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SpotLight

FRUGAL CALIBRATION AND SURVEILLANCE OF CO_2 UNDERGROUND STORAGE WITH SEISMIC

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ABSTRACT

CO_2 underground storage should reach 1.6 Gt CO_2 per year by 2030 to be aligned with the Green House gas control objectives [1].
This development is opening a **massive need for Monitoring, Measurement and Verification (MMV) methods**.

Driven by **regulation**, Carbone Capture Storage (CCS) projects will have to rely on **long term monitoring strategy (50-100 years)** [2] that need to be :

- **Operationally VIABLE**
- **Economically VIABLE**
- **Environmentally VIABLE**

4D seismic images have been proven to be the technically most appropriate technology for CO_2 storage monitoring [4].
The paradox appears: even if frequent full 4D monitoring is technically doable, the more often new images are acquired, the more cost and environmental footprint are increasing.
Therefore **frequent full-scale 4D seismic** are too heavy to represent a viable solution [2].

In this paper we will present a focus seismic monitoring approach that capitalizes on existing data & the capability of seismic to accurately detect CO2 to propose **frequent detection on key area to validate or invalidate the reservoir model**.

BACKGROUND

CCS underground storage have **two untapped features**:

- CO2 injection is generating a strong & fast 4D seismic **response enabling frequent seismic detections (monthly)** [2] [3].
- Unlike O&G reservoirs, CCS are targeting **simple geological sites**: the injection points are chosen to avoid highly complex traps.

With **simpler geology, flow models of CCS are more predictive**: on Sleipner, model predictions were matching with the 4D measurements [2]. As a results:

CO_2 flow simulations should be at the heart of MMV strategies

Yet all conventional monitoring methods (full 4D seismic, microseismic, Gravimetry or INSAR) aren't really considering the flow simulations input → **They will provide a full field coverage.**

A **new monitoring solution,** simulation oriented is needed

SIMULATION DRIVEN MONITORING

To demonstrate that flow models are accurate and reduce the attached uncertainties. All flow model's simulation outcomes can be screened in order to identify several strategic calibration points (Spots) in Space & Time that can validate or discard some scenarios.

These Spots dynamic behavior can be detected using focused active seismic measurement to see if changes happened as per predicted or not. Figure 1 [5] illustrates how the monitoring of the Sleipner field could have looked like with a simulation driven monitoring.

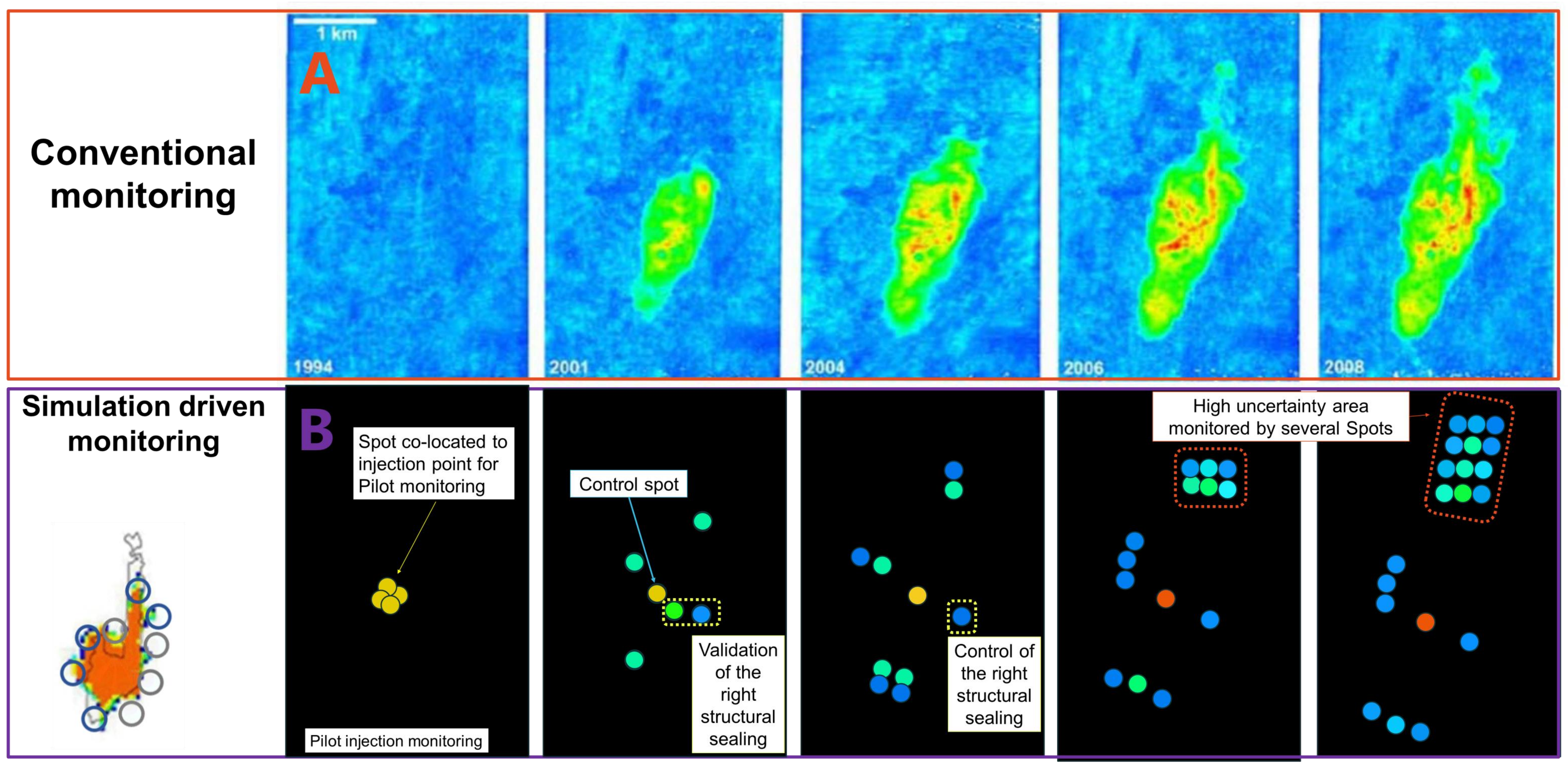
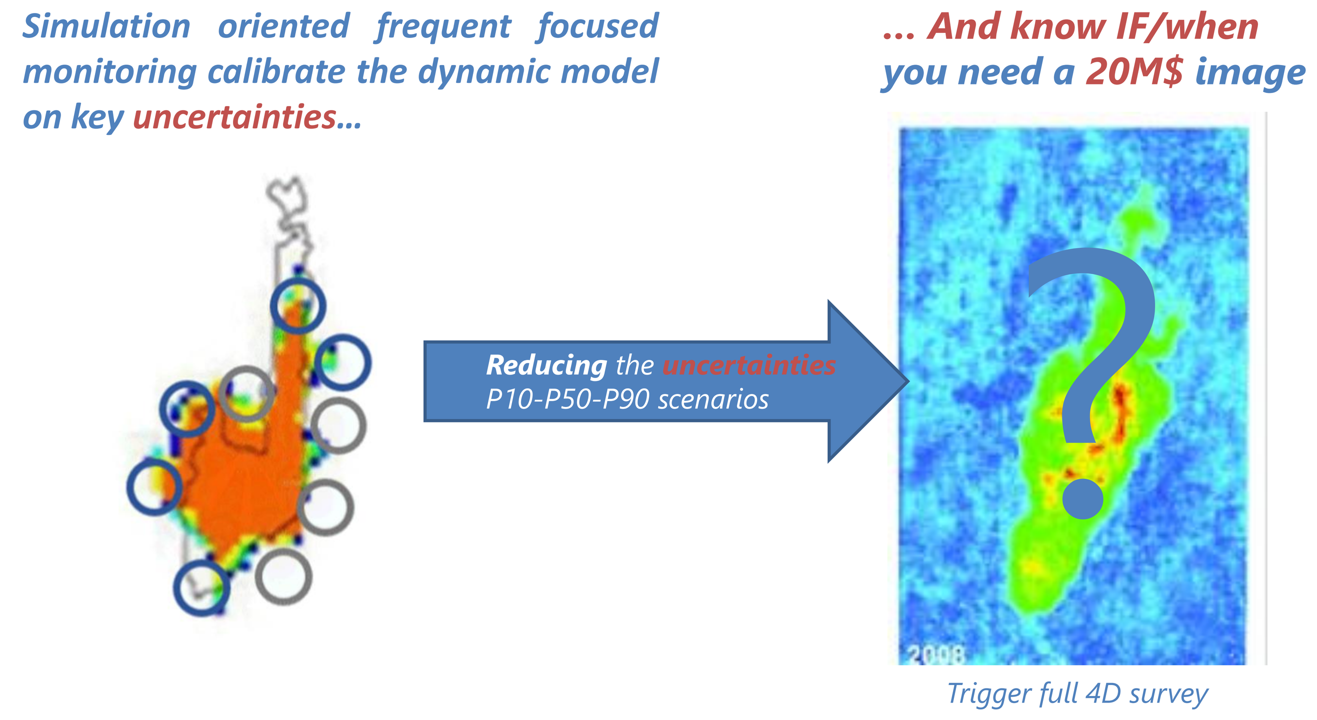


*Figure 1 - Comparison between **conventional** monitoring & **simulation driven monitoring** concept [5]*
A: Time-lapse seismic images showing CO_2 detailed plume evolution B: Modeling of a focused detection on several spots of interest driven by simulations. The average 4D value had been taken to model the focused seismic 4D response.
Thanks to the cost reduction enabled by focused seismic, more frequent detection than full 4D seismic can be done.

If the Spots measurements are validating the same changes than simulations were able to predict, they can be trusted. If not, they must be discarded.

Such method could be used to discard some of the P10-P50-P90 scenarios and reduce drastically dynamic model uncertainty.

If Spots measurement isn't validating any simulation, heavier & more expensive monitoring methods like a **full field 4D seismic could be triggered** to provide enough information to correct and understand models and predictions.



From Chadwick et al. 2015

Figure 2 – Frequent simulation-oriented focused monitoring can provide enough information to know if and when you need to trigger more expensive and heavy monitoring on a CCS project.

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CAPITALIZING ON EXISTING ASSETS

CCS sites use **3D seismic images** to identify the most suitable locations for a safe storage and build their models.

These images worth **millions of investments** and **hours of expertise**.

The amount of data and information is even greater for the CCS sites that are using depleted O&G fields as storage (the Project Greensand for example).

For the simulation driven monitoring, it represents a "**big data**" base that can be mined [6] to identify for each spot of interest the optimal source and receiver location on earth or at sea to detect a reliable change.

Amongst the millions of raw seismic traces available in the 3D dataset, we have designed a methodology to select the optimal trace made of a unique* source and receiver location to detect changes at each spot. Thus, enabling the world lightest active seismic monitoring system. This solution is illustrated on the figure 2 [5] on a real case example.

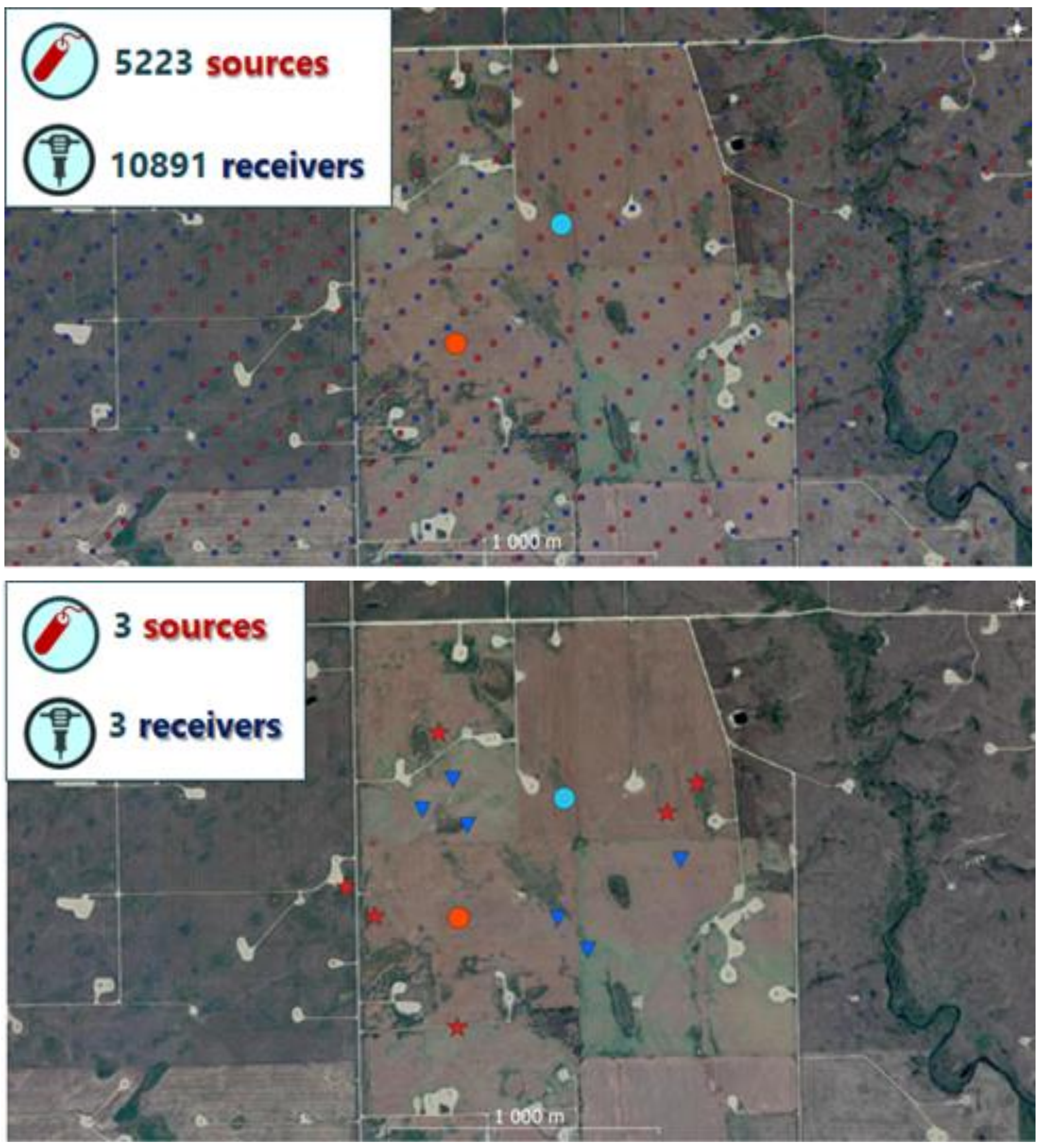

Figure 3 – Optimum selection for a focused detection [5]. **Upper panel** *- Original 3D acquisition design and 3 spots to monitor.* **Lower panel** *– Focused detection final design (1000 time less equipment used on the field).*

**When needed, dedicated source/receiver antennae could be designed instead of a single receiver/source*

Equipment **reduction in the field is massive (%1000),** enabling a **cost and environmentally efficient** acquisition with **much less footprint** and negligeable CO_2 emissions compared to conventional solutions.

In a nutshell, the complexity and massiveness of existing data allows the design of a simple and reliable solution.

SIGNAL PROCESSING & DETECTION

Local provider will install conventional receivers very carefully in order to maximize signal to noise ratio. When needed, several shots will be performed at the same location to increase signal o noise ratio through temporal stack.

Newly acquired traces in this setup have been analyzed using signal processing methods to extract reliable detection information and provide a qualitative "virtual observation well" with capabilities to detect changes above the reservoir for caprock integrity as presented in figure 4.

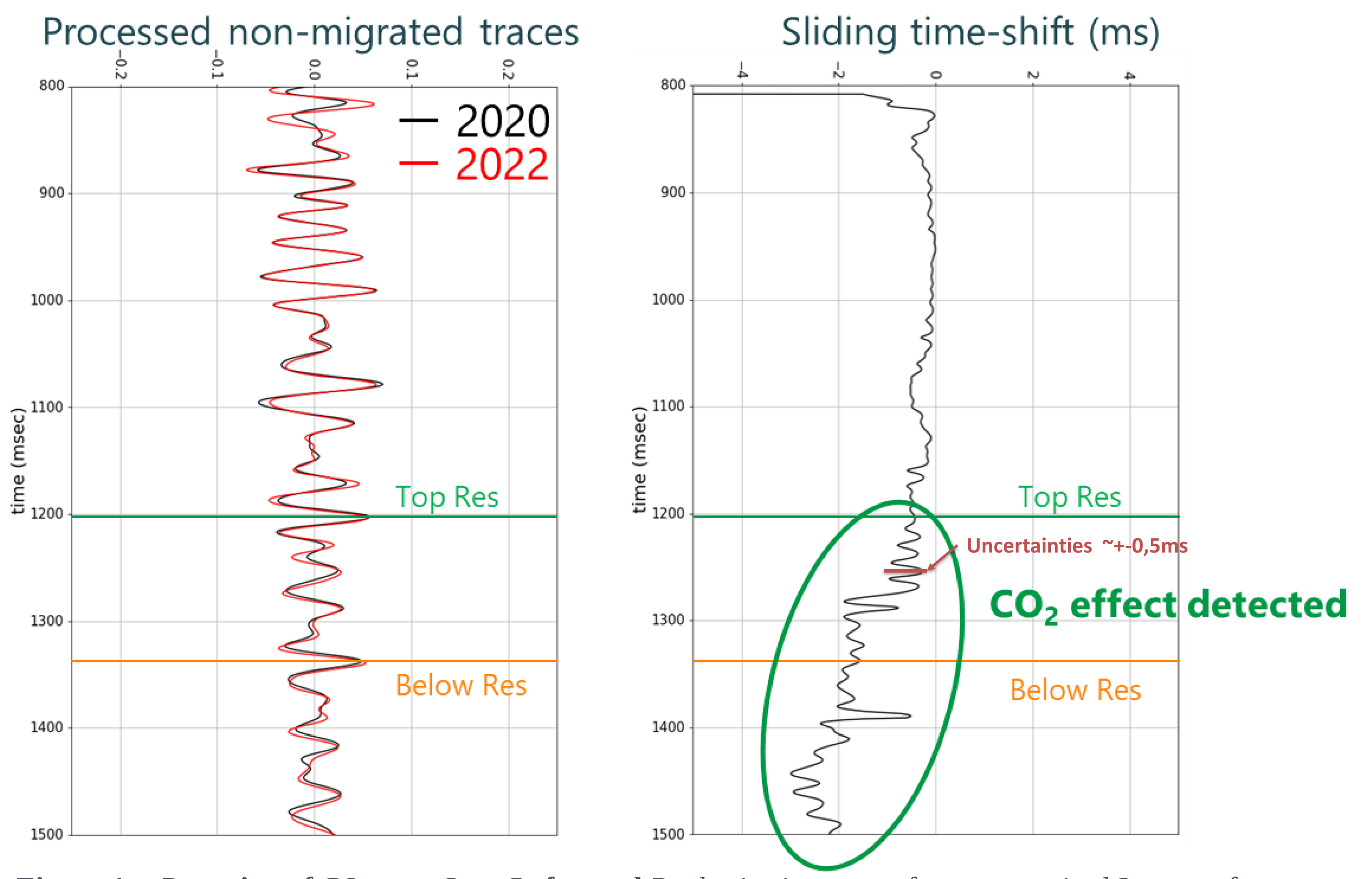

***Figure 4** – **Detection of CO_2 on a Spot.** **Left panel** Real seismic traces of a spot acquired 2 years after baseline (3D exploration seismic) on a EOR CO_2 case. **Right panel** – Sliding time shift (base minus monitor) showing a slowing in velocity indicated by a negative time shift that is compatible with CO_2 arrival*

As show above, the strong seismic response of a CO2 injection [3] makes this "on-off" detection very effective & reliable.

The proposed solution is light and agile enough to modify the location of spots under surveillance during the lifetime of the project and quickly adapt to new uncertainties and/or requirements.

CONCLUSION

Detection using this approach were successfully performed on a gas storage [7], a **Steam injection [6]** and on a CO2 injection site onshore Canada [5].
Offshore the technology is under validation in Norway, and this approach was selected as the seismic monitoring solution of **Project Greensand** where the consortium will invest ~1,3M€ on spots monitoring under an ambitious R&D plan.

Way forward will be to further explore the synergies with other monitoring tools & equipment [8] particularly with **microseismic**.

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