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Near-surface monitoring of CO2 storage sites: Case study from CaMI FRS

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Summary

No Summary.

Introduction

Distributed Acoustic Sensing (DAS) can play a critical role in monitoring industrial subsurface activities, such as Carbon Capture and Storage (CCS), due to its relative low cost and high spatial resolution. The DigiMon project (https://digimon.norceprosjekt.no/) seeks to incorporate this technology into an early warning system for monitoring CO_2 storage projects. DAS is an optical fibre sensing technology that offers very wide frequency band recordings and near continuous spatial sampling of seismic signals. The sensing element of DAS is simply optical fibre, without any electronic components, which makes it an attractive option for long-term, low maintenance deployments in harsh environments.

A key goal of the project is to assess the suitability of DAS networks for CO_2 injection monitoring using active (refraction and reflection) and passive (i.e., Ambient Noise Interferometry or microseismicity) seismic methods and develop processing workflows for these techniques. The Containment and Monitoring Institute's (CaMI) Field Research Station (FRS), Alberta, Canada, was selected as a field test location. CO_2 has been injected at the site since 2019 at approximately 300m below ground level. The site comprises an injection well and two observation wells and several different seismic monitoring arrays, including: a 5km loop of DAS optical fibre, with a 1.1 km surface trench and two observation wells; an array of surface and borehole geophone nodes; and 6 broadband (BB) seismometers. The site, therefore, provides the opportunity for a dataset containing both active and passive measurements acquired on DAS, geophones, and BB seismometers, presenting a unique chance to test the capabilities of these instruments for CO_2 storage monitoring in the near surface.

Methods and Results

During September 2021, field surveys were conducted using mini-vibroseis and ICIS Propane sources, which were recorded on the DAS, broadband and seismic node networks. These networks operated in continuous recording mode so that passive seismic methods could also be applied to the resulting dataset. During the survey period, 452kg of CO_2 was also injected into the Basal Belly River Formation at a depth of about 285m.

Active seismic measurements are clearly captured on all seismic networks including the DAS array, which comprised of both linear and helically wound cable (HWC) fibre. Although there are differences between the response of the two fibre types, in general we find that the near offset direct waves are poorly recorded on the DAS surface network when compared to the seismic nodes (Figure 1). This is primarily due to nature and directional sensitivity of measurements with the DAS relatively insensitive to direct P-waves which arrive at a near normal incidence angle. In contrast, surface waves appear more prominent on the DAS array, on both the linear and HWC, and can be used to produce near-surface velocity models. The resulting dispersion curves from the vibroseis survey are however bandlimited due to the sweep frequency range, which was 10-150 Hz (Figure 2).

To complement this dataset, passive seismic measurements were processed using the methods outlined in Zhou et al (2022). These show relatively stable surface wave responses can be retrieved from hourly measurement of ambient noise interferometry at frequencies from 1 to 10 Hz. Velocity variations down to 0.5% can be monitored using the passive dataset for temporal sampling down to 1 hour. There is a good agreement between the dispersion curves produced from active and passive surveys. When combined with the active seismic data, these high-frequency surface wave provide velocity measurements which are mostly sensitive to near-surface (10s metre deep).

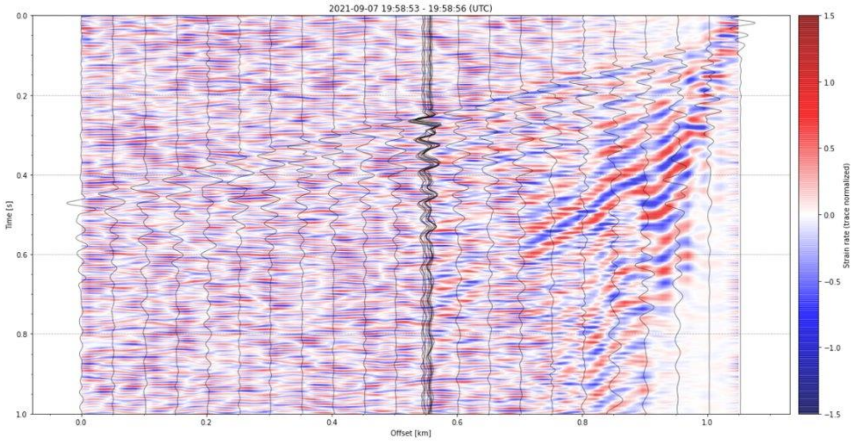

Figure 1: *Vibroseis shot recorded on helically wound fibre (coloured background) and vertical component seismic nodes (black traces).*

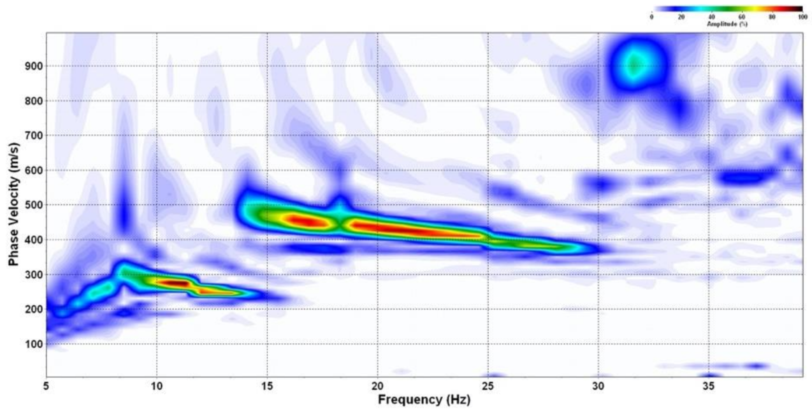

Figure 2*: Dispersion curve created from the active vibroseis survey recorded on the DAS array showing high quality fundamental and higher modes.*

Conclusions

DAS shows good promise for characterising the shallow subsurface using surface waves studies. Active and passive seismic surveys provide complementary methods for imaging the dispersive properties of surface waves, with passive methods also offering the potential to continuously monitor velocity variations and CO_2 movement. The results indicate that near-surface velocity variations can be determined from DAS data with high-resolution, providing a potentially useful approach for monitoring CO_2 leakages at shallow depths.

Acknowledgements

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