Probing Seismicity Secrets with Five Nodal Arrays around the San Jacinto Fault

Taiga Morioka[1], Florent Brenguier[2], Elizabeth Cochran[3], Wenyuan Fan[1], Quentin Higueret[2], Daniel Hollis[1,4], Peter Shearer[1], Frank Vernon[1], John Vidale[5], Ruoyan Wang[5], Hao Zhang[5, 6]

1. Scripps Institution of Oceanography, University of California San Diego, La Jolla, USA, 2. Université Grenoble Alpes, Grenoble, France, 3. United States Geological Survey, Pasadena, USA, 4. Sisprobe SAS, 5. University of Southern California, Los Angeles, USA, 6. California Institute of Technology, Pasadena, USA

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1. Introduction

- The relationship between frequent small earthquakes and the much rarer occurrence of large earthquakes is not yet clear
- With a more complete catalog, we can address key questions such as:
  - Prevalence and characteristics of foreshocks
  - Spatiotemporal evolution of swarms
  - Fine-scale structure of faults

2. Array Experiment and Data

- Installed **5 nodal arrays** around the San Jacinto Fault (SJF)
- Each array had **81 elements** with **100-m aperture**
- Recorded **3 components** from November 6th, 2024, to February 9th, 2025

2.1. Why target the San Jacinto Fault?

- Seismically active region with **varied faulting and fault slip behaviors**
- Prone to different types of events
  - Swarms and seismicity rate changes
  - Triggered earthquakes
  - Triggered tremor
  - Accelerated creep events

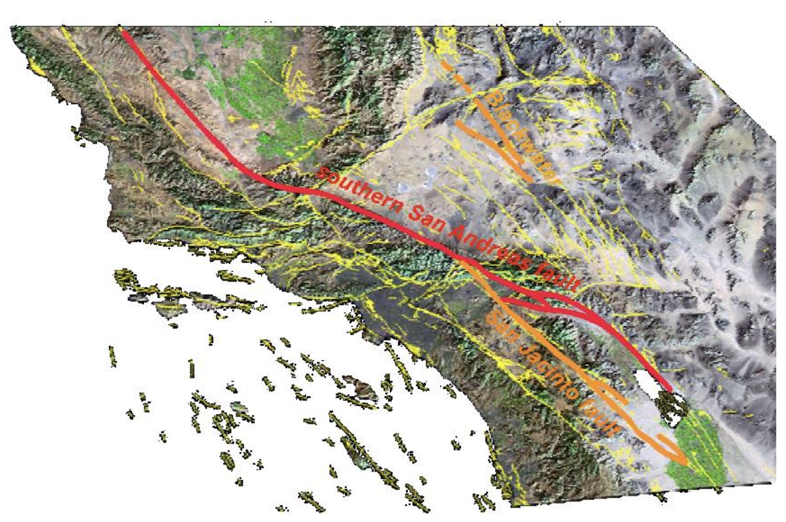


Figure 1: Map of southern California with fault lines (red: San Andreas Fault and orange: San Jacinto Fault) [4]

2.2. Why use a nodal array?

- Better signal-noise ratio in stack from seismic array than the co-located borehole instrument record[3]

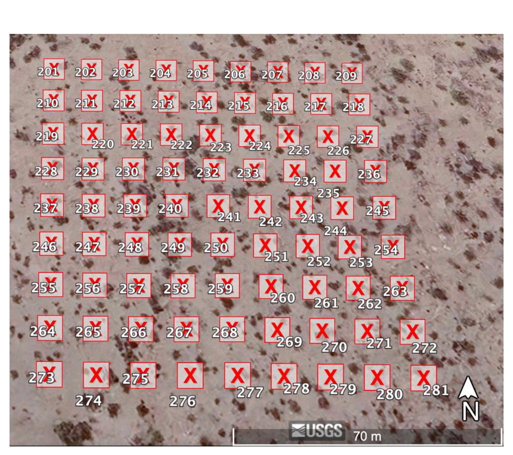


Figure 2: Close up map of the CVCC array, one of the five arrays deployed for this experiment as shown in Figure 3. X symbols show station locations.

2.3. Why not using existing arrays?

- Previous array deployments:
  - **Not long enough** duration to record events with multiple arrays
- Single array:
  - Cannot **verify event detections**
  - Cannot accurately **locate small earthquakes**

2.4. Procedure to create seismic catalog

I. Pick phases using Earthquake Transformer (EQ Transformer) [2]

II. Associate picked phases using Bayesian Gaussian mixture model-based phase associator (GaMMA) [6]

III. Estimate event locations with COMPLOC absolute relocation algorithm[1] considering southern California 1D velocity model

IV. Further relocate the events with GrowClust relative relocation algorithm[5]

V. Estimate local magnitudes of array-detected events by using calibration relation between amplitudes and SCSN magnitudes

3. Results

- GrowClust algorithm refines fine-scale seismicity structures.

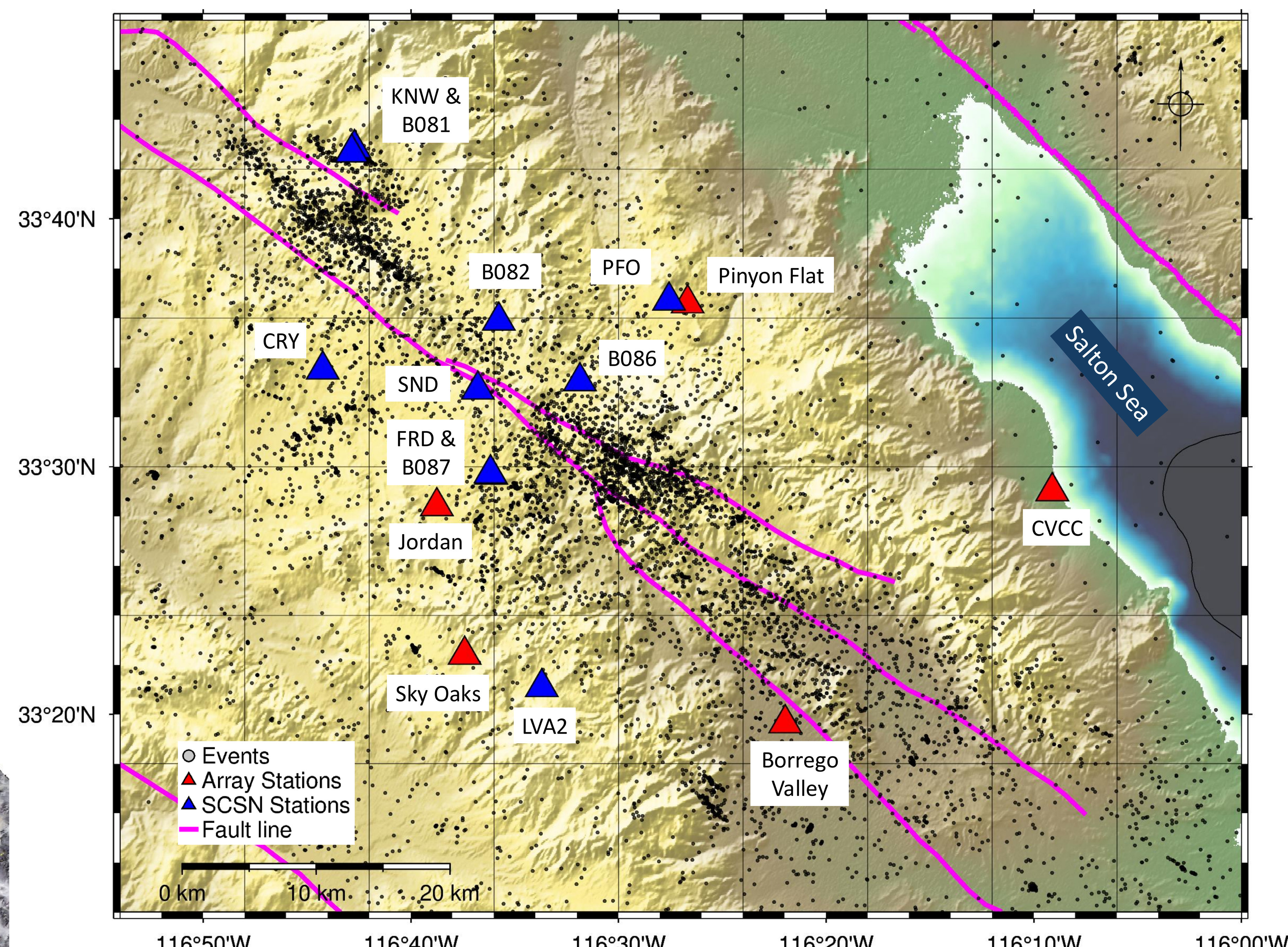


Figure 3: Map of the five arrays installed in this experiment (red triangles) and nearby SCSN stations (blue triangles) used to create the seismic catalog , with relocated events (black dots) from GrowClust algorithm. Red triangles show the locations of the Pinyon Flat Observatory, CVCC, Sky Oaks, Borrego Valley and Jordan arrays. Blue triangles show the locations of the CRY, FRD, KNW, LVA2, PFO, B081, B082, B086 and B087. Pink lines show major faults.

- Within 20km of our array and nearby SCSN stations, **9438 events are detected in our experiment** vs. 983 events in SCSN catalog

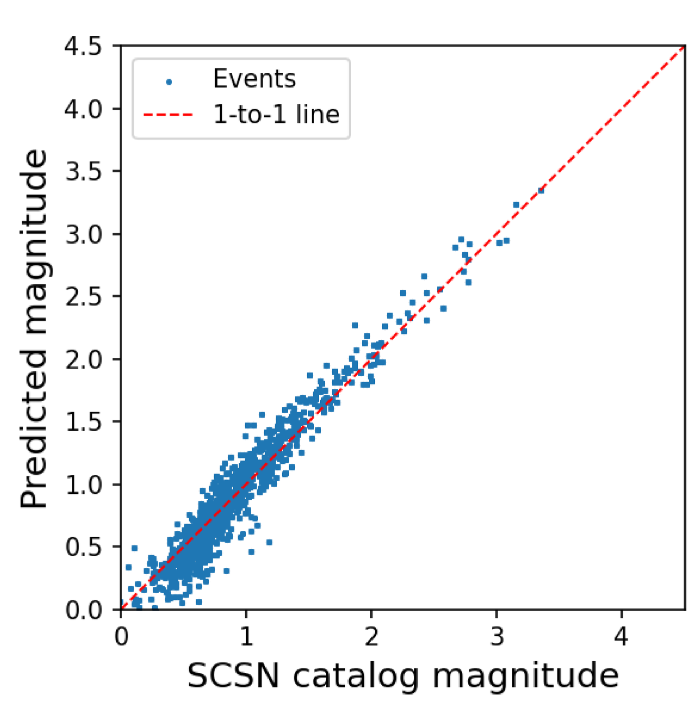


Figure 4: Comparison between magnitude estimates from SCSN catalog (x-axis) and predicted ones based on maximum amplitude of S-waves in our catalog (y-axis). Red dashed line shows the reference line for 1-to-1 relationship between them.

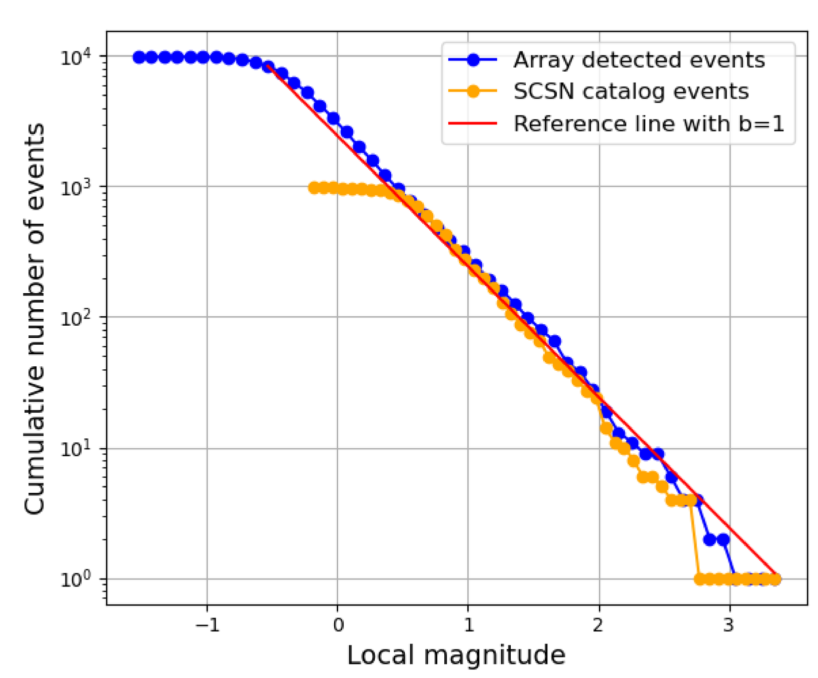


Figure 5: Cumulative number of events within 20km of our array and nearby SCSN stations over local magnitude for seismic catalog from array observation (blue) and SCSN catalog (orange). Red line shows b=1 reference slope.

- For 24 M ≥ 2 "mainshocks" near our array, we find **increased seismicity at nearby times**, consistent with foreshock and aftershock behavior.

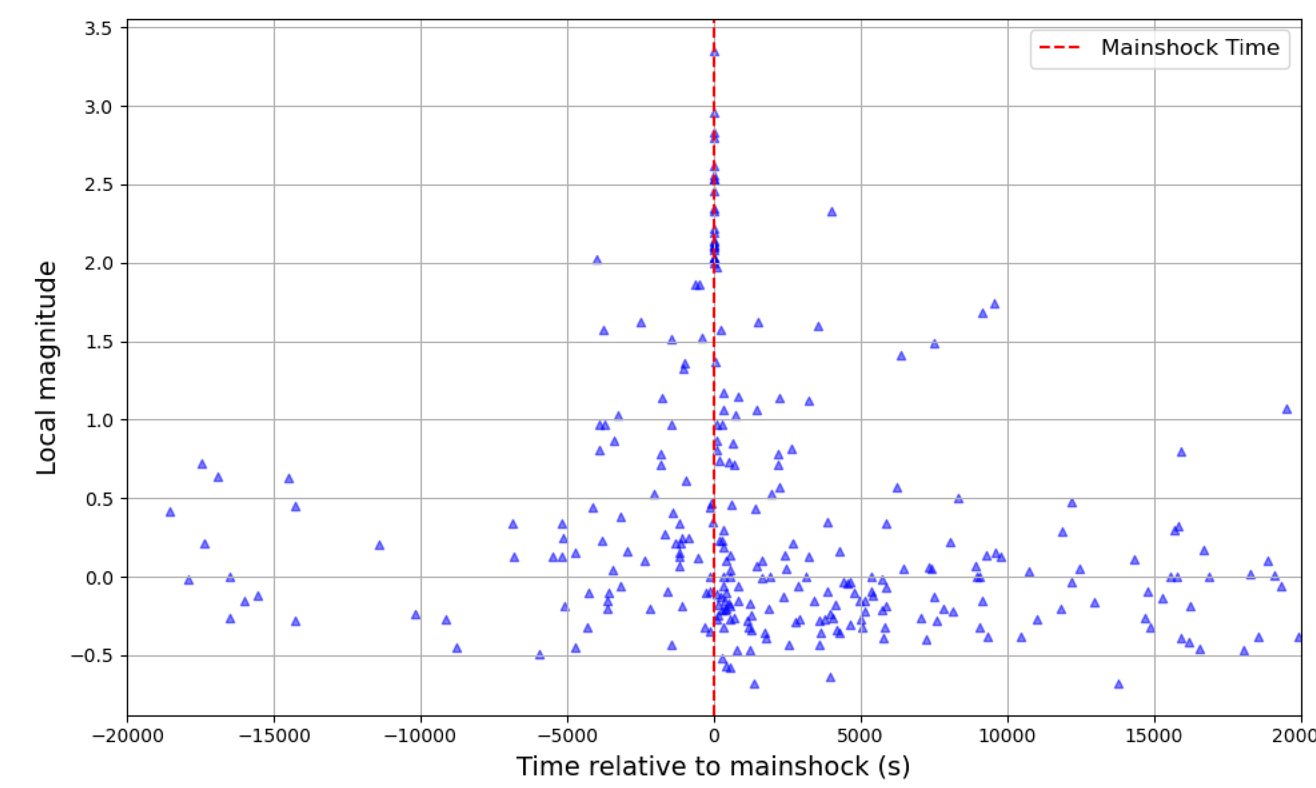


Figure 6: Local magnitudes of foreshocks, mainshocks and aftershocks that are located within 5km of mainshock locations as a function of time relative to the mainshock times (red dashed line).

- Our catalog contains **many clusters defining fault planes**.

Figure 7: Example of a cluster detected by the array experiment. Event locations are colored by the time in days since the first event in the cluster, and its size is scaled by magnitude. X marker shows centroid of the cluster.

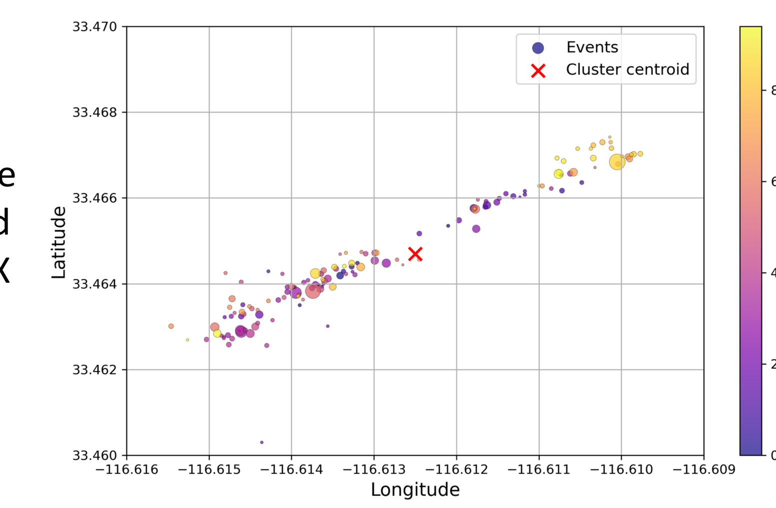
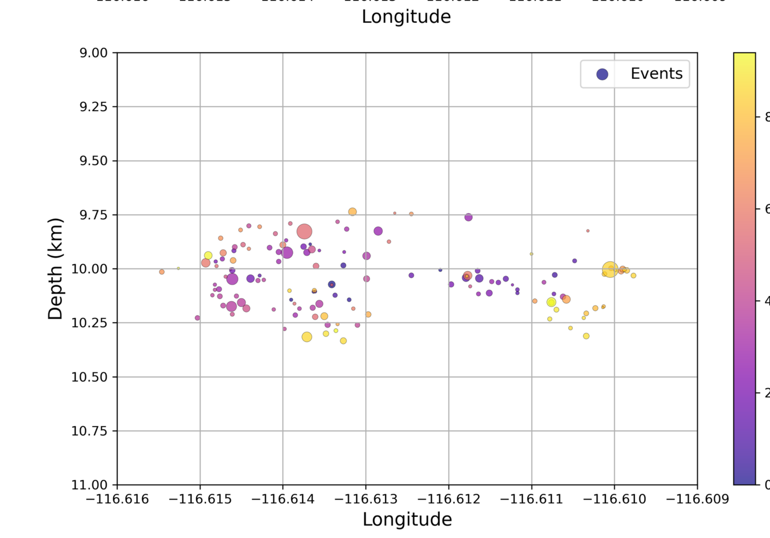


Figure 8: Depth profile of the events in the example cluster shown in Figure 7. Each event location is colored by the time in days since the first event in the cluster, and its size is scaled by magnitude.



4. Conclusions and Future Work

- We recently recorded over **3 months of continuous three-component data** from **five 81-element nodal arrays** located around the SJF.
- Our seismic catalog contains **ten times more events** than the SCSN catalog, including many M < 0 quakes.
- Our catalog exhibits clustering from both swarms and foreshock-aftershock activity.
- Application of template matching should further increase our detection sensitivity and reveal additional events.
- We plan to test ETAS and other models to explain the clustering behaviors that we observe.
- We also will use the array data to search for tremor and other exotic sources.

References

[1]. Lin, G., & Shearer, P. (2006). The COMPLOC Earthquake Location Package. Seismological Research Letters, 77(4), 440–444.
[2]. Mousavi, S. M., Ellsworth, W. L., Zhu, W., Chuang, L. Y., & Beroza, G. C. (2020). Earthquake transformer—An attentive deep-learning model for simultaneous earthquake detection and phase picking. Nature Communications, 11(1), 3952.
[3]. Shearer, P. M., Meng, H., & Fan, W. (2023). Earthquake Detection Using a Nodal Array on the San Jacinto Fault in Califomia: Evidence for High Foreshock Rates Preceding Many Events. Journal of Geophysical Research: Solid Earth, 128(3), e2022JB025279.
[4]. Toth, C., Grejner-Brzezinska, D. A., & Bevis, M. (2006). HIGH-RESOLUTION AIRBORNE LIDAR/CCD MAPPING OF SAN ANDREAS FAULT.
[5]. Trugman, D. T., & Shearer, P. M. (2017). GrowClust: A Hierarchical Clustering Algorithm for Relative Earthquake Relocation, with Application to the Spanish Springs and Sheldon, Nevada, Earthquake Sequences. Seismological Research Letters, 88(2A), 379–391.
[6]. Zhu, W., McBrearty, I. W., Mousavi, S. M., Ellsworth, W. L., & Beroza, G. C. (2022). Earthquake Phase Association Using a Bayesian Gaussian Mixture Model. Journal of Geophysical Research: Solid Earth, 127(5), e2021JB023249.