Australia-wide downhole DAS array for observational seismology

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SUMMARY

Downhole seismic acquired with distributed acoustic sensors (DAS) provides a unique opportunity to record genuinely broadband data with a frequency range varying from sub-milli-Hertz to several kilo-Hertz. As such, downhole DAS is used to detect and track local microearthquakes caused by fluid injection into a reservoir, analyse natural seismicity or look at lower frequency signals like oceanic microseisms. In most cases, the published studies deal with local single-well installations or multi-well installations with the wells located within first kilometres of each other.
In the last two years (2020-2022) we acquired continuous DAS data in three different locations across Australia, namely Otway International Test Centre, Victoria, NGL training well at Curtin Campus in Perth and Harvey-3 well, located 120 km south of Perth in Western Australia.
In this presentation, we discuss the outcomes of this trial.

Key words: DAS, VSP, borehole seismic

INTRODUCTION

Distributed acoustic sensing is a powerful technology allowing to convert optical fibres into pretty versatile seismic sensors (Parker et al. 2014), which can be used for various applications, including active and passive seismic imaging and monitoring (Daley et al. 2013) as well as various seismological applications (Nishimura et al. 2021, Glubokovskikh et al. 2021, Biondi et al. 2017). While multiple research groups have successfully applied DAS technology for earthquake monitoring using independent local receiver arrays, analysis of regional or large seismic events would benefit from a more global approach, involving multiple arrays with concurrent data acquisition. This can either be achieved by sharing legacy data (Spica et al. 2023) or by trying to promote concurrent acquisition performed by multiple groups from various institutions (Wüstefeld 2022).
Australia has several permanent DAS receiver arrays deployed across the country for different projects. These, among others, include CO2CRC Otway site, which has multiple downhole and near-surface receiver arrays designed and used for the monitoring of CO2 geosequestration experiments (Pevzner et al. 2021), Curtin NGL well facility (Shulakova et al. 2022) designed for both research and training purposes and an abandoned Harvey-3 well, which was converted into a permanent receiver array during the P&A operation (Sidenko et al. 2022). Starting from 2016 (for Otway), these facilities were used to record continuous data for extended periods of time. From mid-2020, DAS data was virtually continuously acquired at Otway. NGL training well was used to record data over the same period of time with some gaps. Harvey-3 data acquisition trial lasted for 45 days in 2021-2022.
In this presentation, we discuss the analysis and provide preliminary outcomes of this concurrent data acquisition.

DATA ACQUISITION AND AVAILABILITY

At Otway, we used five ~1.5 km deep wells instrumented with DAS cables behind the casing and ~1 km long helically would cable deployed at 1 m depth; more than 830 days of data was acquired. The data was acquired using three iDASv3 (Silixa) units paired with engineered fibre.
NGL training well DAS facility comprises of 900 m deep well with fibre optic cable cemented behind the casing and ~2.5 km of dark fibre in communication cables running around the campus. More than 300 days of data are available for this location. We use iDASv2 and conventional single-mode fibre.
Harvey-3 is an abandoned well drilled as a part of the South West CCS Hub appraisal and characterisation program. Fibre optic cable is installed during P&A operations inside of the sacrificial tubing used to cement the well,

transforming the meant-to-be-lost asset into a permanent sensor array. Over a month of passive DAS recording is available which was acquired with iDASv2 unit.

In all cases, we use a 10 m gauge length, and 16 kHz pulse repetition frequency down sampled to 1 kHz sampling rate. Data availability for these three sites is summarised in figure 1.

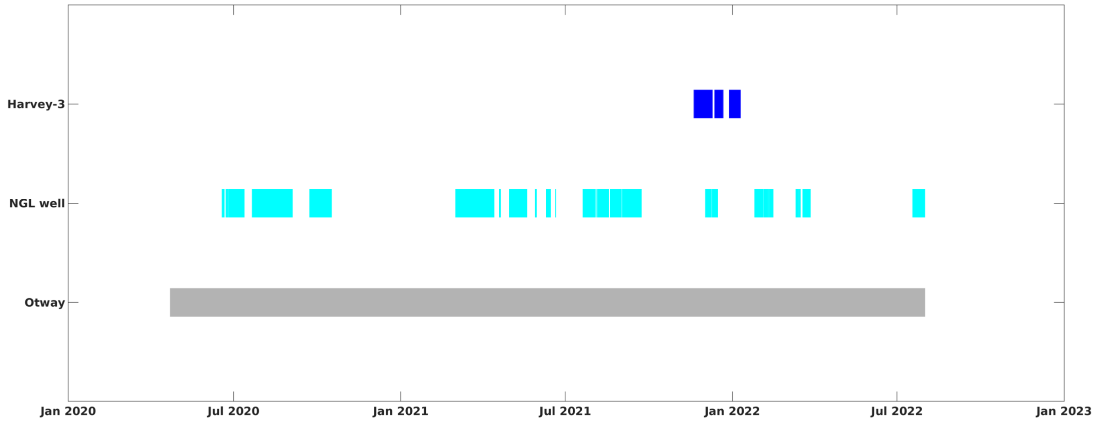

Figure 1. DAS data availability for different sites.

PRELIMINARY DATA ANALYSIS

The goals of the preliminary data analysis are the detection and identification of various seismic events on the record, including earthquakes and mine site blasts, the study of the spectral composition of the ambient wavefield and the evaluation of the relative performance and sensitivity of different cables and ways of deployment.

In order to detect seismic events on the seismograms, we routinely utilise a semblance-based algorithm tuned to the travel time curves of the diving waves of regional earthquakes. Detected earthquakes are used to develop methods for monitoring the changes in elastic properties along the well (Shashkin et al. 2022, Pevzner et al. 2020). While several hundred events were detected for each location, most of those are small-scale regional earthquakes, which can't be detected from other sites. However, several larger (including teleseismic) events, can be seen across all three locations. An example of a Welch periodogram for such an earthquake record is provided in figure 2. While the earthquake record looks very similar to all three periodograms, the ambient noise composition for each site is different. NGL well is the only site located in the urban environment; as such, it has a significant contribution of a relatively high-frequency noise related to vehicle traffic. While all three records have a significant contribution of oceanic microseisms, the data from Otway has it more pronounced. It can be both related to the closer proximity of the Otway site to the ocean or to the difference in the regional weather (and the wave climate) between the areas.

In general, spectral analysis were performed for all the locations using Welch method using each depth receiver location. This allowed to reveal vertical and temporal structure of the wavefield.

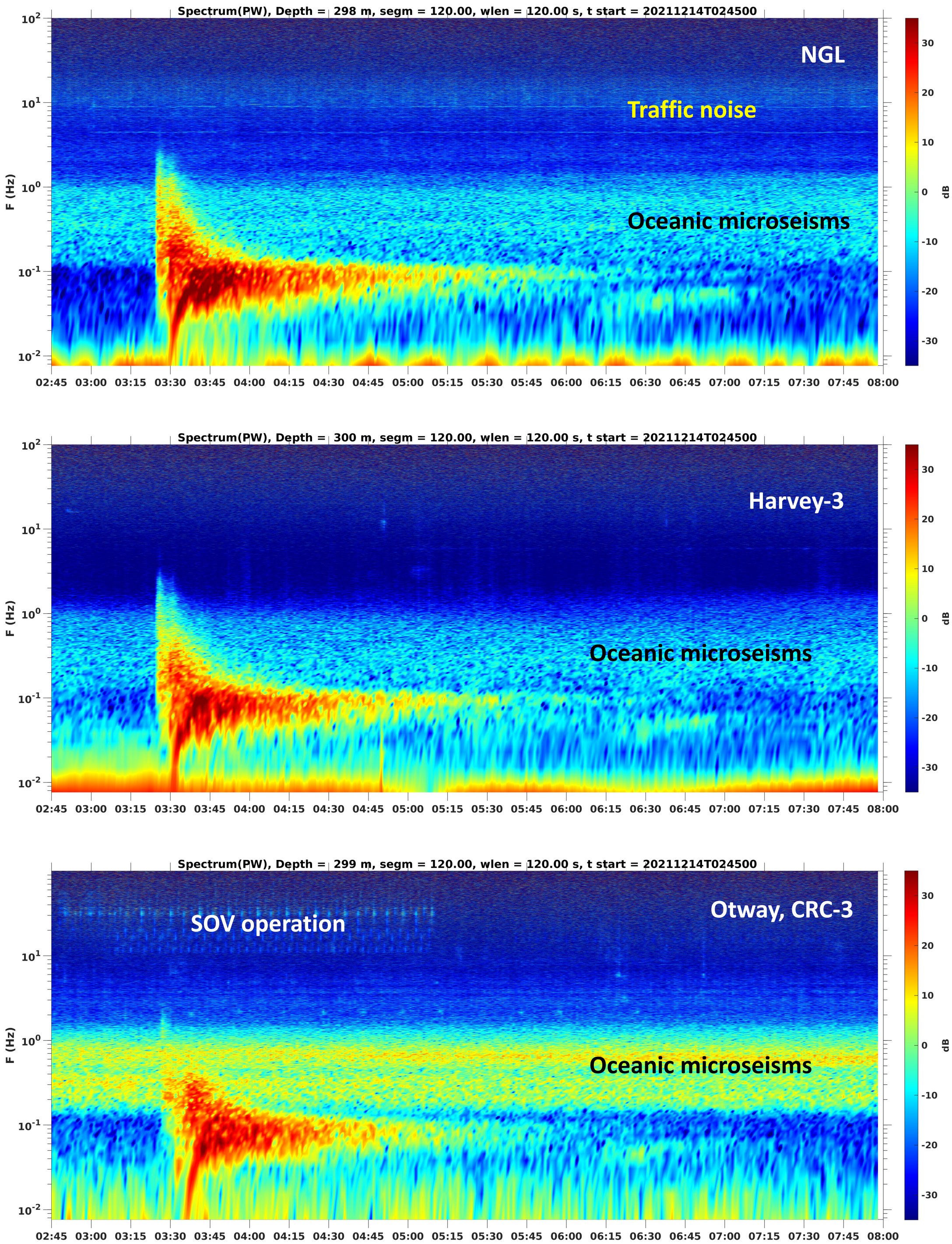

Figure 2. Welch periodogram for magnitude 7.2 earthquake from Flores Sea (2.8 thousand km from NGL well), 21/12/14.

CONCLUSIONS

Observational seismology deals with the events and processes which require global data acquisition and analysis, ideally including multiple facilities spread around the globe. Australia has several permanent downhole DAS research facilities spread across the continent. While the facilities were built for different projects and purposes, continuous seismic data were acquired in all of those other of the last two years with significant overlap between the locations in the recording periods. The data contains shared records of regional (for the wells within a state) and teleseismic events and other components of the ambient wavefield. While the main purpose of passive data analysis in all the projects was predominantly oriented to the monitoring of the local (near-well) variations of the elastic properties, extra value can be obtained from the joined analysis.

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