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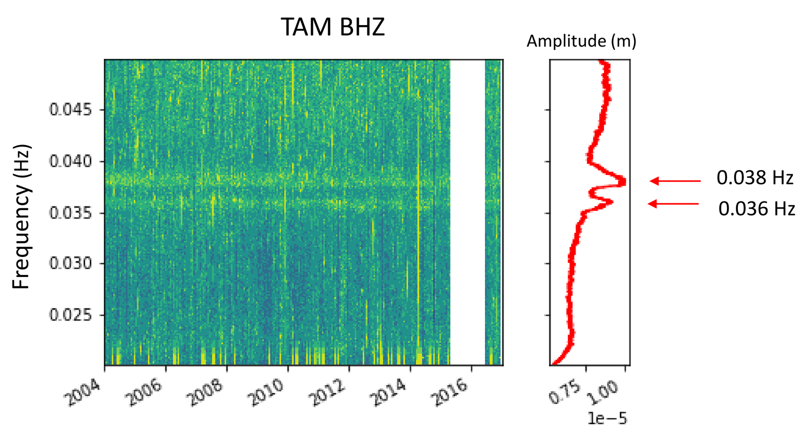
Source location and evolution of the 26 s microseism from 3-C beamforming

Charlotte Bruland[1], Sarah Mader[2] and Celine Hadziioannou[1]
1 Institute of Geophysics, Center for Earth System Research and Sustainability (CEN), University of Hamburg, Germany
2 Karlsruher Institut für Technologie, Karlsruhe, Germany
Contact: charlotte.bruland@uni-hamburg.de

1. Introduction

In 1962 a peak in seismic amplitude spectra around 26 s was discovered and detected on stations worldwide [Olivier, 1962]. The source was located in the Gulf of Guinea [Shapiro, 2006] and is believed to be continuously generated, but the source mechanism is still unknown. Below is the normalized spectrogram for station TAM from 2004 to 2016. Two peaks around a period of 26 s are visible.

By utilizing different arrays around the Gulf of Guinea, this work aims to locate the source of the 26 s microseism, find out what wave types are excited and look into how it changes over time by using beamforming. Better constraints on location and behavior of noise sources will help us understand the processes driving them.

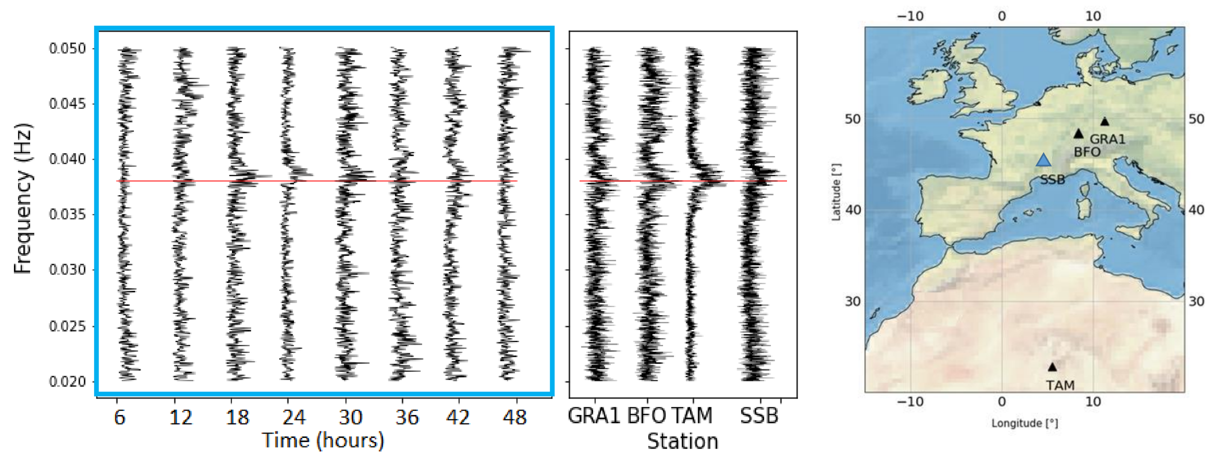


-> Aim: Source location, wave types and evolution over time

2. Amplitude spectrum – Is the peak always visible?

The 26 s microseismic peak is observed on stations all over the world. However, it is not always possible to detect it. Burst periods are defined as when the peak is visible on stations globally.

The figure shows the evolution of a burst event on station SSB from 2013-01-06 to 2013-01-08, and the amplitude spectrum the same time period for the permanent stations shown in the map.

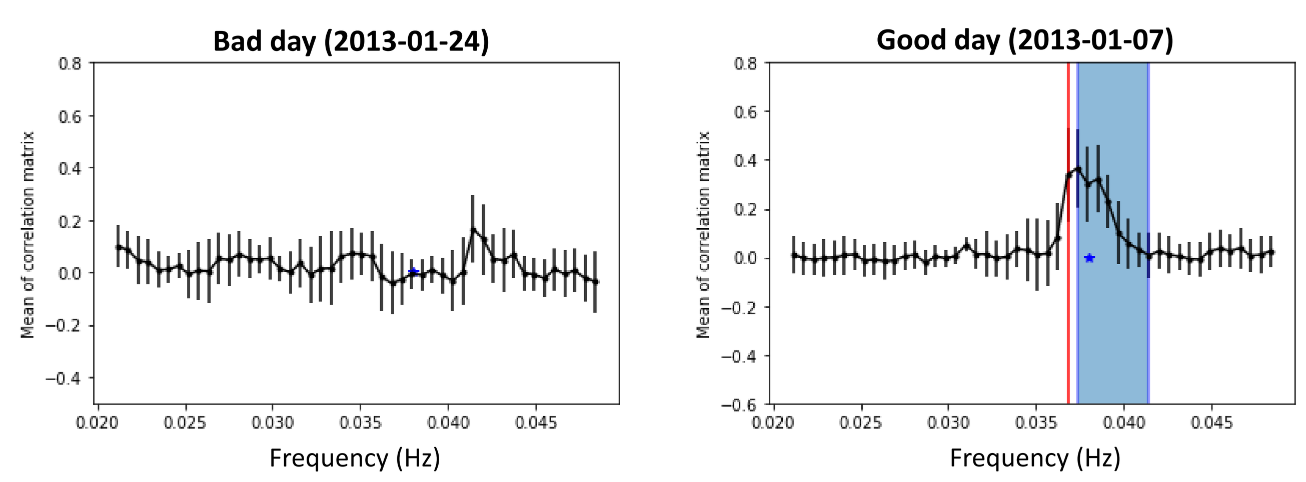


-> Strong temporal variation in peak amplitude

3. Automatic detection – When is the peak coherent?

Since the source of the 26 s microseism is so weak, it is difficult to get good results from beamforming. Therefore the amplitude spectra are analyzed to find out when the peak at 26 s is easily distinguishable from the noise levels. The four stations shown above with corresponding spectra, are used for automatic picking.

The correlation matrix for the four spectra is calculated for different overlapping frequency intervals and the mean and the standard deviation for each matrix is calculated. The examples are from a day when the peak is prominent (Good day) and a day where the peak is not visible (Bad day).



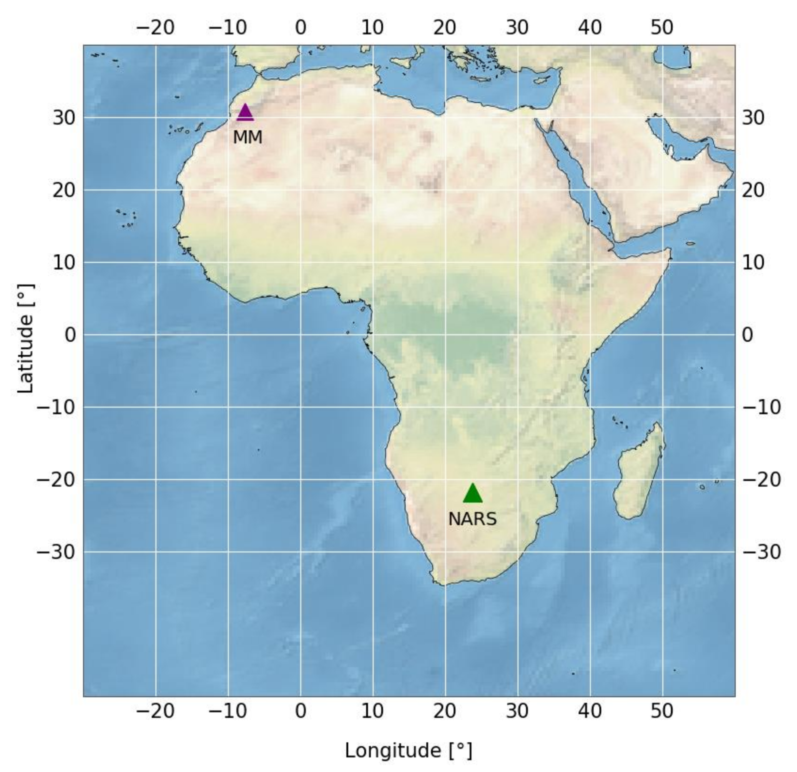
A day is selected if:
- The jump between neighboring frequencies is larger than the standard deviation (red)
- The average of a part of a segment (1/6) is larger than the overall average (blue)

Once the days with a distinct, coherent peak are selected, beamforming is carried out for the resulting dates.

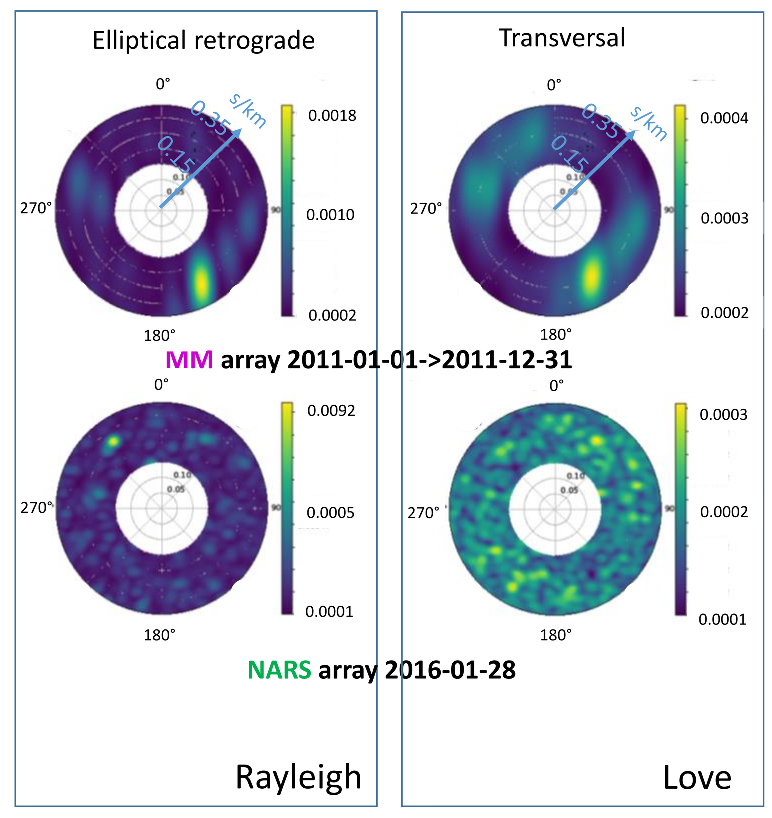
4. Beamforming – Determine wave type and source location

We use a three-component beamforming method in the frequency domain to distinguish between differently polarized waves and get an estimate of beam power, back azimuth and slowness. [Esmersoy, 1985; Juretzek,2016]. A window length of 500 s, slowness range of 0.15-0.35 s/km and frequency interval of 0.01-0.06 Hz is used. The results are averaged over all time windows and plotted for frequency 0.038 Hz. Amplitudes are disregarded and the beam power spectral density normalized.

FDSN code	3D	NR
Network name	MM	NARS
Timespan	2011	2016
Number of stations	15	21
Aperture (km)	383	888



Wave types

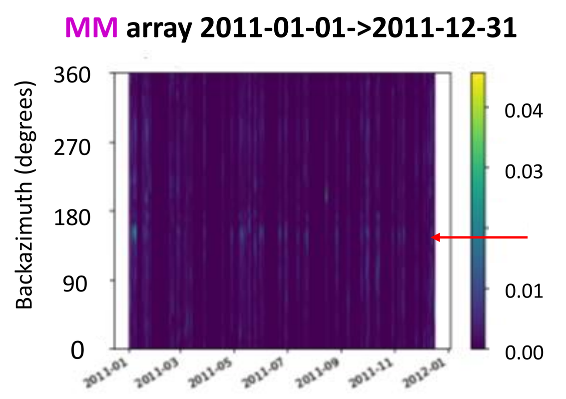


The map shows the location of the two arrays used in beamforming. Here, examples of beamforming outputs are shown for both arrays. Whenever Rayleigh waves are detected on the MM array, Love waves coming from the same direction are also detected. For the NARS array, noise levels usually do not permit the detection of Love waves.

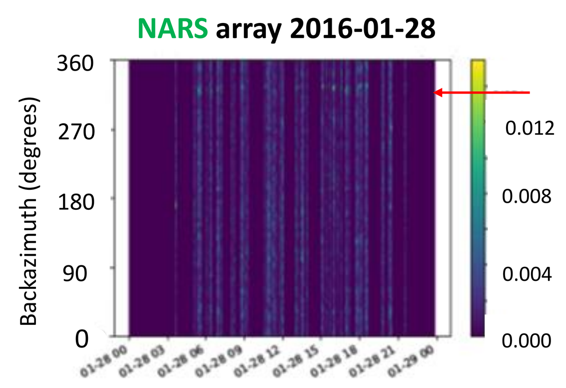
We get a Rayleigh wave velocity between 3.5 and 3.7 km/s and a Love wave velocity of 3.8-4.1 s.

-> Source emits Love and Rayleigh waves

Location stability

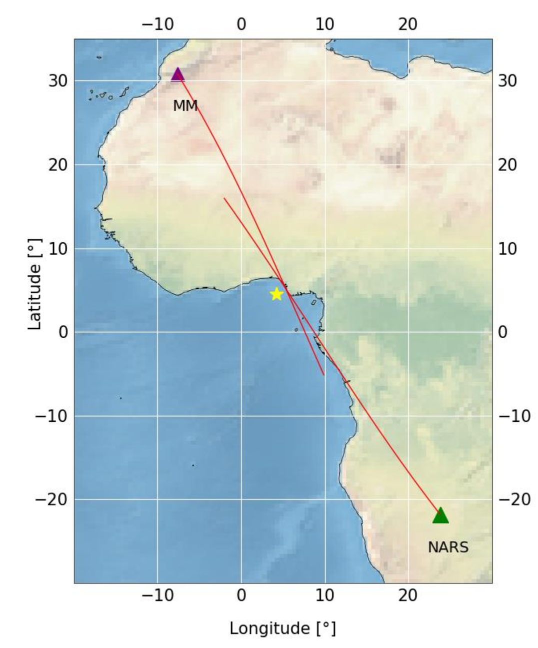


Shown here is the beam power as a function of backazimuth and time for 0.038 Hz. The MM array shows that the energy is coming from the same direction throughout 2011. Beamforming from January, February, March and beginning of April 2013 displays the same result.



When the peak is detected on the NARS array, the direction is consistent.

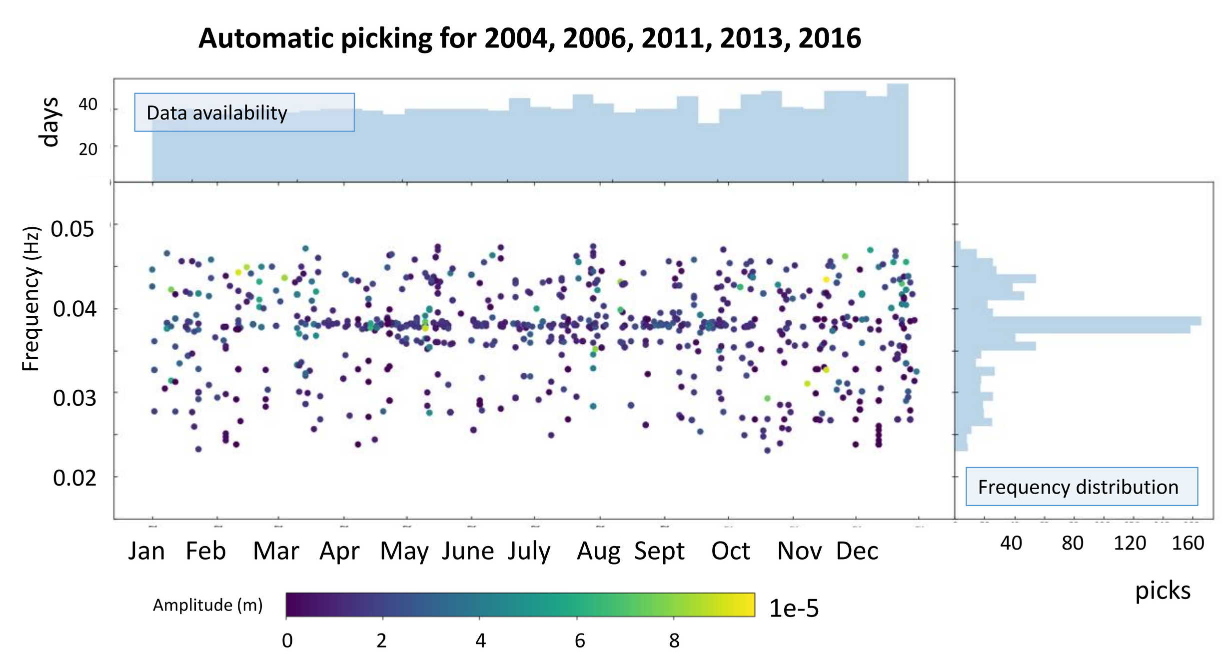
-> Direction is temporally stable



Location found by Shapiro, N. M., Ritzwoller, M. H., & Bensen, G. D. (2006)

Source mechanism

Oceanic? -> Seasonal variations expected
- Less detections in winter months
- Spectral amplitude of detections slightly higher during the winter
- Higher noise level during the winter
- Beampower varies over the year, but no seasonal variation in beampower



Volcanic? -> Long period volcanic tremor characteristics
- Harmonic or narrow band signal
  - ->Do not see any harmonics, but the signal is narrow band
- Non-linear process that varies with time, since the physical processes of the system changes
  - -> Amplitude displays strong temporal variation
  - -> Frequency does not seem to change
- Transient or long-lived
  - -> Source been active for 50 + years
  - -> Not active all the time, but in bursts

A simple harmonic resonator (organ pipe) model:
- f0 = v/2L
  v: speed of crack wave
  L: length of crack

Approximate size of system needed for 26 s signal:
L=(400m/s)/(2*0.038Hz)=5,6 km/s

References and acknowledgements

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- Most data processing was done with ObsPy: https://doi.org/10.5281/zenodo.1040769

Summary

Based on literature and our analysis:
- Stable properties over the course 50+ years in terms of frequency, amplitude/beampower and location
- Not active all the time, but rather in bursts
- Love and Rayleigh waves are generated
- Apparent seasonal variations are likely due to noise levels and not actual seasonal variations
- If no seasonal variations, probably not oceanic origin
- Volcanic? Harmonic tremor? Harmonics drowned by noise?
- Other mechanism?