Fundamental frequency values of Brazil trough the Brazilian seismographic network (RSBR) and its implications on the seismic hazard assessment and tectonic framework

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Abstract

The Horizontal- to Vertical Spectral Ratio (HVSR), is commonly used to characterize ambient noise and local amplification frequency, as well as depth of sedimentary layers, mapping faults and mineral deposits. In this work, we used data from the Brazilian Seismographic Network (RSBR) to calculate fundamental frequency ($f0$) values for the whole Brazilian territory. The dataset consisted in 45 minutes to 2 hours signal of 40 stations during March, 2020, over night time. The results ranged from 0.22 Hz to 16.68 Hz, with most of the values in the range 0.22 - 9.34 Hz. Overall, the high $f0$ values are concentrated in the Central Brazil, near the Az 125 and Transbrasiliano Lineaments. The values are also close to areas with high density of seismic events. Therefore, it is possible that the high $f0$ values are related to the reactivation of old crustal structures. The results have implications for the seismic hazard assessment of Brazil, as well as the identification of cryptic crustal structures.

Introduction

The Horizontal-Vertical Spectral Ratio (HVSR), also known as the Nakamura Technique (Nakamura, 1989), is a widely used methodology for the characterization of ambient noise and local amplification frequency. The technique uses data from triaxial sensors and ambient noise to measure the frequency of the natural vibration of the soil and bedrock. Other uses for this technique include the mapping of faults, mineral deposits and construction of velocity and density profiles (Khalili & Mirzakurdeh, 2019; Nasser Abu Zeid et al 2017; Bignardi et al, 1996). The Brazilian Seismographic Network (Rede Sismográfica Brasileira - RSBR) offers a catalog of seismic stations that, although spaced, cover the whole Brazilian territory (Figure 1). Therefore, the present works aims to use seismic data from the RSBR to calculate the natural frequency ($f0$) and develop a map at country scale. The results have implications for seismic hazard assessment and regional geological interpretations.

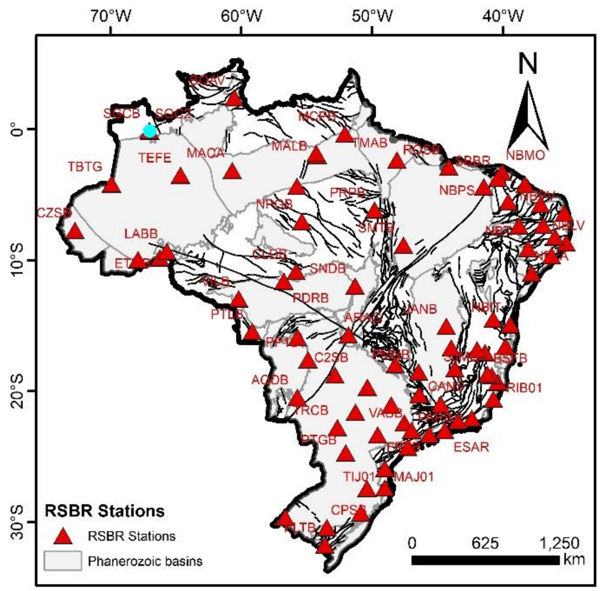

Figure 1 – Location of the seismic stations of the RSBR used in this work.

Method

For the calculation of the HVSR, in a simplified manner, the components of the signal are transformed to the frequency domain. The sum of the horizontal components is divided by the vertical spectrum. The HV Curve as a function of the frequency shows the dominant frequency and the average value of $f0$.

The dataset consists in 45 minutes to 2 hours signal of each station during March 2020, over nigh time The processing was performed using the python package HVSRPY (Vantassel, 2020). For each curve, peak clarity and confibility tests were performed according to the SESAME (Site Effects Assessment using Ambient Excitations) guidelines.

The spatial data was analysed using the software ArcMap 10.8.1. The $f0$ values were interpolated using the Kriging tool, with a 0.5 decimal degrees cell size and exponential semivariogram. The density of seisms was calculated using the Kernel Density tool.

Results

The calculated values of frequency for the 40 stations of RSBR ranged from 0.22 to 16.68 Hz. Since the highest values is clearly outlier from the frequencies obtained from the other stations, mostly below 10 Hz, this station was not included in the interpolated map. Examples of peaks and curves for stations with low, moderate, and high $f0$ are shown in Figure 2. A detailed analysis of each curve needs additional data regarding the installation setting of each station, once wether the station is over an outcrop, or the soil influences the peak shape.

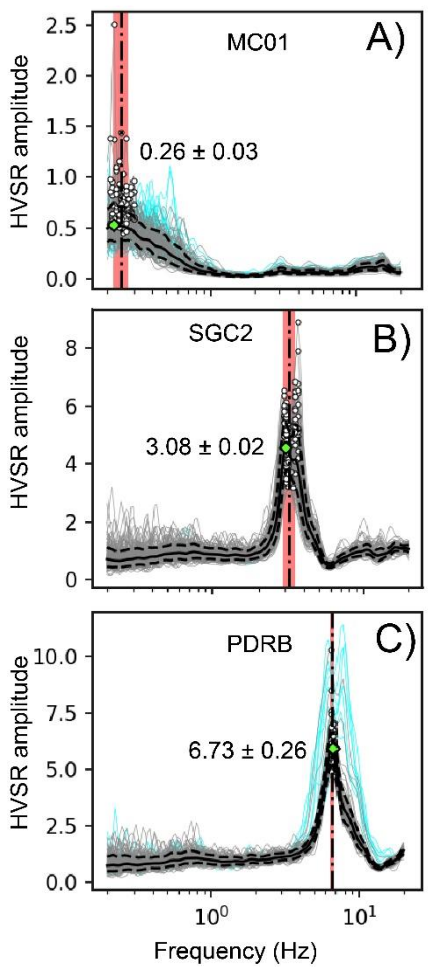

Figure 2 – Examples of curves obtained after the processing of seismic data. A) Low frequency: 0.26 Hz. B) Moderate frequency: 3.08 Hz. C) High frequency: 6.73 Hz. The standard deviation in lognormal scale is also shown.

Overall, the northeastern Brazil shows a moderate range of values, from 0.22 Hz to 2.0 Hz. The same pattern applies to most of the east coast of Brazil. Higher $f0$ values are mostly related to the Central Brazil, close to the Transbraziliano and Az 125 lineaments (Figure 3).

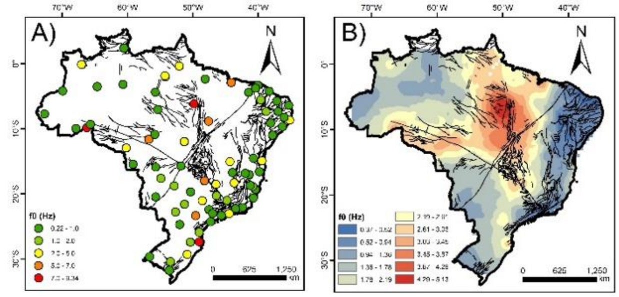

Figure 3 – A) Fundamental frequency values ($f0$) for each station of the RSBR. B) Interpolation of $f0$ alues. In both maps are shown the regional lineaments of Brazil, including the Transbrasiliano and Azimuth 125 lineaments that cross in the Central Brazil.

Comparing the maps of fundamental frequency (Figure 3) with the catalog of seisms in Brazil (Figure 4), it is possible to observe a correlation between areas with a high density of seismic events and areas with high values of $f0$. As an exception, the extreme northeastern of Brazil shows a high density of seismic events but moderate to low $f0$ values.

Altogether, the high $f0$ values are related to the boundaries between crustal blocks that compose the South American Shield. Examples include the limit between the Amazon Craton and the Tocantins Province, as well as the eastern limit with the Borborema Province and São Francisco Craton (Figure 3). Therefore, it is possible that there is a correlation between high $f0$ values and the reactivation of old crustal structures.

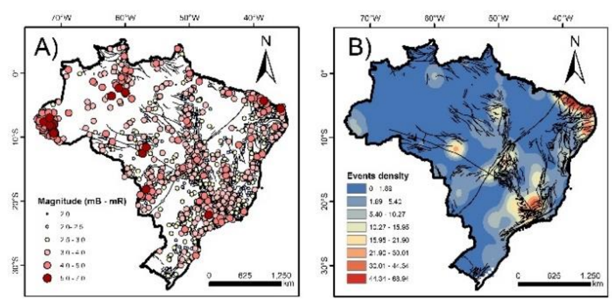

Figure 4 – Location and distiction of the seismic events in Brazil until 2020. The catalog is the product of the cooperation between the University of Brasília, University of São Paulo and Federal University of Rio Grande do Norte. For this study, only events with magnitude higher than 2 were considered. B) Kernel density estimation of the seismic events in Brazil.

Conclusions

Altough the present study shows promising preliminary results, a higher level of detail on what concerns the installation setting of the seismic stations is needed for accurate interpretations. The incorporation of data from local networks and a higher density of points might add the construction of a more precise map. The data might also aid on the calculation of seismic hazard maps (e.g., Assumpção et al., 2014). Other implications for the use of $f0$ values in regional-scale studies include the identification of cryptic crustal structures that are not easily identifiable. The methodology takes advantage from other conventional methodologies since it can be applied on already existing and free to use data that can be easily processed and interpreted.

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