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Strong Ground Motion during the 8 September 2021 (M_w7.0) Acapulco Earthquake: Rupture Directivity and its Effect on Simulated Motions in Mexico City from Postulated M_w 7.5 – 8.0 Earthquakes

Danny Arroyo[1], Shri K. Singh[2], Mario Ordaz[3] and Arturo Iglesias[2]

Abstract

The 8 September 2021, M_w7.0, earthquake occurred in the SE Guerrero seismic gap along the Mexican subduction zone, just below Acapulco. The earthquake was strongly felt in Acapulco with peak ground acceleration (PGA) exceeding 0.6 g at some sites. An analysis of seismograms and accelerograms reveals a strong azimuthal variation of the seismic intensities. Unusually large intensities are observed in the NE direction with respect to the regional ground motion prediction equation (GMPE). This is consistent with the reported rupture directivity towards NE inferred from the slip distribution on the fault obtained from the inversion of local strong motion data. Using recordings of the 2021 earthquake and five other Guerrero thrust events ($5.8 \leq M_w \leq 7.3$) at CU as empirical Green´s functions (EGFs), we simulate ground motions for postulated M_w 7.5, 7.7, and 8.0 earthquakes in the Guerrero seismic gap. The simulated motions strongly depend on the source directivity of the EGF. The largest and smallest synthesized motions occur when the 8 May and 10 May 2014 events are used as the EGFs, respectively. Directivity towards and away from CU during the 8 May and 10 May earthquakes, respectively, is well-documented in a previous study. Three of the six EGFs yield synthesized motions from a postulated M_w 8.0 earthquake that exceed, two EGFs produce motions which are smaller, and one EGF gives similar motions to those observed at CU during the devastating1985 Michoacan earthquake. Under adverse directivity conditions, as observed during the 8 May 2014 earthquake, even an M_w 7.5 event in Guerrero seismic gap may produce motions similar to that recorded in1985. This may have been the case during the 28 July 1957 (M_s7.5) Guerrero earthquake, the third most damaging event in the history of Mexico City.

Key words: rupture directivity, Mexico seismic gap, strong ground motion records, variability of seismic intensities.

Resumen

El 8 de septiembre de 2021 un sismo de magnitud M_w7.0 ocurrió en la región SE del GAP de Guerrero en la zona de subducción de México justo bajo la Ciudad de Acapulco. El sismo se sintió fuertemente en Acapulco con una aceleración máxima del suelo mayor a 0.6 g en algunos sitios. El análisis detallado de los sismogramas y acelerogramas muestra una fuerte variación de la intensidad sísmica con respecto al azimut. Intensidades excepcionalmente altas, con respecto al modelo de atenuación regional, fueron observadas en dirección NE del epicentro, lo cual es consistente con la directividad en la ruptura hacia la dirección NE inferida de la distribución del deslizamiento en la falla calculada a partir de la inversión de los registros locales. Usando los registros del evento de 2021 y 5 eventos mas en Guerrero con M_w entre 5.8 y 7.3 medidos en la estación Ciudad Universitaria en la CDMX como funciones empíricas de Green (EFG) se simularon registros para eventos con magnitudes postuladas de 7.5, 7.7 y 8. La intensidad de los registros simulados depende fuertemente de la directividad en la ruptura de la EGF. Las mayores intensidades en las simulaciones se observaron en el caso de directividad en dirección de la CDMX (EGF del 8 de mayo de 2014) y las menores intensidades se observaron para directividad en dirección contraria a la CDMX (EFG 10 de mayo de 2014). Los análisis revelan que bajo condiciones adversas de directividad inclusive un sismo con M_w7.5 en el Gap de Guerrero puede producir intensidades en la CDMX similares a las registradas durante el sismo del 19 de septiembre de 1985. Esto pudo ser lo que ocurrió durante el sismo del 28 de Julio de 1957 (M_s7.5) el cual ha sido el tercer sismo más destructivo en la historia de la CDMX.

Palabras clave: efectos de directividad, brecha sísmica México, registros de movimiento fuerte, variabilidad de intensidades sísmicas.

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1. Introduction

Large subduction thrust earthquakes along the Mexican subduction zone not only cause damage in the epicentral zone but also at distances greater than 300 km in the Valley of Mexico where Mexico City is situated (Figure 1). This was the case during the Michoacán earthquake of 19 September 1985 (M_w8.0). The disaster in the city during the 1985 event brought into sharp focus the necessity of reliable estimation of ground motion from future earthquakes. As a result, strong motion stations in Mexico, especially in the Valley of Mexico, rapidly increased. Analyses of the recordings at these stations soon produced a flurry of studies dealing with amplification of seismic waves in the valley, spectral attenuation of seismic waves with distance, and GMPEs for Mexico and Mexico City.

Since 1985, $M_w \geq 7.5$ earthquakes along the coast of Guerrero have been of special concern because the plate interface along this segment of the subduction zone is a seismic gap and the distance of this segment to Mexico City is shorter than from the rupture area of the 1985 earthquake (Figure 1). Between 1899 and 1911 several large ($6.9 \leq M_s \leq 7.7$) earthquakes occurred in Guerrero. Thus, earthquakes in the magnitude range 7.5 - 8.0 may be expected in the gap. A critical issue in the seismic hazard study of Mexico City is the estimation of the ground motions from postulated M_w 7.5 - 8.0 earthquakes in the Guerrero segment: would they be greater, similar or smaller than that recorded during the 1985 earthquake? Needless to emphasize that larger motions than those observed in 1985 pose an alarming scenario for the city.

Some attempts have been made to estimate ground motions in the city from such an event. Ordaz *et al.* (1993) applied the stochastic method (Boore, 1983) as well as a technique of summation of empirical Green's function (EGF) proposed by Joyner and Boore (1986) to estimate ground motions in Mexico City from a postulated M_w8.2 earthquake in the gap. Later, Ordaz *et al.* (1995) applied an improved scheme of random summation of EGF and re-estimated the ground motions. Kanamori *et al.* (1993) used recordings from earthquakes in the Guerrero gap as EGFs and, assuming ω^{-2} source model, estimated ground motion at a site in Mexico City from $7.5 \leq M_w \leq 8.0$ earthquakes. In many of the simulations, the spatio-temporal rupture pattern retrieved from teleseismic P waves of the 1985 earthquake was used. The authors concluded: (a) The ground motions in Mexico City during 1985 were unusually large at 2 to 4 sec periods because the rupture sequence enhanced the motions due to constructive interference. A similar conclusion was also reached by Singh *et al.* (1988,1990). (b) If the rupture pattern of the postulated Guerrero earthquake is similar to the 1985 event, then the response spectrum in Mexico City will be approximately twice as large as that of the 1985 Michoacan earthquake at periods, T, longer than 2 sec. At T shorter than 2 sec, the amplitude will be 2 to 3 times larger than that for the Michoacán earthquake.

In this study, we analyze characteristics of the ground motions produced by the 2021, M_w7.0, Acapulco earthquake. The motions exhibit a strong azimuthal variation, consistent with a rupture directivity toward NE reported in previous studies (Iglesias *et al.* 2022). We take advantage of the recordings to revisit the question of expected ground motions in Mexico City from a postulated $7.5 \leq M_w \leq 8.0$ earthquakes in the Guerrero gap. In particular, we use the CU recordings of the 2021 event and 5 other earthquakes located in the Guerrero segment (Figure 1, Table 1) as EGFs to synthesize the expected motions. The source parameters of the earthquakes are listed in Table 1. We focus at CU, located in the hill-zone of the city, because it is often taken as the reference site in ground motion studies. Simulated ground motions at CU may be used to estimate motions at other sites through known transfer functions and application of the stochastic method (Boore, 1983), an approach that is routinely being used in the publication of near real-time ground motion map for Mexico City (Ordaz *et al.*, 2017).

2. Data

Because of relatively dense instrumentation in the region, the 2021 event was well recorded by accelerographs and broad band seismic stations. Here we consider a set of 37 recordings; 36 at hard rock sites outside the Valley of Mexico (NEHRP B class; BSSC 2004) and at CU. Figure 2 shows the epicenter of the earthquake, the recording stations and ray paths. Table 2 gives relevant station information, the peak ground acceleration (*PGA*), and pseudo-acceleration response spectrum (5% damping) at 2-sec period, *SA* (T=2 sec). The intensity measure considered here is the quadratic mean of two horizontal components. The closest distance to rupture area (R_{rup}) ranges between 16 km and 512 km, the azimuths of the stations lie between -65° and 105° (an azimuthal gap of 190°).

3. Evidence of Directivity during the M_w7.0 Acapulco Earthquake

Figure 3 illustrates contour maps of *PGA* and *SA* (T=2 sec) of the 2021 earthquake. These contours suggest a directivity toward NE; the effect is especially pronounced at *SA* (T=2 sec). Although not shown, similar trend is observed at other structural periods. The effect of directivity may be further appreciated in Figure 4 where we compare displacement response spectra (SD) at stations located at similar epicentral distances but at nearly opposite azimuths. The distance to CAIG and DAIG

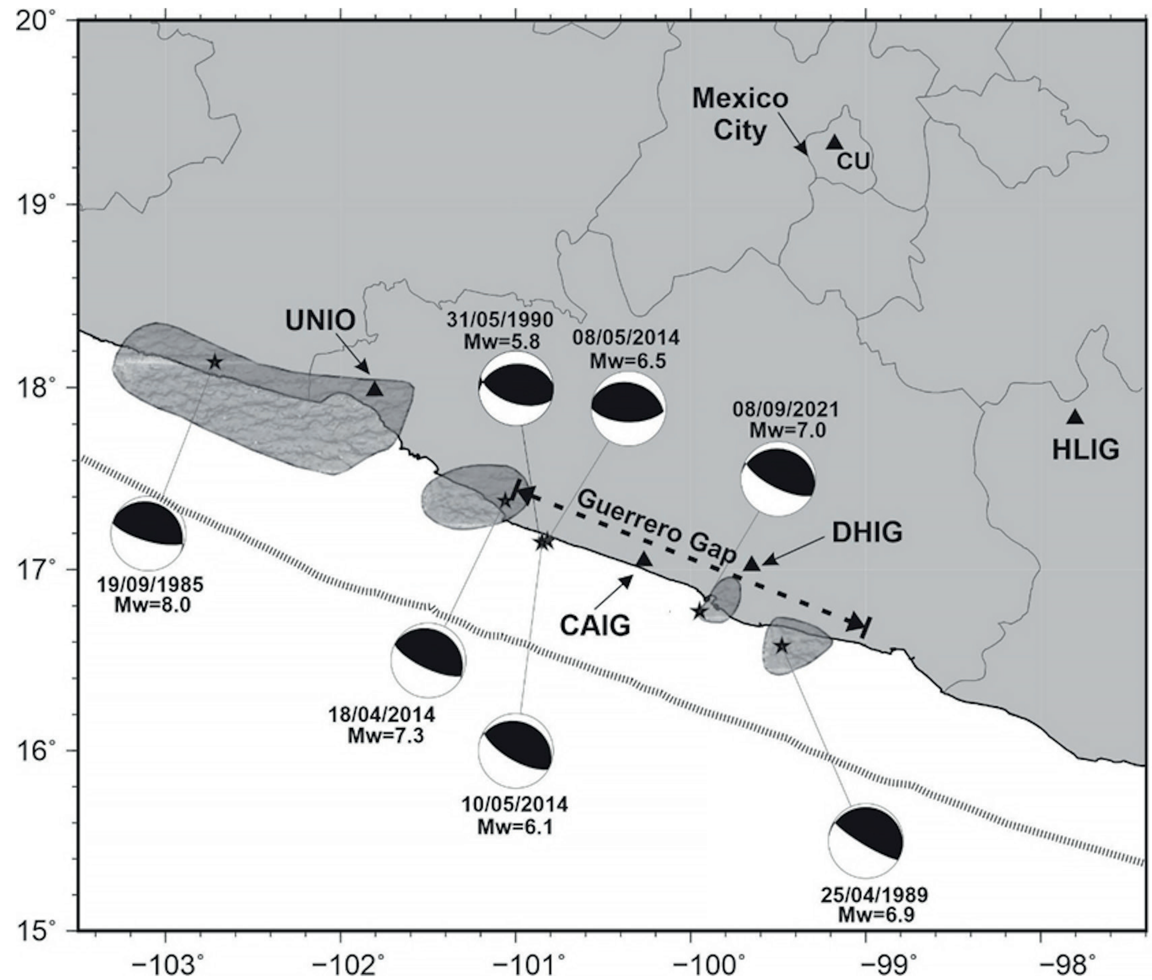

Figure 1. Location and focal mechanism of earthquakes whose recordings are analyzed in this study. Approximate rupture areas of larger ($M_w \geq 6.9$) earthquakes are contoured. Triangles: stations mentioned in the text. CU is the reference station located in the hill-zone of Mexico City. Recordings of 6 earthquakes ($5.8 \leq M_w \leq 7.3$) at CU have been used as empirical Green´s function to synthesize ground motions from postulated M_w7.5, 7.7, 8.0 earthquakes in the Guerrero gap.

Table 1. Source parameters of the subduction thrust earthquakes whose strong motion data are analyzed in this study.

Date	Lat °N	Long °W	Depth km	M_0 N-m	M_w	Focal Mechanism Strike °	Dip °	Rake °
19 Sep. 1985	18.14	102.72	21	$1.1\text{x}10^{21}$	7.96	301	18	105
25 Apr. 1989	16.58	99.48	15	$2.39\text{x}10^{19}$	6.95	276	10	66
31 May 1990	17.14	100.86	26	$7.5\text{x}10^{17}$	5.85	265	35	71
18 Apr. 2014	17.38	101.06	19	$1.0\text{x}10^{20}$	7.27	303	18	98
8 May 2014	17.16	100.82	21	$6.22\ 10^{18}$	6.46	289	22	80
10 May 2014	17.15	100.85	21	$1.63\ 10^{18}$	6.07	285	22	77
8 Sep. 2021	16.77	99.95	22	$3.5\text{x}10^{19}$	6.96	279	20	73

Location from local and regional data. M_0 and focal mechanism from Global CMT catalog.

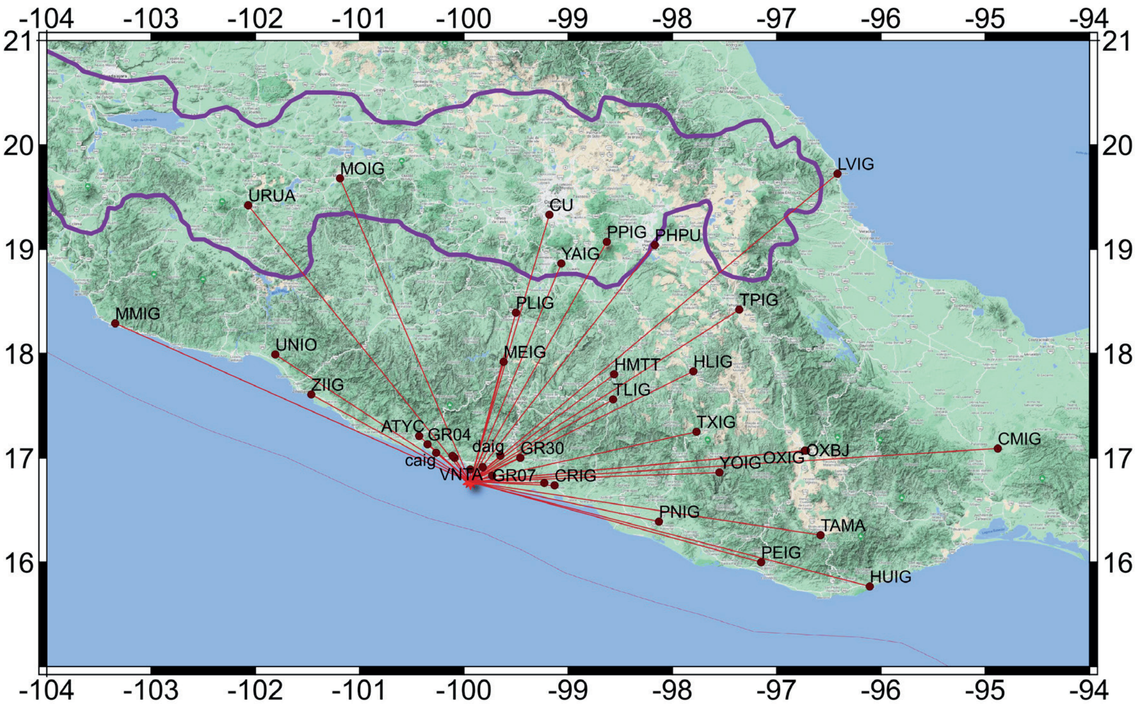

Figure 2. Map showing epicenter of the 8 September 2021, M_w7.0, Acapulco earthquake (red star), stations and ray paths. Thick purple contour delineates the Trans Mexican Volcanic Belt. Thin purple line offshore: middle America trench.

is ~40 km, while UNIO and HLIG are located ~230 km from the source (Figure 1). The dependence of ground motion on azimuth is evident. Compared with CAIG (azimuth 312°), the ground motion at DAIG (azimuth (48°) is strongly enhanced at all structural periods. Similarly, the ground motion is enhanced at HLIG (azimuth 62°) with respect to UNIO (azimuth 304°) at structural periods between 1 and 10 sec.

Attenuation of seismic intensities with distance during the 2021 earthquake is shown in Figure 5. Superimposed in the figure is the median and ± 1 sigma predictions from the GMPE of Arroyo *et al.* (2010). Relative to the GMPE, the ground motions are enhanced at sites in the azimuthal range 0°-105°; especially for *SA* (T=2 sec). This intensity is important because the natural period of sites in the lake-bed zone of the Valley of Mexico is ~ 2 sec. Strong amplification of seismic waves at this period is the main cause of damage in the city from subduction thrust earthquakes.

In Figure 6 we plot the normalized logarithmic residual of *SA* (T=2 sec) as function of azimuth. The normalized logarithmic residual was computed by subtracting the predicted *ln*(*SA*) (using the GMPE of Arroyo *et al.*, 2010) from the observed *ln*(*SA*) and dividing it by the logarithmic standard deviation (as estimated in the derivation of the GMPE). A strong variation of ground motion with azimuth is observed in the figure. Figures 3, 4, 5 and 6, taken together, provide convincing evidence of NE directivity during the M_w7.0 Acapulco earthquake. As mentioned earlier, support for the directivity also comes from the inversion of near-source displacement seismograms (Iglesias *et al.*, 2022).

Normalized logarithmic residuals (henceforth denoted residuals) of five other Mexican subduction thrust earthquakes are also shown in Figure 6. The earthquakes include the Michoacan earthquake of 1985 (M_w8.0) and 4 from the Guerrero segment (25 April 1989, M_w6.9; 18 April 2014, M_w7.3; 8 May 2014, M_w6.5; 10 May 2014, M_w6.1). From these plots, we note: (a) Directivity during the two May 2014 events as previously documented: towards CU during the 8 May and away during the 10 May (Singh *et al.*, 2019). Largest positive residual at CU, 4.8, is observed during the 8 May 2014 earthquake. (b) No evidence of directivity during the 18 April 2014 earthquake. (c) Large positive residual at CU of ~ 4 for the 1989 earthquake suggests a directivity towards the city. (d) Because of limited data, it is not clear from the residual plot whether the directivity effect was present during the 1985 Michoacan earthquake. The normalized residual of ~2.8 at CU is inconclusive.

A rupture propagation towards ESE during the 1985 earthquake is, however, well established (Anderson *et al.* 1986; UNAM Seismology Group 1986; Mendoza and Hartzell 1989; Mendez and Anderson 1991; Kanamori *et al.* 1993). Mexico City is located to the NE of the rupture area (Figure 1), in the

Table 2. Stations, their distances and azimuths, and recorded seismic intensities. *PGA* and *SA*(T=2 sec) are the cuadratic mean of the two horizontal components.

Station	Latitude	Longitude	Rrup, km	Azimuth	*PGA* cm/s²	*SA* (T=2.0 sec) cm/s²
VNTA	16.910	-99.820	16	39	185.92	63.46
GR06	16.890	-99.940	16	19	585.60	63.80
GR07	16.830	-99.730	16	75	543.33	57.23
DAIG	17.021	-99.651	19	48	287.10	49.24
COYC	17.000	-100.090	30	328	152.80	16.03
GR30	17.000	-99.460	31	66	410.80	82.87
GR05	17.020	-100.110	33	329	126.76	12.52
CAIG	17.048	-100.267	49	312	32.56	4.55
VIGA	16.760	-99.230	50	91	293.90	74.60
CRIG	16.736	-99.131	60	92	205.68	40.38
GR04	17.130	-100.350	61	316	64.74	7.94
ATYC	17.210	-100.430	72	313	35.33	9.25
MEIG	17.920	-99.620	114	15	44.24	10.36
TLIG	17.560	-98.570	143	59	19.12	28.84
HMTT	17.800	-98.560	159	52	27.23	17.10
PLIG	18.392	-99.502	167	15	9.77	23.43
PNIG	16.390	-98.130	172	102	12.31	10.24
ZIIG	17.607	-101.465	189	300	5.09	2.69
TXIG	17.250	-97.770	209	77	24.16	34.10
YOIG	16.860	-97.550	227	88	22.16	33.29
HLIG	17.830	-97.800	228	62	9.78	20.80
YAIG	18.862	-99.067	229	22	12.05	16.57
UNIO	17.990	-101.810	242	304	6.43	2.50
PPIG	19.070	-98.630	268	29	14.01	27.10
CU	19.330	-99.181	276	16	13.73	25.61
PEIG	16.000	-97.150	285	105	7.41	7.46
PHPU	19.040	-98.170	290	37	17.01	20.82
TPIG	18.420	-97.360	302	56	18.60	27.69
OXIG	17.070	-96.730	316	84	9.56	19.71
OXBJ	17.070	-96.720	317	84	8.40	20.86
TAMA	16.260	-96.580	337	98	6.93	14.19
MOIG	19.678	-101.189	341	338	5.78	6.52
URUA	19.420	-102.070	367	323	3.78	4.03
HUIG	15.768	-96.108	399	105	2.19	3.51
MMIG	18.289	-103.346	402	295	0.95	0.83
LVIG	19.723	-96.418	470	48	1.41	3.83
CMIG	17.090	-94.880	512	86	3.13	9.65

forward direction, so enhanced ground motion in the city is expected. Furthermore, Singh *et al.* (1990) studied spectral ratio of teleseismic P waves of the 1985 earthquake with respect to five large Mexican subduction zone earthquakes ($7.0 \leq M_w \leq 7.7$). They reported that the ratios were anomalously more energetic at stations in the NE quadrant than that predicted by the ω^{-2} source model in the critical frequency range for Mexico City (0.3 -0.7 Hz). This implies that ESE directivity during the rupture may have enhanced ground motion at CU and in Mexico City and may have been an important factor in the damage.

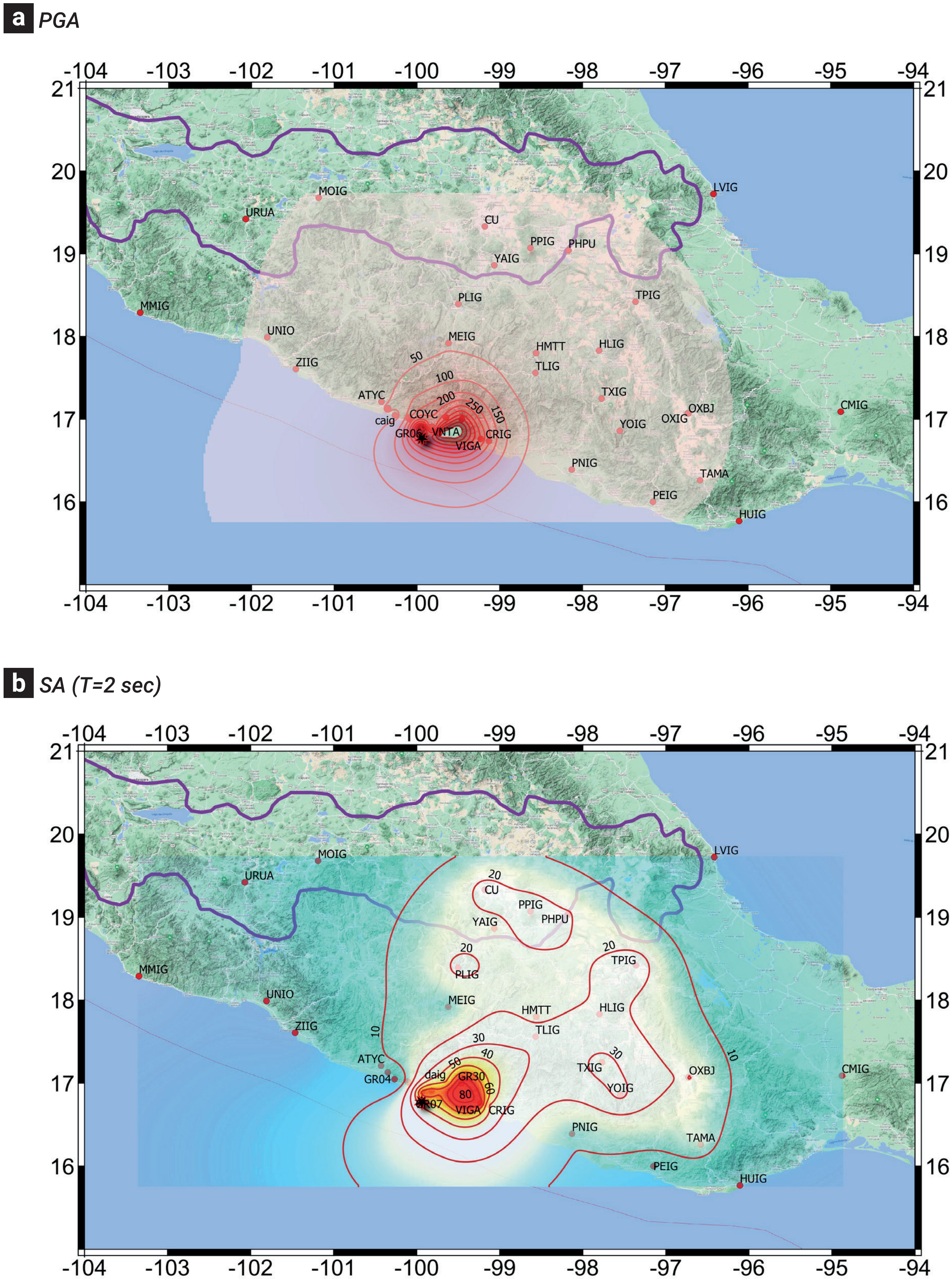

Figure 3. Contours of a) *PGA* and b) *SA* (T=2 sec) during the 8 September 2021, M_w7.0, earthquake. The contours suggest directivity toward NE; the effect is more pronounced for *SA* (T=2 sec) than *PGA*.

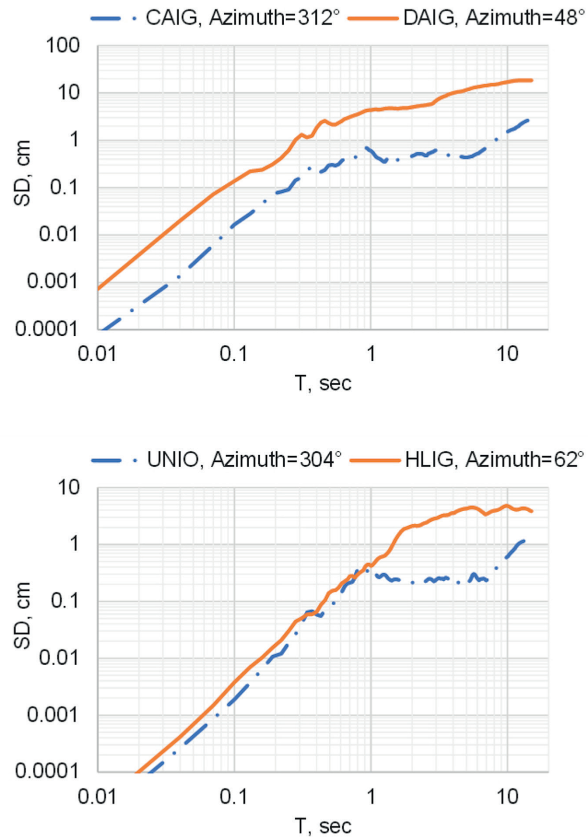

Figure 4. Comparison of *SD* spectra at stations located at similar epicentral distance but at nearly opposite azimuth. Distance to CAIG and DAIG is ~ 40 km while the distance to UNIO and HLIG is ~ 230 km (Figure 1). The stations are located on NEHRP B class soil condition.

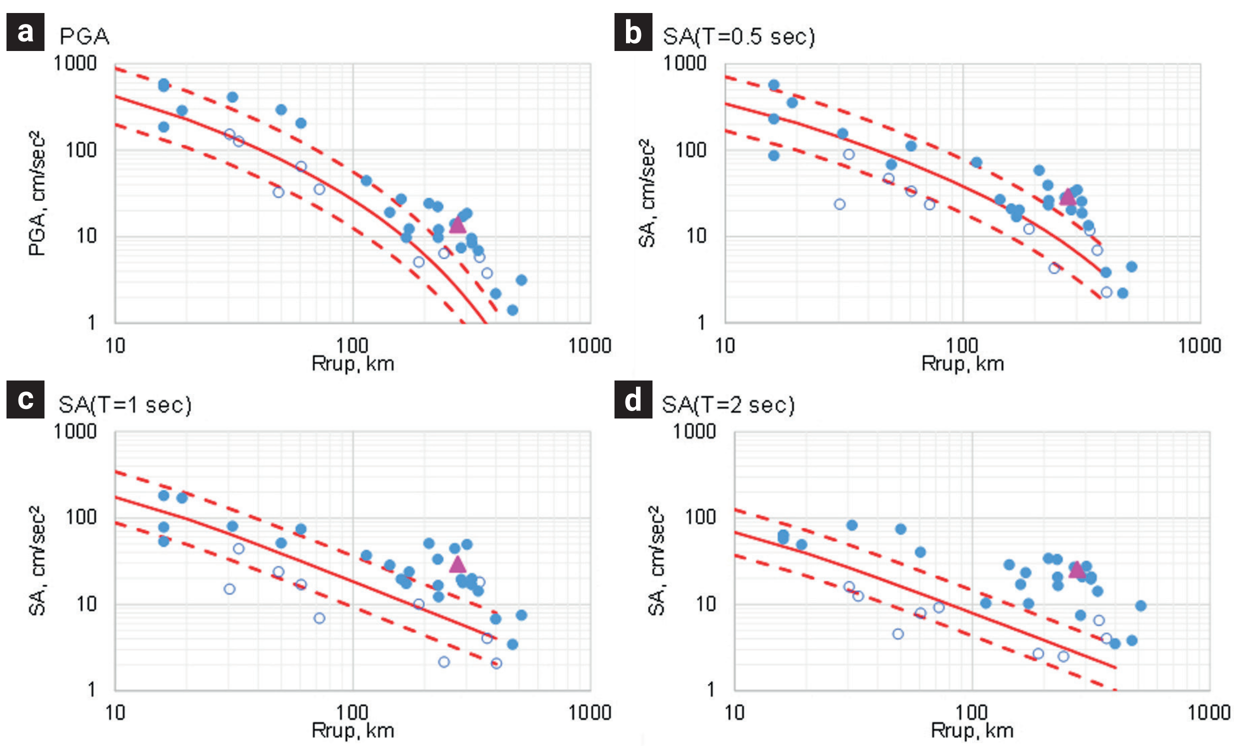

Figure 5. Seismic intensities as function of distance, Rrup, during the 2021 M_w7 earthquake. Dot: station azimuth between 0° and 105°. Circle: station azimuth between -65° and -22°. Red triangle: CU. Continuous and dashed lines are median and ± 1 sigma predictions from the GMPE (Arroyo *et al.*, 2010). Ground motions are enhanced in the azimuthal range 0° -105°.

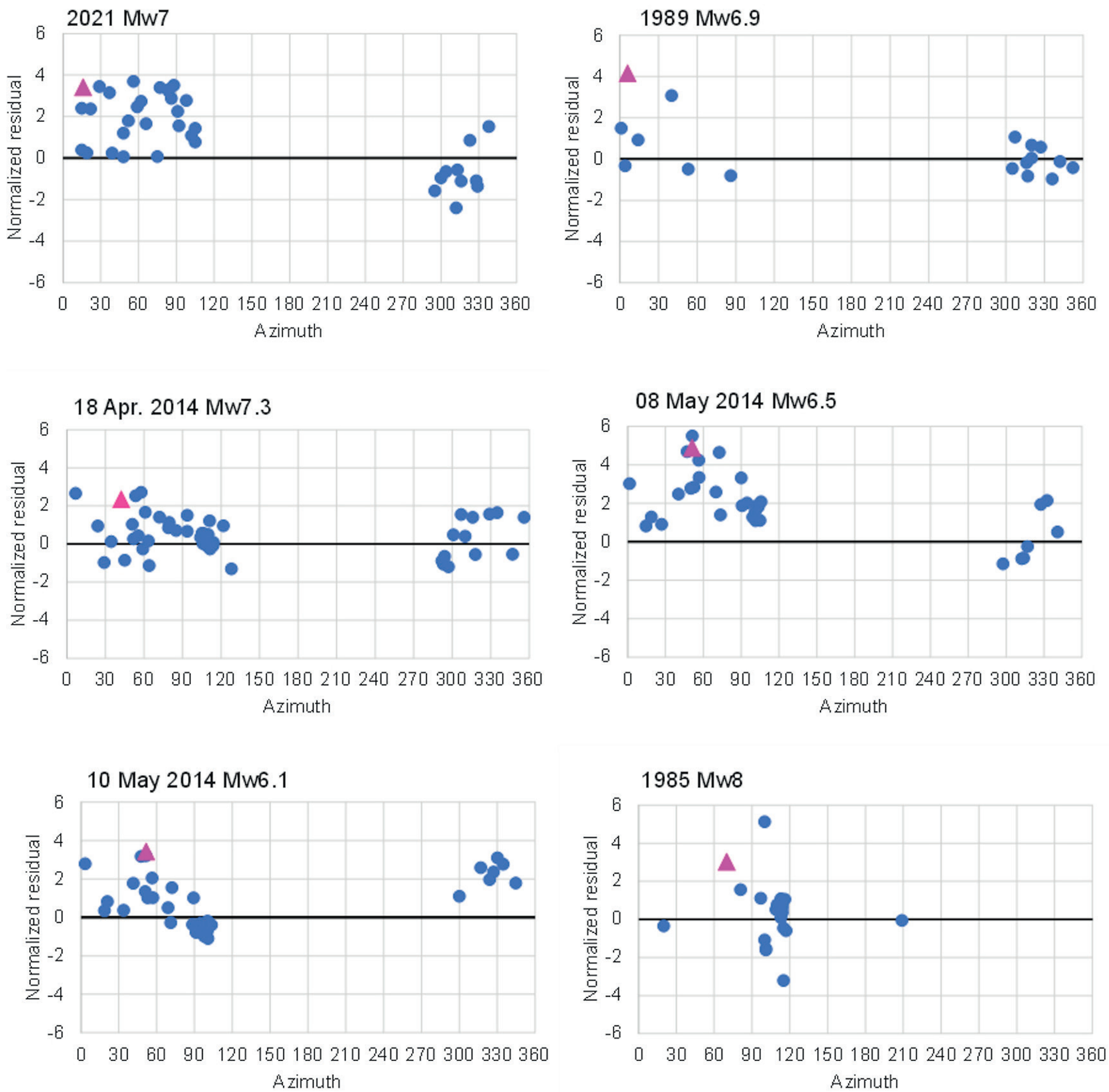

Figure 6. Variation of normalized residuals of *SA* (T=2 sec) as function of azimuth during different earthquakes. Red triangle: CU. Note that the largest two positive residuals at CU occurred during the 8 May 2014 M_w6.5 and 25 April 1989, M_w6.9 earthquakes.

4. Ground Motion at CU from Postulated Earthquakes in the Guerrero Gap

We use CU recordings of the earthquakes of 1989 (M_w6.9), 31 May 1990 (M_w5.8), 18 April 2014 (M_w7.3), 8 and 10 May 2014 (M_w6.5, 6.1), and 2021 (M_w7.0) as Empirical Green's Functions (EGFs) to synthetize ground motions from postulated M_w 7.5, 7.7, and 8.0 earthquakes in the Guerrero gap.

We apply the stochastic method proposed by Ordaz *et al.* (1995) in the synthesis. It consists of adding N scaled EGF records, each differed in time with a random delay. The probability distribution of the delays is such that, on average, the simulations follow an ω^{-2} source spectral scaling at all frequencies. The simulation assumes a point source. It only requires specification of seismic moment (M_0) and stress parameter ($\Delta\sigma$) of both the target and EGF events, and shear wave velocity (β) at the source. We assume $\Delta\sigma = 3$ MPa for both the target and EGF events, and $\beta = 3.2$ km/sec. Any other choice of $\Delta\sigma$ between 1 and 5 MPa has minor effect on the results, provided it is taken the same for both events. EGF method has the virtue that it automatically includes path and site effects. A limitation of the method is the assumption of a point source. The distance, R_{rup}, to CU is about 300 km from the Guerrero coast, ~ 3 times the expected dimension, L, of an earthquake of magnitude 8.0. Thus, the point-source approximation, $R_{rup} >> L$, is not strictly valid.

Examples of simulated acceleration traces (EW component) at CU for a postulated M_w 8.0 earthquake corresponding to the six EGFs are illustrated in Figure 7. For reference, the figure also

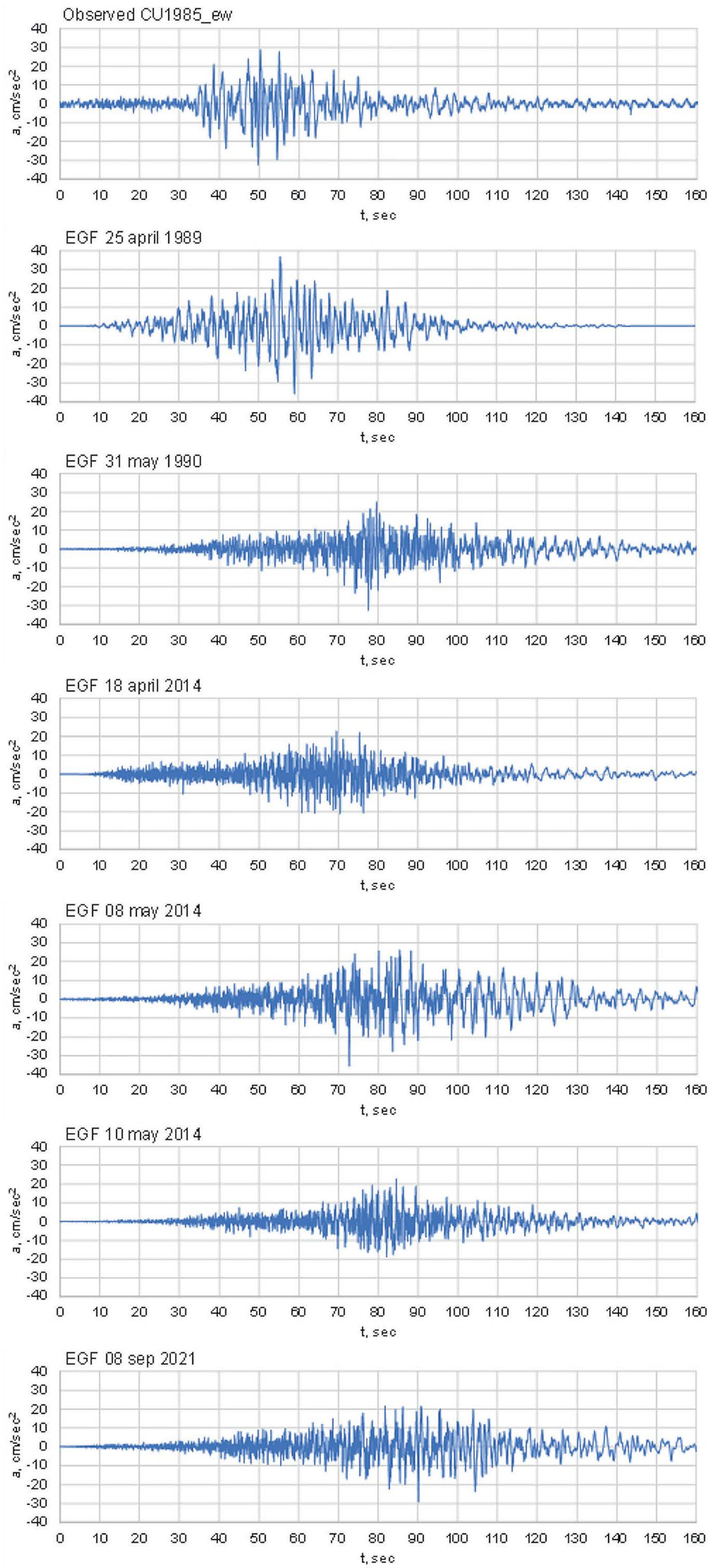

Figure 7. Samples of simulated accelerograms (EW component) at CU for a postulated M_w8.0 event in the Guerrero gap using different EGFs. Observed accelerogram during the 1985 M_w8 Michoacan earthquake is shown for reference (top panel).

includes the observed EW accelerogram during the 1985 M_w8 Michoacan earthquake. Synthesized traces look quite realistic. The observed duration, defined herein as the duration between the 2.5 and 97.5 percent of the Aria's intensity, during the 1985 M_w8 earthquake at CU was about 56 seconds while the duration for the M_w8 simulations is larger. The durations for the different simulations are 70, 99, 53, 68, 98 and 80 seconds corresponding to the EGFs of the 8 May 2014 M_w6.5, 10 May 2014 M_w6.1, 25 April 1989 M_w6.9, 31 May 1990 M_w5.8, 8 September 2021 M_w7 and 18 April 2014 M_w7.3, respectively. Larger durations of the simulated traces are a reflection of relatively greater durations of the EGFs.

In Figure 8, the median and median +/- sigma of simulations of the response spectra, *SA*, for the postulated M_w8.0 event are compared with the observed *SA* of the 1985 M_w8 earthquake. Table 3 summarizes the results of the simulations. Synthesized *SA* using 1989 (M_w6.9) earthquake as the EGF is greater than the observed one at all periods except between 0.7 and 1 sec. Use of 2021 (M_w7.0) earthquake as the EGF produces *SA* comparable to the observed *SA*. Synthesized motions are smaller than the observed one when 1990 (M_w5.8) and 14 April 2014 (M_w7.3) earthquakes are used as EGFs. The largest and smallest simulated *SA*s are obtained when 8 and 10 May 2014 (M_w6.5, 6.1) events, respectively, are taken as the EGFs. This is in agreement

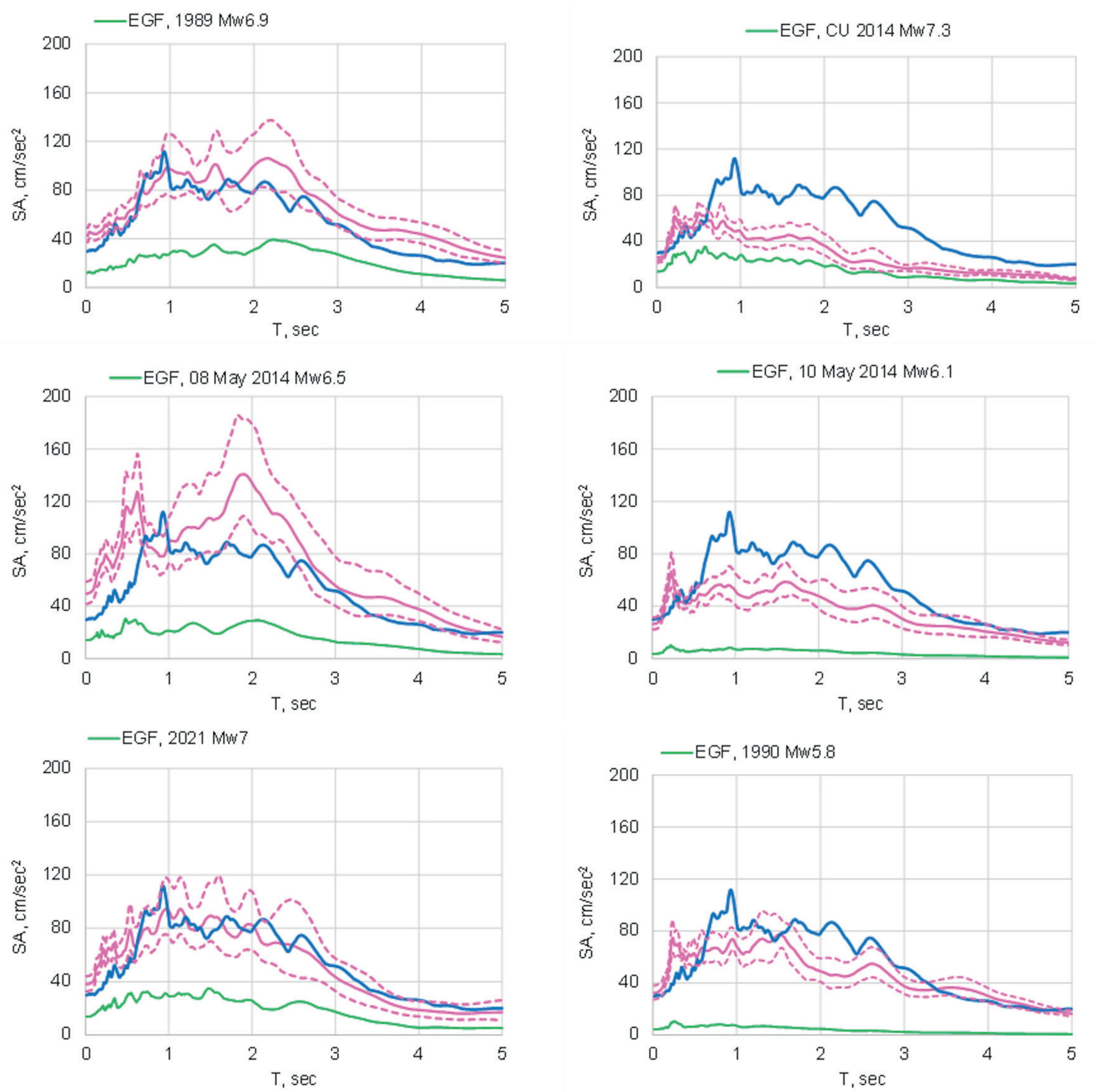

Figure 8. Simulated *SA* at CU of a postulated M_w8.0 earthquake in the Guerrero ga p (magenta curves) using different EGFs. *SA* of EGFs are shown by green curves. Observed *SA* during the 1985, M_w8.0, Michoacan earthquake is shown (in blue) for comparison. Simulated *SA*s using 1989 and 8 May 2014 as EGFs exceed the observed 1985 *SA*.

Table 3. Simulated median *PGA* and *SA* (T=2 sec) at CU from postulated M_w8.0, 7.7, 7.5 earthquakes in the Guerrero gap using different EGFs. Observed *PGA* and *SA* (T=2 sec) during the 1985 M_w8.0 Michoacan earthquake at CU was 29.8 and 78.4 cm/s^2, respectively. Simulated value is shaded if it exceeds the observed 1985 one.

EGF Date, Mw	M_w7.5		M_w7.7		M_w8.0	
	PGA cm/sec^2	SA(T=2 sec) cm/sec^2	PGA cm/sec^2	SA(T=2sec) cm/sec^2	PGA cm/sec^2	SA(T=2sec) cm/sec^2
25 Apr. 1989, 6.9	23.1	56.2	29.4	78.5	42.7	99.8
31 May 1990, 5.9	21.1	36.1	24.6	39.6	32.3	49.1
18 Apr. 2014, 7.3	n/a	n/a	17.9	26.9	23.7	36.3
08 May 2014, 6.5	32.5	83.7	37.0	98.1	49.6	133.9
10 May 2014, 6.1	15.4	24.4	20.1	33.5	18.3	34.8
08 Sep 2021, 7.0	17.3	37.5	25.5	48.8	38.0	82.4

with the strong directivity towards and away from CU observed during the 8 and 10 May events (Figure 6). The simulated *SA* clearly depends on the directivity of the EGF source. Our results show that *PGA* and *SA* (T=2 sec) at CU could be 70% more than the 1985 values if the postulated M_w8.0 earthquake develops a directivity similar to the 8 May 2014 event.

Because of the difference in the summation scheme used in the simulation, the results obtained in this study differ somewhat from those presented in Kanamori *et al.* (1993). Simulations by Kanamori *et al.* (1993) yield largest motions when the 1985 rupture pattern is assumed to repeat during the postulated M_w8.0 event. In these simulations, the directivity effect is included in the EGF as well as in the rupture pattern. In the EGF summation technique used here, the directivity effect is included in the EGF. It is similar to simulation S3 of Kanamori *et al.* (1993) in which the rupture pattern is randomized both in space and time; it results in 30% decrease in the amplitude.

5. Conclusions

The ground motions recorded during the 2021 Acapulco earthquake reveal strong azimuthal variation, consistent with a rupture directivity toward NE. This directivity is confirmed from the slip distribution on the fault plane retrieved from the inversion of local strong motion data (Iglesias *et al.*, 2022). We studied azimuthal variation of ground motion during other earthquakes which occurred in or near the Guerrero gap (6.1 ≤ M_w ≤ 7.3). A strong directivity was previously reported during the earthquakes of 8 May and 10 May 2014 (M_w6.5, 6.1), both of which occurred in the Guerrero gap (Singh *et al.*, 2019). We used the recordings of the 2021 Acapulco earthquake and 5 other earthquakes along the Mexican subduction zone earthquakes, including the two May 2014 events, as EGFs to compute ground motions in the city from a postulated M_w7.5, 7.7, 8.0 earthquake in the gaps. The simulations were performed at CU a site located in the hill-zone of the city. CU is often taken as the reference site in ground motion studies in the valley.

As expected, the simulated ground motions depend strongly on the directivity of the EGF source. For example, the largest simulated ground motion at CU occurs when 8 May 2014 earthquake is used the EGF. It is also the event with strongest directivity towards CU. Simulated *SA* at 2-sec period for a postulated M_w8.0 event in this case is 70% greater than the *SA* during the 1985 earthquake. Opposite is the case when 10 May 2014 event is taken as the EGF; the simulated *SA* at CU in this case is ~ half the *SA* recorded during the 1985 earthquake. The simulations with 4 other earthquakes as EGFs produce ground motions between the two extremes. Since the occurrence of source directivity during a future earthquake can´t be predicted, it contributes significantly to the aleatory variability of the strong ground motion.

Thus, it is possible that a future M_w8 event in the Guerrero seismic gap produces much less damage than that observed during the devastating 1985 M_w8.0 earthquake if the directivity is away from Mexico City. Unfortunately, greater damage is also possible if the directivity is towards city.

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