Report of Transnational Access Projects

(Note: the information here will be publicly disclosed in the Geo-INQUIRE website, do not include sensitive information)

Project ID: C3-TA3-85-1-2

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Project team (if applicable):

Project title: MAREA

Project acronym: Magnitude estimAtion in Real TimE using DAS

Hosting installation: EMSO Ligure-Nice (TA3-85-1)

Hosting team: Diane Rivet, Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, IRD, Géoazur.

Period of access: 08/09/2025 – 08/10/2025

Report of activities:

The MAREA project addresses the integration of Distributed Acoustic Sensing (DAS) data into operational Earthquake Early Warning (EEW) systems. By exploiting offshore fiber-optic cables located closer to seismogenic sources, DAS has the potential to significantly improve EEW performance, increasing warning lead times by up to several tens of seconds.

The growing availability of offshore fiber-optic infrastructure for seismic monitoring offers new opportunities for EEW. In the Mediterranean Sea, a new DAS observatory has recently been deployed along the offshore cable connecting Monaco (France) and

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Savona (Italy). To fully exploit these data, robust real-time processing frameworks for DAS observations are required.

A key challenge is the real-time estimation of earthquake source parameters, including event detection, location, and magnitude. While detection and location can rely on methodologies developed for conventional seismic networks, magnitude estimation requires dedicated investigation because of the different characteristics of DAS measurements. In offshore environments, fiber-optic cables are typically installed within sedimentary basins, where wave propagation is strongly affected by sedimentary structures. During the first few seconds of the recordings—critical for EEW—secondary phases generated at the sediment–bedrock interface can dominate the signal, potentially biasing magnitude estimates. Quantifying these effects is therefore essential for reliable DAS-based EEW.

To investigate this problem, we analysed data from the ABYSS DAS network in central Chile, which monitors approximately 450 km of offshore fiber-optic cables. This tectonically active region provides an ideal dataset, with frequent seismicity spanning a broad magnitude range, making it well suited for evaluating real-time magnitude estimation from DAS data and assessing the transferability of the methodology to other offshore DAS installations.

Our analysis includes more than 100 earthquakes with magnitudes ranging from M 2.5 to 7.3. For each event, we manually identified the direct P wave, the P-to-S converted phase (Ps), and the direct S wave (Figure 1). After correcting for propagation effects, we evaluated the magnitude information carried by the peak amplitudes of each phase. The analysis was repeated for different physical observables derived from DAS measurements, including strain rate, displacement, and the time integral of strain, highlighting their different sensitivities to earthquake source properties (Figure 2).

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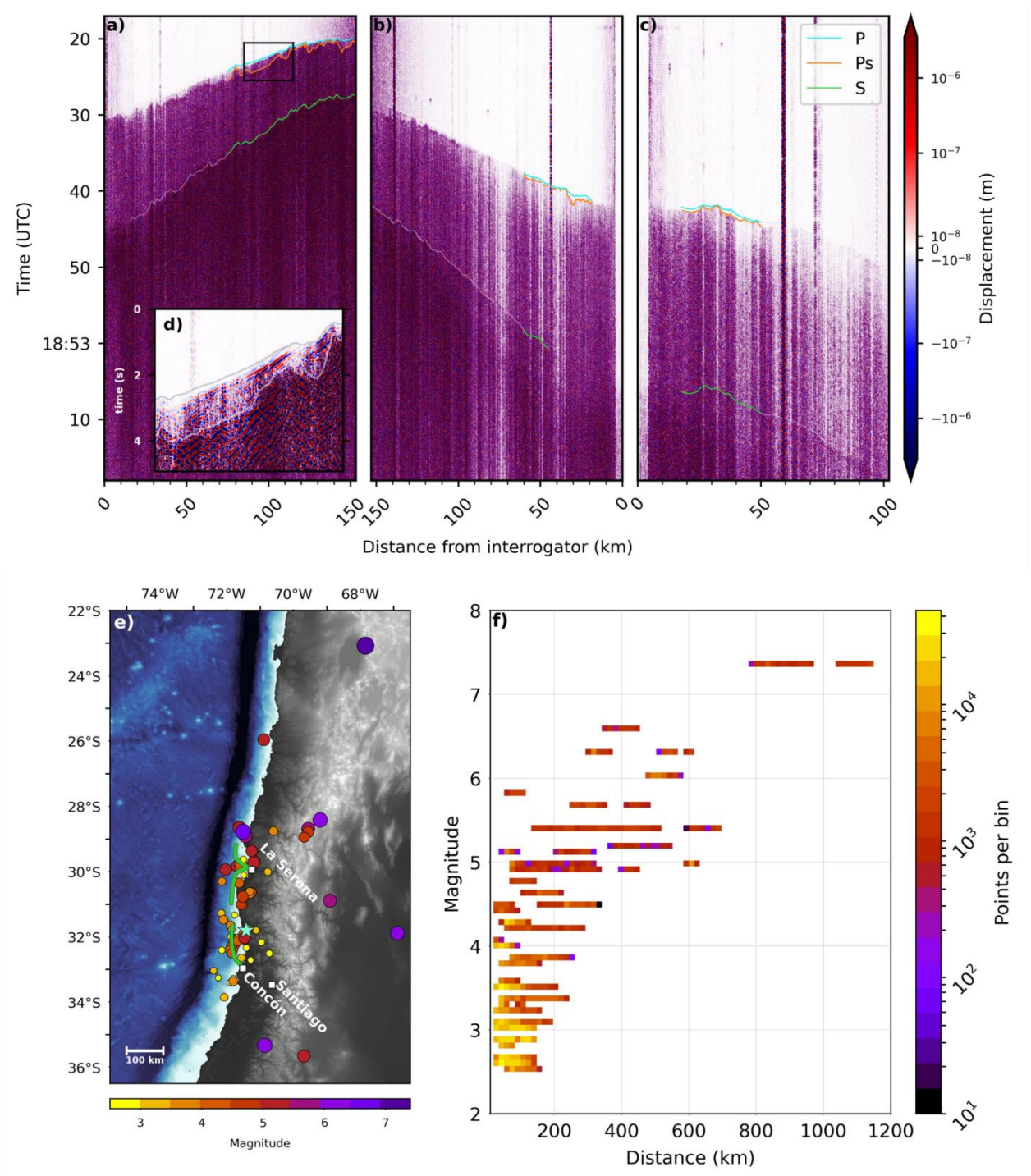

Figure 1:DAS waveforms **(a-c)** recorded by the ABYSS network for a M4.3 earthquake (cyan star in panel (**e**)). Manual P, Ps, and S picks are represented by continuous curves.. Inset (**d**) shows a zoom on the Ps phase arrival after the P wave. both marked by the manual picks displayed as continuous lines. (**e**) Map showing the epicentral distribution of earthquakes in the dataset, and the geometry of the fibre network (green curves). Panel (**f**) is a 2D representation of the dataset in terms of magnitude and hypocentral distance distributions. (Strumia et al., 2026)

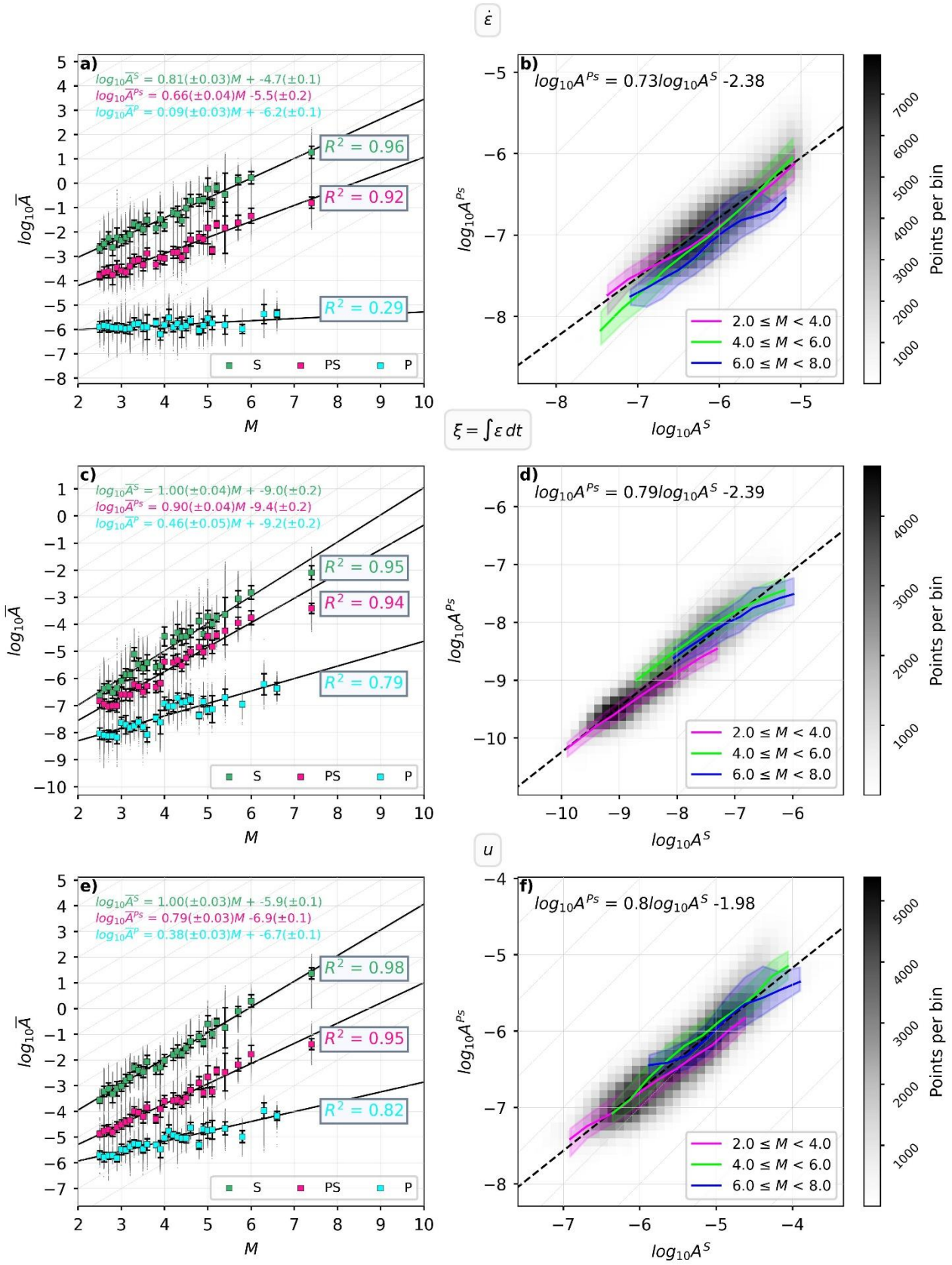

Figure 2: Peak amplitude analysis for P, Ps and S waves in different measurand domains: strain rate (a, b), time integral of the strain (c, d), displacement (e, f). Left column contains plot of the logarithm of peak amplitudes as a function of

magnitude, while the right column showcases the relation between peak amplitudes from Ps and S waves in term of their logarithms. (Strumia et al., 2026)

Finally, we calibrated magnitude laws to be used in real time to estimate magnitude from peak amplitude measurements using the early Ps wave (Figure 3). This framework can be adapted to other offshore environments where converted phases might dominate the direct P wave train.

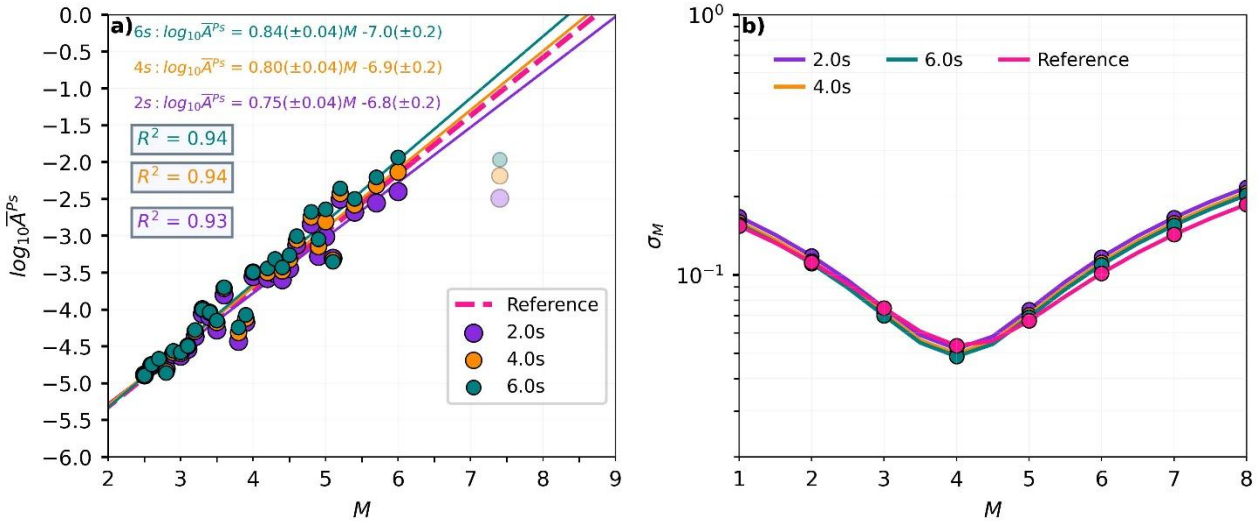

Figure 3: Calibrated magnitude laws for real time magnitude estimation with DAS **(a)**. Each law is calibrated on different time window's length to adapt to real time scheme where the information increases as time evolves during the acquisition. Expected errors on magnitude estimates are also indicators of the possibility to obtain robust estimates even within short time windows **(b)**. (Strumia et al., 2026)

Project outcomes:

As of July 15th, 2026 the MAREA project has the following outcomes:

a) Oral presentation at EGU 2026:
Strumia, C. et al. (2026). *Strategies and Challenges in Applications of DAS-based Earthquake Early Warning Systems* (No. EGU26-12675). Copernicus Meetings.

b) Scientific Paper published:
Strumia, C., Trabattoni, A., Scala, A., Rivet, D., Festa, G. Harnessing converted phases for rapid magnitude estimation and early warning with distributed acoustic sensing offshore Chile. Commun Earth Environ 7, 212 (2026). https://doi.org/10.1038/s43247-025-03167-3

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c) Presentation at the Geo-Inquire Jupyter Notebook Meeting, Ifremer Brest Centre. 28th-29th May 2026.

d) Distribution of Jupyter Notebook for testing the developed approach for magnitude estimation: https://doi.org/10.5281/zenodo.21360273

Note: Data, products, software and publications resulting from TA activities must be publicly accessible under a CC-BY 4.0, GPLv3 or equivalent open license. No embargos beyond June 2026 are allowed. They must cite Geo-INQUIRE as the source of funding. Minimal citation: "*Geo-INQUIRE is funded by the European Union (GA 101058518)*".