1. Line 200. How are the probabilities of seismic hazard obtained? I checked Wu et al. 2020, but did not think that the details had been given in it.

Reply: Thanks for your comments. The probabilities of seismic hazard are obtained based on Monte Carlo method. The following is the detail process of the method

The Monte Carlo method uses random numbers to perform computer simulations. The basic idea is that when the number of experiments is large sufficiently, the frequency of an event appears to approximate the probability of occurrence of the event.

Based on the geophysical data of various regions in China, the seismic zoning map of China (GB18306-2015) shows the seismic zones and potential source areas, has established the corresponding probability model and spatial distribution model of earthquake occurrence, and gives the basic parameters of each seismic zone. Fig. 1 shows the potential seismic sources around Xichang.

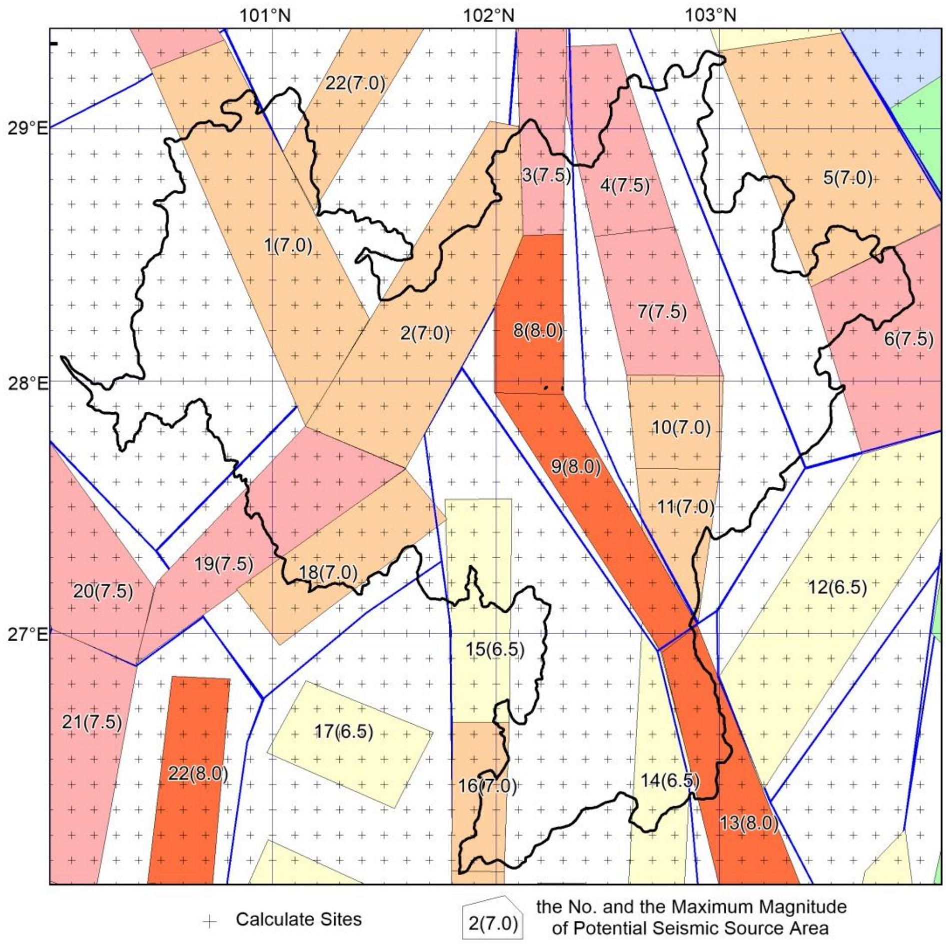

Fig. 1 The calculate sites and the potential seismic sources around Xichang

According to the basic assumptions and seismicity parameters of the zoning map (Table 1), the following steps are used to synthesize the sets of earthquake sequences (Guo, 2008; Wu & Gao, 2018):

(1)Based on the assumption that the occurrence of earthquakes in seismic zones satisfies Poisson distribution, the time length T of the simulated earthquake sequence and the average annual occurrence rate ν_4 of earthquakes with magnitude 4 and above in the seismic zone should be determined firstly. Randomly generate a Poisson distribution random number L with T and ν_4 as parameters, then L is the number of earthquakes in the seismic zone for the length of time T to be simulated.

Table 1 List of seismicity parameters of potential seismic sources around Xichang

No.	M_{UZ}	b value	ν_4	Strike	No.	M_{UZ}	b value	ν_4	Strike
1	7.0	0.85	32	120°	12	6.5	0.85	32	50°
2	7.0	0.85	32	55°	13	8.0	0.85	32	120°
3	7.5	0.85	32	90°	14	6.5	0.85	32	80°
4	7.5	0.85	32	115°	15	6.5	0.85	32	90°
5	7.0	0.85	32	120°	16	7.0	0.85	32	90°
6	7.5	0.85	32	120°	17	6.5	0.85	32	150°
7	7.5	0.85	32	115°	18	7.0	0.85	32	30°
8	8.0	0.85	32	90°	19	7.5	0.85	32	45°
9	8.0	0.85	32	125°	20	7.5	0.85	32	120°
10	7.0	0.85	32	90°	21	7.5	0.85	32	55°
11	7.0	0.85	32	80°	22	7.0	0.85	32	55°

(2) Based on the assumption that the magnitude distribution of seismic zones satisfies the truncated Gutenberg-Richter relationship (magnitude-frequency relationship), and the minimum magnitude level M_0 and the maximum magnitude M_{UZ}, the magnitude of earthquakes to be simulated are determined.

The magnitude-frequency relationship is represented as:

$$\log \mathrm{N} = a - bM \tag{1}$$

Where a and b are coefficients, N is the number of earthquakes whose magnitude is equal to or greater than M, and the initial magnitude of the zoning map is 4. The cumulative number of earthquake events is:

$$N(\mathrm{M}) = \mathrm{e}^{a-bM} \tag{2}$$

If take $\Delta M = 0.1$, then

$$N(\mathrm{M}) > \mathrm{N}(\mathrm{M}+\Delta \mathrm{M}) \tag{3}$$

Take M=4.1, 4.2, 4.3,…, M_{UZ} .Generate a random number u satisfied uniform distribution between 0 and 1. Determine whether

$$u \in \frac{N(\mathrm{M}+\Delta\mathrm{M})}{N(4)} \sim \frac{N(\mathrm{M})}{N(4)} \quad (4)$$

If the above formula is true, the magnitude M of an earthquake event is determined.

(3) Determination of epicenter location. Firstly, the potential source area H where the earthquake located should be determined. According to the magnitude M determined in the previous step, the magnitude range d which the earthquake belongs to is determined. Because the probability $P_d(\mathrm{h})$ of each magnitude range locating in each potential source area is known, then generate a random number u satisfied uniform distribution between 0 and 1. Determine whether

$$u \in \sum_{\mathrm{h}=1}^{H-1} P_d(\mathrm{h}) \sim \sum_{\mathrm{h}=1}^{H} P_d(\mathrm{h}) \quad (5)$$

If so, the potential source area H where the earthquake event is located is determined. Based on the assumption that the epicenter is evenly distributed in the potential source area, a point is randomly selected in the potential source area H as the epicenter location of an earthquake.

(4) According to the azimuth of the potential source area, the azimuth of the earthquake is determined.

So far, the basic elements of an earthquake have been determined. Repeat (2) ~ (4) steps until the required number L of earthquakes in the seismic zone, taking into account all possible seismic zones that may affect the site, thus determining a seismic sequence and completing one sampling.

If the time length T is set to one year, the seismic sequence obtained by one sampling is called one-year seismic sequence in this paper. The time length is set to 10 years, which is called 10-year earthquake sequence.

According to the principle of Monte Carlo method, the more samplings, the more stable the result is. But the more samplings, the more calculations. Therefore, in order to consider the accuracy of the results and the calculation quantity as a whole, it is necessary to carry out experiments with different number of samplings. When the calculation results tend to be stable, it is considered that there is no need to increase the number of samplings.

For each earthquake in seismic sequences, the peak ground acceleration (PGA) of each site is calculated by the optimal ellipse search algorithm through the ground motion prediction equations (GMPEs).

For 5000000 simulations of a 1-year earthquake sequence, if a site is affected by ground motions exceeding specific values, the sequence is identified as 1. The sum of earthquake sequences identified as 1 is counted, and is divided by the total number of earthquake sequence simulations of 5000000, that is the annual exceedance probability of specific ground motions. Through the annual exceedacne probability, the 50-year exceedance probability of 10% and 2% can be calculated.

That is how the probabilities of seismic hazard are obtained.

We will add the details into the manuscript during the revision process.

2. How are the aftershocks simulated?

Reply: We used the Omi-R-J model to calculate the aftershock sequence parameters of 4 M7.0+ and 40 M4.5-7.0 mainshocks, which occurred in the study region (the Xianshuihe East-Yunnan seismic belt) from 1970 through 2018. The results were shown in Table 2 in lines 230-255, we introduced that the median values of the estimated p, c, K and b from the 44 aftershock sequence samples are 0.8747, 0.0187, 0.0133 and 0.8361, respectively. When the magnitude threshold for the mainshock is met ($M \geq 6.0$ in this study), the aftershocks are simulated as follows:

(1) With respect to the magnitude and time: the minimum magnitude of the aftershock sequence is set to 4.0, and the maximum magnitude is equal to the magnitude of the mainshock. The aftershock sequence satisfies the magnitude-frequency relationship $N(M)=10^{a-bM}$. The aftershock occurrence time t is within 30 days after the mainshock and follows the Omori-Utsu formula $N(t)=\frac{K}{(t+c)^{p}}$. According to the median value of p, c, K and b, the magnitude and time series of aftershocks with $M \geq 4$ are simulated.

(2) With respect to the spatial distribution: according to the empirical relationship between the magnitude of the mainshock and the rupture scale (Wells & Coppersmith, 1994), the rupture length L and width W are calculated by:

$$L=10^{(-3.22+0.69Mw)} \tag{6}$$

$$W=10^{(-1.01+0.32Mw)} \tag{7}$$

The rupture strike is taken the same as the direction of the mainshock, and the model of Felzer & Brodsky (2006) is adopted; that is, the aftershock density decays exponentially with increasing distance r from the fault, $\rho(r) = cr^{-n}$, where n is 1.37, and c is a constant. Thus, the locations of the aftershock epicenters can be determined.

(3) The number of aftershocks. We have accounted the number of M4.0+ aftershocks for M5.0+ mainshocks in the Chinese mainland and its surrounding area, and found that when the mainshock is greater than 6.0, the number of M4.0+ aftershocks within a month (30 days) increase with the magnitude of mainshock, and they meets the statistical relationship: $\log_{10}(N)$=0.84M-4.57 (shown by the red line in the middle in Fig. 2, which fluctuates within the range of ±0.8 (shown by the other two red lines), and obeys the Normal distribution under the linear coordinates. The number of aftershocks corresponding to a certain magnitude is generated according to this law.

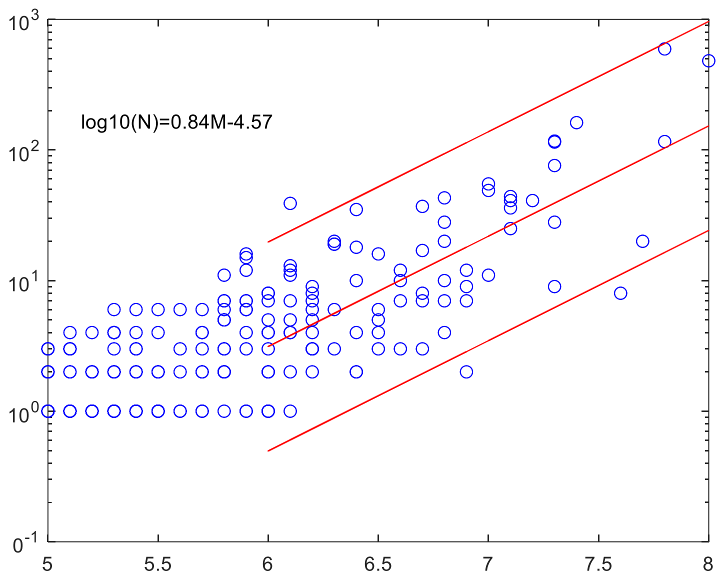

Fig. 2 The M5.0+ mainshocks and the number of their M4.0+ aftershocks for the Chinese mainland and its surrounding area

3. How is the ETAS model, given in Section 2.2, used in the evaluation?

Reply: When using the ETAS model to fit the parameters of aftershock sequences, there is a high requirement for the number of aftershocks with magnitude higher than the completeness magnitude, and only small part of earthquake sequence samples can meet the conditions. Therefore, we used the ETAS model to calculate the aftershock sequence parameters for 4 M7.0+ mainshocks. For moderate size of mainshocks, the aftershock sequences are usually not complex. We choose to use the Omi-R-J model to calculate the parameters of their aftershock sequences. Compared to the R-J model, a detection rate function is introduced to describe the detection rate of the incomplete part of the earthquake catalog, which considers aftershocks below the completeness magnitude in the early stage of the earthquake sequence during the model parameter fitting. The ETAS model was used for comparison. We will delete it and focus on the Omi-R-J model in the revision process.

Other:

1. Line 150. Is EM algorithm necessary? How are p, c, k estimated?

Reply:

(1) Yes, we think it is necessary. In the early period after a mainshock, the waveforms of small earthquakes were submerged by the waveforms of large earthquakes, making it difficult to identify small earthquakes and resulting in the lack of catalog of small earthquakes. The EM algorithm is based on the super parameter estimation of the Newton iterative algorithm. It can optimize the parameters in case of missing small earthquakes in the early period, reducing the error of the Newton iterative algorithm and obtain more objective parameters.

(2) The earthquake detection rate function considering incomplete earthquake records can be expressed as $\nu(t,M) = \lambda(t,M)q(M|\mu(t),\sigma)$. The logarithmic likelihood function related to parameters p, c, k is:

$$\ln L(k,c,p) = \sum_{M_i \geq M_c} \ln \nu(t,M) - \int_{M_c}^{\infty} dM \int_0^T dt\nu(t,M) \quad (8)$$

Where t_i and M_i are the time and magnitude of the i-th aftershock that occurred within the "learning period" [0, T] during model fitting.

We will add the details into the manuscript during the revision process.