Surveillance Pioneer on the Greensand Project

SPOTLIGHT

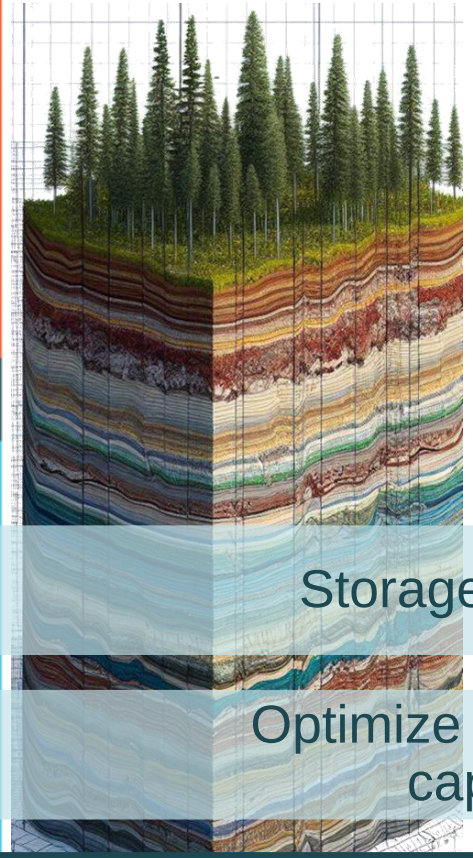
Offshore CCS surveillance

CO2 GEONET 2024

Elodie Morgan

May 2024

CO_2 Storage in the Subsurface



Storage volume

Optimize injection capabilities

MMV Plan

Permit application

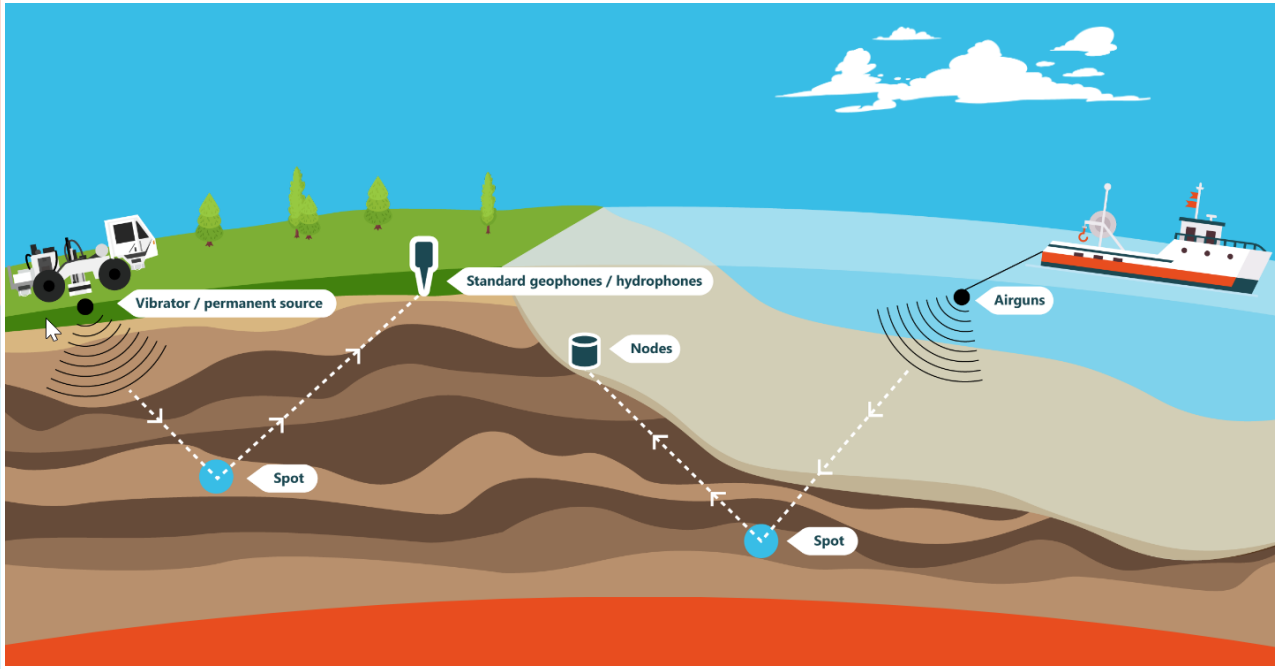
Monitoring

Challenge – Building a **convincing MMV plan** sustainable throughout site life cycle

Environmental footprint & Social Impact

Cost

Frequent focused seismic monitoring



CCS Conformance & Compliance
Subsurface frequent focused seismic detection to confirm the compliance of the CO_2 plume in the AOR

Technology has a small footprint, is low cost, and environmentally friendly

Dual use (multipurposed sensors) – monitor saturation and caprock integrity at the same time

→ Our monitoring technology save costs and improve societal acceptability

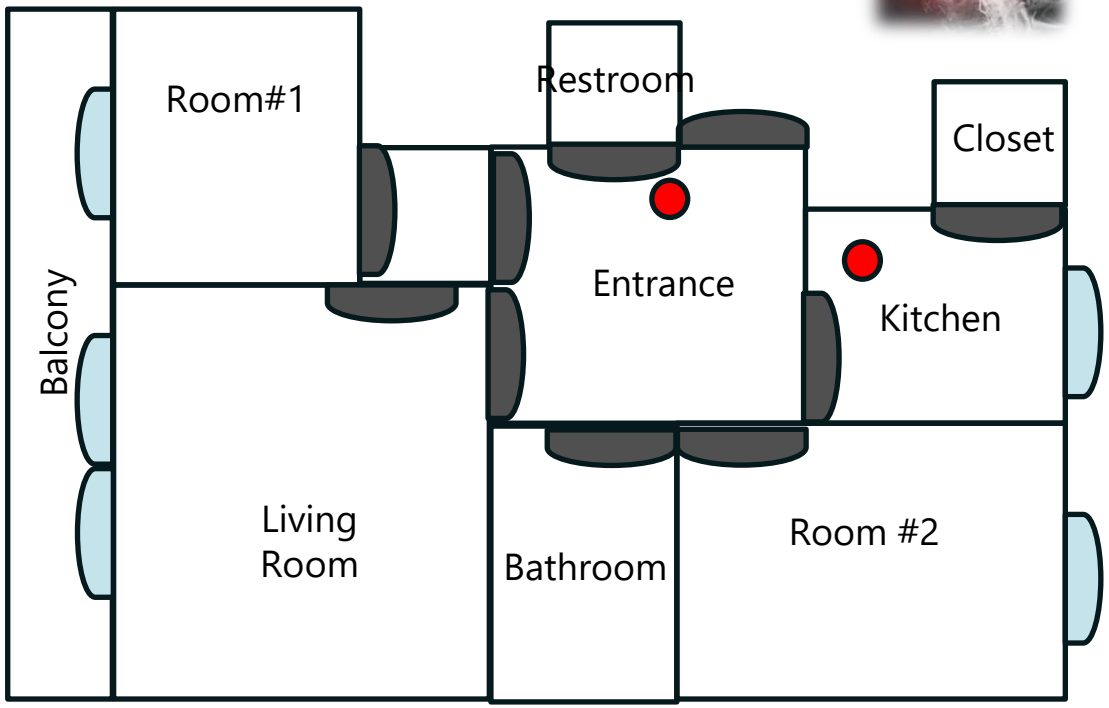
CCS projects

O&G projects

What for?

Predictive maintenance

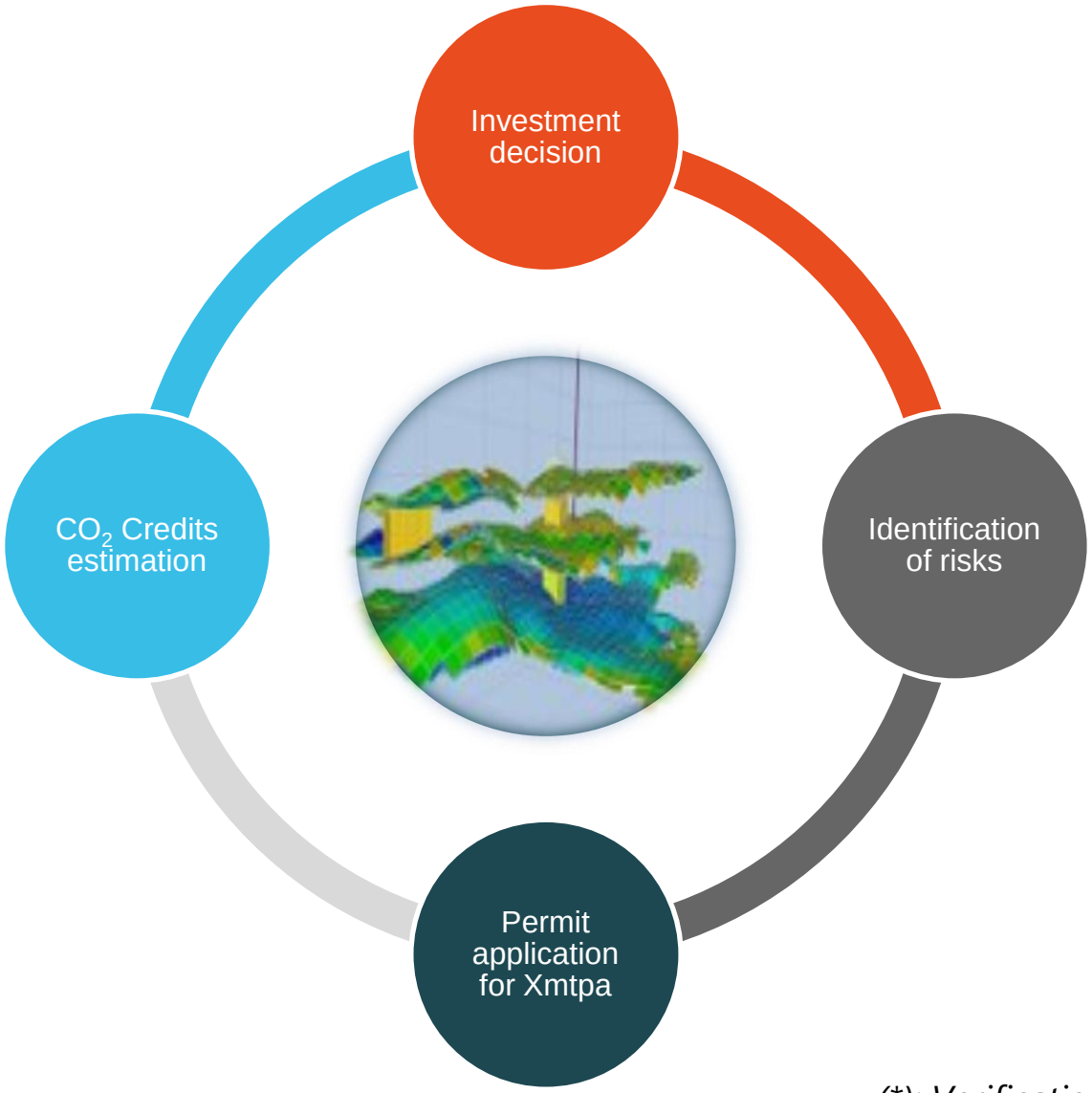
To prevent fire hazard



You don’t need a new “image” to check that the strong hypothesis* & unacceptable outcomes** of CCS injection are accurate

*Conformance || **Containment

Why validating model is paramount?



Trigger technology: to know if/when models are getting wrong and call for **Verification methods***

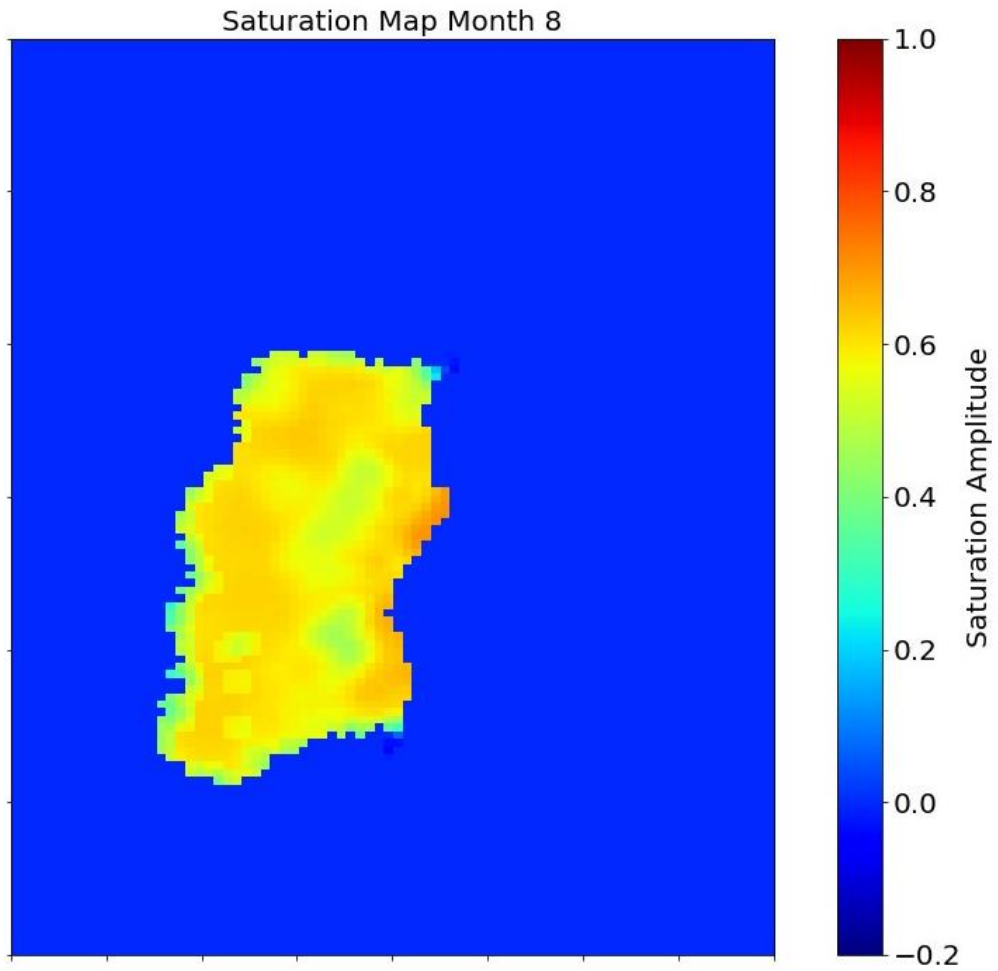
(*): Verification Methods: More expansive monitoring technologies such as, walk-away VSP, 2D lines, 4D seismic to maximize their value of information

Enabling CCS economics by answering several $M question:

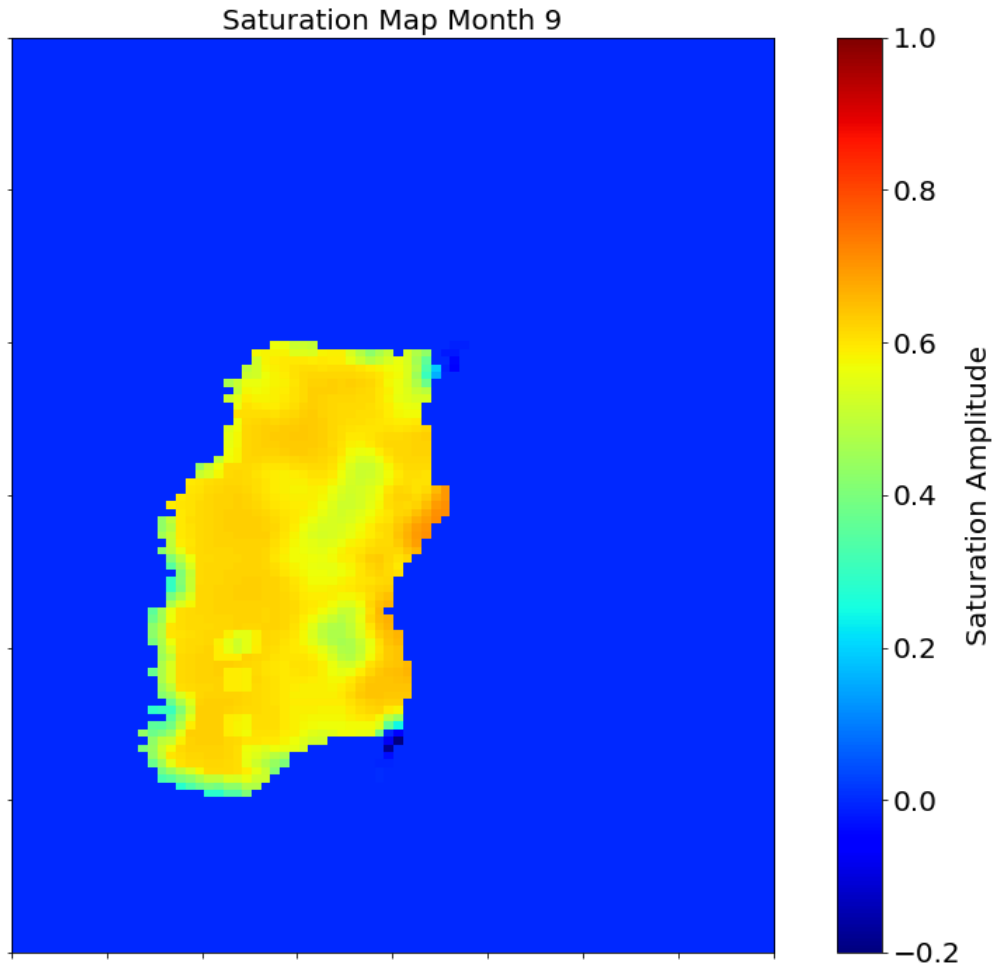
How often do you need to monitor?

*Conformance || **Containment

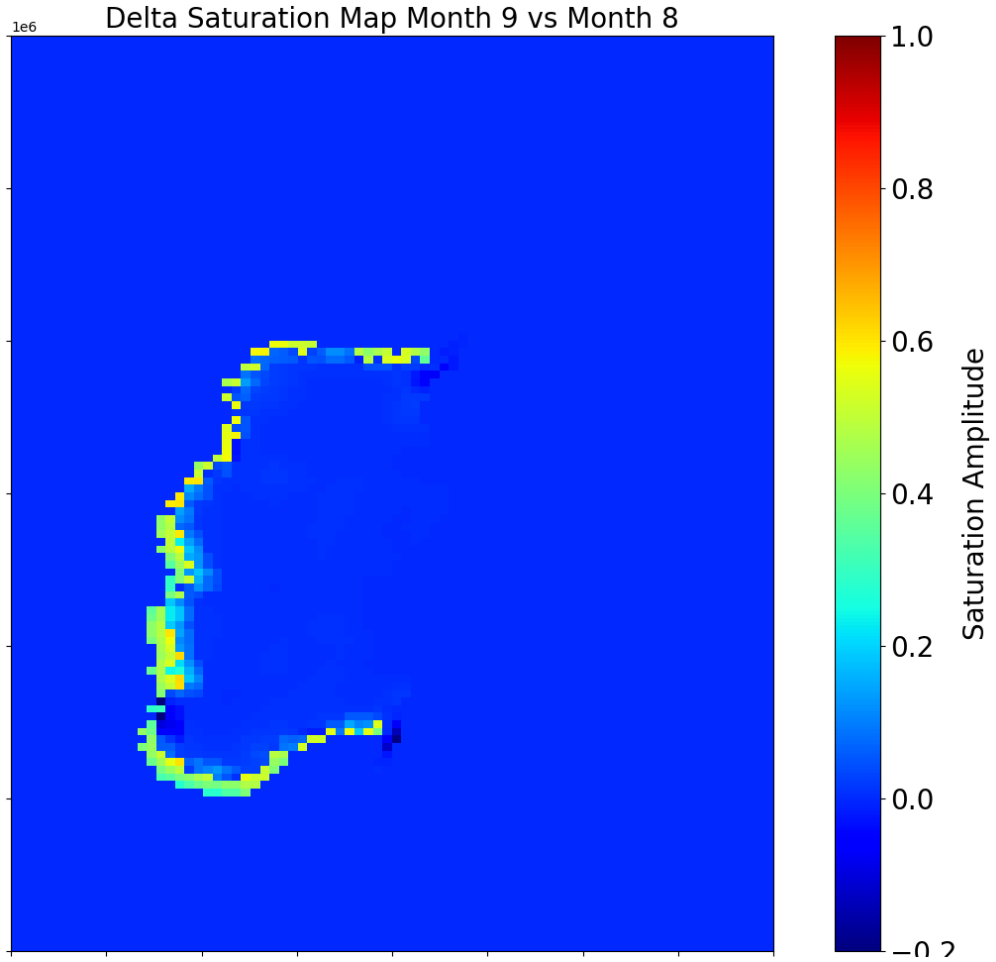
Example between 2 months



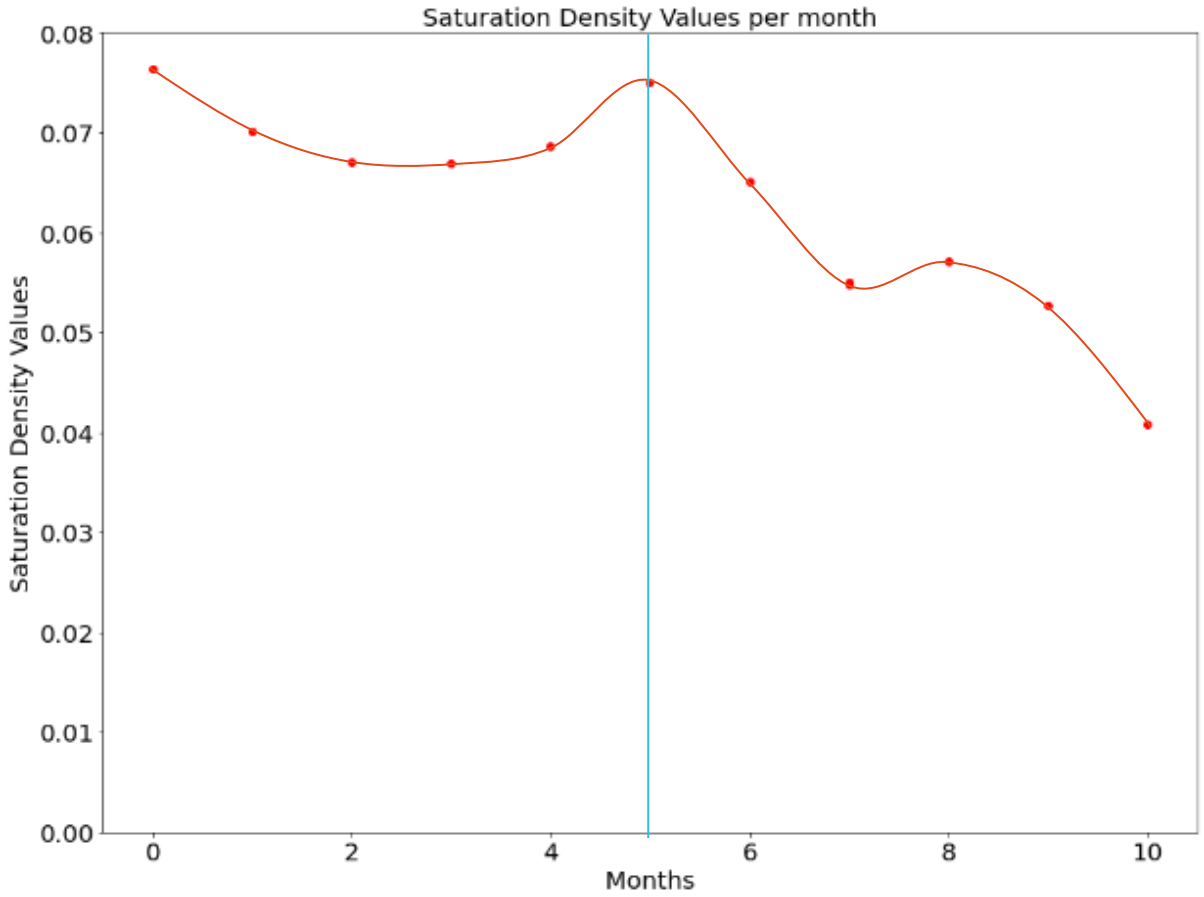
Example between 2 months

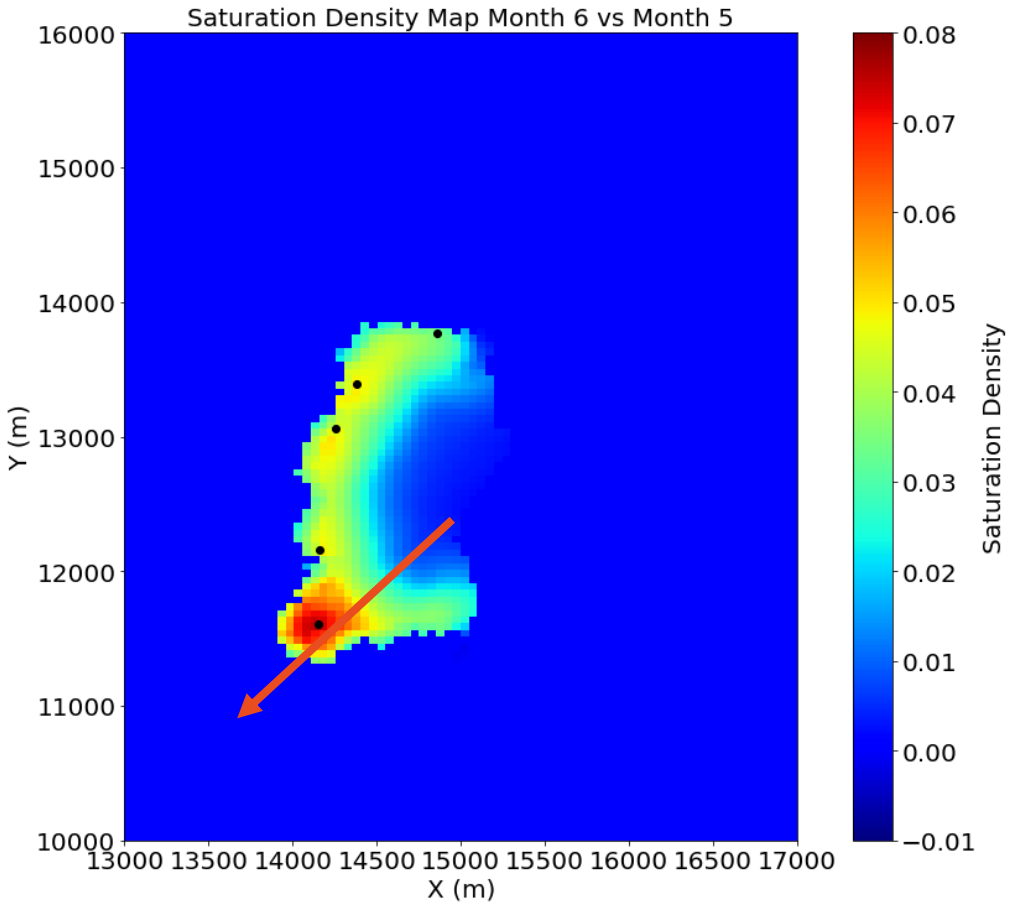


Example between 2 months



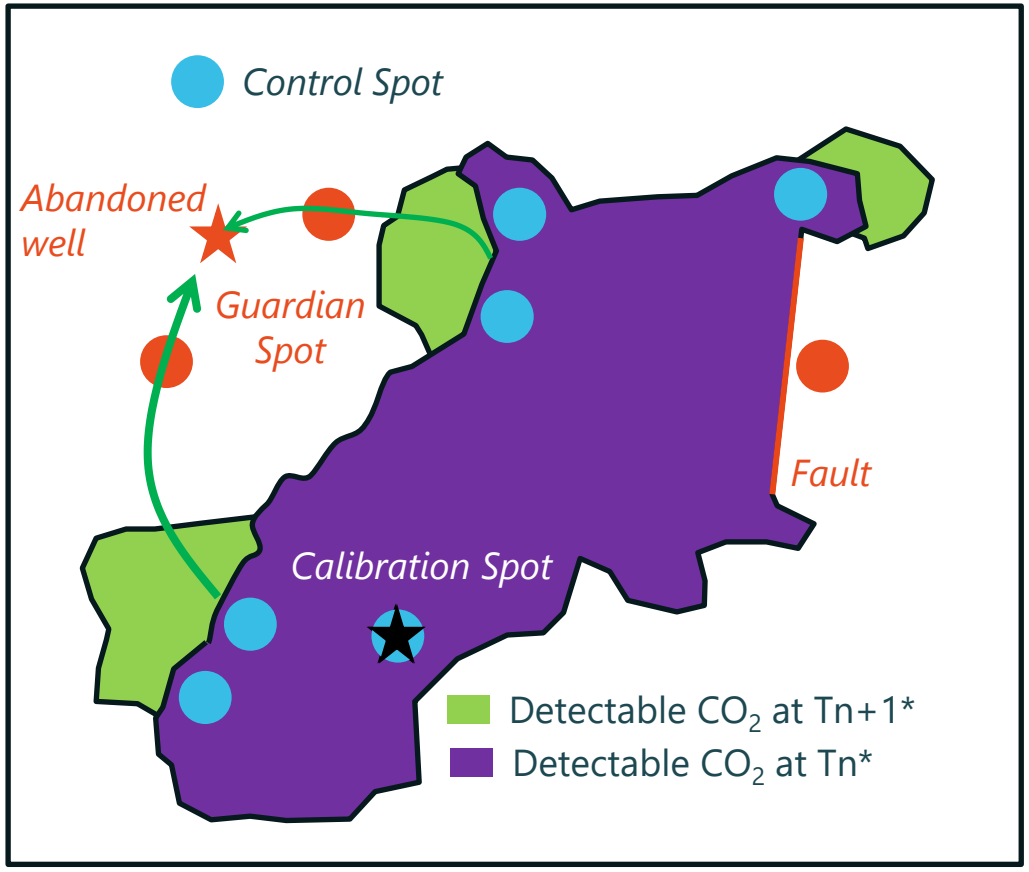
Saturation intensity maps





This is predictive maintenance

CO_2 forecast after one year of injection: Flow model output



*as per flow model

Predictive maintenance

Conformance

Validate the strong certainties of the flow model at Tn

Containment

"systematically eliminate the unacceptable outcomes"

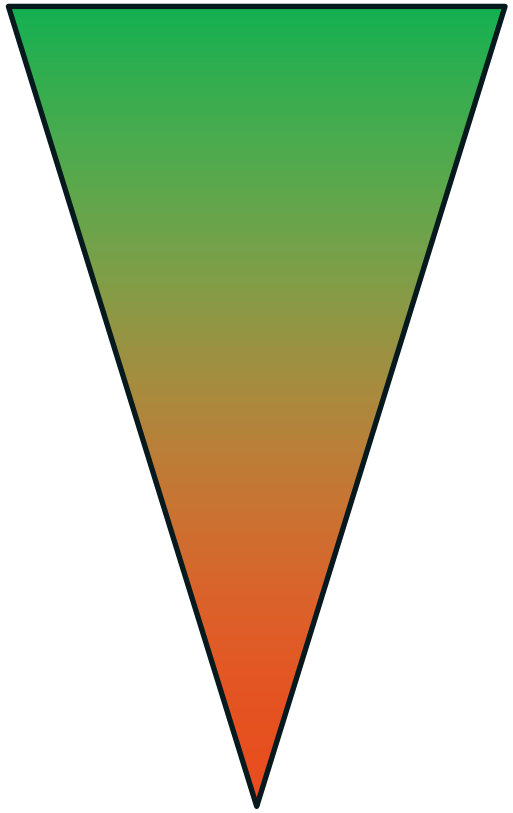
Define when & where to monitor

What if models prediction aren’t matching prediction ?

Trigger technology

To finish our analogy

99,9%



0,1%

Trigger technology

Do nothing

Model update

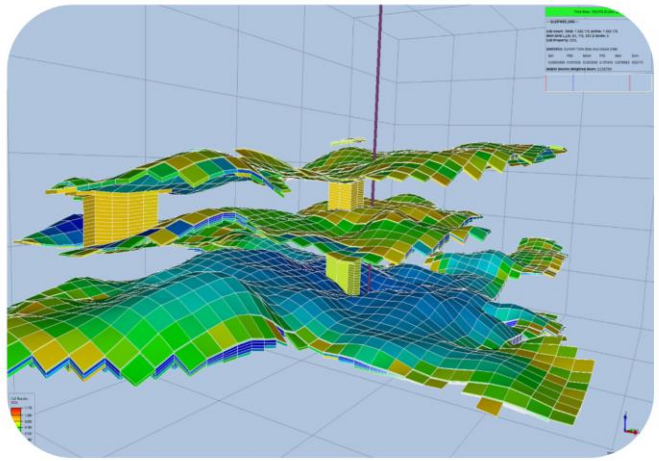
2D line, walk away VSP…

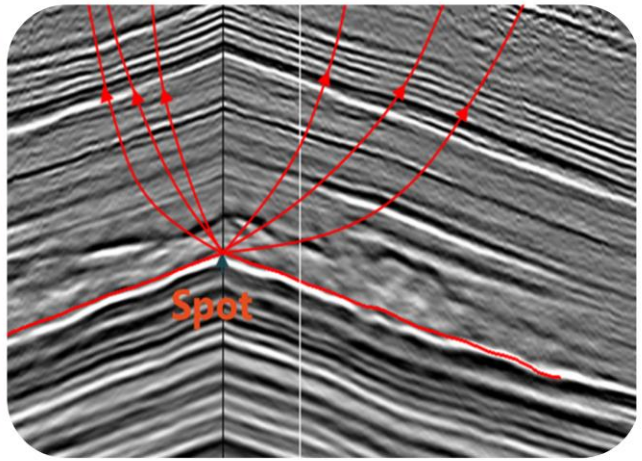
Full 4D seismic

Our competitive advantage, we enhance the power of your existing data & assets

Step 1 – Survey design

Flow model, subsurface risks/strong hypothesis + migrated seismic





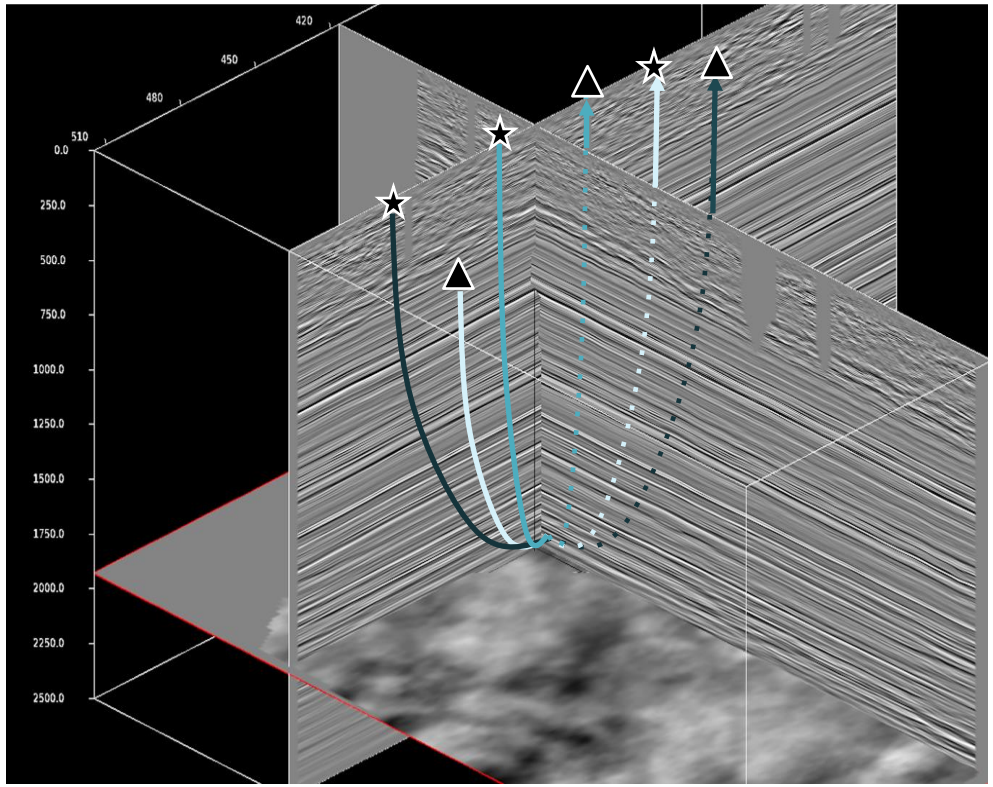
1- By **analyzing** flow models, production certainties, risk models, and the petro-elastic response of the field, key "**Spots**" of interest identification that require monitoring in terms of location (X, Y, Z) and the optimal timing for monitoring.

2- For **each identified Spot**, leverage legacy seismic data to precisely determine the optimal source/receiver parameters and define the acquisition parameters, ensuring accurate and **frugal smart** monitoring strategies

Capitalization on existing data

Ray tracing algorithm

Example for 3 source-receiver combinations but we extract plenty of combinations ! 400 in this case.

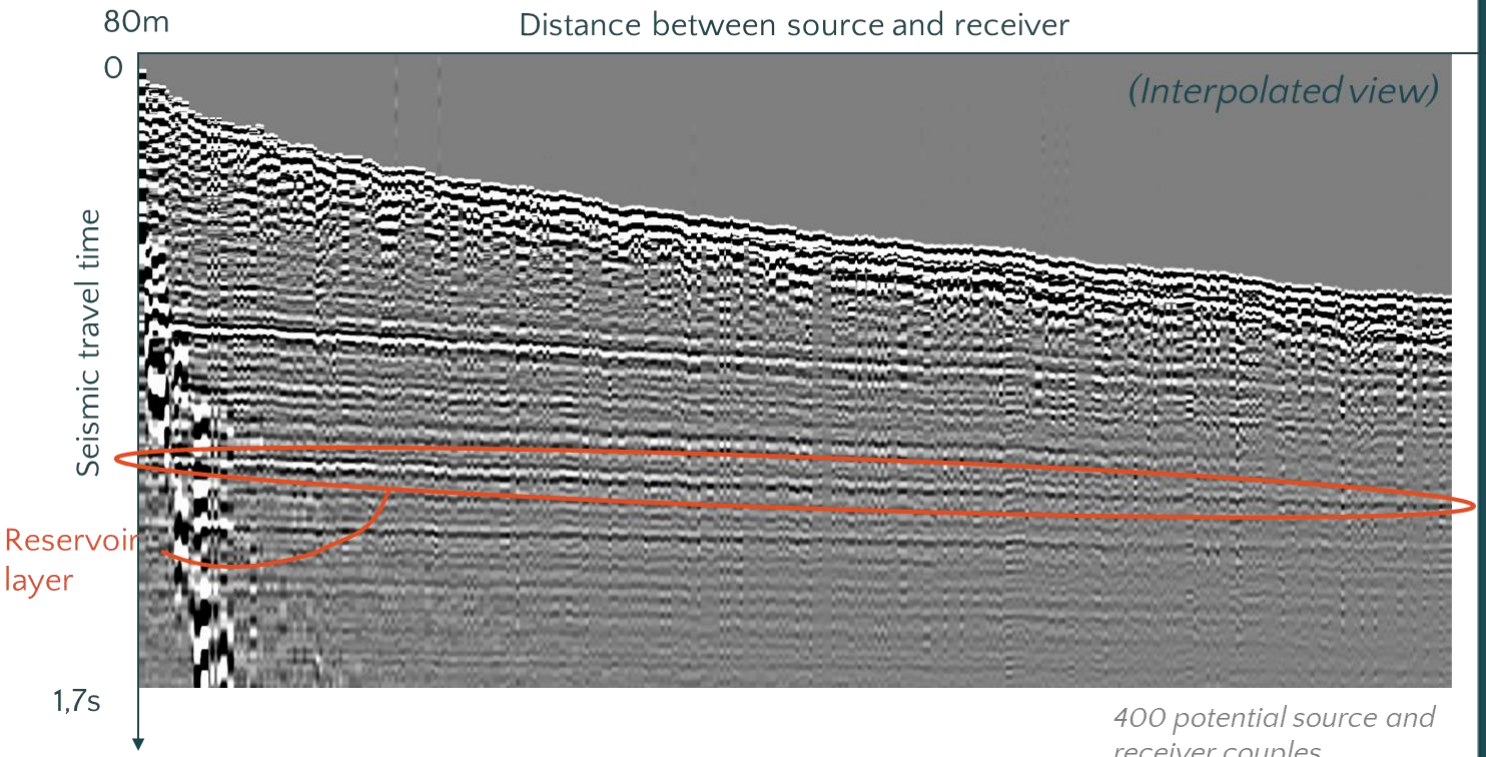


★ Sources & ▲ receivers from 2020 3D seismic

Common Spot Gather (CSG)

Seismic traces useful to see the spot

400 potential source-receiver couples



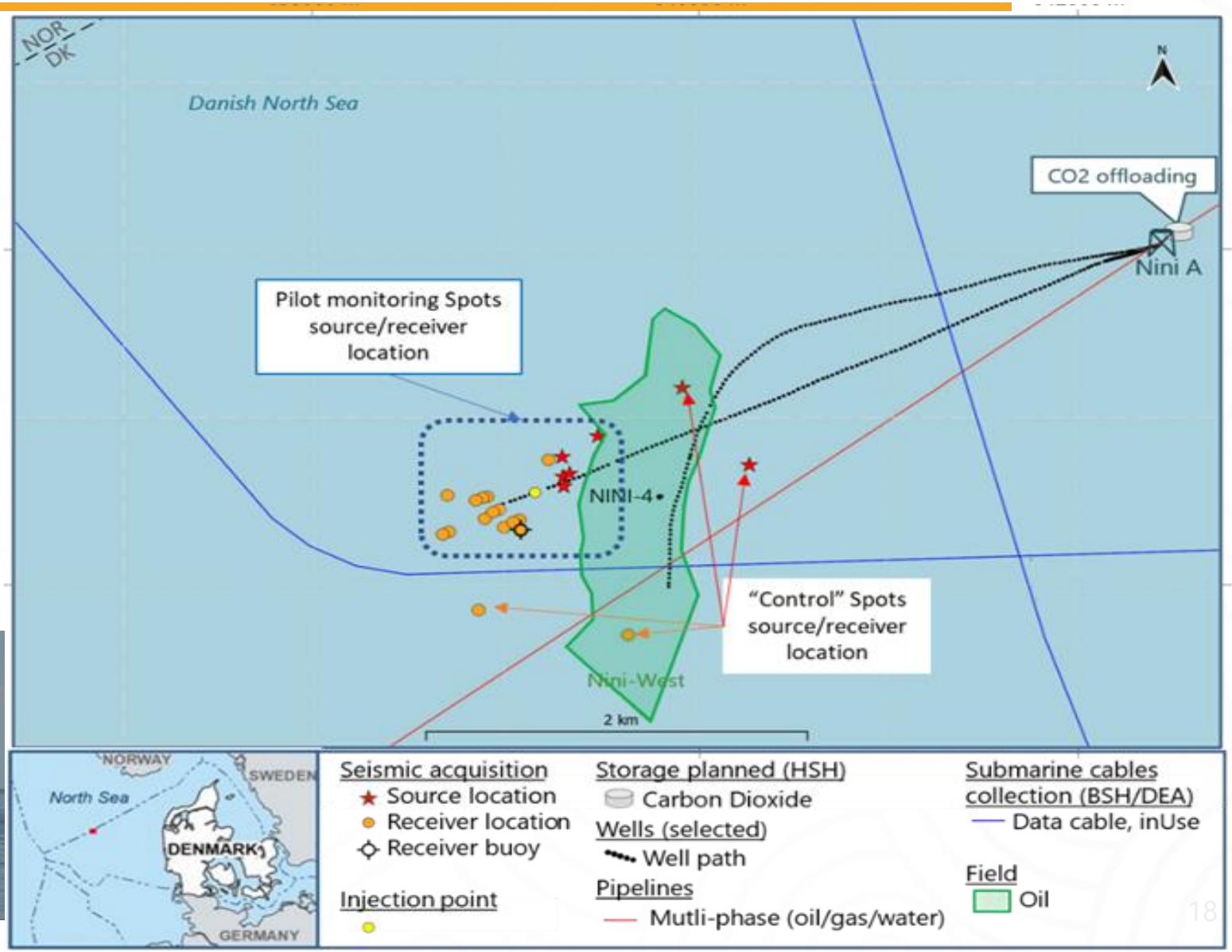
400 potential source and receiver couples

Seismic Monitoring Greensand

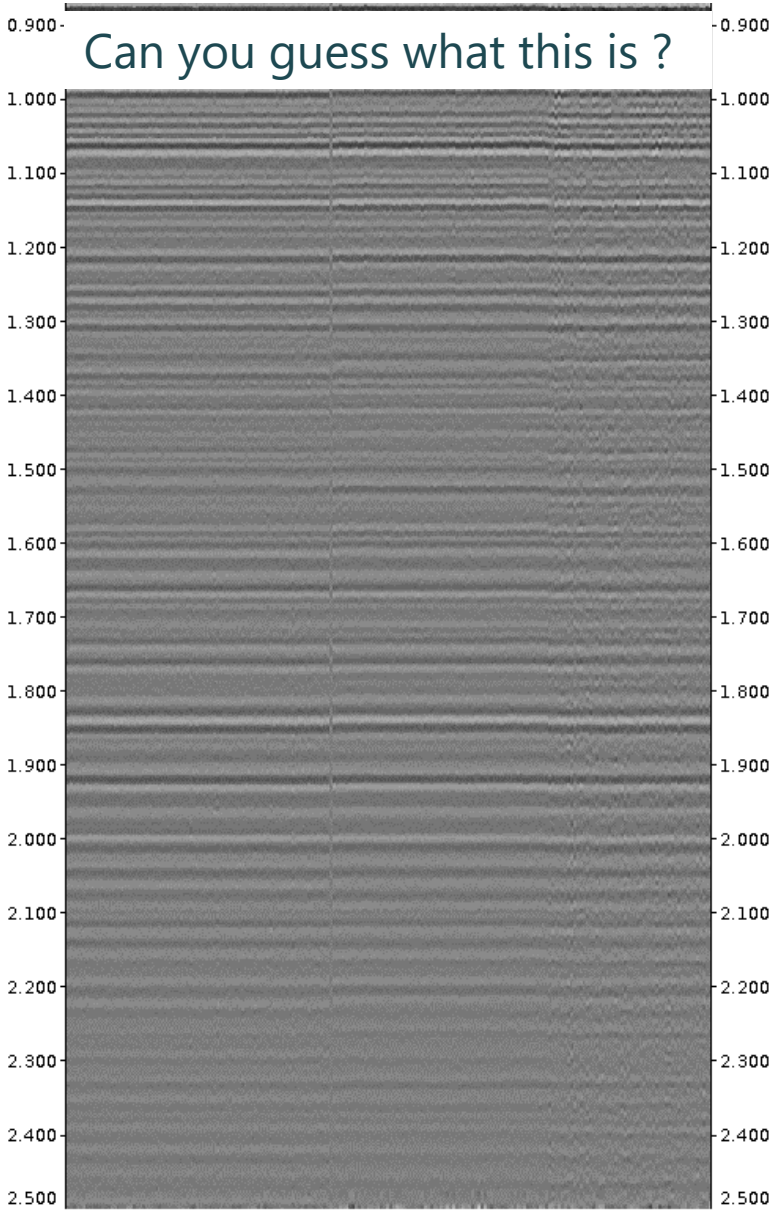
GET2022

Key Objectives

- Demonstrate detectability of CO_2 by means of focused seismic, 1st offshore trial
- Low energy air gun (600 cu) selected
- 16 receiver -, 7 source locations planned. 80 shots planned per source location
- 3 seismic campaigns planned to monitor injection pilot (1-5 days each)
- Learn to acquire seismic from a platform supply vessel (ESVAGT INNOVATOR)
- Magseis Fairfield MASS III nodes used

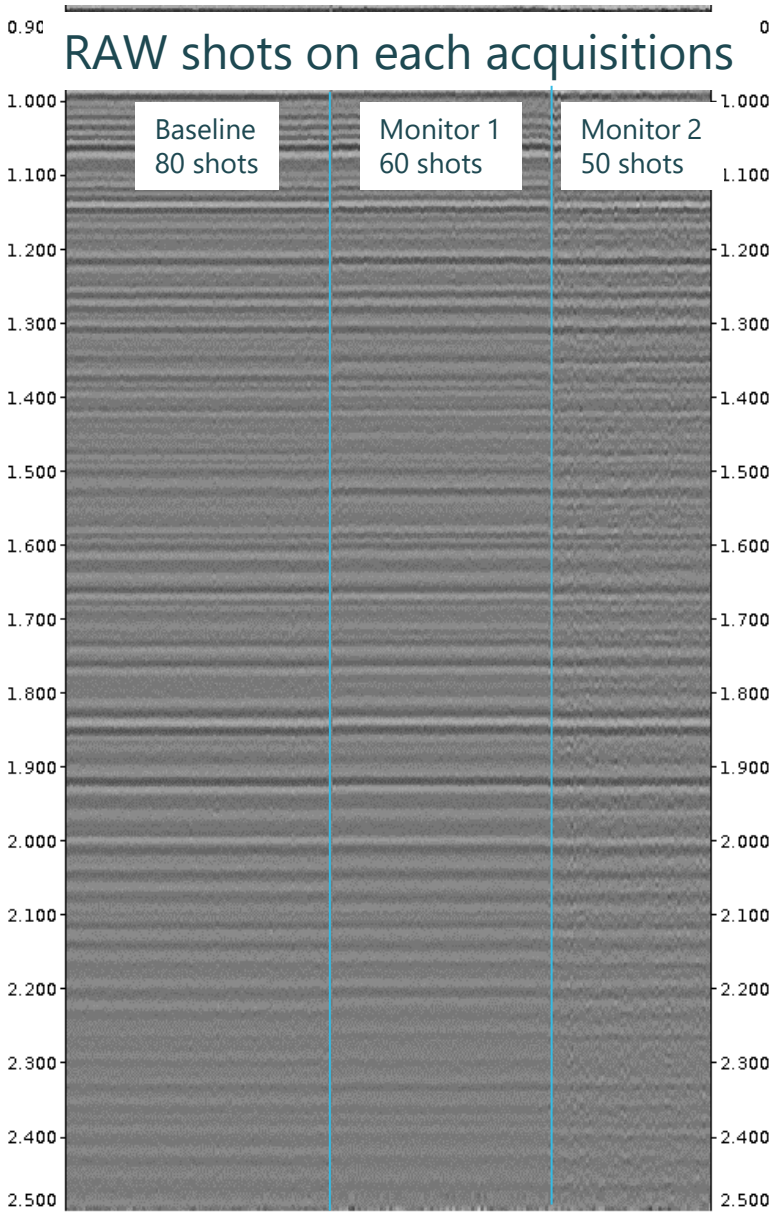


RAW data analysis



High repeatability

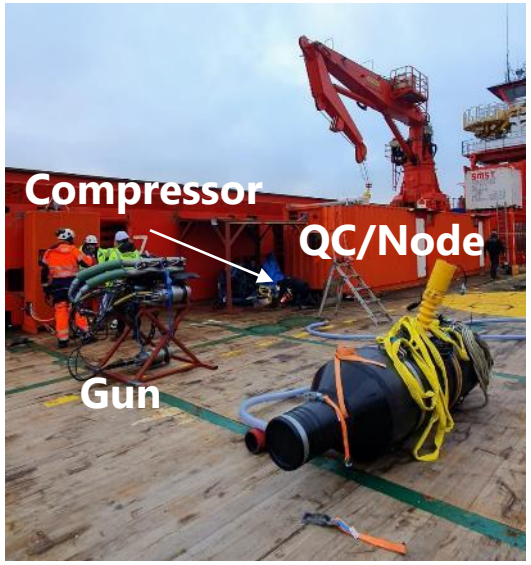
RAW data analysis



High repeatability

Early warning ultra-light marine seismic 4D time-lapse detection system

Chartered supply vessel used
Cost of vessel is marginal



Small setup
cargo runs while shooting

Can operate during the winter
12H operation are needed

ESVAGT TGS

Environmental footprint

	Full 4D (streamer baseline)		(for 3 monitors)
Obstruction area	370 km²		**12 km²**
Duration	33 days	-83%	**5 days**
CO_2 emitted	4,500 tons	-91%	**400 tons**
Airgun size	3 600 Cui		**600 Cui**
Number of shots	60,000		**3,780**

acquisition **didn't require** a fisherman liaison officer onboard and can **accommodate with** heavy Maritime traffic area.

Airgun emission to water : **-98%**
(better for mammals)

Looking for the stars

GreenSand – North Sea
January 2023

GreenSand – North Sea
February 2023

GreenSand – North Sea
March 2023

Agile enough to synergies with operations

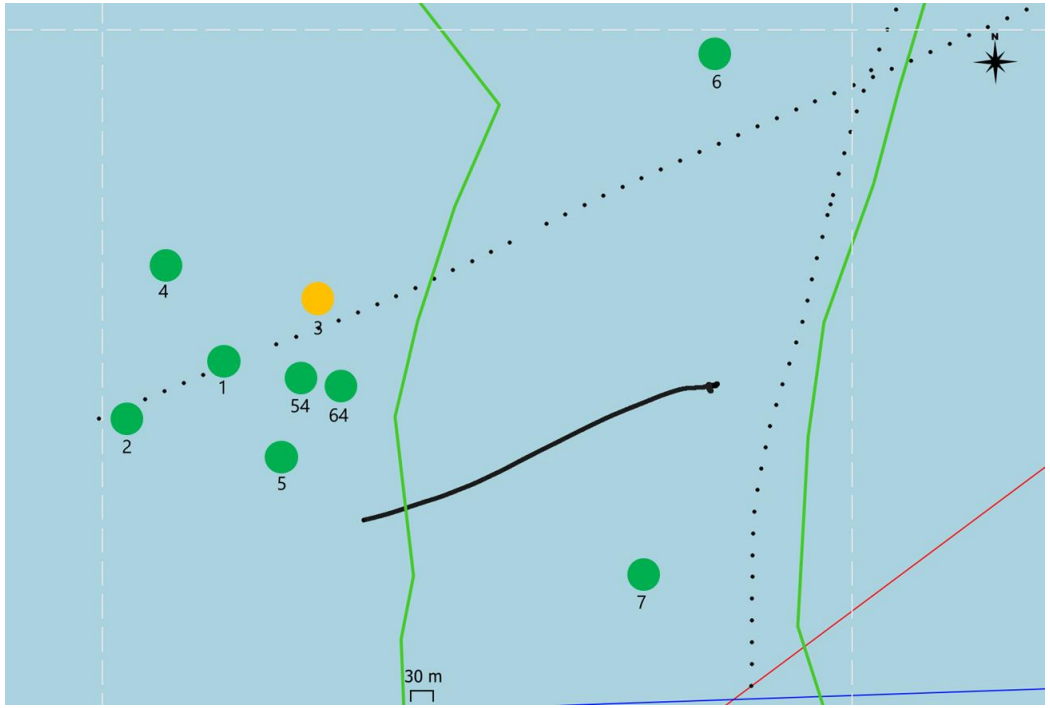
We've managed to accommodate with tiny good weather windows. And **therefore operate in winter**

Valid	Tuesday, February 28, 2023											Temperature (C): 7 / 5			
0600	NNW	10	13	11	14	0.4	NNW	0.9	7	1.0	1.9	14.5	2	0%	0%
1200	N	16	23	18	25	1.4	NW	1.3	7	1.9	3.6	15.0	2	0%	0%
1800	N	18	26	20	27	1.9	NNW	1.6	8	2.4	4.5	15.0	1	0%	0%
Valid	Wednesday, March 01, 2023											Temperature (C): 7 / 4			
0000	NNE	16	22	18	24	1.1	NNW	1.9	8	2.2	4.1	18.0	1	0%	0%
0600	NE	14	20	16	22	0.8	NNW	1.7	7	1.9	3.5	19.5	1	0%	0%
1200	ENE	12	16	12	17	0.5	NNW	1.5	7	1.5	3.0	13.0	2	0%	0%
1800	E	7	9	7	10	0.2	NNW	1.5	7	1.5	2.8	13.0	3	0%	0%
Valid	Thursday, March 02, 2023											Temperature (C): 7 / 4			
0000	ESE	4	7	5	7	0.1	NNW	1.2	7	1.2	2.3	17.0	3	0%	0%
0600	N	2	4	2	4	0.0	NNW	1.1	7	1.1	2.0	19.5	3	0%	0%
1200	NW	6	9	7	10	0.2	NNW	1.0	7	1.0	1.9	19.5	2	0%	0%
1800	NW	14	20	15	21	0.7	NNW	0.8	8	1.1	2.0	18.0	1	0%	0%
Valid	Friday, March 03, 2023											Temperature (C): 8 / 6			
0000	NW	19	26	21	28	1.4	NNW	0.7	10	1.6	2.9	15.0	1	0%	0%
0600	NNW	22	28	24	31	2.1	N	0.9	10	2.3	4.2	15.0	1	0%	0%
1200	NNW	25	32	27	35	2.7	NNE	0.3	5	2.7	5.1	15.0	1	0%	0%
1800	NNW	24	32	27	35	2.9	NNE	0.9	7	3.0	5.6	15.0	1	0%	0%
Valid	Saturday, March 04, 2023											Temperature (C): 7 / 4			
0000	NNW	26	33	29	37	2.8	N	0.6	8	2.9	5.4	15.0	1	5%	0%
0600	NNW	24	32	27	35	3.0	N	0.9	7	3.2	5.9	15.0	0	10%	0%
1200	NNW	25	33	28	36	3.4	NNE	0.1	6	3.4	6.3	19.5	-1	5%	0%
1800	NNW	24	31	26	34	3.3	SSW	0.1	6	3.3	6.0	19.5	1	5%	0%
Valid	Sunday, March 05, 2023											Temperature (C): 5 / 3			
0000	NNW	23	30	25	33	3.0	NNE	0.5	5	3.0	5.6	19.0	-2	15%	0%
0600	NNW	24	32	27	35	3.0	NNE	0.2	4	3.1	5.7	19.0	-2	15%	0%
1200	NNW	24	32	26	35	3.0	NW	0.2	11	3.0	5.6	19.5	2	15%	0%
1800	N	25	33	28	36	3.1	W	0.1	6	3.1	5.7	19.5	-2	20%	0%
Valid	Monday, March 06, 2023											Temperature (C): 5 / 2			
0000	N	20	28	22	30	2.5	NW	1.0	8	2.8	5.1	18.5	-2	20%	0%
0600	N	16	22	17	24	1.4	NNW	1.7	8	2.3	4.2	16.5	2	25%	0%
1200	N	4	8	4	8	0.2	NNW	1.6	7	1.6	3.0	15.5	1	15%	0%

48H operation port to port

Successful monitoring of project Greensand

2023 spots detections map on Greensand



- **Match predictions & models**
- Not matching prediction but not concerning → model update
- Not matching & concerning → triggers further monitoring
- Warning - Stop injection

SPOTLIGHT

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