

## **A Numerical Simulation Framework for the Design, Management and Optimization of CO<sub>2</sub> Sequestration in Subsurface Formations**

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**Sponsor:** Global Climate and Energy Project

**Description:** Based on the current understanding of associated risks and costs, the sequestration of CO<sub>2</sub> in subsurface formations, including deep saline aquifers and depleted oil and gas reservoirs, appears to be a viable option for CO<sub>2</sub> disposal. However, in order to operate efficiently and responsibly, a deeper understanding of the process and key interactions, as well as significant advances in modeling capabilities, are essential.

The goal of this project is the development of numerical procedures suitable for the design, management and optimization of real-world CO<sub>2</sub> sequestration projects. Toward this aim, we plan to develop accurate and computationally efficient numerical techniques to describe in detail the physical mechanisms relevant to CO<sub>2</sub> sequestration. This will entail the development of scalable (i.e., efficient for large-scale problems) algorithms that will enable field-scale modeling and optimization of CO<sub>2</sub> sequestration sites. We are using a flexible, modular, object-oriented computational platform as a delivery vehicle for the formulations and numerical methods we develop. This will allow us, as well as other investigators, to readily extend the software capabilities, both in terms of physical models and integrated functionality, as required in the future.

The physical and numerical modeling issues arising in CO<sub>2</sub> sequestration are closely related to the modeling of flow in oil and gas reservoirs. Both processes involve complex multiphase flow and transport in heterogeneous subsurface formations, with formation properties varying on a variety of length scales. We have recently developed an object-oriented general purpose research simulator (GPRS), which has quickly become a widely used research platform [1]. This simulator provides an ideal foundation for our CO<sub>2</sub> sequestration code and will enable us to immediately apply developments in reservoir simulation technology to the modeling of CO<sub>2</sub> sequestration.

The time frame for the proposed work is three years and will involve, in addition to the PIs, four PhD students (three in the Petroleum Engineering Department at Stanford and one student at the Institute of Fluid Dynamics at ETH Zurich, Switzerland), and a post-doctoral researcher at Stanford.

**Status:** We have recently introduced several extensions into our general purpose research simulator that will enable the efficient modeling of CO<sub>2</sub> sequestration in subsurface formations. These include a more efficient treatment of phase behavior calculations (explicit flash model) and advances in the adaptive implicit formulation. Testing of these options and evaluation of the

performance of the simulator on benchmark CO<sub>2</sub> sequestration problems is underway. In addition, we have begun investigating the application of recently developed multiscale procedures [2] for modeling CO<sub>2</sub> sequestration. In the near future, we plan to extend and apply optimization procedures [3] developed within the context of reservoir simulation to CO<sub>2</sub> injection operations.

**References:**

[1] Cao, H. 2002. *Development of techniques for general purpose simulators*. PhD thesis, Stanford University.

[2] Jenny, P., Lee, S. H., Tchelepi, H. A. 2003. Multiscale finite-volume method for elliptic problems in subsurface flow simulation. *J. Comp. Phys.* 187:47–67.

[3] Sarma, P., Aziz, K., Durlofsky, L. J. 2005. Implementation of adjoint solution for optimal control of smart wells. SPE paper 92864 presented at the SPE Reservoir Simulation Symposium, Houston, Jan. 31 – Feb. 2.

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