Postdoc position: Ocean Bottom Noise Shazam
Signal processing & data science applied to marine seismology data
2022–2023, France, Brittany, Brest

- Document date: 2022-01-25 23:30:51+01:00
- Project: ANR BRUIT-FM, Compréhension, prévention et utilisation du bruit sismologique en fond de mer (PI: Wayne Crawford)
- Postdoctoral offer details and updates

Context

Marine seismology has made tremendous technological advances in the past decades: data recorded at the seafloor by ocean bottom seismometers (OBSs) are becoming widely available (*e.g.* IRIS consortium `https://ds.iris.edu/ds/nodes/dmc/data/types/waveform-data/`). An OBS is a multicomponent instrument able to continuously record pressure and earth motion. There are two types of OBSs: short-period instruments for recording high-frequency motions, and long-period instruments for acquiring a wider range of motions (*cf.* INSU-IPGP national OBS facility `https://parc-obs.insu.cnrs.fr/`). With both instruments, OBSs record a superposition of a broad variety of signals generated by solid earth, ocean wave, biologic, ship sources and noise. These signals can be very different in amplitude, duration and frequency content. However, they can also overlap in those domains, making them hard to isolate from each other. That is why OBS data cannot yet be fully exploited by the seismological community, as they require more advanced processing and identification techniques.

The multidisciplinary ANR project BRUIT-FM (PI: Wayne Crawford) aims at identifying and exploiting OBS-recorded signals. Its goal is to catalogue the diversity of signal sources, understand their contributions to local and global seismic noise and to enhance specific signals of interest by removing others. The project emphasizes on three main axes:

i understanding the generation of ocean-wave induced seismic noise,

ii characterizing the seafloor soundscape at frequencies higher than 1 Hz,

iii improving signals' separation and noise removal at seafloor stations.

The project gathers experts in Seismology, Acoustics, Oceanography and Signal Processing from French Research Organisms or laboratories (IPGP, Ifremer, SHOM, UBO, ESIEE/IFPEN, GIPSA-Lab, ENSTA), one industrial partner (iXblue) developing the technology of a rotational seismometer and international experts from GEOB3N (Spain) and LDEO (USA).

Subject

This postdoctoral position funded by the BRUIT-FM project primarily aims at developing signal processing and machine learning techniques to classify and separate signals recorded by OBSs and to enhance earthquake waveforms and microseismic noise. It devotes to a better exploitation of non-seismological signals for defining a seafloor soundscape. Hence the moniker "Ocean Bottom Noise Shazam", from the famous music retrieval/identification application (Wan03).

A first step will be focused on characterizing the main features of signals recorded by OBSs in time, frequency, time-frequency/scale (GDP09), multisensor domains to define specific patterns. Targeted signals to isolate/remove are in the low frequency spectrum (<1 Hz):

i compliance noise generated by ocean waves characterized by a frequency content below 0.04 Hz dependent on the water depth (CW00);

ii amplitude-varying noise induced by bottom currents much larger on horizontal components but that can leak on the vertical sensor when the seismometer is tilted (CW00; BFR15; JGA+19).

The ANR BRUIT-FM will also focus on detecting different sources, varying in time and space, constituting the seismic noise related to primary and secondary microseisms in this part of the frequency spectrum (MSS19).
In the high frequency spectrum (> 1 Hz), earthquake signals can be polluted by:

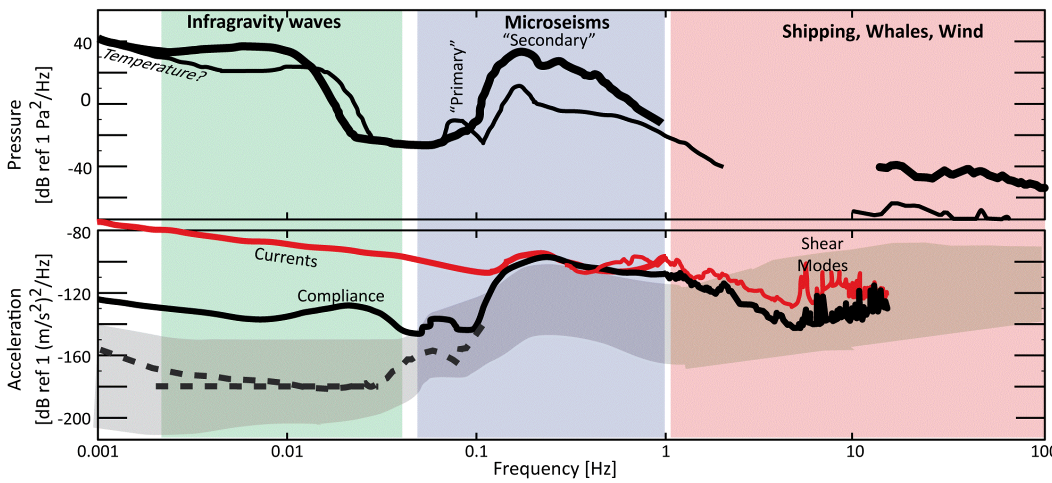

Figure 1: Seafloor seismometer spectra. Green region is the "soundscape" band. Top: Pressure. Thick lines are relatively high, thin relatively low values. Bottom: Acceleration. Red line: horizontal channels; black lines; vertical. Dashed black line is cleaned spectra (CW00). Grey background: Global seismometer noise bounds (Pet93; WM19). Spectral lines derived from (BSDO97; CSB06; Web98; MAW08; Hil09).

i marine mammal vocalizations such as chirp-like signals emitted by fin whales (KN21) or chorus footprint (BDBB18), which may overlap with seismic signals while sharing a same frequency content (Figure 2),

ii ship noise characterized by sparse frequency peaks (TBD$^+$20).

The second step will dealing with exploiting the above features/patterns, global communications schemes, and sensor fusion to develop efficient algorithms for adaptive signal separation and noise removal. A first approach would consist in using adaptive template subtraction obtained by recording, modelling or learning signals of interested, following the methodology from (VLRH$^+$12). Shaping filters will first be developed, in a complex domain (Fourier, spectrogram, wavelet (GDP09)), to perform an optimization of matched template adaptation in amplitude, time and frequency. In addition, frontier techniques will be explored such as broad source separation methods relying on very-limited modelling assumptions (*e.g.* sparsity in (NSD14)). The latter could be used to account for non-stationnary noise floor drifts in a time-frequency or time-scale domain. If suitable, deconvolution or restoration from the template database could be devised (CCDP20). The performance of developed approaches will be quantified by using reference algorithms such as the transfer function method first introduced by (CW00) for removing compliance signal and tilt noise that will be revisited by Martin Schimmel during the project based on improved data selection and segmentation (SSL$^+$21). Additional insights could be borrowed from recent work on marime mammal communication and deep learning ((VML21) or Project CETI, Cetacean Translation Initiative, `https://www.projectceti.org/`).

Contact information

- Supervision: Stéphan Ker (Ifremer, stephan.ker@ifremer.fr); Laurent Duval (ESIEE/IFP Energies nouvelles, laurent.duval@ifpen.fr)
- Location: Ifremer, Centre de Brest
- Duration: 16 months
- Starting date: Spring/Summer 2022

Application

- Candidate profile: PhD with strong interest in spectral analysis, adaptive filtering, machine learning, with a taste of physics. Languages: C/C++, Python/Matlab or similar

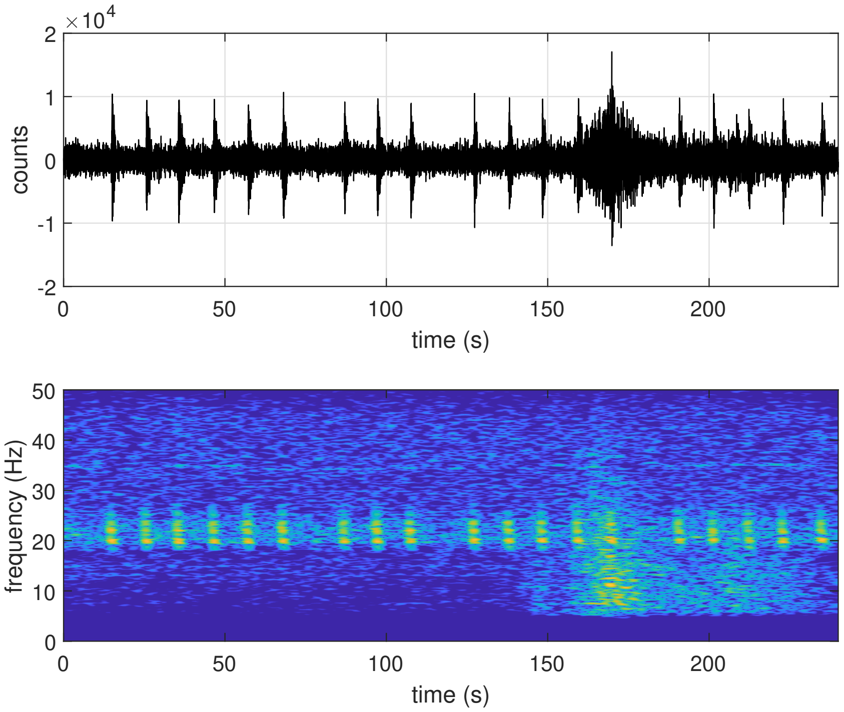

Figure 2: Fin whale vocalization overlapping with a seismic signal in time and frequency.

- Send resume, motivation letter (specific to this offer) and useful information (publication list, relevant papers) to supervisors (naming pattern: **LASTNAME_Firstname-Resume.*** or **LASTNAME_Firstname-Letter.***)

References

[BDBB18] L. Bouffaut, R. Dreo, A.-O. Boudraa, and G. Barruol. Passive stochastic matched filter for Antarctic blue whale call detection. *J. Acoust. Soc. Am.*, 144(2):955–965, 2018.

[BFR15] S. W. Bell, D. W. Forsyth, and Y. Ruan. Removing noise from the vertical component records of Ocean-Bottom Seismometers: Results from year one of the Cascadia initiative. *Bull. Seismol. Soc. Amer.*, 105(1):300–313, 2015.

[BSDO97] C. R. Bradley, R. A. Stephen, L. M. Dorman, and J. A. Orcutt. Very low frequency (0.2-10.0 Hz) seismoacoustic noise below the seafloor. *J. Geophys. Res. Solid Earth*, 102(B6):11703–11718, 1997.

[CCDP20] A. Cherni, E. Chouzenoux, L. Duval, and J-C. Pesquet. SPOQ ℓ_p-over-ℓ_q regularization for sparse signal recovery applied to mass spectrometry. *IEEE Trans. Signal Process.*, 68:6070–6084, 2020.

[CSB06] W. C. Crawford, R. A. Stephen, and S. T. Bolmer. A second look at low-frequency marine vertical seismometer data quality at the OSN-1 site off Hawaii for seafloor, buried and borehole emplacements. *Bull. Seismol. Soc. Amer.*, 96(5):1952–1960, 2006.

[CW00] W. C. Crawford and S. C. Webb. Removing tilt noise from low frequency (<0.1 Hz) seafloor vertical seismic data. *Bull. Seismol. Soc. Amer.*, 90(4):952–963, 2000.

[GDP09] J. Gauthier, L. Duval, and J.-C. Pesquet. Optimization of synthesis oversampled complex filter banks. *IEEE Trans. Signal Process.*, 57(10):3827–3843, Oct. 2009.

[Hil09] J. A. Hildebrand. Anthropogenic and natural sources of ambient noise in the ocean. *Mar. Ecol. Prog. Ser.*, 395:5–20, 2009.

[JGA+19] H. A. Janiszewski, J. B. Gaherty, G. A. Abers, H. Gao, and Z. C. Eilon. Amphibious surface-wave phase-velocity measurements of the Cascadia subduction zone. *Geophys. J. Int.*, 217:1929–1948, 2019.

[KN21] V. Kuna and J. L. Nábelek. Seismic crustal imaging using fin whale songs. *Science*, 371:731–735, 2021.

[MAW08] M. A. McDonald, J. A. Hildebrand, and S. M. Wiggins. A 50 Year comparison of ambient ocean noise near San Clemente Island: A bathymetrically complex coastal region off Southern California. *J. Acoust. Soc. Am.*, 124(4), 2008.

[MSS19] M. Meschede, E. Stutzmann, and M. Schimmel. Blind source separation of temporally independent microseisms. *Geophys. J. Int.*, 216(2):1260–1275, 2019.

[NSD14] X. Ning, I. W. Selesnick, and L. Duval. Chromatogram baseline estimation and denoising using sparsity (BEADS). *Chemometr. Intell. Lab. Syst.*, 139:156–167, Dec. 2014.

[Pet93] J. R. Peterson. Observations and modeling of seismic background noise. Technical report, U.S. Geological Survey, 1993.

[SSL+21] M. Schimmel, E. Stutzmann, P. Lognonné, N. Compaire, P. Davis, M. Drilleau, R. Garcia, D. Kim, B. Knapmeyer-Endrun, V. Lekic, L. Margerin, M. Panning, N. Schmerr, J. R. Scholz, A. Spiga, B. Tauzin, and B. Banerdt. Seismic noise autocorrelations on Mars. *Earth Space Sci.*, 8(6), June 2021.

[TBD+20] A. Trabattoni, G. Barruol, R. Dreo, A. O. Boudraa, and F. R. Fontaine. Orienting and locating ocean-bottom seismometers from ship noise analysis. *Geophys. J. Int.*, nov 2020.

[VLRH+12] S. Ventosa, S. Le Roy, I. Huard, A. Pica, H. Rabeson, P. Ricarte, and L. Duval. Adaptive multiple subtraction with wavelet-based complex unary Wiener filters. *Geophysics*, 77(6):V183–V192, Nov.-Dec. 2012.

[VML21] W. Vickers, B. Milner, and R. Lee. Improving the robustness of right whale detection in noisy conditions using denoising autoencoders and augmented training. In *Proc. Int. Conf. Acoust. Speech Signal Process.*, 2021.

[Wan03] A. L.-C. Wang. An industrial-strength audio search algorithm. In *Proc. International Society for Music Information Retrieval (ISMIR) Conference*, pages 7–13, 2003.

[Web98] S. C. Webb. Broadband seismology and noise under the ocean. *Rev. Geophys.*, 36(1):105–142, 1998.

[WM19] E. Wolin and D. E. McNamara. Establishing High-Frequency noise baselines to 100 Hz based on millions of power spectra from IRIS MUSTANG. *Bull. Seismol. Soc. Amer.*, 110(1):270–278, 2019.