Acoustic Velocity Signatures of Airguns - Preliminary Results

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ABSTRACT

Arrays of airguns are routinely used as sound sources for seismic surveys of the seafloor substrate. While their acoustic pressure signature is well understood, less is known about the acoustic velocity signature of airgun arrays. By gaining a better understanding of airgun acoustic velocity signatures, the impact they have on marine fauna that rely on acoustic velocity to 'hear' can be more accurately assessed. This presentation outlines a data set gathered by CMST in order to characterise airgun acoustic velocity signatures, and presents preliminary results of the analysis conducted to date.

1 INTRODUCTION

Many species of fish sense underwater sound as motion of the water disturbed by the passing acoustic energy wave, as well as (or instead of) the accompanying pressure fluctuation that most land-animals' hear (Ladich, 2014). In order to determine the impact of sound-generating activities on these species, it is therefore important to understand the acoustic particle velocity signature of the sound source as well as the more common acoustic pressure signature.

One activity that generates underwater sound is airgun seismic surveying, used extensively for oil and gas exploration. Airguns are towed behind a ship, suddenly releasing a reservoir of pressurised air to generate an impulsive acoustic wave (Dragoset, 2000). This wave travels through the water column and penetrates the seafloor below, reflecting off any interface between differing media that the wave propagates through. These reflections are captured by acoustic sensors and analysed to infer details of the seafloor substrate.

The acoustic pressure signature of airguns is well known (de Graaf, 2014), but the acoustic particle velocity signature is less understood. With the recent rapid expansion of underwater acoustic particle velocity sensors into commercial and research domains, it is now possible to gain this understanding. In 2018, staff at CMST collected a series of acoustic pressure and particle velocity data sets near the coastal town of Broome, Western Australian for this purpose. The data and its analysis are the focus of this paper.

2 DATA COLLECTION

Five data sets were collected across three distinct sites WSW of Broome, Western Australia between the 2nd and 11th April, 2018. The sites are named "Pearl", "GA" and "Fish" and the data sets "Pearl-1", "Pearl-2", "GA", "Fish-1" and "Fish-2". The locations are shown in figures 1-3, overlaid on bathymetry sourced from the Australian Bathymetry and Topography Grid, 2009 (for brevity, only the Fish site is shown in detail).

At each site a variety of hydrophones, geophones and acoustic vector sensors (AVS) were deployed. The hydrophones and geophones were recorded on CMST noise loggers. The two AVS deployed were Geospectrum M20s with tri-axial velocity sensors, an omni-directional pressure sensor, and a tri-axial magnetometer for orientation, all collected on an AMAR digital recorder. Sensor calibration was achieved through a combination of injected white-noise (for the voltage and digitisation gains) and manufacturer specifications (for transducer sensitivity).

At each site, after deploying the sensors, a 2.46 l (150 in^3) airgun was deployed at a depth of 6 m and triggered roughly every 40 s, resulting in ~100 - 200 airgun signals being captured in each data set.

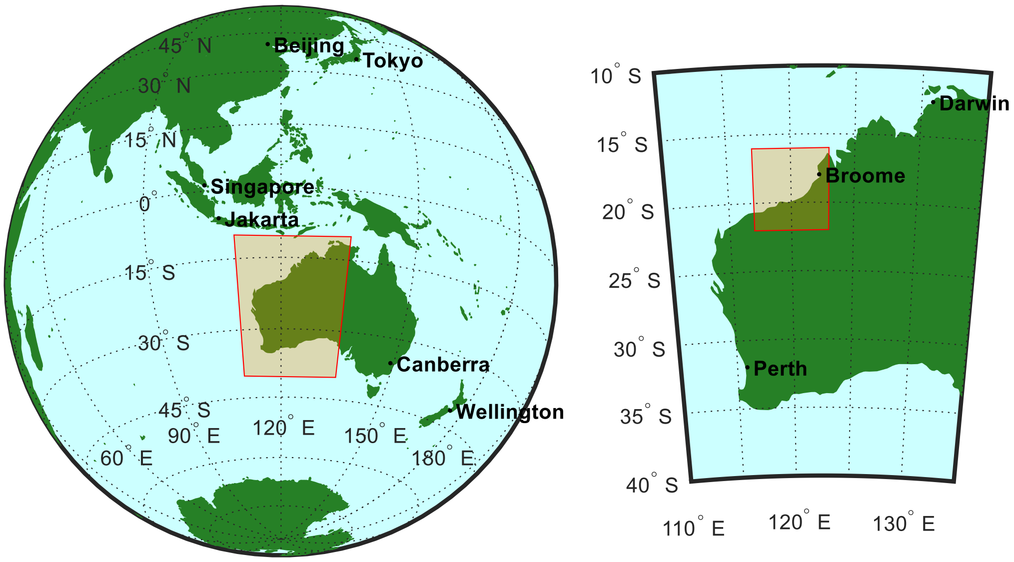

Figure 1: Geographic location of the data collection sites near Broome, Western Australia.

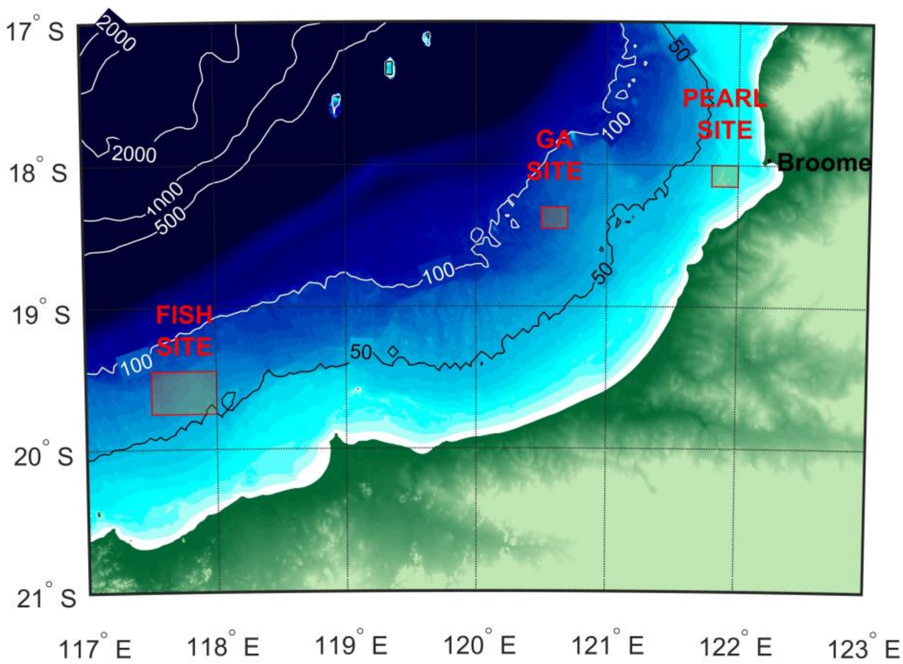

Figure 2: Bathymetry (in metres) surrounding the data collection sites “Pearl”, “GA” and “Fish”.

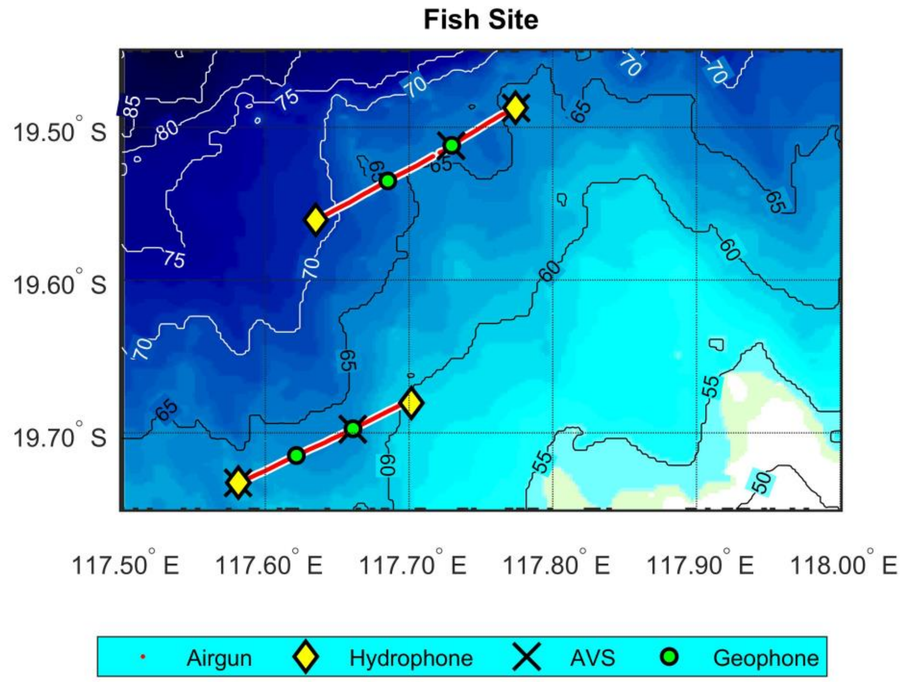

Figure 3: Bathymetry (in metres), sensor deployment and airgun shot locations for the Fish-1 (upper trace) and Fish-2 (lower trace) data sets

3 DATA ANALYSIS

Unique patterns in the airgun trigger timing were used to roughly synchronise the airgun signal arrival at the disparate sensors, once propagation delays had been accounted for. Finer alignment of the signal arrival required manual adjustment, though this was not straightforward. At close ranges, alignment based on the first exceedance of a pressure threshold is a reasonable assumption, but can be complicated by strong headwaves (Choi, 2006) and saturated sensors. The multi-path arrival structure of consecutive airgun signals was found to provide a reliable means to fine-tune the alignment of the data to within several samples.

An example of the aligned data is shown in figure 4. Each received airgun signal is stacked in the vertical axis against the range at which it was produced, with ranges prior to the closest point of approach delineated as negative. Colour corresponds to instantaneous pressure, normalised so that each row has a maximum amplitude of unity. Time on the horizontal axis is relative to the through-water arrival time of each airgun shot at the sensor.

Structure evident prior to 0 s indicates the presence of headwaves. These occur when there is a layer beneath the seafloor that supports acoustic propagation faster than that in water. Sound enters this layer at the critical angle, overtakes the through-water wave, then exits the layer at the critical angle and reaches the sensor first. A simple geometric model of this phenomenon fitted to the data provides an inference of this significant structure below the seafloor.

The structure after 0 s is reverberation and multipath arrivals. Due to the shallow water and strong signals, the sound bounces off the sea surface and seafloor many times resulting in longer and longer propagation paths. Once more, fitting a simple geometric model of this scenario to the data reveals further detail of the environment such as airgun and water depth.

Further structure evident after the through-water arrival suggests the presence of slower moving waves. It is possible that Scholte waves (Dong, 2013), travelling along the seafloor boundary, are giving rise to this behavior.

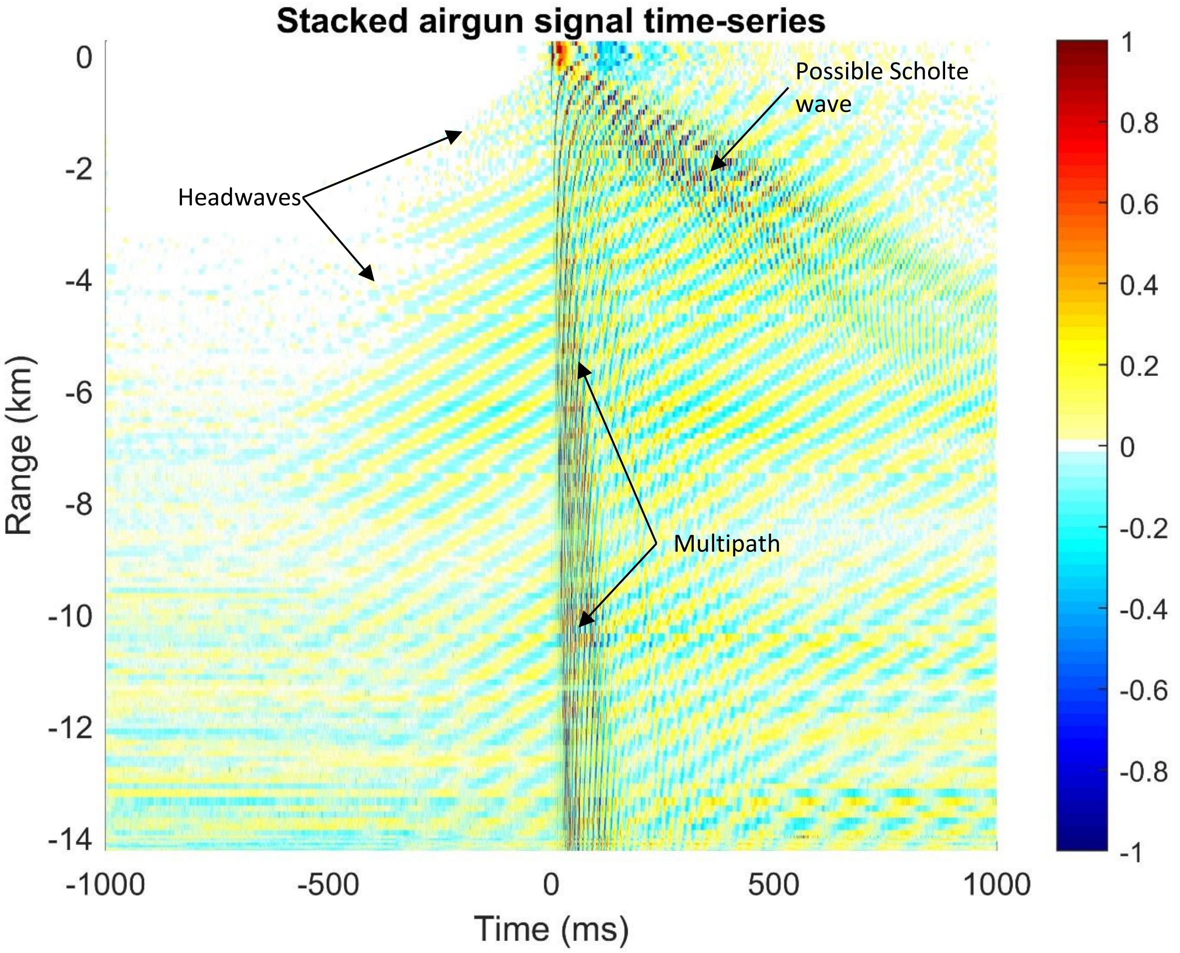

Figure 4: Example of a stacked normalised pressure time-series of airgun shots aligned by arrival time.

4 FURTHER WORK

This paper presents a work in progress that will be updated with the most current findings presented during the conference. The collected particle velocity data are currently being analysed to produce measurements of the airgun acoustic velocity signature, and combined with pressure measurements to estimate intensity levels.

This work forms part of the primary author's PhD thesis aimed at improving airgun acoustic velocity signature models through this comparison with data measured at-sea. Geo-acoustic inversion techniques will need to be applied to estimate the acoustic environment's impact on these measurements in order to facilitate comparison with existing and new airgun acoustic velocity signature models.

5 SUMMARY

A series of data sets has been collected for the purpose of measuring the acoustic velocity signature of a seismic airgun. The analysis to date shows that the trial has successfully gathered data suitable for this purpose, and is of sufficiently high quality to determine important geo-acoustic properties of the environment at the location. Work is ongoing to extract the airgun velocity signature from the data, which will be presented at the conference.

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