of injected CO_2 rich water in depleted sandstone reservoirs.

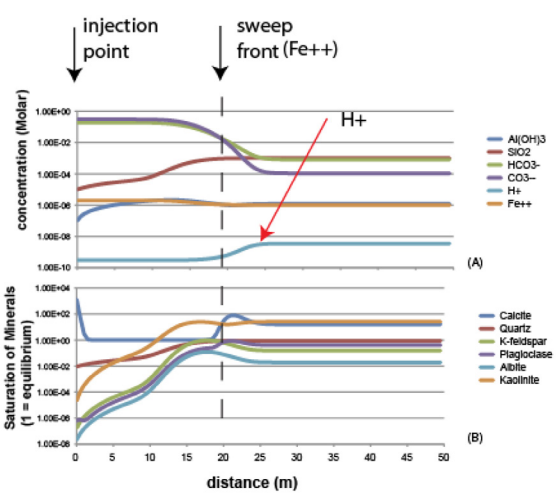

Figure 1. Example of chemical-based simulation and modeling as a function of distance from the injection wellbore. Web-based simulations, as shown, were taken from modeling of the CO_2 injection in the Frio Formation.

- Integration of rock fracture dynamics, multi-phase flow, and heat-transfer codes being developed at SDSU together with an already developed water-rock interaction code.

Accomplishments

- At the conclusion of the project, two students had accumulated 1,621 training-related hours under the program. Additionally, the project led to the successful training of three new computational science students and one geological science student in technologies relevant to carbon storage and problems related to flow in subsurface media.
- Developed a Web-based interface that is publically accessible via URL http://symc.sdsu.edu/ (Figure 2). The interface enables rapid prototyping of CO_2 injection scenarios and allows students without advanced knowledge of geochemistry to set up a typical storage scenario, invoke a simulation, analyze results, and then vary one or more problem parameters and quickly re-run a simulation to answer what-if questions.
- Used web-based application to develop a new computational science course at San Diego State University, *COMP 670: Numerical Simulation of CO_2 Sequestration*. The class introduces graduate students to CCS through numerical modeling and simulation, and teaches students how to interpret simulation results to make predictions about long-term CO_2 storage capacity in deep brine reservoirs.
- A final report has been completed and is now available.

Benefits

Overall, the project made a vital contribution to the scientific, technical, and institutional knowledge necessary to establish frameworks for the development of commercial-scale CCS, particularly in the simulation and modeling of the fate of injected CO_2 in subsurface geologic systems. The resulting simulation package provides a new, flexible, user-friendly, and innovative foundation for CO_2 modeling that contributes to the storage goals of 99 percent storage permanence as well as storage capacity estimation. Additionally, the project has helped to train students in the skills and competencies that are required from a workforce needed to implement CCS technologies on a commercial-scale.

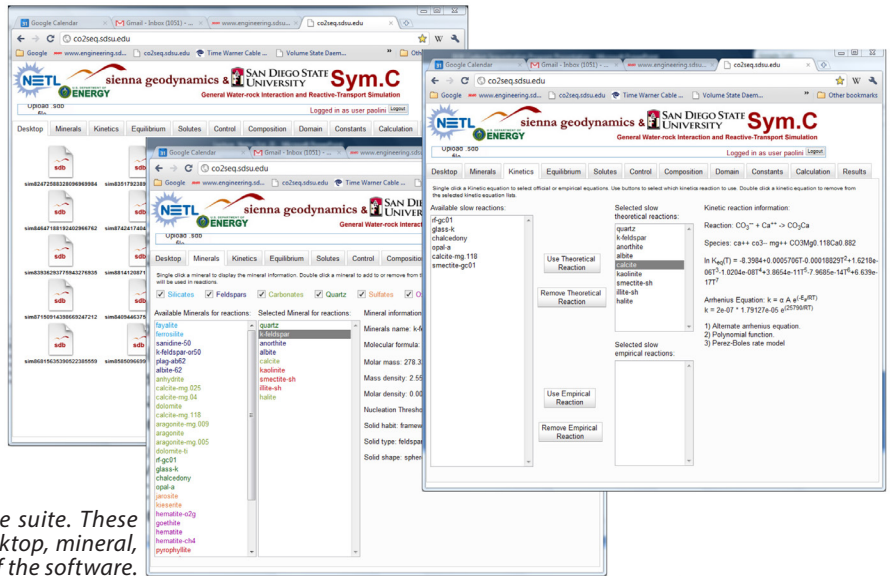

Figure 2: Screenshots from the Sym.C software suite. These screenshots demonstrate the drag and drop desktop, mineral, and kinetic reaction specification capability of the software.