Geophysical monitoring offshore: past, present and future

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Norway CCS: Building on experience

- 21 years of operations
- Building confidence in CCS
- >21 Mt CO₂ stored
- New full-scale CCS project operational in 2022
Sleipner Summary

Net/gross: 0.98
Porosity: 35-40%
Permeability > 1 D
~ 200 m thick

Insights from geophysical time-lapse monitoring

Klær et al. 2016
Sleipner monitoring programme overview

Past: experimental learning phase

1996:
Injection start

2015
Re-permitting

Present: Regulatory compliance

2018:
17Mt

Future of monitoring?

Seismic

Gravimetry

Visual monitoring

Chemical sampling

From Furre et al. (2017)
Snøhvit Monitoring Overview

- Continued and confirmed the value of 4D seismic monitoring
- Demonstrated value of downhole P/T gauges
- Developed operational value of monitoring

Value of monitoring:
- Reservoir management / operations
- Regulatory compliance

Seismic sections

Top Fuglen Fm.

Base Tubåen Fm.

2009 Seismic Survey

4D (Amplitude difference)

Down-hole pressure data

From Hansen et al., 2013, Pawar et al., 2015
The Norwegian CCS Demonstration project

Smeaheia site

Future monitoring needs to be:
- Cost-effective
- Smart
What are the smart offshore monitoring solutions?

Developments in the offshore oil and gas sector include:

1. Increasing use of permanent reservoir monitoring (PRM) systems
2. Increasing use of downhole fibre monitoring
3. Use of advanced AUVs for environmental monitoring,
4. Use of advanced and integrated data analysis (digital world)

Challenges for CO₂ storage monitoring:
- Is it fit for purpose?
- Is it affordable?
Learning from onshore test sites

CaMI Field Research Station (FRS) in Alberta, Canada:

- Unique opportunity to develop and test monitoring technologies and integrated monitoring systems.
- Useful to build experience that could be taken offshore

Images courtesy of Don Lawton, U. Calgary
Working ideas for future offshore monitoring

1. Marine-streamer seismic acquisition – good baseline, fewer repeats
2. More use of downhole fibre-based monitoring - DTS/DAS
3. Development of trigger survey concepts – survey only if anomaly is detected
4. Environmental monitoring programme – using smart AUV based sensors
5. Advanced data analysis – Integrate multi-physics data, continuous/real-time

Challenges:
• Cost model (PRM needs upfront investment)
• Fibre-optic deployment in subsea injectors
• Handling multiple monitoring objectives
Value of permanent reservoir monitoring systems

PRM for CO₂ storage has several potential benefits:

- Continuous monitoring data
- More frequent repeat surveys
- Improved imaging of reservoir and overburden
- Passive listening (seismicity)
- Use of ambient noise methods
- Combining down-hole sensing with surface seismic
- Monitor geomechanics and plume
- Enables advanced processing (FWI, SWI, microseismic)

But it costs more …

... so can we trim the costs and demonstrate the value?

PRM study: Illumination heatmap at Top Sognefjord reservoir and at shallow overburden level (seabed plus 200m) from 2km x 2km seabed array (Roger Bakke, Statoil).

From Ringrose et al. (to be presented at GHGT-14 in 2018)
Conclusion

- How can we make monitoring smart and affordable?
- Will CO$_2$ storage move into the digital age?
References


