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STUDY ON THE CORRELATIVITY OF EARTHQUAKE'S IMPACT ON CITIES

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SUMMARY

City groups (or belts) with extra-large cities as the centers have been formed in China, and they usually has extensive area and dense population. When a strong earthquake hits them, cities that have weak correlativity of earthquake's influence will have more possibility to provide mutual aid in the early time to reduce the loss of life.

In this paper, the simultaneous rate of seismic intensity is defined firstly and then is used to characterize the correlativity of earthquake's impact on cities. It can be calculated by seismic intensity data appearing in cities. Considering lack of observered seismic intensity data of historical earthquakes in cities, one computer simulation method is introduced to generate artificial earthquake catalogue data and then the affected intensity in each city is calculated by seismic intensity attenuation relationship. The probabilistic models for simulating are built on the statistical features of regional seismicity, such as the recurrence law, spatial distribution of earthquake occurrence, etc. As an example, nine prefecture-level cities of FuJiang Province are chosen to be research objects. The simultaneous rate of seismic intensity VI, VII and VIII are calculated for each two cities. The results show that the correlativity does exist, and it is independent of spatial distance but dependent on seismic belt.

INTRODUCTION

With rapid development and advancement of economy and society, lots of city groups or city belts with extra-large cities as their centers have been formed in China. The regions these city groups lying usually have well-developed economy, dense population, and are regional politics and culture centers. Some groups lie in the regions with high level of earthquake activity, such as the Surrounding Capital City Group with the centers of Beijing and Tianjin. Once a large earthquake occurs, its influence will spread to

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very extensive region and its disaster will be tremendous too. So earthquake disaster prevention and mitigation of city group will be very significant issue.

The cities in a group have close distance with each other, they can carry out consistent preparation for disaster as one whole entity and cut down the heavy load of single city before an earthquake, and have an advantage in prompt mutual-aid after an earthquake because of close distance. It is specially important to mitigate the lose of lives. One important precondition is that all the cities in one group can not be exposed to the same level of destroy during one earthquake. So the division of city group in the region with dense cities distribution shall be very significant to the emergent mutual-aid in early time after a large earthquake among group members.

For the aim above, the characteristics and correlativity of earthquake's impact on cities need to be clearly considered. The cities with similar features and strong correlativity of historical earthquake influence have large chance to suffer same level destroy during the future strong earthquake and will lose advantage to provide mutual-aid, so they can not be divided into one group.

The purpose of this paper is to probe into the research way of correlativity earthquake influence and the proper presentation of correlativity.

METHODOLOGY

By earthquake catalogue and the isoseismal data, the cities one earthquake can impact on and their affected intensity will be determined. Assuming that the matrix of cities affected seismic intensity (*n* cities and *m* earthquakes) is as follows Table 1:

Table 1 the matrix of cities afected seismic intensity

	City *1*	City *2*	…	City *n*
Earthquake 1	I_{11}	I_{12}	…	I_{1n}
Earthquake 2	I_{21}	I_{22}	…	I_{2n}
…	…	…	…	…
Earthquake m	I_{m1}	I_{m2}	…	I_{mn}

According to the above sheet, the appearing times of intensity i in city C_i and C_j totalize $K(i)$, and the appearing times of intensity i in both city C_i and C_j for the same earthquake is $l(i)$. It has:

the simultaneous rate of seismic intensity i: $$\lambda(i) = \frac{l(i)}{k(i)}$$

The simultaneous rate of seismic intensity characterizes the correlativity of earthquake's impact on cities.

Theoretically, the historical earthquakes catalogue can be used for this analysis, however, it usually is incomplete because of lack of history records. Table 2 lists the distribution of the times of seismic intensity of histrorical earthquakes in several province-level capital cities of North China where has relatively complete records. It documents that historical data is not enough to perform the analysis, especially lack of the high intensity data.

Table 2 the distribution of cities affected seismic intensity in several province-level capital cities of the North China

city	VI	VII	VIII	IX	X	XI	Sum
Beijing	5	3	3	1	0	0	12
Tianjin	8	2	2	0	0	0	12
Taiyuan	9	7	0	0	0	0	16
Shijiazhung	10	2	0	0	0	0	12
Jinan	2	1	0	0	0	0	3
Zhengzhou	8	0	0	0	0	0	8
Hohhot	3	0	0	0	0	0	3

In this paper, according to the statistical characteristics of regional seismic activity, lots of groups of artificial earthquake catalogue are produced by a simulation method for the purpose of corresponding statistical analysis[1]. Firstly, according to the assumption of Poisson distribution and the probabilistic distribution of earthquake magnitude (depended on the recurrence relationship of a seismic belt), the total number of earthquakes during a period time of T years in the belt and each earthquake's magnitude can be determined by computer simulation. Then, the location of each earthquake can be determined by the potential sources, their discrete distribution of earthquake potential of different magnitude, and their inner random distribution assumption. Finally, considering the shape of the envelope of the same seismic intensity of historical earthquakes are usually ellipse in China, so the affected intensity in a city for each earthquake will be calculated by a given ellipse attenuation relationship including a long aixs and a short aixs equation. The fracture direction of each earthquake (the long axis) can be determined by the discrete probabilistic distribution of fracture direction of potential source. All those probabilistic parameters can be obtained from the earthquakes samples in one seismic belt by statistical method.

CASE STUDY

In this paper, nine prefecture-level cities of Fujian Province (Figure 1) are chosen to explore the correlativity of earthquake's influence among them.

The period of time for earthquake catalogue simulating is 5000 years. The probabilistic distribution of regional seismic activity, such as the delimitation of seismic belts, potential sources and their seismicity parameters, are from the data proposed by Institute of Geophysics, China Earthquake Administration and adopted by the China Seismic Ground Motion Parameters Zoning Map. The main parameters are listed in Table 3.

Table 3 Main seismicity parameters of seismic belts

Seismic belts	*b*	ν_4	M_{uz}	Number of Sources
East Taiwan	1.05	435	8.0	30
West Taiwan	0.80	18.8	7.5	25
Coast Region of South China	1.17	2.12	7.0	60
Region of the Middle Reaches of YanZi River	0.685	2.7	8.0	154

Annotation: b is the coefficient of the recurrence relationship of a seismic belt; ν_4 is annual average rate of earthquakes larger than or euqal to 4.0; M_{uz} is the upper limit magnitude of a seismic belt.

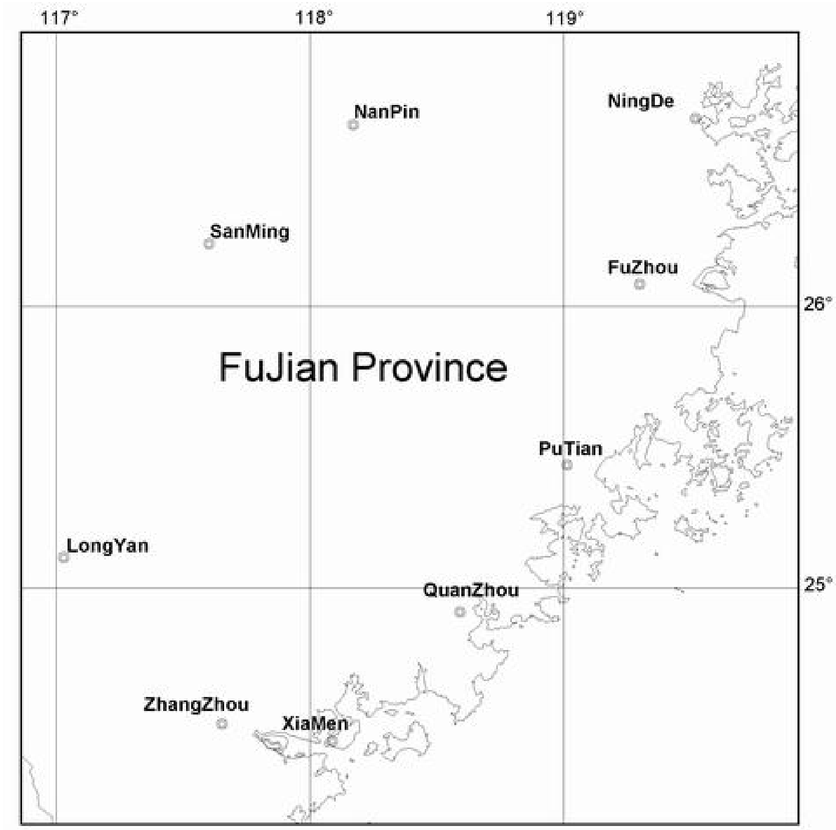

Figure 1 The location sketch map of the 9 cities of FuJian Province

The long axis and short axis intensity attenuation relationships of South China[2] is used here:

$$\text{Long axis:}\ I_a = 2.401 + 1.586M - 1.429\ln(R_a + 15) \quad \sigma = 0.536$$

$$\text{Short axis:}\ I_b = 0.815 + 1.676M - 1.321\ln(R_b + 9) \quad \sigma = 0.546$$

According to above attenuation relationships, the seismic intensity isoseismals of each earthquake and affected intensity of each city can be calculated, and then the simultaneous rate of each intensity can be calculated too. Table 4 is the result.

Table 4 the simultaneous rate of different intensity

City	FuZhou	XiaMen	PuTian	SanMing	QuanZhou	ZhangZhou	NanPin	NingDe	LongYan
FuZhou	1.00 1.00 1.00								
XiaMen	0.38 0.30 0.00	1.00 1.00 1.00							
PuTian	0.70 0.31 0.17	0.36 0.23 0.18	1.00 1.00 1.00						
SanMing	0.08 0.09 0.00	0.03 0.06 0.00	0.02 0.00 0.00	1.00 1.00 1.00					
QuanZhou	0.56 0.29 0.17	0.52 0.40 0.30	0.67 0.53 0.50	0.01 0.00 0.00	1.00 1.00 1.00				

ZhangZhou	0.35 0.30 0.00	0.57 0.39 0.25	0.29 0.23 0.13	0.07 0.06 0.00	0.36 0.23 0.13	1.00 1.00 1.00			
NanPin	0.11 0.09 0.00	0.05 0.06 0.00	0.05 0.00 0.00	0.72 1.00 0.00	0.03 0.00 0.00	0.10 0.06 0.00	1.00 1.00 1.00		
NingDe	0.59 0.36 0.00	0.33 0.24 0.00	0.39 0.00 0.00	0.20 0.40 0.00	0.34 0.13 0.00	0.36 0.17 0.00	0.27 0.40 0.00	1.00 1.00 1.00	
LongYan	0.09 0.25 0.00	0.13 0.11 0.00	0.08 0.07 0.00	0.43 0.04 0.00	0.10 0.00 0.00	0.20 0.17 0.00	0.33 0.40 0.00	0.12 0.25 0.00	1.00 1.00 1.00

Annotation: The line 1,2,3 in each cell is the simultaneous rate of seismic intensity *VI, VII, VIII* separately.

From the Table 4, several primary conclusions can be drawn as follows:

(1) Because the larger area of distribution of seismic intensity VI of one earthquake, the number of cities which have same intensity is larger too and the correlativity among these cities is relatively high. According to the simultaneous rate of seismic intensity VI (the first line of each cell in Table 4), all the 9 cities can be divided into two groups. One includes FuZhou, PuTian, QuanZhou, XiaMen, ZhangZhou; another one includes SanMing, NanPin, LongYan. These two groups of cities lie in two northeast linear belts separately. In the Seismic Intensity Zoning Map of China (1990) [3], the first belt is in the division of intensity VII, and the second belt is in the division of intensity VI or V. For each two cities in the same group, the simultaneous rate of seismic intensity VI is larger than 30% commonly. But for each two cities in the different group, the simultaneous rate of seismic intensity VI is less than 10% usually. NingDe has relatively high correlativity with all the cities in both two groups.

(2) For the simultaneous rate of seismic intensity VII and VIII (the second and the third line of each cell in Table 4), the above divisions of cities still exist. So for the aim of classification of cities by the correlativity of earthquake's impact on cities, it is feasible to use the simultaneous rate of seismic intensity VI as a primary basis. Considering the higher intensity values are more significant for evaluating the future earthquake disaster of a city, so the simultaneous rate of higher intensity should be taken into account to cut down the larger area of city group dividing by intensity VI.

(3) Among the 9 cities, FuZhou, PuTian, QuanZhou, XiaMen, ZhangZhou and NingDe have strong correlativity and they should not be put into one same group; SanMing, NanPin, LongYan are also strongly correlative and they should not be in one same group too.

(4) Table 5 lists the spatial distance between each two cities among this 9 cities. The data point to the fact that the correlativity is not always relatively higher for two closer cities and lower for two farther cities. It is mainly upon seismotectonics circumstance of cities. For example, ZhangZhou is farther to QuanZhou than to LongYan, but ZhangZhou and QuanZhou are both in the Southeast Coast Outside Seismic Belt, whereas LongYan is in the Southeast Coast Inside Seismic Belt, these two seismic belts have very different seismogological circumstance and seismic activity, so the earthquake's impact on ZhangZhou has stronger correlativity with QuanZhou than with LongYan.

Table 5 Distance between cities (km)

City	FuZhou	XiaMen	PuTian	SanMing	QuanZhou	ZhangZhou	NanPin	NingDe	LongYan
FuZhou	0								
XiaMen	219	0							
PuTian	77	144	0						
SanMing	170	202	166	0					
QuanZhou	148	72	71	176	0				
ZhangZhou	245	44	170	90	104	0			
NanPin	129	244	159	74	197	242	0		

NingDe	68	285	147	197	216	303	134	0	
LongYan	252	129	202	136	159	91	205	303	0

CONCLUSIONS

The correlativity of earthquake's influence on cities presents the possibility of suffering from large destroy simultaneously in these cities. It is a very important basis for city groups dividing. From above research work, some basic understanding are obtained.

(1) The influence of earthquake is indeed correlative for some cities, and the simultaneous rate of seismic intensity can be used to present this type of correlativity.

(2) The correlativity of earthquake's impact on cities correlates with seismotectonic circumstance surrounding cities and has indeterminate relation with spatial distance between cities.

(3) The simultaneous rate of seismic intensity VI can be a primary basis for city group dividing and the rate of larger intensity can only be a reference.

(4) The cities which have higher correlativity have large chance to suffer from same level destroy in the same time, and they will hard to provide mutual-aiding during the future destructive earthquake. The knowledge about the correlativity of earthquake's impact on cities will be very helpful to constitute regional general plan of earthquake prevention and mitigation.

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