Thrust Area 5: Carbon Capture & Nuclear

Creation of Carbon Sequestration Data, Technologies and Professional Cohorts for Florida

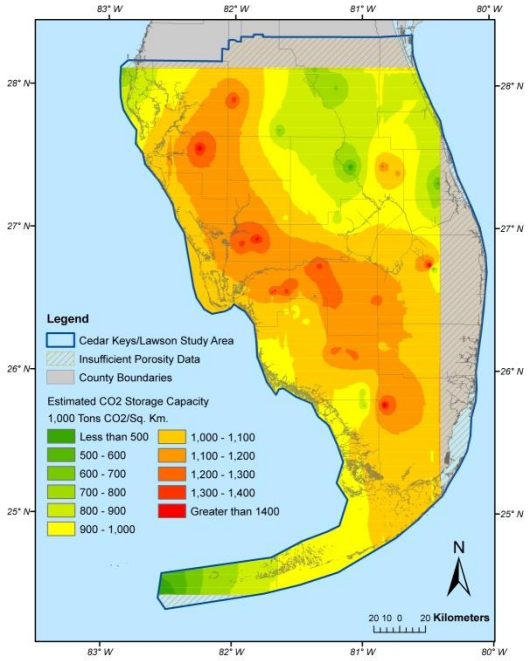
PI: Mark Stewart **Co-PIs:** Jeffrey Cunningham, Maya Trotz
Students: Arlin Briley, PhD, Mark Thomas, PhD

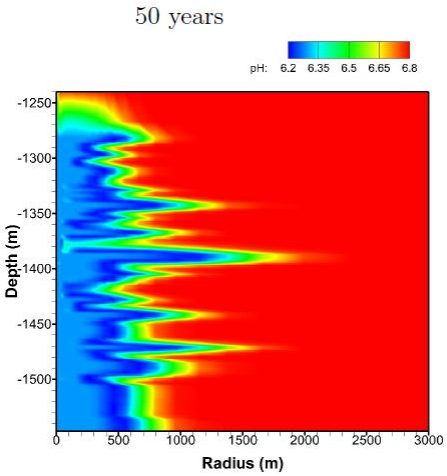
Description: Rising concerns over increasing levels of greenhouse gases, especially carbon dioxide, have led to suggestions to capture carbon dioxide at fixed sources, such as fossil fuel power plants, and sequester the carbon for millennia by injecting it underground. Florida overlies many thousands of feet of carbonate rocks which may be suitable for geologic sequestration of carbon dioxide. This project is investigating the potential for geologic sequestration of carbon dioxide in Florida, the physical and chemical changes that may occur as a result of injection, assess the potential for escape of injected carbon dioxide, determine the risk, if any, to aquifer systems used for water supplies, develop methodologies for Florida utilities to predict the performance and risks of proposed sequestration projects, and educate a cohort of geologic sequestration professionals to create a carbon sequestration industry in Florida. This project has graduated two PhD students, Tina Roberts-Ashby, US Geological Survey, and Roland Okwen, Illinois State Geological Survey, one post-doctoral student, Anwar Shadab, Missouri University of Science and Technology, and currently supports two PhD students.

Budget: $479,640
Universities: USF
External Collaborators: TECO, RTI, ECT, DOE

Progress Summary

Progress continues on the collaboration with Tampa Electric Co, DOE and RTI on the carbon sequestration and wastewater injection pilot project at the Polk Power Station (PPS). The total DOE funding for this project is $160 million. USF is responsible for the mathematical modeling of the pilot carbon sequestration and wastewater injection project at the PPS. In conjunction with this project, USF has a continuing grant through Tampa Electric/ECT Inc that currently supports two PhD students. Four refereed publications on carbon sequestration appeared in print in 2011, one is in press, and one is in review. Ten presentations on research results were given at national and regional meetings by faculty members and graduate students. A proposal was submitted to DOE to investigate an innovative and potentially very important conjunctive injection of carbon dioxide and wastewater and is in review. This proposed project would provide a new source of potable water, help municipalities deal with wastewater disposal, increase the efficiency and safety of carbon sequestration, and reduce costs through shared facilities. This proposal would leverage current Federal funding at the PPS project. Two USF GCS PhD students, Tina Roberts-Ashby, USGS, Washington, DC, and Roland Okwen, Illinois State Geological Survey/Univ Illinois, are continuing to collaborate with the USF Carbon Sequestration Group on GCS research. The USF GCS group has achieved international recognition through its refereed publications in international journals and presentations at national meetings. As a result of USF GCS Group work, Florida was selected for one of the few DOE funded carbon sequestration pilot projects in the US. The USF GCS group will continue to attempt to leverage the existing funding at PPS to further funded research and graduate training in carbon sequestration.





Funds leveraged/new partnerships created: The USF Geological Carbon Sequestration (GCS) group has a continuing collaborative relationship with Tampa Electric and DOE to provide mathematical modeling expertise for the DOE-funded carbon sequestration and wastewater injection project at the Polk Power Station in Polk County, Florida. This collaboration provides research funding and training for two PhD students, Arlin Briley and Mark Thomas. This project was used as leverage for a proposal submitted to DOE in September, 2011, to investigate the conjunctive injection of wastewater from a reverse osmosis plant and CO2 captured at the Polk Power Station. Municipal wastewater from the City of Lakeland will be treated to potable water standards in a reverse osmosis plant. Ninety percent of the original wastewater will become potable water, and the 10% reject water from the RO plant will be injected in a deep well after CO2 injection. Preliminary modeling suggests that the waste water injection transfers the CO2 from a supercritical gas phase to a dissolved phase, safely sequestering it for millennia. This process could provide for efficient wastewater reuse, safe CO2 sequestration, and lowered costs through shared facilities.

2011 Annual Report

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Publications:
In 2011 four refereed publications appeared in print, one has been accepted, and one is in review. Two articles are in the *International Journal of Greenhouse Gas Control,* and one each in *Transport in Porous Media*, *Computational Geoscience*, *International Journal of Remote Sensing*, and *Chemical Geology*.

Okwen R, Stewart M, Cunningham JA. 2011. Effect of well orientation (vertical vs. horizontal) and well length on the injection of CO2 in deep saline aquifers. *Transport in Porous Media*, 90(1), 219-232. doi: 10.1007/s11242-010-9686-5.

Okwen R, Stewart M, Cunningham J. 2011. Analytical model for screening potential CO2 repositories. *Computational Geosciences*, 15(4), 755–770. doi: 10.1007/s10596-011-9246-2

Okwen R, Stewart M, Cunningham J. 2011. Temporal variations in near-wellbore pressures during CO2 injection in confined aquifers. *International Journal of Greenhouse Gas Control*, 5, 1140–1148. doi: 10.1016/j.ijggc.2011.07.011

Okwen R, Pu R, Cunningham JA. 2011. Remote sensing of temperature variations around major power plants as point sources of heat. *International Journal of Remote Sensing*, 32(13), 3791–3805. doi: 10.1080/01431161003774723.

Roberts-Ashby, Tina, Stewart, M., 2011. Evaluation of the Sunniland Formation of the South Florida Basin for carbon sequestration. *International Journal of Greenhouse Gas Control*, accepted 9/2011, in press.

Thomas MW, Trotz MA, Stewart M, Cunningham JA. Geochemical modeling of CO2 sequestration in deep, saline, dolomitic-limestone aquifers: 1, Critical evaluation of thermodynamic sub-models. Under review at *Chemical Geology*, submitted July 2011.

Presentations:
Faculty members and students presented 11 papers at national and regional meetings.

Anwar S (presenter), Cunningham JA, Trotz M, Thomas MW, Stewart M. Pore-scale modeling of reactive-multiphase-buoyant flow for carbon capture and storage. Presented at the 2010 Fall Meeting of the American Geophysical Union: December 13-17, San Francisco, California.

Roberts-Ashby, Tina (presenter), Stewart, M, 2010. Evaluation of the Cretaceous-Paleocene Cedar Keys-Lawson injection zone for geological carbon sequestration in Florida. Presented at the 2010 Fall Meeting of the American Geophysical Union: December 13-17, San Francisco, California.

Thomas MW (presenter), Briley A, Trotz M, Stewart M, Cunningham JA. Geochemical modeling of CO2 sequestration in deep saline aquifers in Florida. Presented at the 2010 Fall Meeting of the American Geophysical Union: December 13-17, San Francisco, California.

Cunningham JA (presenter), Trotz MA, Stewart MA, Goswami DY. , 2011. Potential for carbon capture and sequestration (CCS) in Florida. Presented at the 2011 AEESP Research and Education Conference: July 10-12, Tampa, Florida.

Anwar S (presenter), Cunningham JA, Trotz M, Thomas M, Stewart M., 2011. Pore-scale modeling of reactive multi-phase flow for carbon capture and storage. Presented at the 2011 AEESP Research and Education Conference: July 10-12, Tampa, Florida.

Anwar S, Cunningham J (presenter), Thomas M, Trotz M, Stewart M., 2011. Pore-scale modeling of reactive multi-phase flow for carbon capture and storage. Presented at the 242nd American Chemical Society National Meeting & Exposition: August 28 - September 1, Denver, Colorado.

Thomas MW, Cunningham J (presenter), Briley A, Trotz M, Stewart M., 2011. Geochemical modeling of CO2 sequestration in carbonate aquifers: Critical evaluation of thermodynamic models used to predict mineral dissolution and precipitation. Presented at the 242nd American Chemical Society National Meeting & Exposition: August 28 - September 1, Denver, Colorado.

Stewart M (presenter), Cunningham J, Trotz M, Okwen R, Thomas M, Briley A, 2011. Geochemical modeling of CO2 and wastewater injection to maximize sequestration efficiency. 2011 Aquifer Storage and Recovery Conference, American Ground Water Trust, September 12, Orlando FL

Cunningham J (presenter), Goswami DY, Stewart M, Trotz M. , 2011. Carbon capture and sequestration: Opportunities in Florida. Presented at the Florida Energy Systems Consortium (FESC) Summit: September 27-28, Gainesville, Florida.

Okwen R, Thomas M (presenter), Briley A, Stewart M, Trotz M, Cunningham J. , 2011. Simulation of alternating wastewater/CO2 injection into a deep saline aquifer. Presented at the Florida Energy Systems Consortium (FESC) Summit: September 27-28, Gainesville, Florida.

Briley A (presenter), Thomas M, Trotz M, Cunningham J, Stewart M., 2011. Practical heuristic for selection of geochemical model basis of supersaturated water and mineral precipitation. Presented at the Florida Energy Systems Consortium (FESC) Summit: September 27-28, Gainesville, Florida.

Funded research:

a. **Project:** : Physical and geochemical modeling of geologic sequestration of carbon dioxide and RO reject water at the Polk Power Station (PPS), Polk County.
Principal Invstigators: M Stewart (USF), J Cunningham(USF), M Trotz(USF), R Okwen(ISGS)
Students: Arlin Briley (CEE, PhD), Mark Thomas (CEE, PhD)
Grantors and Collaborators: Tampa Electric Company, ECT Inc.

Funding: Funding is provided on a continuing and as needed basis, for specific tasks. Current funding is about $40,000-$50,000 per year. Funds provide research support for faculty members Cunningham, Trotz, and Stewart, a sub-contract with Dr Roland Okwen (USF PhD) of the Illinois State Geological

Survey, licenses for advanced modeling software, and support for two current PhD students, Arlin Briley and Mark Thomas in CEE.

Description: This project is part of a >$160,000,000 project funded by DOE and the SWFWMD. SWFWMD funded two deep injection wells at PPS to dispose of reverse osmosis reject water from a RO plant that will process City of Lakeland wastewater. The potable water from the RO plant will replace Floridan Aquifer water currently used by Tampa Electric at the PPS. The existence of a suitable deep injection zone was confirmed by earlier USF research. As a result of the availability of deep injection wells and the integrated coal gasification-combined cycle (IGCC) power plant at PPS, the PPS was selected by DOE for a pilot project for hot-gas clean up, carbon capture, and carbon sequestration. USF is responsible for modeling the physical and chemical behavior of both the injected carbon dioxide that will be captured by the CCS pilot plant and the reject water from the RO plant. This project provides a unique research opportunity, as it is the only CCS project where injection of CO2 will be followed by wastewater injection. The majority of the refereed publications and meeting presentations of the USF Carbon Sequestration group have been based on research results from this project.

Project lifespan: Carbon sequestration will begin in 2013, and continue for 1 year and the wastewater injection will start in 2014 and continue indefinitely. USF expects to be involved in this project at least through 2015.

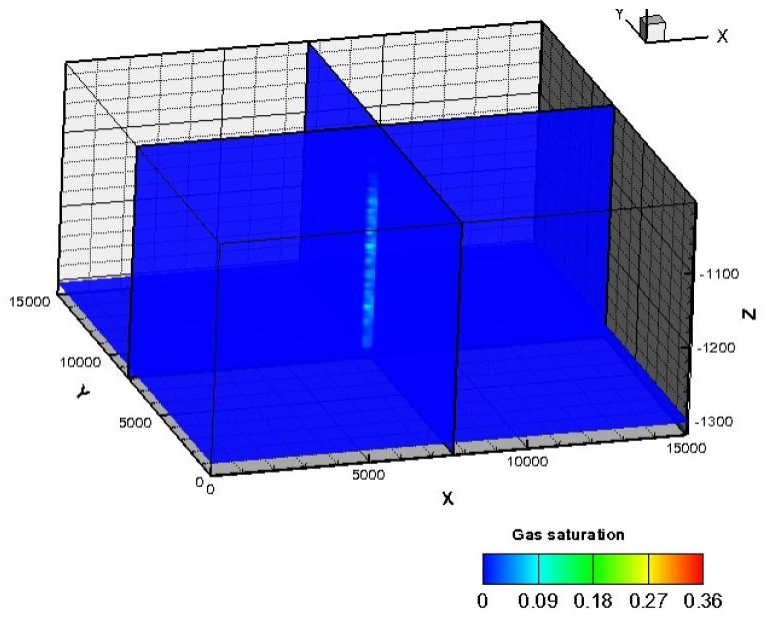
b. Project: Monitoring of carbon sequestration using InSAR
Principal Investigator: Tim Dixon (USF)
Grantor: DOE
Funding: This part of a larger grant from DOE held by Tim Dixon. Funding on the FESC project is probably about $50,000
Project description: This project will use the carbon dioxide and wastewater injection projects at the Polk Power Station (PPS) to investigate the use of radar interferometry to monitor the progress of CO2 injection at CCS sites. Dixon has received permission to include the PPS site as one of the investigative sites for this DOE grant.

Proposals submitted:

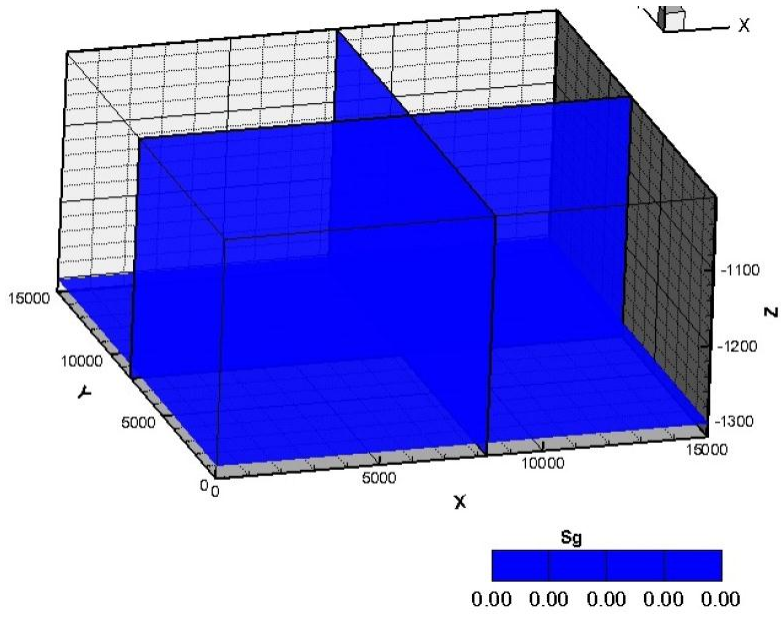
a. **Project:** The current CCS and wastewater injection project at the Polk Power Station (PPS) provides a unique research opportunity. In 2013 approximately 300,000 tons of carbon dioxide will be injected in the second of two deep injection wells at PPS drilled to 8,000 ft below land surface. As the principal purpose of the deep wells is disposal of RO plant reject water and waste streams from PPS facilities, after CO2 injection wastewater will be injected into the deep disposal well. Preliminary modeling (see figures below) suggests that the carbon dioxide sequestered as a supercritical gas phase will dissolve in the injected waste water. This will convert the CO2 from a very buoyant supercritical gas to a more dense dissolved phase. This nearly eliminates the buoyancy effect of sequestered CO2, greatly reducing the importance of caprock continuity and sequestering the CO2 in a chemically stable form. The proposed project will create predictive geochemical models for the conjunctive injection of CO2 and wastewater, calibrated to monitoring data from the PPS.

Submission: A pre-proposal was submitted to DOE in September. Funding is expected to be about $250,000/yr for four years, 2012-2016

CO2 gas phase saturation after 1 year of CO2 injection



CO2 gas phase saturation after 1 year of wastewater injection



b. **Project:** Use of high resolution GPS to monitor CO2 sequestration
Principal Investigator: Rocco Malservici (USF)
Grantor: DOE
Funding: Rocco Malservici submitted a pre-proposal for this project, and has been invited by DOE to submit a full proposal. Expected success rate for full proposals is about 50%.