Two dense seismic campaigns in the French Rhône valley for characterizing site effects

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INTRODUCTION & MOTIVATIONS

Superficial geological layers can strongly modify the surface ground motion induced by an earthquake. These so-called **site effects** are highly variable from one site to another and still difficult to quantify for some geological configurations (e.g. deep valleys). That is why **site-specific studies** can greatly contribute to improve the hazard prediction at a specific site. However site-specific studies have historically been considered difficult to carry out in **low-to-moderate seismicity regions**.

The French-German DARE project (IRSN; Univ. of Potsdam; GFZ Potsdam; Univ. Grenoble Alpes; 2020-2023) aims to propose new approaches based on the use of **dense seismic arrays** for the estimation of site effects in low-to-moderate seismicity regions. In particular the contribution of **seismic ambient noise** will be investigated as alternative seismic data of obvious interest in these regions where moderate to large earthquakes have long return periods.

The DARE project targets the **heavily industrialized area** of the **widespread Tricastin Nuclear Site (TNS)** in the French Rhône valley. TNS is located above an ancient Rhône canyon. The strong lithological contrast between the sedimentary filling of the canyon and the substratum, as well as its expected confined geometry make this canyon a good candidate for generating site effects.

In order to characterize the geological medium and its impact on the seismic motion (amplification, duration lengthening…), 2 complementary seismic campaigns have been conducted. These 2 campaigns are presented here.

Beyond the study of this specific canyon, the exploitation of these 2 datasets within the framework of the DARE project will contribute to improve seismic site effect estimation in terms of 1) methodological developments, 2) understanding of physical processes leading to seismic amplifications observed in complex geological structures and 3) observations on deep western European sedimentary valleys.

INSTRUMENT DEPLOYMENTS

Target zone:

- The local geology of the canyon remains poorly documented in the region of Tricastin. *Gélis et al* (subm.) provide some first insights about the canyon rims (Fig. 1) and the subsurface characteristics locally. From these first observations, we targeted a **10 km by 10 km area** surrounding the imprint of sediment deposits and TNS. This extension embeds nearby outcrops of cretaceous series incised by the canyon (↔ « reference rock » sites for site effect estimation).
- We included the area of **La Rouvière fault** that ruptured during the Mw4.9 Le Teil earthquake that occurred about 20 km northward of TNS on Nov. 11, 2019 (*Ritz et al., 2020*).
- Industrialized area: TNS; 5 towns (>45 000 inhabitants); A7 highway; TGV railroad; CNR hydroelectric dam; cultivated fields…

Deployment #1 (target = seismic ambient noise)

- **>400** all-in-one 3-component Geospace GSX **nodes** (5 Hz)
- **1 month**: 17 Feb. 2020 – 18 March 2020
- Mainly public land (roadsides) + TNS and CNR domain
- Interstation distance of ~800 m
- Denser in the SE part (where the canyon is expected to be the deepest and the narrowest – interstation distance of ~250 m – red square on Fig. 1)
- 6 nodes out of the 10 km x 10 km area (including 1 on La Rouvière fault)
- 402 nodes retrieved over 409 deployed (+23 found unburied)

Deployment #2 (target = seismicity – including teleseismic events, local and regional seismicity)

- **49 broadband** stations (47 DATA-CUBE3 + 2 Guralp CMG6-TD)
- **>8 months**: 14 Sept. 2020 – 27 May 2021
- Half/half on public/private land
- Various geological formations (« reference rock » sites) instrumented
- 3 stations on La Rouvière fault
- 3 sites instrumented since 2016 (*Gélis et al.,* 2021)

These 2 campaigns with complementary scales (spatial, temporal) will allow us to compare the results obtained from the analysis of seismic ambient noise and seismicity in the framework of site effect estimation.

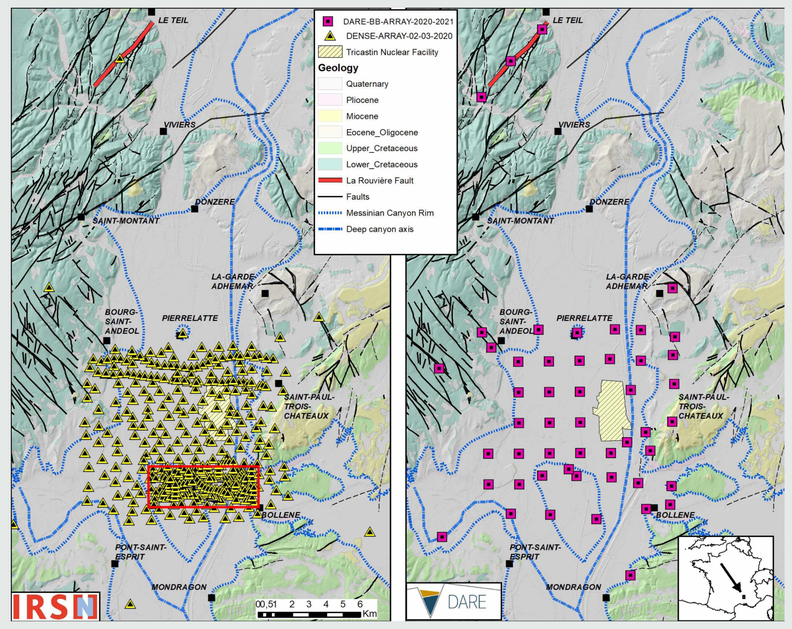

***Fig. 1**: Map of the 2 networks deployed within the framework of the DARE project.*

FIRST DATA ANALYSIS

Dataset #1: Ambient noise Data

- The possibility to use ambient noise data for site effect estimation (i.e. seismic amplification) will be explored. This requires a thorough analysis of the continuous data (industrialized area => strong local noise sources)
- Quality estimate: Catalog for the whole dataset (single-node sheets –Fig. 2)
- <1% of the stations considered unusable; ~2/3 of the stations tagged with a good quality label; ~1/3 tagged with a medium quality label (i.e.must be exploited with caution – e.g. freq./time selection)

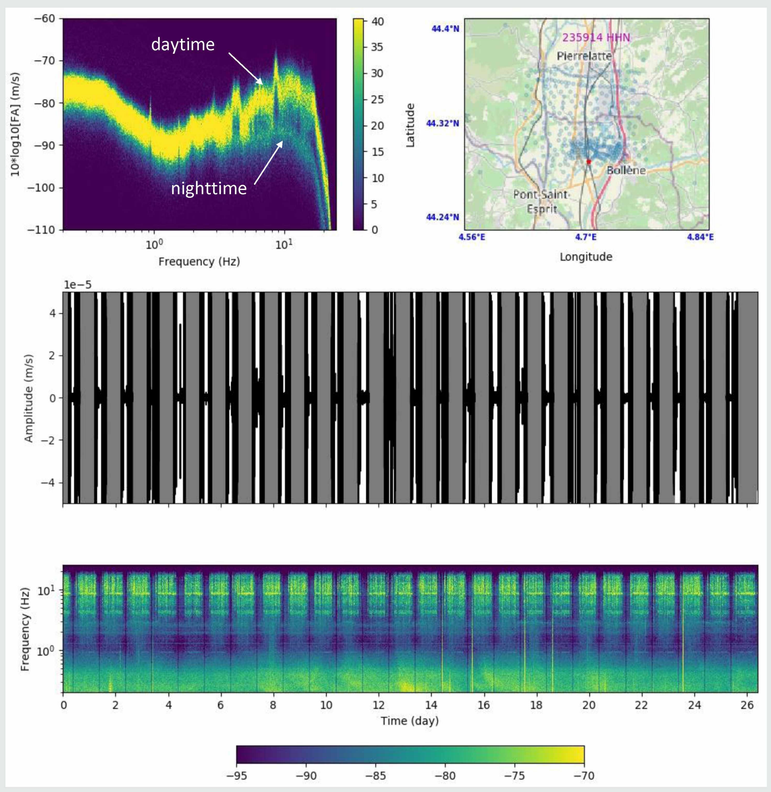

***Fig. 2**: Example of a quality catalog sheet for one node located close to the TGV railroad (PhD of L. Gisselbrecht). A strong diurnal variation is visible in high-frequency noise levels. This illustrates the signature of local anthropogenic noise sources in this industrialized area.*

Dataset #2: Seismicity Data

- Seismicity data will be processed for site effect estimation
- The question of exploitable seismicity in this industrialized area located in a low-to-moderate region will be at the heart of the analysis.
- Dataset #2 has been available late August 2021. As a preliminary information, Fig. 3 and Table 1 give a general idea of the local, regional and global seismicity during the recording period. The actual usable seismicity will result from the data analysis.

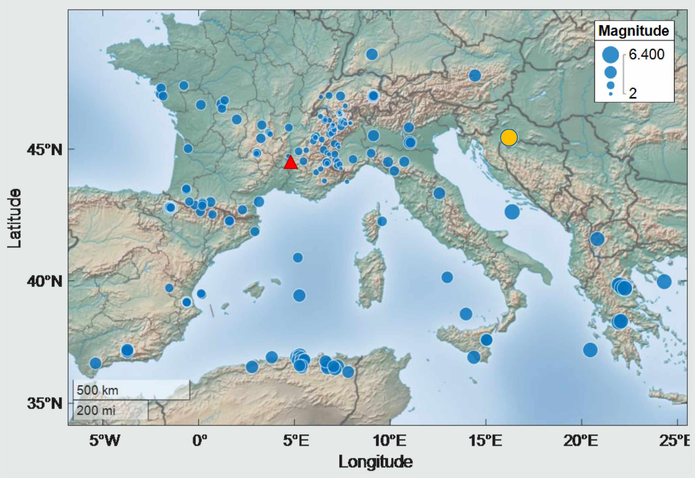

***Fig. 3**: Map of seismicity (2<M<7) in the Euro-Mediterranean region during Deployment #2. A lower-bound magnitude threshold was used (relative to the distance to our network - red triangle).*

***Table 1**: List of worldwide M>7 earthquakes that occurred during Deployment #2.*

Date	Time UTC	Latitude	Longitude	Depth	Mw	Region Name
21/05/2021	18:04:14	34,58	98,36	10	7,4	SOUTHERN QINGHAI, **CHINA**
20/03/2021	09:09:44	38,56	141,51	40	7	NEAR EAST COAST OF HONSHU, **JAPAN**
04/03/2021	19:28:35	-29,54	-177,28	25	8,1	KERMADEC ISLANDS, **NEW ZEALAND**
04/03/2021	17:41:25	-29,6	-177,8	49	7,4	KERMADEC ISLANDS, **NEW ZEALAND**
04/03/2021	13:27:35	-37,52	179,44	16	7,3	OFF E. COAST OF N. ISLAND, **NEW ZEALAND**
13/02/2021	14:07:51	37,7	141,72	60	7,1	NEAR EAST COAST OF HONSHU, **JAPAN**
10/02/2021	13:19:59	-23,25	171,49	10	7,7	SOUTHEAST OF **LOYALTY ISLANDS**
21/01/2021	12:23:04	5,02	127,53	92	7	**PHILIPPINE** ISLANDS REGION
30/10/2020	11:51:25	37,91	26,84	10	7	DODECANESE ISLANDS, **GREECE**
19/10/2020	20:54:40	54,7	-159,76	40	7,5	SOUTH OF **ALASKA**

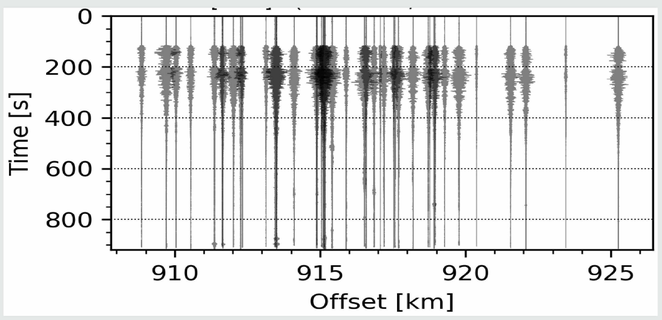

***Fig. 4**: Recordings of the Petrinja Earthquake (Croatia, 12/29/2020, Mw6.4, yellow circle on Fig. 3) on network #2 (Broadband stations). North component filtered between 0.7 and 5 Hz.*

PERSPECTIVES

Scientific perspectives (DARE project)

Several approaches will be adopted to estimate the site effects. This strategy combining different seismic observations (ambient noise & seismicity) and approaches (numerical & empirical approaches) will allow us to propose and compare alternative methods; evaluate their own interests, uncertainties and limitations. In particular, we will investigate the contribution of the use of dense seismic arrays and ambient noise-based techniques for the implementation of site-specific studies using relatively short temporary experiments in low-to-moderate seismicity regions.

Public Distribution

These 2 datasets will be made publicly available in fall 2023.

REFERENCES

C. Gélis et al., *Estimation of the local seismic amplification on an industrialized site in the French Rhône Valley* (in revision at PAGEOPH)

J.F. Ritz et al., *Surface rupture and shallow fault reactivation during the 2019 Mw 4.9 Le Teil earthquake, France,* Nature comm. (2020)

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DARE project: https://anr.fr/Project-ANR-19-CE31-0029