https://sense-act.eu/

# Measurement and inversion techniques for onshore and offshore monitoring

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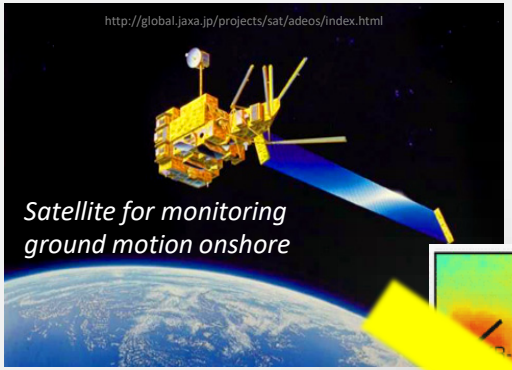
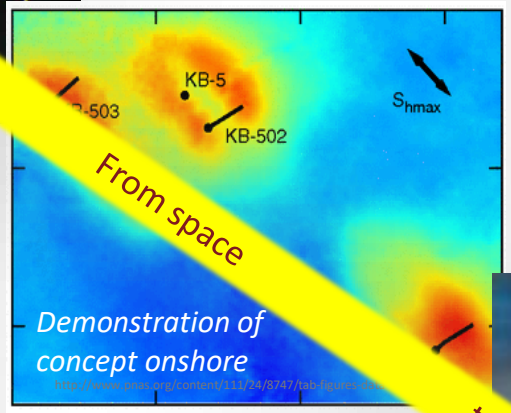
CLIMIT Digit21
10 Feb. 2021

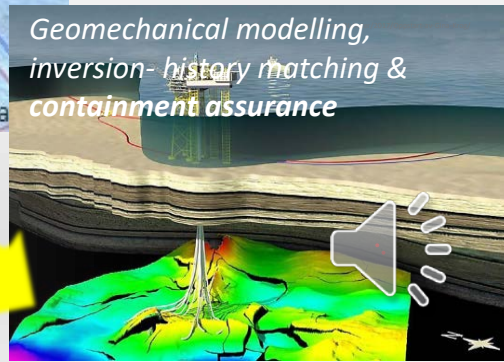
**SENSE (Assuring integrity of $CO_2$ storage sites through ground surface monitoring)**

# SENSE project




From space to the subsurface


**Motivation**:

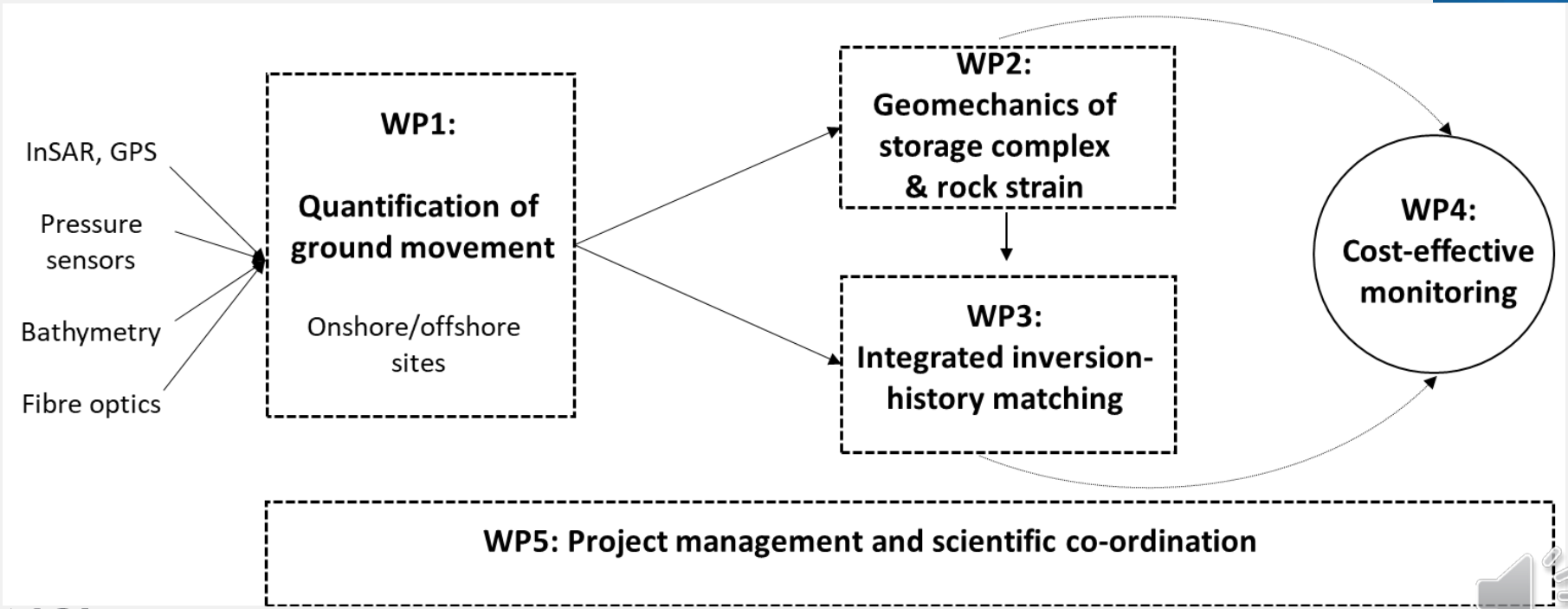
- Ground deformation due to reservoir pressurization contains valuable information on reservoir performance and the subsurface.

**Objective**:

- Ground movement as an **alert system** for **changes** in the subsurface

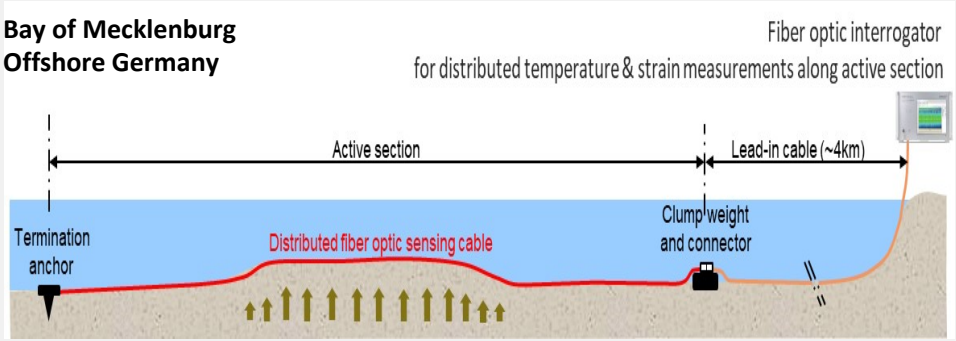
- **Containment assurance & cost-efficient** monitoring for $CO_2$ storage sites.

# Project structure

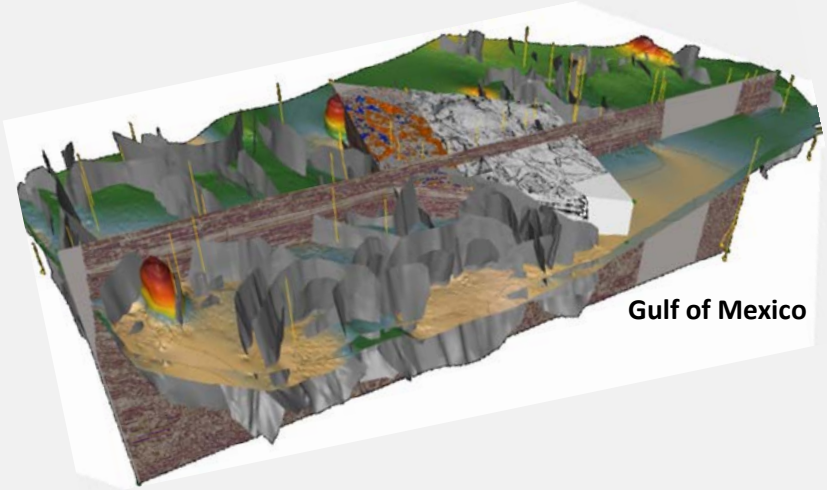


# SENSE case studies


**Bay of Mecklenburg**
**Offshore Germany**




***Hatfield Moors, the UK***

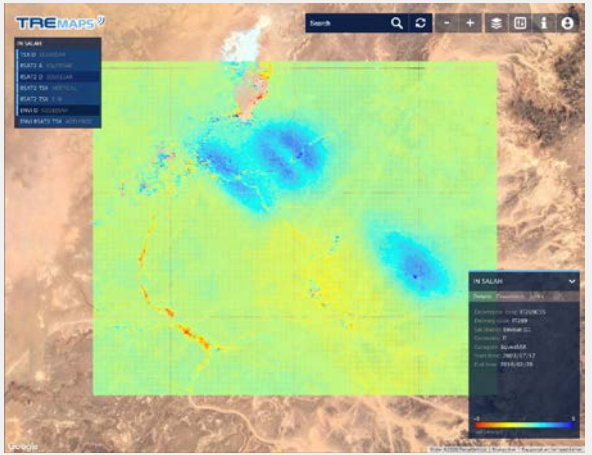


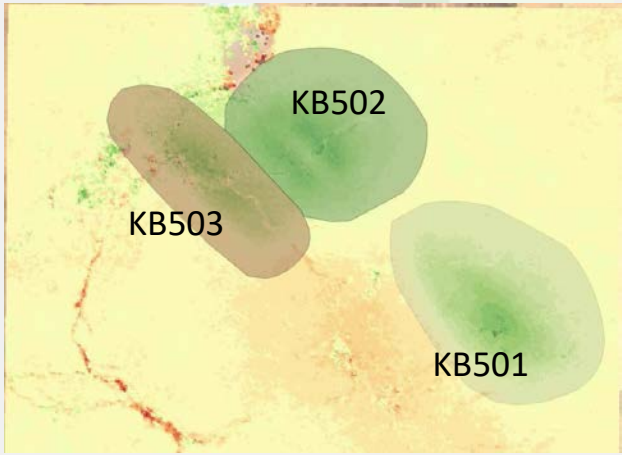
**Gulf of Mexico**

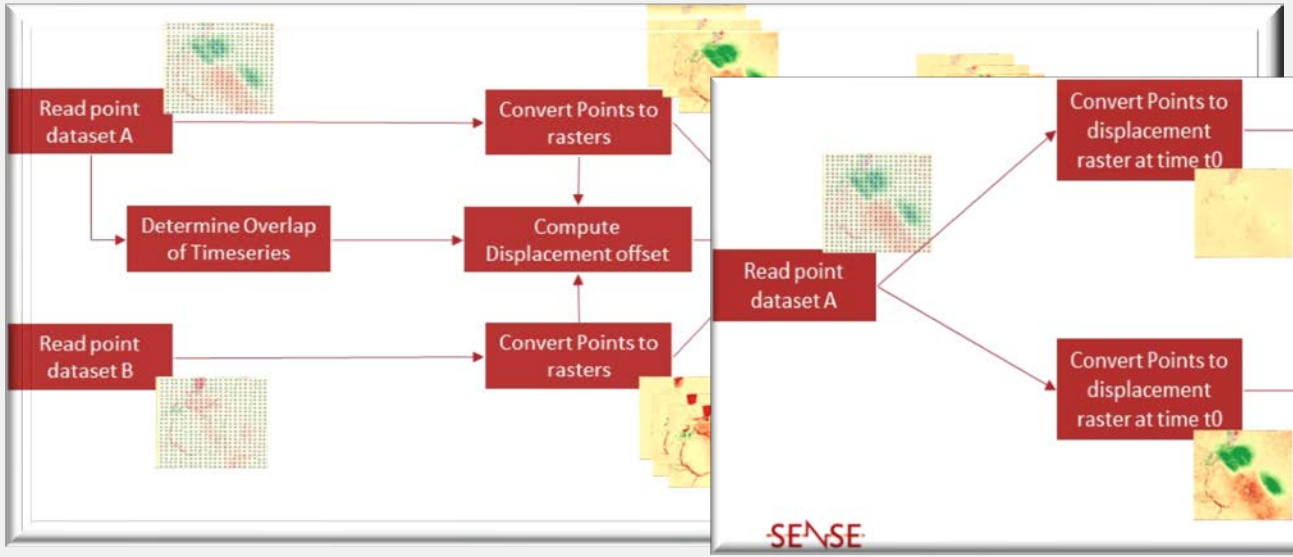
# Case study: In Salah (new InSAR data)

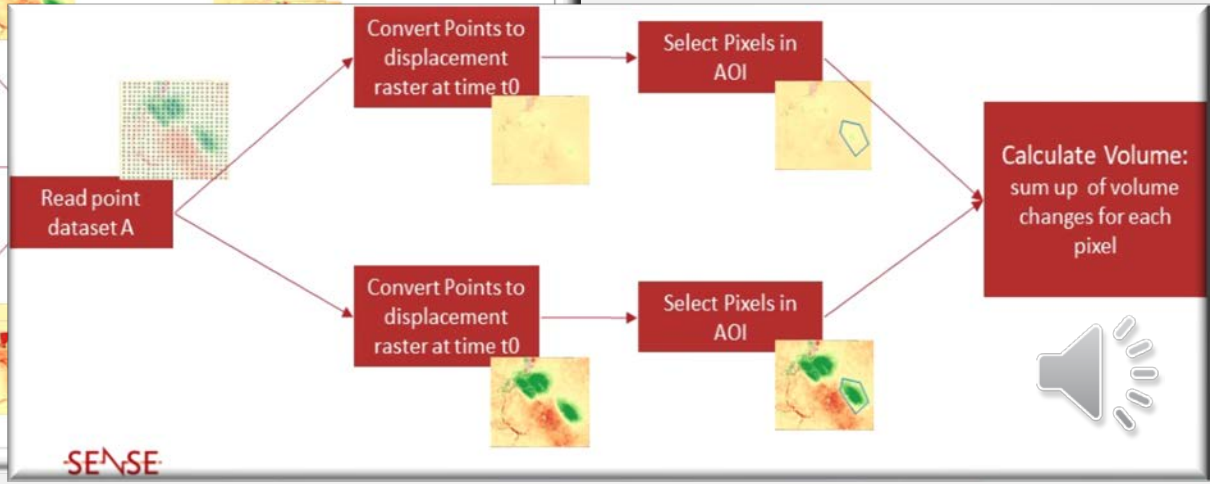
# In Salah InSAR

- From TRE Altamira:
  - EnviSat, 2003–2010
  - Radarsat-2, 2008–2016
  - TerraSAR-X, 2010–2016
- Freely available data:
  Sentinel-1 (ca. 15 x 15 m), 2016-2020

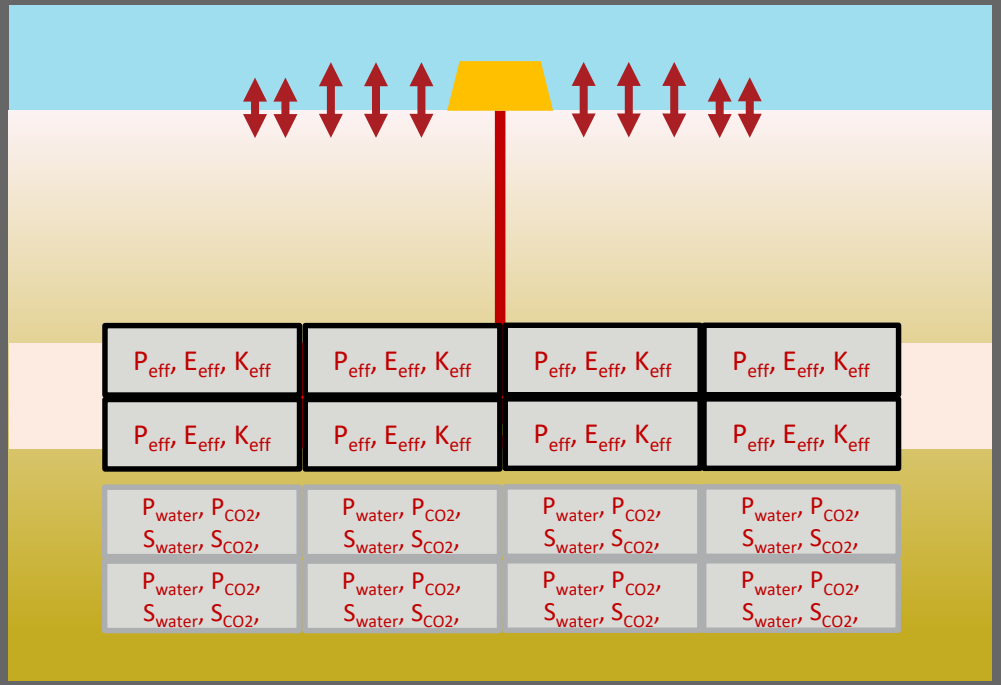


# 2-step inversion strategy




Surface deformation

↓

Invert for $P_{eff}$, $E_{eff}$, $K_{eff}$
via
Generalized Geertsma solution

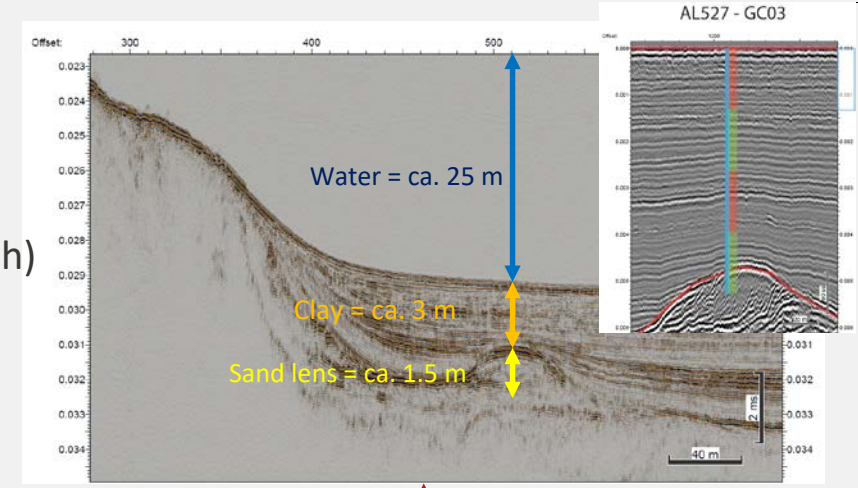
↓

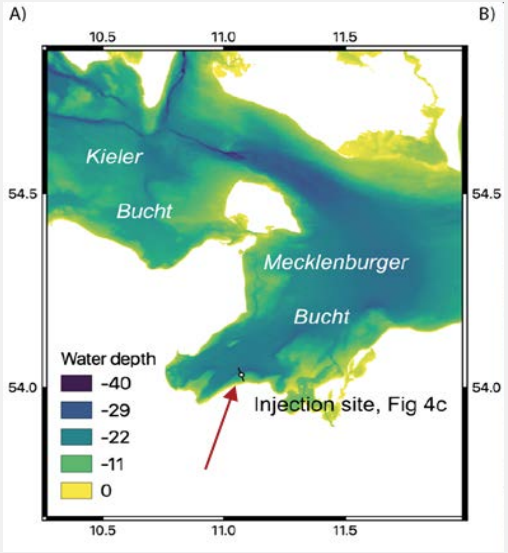
Invert grid-by-grid for $P_{water}$,$P_{CO2}$,$S_{water}$,$S_{CO2}$
via
$P_{water}+P_{CO2}=P_{eff}$
$S_{water}+S_{CO2}=1$
$RPM = f\,(E_{eff}, K_{eff}, P_{water}, P_{CO2}, S_{water}, S_{CO2})$

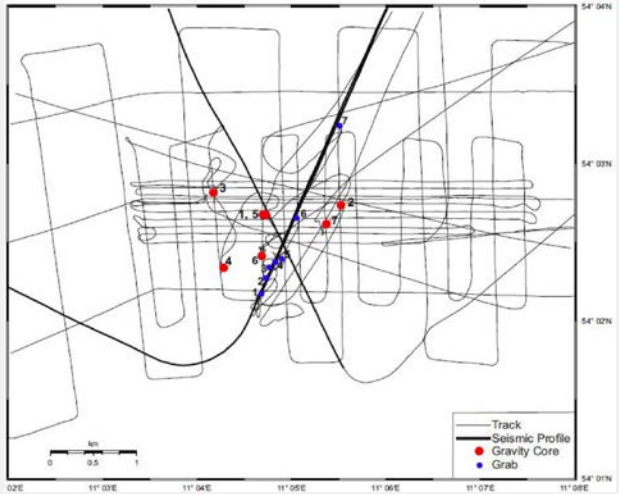
# Case study: Bay of Mecklenburg-offshore Germany

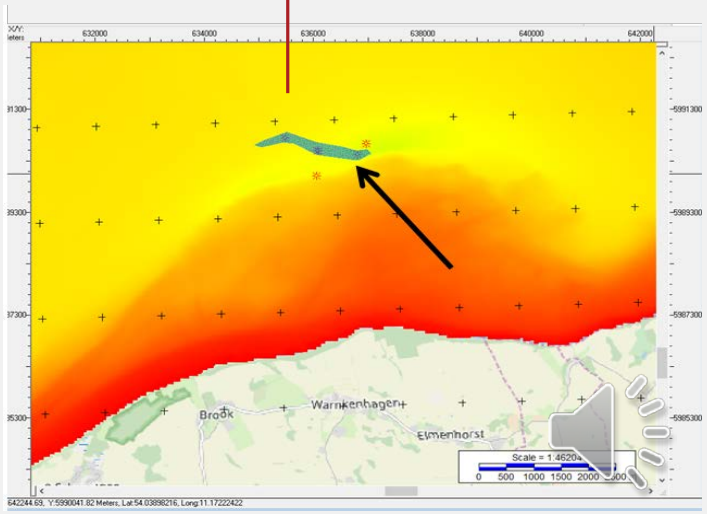
# Bay of Mecklenburg

- Design of air injection test offshore Germany
- Elongated, shallow sand lens (2-3 m thick, 25 m depth)
- Goal: test the newly developed equipment, seafloor instrumentation, data acquisition, expected surface displacement



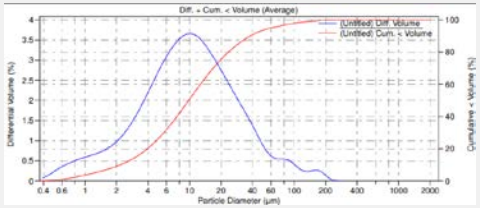



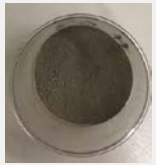



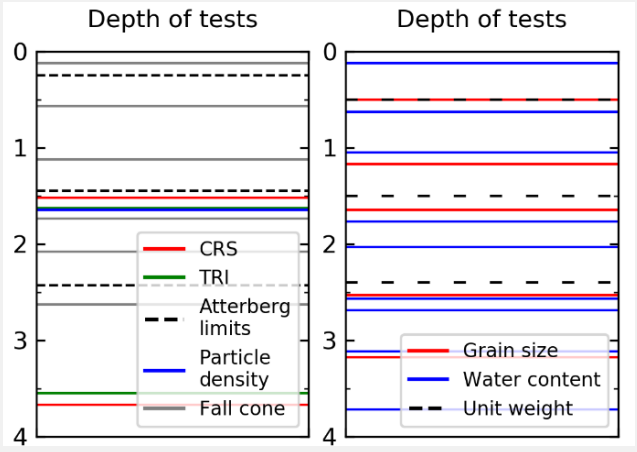
# Site investigation

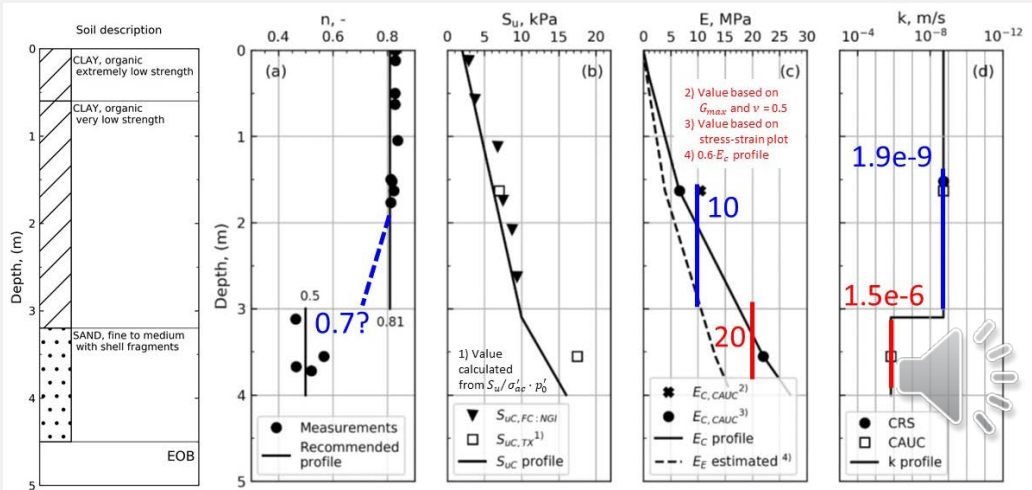
Gravity cores:

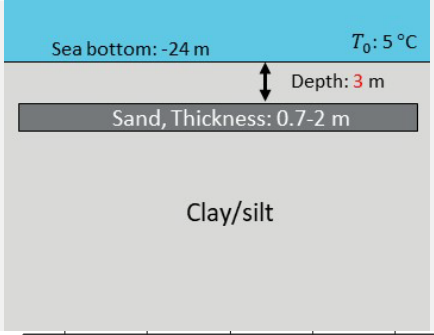
- Physical characterization
- Mechanical tests
- Input for numerical simulations

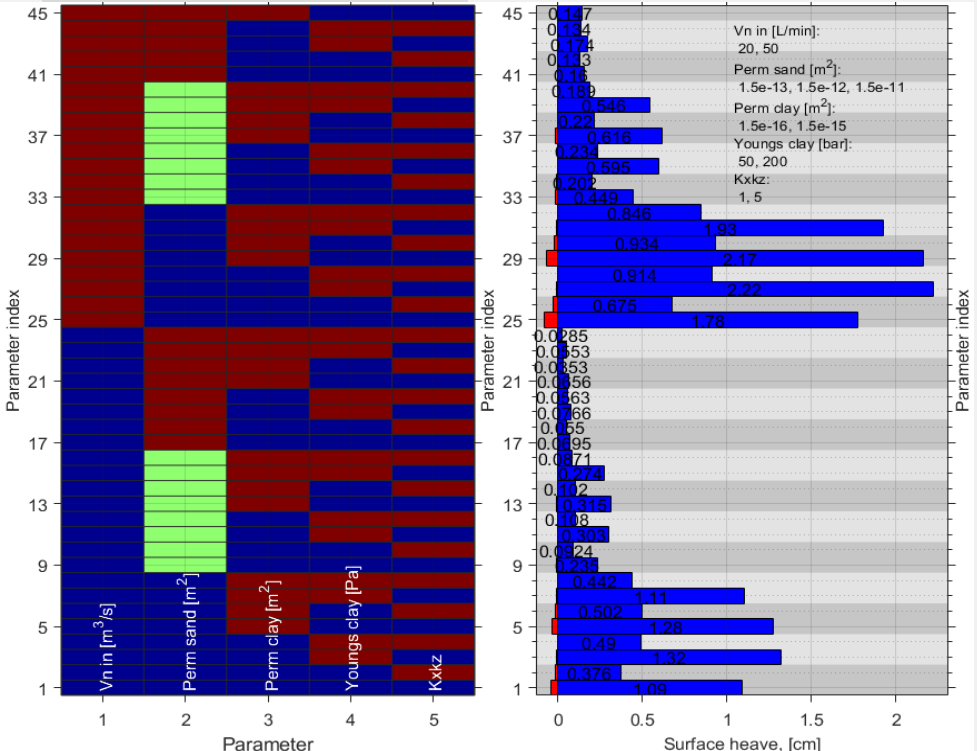



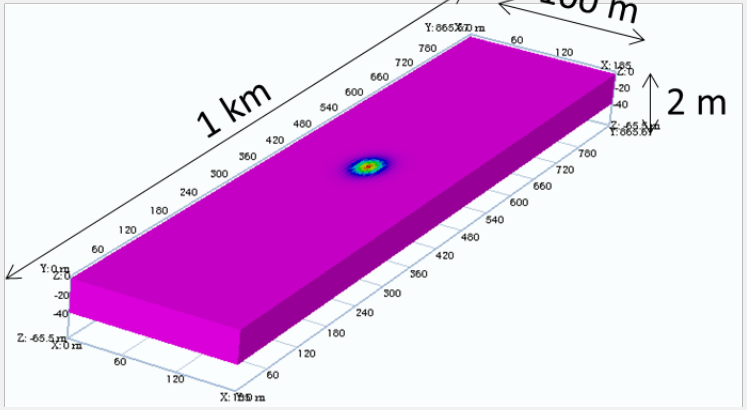


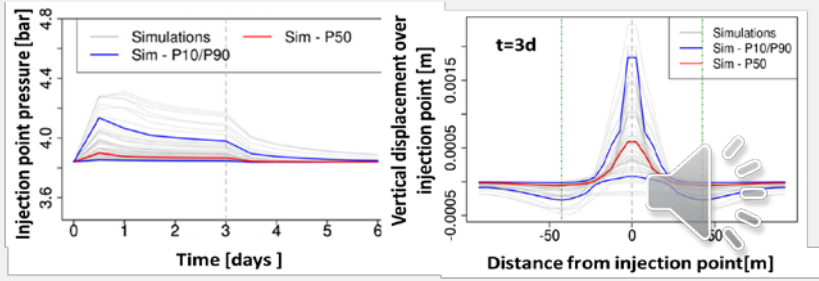






# Simulation of injection and uplift



# A pilot test at our field site (near Tokyo)




*Shallow trench for fiber cable installation*


*fiber cable covered with Soil (Left) and Cement (Right)*

## Dead Weight Test for Surface Deformation Monitoring

*Fiber cables were covered with Soil*

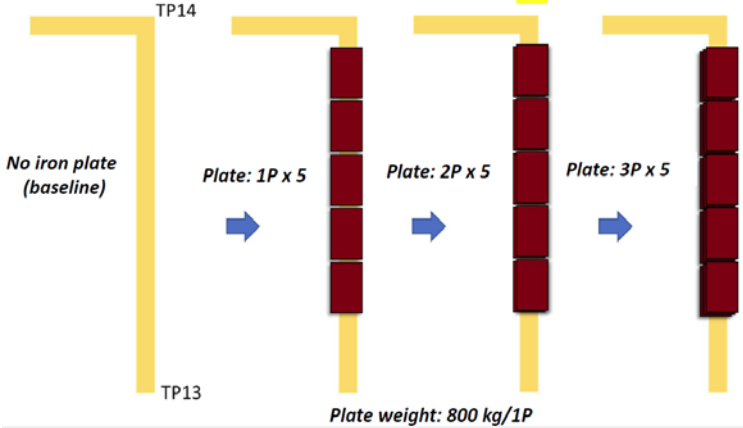
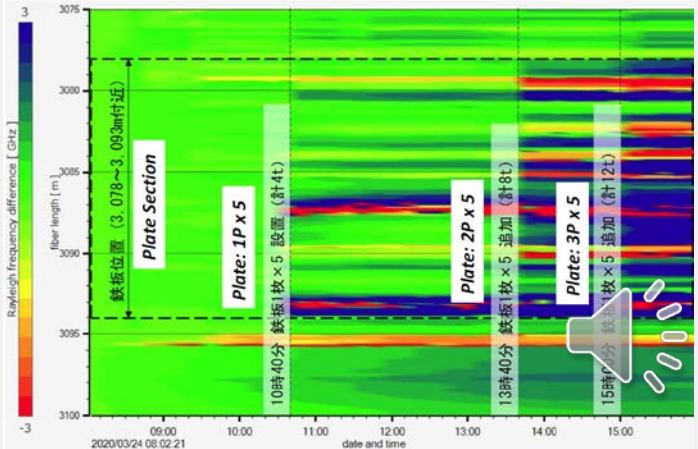


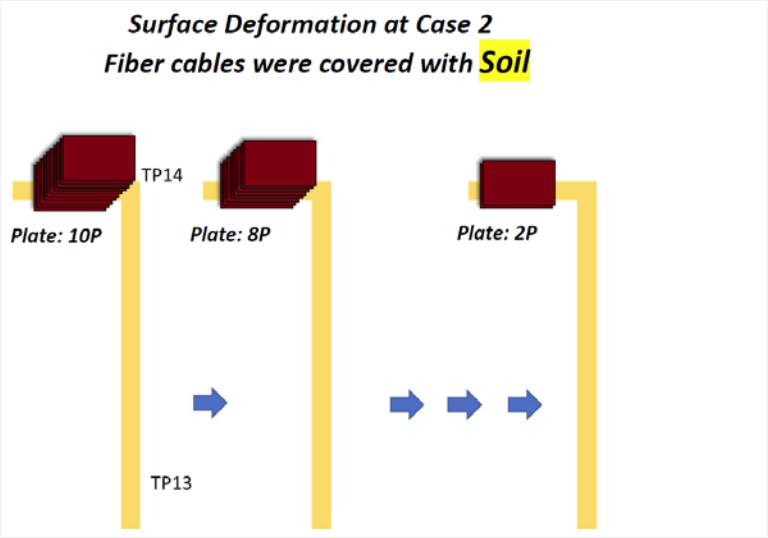

*Plate weight: 800 kg/1P*

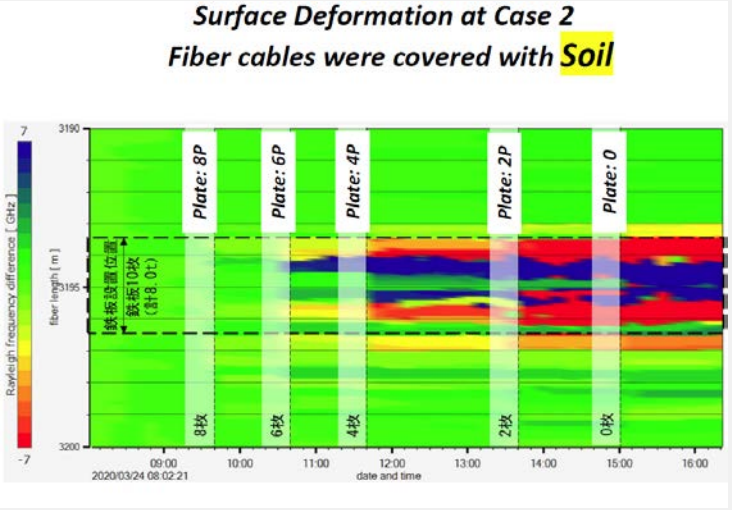
*Surface Deformation at Case 1*

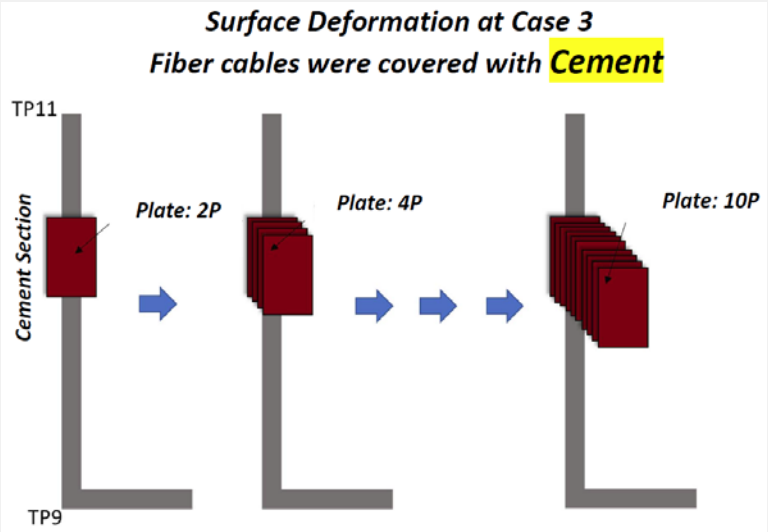
*Fiber cables were covered with Soil*

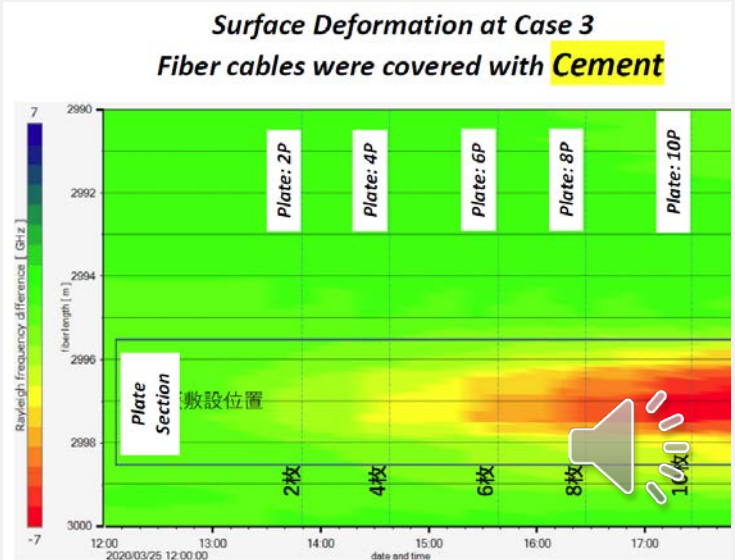


# Fibre optics in soil/ cemented trench



# Dissemination activities

SENSE Website https://sense-act.eu/

SENSE Twitter: @SenseAct

Research Gate: Sense-ACT

- The 5th ACT Knowledge Sharing Workshop 16-17 Nov. 2020, Online.
- State-of-the-art report on $CO_2$ storage site monitoring: accessible at https://sense-act.eu/
- 15th International Conference on Greenhouse Gas Control Technologies GHGT-15, 15-18 March 2021. Abu-Dhabi, UAE
- SENSE case study- NGI lab report 20190570-01-R
- Bohloli B., Park J., Bjørnarå T.I., Sparrevik P., Frauenfelder R., Vöge M., Ritter S., Mondol N.H., Berndt C., Karstens K., 2021. Monitoring ground surface and seafloor deformation caused by subsurface fluid injection. 1st Int. Conference on Sustaiability in Geotechnical Engineering, Lisbon, Portugal.
- Camargoa J.T., White J.A., 2020. Deformation monitoring feasibility at an offshore carbon storage site, Interim progress report, December 2020.
- Dombrovski E., Mondol N.H., Bohloli B., Gaina C., Torabi A., 2021. Applying machine learning on InSAR data for carbon sequestration aite monitoing. Abstracts and Proceedings of the Geological Society of Norway 2021.
- Rogstad A., Bohloli B., Quinteros S., 2020. SENSE Case Study: Geotechnical testing of clay and sand, Bay of Mecklenburg, offshore Germany. NGI report 20190570-02-R, 58 p.
- Mondol N.H., 2020. Grain size analysis of sediment cores from Bay of Mecklenburg, offshore Germany. Report, Department of Geosciences, University of Oslo.
- Park J., Bjørnarå T.I., Bohloli B., 2020. Analytical solution for pressure-induced surface deformation of anisotropic multilayered systems.
- Skomedal E., 2021. $CO_2$ storage is taking off. SPE Geomechanics Technical Section.

NGI

# Summary

- We are working on new InSalah InSAR data (2011-2020) and integrate with data of 2003-2010,
- We have modified Geertsma model to account for inhomogeneous layers and free geometry. Application to case studies is underway,
- Site characterization and modeling of Mecklenburg site shows seafloor deformation will be in the range of mm-cm scale,
- Fibre optics trenched in soil shows a more clear response than that in cement. Coupling of cable to the ground has an important role. Further testing to continue.

# Acknowledgement

Total budget: 4.9 m€
ACT funding: 2.7 m€
Partners: 14
Countries: 9
Timeline: Sep. 2019 - Aug. 2022

SENSE (Assuring integrity of $CO_2$ 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 and State Research Agency, Spain. Additional support from Equinor and Quad Geometrics and permission to use data from the Krechba Field by In Salah Gas JV are appreciated.