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Near real-time channel selection for Distributed Acoustic Sensing technology

Emanuele Bozzi * [1], **Giulio Pascucci** [1], **Giacomo Rapagnani** [1], **Gian Maria Bocchini** [2], **Rebecca Harrington** [2], **Arantza Ugalde** [3], **Gilberto Saccorotti** [4], **Francesco Grigoli** [1]

[1]Department of Earth Sciences, University of Pisa, Pisa, Italy, [2]Institute of Geosciences, Ruhr University Bochum, Bochum, Germany, [3]Department of Marine Geosciences, Institut de Ciències del Mar, CSIC, 08003 Barcelona, Spain, [4]Istituto Nazionale di Geofisica e Vulcanologia, Pisa, Italy

Author contributions: *Conceptualization*: Emanuele Bozzi, Giulio Pascucci, Francesco Grigoli, Gilberto Saccorotti. *Methodology*: Emanuele Bozzi, Giulio Pascucci, Francesco Grigoli. *Software*: Emanuele Bozzi, Giulio Pascucci. *Formal Analysis*: Emanuele Bozzi, Giulio Pascucci. *Resources*: Rebecca Harrington, Arantza Ugalde. *Writing - Original draft*: Emanuele Bozzi. *Writing - Review & Editing*: Giulio Pascucci, Giacomo Rapagnani, Gian Maria Bocchini, Rebecca Harrington, Arantza Ugalde, Gilberto Saccorotti, Francesco Grigoli. *Visualization*: Emanuele Bozzi. *Supervision*: Francesco Grigoli. *Funding acquisition*: Francesco Grigoli.

Abstract Distributed Acoustic Sensing (DAS) technology enhances seismic monitoring by providing dense, array-like observations near earthquake sources. However, the resulting data volumes, typically on the order of thousands of channels, often limit real-time processing capabilities, with most seismological applications focusing on retrospective analysis of seismic sequences. To address this challenge, we introduce ORION (autOmatic near Real-time channel selectION), a near real-time selector of high-quality DAS channels that reduces the amount of data to process while maintaining key array-like features of the subsampled fiber-optic sensor. The method first adopts spatial clustering to identify cable segments with similar geometrical attributes (e.g., azimuth), and then performs channel selection within each segment using waveform attributes (e.g., signal-to-noise ratio). This approach enables spatial subsampling while preserving azimuthal and spatial coverage. We demonstrate the flexibility of ORION across several cable geometries. Finally, we analyze a seismic sequence recorded with a DAS system using ORION-selected channels and compare the resulting source locations with those obtained using a conventional spatially uniform subset of channels along the cable. The results show significant improvements in the accuracy of the estimated hypocenters.

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Non-technical summary Conventional earthquake monitoring relies on networks of individual sparse sensors. Recent advances, such as Distributed Acoustic Sensing (DAS) technology, introduced fiber-optic cables as spatially dense sensors, increasing the number of observations and the computational resources needed to analyze them by orders of magnitude. While DAS provides denser observations, it also produces very large amounts of data, which complicates the analysis in near real time. To improve efficiency, a common approach is to analyze only a subset of the DAS data, such as a limited number of seismic traces. However, common selection methods that rely exclusively on cable geometry or data attributes can miss high-quality signals or reduce spatial coverage. To overcome these challenges, we present a new approach called ORION, which automatically selects high-quality DAS seismograms while maintaining spatial coverage across the entire cable in near real time. We test ORION on various cable geometries and apply it to a natural seismic sequence, demonstrating that it enhances earthquake location accuracy compared to a fixed-interval selection of the same number of channels along the cable.

1 Introduction

Distributed Acoustic Sensing (DAS) is an emerging data acquisition technology that transforms conventional telecommunication, or built-in fiber-optic cables, into ultra-dense arrays of seismic sensors measuring strain/strain-rate (Daley et al., 2013; Parker et al., 2014; Lindsey et al., 2017; Jousset et al., 2018). In seismological applications, DAS systems can fill monitoring gaps in poorly instrumented regions (Klaasen et al., 2023; Walter et al., 2020; Ajo-Franklin et al., 2019; Li et al., 2023b; Piana Agostinetti et al., 2022) and complement existing seismic networks (Nishimura et al., 2021; Zhan, 2019), producing massive and heterogeneous datasets (Spica et al., 2023). The full exploitation of DAS data density allows the adoption of innovative approaches that improve monitoring procedures (Biondi et al., 2023; Li et al., 2023a; Strumia et al., 2024; Porras et al., 2024; Trabattoni et al., 2023; Biagioli et al., 2023; Baillet et al., 2025; Noe et al., 2025; Miller et al., 2024; Pascucci et al., 2025). However, such new techniques remain largely limited to offline analyses due to the lack of efficient processing strategies capable of handling high data complexity both in terms of size and signal quality (Lindsey and Martin, 2021). Although data compression strategies help reduce storage demands (Seguí et al., 2025), thereby mitigating the long-term im-

*Corresponding author: emanuele.bozzi@dst.unipi.it

pact of DAS experiments, rapid processing workflows still rely on spatial sub-sampling and stacking of nearby channels (Song et al., 2021; Lindsey et al., 2020). This necessity is especially reinforced in remote and harsh environments, such as volcanic flanks (Nishimura et al., 2021), glaciers (Klaasen et al., 2023; Walter et al., 2020; Hudson et al., 2021), or prospective planetary deployments (Zhai et al., 2024), where limited data transmission bandwidth makes in-situ channel selection not just a practical convenience but an operational necessity. Furthermore, joint analyses of seismic events using conventional networks and fiber-optic sensors are challenged by the highly unbalanced number of observation points (Li et al., 2023b; Lindsey and Martin, 2021), making spatial sub-sampling of DAS data/channels essential.

A common practice to manage massive DAS datasets in near real-time involves the tailored selection of a subset of channels, which are then integrated into conventional seismic data processing algorithms in a second step (van den Ende and Ampuero, 2021; Baba et al., 2024; Biondi et al., 2026). One possible approach is to focus on waveform attributes, identifying good-quality channels that can help manage the complex spatio-temporal variations of signal properties (e.g., caused by coupling or the uniaxial sensitivity of the sensor). For example, Rodriguez et al. (2025) introduced an efficient automatic selection method based on a machine-learned channel quality index that integrates multiple waveform attributes (e.g., signal mean, median, variance, kurtosis). On the other hand, to perform seismic event location with DAS sensors, channel selection must also account for network configuration (Strutz et al., 2026), as the final set of channels should ideally provide sufficient azimuthal coverage (Fuggi et al., 2024; Bormann and Bergman, 2000). Moreover, the number of sensors within azimuthal wedges of a given width should remain roughly constant to avoid over- or under-sampling along specific directions and thus bias source location. A common strategy to deal with the above criteria is to select traces at fixed intervals along the cable, though this does not guarantee the exclusion of poor-quality channels. A possible alternative is to relax pure waveform attribute-based selection strategies and allow the inclusion of suboptimal channels (i.e., channels of relatively high quality within each cluster, but not necessarily the highest-quality channels across the entire cable) to accommodate azimuthal requirements.

Here, we introduce ORION (autOmatic near Real-time channel selectION), an automatic DAS channel selector that combines waveform attributes and geometry information by jointly balancing waveform quality and spatial coverage in a single workflow (Fig. 1). ORION is designed to meet the following requirements:

- Robustness: i.e., applicable to cable geometries ranging from rectilinear to highly curvilinear configurations,
- Distribution: i.e., ensuring spatial and azimuthal coverage of selected channels along the cable,
- Tunability: i.e., allowing users to adjust the relative weighting of waveform attributes and spatial coverage, enabling them to focus on either quality metrics (signal-to-noise ratio, local coherence, and pre-event noise levels) or spatial/azimuthal coverage,
- Scalability: i.e., supporting the retrieval of a defined number of channels, e.g., for a subsequent integration of DAS data with existing conventional networks,
- Streaming: i.e., operating in near real-time to spatially reduce DAS data.

We evaluate the performance of ORION in two steps: (i) an application to several DAS cable geometries to test its versatility, and (ii) an analysis of its impact on earthquake location procedures. In the latter step, we compare ORION-selected traces with a spatially uniform sub-sampling strategy. The results show that integrating waveform-driven and geometry-based criteria offers support for both near-real-time data processing and more accurate seismic monitoring.

2 Data

We use synthetic cable geometries (Fig. S2) and DAS data (Figs. S3 and S4) to test the two principal components of the proposed algorithm, that is, spatial clustering and waveform-attribute-based selection. We then use seven publicly available real DAS datasets, each containing at least one recorded seismic event, to evaluate the complete ORION workflow (Figs. 2 and 3). The synthetic dataset features simple signal harmonics and full-wavefield simulations with varying levels of Gaussian noise. The real datasets span different environments: a) offshore, namely Monterey, SAFE, and CANDAS2 (Lindsey et al., 2019; Arantza Ugalde et al., 2023; Ugalde et al., 2023); b) hybrid onshore-offshore, namely Kefalonia, (Bocchini et al., 2026); c) urban, namely FORESEE (Zhu et al., 2021); d) volcanic, namely Azuma Volcano (Nishimura et al., 2021); and e) geothermal areas, namely POROTOMO (Feigl et al., 2016). All datasets except Kefalonia are used to test ORION across various cable geometries and, consequently, its spatial clustering step on individual seismic events.

The Kefalonia dataset is used for a full real-data application involving a seismic sequence, with event-location accuracy serving as the evaluation metric to compare the proposed selector against a more conventional spatial subsampling technique. This dataset consists of two weeks of continuous DAS recordings acquired from 1 to 15 August 2024 along a 15 km fiber-optic cable connecting the islands of Kefalonia and Ithaca in Greece (Figs. 3, 4, S1a). The recordings include waveforms from a seismic sequence that occurred north of Kefalonia, which enabled the detection of more than 5,700 local earthquakes using DAS data. We use a subset of 284 high-signal-to-noise-ratio events (SNR > 15 dB), originally identified by Bocchini et al. (2026) and part of an enhanced earthquake catalog (Bocchini et al., 2025) which exploited a combination of a local network of seismometers and DAS observations. This catalog is

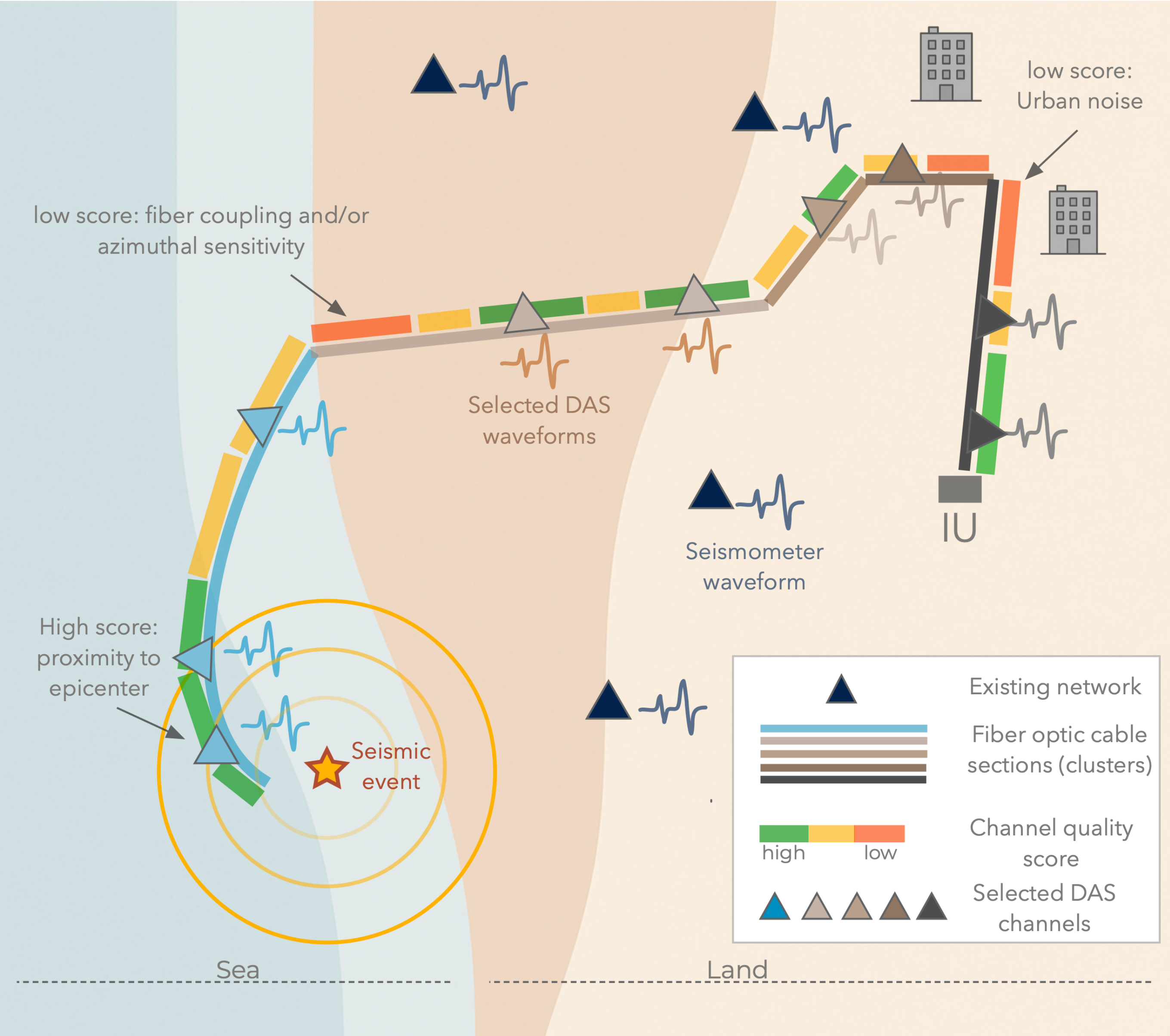

Figure 1 Sketch of the proposed automatic DAS channel selector for a hybrid land–marine cable deployment (coloured line) with offshore seismicity and an onshore seismic network (dark blue triangles). The selection procedure is schematized as follows: (1) Spatial clustering, illustrated by different colours of the cable; (2) Waveform (channel) quality scoring, simplified with three colours, red, yellow, and green; (3) Final channel selection, identified by triangles (additional channels are shown to illustrate its necessity for long clusters, e.g., offshore in light blue). IU = Interrogator unit

used as the reference for evaluating location accuracy using ORION and conventional channel selection.

Earthquake signals recorded at the Kefalonia DAS array provide an ideal test case for ORION, as the cable geometry includes both curvilinear onshore (running along public roads) and quasi-rectilinear marine sections, with the offshore portion exhibiting significantly lower noise levels than the onshore part in the 1-30 Hz frequency band (Fig. S1b) (Bocchini et al., 2025). Most earthquakes occur 10–15 km from the cable, with a few at greater distances. The azimuthal coverage of the seismic sequence is therefore limited, and events are generally more clearly recorded along the offshore segment, which potentially further reduces the covered angle. To efficiently locate earthquakes using spatially subsampled DAS, it is therefore essential to maximize azimuthal coverage, thereby favouring the selection of onshore channels, even if they exhibit the overall lower SNR. This configuration is thus particularly well suited for testing a selector that combines geometrical and waveform features.

3 Automatic DAS channel selection workflow

ORION is designed to spatially down-sample DAS recordings of seismic events, thereby supporting more efficient monitoring procedures. Selected channels are intended to support near real-time analysis without recurring to selection based exclusively on channel quality (possibly lacking azimuthal coverage) or fixed-interval decimation (possibly lacking sufficient waveform quality). In this context, non-selected channels are not discarded and can be preserved for successive offline analysis, supported by algorithms that perform efficient low-loss compression for long-term experiments (Seguí et al., 2025). Event detection on continuous DAS data is outside the scope of this work; ORION assumes that an event window has already been declared. The seismic events presented here are provided by principal investigators of the respective experiments, detected using different approaches, e.g., semblance-based for the Kefalonia dataset case (Porras et al., 2024).

The selection of DAS channels is performed in three steps using a scoring approach: (i) subdivision of the DAS cable into subsections through automatic spatial clustering, which is based entirely on the geometry of the fiber; (ii) waveform-attribute–based selection within each spatial cluster, where attributes are converted to normalized scores; and (iii) refinement of the selected channel pool based on user inputs. In this final step, the user may adjust the weighting of data attributes by acting on score percentiles, thereby avoiding the constraint of selecting at least one channel per subsection, or, alternatively, imposing a maximum number of selected channels for each spatial cluster. While spatial clustering is performed once for a given DAS deployment, high-quality channel selection is waveform-dependent, taking into account the spatio-temporal variation in noise conditions of DAS data (Pecci et al., 2024). The following subsections describe the three steps operated by ORION.

3.1 Spatial clustering

DAS arrays often exhibit strong azimuthal variations over short distances. Combining channels with different azimuths can degrade signal coherence during stacking due to incompatible axial sensitivities, and signals may undergo severe degradation near abrupt changes in fiber direction. We address these issues with a modified version of the DBSCAN algorithm (Ester et al., 1996) that enforces spatial contiguity while clustering channels considering the local azimuth as clustering metrics (Fig. S2). The local azimuth at each channel is estimated over a sliding window of N_w contiguous channels, converted to vector components to handle the circular nature of azimuth for successive clustering. A channel is added to an existing cluster if its Euclidean distance in the standardized feature space, comprising cumulative along-fiber distance and the two azimuth components, does not exceed a certain value ε (possibly estimated automatically, Satopaa et al., 2011). The method requires a minimum of $N_{\min}$ contiguous channels to form a valid cluster and excludes channels with abrupt azimuthal changes. When few unclustered channels occur inside an otherwise quasi-rectilinear section, a new cluster is initiated to maintain spatial continuity. This design permits smooth azimuthal variations within a cluster, which are less problematic for channel stacking than sharp changes. To prevent excessively long rectilinear or gently curved sections from biasing the spatial distribution of selected channels, clusters exceeding a maximum number of channels $L_{\max}$ are further subdivided into shorter segments. This procedure ensures balanced spatial coverage, especially for rectilinear cables or borehole deployments. Tables S1 and S2 present the main parameters used for spatial clustering in the DAS datasets under study.

3.2 Waveform-attribute-based channel selection

After spatial clustering of a DAS array, we perform spatial data subsampling by evaluating waveform attributes within each section for every detected event (Fig. S3). Three attributes are used for channel selection: (i) SNR, evaluated as the ratio of the mean squared amplitude of the signal window to that of the preceding noise window, expressed in decibels; (ii) local coherence, defined as the median cross-correlation coefficient between neighbouring channels; and (iii) pre-event root-mean-square (RMS) trace amplitude. Together, these metrics quantify both the quality of the recorded event and the overall background noise of the channel. We intentionally keep the selector computationally efficient by choosing a few attributes, which also reduces the number of tunable parameters. Attributes are computed over time windows defined by the event P-onset time, with onsets taken from previously-estimated picks (e.g., PhaseNet-DAS; Zhu et al., 2023). When unavailable, onsets are estimated using a conventional sliding-window SNR approach: the SNR profile is computed, smoothed, and the first prominent peak above background is identified (Allen, 1978). Each attribute is normalized in the range 0-1 (with 1 representing the relative maximum SNR, MCC and minimum pre-event root-mean-square (RMS) trace amplitude) and combined into a final channel quality score. Quality scores are then used to select the channel(s) for each section and, for very long sections, additional channels in the subsections. Finally, we prevent selecting localized and energetic coherent noise bursts, possibly misclassified as high-quality channels, by discarding quality scores outside the 10th–90th percentile range. Although this may omit some of the highest-scoring channels, it provides a more robust selection for near-real-time applications.

3.3 Final refinement

After the waveform-attribute-based selection, users can further refine the pool of DAS channels by applying a lower-bound percentile threshold on the quality scores to restrict the subset to the highest-quality channels, thus relaxing the requirement to pick one channel for each section or subsection. This refinement step may be necessary in several situations, for example, when only a few (few tens) "virtual DAS stations" are desired along the DAS cable, when manual waveform inspection is planned, or when an event is clearly visible only in a subsection of the cable. The user can then choose to stack channels with neighboring ones to form a "super-channel," using a default spatial window that corresponds to the gauge length; alternatively, it can also be user-defined.

4 Tests and applications

We first validate ORION using synthetic tests targeting its core components. For the spatial clustering step, we employ a complex cable geometry consisting of a rectilinear section with both abrupt and gentle bends (Fig. S2), which is used to compare the contiguity-reinforced clustering with a standard DBSCAN approach. Then, for the waveform-attribute–based channel selection and to retrieve a fixed number of traces, we use two synthetic datasets: one using simple harmonic signals and another using full-waveform seismograms (Afanasiev et al., 2018), the latter simulating a local event recorded by a fiber cable deployed in a vertical well. Gaussian noise is added to emulate noise contamination and poorly sensitive cable sections, thereby testing ORION's capability to select high-quality DAS channels.

We test channel selection on real data from individual events in six different acquisition setups. Then we apply ORION to the Kefalonia seismic sequence, targeting an event location workflow with selected channels. For this goal, we use a waveform-stacking-based locator (Grigoli et al., 2013), adapted to handle single-component DAS data, using a local 1-D velocity model (Haslinger et al., 1999). Locations using channels selected with the full ORION workflow, including stacking, are compared with those from channels uniformly sampled along the cable. To quantify location accuracy, we compute relative hypocentral distances with respect to the reference catalog of Bocchini et al. (2026). Tables S1 and S2 summarize the principal features of each dataset (e.g., sampling rate, total data volume) and the selector parameters.

5 Results

5.1 Synthetic tests

ORION identifies cable sections with coherent azimuths, similar to a standard DBSCAN algorithm. However, it additionally separates distant sections with comparable azimuths, thereby avoiding misclassification into a single cluster (Fig. S2). ORION also recovers less noise-contaminated signals across a set of 50 channels for which we have full control of the waveform attributes (Fig. S3). Alternatively, when applied to full-waveform synthetic data, ORION effectively avoids noisy segments and selects channels across multiple clean sections, without over-representing the shallow section of the well, where signals are the most clear (Fig. S4).

5.2 Real data tests

ORION identifies spatial clusters across six real-data test geometries (Fig. 2a, c, d, f), detecting abrupt (i.e., on a window length smaller than the contiguity window) azimuth variations. In portions of the cable with repetitive short-wavelength azimuth fluctuations or sharp bends (Figs. 2a–f), channels are automatically flagged as "noise" and not assigned to any spatial cluster (Figs. 2a, b). In contrast, segments where azimuth changes occur over distances larger than the contiguity window (see Tab. S1) are correctly grouped into single clusters (Figs. 2a, b). A notable case is the zig-zag configuration of the POROTOMO array (Fig. 2e), where ORION successfully resolves each branch.

With a user-defined target of 50 traces and a weak lower-bound percentile of 1% on final scores, selected channels remain well distributed along the cable (Figs. 3a–d). For events recorded only weakly in specific sections (Figs. 3e, f), the algorithm excludes channels where events are weakly recorded, as a consequence of the percentile threshold. Finally, in very-long clusters (Fig. 3b), ORION subdivides sections into subsections to ensure sufficient spatial coverage of selected channels.

5.3 Application to the Kefalonia seismic sequence

Figures 4 and 5 illustrate the application of ORION to earthquake location using spatially subsampled DAS data in the context of the 2024 seismic sequence northwest of Kefalonia Island. Spatial clustering results are consistent with those from other DAS geometries: the onshore cable portions are divided into 27 segments, while the gently-varying-azimuth marine segment forms a single cluster (Figs. 4a, b). This marine cluster comprises roughly 2,500 channels and spans nearly 90° of azimuthal change (Fig. 4b). Nevertheless, because ORION automatically subdivides long clusters into subsections, channels with different orientations are not mixed during the subsequent stacking phase and therefore do not affect the traces used for event location.

The final set of DAS channels selected for all 284 events provides broad spatial coverage along the cable and does not over-represent the marine segment, despite its higher data quality compared with the noisier onshore sections (Fig. 4b). Spatial coverage is further ensured by adopting a weak threshold on final quality scores (1st percentile), chosen to maximize azimuthal coverage for event location.

We compare event locations using ORION-selected channels with a uniform spatial selection, using the same reduced number of traces. The comparison reveals substantial differences in both signal quality and relocation performance. ORION-selected channels exhibit a higher median SNR (Fig. S5a), particularly benefiting the noisier onshore portions (Fig. S5b) and providing clearer P- and S-wave signals. When using ORION-selected channels, events cluster within the active seismicity region northwest of Kefalonia. By contrast, using uniformly selected channels, the same earthquakes tend to be mislocated near the cable (Fig. 5a). Overall, the use of ORION-selected channels for source location reduces the median distance to the high-resolution reference catalog from over 10 km (with uniformly spaced channels) to less than 4 km, with most mislocated events having smaller magnitudes (Fig. 5b).

5.4 Computational costs

ORION achieves near-real-time performance through a two-step process. First, the computationally inexpensive spatial clustering step is performed only once per

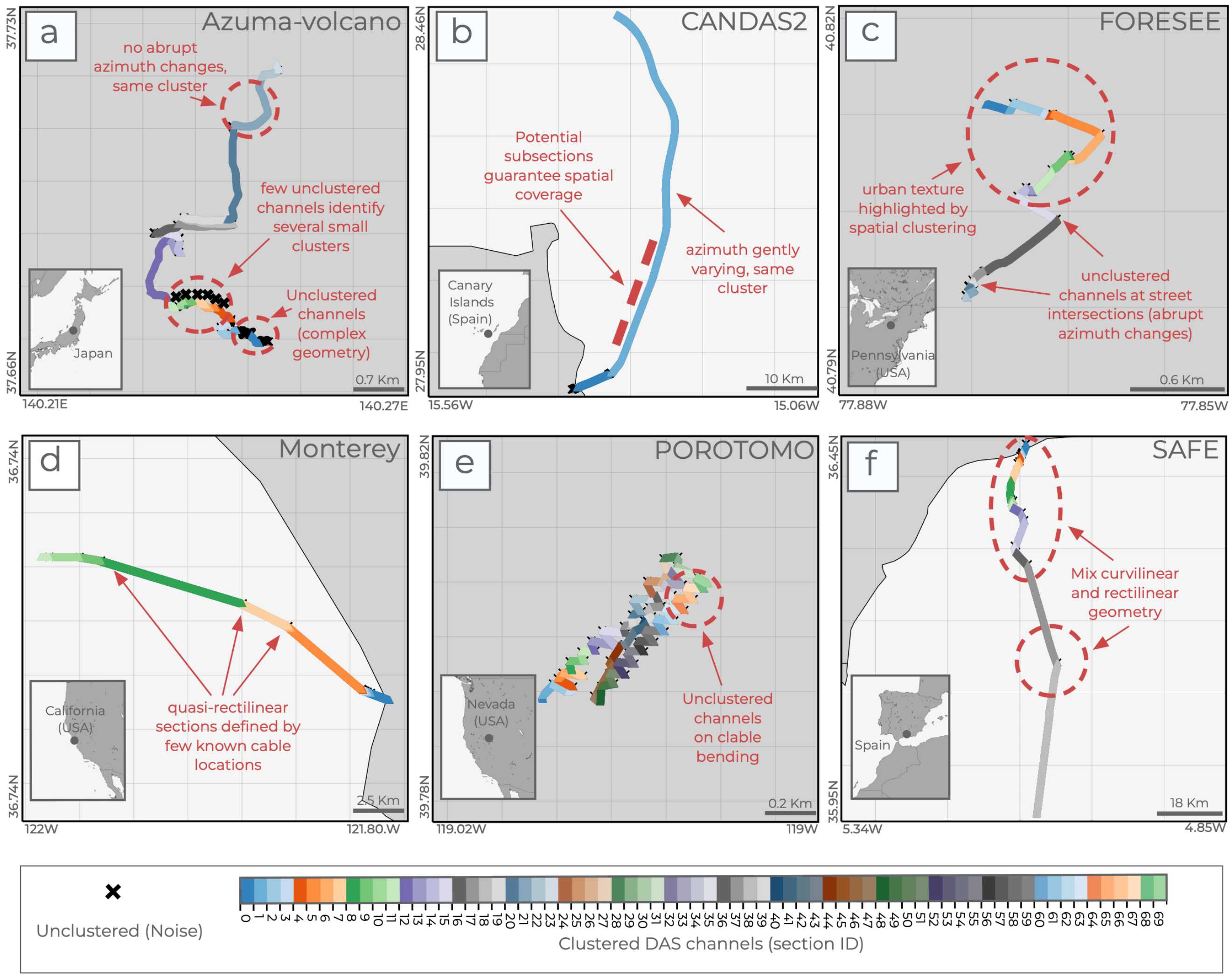

Figure 2 Spatial clustering with ORION tackling six different fiber optic cable scenarios. a) Azuma-Volcano DAS deployment (Japan): The cable follows a public mountain road. ORION identifies 24 clusters, mainly after the un-clustered southern section (identified as noise). The northern part, with gentler curvature, is characterized by fewer clusters. b) CANDAS-2 DAS (Spain): An extremely long-wavelength geometry results in only two clusters. c) FORESEE DAS (USA): An urban cable strictly following roads. The clustering spans all road azimuths, with un-clustered channels correctly flagged at bends. d) Monterey DAS (USA): Submarine cable running below sea level. Given the weak geometrical constraints, ORION recovers clusters for the sections defined by the known location points. e) POROTOMO DAS: The zig-zag layout allows recovery of 69 clusters, with noise identified at bending points. f) SAFE DAS: Oceanic cable combining short curvilinear and long rectilinear segments, all correctly recovered by ORION.

DAS experiment, requiring less than one minute on an 8-CPU machine (Intel i5-11320H @ 3.20 GHz) and allowing for parameter adjustments during the experiment. The more computationally-expensive channel selection relies on three channel quality scores providing the final set of selected DAS channels within one to two minutes per event, with minimal dependence on the total channel count.

6 Discussion

We developed ORION, a tool that automatically selects DAS channels in near real-time with a focus on seismic monitoring tasks. Spatial subsampling of DAS arrays has been previously addressed either through waveform-attribute-based selection (Rodriguez et al., 2025) or fixed interval selection along the cable. ORION offers a complementary approach: it preserves spatial coverage defining clusters of DAS channels with similar geometrical attributes, while evaluating waveform attributes to choose the optimal traces within each cluster.

ORION provides near real-time performances with a final spatial subsampling factor exceeding one hundred in less than two minutes, even on a standard laptop hardware. This efficiency is possible because the initial spatial clustering is a one-time process performed only once per cable, and the adopted waveform attributes are limited to three (SNR, local waveform coherence, and pre-event noisiness of the channel), while remaining effective for describing channel quality. It is notable that computational costs required for channel selection

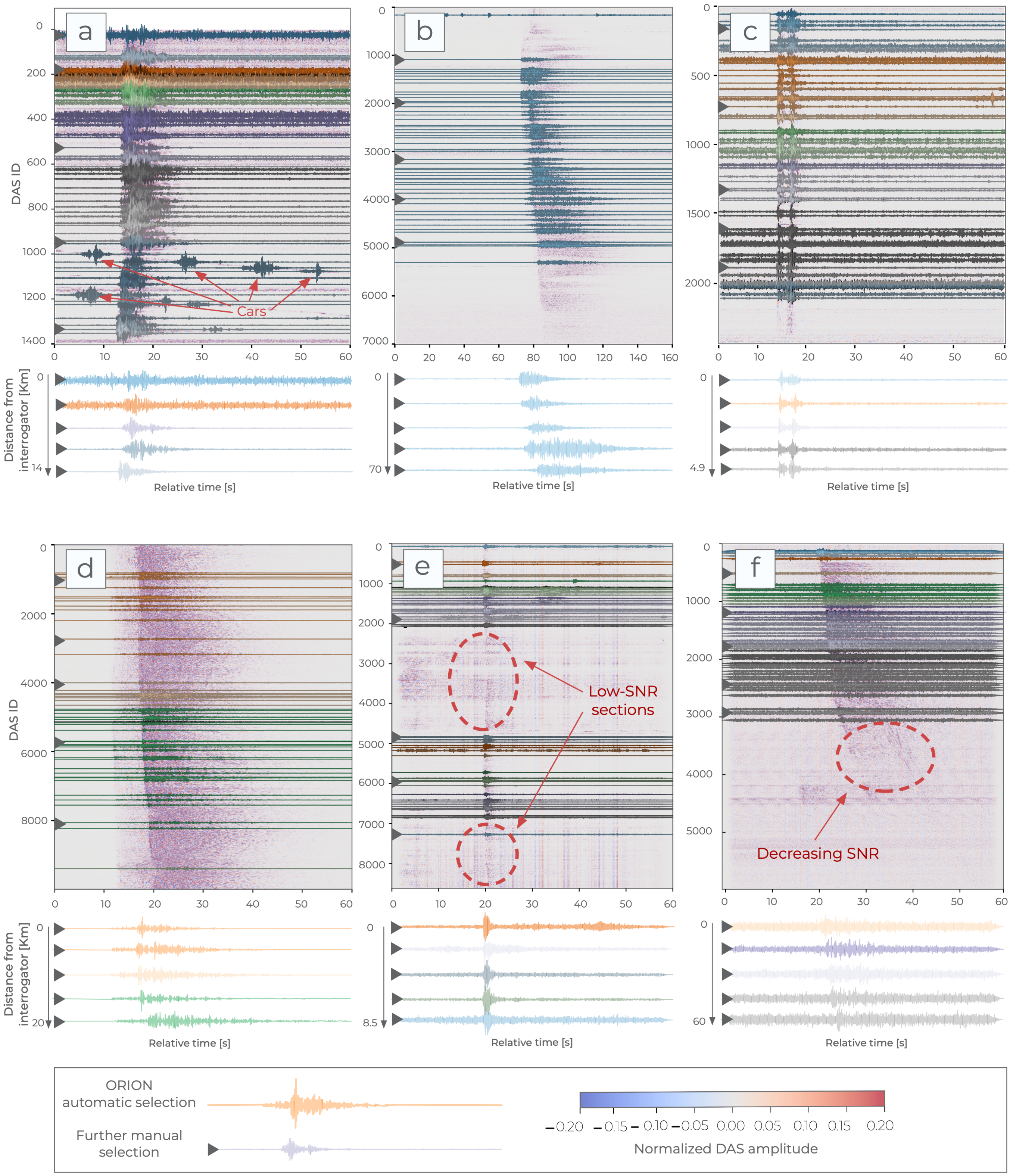

Figure 3 Automatic DAS channel selection using ORION. Panels refer to the datasets in Fig. 2, and colors correspond to the different spatial clusters. A 90th-percentile threshold is applied to data attribute scores; thus, not all clusters contain a selected trace (a–f). (b) A single cluster can include multiple traces if the user-defined minimum spatial coverage threshold is exceeded (subsections are identified at fixed steps). (e-f) Cable sections dominated by noise are excluded from selection due to the threshold on scores. (a-f) A further manual subset of selected channels (marked with grey triangles) is highlighted below each panel to illustrate that the reduced channel count provided by ORION allows straightforward visual inspection for e.g., seismological analysis.

remain negligible if compared to processing full DAS datasets, which routinely contain thousands of individual channels. Conventional uniform subsampling is inherently faster because it bypasses waveform attribute evaluation; however, it may fail to select good-quality channels, thus impacting the accuracy of subsequent

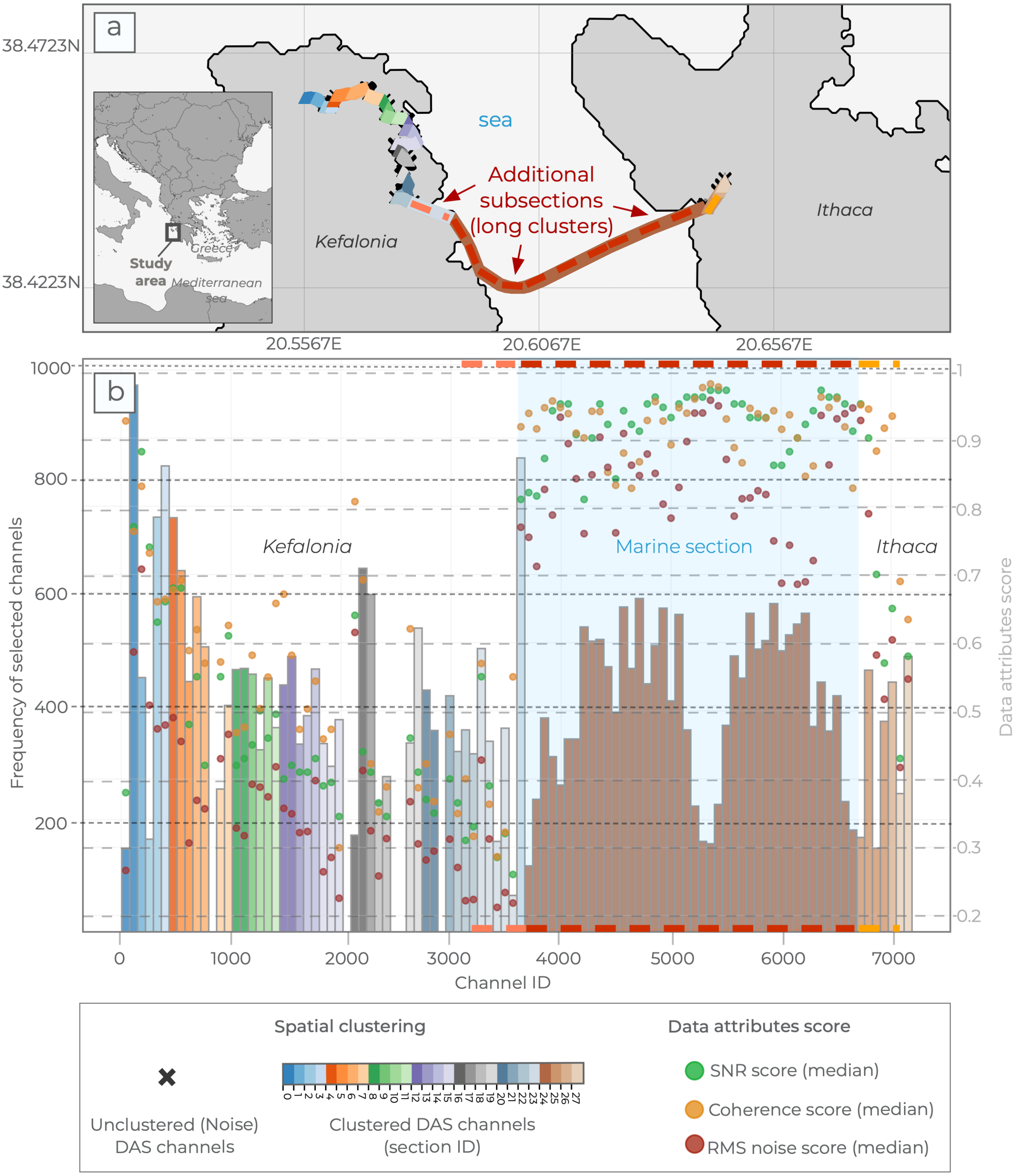

Figure 4 Overview of automatic DAS channel selection for 284 events from the August 2024 sequence north of Kefalonia. a) Spatial clustering by ORION identifies 27 sections, with shorter segments on land (Kefalonia and Ithaca) and the longest in the marine section. Long segments spanning multiple azimuths indicate curvature wavelengths longer than the neighbour-evaluation window. This approach accounts for successive stacking, preventing traces with sudden azimuth changes or differing sensitivities from being combined. Subsections are extracted every 50 channels to ensure full spatial coverage over those sections. b) Histogram of selected channels per cluster, showing median SNR, coherence, and pre-event noise RMS amplitudes (colored circles) used to pick optimal DAS traces. Although strong signals in the marine section (light blue around channel ID 3500-6500) yield higher scores, ORION maintains sufficient spatial coverage, avoiding its over-representation in the final selection. Notably, the slightly lower frequency of selected channels in the middle of the marine section reflects the overall highest SNR, coherence, and RMS noise scores in that region, which are often excluded by the 10th–90th percentile thresholds used in ORION to ensure robustness to noise bursts.

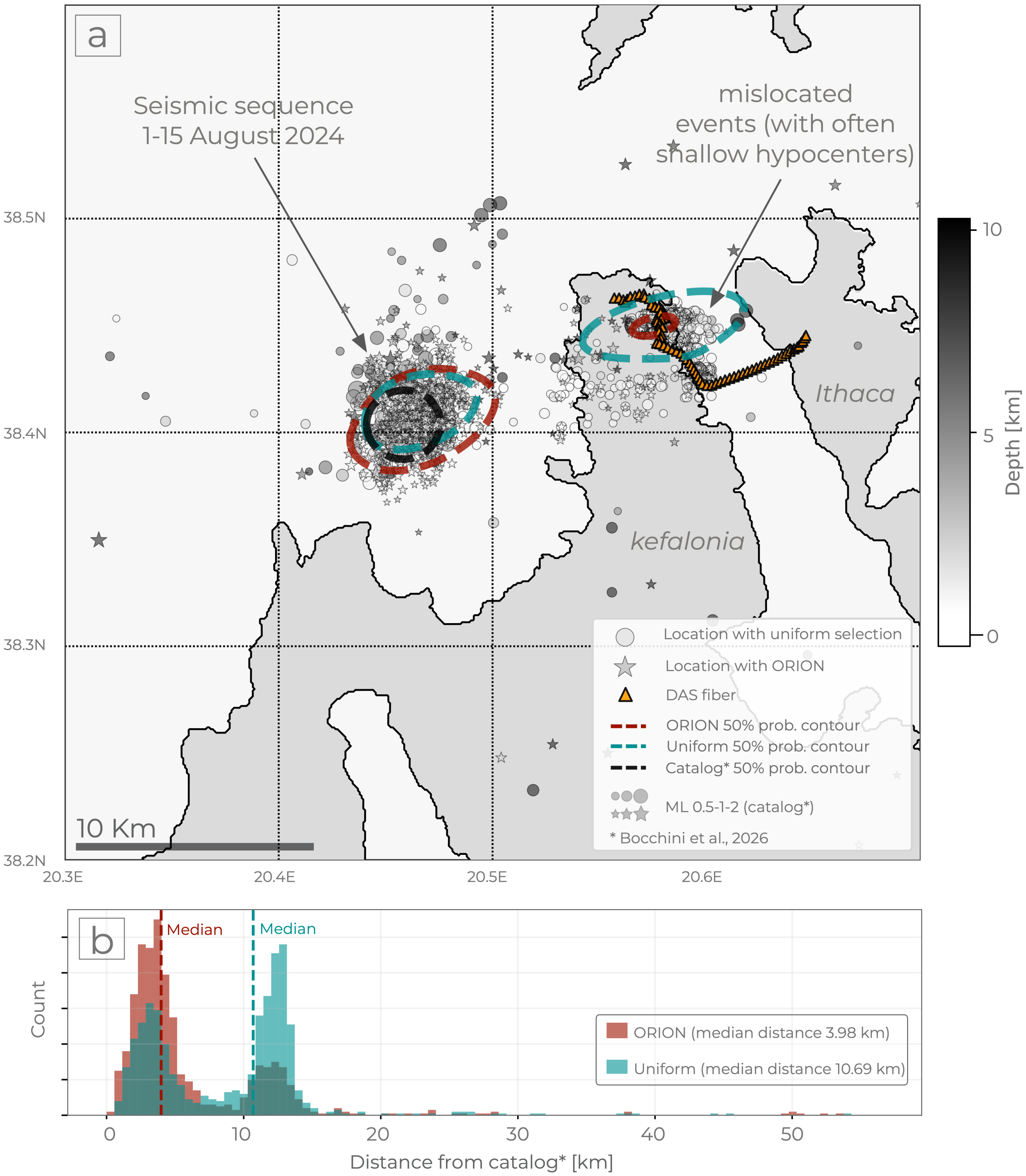

Figure 5 Relocation of the August 2024 Kefalonia seismic sequence using selected DAS channels and a waveform-based locator adapted for single-channel sensors (Grigoli et al., 2013). Relocations use both ORION-selected and uniformly selected channels with the same number of traces (see Fig. S5). Due to the large azimutal gap, results do not outperform the catalog obtained with both land seismometers and DAS (Bocchini et al., 2026), which is used as a reference. a) Event locations are concentrated in two clusters (red and blue dotted lines: 50% probability contours for ORION and uniform selection): one near the expected location north of Kefalonia and another mislocated near the cable (orange triangles). Locations with ORION-selected concentrate in the expected cluster, whereas locations with uniform selection mostly fall in the mislocated cluster. b) Histograms of distances to the reference catalog for all 284 events. Locations with ORION show a lower median distance, demonstrating improved relocation accuracy over uniform selection.

seismological analysis. In this context, ORION offers rapid spatial subsampling designed for seismic monitoring applications, allowing more accurate source parameter estimations.

We propose a selection based on three representative waveform attributes: SNR, local waveform coherence, and pre-event noisiness of the channel. However, the same framework is extendable, without altering the basic code architecture, to any other quantifiable channel or waveform attribute. Given that the code is open source, users can tailor the attribute-based selection to their specific application, incorporating alternative or additional features that may be better suited to a given dataset. Moreover, prior information about the cable, such as proxies for ground coupling, can potentially contribute to the selection of the channels as stable or quasi-stable attributes.

ORION has the potential to be integrated into standard operational seismic monitoring workflows, given its two-stage structure. Specifically, the spatial clustering step is performed only once per deployment and therefore implies no additional computational cost after this operation. In contrast, the waveform-attribute–based channel selection requires typically less than two minutes per event on an average laptop. This performance places ORION, even in its current form, within a near–real-time processing window compatible with routine post-trigger analysis in seismic monitoring centres. Furthermore, to reduce the computational cost and make it more suitable for near-real time applications, ORION could be converted into more efficient programming languages exploiting GPU parallelization and installed at interrogator level. This would enable the selector to operate on triggers with computational times on the order of less than one minute.

We showed how ORION-selected DAS channels can provide more accurate event location estimates, closely matching a reference catalog, while simultaneously reducing data volume by two orders of magnitude. Moreover, the ability to define an output, user-specified, number of traces makes ORION suitable for the next generation integrated seismic networks, where dense DAS arrays complement sparse conventional stations. Selected channels can indeed mitigate imbalances in the seismological analysis originating from the discrepancy in the number of sensors of the individual sub-networks (conventional and fiber optic-based), without resorting to tailored/complex data weighting (better suited for offline analysis).

Although we demonstrated the effects of the proposed channel selection strategy on event location for a seismic sequence, such an approach is expected to positively impact other source parameter estimations as well. Higher-quality traces should, in principle, enhance waveform-fitting–based methods for source parameter estimation (Dziewonski et al., 1981; Tarantola, 2005). Moreover, clustering the cable into sections with similar geometrical properties may benefit array-processing techniques, such as beamforming, given their assumptions about local spatial coherence of the seismic wavefronts (Rost and Thomas, 2002). Importantly, some of the principles proposed here can be translated into a more computationally efficient version of the algorithm for earthquake early warning (EEW) applications or any other application requiring a latency on the order of seconds (Strumia et al., 2026). Assuming that spatial clustering has already been performed, long-period channel attributes could be used to identify a subset (e.g., few tens of channels) of quasi-stable channels (Biondi et al., 2026), supported by a final selection based on current waveform attributes. As a result, the number of these channels would be comparable to the station density typically employed in operational EEW systems. These procedures would also help to identify persistently low-quality or poorly coupled fiber sections.

ORION currently operates on detected events, but can in principle be applied to continuous data. For instance, waveform statistics computed over a rolling window (e.g., the preceding 24 hours or longer) could replace per-event scoring to guide channel selection. If a fixed channel geometry is required, noise statistics from a pre-operative period could instead be used to define a static set of representative channels for each spatial cluster.

7 Conclusions

We present ORION, a near–real-time selector of good-quality DAS channels. ORION ensures the selection of high-quality traces while preserving sufficient spatial coverage along the cable and minimizing azimuthal gaps in subsequent seismic data analyses.

ORION is flexible across different DAS layouts, as we show its application to a range of DAS experiments without the need for extensive parameter tuning. The selection procedure runs in near real-time on a standard laptop computer, supporting expedited analysis in DAS experiments, moving beyond the typical offline procedures. Moreover, when inserted into an event location workflow, it provides more accurate hypocenter estimations compared to uniform spatial sub-sampling.

Looking forward, ORION offers potential for next-generation seismic monitoring procedures with hybrid networks, as it provides a few high-quality channels to be merged with sparse conventional networks, thereby mitigating biases that arise from differing sensor densities.

Data and code availability

Data availability

All presented DAS datasets are described in open-access papers (Nishimura et al., 2021; Zhu et al., 2021; Lindsey et al., 2019; Ugalde et al., 2023; Arantza Ugalde et al., 2023; Feigl et al., 2016; Spica et al., 2023).

The full Kefalonia DAS dataset can be found at Bocchini et al. (2025).

Software availability

The ORION Python class and the data required to reproduce the results are available in a Zenodo repository (Bozzi, 2025). Additionally, future updates of the Python class will be uploaded in the following GitHub repository https://github.com/emanuelebozzi/ORION.

Conflicts of interests

The authors declare there are no conflicts of interest for this manuscript.

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