Gravity and seabed displacement monitoring for CO_2 injection

29/October/2024

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Gravity and seabed displacement monitoring

- Time-lapse geophysical surveys: established technology
  - Time-lapse gravity –> **mass changes**
  - Seabed displacement –> **pressure changes**

- Offshore gravimetry: instruments **carried by ROV**
  - Operations are easily combined with windfarms or other infrastructure
  - Typical duration: 2-4 weeks

- **Cost-effective**
  - **Significantly lower cost, compared to 4D seismic**
  - Simplified operations and logistics

- Minimal environmental footprint
  - Passive method with **no active source**

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Time-lapse gravity: a mature technology

Field	First survey	Nº of surveys	Burial depth (m)	№ concrete pads
Troll	1998	9	1400	113
Sleipner	2002	4	800 - 2350	50
Mikkel	2006	5	2500	21
Midgard	2006	5	2500	60
Ormen lange	2007	8	2000	120
Snøhvit/Albatross	2007	4	1800 - 2300	88
Statfjord	2012	2	2750	53
Aasta Hansteen	2018	3	2300	31
Askeladd	2019	2	1900 - 2000	21

Alnes, H., et al. [2010] Experiences on Seafloor Gravimetric and Subsidence Monitoring Above Producing Reservoirs: 72nd EAGE Conference and Exhibition.

Vevatne J., et al. [2012] Use of field-wide seafloor time-lapse gravity in history matching the Mikkel gas condensate field: 74th EAGE Conference & Exhibition.

Agersborg, R., et al [2017] Density Changes and Reservoir Compaction from In-situ Calibrated 4D Gravity and Subsidence Measured at the Seafloor: SPE Annual Technical Conference and Exhibition.

Lien, M., et al. [2017] How 4D Gravity and Subsidence Monitoring Provide Improved Decision Making at a Lower Cost: First EAGE Workshop on Practical Reservoir Monitoring.

Vatshelle, M., et al. [2017] Monitoring the Ormen Lange field with 4D gravity and seafloor subsidence: 79th EAGE Conference & Exhibition.

Ruiz, H., et al. [2022] Monitoring the Snøhvit Gas Field Using Seabed Gravimetry and Subsidence: First Break, Volume 40, Issue 3, Mar 2022, p 93-96.

Solbu, Ø. H., et al. [2023] Time-Lapse Gravity and Subsidence Applied in History Matching of a Gas-Condensate Field: First Break, Volume 41, issue 9, 69-74.

Borges, F., et al. [2024] Monitoring CO2 Storage in the Morecambe Depleted Gas Reservoirs through Seafloor Deformation and Time-Lapse Gravimetry Measurements: First Break, 42(3), 71-75.

Alsos, T., et al. [2024] Gravity and 4D Seismic Monitoring Data in History Matching of the Snøhvit Reservoir Model: 85th EAGE Conference & Exhibition.

Sensitivity evolution

- Dozens of surveys over the last two decades
  - Continuous improvement in accuracy (advances in equipment/survey procedures)

Published results of gravity and seabed deformation monitoring

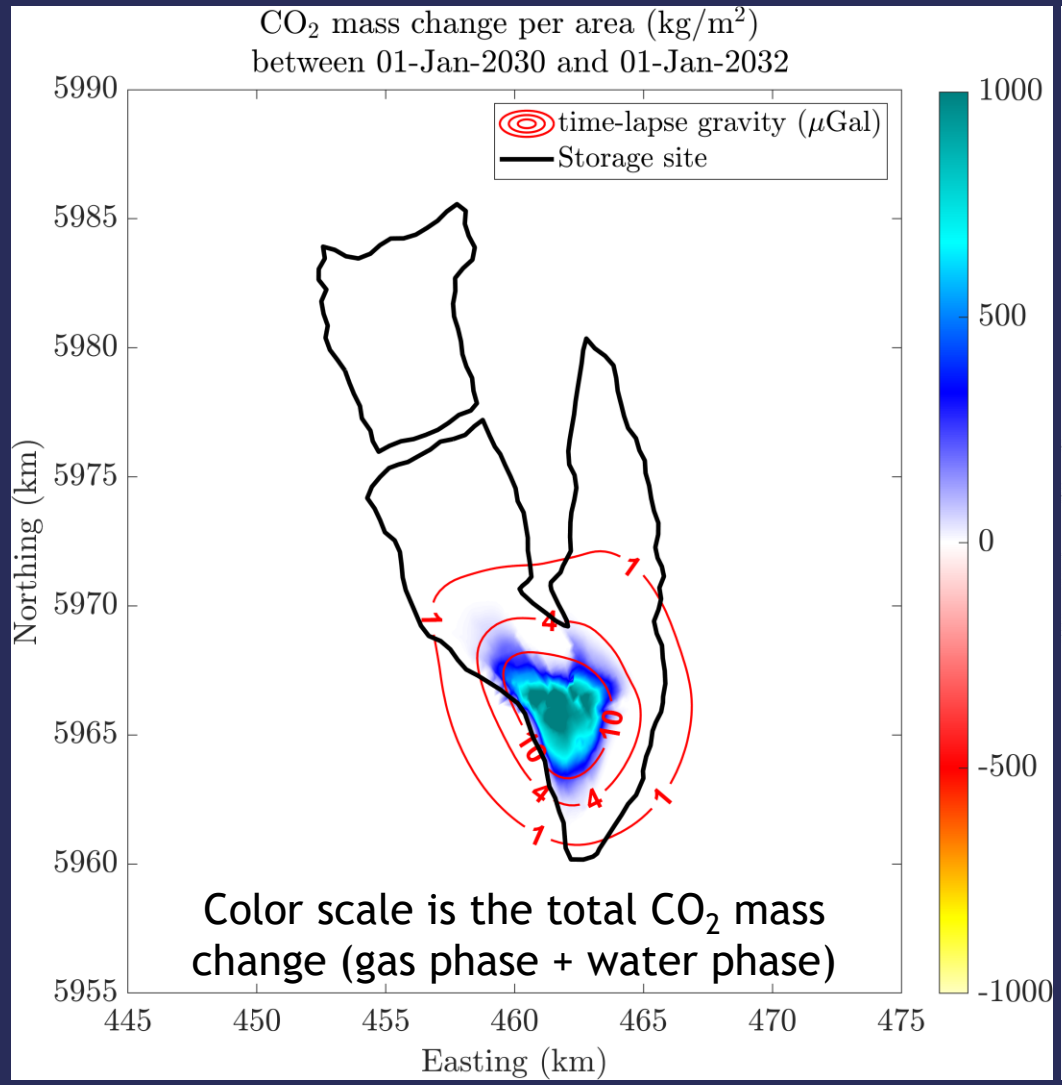
Field	Survey year	Time-lapse Repeatability	
		Gravity (µGal)	Depth (mm)
Snøhvit	2011[1]	3.7	4.6
	2019[1]	1.6	2.8
Mikkel	2022[2]	1	1.4

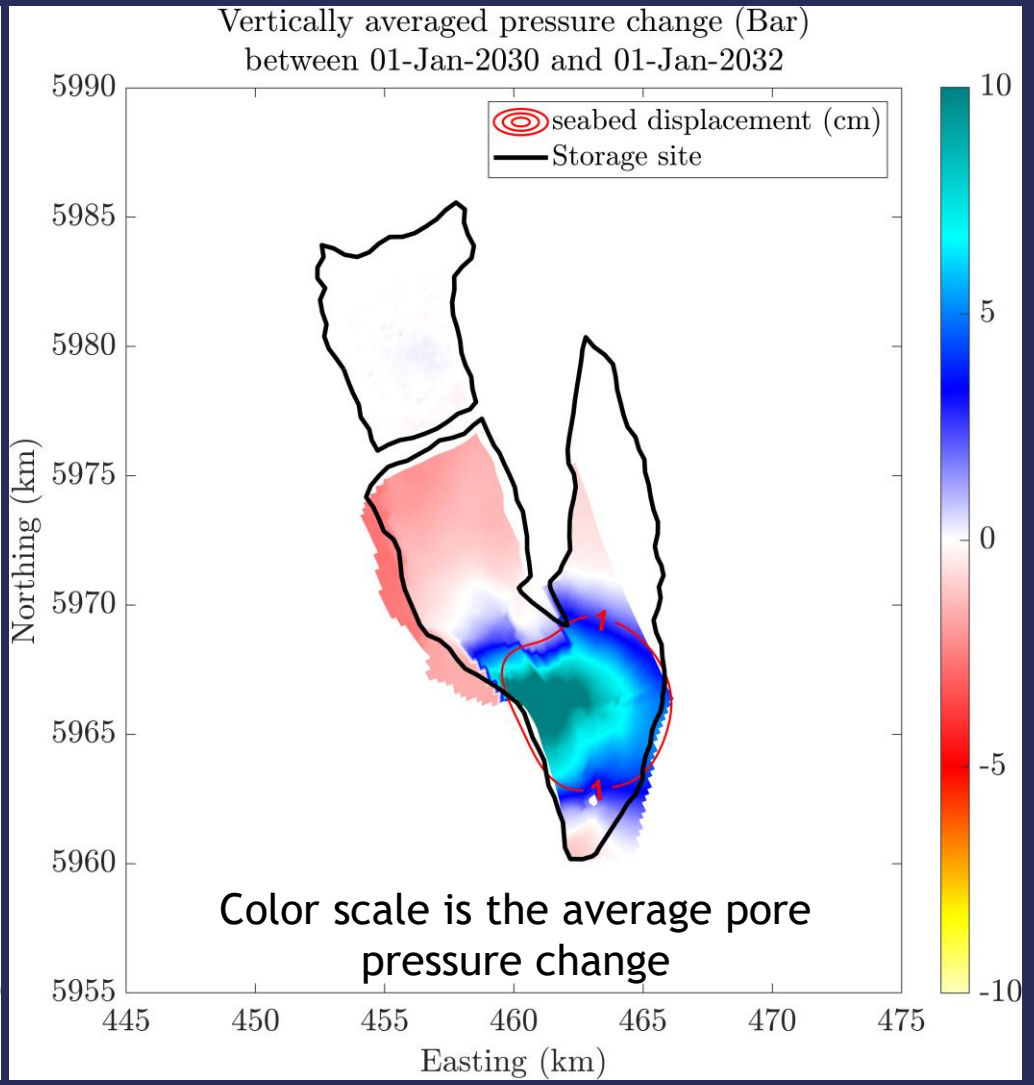
(1) Ruiz et al., 2022. Monitoring the Snøhvit gas field using seabed gravimetry and subsidence.

(2) Solbu at al., 2023. Time-Lapse Gravity and Subsidence Applied in History Matching of a Gas-Condensate Field.

- 1µGal: gravity signal generated by a 150-kiloton mass change at a depth of 1000 m

Feasibility Analysis – Morecambe Net Zero (MNZ)





Modified from Basford *et al.* (2024). Monitoring of CO2 injection in depleted gas reservoirs through measurements of seafloor deformation and 4D gravity.

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John Even Lindgård
Commercial Director

Nils-Eivind Holmedal
Sales Manager

Filipe Borges
Geoscientist

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