Shallow crustal imaging with distributed acoustic sensing (DAS) offshore central Chile

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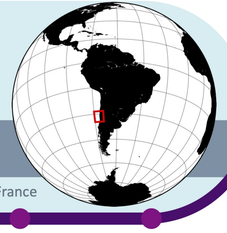
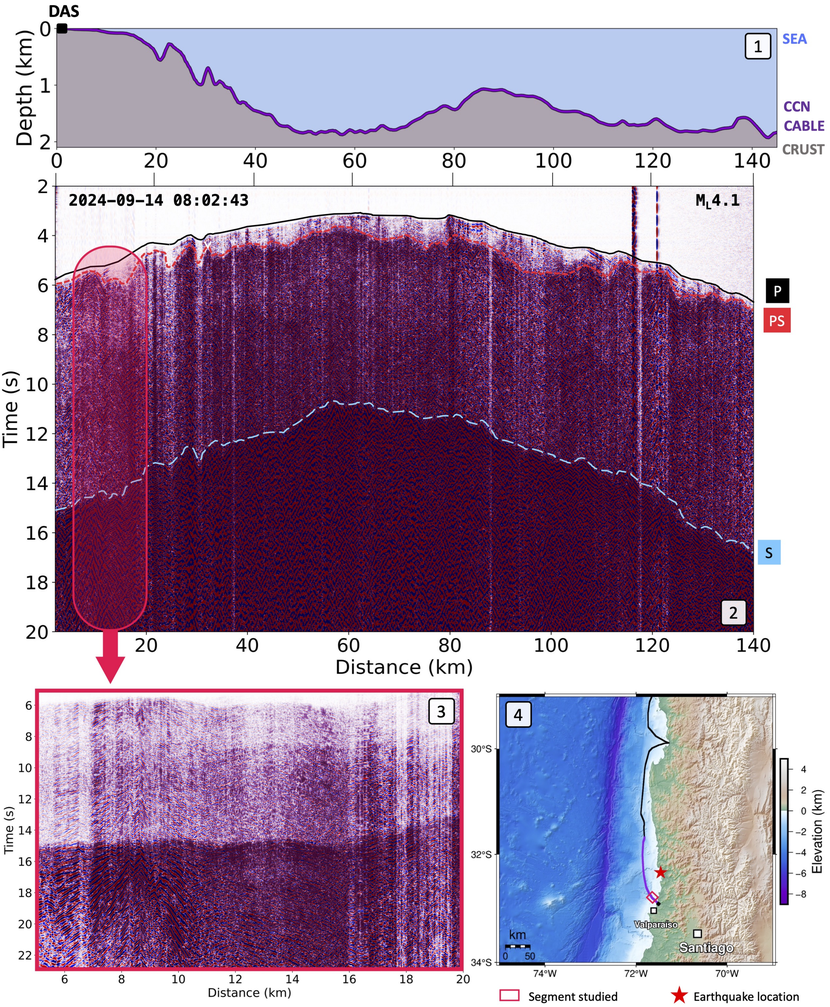


CONTEXT

Distributed acoustic sensing (**DAS**) is becoming a standard solution for ocean-bottom **seismological acquisition** by providing a dense and long-distance measurement of ground deformation along **offshore submarine fiber-optic cables**. In the context of an offshore deployment in central Chile, fiber-optic cables provide **real-time seismic data** dominated by scattered and converted phases[1]. In a previous study, we used such waves to determine both the velocity and thickness of the shallow sedimentary layer under the fiber using surface waves and converted P-waves[2].

This work focuses on **body-to-surface wave scattering** to image lateral discontinuities such as **fault zones** and **basins** which are crucial for understanding tectonic processes and assessing earthquake hazard.

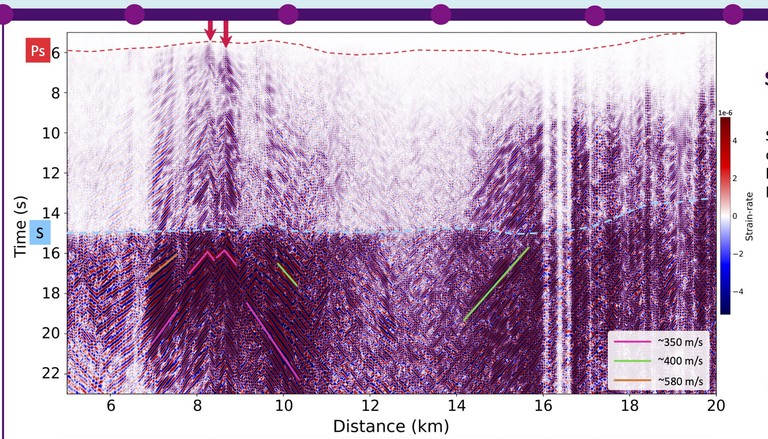
We report here on the analysis of subsurface structures and lateral discontinuities using DAS data.

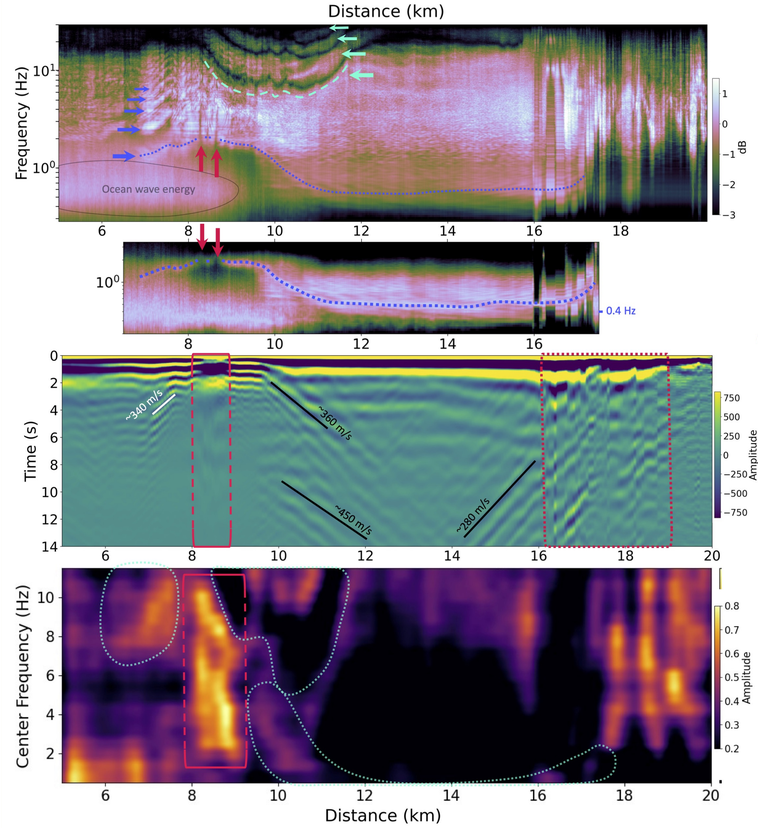


DATABASE

Focus on a **15 km segment** along the *CCN* cable, a 150 km fiber-optic cable starting from the coast, near Valparaíso, and going North parallel to the subduction. DAS measurements were acquired recording **strain rate** with a time sampling of 62.5 Hz, a gauge length set to 30.6 m and a corresponding channel spacing of 15.3 m. We used **Xdas** to process the data[3].

1. Bathymetry of the *CCN* cable. The cable is trenched from the coast line to ~16 km.
2. Earthquake detected by DAS where 3 wave arrivals are visible: direct P wave, Ps wave (converted P wave into an S wave at a sediment interface[4]), and direct S wave. Data are high pass filtered at 2 Hz.
3. Close up of the earthquake between 5 and 20 km. Some surface scattered waves are visible between 7 and 10 km.
4. Map of central Chile with the *CCN* cable in purple. The segment studied is located on the continental shelf.





SCATTERED WAVEFIELD

What is it ?

Scattered waves are isolated by filtering data below 450 m/s, suppressing most contributions from non-scattered waves (e.g., direct body waves)[5]. They result from body wave conversion into Scholte waves at subsurface heterogeneities (e.g., faults, basins).

Observations

- Chevron-like patterns characteristic of seafloor faults, which act as point scatterers[5]
- Coherent scattered surface waves with low-apparent velocity, produced by strong lateral impedance contrasts (e.g., basin edges)

POWER SPECTRAL DENSITY (PSD)

What is it ?

Stacked PSDs from 20 earthquakes (5-min time window), highlighting frequency-dependent resonances and basin amplification effects.

Observations

8-12 km → Resonances at high frequency (f_0 > 8 Hz) = very shallow low velocity structure

7-17 km → Resonances at lower frequency (f_0 = 0.4 Hz) = deeper low velocity structures

Lateral increase of the frequency of the higher modes = basin edge effects

High-amplitude of the higher modes (up to 30 Hz) = very shallow basin

Normalized PSD on ambient noise

7-8 km → Fundamental mode of a deep structure (f_0 = 1.5 Hz)

9-17 km → Fundamental mode of a deep structure (f_0 = 0.4 Hz)

AMBIENT NOISE AUTO-CORRELATION (60 days)

What is it ?

Zero-offset correlations of ambient noise is used to identify strong impedance structures and local amplification of seismic waves beneath the cable[6].

Observations

- High frequency reflected surface waves (340 m/s) = shallow basin edge
- Lower frequency reflected surface waves = deeper sedimentary basins

10-16 km → Strong coherent wavefield

- Local discontinuities that damps seismic waves (e.g., fault zones)
- Cable not trenched zone, with varying coupling with the ground

ENERGY PROFILE OF SCATTERED WAVES

What is it ?

Local back-projection method is used to locate point scatterers by identifying where scattered energy from body-to-surface wave conversions come from[5].

Observations

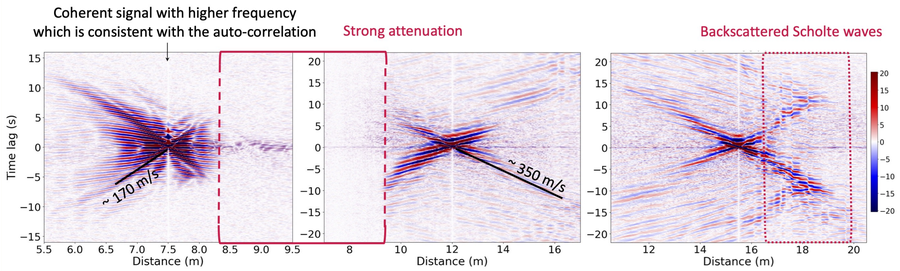
- Scatter point reflecting from 2 to 10 Hz = fault zone
- Effect of the shallow and deeper basins

AMBIENT NOISE CROSS-CORRELATION

What is it ?

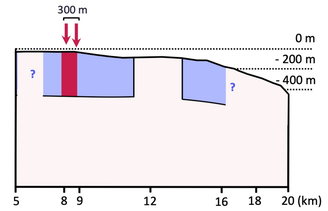
Cross-correlation of ambient noise is used to retrieve seismic wave propagation between stations, allowing analysis of dispersion and local reflections.

Observations

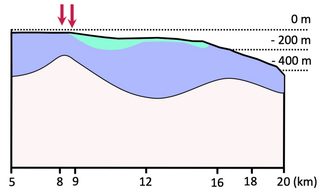


INTERPRETATIONS

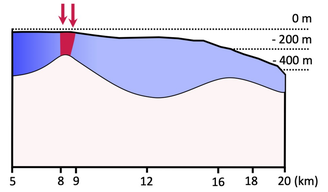
MODEL 1: From scattered waves



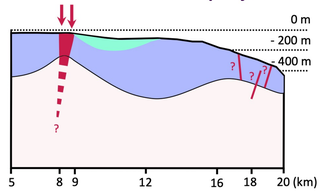
MODEL 2: From PSD



MODEL 3: From auto-correlation



MODEL 4: From back-projection



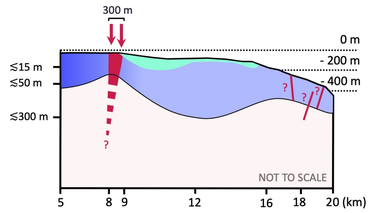
TO SUM UP

Before 8 km → **Shallow basin** (~60 m at most) with low velocity sediments

Between 8 and 10 km → Scattering fault zone with **two main structures** separated by ~300 meters. Normal faults are preferentially involved in subduction erosion. The fault zone act as a scatter point down to 2 Hz, therefore we expect a depth of ~50 m.

Between 9 and 16 km → **One large sedimentary basin** (~300 m, low velocity sediment) with a very high frequency **embedded sub-basin** (~15 m at most, lower velocity sediment)

After 16 km → Poor coupling is a limiting factor, we suggest **another fault zone** with variability in the depth and geometry (different frequency dependance)



LEGEND

- Fault zone
- Shallow basin
- Large basin
- Shallow basin
- Basement

My abstract!

[1] Baillet, M.; Rivet, D.; Trabattoni, A.; Chèze, J.; Peix, F.; Ambrois, D.; Ende, M. van den; Vernet, C.; Sánchez-Olavarría, R.; Barrientos, S. E. Automatic Earthquake Catalogs from a Permanent DAS Offshore Network. [2] Vernet, C.; Trabattoni, A.; Rivet, D.; Baillet, M.; van den Ende, M. Imaging the Sediment Cover Offshore Central Chile with Surface-Wave Dispersion and P-Wave Conversion Using DAS, 2025. https://doi.org/10.5281/zenodo.15100337. [3] Trabattoni, A.; Baillet, M.; van den Ende, M.; Rivet, D.; Stutzman, E.; Strumia, C.; Biagioli, F. Xdas: A Python Framework for Distributed Acoustic Sensing. 2024. [4] Trabattoni, A.; Vernet, C.; van den Ende, M.; Baillet, M.; Potin, B.; Rivet, D. Sediment Corrections for Distributed Acoustic Sensing. Journal of Geophysical Research: Solid Earth 2024, 129 (10). https://doi.org/10.1029/2024JB029054. [5] Atterholt, J.; Zhan, Z.; Yang, Y. Fault Zone Imaging With Distributed Acoustic Sensing: Body-To-Surface Wave Scattering. JGR Solid Earth 2022, 127 (11). https://doi.org/10.1029/2022JB025052. [6] Cheng, F.; Chi, B.; Lindsey, N. J.; Dawe, T. C.; Ajo-Franklin, J. B. Utilizing Distributed Acoustic Sensing and Ocean Bottom Fiber Optic Cables for Submarine Structural Characterization. Sci Rep 2021, 11 (1), 5613. https://doi.org/10.1038/s41598-021-84845-y.