Submission code: 6JPWBRNDYK

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New opportunities from old cables - delivering the value of surface DAS measurements

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Abstract

Distributed acoustic sensing (DAS) is an emerging measurement technique for geophysical applications. In 2022 during the acquisition of a conventional 3D marine towed-streamer survey, a 2D line, closely following a fibre optic communication cable to a production platform offshore Norway, was also acquired. In this study, we show tests that prove potential uses of surface-DAS measurements for low-cost monitoring, including PP and PS imaging and passive seismic for subsurface characterization.

Introduction

Distributed acoustic sensing (DAS) is an emerging measurement technique for geophysical applications. Sayed et al. (2023) showed that 3D DAS vertical seismic profile (VSP) surveys have superior resolution when compared to surface seismic even in producing wells. Busanello et al. (2023) showed that DAS cables deployed onshore can be used for high-resolution near-surface characterization. In 2022 during the acquisition of a conventional 3D marine towed-streamer (TS) survey, a 2D line, closely following a fibre optic communication cable to a production platform offshore Norway, was also acquired. We evaluated the potential of using a pre-existing communication cable deployed on the seabed for surface seismic imaging and compared surface DAS (S-DAS) and conventional TS data. In this study, we show tests that prove potential uses of S-DAS measurements for low-cost monitoring, including PP and PS imaging and passive seismic for subsurface characterization.

Method

Bachrach et al. (2023) showed that S-DAS data collected using a communication cable pose new challenges and opportunities when compared to conventional surface seismic data. The S-DAS is a single component horizontal (axial) sensor that is sensitive to body waves and surface wave energy. The strong axial response is sensitive to the horizontal strain that is rich in converted modes at the mid-angle ranges. The PP arrivals are typically weak, especially for sub-vertical incidence angles, as their amplitude is damped by a cosine square factor (Sayed, 2020). Shallow water and strong axial sensor response meant denoise, wavefield separation, and demultiple were specific challenges that required addressing during the processing of these S-DAS data.

Heavy noise contamination on the raw S-DAS recordings poses a challenge to signal processing. The input data are contaminated by the slow velocity dipping noise (Scholte waves) as well as by scattered noise and higher velocity linear noise. To address these noise patterns, we applied attenuation of coherent noise in both shot and receiver domains. The data then went through a gauge-length correction and strain rate to velocity domain transformation (Sayed et al., 2020) prior to the designature and deghosting phase.

To obtain both PP and PS images from the same axial sensor, a wavefield separation step is needed. We used a workflow consisting of curvelet transforms and dip filters in combination with velocity discrimination between PP and PS.

In general, S-DAS is less sensitive to near-vertical incidence wavefield at near-offsets. Therefore, modelling of water-layer multiples using data-driven methods like 3D surface-related multiple elimination (SRME) is challenging. We addressed the free-surface multiples, using model-based wavefield extrapolation techniques like deterministic water-layer demultiple (Moore et.al 2006).

PP and PS velocity model building

We performed a velocity-model-building exercise to constrain P and S velocities and produce complementary PP and PS images. We deployed a workflow that exploits both guided-wave and early-arrival full-waveform inversion (FWI) (Jiao et al., 2015), followed by PP-PS tomography (Mathewson et al., 2013) to update both compressional and shear velocity fields in a data-driven fashion. The availability of early arrivals with long offset in the S-DAS dataset enables us to produce deeper velocity updates. Including the guided waves in the inversion fills the illumination gap for the P-waves near angles. Elastic FWI achieves more accurate near-seafloor updates due to the improved guided-waves modelling. Further compressional velocity model updates along with shear velocity model updates come with the application of joint PP-PS tomography.
Figure 1 shows the final images from TS and S-DAS processing performed in this study. We observe that careful processing of S-DAS data can generate interpretable PP as well as PS images from a single record, thus bringing a potential benefit with a minimal acquisition and processing cost when compared to the conventional TS survey approach enabling only the generation of PP products.

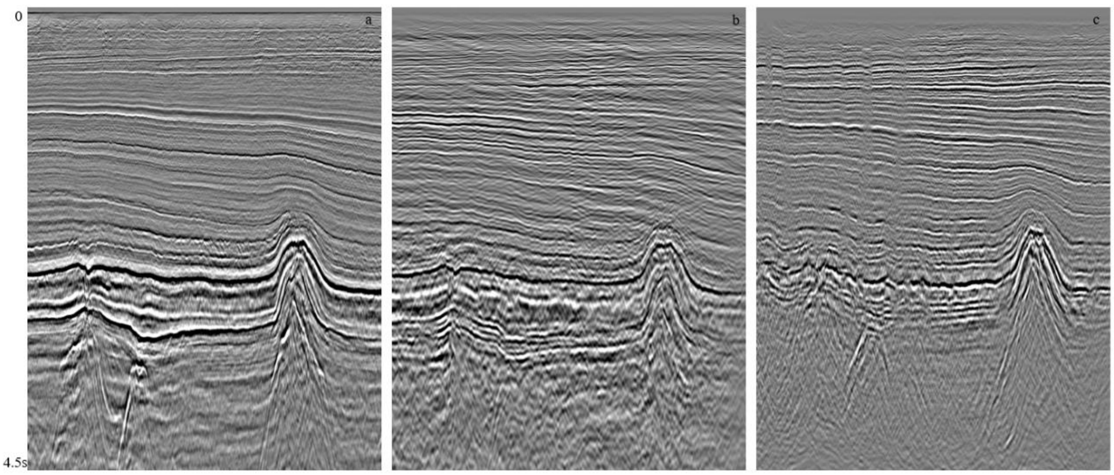

Figure 1 *Final migrated images of: a) TS data, b) PP S-DAS signal, c) PS S-DAS signal*.

Passive seismic

Approximately 18 days of passive data were acquired in the same acquisition campaign. Virtual shot records were constructed using interferometry. We then modeled, analyzed, and inverted Scholte waves from active and passive S-DAS measurements. Analysis included computing dispersion spectrum by combining active and passive recordings. We observed that for frequencies below 3 Hz, the fundamental mode and the first mode are mainly supported by the passive recordings, while active source data support the analysis above 3 Hz for which we can clearly identify and track higher order modes. We could then invert the spectrum for shear wave velocities (as shown in Figure 2). Active and passive recordings on S-DAS enables the correct identification of modes and provides the broadband, multimodal data that the synthetic analysis have shown to enable detection of shear-wave velocity perturbations around 1 km depth.

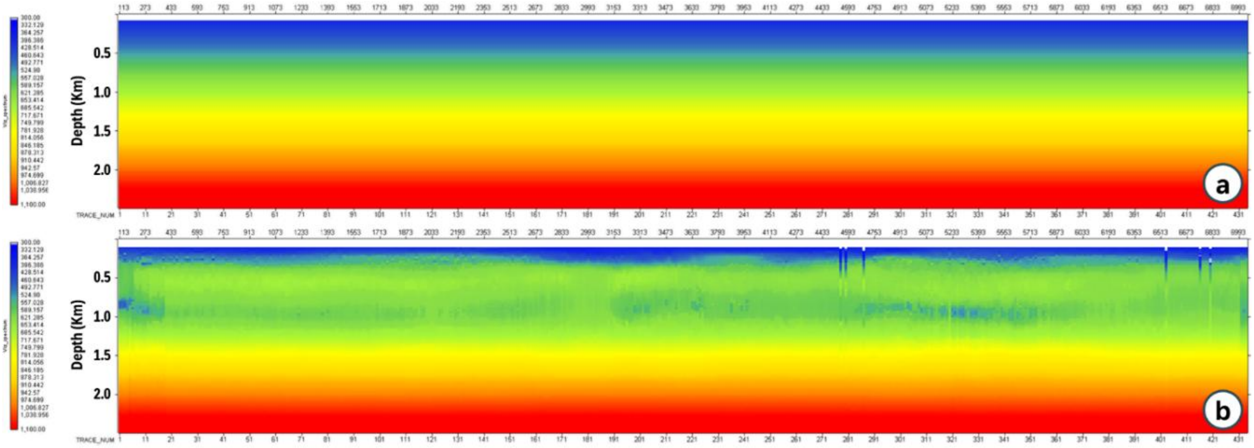

***Figure 2**. (a) Starting S-velocity model used for the inversion of fundamental and first mode of Scholte waves obtained from passive data. (b) S-velocity model resulting from multimode Scholte wave inversion. The horizontal extension of the section is approximately 45 km.*

Conclusions

We presented a case study that demonstrates that S-DAS provides complementary PP and PS images of the subsurface. It can be used to derive robust PP and PS velocity models. Passive seismic recordings on S-DAS can be used to analyze and invert for surface waves, which facilitate subsurface characterization. The opportunities that S-DAS measurements provide can be extended to low-cost monitoring solutions that facilitate the energy transition.

Acknowledgments

We thank Aker BP and partners for permission to publish the examples from this analysis. We thank SLB for permission to publish this case-study. We thank our colleagues Ali Sayed, Ran Bachrach, Dimitri Skorinski, Simone Re, Olivia Lewis, Pilar Di Martino and Andrea Murineddu for fruitful discussions and feedback on this study.

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