Toward monitoring ocean wave activity using seismic stations

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Greece - Magnitude: 6.1
No ocean on Mars → No microseisms → Noise level 1000 lower between 0.1-1 Hz
Noise spectrum
Noise spectrum
Noise spectrum

![Noise Spectrum Graph]

- **G SSB 00 Z**
- **2019-1-3 (3)**

**PSE [10 log_{10}(m^2/s^3)] [dB]**

- **BH: 24 hours**
- **LH: 72 hours**

**Period [s]**

- 10^0
- 10^1
- 10^2
- 10^3
Noise spectrum

[Graph showing noise spectrum with different periods and labels such as G SSB 00 Z, BH: 24 hours, 2019-1-4 (4), and LH: 72 hours.]
Noise spectrum

Noise with periods between 1 and 500 sec are generated by oceans waves
Wind sea and swell → primary and secondary microseisms
Infragravity waves → hum

Longuet Higgins, 1950
Hassselman 1963
Ardhuin, Gualtieri, Stutzmann, 2015
Secondary microseisms (period 1-10 s)

Waves are computed every 6 hours
Code WAVEWATCH III
6-hourly wind analysis from ECMWF

Ardhuin et al., 2011
Secondary microseisisms (period 1-10 s)

Pressure sources every 3 hours (IFREMER model)

large amplitude surface waves and tiny body waves
Surface waves:
Rayleigh waves source site effect

Amplification factor for the seismic wave period $T=6s$

Amplification factor for the seismic wave period $T=10s$

Longuet Higgins, 1950, Kedar et al., 2007, Ardhuin et al., 2011, Stutzmann et al., 2012
Spectrograms are well modelled (frequency content and amplitudes).
Strongest PSD are due to large storms.
Weaker PSD is due to coastal sources related to ocean wave coastal reflection.

Stutzmann, Ardhuin et al., GJI, 2012
Secondy microseism surface waves

Continent

Island

Antarctica

Stutzmann, Ardhuin, et al., GJI, 2012
In winter, decrease of the amplitude of
- the primary microseism (10-15 sec)
- the short period secondary microseism

Stutzmann, Schimmel et al., 2009; Grob et al., 2011
On going work:
Data and model for 1988-2019
For all global seismic networks
⇒ Improve the accuracy of the model
Secondary microseismism body waves

Microseism source from IFREMER model

Seismic network
Secondary microseisms body waves detection

The array record P-waves from multiple sources

Each source is defined by its location, corresponding to a P-wave slowness: \( s = (s_x, s_y) \) and its dominant frequency \( f \)

Beam averaged over 1 day of data

Back projection
Beamforming using the seismic array in California

→ Location and amplitude of the source

Farra, Stutzmann et al., 2017
Beamforming using the seismic array in California

→ Location and amplitude of the source

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Farra, Stutzmann et al., 2017
Beamforming using the seismic array in California

→ Location and amplitude of the source
Beamforming using the seismic array in California

→ Location and amplitude of the source
Secondary microseism sources at global scale

Strongest sources per day (5 years of data)

Histograms of the sources

Meschede, Stutzmann et al., JGR, 2017
Comparison of back projected sources

California array

Alaska array
Energy and dominant frequency are accurately modeled.

Meschede, Stutzmann et al., JGR, 2017
BLIND SOURCE SEPARATION:
Extract more sources from the seismic signal

Microseism source from IFREMER model

BEAM AVERAGE OVER ONE DAY

Meschede, Stutzmann, Schimmel, 2019
Conclusions

- Seismic data provide long time series that can be accurately modeled using sources from oceanographic models
- Body waves enables to extract individual sources
- Seismic data are very sensitive to the wave coastal reflection coefficient

On going work:
- Analysis of longer time series
- Machine learning for building new catalogue of sources
- Improve the modeling of noise