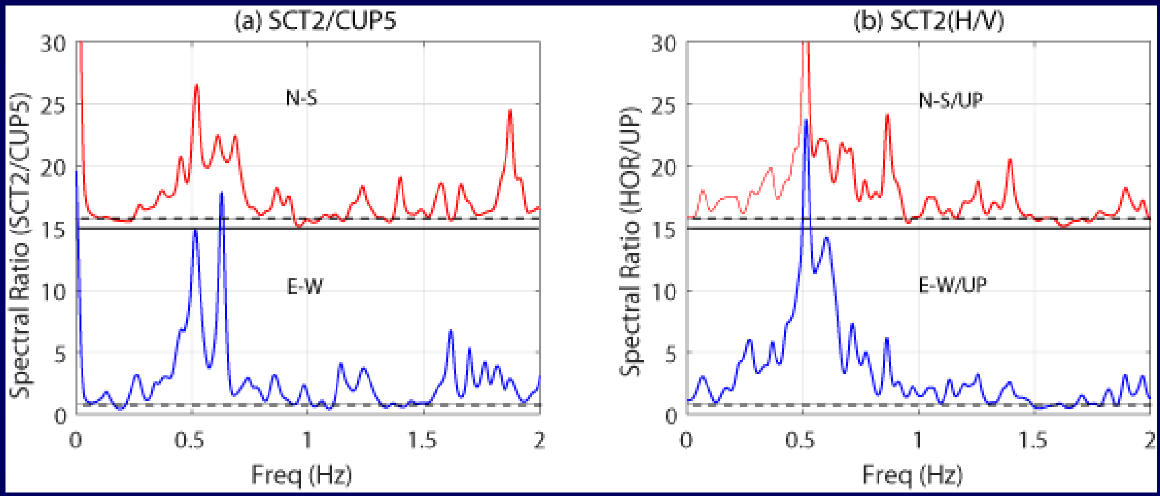
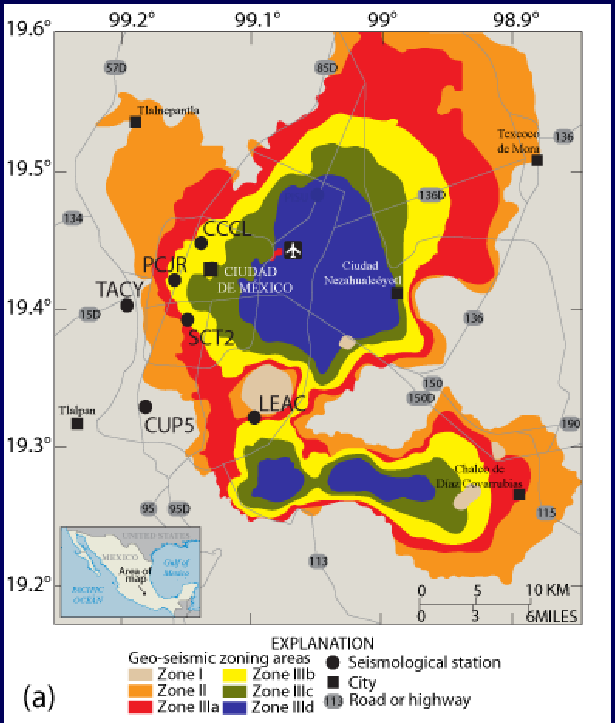
The M7.1 September 19, 2017 Puebla-Morelos City Earthquake: Spectral Ratios Confirm Mexico City Zoning





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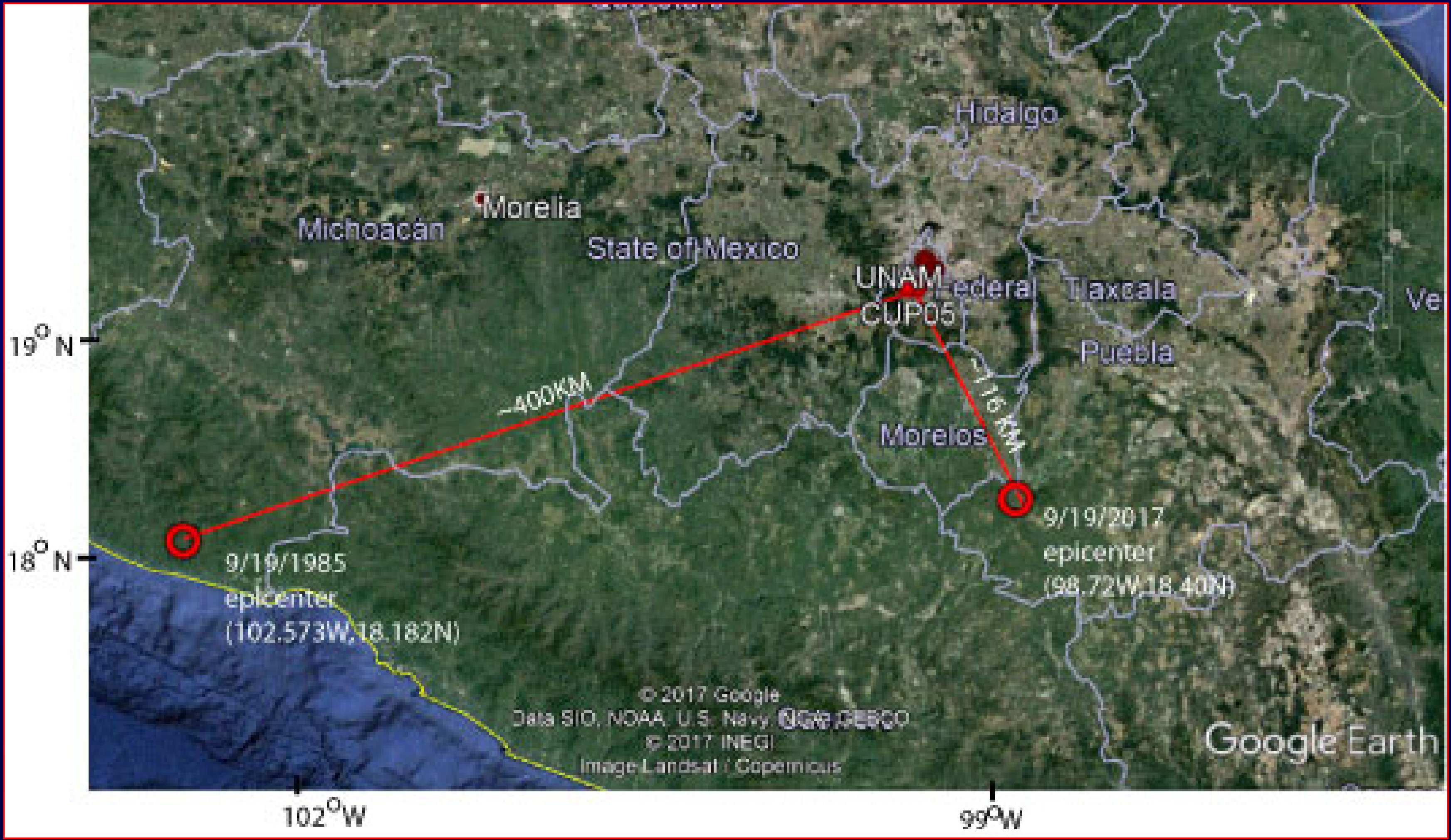
OUTLINE

- Statement of Purpose
- 19 September 2017 Earthquake Info – Mexico city Zoning
- 1985 Michoacan earthquake – Mexico City Zoning
- 1985 Earthquake effects and summary of a study (e.g. SCT data and SCT building)
- 2017 earthquake data, organization, standardization
- Spectral Ratios – Two types computed from data according to sub-zones
- Discussion of Results
- Conclusions

Purpose

- The purpose of this study are to :
  - analyze the spectral ratios computed from retrieved strong motion data recorded by several stations in Mexico City during the most recent **M**7.1 19 September 2017 Puebla-Morelos earthquake.
  - identify the predominant frequencies at the select sites for which data are available.
  - compare, as applicable, the frequencies and spectral ratios with observed predominant frequencies from the 1985 Michoacan earthquake.
  - compare 2017 frequencies with the current site periods (frequencies) interpolated from the seismic zoning map of Mexico City (Mexican Seismic Design Code of 2004).
- The scope of the paper will not include tectonics, seismicity, earthquake damage reconnaissance and/or assessment.

Relative locations of the 1985 and 2017 earthquakes with respect to Mexico City. Coordinates [latitudes and longitudes] of the epicenters of both 1985 and 2017 events are also indicated



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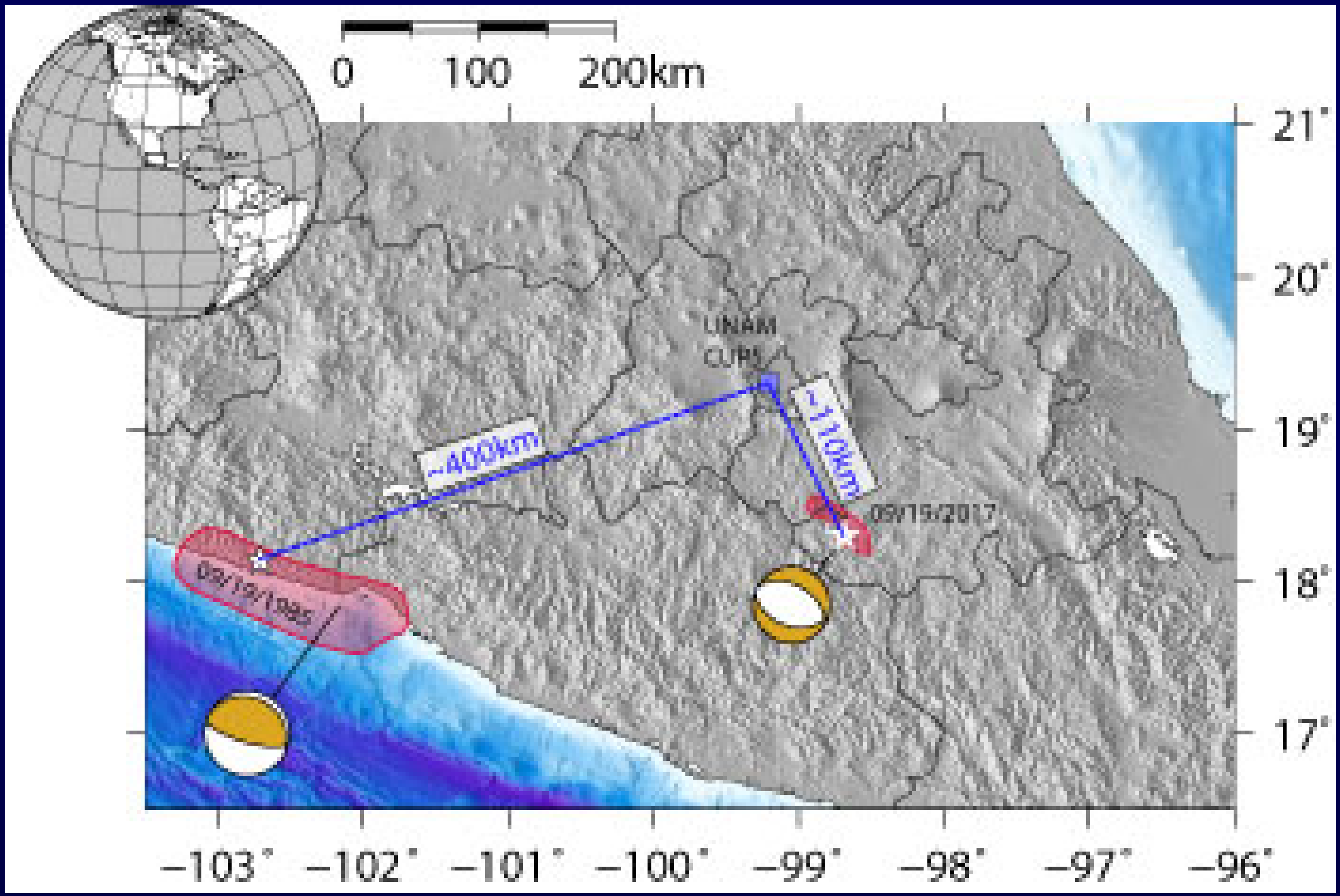
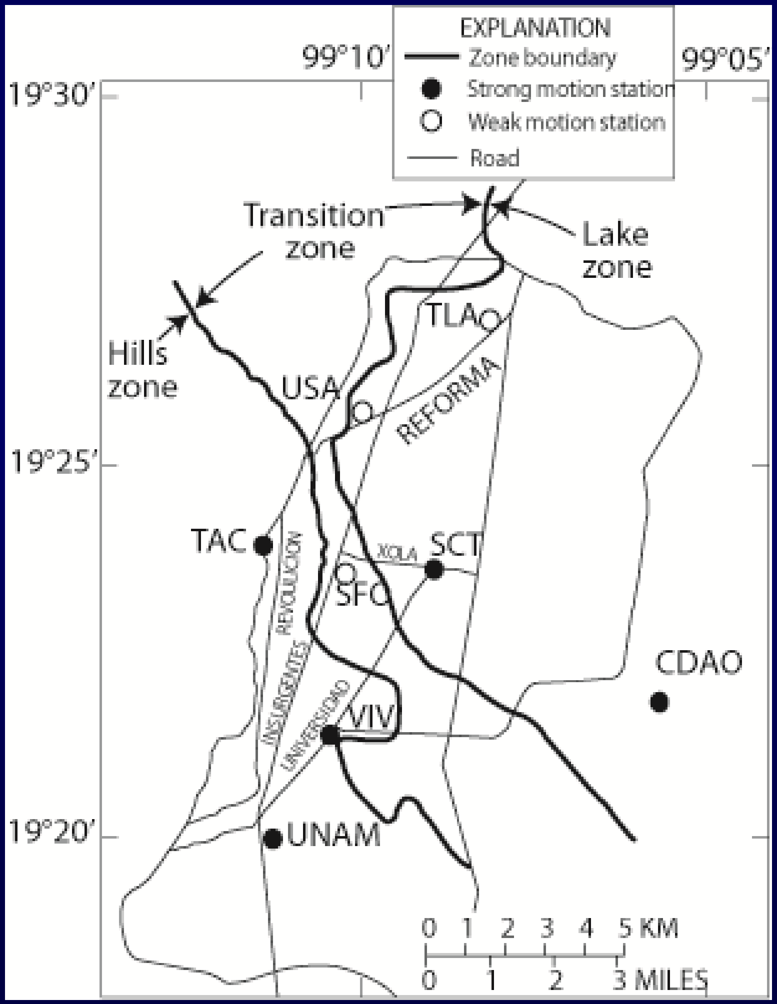
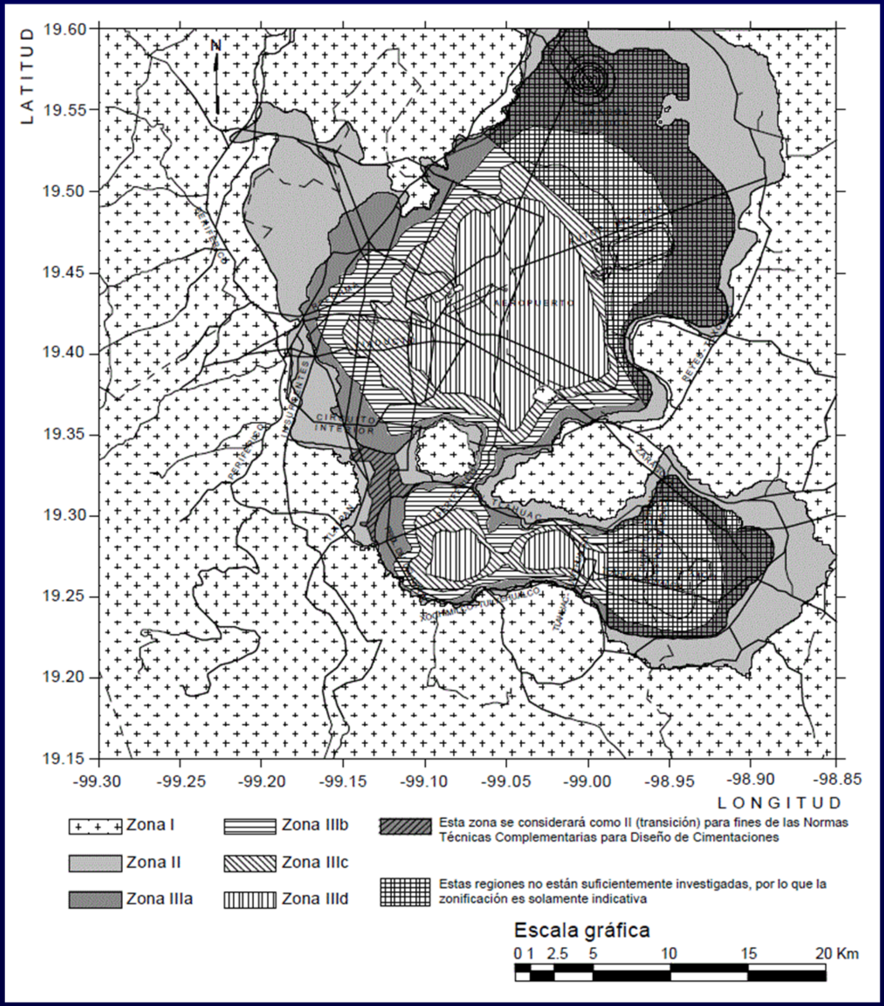


(LEFT) Zoning map of Mexico City that was in effect in 1985 (Çelebi and others, 1987). Solid lines are major avenues and thick solid lines are boundaries of zones. Stations included in the study are marked with circles. (RIGHT) Much more detailed zoning map that was in effect in 2017 (Mexican Seismic Design Code of 2004), with Zones denoted as Zona. Escala gráfica: Map scale.





1985 EQ Studies

5.

The Culprit in Mexico City—Amplification of Motions

M. Celebi, M. EERI, J. Prince, M. EERI, C. Dietel, M. Onate, and G. Chavez

Mexico City has repeatedly suffered from the long-distance effects of the earthquakes that originate as far away as the subduction trenches near the Mexican Pacific Coast. The Michoacan, Mexico earthquake of 19 September 1985 was no exception and caused extensive damage to property and numerous loss of lives. The unique subsurface condition resulting from the historical lakebed has distinct resonant low frequencies around 0.5 Hz. The strong earthquake motions from long distances as well as the locally originating weak motions cause large amplifications at resonant low frequencies in the subsurface environment of Mexico City lakebed. In this paper, the resonant frequencies and associated amplification of motions in Mexico City are quantified in terms of spectral ratios using 19 September 1985 strong-motion data and weak

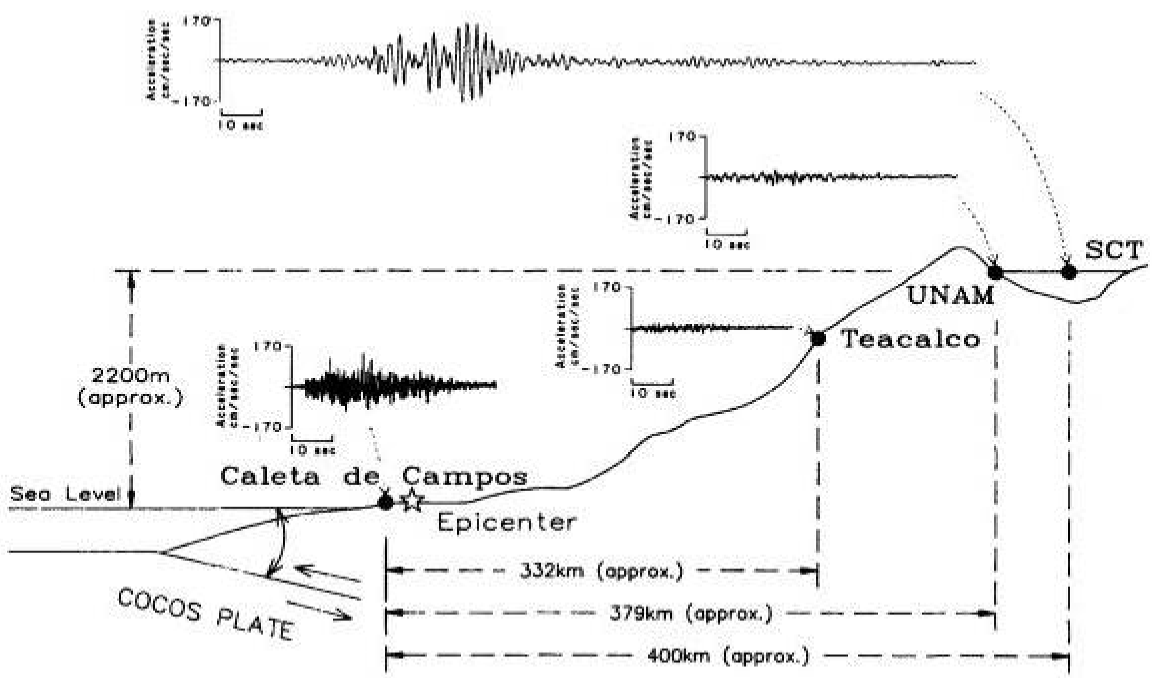


Figure 2 – Schematic section showing relative locations of the epicentral station at Caleta de Campos, Teacalco station (closest to Mexico City), and Mexico City stations, UNAM (hills zone) and SCT (lake zone). The seismograms are east-west components of 19 September 1985 acceleration time-histories (all plotted to the same scale) recorded at respective stations and demonstrate the attenuation of motions with distance from the coast as well as amplification of motions at the lakebed of Mexico City.

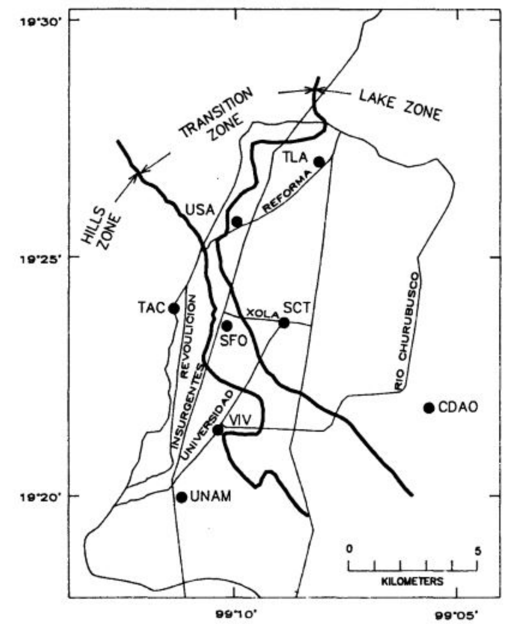
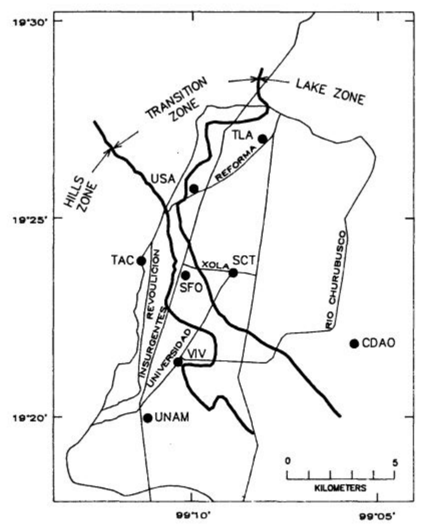


Figure 3 – Map showing the three zones of Mexico City as well as the locations of stations discussed in the manuscript. UNAM, SCT, CDAO, VIV and TAC are strong motion stations. SFO, USA and TLA are the temporary stations established in January 1986 to facilitate recording of weak motions. (Note: The location of Viveros being in the transition or the hills zone is a disputed issue).

1985 EQ:
Amplitude Spectra and Spectral Ratios (limited number of strong motions)



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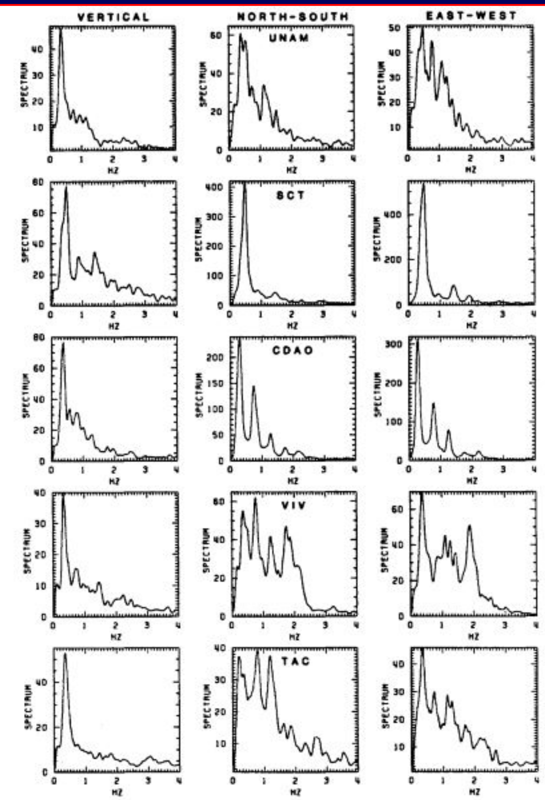


Figure 5 – Fourier spectra for the vertical and horizontal components (NS and EW),respectively, derived from the strong-motion records of stations UNAM, SCT, CDAO, VIV and TAC in Mexico City. All plots demonstrate the significant low-frequency energy at all stations.

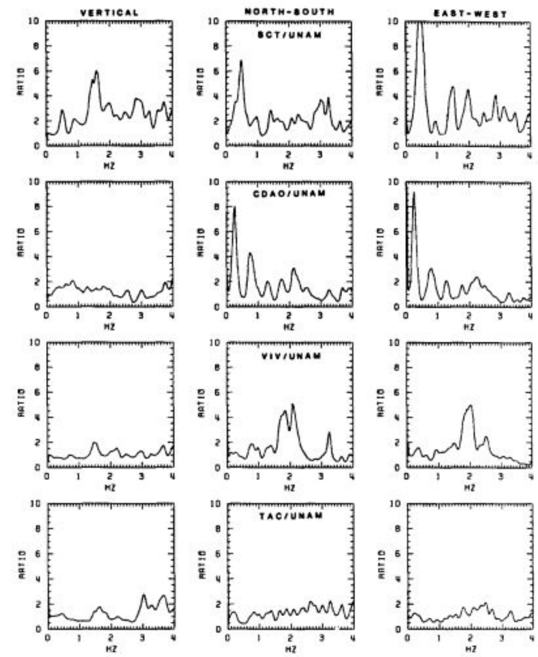
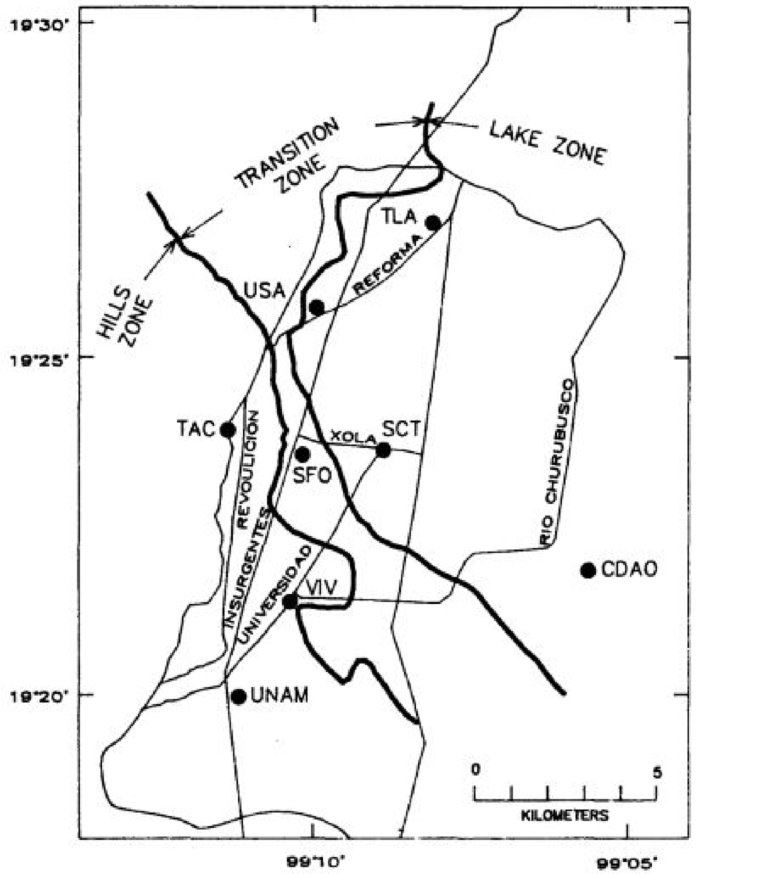


Figure 4 – Spectral ratios for the vertical and horizontal components (NS and EW),respectively, derived from the strong motion records of the 19 September 1985 earthquake. Ratios shown are for stations SCT, CDAO, VIV and TAC with respect to UNAM. All plot have same format and scale to provide easy comparison. SCT and CDAO stations are in the lake zone, VIV is in the transition zone and TAC and UNAM are both in the hills zone. The plots clearly and quantitatively show the frequencies and amplitudes of amplification of motions experienced in Mexico City.

1985 EQ: from weak motions (USGS study)



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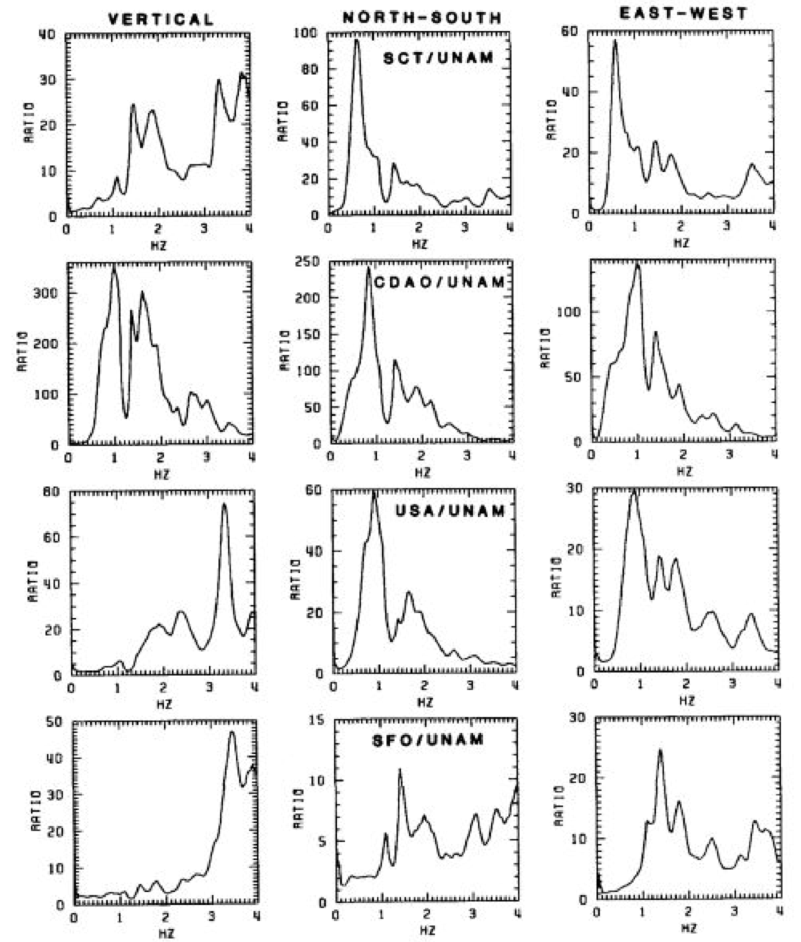


Figure 6 – Spectral ratios for the vertical and horizontal components (NS and EW),respectively, derived from weak motions recorded at stations CDAO, SCT, USA, SFO and UNAM. All plots are made with respect to UNAM. CDAO, SCT and UNAM stations are same as the strong-motion stations.

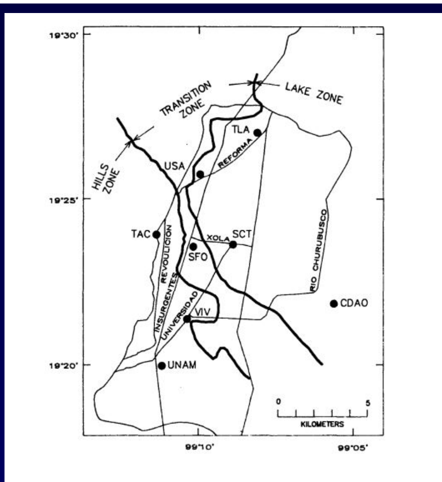
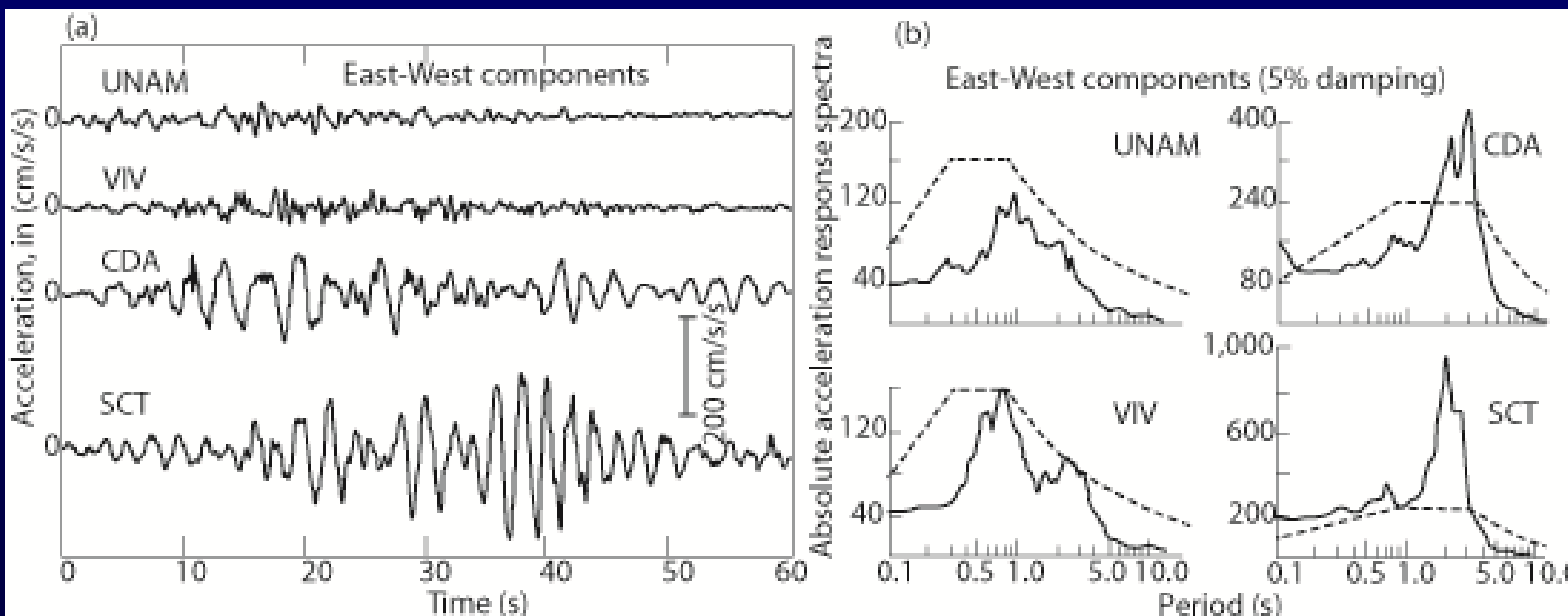


Figure 3 – Map showing the three zones of Mexico City as well as the locations of stations discussed in the manuscript. UNAM, SCT, CDAO, VIV and TAC are strong motion stations. SFO, USA and TLA are the temporary stations established in January 1986 to facilitate recording of weak motions. (Note: The location of Viveros being in the transition or the hills zone is a disputed issue).

1985 mainshock acceleration time histories depict the amplification of accelerations in different locations in Mexico City as compared to UNAM station.

Response spectra of the accelerations also depict the amplification. Design response spectra in effect in 1985 are superimposed as dashed lines on each for comparison purposes) **[Figure adopted from Anderson and others, 1986].**



During 1985, SCT building (Ministry of Telecommunications) (Secretaria de Communicaciones y Telegrafos) was severely damaged (several collapsed floors)(http://libraryphoto.cr.usgs.gov/cgi-bin/show_picture.cgi?ID=ID.%20Celebi)

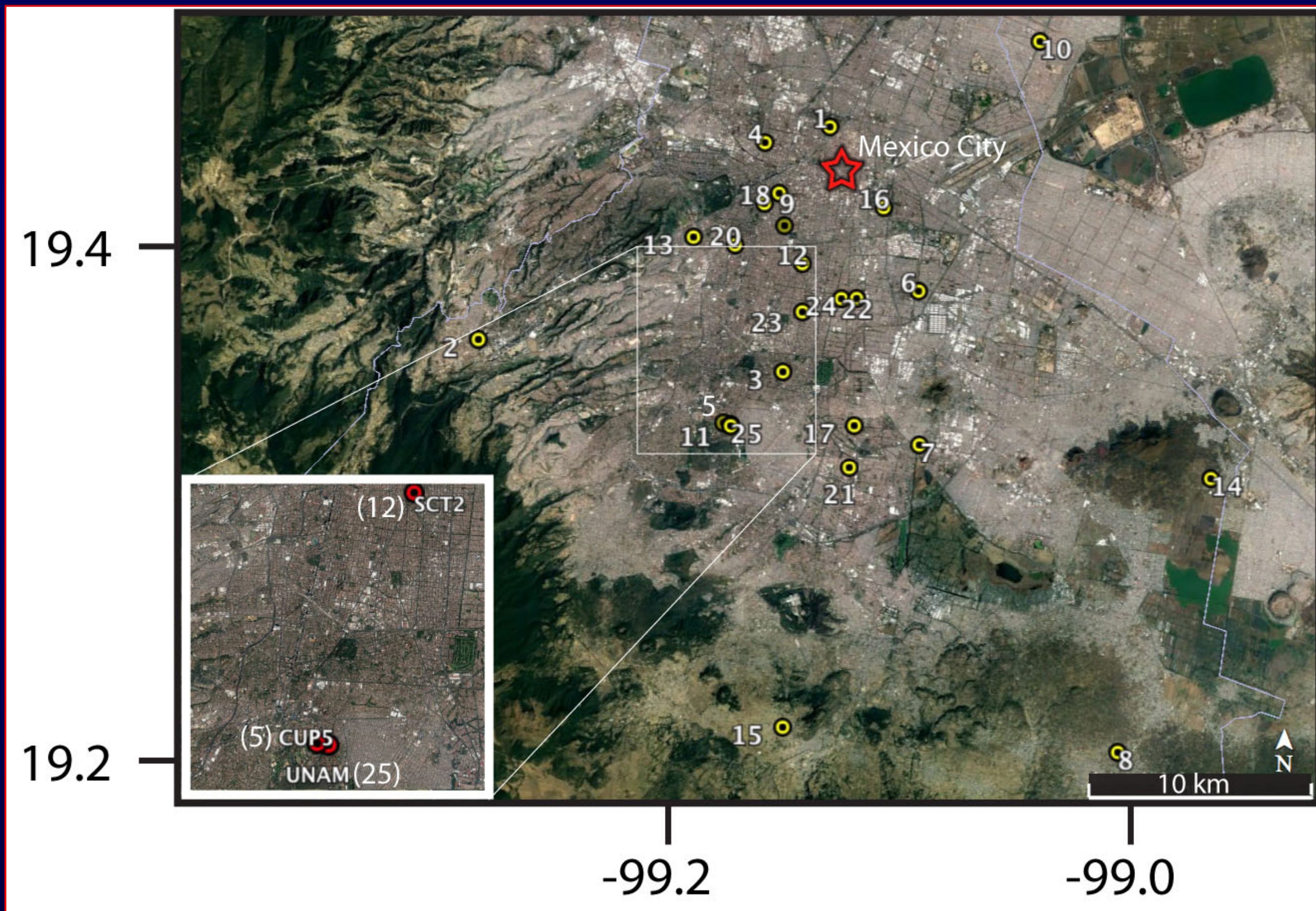
The picture on the left is from Google Earth (January 2018). It must have been taken before September 19, 2017 EQ.

It is reported that in 2017 EQ, this building again is severely damaged and will be demolished.
We do not have any pictures of the damages that the building experienced during 2017 EQ.

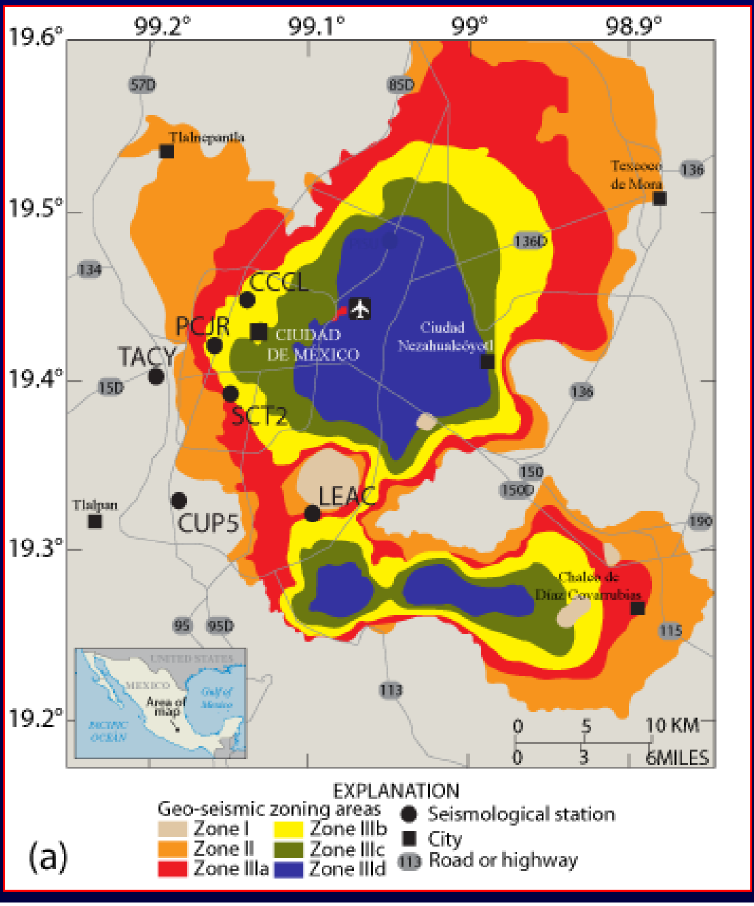
Representative number of peak accelerations of the 1985 and 2017 mainshocks. Zone designations are according to the current zoning map in the 2004 Seismic Design Code.

		1985 Peak Acc. (g)*		2017 Peak Acc. (g)**	
	ZONE	NS	EW	NS	EW
UNAM	I	.03	.035	.046***	.055***
CUP5	I	-	-	.05	.06
TACY	I	.03	.03	.06	.06
VIV	III	.049	.024		
JC84	II	-	-	.22	.21
CH84	II	-	-	.15	.23
SI53	IIIa	-	-	.13	.18
SCT	IIIb	.098	.168		
SCT2	IIIb			.09	.09
Source*NIST Report, **GEER Report, *** www.strongmotioncenter.org					

Google Earth Map of Mexico City with strong motion stations used in this study, that recorded the EQ of 19 September 2017 (yellow circles with station numbers labeled, SCT, CUP5 and UNAM stations are highlighted in red in the inset.



(LEFT) Zoning map modified from the 2004 Mexican Seismic Design Code of 2004 – showing some of the stations in different zones that recorded the 19 September 2017 M7.1 earthquake. Station CUP5 in close proximity to UNAM station . (RIGHT) Map showing predominant periods in the different zones (digitized by authors using the map in the 2004 Mexican Seismic Design Code) - used later to compare periods from the code with those from strong motion data of 2017 earthquake. Stations included in this study are shown as yellow circles



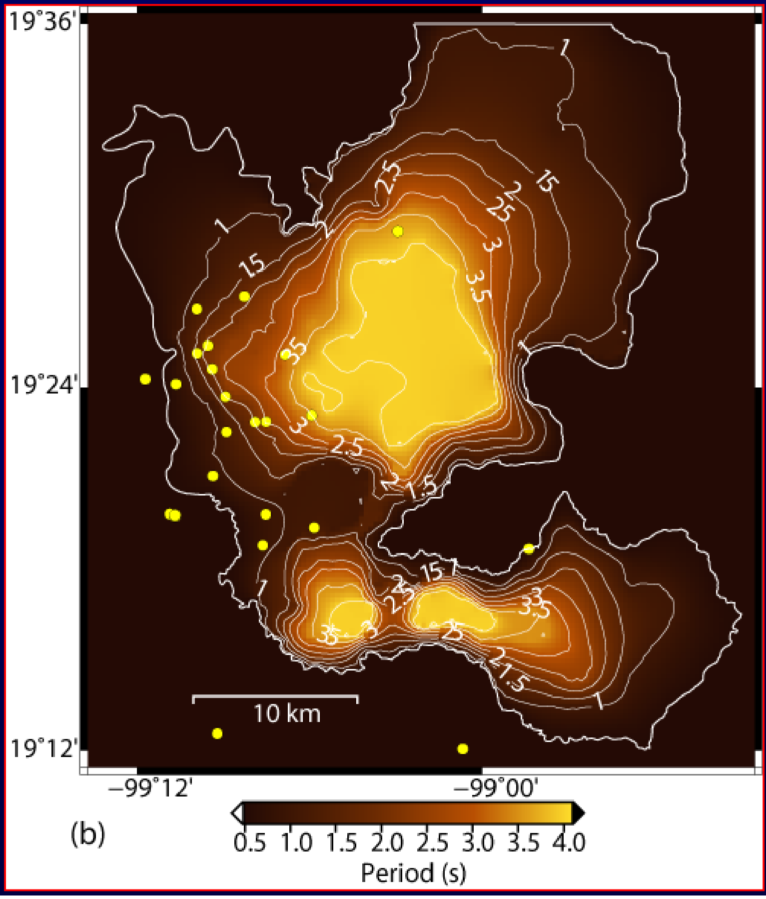


Table 2. Data Information

(a) site classification according to Mexican Seismic Code Map (2004),
(b) original data station name
(c) coordinates of stations
(d) delta time (sampling rate),
(e) number of points [npts],
(f) record length (s).

AS A RESULT:

Data characteristics are **standardized** to:
(a) length of 260 s for each station and channel and with Δt =0.01s (100 sps),
(b) reduced to or padded to 26001 points.
(c) All acceleration time history units are standardized to m/s/s units

NOTES:
(a) [LEAC could be either IIIa or IIIb; hence accepted here as IIIa.
(b) **CH84 GEER(2017) identifies as II but could be IIIa also; hence accepted as II.
(c) (c) + note the short length of PZIG.
(d) ***UNAM operated station.

UNAM IINGEN Stations							
			(c) Coordinates		Original		
This study	(a) Site Class	(b) Station name	Longitude (W)	Latitude (N)	(d) Δt	(e) npts	(f) Record length(s)
1	IIIb	CCCL	-99.1379	19.4498	.01	61849	615
2	I	CJVM	-99.2850	19.3616	.01	E(10516] N[10065] Z[10298]	E[105.15s] N[100.60s] Z[103s]
3	II	COVM	-99.1561	19.3511	.01	26001	260
4	II	CTVM	-99.1655	19.4430	.01	26001	260
5	I	CUP5	-99.1811	19.3302	.01	41181	411.8
6	IIId	ICVM	-99.0990	19.3845	.01	26001	260
7	IIIa*	LEAC	-99.0976	19.3228	.005	68491	342.45s.
8	I	MPVM	-99.0114	19.2010	.01	26001	260
9	IIIb	PCJR	-99.1591	19.4228	.01	38791	387.9
10	IIId	PISU	-99.0490	19.4857	.01	38891	388.9
11	I	PZIG+	-99.1780	19.3290	.01	E[14505] N[14460] Z[14624]	145.04s 144.59s 146.23s
12	IIIb	SCT2	-99.1489	19.3947	.01	31591	315.9s
13	I	TACY	-99.1953	19.4045	.005	46891	234.45s
14	I	THVM	-98.9732	19.3110	.01	26001	260s
15	I	TLVM	-99.1537	19.2094	.01	26001	260s
16	IIId	VRVM	-99.1144	19.4179	.01	26001	260s
CIRES Stations							
17	II**	CH84	-99.1254	19.3300	.01	33860	338.6
18	IIIb	CI04	-99.1566	19.4098	.01	60000	600.0
19	IIIb	CI05	-99.1653	19.4186	.01	32901	329.0
20	II	ES57	-99.1775	19.4017	.01	28220	282.2
21	II	JC54	-99.1272	19.3130	.01	35280	352.8
22	IIIb	PE10	-99.1318	19.3809	.01	35260	352.6
23	IIIa	SI53	-99.1483	19.3753	.01	38660	386.6
24	IIIc	VM29	-99.1253	19.3811	.01	32901	329.0
25***	I	UNAM	-99.1780	19.3296	.01	26001	260

DATA ANALYSES: SPECTRAL RATIOS

- Spectral ratios are computed:

(1) using the transfer function relationship:

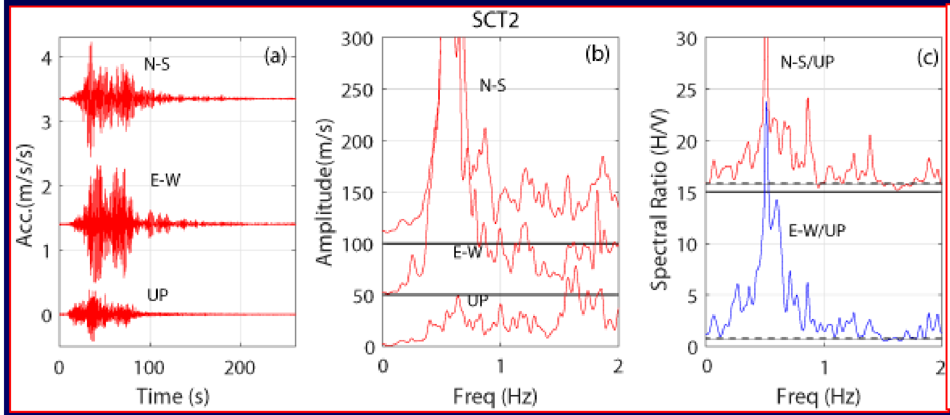
$$R_{ij}(f) = A_{ij}(f)/A_{ref,j}(f) \text{ where}$$

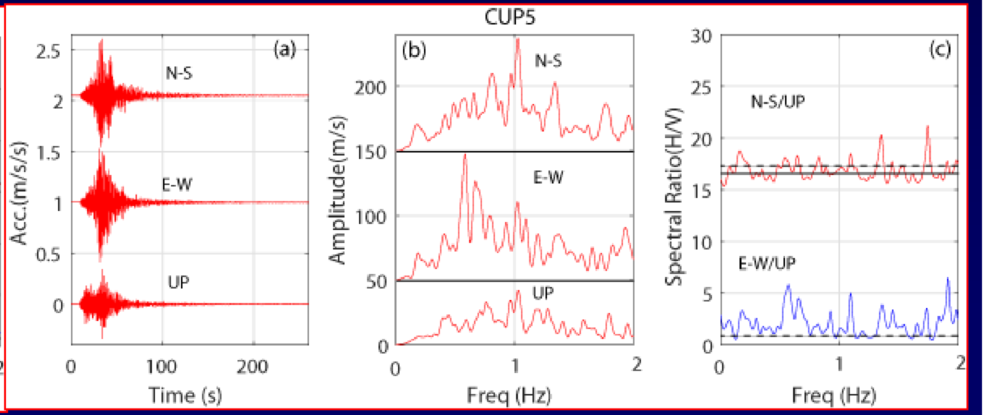
$A_{ij}(f)$ is the *jth* component of the smoothed amplitude spectrum at recording station $_i$ and similarly, $A_{ref,j}(f)$ is the *jth* component of the smoothed amplitude spectrum at the reference recording station. This relationship is valid assuming the differences in distance between the recording station i and reference station is negligible when compared to an overall distance of ~106 km of the reference station from the epicenter

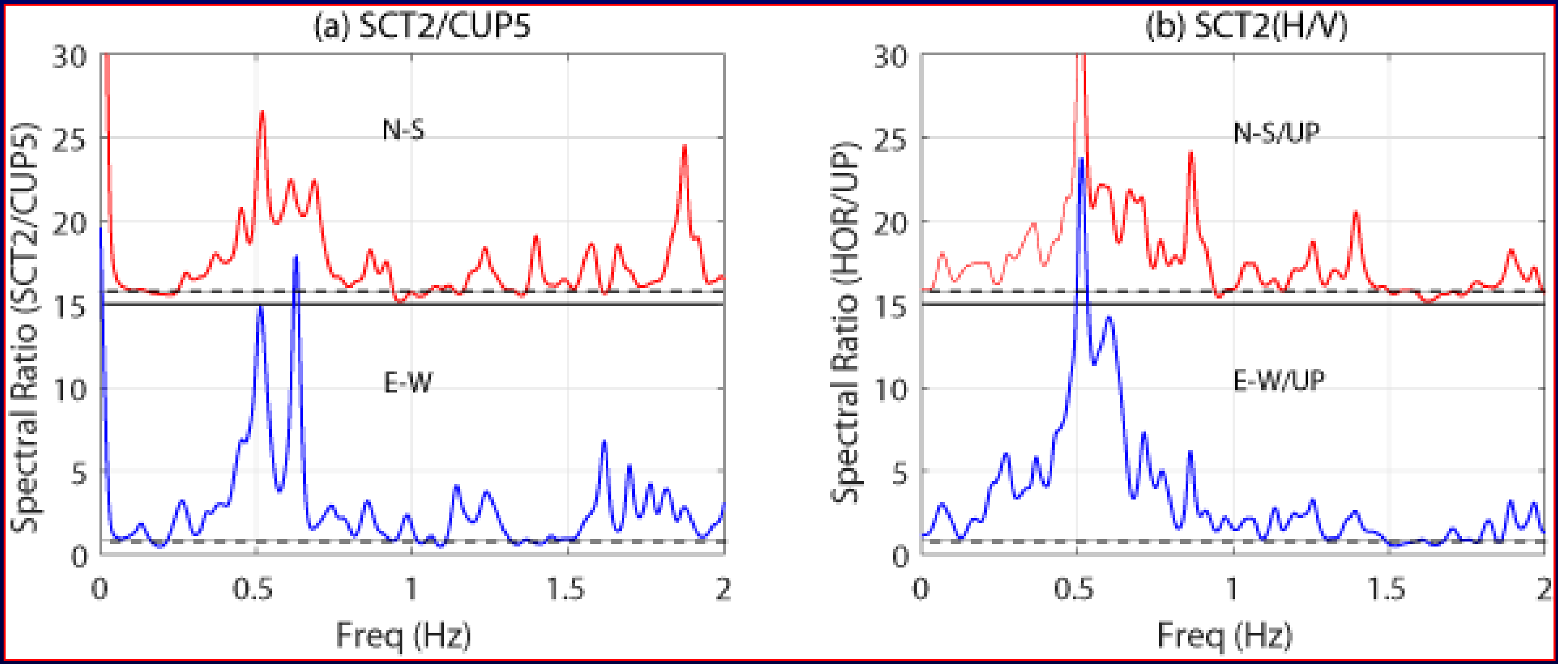
- H/V (or Nakamura Method [1989, 2008])

Sample Computations

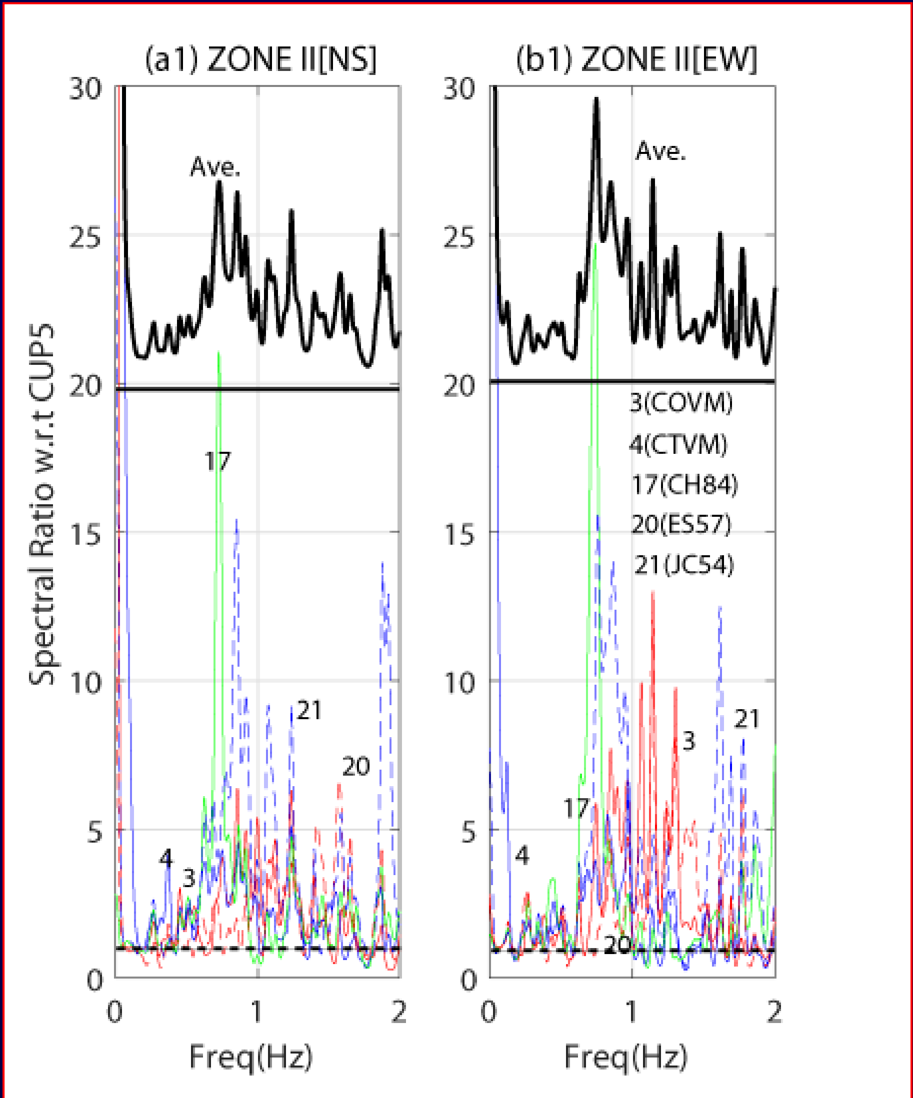
(also to compare Rij and H/V methods)

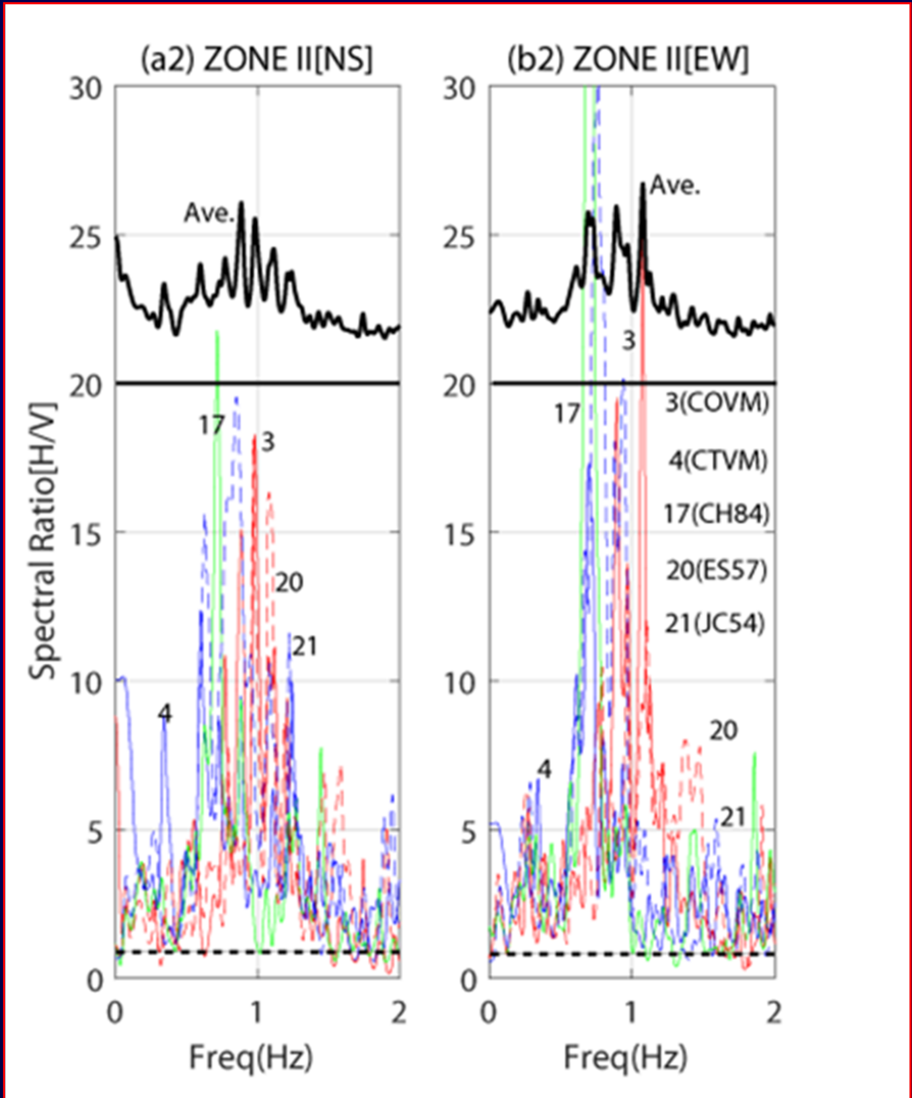




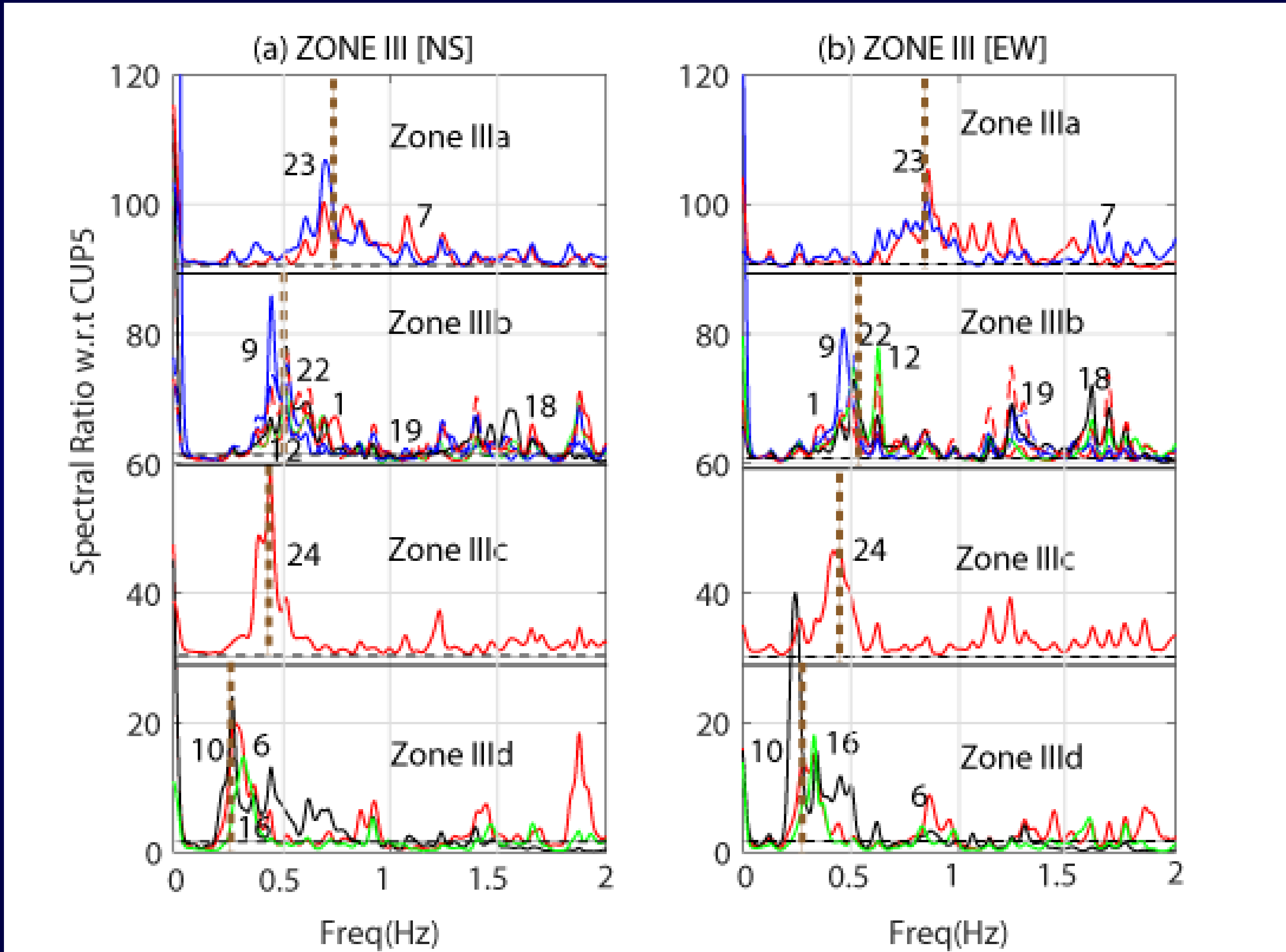


RESULTS: SPECTRAL RATIOS FOR ZONE II

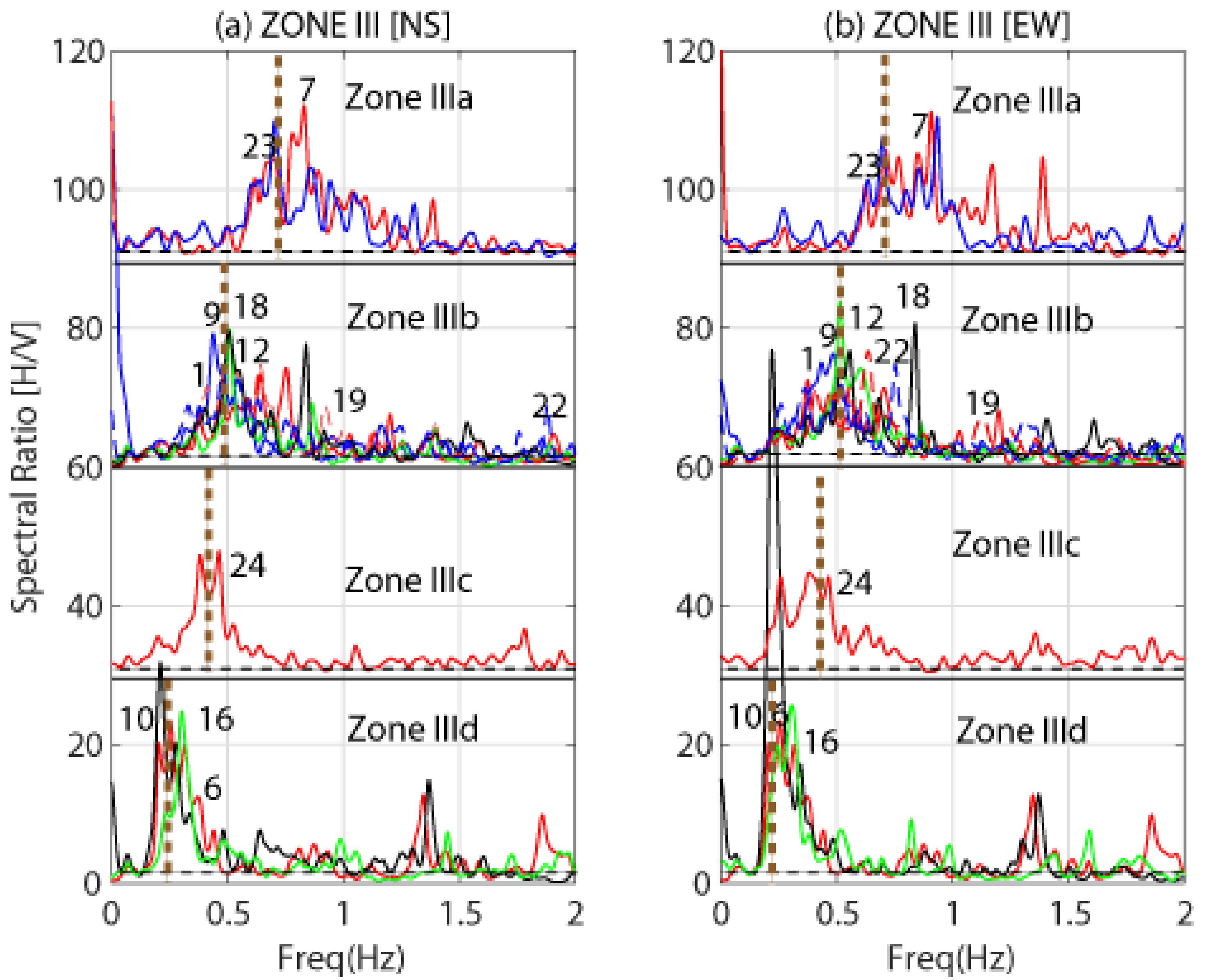




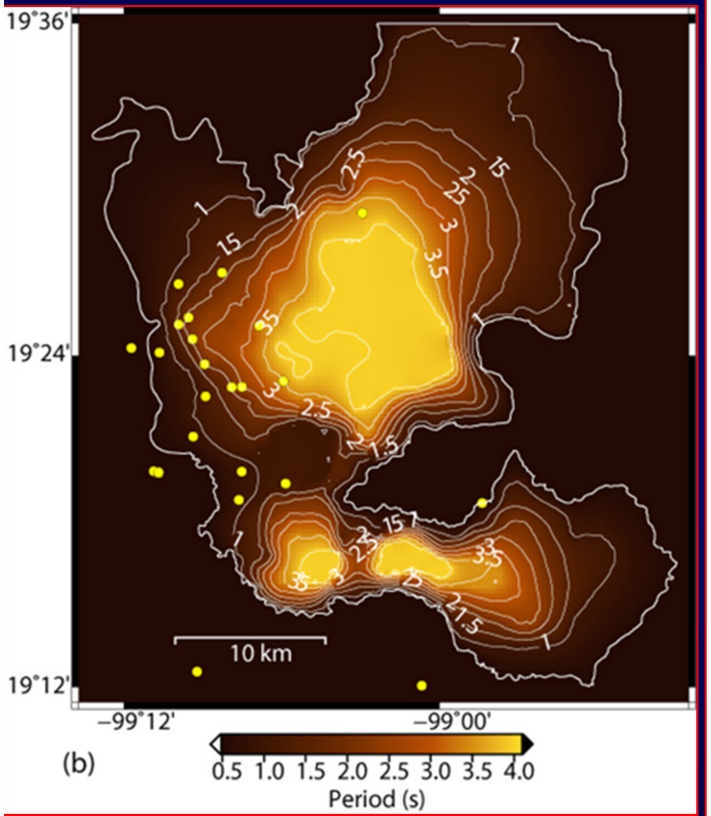
RESULTS: SPECTRAL RATIOS FOR ZONE III (R_{ij})

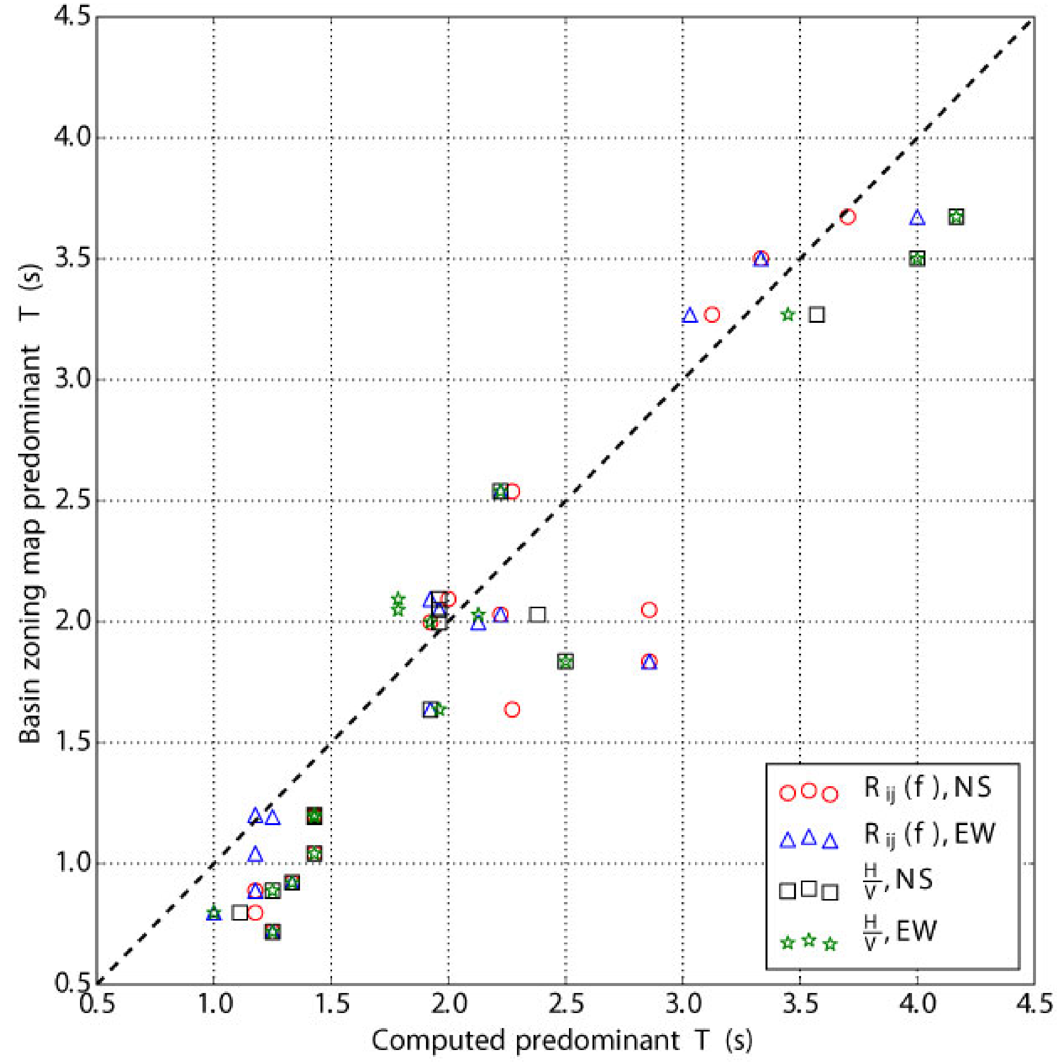


RESULTS: SPECTRAL RATIOS FOR ZONE III (H/V)



COMPARISON: Computed vs. 2004 Code





Comparison

	2004 Code designated Zones II and III				
	II	IIIa	IIIb	IIIc	IIId
Depth [h(m)] 2004 Code	-	10-60m			
f(hz)/T(s) 2004 Code	-	0.29-0.67 (1.5-3.5)			0.25-0.67 (3.5-4.0)
This study f(hz)/T(s)	0.7-1.1Hz (1.25-1.54s)	0.65-0.80 (1.25-1.54)	0.8-1.0 (1.0-1.25)		0.25 (4.00)

Conclusions (1/2)

- Predominant site frequencies (periods) identified from spectral ratios computed for ground motions recorded in Mexico City during the mainshock of 19 September 2017 (**M**7.1) Puebla-Morelos earthquake are in relatively good agreement with those indicated in the site period map of the 2004 Mexican Seismic Design Code.
- The agreement is best for Zone III, and relatively good for Zone II stations.

Conclusions (2/2)

- The differences can be attributed to one or combination of several factors including (a) interpolation errors from the maps, (b) peak picking errors of the frequencies from spectral ratios, (c) variations of depth, (d) associated Vs values of the underlying soil at the different locations and (e) differences in H/V to H/H (soil/rock) ratios. Most important difference is most likely due to physical difference between H/H spectral ratio computed with respect to a reference station and H/V spectral ratio computed with respect to vertical motion at same station.

- Furthermore, we conclude that H/V method can be reliably used with Mexico City data (as well as other regions of the world).

2017 EQ DATA: SOURCES & ORGANIZATION

- Institute of Engineering's (IINGEN) Strong Ground Motion Network of the Seismic Instrumentation Unit within the Engineering Seismology Laboratory of the Universidad Nacional Autonoma de Mexico (UNAM) [www.**iingen**.**unam**.mx] and
- Centro de Instrumentación y Registro Sísmico (CIRES) [*www.cires.org.mx/]*.