# Intro to CFSES and Carbon Capture and Geological Storage

Overview of carbon capture and geological storage.

Sathaye et al. (2014) Constraints on the magnitude and rate of CO2 dissolution at Bravo Dome natural gas field, Proc. Natl. Acad. Sci., 111(43), 15332-15337, doi:10.1073/pnas-1406076111

Work was performed at the University of Texas at Austin

## Carbon Capture and Geological Storage

1. Capture $CO_2$ at a large point source.
2. Transport to storage site vie pipeline.
3. Injection into deep geological formations

Currently the **only** technology for de-carbonation of base-load fossil-fuel based power generation.

## Barriers to CCGS implementation

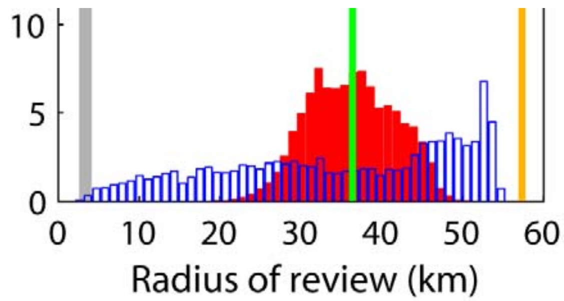
1. Can CCGS be implemented at scale?
2. Is geological carbon storage safe/permanent?
3. Verification of site performance?
4. Cost of CCS?

## The CFSES Challenges

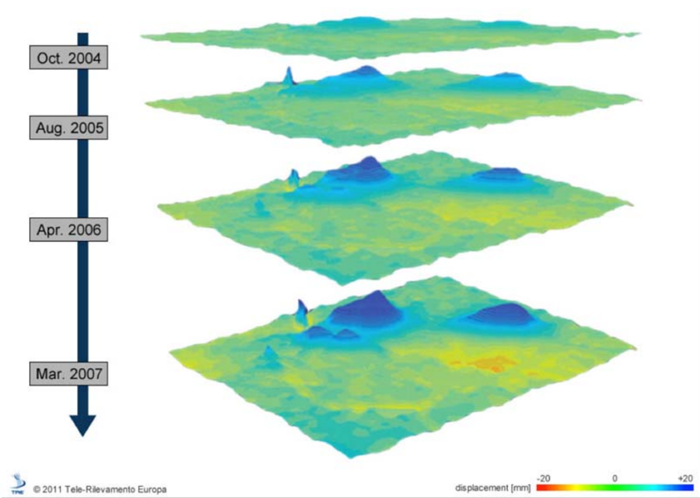
1. Sustaining large storage rates.
2. Using pore space efficiently.
3. Controlling undesired/unexpected behavior.

If CFSES achieves any of these challenges it removes a barrier to CCGS implementation.

# Geodetic monitoring of subsurface fluid migration




Uncertainty of radius of review due to uncertainty in properties of surrounding mudrock (Chang et al. 2010).




Geodetic imaging of surface deformation at InSalah, Image from TRE Europe.

## Sustaining large storage rates

The pressure build up limits injection rates and may induce earthquakes on preexisting faults.

Pressure plume is 4 to 10 times the radius of the $CO_2$ plume and limits storage capacity.

## Geodetic monitoring of storage sites

At the InSalah storage site in Algeria satellite geodesy revealed surface uplift around the injection wells.

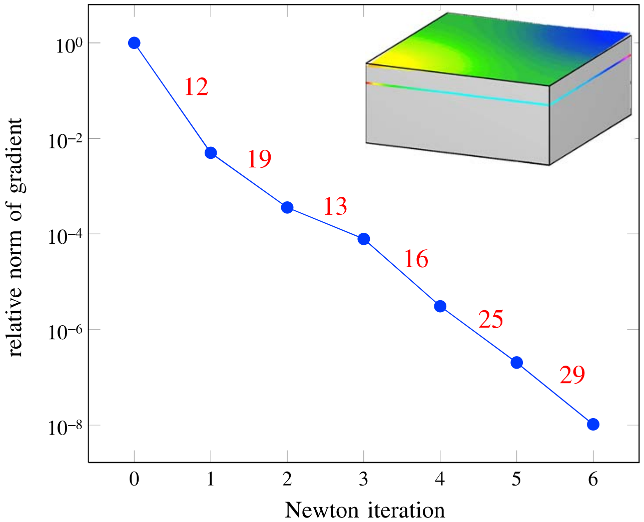
Surface uplift is linked to the pressure build up!

Satellite geodesy may provide cheap real-time pressure monitoring to verify site performance.

## Controlling undesired behavior

Monitor stress changes on nearby faults and adjust injection schedules to reduce risk of induced seismicity.

# Joint inversion for coupled quasi-static poroelasticity




Convergence of the Newton iteration used to solve the non-linear optimization problem for joint poroelastic inversion.

**Publication:**

Hesse and Stadler (2014) Joint inversion for coupled quasi-static poroelasticity, *J. Geophys. Res.*, **119**(2), 1425-1445, doi:10.1002/2013JB010272

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## Scientific Achievement

Developed *efficient* algorithm that integrates both geodetic and hydrological data to estimate subsurface permeability field in a Bayesian framework.

## Significance and Impact

Enable *real-time* monitoring of the propagation of the pressure perturbation due to $CO_2$/fluid injection.

## Research Details

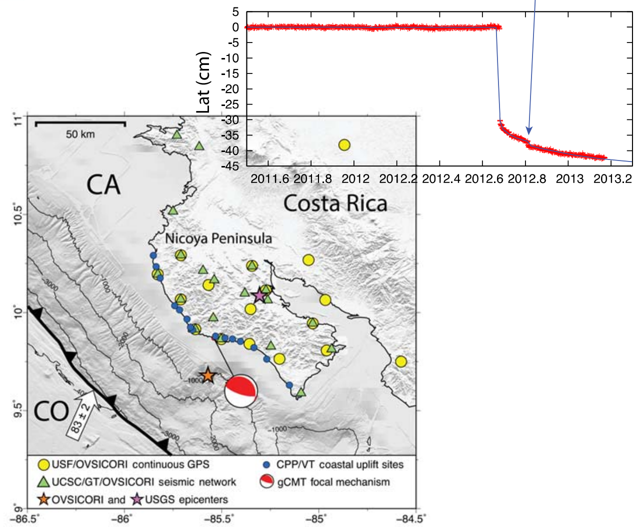
Estimation of high-dimensional parameter fields requires efficient inversion algorithms based on gradient information.

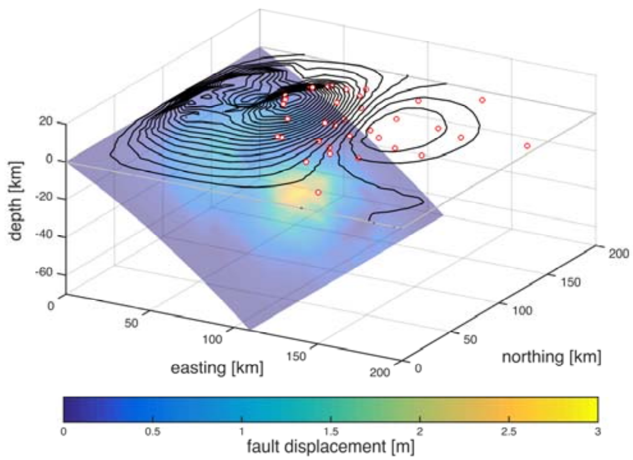
Combination of black-box optimization algorithms with stand-alone simulators do not provide this efficiency.

Instead we propose an *intrusive* algorithm that tightly couples forward and inverse problems by computing high-dimensional gradients from the solution of poroelastic state and adjoint equations.

Interpret the inverse problem in a Bayesian context. The required regularization term is interpreted as prior information or assumptions. The the maximum of the posteriori probability distribution is computed efficiently with gradient based optimization. Sample the posterior distribution to generate multiple equally probably solutions to illustrate uncertainty.

# Ongoing work: Earthquake induced subsurface flow




Inversion of time-series GPS surface displacement data for the earthquake slip distribution on the subduction interface.

## Coupling of flow and seismicity

Earthquakes induced by subsurface flow.

Subsurface flow induced by earthquakes.

## 2012 Costa Rica 7.6 megathrust earthquake

Only subduction zone where the seismogenic zone is not off-shore. Unique data set due to presence of a dense GPS network in the area during the earthquake. Post-seismic deformation likely due to poroelastic relaxation.

## Geothermal energy exploration

Costa Rican government is investing 1 billion in geothermal energy. Geothermal exploration in region of the 2012 earthquake is ongoing.

Aim is to constrain large scale crustal permeability variation from from post seismic deformation.