



Sleipner

Knowledge sharing in CCS projects - Workshop Mobile, Alabama

Sveinung Hagen and colleagues - Statoil

May 16 and 17 – 2012

Talk Outline and Context

- Storage operations overview
- Sleipner background
- Technology used and outcomes
- Lessons learned



Sleipner



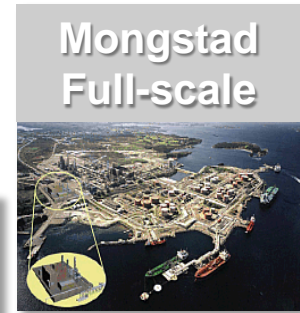
In Salah



Snøhvit
LNG



Test Centre
Mongstad



Mongstad
Full-scale

Statoil's CCS projects
An Industrial Approach to the Climate Change Challenge

1996-

2004-

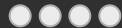
2008-

2012-

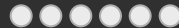
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Overview



Sleipner Background



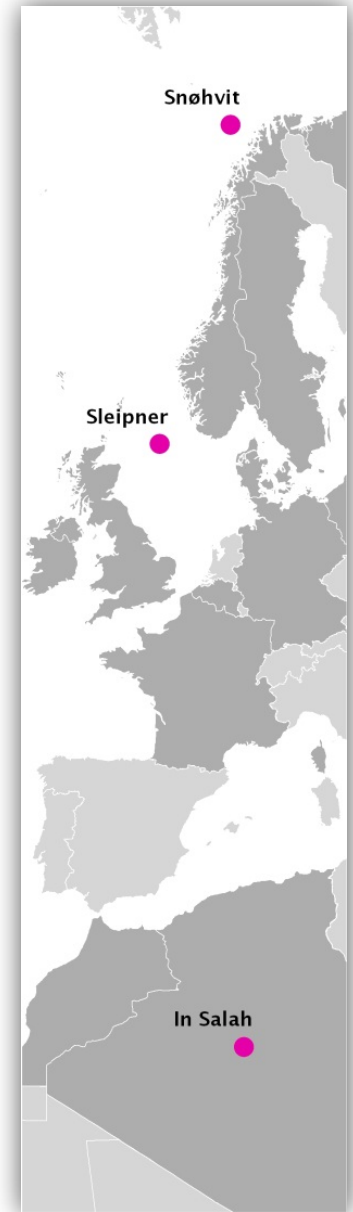
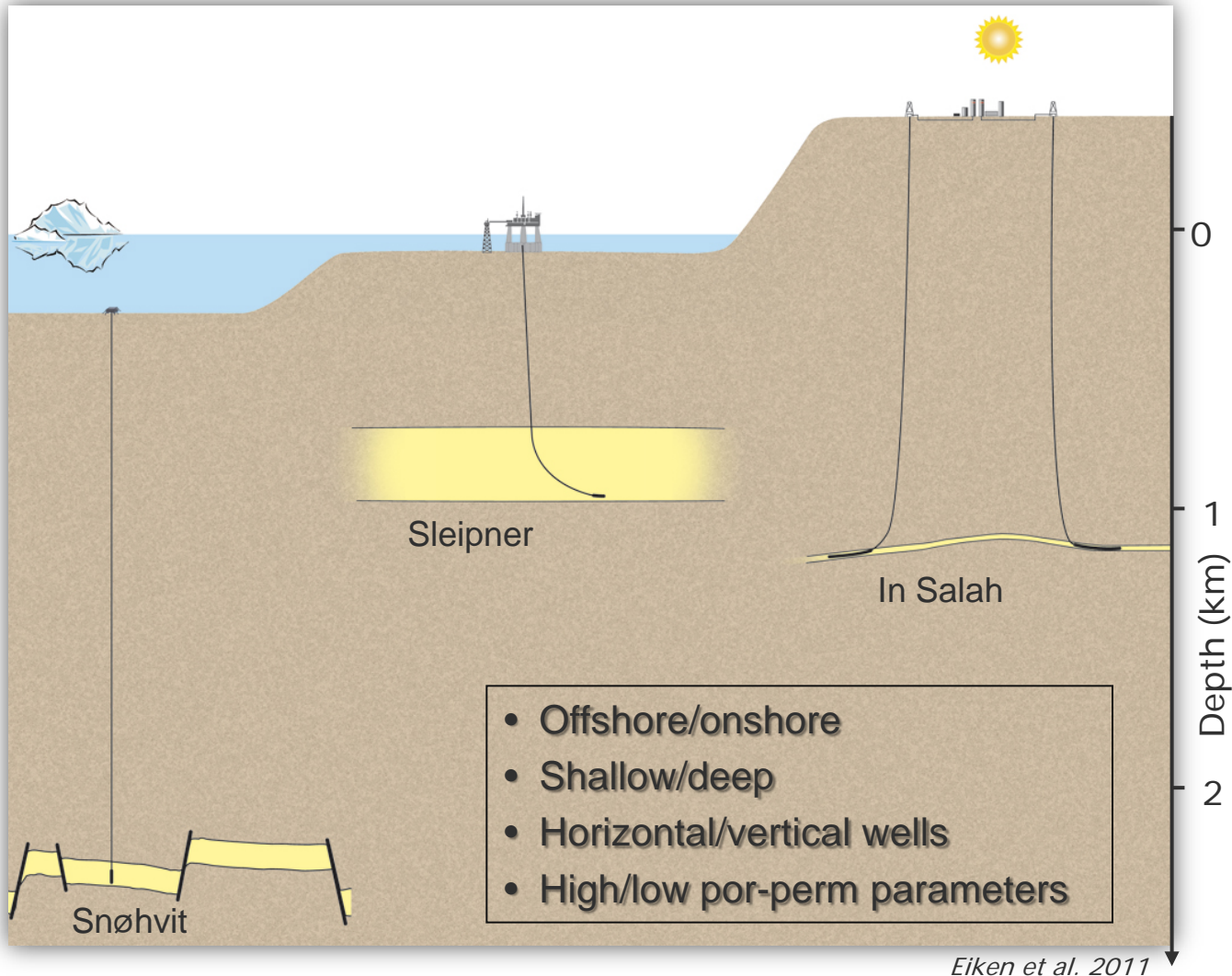
Technology used and...



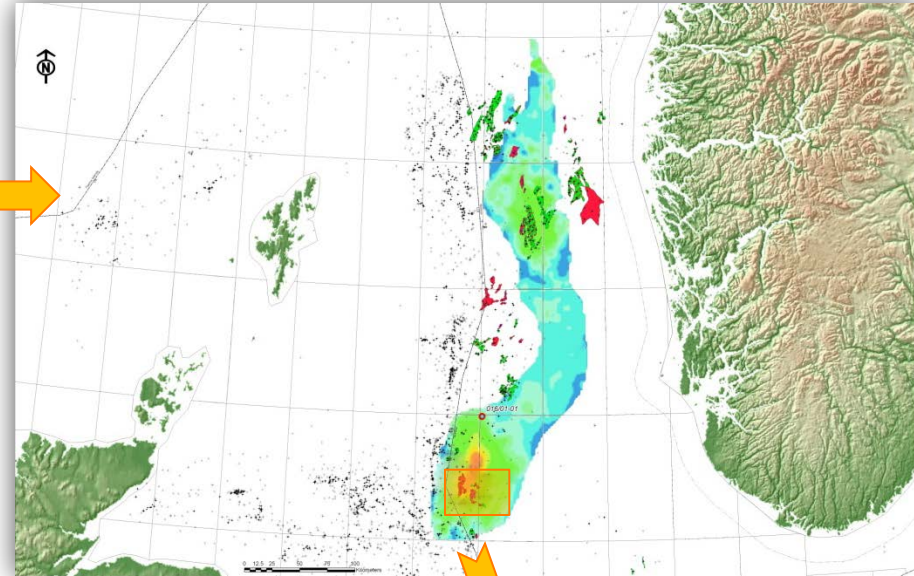
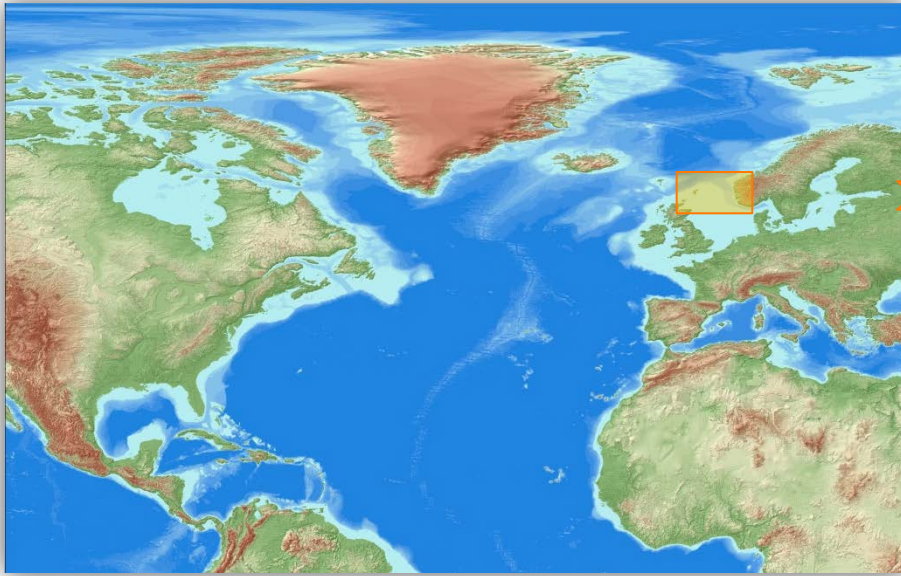
Lessons learned



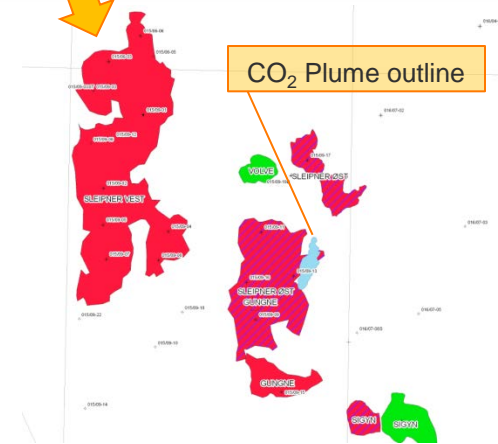
Diverse Storage Experience



Sleipner CO₂ injection site - Location



- CO₂ from the Sleipner field is stored in the Utsira Formation, North Sea
- Reservoir unit at 800-1100 m depth
- One CO₂ injector - 36 meter perforation at ~1012 meter (TVD)
- Injected gas is ~98% CO₂
- 13,5Mt CO₂ have been injected (as of May 2012, ~0,9M per annum)



The Sleipner Vest Field - Key Characteristics

- Largest gas/condensate field in the Sleipner area (North Sea), on stream in 1996
- Partners: Statoil - operator (58,35 %), ExxonMobil* (32,24 %), Total** (9,41 %)
- Higher CO₂ content (4-9%) than the gas export quality specification allows (2,5%)
- Capture absorption at 100 bar, 60-80°C, Amine 45wt% MDEA
- Decision to store geologically the captured CO₂ was based on willingness to try out new technology and the CO₂ tax incentive
- Sleipner CCS is an internationally-recognised benchmark project

* ExxonMobil Exploration & Production Norway AS

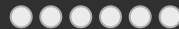
** Total Norge AS



Overview



Sleipner Background



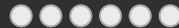
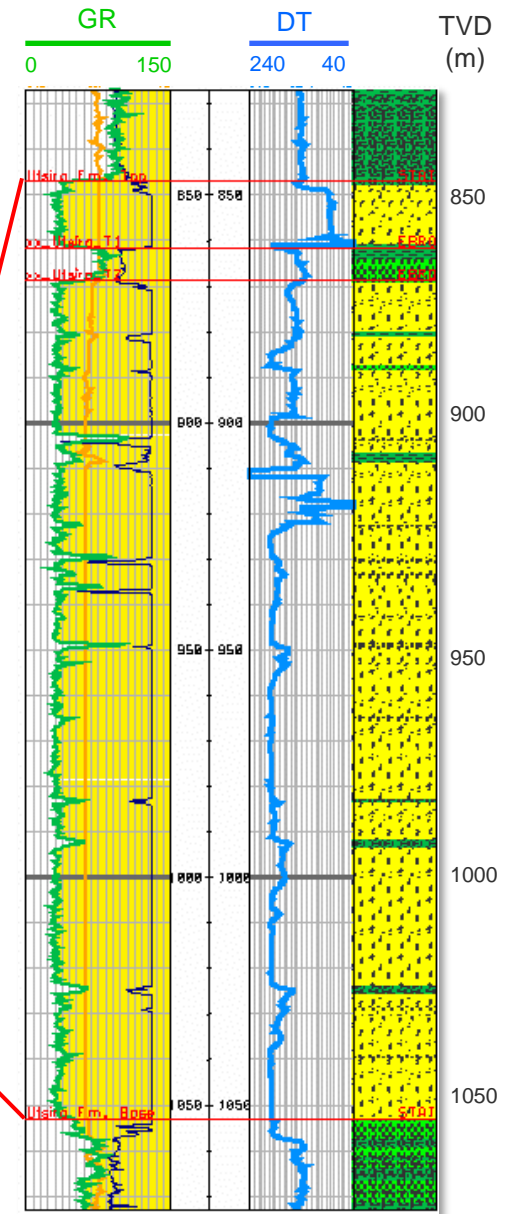
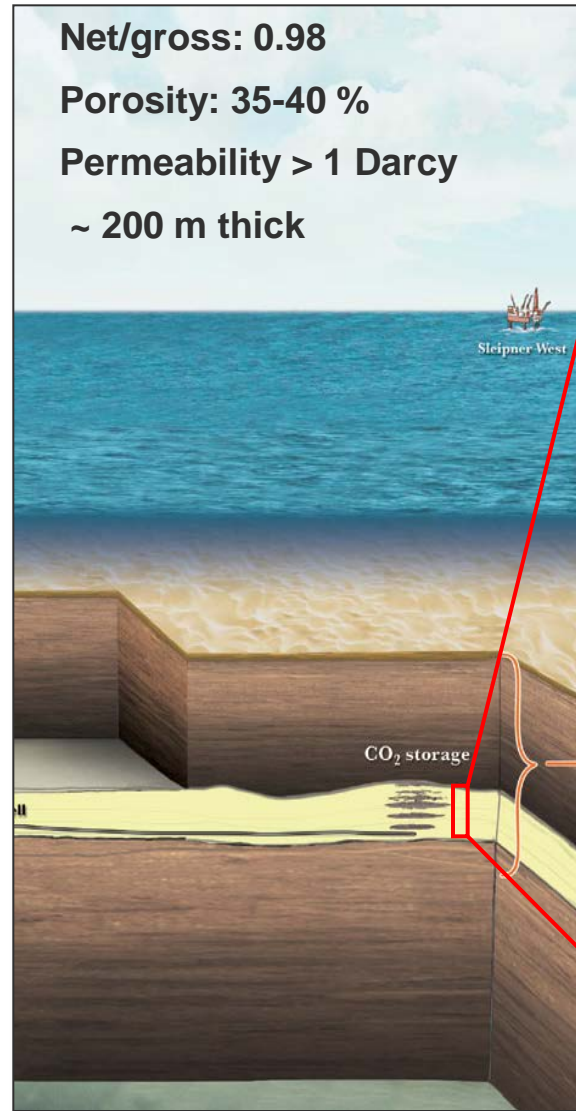
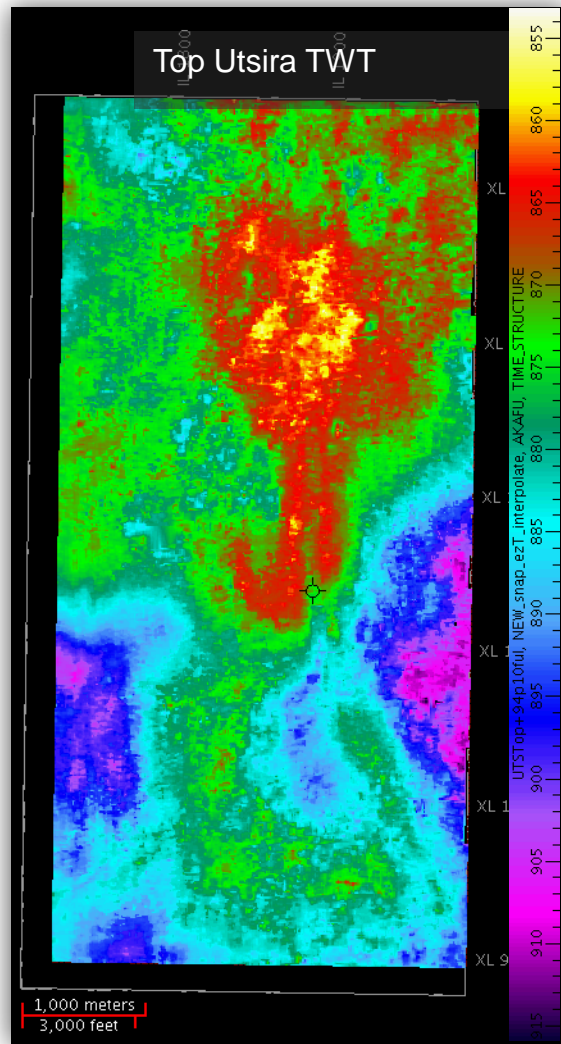
Technology used and...



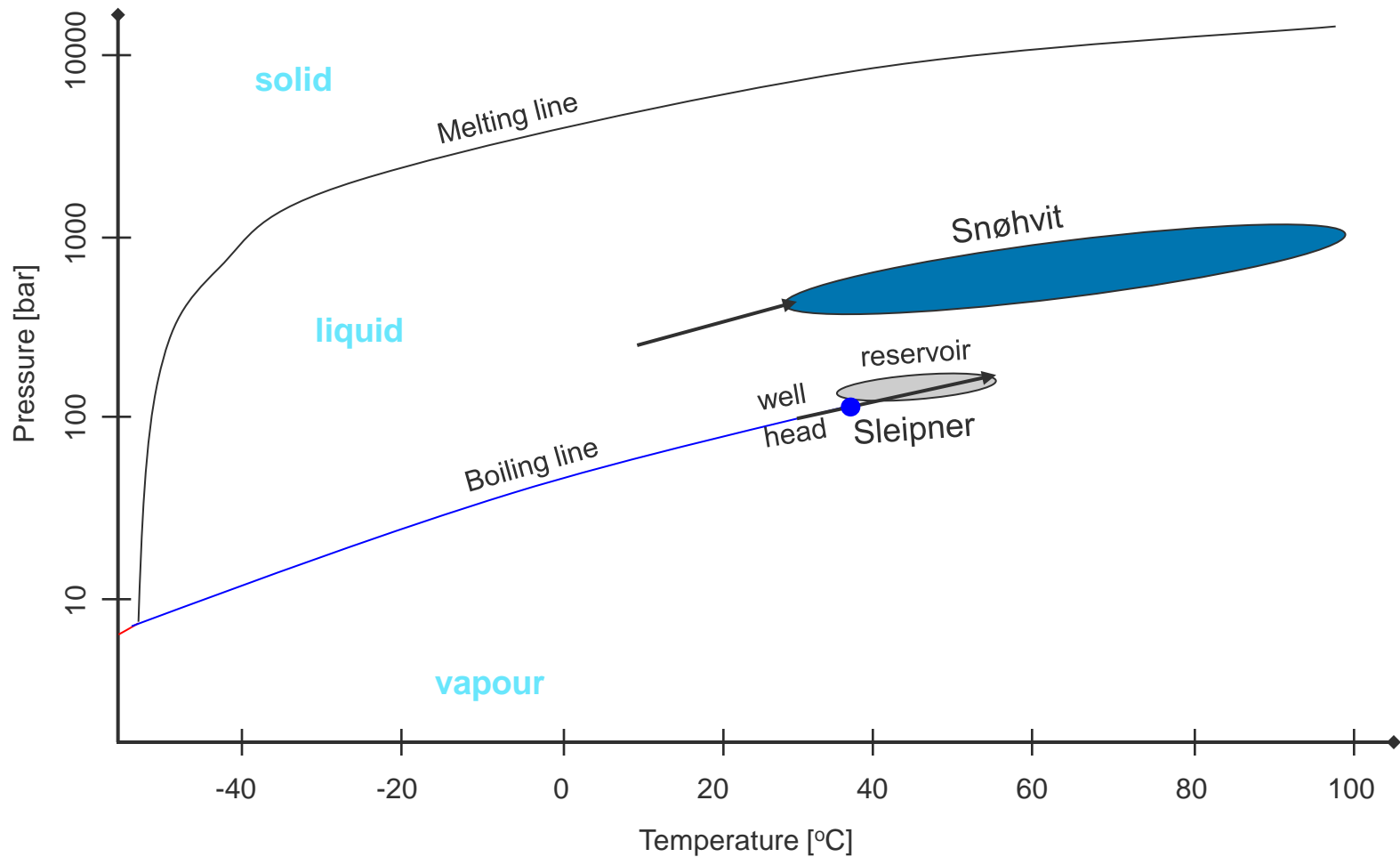
Lessons learned



The Utsira Formation



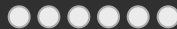
Phase Behaviour at Operating Conditions



Overview



Sleipner Background



Technology used and...



Lessons learned



Operating the Sleipner CO₂ Project

Operational Performance

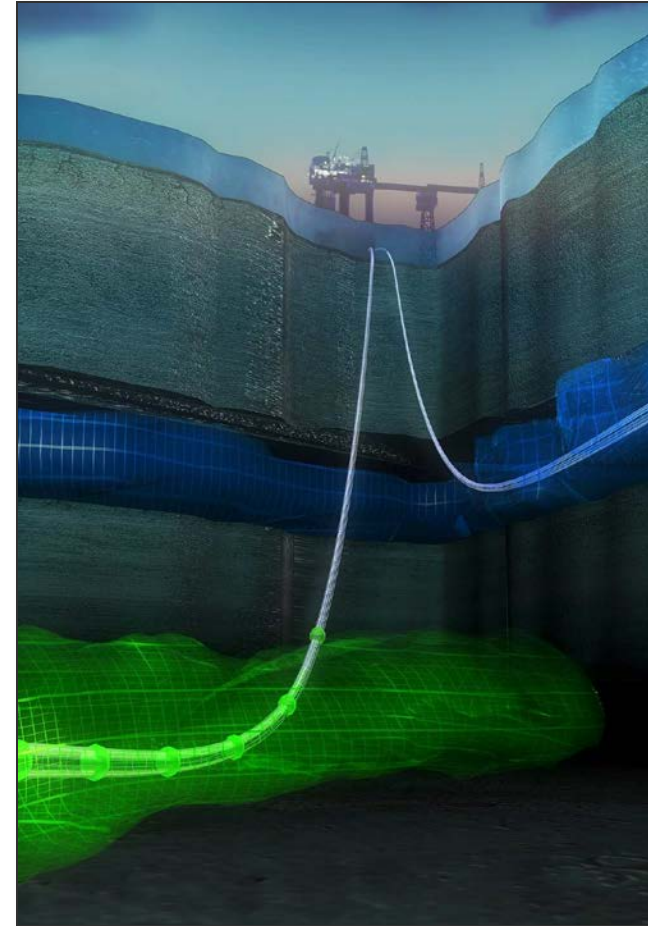
- Stable wellhead pressure ~65bar
- Wellhead temperature held at 25°C

Monitoring Data

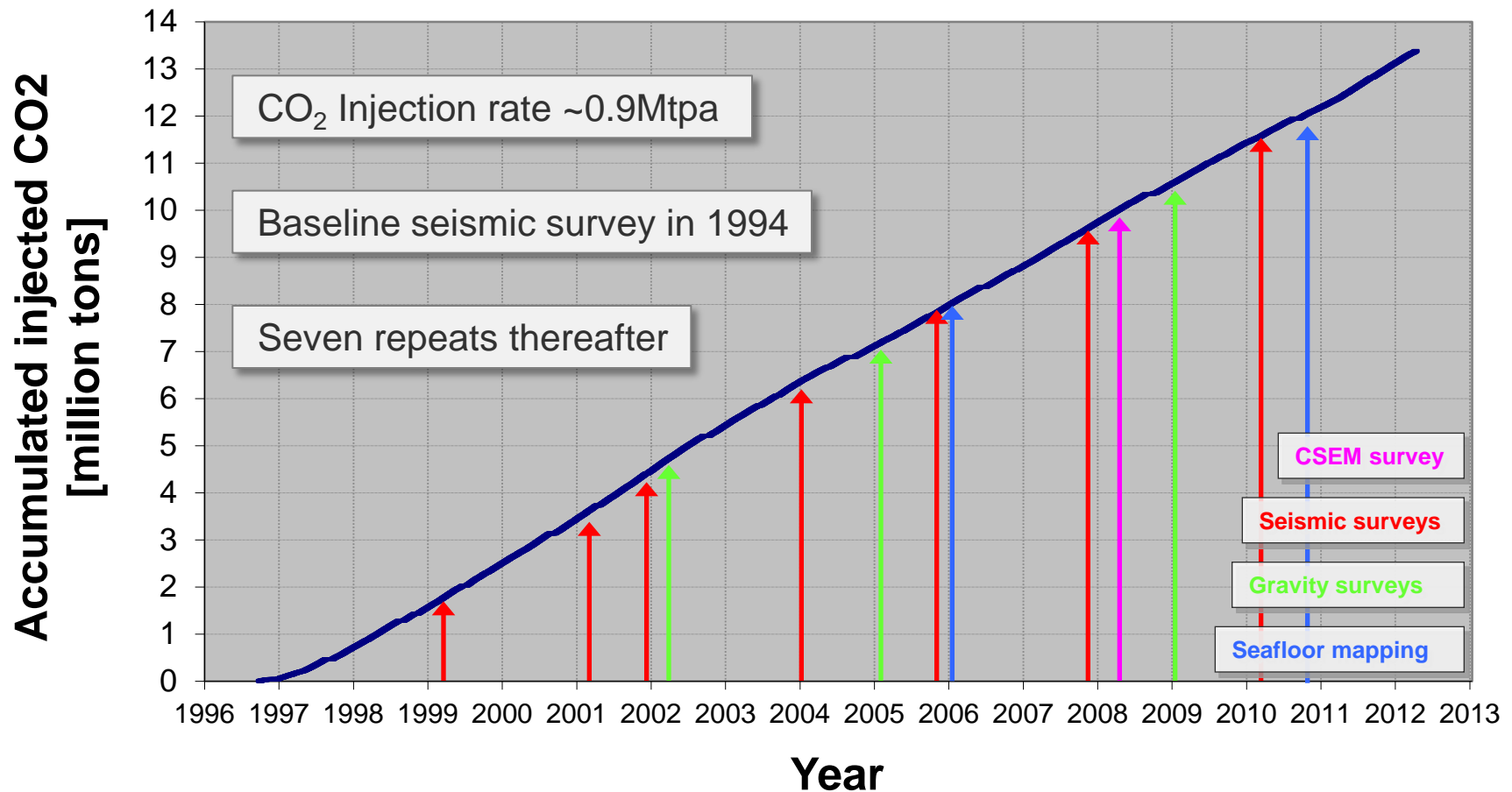
- Wellhead pressure and flow rate is monitored continuously
- Gas composition samples are taken intermittently
- Seven time-lapse (4D) seismic surveys
- Two repeat gravimetric surveys
- Electromagnetic survey
- Seabed surveys (2006 & 2011)

Key subsurface uncertainties

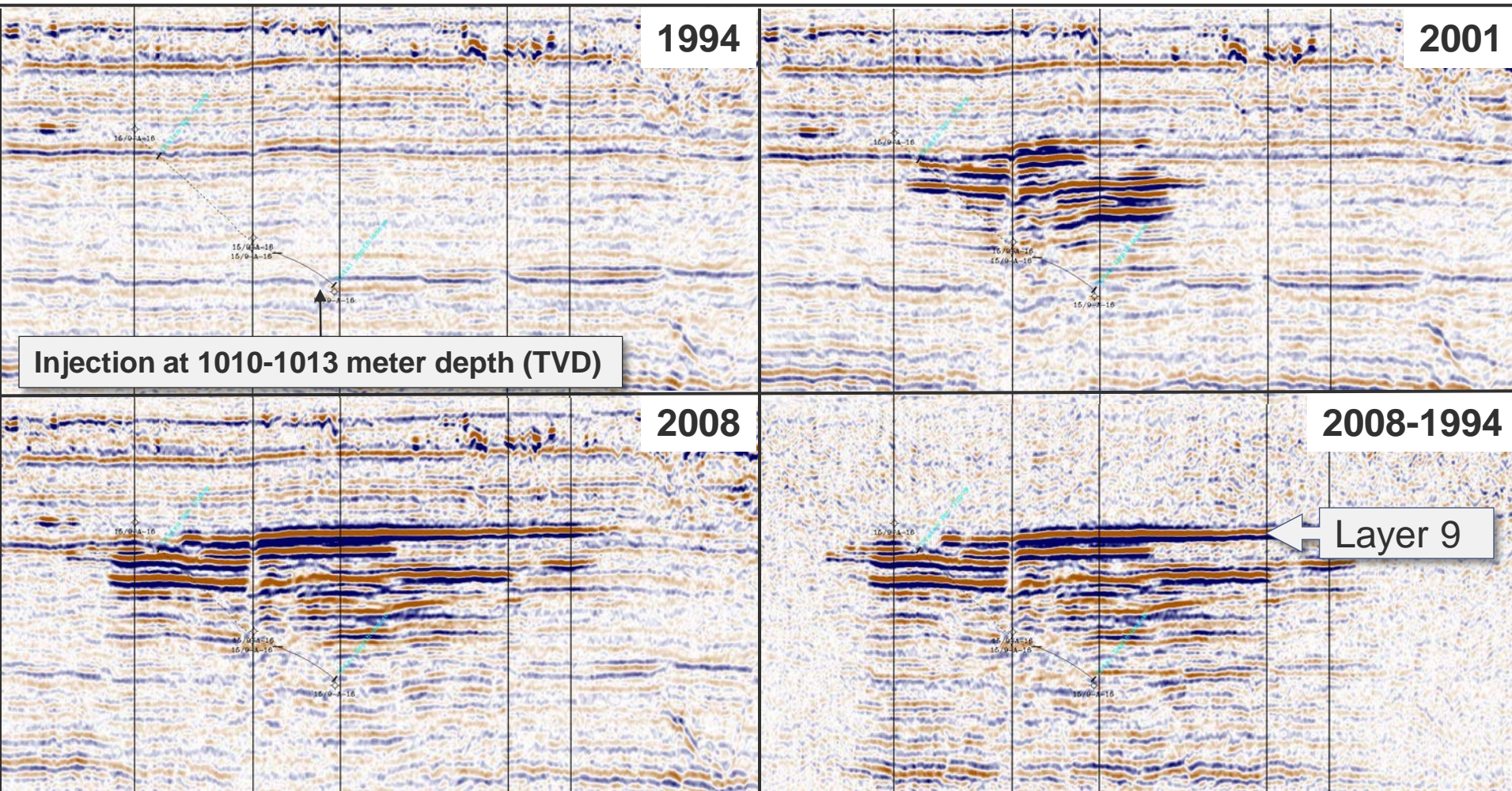
- Role of internal Utsira shale layers, plume propagation
- Reservoir and wellbore processes
- Maximum injection capacity (rate)



Cumulative CO₂ injection to date



Sleipner CO₂ Time-lapse Seismic Data



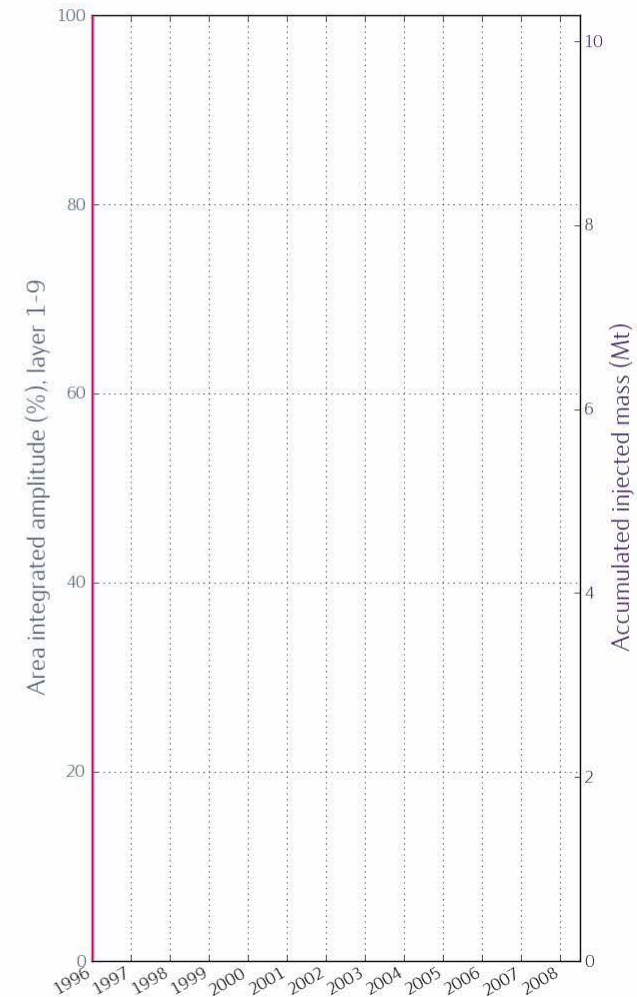
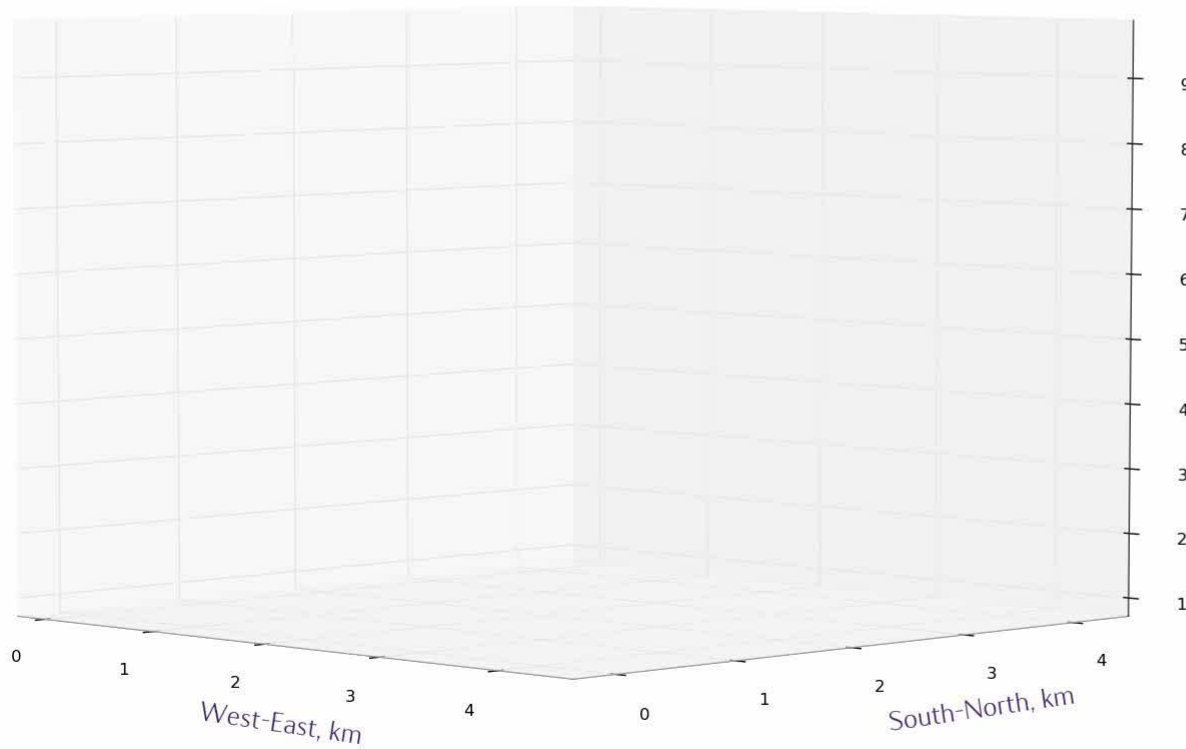
Overview

Sleipner Background

Technology used and...

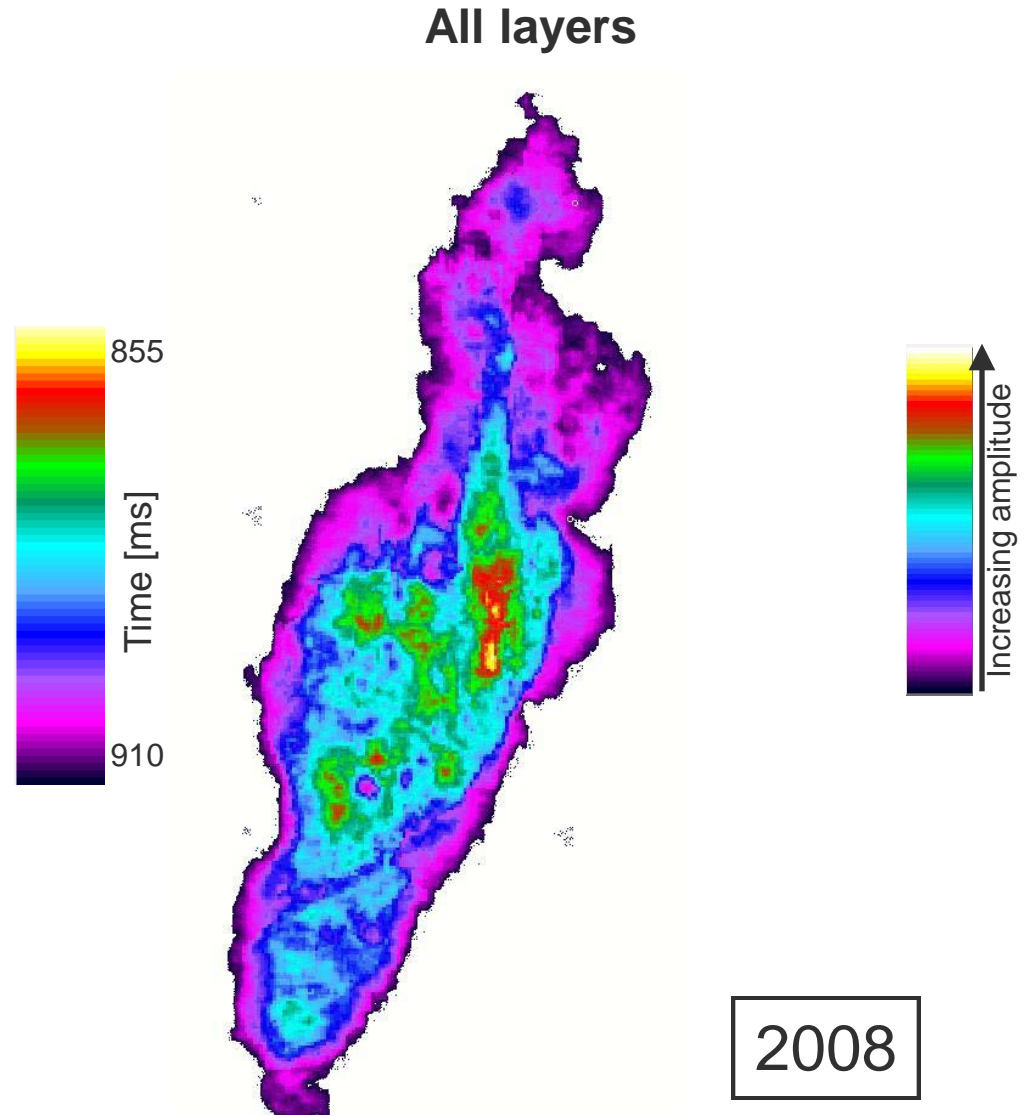
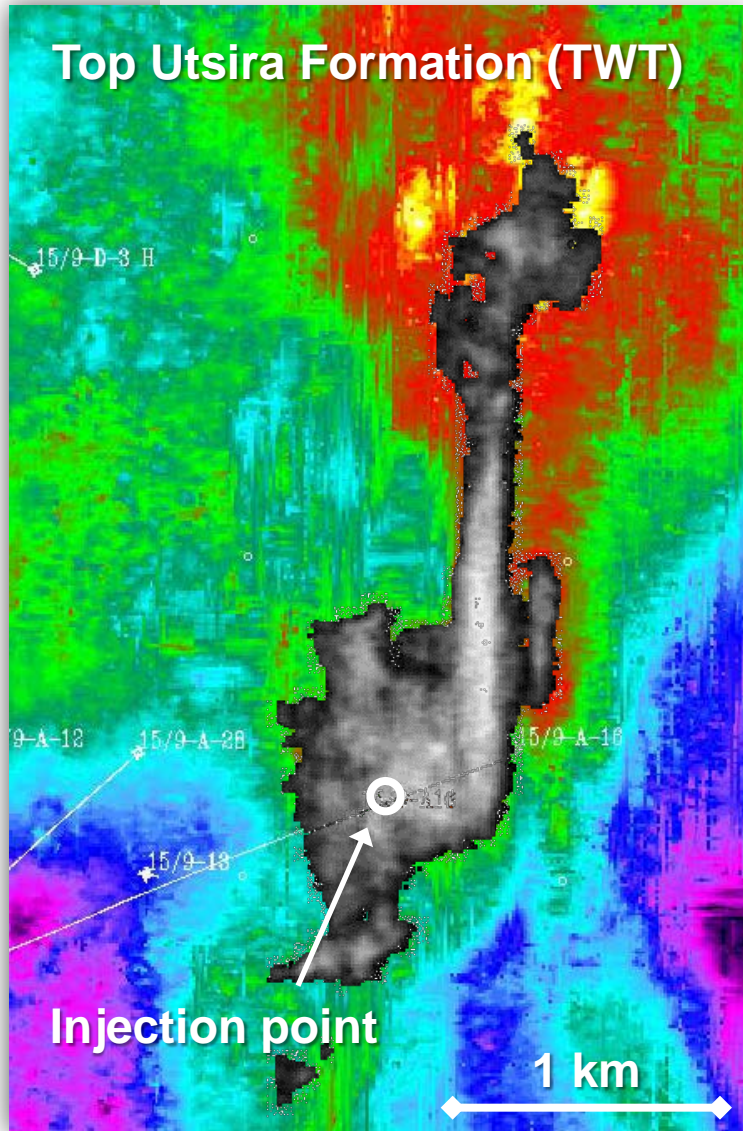
Lessons learned





Sleipner CO₂ seismic monitoring

(Alternative if movie does not work)



Overview



Sleipner Background



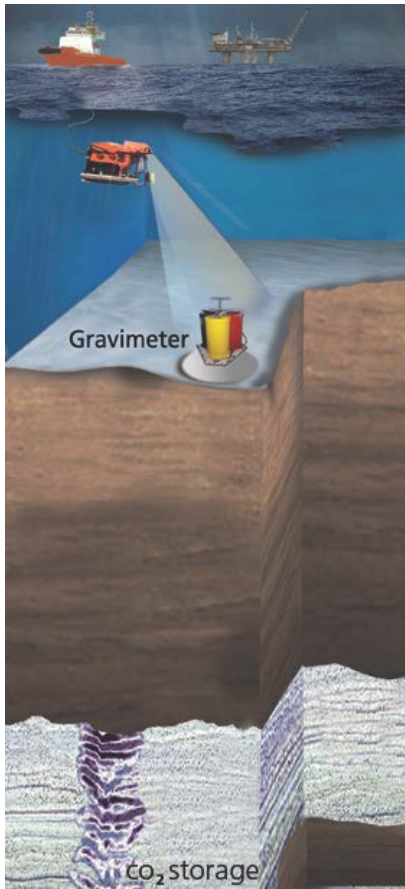
Technology used and...



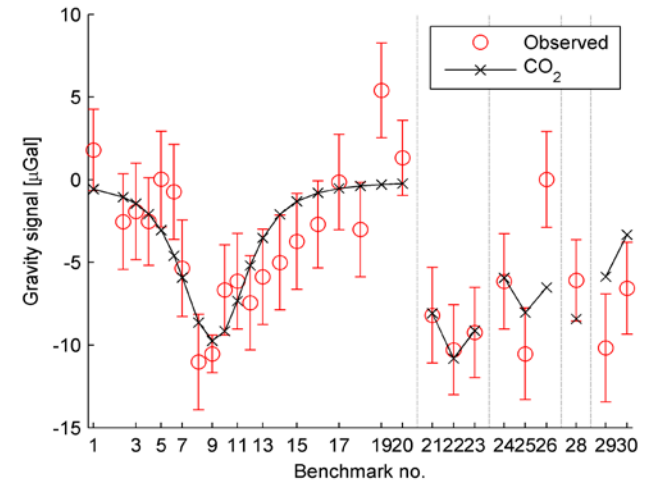
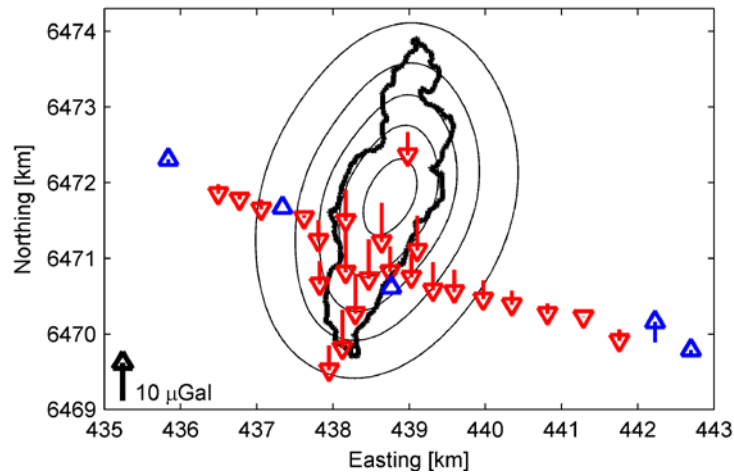
Lessons learned



Gravimetric monitoring



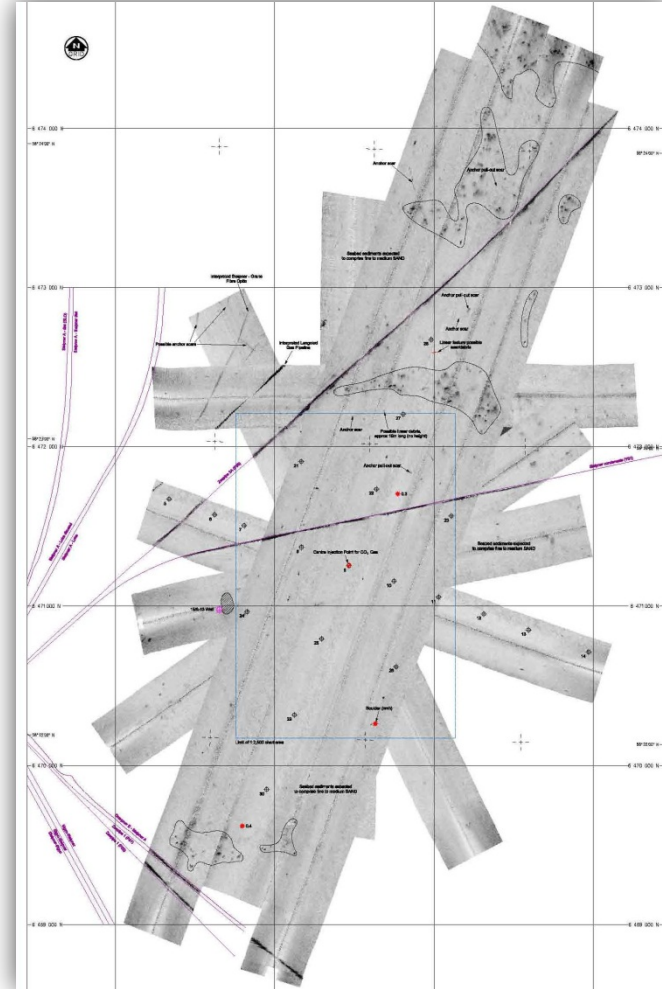
- CO₂ displacing water causes a negative change in the gravity field
- Temperature measurements imply an average density from 705 to 675 kg/m³
- Gravimetric measurements constrain the in-situ CO₂ density to 720 +/- 80 kg/m³
 - Seismic data is used for geometry definition
- This suggests a maximum dissolution rate of 1.8% per year*



*Alnes et al. 2010

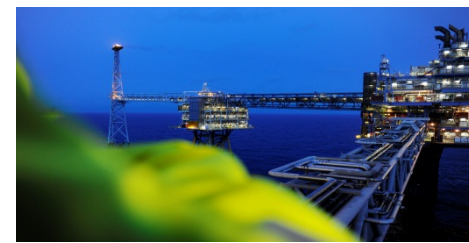
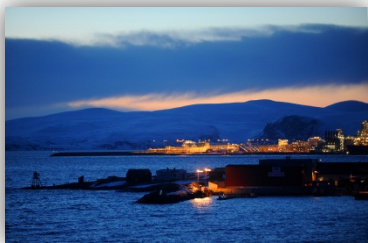
Other monitoring at Sleipner

- Seabed surveys in 2006 - side scan sonar and multi beam echosounding
- Synthetic Aperture sonar 2011 from Autonomous Underwater Vehicle (AUV)
- CSEM survey also done (no clear signal interpretable so far)
- Visual observations of the seafloor (ROV), no gas bubbles observed



Lessons learned

- Geophysical, non-invasive monitoring at Sleipner has been extremely valuable and has been used to address most of the operational questions
- Down hole gauges, which are now available in the industry, would have improved the accuracy to constrain temperature/pressure
- Improved understanding of fluid dynamic processes (CO₂ brine) has resulted from the Sleipner pioneering case (sharing of data has improved this)
- Detailed geological features controls the CO₂ distribution and are difficult to predict in advance



Overview



Sleipner Background



Technology used and...



Lessons learned



References

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Thank you

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