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The meteorological warning method of China geological disasters induced by precipitation

Y. Li[1], W. Li[2], J. Di[1], G. Zhang[2], H. Bao[1]

[1]National Meteorological Centre, Beijing, China, liyum@cma.gov.cn

[2]Public Meteorological Service Centre of CMA, Beijing, China, liwh@cma.gov.cn

Landslides, debris-flows and rockfalls are caused by precipitation frequently. Studies of potential risk of geological disasters and national zonation were carried out, and by considering topography, geology and climate precipitation characteristics, the whole country can be divided into 9 big warning partitions. Based on the relationship between rainfall and geological disasters from 1950 to 2010, 16 days effective rainfall of disaster was chosen to be the key meteorological factor for modeling. Multiple mathematical fitting equations were used for simulating the relation of effective rainfall to disasters, and the piecewise Cubic fitting equation is the best simulation of probability of disasters in all warning partitions. By combing the risk grades of geological disasters in business, forecast indexes of geological disaster were established and can be called critical precipitations that came from 16 days effective rainfall. The practical application had shown that the model had a good effect and the discriminant method of 16 days effective rainfall indexes was feasible and effective.

effective rainfall, geological disaster, potential risk, zonation, sample inspection

Метод метеорологического оповещения о геологических катастрофах в Китае, вызванных осадками

Ю. Ли[1], В. Ли[2], Ц. Ди[1], Г. Чжан[2], Х. Бао[1]

[1]Национальный метеорологический центр, Пекин, Китай, liyum@cma.gov.cn

[2]Центр общественной метеорологической службы СМА, Пекин, Китай, liwh@cma.gov.cn

Оползни, сели и осыпи часто связаны с атмосферными осадками. Были проведены исследования потенциального риска геологических катастроф и национальное районирование. Учитывая характеристики рельефа, геологического строения и климата, всю страну можно разделить на 9 больших регионов в отношении предупреждения опасностей. Основываясь на взаимосвязи между осадками и геологическими катастрофами с 1950 по 2010 год, был выбран параметр 16-дневное эффективное количество осадков перед стихийным бедствием, который стал ключевым метеорологическим фактором для моделирования. Для моделирования связи эффективных осадков с бедствиями использовались несколько эмпирических математических уравнений. Частное кубическое уравнение было признано лучшим для моделирования вероятности бедствий во всех районах, выделенных для предупреждения. Сочетая шкалы риска геологических катастроф, были установлены индексы для прогноза геологической катастрофы, и может быть названо критическое число осадков, которые достигались за 16 дней. Практическое применение показало, что эта модель имела хороший эффект, а метод дискриминантов с эффективными показателями осадков за 16 дней был осуществимым и эффективным.

эффективные осадки, геологическая катастрофа, потенциальный риск, районирование, контроль образцов

Introduction

China is one of the most serious geological disasters countries in the world, a lot of debris flows, landslides and rockfalls are happened at wide range and to destroy buildings, public facilities, fields and so on, even took away people's lives, the number of casualties by geological disasters is account about a quarter of the casualties' number by all natural disasters. In the regions there were prone and high frequency happened to geological disasters, the losses by disasters came to be an important factor that could be hindered local economic and social development and threaten people's lives and property safety. According to statistics, the mean occurrence number of debris flows, landslides and rockfalls is about 24,000 per year from 2001 to 2015, and mostly caused by natural factors, such as precipitation, earthquake and snowmelt, and took away about 800 people's lives and 4.5 billion yuan directly economic losses per year.

Precipitation is the most important key to induce debris flows, landslides and rockfalls [*Yao X X.et al., 2005; Zhang Y Y., 2007*]. In the framework of global warming, extreme weather events had showed the increase tendency [*Du Y Q., 2013*], short-time strong rainfall and typhoon precipitation events were also showed the same tendency and induced more geological disasters [*Yun T., et al., 2013*]. Only in 2013, geological disasters caused economic losses as high as 10.1billion yuan.

In the general, at the area of high occurrence of geological disasters, when more antecedent rainfall, the soil moisture significantly increased and even becomes saturated, and if there is heavy rain again, the probability of geological disasters outbreak would be greatly increase. In 2006, Jibson R.W. had researched twice landslides of the same landslide slope of Cleveland Corral area in USA, he had found that continuous precipitation (monthly cumulative precipitation) infiltrated and percolated, could be caused slow down deformation in deep of the slope, and after rainfall, the landslide could be take place about few weeks or few months later, and if there was obviously rainfall in two weeks, the shallow landslide could be take place at later rainfall period. Italian scholar Del Ventisette C. et al. studied landslide in Ruinon area in 2012 and found the anural mean precipitation was 750mm, the downward acceleration of landslide with low intensity (8-10 mm/d) and short time rainfall in few days wasn't very obvious, but it would be increase with 10-15mm/d rainfall during 2-3 days. South Korea scholar Chae B G et al. analyzed a few extreme precipitations of typhoon s triggered intensive landslide events in 2012, he found that typhoon Rusa in 2002 brought more than 895mm precipitation in 12 hours and triggered 1,500 landslides, and in 2003, typhoon Maemi brought maximum 410mm/d and 89.5mm/hrs. precipitation and triggered 1,200 landslides. Florence W.Y. Ko [*2016*] accounted 27 landslides induced by storms between 1984 and 2008, and found daily precipitation exceeded 300 mm will cause fatal landslide disasters. Due to the precipitation is closely related to the occurrence of geological disaster, so usually simplify the geological disaster forecast to the simple discriminant relations between rainfall and geological disaster, scholars generally believe that the current precipitation, antecedent rainfall, rainfall intensity and duration were mainly rainfall factors to set up geological disaster forecast method [*Gao S. et al., 2002; Zhou M.L. et al. 2014; Xue Q.W. et al., 2013*].

Based on vast territory, regional difference in China and more complicated geological conditions and huge terrain changes in western China rainfall values of triggering geological disasters are large different in regions, so that needs to divide potential geological disasters area and carry out the research of rainfall threshold triggered geological disasters in partition. The study investigates potential risk zoning, rainfall factor selecting and to build national geological disaster meteorological forecast method, establish early rating warning indicators of rainfall threshold.

Geological disaster distribution and potential risk zoning

Geological disaster distribution

The debris-flow distribution range is very wide, but also relatively concentrated (fig.1), in addition to Jiangsu, Shanghai and Macao special administrative region, the rest of the provinces (municipalities) all have the debris flows. The occurrence of debris flow is relative to the terrain, fault, lithology and human activity factors and so on, so that debris flows are centralized distribution in these areas.

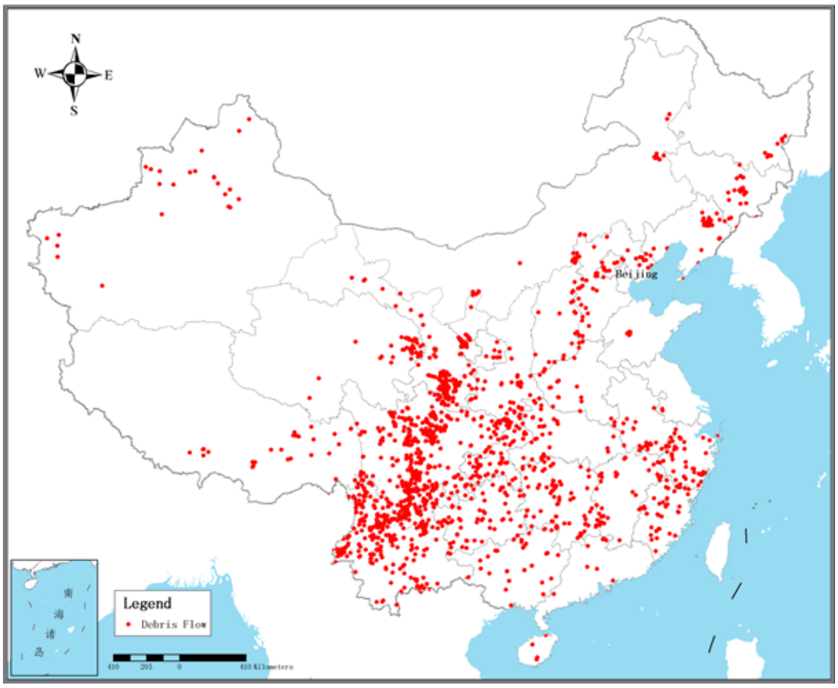

Fig. 1. The distribution of debris flows in China.

The land descends from west to east in China and roughly presents three ladder-like distributions, debris flows concentrate in two transition zones between three ladders. Among them, the south of the Qinghai-Tibet Plateau, with an average altitude above 4,000 meters for the first ladder. The second ladder includes the Inner Mongolia, Loess and Yunnan-Guizhou plateaus, and the Tarim, Junggar and Sichuan basins, with an average elevation of between 1,000 m and 2,000 m. The third ladder, about 500 -1000m in elevation, begins at a line drawn around the Greater Hinggan, Taihang, Wushan and Xuefeng mountain ranges and extends eastward to the coast. In the transition zone between the first to second ladder, that is most active region of debris flows, because of the remarkable differences of elevation and slope that lead to abnormal development of debris flow and intensive distribution. In the transition zone between the second to third ladder, debris flows less than the transition zone mentioned earlier, because of less differences of elevation and slope. In the transition zone between the first to second ladder, the climate presents obvious seasonal character that dry winter and wet summer, and summer precipitation profusion and lot of local heavy rainfall, corresponding debris flows are active.

China landslide and rockfall distributions have the characteristics of a large quantity and a wide range, mainly distribute in the east of the first ladder mountain region with annual precipitations are greater than 400 mm, and present two regional distributions roughly: southwest China and southeast China (Fig. 2). Southwest China due to the steep topography, active geological structure, dense fault zone with abundant precipitations lead to abnormal development of geological disaster, so it’s the most active region of landslide and rockfall too, contrasted to other place of China, landslide and rockfall in southwest China have highest occurrence frequency, largest scale and most heavy disaster. Compared with Southwest China, landslide and rockfall scales and numbers are less due to less change in terrain in Southeast China, mostly are small scale rockfall, shallow landslide and relatively small damage. But occurrence frequency is relatively higher because the typhoon rainstorm, human activities more closely. landslide and rockfall are more prone on the Loess plateau region because the complex landform and diversified structure, but due to less rainfall, occurrence frequency is relatively low. And as topography in Northeast and North China, geology and precipitation conditions are unfavorable to geological disasters, thus less landslide and rockfall distribution.

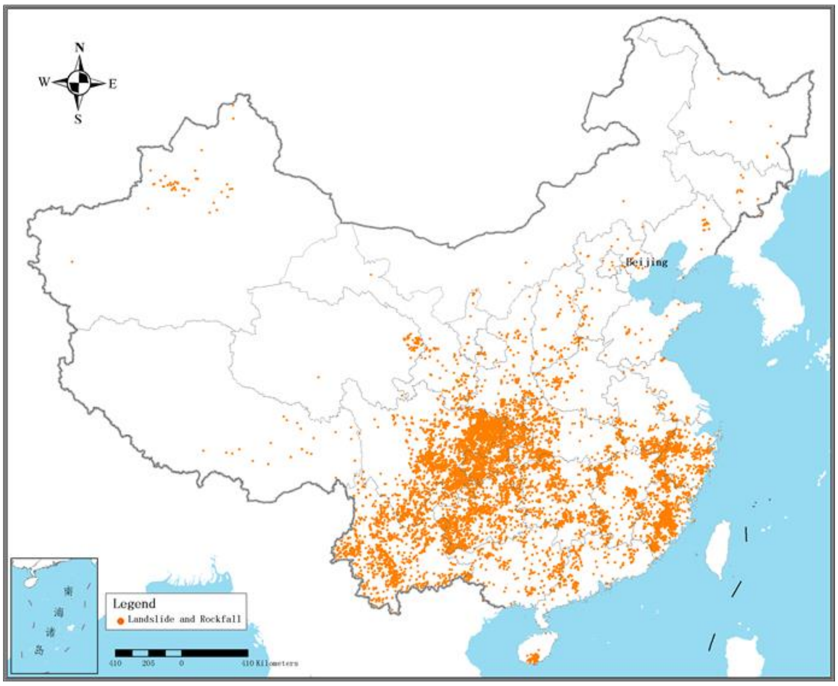

Fig. 2. The distribution of landslides and rock falls in China.

Potential risk zoning

Dynamic and material conditions are necessary for geological disaster occurrence, steep terrain to provide dynamic conditions, weathered rock, clastic rock, vegetation clastic, loose soil to provide solid material sources. The common geological disaster potential risk zoning method is the underlying surface environment information model [*Zhu L F. et al., 2004; Zhang G.P., 2014*] to extract elevation, altitude difference, slope, rock type, fault density and vegetation types as evaluation factors, and to assess geological disaster potential risk comprehensively. According to the evaluation results and climate characteristics, whole country area is divided into several subdomains, supposed that subdomains geographic and geological conditions, climate background are similar, so that ignored the environment differences in subdomain when established geological disaster meteorological forecast model. Dr. Zhang G.P. et al. had completed geological disaster potential risk zoning in 2009, and the study applies this research achievements, the country is divided into 9 geological disaster forecast areas (Fig.3), respectively, the Northwest region, Northeast region, Tibetan plateau, Loess plateau, Qinling and Dabashan Mountains, North China, Yungui plateau, South-central region, and Southeast region.

The Northwestern region contains most part of the Xinjiang province, the north-central part of Qinghai province, Inner Mongolia, the north part of Gansu and Ningxia provinces. The Northeast region contains Heilongjiang, Jilin provinces and the east-central part of Liaoning provinces. Tibetan plateau region contains the south part of Xinjiang province, Tibet, the south part of Qinghai province and the western Sichuan Plateau. Loess plateau region contains central Gansu province, southern Ningxia province, northern Shaanxi province and west-central

Shanxi province. Qinling and Dabashan Mountains region contains southern Gansu province, southern Shaanxi province, western Henan province, east-central Sichuan province, Chongqing city, western Hubei province and northwestern Hunan province. The North China region contains eastern Shanxi province, Hebei and Shandong provinces, Beijing and Tianjin cities, western Liaoning province, eastern Henan province, northern Anhui province and northern Jiangsu province. Yungui plateau region contains Yunnan province, western-central Guizhou province and western Guangxi province. The South-central region contains eastern Guizhou province, south-central Hunan province, northwest Jiangxi province, east-central Hubei province, central Anhui and southwest Jiangsu province. The Southeast region contains southeast Guangxi province, Guangdong, Hainan, Fujian and Zhejiang province, eastern Jiangxi, southern Anhui and Taiwan.

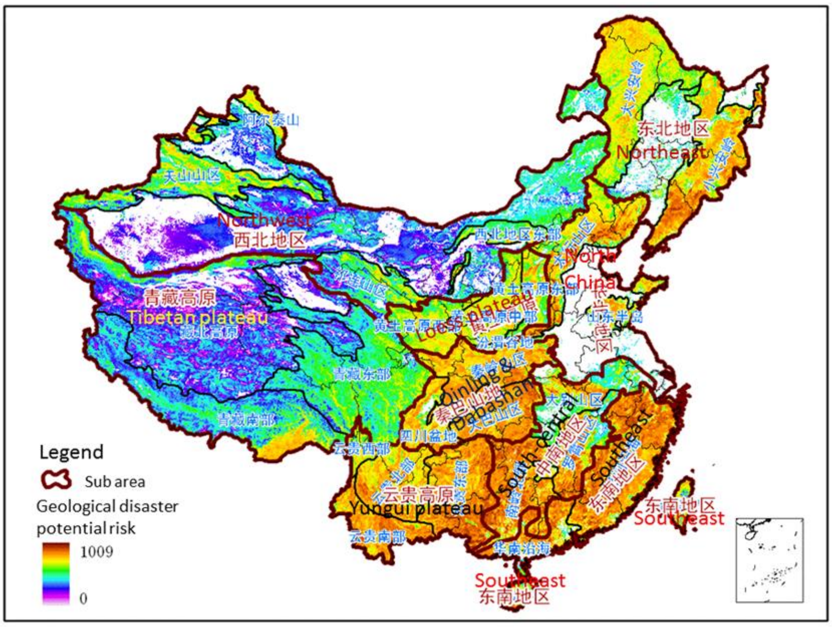

Fig. 3. The geological disaster potential risk distribution and nine warning areas in China.

Data source and induced factor

Data source

In study, historical geological disasters with significant casualties, economic losses, weather-related were selected to analyze, and extracted total 18,069 disasters from January 1950 to October 2010, including 2,155 debris flows, 15,914 landslides and rockfalls, all historical geological disasters data are coming from China Geo- Environmental Monitoring Institute. As the principle, to select precipitation of the nearest weather station (Fig.4) from the geological disaster point, extracted daily rainfall data set of them. In order to eliminate the earthquake and man-made factors, rainfall data set need to rule out by considering situations such as no rain but with earthquake induced geological disaster, or recently no rain in two days but with debris flow. In the same county, it recorded several geological disasters on the same day, corresponding to only one weather station in each country, just regarded as one geological disaster point to extract daily rainfall. Finally, collected 12,777 rainfall datasets to be used in analysis and modeling.

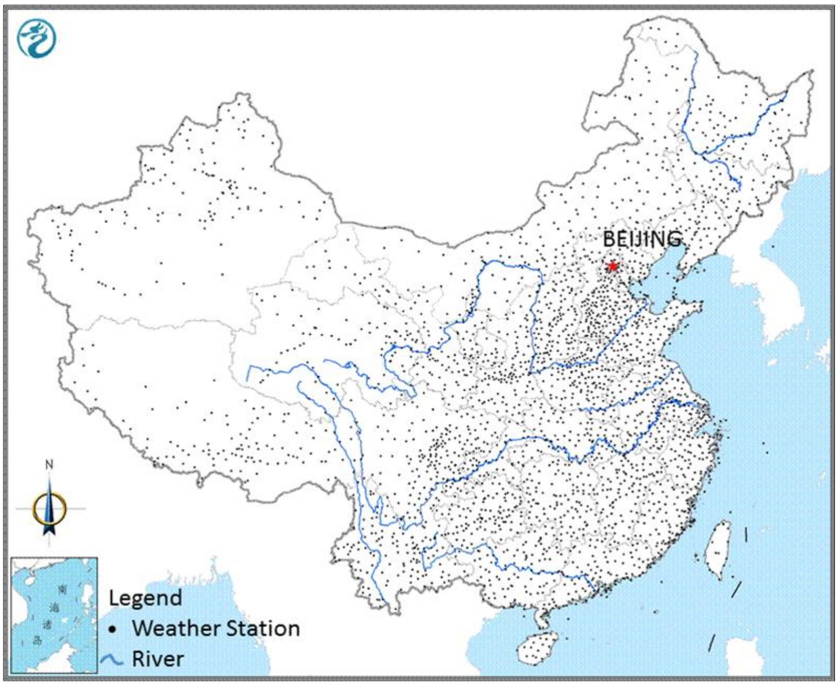

Fig. 4. Meteorological observation stations in China (total 2,513 stations).

In model verification, the samples of geological disaster of 2015, which had collected from the disaster website of China meteorological administration, were used for nine waring areas model test, and in the case test of Jiang xi province, group-occurring geological disasters with field survey were used in southeast waring area model test.

Geological disasters induced factors

The precipitation of the early day and the day when geological disasters occurred both can lead to geological disasters, but how long of antecedent rainfall depend on the conditions of geological and climate, the present study selected days for 3-30 days [*Zhang G.C., 2014*]. First, selected 16-day daily rainfall before geological disasters for factor analysis, the daily average rainfall characteristics as show in Fig. 5: the rainfall of the disaster day and the day before are significantly greater than the other days; the mean daily rainfall in 3-16 days before geological disasters occurred have little difference. Considered daily rainfall of 16-day are induced factors and to analysis. Further factors analysis found that factors correlation of the daily rainfall of 16-day are poor, and principal component analysis found that 16-day daily rainfall not suit for this simulation method and the rainfall of the disaster day and the day before cannot have represented other daily rainfall. Cluster analysis also showed that all daily rainfall of 16-day was fit to merger analysis as one class. Referent to debris flow study of Jiangjiagou [*Tian, 2008*], selected effective rainfall to combine together as induces factor, and the calculation formula is:

$$R = \sum_0^n 0.8^n r_n, \quad (1)$$

where R is effective rainfall, r_n is daily rainfall, 0.8 is decreasing coefficient, n is days of effective rainfall. In modeling, let n = 15.

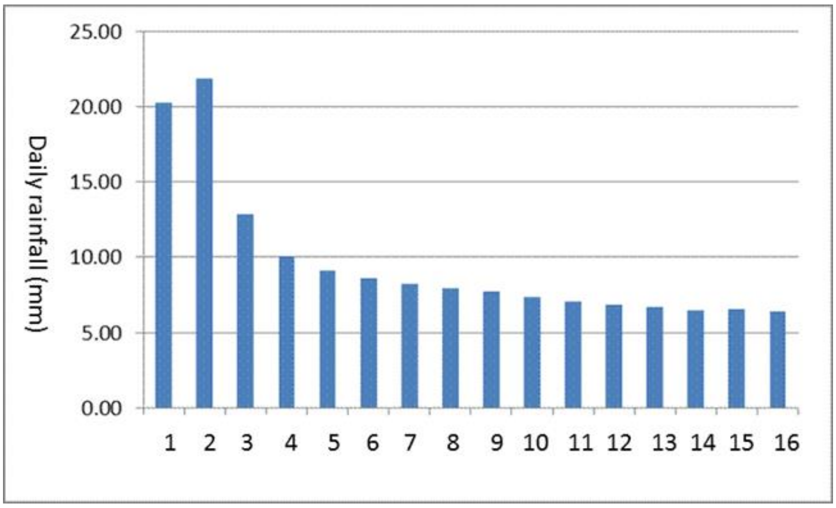

Fig. 5. Daily average precipitation of geological disaster before 16 days

The determination of geological disaster warning critical rainfall

Factor probability fitting method

To calculate all 16 days effective rainfalls in geological disasters according to the formula (1), and percentile in the 1% interval, and regard as effective rainfall induced geological disaster probability samples (frequency), totally 100 sample points to carry on the Logarithmic, Quadratic terms, Cubic, the Power function fitting. By the Table 1, four kinds of fitting methods determination coefficient R^2 values were greater than 0.9 and Cubic fitting R^2 is the greatest one with value 0.991, in principle, all fitting methods can be used for simulation, but by the Fig. 6, only Cubic fitting curve is much more consistent as sample, except the curve at high probability on 94%, corresponding 238.6mm effective rainfalls. So, try to take sectional curve fitting and see if that can improve overall performance. According to the sample sequence, divide into two sequences as 1%-94% and 95%-100%, fitting respectively.

Table 1. Evaluation of 3 kinds of fitting and parameter estimates

Equation	**The model summary**					**Parameter estimates**			
	R^2	**F**	**df1**	**df2**	**Sig.**	**constant**	**b1**	**b2**	**b3**
Logarithmic	-0.907	955.404	1	98	-0.000	-0.351	0.217		
Quadratic	-0.915	520.316	2	97	-0.000	0.162	0.005	-4.201E-6	
Cubic	-0.991	3637.581	3	96	-0.000	0.058	0.008	-2.121E-5	1.500E-8
Power	-0.957	2196.939	1	98	-0.000	0.023	0.714		

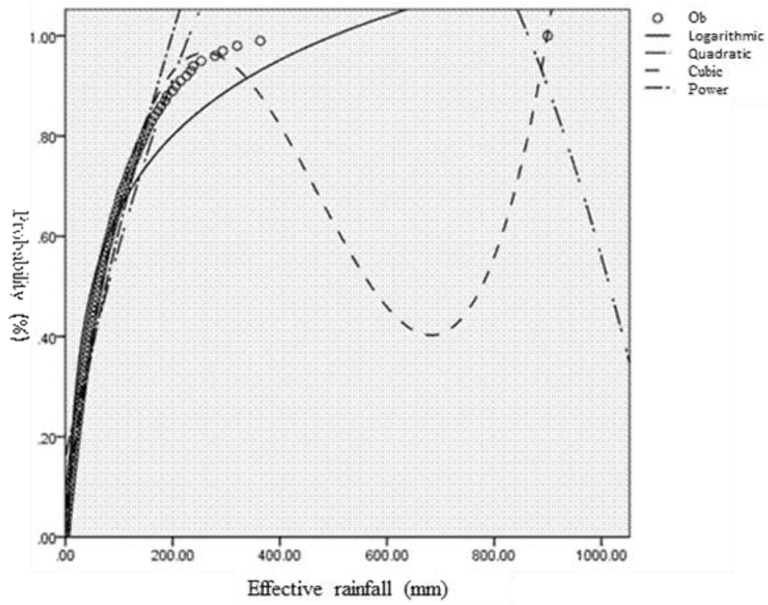

Fig. 6. Four kinds of Probability fitting curve

First to simulate 1%-94% sample sequence with Quadratic terms, Cubic, the Power function fitting methods, and results shown as Table 2 and Fig. 7, the R^2 of Cubic fitting method is up to 1 with perfect simulation, in contrast, fitting effects on the quadratic curve and power function curve are slightly less perfect.

Table 2. Evaluation of 3 kinds of fitting and parameter estimates between 1% and 94%

Equation	The model summary					Parameter estimates			
	R^2	F	df1	df2	Sig.	constant	b1	b2	b3
Quadratic	0.994	7021.743	2	91	0.000	0.048	0.008	-2.013E-5	
Cubic	1.000	81858.624	3	90	0.000	0.012	0.011	-4.806E-5	8.437E-8
Power	0.981	4636.790	1	92	0.000	0.020	0.762		

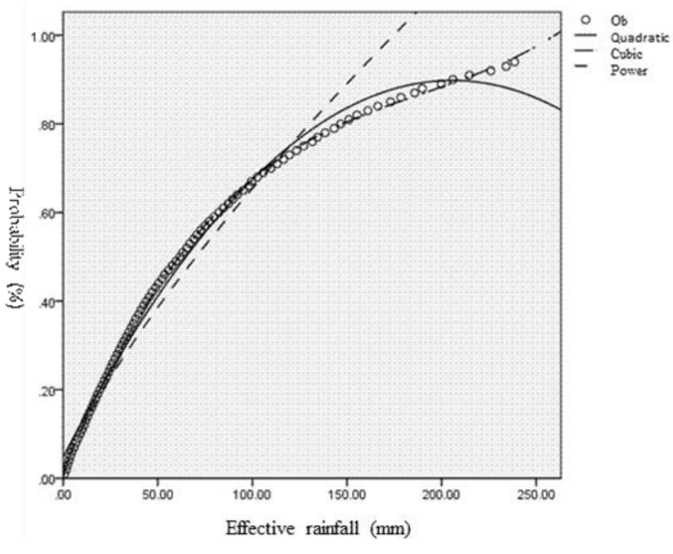

Fig. 7. Three kinds of Probability fitting curve between 1% and 94%

In the 95%-100% sample sequence, it's only 5 sample points and value of effective rainfall vast as 253.2mm to 899.6mm, so needed to divide into more samples by percentile with interval 0.5%, and simulate as same methods used in 1%-94% sample sequence, and results shown in Table 3 and Fig.8, the R^2 of Cubic and quadratic fitting are both 0.985, same simulative effect, but Power function simulation is general fitting effect.

Table 3. Evaluation of 3 kinds of fitting and parameter estimates between 95%and 100%

Equation	The model summary					Parameter estimates			
	R^2	F	df1	df2	Sig.	constant	b1	b2	b3
Quadratic	0.985	269.250	2	8	0.000	0.812	0.001	-5.302E-7	
Cubic	0.985	269.250	2	8	0.000	0.812	0.001	-5.302E-7	0.000
Power	0.608	13.971	1	9	0.005	0.781	0.038		

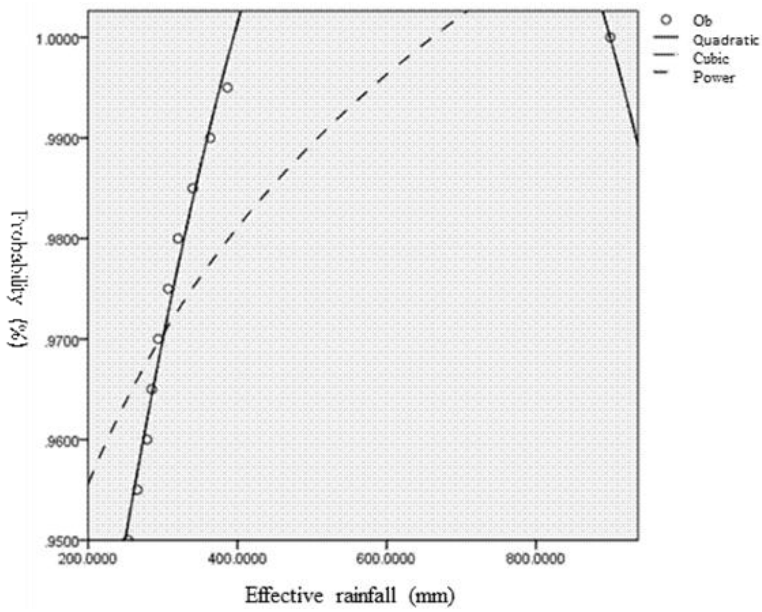

Fig. 8. Three kinds of probability fitting curve between 95% and 100%

By the analysis, the subsection Cubic fitting method is the best method in the geological disaster occurrence probability modeling, so in the next step, modeling in 9 waring areas with the subsection Cubic fitting method. But sometimes subsection quadratic fitting method also well enough in modeling.

Partition modeling

Assume in same warning area, other underlying conditions of geological disaster occurrence are similar, but precipitation as the sole determinant, so only need to focus on statistical relationship between precipitation factor and the geological disasters, and establish the geological disaster probability forecast model.

In each warning area, due to less sample contrast to whole country, so need to carry out the percentile ranking with 0.5% interval in 16-day effective rainfall, get total 200 samples to simulate, follow the subsection fitting way, fitting by Quadratic terms, Cubic, the Power function fitting methods. In all warning area, Cubic fitting is the best one in fitting, and second is the Quadratic terms fitting, the value of subsection point is not same in each warning area. The selection of subsection point is decided by subjective judgement, observing the overall sample fitting curve form, and to choose the point in most different fitting curve part. In this way, eventually have 18 built subsection fitting equations in 9 warning areas, basically Cubic fitting equations, that can calculate geological disaster occurrence probability by given 16-day effective rainfall.

Then, for example, choose Yungui plateau and Southeastern region to simulate analysis. Yungui plateau region were extracted 3148 effective rainfall samples, rainfall values range from 0.01 mm to 328.94 mm, at 0.5% intervals percentile sorting, sort out 200 sample points to simulate by Quadratic terms, Cubic, the Power function fitting methods. In the results, the R^2 in Cubic fitting is the greatest (R^2=0.996) and simulation is best, but the fitting curve has more difference in the point of 92.5% (corresponding effective rainfall 114.12 mm), so choose the point to divide into 0.5%-92.5% and 93%-100% sequences to simulation again, at last, as Fig. 9 shown, in the previous sequence, Quadratic terms fitting effect is best and R^2=0.997; in the second sequence, Cubic fitting effect is best and R^2=0.999.

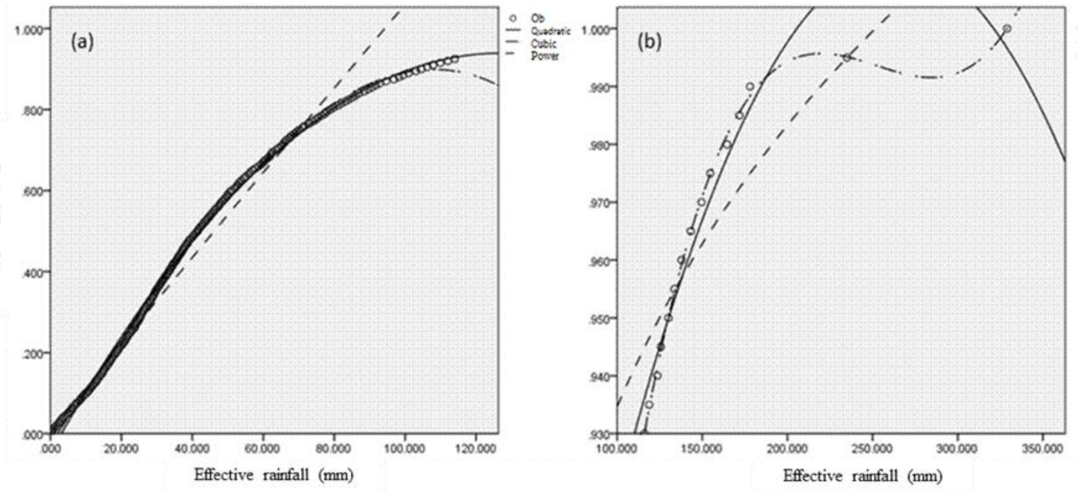

Fig. 9. Three kinds of Probability piecewise fitting curve in Yungui plateau region (a) 0.5% - 92.5%, (b) 92% - 100%

Therefore, according to division value 114.12 mm of 16-day effective rainfall, constructs two fitting equations in Yungui plateau region:

$$P_{13} = -0.047 + 0.0156x - 6.131x^2 \times 10^{-5},\ \mathrm{x} \leq 114.12, \tag{2}$$

$$P_{14} = 0.531 + 0.0057x - 2.295x^2 \times 10^{-5} + 3.033x^3,\ x \leq 114.12, \tag{3}$$

where P_{13} and P_{14} are geological disaster occurrence probability, x is 16-day effective rainfall.

Southeastern region was extracted 2202 effective rainfall samples, rainfall values range from 0.03 mm to 899.58 mm, at 0.5% intervals percentile sorting, sort out 200 sample points to simulate by Quadratic terms, Cubic fitting methods. In the results, the R^2 in Cubic fitting is the greatest (R^2=0.993) and simulation is best, but the fitting curve has more difference in the point of 81.5% (corresponding effective rainfall 182.33mm), so choose the point to divide into 0.5%-81.5% and 82%-100% sequences to simulation again, at last, as Fig. 10 shown, in both sequences, Cubic fitting effect is best and first sequence, R^2=1, in the second sequence, R^2=0.999.

Therefore, according to division value 182.33 mm of 16-day effective rainfall, constructs two fitting equations in southeastern region:

$$P_{17} = 0.001457 + 0.00933x - 4.052x^2 \times 10^{-5} + 7596x^3 \times 10^{-8},\ x \leq 182.33, \tag{4}$$

$$P_{18} = 0.34437 + 0.003716x - 6.807x^2 \times 10^{-6} + 3.875x^3 \times 10^{-9},\ x \leq 182.33, \tag{5}$$

where P_{17} and P_{18} are geological disaster occurrence probability, x is 16-day effective rainfall.

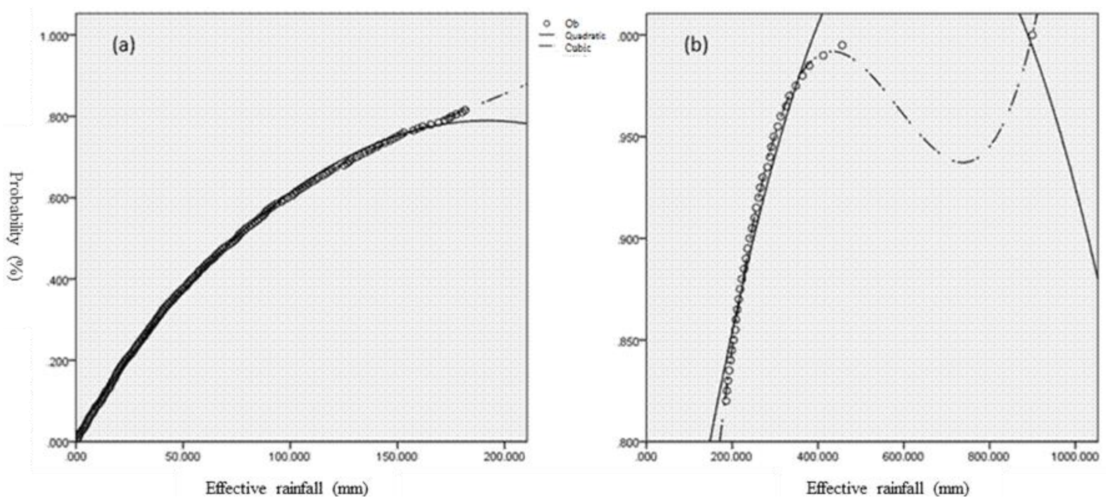

Fig.10 Three kinds of Probability piecewise fitting curve in Southeast China (a) 0.5% -81.5%, (b) 82% - 100%

Critical rainfall

Due to the geological disaster potential risk has very little temporal and spatial variation, can be used as a static background in the warning business of geological disaster forecast, but precipitation is the dynamic change of every day. So mainly consider dynamic precipitation induced geological disaster, regard high probability effective rainfall is high risk critical rainfall. In practice, when the geological disaster occurrence probability of 20%, 40%, 60%, 80%, it corresponds effective rainfall, and regarded as critical rainfall, and corresponding as blue, yellow, orange, red alert critical rainfall (Table 4). Because effective rainfall is the sum of the disaster day rainfall and antecedent rainfall, therefore critical rainfall criterion is a dynamic change, for the same forecast station (warning), in the case of it will be rain in the 2 days, today and tomorrow the same warning level are needed different precipitation. In actual situation, same warning area has different precipitation distribution in same period, so if forecast same precipitation in all region, the forecast stations have different warning level distribution. So, in business, forecaster may calculate for 1-100% probability of effective rainfall in warning area, combined to business reference table, and then calculate 15 days effective rainfall in forecast sites, then only need to focus on 24h precipitation forecast, look-up table, and can quickly get the probability value of forecast site and judge the geological disaster meteorological warning level, the judgement operation of warning level is simple and quick, correction is relatively easy.

Table 4. Critical warning values of effective rainfall

Warning Level	**Regions**								
	Northwest	**North east**	**Tibetan plateau**	**Loess plateau**	**Qinling and Dabashan**	**North China**	**Yungui plateau**	**South-central**	**Southeast**
Blue	1.8	10.9	11.3	5.1	15.0	10.6	18.8	15.8	23.6
Yellow	4.9	25.9	18.4	12.1	34.1	26.8	33.6	34.2	54.8
Orange	11.3	47.4	26.2	20.4	61.5	57.6	51.4	65.5	99.7
Red	21.7	98.7	39.5	40.2	104.4	138.6	79.2	122.9	175.7

Model test

In the case test in all warning regions, selected totally 172 geological disasters as test samples in April to October, 2015, those disasters both caused directly economic loss and casualties. To extract daily precipitation of weather station nearby disaster, calculate 16 days effective rainfall, according to table 4 discriminant warning level and analyze model forecast performance (Table 5). Analysis results show that the model in blue and the above levels forecast 152 times, accounting for 88.4% of the total samples, percentage of yellow, orange and red warning prediction respectively is 17.4%,30.8% and 26.2%, and the yellow and above levels successful prediction ratio over 74.4%, it's proof that the effective rainfall probability model has a good reference.

Table 5. Forecast times and proportions of different geological disaster warning level

Warning levels	**No warning**	**Blue**	**Yellow**	**Orange**	**Red**	**Blue and above levels**	**Yellow and above levels**	**Orange above level**
times	20	24	30	53	45	152	128	98
Ratio/%	11.6	14.0	17.4	30.8	26.2	88.4	74.4	57.0

The other case test is located in Jiangxi province of the Southeast region, there had heavy rainfall in the south-central of Jiangxi province between May 18-20, 2015, the process accumulation rainfall of Xingguo, Yudu and Shicheng counties are more than 100 mm, north and central part of Xingguo county reached 200-497mm, the heaviest rainfall time mainly among the night of 18 to the day time of 19.

Influenced by the heavy precipitation process, Xingguo, Yudu and Shicheng counties was appeared a lot of geological disasters. Through disaster survey and field investigation, a total of 1806 geological disasters with detail latitude and longitude and occurrence time accurate to hours, are collected. By occurrence time, to extract hourly precipitation in 16 days from automatic meteorological station nearby disaster, and finally get 645 effective rainfall test samples.

According to the early warning critical rainfall of southeast region, combined with effective rainfall of disasters, discriminant early warning level, and to analyze model prediction performance (Table 6), found that the model in blue warning accounted for 11% of the total number of forecast, percentage of yellow, orange and red warning prediction respectively is 18%,42% and 33.3%, the yellow and above levels successful prediction ratio over 87.3%, only 1.7% disasters did not identify. The model criterion effect is good and strong prediction ability.

Table 6 Forecast times and proportions of geological disaster risk

Warning levels	**No warning**	**Blue**	**Yellow**	**Orange**	**Red**
times	11	72	78	275	218
Ratio/%	1.7	11.0	18.0	42.0	33.3

EC numerical model in the process of the precipitation forecast in Xingguo, Yudu and Shicheng counties is generally medium to heavy rain, less one magnitude than real rainfall, even less than two orders of magnitude, precipitation numerical model have modest forecast effects. By the EC's precipitation forecast and 15days effective rainfall, to judge the early warning level of samples, and forecast level basically to blue level, a few to yellow level and seldom to orange level.

Summary

By the study of geological disaster potential risk zoning, induced factor analysis and selection, modeling, and the critical rainfall, the article gets the following conclusion:

a) It can be divided into 9 early warning regions by geological disaster potential risk zoning.
b) The factor of geological disaster induced by precipitation is effective rainfall.
c) In the simulation of effective rainfall probability, the subsection Cubic fitting method is the best, and establish geological disaster occurrence probability model
d) The case tests verify critical rainfall which draw by geological disaster occurrence probability model, determine early warning level method is simple, easy to operate, and practical with high waring accuracy.

In addition, 9 warning regions isn't enough in research, need further refinement of partitions, to establish forecast equations, and next step, explore double factors forecast model with the geological disaster potential risk degrees and effective rainfall factor, to judge the geological disaster meteorological warning level more reasonable and comprehensive.

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