Seismic noise characterization in NE Iberia

Samuel Jorde[1], Martin Schimmel[1], Pilar Sánchez-Pastor[1], Helena Seivane[1] and Jordi Díaz[1]

[1]Geosciences Barcelona (GEO3BCN – CSIC), Barcelona, Spain

sjorde@geo3bcn.csic.es

Study motivation

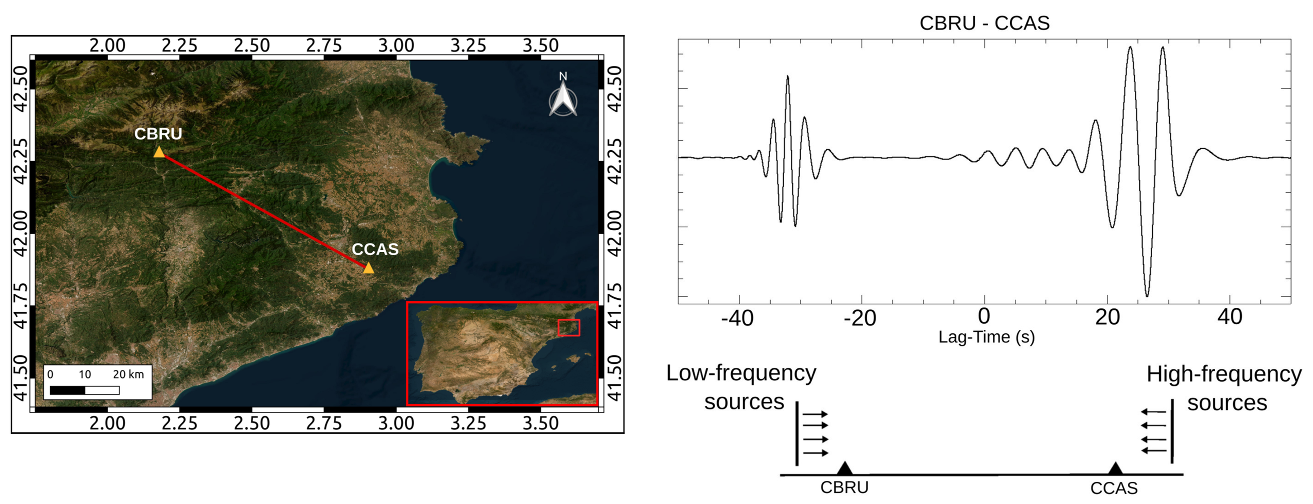


Fig. 1. CBRU - CCAS cross-correlation showing the bimodal distribution of frequencies.

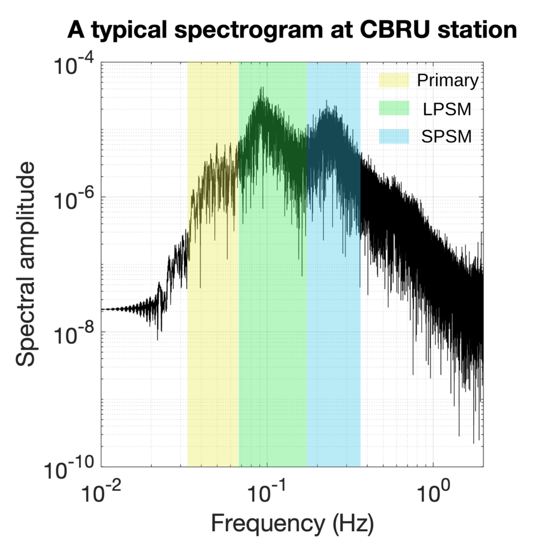


Fig. 2. Typical spectrogram at the CBRU permanent station.

While performing cross-correlations of seismic noise recordings from the permanent stations in NE Iberia, we observe a clear bimodal distribution of frequencies between the causal and acausal part.

The typical noise spectrograms of the permanent stations show a splitting of the secondary microseism into the Long-Period Secondary Microseism (LPSM) and the Short-Period Secondary Microseism (SPSM).

Seasonal variations

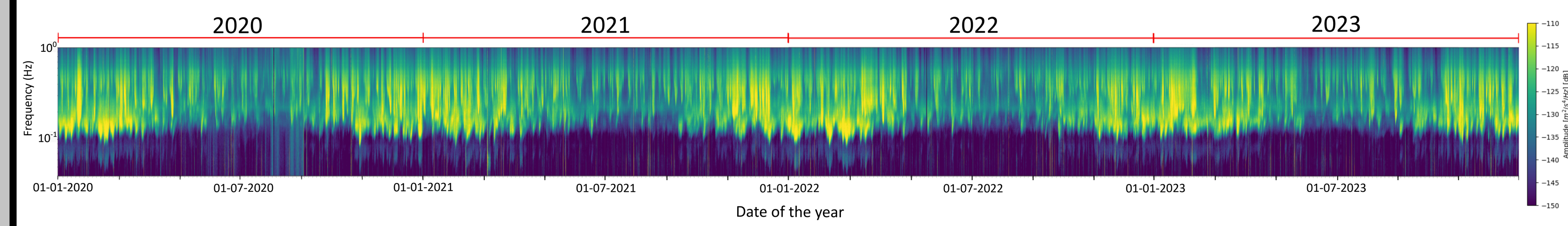


Fig. 3. Amplitude spectrum over four years for the CBRU permanent station.

We observe the splitting of the secondary microseism into LPSM and SPSM throughout four different years, with stronger amplitudes during the Northern Hemisphere winter. Using only cross-correlations, we are able to study these seasonal variations independently for LPSM and SPSM by considering the causal and acausal parts, respectively. By using monthly stacks for each year, we observe seasonal variations in both amplitude and frequency. Amplitude increases during the winter months for LPSM, while SPSM does not show any significant amplitude variation. Furthermore, LPSM and SPSM exhibit an increase in the frequency of the maximum amplitude during the summer months.

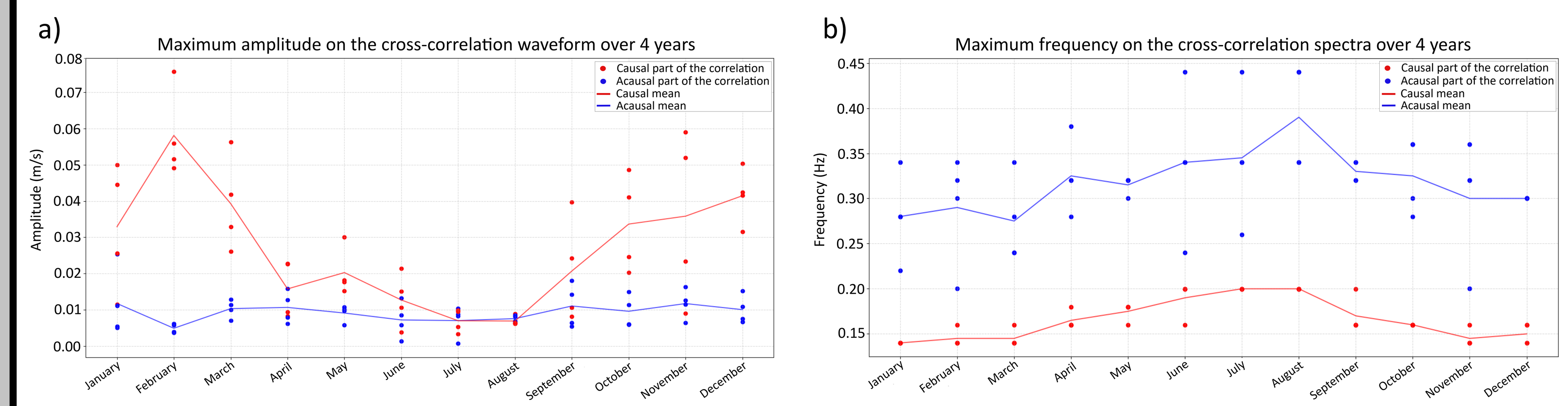
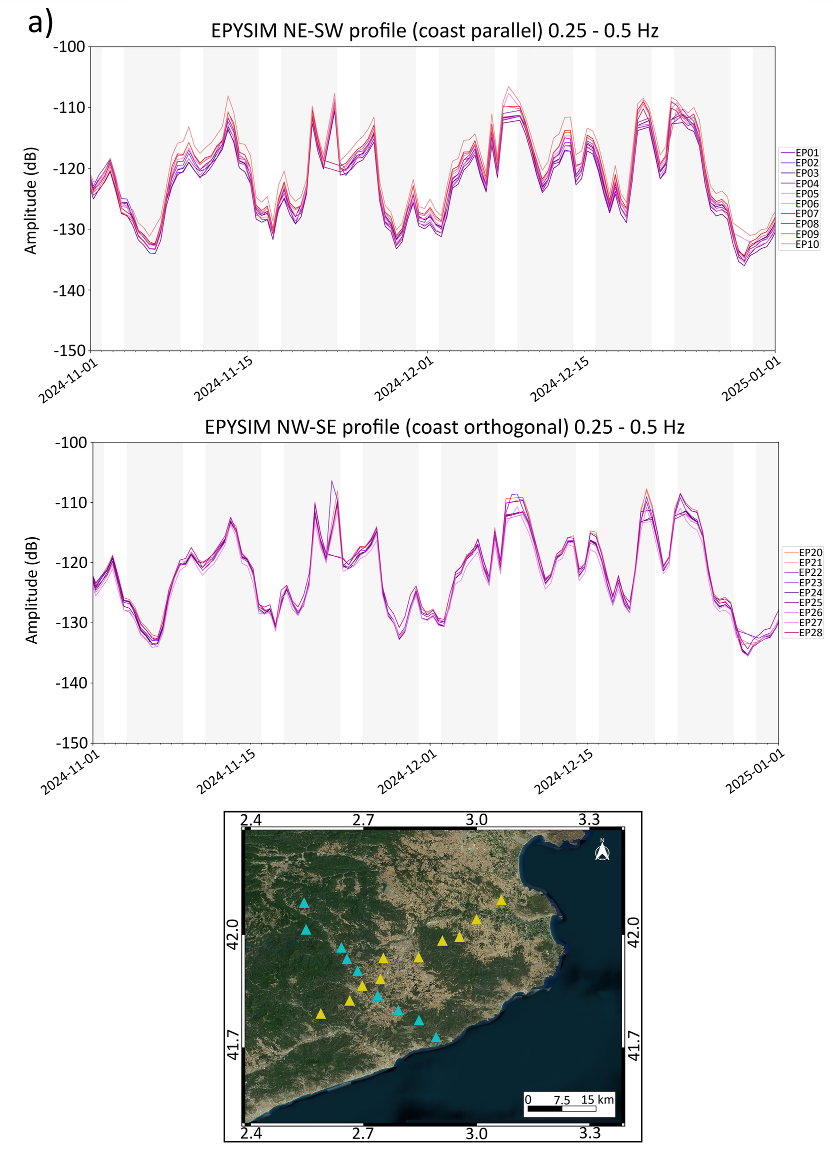


Fig. 4. Maximum amplitude (a) and their corresponding frequencies (b) for the causal and acausal part of the cross-correlations, divided into monthly stacks over four years.

Attenuation



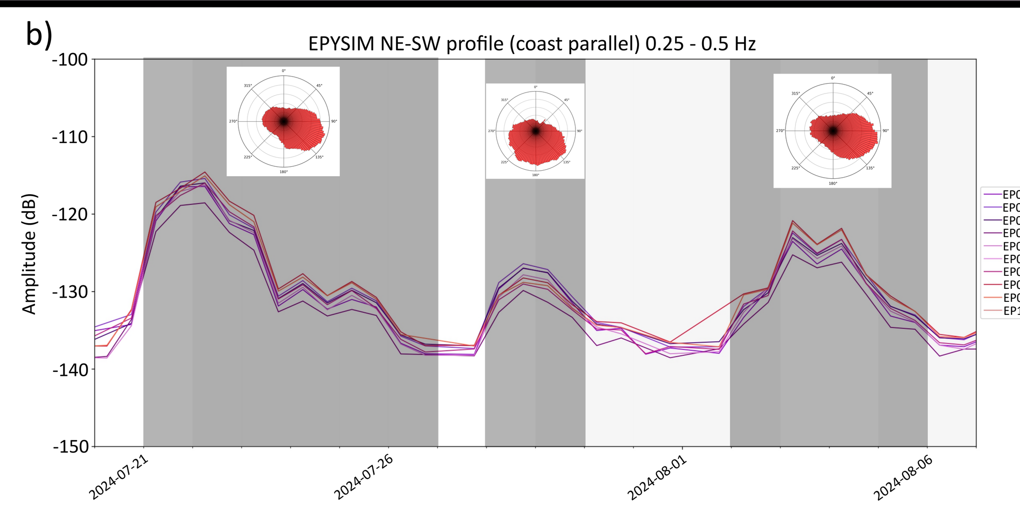


Fig. 5. a) Amplitude attenuation along the two profiles: parallel (upper panel) and orthogonal (lower panel) to the coast. b) Zoom of the parallel profile, showing back-azimuths of Rayleigh waves for different time periods.

Within the EPYSIM project, we deploy two different broadband profiles: one parallel and the other orthogonal to the coast. Figure 5 shows the amplitude evolution along these two station profiles.

We observe stronger amplitude attenuation along the profile parallel to the coast, compared to the orthogonal one. By analyzing specific time periods along the parallel profile, we identify several intervals where the attenuation pattern is reversed. We perform a Rayleigh-wave polarization analysis during these intervals and find that the back-azimuth, which points in the direction of the noise sources, changes significantly for these two distinct patterns.

Polarization analysis

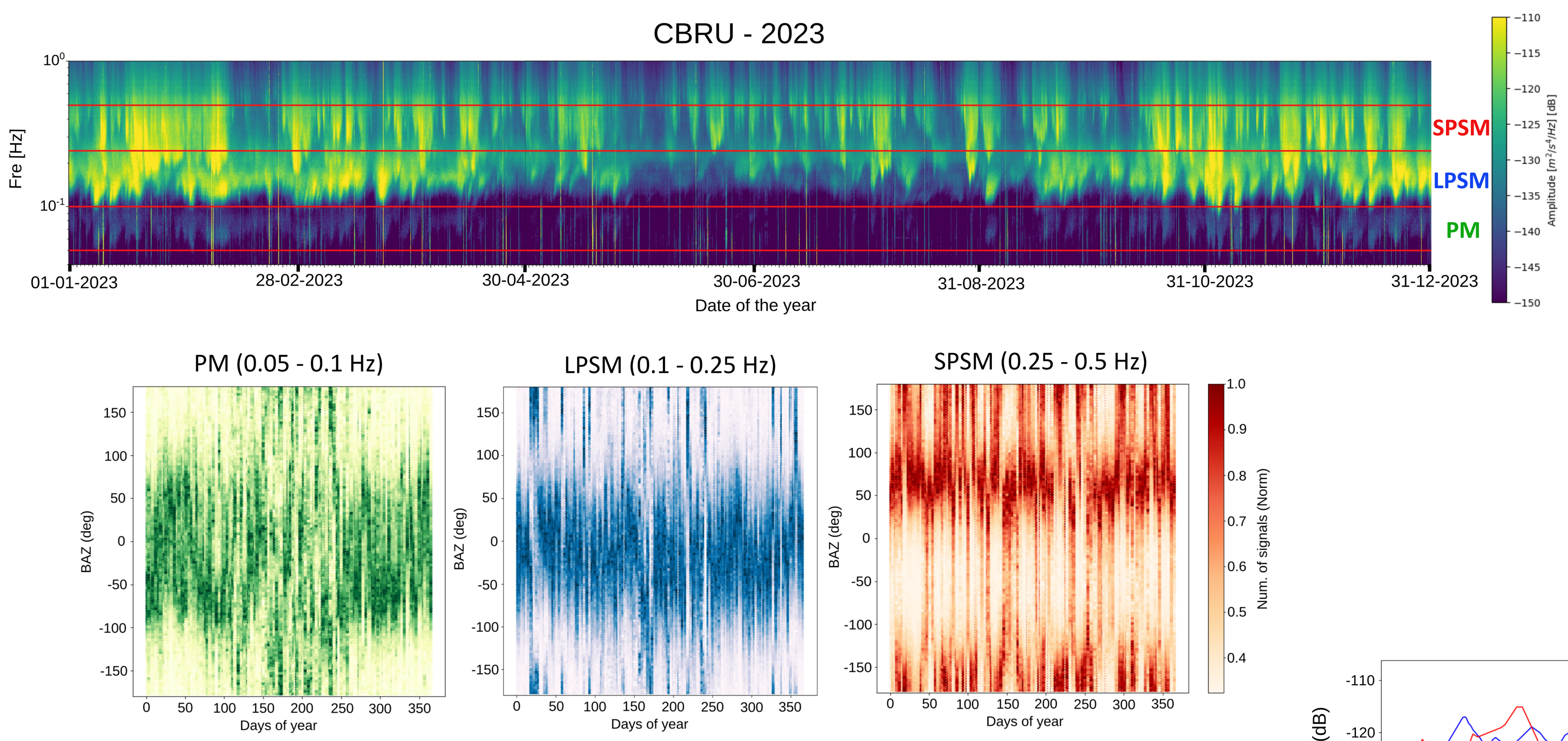


Fig. 6. Different frequency ranges used across the spectrum and the results obtained with the polarization analysis for each of these ranges.

For this analysis, we divide the spectrum into three different frequency ranges: Primary Microseism (0.05 - 0.1 Hz), LPSM (0.1 - 0.25 Hz), and SPSM (0.25 - 0.5 Hz). We then apply a Rayleigh-wave polarization method, as described by *Schimmel et al. (2011)*, to each of these frequency ranges. The results are normalized based on the number of signals obtained and are plotted as a function of back azimuth (BAZ) and time. The outcomes are consistent across all four years analyzed.

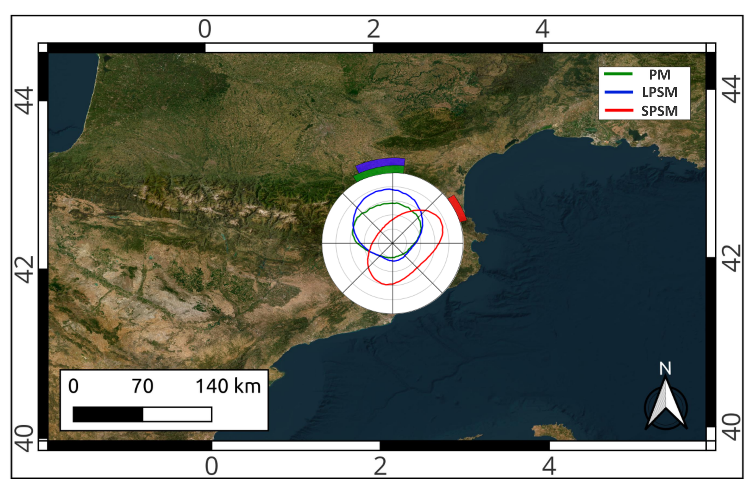


Fig. 7. Results obtained from the polarization analysis plotted on a polar graph.

The results obtained from the polarization analysis suggest the presence of distinct seismic sources for PM and LPSM, both pointing toward the North Atlantic Ocean, and a separate source for SPSM, oriented toward the Mediterranean Sea. This interpretation is further supported by the different energy patterns observed across the frequency ranges: PM and LPSM share a similar energy pattern, whereas SPSM exhibits a clearly distinct one.

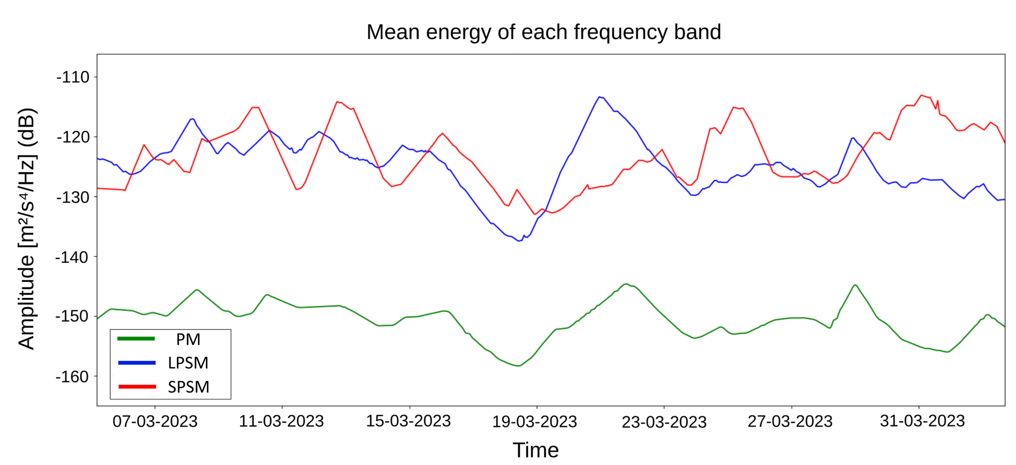


Fig. 8. Energy patterns over one month for each frequency range show a notable similarity between PM and LPSM, while SPSM shows a different pattern.

How do we measure polarized signals?

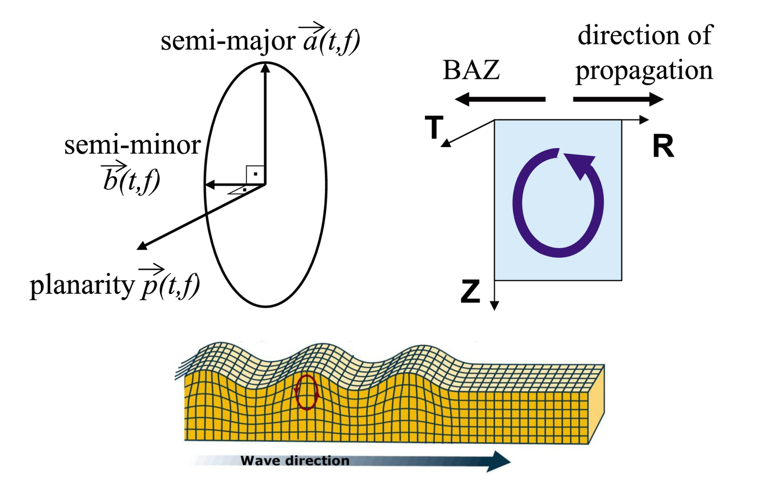


Fig. 9. Polarization methodology used in this study (Schimmel et al., 2011).

Conclusions

- We identify a distinct pattern in the seasonal variations through cross-correlation analysis: the LPSM source shows an increase in amplitude during the winter months, whereas the SPSM source does not exhibit any significant amplitude change.

- We observe stronger amplitude attenuation along the profile parallel to the coast compared to the orthogonal one. Additionally, we identify time periods in which this attenuation pattern is reversed and associated with completely different back-azimuths, suggesting that SPSM sources in the Mediterranean Sea are both well-defined and dynamic.

- Polarization analysis reveals the presence of distinct seismic sources for PM and LPSM on the one hand, and SPSM on the other. This interpretation is further supported by the observed energy patterns: PM and LPSM display similar behavior, clearly distinct from that of SPSM. We also extend this analysis to stations distributed across the Mediterranean Sea and observe consistent results throughout the region.

References

-Ardhuin, F., Stutzmann, E., Schimmel, M., & Mangeney, A. (2011). Ocean wave sources of seismic noise. Journal of Geophysical Research: Oceans, 116(C9).

-Bromirski, P. D., Duennebier, F. K., & Stephen, R. A. (2005). Mid-ocean microseisms. Geochemistry, Geophysics, Geosystems, 6(4).

-Schimmel, M., & Gallart, J. (2004). Degree of polarization filter for frequency-dependent signal enhancement through noise suppression. Bulletin of the Seismological Society of America, 94(3), 1016-1035.

-Schimmel, M., Stutzmann, E., Ardhuin, F. and Gallart, J. (2011). Polarized Earth's ambient noise microseismic noise. Geochemistry, Geophysics, Geosystems, 12(7).