ANALYSIS OF GROUND MOTION CHARACTERISTICS OF THE 2017 Ms 7.0 JIUZHAIGOU EARTHQUAKE

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Abstract

A Ms 7.0 earthquake occurred on August 8, 2017 in Jiuzhaigou Country, Sichuan Province, China. 82 strong motion records were accumulated by the National Strong Motion Observation Network System (NSMONS). The strong motion records were processed following the China Strong Motion Network Center (CSMNC) procedure. In order to get the standard format acceleration, the data format of the original data was transformed, the baseline was corrected, and the metadata were complemented before the normal analysis and processing. The peak ground acceleration varies from 0.33 cm/s^2 to 185.02 cm/s^2 and the peak ground velocity varies from 0.04 cm/s to 6.55cm/s. The instrumental seismic intensity varies from 1.0 to 6.2 in China seismic intensity scale. We compared the observed peak ground acceleration and peak ground velocity with the attenuation relationship used in the fifth generation seismic ground motion parameter zone map of China .It shows that the observed peak ground acceleration and peak ground velocity within the epicenter distance less than 200 kilometers is consistent well with the Yu 2013 short axis attenuation relationship, but it decay slower than the prediction attenuation relationship with epicenter distance larger than 300 kilometers, the record with epicenter distance larger than 300 kilometers mainly located in the Weihe basin. It may be caused by the site amplification of the Weihe basin with deep soil layer. We also find the observed peak ground acceleration and peak ground velocity of 51JZZ is much larger than the Yu 2013 attenuation relationship, more research are needed on the reason why peak ground acceleration of 51JZZ station reached almost 2g.The two largest acceleration response acceleration with damp 5% damping ratio were calculated, the response spectrum of NS component of 51JZB is larger than China seismic design response spectrum under the rare earthquake in China, The peak period of response spectrum is mainly between 0.1 second and 0.4 second at 51JZB and 51JZW.The natural frequency of buildings in Jiuzhaigou Country is mainly 0.3 second to 1.0 second. The spectral acceleration is very small when the period larger than 1.0 second, so it will not cause severe damage to the dam, bridge, and ultra-high rise building with long natural period. The 5%-75% significant duration and 5%-95% significant duration were calculated, the 5%-95% significant duration varies form 3.600 second to 86.455 second, and most of them varies from 20 second to 50 second. The 5%-75% significant duration varies form 2.555 second to 59.935 second, and most of them varies from 10 second to 40 second. The significant duration grows with the epicenter distance in the whole. We compared the significant duration with the empirical prediction equation, the 5%-75% significant duration and 5%-95% significant duration are larger than the global empirical prediction equation. The 5%-95% significant duration is consistent well with California empirical prediction equation with epicenter distance less than 200 kilometers, but higher than California empirical prediction equation with epicenter distance larger than 200 kilometers.

Keywords: Jiuzhaigou earthquake, acceleration, attenuation relationship, response spectrum, significant duration

1. Introduction

At 21:19:46 on August 8, 2017, a Ms 7.0 earthquake occurred in Jiuzhaigou County, Sichuan Province, China (103.82◦ E, 33.20◦ N). Jiuzhaigou County is 39 km away from Yongle Town, 66 km from Songpan County, 83 km from Zhouqu County, 85 km from Wen County and 285 km from Chengdu City. During this earthquake, 37 strong motion records triggered from Sichuan digital strong seismic network, 25 strong motion records from Shaanxi digital strong seismic network, 14 strong motion records from Gansu digital strong seismic network and 6 strong motion records from Ningxia digital strong seismic network. So, in totally, there are 82 strong motion records were obtained from the digital strong seismic networks deployed in Sichuan, Gansu, Shaanxi, and Ningxia. Among them, the peak ground acceleration recorded by 51JZZ strong motion station is almost close to 2g, which needs further on-site investigation and verification. The basic information of the station was listed in Table 1, and the triggered station distribution map is shown in Fig.1. The data format was converted according to the standard data processing procedure of China Strong Motion Network Center, and 82 strong motion records were corrected [1]. The epicenter distance varies from 11 km to 630 km. The acceleration time history recorded by 51JZB and 51JZW strong motion station is shown in Fig. 2. These records provide valuable information for us to understand and analyze the characteristics of the earthquake. Firstly, 82 strong motion records were processed following the China Strong Motion Network Center (CSMNC) procedure and then the amplitude characteristics, spectrum characteristics and duration characteristics of the strong motion records were analyzed in this paper.

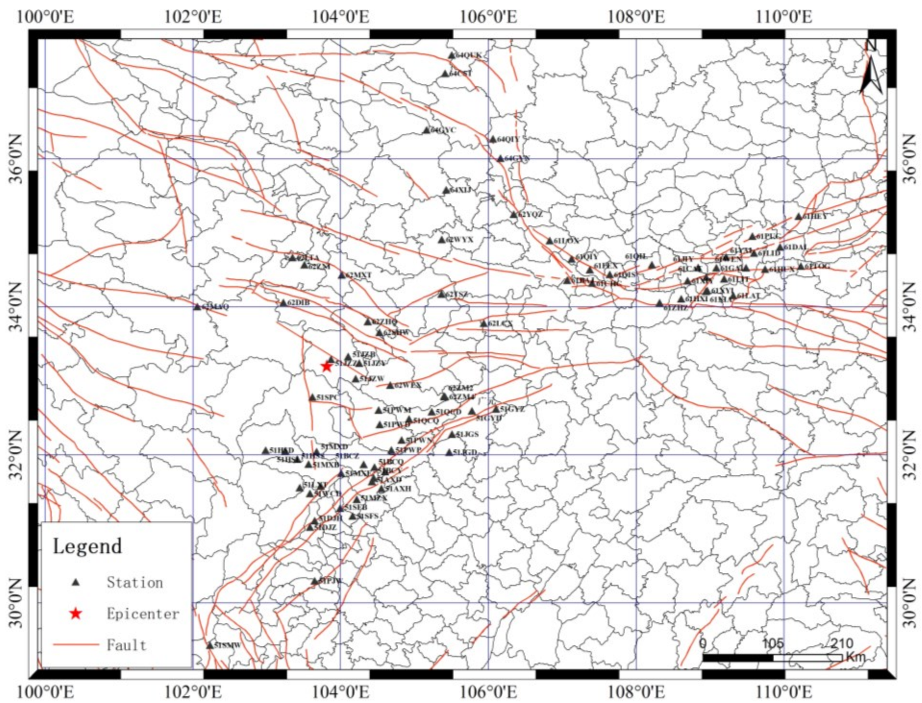


Fig. 1 Distribution map of the triggered stations

Table 1 Basic station information

Site Code	Long.	Lat.	Site condition	Epicenter Distance	Site Code	Long.	Lat.	Site condition	Epicenter Distance
51JZZ	103.9	33.3	Soil	11.2	62LCX	106.0	33.8	Soil	207.2
51JZB	104.1	33.3	Soil	30.5	51SFB	104.0	31.3	Soil	214.4
51JZW	104.2	33.0	Soil	40.9	51GYZ	106.1	32.6	Soil	223.1
51JZY	104.3	33.2	Soil	40.8	51SFS	104.2	31.2	Soil	227.6
51SPC	103.6	32.8	Soil	50.2	51DJH	103.7	31.1	Soil	232.8
62SHW	104.5	33.7	Soil	83.3	62WYX	105.4	34.9	Soil	238.0
62ZHQ	104.4	33.8	Soil	84.1	51DJZ	103.6	31.0	Soil	243.1
62WEX	104.7	32.9	Soil	84.9	64XIJ	105.4	35.6	Soil	303.2
51PWM	104.5	32.6	Soil	92.9	51PJW	103.7	30.3	Soil	323.0
62DIB	103.2	34.1	Soil	109.9	62YQZ	106.4	35.3	Soil	325.7
51PWD	104.5	32.4	Soil	110.4	61BAJ	107.1	34.4	Soil	326.9
51MXD	103.7	32.0	Soil	129.5	61LOX	106.8	34.9	Soil	335.7
51QCQ	104.9	32.5	Soil	130.8	61QIY	107.1	34.7	Soil	345.2
51HSL	103.3	32.1	Soil	137.7	61CHC	107.4	34.3	Soil	354.5
62MXT	104.0	34.4	Soil	137.9	61FEX	107.4	34.5	Soil	359.1
51HSS	103.4	31.9	Soil	144.6	64GYC	105.2	36.4	Soil	375.5
51PWN	104.8	32.2	Soil	146.2	64GYN	106.2	36.0	Soil	379.0
51HSD	103.0	32.1	Soil	148.5	61QIS	107.7	34.4	Soil	379.5
51QCD	105.2	32.6	Soil	149.1	64QIY	106.1	36.3	Soil	398.1
51MXB	103.6	31.9	Soil	149.2	61ZHZ	108.3	34.1	Soil	427.4
51PWP	104.7	32.1	Soil	150.3	61QIL	108.2	34.6	Soil	433.5
62ZNI	103.5	34.6	Soil	154.7	51SMW	102.2	29.4	Soil	445.6
62ZM2	105.4	32.8	Soil	154.7	61HXI	108.6	34.1	Soil	455.2
51BCZ	104.3	31.9	Soil	154.8	64CST	105.4	37.2	Soil	463.1
62ZM4	105.4	32.8	Soil	156.0	61XIY	108.7	34.4	Soil	468.8
51MXF	104.0	31.8	Soil	162.2	61JIY	108.8	34.5	Soil	486.6
51BCQ	104.5	31.8	Rock	163.5	61XIA	109.0	34.2	Soil	487.5
62LTA	103.4	34.7	Soil	168.6	61XYI	109.0	34.2	Soil	489.3
51JYH	104.6	31.8	Soil	175.0	64QUK	105.5	37.4	Soil	491.8
51BCY	104.5	31.7	Soil	178.3	61CAT	109.0	34.4	Soil	492.5
62TSZ	105.4	34.2	Soil	179.6	61GAL	109.1	34.5	Soil	508.5
51MXN	103.7	31.6	Soil	180.4	61LIT	109.2	34.4	Soil	513.5
51AXD	104.4	31.6	Soil	182.9	61LAT	109.3	34.2	Soil	519.6
62MAQ	102.1	34.0	Soil	185.2	61YAL	109.2	34.7	Soil	524.6
51LXT	103.5	31.6	Soil	185.9	61WEN	109.5	34.5	Soil	544.0
51JGS	105.5	32.3	Soil	188.5	61LID	109.6	34.7	Soil	559.4
51WCD	103.6	31.5	Soil	192.8	61PUC	109.6	35.0	Soil	565.0
51GYD	105.8	32.6	Soil	195.2	61HUX	109.8	34.5	Soil	566.6
51AXH	104.6	31.6	Soil	196.6	61DAL	110.0	34.8	Soil	592.7
51JGD	105.5	32.0	Soil	201.8	61TOG	110.2	34.6	Soil	610.6
51MZX	104.2	31.4	Soil	203.9	61HEY	110.2	35.2	Rock	628.5

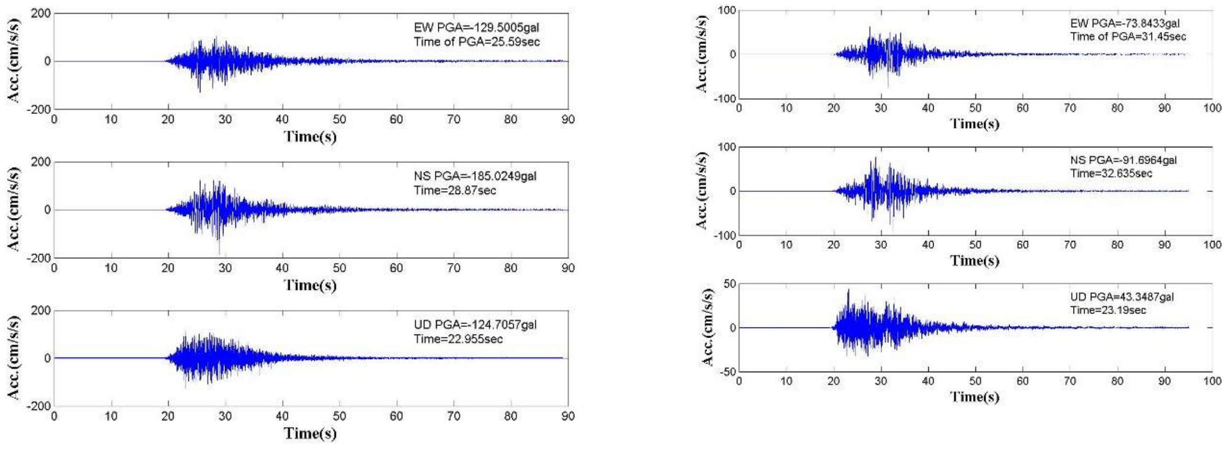


Fig.2 The acceleration time history of 51JZB (left) and 51JZW (right)

2. Characteristics of Amplitude

Fig. 3 shows the corrected peak acceleration distribution maps of east-west, north-south, and vertical component of 81 strong motion records obtained during this earthquake. The larger PGA and PGV are mainly distributed near the epicenter. The PGA of east-west component varies from 0.95 to129.50 cm/s^2, the PGA of north-south component varies from 0.68 to185.02 cm/s^2, and the PGA of vertical component varies form 0.33 to124.71 cm/s^2. The maximum PGA was obtained from the north-south component of 51JZB Station. There are 19 records greater than 10 gal in east-west component, 19 records greater than 10 gal in north-south component, 8 records greater than 10 gal in vertical component. There are 46 records greater than 10 gal in total. Fig. 4 shows the distribution map of corrected peak velocity from left to right for this earthquake. The PGV of east-west component varies from 0.25 to 3.94cm/s, the PGV of north-south component varies from 0.09 to 6.55 cm/s, and the PGV of vertical component varies from 0.04 to 4.06 cm/s.

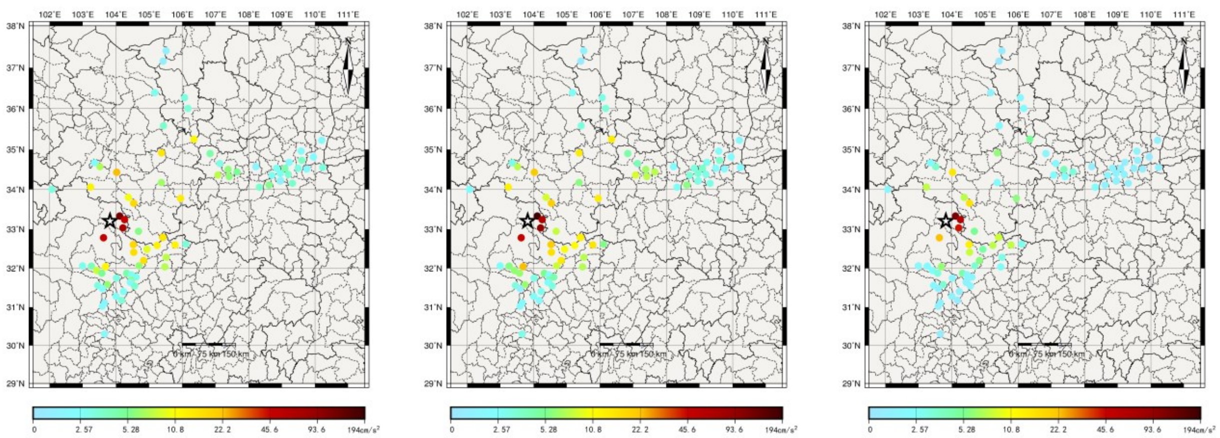


Fig.3 Corrected peak ground acceleration distribution map（from left to right stands for EW、NS、UD component, respectively）

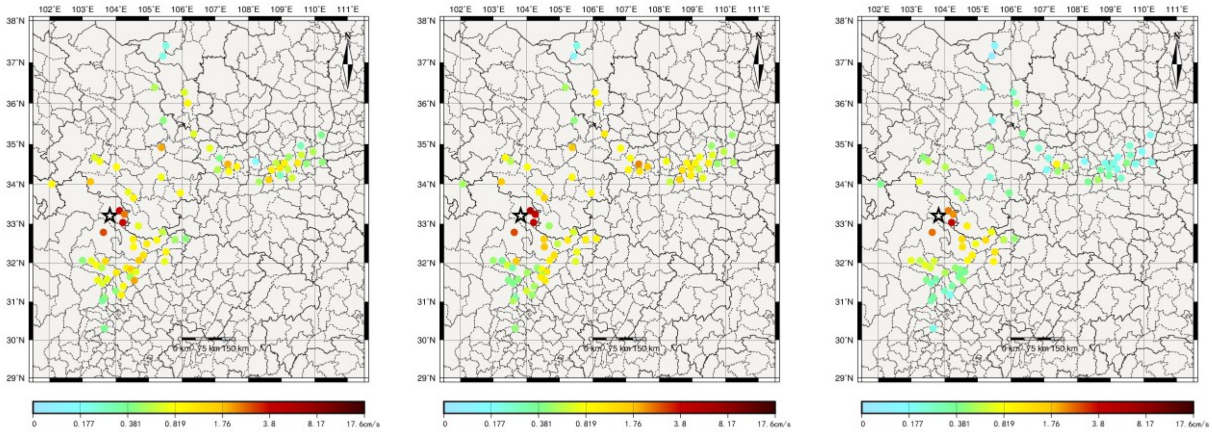


Fig.4 Corrected peak ground velocity distribution map（from left to right stands for EW,NS,UD component respectively）

According to the Temp Specification for Instrumental Seismic Intensity calculation [2] issued by China Earthquake Administration, the PGV was calculated from the acceleration data, then the instrumental seismic intensity was calculated based on the observed PGA and calculated PGV. The instrumental seismic intensity map is shown as Fig.5.The maximum seismic intensity is 9 according to the scientific investigation. At present, the instrumental seismic intensity of 51JZB and 51JZW is 6.2 and 6.1, respectively.

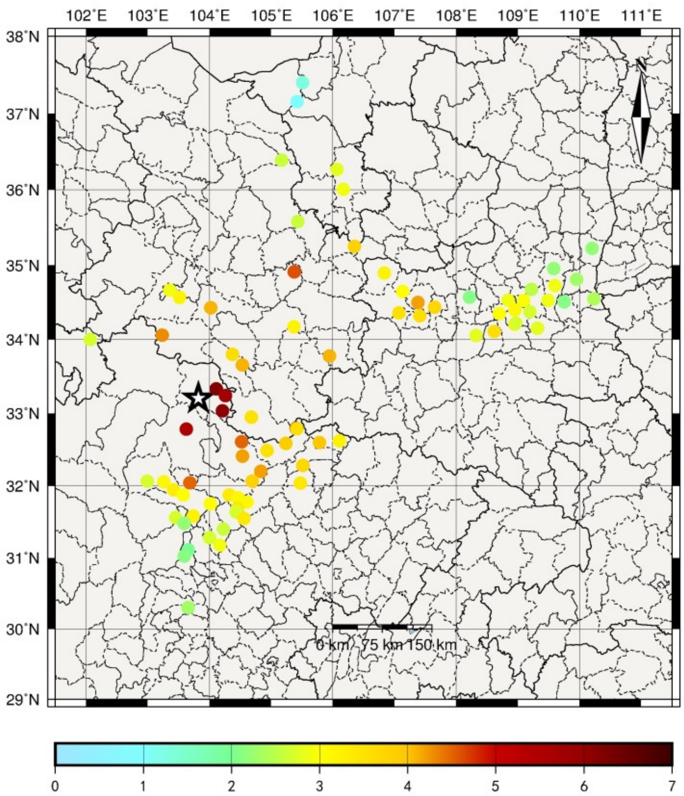


Fig.5 Instrumental Seismic Intensity Map

This article selects the regional attenuation relationship used in the seismic ground motion parameter zonation map of China (GB18306-2015) to analyze the attenuation characteristics of the peak acceleration and velocity peaks of this earthquake [3]. This article is referred to as Yu 2013. The formula is as follows:

$$lgY = A + B*M + C*lg(R + D*e^{E*M}) \quad (1)$$

In formula (1), Y represents the ground motion parameter, M represents surface wave magnitude, R represents epicenter distance, A, B, C, D, E represents the regression coefficients.

According to the epicenter location of this earthquake and the regulation of the ground motion zonation, the ground motion attenuation relationship of Qinghai-Tibet region was selected for this analysis. The specific regression coefficient is taken from Yu et al. 2013[3]. Fig. 6 shows the comparison result of the horizontal peak ground acceleration and the long- and short-axis attenuation relationships of Yu 2013. The red solid line is the long-axis attenuation relationship of Yu 2013, the red dotted line indicates the standard deviation is ±0.236, and the blue solid line is short-axis attenuation relationship of Yu 2013. The. The blue dotted line indicates that the standard deviation is ±0.236. Figure 7 shows the comparison result of the horizontal peak ground velocity and the long- and short-axis attenuation relationship of Yu 2013. The red solid line is the long-axis attenuation relationship of Yu 2013, the red dotted line indicates the standard deviation is 0.271, and the blue solid line is Yu 2013. The short-axis attenuation relationship. The blue dotted line indicates that the standard deviation is 0.271.

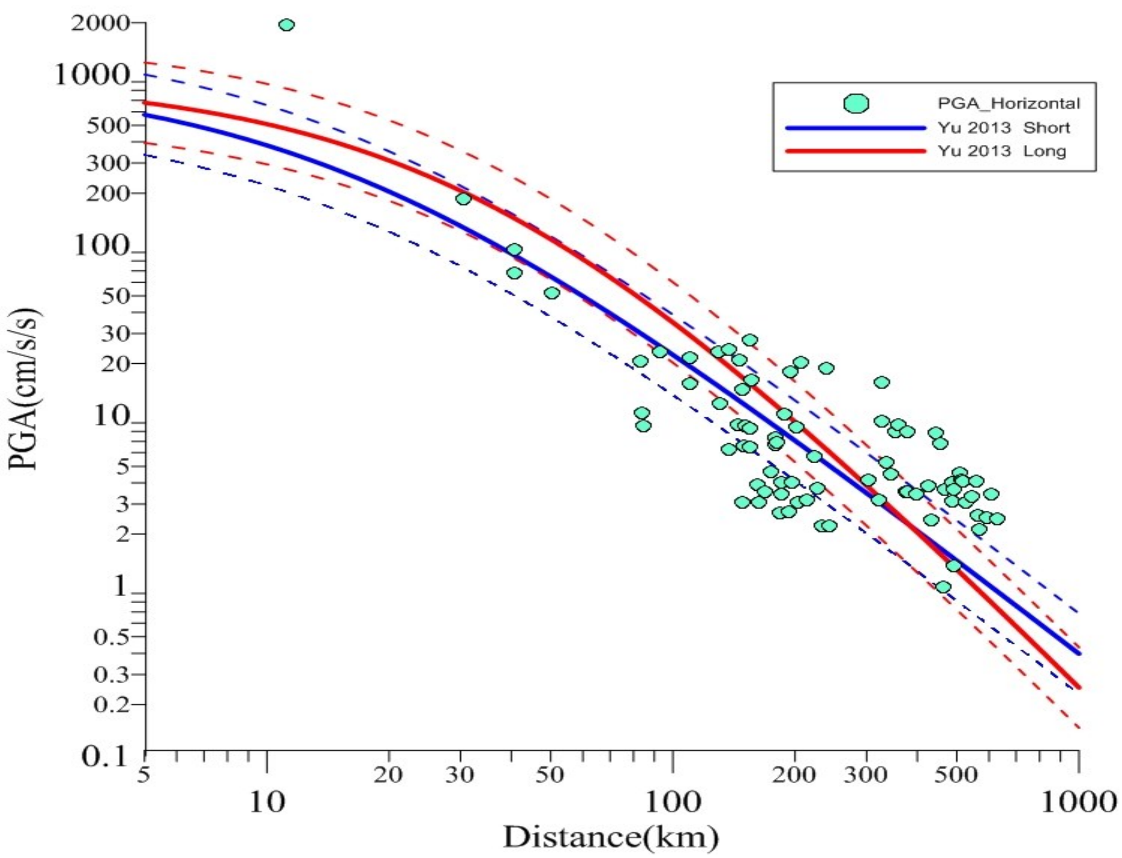


Fig.6 Comparison between the horizontal PGA and Yu 2013 GMPE

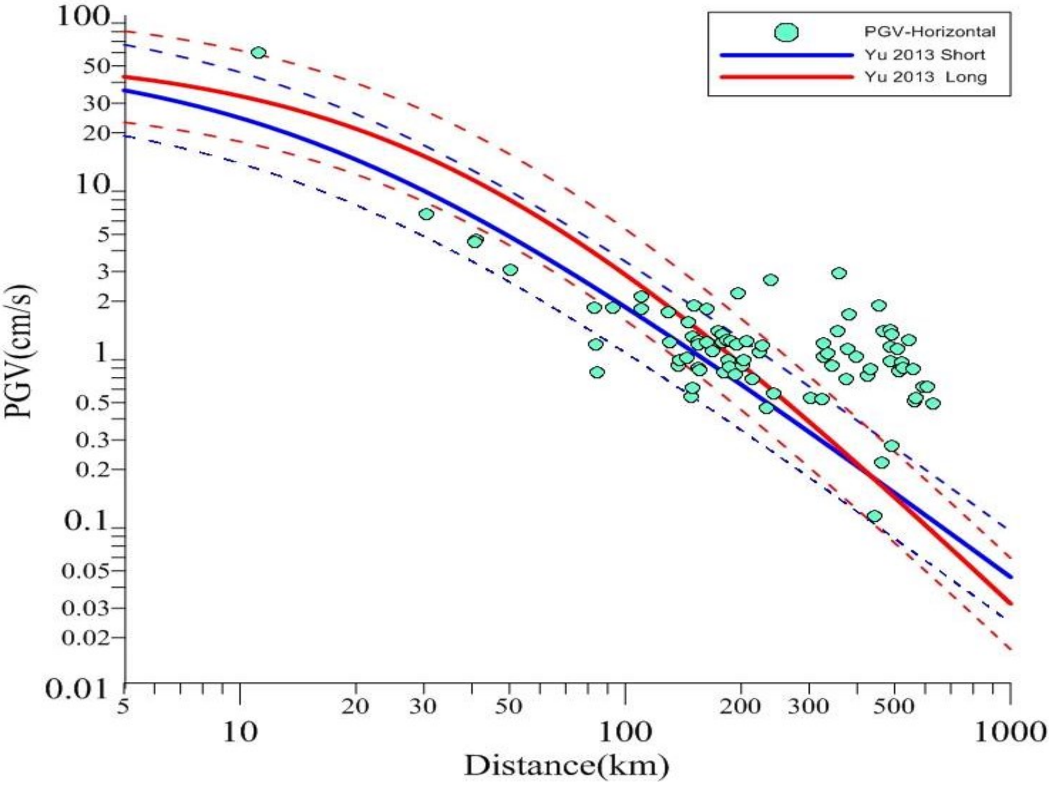


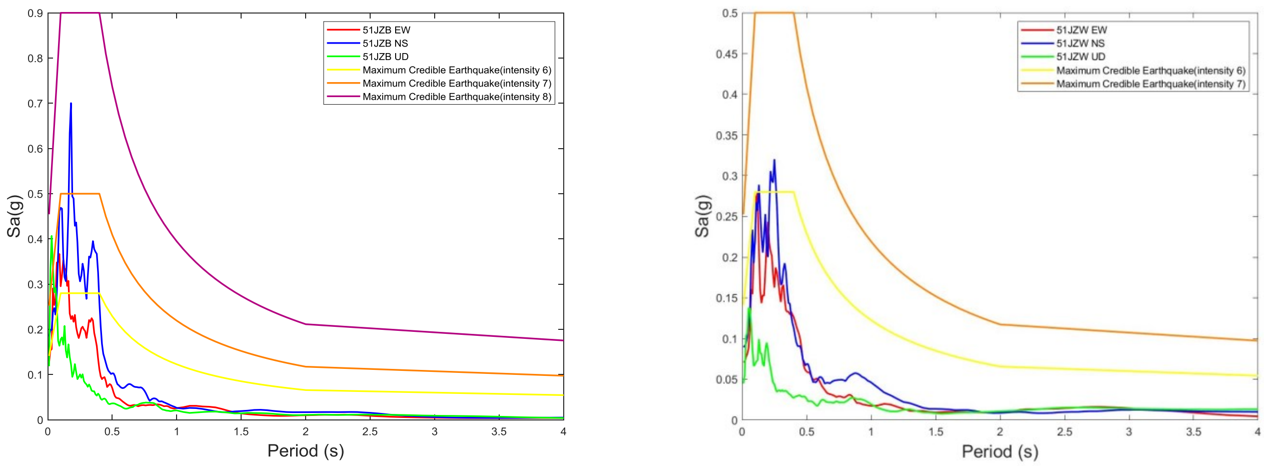
Fig.7 Comparison between the horizontal PGV and Yu 2013 GMPE

In Fig. 6, The horizontal PGA agrees well with the short axis attenuation relationship of Yu 2013. It basically falls within the standard deviation error range from 30 km to 200 km. However, compared with GMPE Yu 2013, the observed peak ground acceleration decays significantly slower when the epicentre distance is larger than 200 km. In Fig.7, the horizontal PGV agrees well with the short axis attenuation relationship of Yu 2013. It basically falls within the standard deviation error range from 30 km to 200 km. Compared with the peak acceleration result, the dispersion is smaller. when the epicentre distance is larger than 200 km, the observed peak velocity is much greater than predicted value of the GMPE. Professor Wang Haiyun found that the deep soil layer of the Weihe Basin amplifies the low-frequency effect of the ground motion significantly, and also amplifies the high-frequency component, but the amplification effect is relatively small compared to the low-frequency component. For example, the soil layer sites in Gaoling, Caotan, and Xi'an have an amplification factor of 9.5-11.2 for low-frequency components and an amplification factor of 5.5-6.8 for high-frequency components [4]. The strong motion records with an epicenter distance larger than 300 kilometers recorded by the Shaanxi strong motion network were located in the Weihe Basin of Shaanxi Province. Therefore, the observed peak ground acceleration and velocity is much larger than the predicted value of the regional attenuation relationship used in the seismic ground motion parameter zonation map of China (GB18306-2015). This phenomenon may be caused by the site amplification effect of the Weihe Basin. The peak acceleration of the 51JZZ station at 11 km from the epicentre in Fig. 6 is much larger than the predicted values of the long-axis and short-axis attenuation relationship of Yu 2013, which further confirmed that the strong motion record of 51JZZ is abnormal due to unknown reasons. So further field investigations and studies to confirm the strong motion records of 51JZZ.

3. Characteristic of Response Spectrum

Fig. 8 shows the comparison between the observed response spectrum and the designed response spectrum under rare earthquake. By calculating the observed acceleration response spectrum of the two stations near the epicenter and comparing it with the design response spectrum curve under the Class II site condition of

Code for seismic design of buildings(GB50011-2010) [5] ,it shows that the acceleration response spectra of the east-west and vertical component of 51JZB exceeds the seismic design response spectrum curve under maximum credible earthquake with intensity 6, and the north-south acceleration responses exceeds the seismic design response spectrum curve under maximum credible earthquake with intensity 7. The acceleration response spectrum of the north-south component of 51JZW exceed the seismic design response spectrum curve under maximum credible earthquake with intensity 6, and the acceleration response spectrum of the east-west and vertical component of 51JZW does not exceed the seismic design response spectrum curve under maximum credible earthquake with intensity 6. The peak periods recorded by these two stations with different epicenter distances all falls into 0.4 seconds. The predominant period platform was relatively narrow, and decreased to a lower level quickly when the period larger than 0.4 seconds. The natural period of the main building structure in Jiuzhaigou County varies from 0.3 to1.0 second. So, the earthquake will not cause large damage to the main buildings in this area. In the long period of more than 1 second, the acceleration response spectrum value is very small, which will not cause serious damage to dams, bridges, high-rises and super high-rise buildings with long natural vibration periods [6-8]. It will cause large damage to the short-period structures.



（a） 51JZB　　　　　（b） 51JZW

Fig.8 Comparison between acceleration response spectra and seismic design response spectra

4. Characteristics of Duration

In 1999, Bommer and Martinez-Pereira summarized the existing ground motion duration definitions into four types [9], namely bracket duration, uniform duration, and effective duration. And energy duration (significant duration). Energy duration refers to the period of time between the acceleration of the ground motion record and the accumulated energy reaching two different thresholds. The process of acceleration integration represents the energy accumulation process, and the square of the acceleration integration is the Arias intensity. Arias intensity is calculated using the following formula [10]:

(2)

In formula (2), *Ia* represents the Arias intensity, *a(t)* represents the acceleration, t_0 represents the whole duration of the accerleration time history, g represents the gravitational acceleration.

At present, there are two main methods of energy duration: (0.05, 0.75) and (0.05, 0.95), which are called 5% -75% significant duration and 5% -95% significant duration. 5% -95% significant duration is currently the most widely used duration in engineering practice. Brendon A. Bradley pointed out that 5% - 75% significant duration usually only contains the energy of body waves, which can provide a basis for distinguishing different types of ground motions [11]. Based on the corrected acceleration data, the 5% -95% significant duration distribution map (Fig. 9) and 5% -75% significant duration distribution map (Figure 10) were calculated. The 5%-75% significant duration and 5%-95% significant duration were calculated, the 5%-95% significant duration varies form 3.600 second to 86.455 second, and most of them varies from 20 second to 50 second. The 5%-75% significant duration varies form 2.555 second to 59.935 second, and most of them varies from 10 second to 40 second. The significant duration grows with the epicenter distance in the whole.

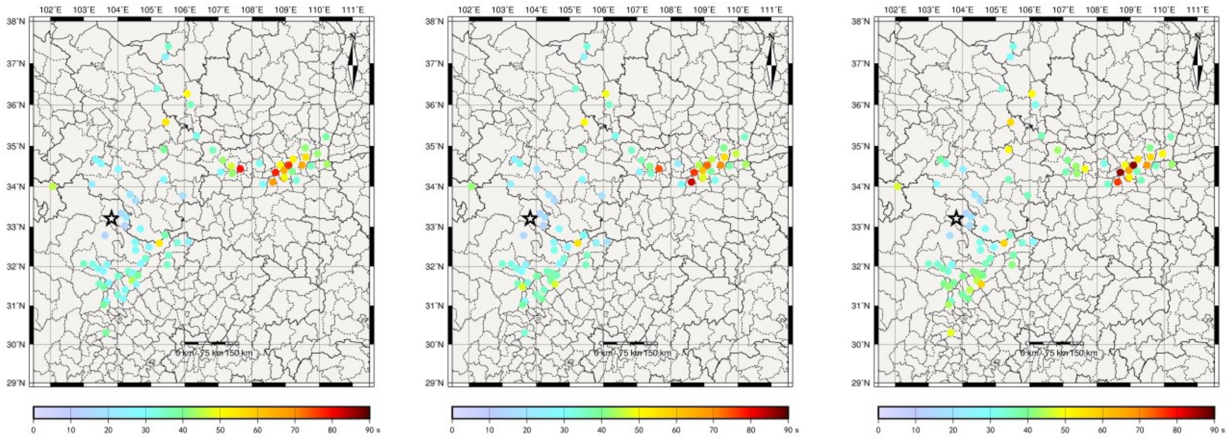


Fig.9 Distribution of 5%-95% significant duration (from left to right stands for EW, NS, UD component respectively)

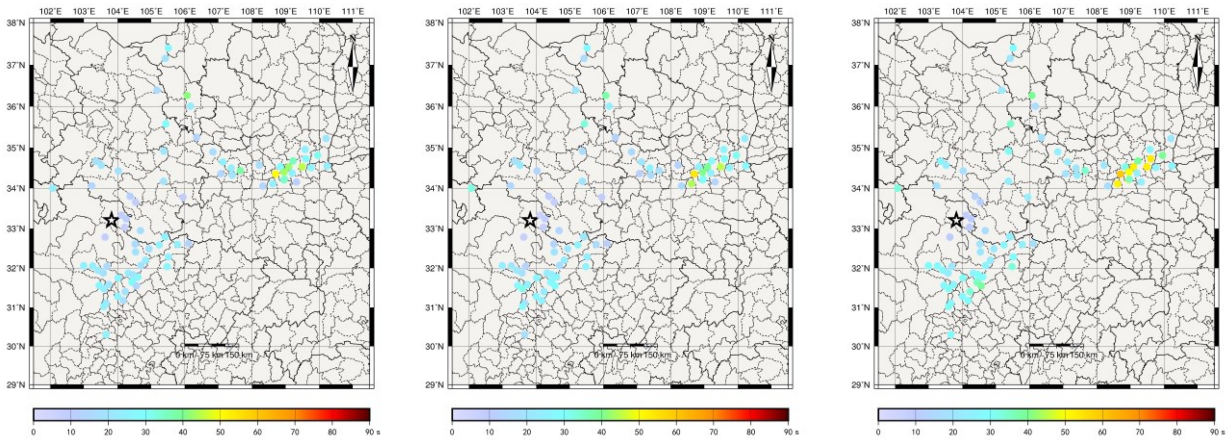


Fig.10 Distribution map of 5%-75% significant duration (from left to right stands for EW, NS, UD component respectively)

We compared the horizontal significant duration with the empirical significant duration prediction equation (Fig.11), the 5%-75% significant duration and 5%-95% significant duration are larger than the global empirical prediction equation [12]. The 5%-95% significant duration is consistent well with California empirical prediction equation [13] with epicentre distance less than 200 kilometers, but higher than California empirical prediction equation with epicenter distance larger than 200 kilometres.

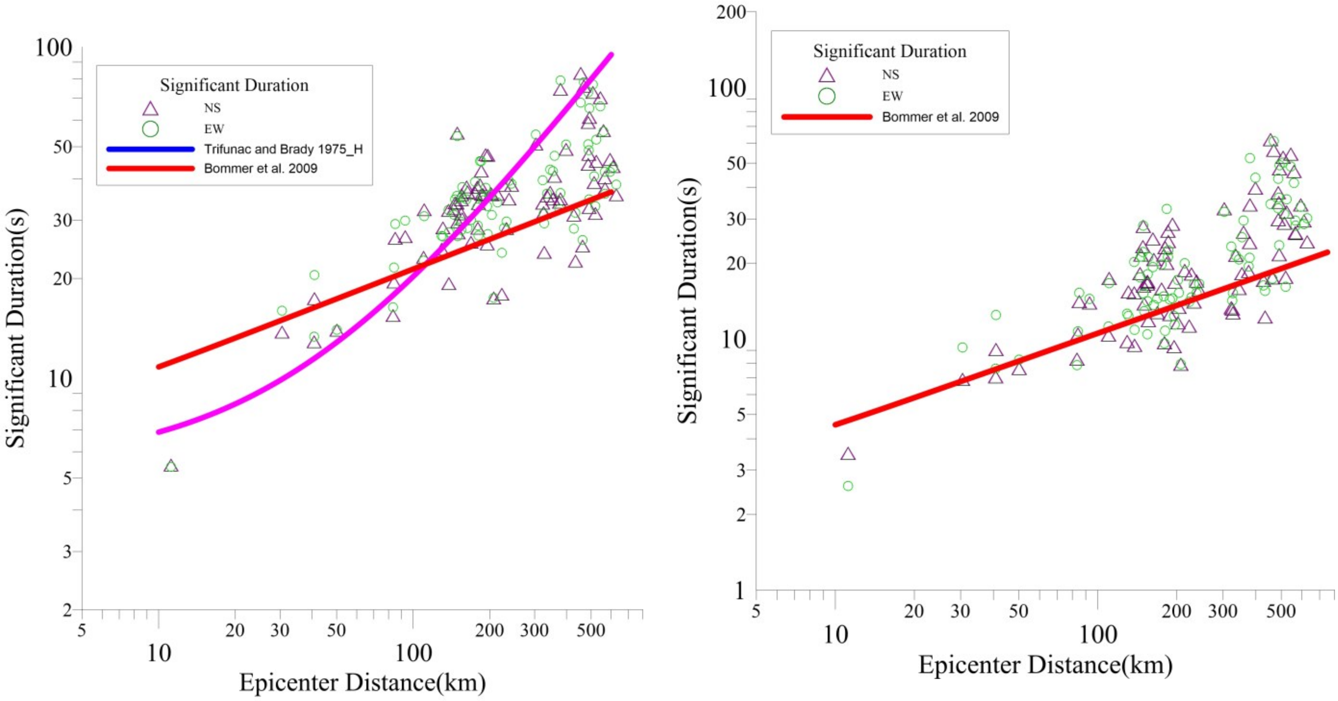


Fig.11 Comparison of the observed 5%-95% (left) and 5%-75% (right) horizontal significant duration with related attenuation relathionship

5. Conclusion

Based on 81 strong earthquake records obtained by the China digital strong motion network during the Ms 7.0 Jiuzhaigou Earthquake. Following the standard data processing procedure of China Strong Motion Network Center. The amplitude characteristics, frequency spectrum characteristics and duration characteristics of the strong motion records were analysed in this paper.

(1) There are 46 records with peak ground acceleration larger than 10 gal. The peak ground acceleration varies from 0.33 to 185.02 gal and the peak ground velocity varies from 0.04 to 6.55 cm/s. The instrumental seismic intensity varies from 1.0 to 6.2. Field investigations and deep research are needed to confirm the strong motion records of 51JZZ. Compared with the Qinghai-Tibet region Yu 2013 long-axis and short-axis attenuation relationships, the horizontal PGA with epicenter distance from 30 km to 200 km consistent well with the Yu 2013 short-axis attenuation relationships, but the observed values with epicenter distance larger than 300 km decays significantly slower. The observed peak ground acceleration and observed peak ground velocity with epicenter distance larger than 300 km are much higher than the predicted value of the GMPE, which is probably caused by the site amplification effect of the Weihe Basin.

(2) Two stations with larger PGA were selected for response spectrum analysis. It was found that the peak periods recorded fallen within 0.4 seconds, and the predomiant period platform was relatively narrow, and quickly decreased to a very low level after 0.4 seconds. The natural vibration period of the main building structure in Jiuzhai County is 0.3-1.0 seconds. This earthquake has little impact on the damage to the main buildings in the area. It contains less long-period components and will not cause serious damage to high-rise buildings. It will cause large damage to the short-period structures in this area.

(3) The 5%-95% significant duration varies form 3.600 second to 86.455 second, and most of them varies from 20 second to 50 second. The 5%-75% significant duration varies form 2.555 second to 59.935

second, and most of them varies from 10 second to 40 second. The significant duration grows with the epicenter distance in the whole. Compared the observed significant duration with the empirical prediction equation, 5%-75% significant duration and 5%-95% significant duration are larger than the global empirical prediction equation. The 5%-95% significant duration is consistent well with the California empirical prediction equation with epicenter distance less than 200 kilometres, but higher than the California empirical prediction equation with epicenter distance larger than 200 kilometres.

6. Acknowledgements

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7. Copyrights

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