ÉCOLE DOCTORALE
SCIENCES DE LA TERRE ET DE L'ENVIRONNEMENT
ET PHYSIQUE DE L'UNIVERS, PARIS

Subject offered for a contract starting October 2017

Doctorat thesis DGA – IPGP/Ecole Navale 2017

Ship detection and tracking from ocean-bottom seismological observations in the ULF range [1-50 Hz]. Application to the south-west Indian Ocean.

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Laboratory : **IPGP**- Equipe sismologie (UMR7154), Paris

IRENav - groupe MOTIM (EA 3634), Brest

Financing : **50% DGA (subject already selected) + 50% ED IPGP**

For more information go to http://ed560.ipgp.fr, section: Offres de these (PhD offer), You must apply on the Doctoral School website

Summary

We propose to analyse the ship noise recorded by a network of 57 ocean-bottom seismological and hydroacoustic stations deployed in 2012-2013 in the Indian Ocean, in an area of dense **marine traffic**. These data provide the unique opportunity to develop methods that may be used for:

i)**Detecting** and tracking vessels from single ocean-bottom seismic sensors,

ii) **Tracking** ships moving above seismological networks deployed in the oceans,

iii) **Orienting** and locating accurately OBS stations by using ship noise polarization.

Description

Ocean-bottom seismology is widely used for investigating the deep Earth structure from passive earthquake recordings. Ocean Bottom Seismometers (OBS) record ground displacements along 3 components from frequencies of 100 Hz to periods of several hundreds of seconds. They record earthquakes in the period range 1-300 s, ocean-induced microseisms in the range 3 to 20 s, but also the **ship noise** in the range 1 to 50 Hz, that corresponds to Ultra Low Frequencies (ULF) in submarine acoustics, but to high frequencies in solid Earth seismology, and which are poorly exploited.

A great advantage of OBS is that they record ground motion along 3 components, providing new potential for locating and tracking sources from signal polarization analysis. A hydroacoustic station indeed records a scalar measurement of the pressure and does not allow by itself to locate a noise source, except by using antennas. A seismic station has the advantage of performing a 3D, vectorial measurement of the ground displacement and allows measuring the **azimuth and incidence** angles of seismic waves. We propose to use this property to detect and locate noise sources from the deep ocean (3 to 5 km depth), with direct applications to ship tracking, but also to ocean noise pollution, illegal fishing detection and whale detection and tracking.

Ship noise can be also very helpful for ocean seismologists to characterize the **OBS orientations** as they were recording on the ocean floor. OBS are indeed deployed from research vessels and go passively down to the ocean bottom, where they orient their vertical component along the Earth's gravity field, but the two horizontal components remaining with unknown orientations. Each OBS experiment therefore requires a first work for *a posteriori* determining the geographic orientations of the horizontal sensors. We recently demonstrated that the ship noise can provide a new and accurate way of determining the OBS orientations but also the OBS locations more precisely than the surface GPS point (Barruol et al., 2016b; Geay and Bouillon, 2016).

Context

The French-German **RHUM-RUM** experiment (Réunion Hotspot and Upper Mantle – Réunions Unterer Mantel, http://www.rhum-rum.net) carried by the Institut de Physique du Globe de Paris (PI G. Barruol) and Munich University (PI K. Sigloch) during the period 2012-2016 allowed deploying **57** seismological and hydroacoustic stations during the period Oct. 2012 - Dec. 2013 in the SW Indian Ocean.

This area represents an important zone of marine traffic between SE Asia and the southern Atlantic Ocean. Numerous ships crossed the seismic network every day, providing the unique opportunity of studying their noise recorded from the ocean bottom in the ULF range [1-50 Hz].

Program and methods

By combining seismic and hydroacoustic data recorded in the SW Indian Ocean, together with the **AIS data of ship locations**, we propose to make advances in:

i)Detecting and tracking ships from isolated OBS in the ULF range,

ii) Tracking vessels moving above an ocean bottom seismic network,

iii) Using ship noise to determine the OBS orientations on the ocean floor.

Seismological data will be analysed by time-frequency (TF) tools. We will optimise the TF representation in term of resolution, interferences and parameters. The Doppler effect, well visible in the data, will be used. For the noise source localisation and tracking, we will use the TDOA calculation and the Kalman filtering. We will also explore antennas processing and evaluate new methods based on power operators. Signal polarisation will be used to locate and track noise sources. A preliminary study demonstrated the high quality of the data and the large potential of the noise polarisation and allowed to develop tools for polarisation analysis.

Available data

This thesis will use seismological and hydroacoustic data recorded in the SW Indian Ocean during the RHUM-RUM experiment. The data are already acquired, validated, and available online at the French RESIF archive center http://seismology.resif.fr

Thesis location

The thesis will be based in the seismology team at the Institut de Physique du Globe de Paris and at the acoustic Lab of the IRENav (EA 3634) in Brest. The subject being at the interface between acoustics and seismology, the candidate will have to share part of his time between the two groups, at a rhythm that will be decided together with the supervisors.

Collaborations

The doctorant will be integrated into the French-German RHUM-RUM project and will feed his research with the other partners, in particular:

- The seismology groups from Oxford and Munich (K. Sigloch and H. Igel) who have the expertise in deep imaging and wave propagation.

- The seismology group at IPGP which has the expertise in microseismic noise (E. Stutzmann), in OBS instruments (W. Crawford) and in polarisation analyses (F.R. Fontaine).

Candidate profile

The subject covering the fields of acoustics and seismology, the candidate will have a background in geophysics or in acoustics (Master or Engineering school) and will have expertise in signal analysis.

Contacts : send CV + evaluation of the last years to :

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Dead Lines and constraints: A proposal has to be filled before 20/04 to benefit of the DGA support. European nationality is required for DGA funding.