An inverse problem approach for acoustic Transmission Loss estimation from the analysis of signals generated by seismic air-gun arrays.

I. Prario, M. Cinquini, R. A. Marques Rojo, S. Blanc, P. Bos

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POSTER

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ABSTRACT

Offshore seismic surveys with **airgun array** sources are currently widespread in all the oceans.

Their sound pulses generate signals that contain sufficient energy in the 5 Hz-60 Hz band to propagate ocean-basin scales at ranges of hundreds to thousands of km and to be received at **CTBT IMS hydrophone stations (HA)**.

This **work in progress** attempts to evaluate whether these signals can provide an insight into the reliability and accuracy of **source** and **propagation models** describing the sound acoustic field **at long distances from an airgun array**.

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INTRODUCTION

SL of the airgun arrays.

- Different acoustic models were used to estimate the sound field generated by airgun array (Ainslie *et al.*, 2015)
- To reduce their uncertainty, a study devoted to comparison with measurements is needed.

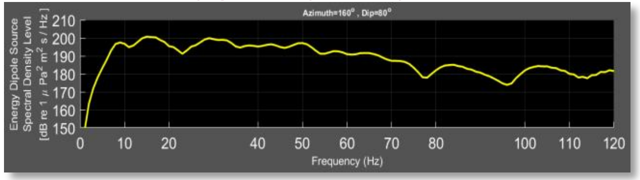
TL predicted by RAM 1.5 for long-range propagation paths.

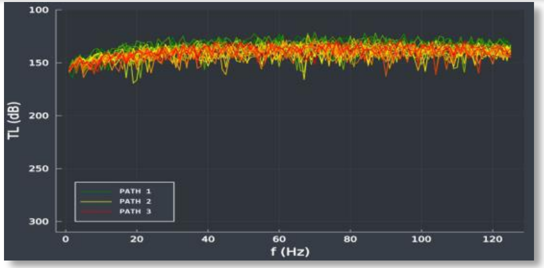
- An own implementation in Julia programming language is used.
- Oceanographic, bathymetric and seabed properties' input data are obtained from Copernicus, GEBCO and Jensen et al. (2011), respectively.

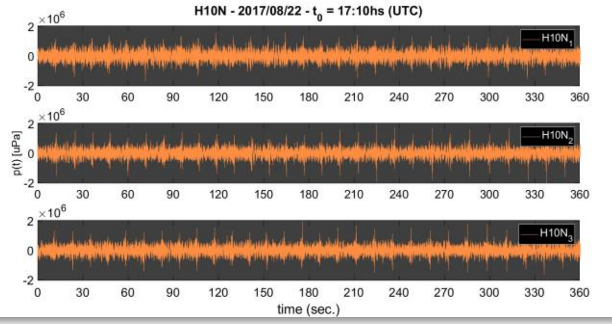
L_{rec} at HA stations obtained from IMS data.

- Access to HA-IMS data allows to analyse recorded time series that contain signals generated by airgun arrays.
- Essentially, IMS data are used to infer *SL* behaviour with frequency or to assess *TL* accuracy when *SL* is known.

Illustrative figures of the left side texts.







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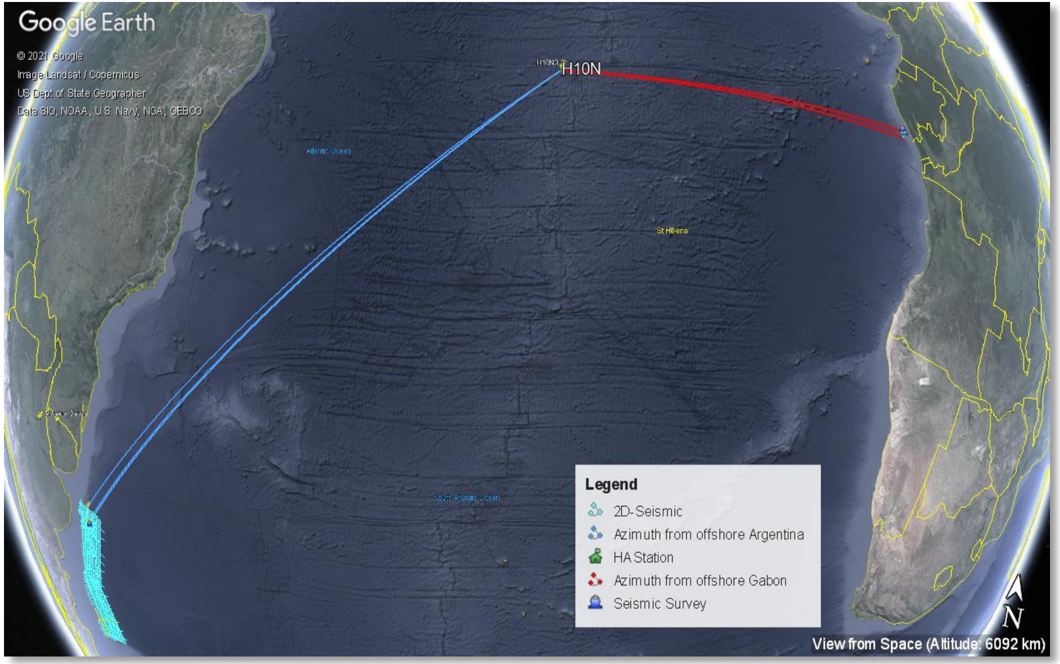
METHODS

Materials: A selection of signals with high signal to noise ratio (SNR) recorded at HA-IMS station and back-azimuths compatible with ground-truth airgun seismic survey.

Two illustrative cases are shown for signals recorded at H10N coming from seismic surveys held:

CASE 1) an airgun array of **unknown** characteristics, offshore Gabon.

CASE 2) an airgun array of **known** characteristics, offshore Argentina.



Examples of two airgun seismic surveys recorded at H10N station. The geodesic paths obtained for the back-azimuths computed from high SNR signals are shown from H10N to seismic surveys areas for two cases: ***1)*** *offshore Gabon ~2760 km and 81.8 deg. (red lines) ;* ***2)*** *offshore Argentina ~5250 km and 223 deg. (blue lines).*

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METHODS

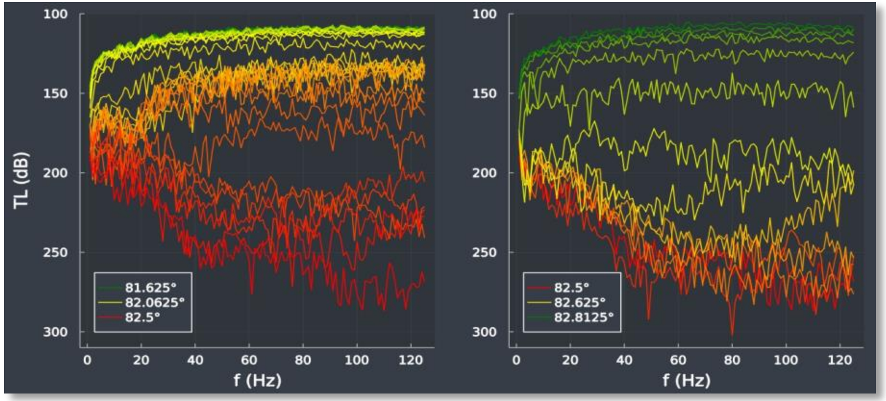
CASE 1)

Backwards computation of $\boldsymbol{TL}$ is performed using the code RAM.jl (Marques Rojo *et al.*, 2021), a range-dependent model based upon the Parabolic Equation approximation, from H10N to ground-truth positions of the seismic source operating offshore Gabon.

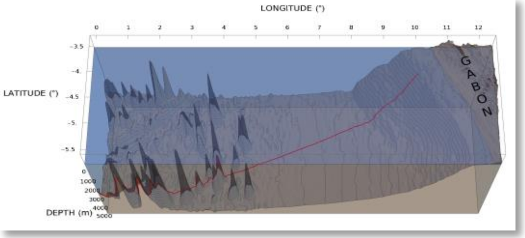
Individual received signals from airgun shots at H10N on 15 January 2021, from 4:00 hs to 6:00 hs (UTC) are isolated and grouped by estimated back-azimuth. Energy Spectral Density Levels (ESD), $\boldsymbol{L_{rec}}$, are obtained by averaging the energy spectra of various shots coming from the same direction.

Consequently, $\boldsymbol{SL}$ (or ESD$_{source}$) estimation in the frequency domain is obtained for the **unknown** source through the classical SONAR equations formulation ($SL=L_{rec}+TL$) for high SNR recorded signals for multiple shots from the source.

Computed TL from H10N to different positions of the source during a seismic survey offshore Gabon.



Strong variations vs. azimuth from H10N is observed principally due to bathymetric features in the acoustic path.



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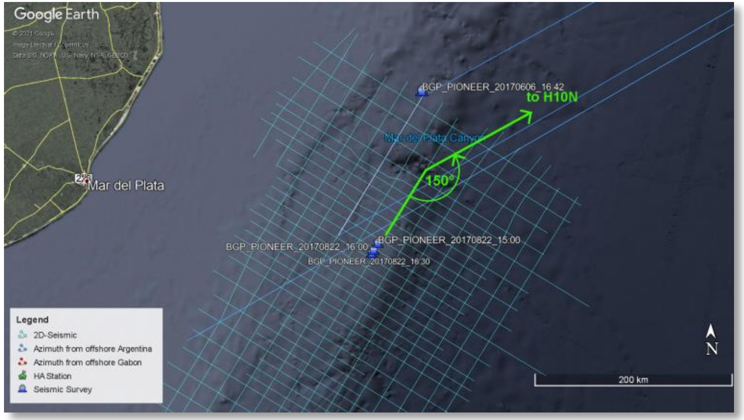
METHODS

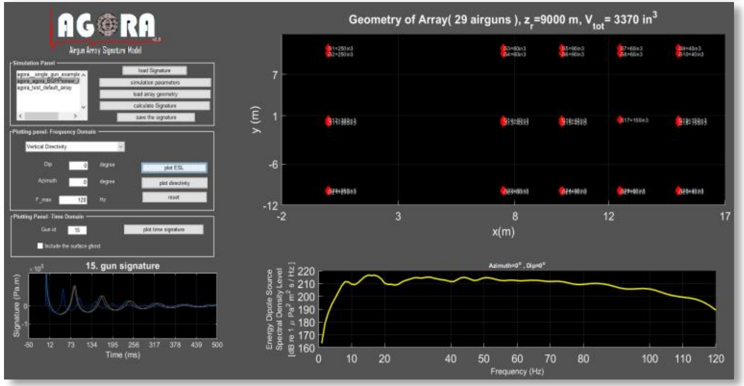
CASE 2)

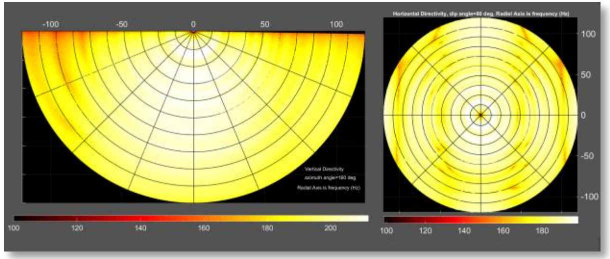
The spectral signature of the source, $\boldsymbol{SL}$ (or ESD_{source}) vs. f, is estimated with available models for cases of **known** airgun array configurations and/or from published references. Directional characteristics of the source are used to estimate its energy spectral density in the H10N direction.

ESD of the received signal at H10N, $\boldsymbol{L_{rec}}$, is obtained by signal processing in the frequency domain of IMS recorded data on 22 August 2017, from 17:10 hs to 18:10 hs (UTC).

Consequently, $\boldsymbol{TL}$ estimation in the frequency domain is obtained through classical SONAR equations formulation for high SNR recorded signals $TL = SL - L_{rec}$







Airgun array, energy spectral density levels and directivity pattern of the source used in offshore Argentina seismic survey, computed with AGORA (Sertlek, 2015).

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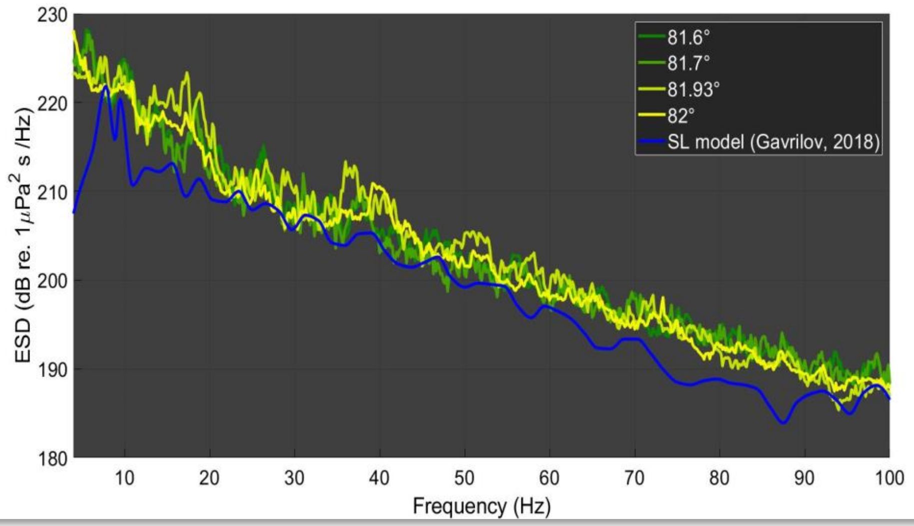
RESULTS

CASE 1)

Semi-empirically estimated **SL** (or ESD_{source}) vs. frequency obtained through analysis of impulsive airgun signals from the seismic survey offshore Gabon recorded on 13 and 15 January 2021 at H10N. Results are compared with modelled ESD results published by Gavrilov (2018) for an airgun array towed at a typical depth below the sea surface.

Energy levels and its trend with frequency are essentially captured by the SL estimations. Differences with the SL model lie within 5 dB in most of the frequency range analysed. Further work is necessary to understand which representative SL would be expected to be recovered from the data since airgun arrays are non-isotropic sources and in practice the elevation angles and azimuths from the source vary over a range of different values during multiple shots.



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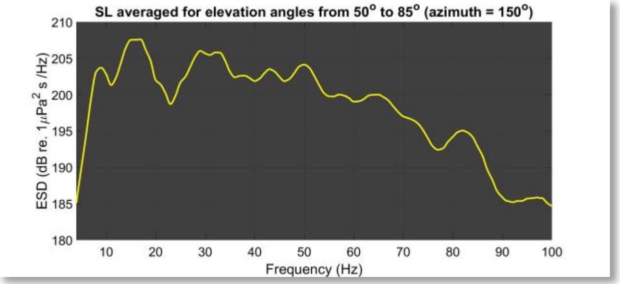
RESULTS

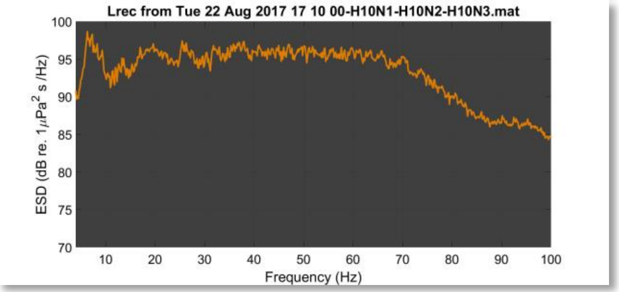
CASE 2)

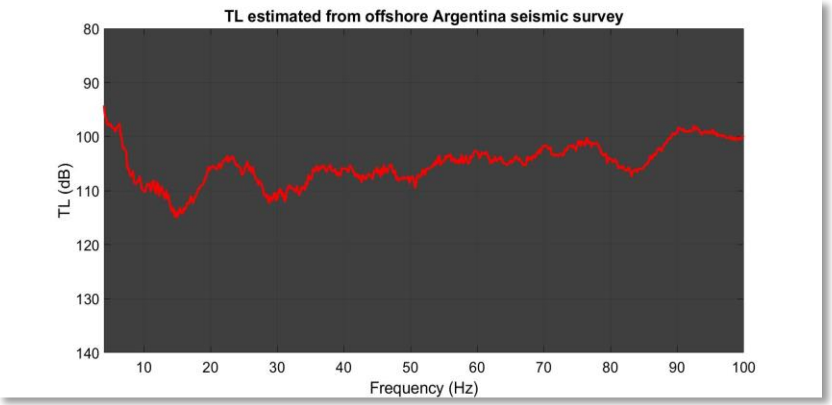
Semi-empirically estimated ***TL*** *vs.* frequency obtained through analysis of impulsive airgun signals from the seismic survey offshore Argentina recorded on 22 August 2017 at H10N.

Energy source spectral density levels averaged over elevation angles from 50 deg. to 85 deg. respect to the vertical



Energy spectral density levels of the received signals at H10N (average of high SNR signals from identified shots).





The *TL* estimation errors are about 5 dB due to uncertainties associated to variability of signal's amplitude and modelled ESD_{source}.
Further work is required in order to compare results with *TL* models and correlate L_{rec} variations with propagation effects or actual variations of the source energy and its coupling in the sound channel.

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CONCLUSIONS

- The methodology that is being undertaken to statistically assess the feasibility of obtaining a reliable and accurate insight into two acoustic relevant properties associated to offshore seismic surveys is illustrated in this e-poster.

- The detected signals from airgun shots recorded at HA-IMS stations contain information of both propagation effects and source properties.

- Ground-truth seismic survey data allow to estimate:
  1. Source Level spectrum of an airgun array of **unknown** characteristics.
  2. Empirical Transmission Loss that affects the signals generated by a **known** airgun array during their travel along the path to HA-IMS stations. This allows for further comparison with different model predictions.

- Variability of the coupling of source energy to the sound channel due to bathymetric features in the survey area and/or diffraction effects in the long range propagation can be inferred from the analysis of these kind of signals. Only much intensive and exhaustive work in the future, including three-dimensional modelling, will provide answers to the these concerns.

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