CO2 REMOVE
research monitoring verification

Monitoring strategies

CSLF Monitoring Workshop
18 April 2013
Rome

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My presentation

- CO2ReMoVe intro
  - CO_2 storage sites
  - Monitoring research goals
  - Shallow and deep monitoring

- Monitoring strategies

- Conclusion

CO2ReMoVe site monitoring

4 industrial sites 3 pilot-scale sites

CO2ReMoVe:
Monitoring research goals

- Deploy and test tools at real injection sites
  - Industrial sites (performance verification)
  - Research pilots (processes)

- Develop and test innovative tools
  - Current tools
  - New tools

- Assess tool efficacies and develop monitoring strategies
  - Compare similar tools in different storage settings
  - Evaluate complementary tool combinations
  - Monitoring strategies for a range of storage scenarios

CO2ReMoVe: Monitoring activities

- Site Performance: Current and future (EC Storage Dir)
  - Image CO_2 in the reservoir
  - Monitor containment risks
  - Show site is currently performing as expected
  - Identify deviations and remediate if necessary
  - Constrain predictions of long-term site behaviour
  - Enable site closure and transfer (follow-up project CO2CARE)

Principally deep - focussed technologies

- Emissions Accounting (EU ETS / National Inventories)
  - Monitor outer envelope of the storage complex
  - Measure and quantify emissions

Principally shallow - focussed technologies

Deep-focussed monitoring at CO2ReMoVe sites

	Sleipner	Snovit	In Salah	Weyburn	Ketzin	K12-B
	offshore (~900m)	offshore (~2700m)	onshore (~1900m)	onshore (~1400m)	onshore (~600m)	offshore (~3800 m)
Deep-focussed						
3D/4D surface seismic	■	■	■	■	■	
2D surface seismic	■	■				
Gravity surface	■					
Seabed CSEM	■					
Wellhead P,T	■			■	■	■
Wellhead/annulus sampling			■			
Downhole P,T		■	■	■	■	■
Continuous temperature (DTS)		■			■	■
Geophysical logs			■	■	■	■
Crosshole seismics				■		
Downhole fluid chemistry				■	■	■
Micro (passive) seismics			■	■	■	
Electromagnetic wellbore					■	
Electromagnetic surface					■	
Spontaneous potential						
Tracers			■		■	■
Monitoring shallow aquifers			■			
Downhole well integrity						■
VSP / MSP				■	■	
Electrical Resistivity Tomography					■	
InSAR			■			

Onshore / offshore ………………… wells / no wells

Shallow-focussed monitoring in CO2ReMoVe

	Sleipner	Snovit	In Salah	Weyburn	Ketzin	K12-B
	offshore (~900m)	offshore (~2700m)	onshore (~1900m)	onshore (~1400m)	onshore (~600m)	offshore (~3800 m)
Shallow-focussed						
Multibeam echosounding						
Sidescan sonar						
Tiltmeters						
Bubble-stream detection						
Bubble-stream chemistry						
Soil gas/surface flux						
Flux towers (eddy covariance)						
Passive detectors						
Ecosystem (including biomarkers)						
Microbiology						
Seabottom ROV video						

Monitoring Strategies

- Importance of baselines
- Key tools
- Cost-effective monitoring programmes

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Baselines – Weyburn


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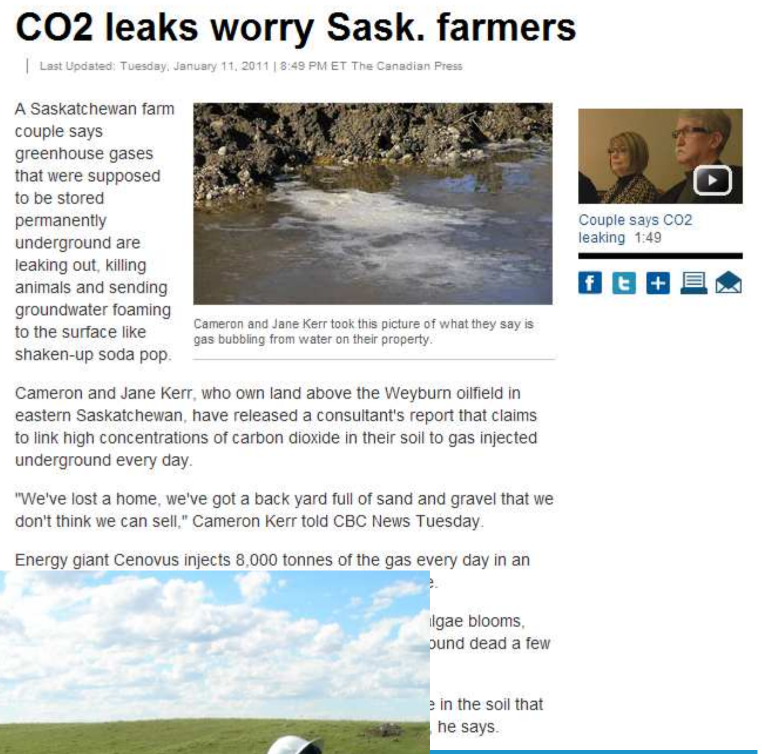
IN PICTURES

Carbon capture leak forces Saskatchewan couple to farm

Published Tuesday, Jan. 11, 2011 6:12PM EST


CO2 leaks worry Sask. farmers

Last Updated: Tuesday, January 11, 2011 | 8:49 PM ET The Canadian Press

A Saskatchewan farm couple says greenhouse gases that were supposed to be stored permanently underground are leaking out, killing animals and sending groundwater foaming to the surface like shaken-up soda pop.

Cameron and Jane Kerr took this picture of what they say is gas bubbling from water on their property.

Couple says CO2 leaking 1:49

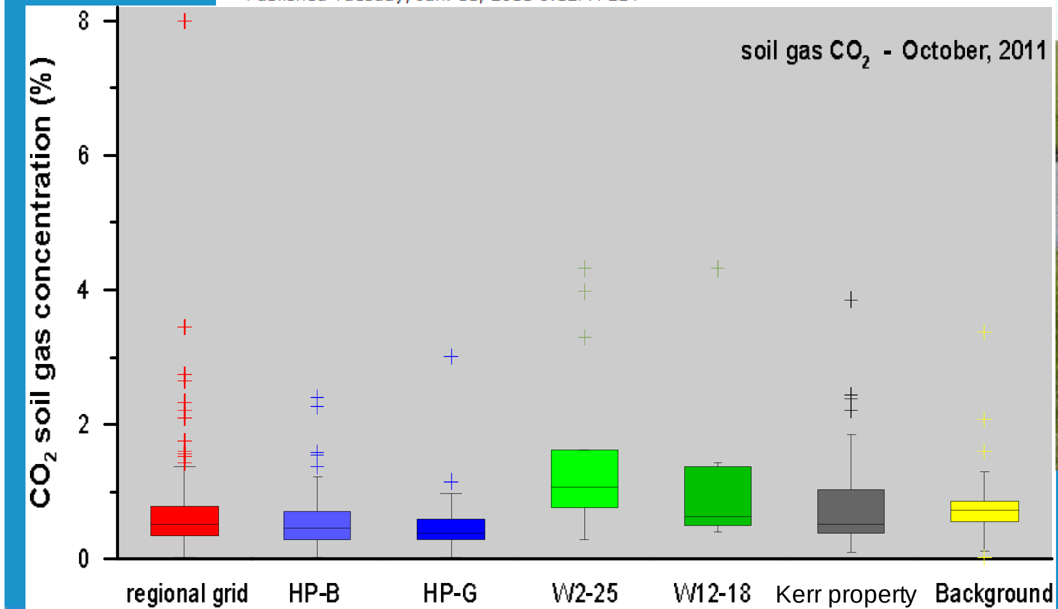
Cameron and Jane Kerr, who own land above the Weyburn oilfield in eastern Saskatchewan, have released a consultant's report that claims to link high concentrations of carbon dioxide in their soil to gas injected underground every day.

"We've lost a home, we've got a back yard full of sand and gravel that we don't think we can sell," Cameron Kerr told CBC News Tuesday.

Energy giant Cenovus injects 8,000 tonnes of the gas every day in an …

… lgae blooms, … ound dead a few …

… in the soil that … he says.



Weyburn soil gas survey (BGS)

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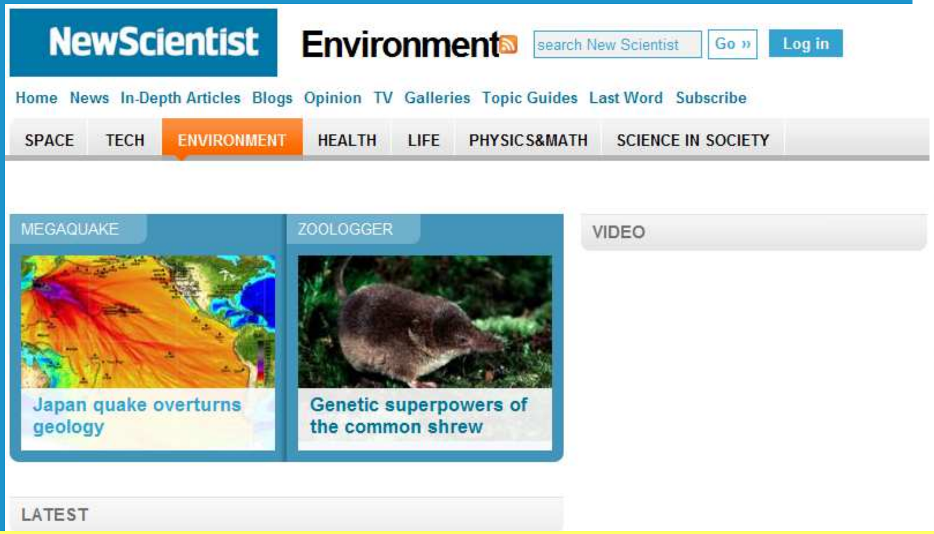
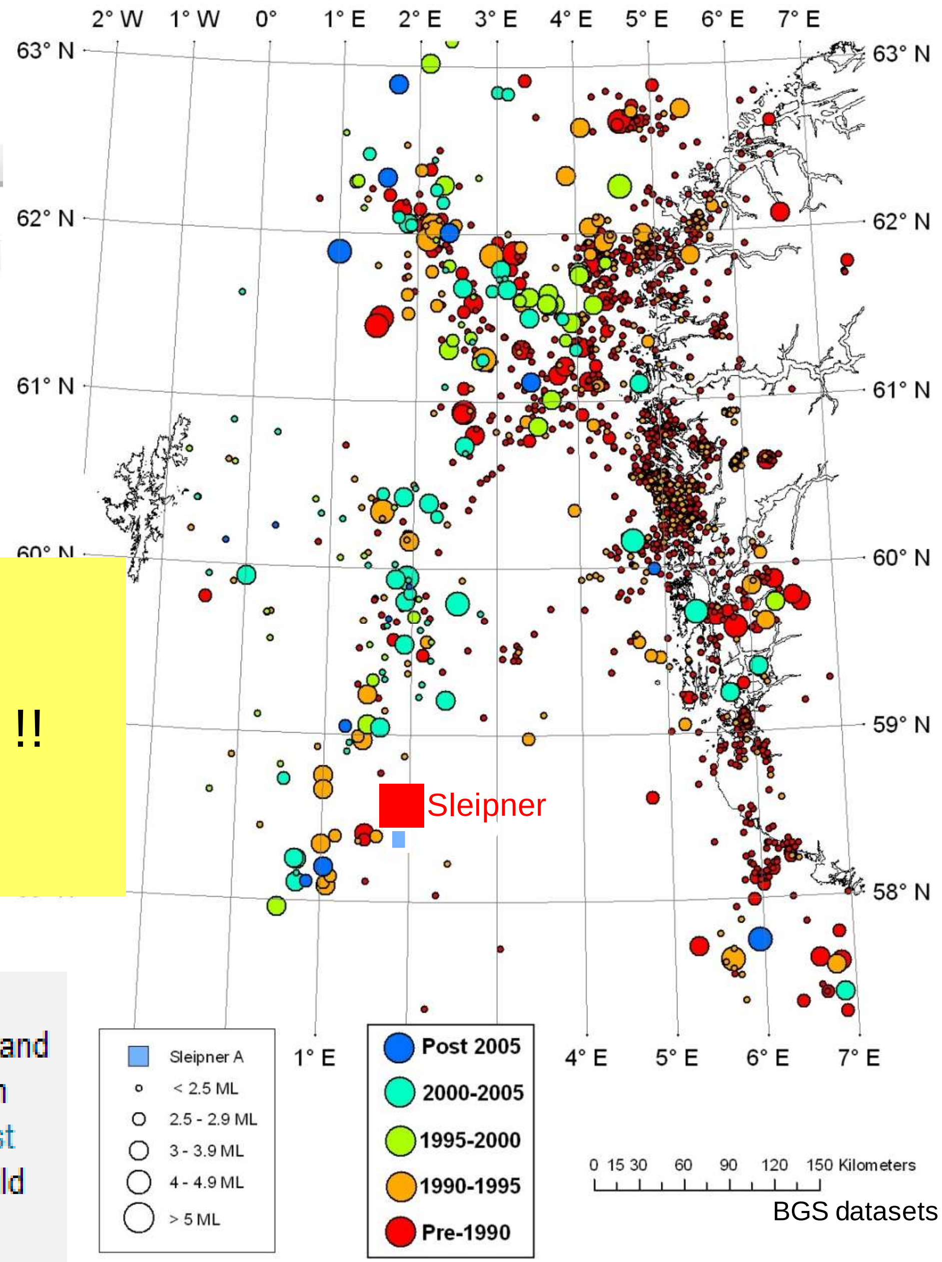
Baselines – Sleipner



New Scientist …… September 2009

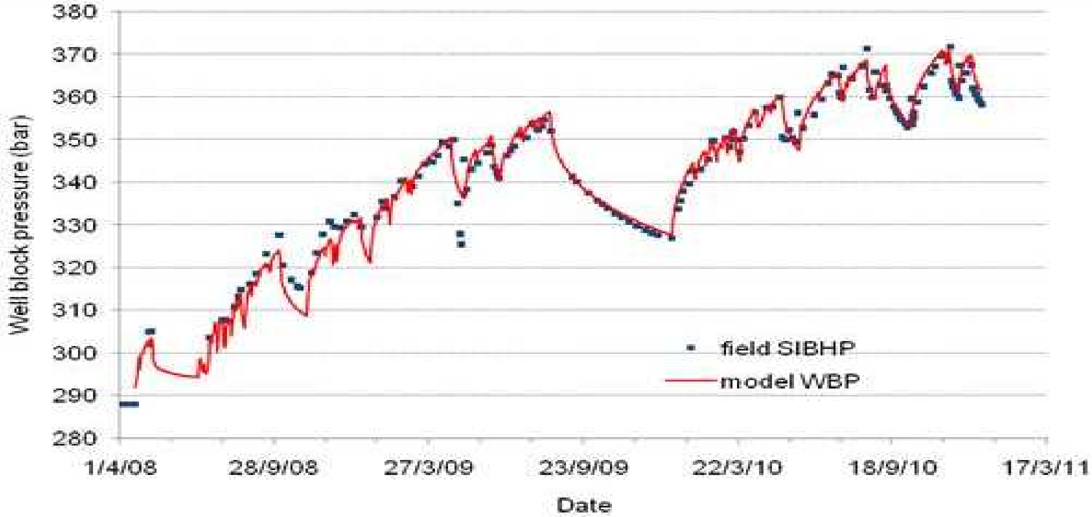
Induced earthquake at Sleipner in 2008 !!
Magnitude 4
Tsunami risk ??



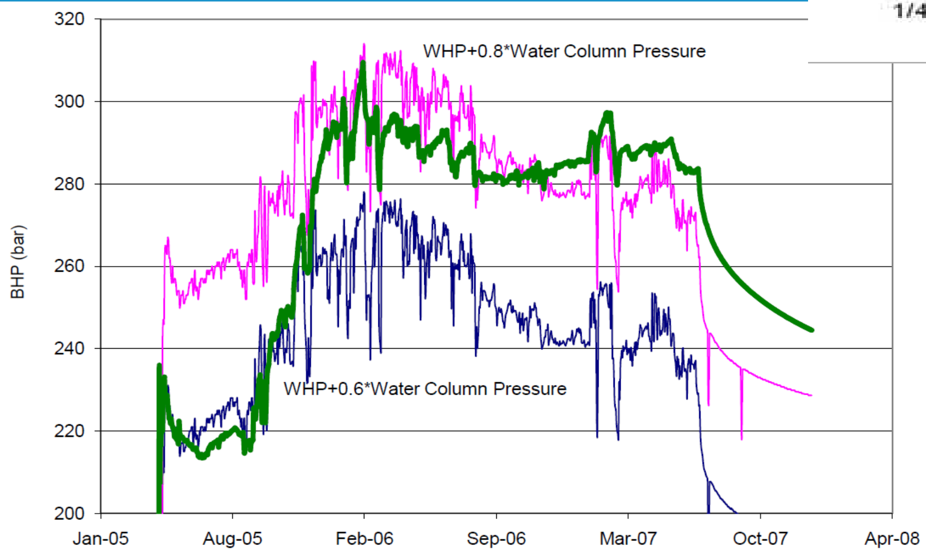
Bury the carbon, set off a quake?

It all looked so promising - tidy carbon dioxide away underground and forget about it. But even as the US's first large-scale sequestration operation is getting off the ground at the Mountaineer plant in West Virginia, geophysicists are concerned that burying the carbon could trigger earthquakes and tsunamis.

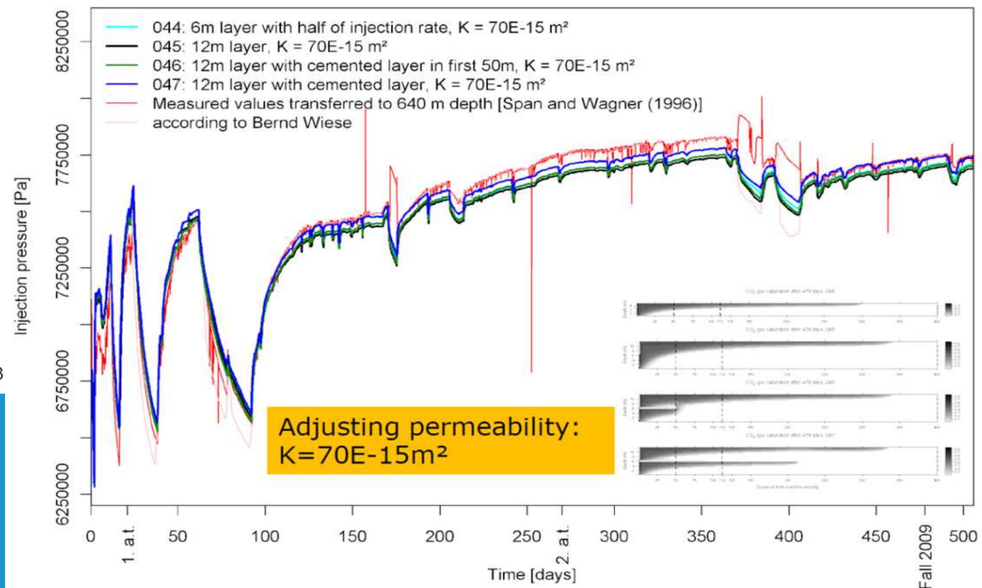
Key deep-focussed tools (reservoir pressure)



Snohvit (downhole)



In Salah (wellhead & downhole)



Ketzin (downhole)

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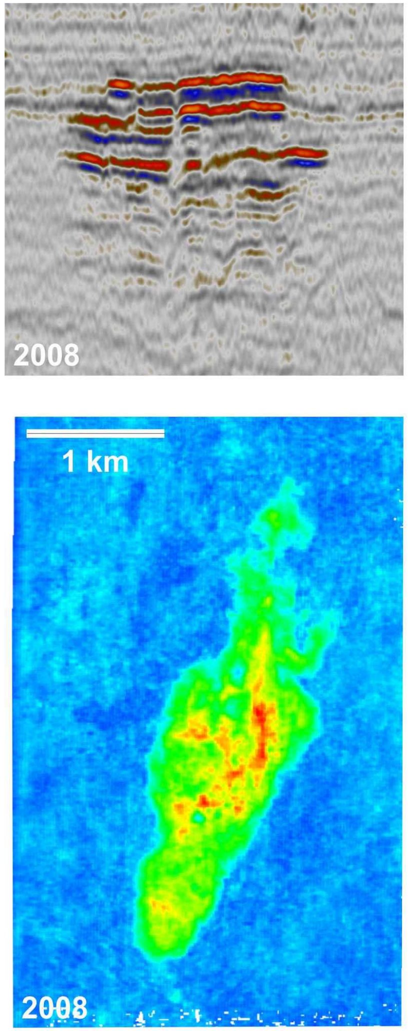
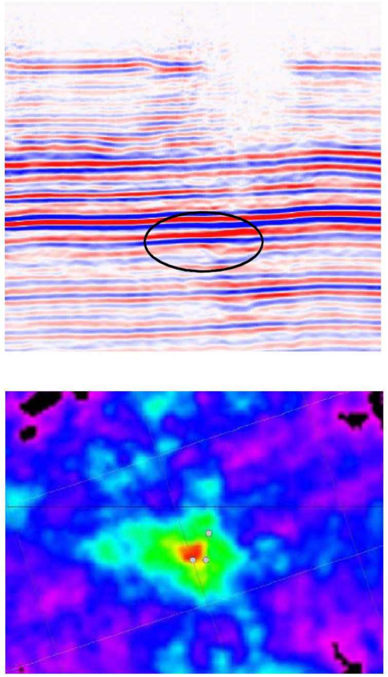
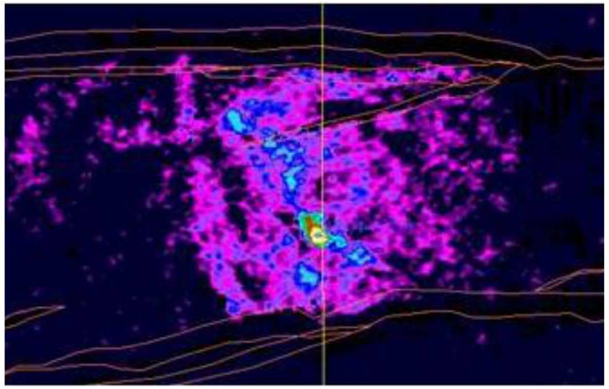
Key deep-focussed tools (3D time-lapse seismic)



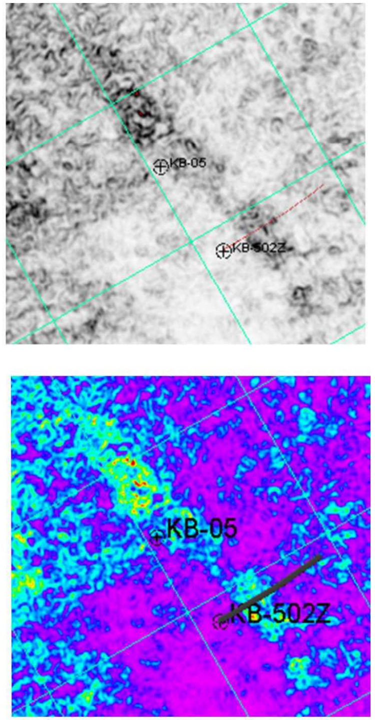
Sleipner
Offshore: 800m



Ketzin
Onshore: 630m

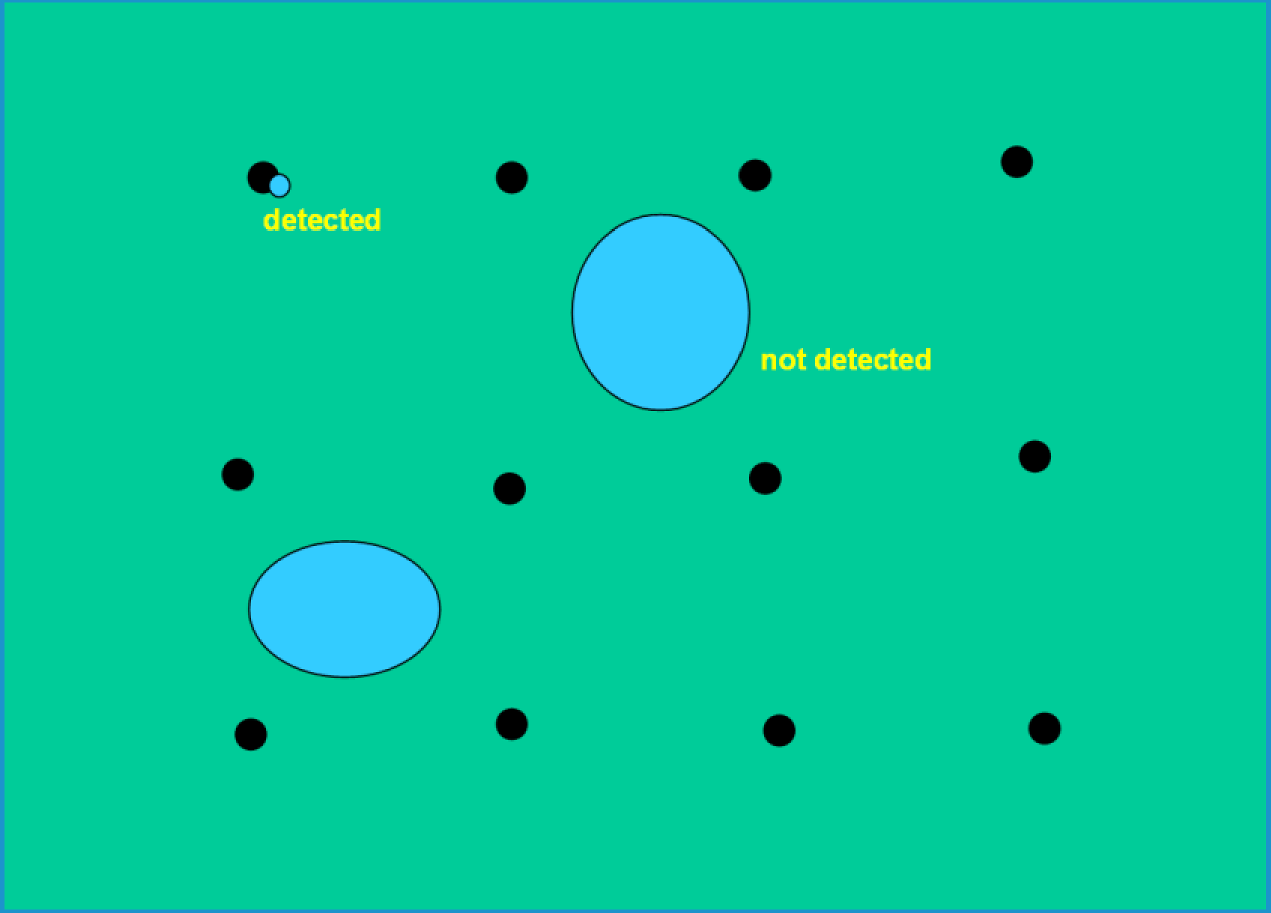


Snohvit
Offshore: 2700 m



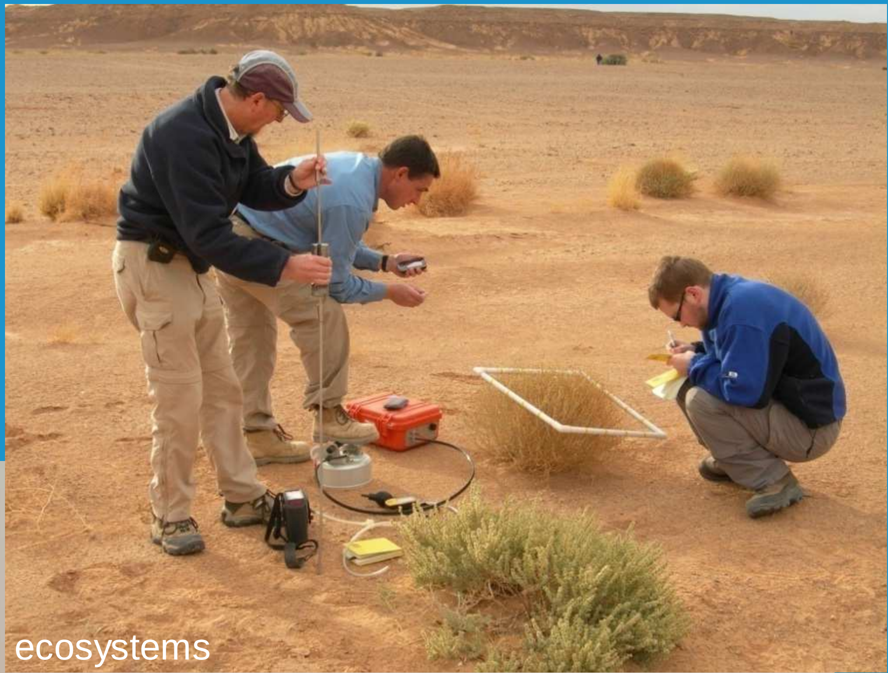
In Salah
Onshore: 1950m

Shallow-focussed methodologies (1)



Need spatial & point-wise measurements

Shallow-focussed methodologies (2)


ecosystems


surface gas flux and soil gas

mobile atmospheric concentrations


permanent
flux towers

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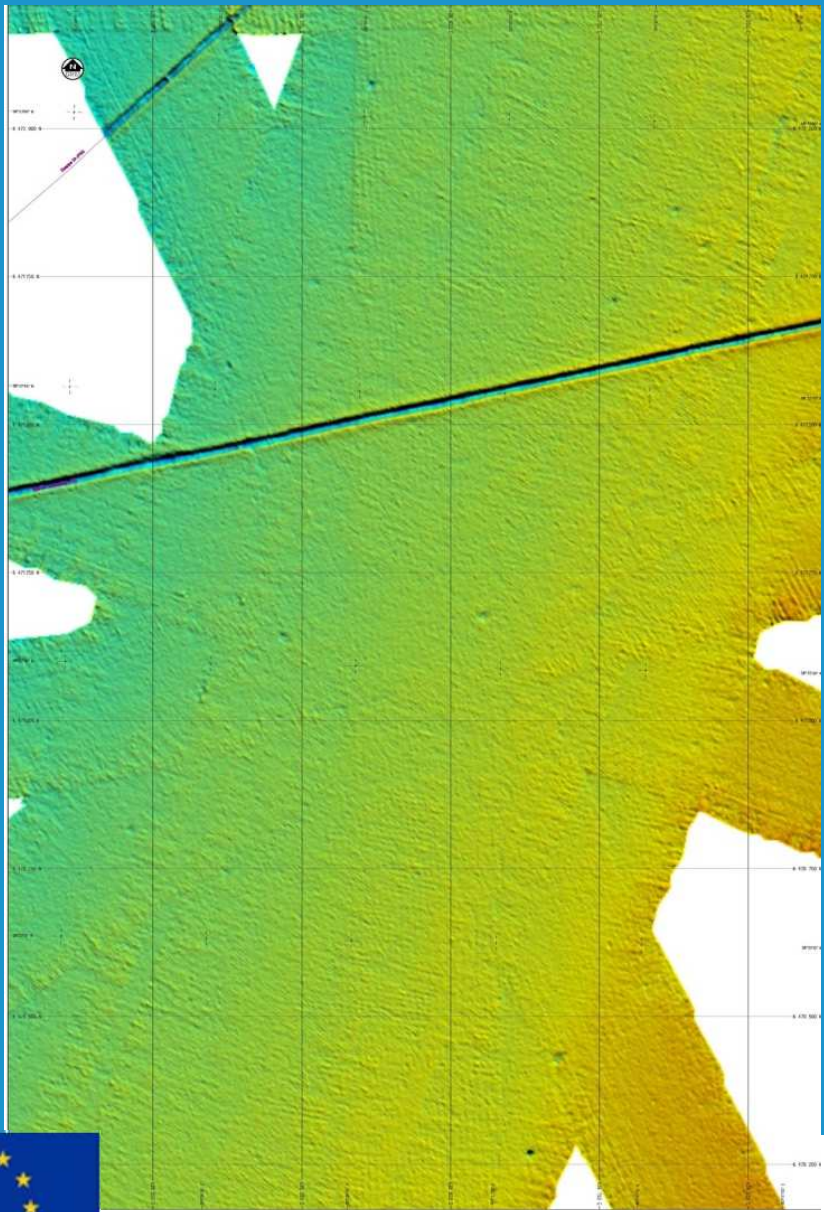
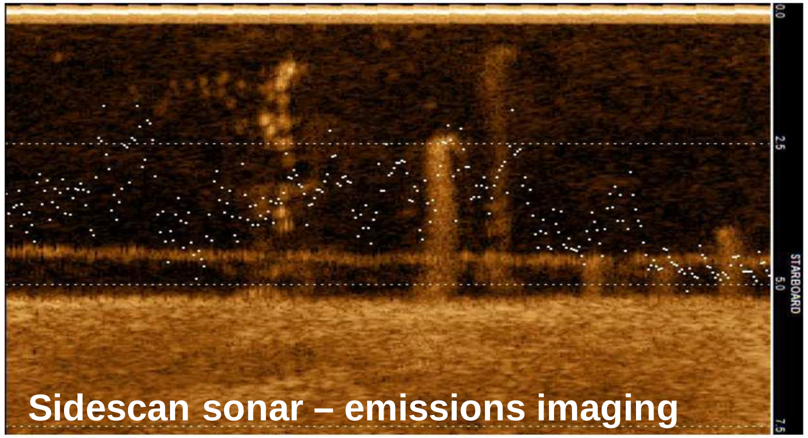
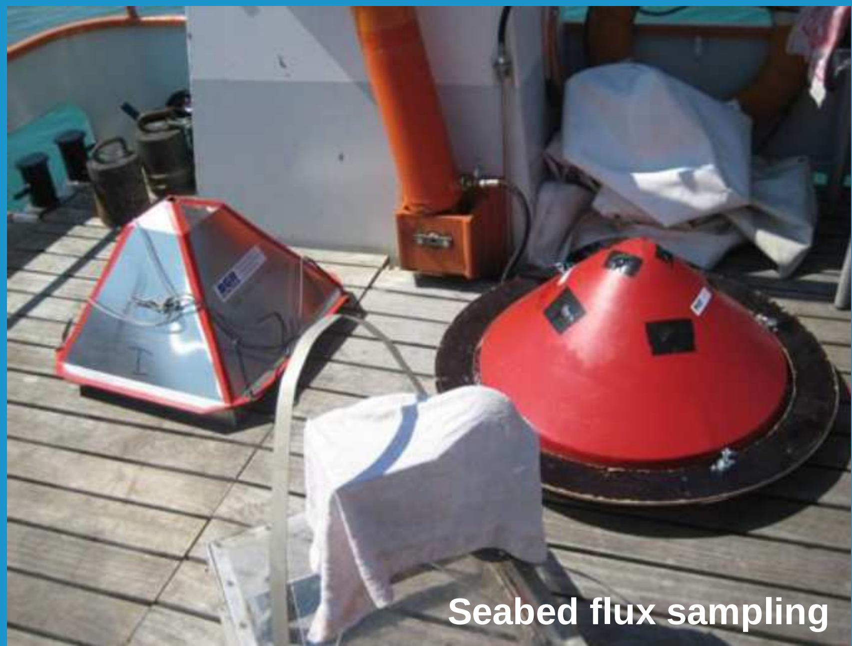
Shallow-focussed methodologies (3)

Multibeam echosounding – seabed at Sleipner





Sidescan sonar – emissions imaging



Seabed flux sampling

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Cost-effective monitoring programmes

High-level objectives (EU Regulatory)

- Assurance of integrity and safety
- Address identified risks
- Verify (predictive) performance models
- Detect leakage (from the Storage Complex)
- Confirm permanent containment within the Storage Complex
- Quantify emissions if leakage detected

Site-Specific Objectives

- Plume imaging in the reservoir
- CO_2 migration in the overburden (storage complex)
- Predictive model calibration and verification
- Storage processes and efficiency
- Top-seal integrity
- Leakage warning and detection
- Emissions measurement
- Public acceptance

The Core Monitoring Programme

- Meeting the regulatory requirements of a conforming site (i.e. one that behaves as expected during its lifetime)
- Aiming at the detection and correction of any site-specific containment risks directed to *early warning of potential leakage*

Monitoring that will be carried out as part of routine site operation.

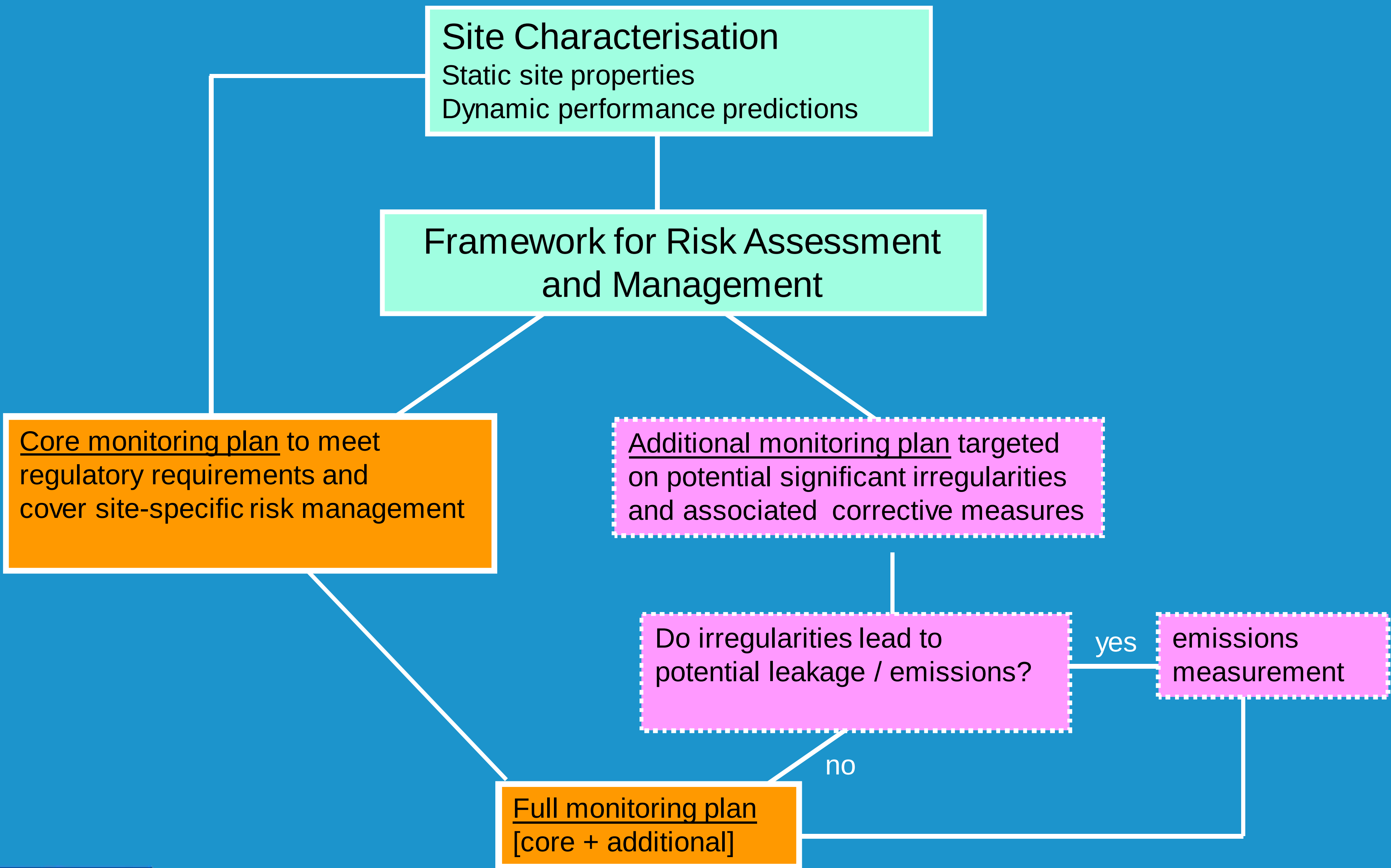
The Additional Monitoring Programme

- Meeting the requirements of a storage site that does not perform as expected (significant irregularities)

- Defining possible range of significant irregularities and the needs of any associated corrective measures

Portfolio of tools held in reserve for use in the event of an emerging significant irregularity.

Monitoring Strategy flowchart



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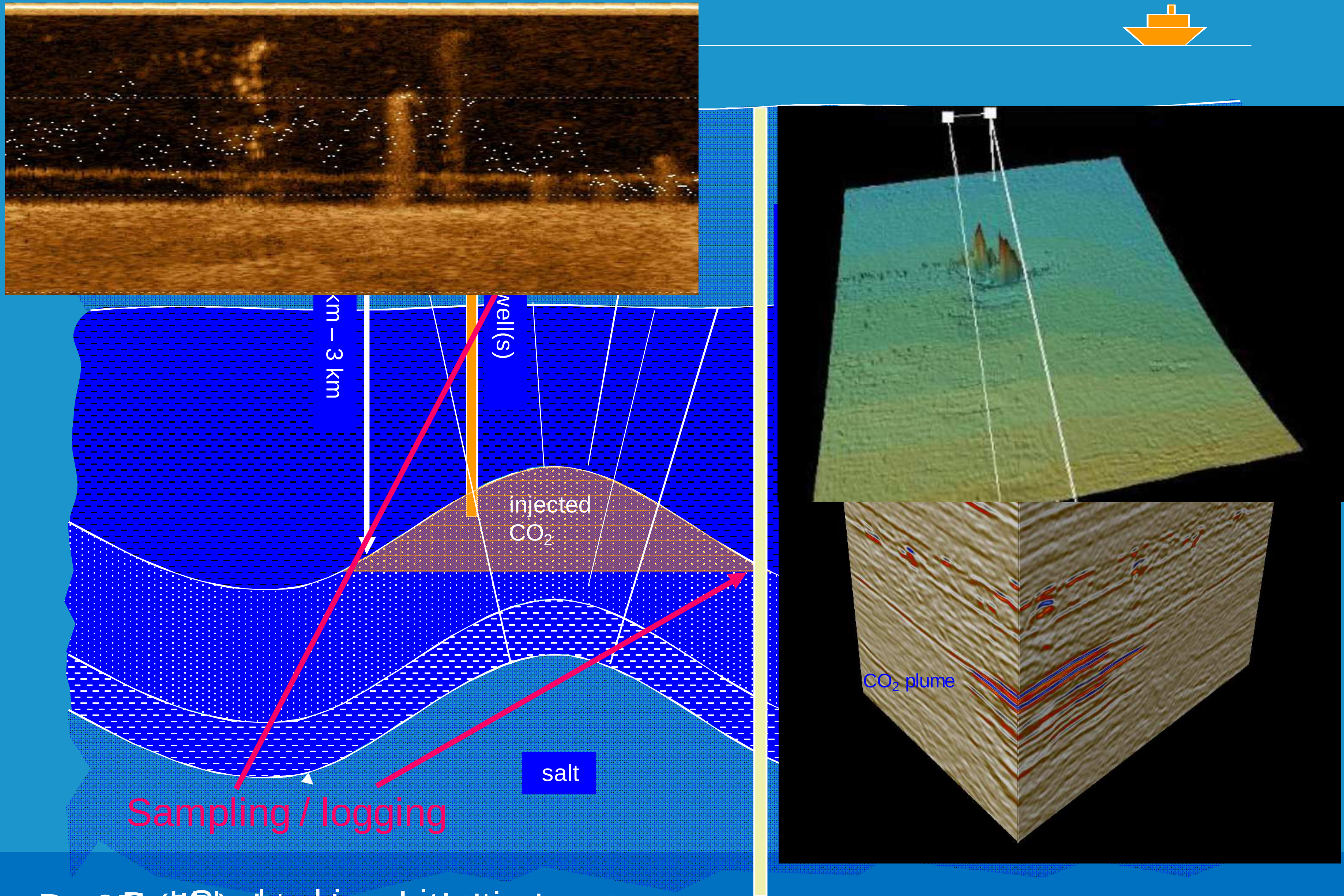
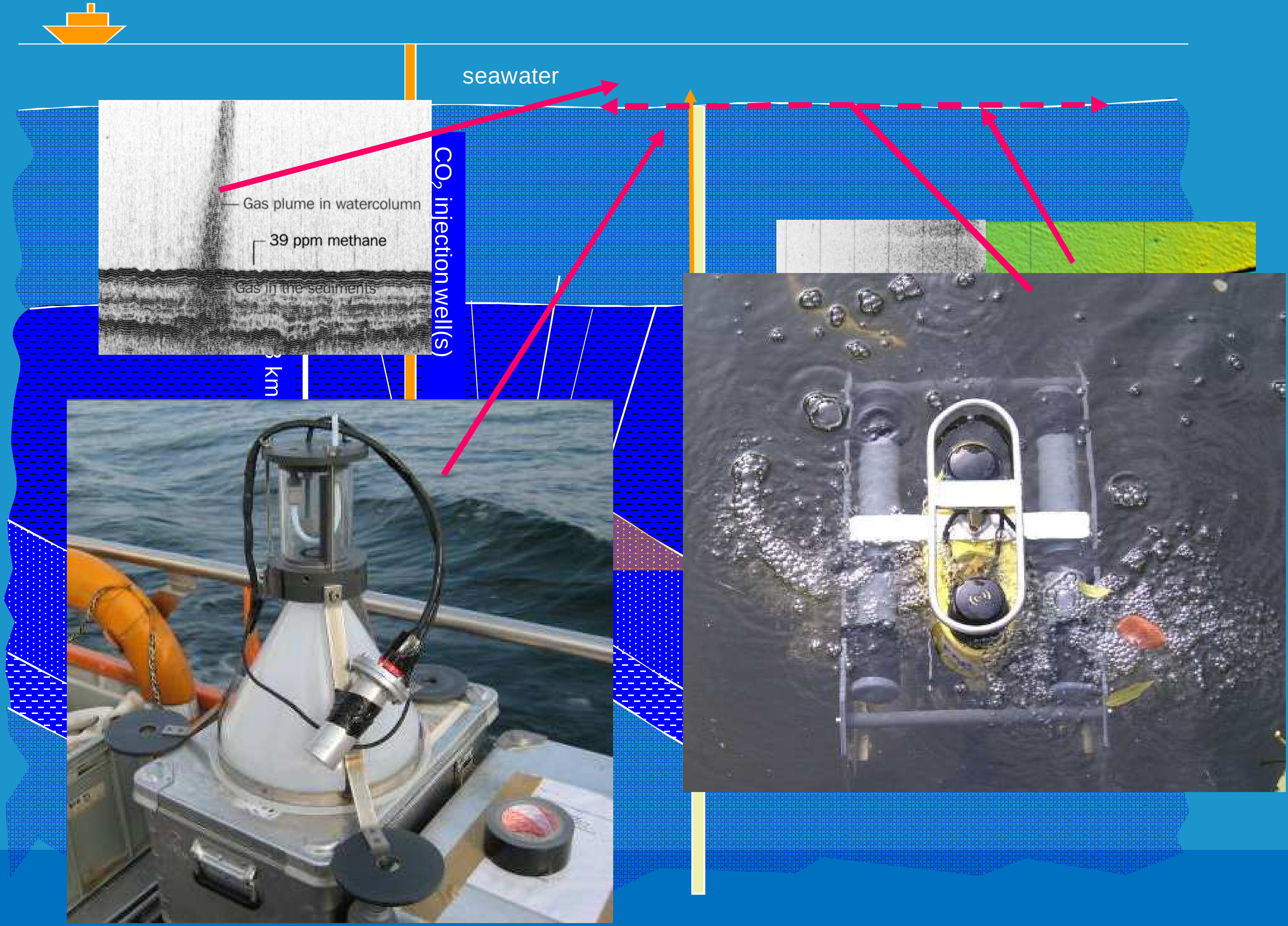
Typical offshore storage site - Core Monitoring



Typical offshore storage site - Additional Monitoring: Emissions



Key monitoring messages

Monitored site performance always deviates from predictions

- Define an acceptable deviation
- Demonstrate convergence of prediction and observations with time (follow-up EU project CO2CARE)

CO_2CARE

Robust monitoring baseline datasets key to effective performance verification

- Weyburn - shallow monitoring baseline proved worth
- In Salah - lack of satisfactory 3D seismic baseline significant drawback

Different monitored parameters can be used to verify performance depending on site characteristics

- Sleipner – plume migration and overburden imaging
- In Salah – pressure and surface displacement
- Snohvit – pressure and plume migration

Emissions measurement (if required) is very challenging

- Point and areal measurements
- Precise quantification likely to be impossible
- Integrate measurements with leakage models to provide quantification
- Needs robust baselines

Acknowledgements

European Commission

Industrial Consortium:
BP, Statoil, Wintershall, Total, Schlumberger, DNV, ExxonMobil, ConocoPhillips, Vattenfall and Vector

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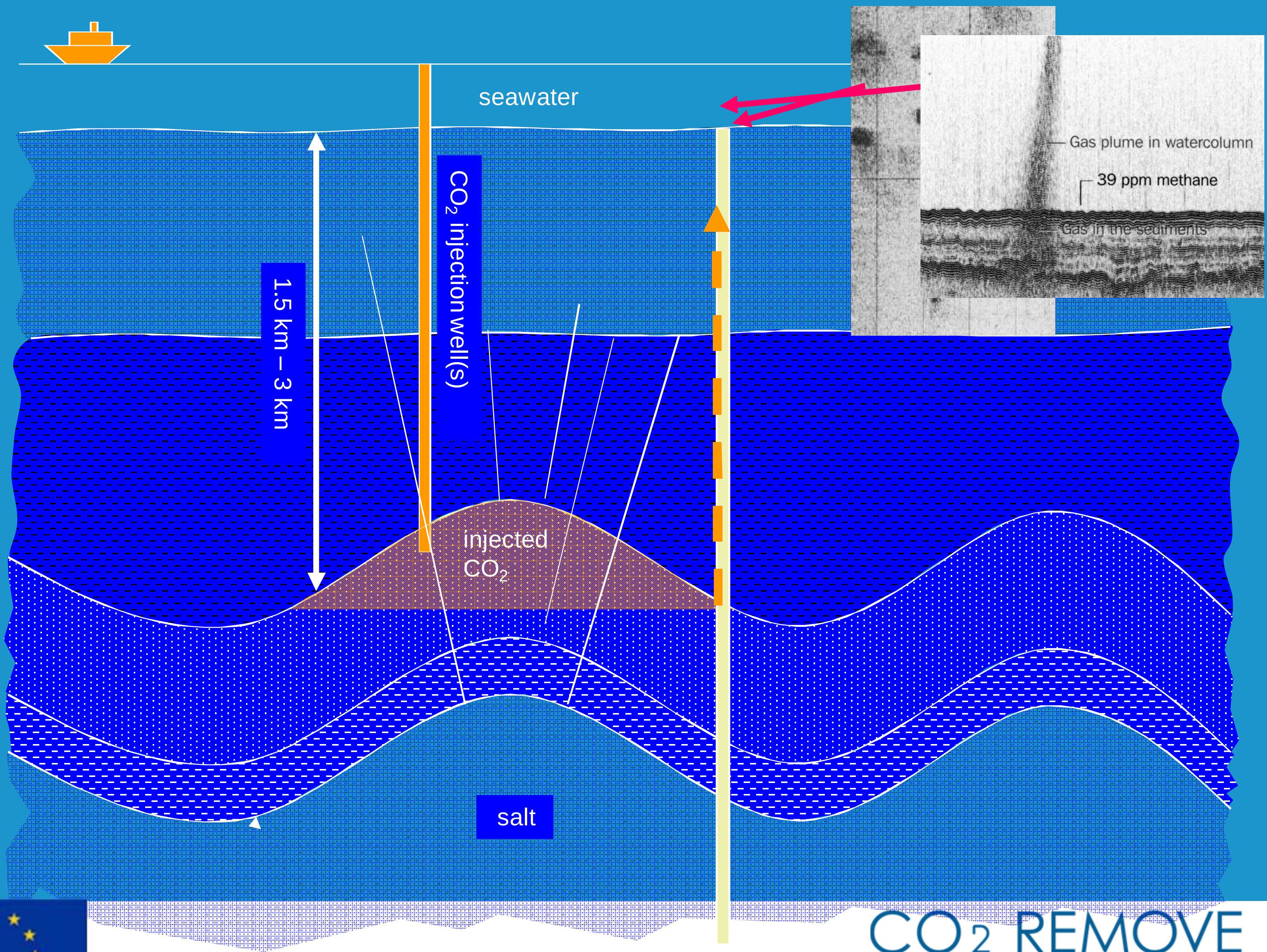
Backup slides

Monitoring purpose (EU regulation)

- Compare the actual and modelled behaviour of CO_2 and formation water, in the storage site;
- Detect significant irregularities;
  - Detect migration of CO_2;
  - Detect leakage of CO_2;
- Detect significant adverse effects for the surrounding environment;
- Assess the effectiveness of any corrective measures taken;
- Update the assessment of the safety and integrity of the storage complex
- Assess of whether the stored CO_2 will be completely and permanently contained
- Quantify emissions

Typical offshore storage site - Additional Monitoring: Leakage



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Conclusion

- Investigated sites well managed without unacceptable impacts on safety or on the environment
- There is no “one-size-fits-all” monitoring programme
- Time-lapse seismic and pressure monitoring appeared to be key in performance verification
- Reservoir pressure and CO_2 saturation are the prime modelling targets
- As predictions will be uncertain, they involve that observations lie within an envelope of predicted safe and effective behaviours
- Evidence gathered during the pre-operational and operational phases is key to transferring responsibility of the storage site

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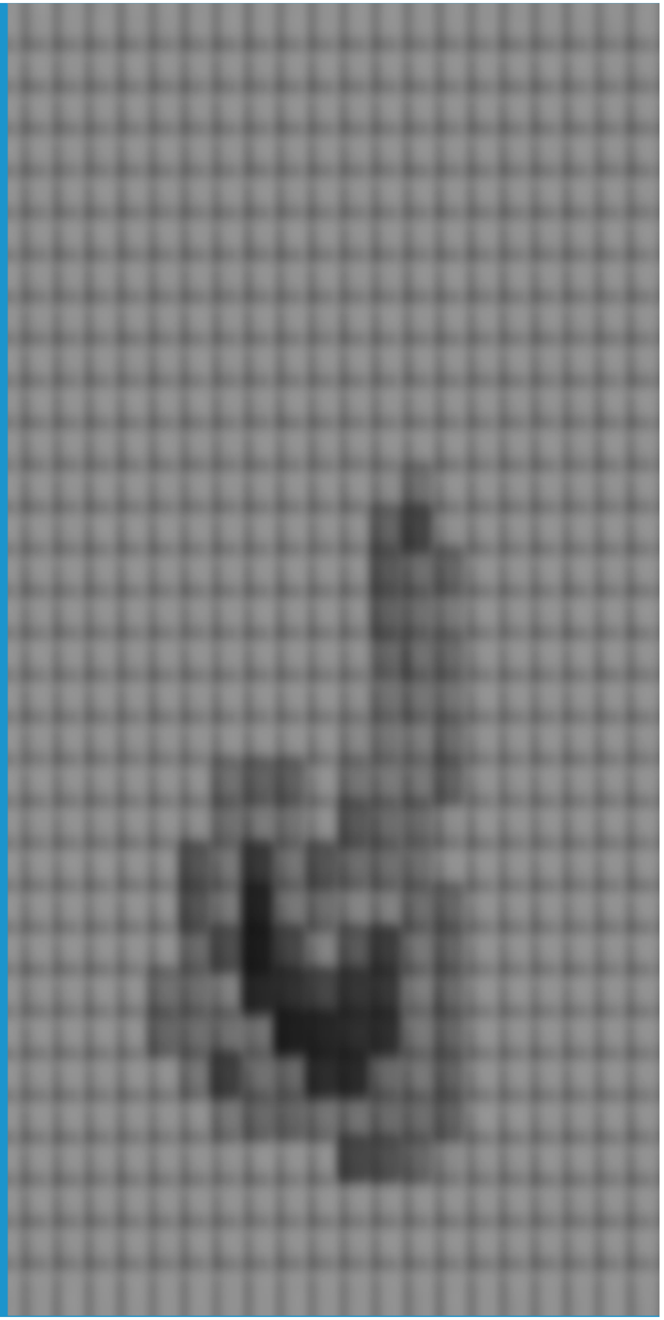
Standardisation (I)

CO_2 storage relies on oil and gas industry practice but is not in all aspects business as usual:

- Integration of wider scope of datasets over a greater spatial extent
- Additional specialist monitoring technologies and modelling of coupled processes
- Consideration of longer time scales

CO_2 storage standards should *not be technology prescriptive*; there is *no one-size-fits-all* monitoring programme



CO₂CARE

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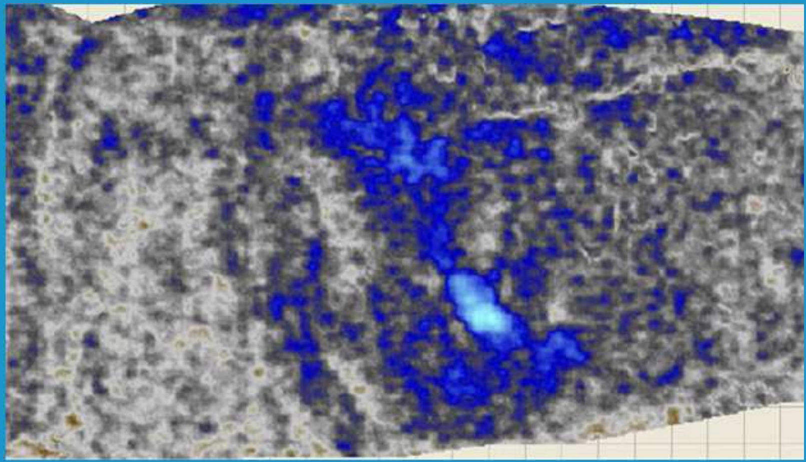
Standardisation (II)

Two deep-focused monitoring techniques – depending on site-specific conditions - stand out:

- Downhole P and T measurements
- Time-lapse seismic imaging



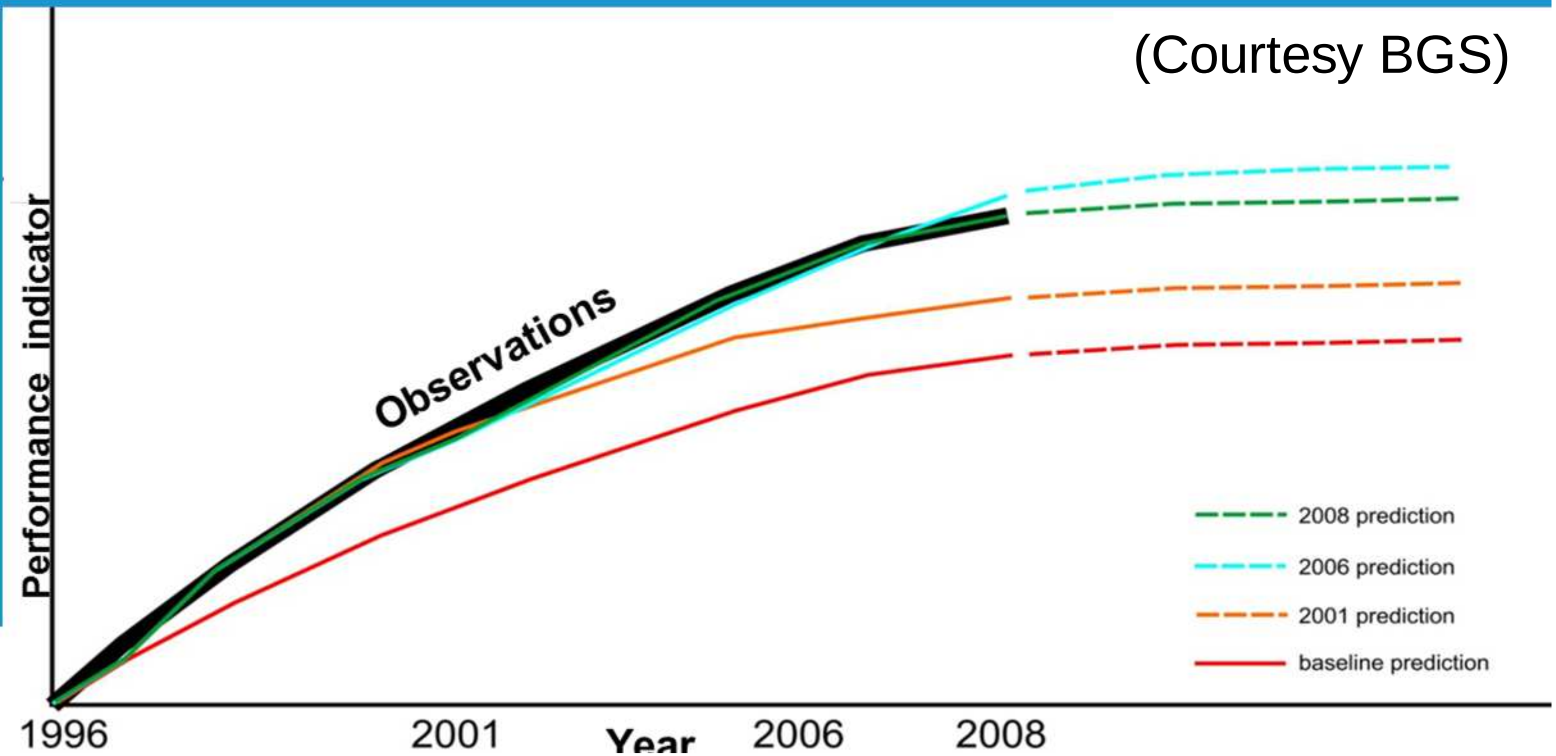
4D seismic response at Snøhvit

Shallow-focussed monitoring has shown that emissions measurement will be very challenging.

Operational performance: Monitoring and verification

- In verification activities monitored site performance can deviate from single predictions.
- Key is to establish acceptable deviations and to demonstrate convergence of model and measurement.

(Courtesy BGS)



Sleipner example