Three progresses reachhed in China during this joint project

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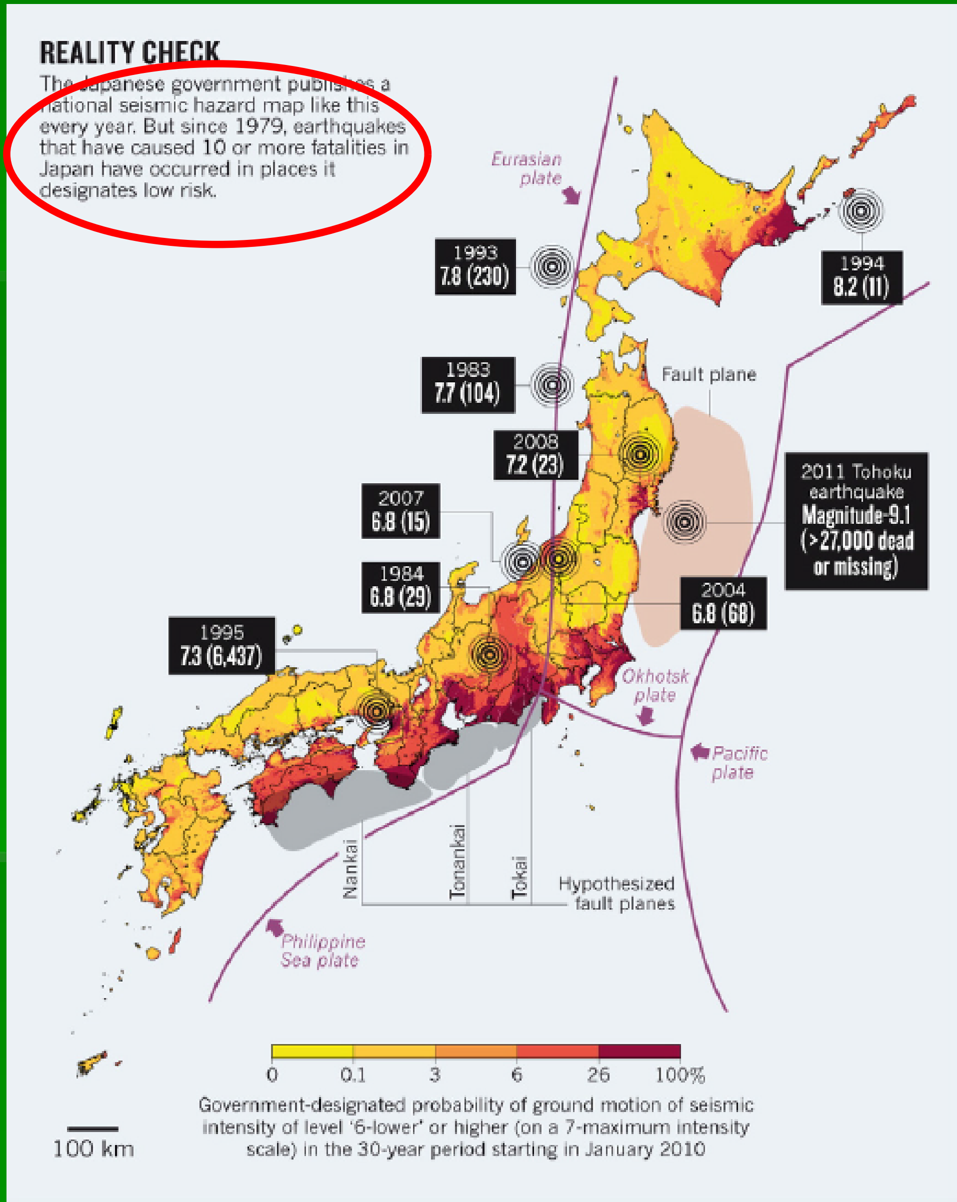
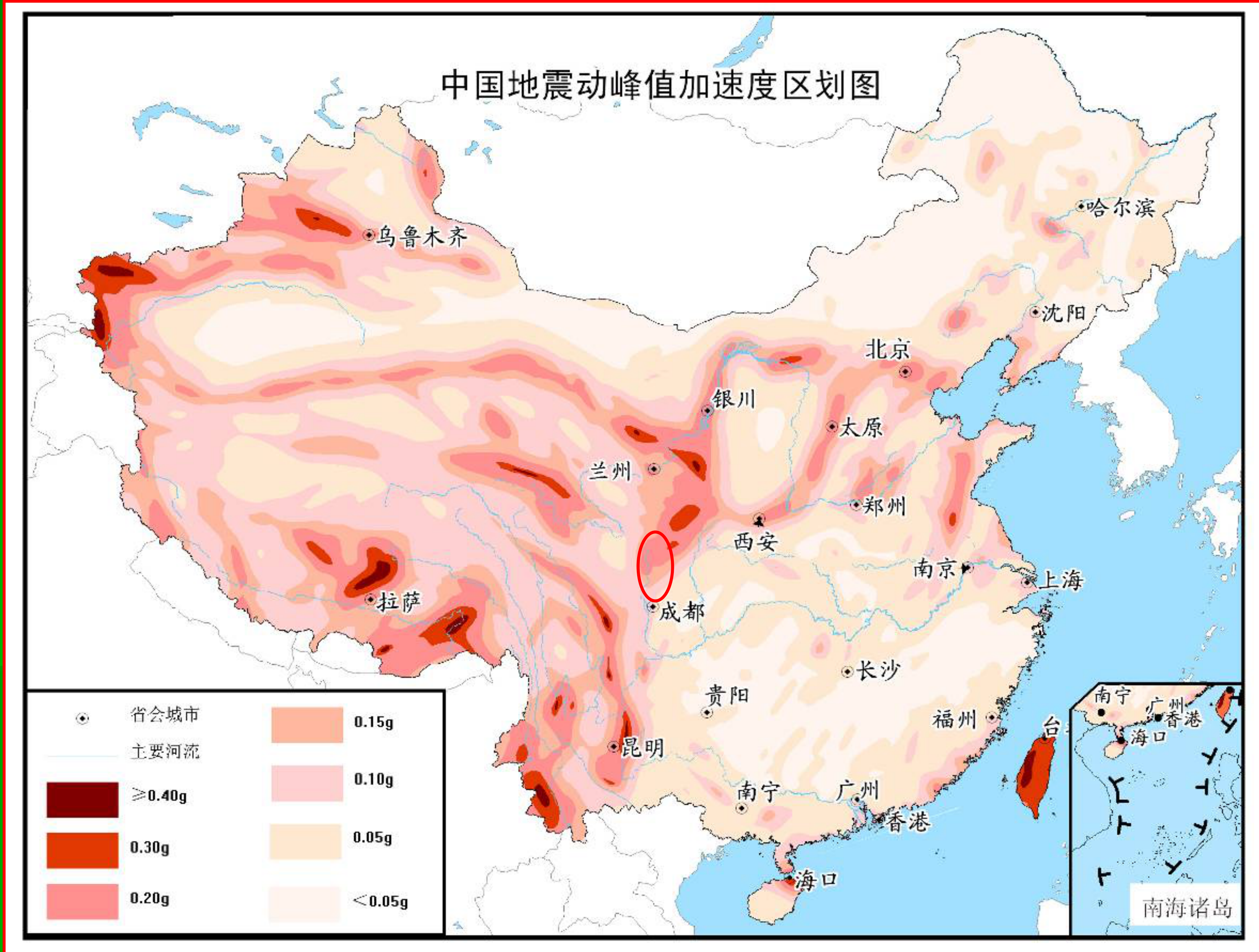
Sendai

- The state-of-the-art of probabilistic Seismic Hazard Assessment (PSHA) in the three countries as well in the world is reviewed.
- We reach a common view to PSHA and the hazard map that in some cases earthquake hazard maps have done well at predicting the shaking from a major earthquake; in other cases they have done poorly.
- Wenchuan earthquake of China on May 12, 2008; Tohoku earthquake of Japan on March 11, 2011: are both very bad examples.


REALITY CHECK
The Japanese government publishes a national seismic hazard map like this every year. But since 1979, earthquakes that have caused 10 or more fatalities in Japan have occurred in places it designates low risk.
Eurasian plate
1993 7.8 (230)
1994 8.2 (11)
1983 7.7 (104)
Fault plane
2008 7.2 (23)
2011 Tohoku earthquake Magnitude-9.1 (>27,000 dead or missing)
2007 6.8 (15)
1984 6.8 (29)
2004 6.8 (68)
1995 7.3 (6,437)
Okhotsk plate
Pacific plate
Nankai
Tonankai
Tokai
Hypothesized fault planes
Philippine Sea plate
0 0.1 3 6 26 100%
Government-designated probability of ground motion of seismic intensity of level '6-lower' or higher (on a 7-maximum intensity scale) in the 30-year period starting in January 2010
100 km



中国地震动峰值加速度区划图
乌鲁木齐
哈尔滨
沈阳
北京
银川
太原
兰州
郑州
西安
南京
上海
成都
拉萨
长沙
贵阳
福州
昆明
台
南宁
广州
香港
海口
南海诸岛
省会城市
主要河流
≥0.40g
0.30g
0.20g
0.15g
0.10g
0.05g
<0.05g

Review Article

Why earthquake hazard maps often fail and what to do about it

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A B S T R A C T

The 2011 Tohoku earthquake is another striking example – after the 2008 Wenchuan and 2010 Haiti earthquakes – of highly destructive earthquakes that occurred in areas predicted by earthquake hazard maps to be relatively safe. Here, we examine what went wrong for Tohoku, and how this failure illustrates limitations of earthquake hazard mapping. We use examples from several seismic regions to show that earthquake occurrence is typically more complicated than the models on which hazard maps are based, and that the available history of seismicity is almost always too short to reliably establish the spatiotemporal pattern of large earthquake occurrence. As a result, key aspects of hazard maps often depend on poorly constrained parameters, whose values are chosen based on the mapmakers' preconceptions. When these are incorrect, maps do poorly. This situation will improve at best slowly, owing to our limited understanding of earthquake processes. However, because hazard mapping has become widely accepted and used to make major decisions, we suggest two changes to improve current practices. First, the uncertainties in hazard map predictions should be assessed and clearly communicated to potential users. Recognizing the uncertainties would enable users to decide how much credence to place in the maps and make them more useful in formulating cost-effective hazard mitigation policies. Second, hazard maps should undergo rigorous and objective testing to compare their predictions to those of null hypotheses, including ones based on uniform regional seismicity or hazard. Such testing, which is common and useful in similar fields, will show how well maps actually work and hopefully help produce measurable improvements. There are likely, however, limits on how well hazard maps can ever be made because of the intrinsic variability of earthquake processes.

Contents

The map reflects the widespread view among Japanese seismologists that M 9 earthquakes would not occur on the Japan Trench off Tohoku (Chang, 2011; Sagiya, 2011; Yomogida et al., 2011). The largest future earthquakes along different segments of the trench there were expected to have magnitude between 7 and 8 (Fig. 2) (Earthquake Research Committee, 2009, 2010). The model assumed that different segments of the trench would not break simultaneously.

Area statistics of the Map 2001 of China

On the map / Actually occurred	Area with Intensity 0.1g or 0.15g	Area with Intensity 0.05g
Area with Intensity Ⅷ (0.2g or 0.3g) occurred	26996 km^2 0.77%	
Area with Intensity Ⅸ (0.4g or more) occurred	15042 km^2 0.43%	2822 km^2 0.22%
Total area	3509184 km^2	1274984 km^2

It seems not too bad, but more than 80000 people dead and $ billions loss caused and dozens million people homeless.

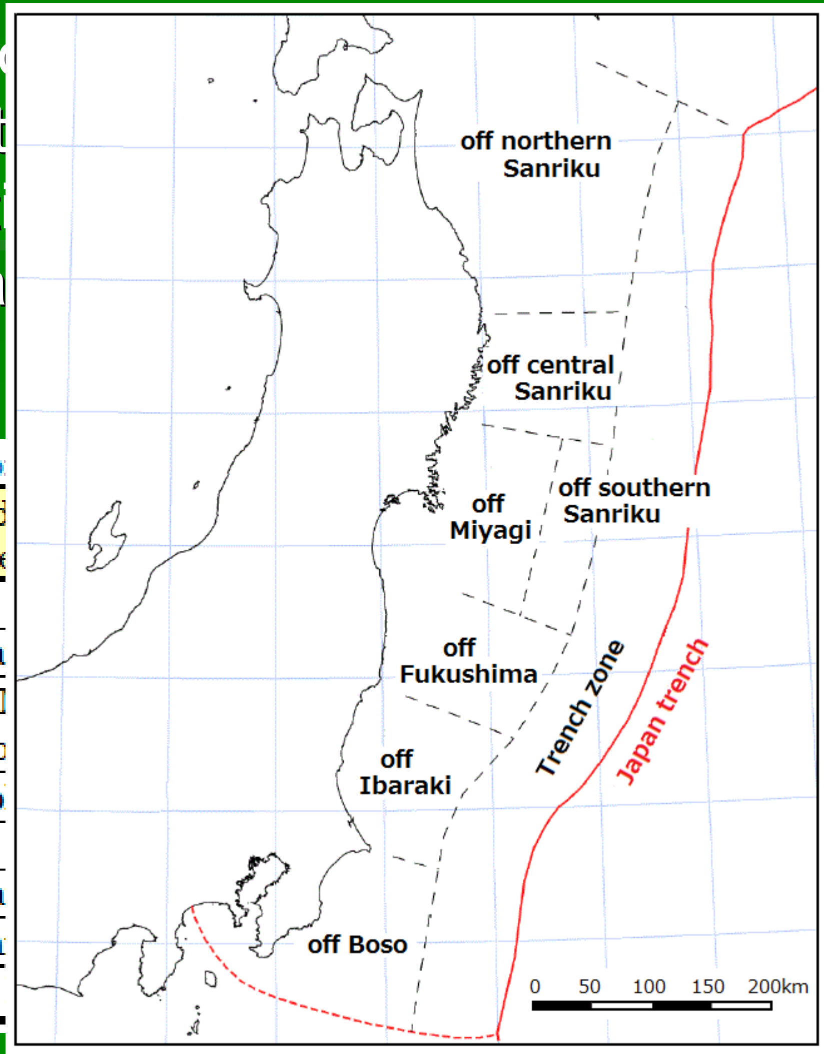
Progress 1

- The main point is to predict the future large earthquakes near big cities, especially those with magnitude more than 7.
- To predict large earthquake with magnitude 8 or more, one should watch quite large area, not from statistics in a small area.

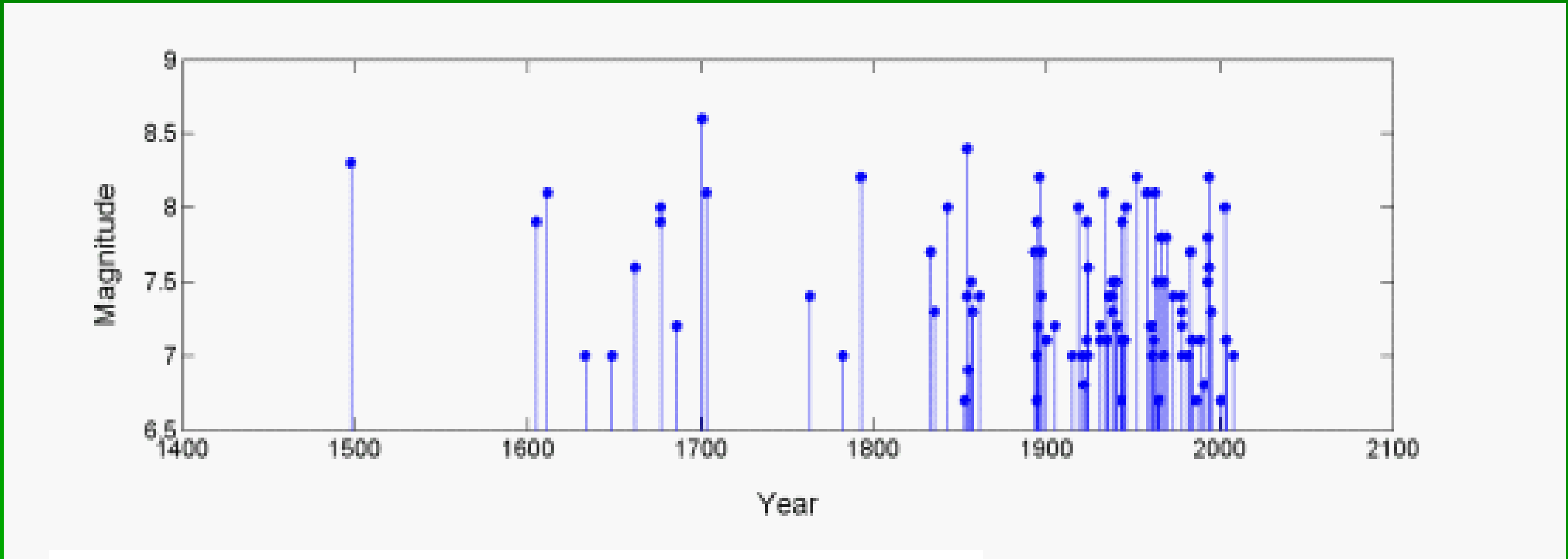
- Even in subduction zo
many earthquake dat
still not reliable if stati
in small areas such a
Sariku.

Table 1 Long-term forecast of subduction-zo

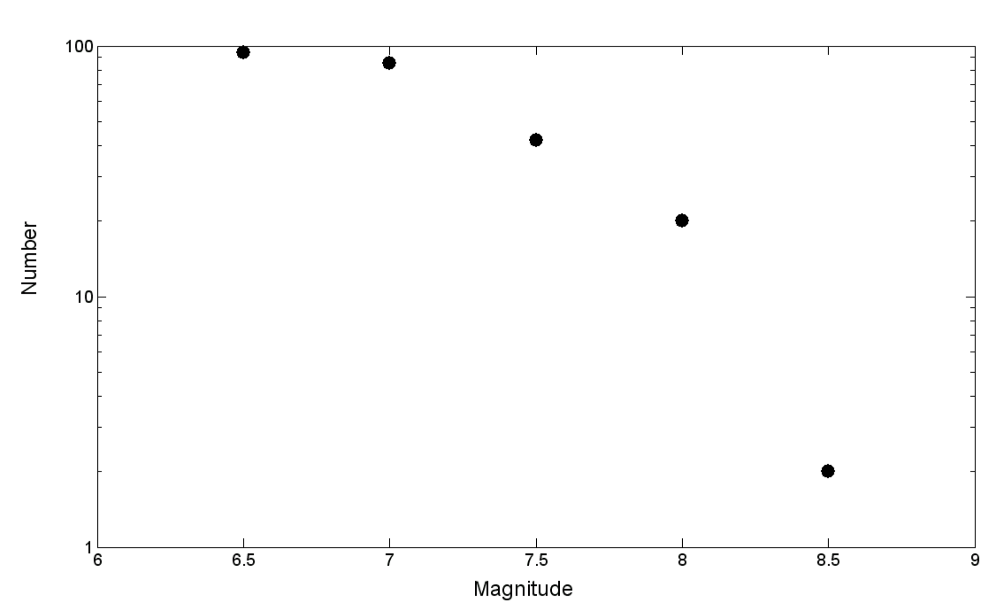
Region	Estimated magnitude	
off northern Sanriku	～M8.0	
off central Sanriku	(cannot evalua	
off southern Sanriku	～M7.7	～l
off Miyagi	～M7.5	if co
off Fukushima	～M7.4 (multip	
off Ibaraki	M6.7～M7.2	
off Boso	(cannot evalua	
Trench zone	～M8.2(Tsunam ～M8.2(Normal	



Progress 1



Magnitude
9
8.5
8
7.5
7
6.5
1400
1500
1600
1700
1800
1900
2000
2100
Year



Number
100
10
1
6
6.5
7
7.5
8
8.5
9
Magnitude

Table 2. The result of seismicity in 2008-2038 in the subduction zone

Magnitude	$7.0 \le M_j < 7.5$	$7.5 \le M_j < 8.0$	$8.0 \le M_j < 8.5$	$8.5 \le M_j$
Possibility	0.958	0.679	0.755	0.323

If the output value can be considered as possibility from the definition of 1 for at least one occurring and 0 for no one, one can see an earthquake with magnitude more than 8.5 may occur with possibility 32.3%, while the quakes in other magnitude interval may occur more possibly.

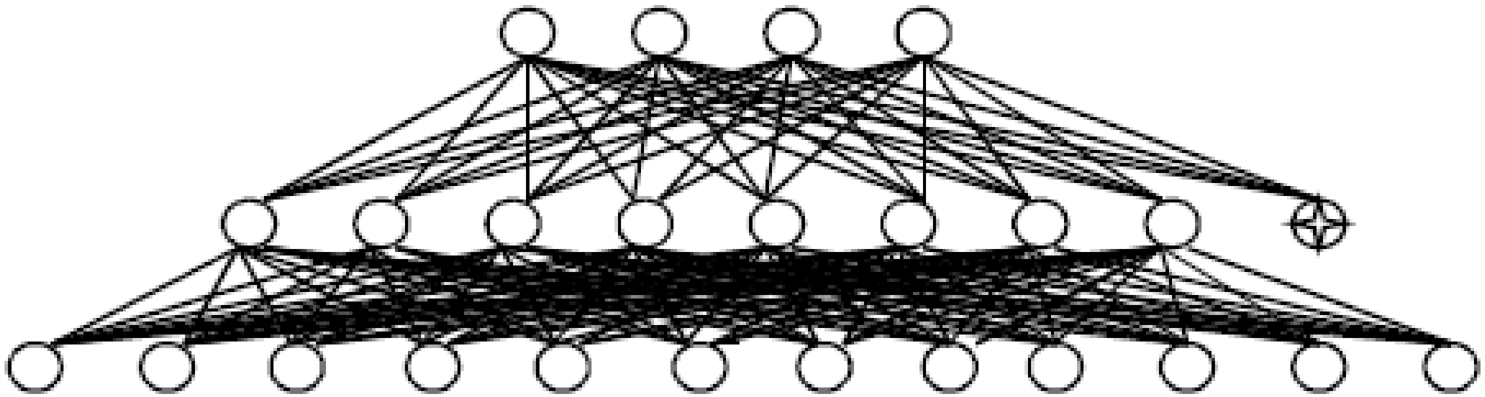


Fig. 2. Structure of the neuron network

- Chinese scientists presented a two or three rank procedure to estimate seismicity parameters in a large enough region and then assign occurrence rates to individual potential source area by weighting factors.
- Then the problem turns on the weighting, it is quite difficult to evaluate the factor values from a comprehensive understand of the earthquake occurrence from seismic, tectonic and crust dynamic evidences, and a logical approach to add up contributions of them is still required further study.

Two (three) rank potential source area delineation

- The first rank PSA, seismic province or zone, for is quite large for enough data to statistics.
- The second rank PSA evaluated with its own upper bound magnitude, to be assigned with seismicity parameters by a set of weighting factors.

$$\sum_i W_{ij} = 1.0$$

- The values of factors are evluated from a comprehensive summary

$$W_{ij} = \sum_k f_{ijk}$$

- There is a query to sum up the all factor values together.

- We are all on the way to a confident SHA, we know something on occurrence of strong earthquake, but can not really predict it in a scientific way even for long-term, that fact is the reason of a P in PSHA.
- In nature P must come from statistical data, so the most principal contradiction in PSHA comes from the detail hazard mapped for construction and development planning and quite large region for enough data.

- The ground motion attenuation in region with enough observation data, such as many regions in China, is benefited to build a relationship from small event records by earthquake observation network with validation from strong motion data of Japan.

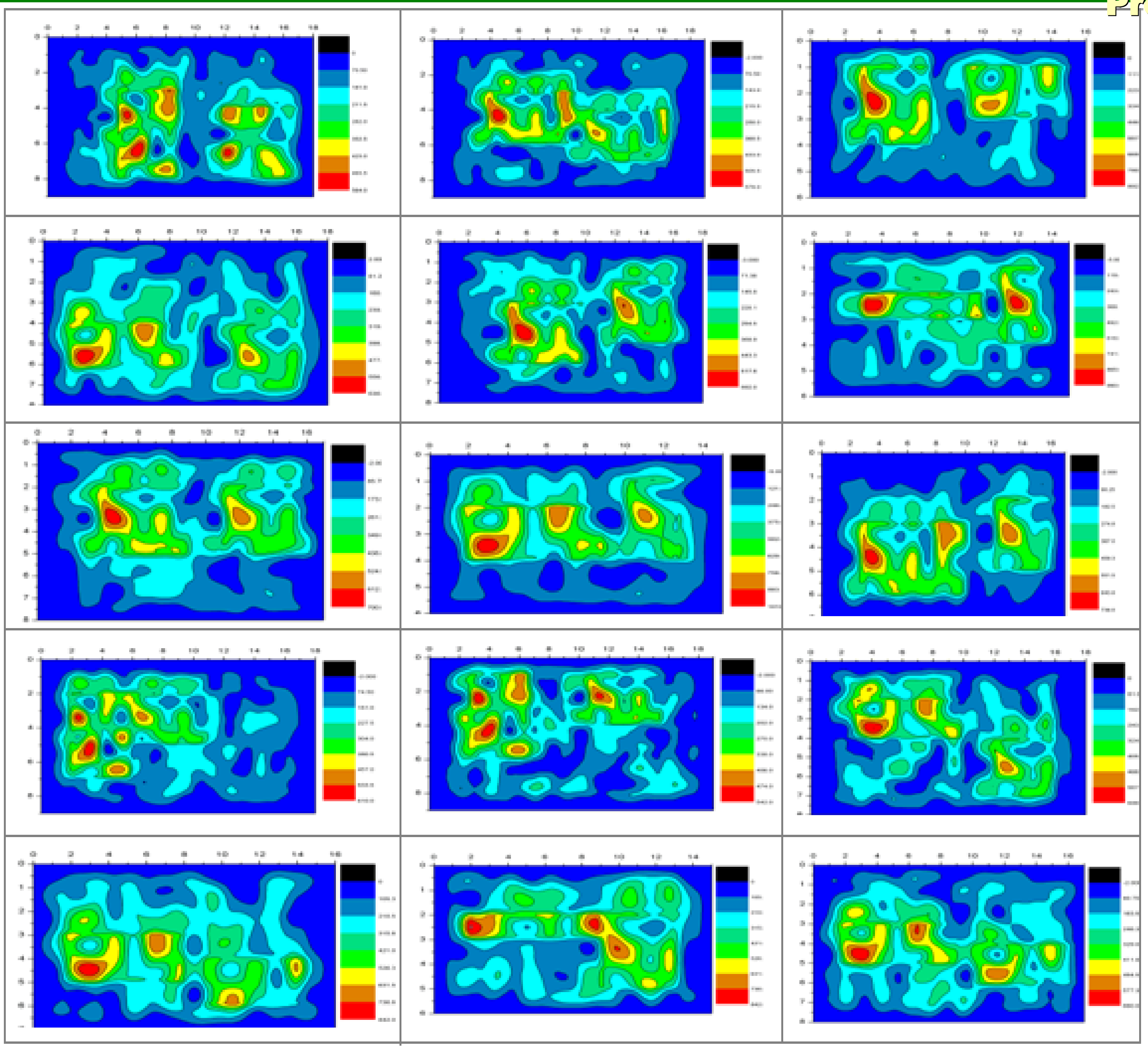
- The idea to take into the deterministic synthesis for the near field of strong earthquake in SHA is talked over during the project, and Chinese team present a procedure.
- In probabilistic seismic hazard assessment, ground motion is estimated by means of attenuation relationship that a kind of simplification, taking magnitude for source mechanism, distance for path of wave propagation, and the source is considered as a point.
- Ground motion at the near field of large earthquake must be overestimated or underestimated, since the energy from a quite large source (rupture plane) is concentrated on a point (hypocenter).

Progress 2

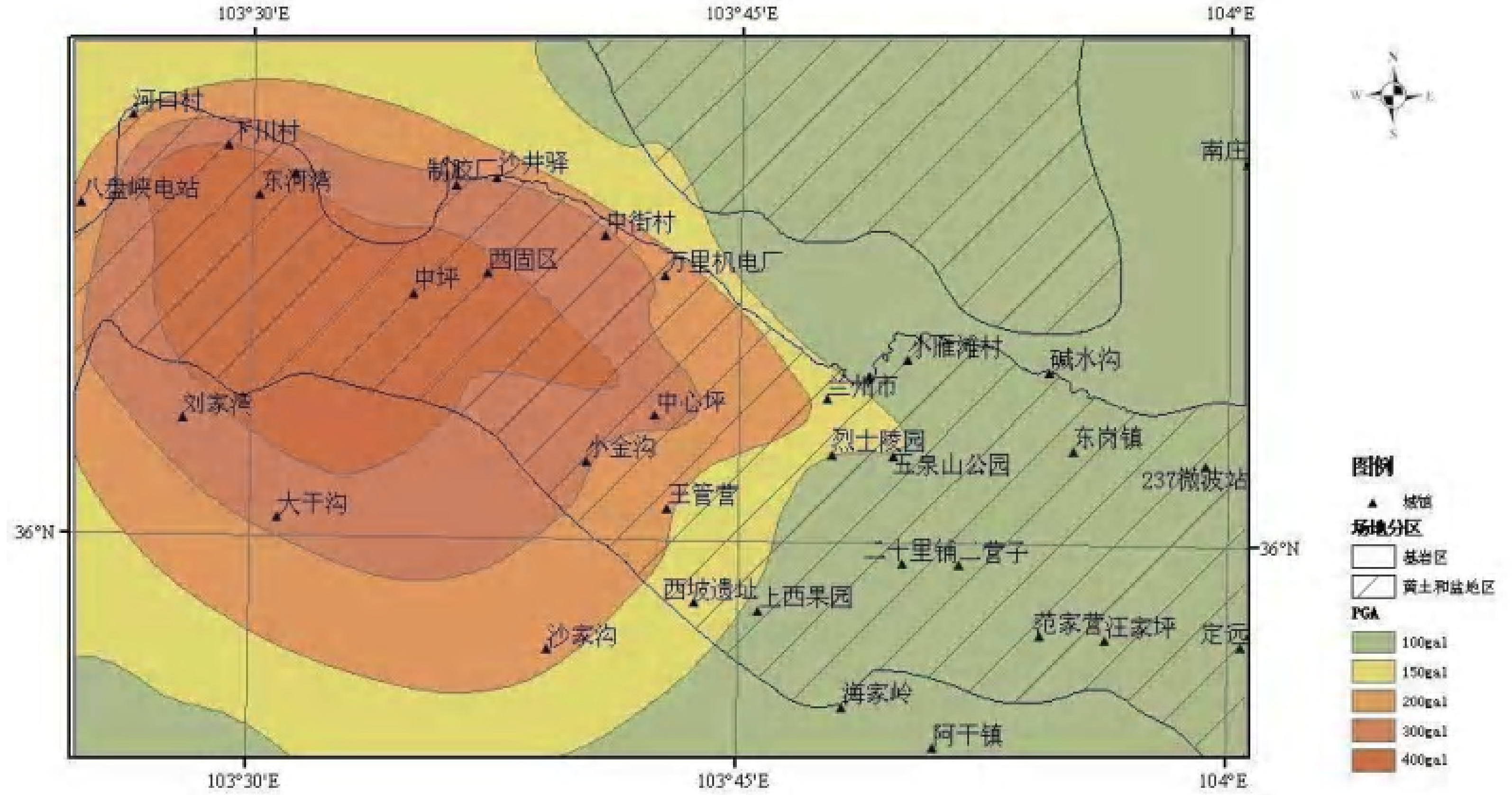
- Finite fault model is currently adopted in strong ground motion synthesis to describe near-fault rupture directivity effect and hanging wall effect which strongly influence the distribution of ground motion amplitudes on rock sites in the near fault region.
- The way to deal with a scenario earthquake is the key step to build a link between PSHA and DSHA.
- To describe the probabilistic seismic hazard of a city, scenario earthquake is widely adopted, with some strong queries, since the difference between hazard from an earthquake and that from earthquakes with various magnitudes in many areas.

潜源编号	40.00	80.00	120.00	160.00	200.00	250.00
4	0.0001					
13	0.0018					
15	0.0024	0.0005	0.0001			
16	0.0009	0.0001				
17	0.0005					
19	0.0000					
20	0.0159	0.0068	0.0034	0.0017	0.0008	0.0002
21	0.0027	0.0003				
22	0.0001					
24	0.0000					
25	0.0040	0.0008	0.0002			
29	0.0002	0.0000	0.0000			

Progress 2

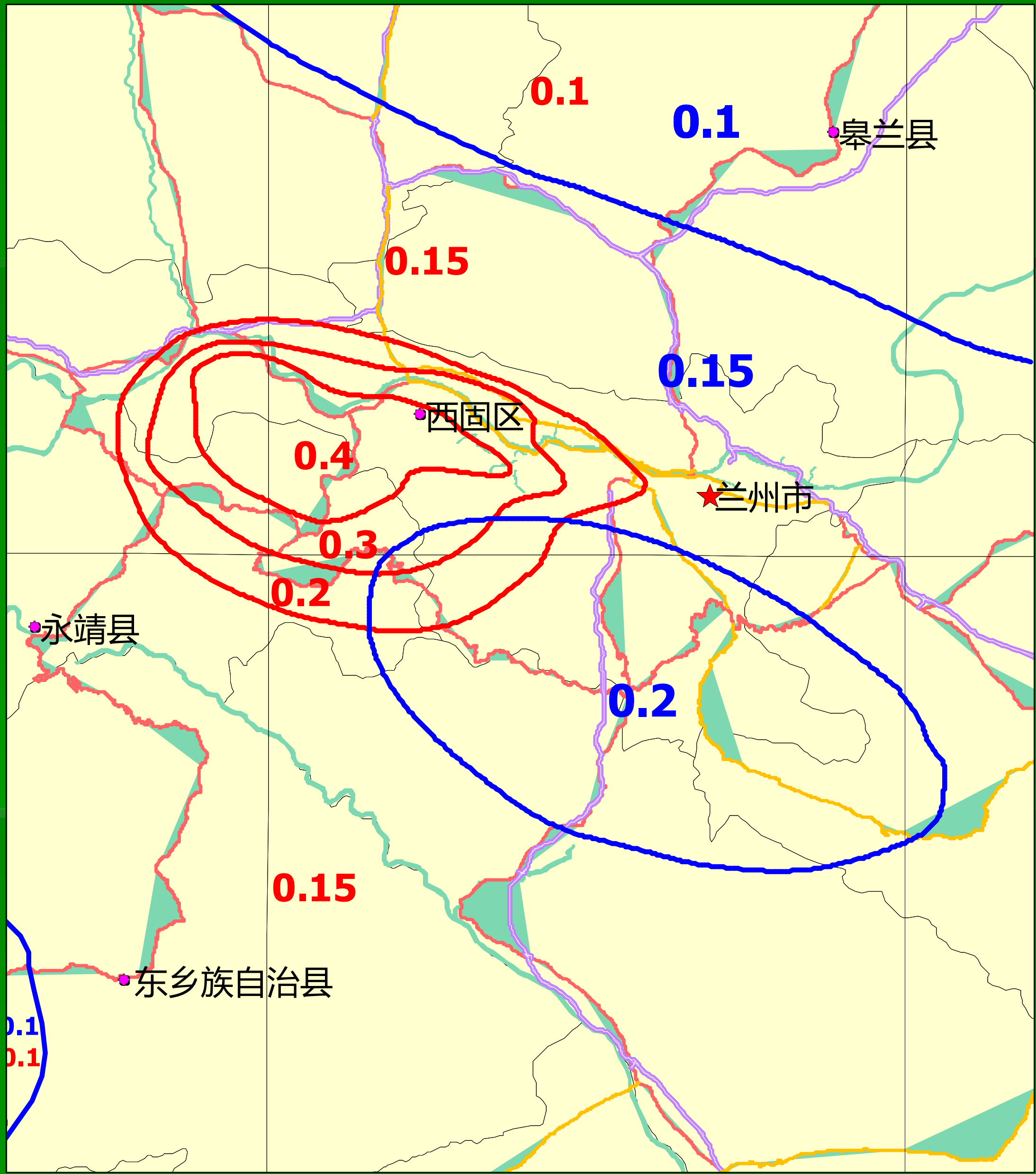


Progress 2



103°30'E
103°45'E
104°E
36°N
河口村
下川村
八盘峡电站
东河湾
制胶厂
沙井驿
中街村
西固区
中坪
万里机电厂
南庄
小雁滩村
碱水沟
兰州市
刘家湾
中心坪
小金沟
烈士陵园
五泉山公园
东岗镇
237微波站
大干沟
王管营
二十里铺
二营子
西坡遗址
上西果园
沙家沟
范家营
汪家坪
定远
满家岭
阿干镇
图例
城镇
场地分区
基岩区
黄土和盆地区
PGA
100gal
150gal
200gal
300gal
400gal

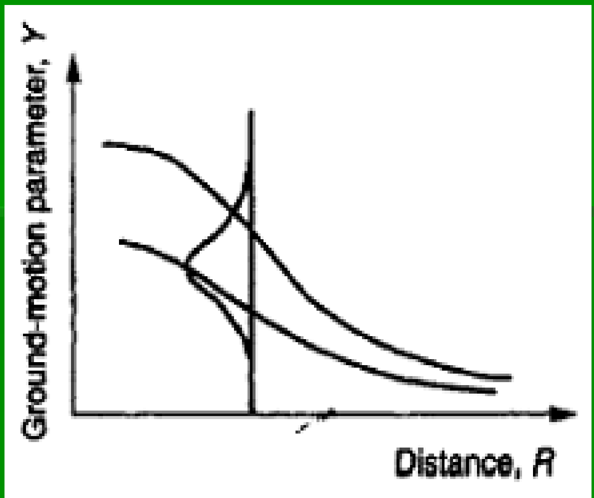
Progress 2



Uncertainty correction of seismic hazard

$$P(Y_C > y) = \int_{-3\sigma}^{3\sigma} P(Y > y \cdot e^{-\varepsilon}) \cdot f(\varepsilon) d\varepsilon$$

$$\lg Y = C_o + C_1 M + C_2 M^2 + C_3 \lg(R + C_4 e^{C_5 M}) + C_6 R + \varepsilon$$

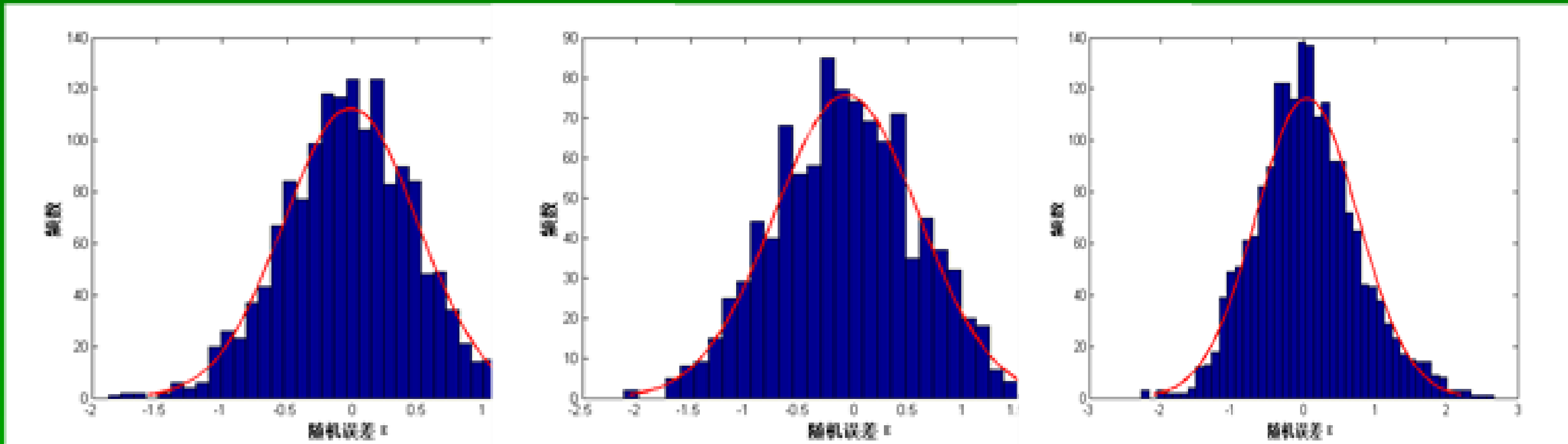


In general, the distribution is truncated at -3σ to 3σ.

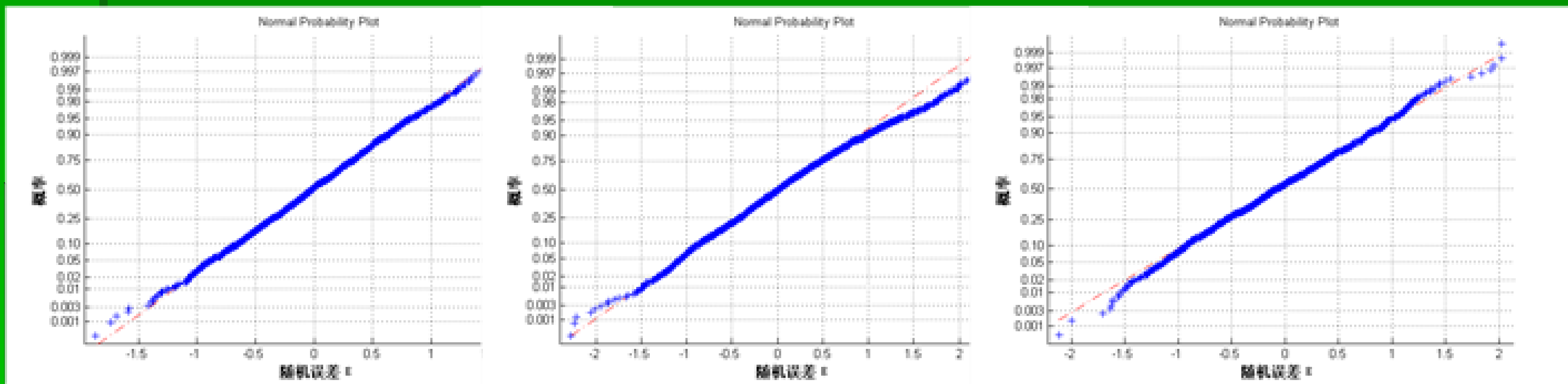
- The correction procedure is queried from the large corrected result especially at hign Intensity.

- There are some problems could be deal with in deep:
- If the truncated range could be narrowed down further?
- If the distribution depends on magnitude?
- Or if it depends on distance?
- Or if it depends on ground motion amplitude, such as PGA?
- How to improve the uncertainty correction procedure with any new findings.

Progress 3

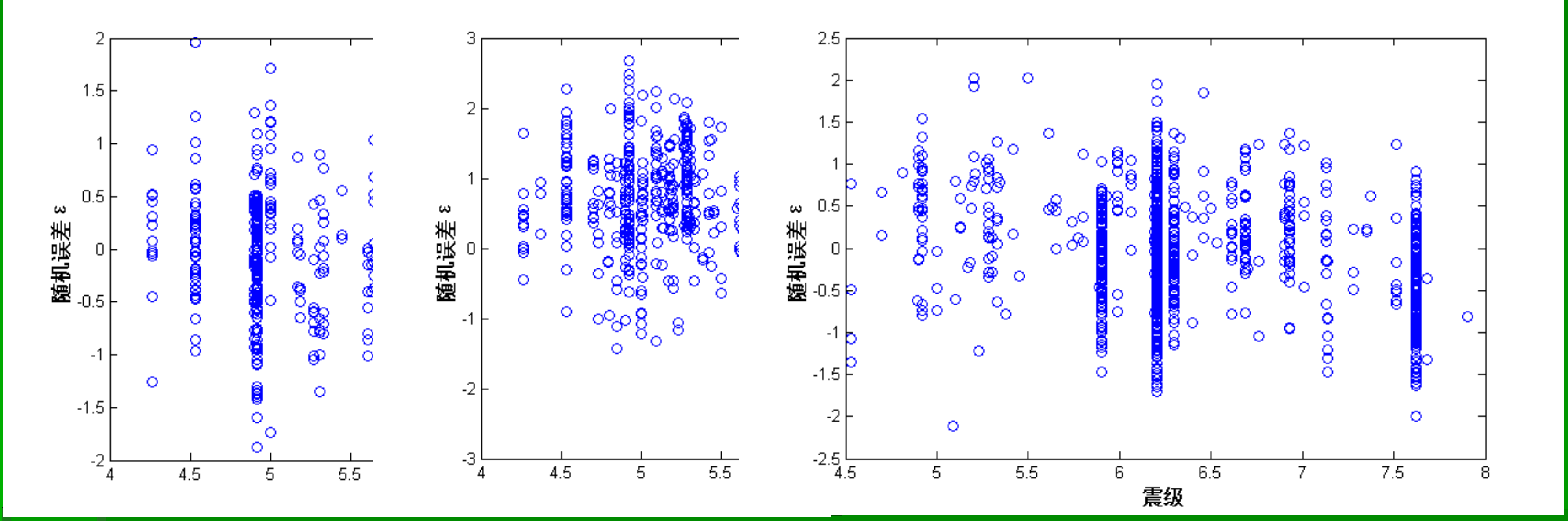


Histograms of C-B, C-y and Id relations



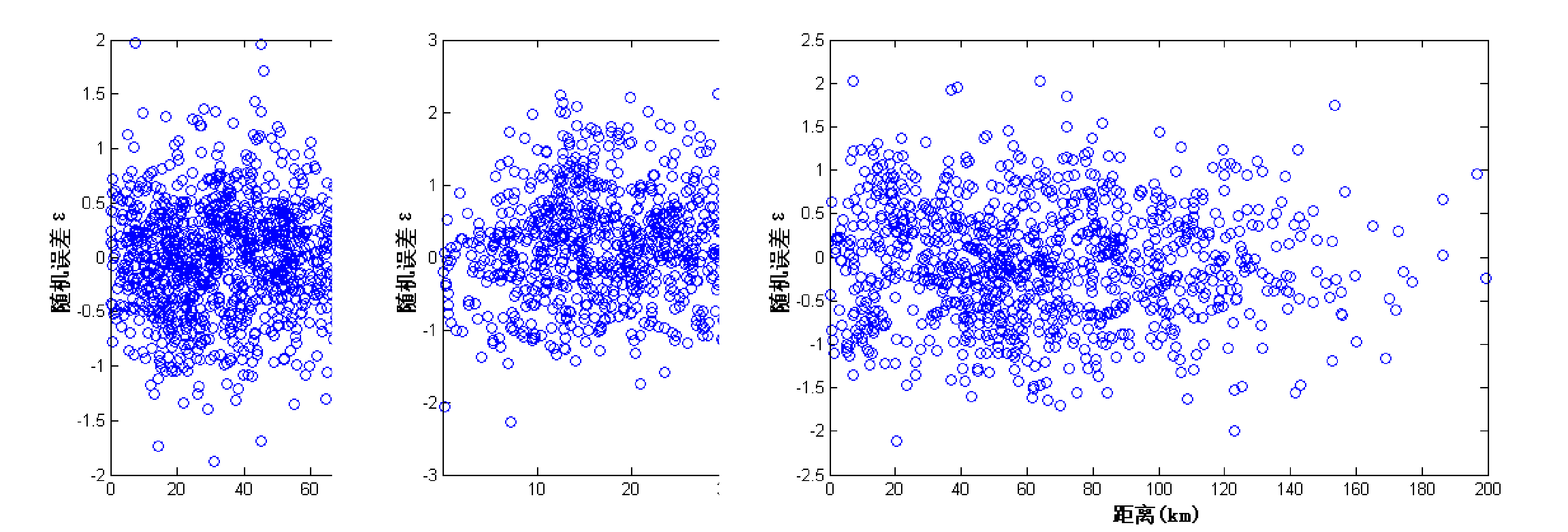
Errors from Normal distribution of C-B, C-y and Id relations

The error distribution with magnitude of C-B, C-Y and Id relation



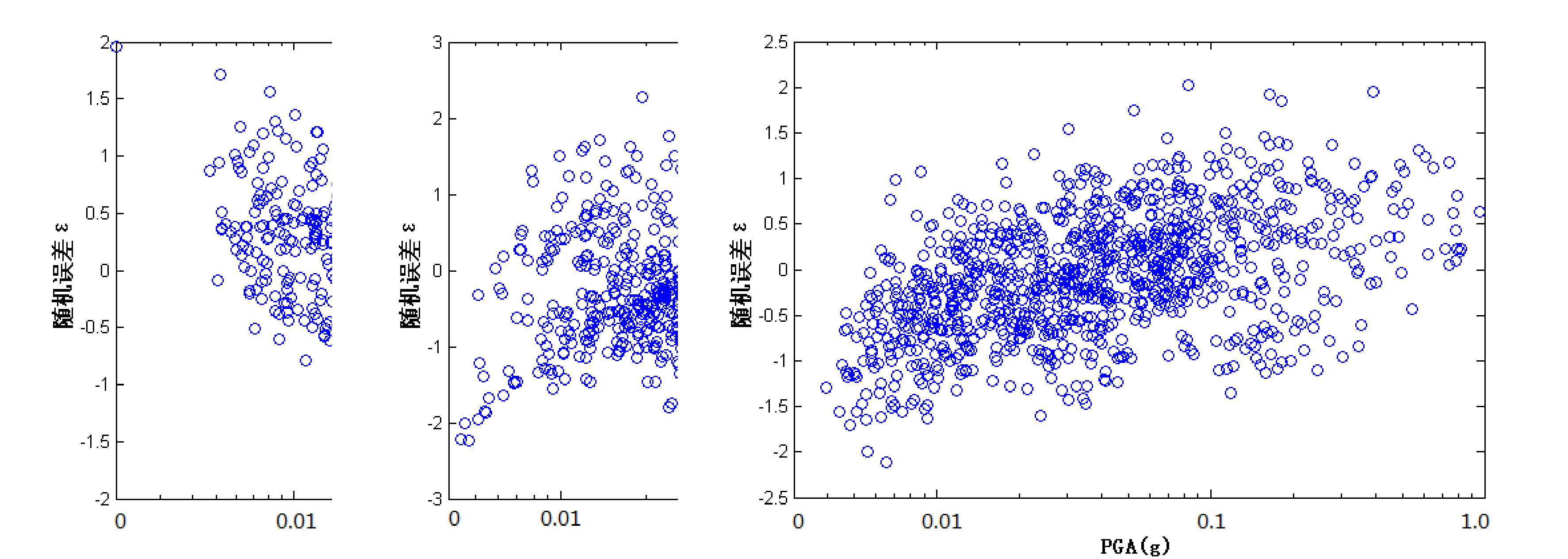
No obvious variation with magnitude

The error distribution with distance of C-B, C-Y and Id relation



No obvious variation with distance

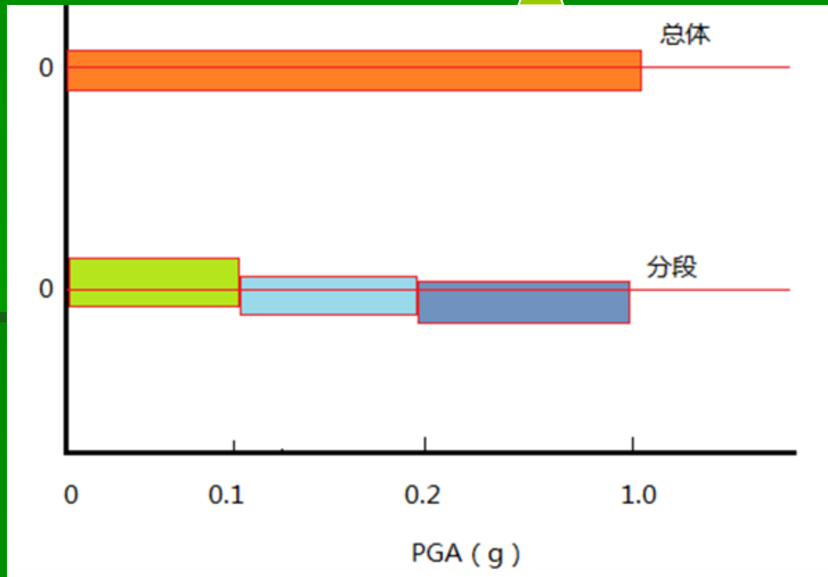
The error distribution with PGA of C-B, C-Y and Id relation



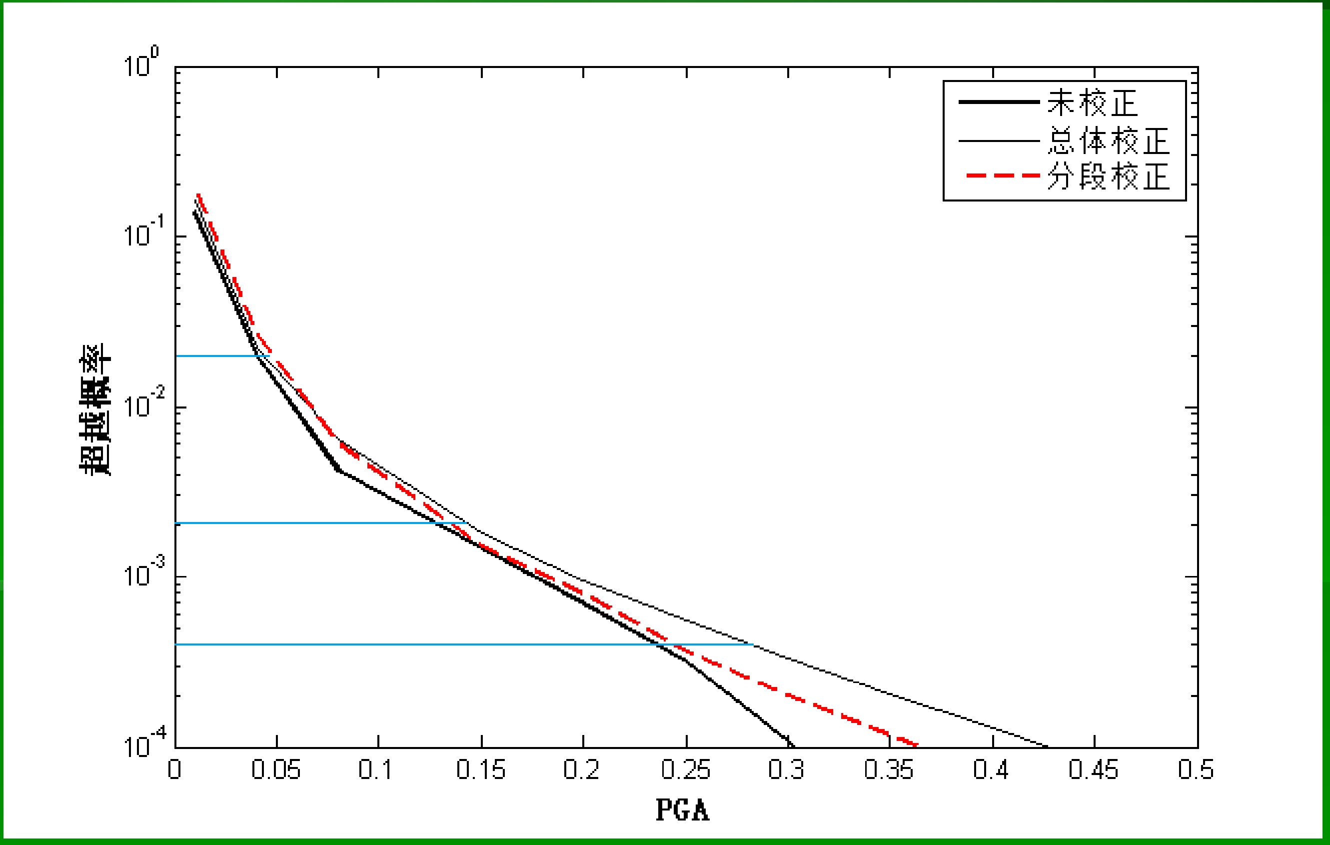
Varies with PGA, the mean decreases of C-B , but increases of C-Y and Id, while all standard deviation increase.

New correction equation with error distribution in segmentations

$$P(Y_c > y) = \int_{-3\sigma}^{3\sigma} P(Y > ye^{-\varepsilon}) f_y(\varepsilon) d\varepsilon$$

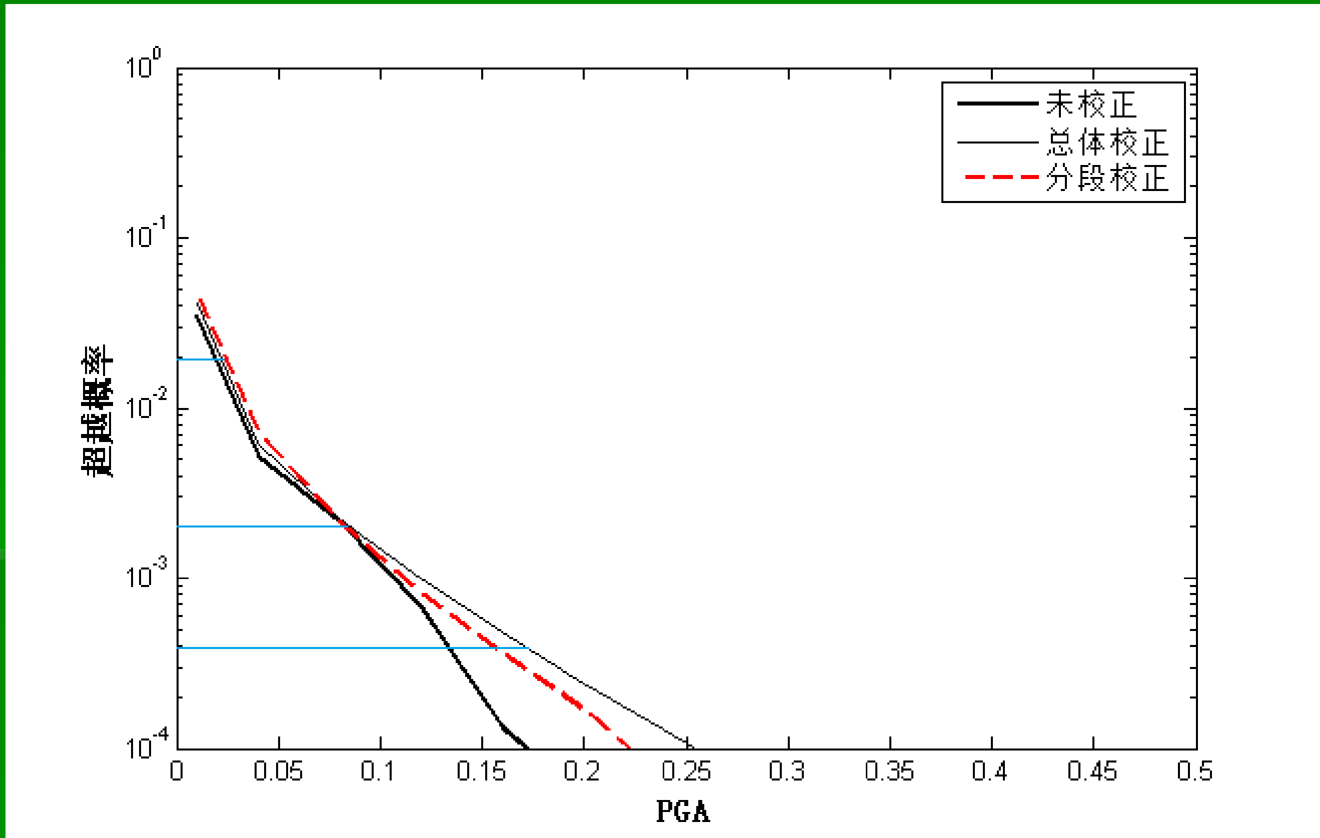


Seismic hazard curves corrected by C-B error distribution for a site with high Intensity



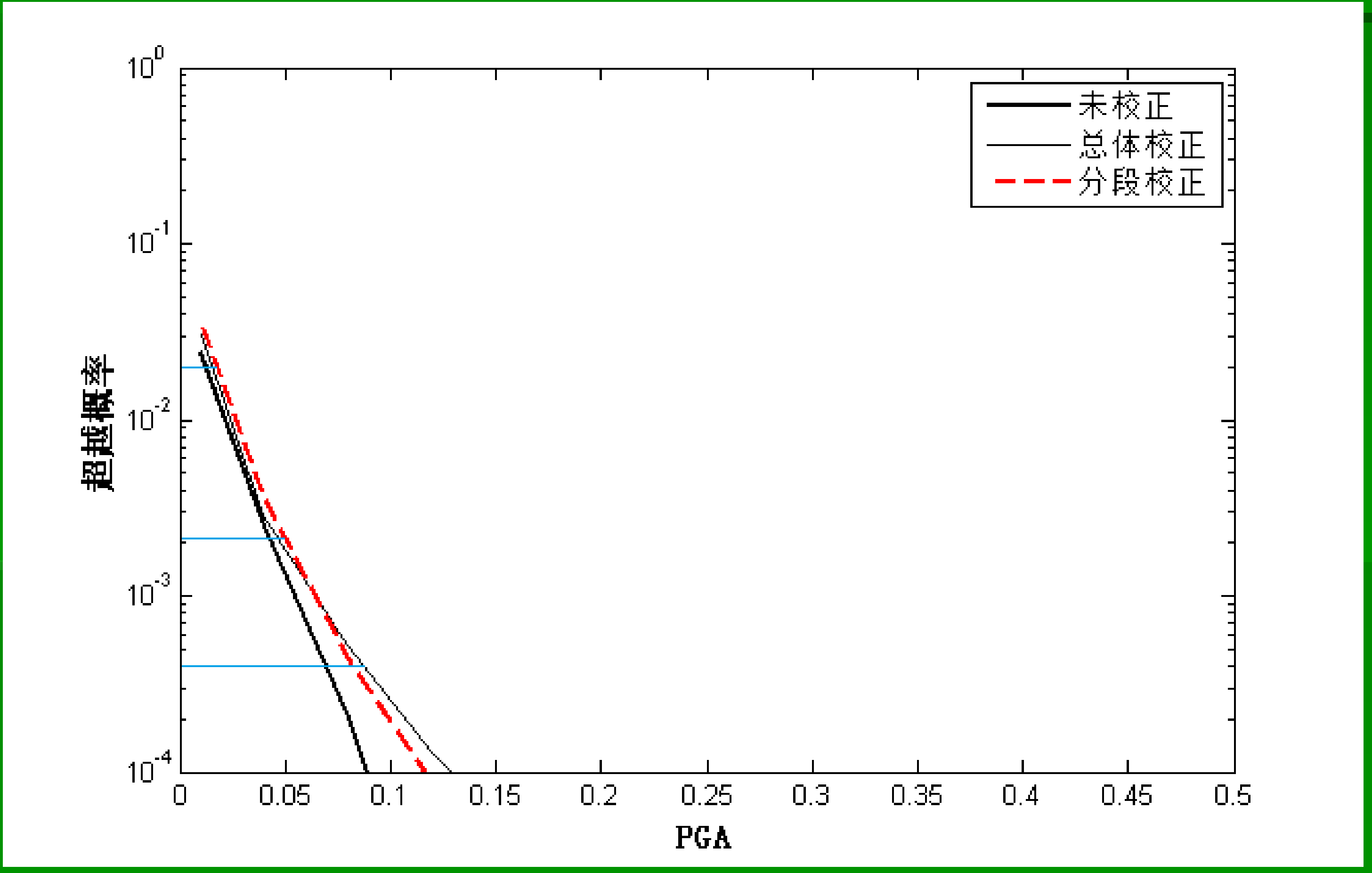
Exceeding P in 50 Yrs	63.2%	10%	2%
Uncorrected PGA	0.040	0.121	0.234
Whole corrected PGA	0.043	0.139	0.281
Segment corrected PGA	0.046	0.130	0.243

Seismic hazard curves corrected by C-B error distribution for a site with moderate Intensity



Exceeding P in 50 Yrs	63.2%	10%	2%
Uncorrected PGA	0.015	0.080	0.131
Whole corrected PGA	0.017	0.083	0.170
Segment corrected PGA	0.018	0.081	0.154

Corrected seismic hazard curves for a site with low Intensity



Exceeding P in 50 Yrs	63.2%	10%	2%
Uncorrected PGA	0.011	0.042	0.066
Whole corrected PGA	0.013	0.046	0.087
Segment corrected PGA	0.014	0.047	0.082

Acknowledgements

- We secerely thank the support by the National Nature Science Foundation of China (51178151 and 51178435), International Science & Technology Cooperation Program of China (2011DFA21460).

- The end

- Thank you for your attention！

- I am very sorry for not able to participate our important annual meeting, also not able to meet you this time.
- Hope to see you at Harbin, or somewhere in China, or somewhere in the world.
- Have a successful meeting.
- Long distance Cheers from Harbin for all of your helth!