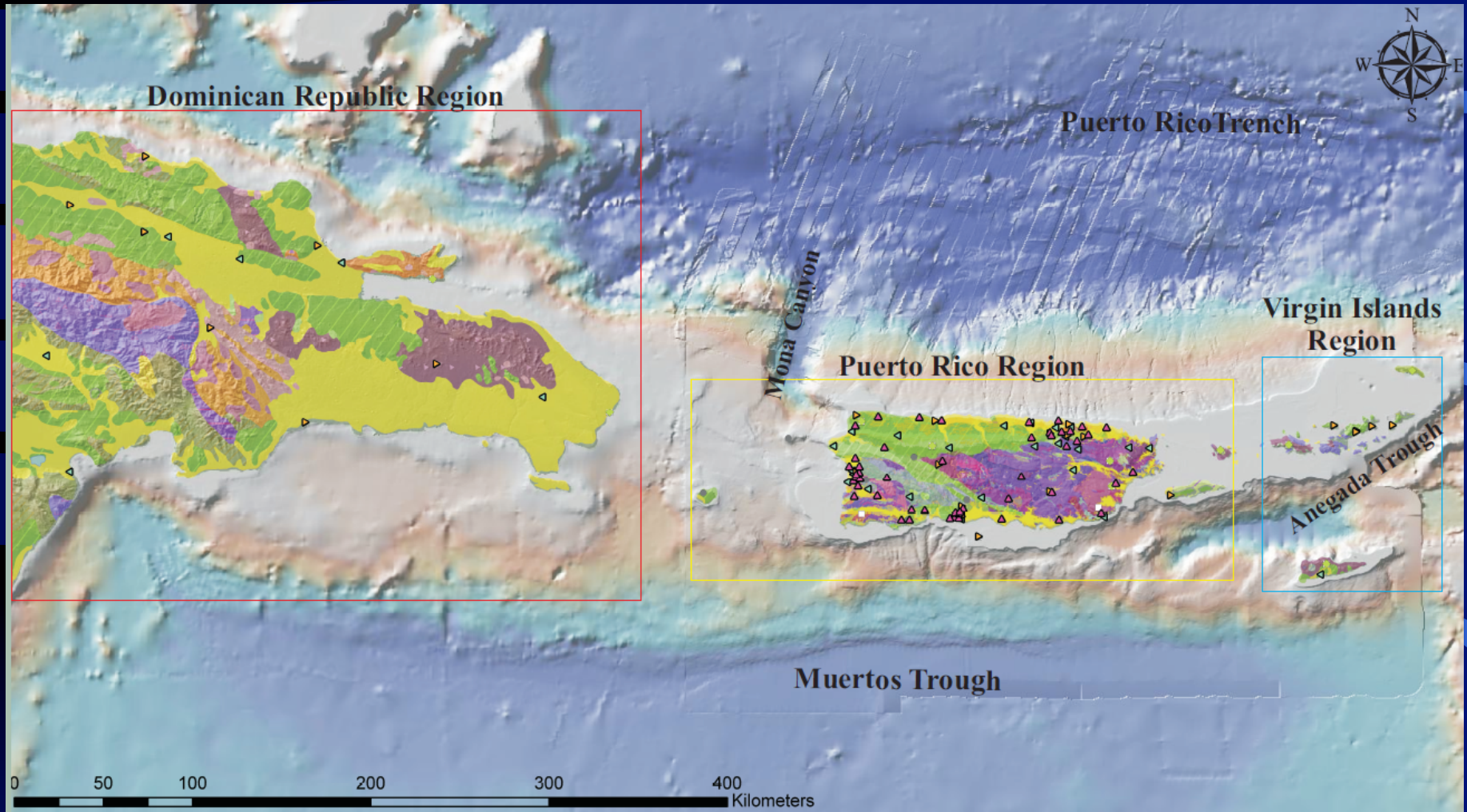




# **Puerto Rico Strong Motion Program**

Civil Engineering and Surveying Department  
University of Puerto Rico at Mayagüez



***Presented by: Carlos I. Huerta López***

AUG. San Diego, CA. 01/2015

# PRSMP

## GOALS:

- ❑ Obtain and provide strong motion data to the scientific/academic/engineering communities for:
  - (i) Performing seismic analysis, earthquake resistant designs, enhance the regulations of the construction codes, improving land use, and support the seismic engineering investigation,
  - (ii) objectively identify and characterize the ground response, as well as the civil infrastructure response upon seismic loads.
- ❑ Mitigate both human and economical losses during high-intensity earthquakes through accurate and reliable seismic records.
- ❑ Identify in an objective manner damaged after an earthquake.

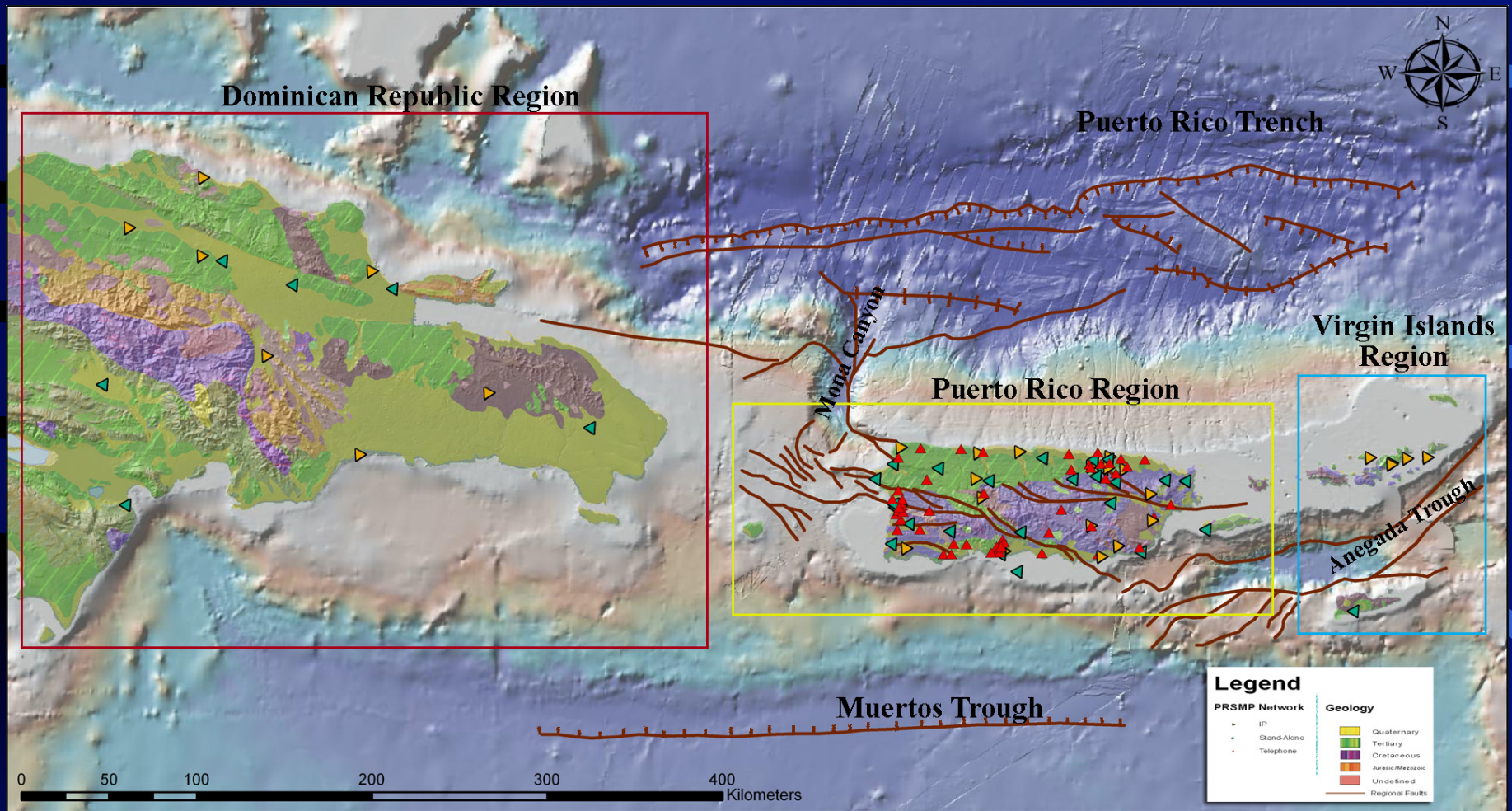
## Duties:

- ❑ (i) deploying/operation seismic instrumentation for monitoring strong ground motions as well as civil structures in the Puerto Rico Island (PRI) and the Caribbean region,
- ❑ (ii) Applied seismology/geophysics/geology in Civil Engineering,
- ❑ (iii) Application of seismic/geophysical methods for site characterization/local site effects/seismic zonation, and seismic risk studies.

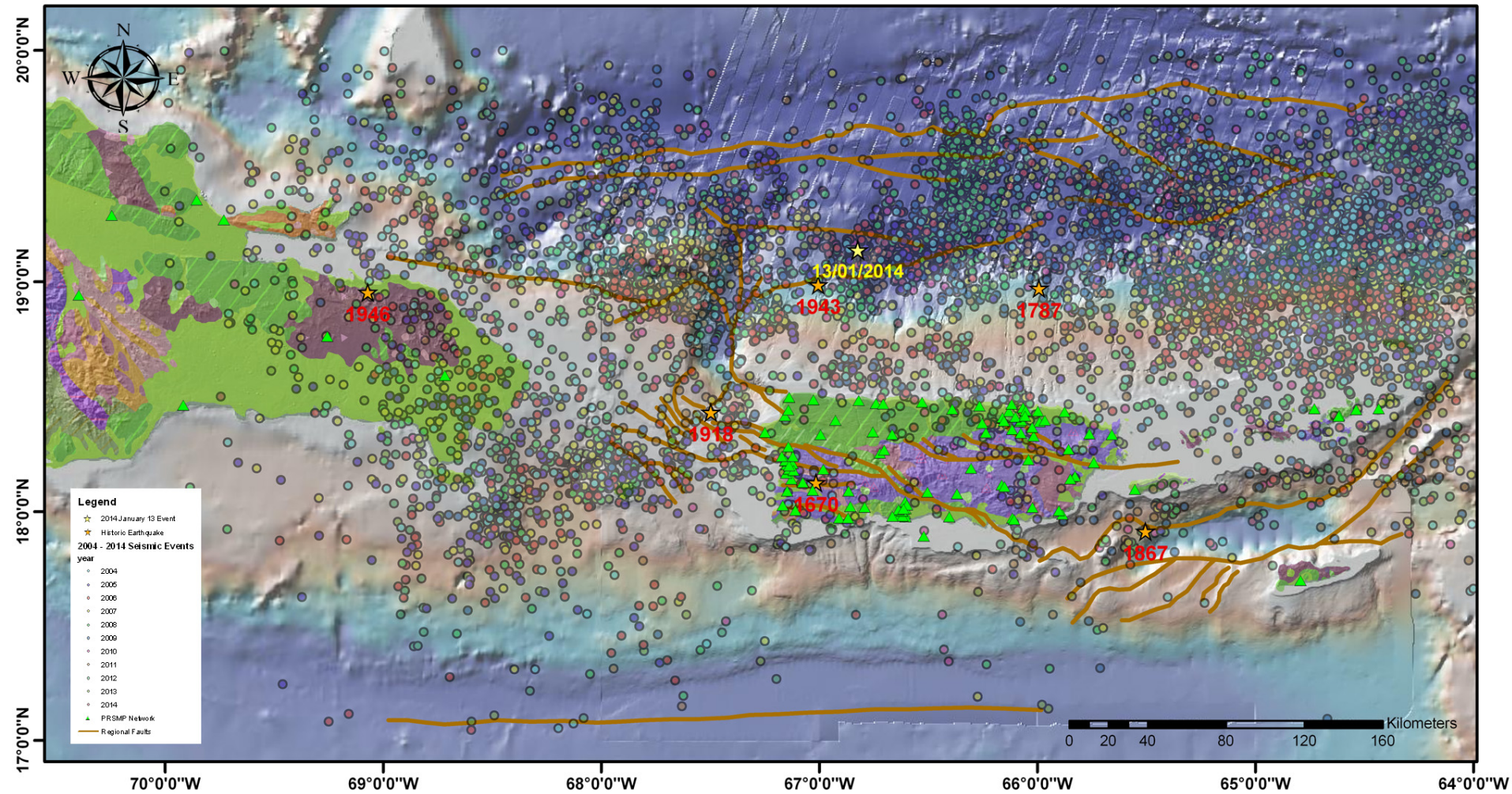
# PRSMP Personnel

- ❑ José A. Martínez-Cruzado.      -PRSMP Director
- ❑ Carlos I. Huerta-López.      -Seismologist
- ❑ Jaffet Martínez-Pagan, Erick Santana-Torres.  
-Technical Support, Network Operation /Maintenance,  
Communication, Data Processing/Archiving.
- ❑ Graduate Students: Francisco Hernández, Denny Mariana  
Torres Ortíz.  
-Earthworm/Antelope/Communication, Data Archives  
(Earthquake Catalog, EVT, wf, mseed), GIS Data Archives .
- ❑ Undergraduate student. Sergio Cardona. -Data processing, GIS.
- ❑ Glorimer Torres-Batista.      -Clerical/Administrative support

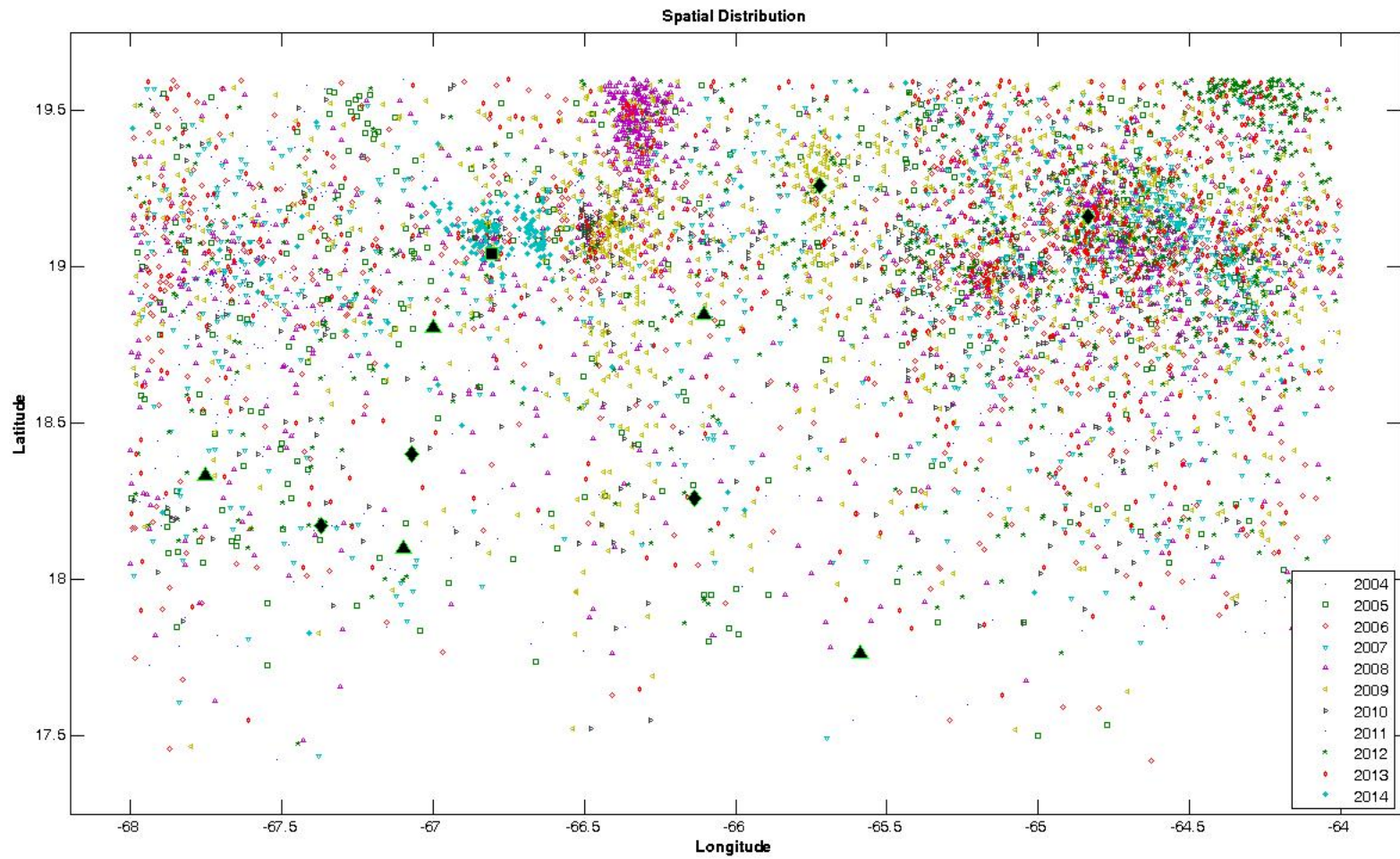




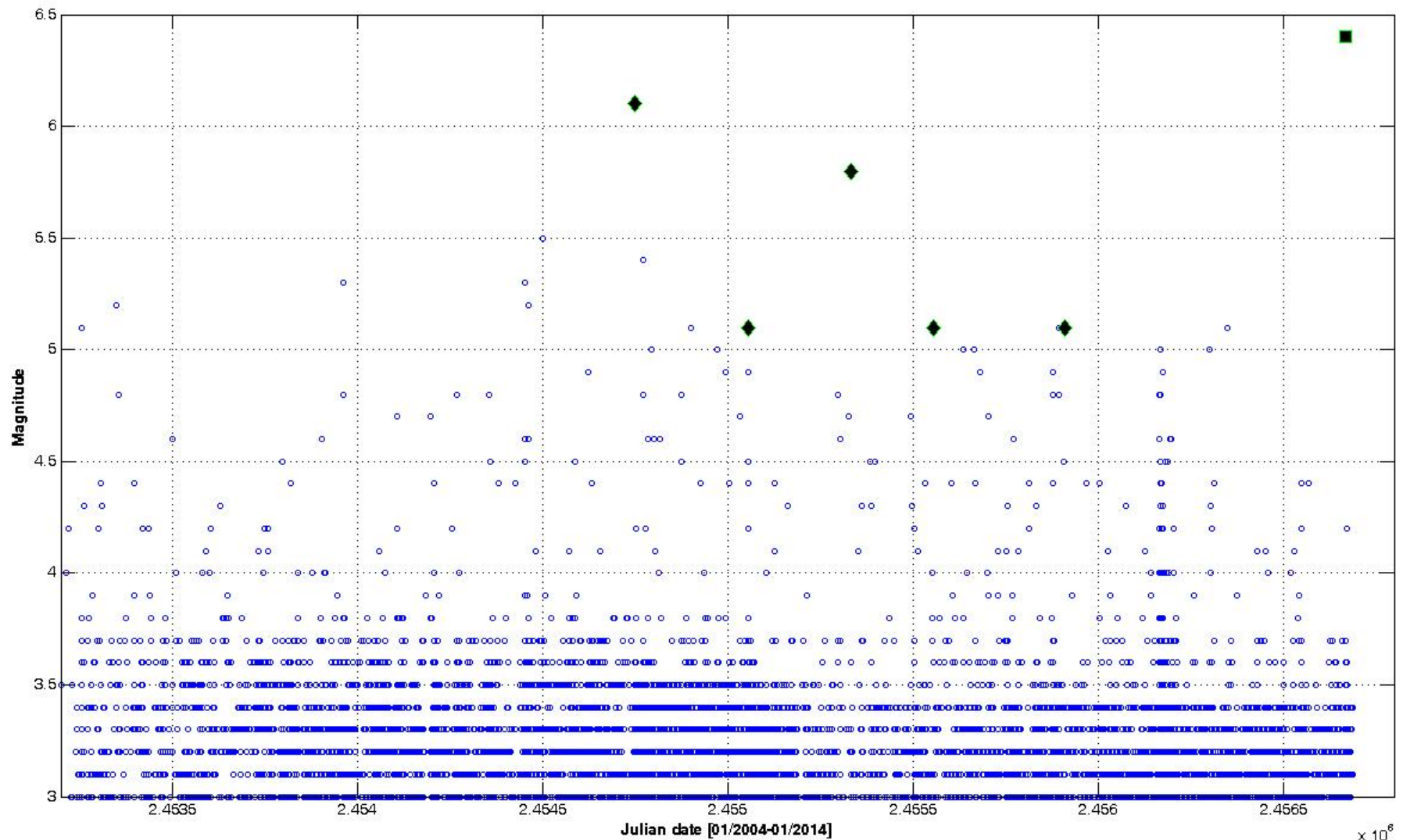












# OUTLINE

## ❑ PRSMP HISTORY

## ❑ PRSMP STATUS:

- INSTRUMENTATION
- NETWORK ADMINISTRATOR
  - ANTELOPE
  - EARTHWORM
- COMMUNICATION
- DATA PROCESSING/ARCHIVING/DISSEMINATION
- MAPS OF EARTHQUAKES PGA/MMI DISTRIBUTION
- PUBLICATIONS/THESIS: STRUCTURAL ANALYSIS/SOIL-SITE CHARACTERIZATION-RESPONSE
- EARTHQUAKES CATALOG
- PRSMP WEB-PAGE



# PRSMP History (Short)

- ❑ 1970's. Eng. José L. Capacete asked to several agencies to contribute for buying accelerographs. The Electrical Power Authority (AEE), the Aqueduct and Wastewater Authority, and the Association of Architects, Engineers and Surveyor provided money to buy nine Accelerographs (SMA-1).
  - The United States Geological Survey was contacted to provide the expertise in installing and maintaining strong motion stations (SMS).
  - Seven free field (FF) stations were established and the Government Minillas (north) building was instrumented.
  
- ❑ 1987, PRSM Network passed to the Civil Engineering Department of the University of Puerto Rico at Mayagüez (UPRM).
  - Prof. Rafael Jiménez, (in charge of the network) obtained a grant from National Science Foundation to install additional eight SMS (SSA-2). Prof. Jiménez leave the university and Prof. Milton R. Martínez-Delgado became in charge of the network. The instruments were bought, and installed in January of 1994. Prof. M. Martínez was responsible for the instrumentation with 15 sensors of the Plaza Inmaculada Building, a 26-story structure with an aspect ratio greater than seven.

# PRSMP History (Short)

- ❑ 1995 Prof. José A. Martínez-Cruzado took over the network.
  - Since then two main grants have been obtained from the Federal Emergency Management Agency, four main projects were carried out:
    - The first one, all the free field stations with SMA-1 installed during the 70's were substitute for ETNA's. The instrumentation of Minillas Government Building was replaced with a six-channel K2,
    - The second project was to install 13 strong motion FF stations in the San Juan Metropolitan Area,
    - The third project was to install a local strong motion network of nine instruments in the city of Mayagüez,
    - The fourth project was to install six joint stations with the Puerto Rico Seismic Network (PRSN). These joint stations include an FBA-23 triaxial sensor and a Broadband Seismometer. The PRSN is actually obtaining the data via telemetry.
- ❑ The second main grant includes several other projects. Some of them are:
  - The establishment of fourteen additional FF station around the Island,
  - A local strong motion network in the city of Ponce,



# PRSMP History (Short)

- The instrumentation of the Lucchetti concrete dam in the town of Yauco, and
- The seismic instrumentation of two bridges.

## ❑ 2002, Law 106

- To consign in the General Budget of Expenditure of the Commonwealth of Puerto Rico the annual assignment of one million dollars to the University of Puerto Rico at Mayagüez, from which the amount of \$440k will be transferred to the PRSN and the amount of \$560k will be transferred to the SMN to be spent in operation and to authorize matching of the assigned funds.

## ❑ 2003-2004,.....2013

- To install GPS in all strong motion stations, and to replace the SSA-2 with ETNAs
- To establish modem communication with most stations: 48 with dialog telephone lines & 10 with Internet.
- Installation/operation of Network Administrator/ANTELOPE
- Hire a strong motion seismologist

## PRSMP History (end)

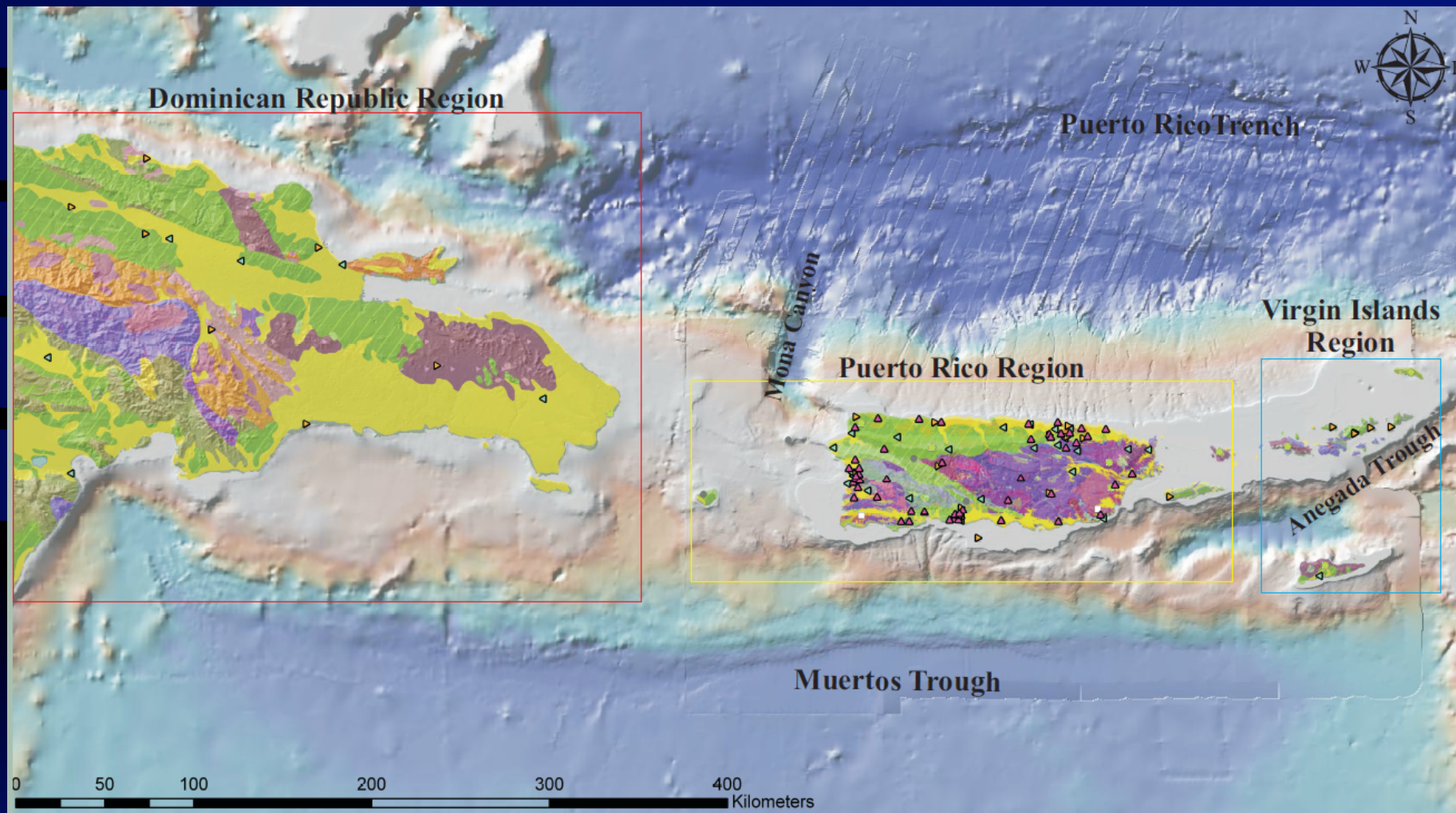
❑ In conclusion:

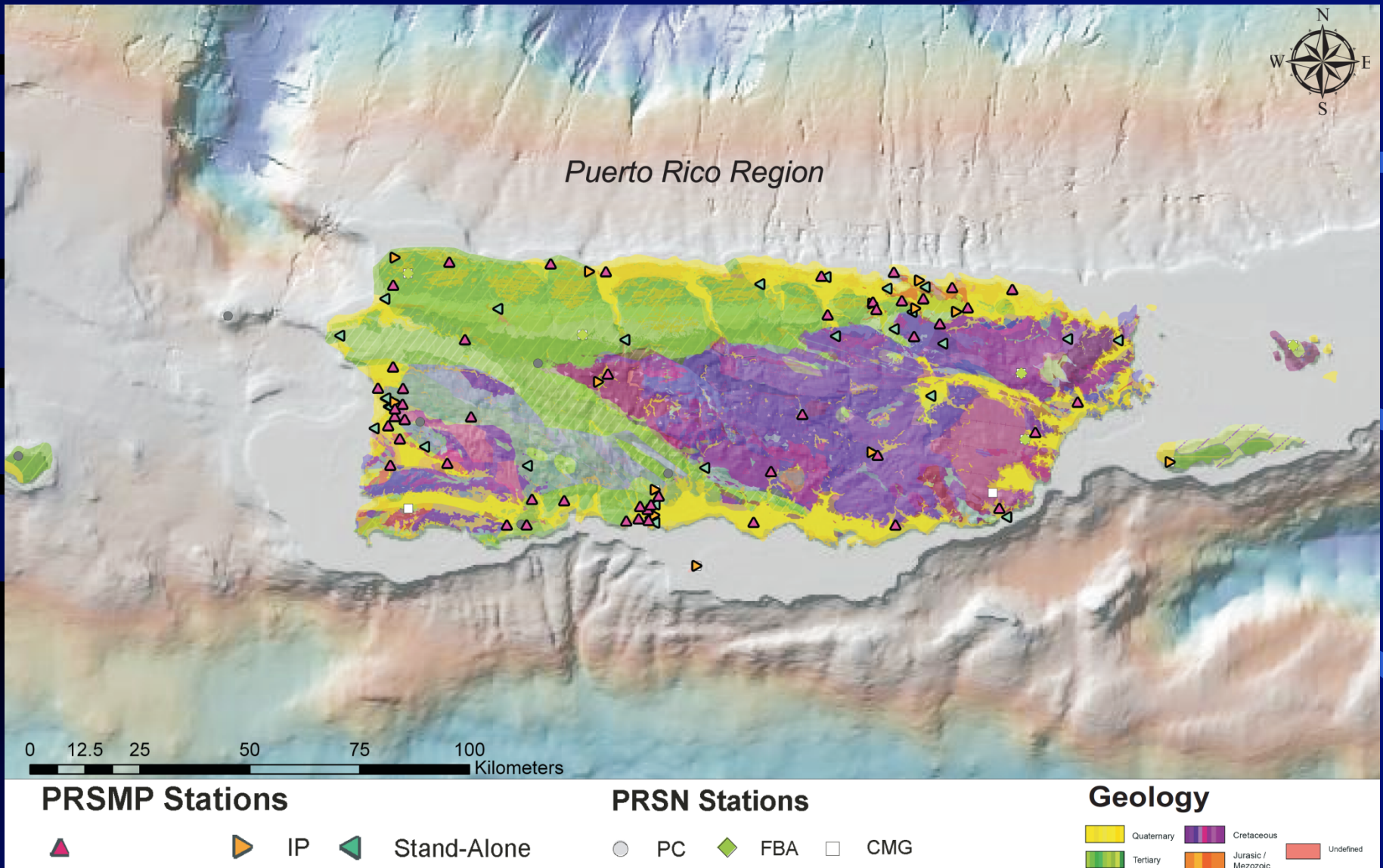
THE PUERTO RICO STRONG MOTION NETWORK (ACTUALLY PUERTO RICO STRONG MOTION PROGRAM, PRSMP) has grown since 1970's from 7 FF strong motion stations and one instrumented building with analog accelerographs to 111 strong motion stations and 16 instrumented buildings with digital accelerographs: PRI: 88 FF, 16 Struct., DOMINICAN REPUBLIC (DR): 13 FF, BRITISH VIRGIN ISLANDS (BVI) : 5 FF, 2 Struct. Collecting data via IP (Internet), DU (telephone), and Stand Alone stations.



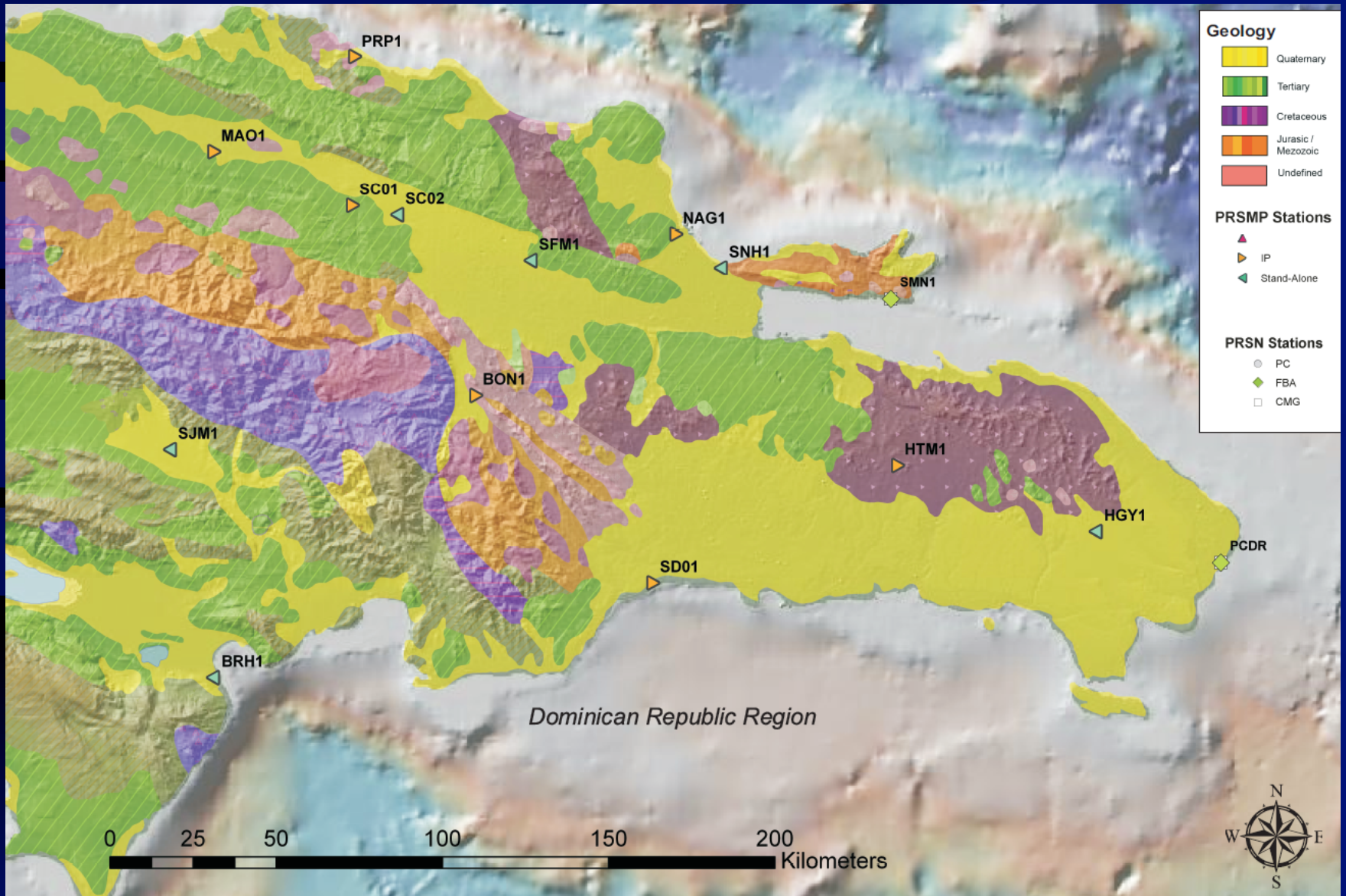


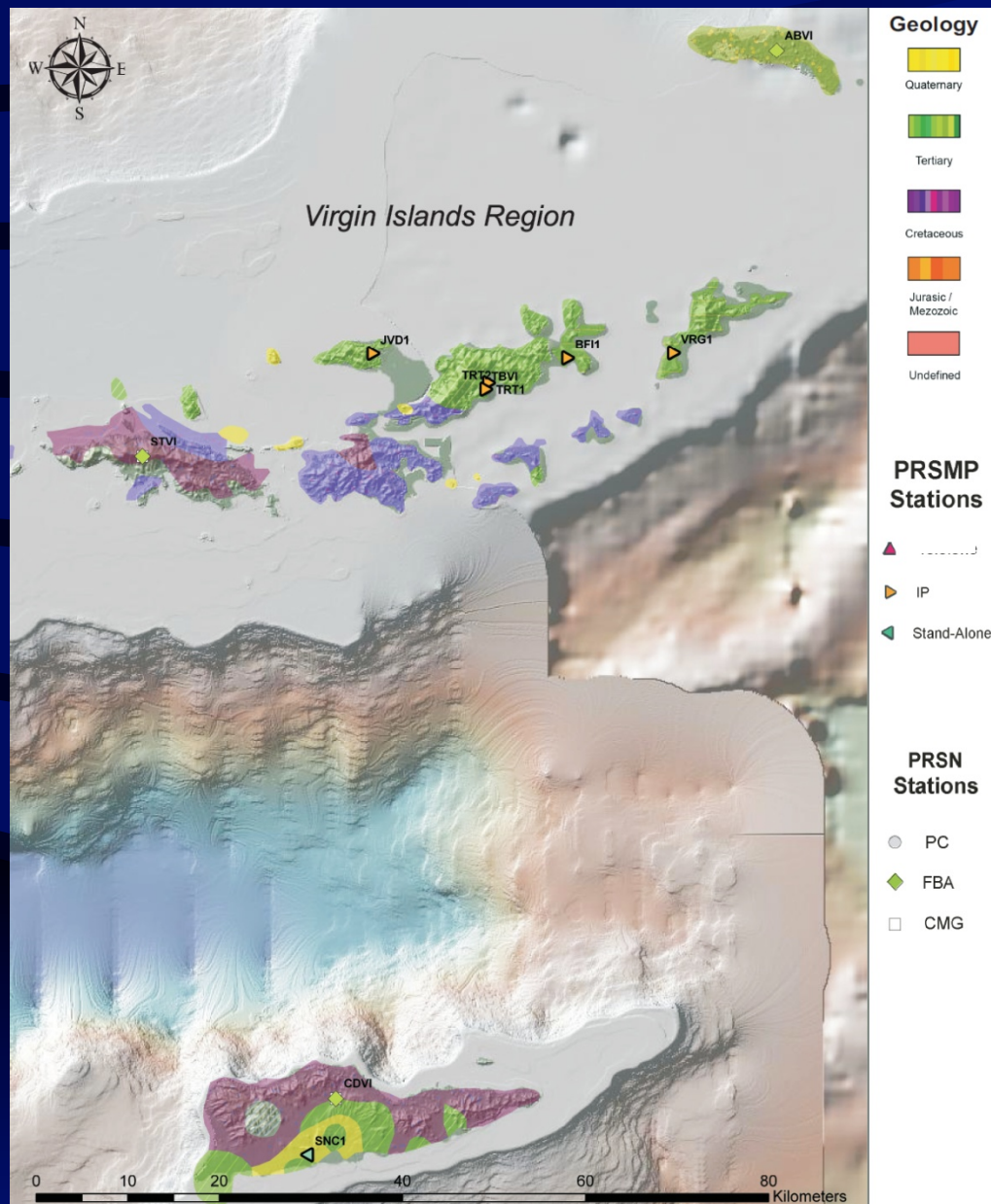












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# PRSMP NETWORK ADMINISTRATOR

## ❑ ANTELOPE 5.4 (BRTT. Three nodes license)

- Run in Dell/PowerEdge servers (At: UPRM/PRSMP)
- Operative System, CentOS 6.5
- UPRM Internet Communication/PRSMP sector: 136:145:117:
- Firewalls: UPRM, PRSMP, Servers
- Automatic power generator backup

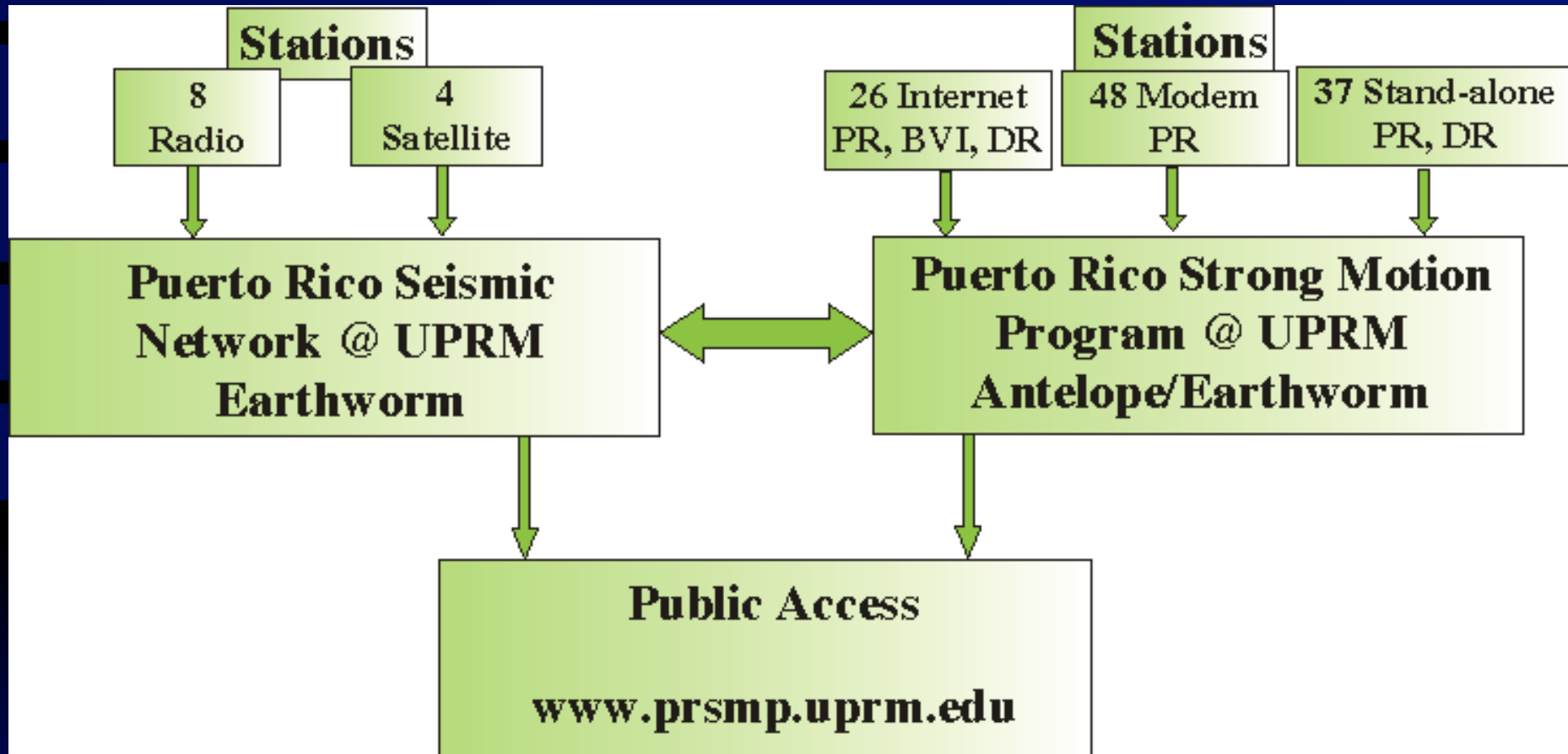
## ❑ EARTHWORM 7.7 (Public domain)

- Run in Dell/PowerEdge servers (At: UPRM/PRSMP)
- Run in Dell/Precision Workstations (At: BVI, AEE)
- Operative System, CentOS 6.2
- UPRM Internet Communication/PRSMP sector: 136:145:117:
- Firewalls : UPRM, PRSMP, Servers
- Automatic power generator backup

# STATION/DATA COMMUNICATION

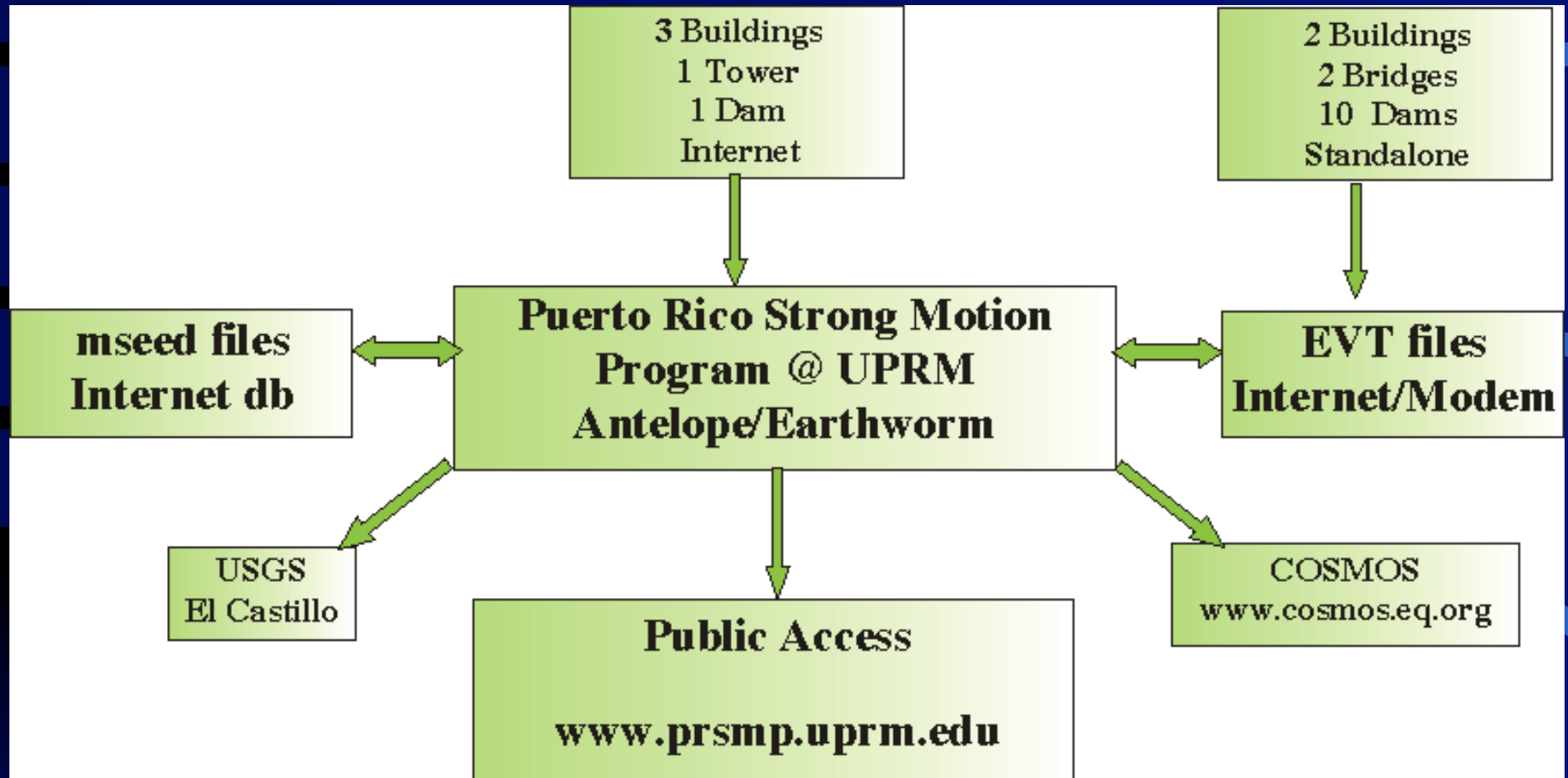
- ❑ ANTELOPE (PRSMP-PRI. FREE FIELD, FF & STRUCT. ST)
  - Via Internet/IP Lantronix, ETNA/K2 (10-IP FF)
  - Telephone Line/Modem (49-DU FF)
  - Stand Alone (27-SA FF)
  - Structures (16-SA ST)
- ❑ EARTHWORM (PRSMP-BVI: FREE FIELD, FF & STRUCT. ST)
  - Via Internet/IP Lantronix ETNA (5-IP FF)
  - Via Internet/IP Lantronix (ETNA/6 Chann., and Granite/12 Chann. ST)
- ❑ EARTHWORM (PRSMP-DR. FREE FIELD, FF & STAND ALONE, SA)
  - Via Internet/IP Lantronix , Stand Alone ETNA (6-IP FF, 7-SA)
- ❑ EARTHWORM (PRSMP-AEE/PRI): FREE FIELD, FF & STRUCT. ST)
  - Via Internet/IP Lantronix ETNA/K2 (1-IP FF, 5 Patillas Dam, ST)

# FREE FIELD STATIONS

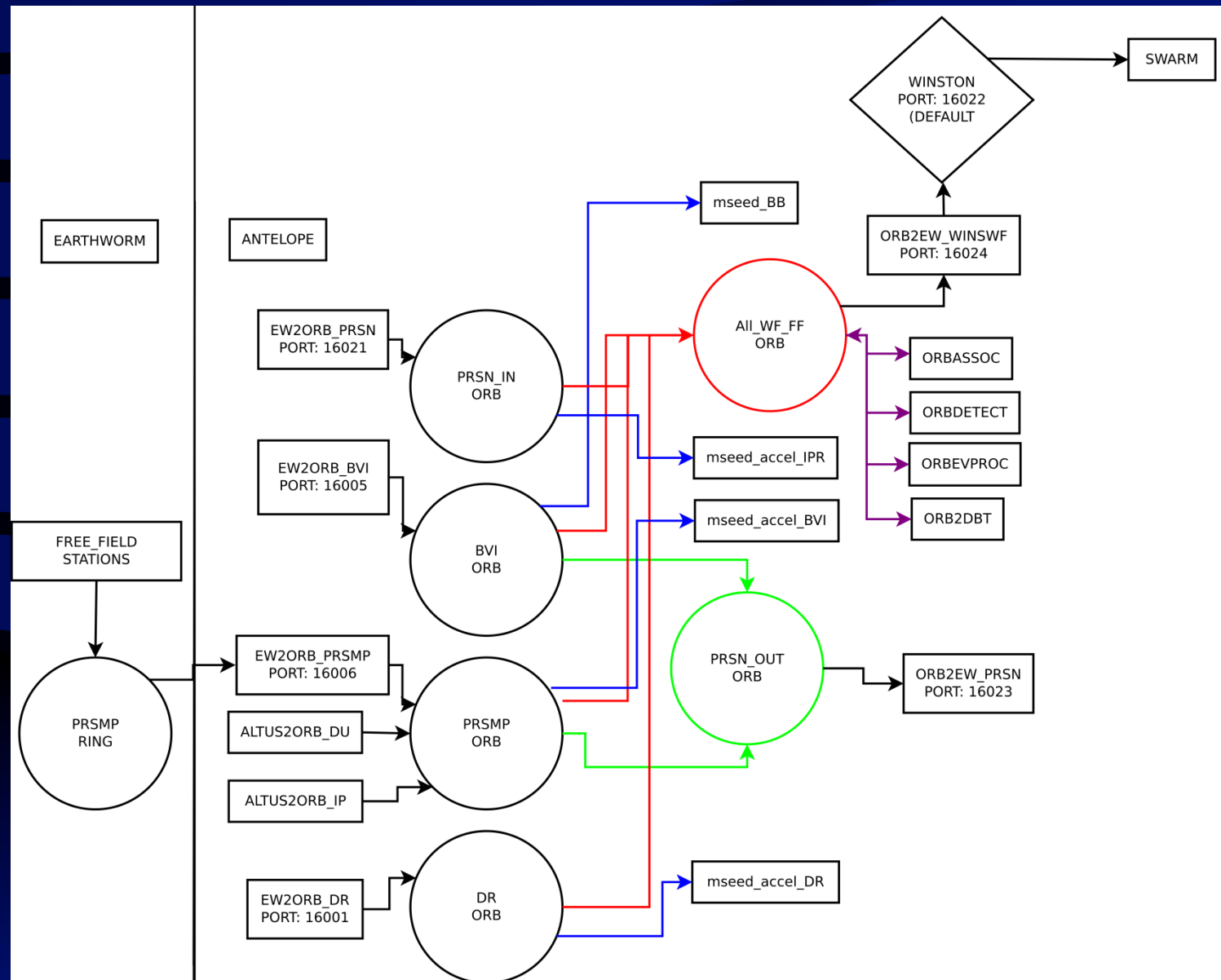




# STRUCTURES



# DATA PROCESSING

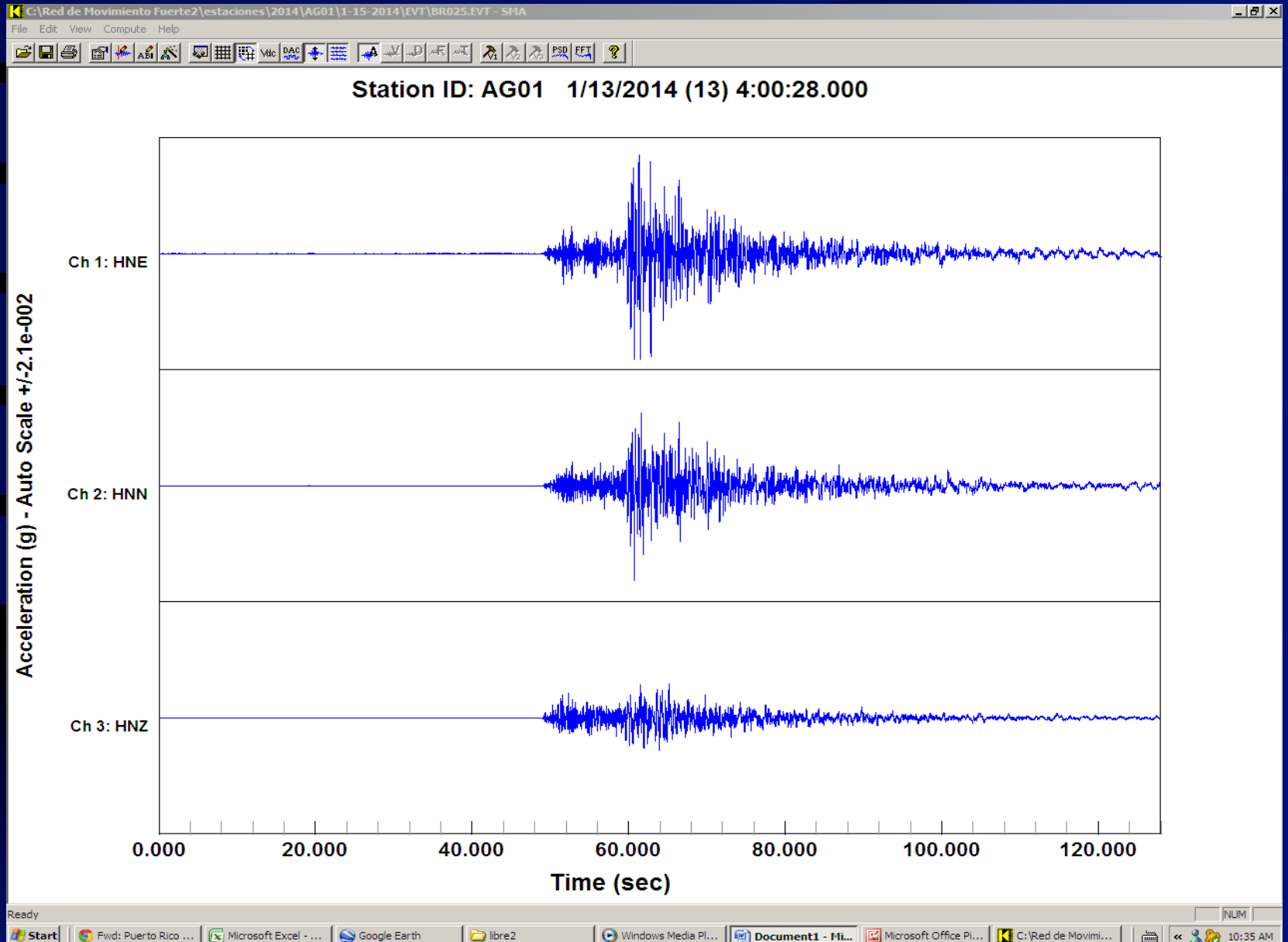


# STRONG MOTION DATA PROCESSING

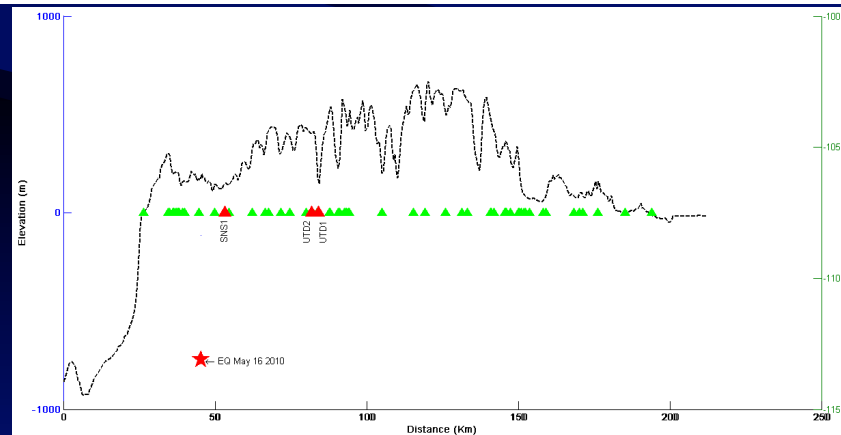
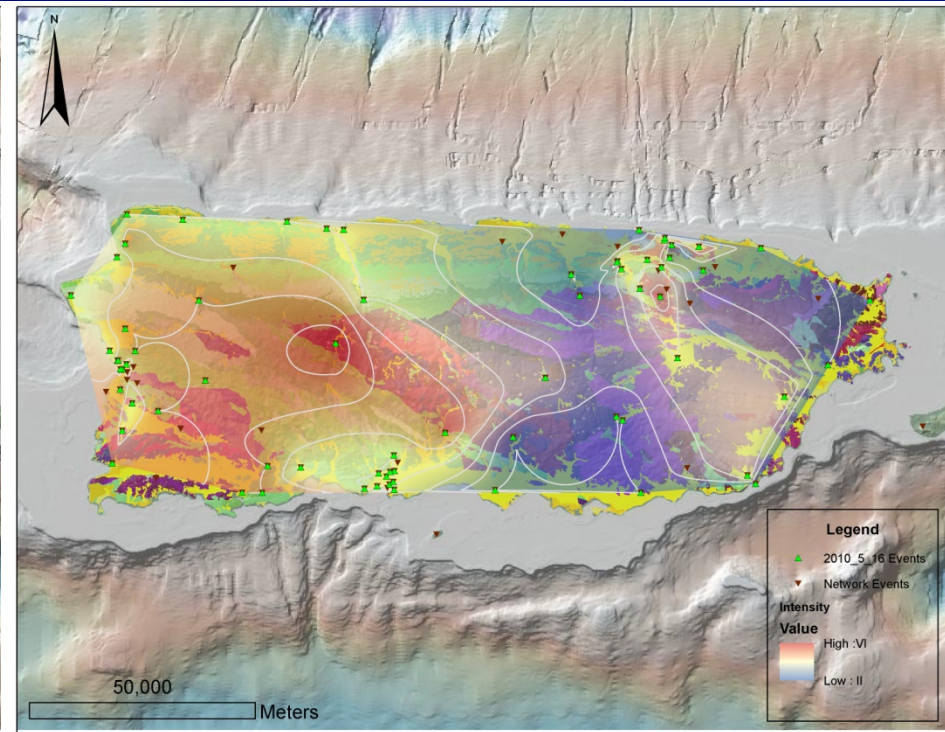
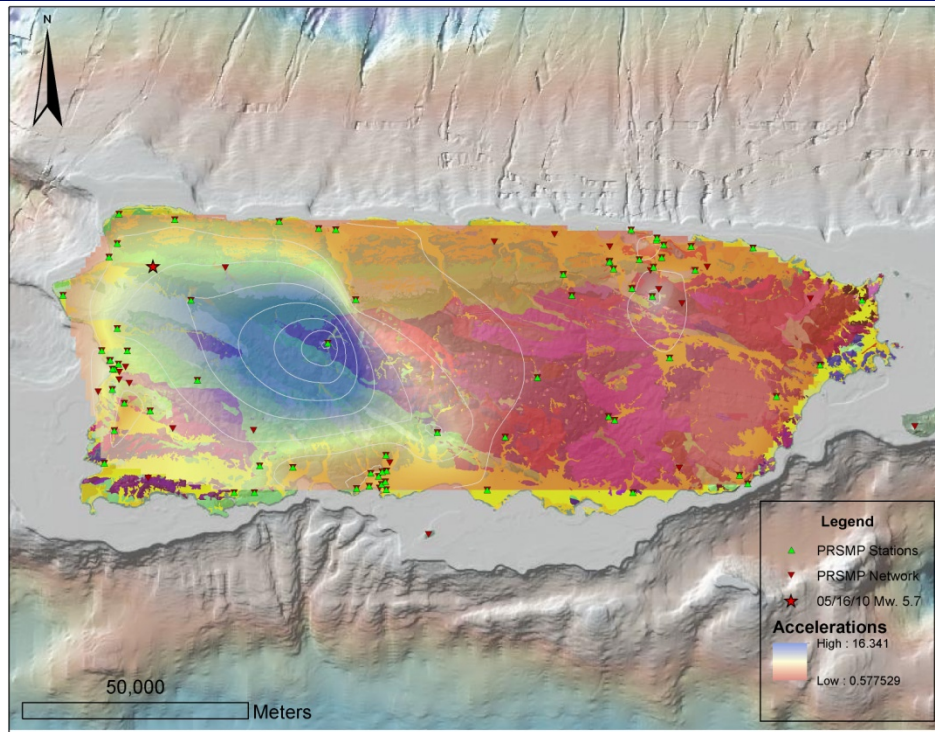
- ❑ Standard strong motion signal processing (SMA-Kinematics and MatLab codes) is used to the recorded data obtaining the .V1, .V2, and .V3 processed data, which correspond to the uncorrected acceleration records converted to physical units, the corrected acceleration record in physical units of acceleration, velocity and displacement, and the spectral representation of all above, respectively.
- ❑ Instrument calibration sheet, PDCC
- ❑ PSD analysis
- ❑ Instrumental intensity (Modified Mercalli Intensity, MMI) using the Wald et al. (1999) equations.

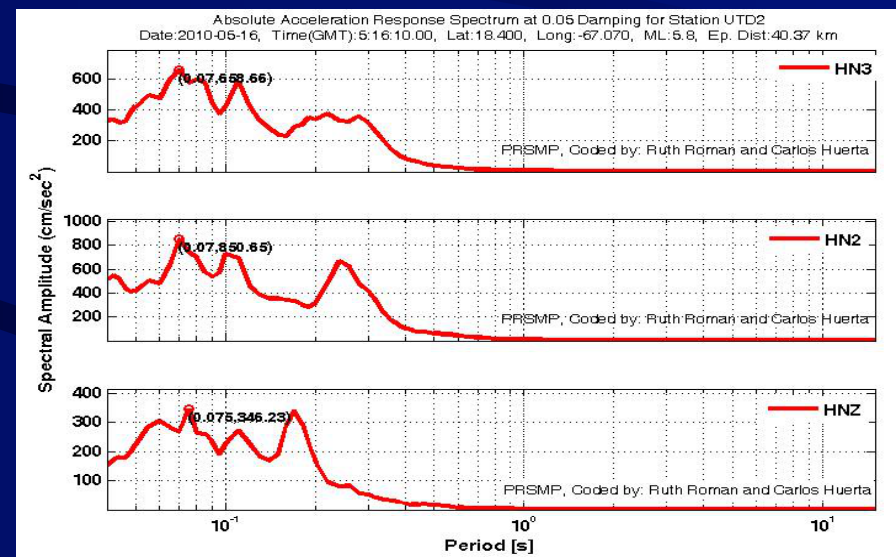
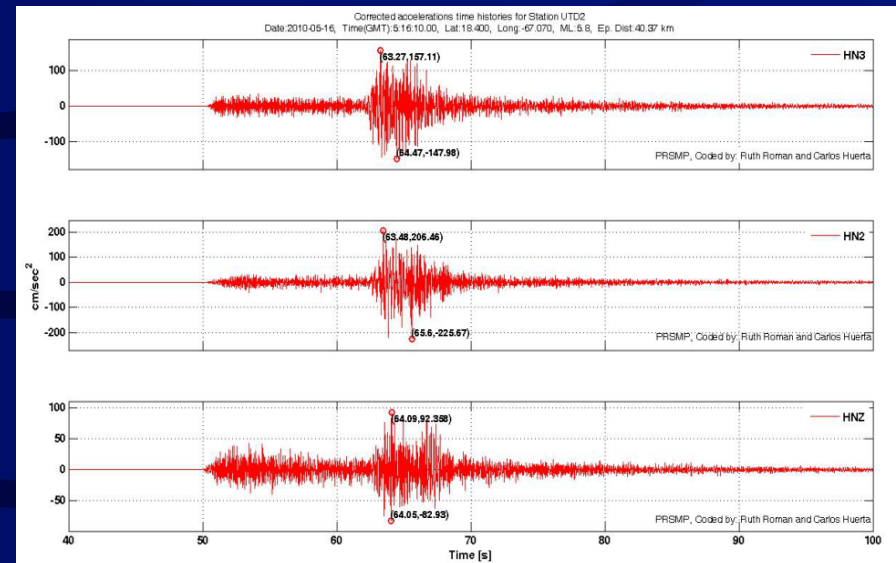
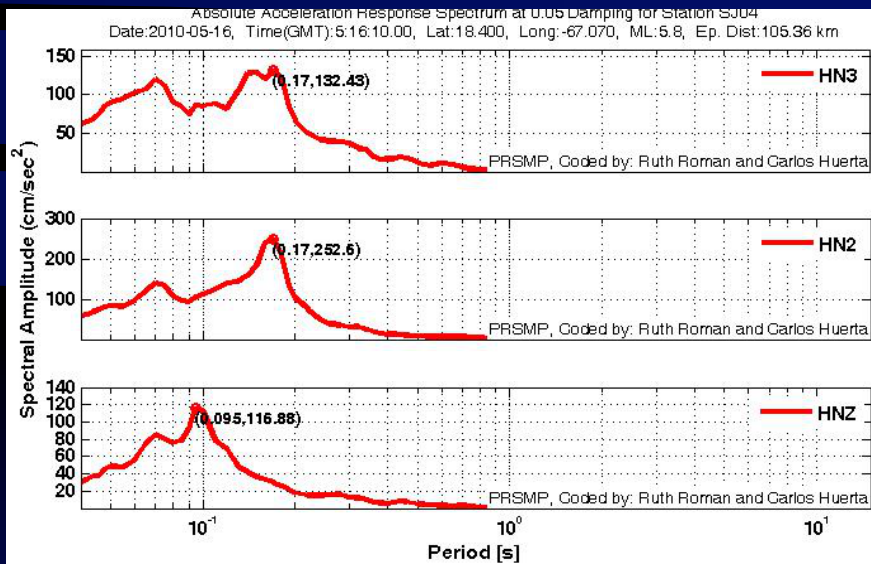
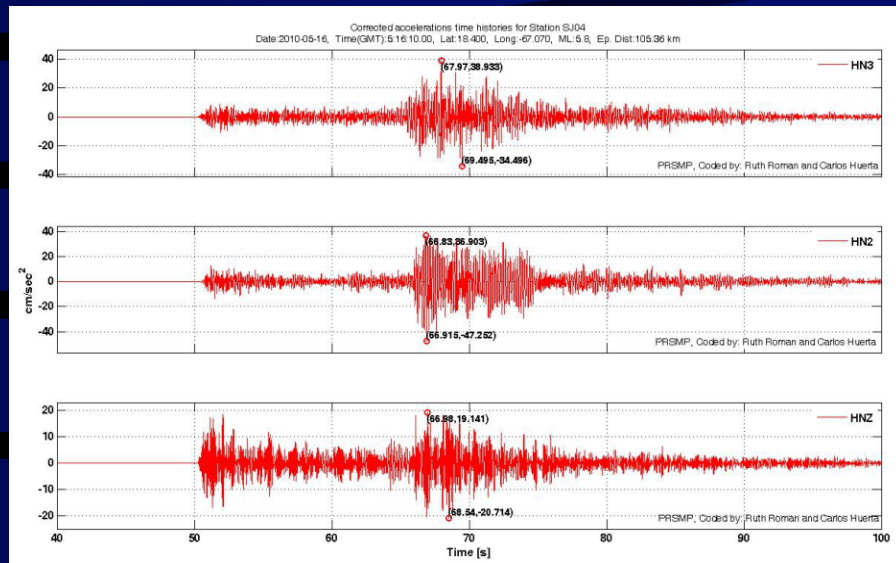


# STRONG MOTION DATA PROCESSING



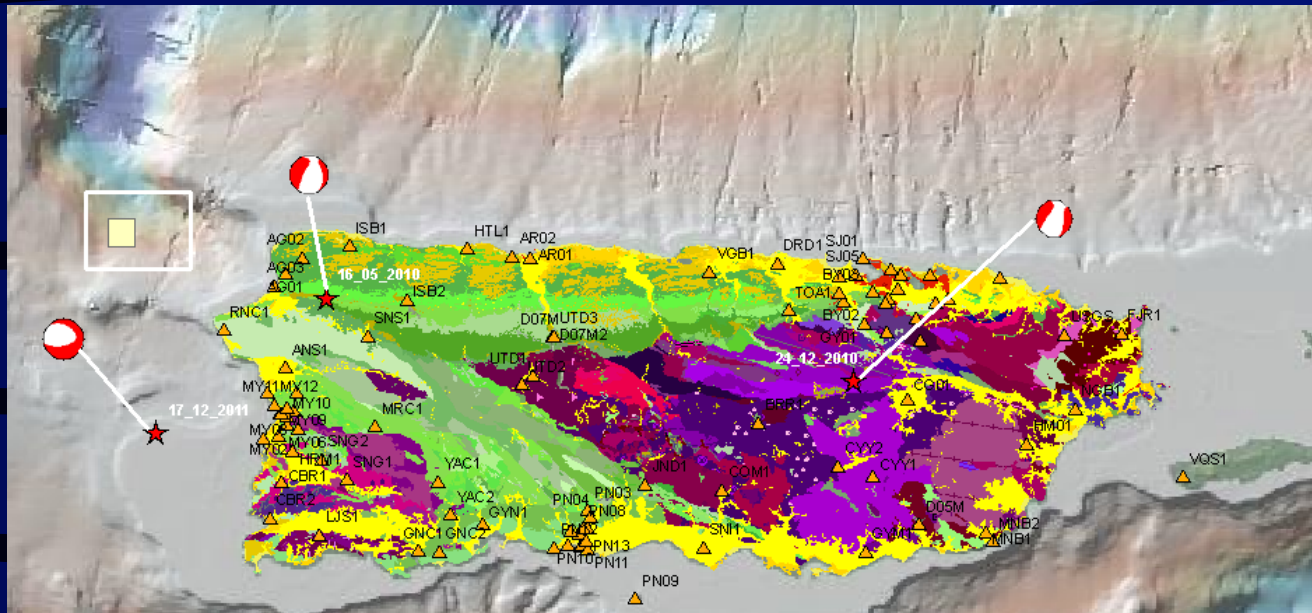
# May 16, 2010 Earthquake: Study case







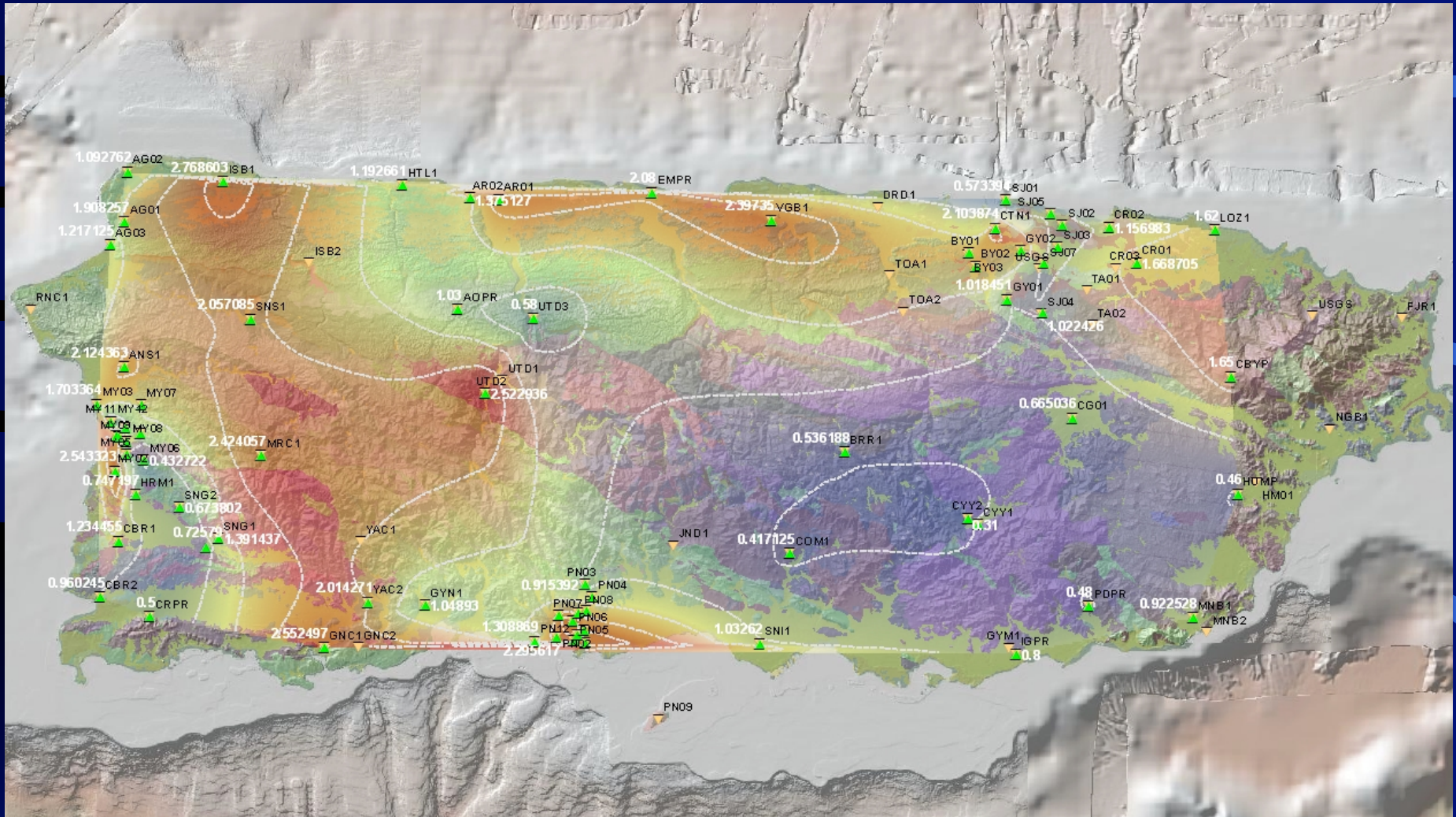
# 05/16/-, 12/24/2010, 12/17/2011, 02/26/2013 Eqks: Study case



Event date	Max_PGA (cm/s <sup>2</sup> )	Station	Distance (Km)	Max_PGA (cm/s <sup>2</sup> )	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

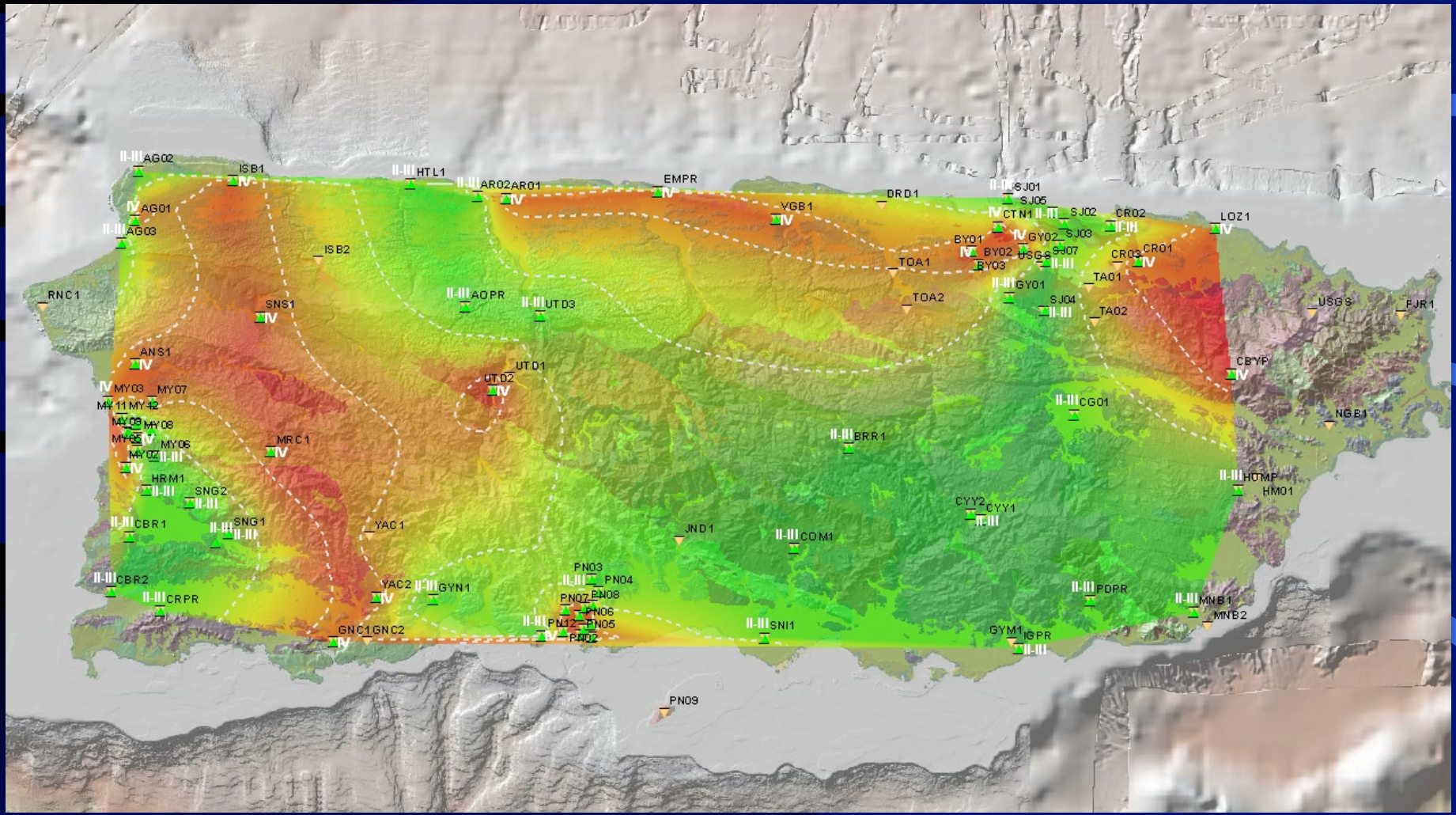


# January 13, 2014 Earthquake: Study case





# January 13, 2014 Earthquake: Study case





# THE PUERTO RICO 5.8 MW EARTHQUAKE OF MAY 16, 2010 and the Distribution of Peak Ground Motion in the Puerto Rico Island

<sup>23</sup>Carlos I. Huerta-López, <sup>3</sup>Jonas De Dios De Basabe-Delgado, <sup>4</sup>Ruth E. Román-Batista, <sup>5</sup>José A. Martínez-Cruzado, <sup>6</sup>Jorge Andrés Caro-Cortes, and <sup>7</sup>Luis E. Suarez-Colche

<sup>1</sup>University of Puerto Rico at Mayaguez, Department of Civil Engineering and Surveying, Puerto Rico Strong Motion Program (josean@upr.edu, martin@upr.edu, rafael@upr.edu). <sup>2</sup>Mailing address: Puerto Rico Strong Motion Program, Department of Civil Engineering and Surveying, University of Puerto Rico at Mayaguez (josean@upr.edu, martin@upr.edu, rafael@upr.edu). <sup>3</sup>Research Center for Higher Education at Eusebio C. Ruiz (ccr@upr.edu, Eusebio C. Ruiz, Seismology Department (josean@upr.edu, martin@upr.edu, rafael@upr.edu). <sup>4</sup>Graduate Student, Department of Civil Engineering and Surveying, University of Puerto Rico at Mayaguez (josean@upr.edu, martin@upr.edu, rafael@upr.edu).



CICES

**ABSTRACT.** An earthquake of M<sub>w</sub>3.0 occurred in the northwest region of Puerto Rico at latitude 18°40' N, longitude 70° 20' W, and focal depth 13.1 km [1] on 16:15–16:20 UTC on May 18, 2010. A new analysis and discussion are presented with the aim to explain the non-normal distribution of aftershocks observed, which may be associated not only by local site effects due to the presence of soft soils, but also by the geometry of the fault plane. The location of the station of Aguadilla, which is located at approximately 41 km from the epicenter, was determined by means of a comparison between the values of  $V_{\text{rms}}$  at similar epipentral distances. An instrumental intensity of VIII was estimated in the area of Usho-don located roughly at 45 km from the epicenter. Aftershock sequences were identified at distances of 9.5 km from the principal rupture zone, and at 10.5 km from the station of Aguadilla. Two stations, (i) AGS1 station, located at an epipentral distance of 9.50 km from the epicenter, and (ii) AGS2 station, located at station UT2 located at an epipentral distance of 41.50 km or more, showed a significant difference in the relationship between the ratio between  $V_{\text{rms}}$  and  $V_{\text{max}}$ , respectively for the two previously described sites.

ties, respectively, to the respective first two strikes (Fig. 1). The 1990 earthquake occurred in the Dominican Republic and the Virgin Islands. It was recorded also by 59 stations of the Puerto Rico Strong Motion Program (PRSM) providing a useful set of acceleration records distributed around the island. According to the USGS Control Moment Tensor solution, this earthquake occurred in an inclined seismic zone that dips south from the Puerto Rico Trench and that consists of subducted lithosphere of the North America plate. Earthquakes that have focal depths between 70- and 300-km, are commonly termed "intermediate-depth" earthquakes and typically cause less damage on the ground surface above their foci than similar magnitude shallow-focus earthquakes. Also, large intermediate-depth earthquakes may be felt at great distance from their

**INTRODUCTION.** The Puerto Rico Strong Motion Program (PSRMP) is dedicated to obtain reliable and precise accelerations and displacements from stations affecting the Puerto Rican region. The PSRMP has 15 free-field stations (range in yellow), and 19 borehole stations and 6 surface stations (range in red). Stations 27 are stand alone, all have telephone data communication, 14 are internet connected, and 10 are equipped with Global Positioning System (GPS) receivers. Stations 12 and 28 with the Puerto Rico Seismic Network, No internet connection, no GPS receiver, and no stand alone, and 4 have internet communication. All the stations are distributed around Puerto Rico, the US and St. Vincent Virgin land, and most of them are equipped with triaxial accelerometers and digital data acquisition systems. This paper presents the results of the Puerto Rico Mw 5.3 (2015-02-07) earthquake to give an insight of the seismicity in the Caribbean Plate (CPA) and the spectral amplitudes ( $S_a$ ) distribution within the island is relatively irregular with respect to the expected decay rate of PCA spectra with increasing distance. Local site conditions (effects), as well as path effects are being discussed in order to explain the observed behavior.

Beyond the observational estimates obtained after processing the recorded acceleration records, we have computed a series of spatial correlation estimates using the second-order spectral element method. The computational domain is a rectangular prism with horizontal and vertical layers. As a first approximation, we used the regional model proposed by Brink (2005). The seismic source was implemented as a planar fault with a fixed wavelet in time with a peak frequency of 0.1 Hz. The numerical results are displayed in the form of topography, rather than the absolute conditions of the structure (local models) available for the considered stations.

Strong motion processing was applied to the recorded data, and the resulting acceleration time series were used to compute the instrumental intensity (Wald et al. (1999) instrumental intensities (Modified Mercalli Intensity, MMI) were estimated and contour maps were generated for each of the 10 stations. The instrumental intensity (MMI) distribution within the

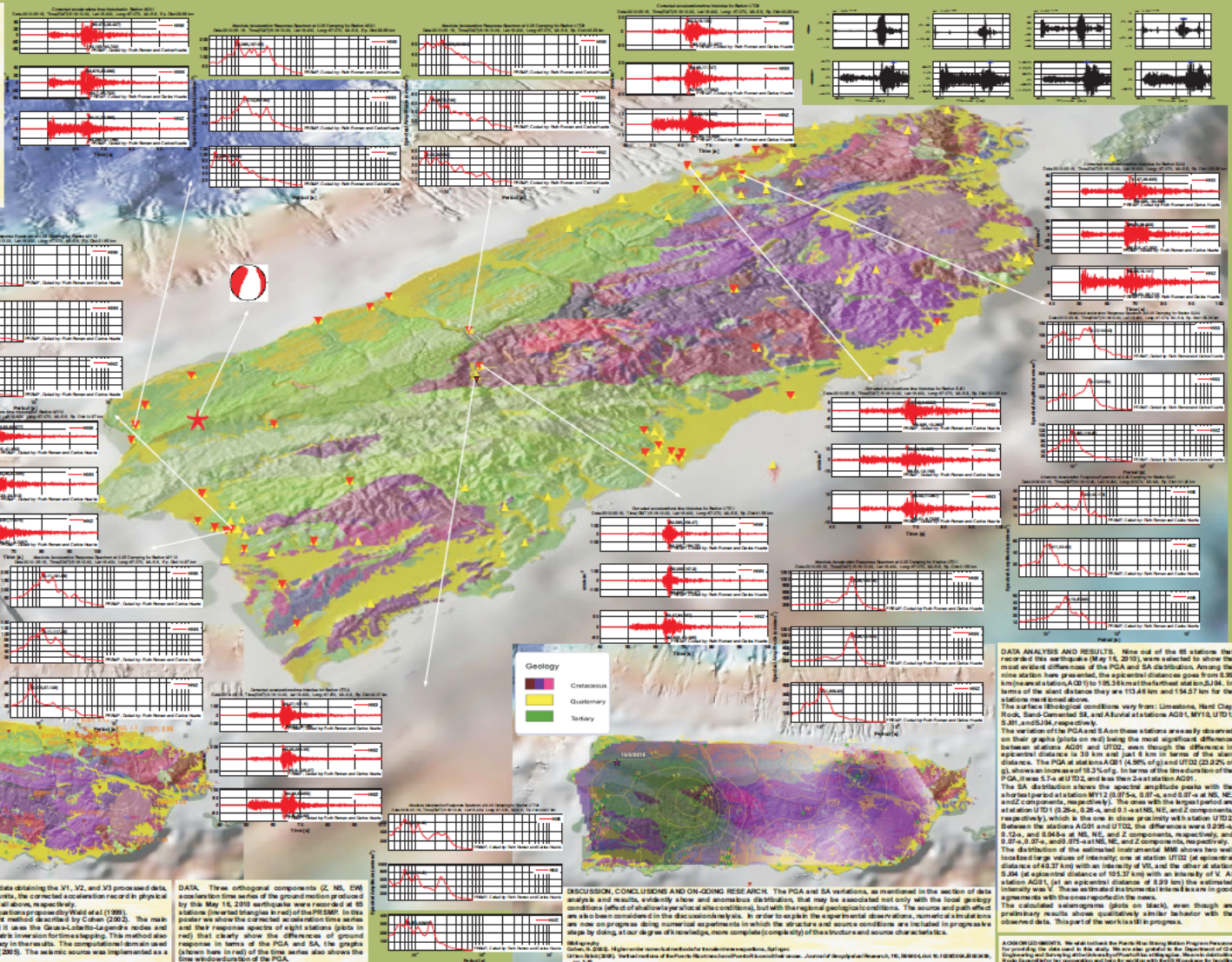
**METHOD.** Standard strong motion signal processing was applied to the recorded data which correspond to the uncorrected data acceleration records converted to physical units of a co-ordinates, velocity and displacement, and the spectral representation of the instrumental seismity (Modified Mercalli Intensity, MMI) was estimated using the geosynthetic seismograms were computed using the second-order spectral wave difference between this method and the classical first element method is that peak amplitudes, yielding an increase in efficiency since it does not require any modification using a frequency higher order approximations to obtain higher derivatives is a 2D rectangle divided into horizontal layers, using the regional model of Blakely (solid surface, topography and a block of sediment in time with an average velocity of 1.9 km/s).

**DATA.** Three orthogonal components (Z, NS, EW) of a co-seismic time series of the ground motion produced by this May 15, 2010 earthquake were recorded at 65 stations (inverted triangles in red) of the FRP-SM. In this poster we show the corrected acceleration time series and their response spectra of eight stations (plots in red) that clearly show the differences of ground response in terms of the PGA and Sa. The graphs (shown here in red) of the time series also shows the time window duration of the PGA.

**DISCUSSION, CONCLUSIONS AND ON-GOING RESEARCH.** The PGA and SA analysis and results, evidently show an anomalous distribution, that may be conditions (effect of shallowly yielded state conditions), but with the regional geol are also been considered in the discussion analysis. In order to explain the geol are now on progress doing numerical experiments in which the structure and so steps by doing, at our degree of knowledge, more complete (complexity) of the structure.

stations, as mentioned in the section of data associated not only with the local geology (physical conditions). The source and path effects of the observed data, numerical simulations under conditions are included in progressive time and source characteristics.

**ACKNOWLEDGMENTS.** We wish to thank the Puerto Rico Strong Motion Program Personnel for providing the data used in this study. We are also grateful to the Department of Civil Engineering and Surveying at the University of Puerto Rico at Mayaguez. We wish to thank the Rodeo Island and Inlet for their cooperation and help in working with the US R package for handling the GIS software regarding the maps.







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

By:

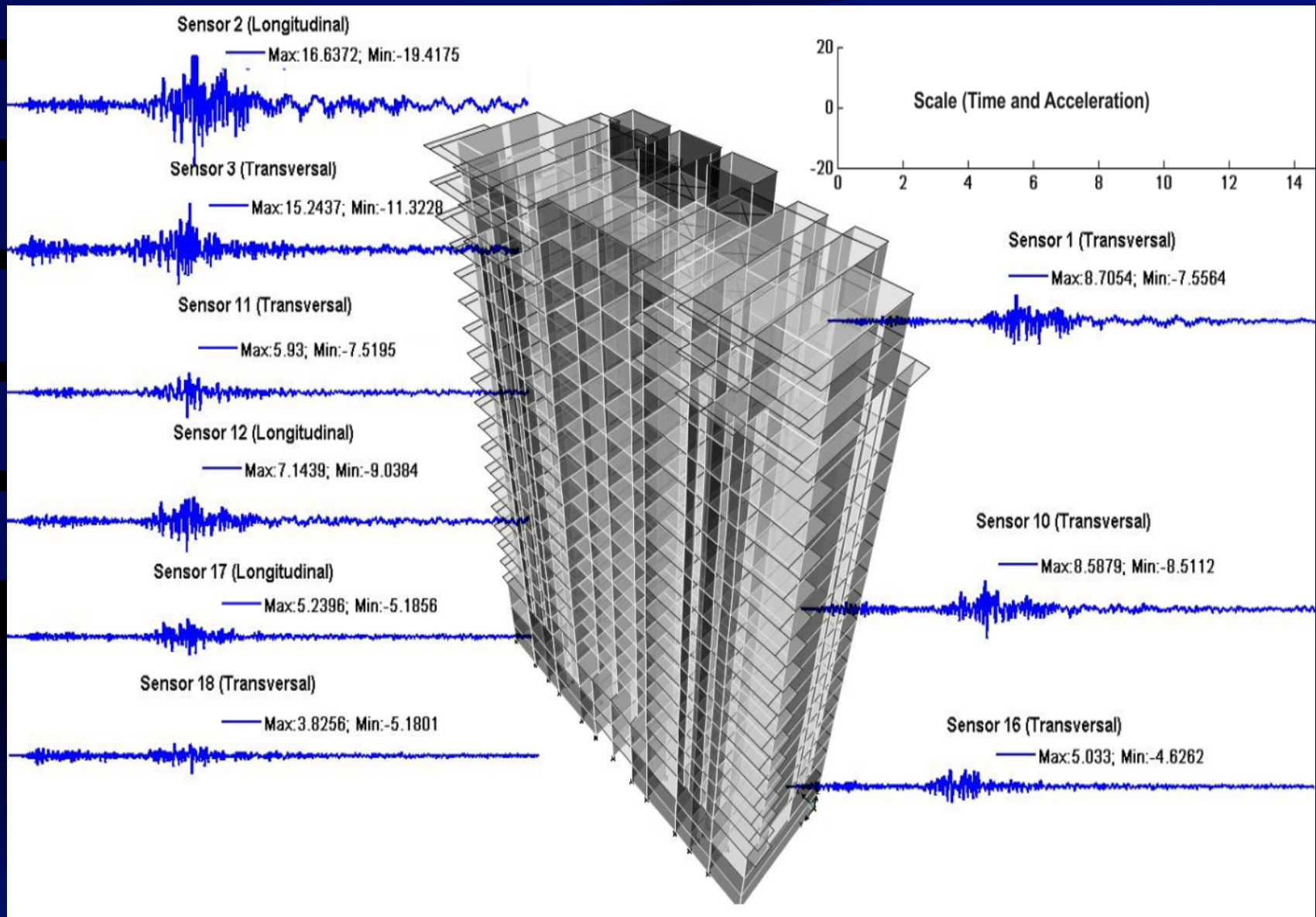
Carlos I. Huerta-López, Ph.D

José A. Martínez-Cruzado, Ph.D

Fabio M. Upegui-Botero, Grad. Stud.

Luis E. Suarez-Colche, Ph.D.

# El Castillo Building. M5.3 Eqk.



[go\\_prsmp\\_webpage](#)

# PRSMP WEB PAGE DATA DISSEMINATION



Thanks,