Seasonal Monitoring of Hydrological Stresses Developed by Varying Degree of Rainfall Induced Pore-Pressures Using Noise Data

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Abstract

The ever increasing urbanization over the thick and less cohesive soil of the Federal District (DF), Brazil has increased the vulnerability of this area to natural hazards, especially to soil erosion and landslides. Such a condition stresses the necessity to deploy geophysical investigations to highlight predisposing conditions as well as local evolution of hazardous processes. More in particular, this study aims at the noise characterization applied to a mass movement in Brasilia, Brazil using Power Spectral Density (PSD). The data acquisition was performed by 10 Sorcel L-4A-3D short period seismometers with natural frequency response of 2 Hz. The data was recorded in a continuous mode at sampling rate of 250 sample/second with DASS-130 RefTek dataloggers. Time and locations are provided by ten GPS- 130 locks. Preliminary results were obtained by analysing changes in noise frequency content; these results clearly showed that possible sources of noise are both man-induced emissions (i.e. due to carbonate mining near the area) and actual earth vibrations. The here reported preliminary results only output that strong correlations exist between peaks in PSD and man-induced noise. Follow research will be focused on possible changes in noise recorded within landslide mass mainly related to natural factors such as saturation conditions due to rainfalls or earthquake occurrence since they can be regarded as responsible for variation of mechanical properties and/or landslide mass movement.

Introduction

The sallow mass movements have greater share in the global terrestrial hazards, especially in Brazil. The tragedies of 1967 in Rio de Janeiro are the tragic reminder of the atrocities caused by the shallow rainfall triggered Landslide (LS). The area of District Federal (DF) is characterized by the thick and weak soil which is less supportive to civil engineering structures. The growth of population in surrounding regions of DF has greatly affected the ecosystem of the area by distrusting the natural drainages that are not compensated with managerial works. The water quality deterioration and soil erosion are two major environmental responses to these unplanned urban growths in DF (Mendonça et al. 1994).

Noise data has a potential to provide high resolution spatio-temporal information about the land-scape dynamics. The geomorphological processes on earth produces seismic signals and the amplitude and frequency characteristics help in identification of these processes (Burtin et al. 2013). The sources of noise are usually dynamic in nature because of this dynamism the levels of noise in a region are not constants. Taking this variability of noise in mind we have applied a statistical analysis to the Power Spectral Density (PSD).

Main objective of this study is to understand, the dynamics of a mass movement in Contagem River Basin. For the time being the characterization of noise sources is done by PSD analysis with three-component short period sensors deployed in a two dimensional array. Finally, we discuss the velocity changes and their relationship with rainfall induced stresses by the seasonal variations in pore pressure. Next, we show ambient noise characteristics in the area and then explain the method to compute CCFs Physically speaking, that most solids emit low level signals when stressed or deformed which are produced due to the sudden release of stored elastic energy within the material.

Material and Methods

DF has an area of 5,783 km^2 and is located between 17^{0}30' and 16^0 03 ' south and 47^0 25' and 48º 12' west (Figure 1). There are intense limestone mining in the study area All landforms of the area are under erosional affects because of rainfall. Laminar soil loss at higher slopes is the problem. The climate in the area is semi-humid tropical with a rainy summer and dry winter. Average annual precipitation is 1500 mm. The technical studies to locate the new capital had indicated a high soil susceptibility to erosion (Mendonça et al. 1994). The slopes chosen for this work are located in the cow farm as shown in Figure 1.

Data acquisition consists of deployment of 10 Sorcel L-4A-3D short period seismometers with natural frequency response of 2 Hz were deployed in the field. The data was recorded in a continuous mode at sampling rate of 250 sample per second (SPS) with DASS-130 RefTek dataloggers. The time and positions are provided by the ten GPS-130 locks. The data was recorded between Julian day of 306 to 324 year 2016. The sensors were placed in 2-Dimensional (2-D) geometry. The average sensor spacing is taken as less than 20 meters.

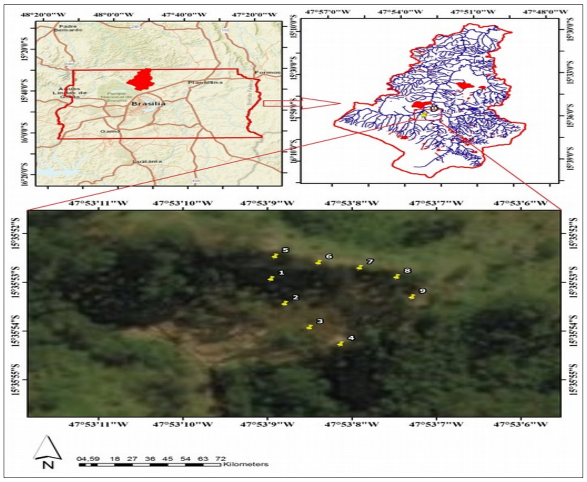

Figure 1 - Location of the study area and ambient noise recording sites

The main features of recoded signal can be assessed by time-frequency analysis (Burtin et al. 2008). The spectrograms are calculated with a Power Spectral Density (PSD) approach as it is described in detail by Burtin et al. 2014. The processing steps are, detrend the signal, mean subtraction, and then finally the instrument response is removed. Then multitaper method (Thomson, 1982) is applied to a 1-hour- time window and power spectrum is estimated. In this way a high frequency resolution is achieved for short record, which decrease the number of computed frequencies in a spectrum.

Results and Discussion

These estimations are poor at frequencies less that 2 Hz due to sensor response. To study the variability of the seismic noise with time, we plot the PSD levels as a function of the period versus time in one day long spectrograms. The spectrograms enhance several interesting patterns with different characteristics. Figure 2 show variable amplitude levels (-135 to -110) between 3 to 8 Hz along record time. For frequencies larger than 8 Hz, amplitude spectra exhibit large PDS values (> -110). We have average spectral values between 3 and 8 Hz in order to explore the stability of the noise at each station. Figure 3 show the mean and standard deviation of PDS spectra values between 3 and 8 Hz. We observe a decrease activity between 22:00 and 06:00 hrs, and increase activity values 8:00 and 20:00 hours with a well dominant frequencies larger that 6.5 Hz. On the weekend, we observe a little standard deviation with a large decrease of activity. This decrease are present for frequencies between 4 and 6 Hz.

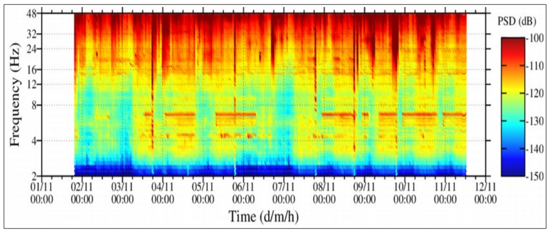

Figure 2 - Spectrogram of PDS for the station S1 on vertical component.

In order to find differences between all pair of stations, we applied Seismic Interferometry (SI) method (Sneider & Wapenaar 2010) and we explore all crossterm components (Wijk et al. 2012). We applied the process of Bensen et al. (2007); normalization of a bit more spectral whiten. After pre-processing of the data, we chose to make cross-correlations between 4s time windows (225 time windows were stacked by each 15 min). This time is much greater than the transit time between receivers with greater spacing (62 m).

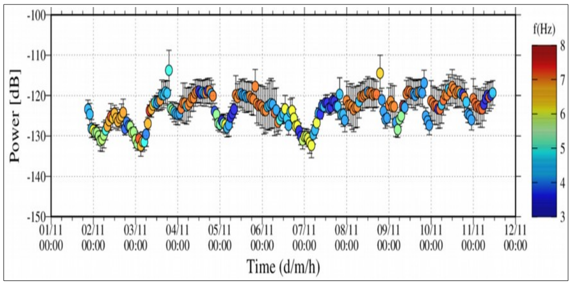

Figure 3 - Mean and standard deviation values at S1 station obtained from the PDS vertical spectrogram (Figure 2) between 3 to 8 Hz. Color bar indicates the dominant frequency of mean value.

Figure 4 shows the cross-correlation functions between S1 and S5 station for ZZ, RR and ZR components for November 2. Traces are filtered between 3 to 8 Hz. We observe that ZZ and RR traces are almost identical, the correlation pulse is close to zero, indicating the proximity of the stations. Same results are observed on TT component. However, ZR component exhibit waveforms in times delays larger than +- 0.5 s, mainly in acausal part. Some of these arrives could be ballistic waves, but in generally, coda waves trains appear and disappear along the day. This result is consistent with PDS analysis, indicating changes in the subsoil structure due to surrounding source noises.

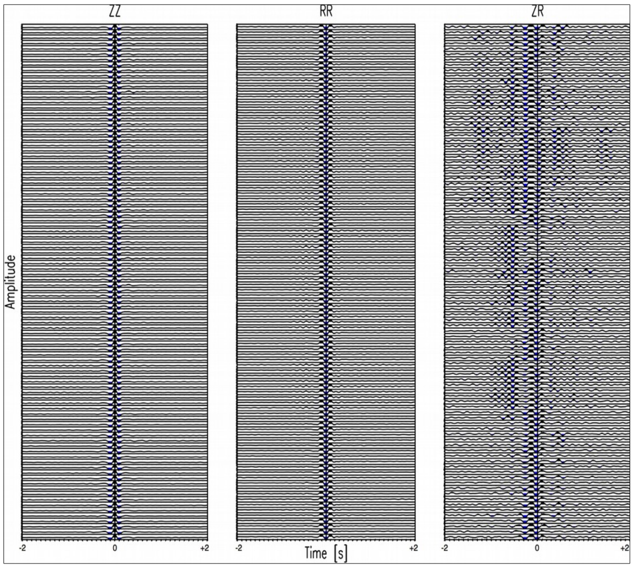

Figure 4 - Cross correlations functions; ZZ, RR and ZR components bandpass filtered between 3 to 8 Hz. One day long cross-correlation calculated for dry period record (November 2).

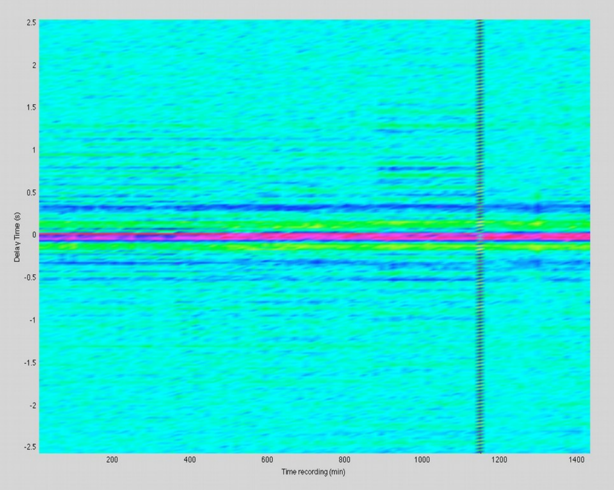

Figure 5 - Green Function (Impulse response) between stations S1 and S2 (Normal component) for the Julian day 308.

In future, the Green Functions among all the possible station pairs will be done at three time scales (seasons) i.e. before, during and after the rainy season. From these seasonal Green function shear-wave velocity will be calculated (Harba & Pilecki, 2016). Then the seasonal impacts on the mass movement will be calculated by measuring changes in shear-wave velocity.

Conclusions

The here obtained results output that the contribution to the noise recorded at stations inside and outside the monitored landslide are likely due to several factors including man-induced disturbance and instrument self-noise. Nevertheless, a significant difference in PSD can be recorded inside and outside the landslide mass which can be referred to different damping levels. Future analyses will be focused on highlighting noise properties changes to be related to variation of physical properties in the landslide mass (i.e. due to soil saturation after rainfalls, or earthquake-induced reactivations). We can finally affirm that the use of ambient noise records showed to be a reliable and not expensive technique for a quick characterization of the seasonal impacts on a mass movement.

Acknowledgments

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