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Assessment of acoustic energy decay from seismic sources in offshore Brazil

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Abstract Summary

In recent years, the Brazilian coastline has seen a significant rise in the demand for environmental licenses related to seismic research activities. This evolving context has required close collaboration between Petrobras and the Brazilian Institute of Environment and Renewable Natural Resources (Ibama), leading to the development of an integrated single licensing framework. This comprehensive framework encompasses both the preliminary license and the seismic research license, covering exploration areas and ring-fences of producing oil fields.

A key component of the environmental licensing process is the evaluation of the impact of sound emissions on the biotic environment, which is essential for delimiting the area of influence of the seismic research activities. This study seeks to address a crucial question: how does acoustic energy produced by seismic sources decay over distance? By utilizing data obtained from Ocean Bottom Nodes (OBN) and acoustic gliders and complementing it with seismic modeling, we aim to quantify and analyze the dispersion of acoustic energy emitted by air guns, clarifying the complexities of sound dispersion in marine ecosystems.

Ultimately, our objective is to produce reliable modeling results that offer accurate estimates of the acoustic impact of acquisition campaigns, thereby supporting informed strategic planning of these activities.

Introduction

The increasing demand for environmental licenses for seismic research activities along the Brazilian coastline has led to significant developments in regulatory frameworks. Recently, a collaboration between Petrobras and Ibama established an integrated single licensing framework. This framework consolidates both the preliminary license and the seismic research license for various exploratory areas and oil producing fields.

A critical aspect of the environmental licensing process is the assessment of the impact of sound emissions on the biotic environment. Understanding this impact is essential for delimiting the area of influence of the seismic research activities (IBAMA/ICMBio, IN Nº 2, 2011). The integrated licensing approach not only streamlines the licensing process but also facilitates the evaluation of new acquisition techniques aimed to minimize the adverse effects of seismic activities on marine ecosystems.

An integrated analysis of seismic data, specifically collected from streamers and Ocean Bottom Nodes (OBNs), combined with acoustic recordings from gliders, enables a comprehensive understanding of acoustic energy dispersion. Ocean Bottom Nodes offer stationary recordings of seismic waves, allowing for continuous long-term monitoring, which is crucial for capturing variations in acoustic emissions over time.

Environmental acoustic monitoring is further enhanced using gliders –autonomous underwater vehicles designed to move vertically and horizontally through the water column– collecting acoustic data at varying depths from the surface to 1,000m depth. By integrating these methodologies with advanced seismic modeling techniques –which simulate the propagation of sound waves through the marine environment using representative regional velocity models– it becomes possible to quantify the dispersion of acoustic energy emitted by air guns across various distance ranges. This multifaceted approach enriches the dataset and supports the development of strategies aimed at mitigating the environmental impacts of seismic research activities.

This study focuses on quantifying the acoustic energy decay from seismic sources at various distances using data collected from Ocean Bottom Nodes (OBNs) and acoustic gliders, supplemented by seismic modeling. The primary objective of this work is to provide information that can be used to assess the environmental impact of seismic surveys on the marine environment (Southall et al. (2007; 2019; 2021), particularly concerning the dispersion of acoustic energy emitted during seismic surveys.

Method

The intensity of seismic source emissions was directly estimated from seismic data, with OBN data offering advantages due to their ability to record continuously over extended periods –up to 90 days. This capability enabled the collection of seismic records at various offsets between the source and receiver.

To assess sound attenuation throughout the entire water column or at distances beyond the coverage of OBN data, acoustic gliders were used to record acoustic data while diving from surface to about 1.000-m depths. Numerical modeling of wave propagation was used to complement those data, being essential to show details that are not present in the dataset used. This modeling relies on region-specific velocity models representative of the areas under analysis.

The calibration of modeled amplitudes was carried out using real measurements obtained from seismic surveys conducted in the same area. The intensity of the wavefield generated by a seismic source was assessed using various metrics, the most common being Sound Pressure Level (SPL) and Sound Exposure Level (SEL), both expressed in decibels (dB) relative to a reference pressure level of 1 µPa.

The results of these evaluations are presented in graphical form, providing insights into exposure levels as a function of the distance between the receiver and the seismic source.

Results

The analysis of OBN data enabled the generation of sound attenuation curves over distances of up to 40 km between the source and the receiver. Regarding the data obtained from gliders, it was possible to generate curves from about 5 km over distances of up to 250 km. Figure 1 illustrates the results of SPL as a function of horizontal distance from the seismic source, based on in-situ measurements conducted on the Santos Basin (Annual Report Cluster BS, 2024). These results show strong agreement of the OBN-based data with the data obtained from glider-based acoustic data. Differences seen in the fitted curves may be related to different propagation conditions, since OBNs and gliders were positioned on different areas relative to the seismic source, and the OBN is on the seafloor, at depths of about 2.000 m, while the acoustic glider maximum depth is 1.000 m.

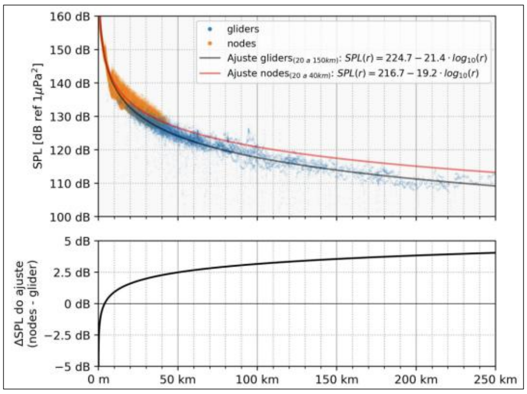

Figure 1: Upper panel: SPL as a function of horizontal distance from the seismic source. Data points for OBNs are shown in orange, while those from gliders are depicted in blue. The fitted curves are displayed in black for gliders and red for OBNs. Lower panel: difference in SPL estimates between gliders and OBNs as a function of distance from the seismic source.

The range of distances considered for curve fitting was 20 to 40 km for OBNs and 20 to 150 km for gliders. The difference in dB between the SPL values along the fitted curves for OBNs and gliders, as a function of horizontal distance from the seismic source, is shown in the lower panel of the same picture.

To complement the seismic observations, we use numerical modelling of wave propagation, calibrated with field data. Figure 2 illustrates the comparison between field data and modeled data (Annual Report Cluster BS, 2025). As a near future goal, we intend to improve the accuracy of modeling derived SPL curves.

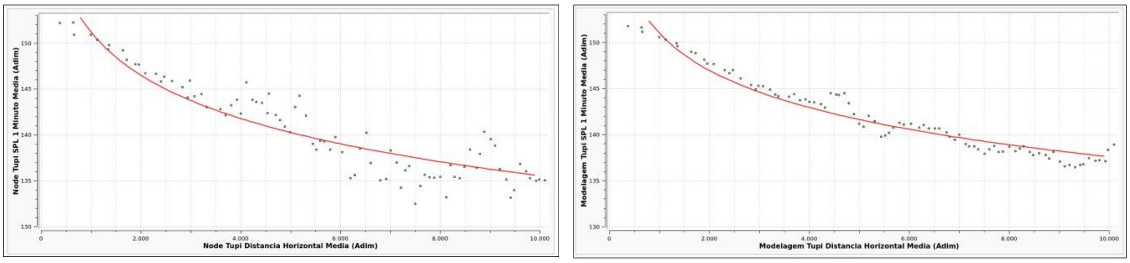

Figure 2: Average SPL as a function of horizontal distance for the field data used in the calibration (on the left) and the data obtained from visco-acoustic modeling (on the right). In red, logarithmic curve fitted to the points follow the model SPL(r) = SL - N * log10(r).

Conclusions

The analysis of OBN and glider data enabled the generation of attenuation curves over distances of up to 250 km between the source and the receiver. As this research continues, the objective is to produce reliable modeling results calibrated with seismic data, enabling accurate estimations of the acoustic impact of acquisition campaigns. This information will be instrumental in planning single or simultaneous acquisitions, ensuring that the environmental implications of seismic survey activities are properly addressed.

The integrated approach to assessing the acoustic energy decay of seismic operations not only deepens our understanding of sound dispersion in marine environments but also supports regulatory compliance and the sustainable management of marine ecosystems.

Acknowledgments

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