How to determine if a CO₂ storage site is performing as expected – quantitative conformance tools developed by the Pre-ACT project

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EU CCS Showcase Event
10/09/2019 Brussels
Background

• ACT (Accelerating CCS Technologies) call 2016

• We wanted to identify and address main storage-related challenges for accelerated deployment of CCS in collaboration with industry.

• Focus on crucial storage challenges: capacity, confidence, and cost

• Least common denominator: pressure

Pressure control and conformance management for safe and efficient CO₂ storage - Accelerating CCS Technologies (Acronym: Pre-ACT)
Pre-ACT

• Pressure control and conformance management for safe and efficient CO2 storage - Accelerating CCS Technologies

• 3 year project

• Research and industry partnership with a focus on North Sea storage
The Pre-ACT approach

• Answering to industry needs
• Learning from demonstration, pilot, and field lab data
• Deliverables with focus on industry uptake
RE-VITALISATION AND UPGRADE

Development and testing of technologies and equipment required for large-scale CCS applications in a rapid and cost efficient manner

ECCSEL INFRASTRUCTURE

- European Carbon dioxide Capture and Storage Laboratory Infrastructure
- Opening access for CCS researchers to a top quality European research infrastructure
- Nine European countries
Saturation, pressure and conformance

- Large scale CO₂ injection generates widespread changes in the subsurface.
- The consequences can be imaged or appraised with active and passive geophysical measurements and downhole monitoring.
- But what controls the size and scale of the subsurface anomalies?
- And what can a point measurement say about the entire storage reservoir?
- How can limited geophysical measurements demonstrate conformance of a storage site?
Conformance: history matching

- CO\textsubscript{2} migration can be accurately imaged with geophysical data.

- Flow simulations, based on the best estimates of reservoir parameters, allow prediction to be made.

- But results do not always match!
Sleipner – top sand wedge

• Additional data, or understanding, allows a new model to be developed.

• Here higher resolution seismic has allowed channel structures to be imaged.
High permeability channel
Conformance

Conformance assessment

• Definition of conformance is case-specific (e.g., pressure limits, CO₂ containment)
• Observed behaviour (measurements) in compliance with expected behaviour (model predictions) and regulations
• Conformance statements must account for uncertainties (model and measurements)

Monitoring strategies to improve conformance assessment

• Well measurements (e.g., bottom-hole pressures, flow rates)
• Field-wide geophysical surveys (e.g., time-lapse seismic)
Injected CO₂ must remain within regulatory/safety bounds

- Quantity of interest: conformance verification at the end of injection period ($t = T$)

Monitoring alternatives:

- Time-lapse survey during interval $t = [0, T]$
- How to design the configuration of such a survey?
- Which configuration is most useful to improve conformance verification?
Geological uncertainty

- Geological structures influence propagation of CO₂ plume (e.g., heterogeneities in rock properties)
  - Ensemble of model realizations to characterize geological uncertainty
  - Ensemble of model predictions $\rightarrow$ Probabilistic conformance assessment

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History matching

- Incorporate data measured during CO₂ injection to update model realizations
  - Ensemble-based data assimilation methods

Prior

Truth #1

Truth #2

Posterior

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Incorporate data measured during CO₂ injection to update model realizations
- Ensemble-based data assimilation methods

History matching

Prior

Truth #1

Truth #2

Posterior

False positive

Data

False negative
Survey considerations

- Varying time of acquisition

![Graph showing varying time of acquisition](image)

![Graph showing total fraction of falses](image)
Case studies

Closure 35 (5/42 Endurance structure)

Seabed outcrop

Closure 36

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Create synthetic data for assessment

Seismic plume footprint, downhole pressure, gravity data are modelled for all realisations to feed into the Pre-ACT conformance assessment tool.
Next steps

• Apply full Pre-ACT conformance assessment to three case studies
• Assessment of downhole pressure data and ability to infer regional response
• Assess different monitoring techniques relative to ability to demonstrate conformance – this is a key output from the conformance tool.
The ACT Pre-ACT project (Project No. 271497) has received funding from RCN (Norway), Gassnova (Norway), BEIS (UK), RVO (Netherlands), and BMWi (Germany) and is co-funded by the European Commission under the Horizon 2020 programme, ACT Grant Agreement No 691712. In addition, we like to acknowledge the following industry partners for their contributions: Total, Equinor, Shell, TAQA.
RE-VITALISATION AND UPGRADE

INJECTION WELL
Convert Svelvik #2 into an injection well for water and \( \text{CO}_2 \) injection @ 64 – 65 m

MONITORING WELLS
Drilling and instrumentation of four vertical 100 m deep wells for cross-well monitoring