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TRACKING BALEEN WHALES WITH A SINGLE OCEAN BOTTOM SEISMOMETER

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CONTEXT / OBJECTIVES

Baleen whales produce strong and stereotyped songs which are often recorded by Ocean Bottom Seismometers (OBS). As they combine hydroacoustic and seismic sensors, these instruments provide a good opportunity to track the whales using their songs.

This study aims at developing a long range tracking method of baleen whales, based on methods previously developed for ship tracking (Trabattoni 2020).

The main goals are to:

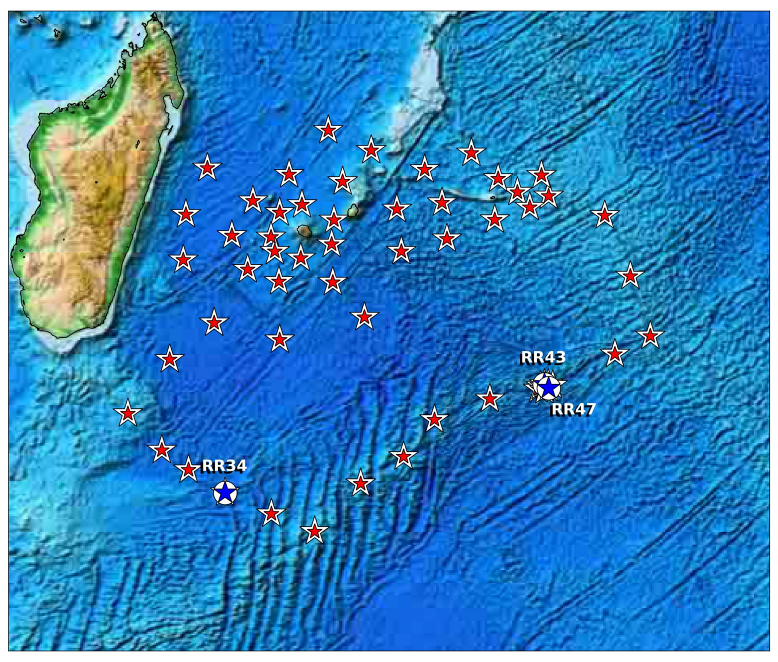
- accurately estimate the distance of the source using the multipath propagation, and improve the usual detection range
- estimate the source azimuth using the 3-components seismometer
- combine the distance and azimuth information to rebuild the whale trajectory

DATA

Data were recorded during the RHUM-RUM experiment (2012-2013) in the Southwest Indian Ocean

Three OBS used in this study (bue stars with white circle)

- RR34 (sampling rate - 62.5 Hz)
- RR43 (sampling rate - 100 Hz)
- RR47 (sampling rate - 100 Hz)



$$C(\tau) = F^{-1}\left(\log \|I(f)\|^2\right)$$

ACOUSTIC INTENSITY VECTOR SPECTROGRAM

Acoustic Intensity Vector is build from the 3-components seismometer and hydrophone (Trabattoni 2020).

The spectrogram parameters are set as follow

- Signal filtering: the boundaries are chosen to include the wideband part of the song affected by the multipath interference
- FFT size: the length of the window must be long enough to include the potential arriving rays. This value is mostly related to the bottom depth.

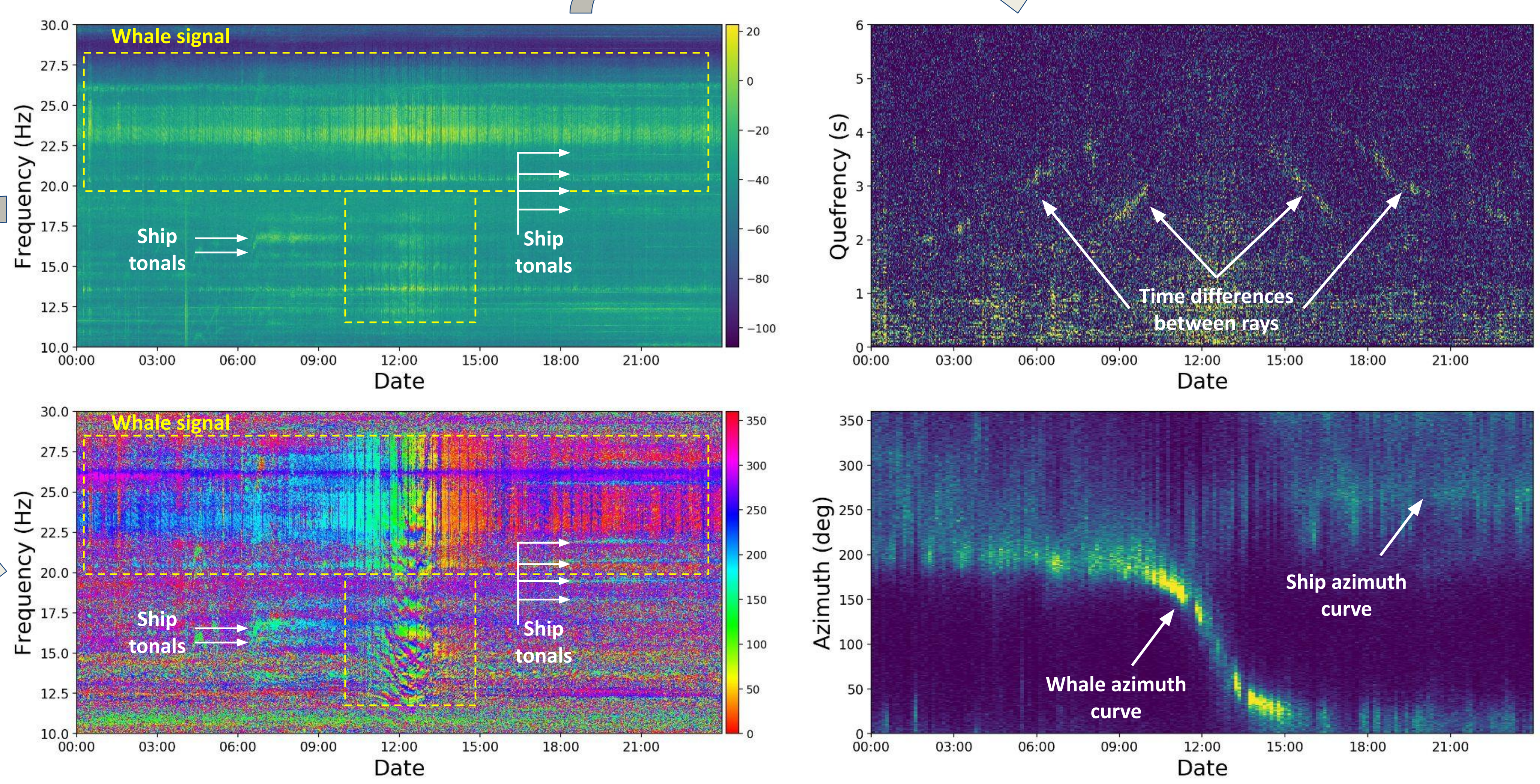
The spectrogram here, is the logarithm of the norm of the intensity vector

AZIGRAM

The azigram is a time-frequency representation of the direction of arrival of the incoming waves. It represents the orientation of the intensity vector for each time-frequency bin.

Each pixel has a color corresponding to its azimuth. This latter varies from 0 to 360. The color scale is given by the colorbar.

As they have the same size, one can easily make the link between the azigram and the spectrogram.



Analysis of a singing Madagascan Pygmy Blue Whale (results below). Filter Boundaries = 10-30 Hz ; FFT size = 2048. Date: 2013/04/17

CEPSTROGRAM

The cepstrogram hilights periodicities in the signal. Thus, it is well suited to detect the time differences between the multiple arriving rays.

The time differences of arrival between the paths are directly related to the distance. A simple propagation model can be applied to get a good estimate of the distance (Trabattoni 2020)

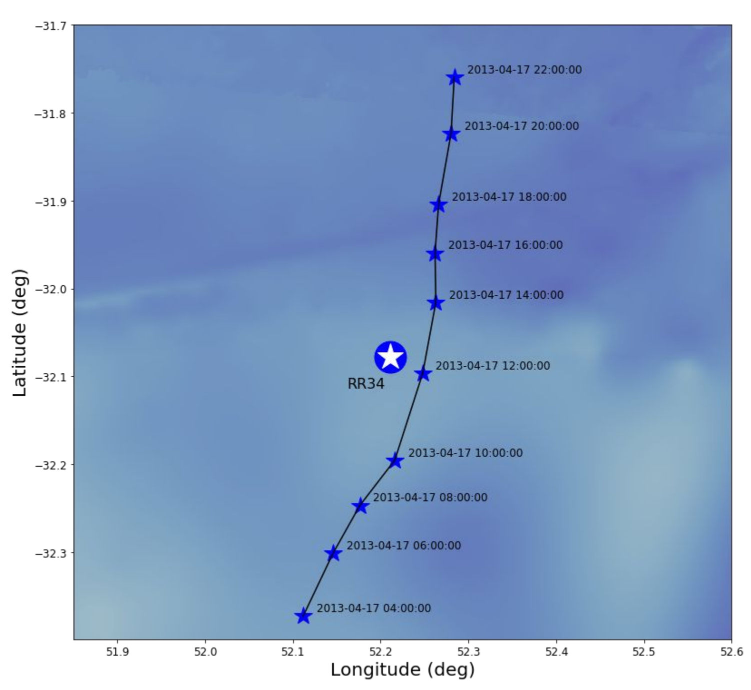
AZIMUTH HISTOGRAM

A sliding time-window is applied to the azigram. For each window, the azimuth histogram is computed. It results in the time-azimuth representation, which provides the azimuth curves of the main sources.

Here, one can clearly see the azimuth curve of the singing whale, and also the curve of a ship in the West after 15:00.

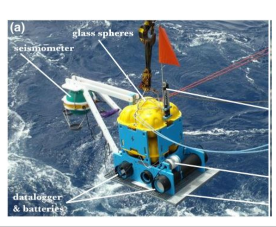
RESULTS OF THE PROCESS ON THREE DIFFERENT WHALE SPECIES

Madagascan Pygmy Blue Whale

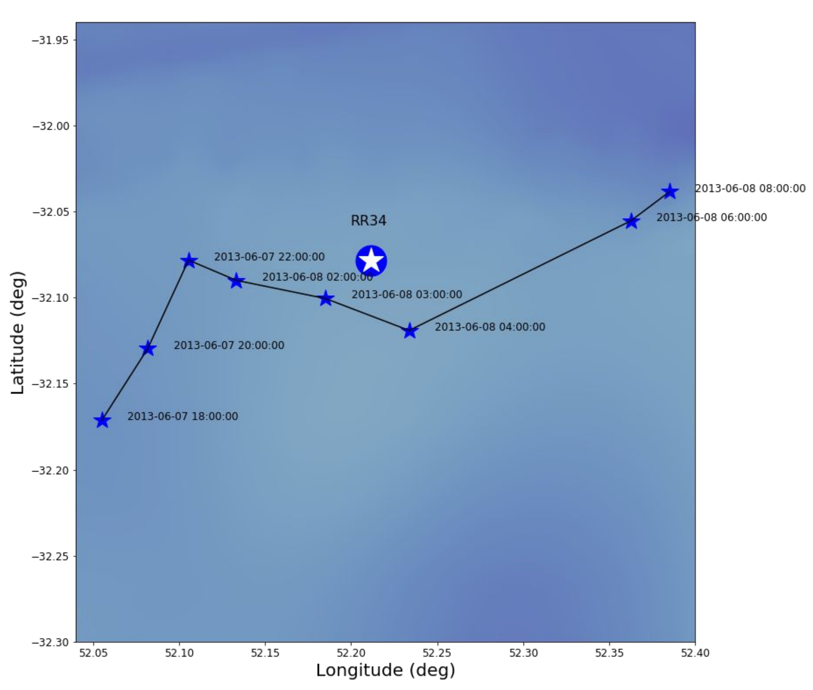


This whale travelled 71 km from South to North during the 18 hours time window, with a mean speed of 4 km/h.

- Maximum tracking range : 36 km.
- RR34 depth: 4265 m.
- Sensor from INSU pool (Trillium 240s)

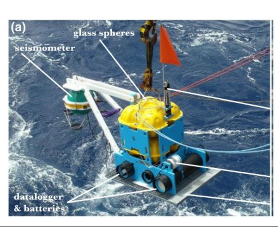


Fin Whale

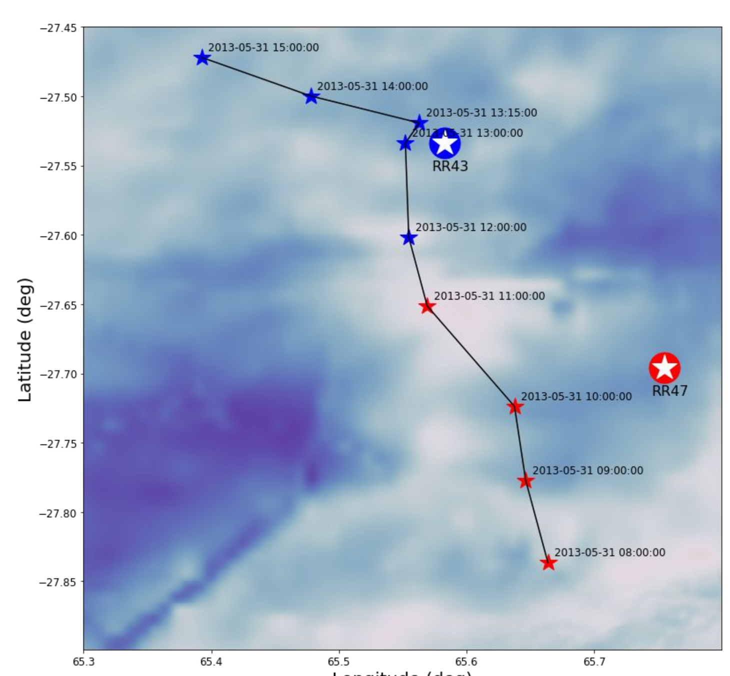


During the 14 hours time window, this Fin whale traveled 41 kilometers at a mean speed of 3 km/h.

- Max tracking range: 18 km
- RR34 depth: 4265 m.
- Sensor from INSU pool (Trillium 240s)

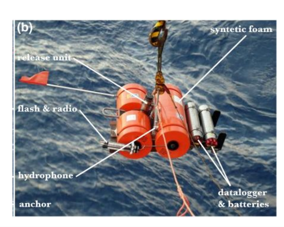


Antarctic Blue Whale



This Antarctic Blue whale was detected and followed separately by two different OBS with a 25 km spacing. The first part of the track was built by the sensor RR47, and the second by the sensor RR43. The track is consistent with TDOA based method (DREO 2018)

- Max tracking range: RR47 19 km, RR43 20km
- RR43 / RR47 depths: 4264 m / 4587 m.
- Sensor from DEPAS pool (Guralp CMG-40T)



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CONCLUSION

Tracking ranges up to 35 km in the best cases

Variability in the results probably due to:

- sensor quality
- environment characteristics (seabed type)
- whale songs spectral content

PERSPECTIVES

Description of the impact of the parameters in the process quality, especially:

- seabed type
- whale song characteristics

Method assessment on other OBS networks, with different environments

Process automatization (big datasets)