



# Assuring integrity of CO<sub>2</sub> storage sites through ground surface monitoring (SENSE)

## Project Overview

4th ACT Knowledge Sharing Workshop

6-7 Nov 2019, Athens

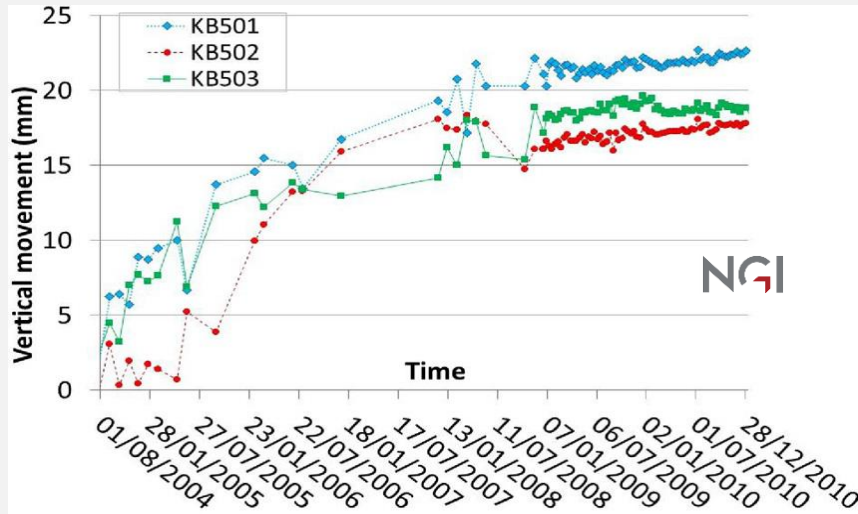
Coordinator: Bahman Bohloli, Norwegian Geotechnical Institute (NGI)

# Outline

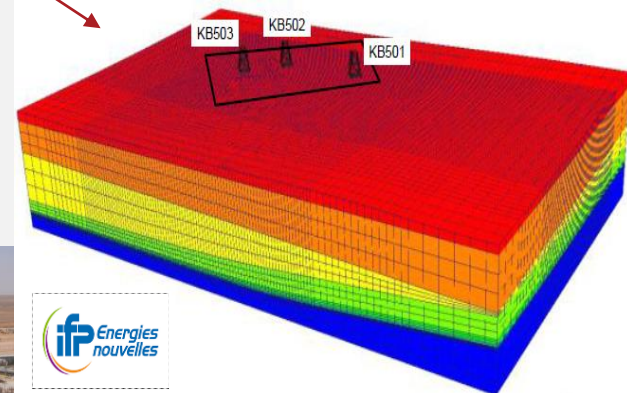
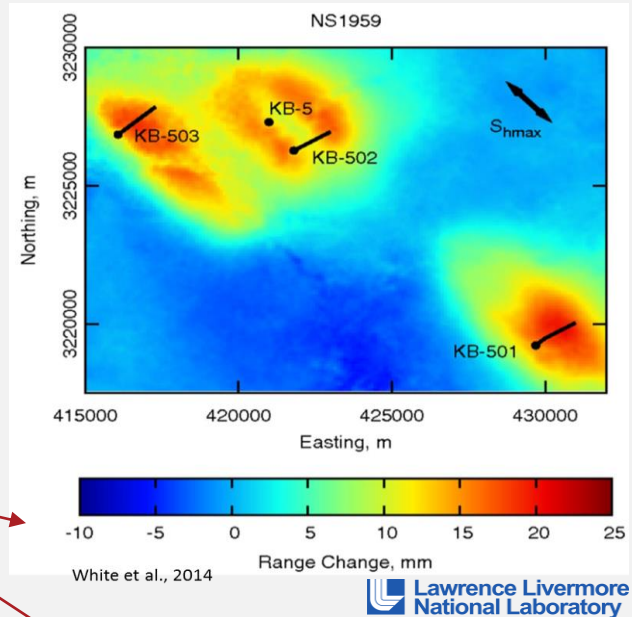
- Introduction and objective
- Project structure and WPs
- Project innovations
- Status for SENSE

# Introduction

➤ In Salah: an important site to understand subsurface flow-mechanics



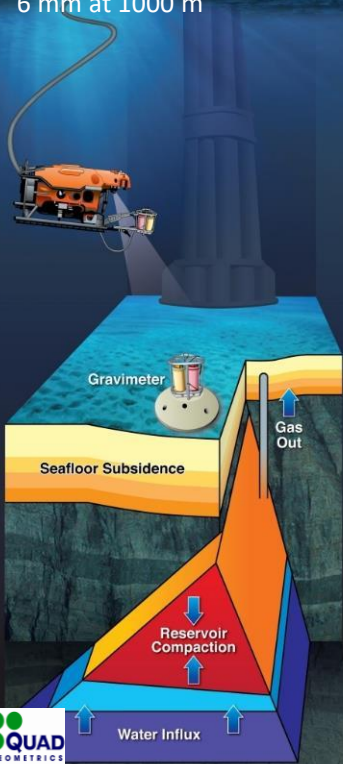
Three SENSE Partners performed independent studies for In Salah (2010-2017).



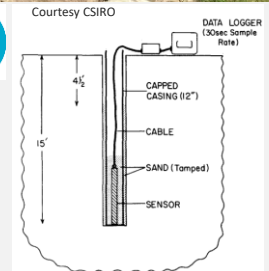
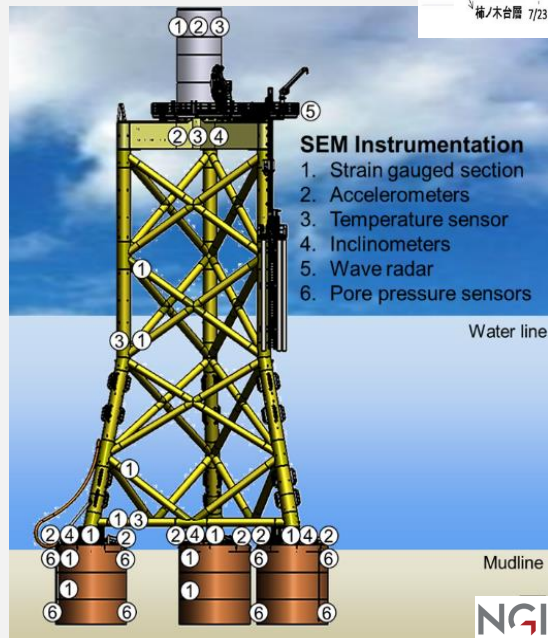
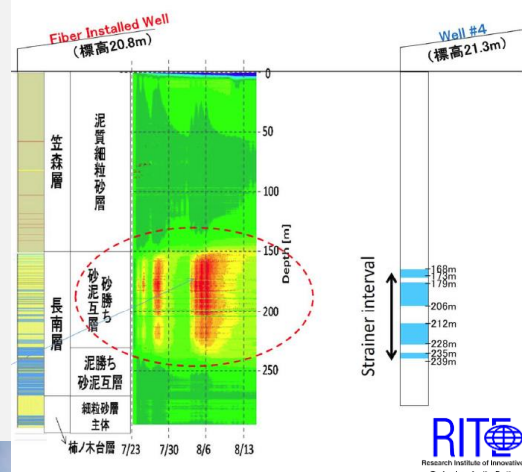
# Experience and facilities

- Gravity survey @ subsea
- Pore pressure & tiltmeter landers
- Seafloor and platform instrumentation

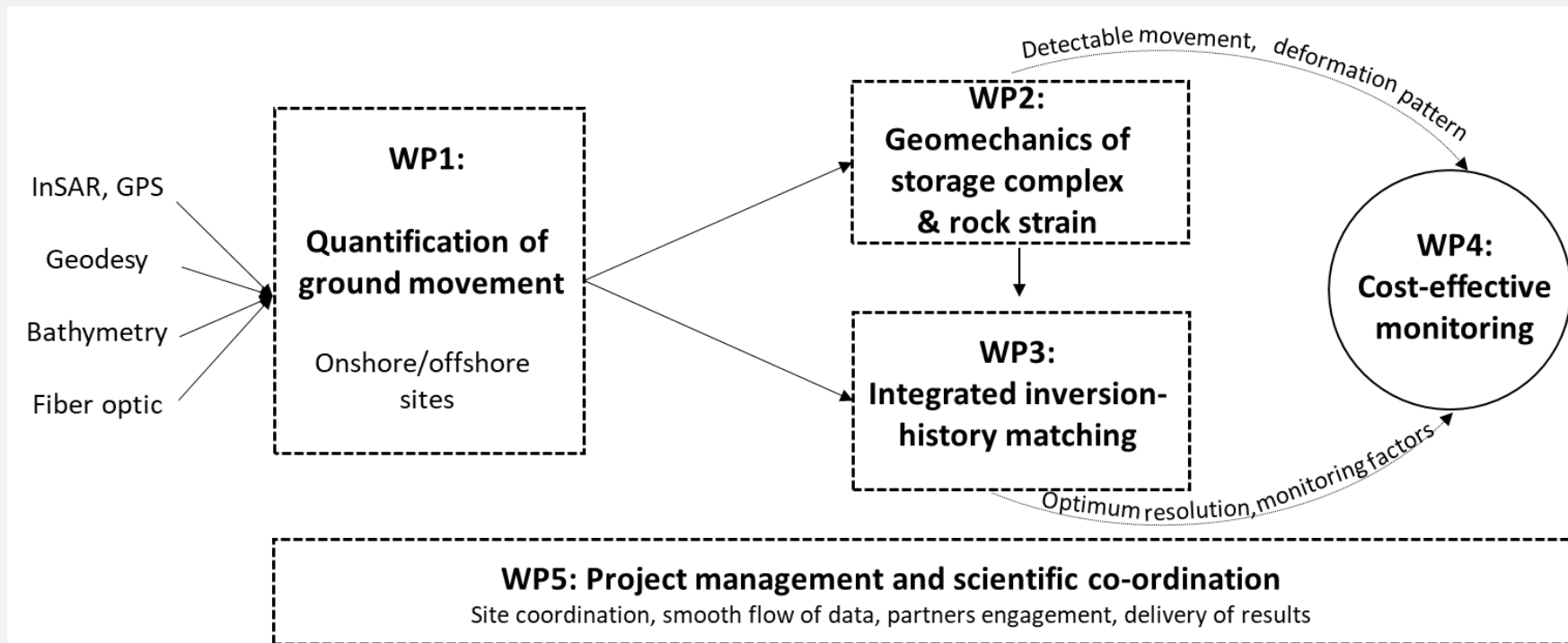
Precision of:  
3 mm at 300 m  
6 mm at 1000 m



- Downhole fiber optic
- Downhole tiltmeter



# SENSE project structure



# WP1: Four proposed field sites (Lead: Geomar)

#1: Hatfield Moors, onshore UK

#2: Hontomin, Spain

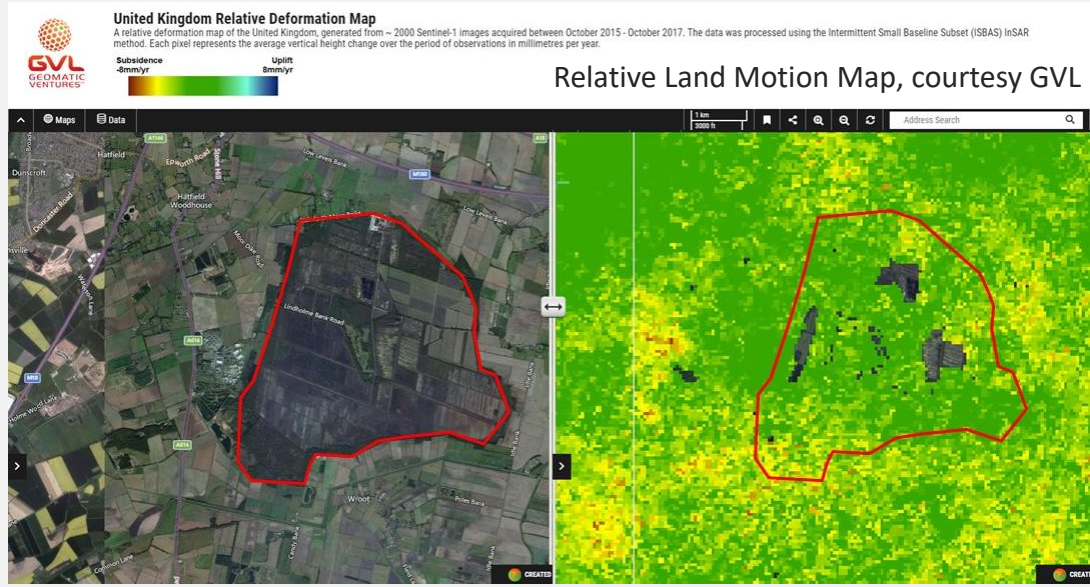
#3: Offshore Germany

#4: Gulf of Mexico

(Troll field-subsidence analysis)

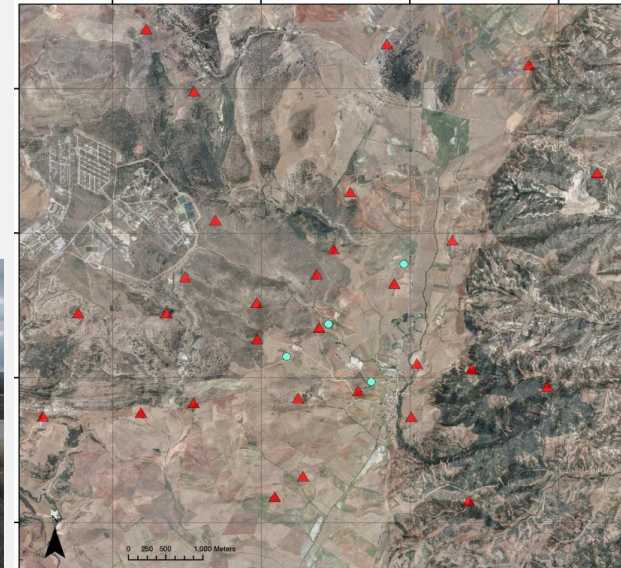
## Site #1: Hatfield Moors, UK

- Hatfield Moors gas storage site sandstone reservoir
- Depth of storage ~450m
- Natural gas storage reservoir
- Plan to use the site to advance geomechanical modelling



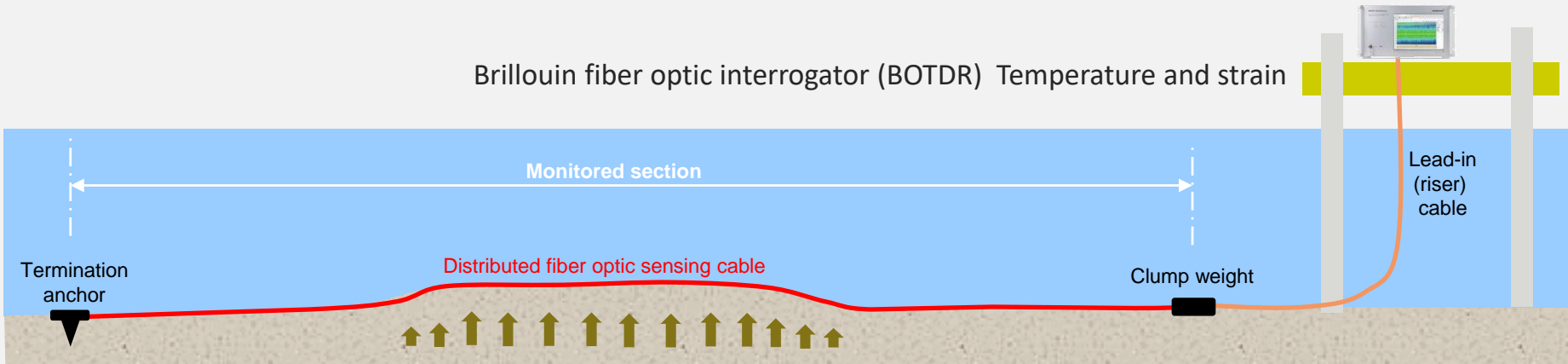
# Site #2: Hontomín Spain (or alternative)

- Hontomín TDP CO<sub>2</sub> injection pilot project
- Testing of integration on InSAR with other onshore monitoring techniques
- Improving data processing techniques, time- and cost -wise

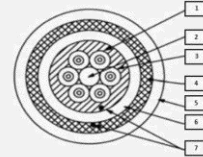
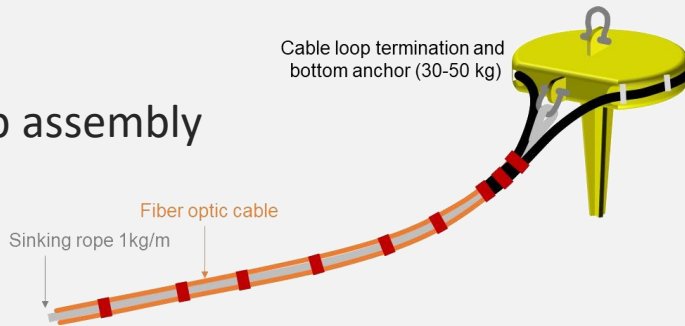


# Site #3: Offshore Germany

## SENSE Fiber optic deformation cable tests



### Cable loop assembly



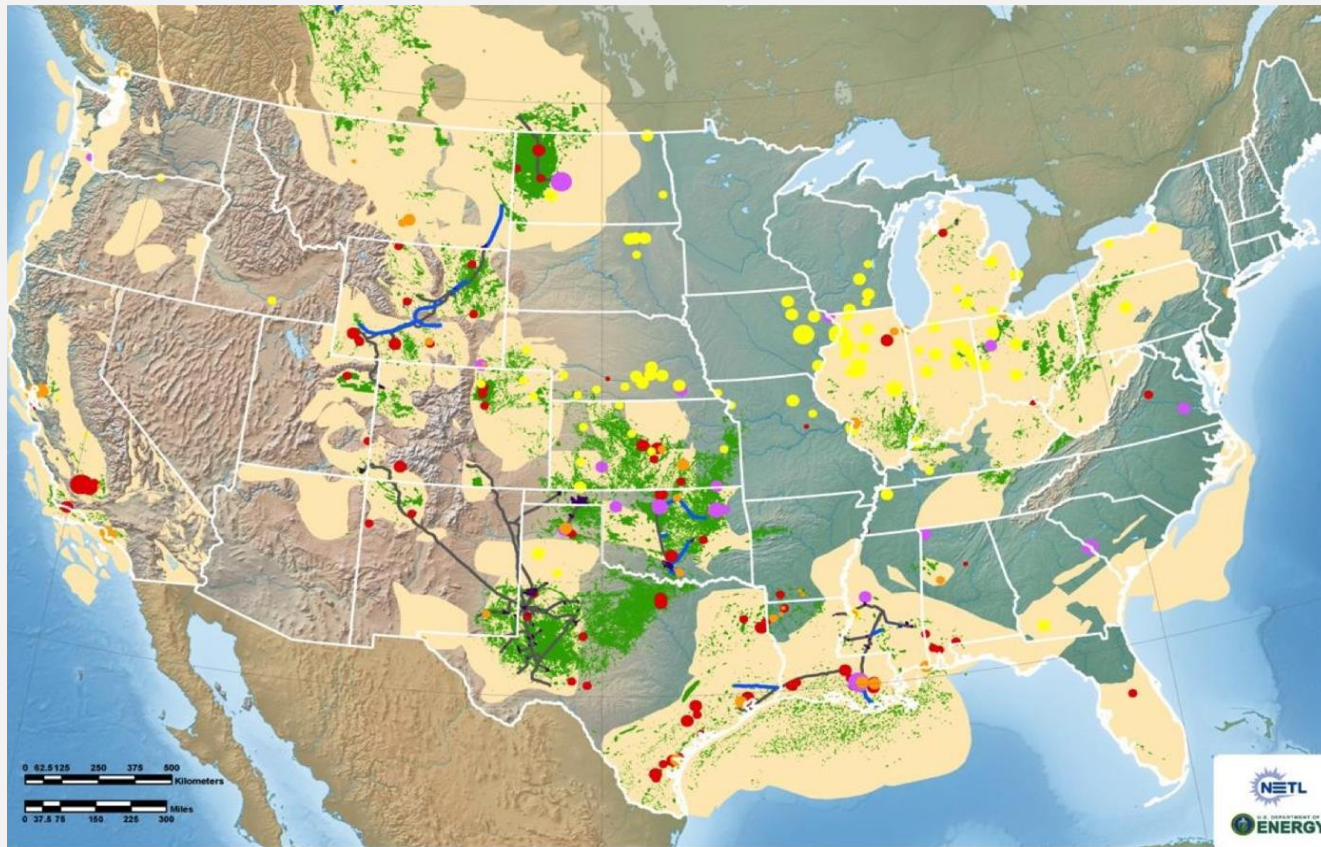
- 1 Aramid Yam Strength Member
- 2 Central Filler / Strength Member
- 3 Tight Buffer Optical Fiber
- 4 Corrugated Steel Tape Armor - CST
- 5 Outer Jacket
- 6 Inner Cable Jacket
- 7 Ripcord

Cable section across the monitored section must lay fixed to the seabed

- Weighted by lead rope
- Buried ?
- Trenched ?
- Scour ?
- Onshore tests ?



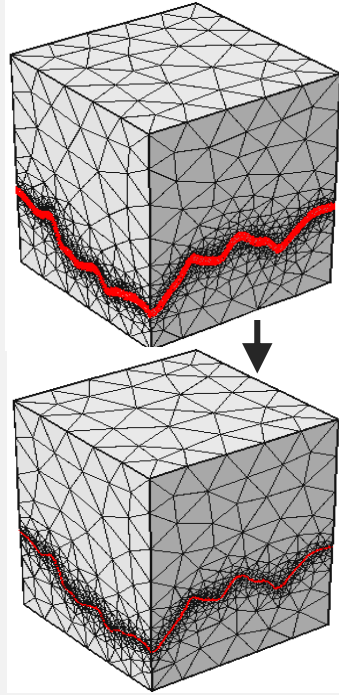
# Site #4: Gulf of Mexico



- saline aquifers
- EOR opportunities
- ethanol plants
- refineries
- chemical plants
- petroleum operations
- existing CO<sub>2</sub> pipeline
- proposed CO<sub>2</sub> pipeline

## WP2

Two-way coupled flow-mechanics model, focus on rock strain



## WP4

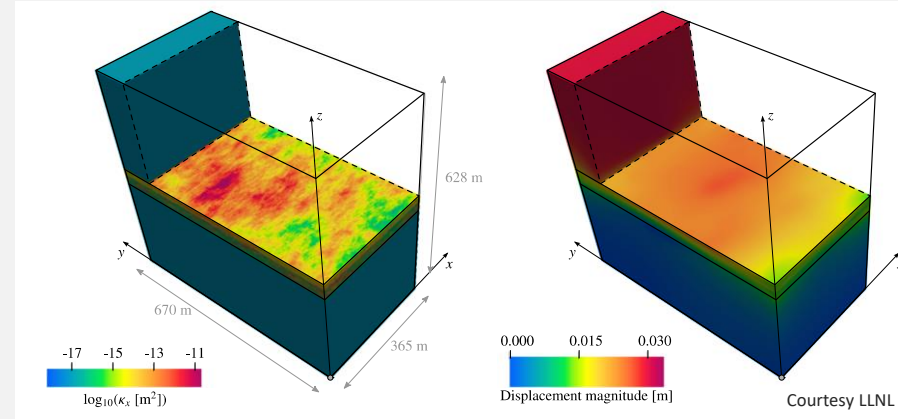
Integration of results

Optimizing monitoring tools/methods, accuracy & costs

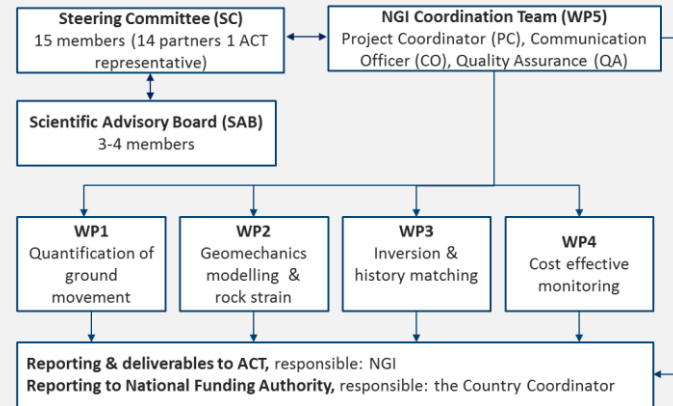


Survey design for the North Sea & US offshore

## WP3 Inversion for permeability and strain to update subsurface behavior

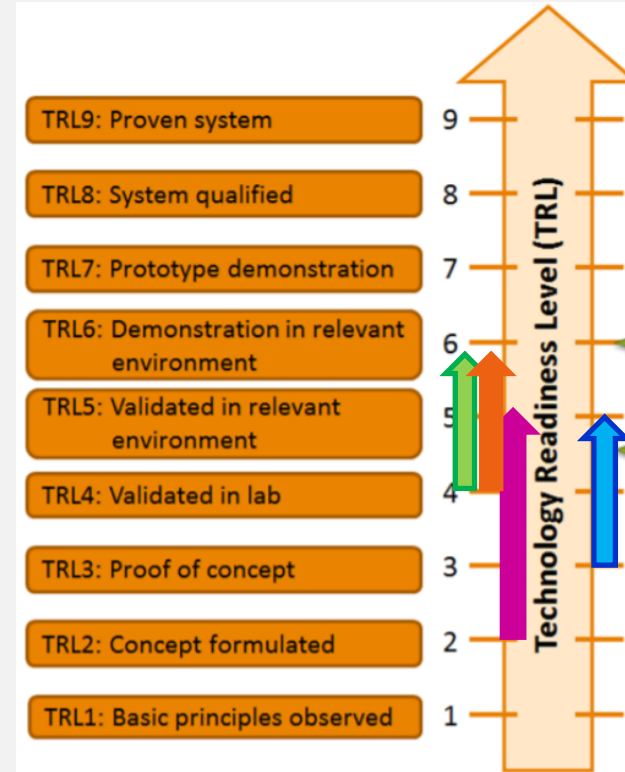


## WP5 Coordination



# SENSE innovations

- Automated monitoring tool for InSAR data:  
TRL2 to TRL5
- Continuous, accurate monitoring of seafloor using fiber optics and a new ocean bottom lander:  
TRL4 to TRL6
- Innovative interpretation/models coupling ground surface deformation to reservoir hydro-mechanics:  
TRL4 to TRL6
- New algorithms for fast and robust inversion for large scale simulations:  
TRL3 to TRL5



# Status for SENSE

- Kick-off meeting held 29-30 Oct in Oslo- 37 attendees
- Work Package meetings held 30 Oct afternoon



# Status for WP1 so far

- Cruise AL527 in September 2019
- Site selection
- Coring performed
- Shipment of cores to Oslo
- Lab testing
- New injection (air in sand) applied for Nov 2020
- Fluid migration modelling to determine injection rate



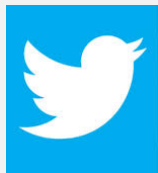
# SENSE project

Total budget: 4.5 m€

ACT contribution: 2.7 m€



[sense-act.eu](http://sense-act.eu)



[@SenseAct](https://twitter.com/SenseAct)



[Sense-ACT](https://www.researchgate.net/publication/Sense-ACT)



# Acknowledgement



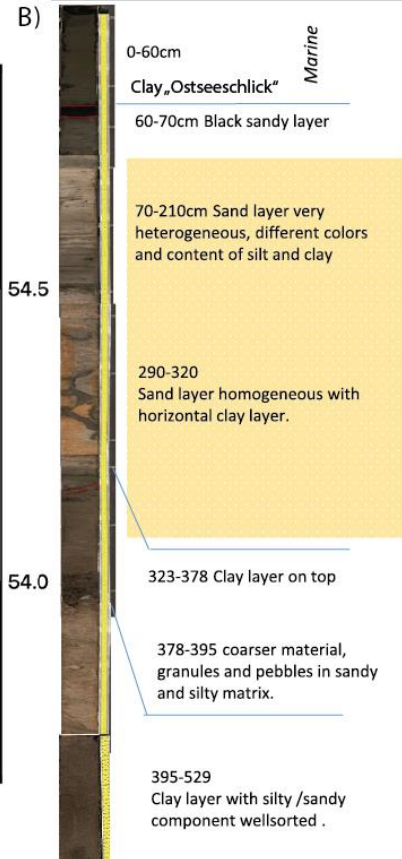
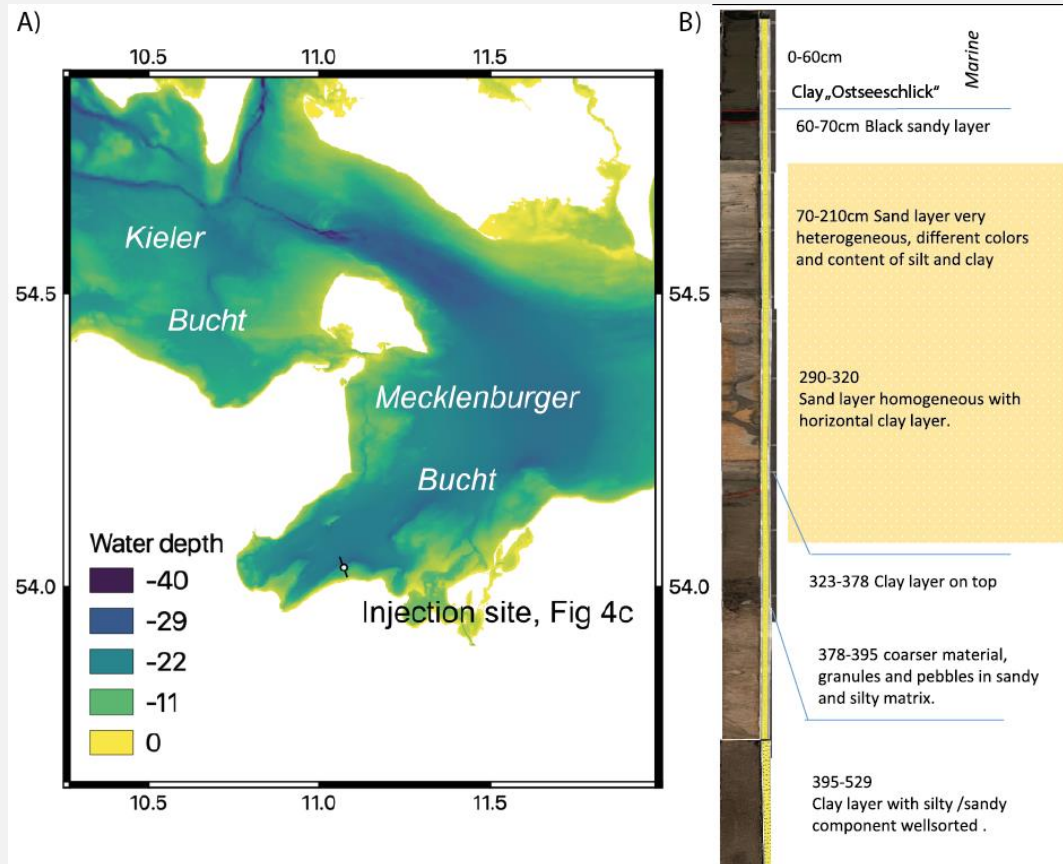
SENSE (Assuring integrity of CO<sub>2</sub> storage sites through ground surface monitoring) project No. 299664, has been subsidized through ACT (EC Project no. 691712) by Gassnova, Norway, United Kingdom Department for Business, Energy and Industrial Strategy, Forschungszentrum Jülich GMBH, Projektträger Jülich, Germany, The French Agency for the Environment and Energy Management, The United States Department of Energy, State Research Agency, Spain, with additional support from Equinor, Quad Geometrics and Geogreen.



Support slides for Q/A follows

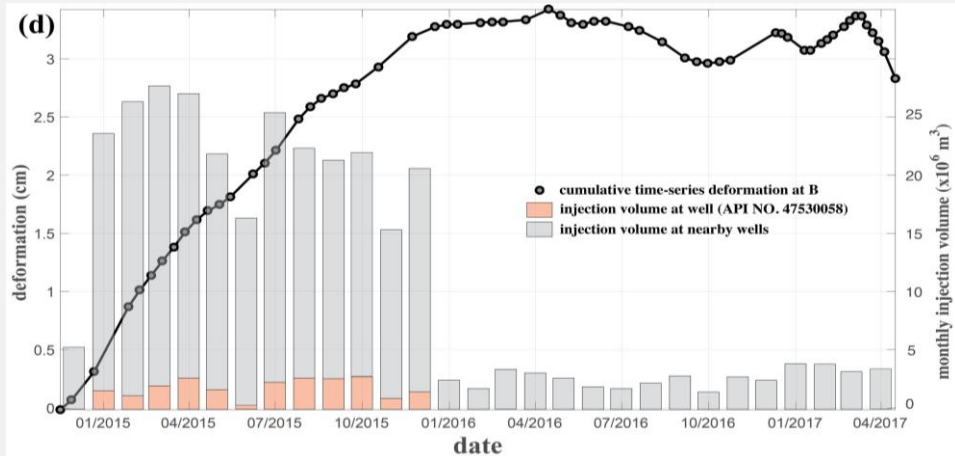
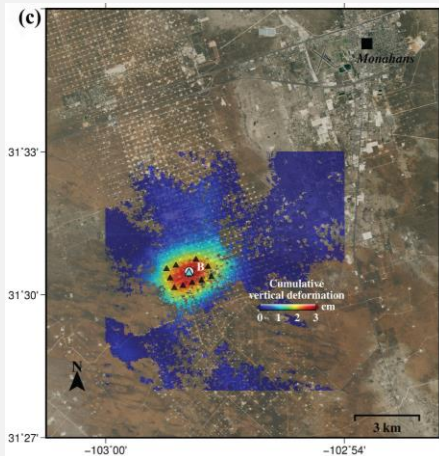


# Injection Site offshore Germany



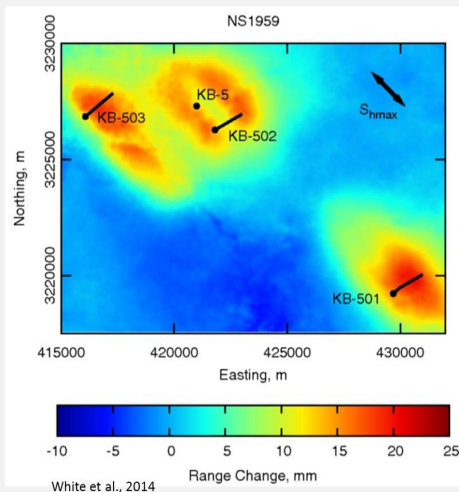
# Ground uplift

- Injection of saltwater & CO2EOR, Midland USA

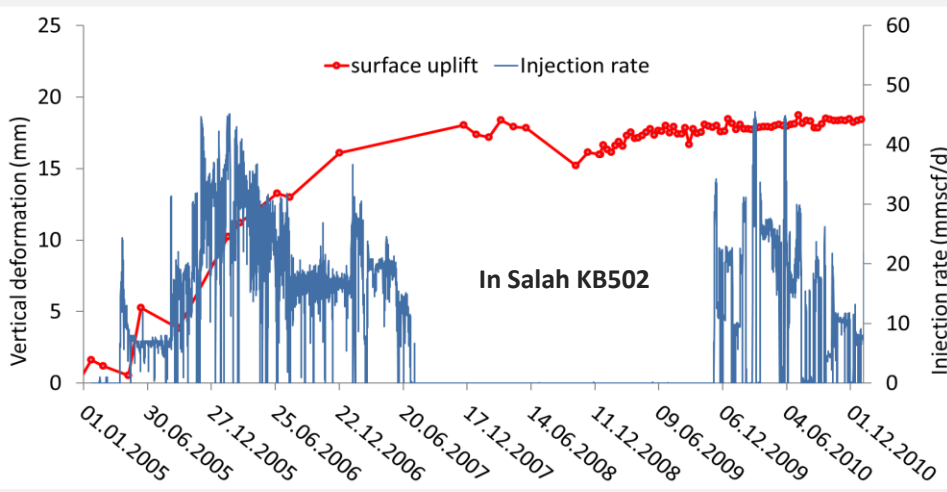


Phys.org, 2018  
<https://phys.org/news/2018-03-radar-images-large-swath-texas.html>

- In Salah CO2 injection

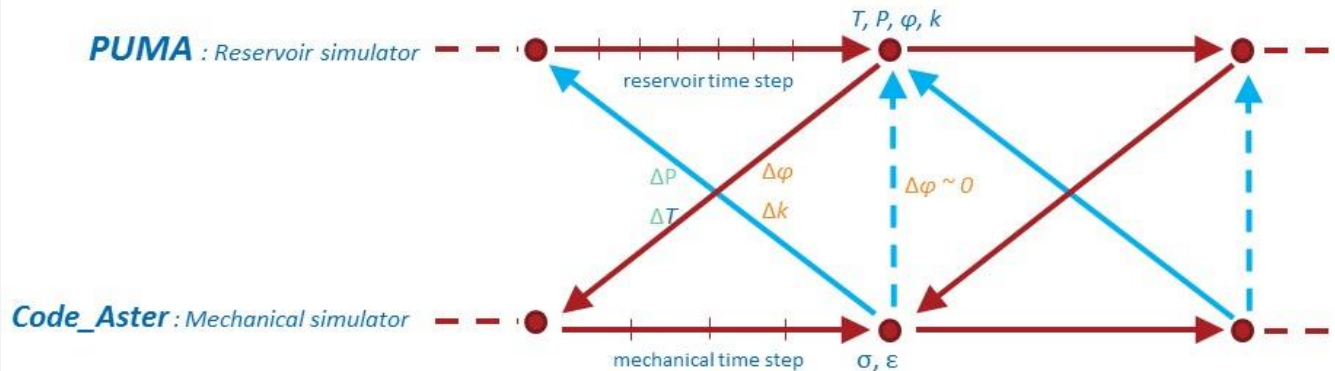
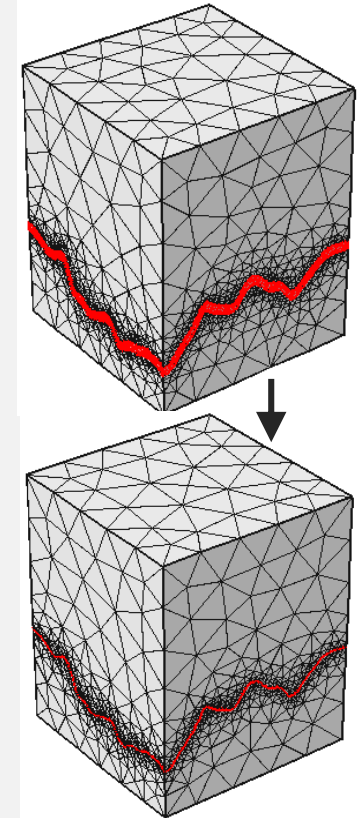
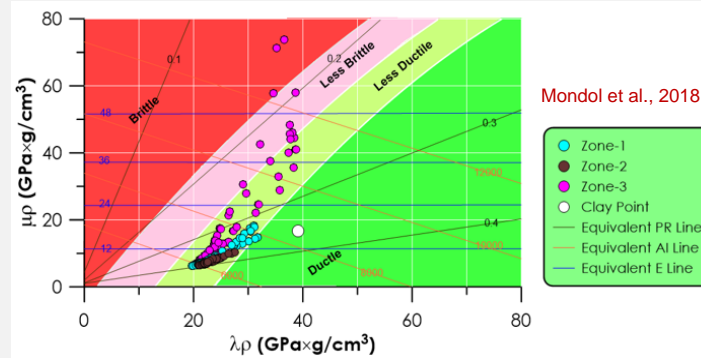


White et al., 2014

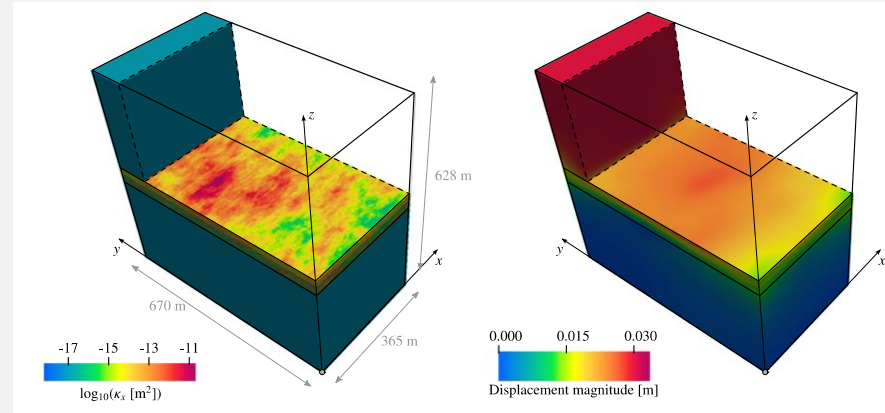
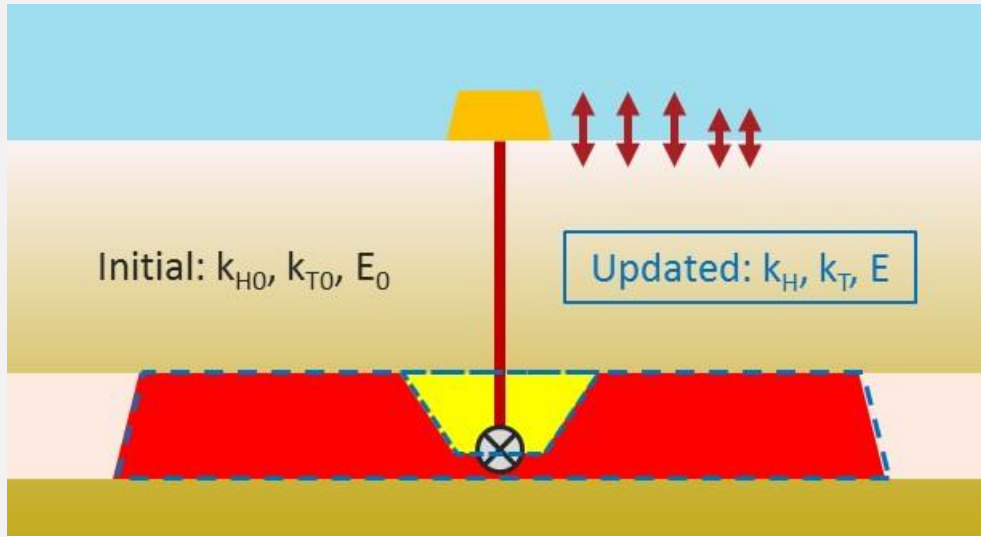


# WP2: Geomechanical modelling- rock strain (Lead: IFPEN)

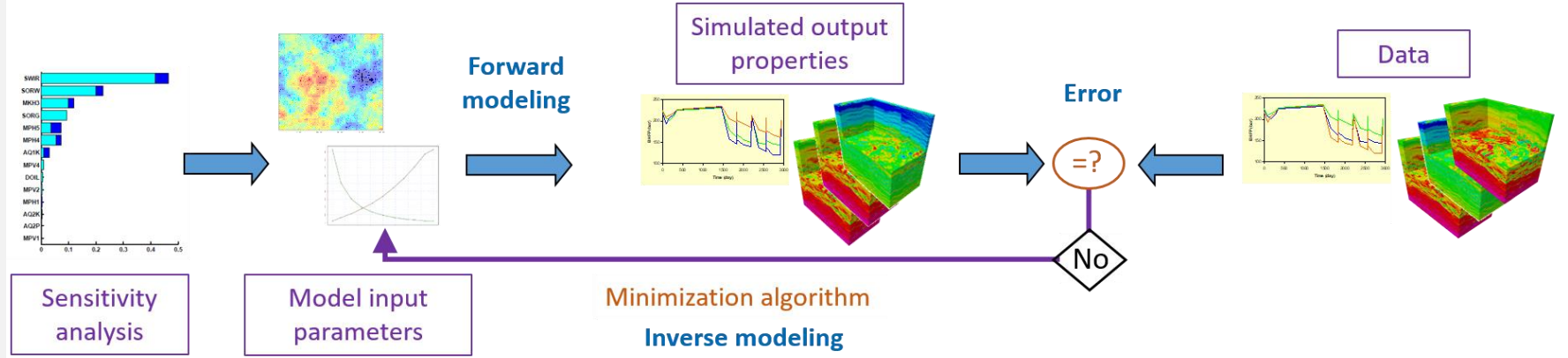
- Objective: Understanding the mechanism of surface movement through conceptual and coupled flow-geomechanics models
- Use of rock physics models developed by SENSE partners
- Use of reduced dimension models



# WP3: History matching inversion (Lead: NGI)

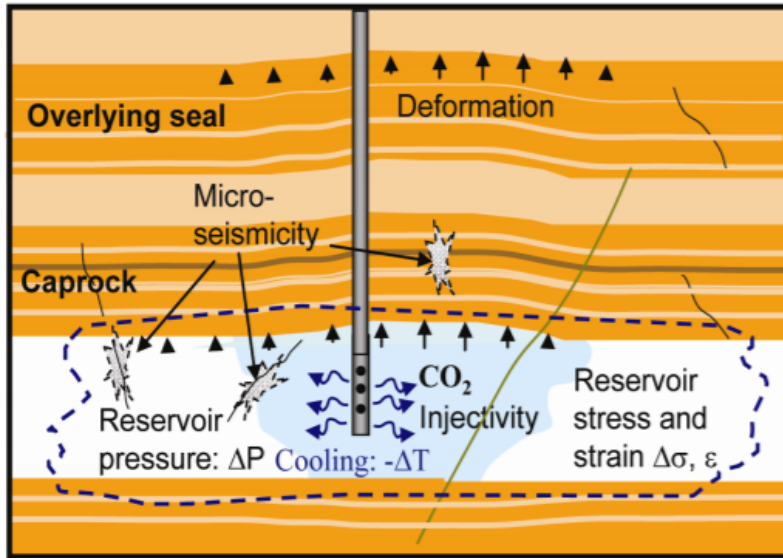


Inversion for permeability and displacement using LLNL inversion codes

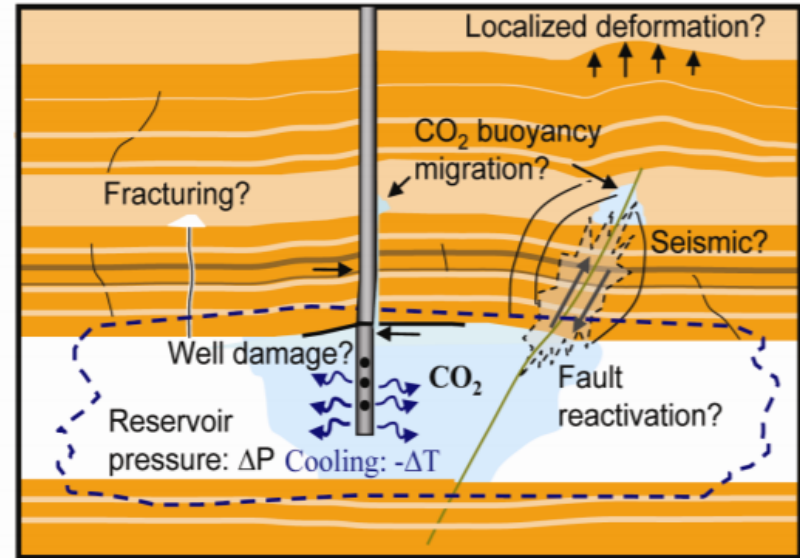


# Theoretical background

## Injection-induced stress, strain and deformation



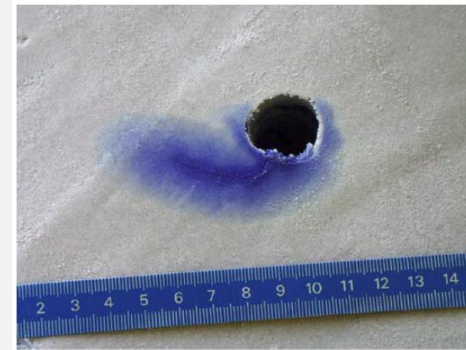
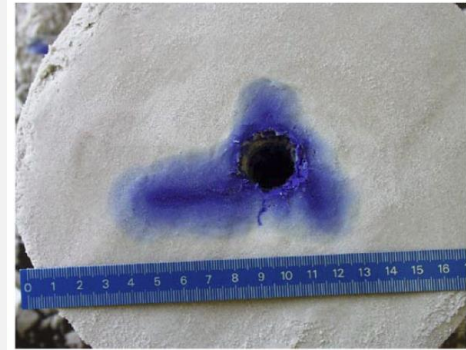
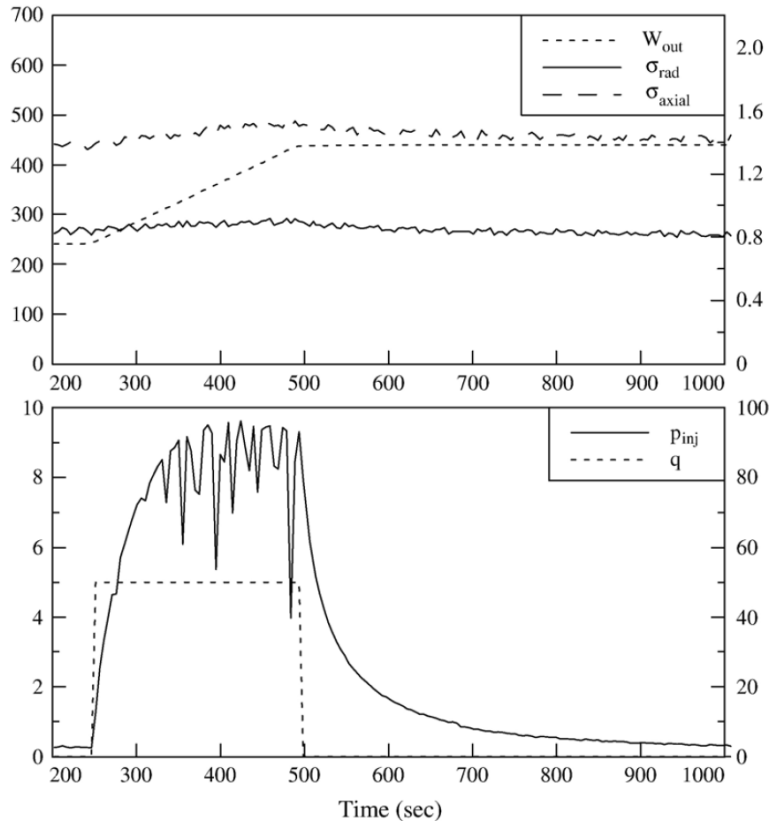
## Unwanted mechanical changes



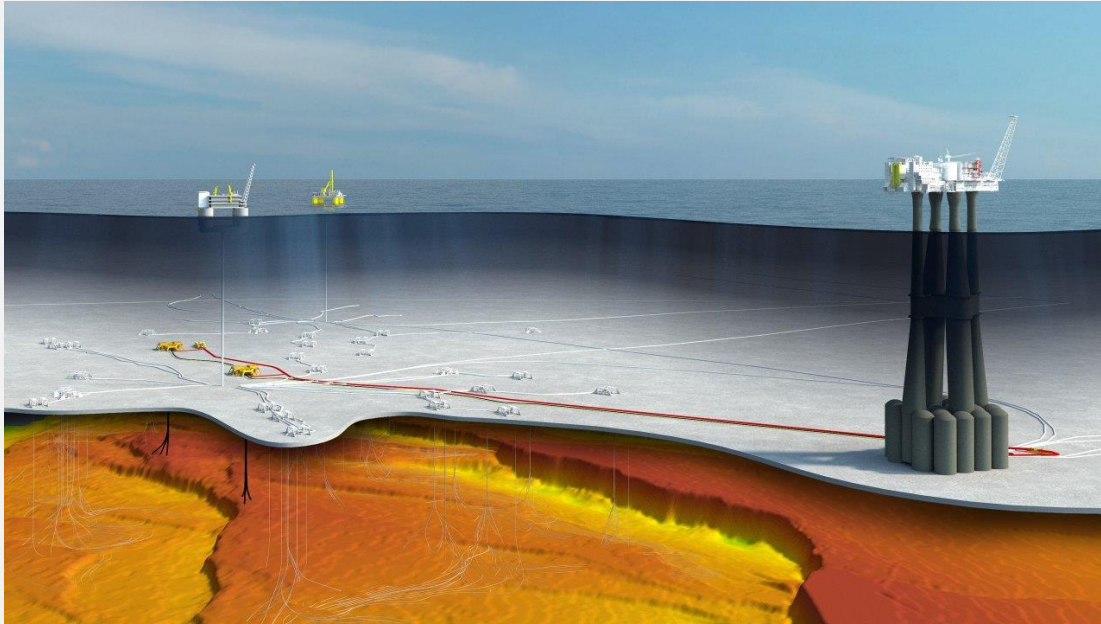
[Rutqvist (2012) Int J Geotechnical and Geological Engineering]

# Pressure build-up and pressure release

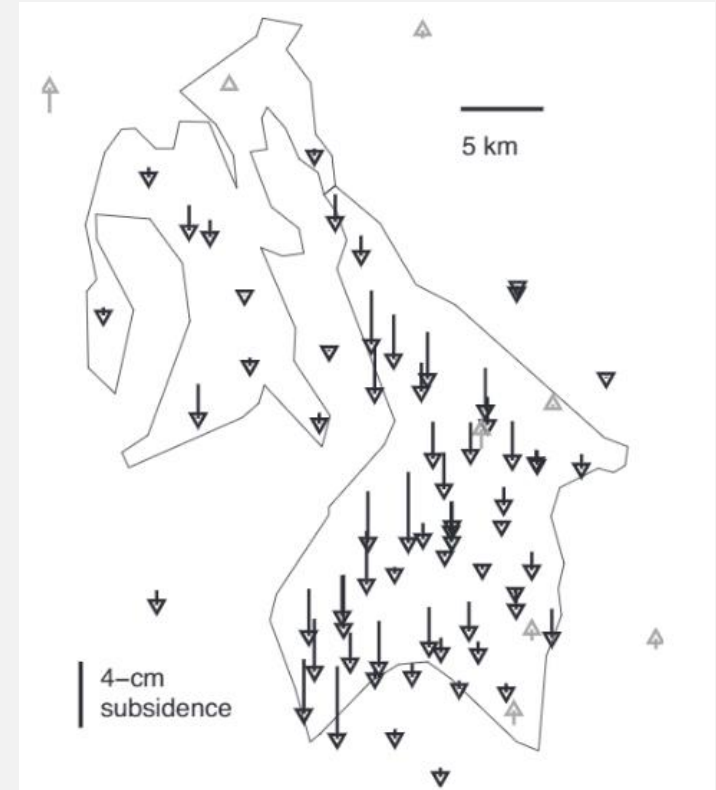
## Example: hydraulic fracturing of compacted sand



# Troll field



Equinor 2018 (<https://www.equinor.com/no/news/03jul2018-troll.html>)



(Eiken et al., 2008)