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Infrasound Detections in the I09BR station

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Abstract

Infrasound monitoring is one of the four technologies used by the International Monitoring System (IMS) to verify compliance with CTBT. Shallow atmospheric and underground nuclear explosions can generate infrasound waves that can be detected by infrasound networks. Of the 60 infrasound stations proposed by CTBT, one has been installed in Brazil since 2001. As the last nuclear tests were underground and on the Asian continent, the Brazilian infrasound station did not detect it. However, there are several other sources of infrasound signals detected by IS09 station. This work aims to present the results of the analysis of data, highlighting the main signal sources that the I09BR station has been detected over the years.

Introduction

The implementation of the International Monitoring System to verify compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT) has generated rapid growth in interest in infrasound technology. The Treaty provides for a worldwide network of infrasound consisting of 60 permanent stations installed around the globe by various research organizations, in partnership with the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO). 91% of these stations are already installed.

Infrasound is an inaudible sound by humans and its study is also called by the same name. As it is an acoustic disturbance, it is characterized by variations in air pressure, whose frequencies vary from 0.001Hz to 20Hz and, due to its high wavelengths, between 17 m and 30 km, it can travel large distances in the atmosphere, as it suffers low attenuation (Gossard and Hooke 1975). The main function of the infrasound station is to measure atmospheric pressure fluctuations and convert them into a digital signal.

Infrasound stations were developed to detect atmospheric nuclear explosions. Each station consists of an array of spatially distributed sensors following a given geometry. One element of this arrangement is composed of a sensor (microbarometer), a noise reduction system, a photovoltaic power supply system, and a data transmission system using a secure communication system. Data from IMS stations are sent in near real-time to the IDC (International Data Center), locate in Vienna - Austria (Christie & Campus, 2009).

The Brazilian Infrasound station is located in Brasília, a subtropical region in the interior of Brazil. The four elements of the triangular arrangement of the I09BR are installed within the ecological reserve of the Brasília National Park (PNB) about 20km away from the Seismological Observatory of the University of Brasília (SIS - UnB) (Barros and Fontenele, 2002). The I09BR for safety and logistics reasons is in an appropriate location, as access to the environmental protection area is only allowed for authorized people, the PNB vegetation collaborates with noise levels, as it helps to filter out wind turbulence, and the station is close to the Central Data Reception and Recording Facility (Central Processing Facility) located at SIS - UnB.

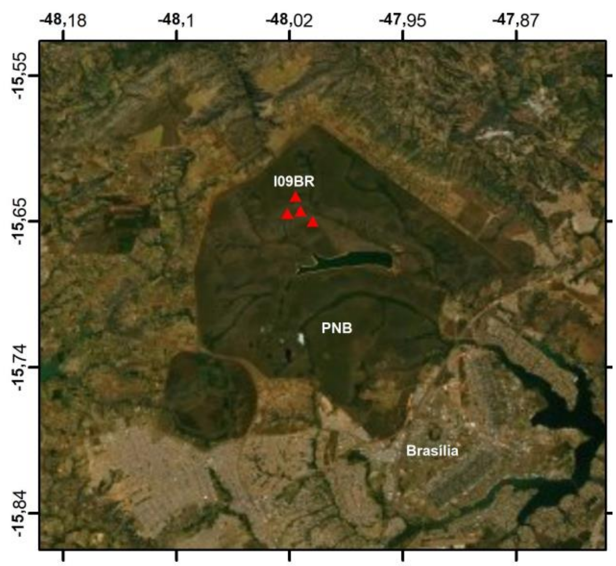

Figure 1: Location of the I09BR infrasund station arrangement.

The IMS network of infrasound stations was designed to reliably detect any atmospheric nuclear explosion with a power equivalent to or greater than one kiloton of TNT (1000 tons of TNT), anywhere in the world (Christie et al., 2001).

In addition to its use in CTBT verification, infrasound technology has application in scientific and social areas, like other natural and anthropogenic phenomena can also generate infrasound. For example large volcanic eruptions (Cotten et al., 1971; Fee et al., 2013; Jeffrey B Johnson et al., 2004; Jeffrey B Johnson & Ripepe, 2011; Matoza R. et al., 2019; Jack W Reed, 1987); severe climates (Waxler & Assink, 2019); detonations in mining companies (Bowman & Bedard, 2010; Georges, 1973; Lin

& Langston, 2009); rocket launch and re-entry in the atmosphere (Cotten et al., 1971; Garces M. et al., 2004); supersonic aircraft (Liszka & Waldemark, 1995), among others.

The infrasound stations of the International Monitoring Network almost always operate 24 hours a day 7 days a week without interruption. The I09BR records daily many infrasound signals from sources located around the station. In this study, 4 years (2015 to 2018) of data collected by the I09BR station were analyzed, showing the behavior of infrasound detections with the variation of the seasons. We also identified from the noisy background the main fixed sources that generate infrasound.

Method

Initially, the signal from the sensor (microbarometer) is converted by the digitizer into a digital signal that convert the analog signal in a digital signal. This data is then sent to IDC and can be requested by registered users from CTBT signatory countries. The first stage of data processing takes place individually, that is, the data from each station is processed individually. In this step, the infrasound detections Multi-Channel Progressive Correlation algorithm PMCC (Progressive Multichannel Correlation), Cansi (1995), and Cansi & Klinger (1997), which is implemented in the DTK-PMCC and DTK-GPMCC software, are produced. This signal detection technique was developed for application to seismic data and has proven to be efficient for extracting low amplitude signals contaminated by noise.

The processing set up to build the International Data Center PMCC Families uses 11 frequency bands between 0.07 and 4.0 Hz, and in adjacent time windows covering the entire analysis period. The length of the processing window depends inversely on the frequency band. This ranges from 60 seconds for the lowest frequencies to 30 seconds for the highest frequency. This first processing stage produces elementary detections, called PMCC pixels, which satisfy the criteria of correlation and consistency (Figure 2 a). The next step is the grouping of individual detection pixels that have similar signal attributes in time, frequency, back azimuth, and horizontal velocity. Neighboring pixel groups constitute a PMCC family (Pichon et al., 2010) – Figure 2 b.

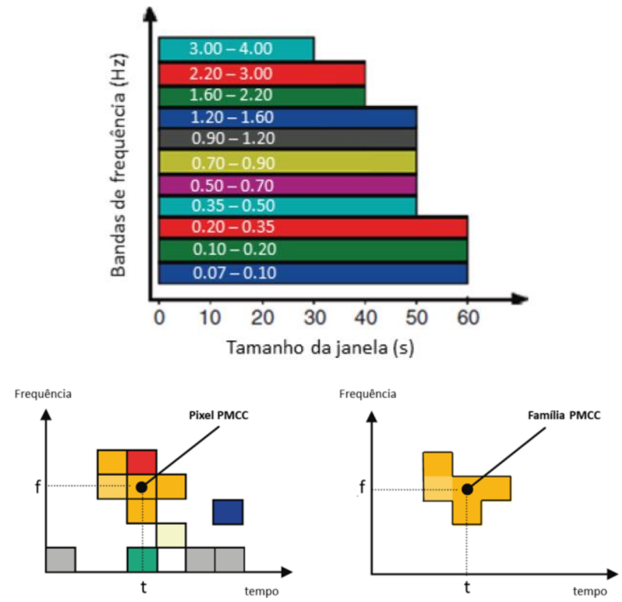

Figure 2: a) IDC configuration b) IDC configuration for PMCC processing, showing the duration of the processing time windows as a function of the frequency band. c) Formation of a PMCC family from pixels with similar characteristics (adapted from le Pichon et al., 2010).

With the infrasound detections of four years of data from the I09BR station, an evaluation of the behavior over time will be made using the DTK-DIVA software. Identify the orientation of the fixed sources that generate the infrared signal.

Average weather conditions in Brasilia

The report available at weatherspark.com shows Brasilia's characteristic weather conditions based on a statistical analysis of historical reports and reconstructions from January 1, 1980, to December 31, 2016. In Brasilia, there are two well-defined seasons, the dry season and the rainy season (Figure 3). The probability of rainy days in Brasilia varies widely throughout the year. The season with the highest rainfall lasts 6.2 months, from October 7th to April 14th, with more than 40% probability that on any given day it will rain. The dry season lasts 5.8 months, from April 14th to October 7th.

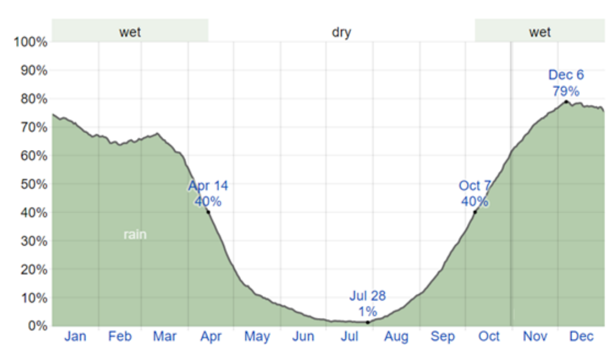

Figure 1: Precipitation probability in Brasilia (Weatherspark.com).

Results

From the 4-year processing (2015 - 2018) using the PMCC algorithm, it is possible to identify a large number of infrasound detections. Unfortunately, for part of the year 2016, the station was inoperable, which is why on some dates it has not been given. Figure 4 shows the infrasound detection graph of the Brazilian station. The x-axis represents time, the y-axis represents the azimuth from which the signals arrived, and the color scale represents frequency in hertz. In this Figure we can identify detections over the months with constant guidance. As is the case with azimuths around 180° and 65°, which throughout all these years have high-frequency signals (red). Low-frequency signals (blue) are also registered over the months. The signal with an orientation of around 200° to 250° of low frequency occurs only during the dry season in Brasília. In Figure 4 it is also possible to see that during the rainy season the I09BR station detects more high-frequency signals compared to the dry season.

From the polar graphs of the number of detections separated by year (Figure 5), we can distinguish the groups as the main fixed sources of infrasound signal that the I09BR station detects. We also have a notion of the evolution of the amount of signal coming from each azimuth allowing us to have a notion of the source generating the signal.

The fixed infrasound signal sources closest to the I09BR station are the Votorantim Cimentos mining companies 15 km away (60°), and the urban center of the Federal District, with great influence from Brasília International Airport to the south. Figure 5 shows the considerable reduction over the years of detections arising from the explosions produced by the Votorantim mining companies. This is due to urban growth around the mining region, and pressure from residents to reduce the amount of blasting.

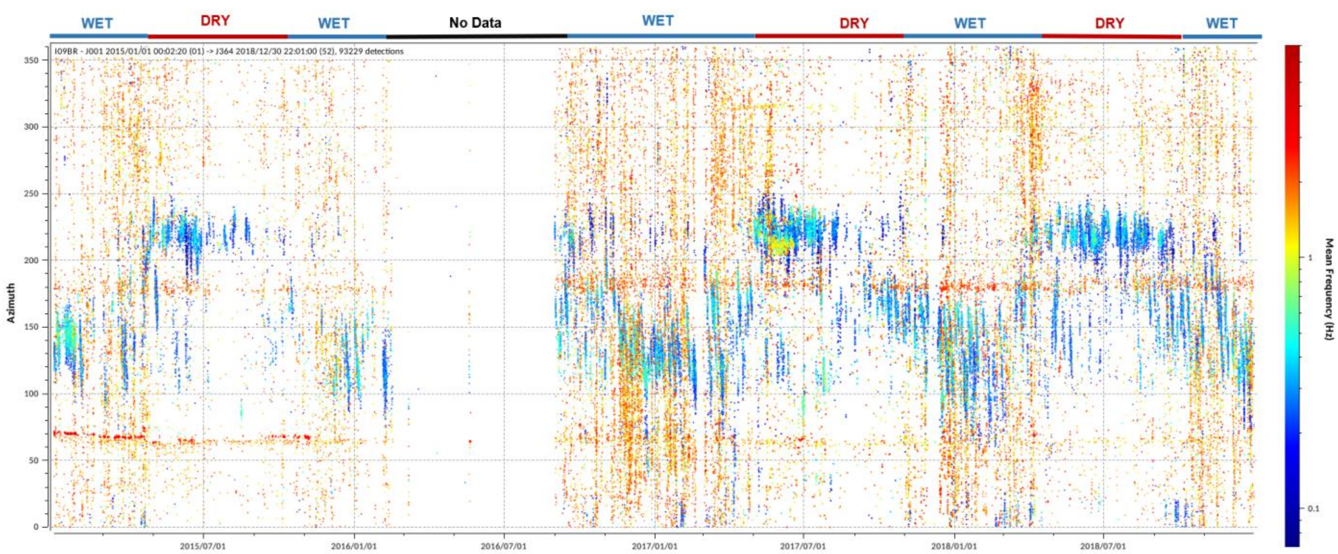

Figure 2: Graph of infrasonic detections by the I09BR station in the period from 2015 to 2018.

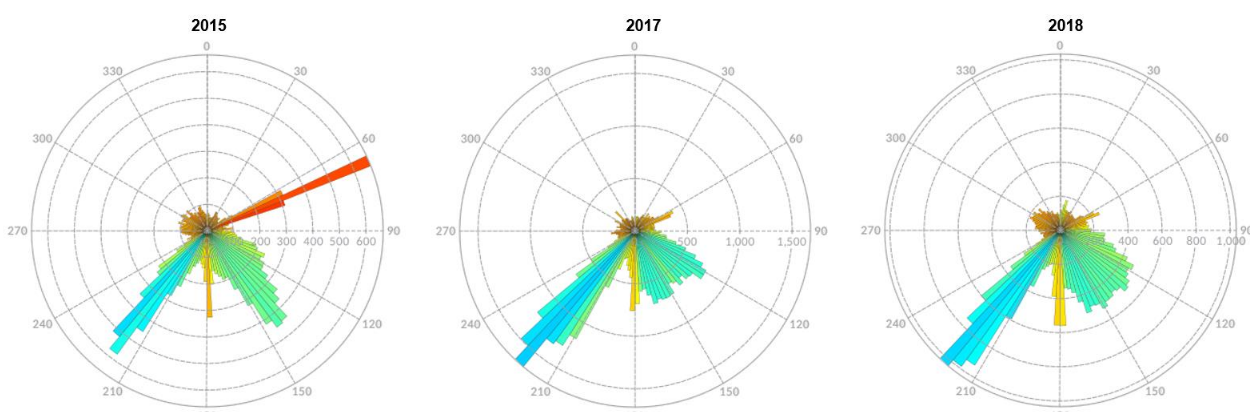

Figure 3: Polar graph of the number of infrasonic detections by the I09BR station.

Part of the low-frequency signal from the 200° to 250° azimuth range are record only in the dry season.

A portion of the infrasound detections comes from the azimuthal range between 90° and 170°, and has the same orientation as the Minas Gerais State that has the most mining companies in Brazil. Most of the signals acquired by the infrasound array are from sources close to the Earth's surface. Blasts in mining companies are typical examples of artificial sources that can be recorded, both in seismology and infrasound (Hagerty et al., 2002). Using the information from the UnB Seismological Observatory reports, it is not always possible to identify the PMCC families generated by the mining explosions. In 2017 for example, only 10% of the blasts were able to generate PMCC families (Figure 6), meeting the azimuth and probable arrival time requirements.

Figure 6 also shows other mining companies, to the south, southeast, and northwest, which also carry out blasts that generate infrasound signals that the I09BR station records, and are present in Figure 5.

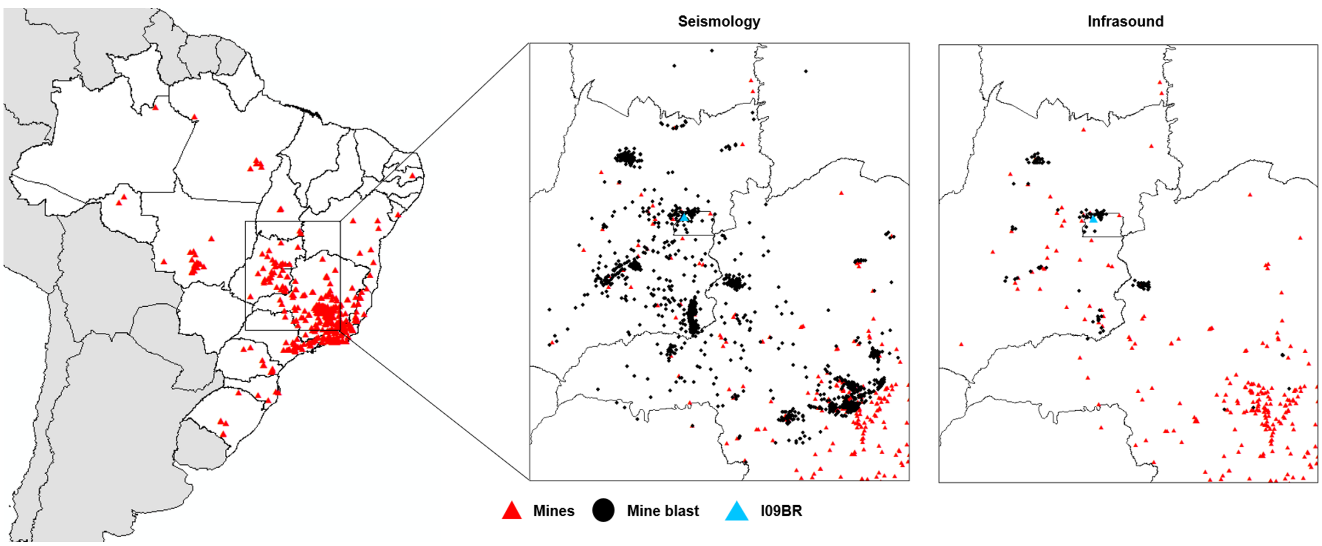

Figure 4: Relation of the number of blast detections in mining companies by the Brazilian seismographic network and by the I09BR station.

Conclusions

The Brasília infrasound station, which belongs to the International Monitoring System, proved to be efficient in detecting signals of different natures. From the processing of a large period of data recorded by I09BR, we can identify the main fixed infrasound sources. The background noise of the infrasound station brings information that we can correlate with the weather conditions in which they are found, favoring or not the detection of a fixed source.

Acknowledgments

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