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Detection and discrimination of low magnitude seismic events: Application to the Armorican Massif

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Context of this study

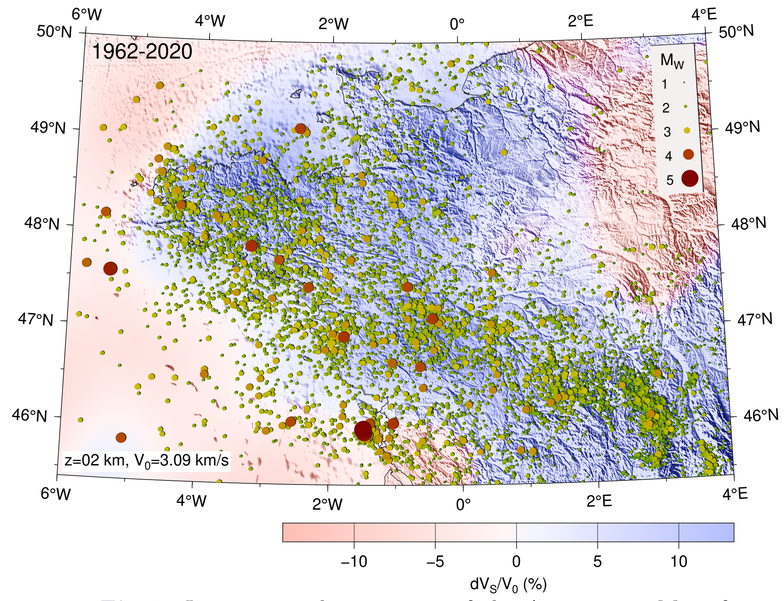

Fig. 1: Instrumental seismicity of the Armoricain Massif between 1962 and 2020 [2]

The instrumental seismicity of the Armorican Massif is often described as diffuse [1] with low-to-moderate magnitude earthquakes (FIG. 1). To study the seismicity of a stable continental region, the detection of seismic events is a crucial step. The unprecedent amount of high quality permanent broadband stations operating since 2018 (FIG. 2), opens the possibility to detect low magnitude seismic events and to better characterize the seismicity of the region. We present here a new toolbox that allows a high sensitive detection/discrimination of natural earthquakes.

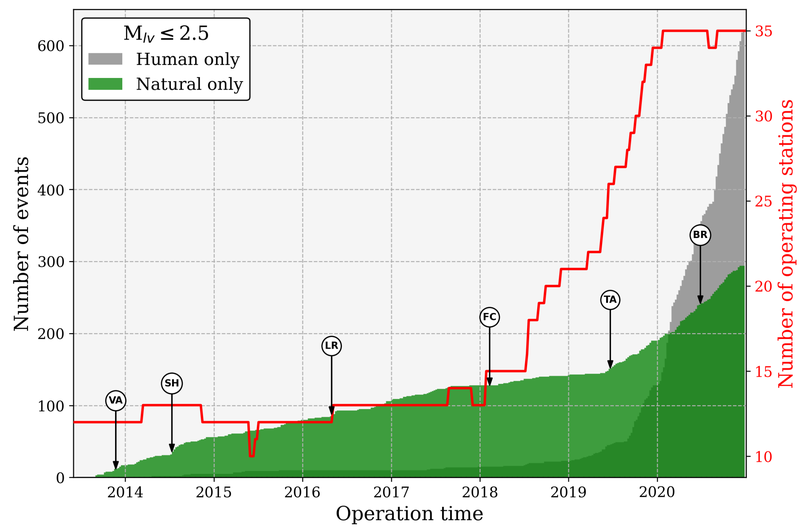

Fig. 2: Cumulative plot of both natural and anthropogenic events of ML $\leq$ 2.5 as a function of time. The amount of permanent operating stations is plotted in red [2]

1. Template Matching

Detection of low amplitude signals by normalized cross-correlation of the raw signal with 55 templates [3,4]. Application from 2021-01-01 to 2021-04-30, using a subset of 20 RLBP stations (FIG. 3).

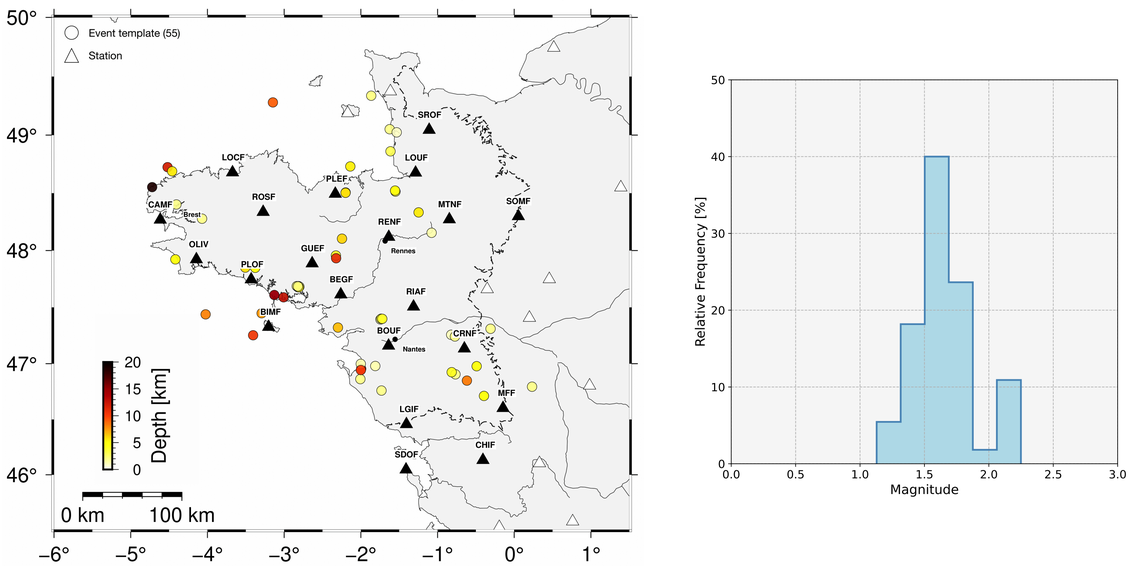

Fig. 3: (left) Location of the 55 events used for template matching. The black triangles correspond to the stations used for the detection. (right) Distribution of the 55 templates magnitudes.

2. Event Discrimination

The events detected can be : seismic events or spurious impulsive signals. The differenciation is made from a **convolutional neural network (CNN)** trained with spectrograms. 2 714 new events were detected during the step 1, of which 603 earthquakes were correctly classified by the CNN (FIG. 4).

Accuracy = 94,8%		**CNN**		
	Events	Seismic	Artefact	Total
Reality	Seismic	603	78	681
	Artefact	62	1971	2033
	Total	665	2049	2714

Fig. 4: Confusion matrix obtained in step 2. This matrix is produced by visual inspection.

3. Seismic Event Discrimination

The final step is devoted to the differenciation between natural and anthropogenic signals. We use the same **CNN** architecture as in step 2 (FIG. 5). Among the 603 events tagged as 'seismic events', 93 natural earthquakes were correctly classified by the CNN (FIG. 6).

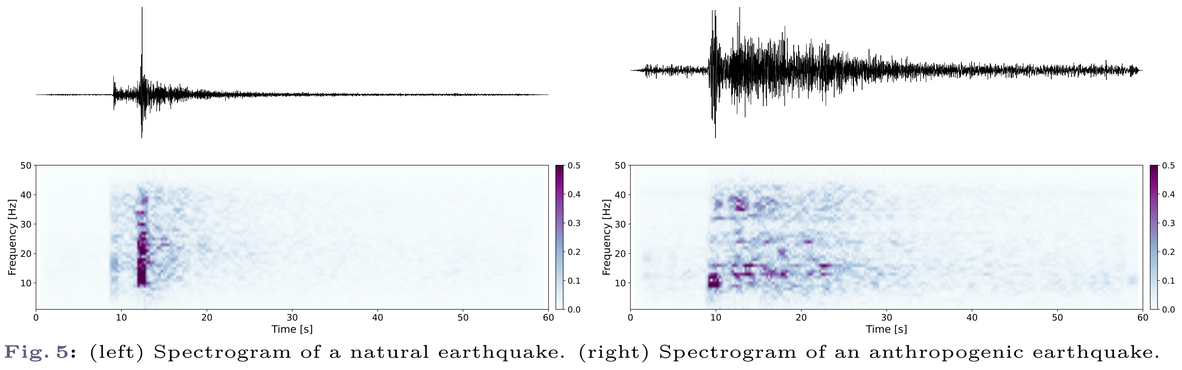

Fig. 5: (left) Spectrogram of a natural earthquake. (right) Spectrogram of an anthropogenic earthquake.

Accuracy = 96,5%		**CNN**		
	Seismic Events	Natural	Anthropogenic	Total
Reality	Natural	93	3	96
	Anthropogenic	18	489	507
	Total	111	492	603

Fig. 6: Confusion matrix obtained in step 3. This matrix is produced by visual inspection.

Preliminary Results

We detect **93 new natural seismic events** and 71 of them are picked at enough stations to be located (FIG. 7). When adding the BCSF-RéNaSS bulletin, the total amount of characterized natural earthquakes reaches 112.

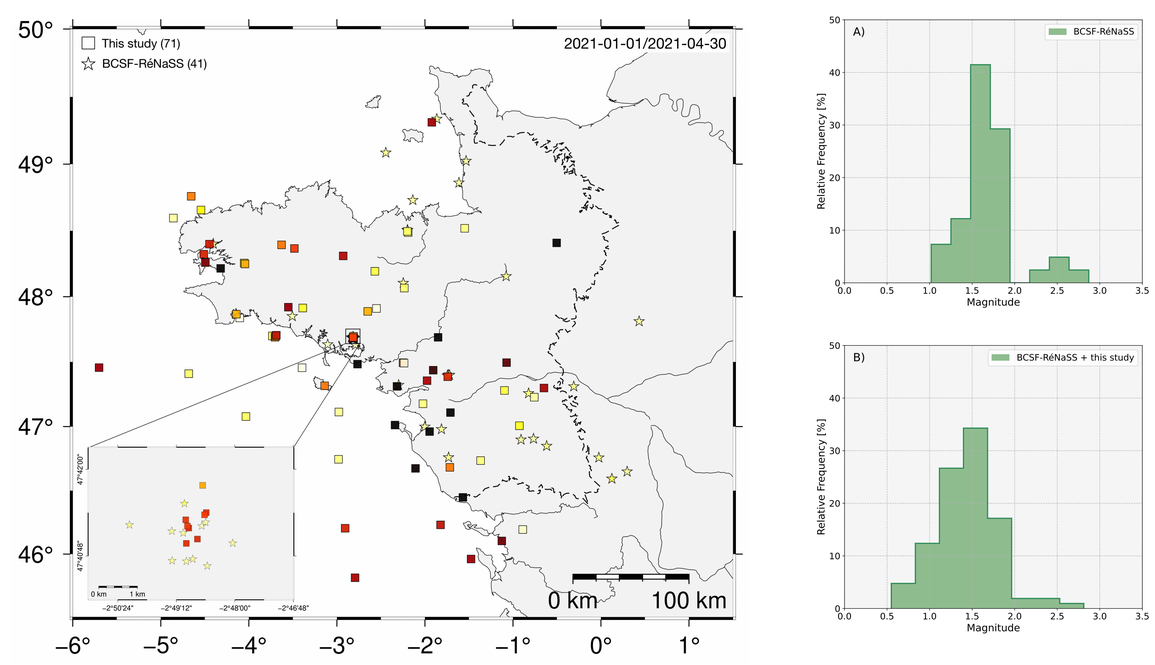

Fig. 7: (left) Location of natural earthquakes located by the BCSF-RéNaSS and by this study. The color scale, corresponding to the depth, is the same as FIG. 3. (right) Distribution of earthquake magnitudes (A) of the BCSF-RéNaSS bulletin, (B) of the BCSF-RéNaSS bulletin with the new earthquakes detected in this study.

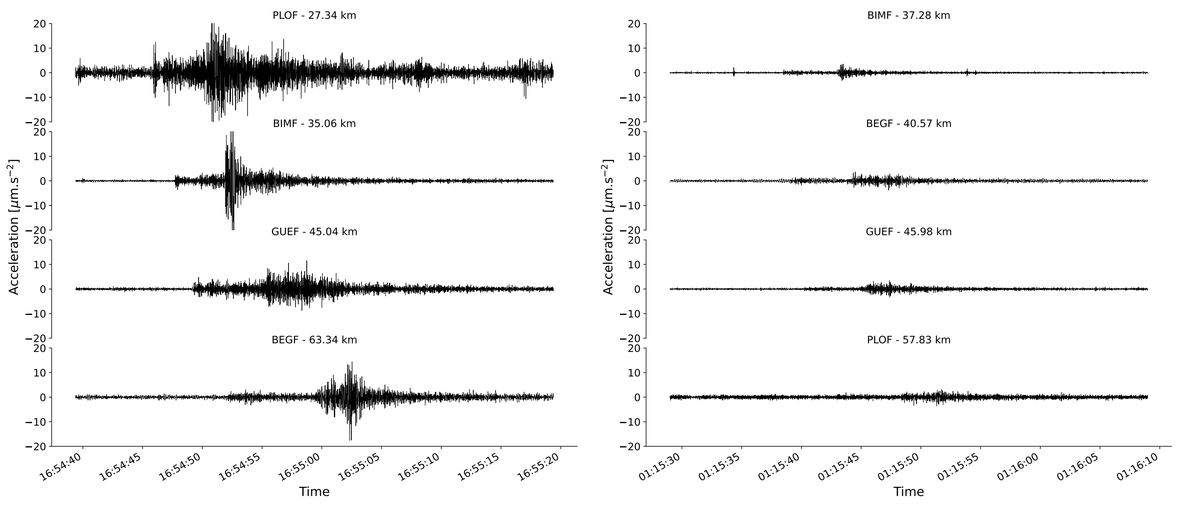

Fig. 8: Seismograms of the lowest magnitude events located (left, Ml=1, 2021-03-20) by BCSF-RéNaSS and (right, Md=0.6, 2021-04-29) in this study. The signals are filtered with a bandpass between 5 and 45 Hz.

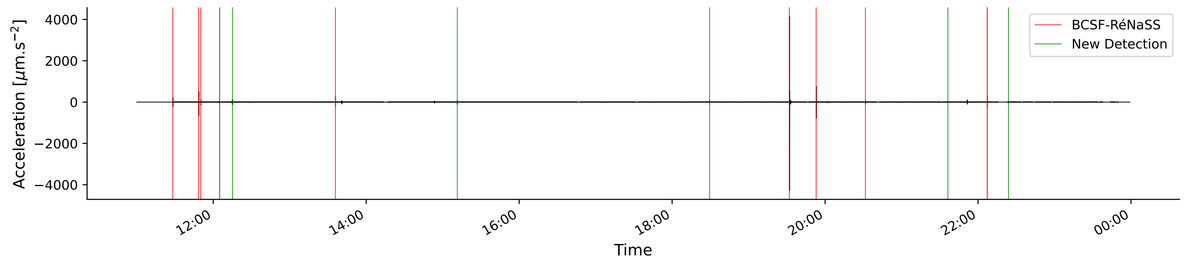

Fig. 9: Signal recorded by the GUEF station on February 17, 2021. In red, the arrival times of the earthquakes detected by the BCSF-RéNaSS and, in green, the arrival times of the additional earthquakes detected by this study.

Conclusions and Perspectives

This method allows to extract, from the raw continuous seismic signal, a **catalog of natural seismic events** including low amplitude earthquakes not present in the bulletins. In the future, this method will be applied on larger databases (permanent and temporary networks and post-seismic experiments).

References

[1] S. Judenherc et al (2002), [2] E. Beucler et al (2021) [3] S. J. Gibbons and F. Ringdal (2006), [4] Peng and Zhao (2009).