Monitoring induced seismicity in northern Alsace (France) with the contribution of “SeismoCitizen” Raspberry Shake dense network

Mathieu Turlure (1), Marc Grunberg (1), Sophie Lambotte (2),
Fabien Engels (1), Helene Jund (1), Antoine Schlupp (2), Jean Schmittbuhl (2)
1. Ecole et Observatoire des Sciences de la Terre, UAR830, Université de Strasbourg / EOST, CNRS, F-67084 Strasbourg, France
2. Institut Terre et Environnement de Strasbourg, UMR7063, Université de Strasbourg / EOST, CNRS, F-67084 Strasbourg, France

Sharing is encouraged

CONTEXT AND OBJECTIVES

The **PrESENCE ANR project** (2022-2026) is a **participatory science research project in seismology in Alsace, France**. Seismological observations are obtained using a large number of **low cost internet-connected equipment** (Raspberry Shake seismic stations).The PrESENCE project is **in the continuity of previous SeismoCitizen projects** in other contexts and regions: Mayotte, Vosges mountains and Mulhouse.

Figure 1: Example of a Raspberry Shake seismic station (3D model) used in the project.

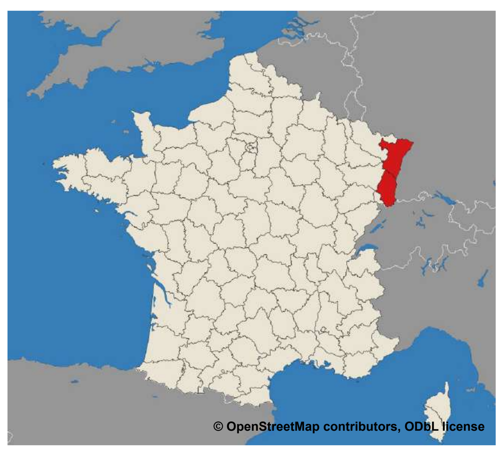


Figure 2: Alsace, France.

Breakthrough strategy:

- **deployment of the stations in residences or administrative buildings of non-seismologist voluntary citizens or authorities**,
- volunteers takes part in a sociological survey to estimate the impact of that participative project on their perception of science.

PrESENCE ANR project **focuses on seismic hazards induced by deep geothermal operations in northern Alsace** and their associated **societal perception**.

Objectives:

- densify the french permanent seismic network near deep geothermal projects in Alsace (Soultz-sous-Forêts and Rittershoffen in operation sites, future lithium exploitation sites),
- improve the detection and location of seismic events, in particularly small ones,
- reinforce interactions between station hosts and seismologists.

NETWORK DEPLOYMENT

75 stations are currently deployed in the two scheduled zones of the PrESENCE ANR project:

- **27 stations** were added (mostly in 2023) to the previously **14** installed stations (2017-2020) in the **area of Strasbourg**,
- **35 stations** were installed in the **area of Outre-Forêt** (2022-2025).

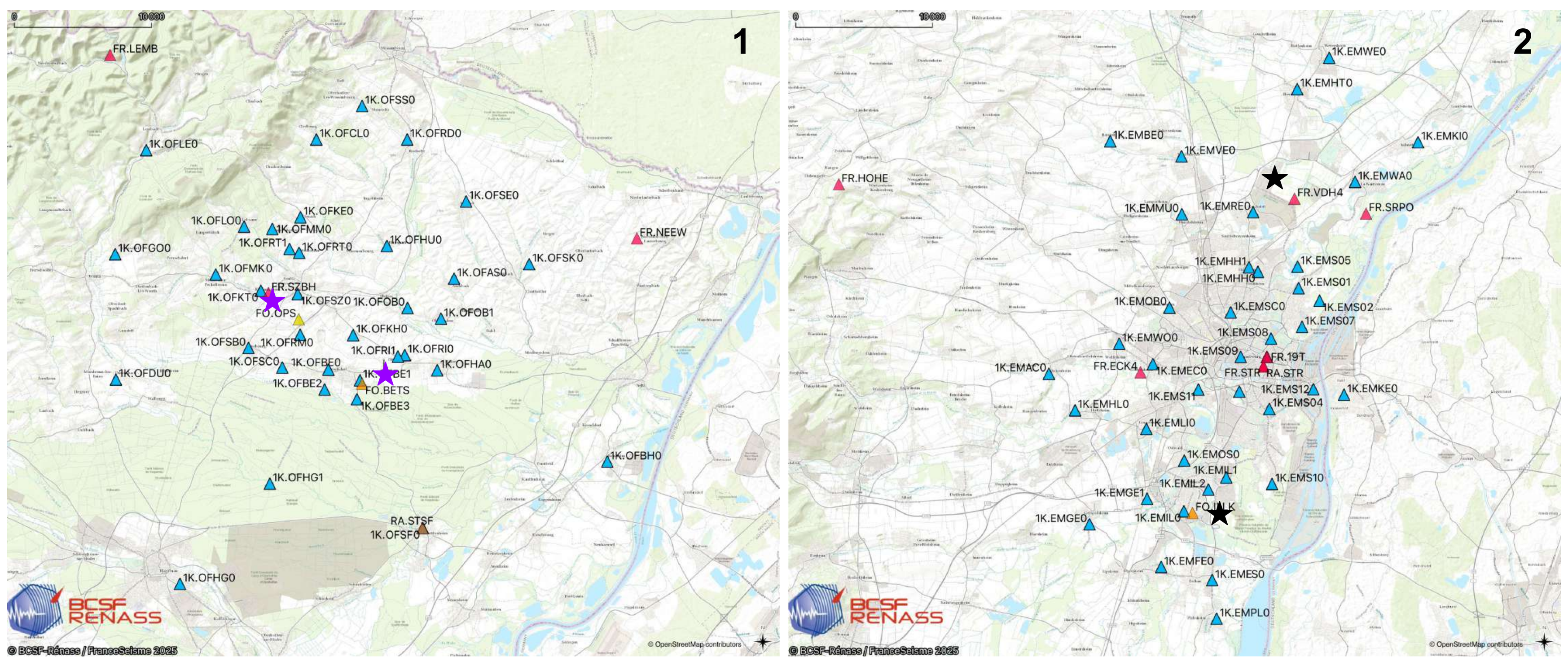
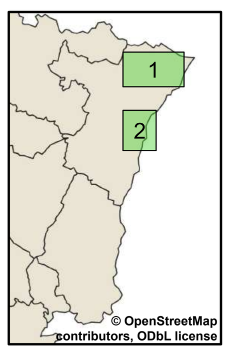


Figure 3: Map of the stations in Outre-Forêt (left) and Strasbourg Eurométropole (right).



- Raspberry Shake stations
- Epos-France permanent stations
- Epos-France accelerometric stations
- Geothermal operators stations
- Deep geothermal sites in operation
- Deep geothermal sites not in operation

NETWORK CONSOLIDATION

Based on our past experience in deploying similar networks involving Raspberry Shake stations, **we have consolidated the network reliability** by using several tools.

WireGuard — VPN

- Direct data transmission to BCSF-Rénass
- Direct access to stations
- Monitoring

Ansible — Open source IT automation platform

Configuration and management tasks:

- Hardware watchdog
- Crontab routine to control VPN

- Reliable data acquisition: **improvement of data completeness** than during acquisition via Raspberry Shake (see Figure 4 below)
- **Rapid and consistent production deployment**

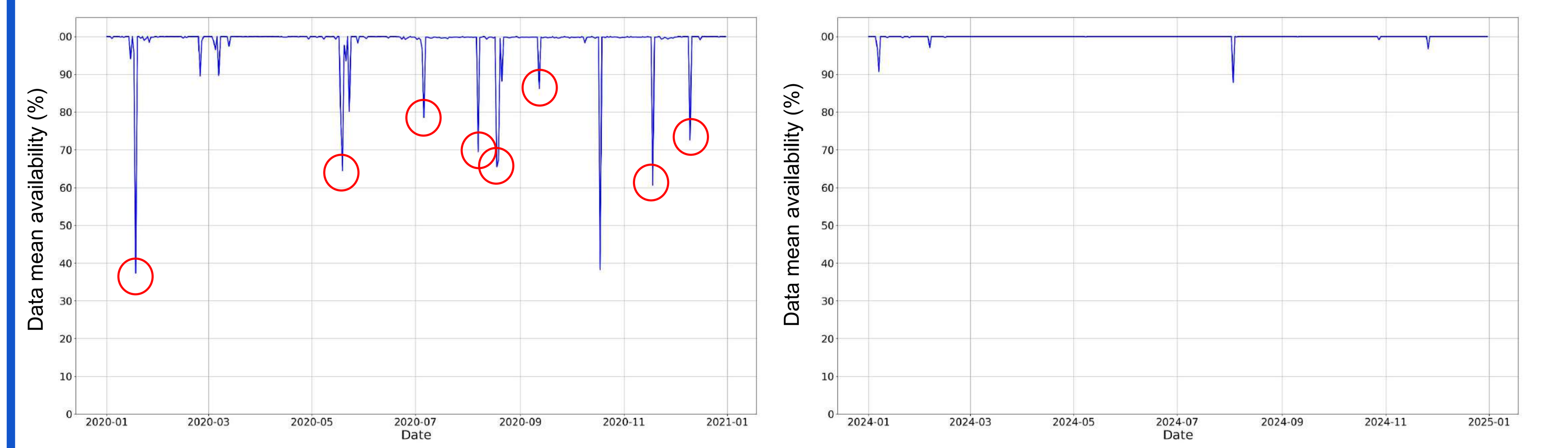


Figure 4 : Example of mean data availability of four stations over time before VPN acquisition (left) and after (right). Data losses common to all stations are highlighted with red circles.

CONTRIBUTION OF THE NETWORK TO THE DETECTION OF SEISMIC EVENTS

Tests of detection and location of seismic events were performed on the 2023-2025/08/14 period using **deep learning automatic picking** (see our detailed workflow on poster #S04p-119).

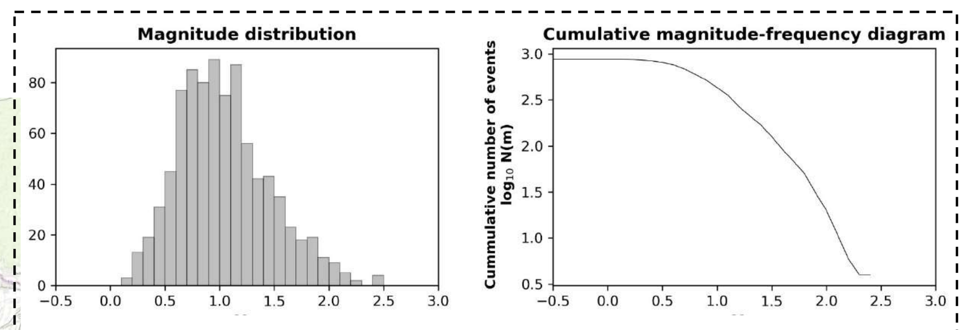


Figure 6: Magnitude (Mw) distribution (left) and cumulative magnitude-frequency diagram (right).

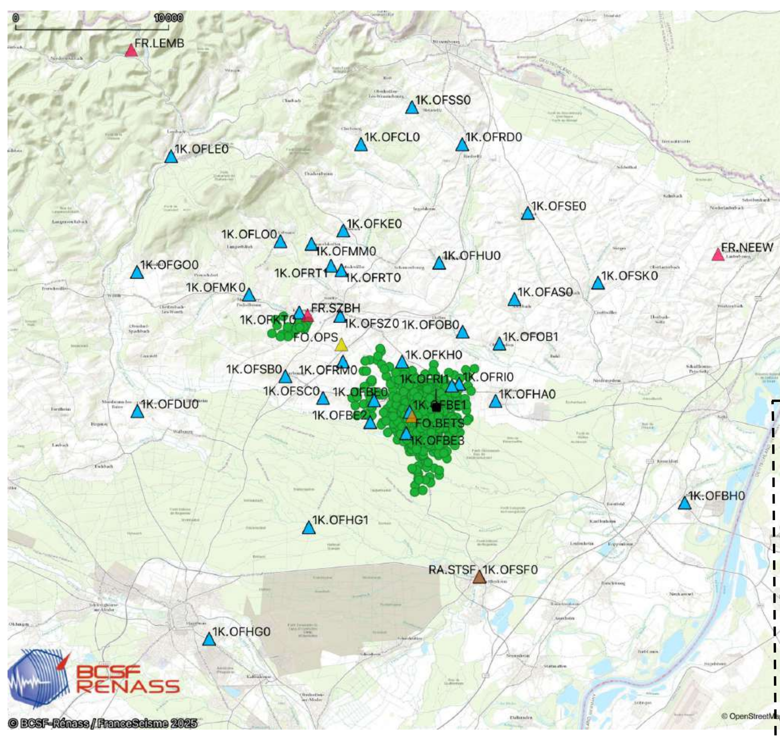


Figure 5: Maps of the seismic events on the 2023-2025-08-14 period located using deep learning method.

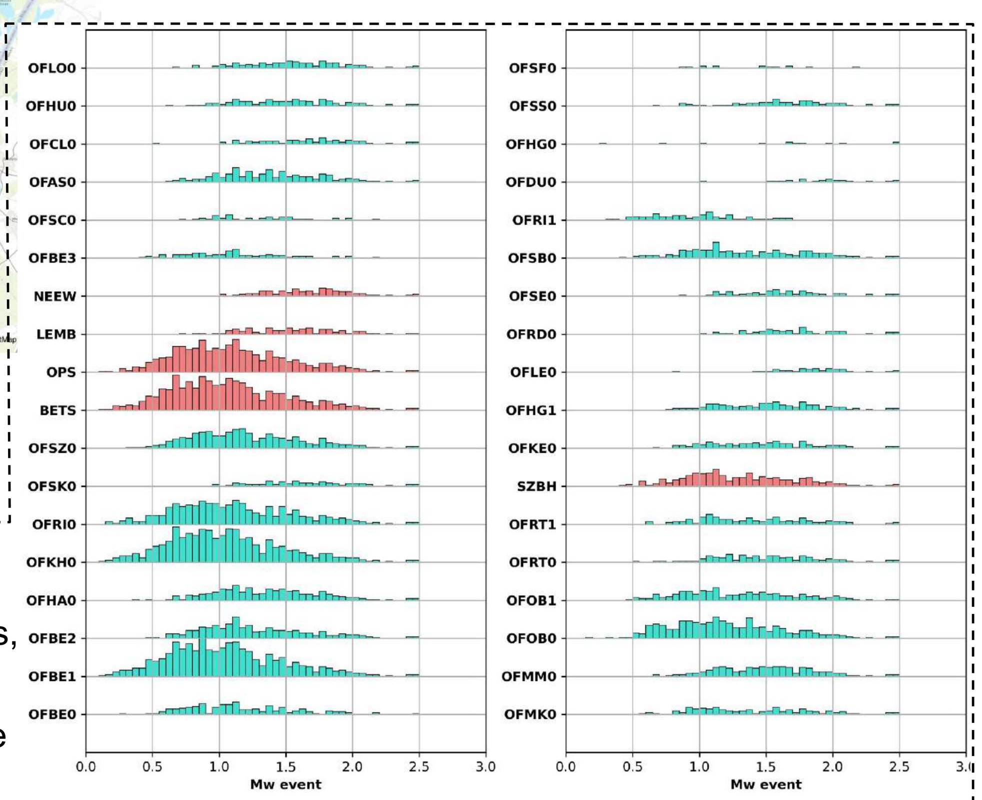


Figure 7: Contribution of each station to magnitude determination (number of events vs. magnitude). Red histograms: permanent stations, cyan histograms: Raspberry Shake stations.

Note: not all station operated over the same time period.

About **1550 small induced seismic events were located using deep learning methods** localized around Rittershoffen and Soultz geothermal power plants, with a high level of confidence. Only a few tens of events were detected by the standard procedure used by BCSF-Rénass, the French National Observation Service.

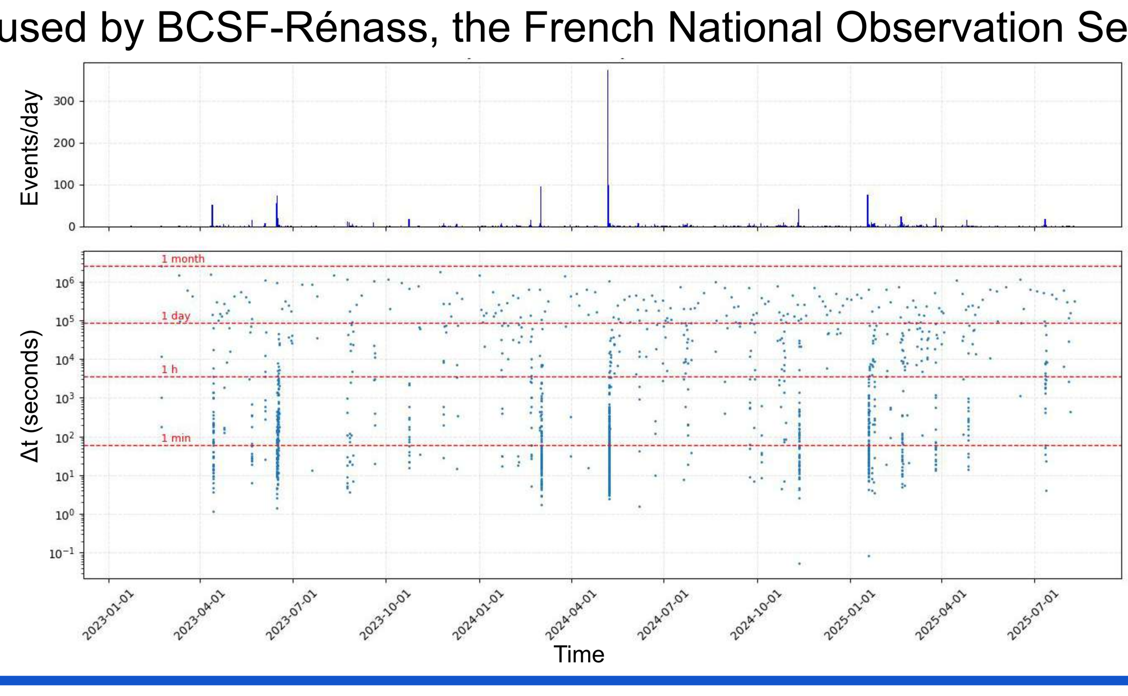


Figure 8: Event activity and inter-event delay plot for automatically detected events.

References:

- Schlupp et al., 2021, Seismocitizen: Contribution of Raspberry Shake dense seismic networks hosted by citizens for natural and anthropic seismicity monitoring. 37th General Assembly of the European Seismological Commission, ESC Athens (Virtual).
- Schmittbuhl et al., 2021, Induced and triggered seismicity below the city of Strasbourg, France from November 2019 to January 2021. DOI: 10.5802/crgeos.71
- Raspberry Shake, S.A. (2016). Raspberry Shake [Data set]. International Federation of Digital Seismograph Networks. https://doi.org/10.7914/SN/AM
- Grunberg, M. and Lambotte, S., 2024: A new workflow for revising the seismicity catalog for mainland France, covering the period 2010-2018, EGU General Assembly 2024, Vienna, Austria, 14–19 Apr 2024, EGU24-5100. https://doi.org/10.5194/egusphere-egu24-5100

Acknowledgements:
This work was supported by ANR PrESENCE (ANR-21-CE05-0033-01) and performed under the framework of the Laboratory of Excellence LABEX ANR-11- LABX-0050-G-EAU-THERMIE-PROFONDE and the Interdisciplinary Thematic Institute GeoT, as part of the ITI 2021-2028 program of the University of Strasbourg, CNRS and Inserm, supported by IdEx Unistra (ANR 10 IDEX 0002) and by SFRI STRAT'US project (ANR 20 SFRI 0012) under the framework of the French Investments for the Future Program.

mturlure@unistra.fr