Active-source seismic experiments with DAS for monitoring reservoir rock in underground laboratories

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OSPP

Motivation & Introduction

We use Distributed Acoustic Sensing (DAS) for active (P-wave sparker) monitoring of the P-wave velocity v_p during an ongoing injection into a potential cap-rock for CO_2 storage, in the Mont Terri Rock Laboratory in Jura, Switzerland. This CSE experiment is a extension of the CSD experiment[1] in Mont Terri, 2021.

- We show the workflow and first results for the tomographic baseline survey with DAS.
- Monthly active seismic repeat campaigns are done during a long-term pressure-controlled injection for a time-lapse tomography.
- We expect a negative change in v_p, which has been in the range of 1% in the previous CSD experiment[2].

AIM: Exploring the capabilities of DAS to monitor the stability of a CO_2 – storage cap rock under injection pressure, by means of **repetitive active seismic experiments**.

Survey Geometry

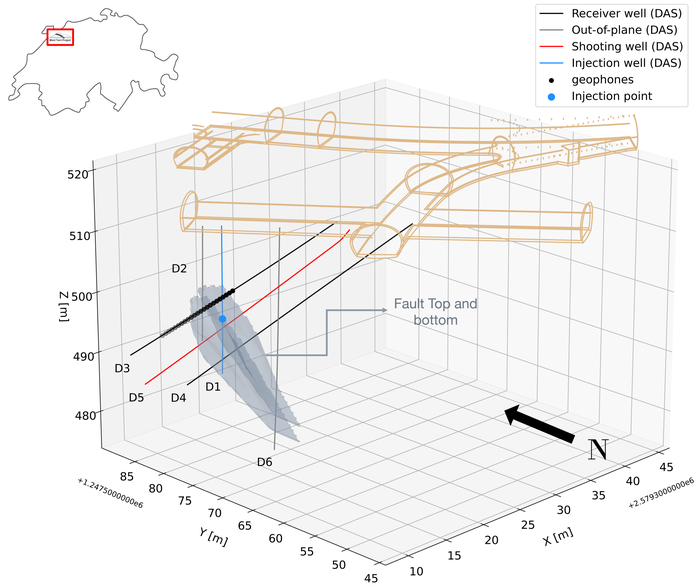


Figure 1: Layout of the Mont Terri underground rock laboratory CSE experiment. Injection in well D1, fibre-optics in all boreholes, with D4 and D3 the time-lapse tomography planes running through the fault zone.

Note: Interrogator is FEBUS A1. Long-term FO recordings with DSS. Other instruments running: ERT.

Parameters	DAS	Geophones	Sparker
Spacing [m]	0.2	0.25	0.5
Gauge length [m]	2	-	-
Sampling [Hz]	10.000	48.000	
Boreholes	1,2,3,4,5,6	3	5
Shots	-	-	10-15

Table 1: Seismic active survey parameters

Survey Workflow

Figure 2: **Step 1 -** Cross-correlate the shot-location fibre to do phase-weighted stacking. We QC the picks by looking at a range of traces. Every 1.0 m we have 15 stacks, and every 0.5 m 10 stacks.

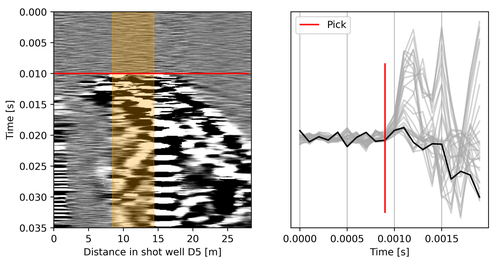


Figure 3: **Step 2 -** Create a stacked and normalised section of the full fibre length. Our special interest is in the planes D5-D3 and D5-D4, that cross the fault zone. Note that each borehole has a down- and upgoing fibre section.

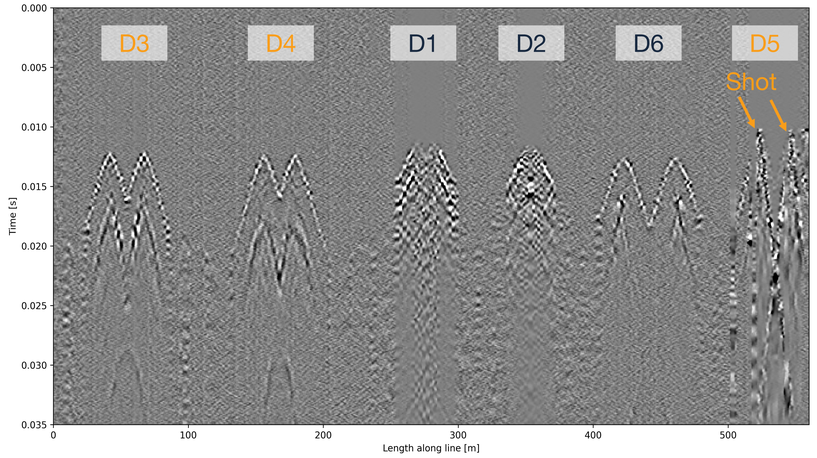
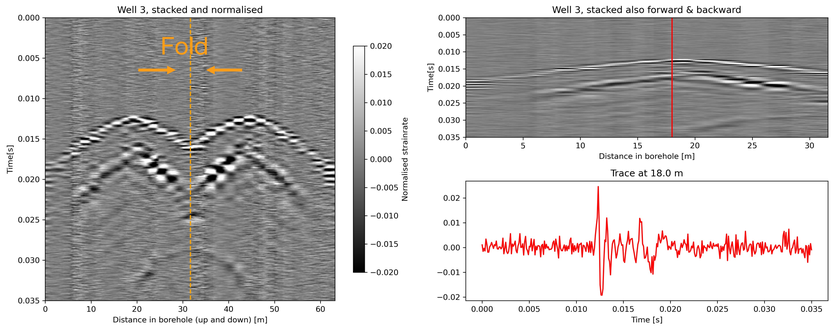


Figure 4: **Step 3 -** Map out the channel locations along the fibre to find borehole start and finish. Stacking is doubled by folding, because each borehole contains a forward and backward fibre. We pick the first arrivals for the P-wave tomography, and in the future the time-lapse tomographies will be done by cross-correlating different surveys.



Note: Picking on individual traces can be challenging. We do cross-correlation picking with a stacked template of the waveform.

First Baseline Results

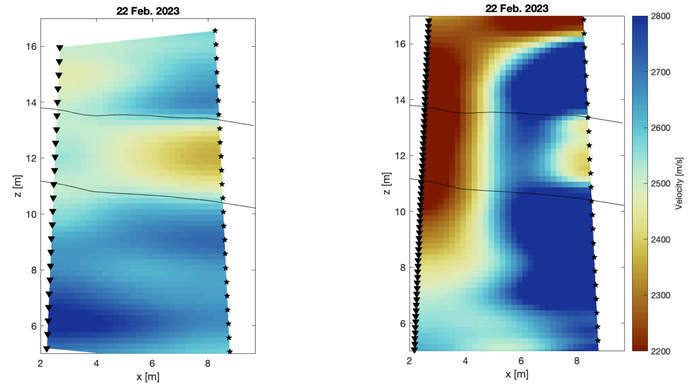
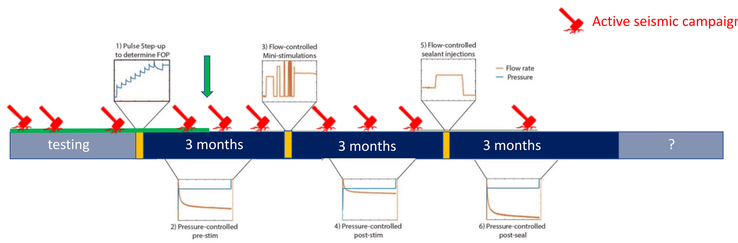


Figure 5: The first v_p tomographic results from a traveltime inversion[3] for the plane D5-D3. DAS has much denser ray coverage and shows a stronger velocity contrast. The fault zone (between black lines) has lower velocities, but the shape of the velocity zones also different. These results are preliminary and show the need for further benchmarking of our DAS routine.

Future Work



- Processing of the monthly datasets into a **time-lapse tomographic image**
- Investigate our **dynamic survey** during stimulation with fibre optics

References & Acknowledgements

1. Zappone, Alba, et al. "Fault sealing and caprock integrity for CO 2 storage: an in situ injection experiment." *Solid Earth* 12.2 (2021)
2. Grab, Melchior, et al. "Fluid pressure monitoring during hydraulic testing in faulted Opalinus Clay using seismic velocity observations." *Geophysics* 87.4 (2022
3. Lanz, Eva, Hansruedi Maurer, and Alan G. Green. "Refraction tomography over a buried waste disposal site." *Geophysics* 63.4 (1998)

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