THE MAY 16,2010 Mw. 5.8 PUERTO RICO EARTHQUAKE: SITE CHARACTERIZATION, LOCAL SITES EFFECTS, AND JOINT TIME-FREQUENCY ANALYSIS

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ABSTRACT

On May 16 2010, at 05:16:10 (UTC), the northwest area of the Puerto Rico Island was struck by a moderate-sized earthquake (Mw. 5.8). It was felt in the eastern Dominican Republic, the Virgin Islands and all over the Puerto Rico Island. The earthquake was recorded by 63 accelerographic stations of the Puerto Rico Strong Motion Program (PRSMP) distributed around the island. Only free-field stations seated on soil or rock were used in this study. In the first stage, the accelerograms were analyzed following the well established data processing procedure for acceleration strong motion records through volume I to III, and the Power Spectral Density (PSD's) was computed. Secondly, a joint time-frequency analysis was carried out using different time-frequency distributions. The aim of the joint time-frequency spectral decomposition is to assess the strength of the signal energy as a function of the variables frequency *"f"* and time *"t"*, in order to generate a distribution which appropriately identifies the energy distribution in the time-frequency plane. The following Cohen class distributions were applied: (i) Short Time Fourier Transform (STFT), (ii) Wigner-Ville Distribution (WVD), (iii) Choi-Williams Distribution (CWD), (iv) Reduced Interference Distribution (RID), and (v) Adaptive Optimal Kernel (AOK). Each of these distributions was applied to the recorded data and a comparison among them was analyzed. Finally, an experimental and numerical modeling of H/V spectral ratio (HVSPR) was performed to characterize the sites in terms of the fundamental vibration frequency, the subsoil geometry and physical properties. The adopted procedure for the site characterization in terms of the subsoil geometry and physical properties was through an iterative forward modeling process until the lowest residual between the experimental and the theoretical HVSPR of the fundamental vibration mode was obtained.

JOINT TIME FREQUENCY ANALYSIS

The Time-Frequency Representation (TFRs) of signals map a one-dimensional signal of time *x(t)*, into a two-dimensional function of Time and Frequency *T(t,f)*.
Any time-frequency representation that fulfill the equations (1) is considered a Time-Frequency Energy Distribution (TFED) *P (t,f)*

$$|x(t)|^2 = \int_{-\infty}^{\infty} P(t,\omega)d\omega \qquad (1)$$

$$|s(\omega)|^2 = \int_{-\infty}^{\infty} P(t,\omega)dt$$

$$P(t,\omega) = \frac{1}{4\pi^2}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{-j\theta t - j\tau\omega + j\theta u}\phi(\theta,\tau)x^*\left(u-\frac{1}{2}\tau\right)x\left(u+\frac{1}{2}\tau\right)du\,d\tau\,d\theta \qquad (2)$$

Where Φ(θ,τ) is the kernel, which for Cohen's Class Distributions is independent of time and frequency.(Cohen,1995)

In equation (2), it is important to note that *x(t) is* the complex associate analytical *xr(t)*. The analytical signal is defined as (Quian and Chen, 1996).

$$x(t) = x_r(t) + jHT(x(t)) \qquad (3)$$

Time-Frequency Distributions Kernel

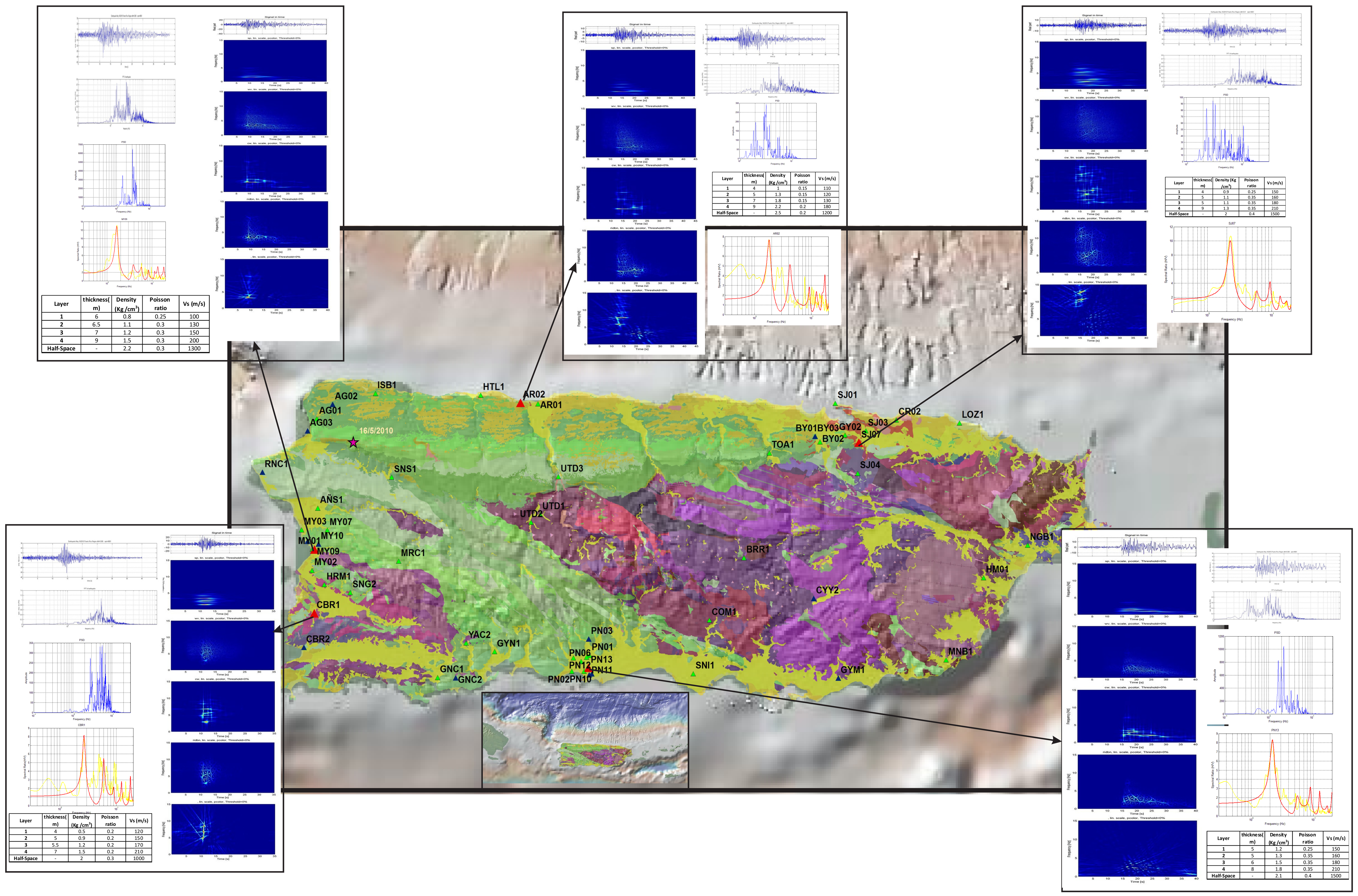
Time Frequency Representation	Kernel $\phi_x(\theta,\tau)$
Spectrogram (SP)	$\int_{-\infty}^{\infty} h^*\left(u-\frac{1}{2}\tau\right)h\left(u+\frac{1}{2}\tau\right)e^{-j\theta u}\,du$
Wigner-Ville (WVD)	1
Choi-Williams (CWD)	$e^{-\frac{\theta^2\tau^2}{\sigma}}$
Reduced Interference (RID)	2D low pass filter in (θ,τ) space
Radial Gaussian Kernel (RGKD)	$e^{-\frac{r^2}{2\sigma^2}(\psi)}$
Adaptive Optimal Kernel (AOKD)	$A(t:\theta,\tau)$ applied to the optimization of $e^{-\frac{(\theta^2+\tau^2)}{2\sigma^2}(\psi)}$

HVSPR

The horizontal to vertical spectral ratio method (HVSPR) was proposed by Nakamura (Nakamura, 1989), it consists in estimating the ratio between the Fourier amplitude spectra of the horizontal and the vertical components. The spectral ratio (HSVPR) is defined as:

$$(H/V) = \frac{\sqrt{\frac{H_1^2+H_2^2}{2}}}{V}$$

In which V is Fourier amplitude of the vertical motion, and H_1 and H_2 are those of two orthogonal horizontal motions.



ANALYSIS AND RESULTS

The seismic records used in this analysis were corrected for instrument effects to provide absolute values of acceleration of the ground motions. At first the characteristics of the earthquake signals were analyzed using the FFT and the PSD. The frequency domain representation of the horizontal component (e.g Station MY09) at least five frequency components, located at 1.5, 1.8, 2.2, 2.5 and 3 Hz, are clearly seen. The SP shows a concentration of energy at ~ 1.4,1.6 Hz correspondig to the dominant frequency, the WVD, CWD, RID show interference and concentration of energy in 9 sec.

The analysis for the HVSPR begins with the transformation of the time domain signals to the frequency domain by using the algorithm of the Discrete Fourier Transform (DFT). From the spectrum, the HVSPR is computed, but first, the average of the two horizontal components was calculated. This process was done for each set of data-station. In modeling the theoretical HVSPR the algorithm developed by Kausel and Roesset (1981), which solve the wave propagation phenomena for SH-, SV- and P-waves was used.

DISCUSSION AND CONCLUSIONS

-Time-Frequency analysis was focused on using five of the most well known and common used TFD. From these, the Spectrogram (SP), the Wigner-Ville distribution (WVD), the Choi-Williams distribution (CWD), the reduced interference distribution (RID), and the adaptive optimal kernel (AOK).

-The frequency resolution of the SP is limited, and restricts its use for highly resolve time-frequency characteristics of earthquake signals. The resolution of WVD is good, nevertheless the presence of interference terms makes the interpretation difficult. The CWD shows an good resolution in time-frequency, it shows interference in the frequency band represented by vertical lines. the RID has a good time-frequency resolution, but some interference terms appear in time and frequency. The AOK has a good resolution in time-frequency,in case of multi-component signals

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