Ground Surface Monitoring for CO_2 injection and storage

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Subsurface Monitoring and Mapping

What?

Using near-surface data and measurements to understand what is going on underground.

Why?

- Improve operational outcomes.
- Know when things are going wrong!

How difficult is it?

VERY DIFFICULT!

'It's much harder than developing self-driving cars!!!'

Paraphrased from an underground energy storage client in the USA

Ground surface monitoring

What is ground surface monitoring?

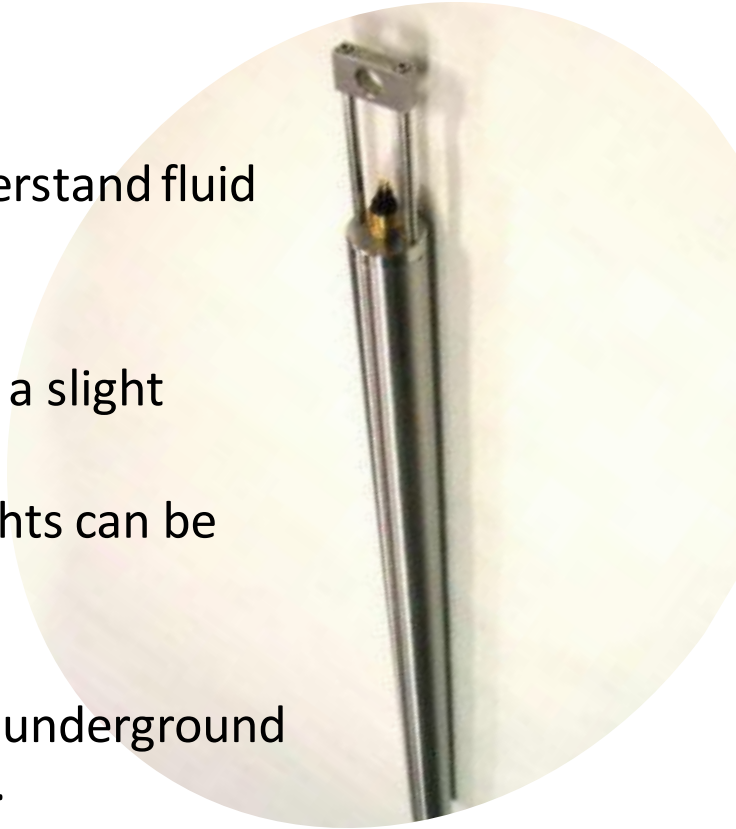
Using measurements of surface deformation to understand fluid movement in the subsurface.

How does ground surface monitoring work?

- Subsurface Injection and extraction of fluids cause a slight deformation at the surface.
- By monitoring the shape of this deformation, insights can be gained on subsurface fluid behaviour.

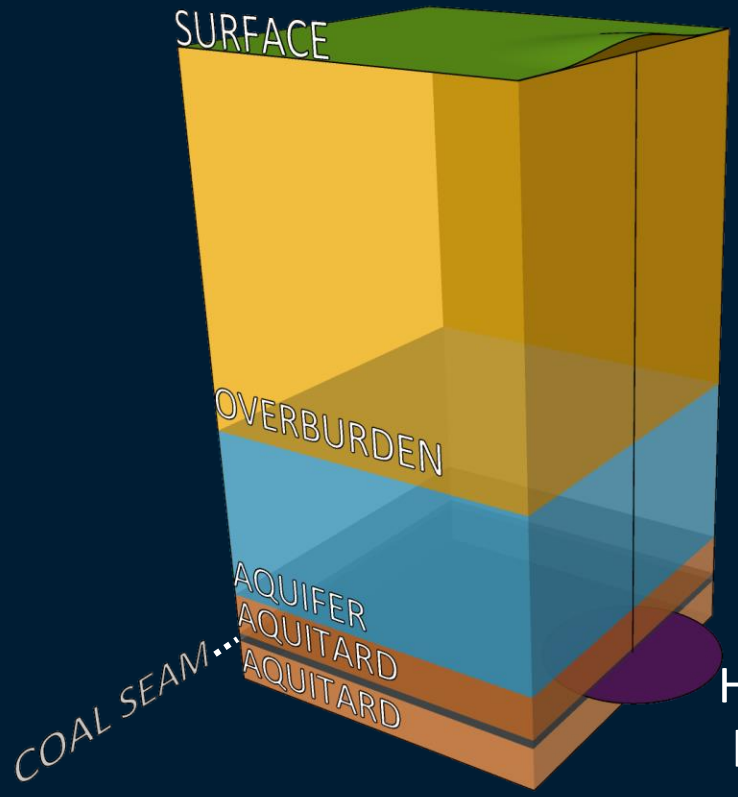
Where can this technique be applied?

Hydraulic fracturing, **CO_2 injection,** CSG dewatering, underground energy storage, H_2 storage, wastewater disposal, etc.



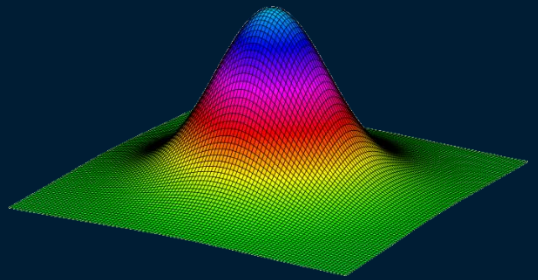
Use case example – Tiltmeter monitoring of a hydraulic fracture

Tiltmeter Monitoring



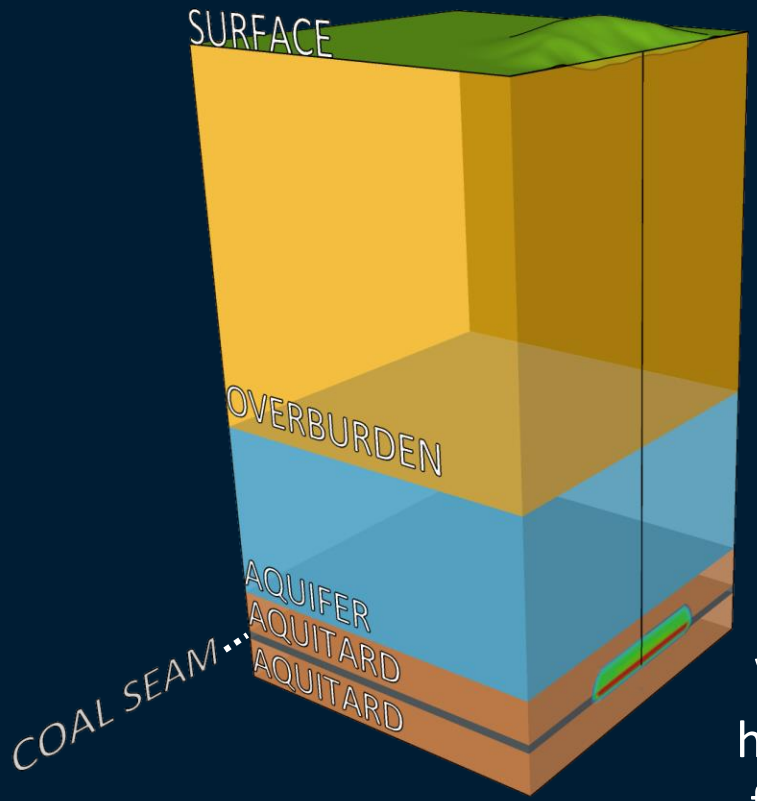
Horizontal hydraulic fracture

Surface deformation



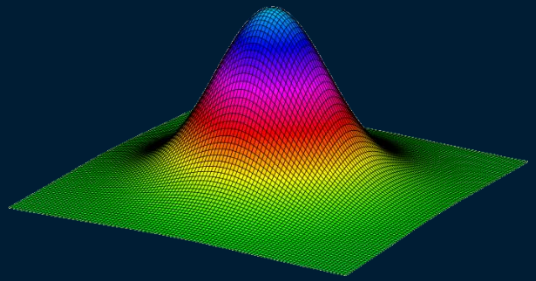
Horizontal fracture

Tiltmeter Monitoring

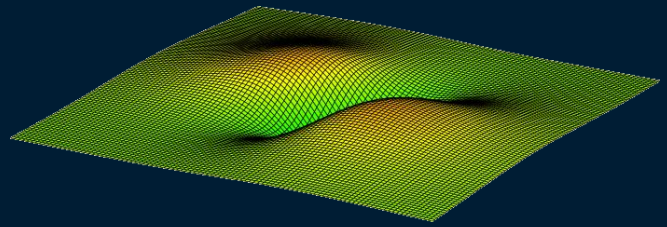


Vertical hydraulic fracture

Surface deformation



Horizontal fracture



Vertical fracture

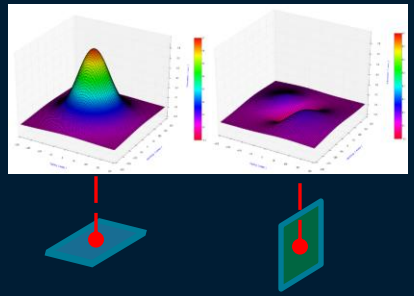
Tiltmeter analysis workflow

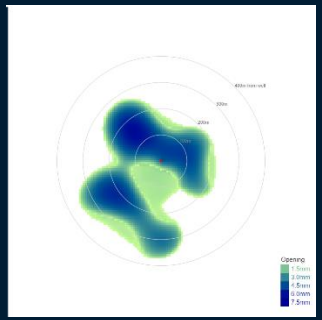
2. Data recording and communications station

3. Data Analysis

1. Tiltmeter instrument hardware – gather data

4. Results access and visualisation

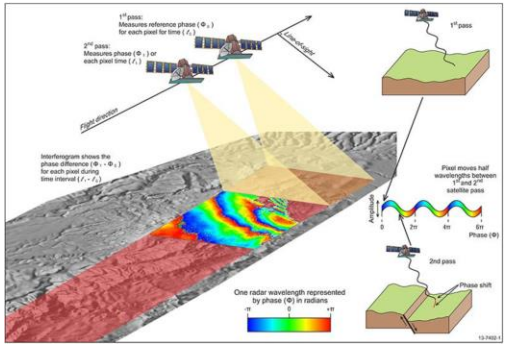




Ground surface monitoring options

InSAR satellite data

- Low cost acquisition
- Large area
- Low resolution (millimetre scale)



https://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/geodetic-techniques/interferometric-synthetic-aperture-radar

Tiltmeter array

- Higher cost
- Smaller area of investigation
- **Much higher** resolution

Fibre optic – distributed strain sensing

- Potentially a middle ground between InSAR and tiltmeters

What value would these methods bring for CO_2 sequestration monitoring?

In Salah Case Study

- 3.8Mt of CO_2 was injected between 2004 to 2011 into the In Salah field at Krechba, Algeria

- The geomechanical responses to the CO_2 injection have been widely used to evaluate different monitoring techniques and geomechanical models

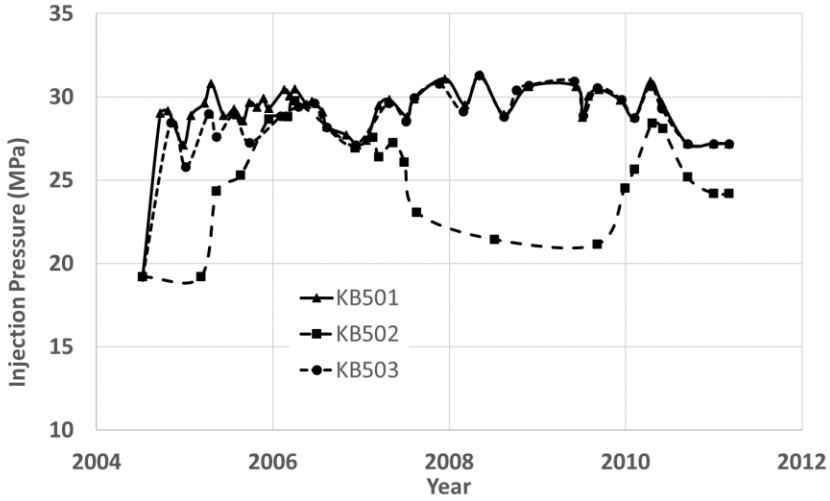
In Salah – Overview

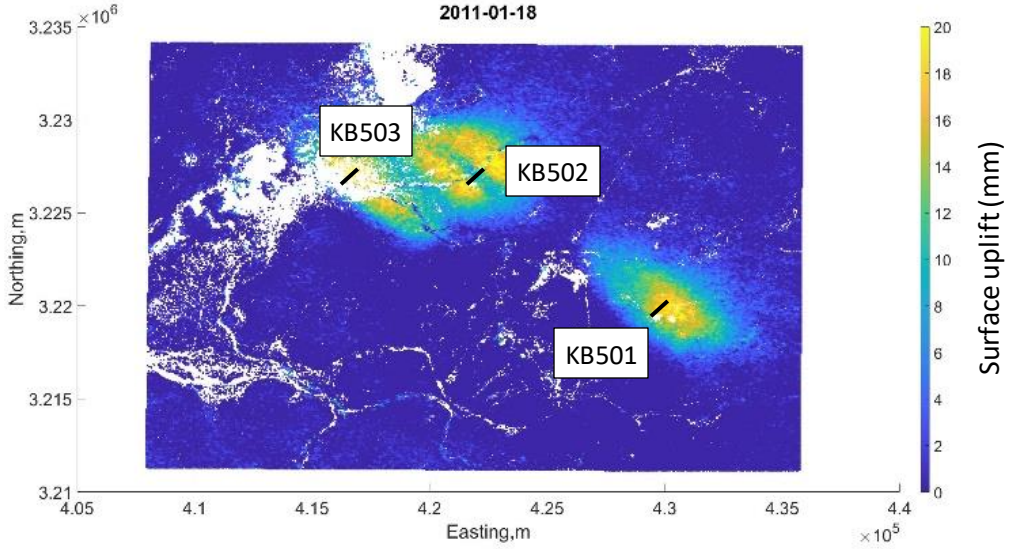
CO_2 was injected into three wells:

- KB501
- KB502
- KB503

The injection wells had depth of 1810m (within the reservoir layer)

A strong ground surface uplift was observed at all three well locations





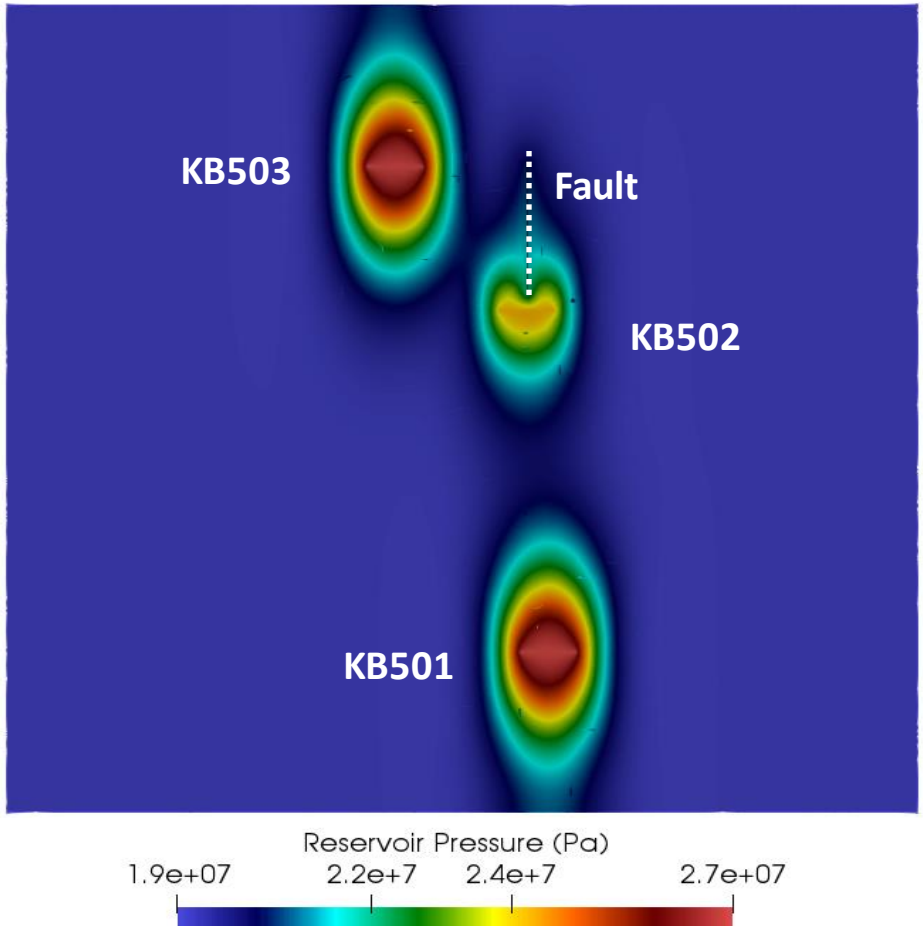
In Salah – Simulation

InSAR (satellite) monitoring the surface deformation shows:

- two of the wells demonstrating 'normal' behaviour (horizontal plume)
- one well (KB502) looks to have **mobilised a fault**

A 3D finite element model of the In Salah field was created including of a vertical conductive fault near KB502

The model was able to replicate the injection pressure and surface deformation behavior

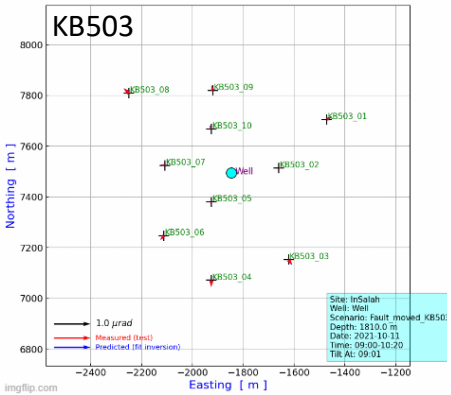


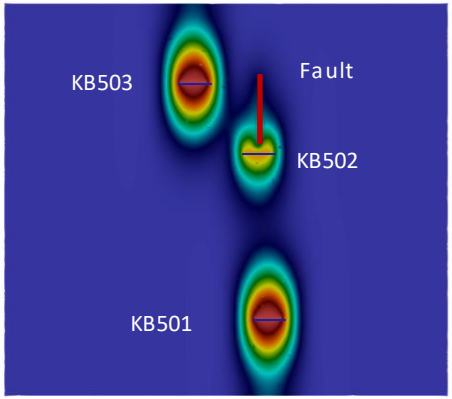
In Salah – Synthetic tilt data from KB503 & KB501

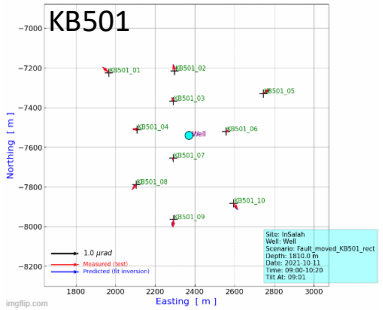
Synthetic tilt data from the 3D FEM simulation was analysed by the inverse analysis (TAL tool)

KB501 and KB503 produced ground surface deformation consistent with a horizontal fluid plume

There is good correlation between the synthetic tilt data from the 3D FEM simulator and the fitted data from the inverse analysis







In Salah – Synthetic tilt data from KB502

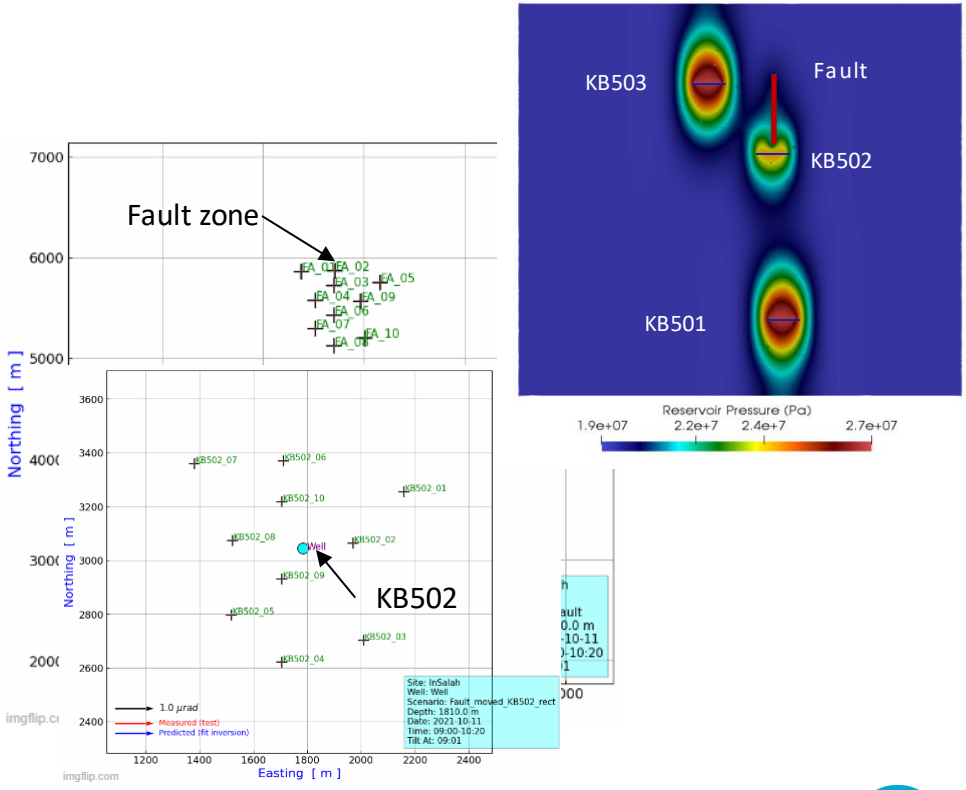
KB502 produced ground surface deformation consistent with the reactivation of a vertical fault to the north-west of the well

Ground surface deformation was calculated for two simulated tiltmeter arrays:

- At the well location
- Surrounding the vertical fault

The simulated tiltmeter array at the fault was a good match for a vertical fluid plume

The simulated tiltmeter array near the well was a less clear match to either a horizontal or vertical fluid plume



Conclusions on Ground surface monitoring of CO_2 injection

- CO_2 injection produces ground surface deformations at a sufficient magnitude to be monitored with InSAR, tiltmeter (and potentially optic fibre)
- 3D finite element simulation is able to accurately replicate ground surface deformations induced by CO_2 injection
- Synthetic ground surface deformation data for different scenarios (from the 3D FEM) can be used to test and train the analysis process
- Tiltmeter arrays have a higher resolution than InSAR and are potentially able to identify problems much earlier

Thank you

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