PRSMP

PUERTO RICO STRONG MOTION PROGRAM

Peak ground acceleration response of three moderate magnitude earthquakes and their implication to local site effects in the Puerto Rico Island

By:

Carlos I. Huerta-López, Ph.D

José A. Martínez-Cruzado, Ph.D

Fabio M. Upegui-Botero, Grad. Stud.

Luis E. Suarez-Colche, Ph.D.

SouthEastern GSA Meeting 03/21-22/2013. V45, No.2. ISSN:0016-7592 (Session 39-1)

Overview

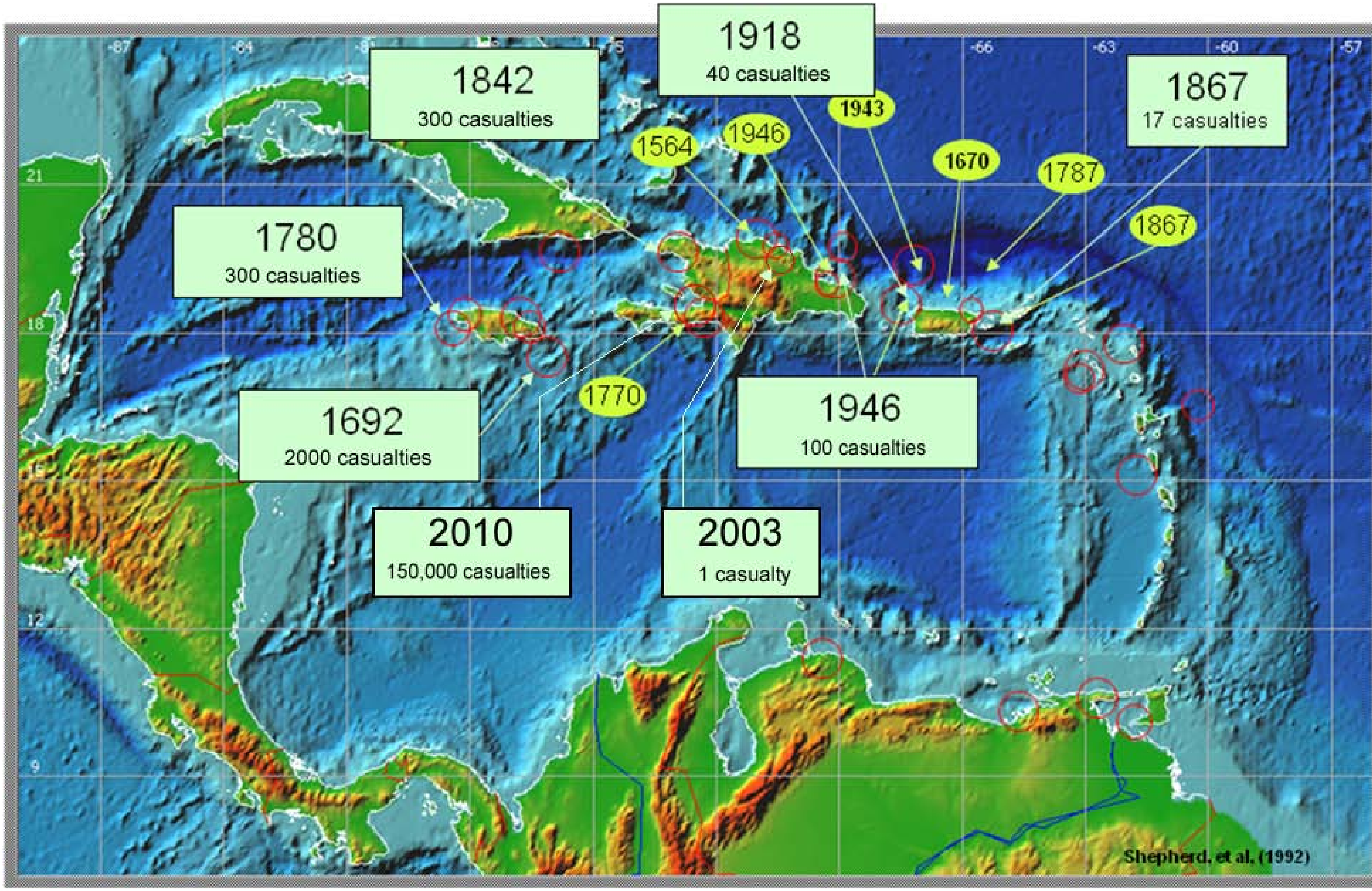
- Introduction.
- Objectives
- Puerto Rico Strong Motion Program (PRSMP)
- Data collection/processing/analysis
- Background
- PGA/SA/and site characterization
- Current results/discussion

Introduction

Puerto Rico island, located in the Caribbean zone, is surrounded by active seismic faults capable to generate strong ground motions.

Several major cities (San Juan/Ponce/Mayagüez) of Puerto Rico, and great portion of the urban areas are located in young poorly consolidated alluvial deposits.

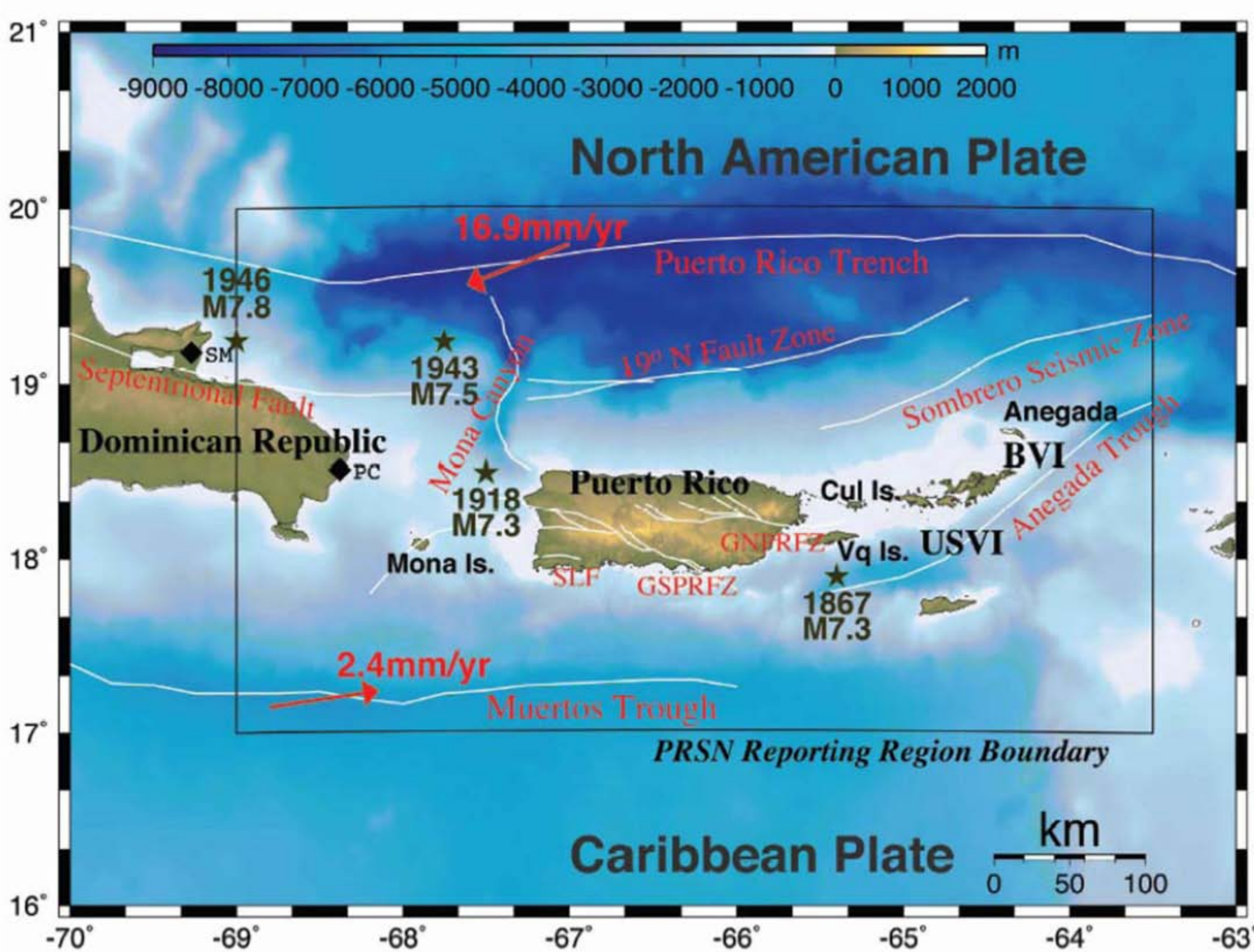
Site characterization studies have been carried out to estimate surface ground motions that incorporate local site effects (e.g. Pérez, 2005; Ritta, 2009; Candelario, 2013).



SouthEastern GSA Meeting 03/21-22/2013. V45, No.2. ISSN:0016-7592 (Session 39-1)

PRSMP

PUERTO RICO STRONG MOTION PROGRAM



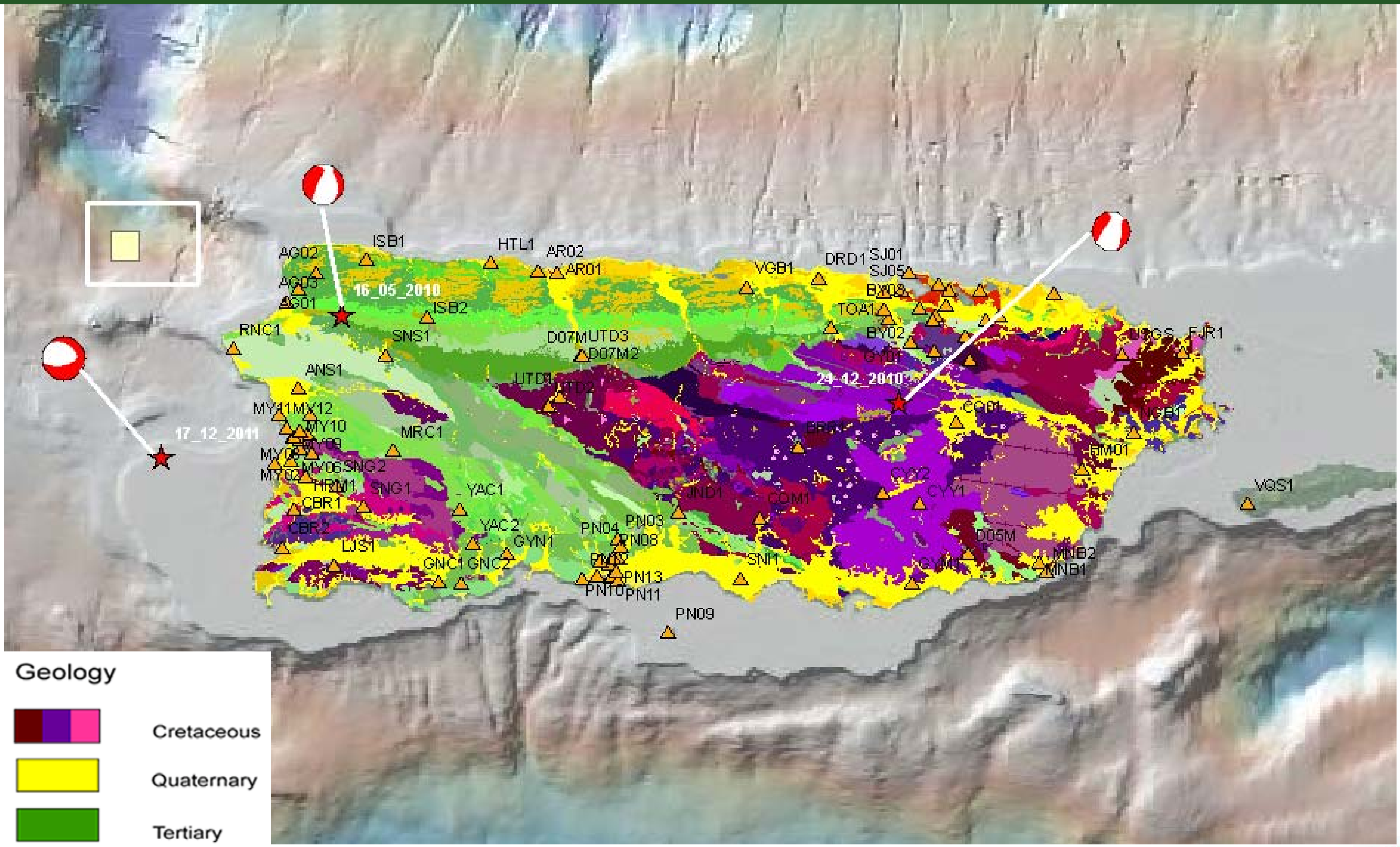
SouthEastern GSA Meeting 03/21-22/2013. V45, No.2. ISSN:0016-7592 (Session 39-1)

Puerto Rico Strong Motion Program (PRSMP)

- PRSMP is dedicated to obtain reliable and precise strong motion records produced by earthquakes affecting the Puerto Rico region. The PRSMP has 101 free-field stations, and 15 instrumented structures and dams. Among the free-field stations 27 are stand alone, 48 have telephone dial-up communication, 14 are connected through the internet and 12 are shared with the Puerto Rico Seismic Network. Regarding the stations at instrumented structures, 11 are stand alone, and 4 have internet communication. All the stations are distributed around Puerto Rico, the US and British Virgin Islands, and the Dominican Republic, and are equipped with tri-axial accelerometers, 24 bits digital recorders, at sampling frequency of 200 Hz.

PRSMP

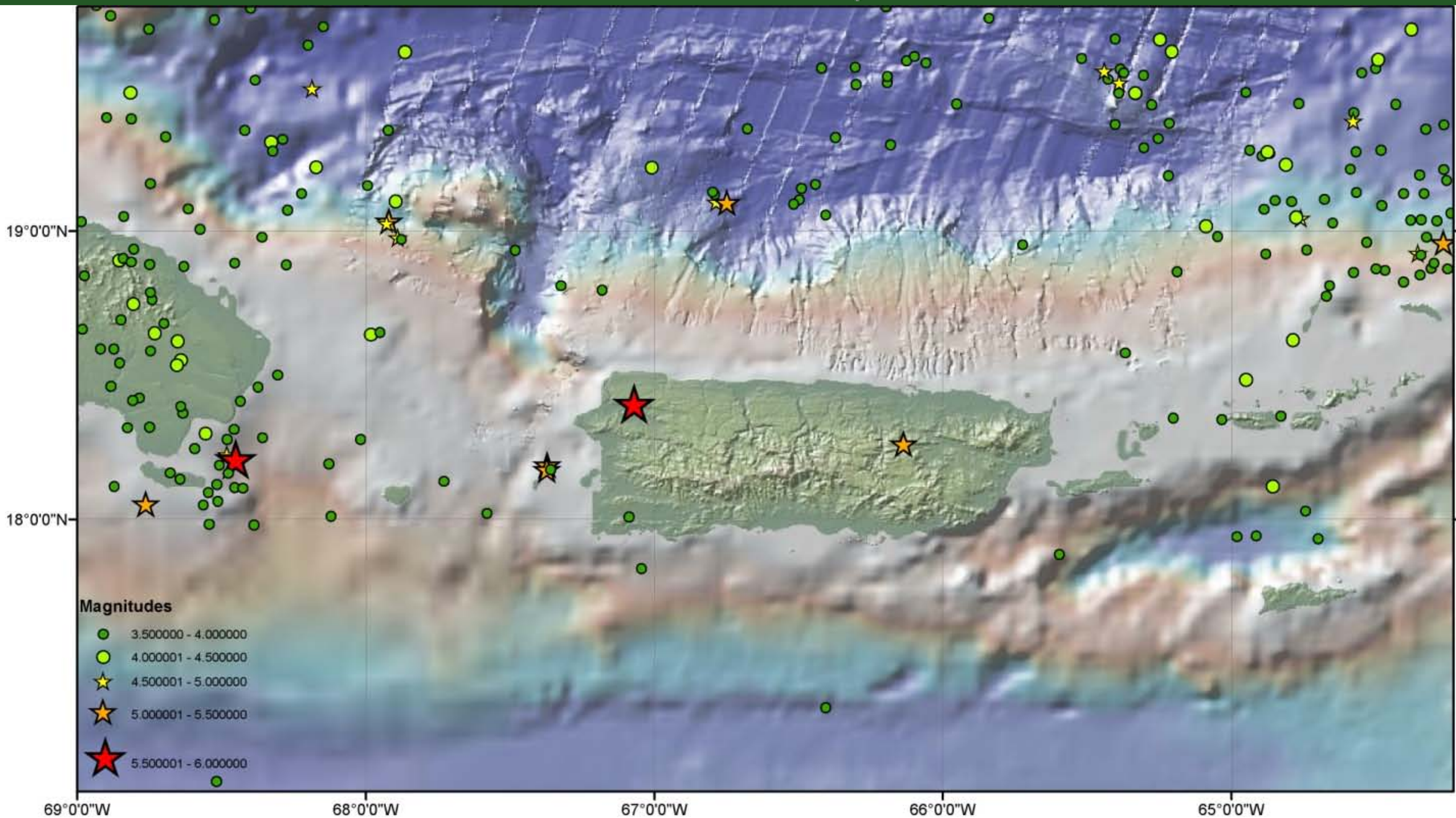
PUERTO RICO STRONG MOTION PROGRAM



SouthEastern GSA Meeting 03/21-22/2013. V45, No.2. ISSN:0016-7592 (Session 39-1)

PRSMP

PUERTO RICO STRONG MOTION PROGRAM



SouthEastern GSA Meeting 03/21-22/2013. V45, No.2. ISSN:0016-7592 (Session 39-1)

Data

- This study is focused on three Puerto Rico earthquakes (05/16/2010 M_W5.8, 12/17/2011 M_W5.3, and 12/24/2010 M_W5.4).
- They are of special interest due to the irregular peak ground acceleration (PGA) and spectral amplitudes (SA) distribution within the island with respect to the expected decay of the PGA and the SA as the distance increase.
- Local site conditions (effects), as well as path effects are here discussed in order to explain this observed behavior.

Method

- **Standard strong motion signal processing was applied to the recorded data obtaining the .V1, .V2, and .V3 processed data, which correspond to the uncorrected acceleration records converted to physical units, the corrected acceleration record in physical units of acceleration, velocity and displacement, and the spectral representation of all above, respectively.**
- **Instrumental intensity (Modified Mercalli Intensity, MMI) was estimated using the Wald et al. (1999) equations.**

SouthEastern GSA Meeting 03/21-22/2013. V45, No.2. ISSN:0016-7592 (Session 39-1)

Ambient vibration (AV) measurements are widely used in different ways to estimate the under-laying subsoil structure and its physical properties.

The SPAC method proposed by Aki (Aki, 1957), which is based on the theory of the stationary random functions, in which the ambient vibrations are considered stationary in both time and space

The H/V Spectral Ratio (HVSPR) that, as proposed by Nakamura (Nakamura, 1989), consists in estimate the ratio between the amplitude Fourier spectra of the horizontal and the vertical components using ambient vibration measurements

SPAC method estimates the correlation coefficients between pairs of measurements in an azimuthal array of sensors from which the dispersion curves of surface Rayleigh waves are estimated.

The HVSPR hypothesis states that the vertical component of ambient noise keeps the characteristics of source to sediments surface ground, is relatively influenced by Rayleigh wave on the sediments and can therefore be used to remove both of the source and the Rayleigh wave effects from the horizontal components (Nakamura, 2000).

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

SouthEastern GSA Meeting 03/21-22/2013. V45, No.2. ISSN:0016-7592 (Session 39-1)

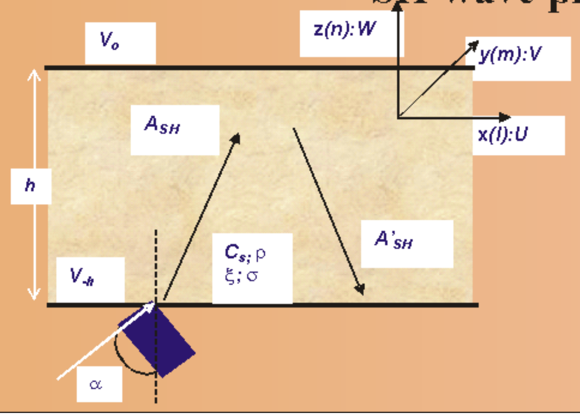
The SPAC coefficients $\rho(r,\omega)$ may be directly calculated from the observed microtremor data in the frequency domain using the Fourier Transform.

$$\Gamma_{o,j}(r,\theta,\omega) = \mathrm{Re}\left(\frac{A_{o,j}(r,\theta,\omega)}{\sqrt{A_o(\omega)\cdot A_j(r,\theta,\omega)}}\right)$$

$$\rho(r,\omega) = \frac{1}{2\pi\Gamma}\int_0^{2\pi}\Gamma_{o,j}(r,\theta,\omega)d\theta = J_o\left(\frac{\omega r}{c(\omega)}\right)$$

The steps followed to estimate the dominant frequency and the sub-soil profile were done in two stages: the first one was the computation of the HVSPR, and the second one was by forward modeling of the theoretical H/V spectral ratios by means of wave propagation of stiffness matrix method developed by Kausel and Roesset (1981).

SH-wave propagation in a single layer



$$\begin{Bmatrix}\tau_0\\ \tau_{-h}\end{Bmatrix}=\frac{Gks}{e^{ksh}-e^{-ksh}}\begin{bmatrix}e^{ksh}+e^{-ksh} & -2\\ -2 & e^{ksh}+e^{-ksh}\end{bmatrix}\begin{Bmatrix}V_0\\ V_{-h}\end{Bmatrix}$$

Where:
G is the elastic shear modulus

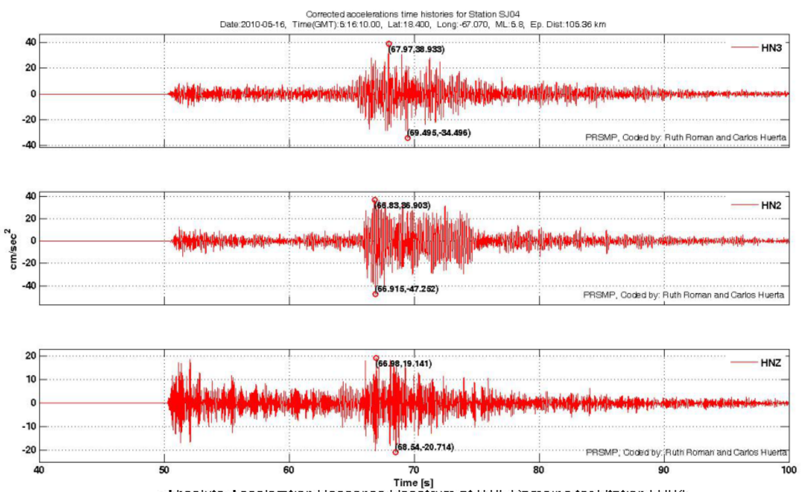
$k = \dfrac{\omega l}{C_S}$: the wave number

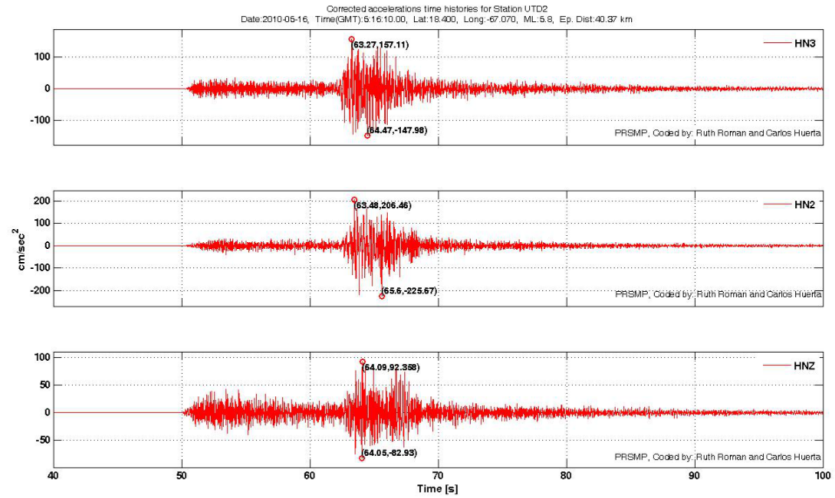
$s = \sqrt{1 - \dfrac{\omega^2}{k^2 C_S^2}}$: a complex number

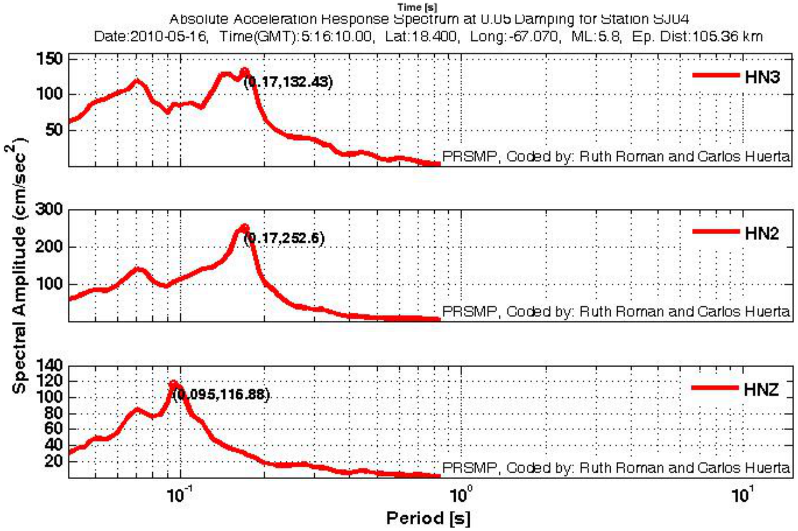
SouthEastern GSA Meeting 03/21-22/2013. V45, No.2. ISSN:0016-7592 (Session 39-1)

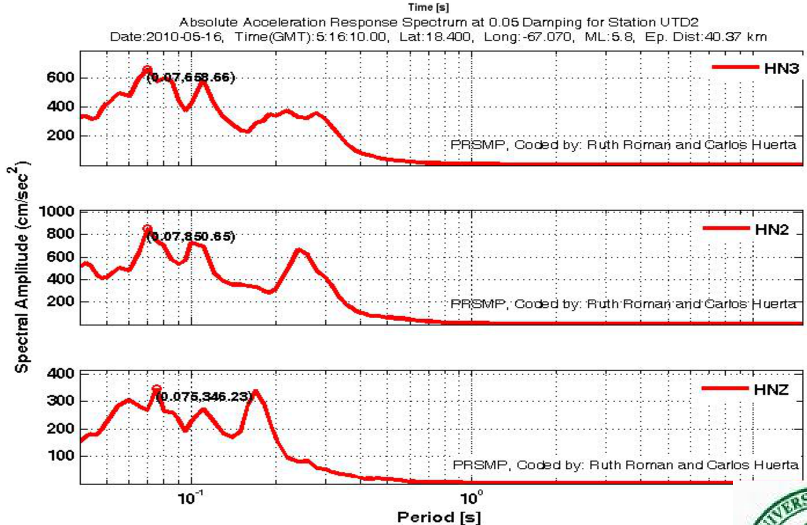
PRSMP

Puerto Rico Strong Motion Program





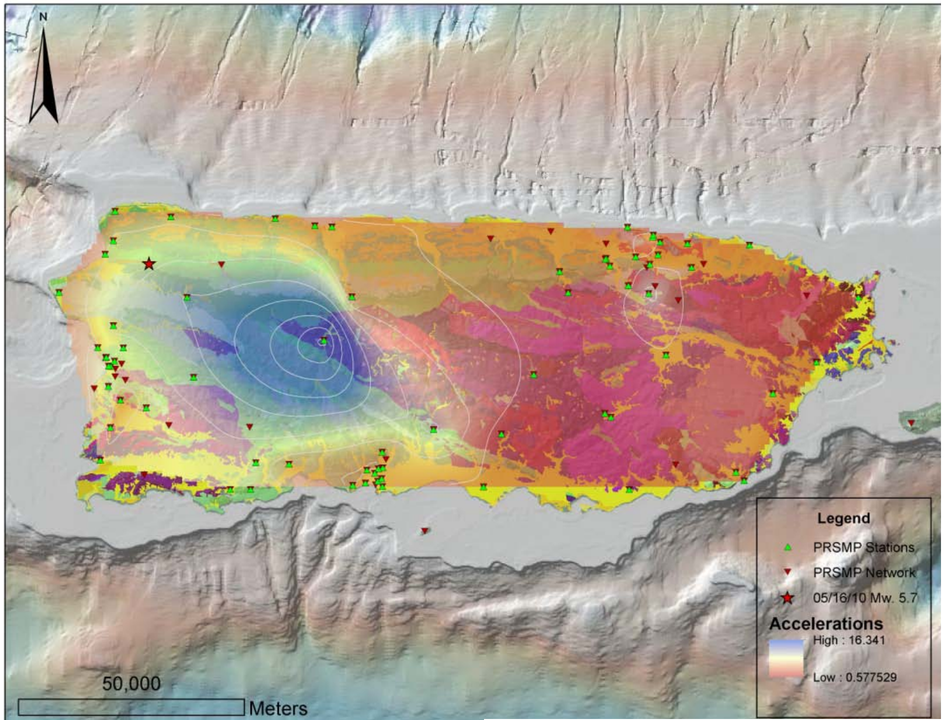


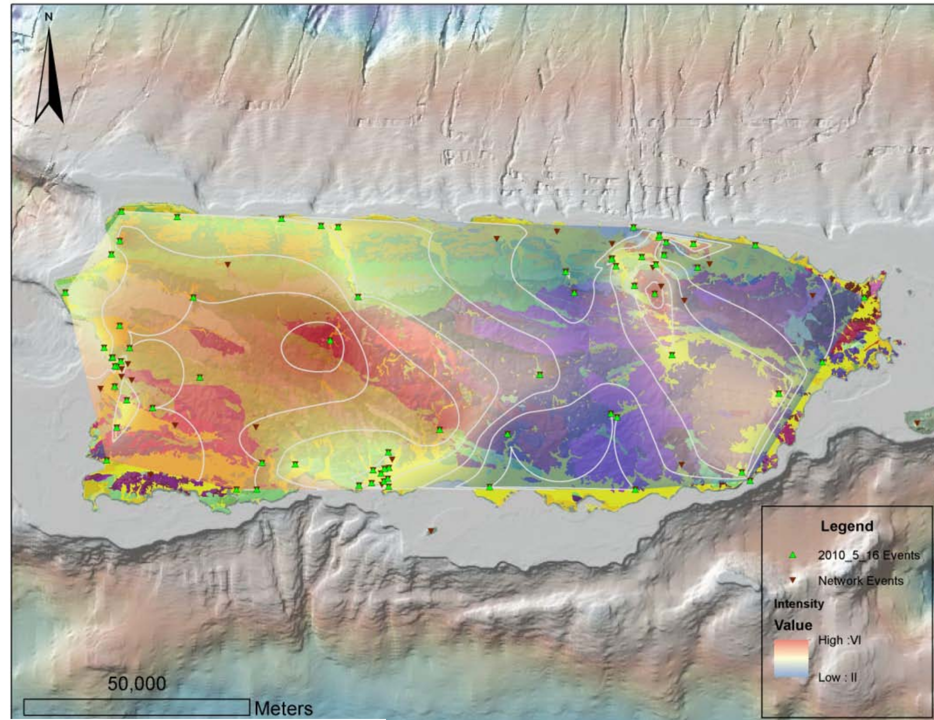


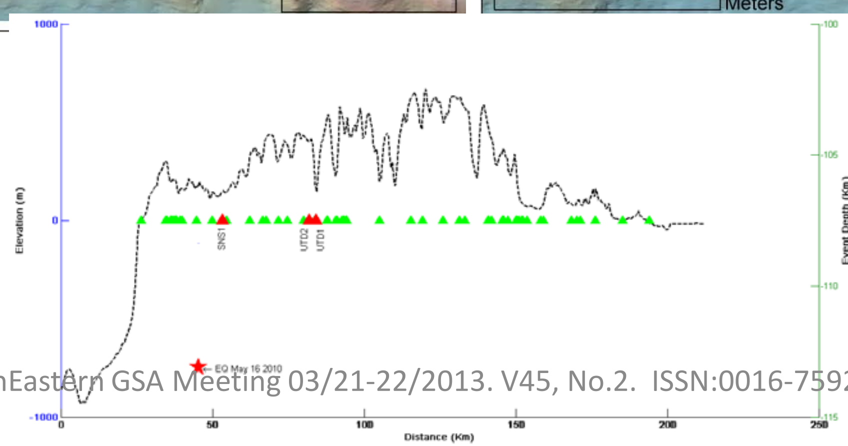
SouthEastern GSA Meeting 03/21-22/2013. V45, No.2. ISSN:0016-7592 (Session 39-1)

PRSMP

PUERTO RICO STRONG MOTION PROGRAM



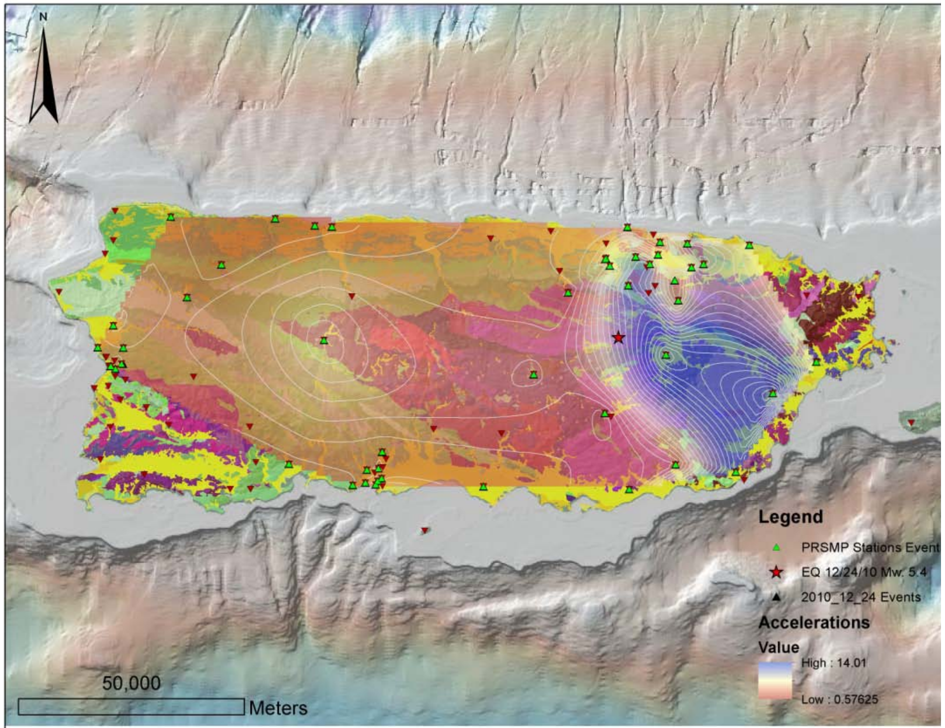


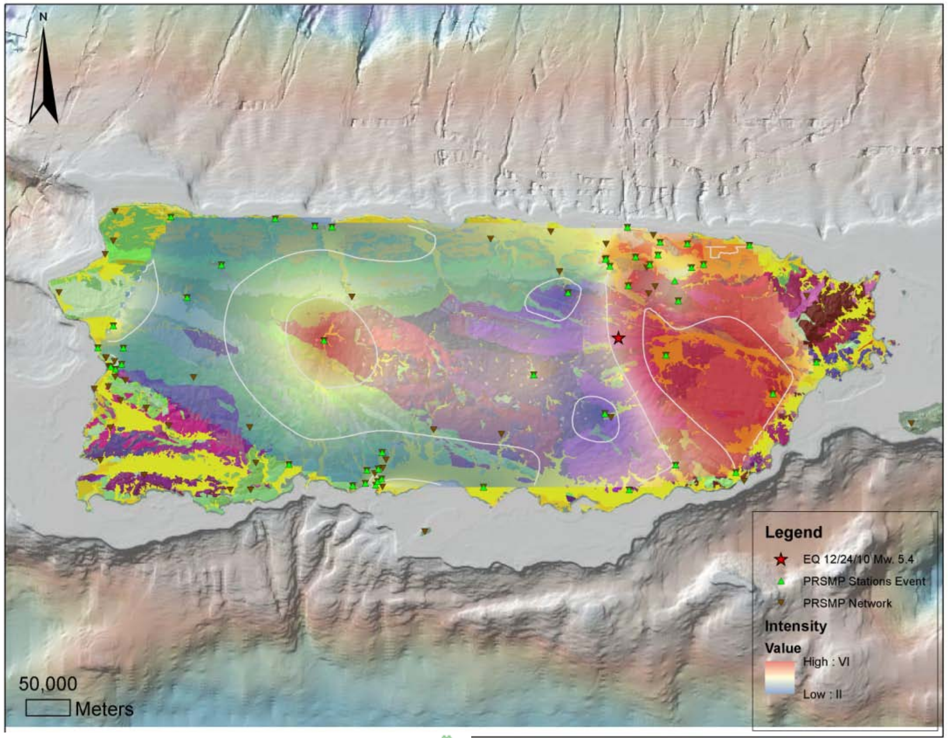


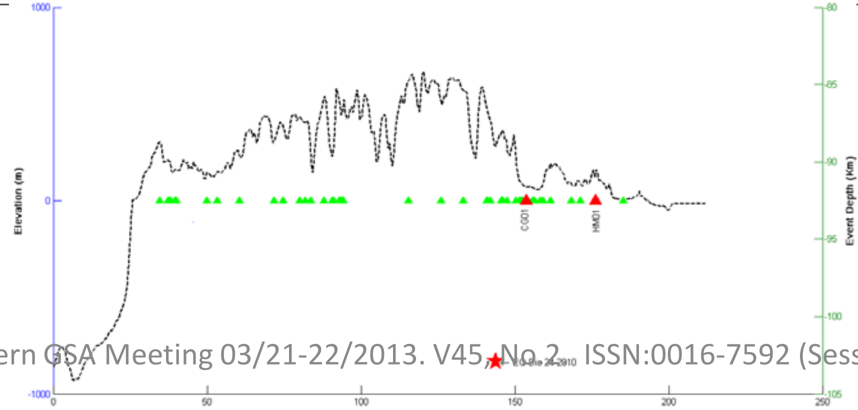
SouthEastern GSA Meeting 03/21-22/2013. V45, No.2. ISSN:0016-7592 (Session 39-1)

PRSMP

PUERTO RICO STRONG MOTION PROGRAM



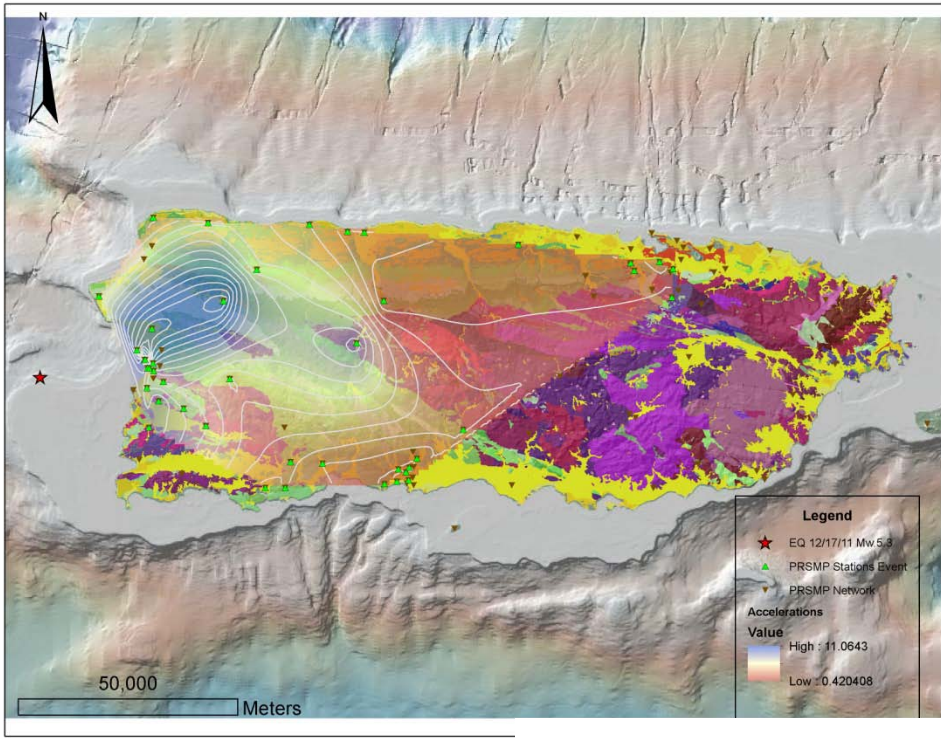


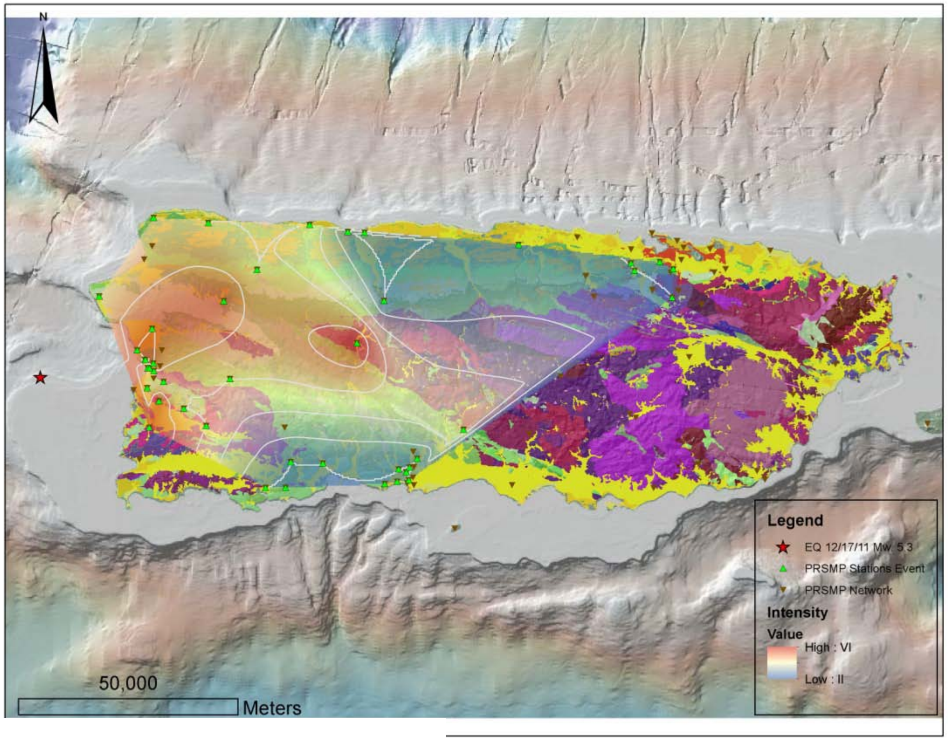


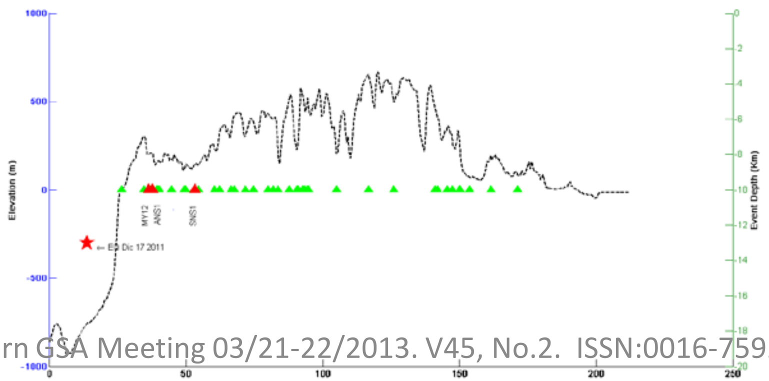
SouthEastern GSA Meeting 03/21-22/2013. V45, No 2. ISSN:0016-7592 (Session 39-1)

PRSMP

PUERTO RICO STRONG MOTION PROGRAM



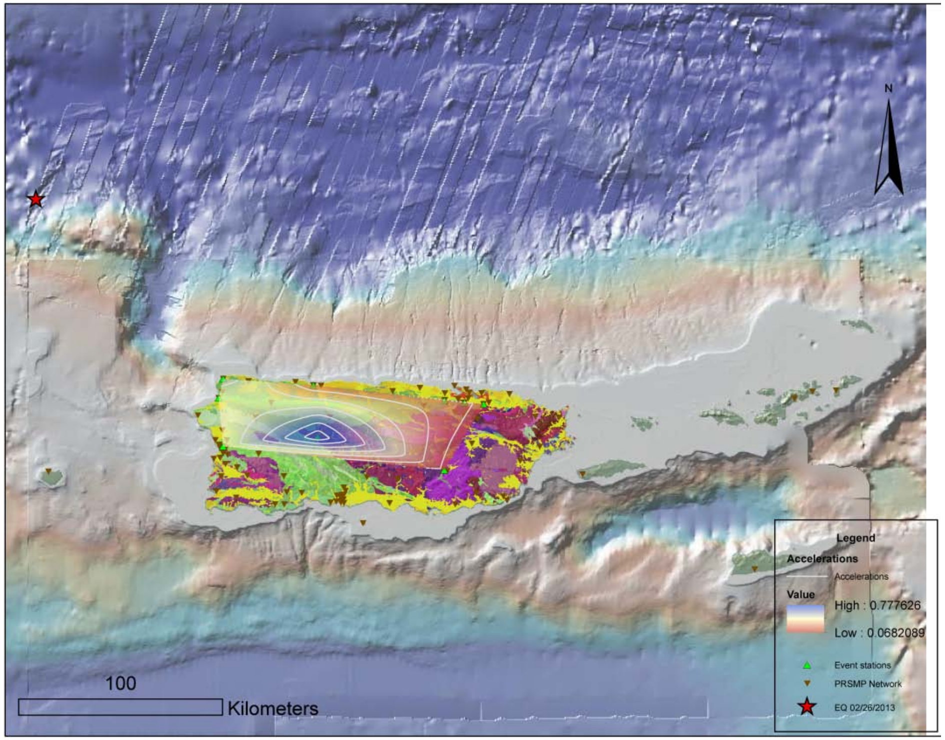


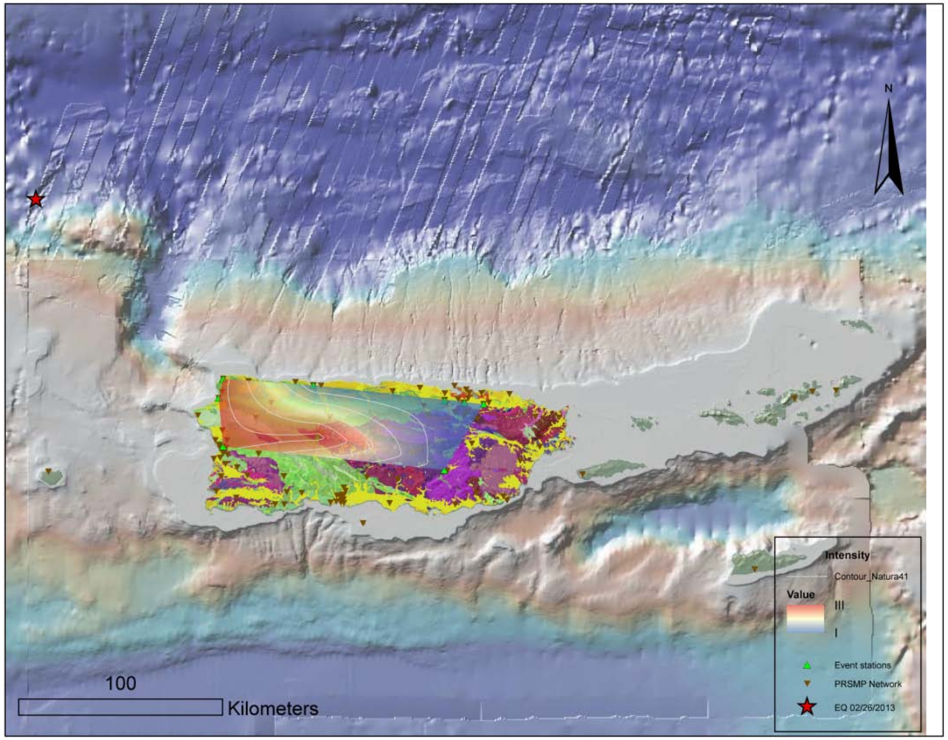


SouthEastern GSA Meeting 03/21-22/2013. V45, No.2. ISSN:0016-7592 (Session 39-1)

PRSMP

PUERTO RICO STRONG MOTION PROGRAM





SouthEastern GSA Meeting 03/21-22/2013. V45, No.2. ISSN:0016-7592 (Session 39-1)

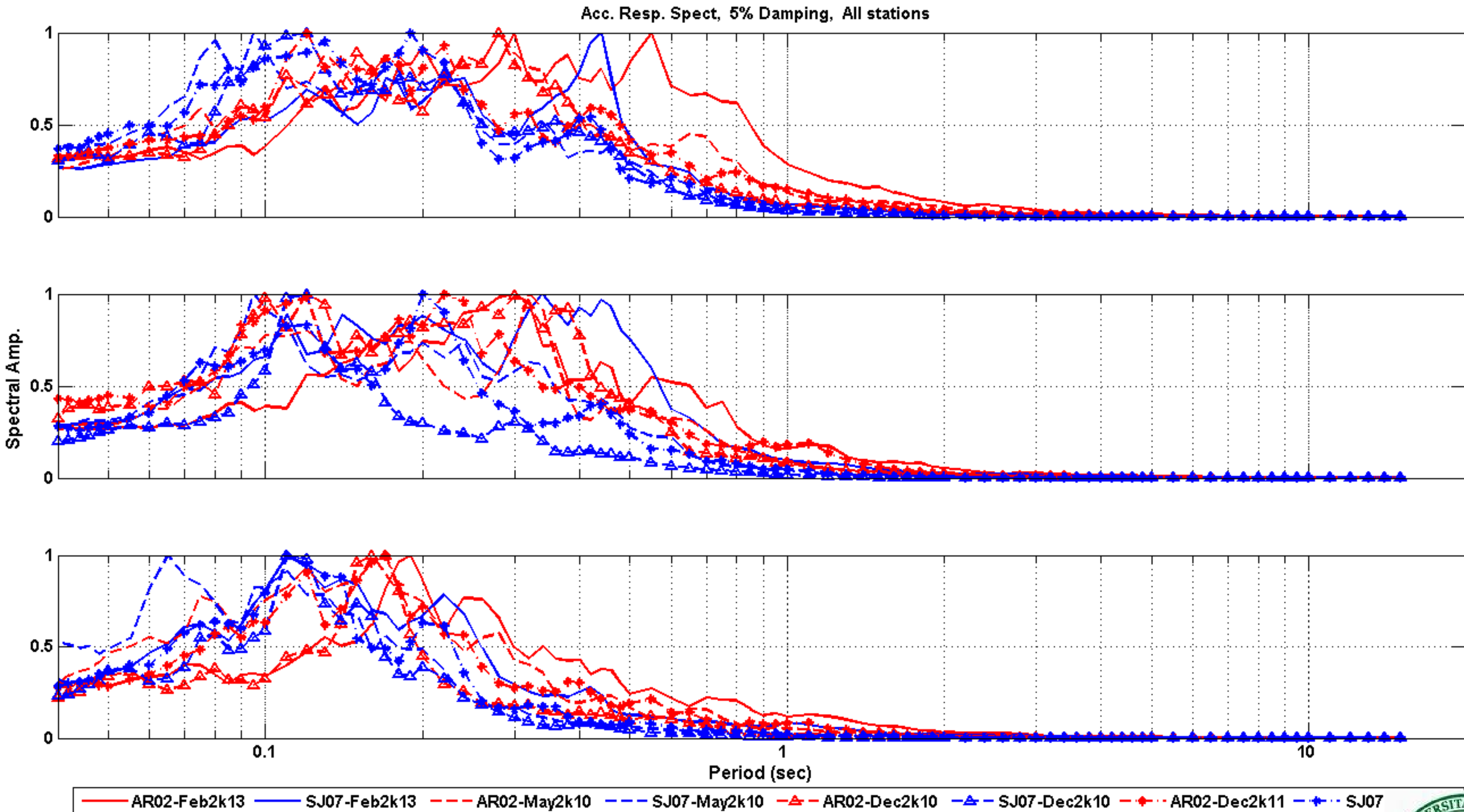
PRSMP

PUERTO RICO STRONG MOTION PROGRAM

Event date	Max_PGA (cm/s^2)	Station	Distance (Km)	Max_PGA (cm/s^2)	Station	Distance (Km)
May-16-2010 (5.8)	23.01	UTD2	E=40.17 H=120.02	2.04	AG02	E=13.03 H=113.84
Dec-24-2010 (5.1)	14.15	HM01	E=34.01 H=108.54	12.13	CG01	E=10.06 H=103.44
Dec-17-2011 (5.3)	11.30	MY12	E=23.38 H=29.01	4.08	UTD2	E=69.3 H=71.3
Feb-26-2013 (5.1)	0.78	UTD2	E=171.5 H=171.7	0.45	AG02	E=120. 72 H=120.99

PRSMP

PUERTO RICO STRONG MOTION PROGRAM



SouthEastern GSA Meeting 03/21-22/2013. V45, No.2. ISSN:0016-7592 (Session 39-1)

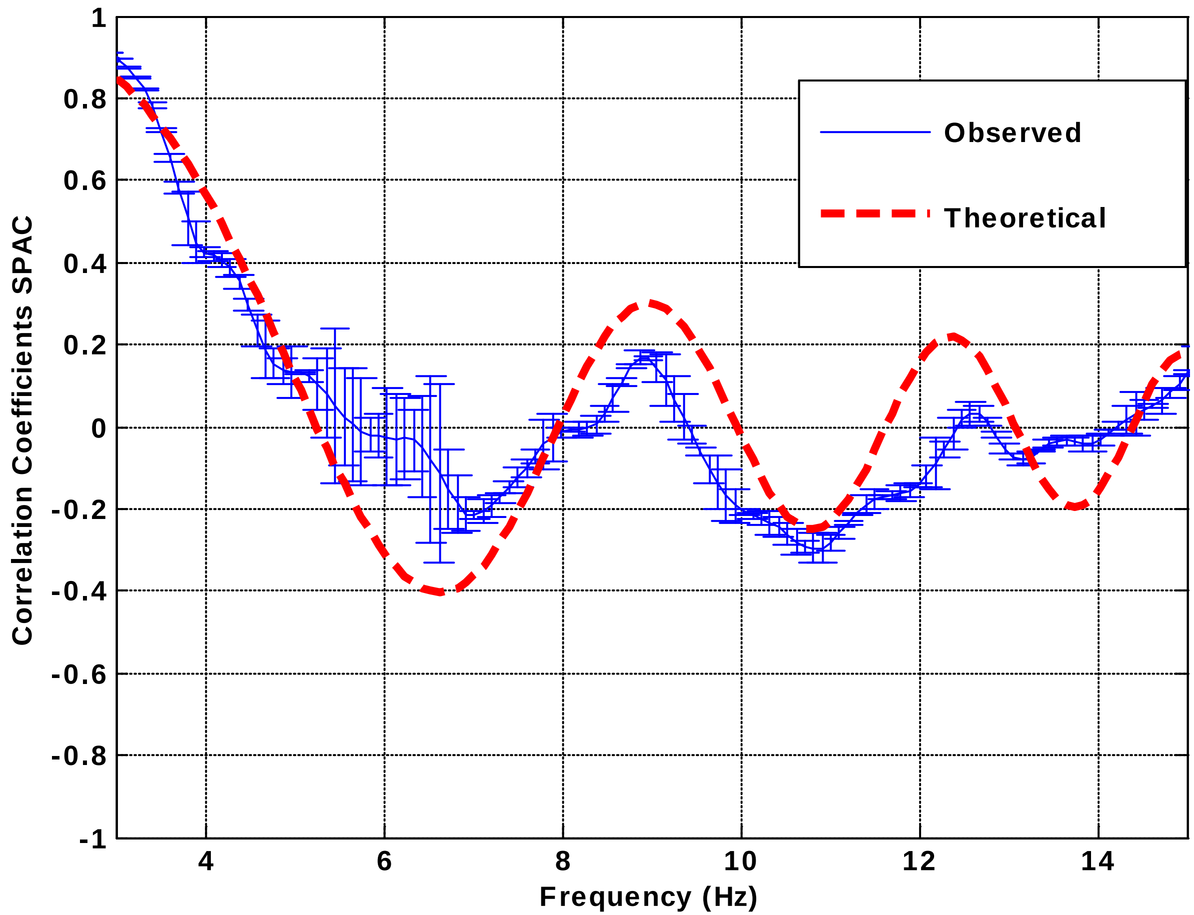


Figure 6 Correlation coefficients observed and their fit to zero order Bessel function

SouthEastern GSA Meeting 03/21-22/2013. V45, No.2. ISSN:0016-7592 (Session 39-1)

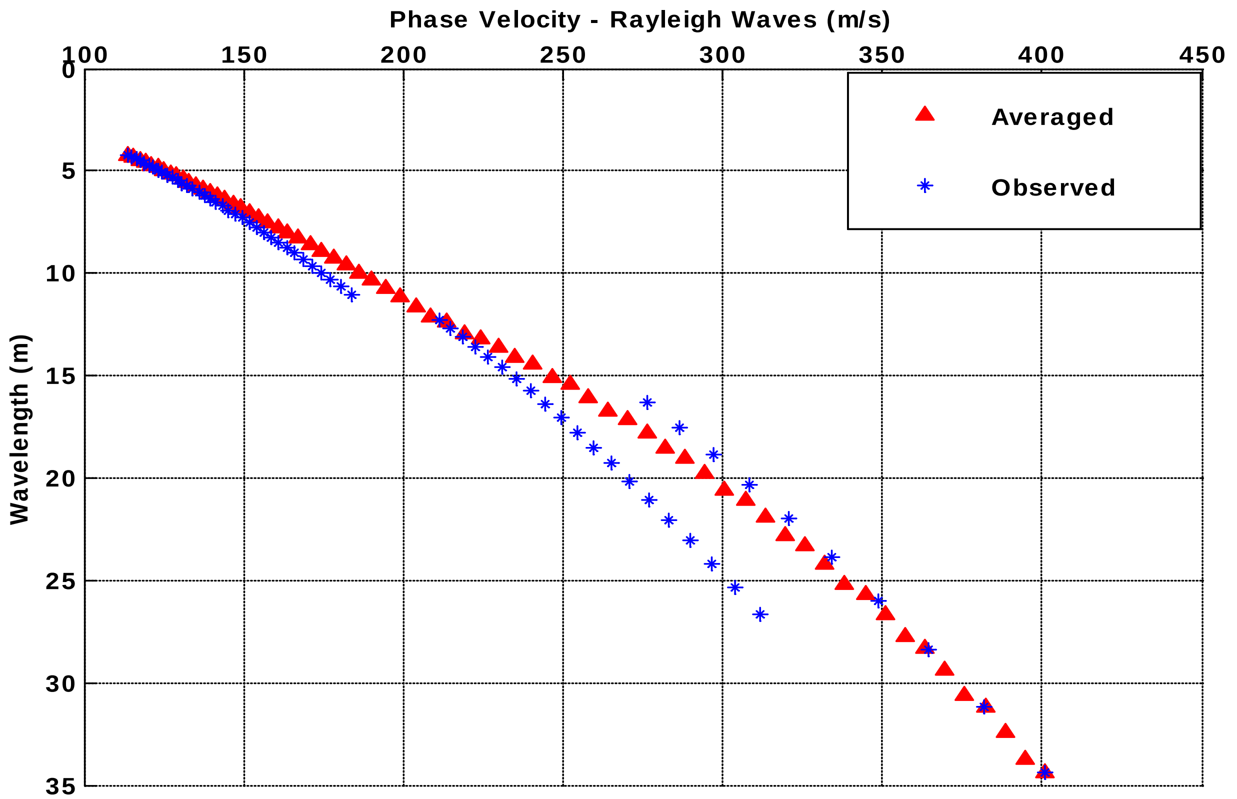
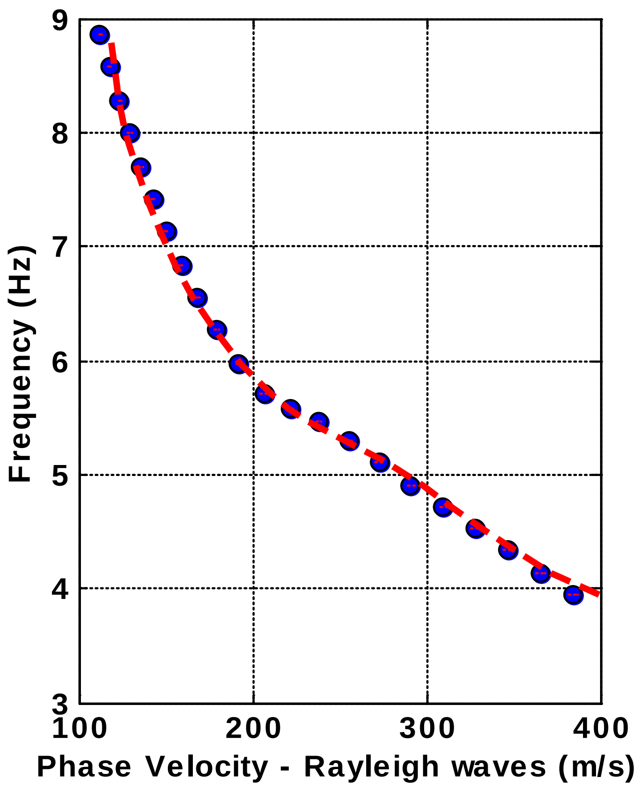


Figure 7 Results from the inversion of the phase velocity dispersion curve

SouthEastern GSA Meeting 03/21-22/2013. V45, No.2. ISSN:0016-7592 (Session 39-1)

PRSMP

PUERTO RICO STRONG MOTION PROGRAM



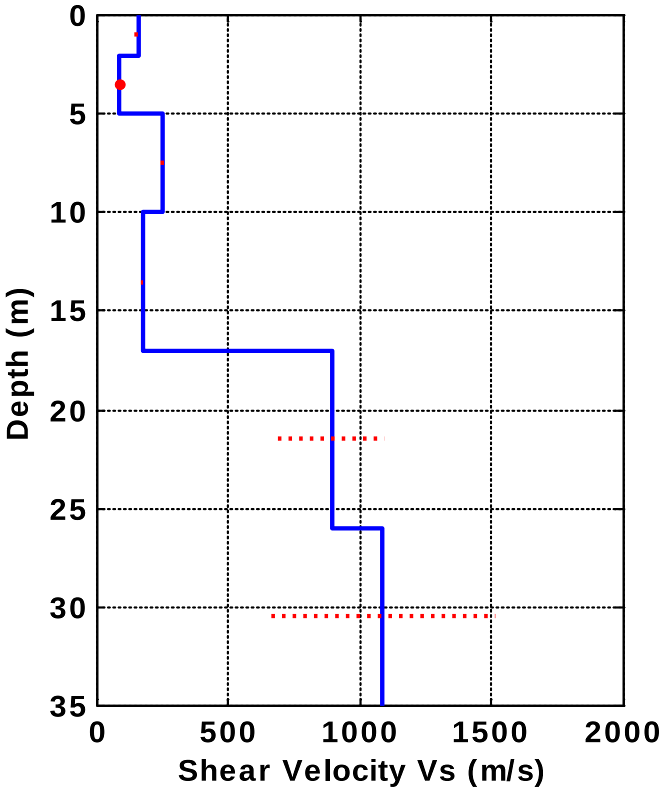
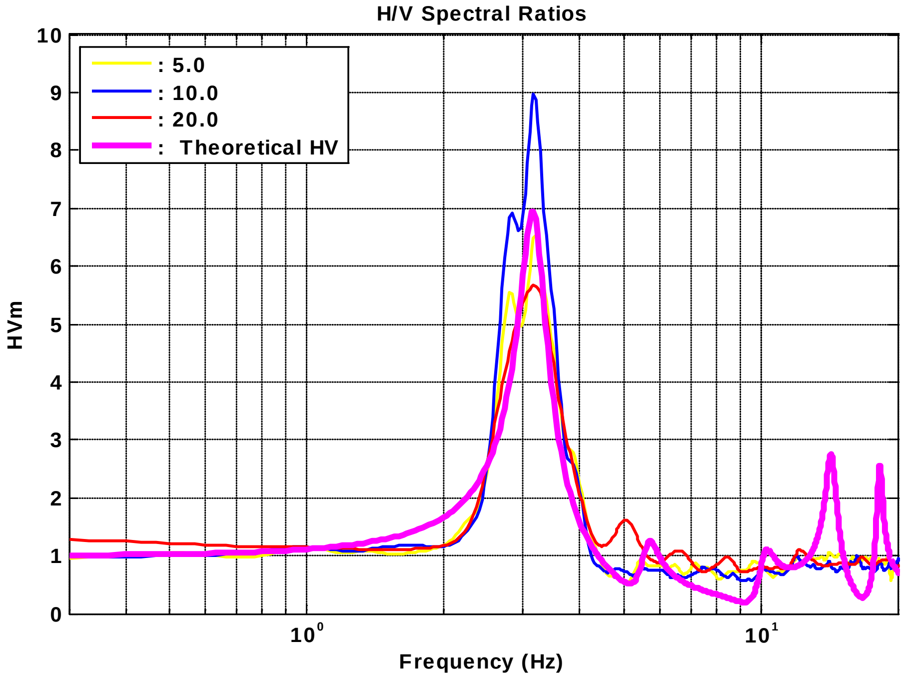


Figure 8 left: Phase velocity dispersion curve inverted from the observed data. Right: Velocity model site A

SouthEastern GSA Meeting 03/21-22/2013. V45, No.2. ISSN:0016-7592 (Session 39-1)



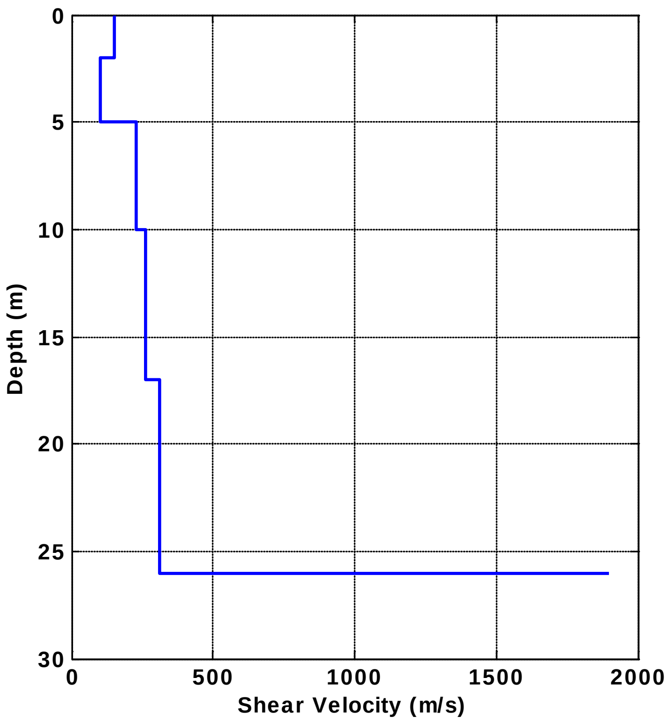


Figure 9 left. H / V Spectral Ratios site B - right Velocity model

SouthEastern GSA Meeting 03/21-22/2013. V45, No.2. ISSN:0016-7592 (Session 39-1)

PRSMP

PUERTO RICO STRONG MOTION PROGRAM

Thanks,

Carlos I. Huerta-Lopez: m-huerta@alumni.utexas.net

José A. Martínez-Cruzado: jose.martinez44@upr.edu

Fabio M. Upegui-Botero: fabio.upegui@upr.edu

Luis E. Suarez –Colche: luis.suarez3@upr.edu

UPR

RECINTO UNIVERSITARIO DE MAYAGÜEZ · CAAM · UNIVERSIDAD DE PUERTO RICO