Assuring integrity of CO$_2$ storage sites through ground surface monitoring (SENSE)

Results and highlights

Bahman Bohloli and the SENSE team

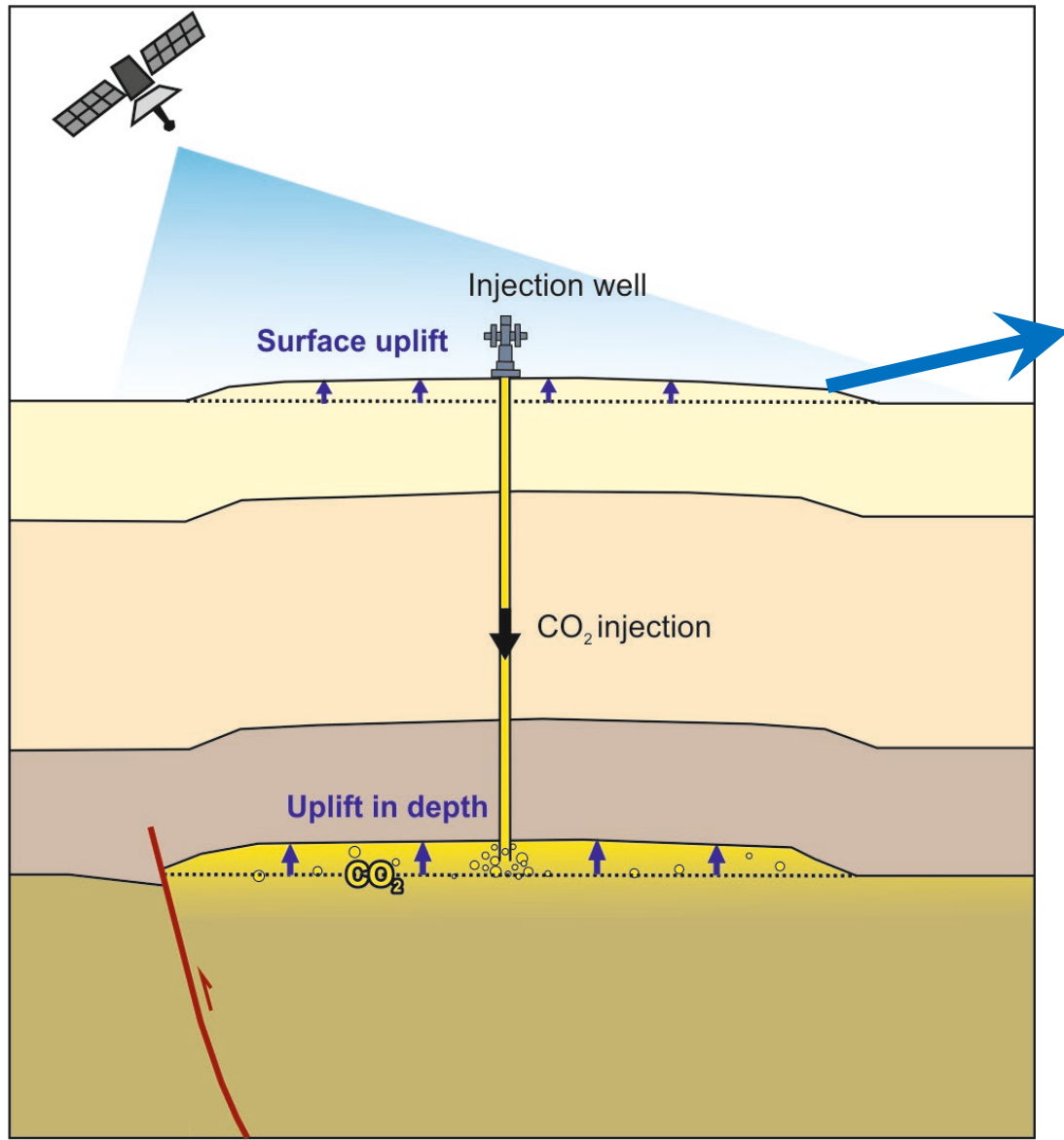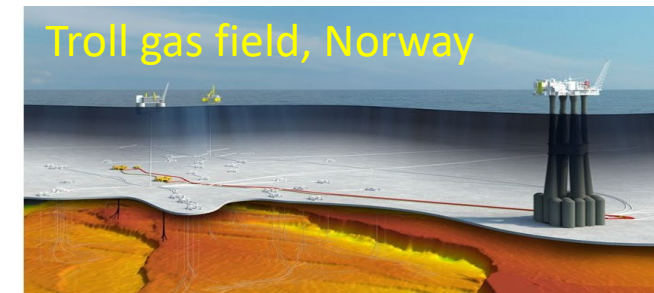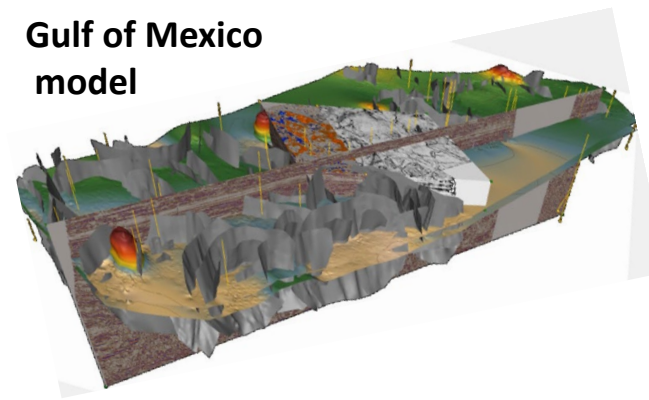CCUS Conference Rotterdam

8-10 June 2022

SE∧SE

Outline

- SENSE project narrative

- Achievements and Highlights

- Dissemination activities
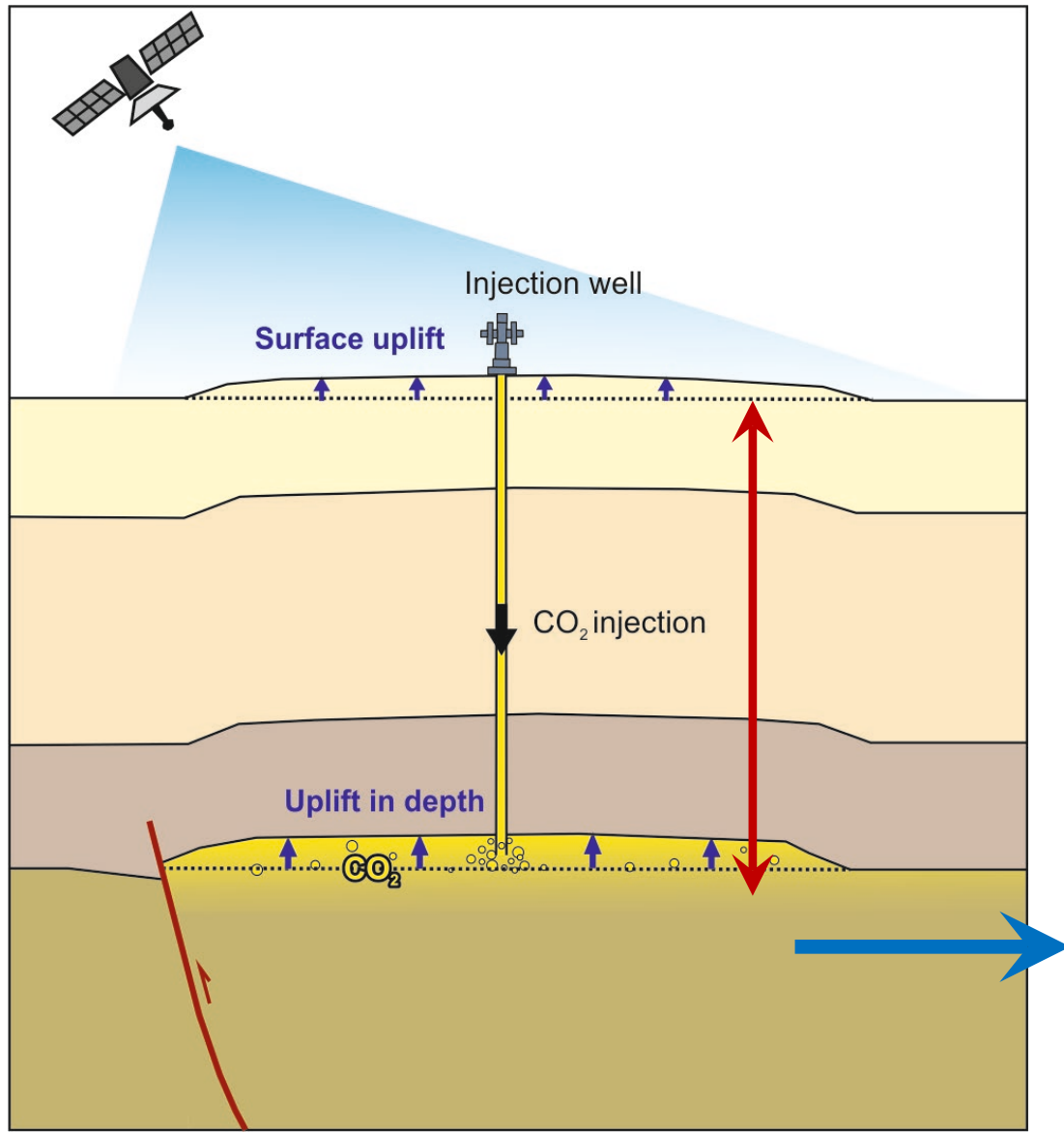
- Summary

SENSE project narrative

Case studies

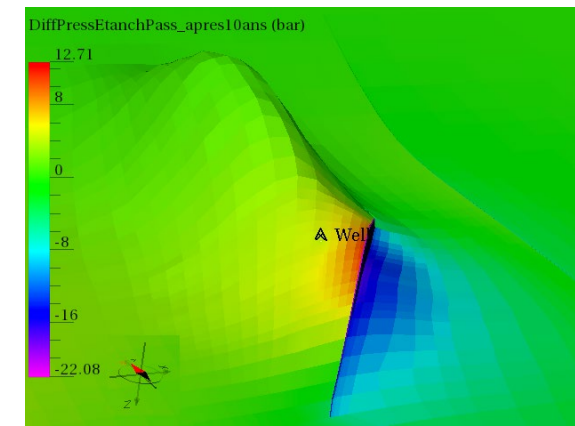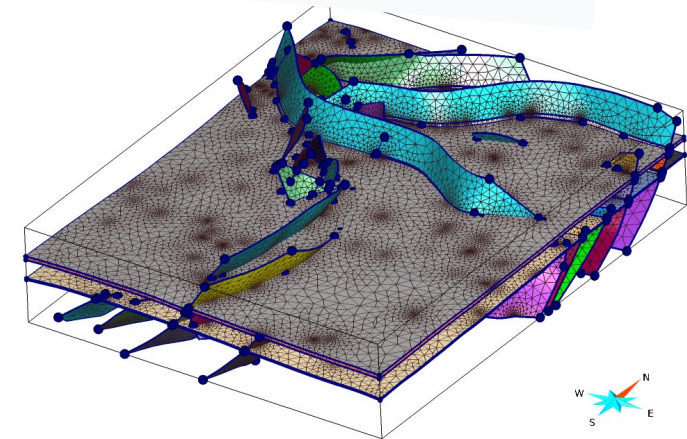In Salah, Algeria

Hatfield Moors, UK

Gulf of Mexico model

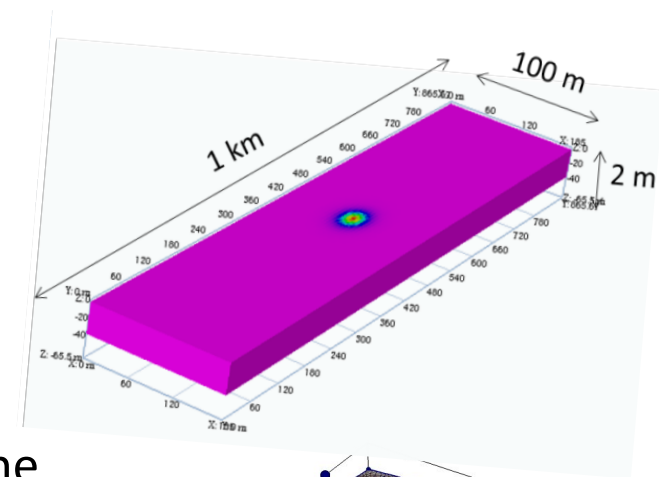Troll gas field, Norway
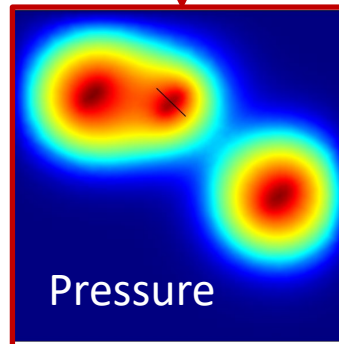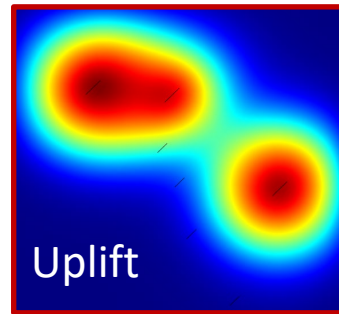
Boknis Eck, Germany

Hontomin, Spain

SENSE project narrative
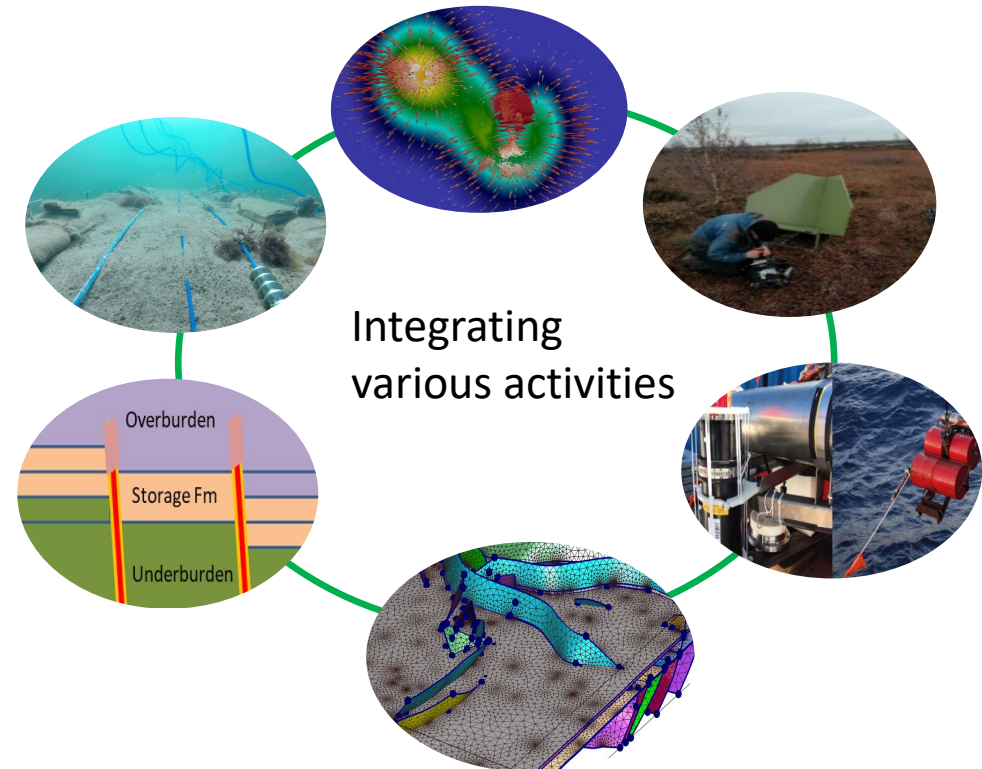
Numerical simulations

Inversion & Machine Learning

Uplift

Pressure

SENSE project narrative

Injection well

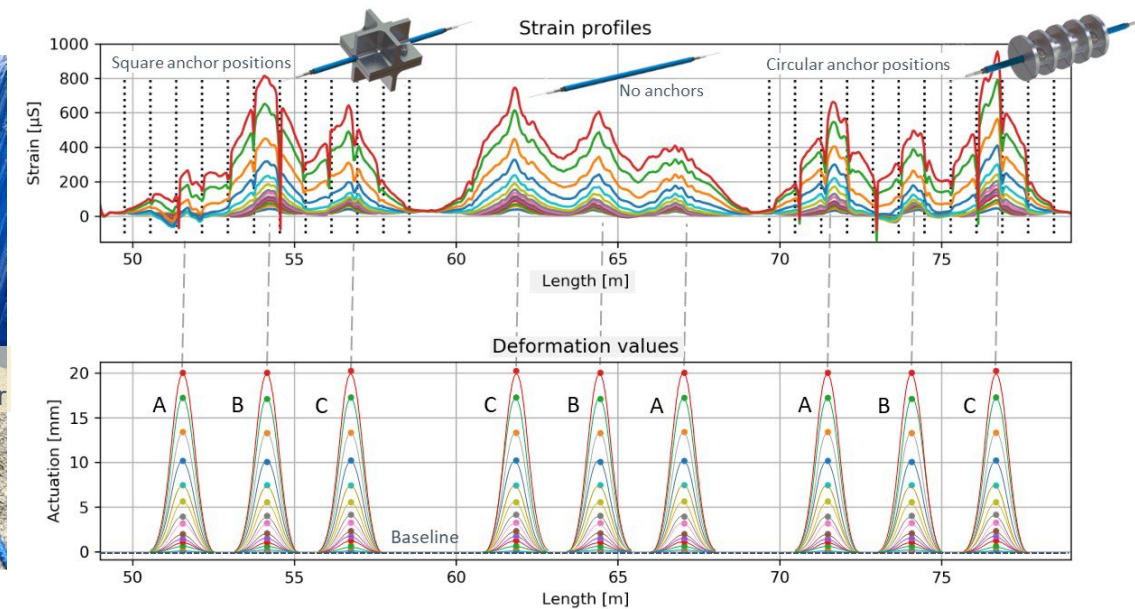Surface uplift

CO_2 injection

Uplift in depth

CO_2
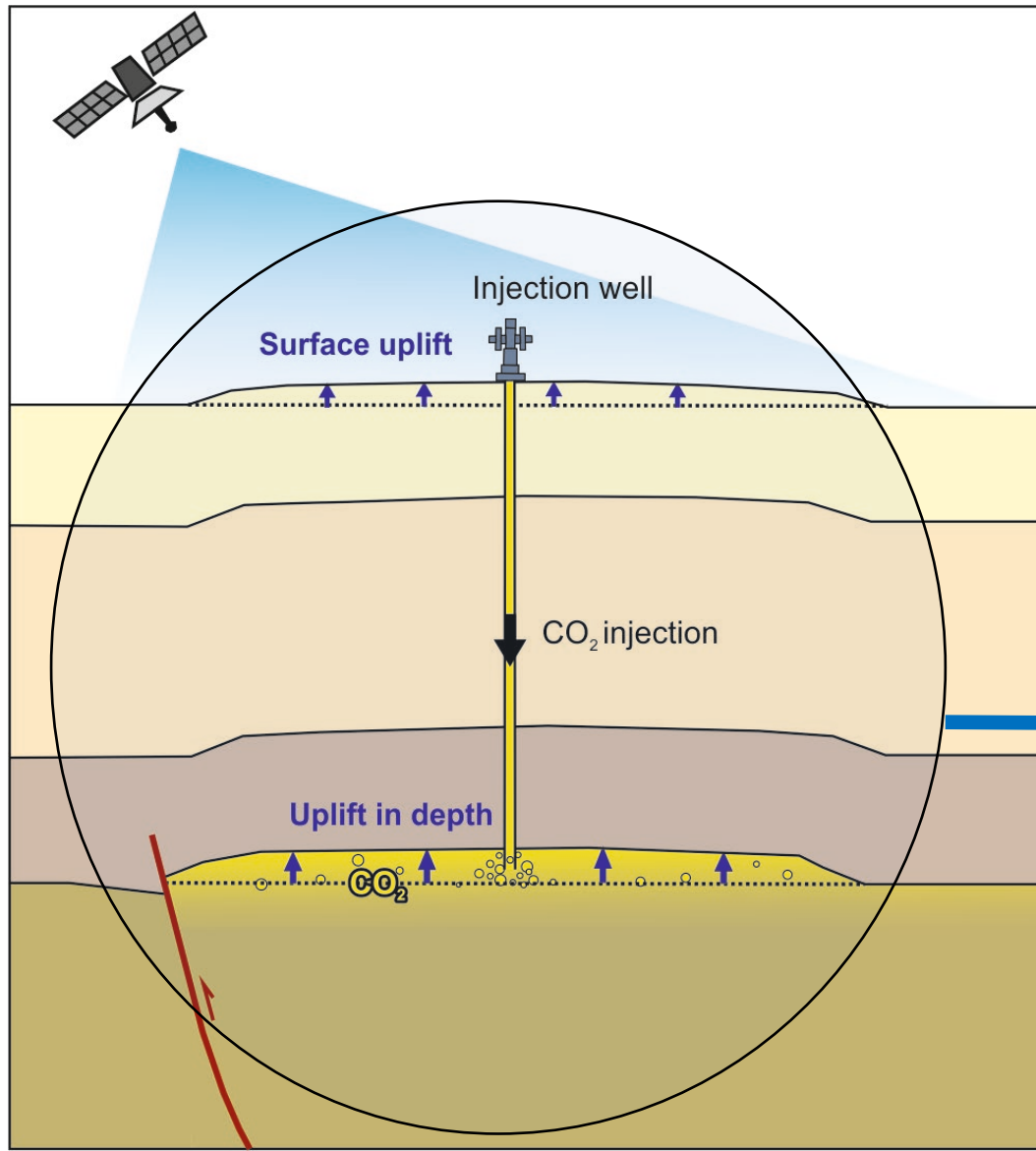
Integration (WP4)

Value of ground deformation for monitoring; tools, methodologies, etc.

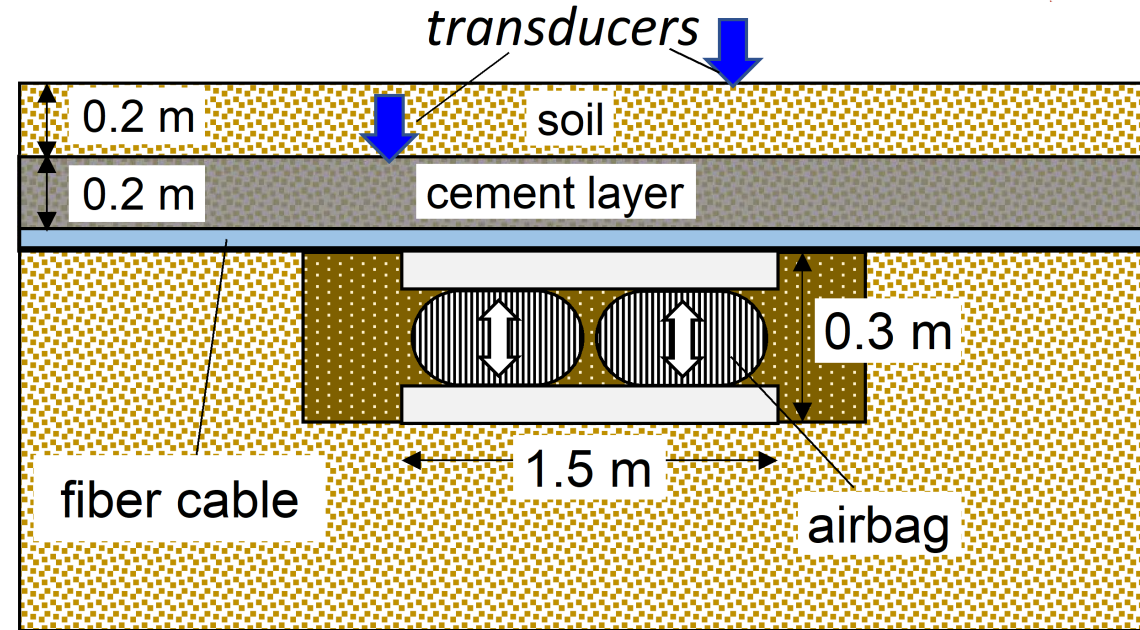Integrating various activities

Overburden

Storage Fm

Underburden

Q1: Advancing measurment techniques in lab (WP1)-Norway

Large scale tests in a sand box

Plane view of 10.5m long sand box with embedded DSS cable and 3 lifting points
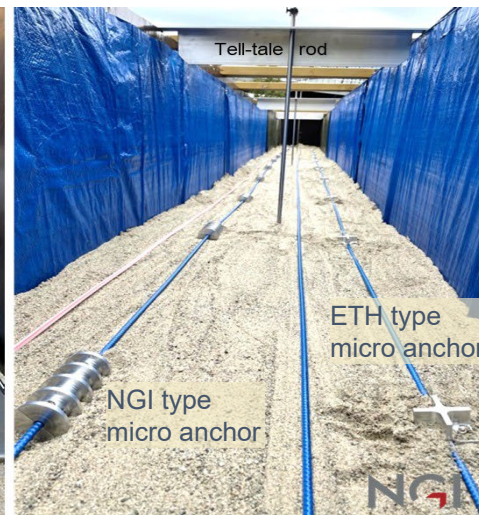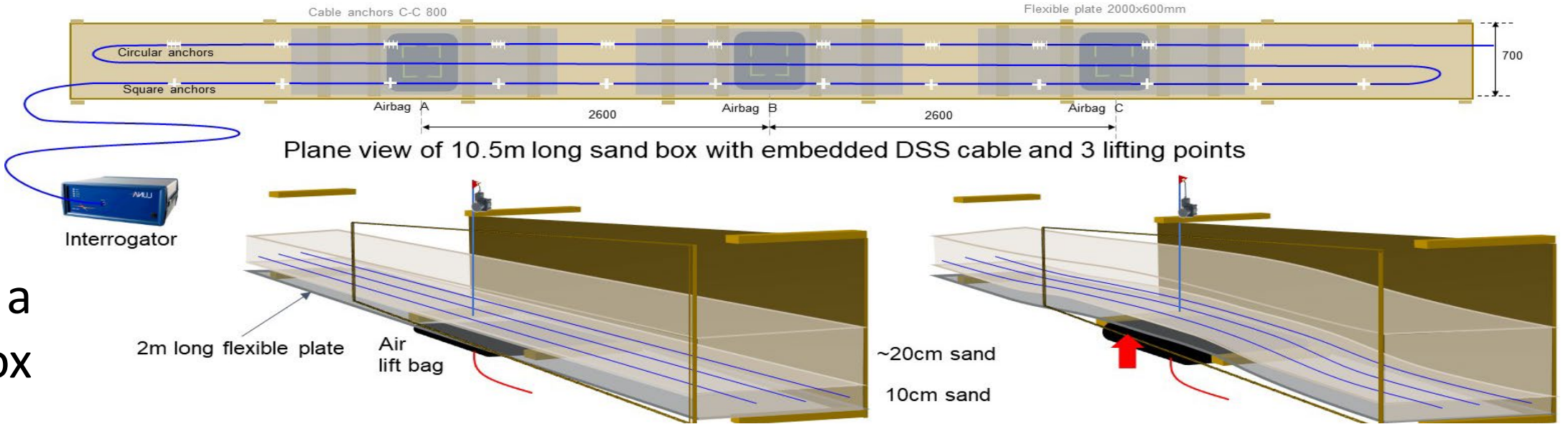
Q1: Advancing measurment techniques- field scale (WP1)-Japan

transducers

0.2 m — soil

0.2 m — cement layer

0.3 m

fiber cable

1.5 m

airbag

displacement transducers

A target plate

wooden board

cement

a   Pressure increment

Frequency shift (GHz)

0	
25 KPa	
50 KPa	
75 KPa	
100 KPa	
125 KPa	

Distance (m)

b   Pressure reduction

Frequency shift (GHz)

125 KPa	
100 KPa	
75 KPa	
50 KPa	
25 KPa	
0 KPa	

Distance (m)
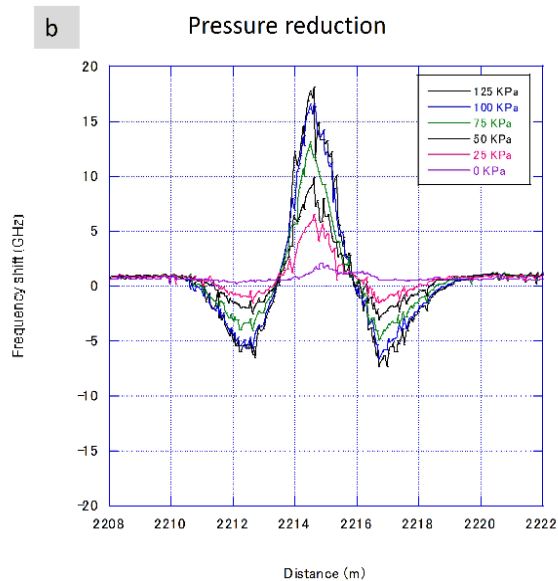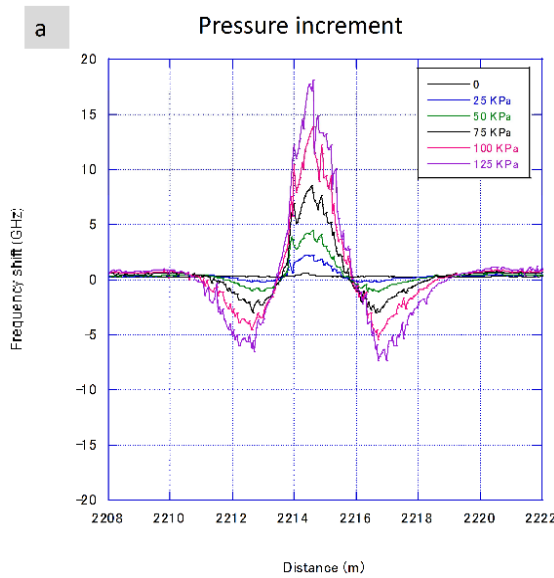
~300 m

Test area with adjustable "seabed"
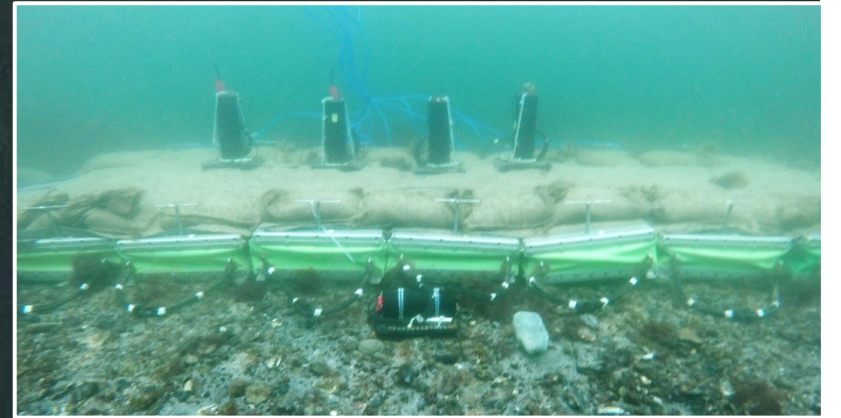
~300 m

Fiber optics cable test at Boknis Eck

Although nearshore tests were challenging, similar ground deformation sensitivity as in the sandbox was demonstrated.

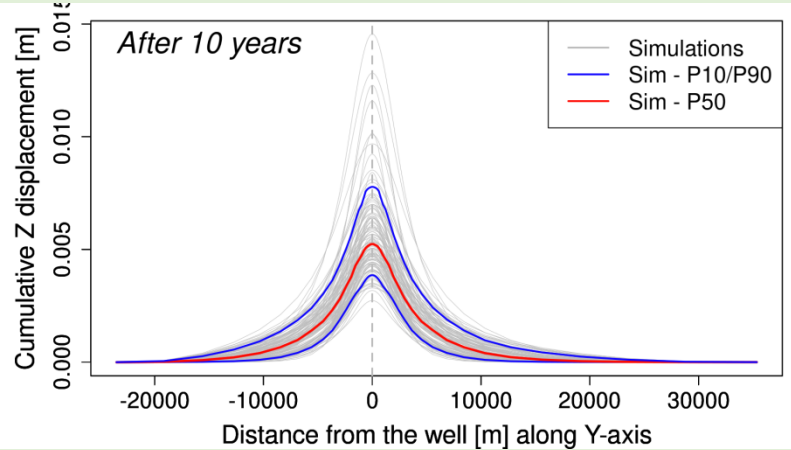# Q2: How reservoir deformation is transferred to the surface? (WP2)

We introduced a new analytical solution (Geertsma Generalized Solution) published in Park et al. (2021)- *fast calculation method with good accuracy*

Pressure distribution

Surface Displacement

Machine learning
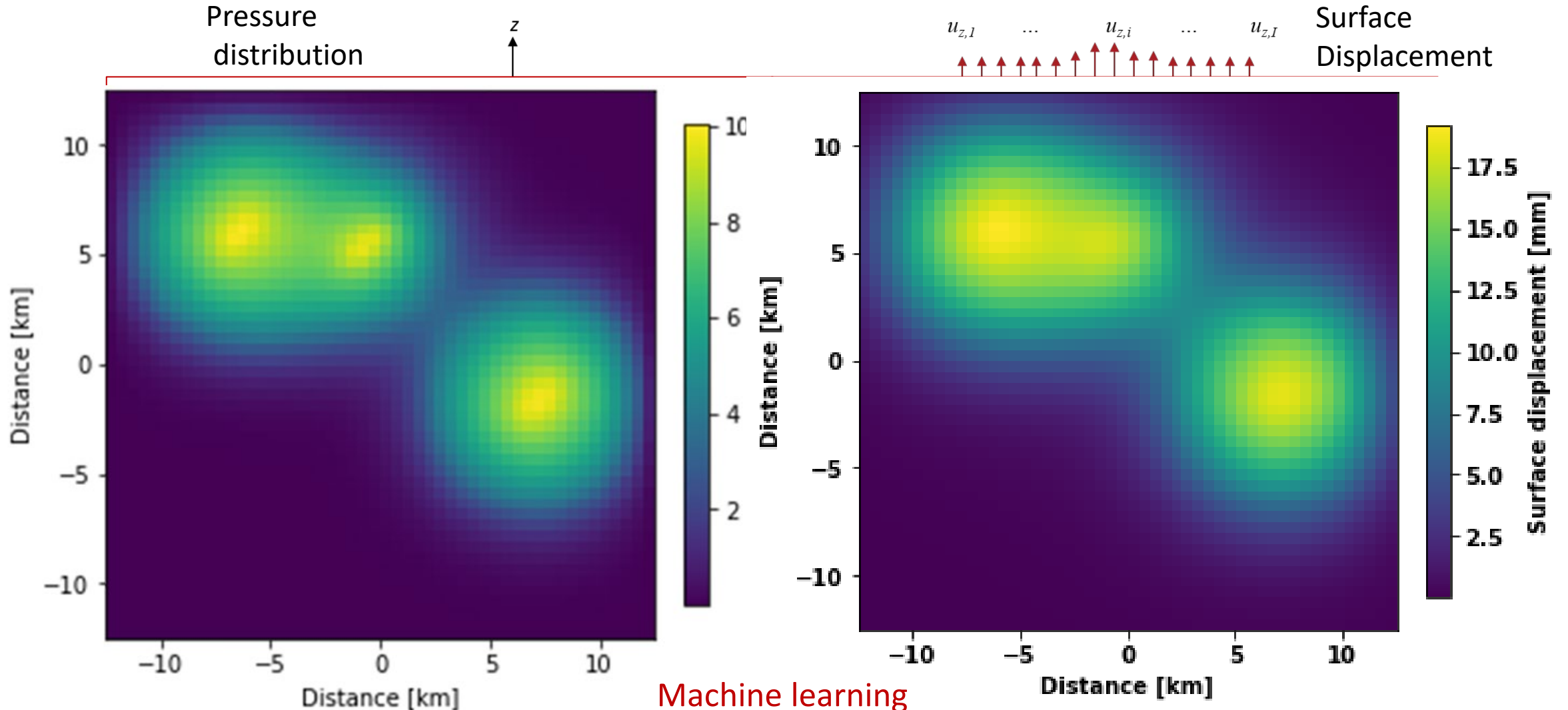
Q2: How reservoir deformation is transferred to the surface?

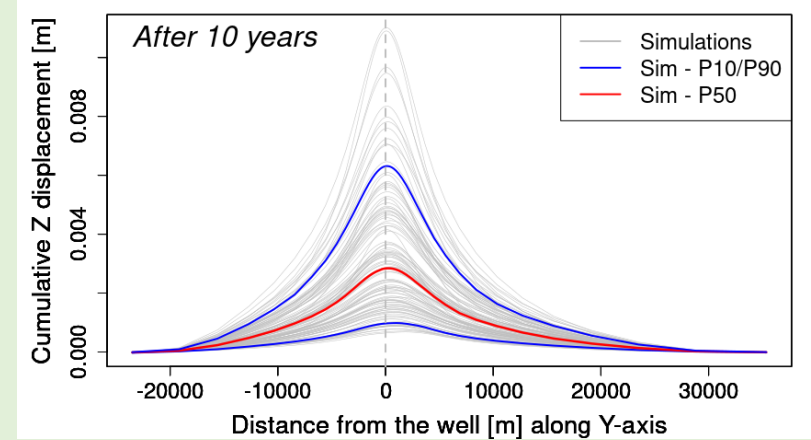## Numerical simulation of various types of reservoirs and uplift response
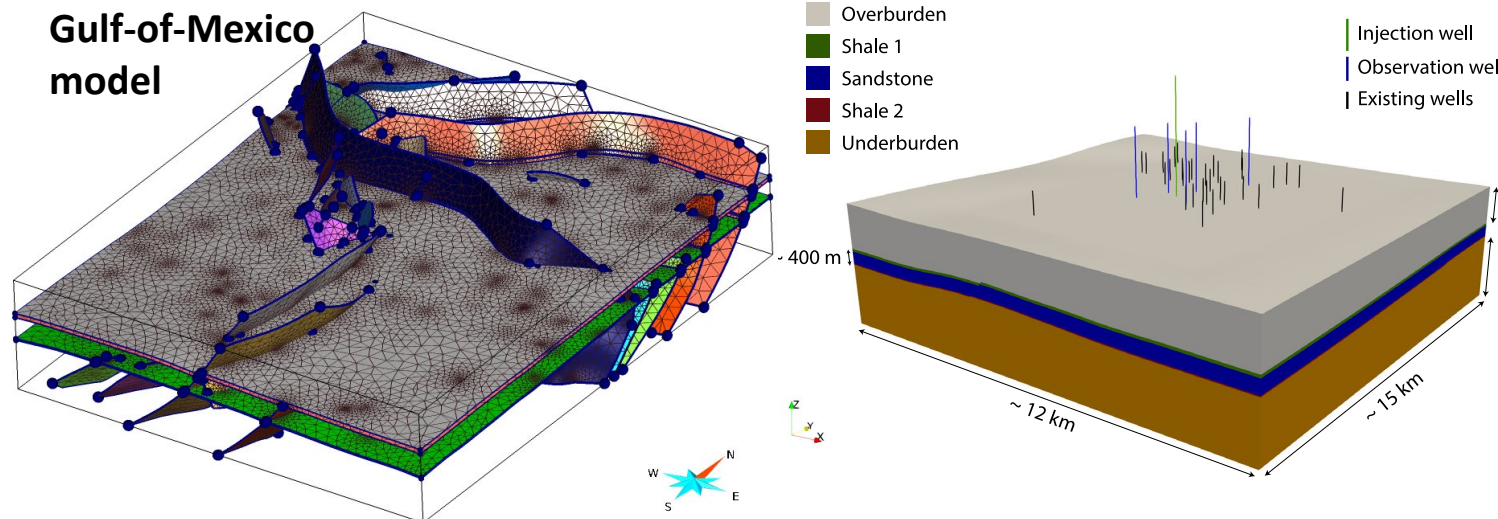

Carbonate — Uplift ca 2-15 mm in 10 years
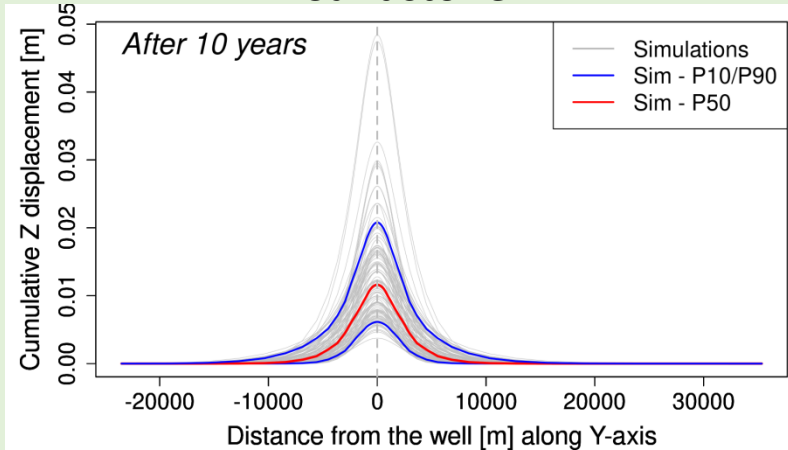
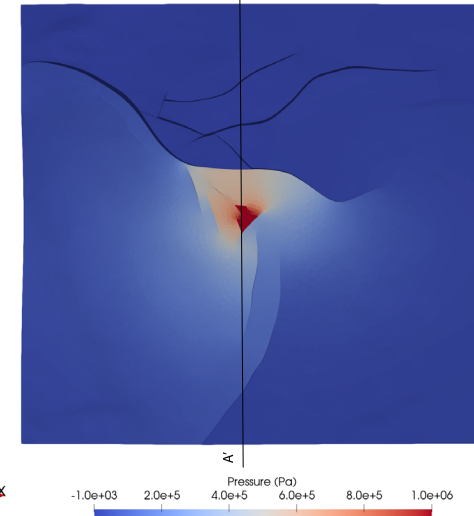Sandstone I — Uplift ca 5-50 mm in 10 years
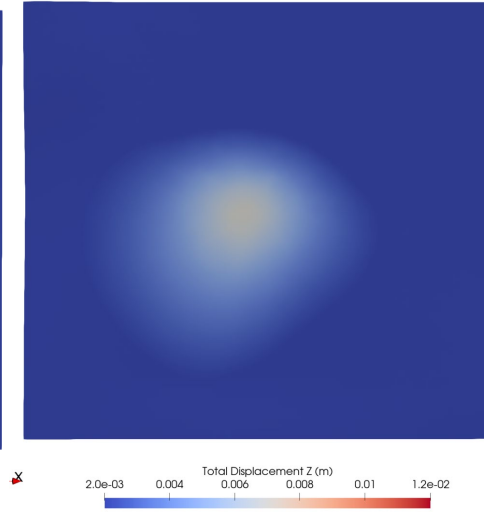
Sandstone II — Max. uplift <10 mm in 10 years

Gulf-of-Mexico model

Overburden
Shale 1
Sandstone
Shale 2
Underburden

Injection well
Observation well
Existing wells

~ 400 m

~ 12 km

~ 15 km

Reservoir excess pressure

Seabed deformation

Q2: How reservoir deformation is transferred to the surface- Impact of faults

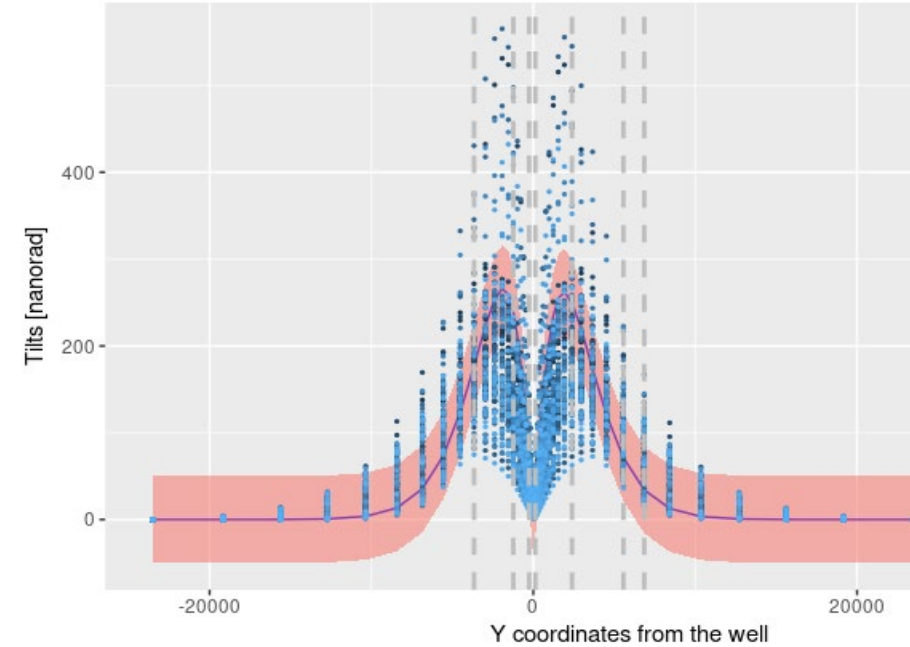Sealing fault

Draining fault

*Difference*
Sealing – Draining [m]
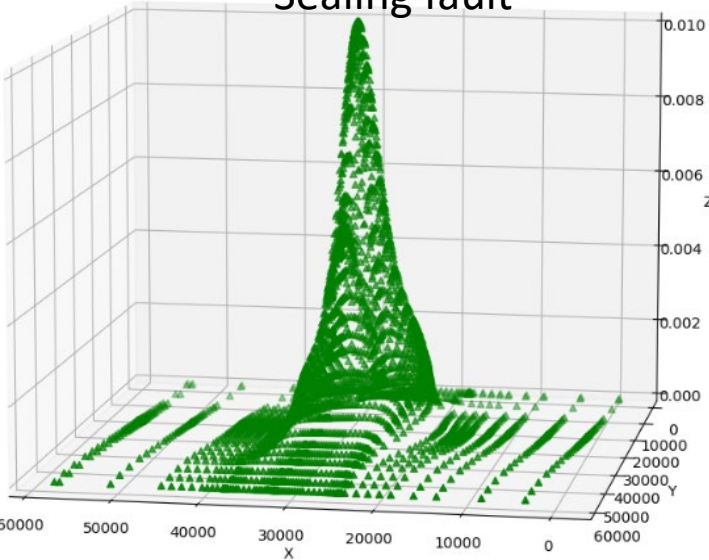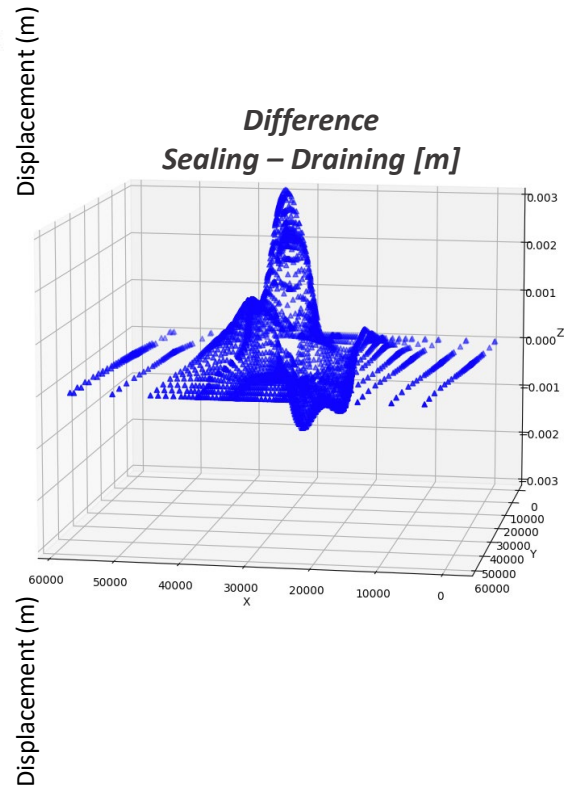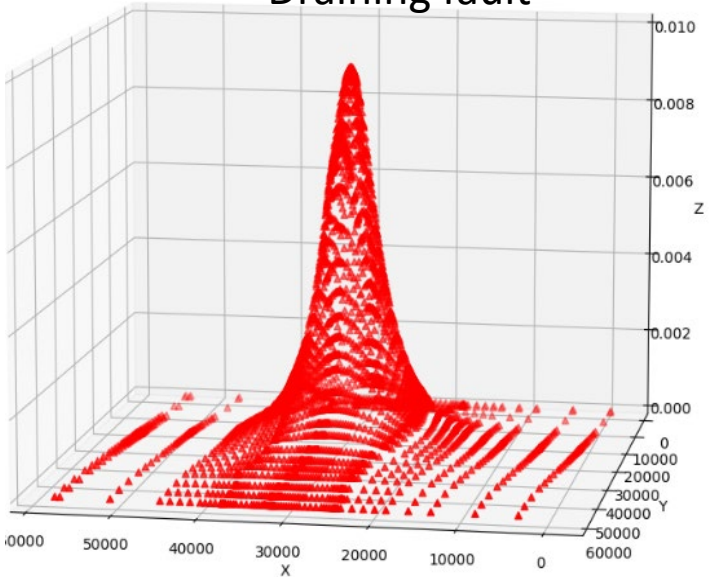
Optimize monitoring survey
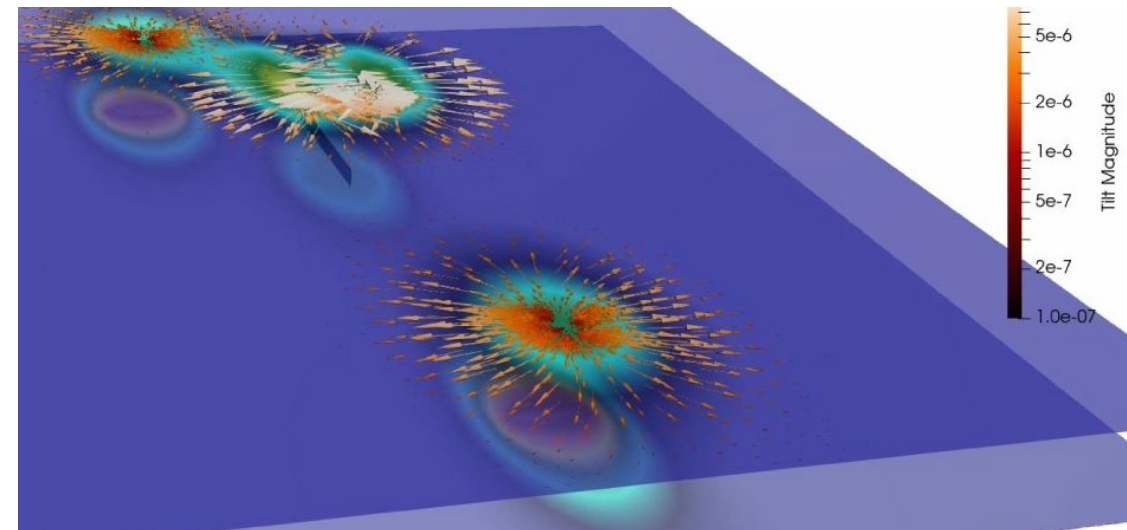
Q3: Integration - Contribution to CO$_2$ storage monitoring

- Ground deforamtion as a cost-effective monitoring:
  - Offshore
    - Norwegian Continental Shelf (NCS): We have developed routines, codes and inversion techniques that work well to model & estimate deformation at Troll field. It will likely work for Northern Lights storage site too.

    - US Gulf Coast: Simulations that stimate deformation and uplift and suggest the range of deformation→ *fiber optics may be more feasible* to monitor deformation

  - Onshore:
    - InSalah & UK analogue gas storage site, Hontomin: automatic InSAR processing → reduces monitoring cost, robust numerical simulations
    - Suggest tiltmeter for monitoring deformation hot spots
    - Integration of deformation with microseismic (MS & deformation are linked).
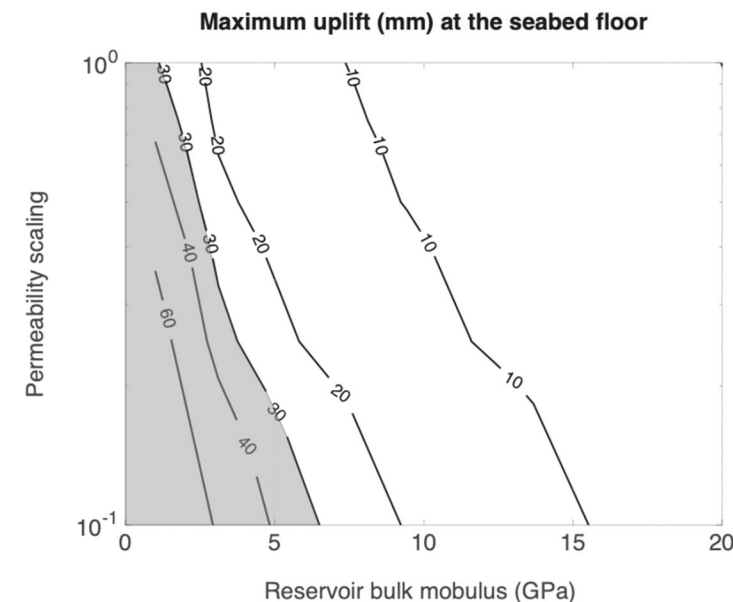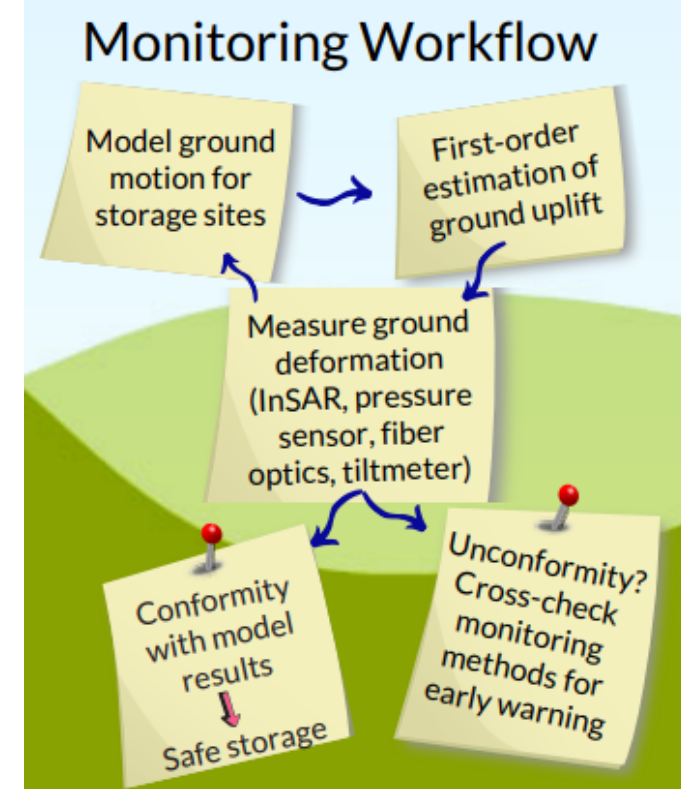
Dissemination activities

Deliverable	Quantity
Journal papers	6
Conference articles	25
Project reports	4
Outreach to industry, the public, Professional societies, regulators	24
Total	**59**

Collaboration with ACT projects: DIGIMON, ACTOM
(joint meetings, plan for joint events during 2022)

SENSE has held its first webinar

SENSE webinar no 1: InSAR data and theoretical aspects

Acknowledgement

https://sense-act.eu