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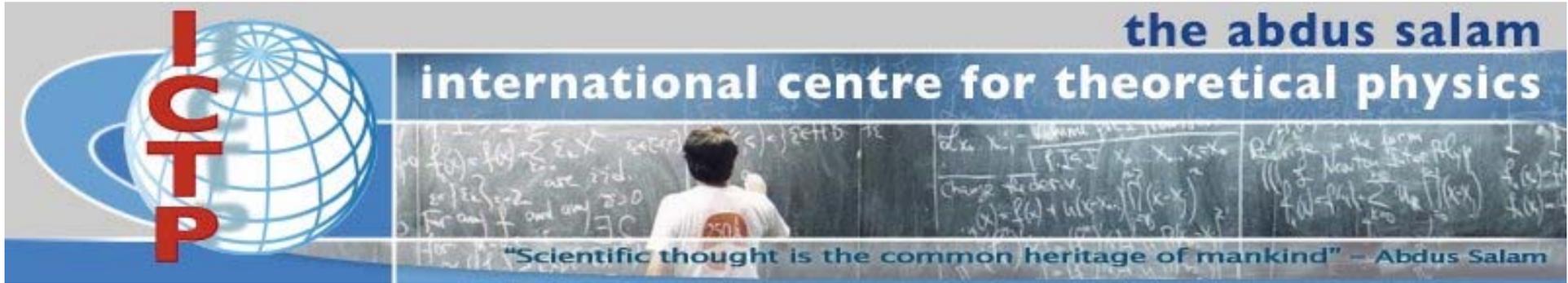
2142-11

**Advanced Conference on Seismic Risk Mitigation and Sustainable
Development**

10 - 14 May 2010

**Designing the monitoring and modeling
for the preparedness of seismic risk**

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*Institute of Geophysics
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Beijing
China*



Designing the monitoring and modeling for the preparedness of seismic risk

Lessons learnt from the
May 12, 2008 Wenchuan earthquake

Wu Zhongliang

Institute of Geophysics, China Earthquake Administration

Presented at the ICTP Advanced Conference
on Seismic Risk Mitigation and Sustainable Development
Trieste, Italy, May 12, 2010



introduction

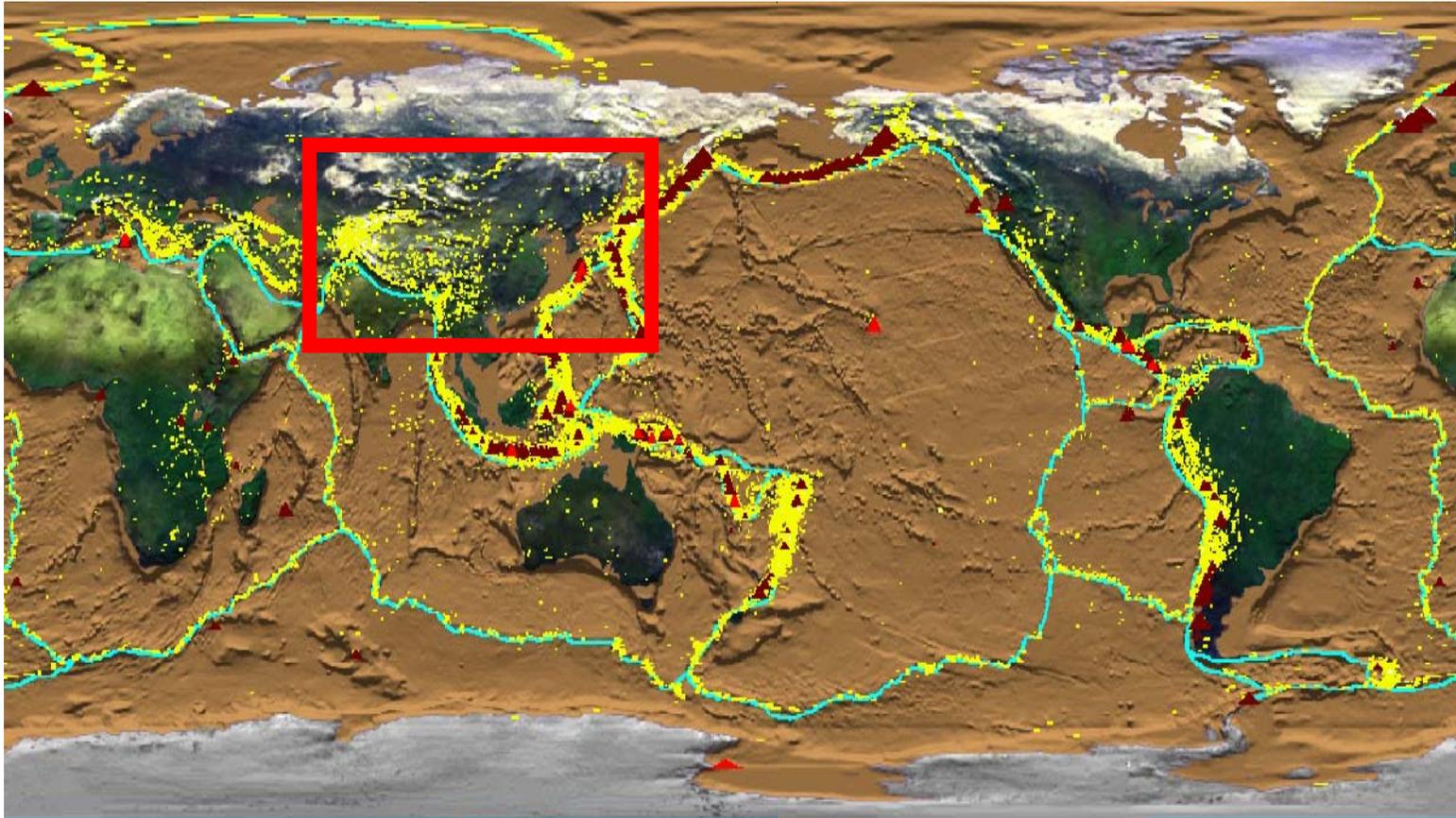
"Scientific thought is the common heritage of mankind" – Abdus Salam

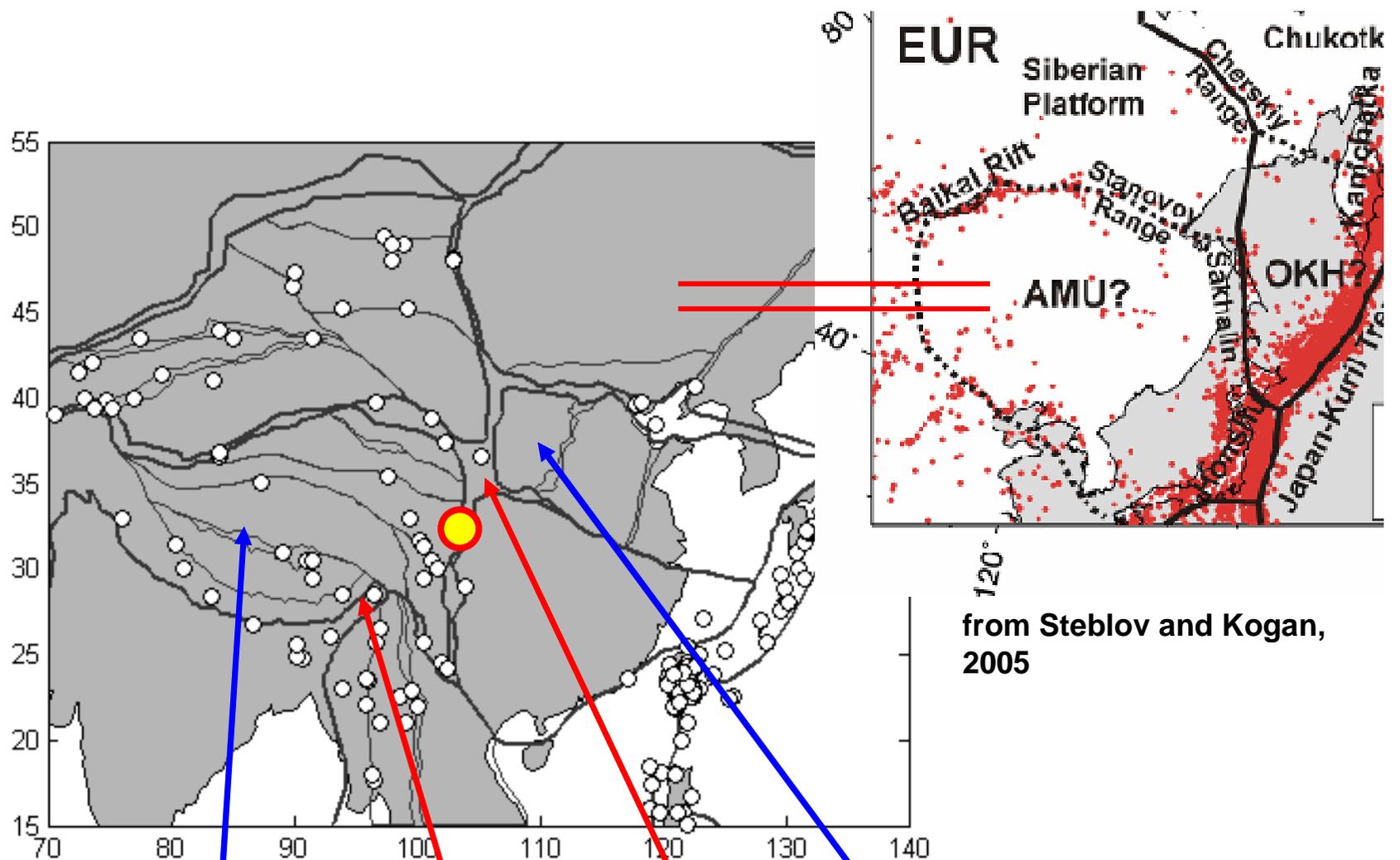
- preparedness of seismic risk includes three perspectives:
- science: monitoring and modeling for the estimation of seismic hazard
- engineering: estimation of seismic risk based on hazard and vulnerability
- management: activities planned and implemented by considering both seismic and social factors
- this talk will be focusing on the first one



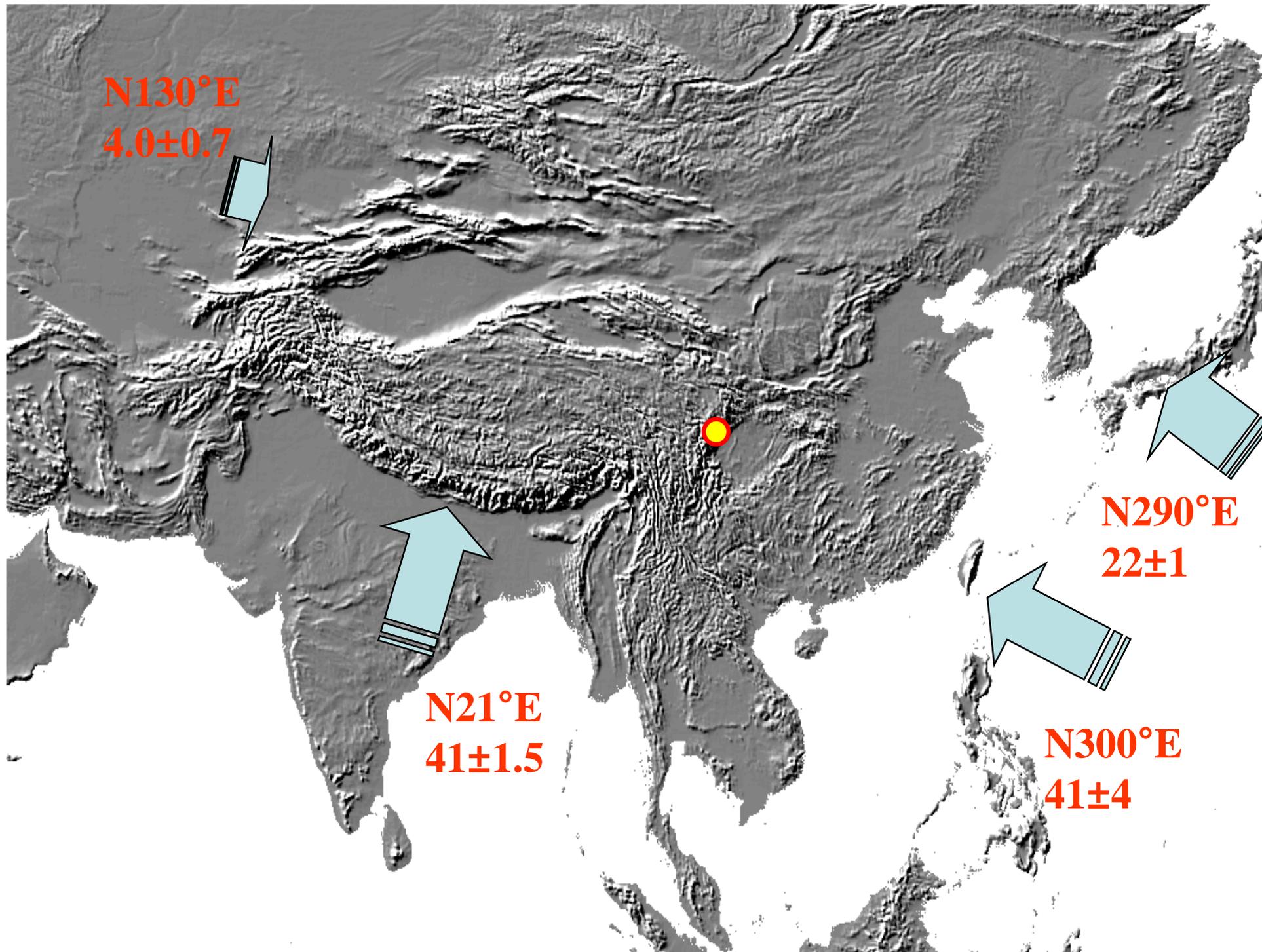
firstly
a few words about China and
about the 2008 Wenchuan earthquake

what did we see before the earthquake

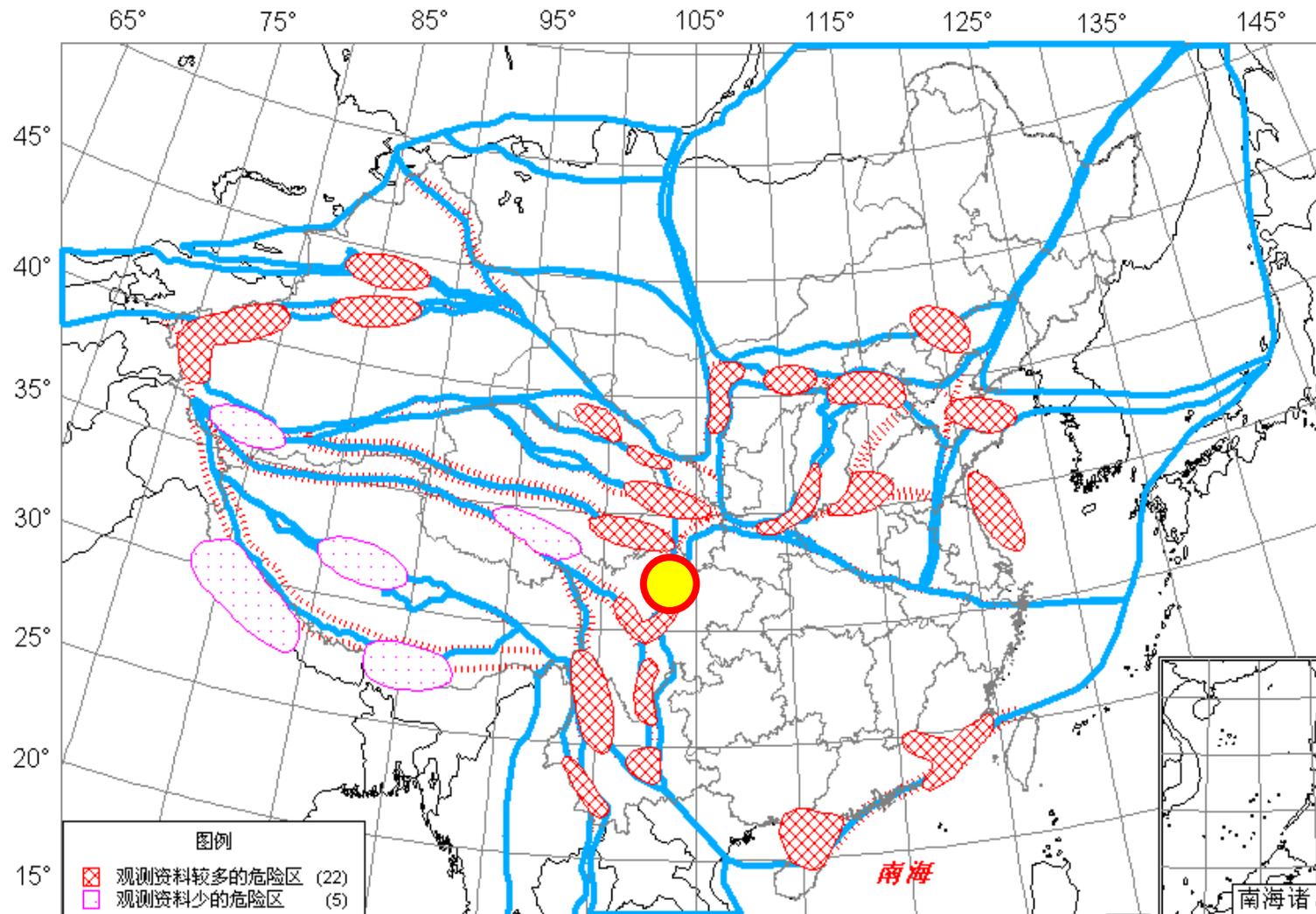




when we say **continental** earthquakes in China,
 we are saying a mixture of **interplate** and **intraplate** earthquakes.
 when we say tectonic **blocks**,
 we are saying different kinds of tectonic units, some are **rigid**, but
 others are **deformable**.

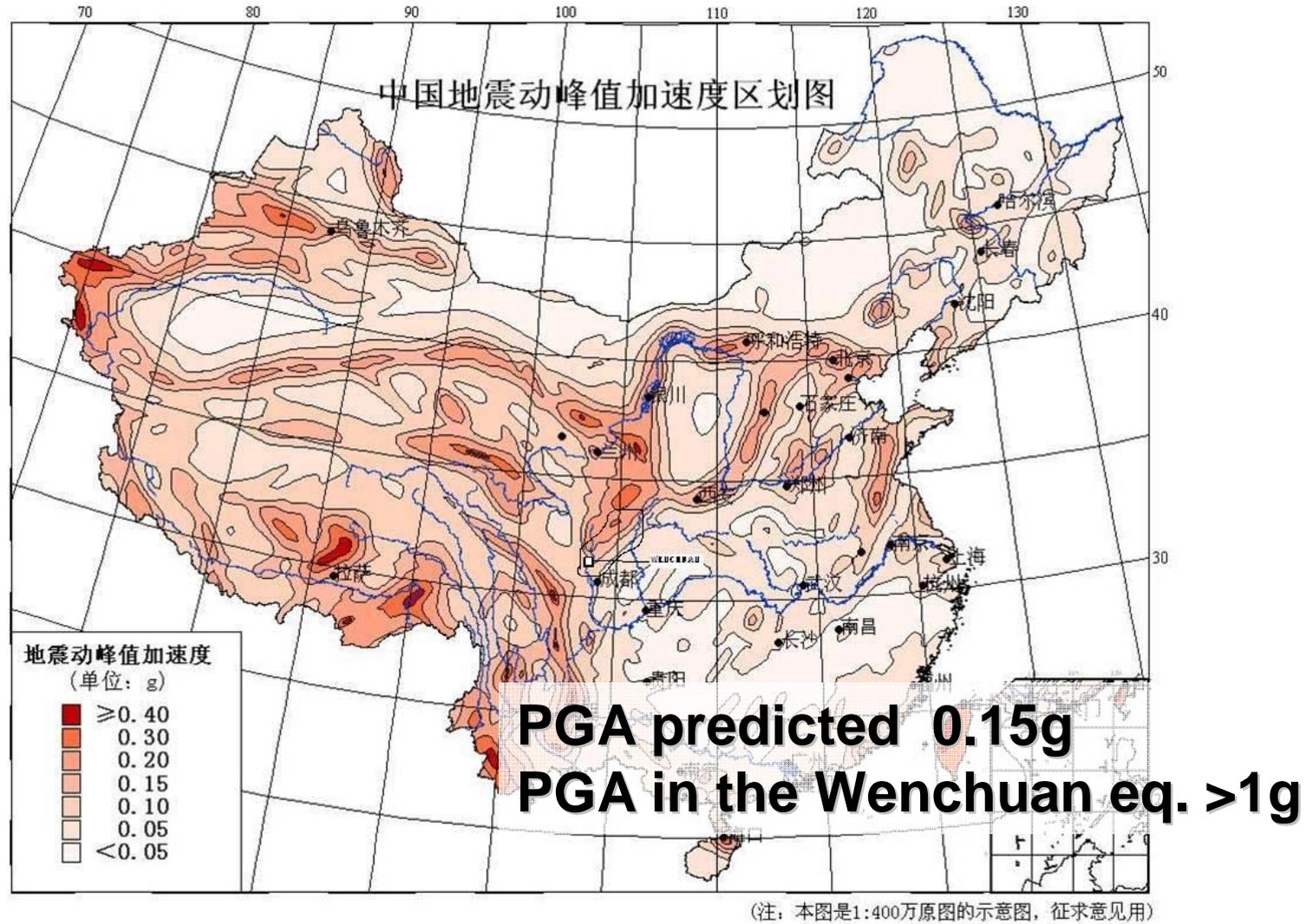


key regions subject to intense seismic risk 2006~2020 and the concept of block tectonics for continental earthquakes in China



From Department for Monitoring and Prediction, CEA

seismic intensity zonation seems to be problematic



not only the result in China but also those in other places...

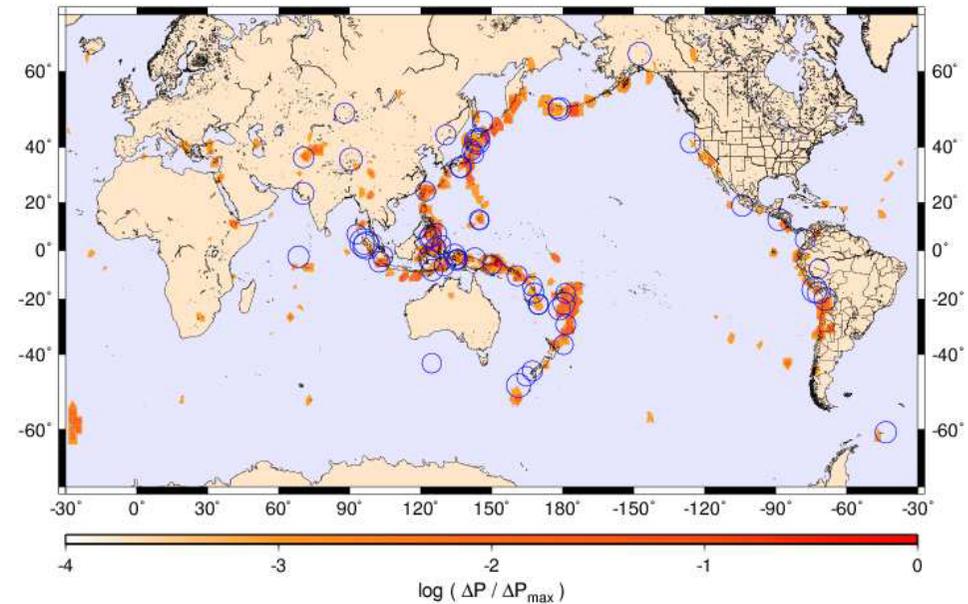
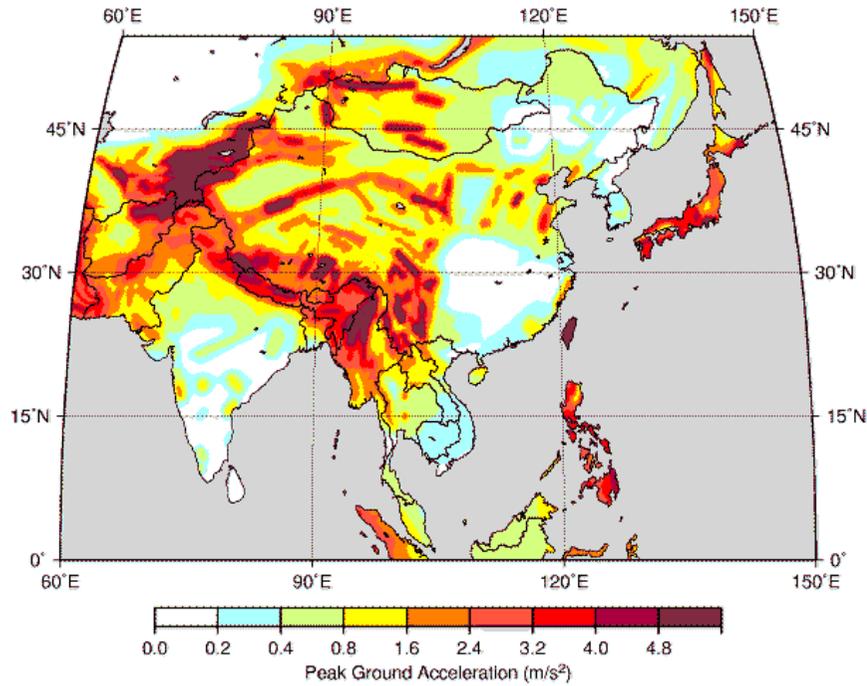
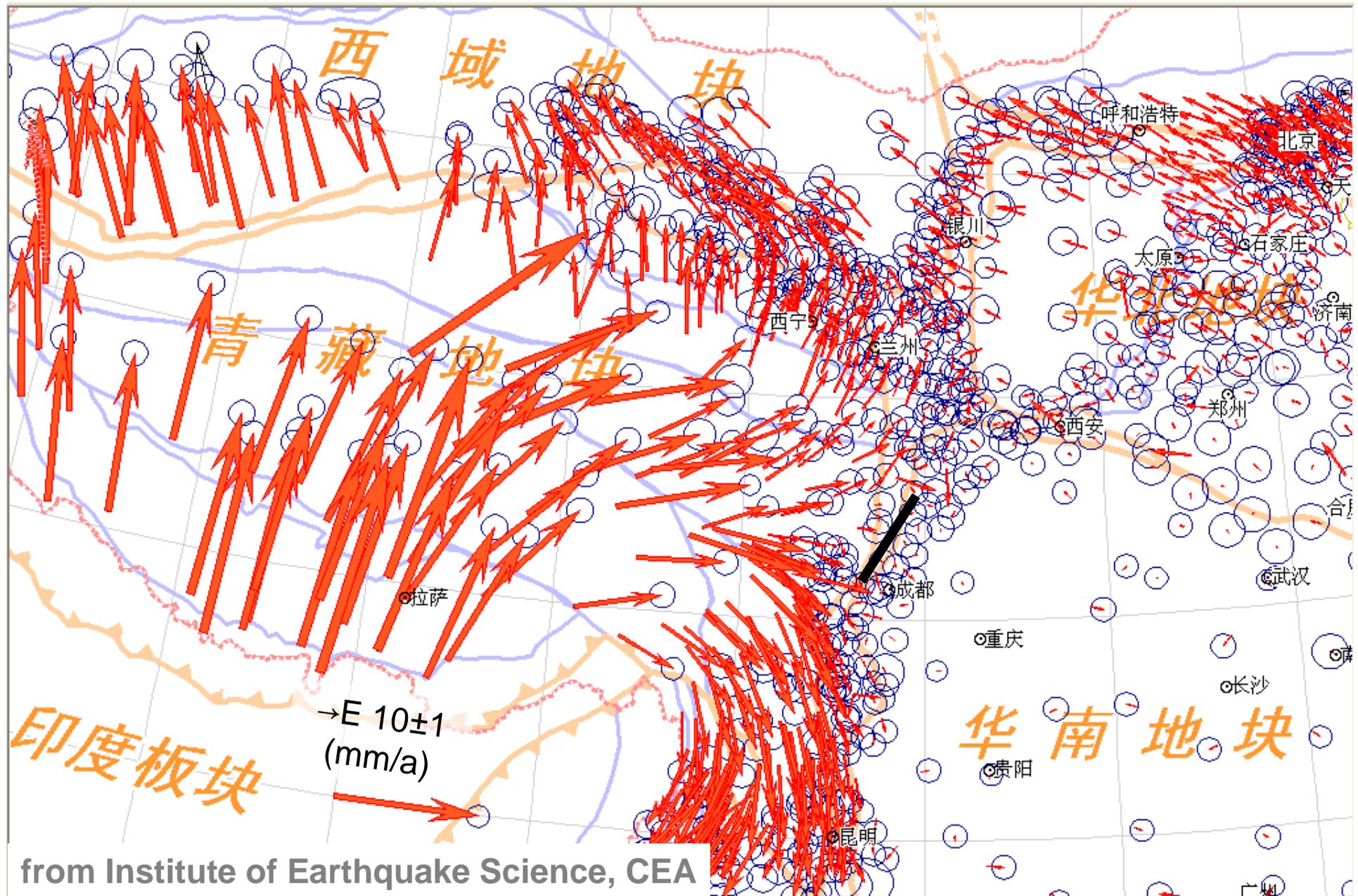


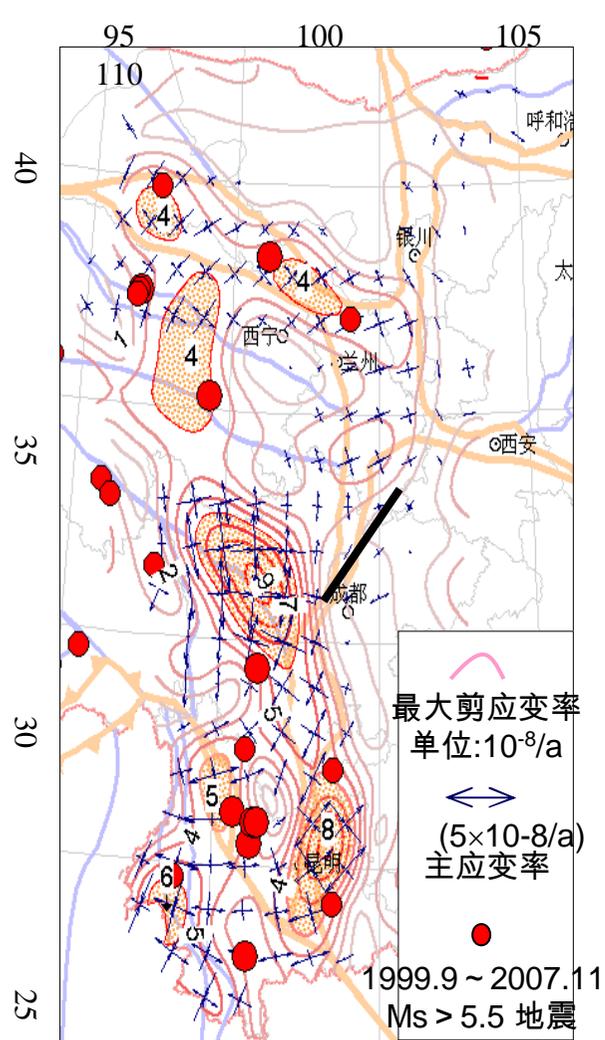
Fig. 3. World-wide application of the PI method. Colored areas are the forecast hotspots for the occurrence of $M \geq 7$ earthquakes during the period 2000-2010 derived using the PI method. The color scale gives values of the $\log_{10}(P/P_{max})$. Also shown are the locations of the sixty three earthquakes with $M \geq 7$ that have occurred in the region since 1 January 2000.

after the Wenchuan earthquake GPS measurement was criticized...

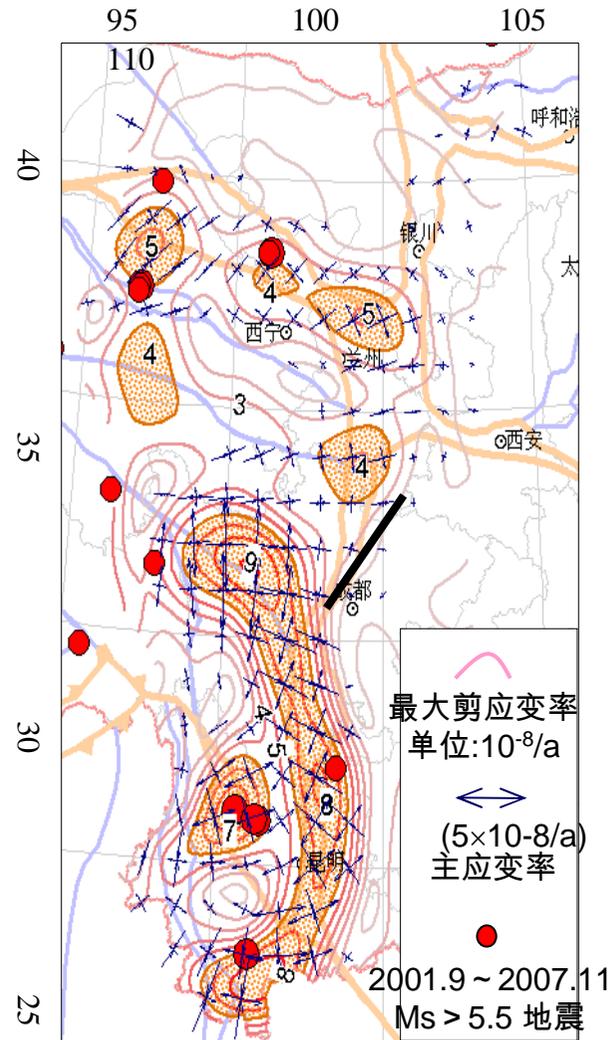


from Institute of Earthquake Science, CEA

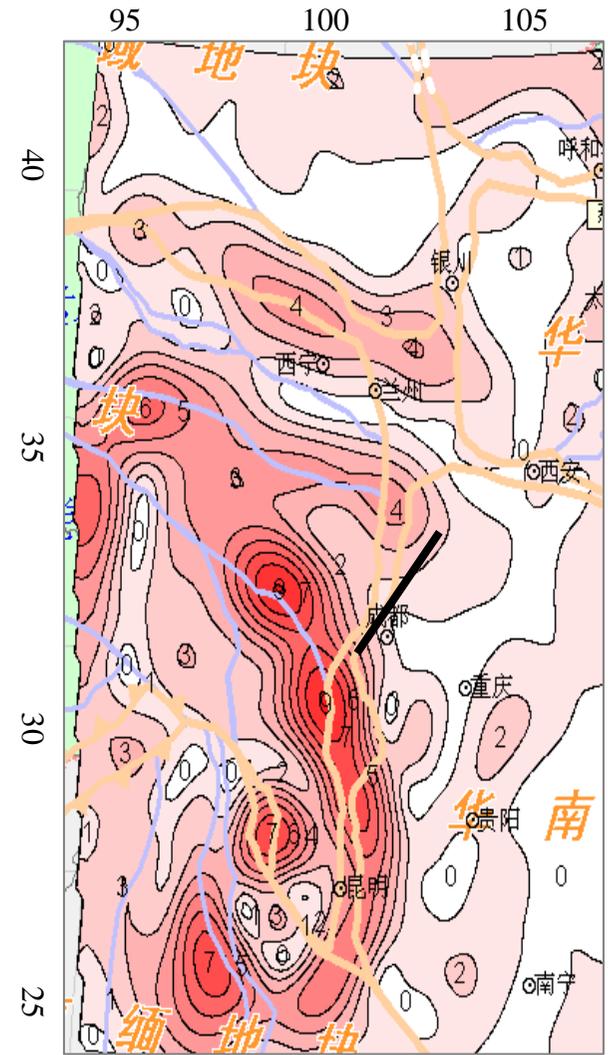
strain rate calculated by GPS result



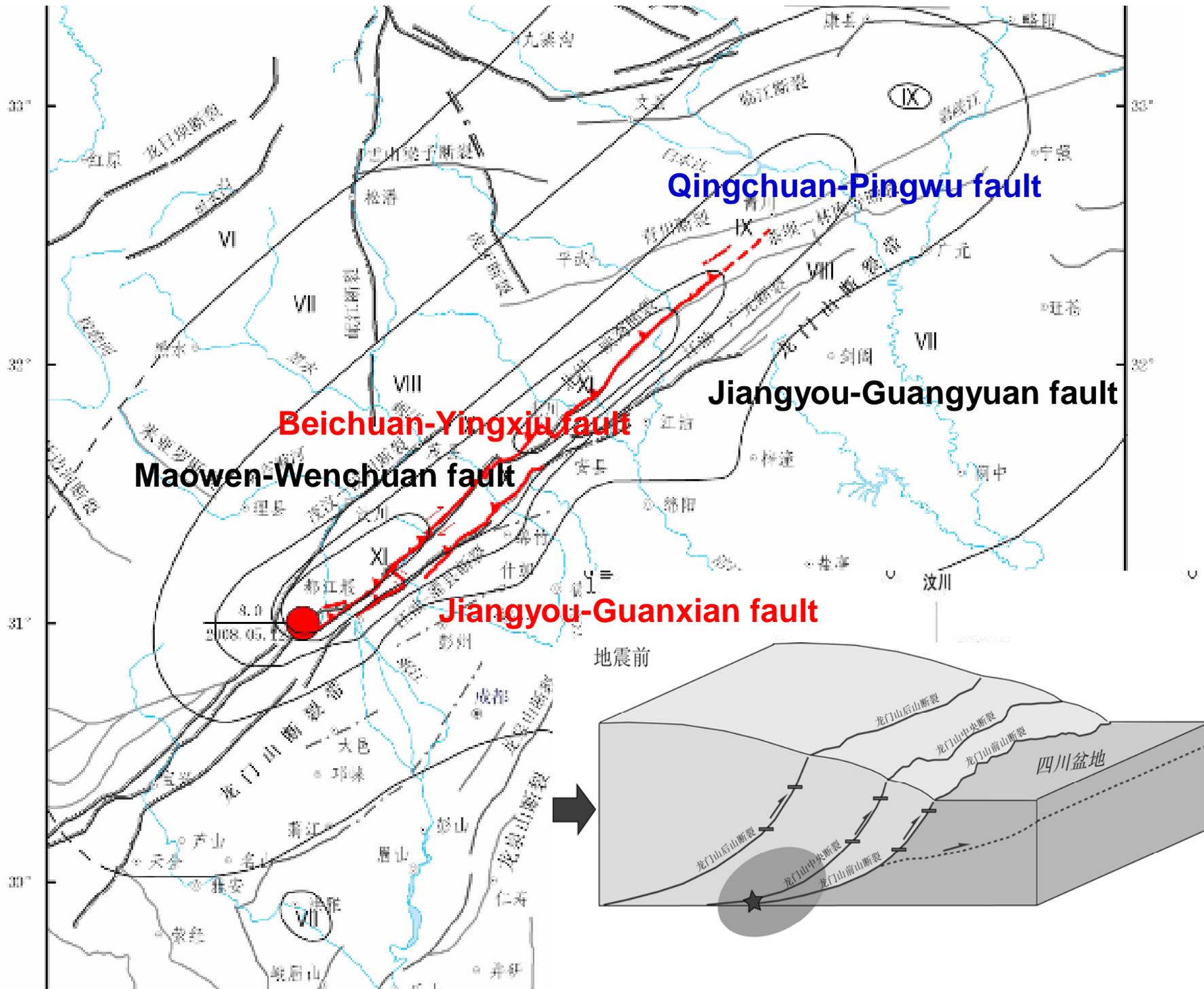
1999-2001



2001-2004



2004-2007





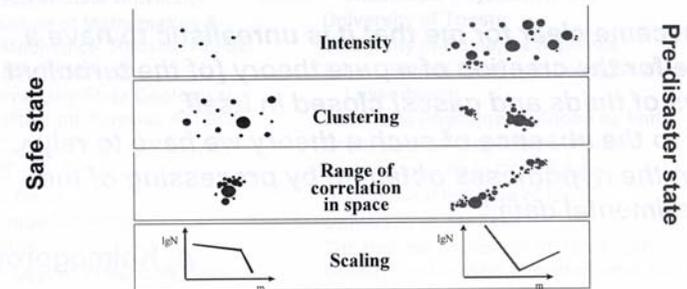
**secondly
monitoring and modeling for
forecast/prediction/preparedness**

what could be learnt from Wenchuan

'premonitory anomalies' (in a general sense) considered for the forecast/prediction/preparedness

BASIC TYPES OF PREMONITORY PHENOMENA

An extreme event is preceded by the following changes in relevant observed fields:



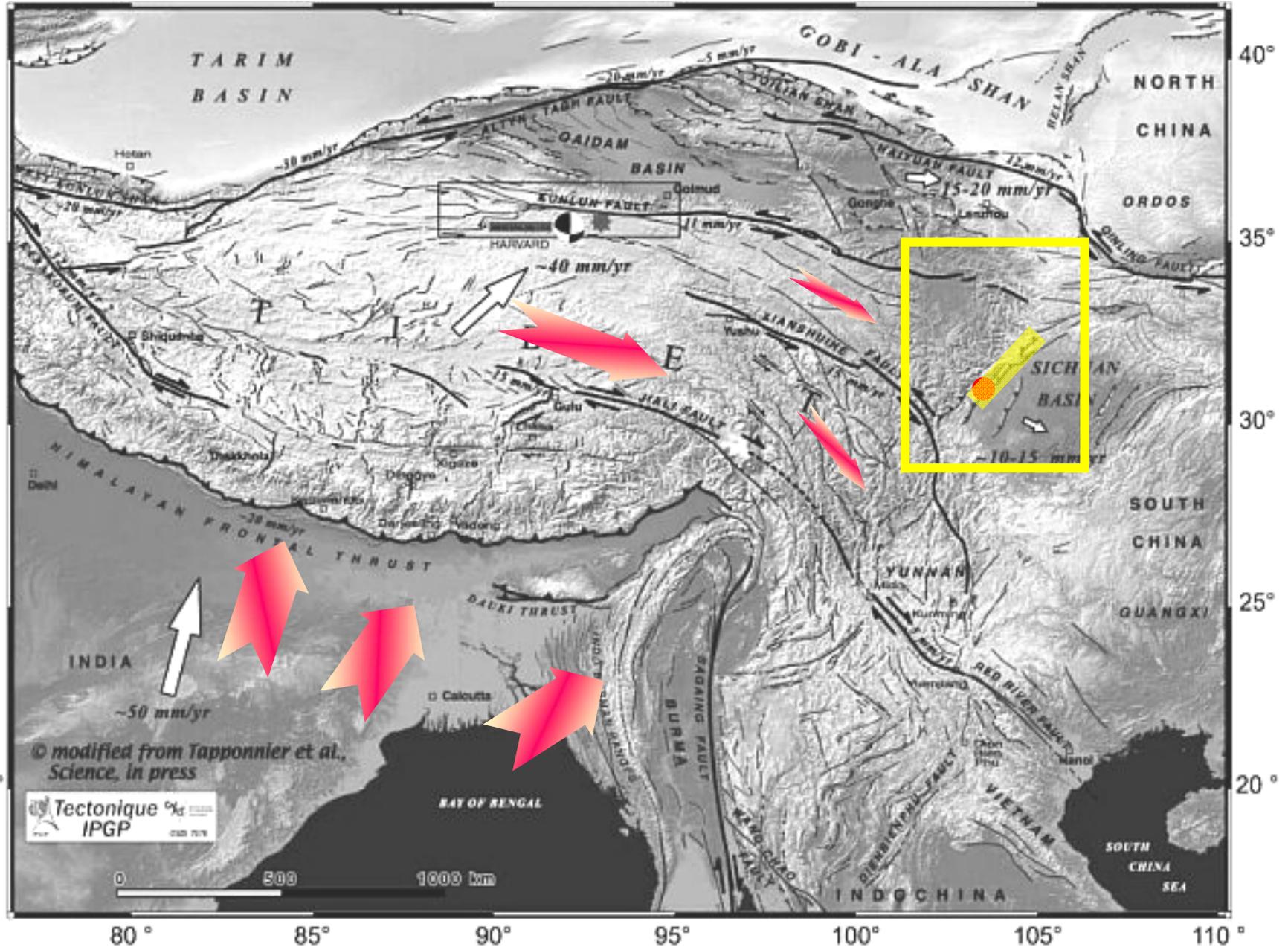
These phenomena are reminiscent of asymptotics near the phase transition of second kind. However, we consider not the return to equilibrium, but the growing disequilibrium, culminated by an extreme event.

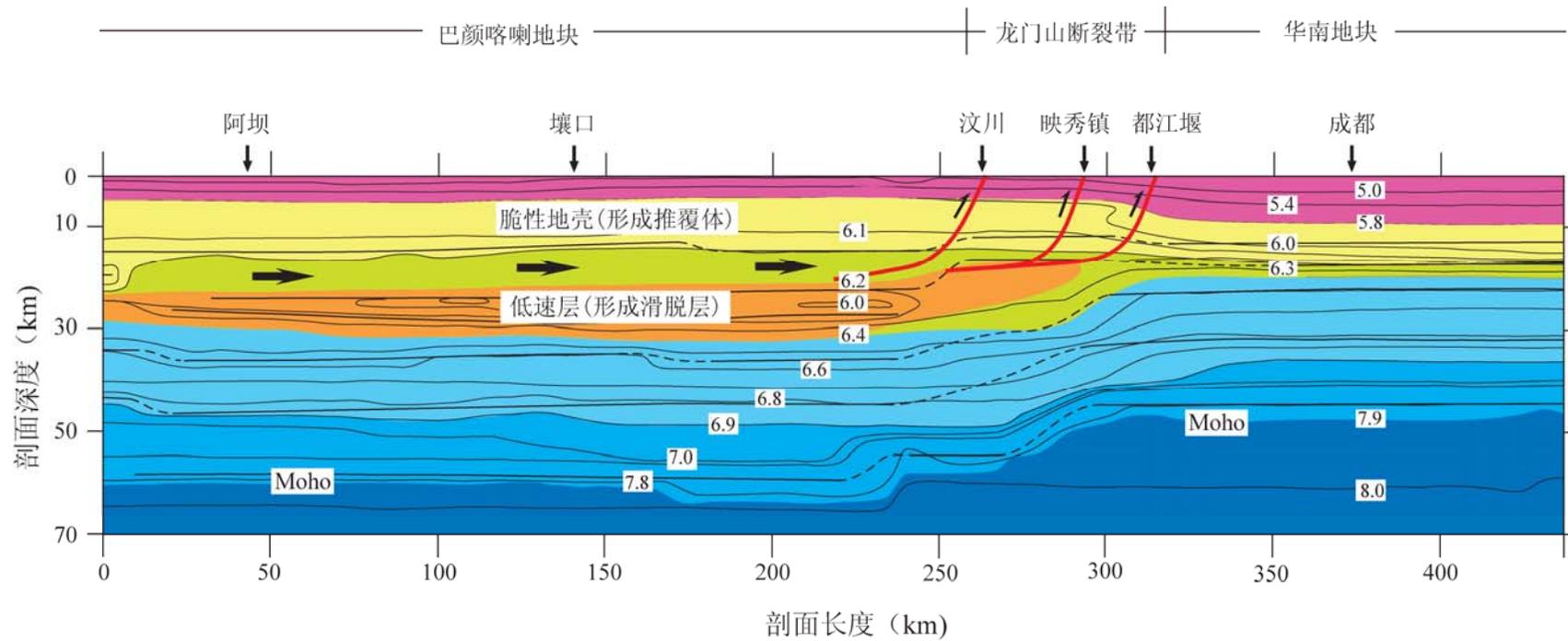
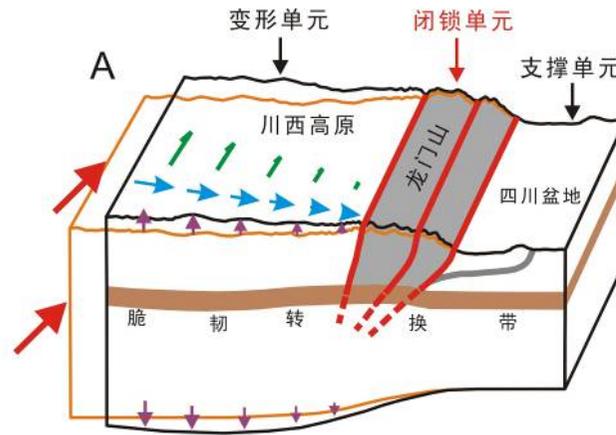
- regularities of seismic activity (statistical – intermediate-term)
- time-dependent average of (small) earthquake population (statistical – intermediate-term)
- abnormal change of geophysical fields (empirical – short-term)
- response of local seismic activity to some stimulating/loading factors such as the stress change caused by Earth tides or by other earthquakes (physical – intermediate-term/short-term)
- stories of stress or deformation (physical – long-term and intermediate-term)
- one of the problems of the current study on time-dependent earthquake hazard is that even if the idea of 'premonitory anomalies' is correct, the test of these 'premonitory anomalies' is still problematic – why ?

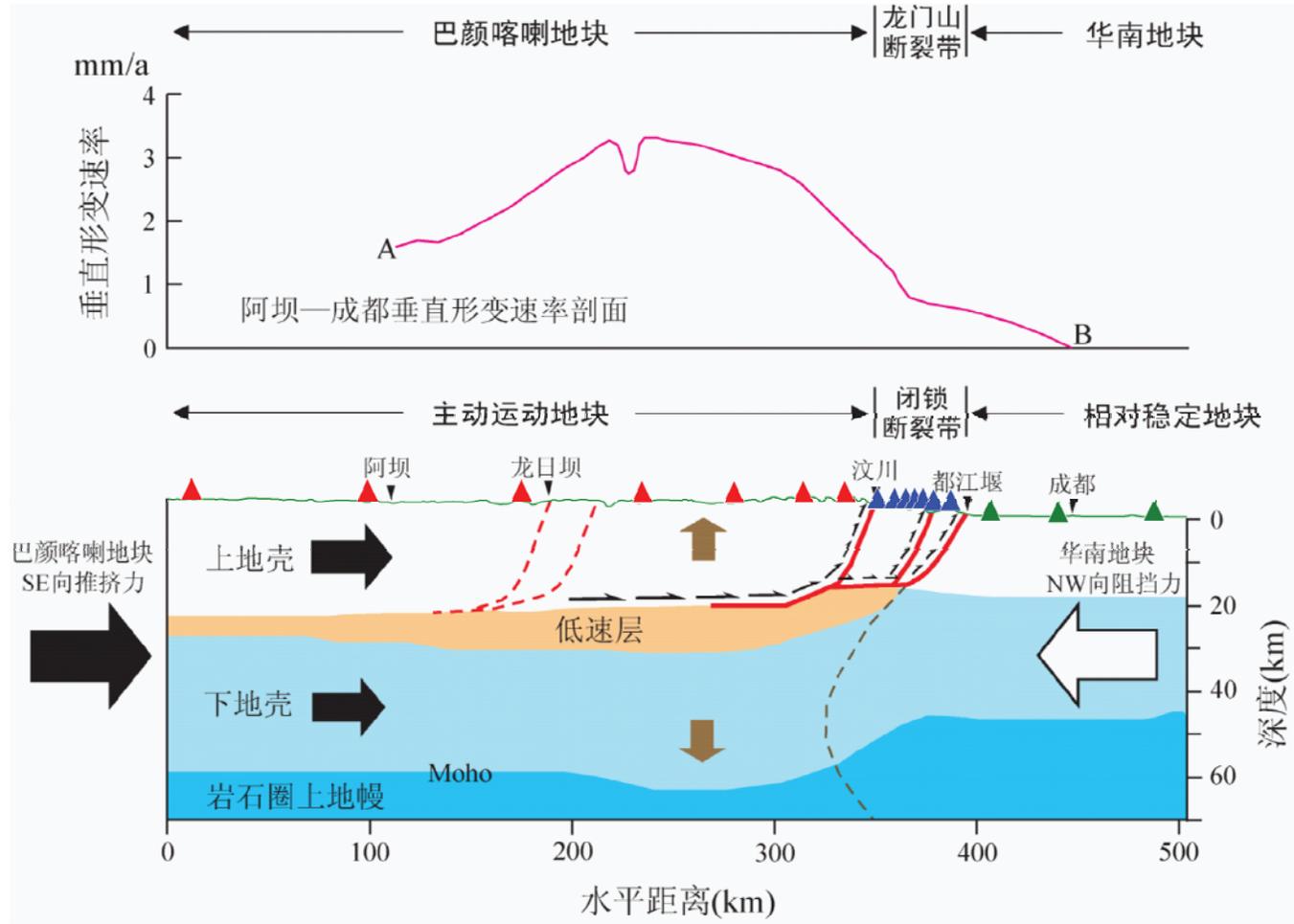
new techniques potentially important for providing new ingredients to the estimation of time-dependent seismic hazard

- **active source**
- **continuous GPS**
- **earthquake interaction calculation**
- **ETS or DLF**
- **high-precision seismology**
- **NCF and CWI technique**
- **PI algorithm**
- **repeating events and slip rate in deep**
- **RTP**
- **stress measurement techniques**

- **test of these new techniques also needs a correct road-map**

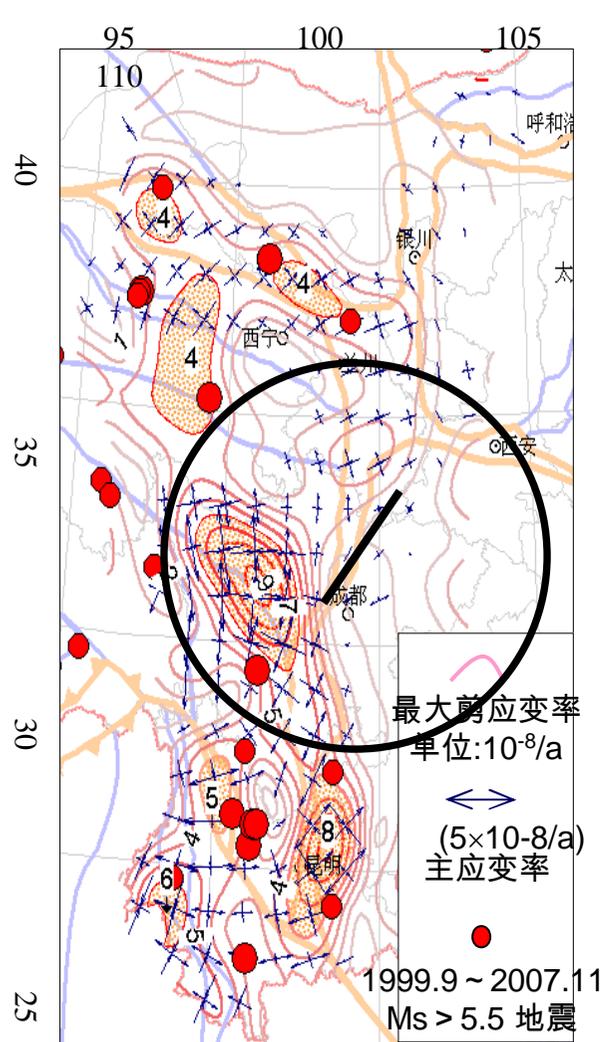




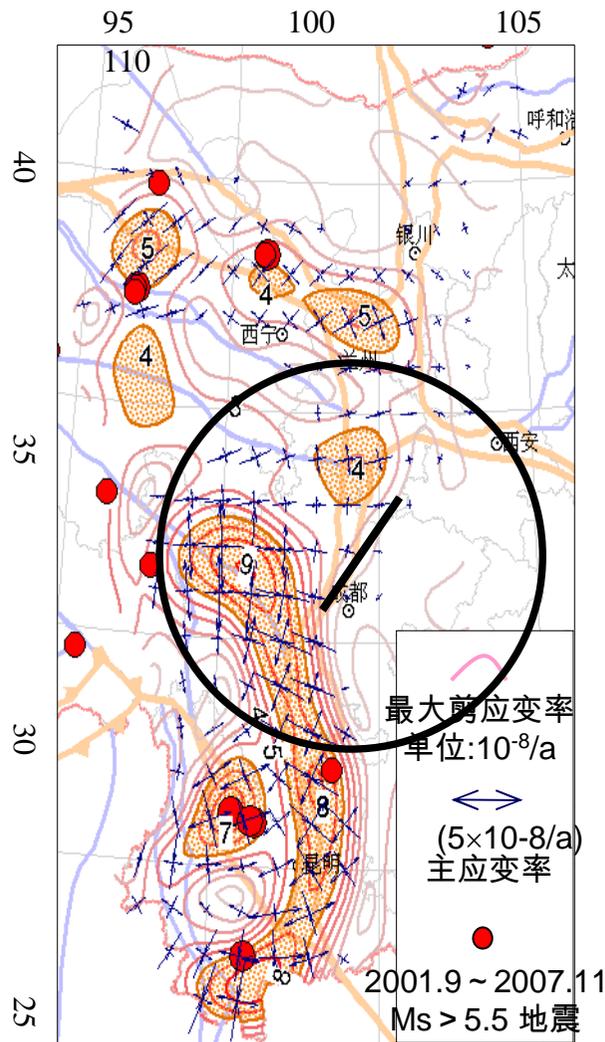


expected 'premonitory anomalies' drawn from the model of earthquake preparation tested by observational data

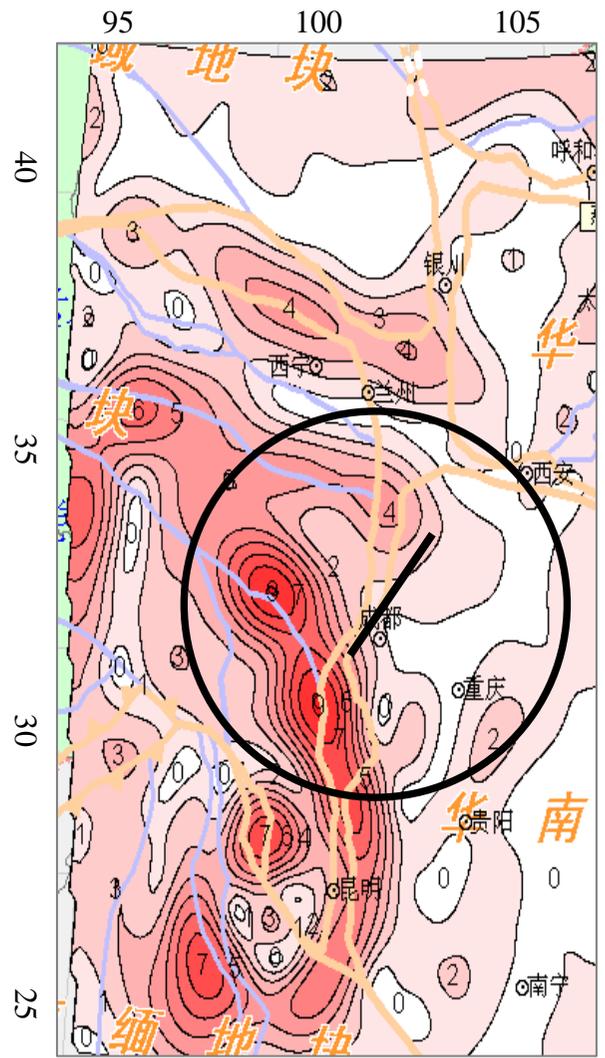
looking back at the strain field



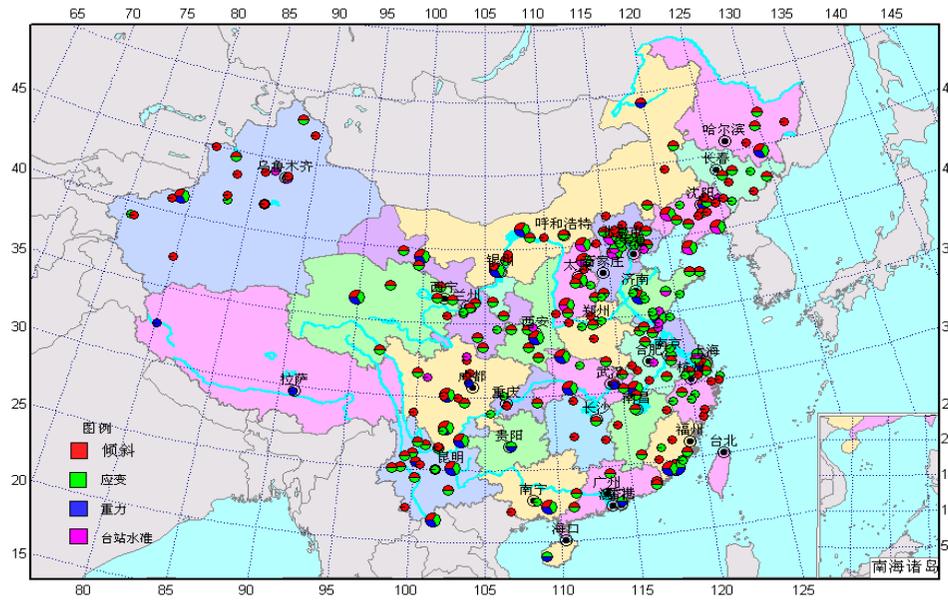
1999-2001



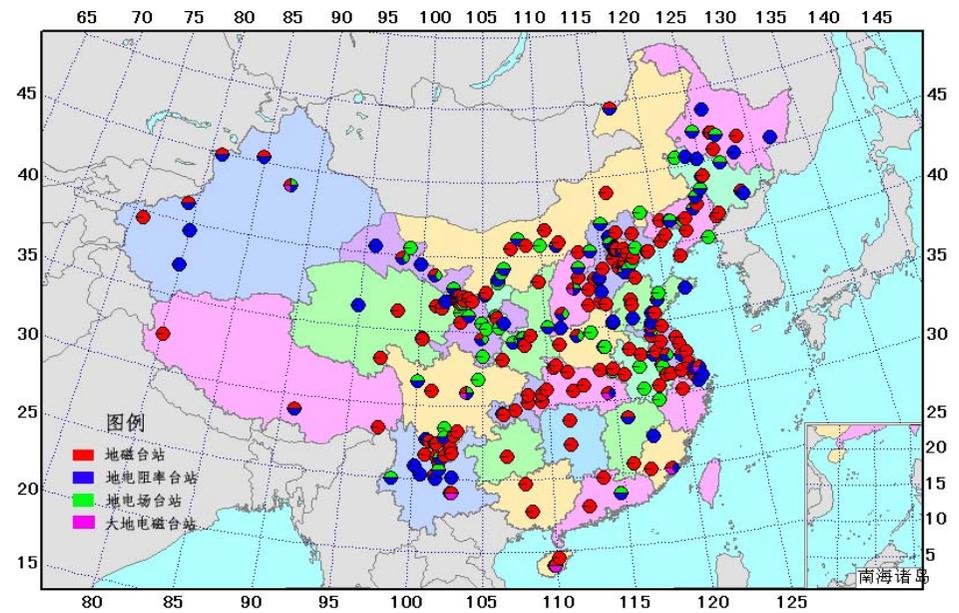
2001-2004



2004-2007



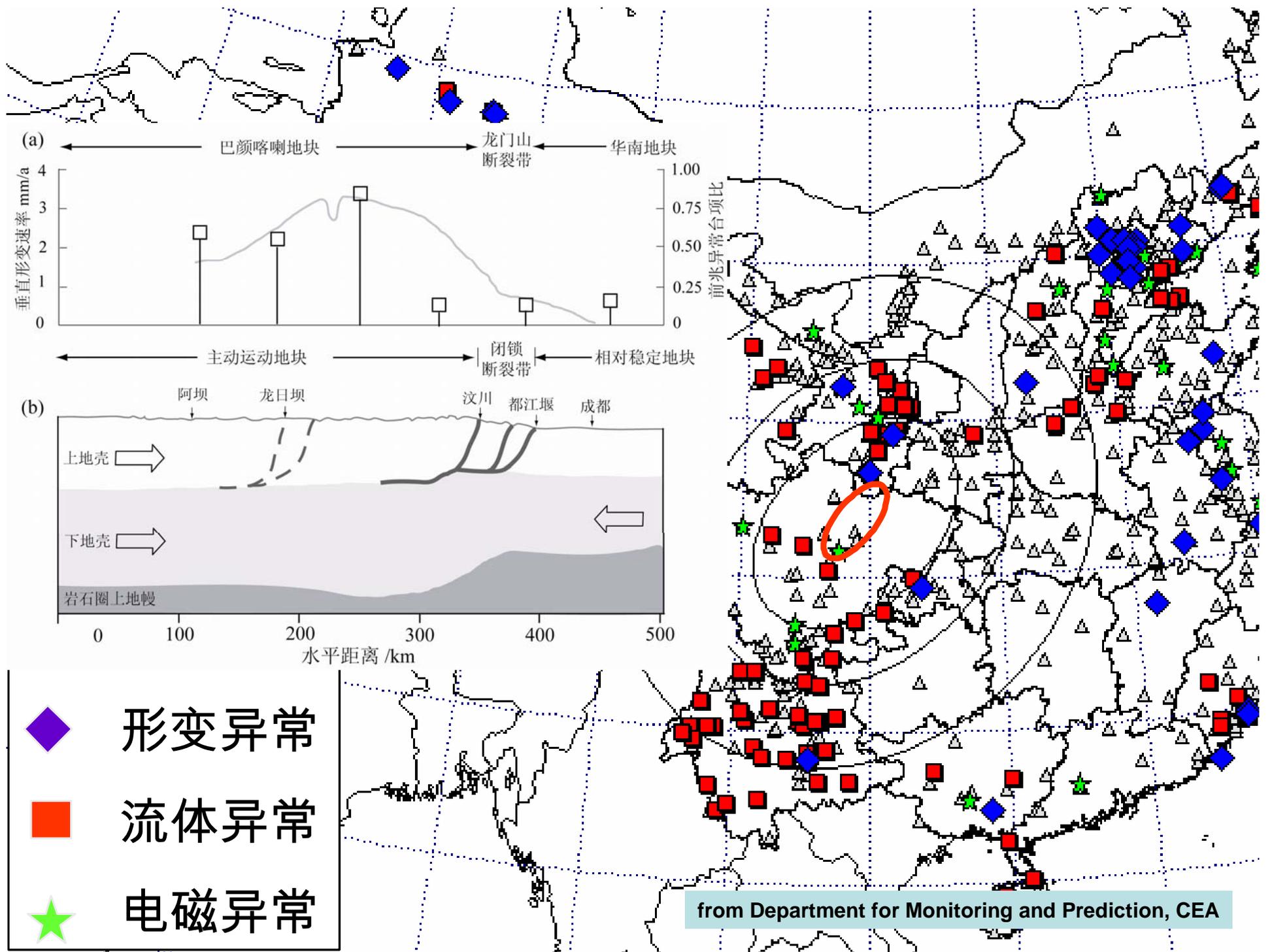
gravity and deformation monitoring

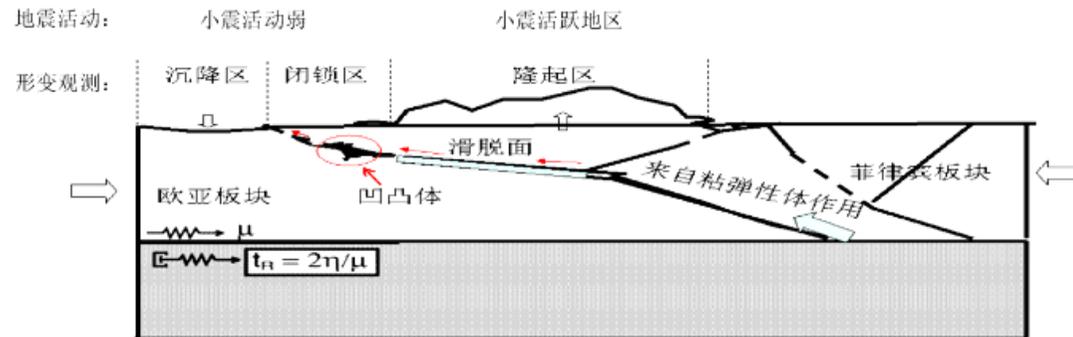
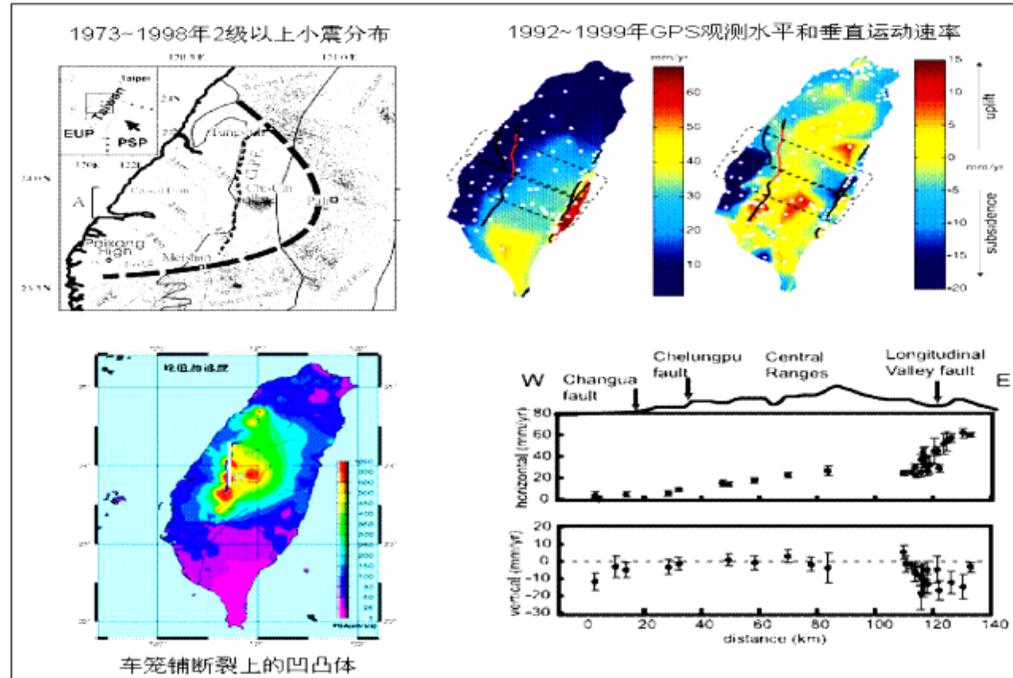


geomagnetism and geo-electricity monitoring



underground water and geochemical monitoring

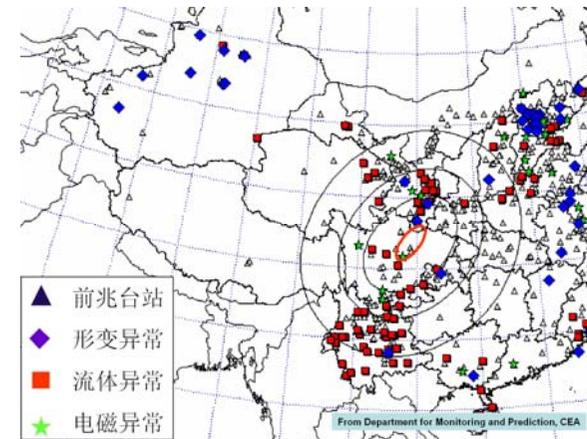
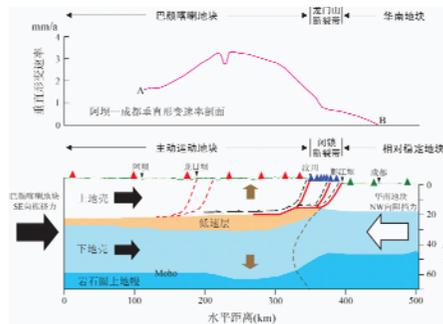
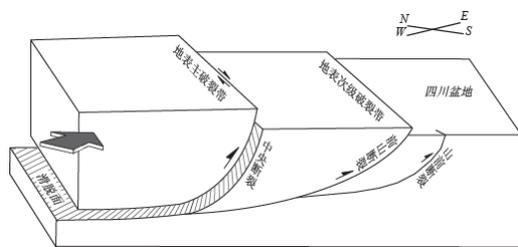




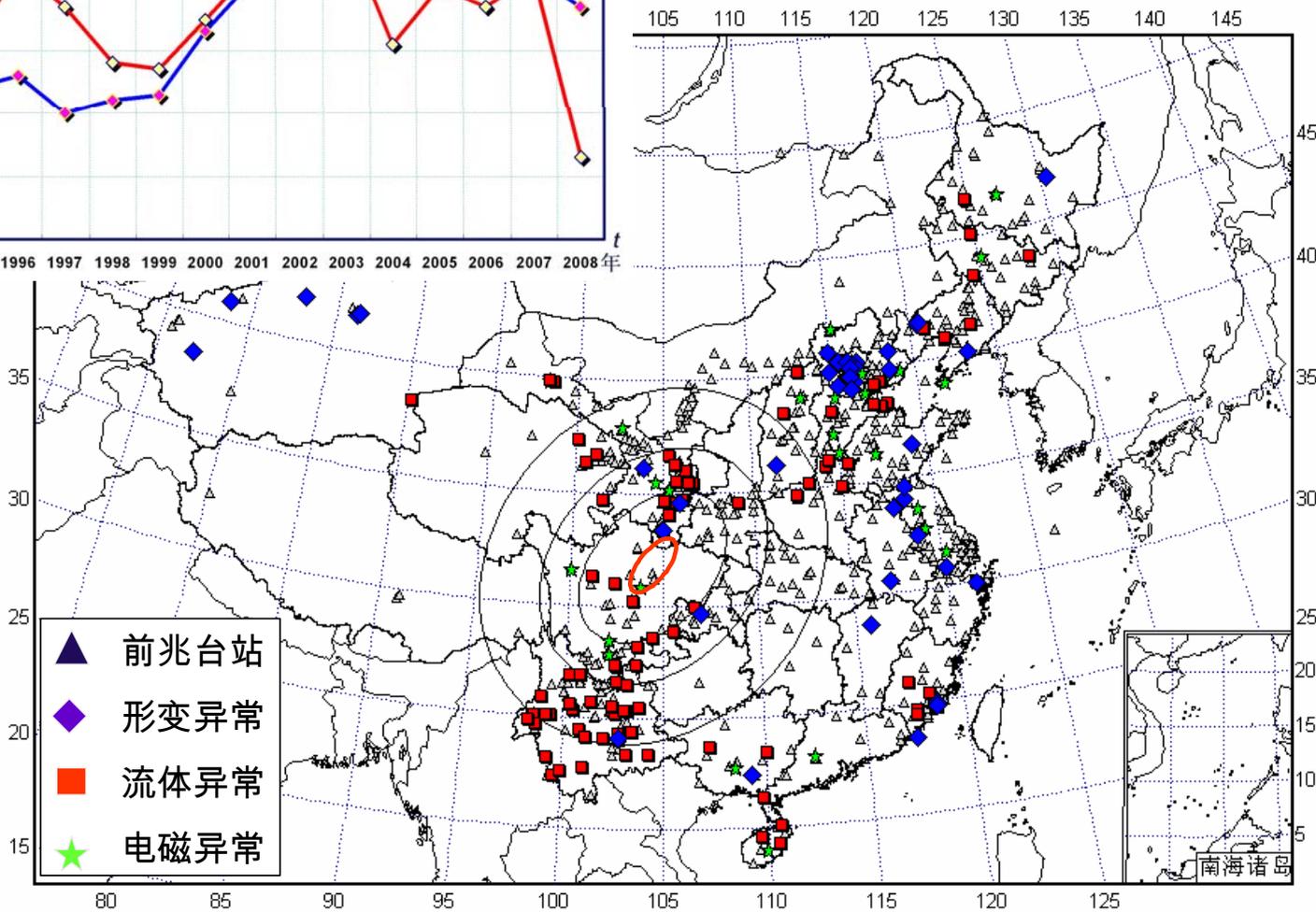
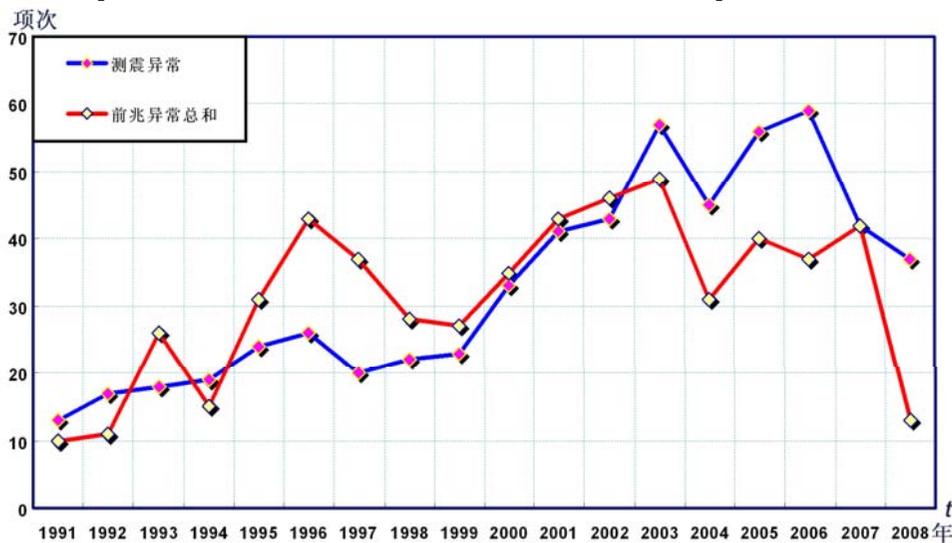
the 1999 Chi-Chi earthquake

before the earthquake – **not after**

- scenario rupture
- expected ‘premonitory anomalies’
- effective constraint of the earthquake preparation model
- effective monitoring of the expected ‘premonitory anomalies’
- effective test of the proposed forecast or hazard assessment



temporal variation of anomalies reported in Sichuan



distribution of anomalies reported and the location of the Wenchuan earthquake

proposing a concept
‘seismological engineering’
different from
earthquake engineering
and
engineering seismology

indicating the
design, evaluation, and implementation of
monitoring systems
to facilitate the monitoring and modeling for
forecast/prediction/preparedness



thirdly
why some of the worldwide-valid algorithm
failed to indicate the approaching of the
Wenchuan earthquake

importance of the consideration
of local situations

Plot of Log_{10} (Seismic Potential)

Increase in Potential for significant earthquakes, ~ 2000 to 2010

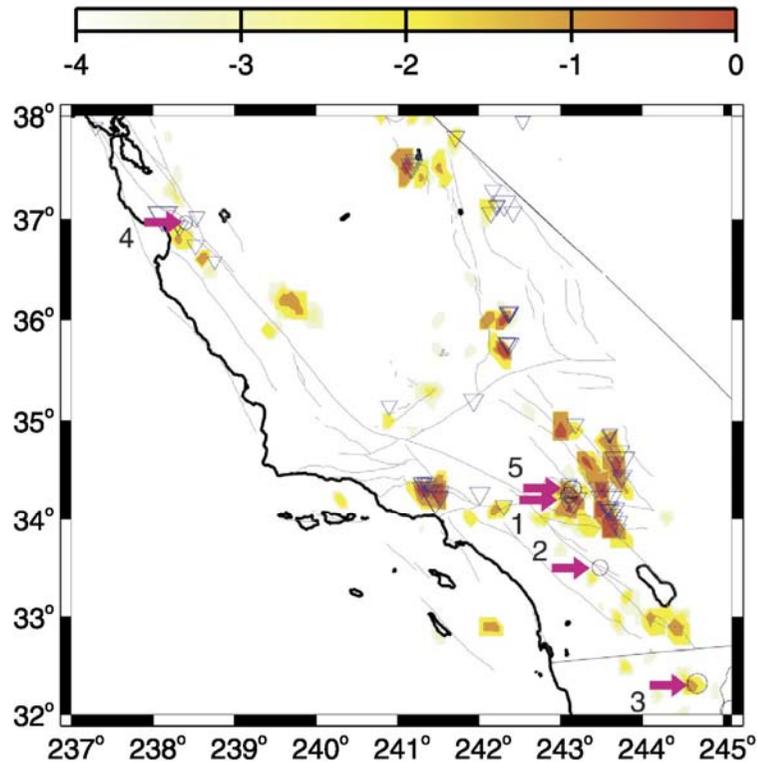
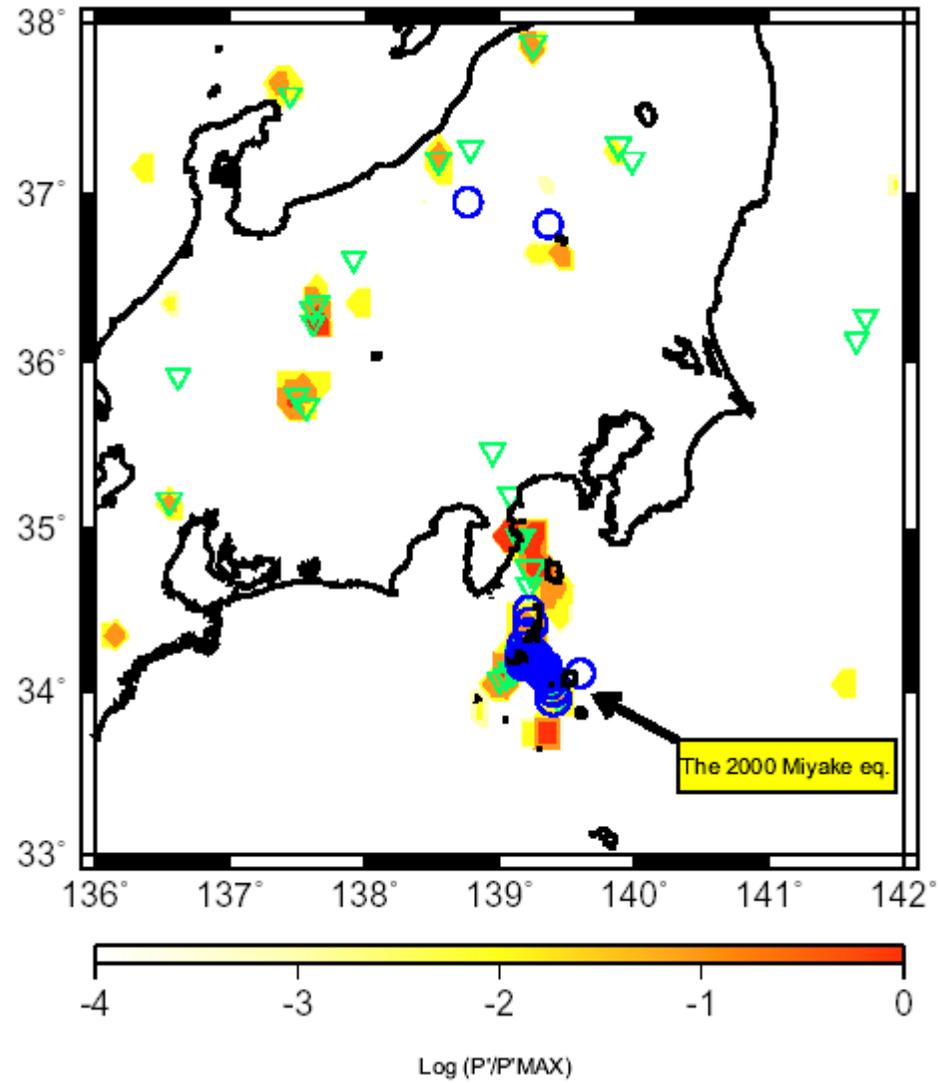


Figure 14. Pattern informatics method forecast for southern California for the period 2000–2010 [Tiampo *et al.*, 2002a; Rundle *et al.*, 2002]. Relative probabilities $\log_{10}(\Delta P/\Delta P_{\max})$ are given using the color code at the top of Figure 14. The times used were $t_0 = 1$ January 1932, $t_1 = 1$ January 1990, and $t_2 = 31$ December 1999. Earthquakes with $m > 5.0$ that took place during 1990–1999 are shown as inverted triangles. Circles represent events with magnitude $m > 5.0$ that have occurred so far during the time period of the forecast.

from Rundle *et al.*, 2003, *Reviews of Geophysics*



from Nanjo et al., 2004. *Pure appl. Geophys.*

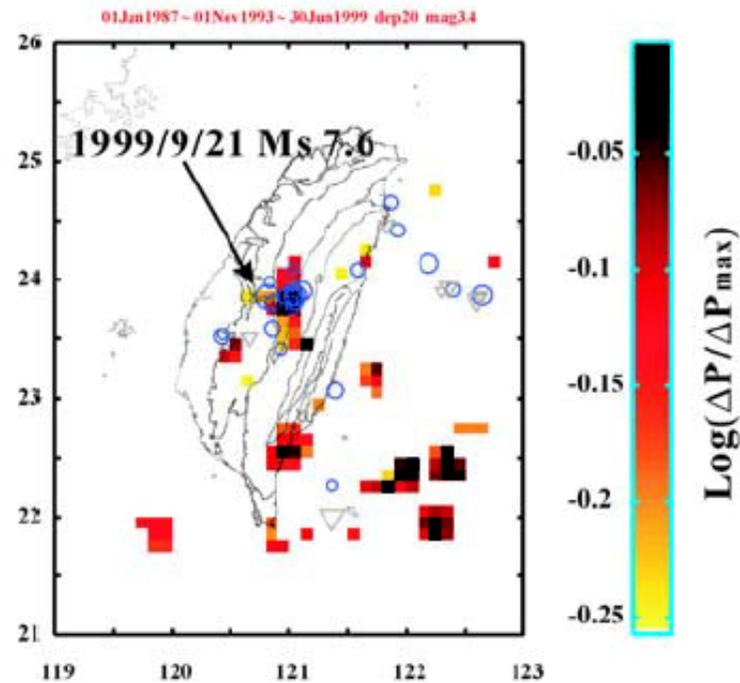
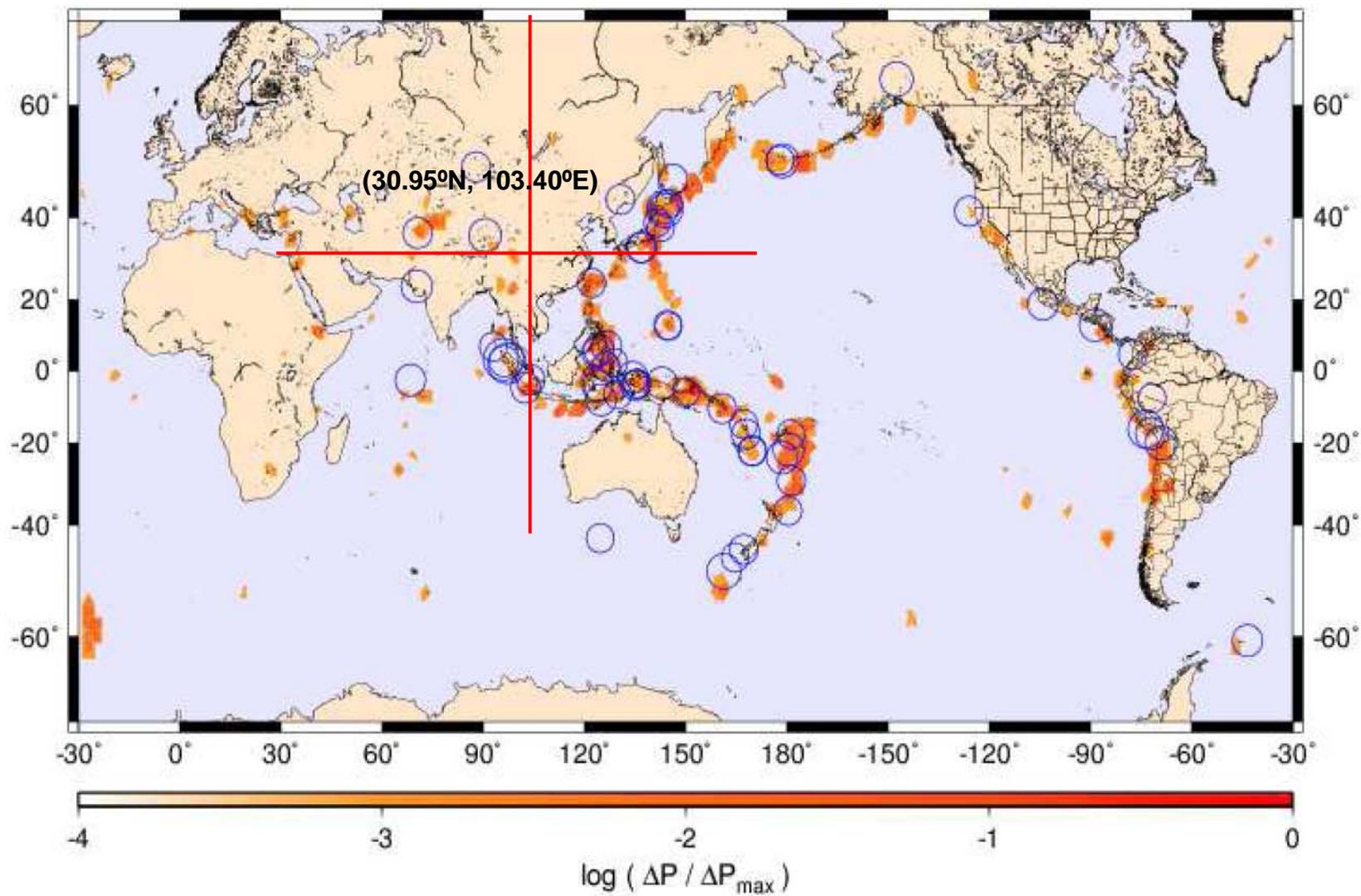
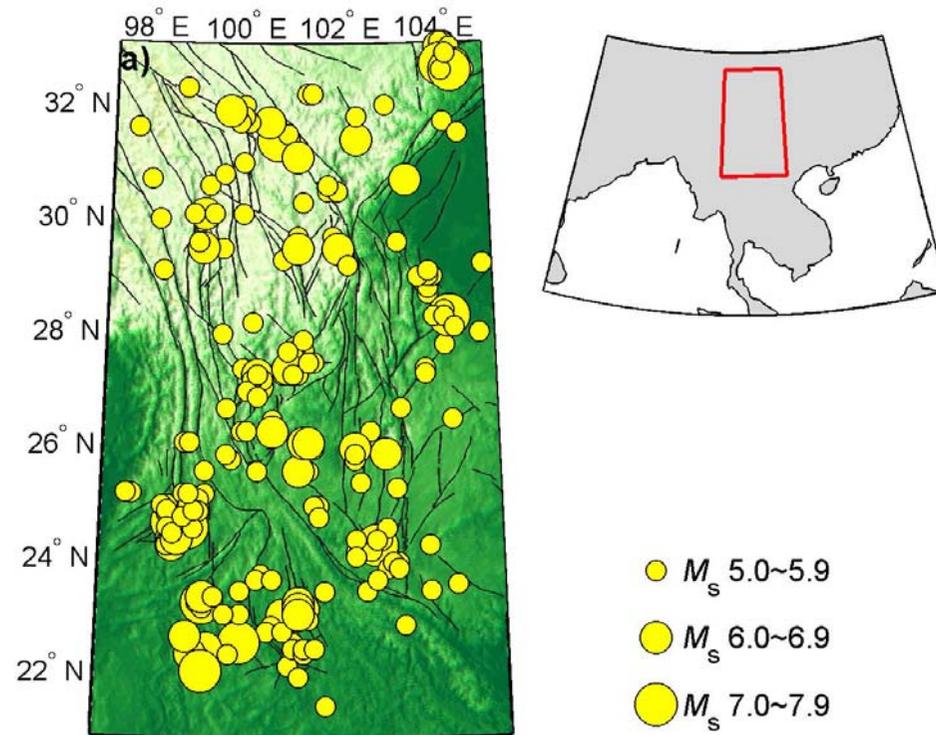


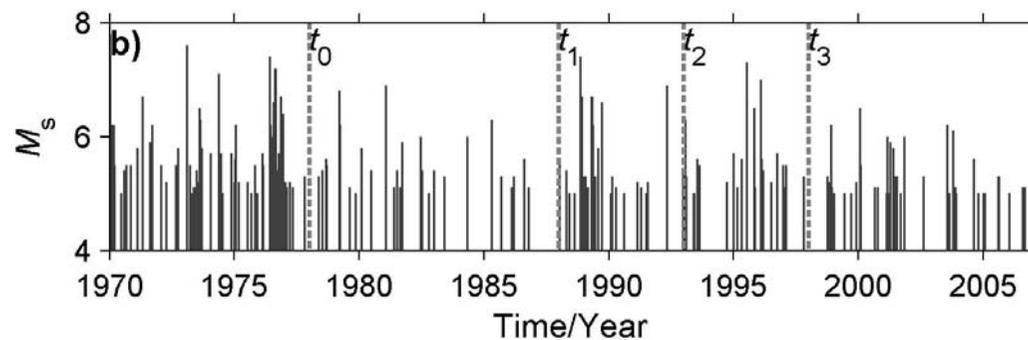
Figure 2. Taiwan PI map over the change interval from $t_1 =$ November 1993 to $t_2 =$ June 1999. Circles represent earthquakes with $M \geq 6$ that occurred after t_2 and inverted triangles represent earthquakes with $M \geq 6$ that occurred between t_1 and t_2 . Colored pixels (hotspots) represent areas with large seismicity change caused by both the seismic activation and quiescence, indicating high probability for future large events.

from Chen et al., 2005. *Geophys. Res. Lett.*





spatial distribution of earthquakes larger than M_s 5.5 since 1970 in Sichuan-Yunnan region.



temporal distribution, with the three vertical dash lines to the right representing t_1 the starting time of the 'anomaly training window', t_2 the ending time of the 'anomaly training window' and the starting time of the 'forecast window', and t_3 the ending time of the 'forecast window'. For the sliding window considered in this figure, the catalogue is selected to start from t_0 .

parameter settings of the retrospective forecast test:

earthquakes in Sichuan-Yunnan region since 1988.

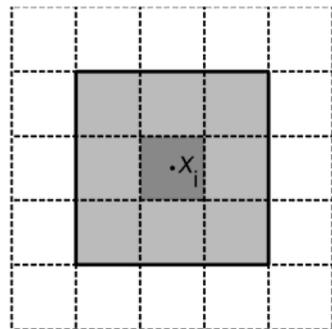
regional earthquake catalogue down to $M_L 3.0$ from 1970 to 2008 was used.

the 'target magnitude' for the forecast test was $M_S 5.5$.

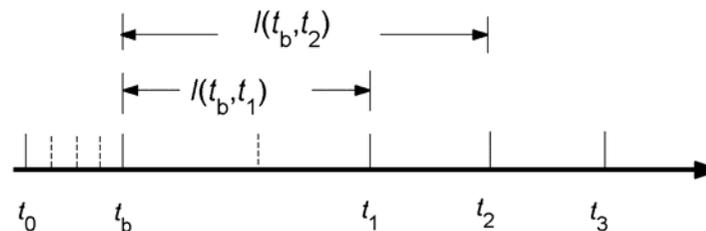
fifteen-year long 'sliding time window' was used in the PI calculation, with 'anomaly training time window' being 5 years and 'forecast time window' being 5 years, respectively.

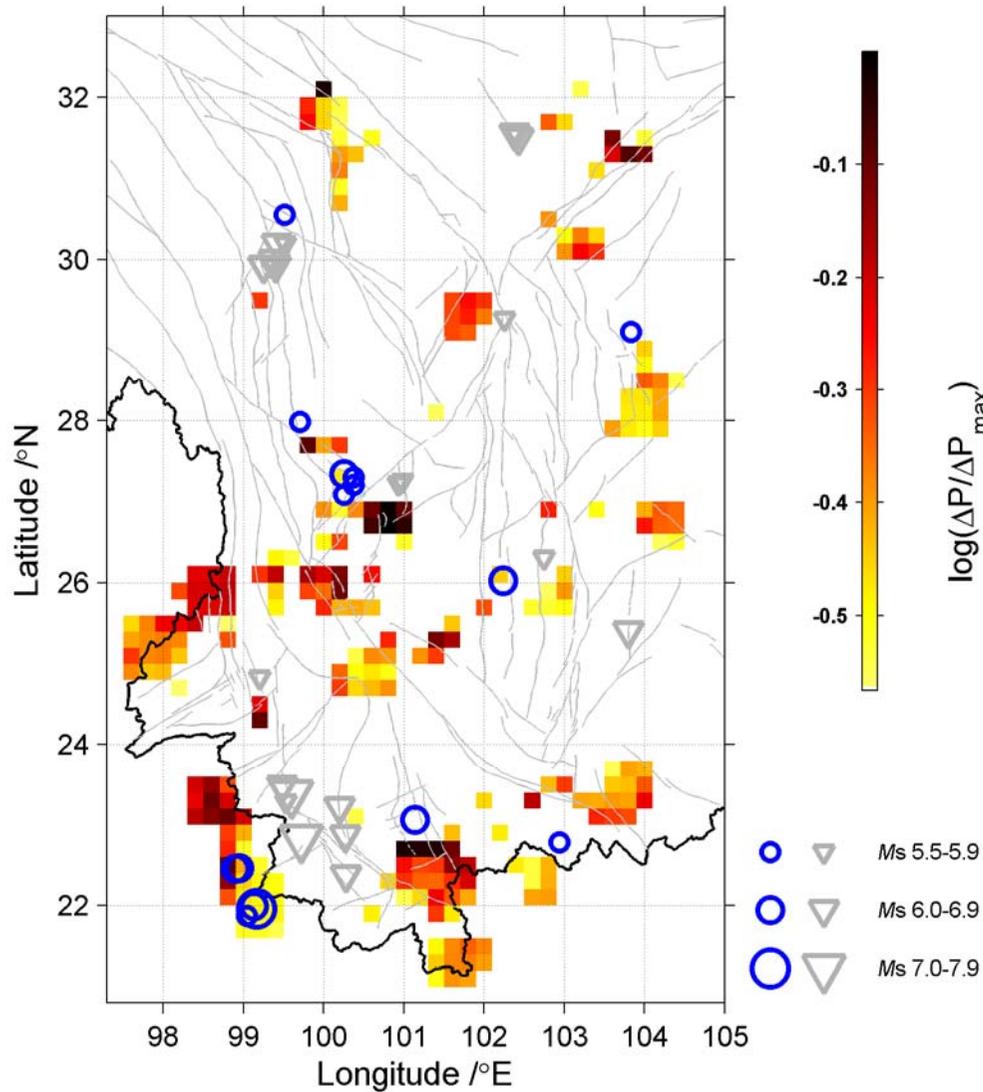
spatial grid size is selected as 0.2° .

(a)

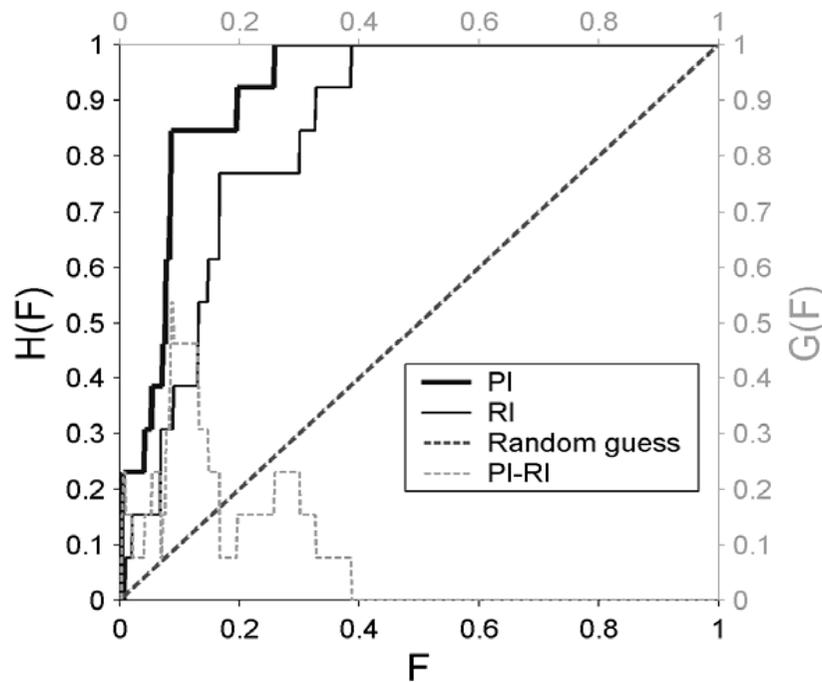


(b)

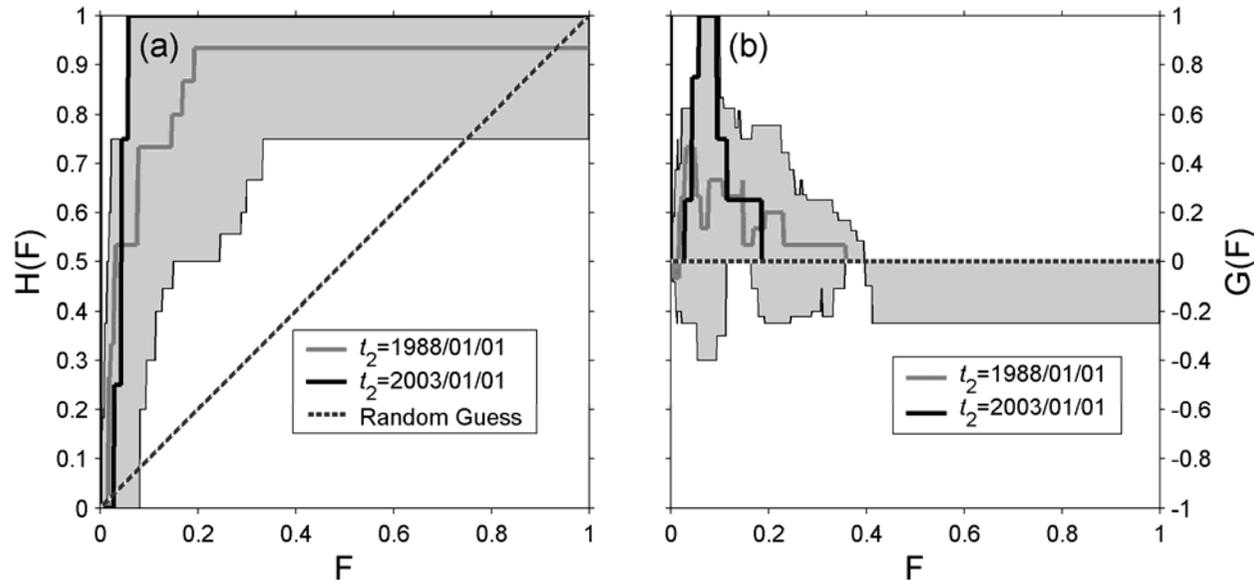




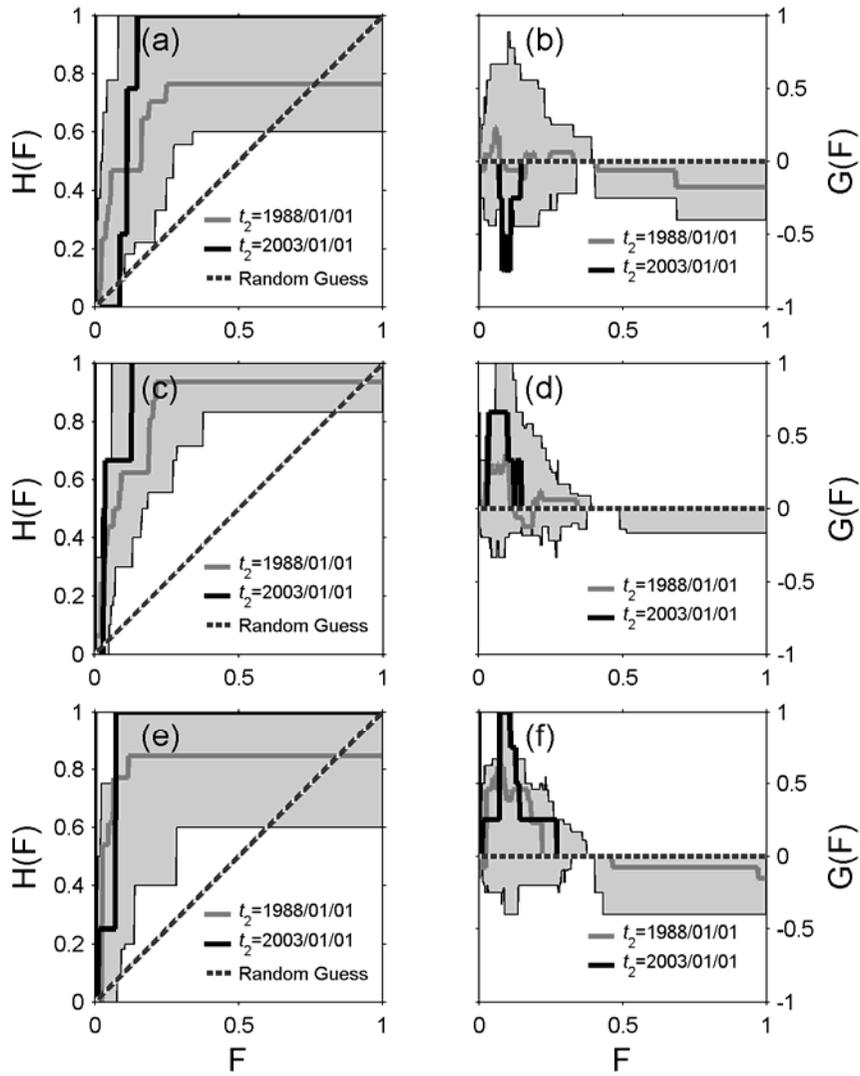
- retrospective test of PI algorithm: Sichuan-Yunnan region, period of 01/01/1992~01/01/1997.
- color-coded hot spots highlight the relative probability increase for earthquakes above M_s 5.5.
- blue circles stand for the earthquakes above M_s 5.5 occurring within the 'forecast window', while gray reverse triangles show the earthquakes above M_s 5.5 occurring within the 'anomaly training window'.



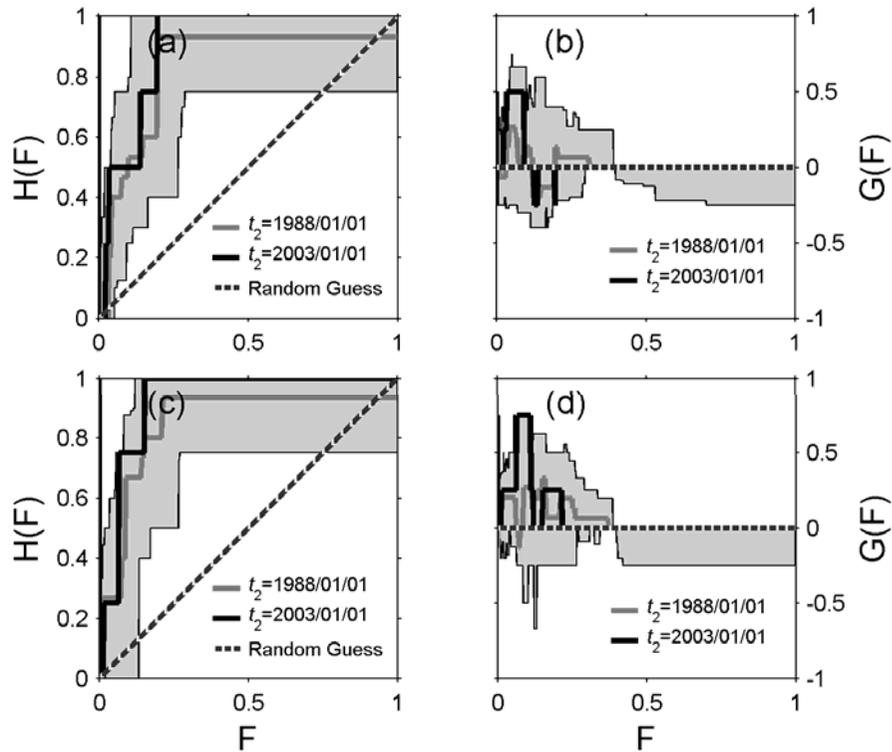
- **ROC test for Sichuan-Yunnan region: period of 01/01/1992~01/01/1997. Thick solid line represents the ROC result for the PI forecast, thin solid line the ROC result for the RI forecast, and black broken line the result for random forecast.**
- **gray broken line shows the difference between the 'hit rate' of PI algorithm and that of RI algorithm.**



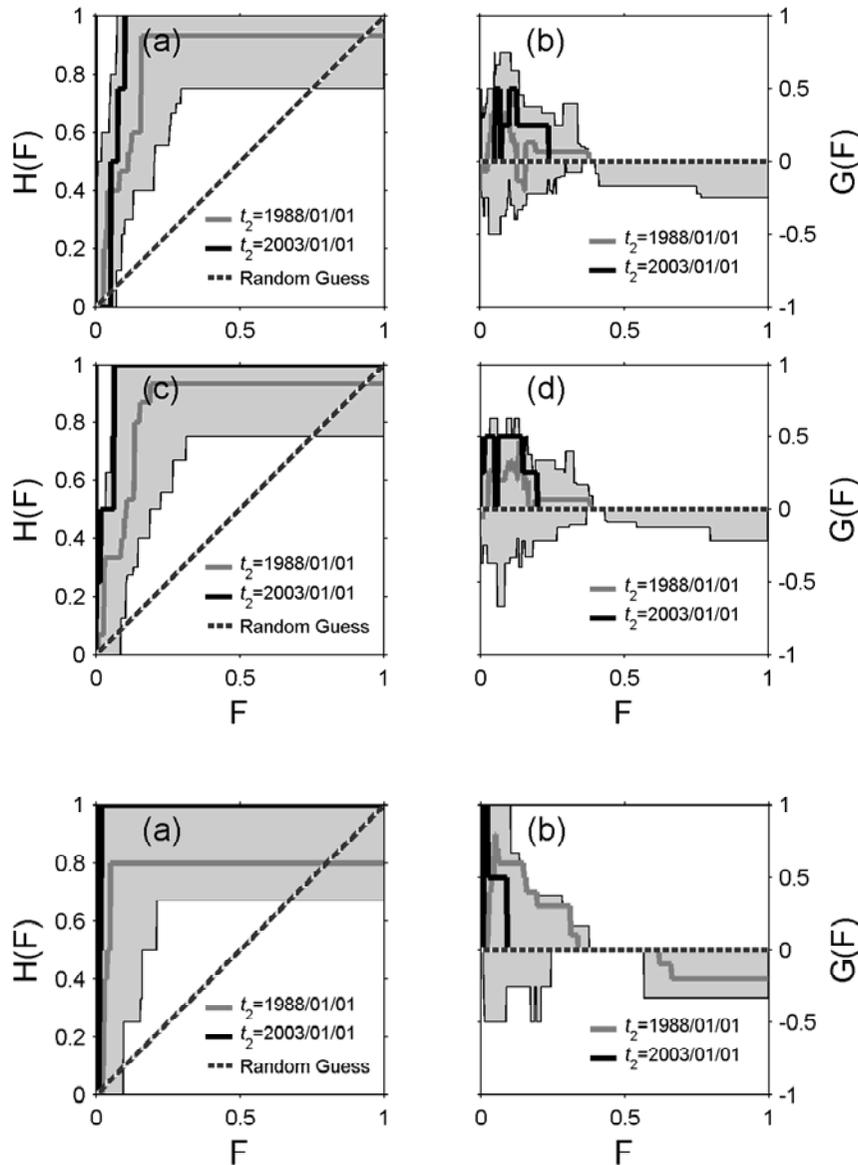
- ROC test of PI algorithm **for different time window**. ‘Anomaly training window’ and ‘forecast window’ are taken as 5 years. The sliding window is taken as 15 years. ‘Forecast window’ slides from $t_2 = 01/01/1988$ to $t_2 = 01/01/2003$, with sliding step being 0.5 year.
- (a) ROC curve for PI forecasts. Gray zone delimitates the range of all the ROC curves, with gray line and black line representing the results of the first and the last sliding, respectively.
- (b) PI forecast versus RI forecast – difference between the hit rate of PI algorithm and RI algorithm changing with false alarm rate. Gray zone delimitates the range of all the curves, with gray line and black line representing the results of the first and the last sliding, respectively.



- ROC test for the forecasts **using different grid sizes.**
- (a-b): grid size 0.10° ;
- (c-d): grid size 0.15° ;
- (e-f): grid size 0.25° .

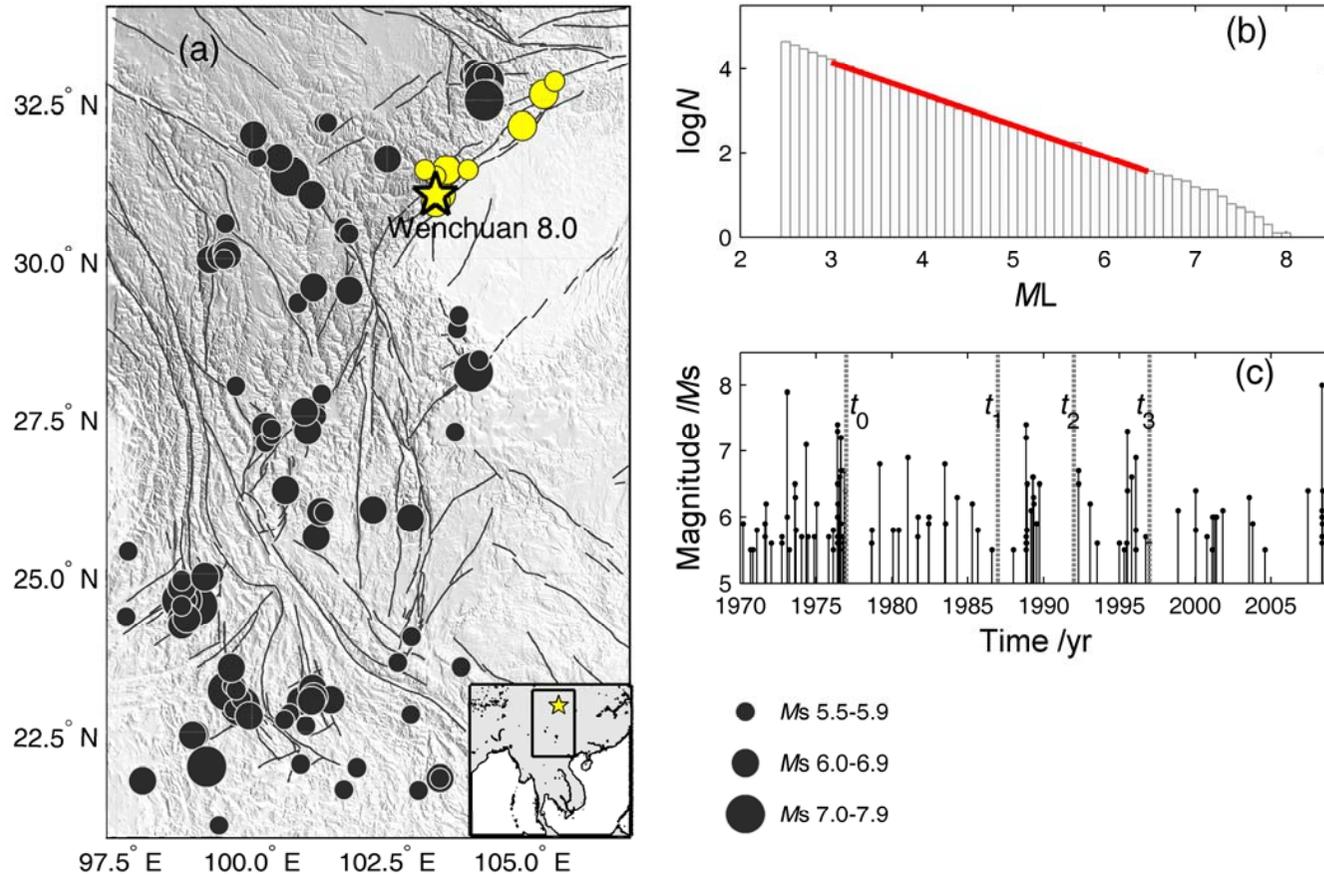


- ROC test for forecasts using **different lengths of earthquake catalogues.**
- (a-b): earthquake catalogue for 13 years; (c-d): earthquake catalogue for 17 years.



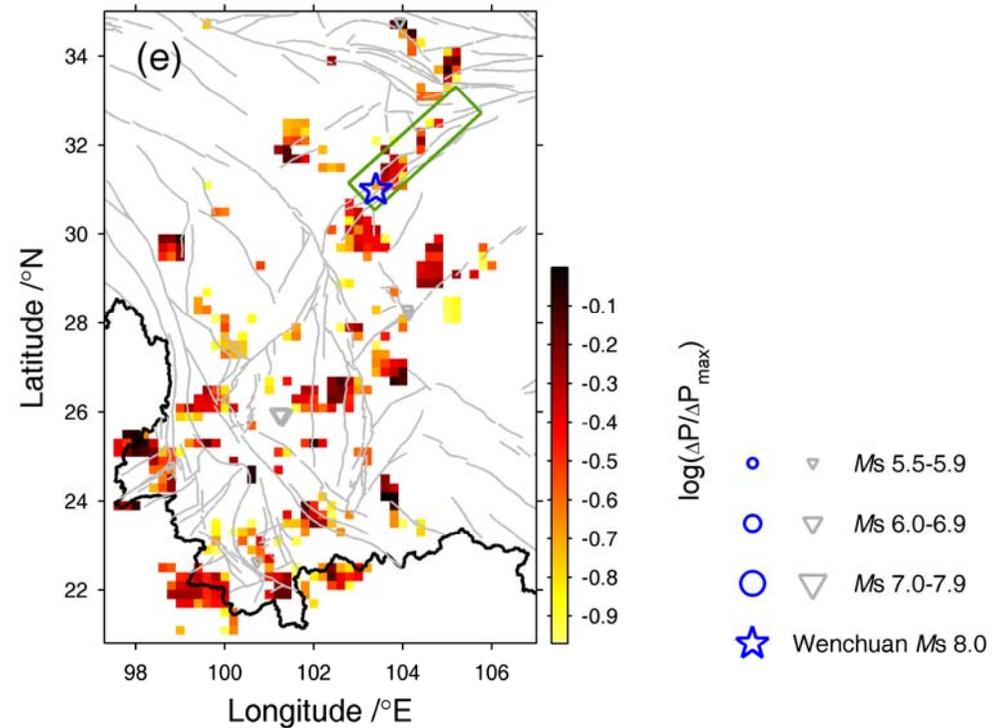
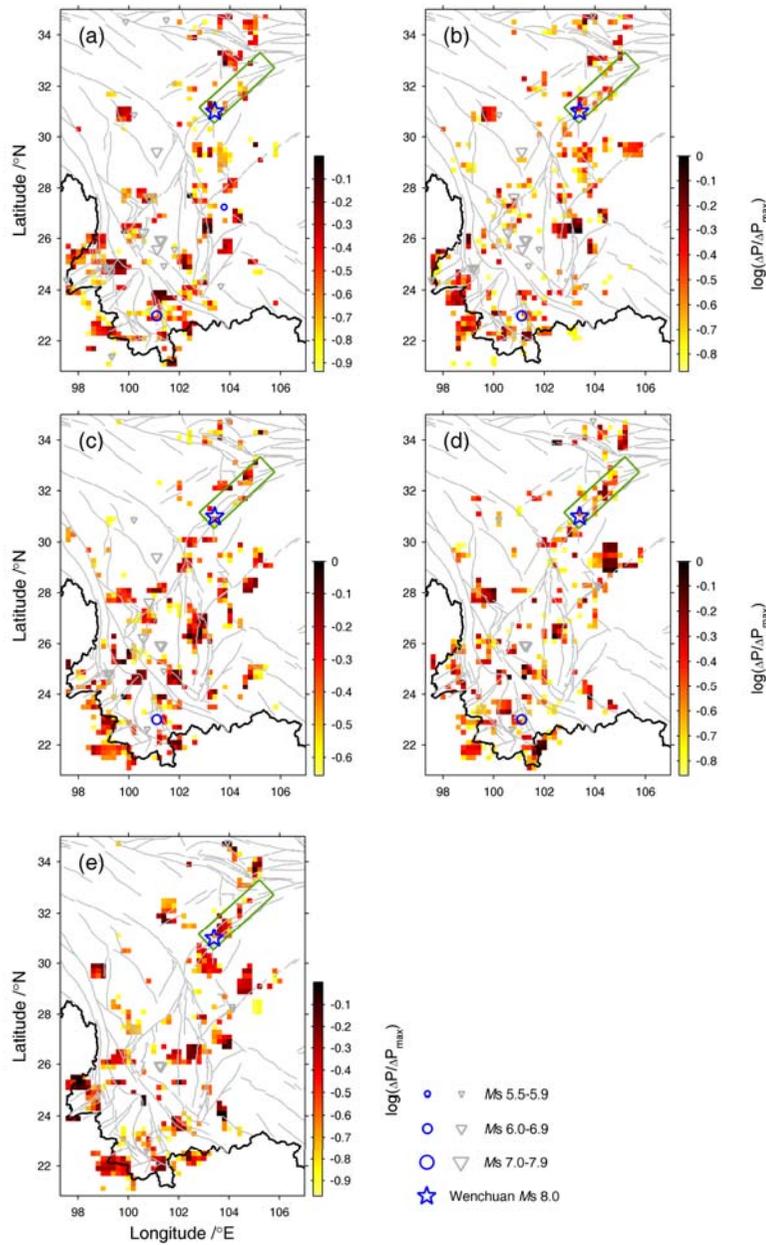
- ROC test for **different cutoff magnitudes of earthquake catalogues in use.**
- (a-b): cutoff magnitude $M_L 3.2$;
(c-d): cutoff magnitude $M_L 3.4$.

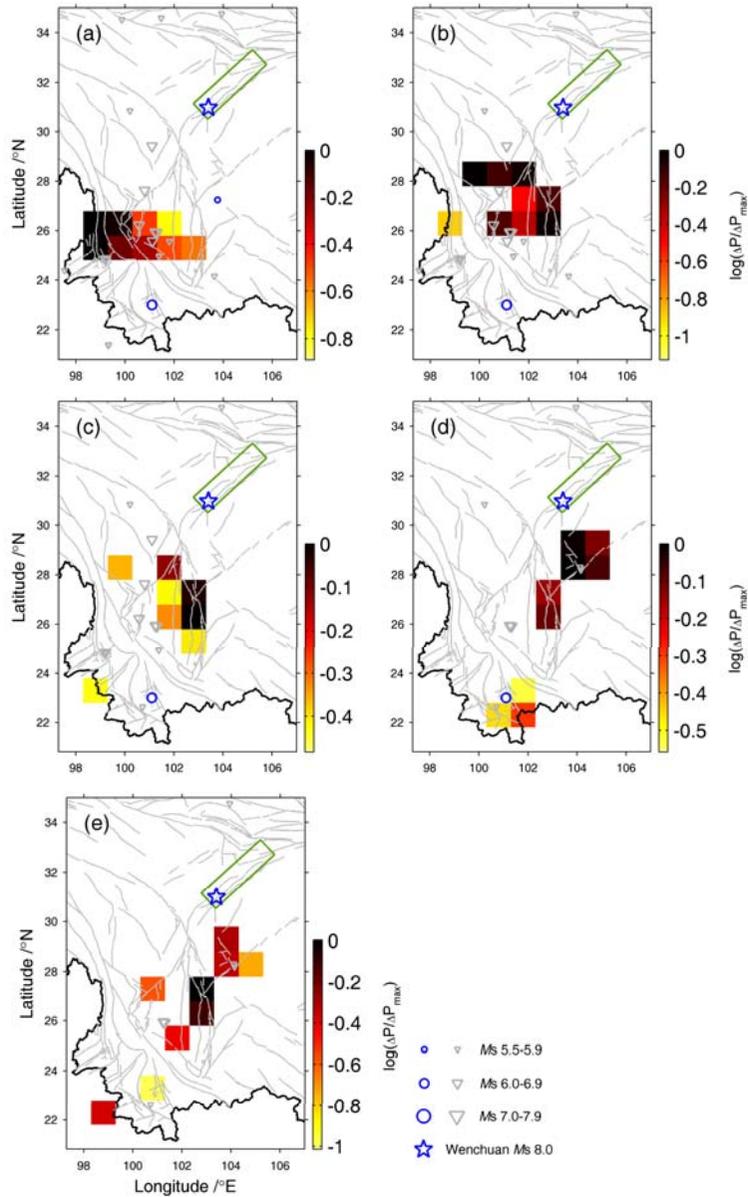
- ROC test for **another target earthquakes magnitude:** for earthquakes above $M_S 6.0$, with grid size $D = 0.30^\circ$.



(a) earthquakes larger than $M_s 5.5$ since 1970 in Sichuan-Yunnan region, with tectonic faults shown by gray lines. Yellow star and yellow dots indicate the epicenters of the Wenchuan mainshock and its aftershocks. (b) frequency-magnitude distribution showing the selection of the magnitude of completeness. (c) temporal distribution.

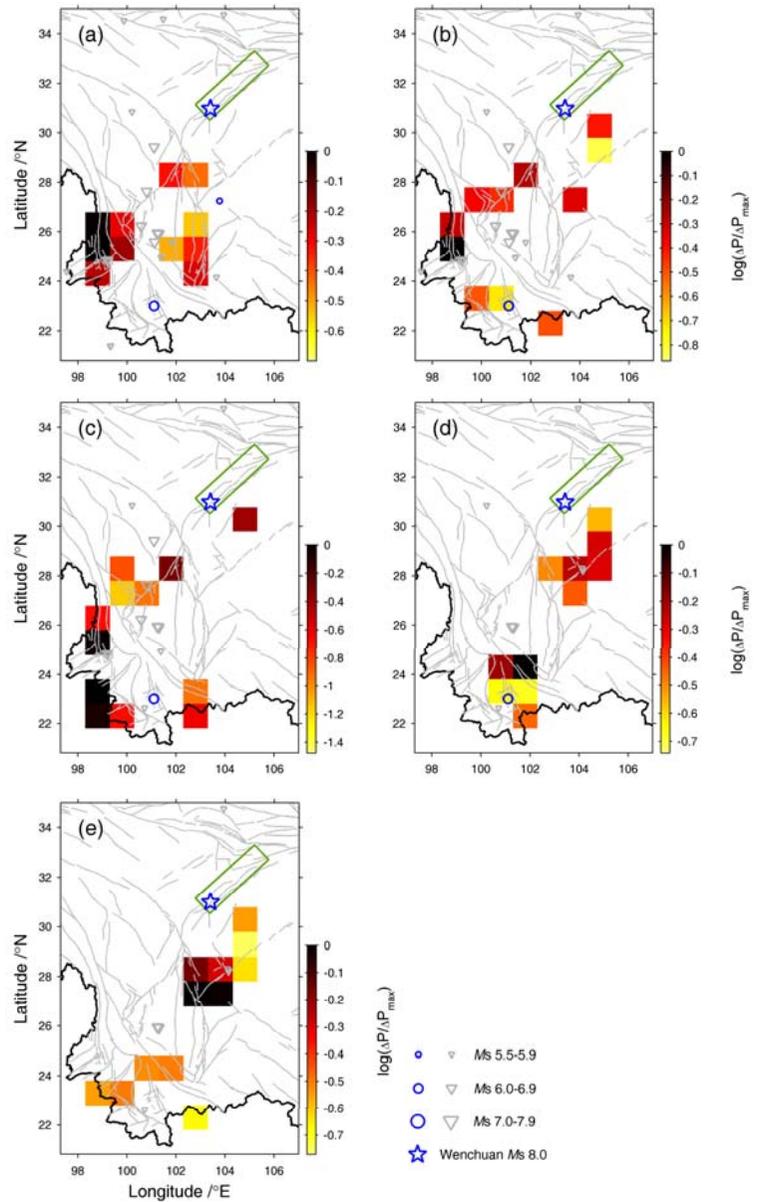
hotspot maps of PI algorithm for different 'forecasting time windows'. (a) $t_2=01/01/2004$; (b) $t_2=01/01/2005$; (c) $t_2=01/01/2006$; (d) $t_2=01/01/2007$; (e) $t_2=01/01/2007$. 'Forecast time window' $t_3-t_2 = 5$ years. Green thin lines delimitate the northern segment of the Longmenshan fault which accommodated the Wenchuan earthquake. Star shows the epicenter (or, nucleation point) of the great earthquake.





increasing the grid size?

hotspot maps of PI algorithm for different 'forecasting time windows' with **grid size 1.0°** and cutoff magnitude $M_L 3.0$. (a) $t_2=01/01/2004$; (b) $t_2=01/01/2005$; (c) $t_2=01/01/2006$; (d) $t_2=01/01/2007$; (e) $t_2=01/01/2007$. 'Forecast time window' $t_3-t_2 = 5$ years.



increasing cutoff magnitude?

hotspot maps of PI algorithm for different 'forecasting time windows' with grid size 1.0° and cutoff magnitude $M_L 4.0$. (a) $t_2=01/01/2004$; (b) $t_2=01/01/2005$; (c) $t_2=01/01/2006$; (d) $t_2=01/01/2007$; (e) $t_2=01/01/2007$. 'Forecast time window' $t_3-t_2 = 5$ years.

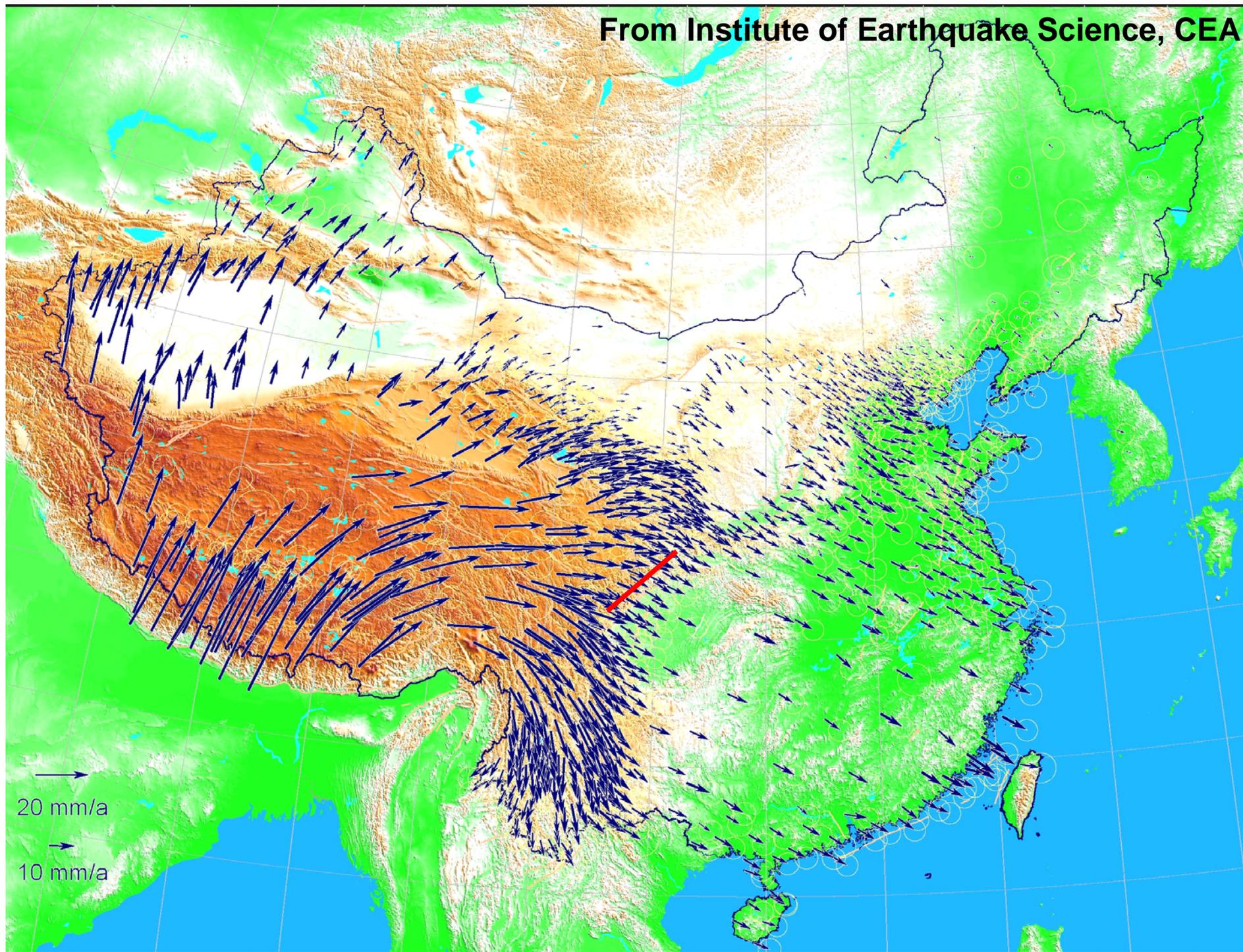
what is the nature of the roles of local seismic data ?

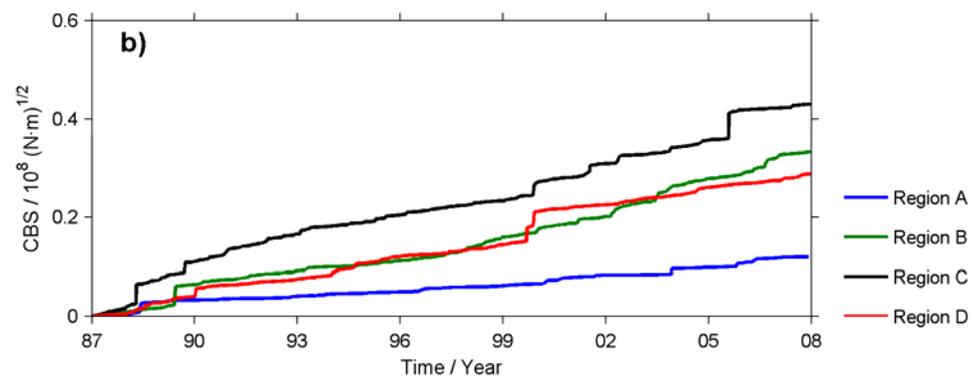
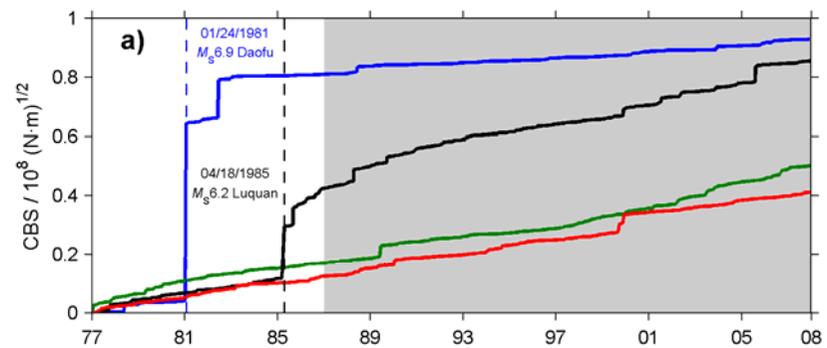
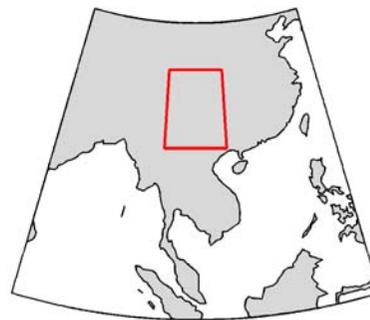
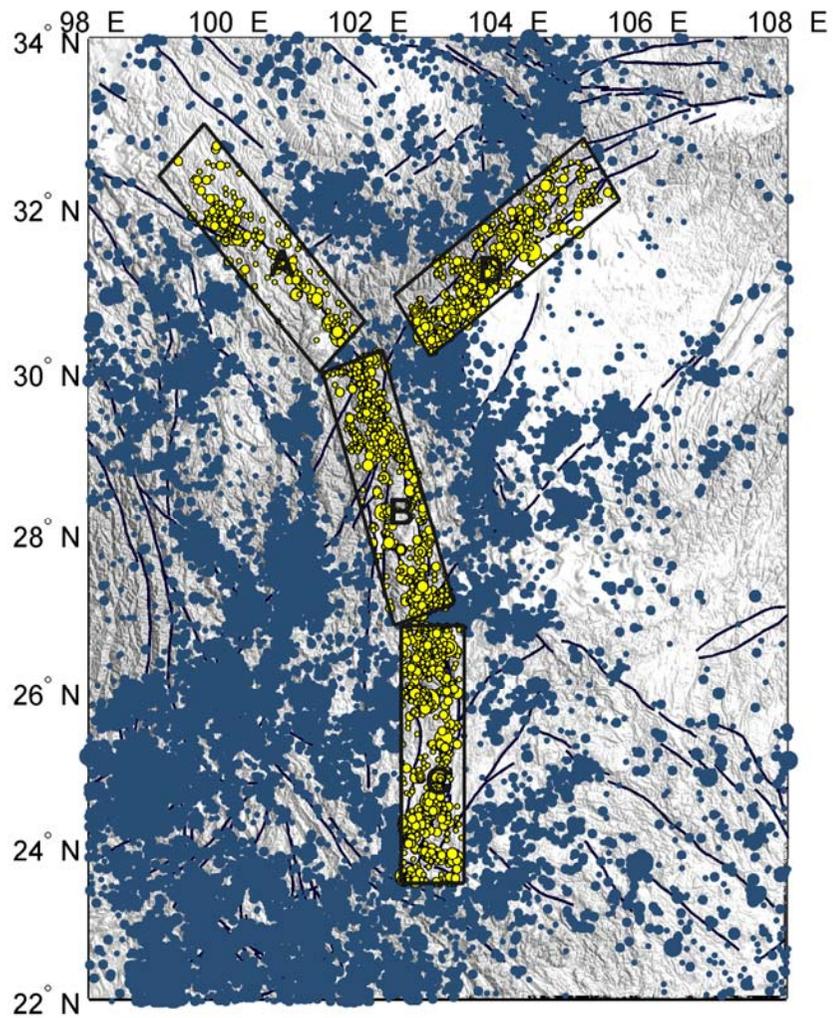
information provided as an input of the algorithm/s

**local seismic data seems much more useful
than we thought**

**also related to Wenchuan there are still
some puzzles to be solved**

From Institute of Earthquake Science, CEA







**at last
serving the society within the present limit
of scientific capability**

**be prepared so as to avoid the
next Wenchuan disaster**

- values of **retrospective case** studies: limited, but uniquely useful

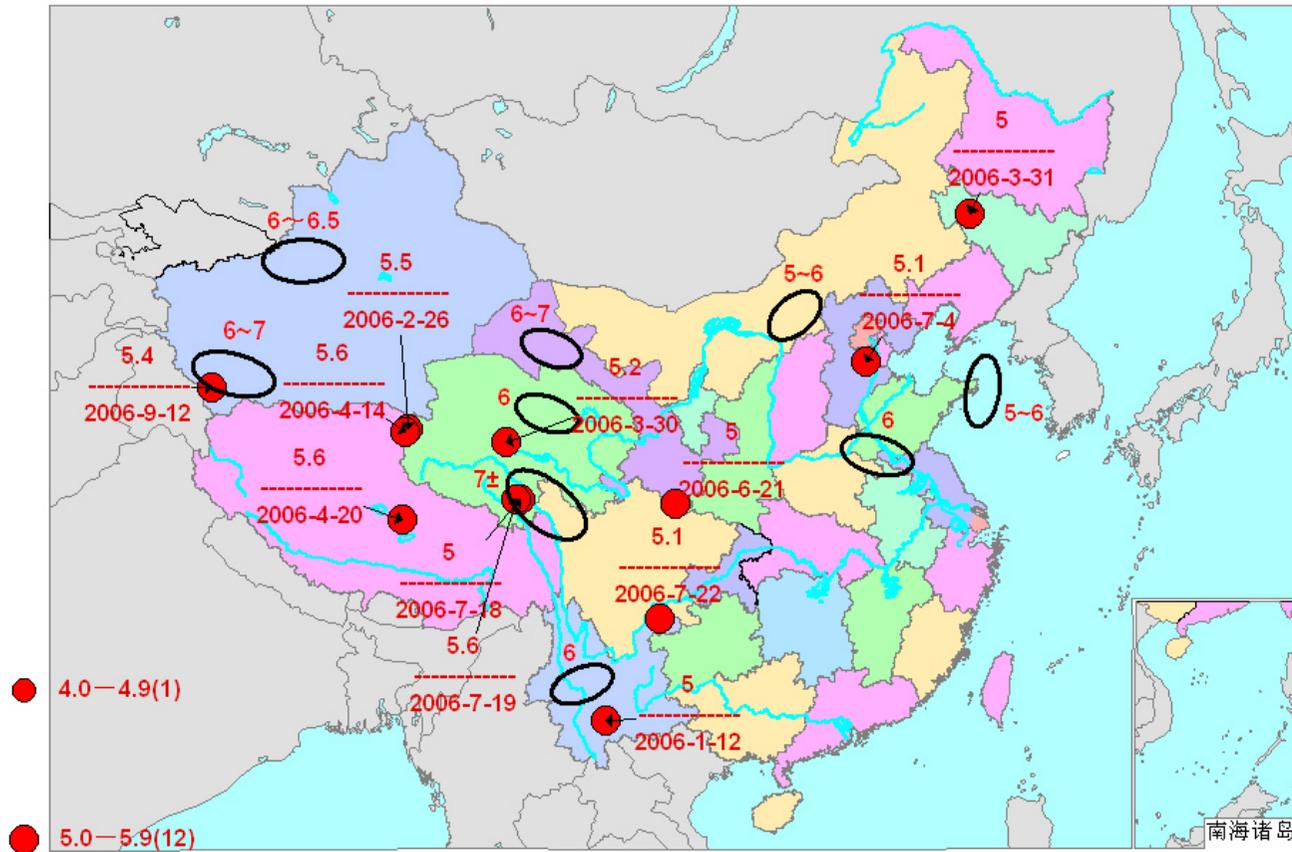


earthquake forecast/prediction or seismic hazard assessment products in China

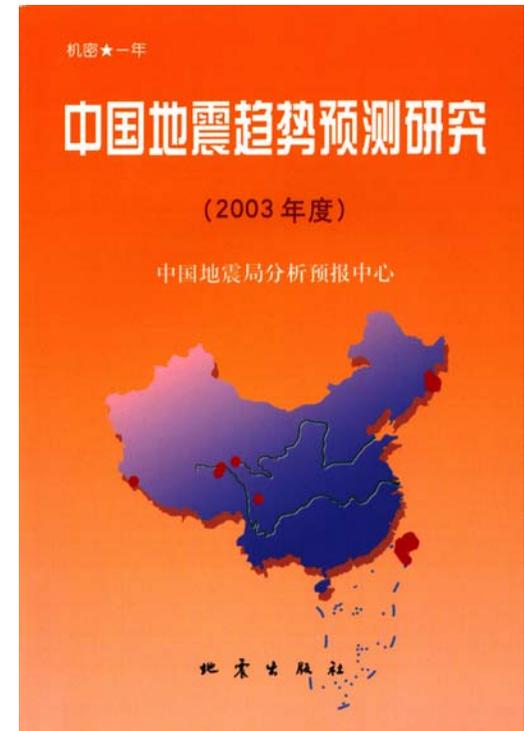
- zonation map (intensity and/or strong ground motion parameters, probability of exceedance 10% for 50 years)
 - long-term (10~15 years) key-regions with higher probability of earthquakes and key-regions with higher needs for preparedness
 - three year estimation of earthquake probabilities
 - annual earthquake probabilities (the Annual Consultation on the Likelihood of Earthquakes)

 - evaluation of short-term precursors/anomalies and predictions
 - earthquake alarm – hardly to be successful as that of Haicheng
 - evaluation of aftershock/swarm tendencies
-
- a wide spectra of products serving the public within the present limit of seismology

annual forecast for 2006 by IGP, CEA



H=2 F=7 M=6



simplified evaluation score of the performance of forecast used in China – R value

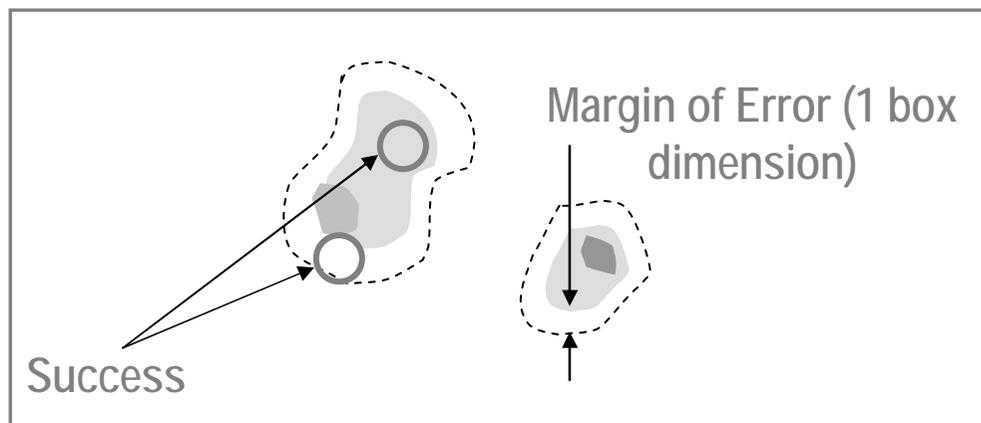
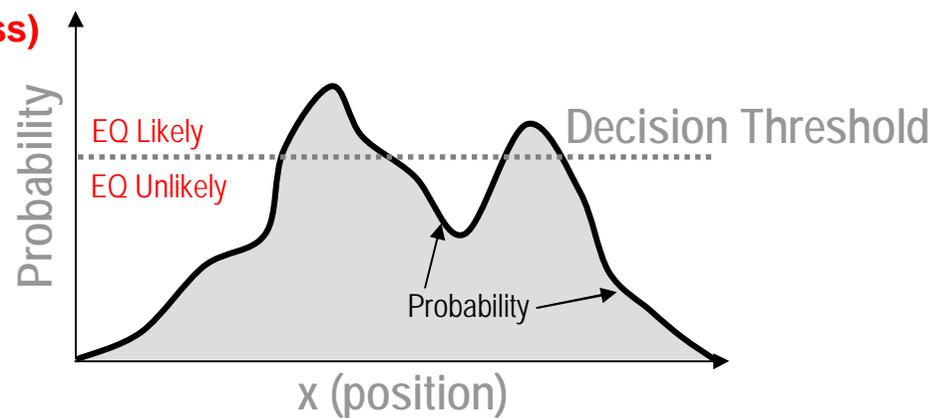
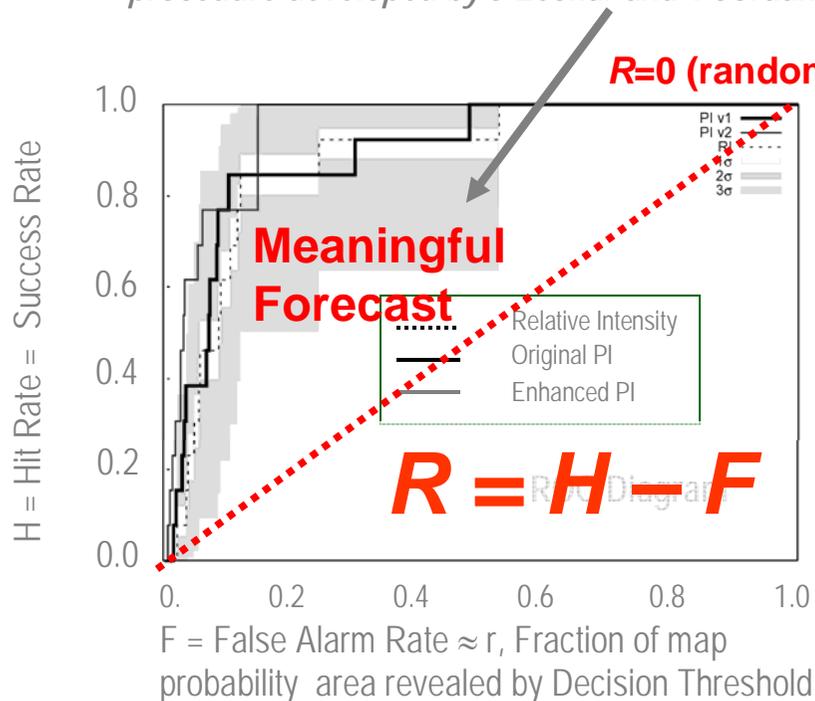
- $R = N_S/N_E - S_F/S_A$
- (hit rate) – (false alarm rate)

- N_S = successful predictions
- N_E = total number of earthquakes
- S_F = false alarm area
- S_A = total aseismic area

- When all the predictions are successful, $R = 1$
- When all the predictions are wrong, $R = -1$
- For random prediction, $R = 0$

Receiver (Relative) Operating Characteristic (ROC) Diagrams

Bounds on confidence limits were computed by a procedure developed by J Zechar and T Jordan (2005)



Courtesy of Prof. J. Rundle

3. 2007 年度地震重点危险区的预测较好

2007 年地震趋势会商会共确定 7 个地震重点危险区（图 3.1），2007 年我国大陆共发生 5 级以上地震 6 次，其中在我国大陆监测能力低的地区以外共发生 3 次 5 级以上地震，这 3 次地震中有 2 个落在危险区内。

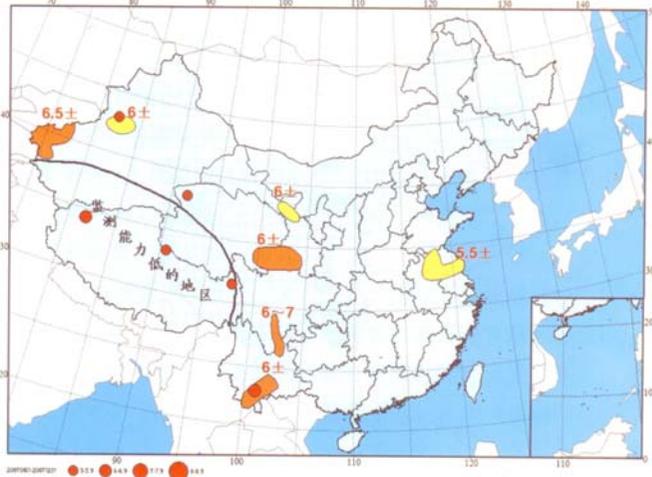


图 3.1 2007 年度危险区范围及对应地震情况

表 3-2 2007 年度中期预测效果检验

序号	预测危险区 地区	震级	三要素	实发地震		备注
				正确	不正确	
1	苏鲁皖交界至南黄海	5~6	时空强		● ● ●	
2	祁连山中东段	6±	时空强		● ● ●	
3	甘青川交界	6±	时空强		● ● ●	
4	川滇交界东部地区	6~7	时空强		● ●	
5	滇西南至滇南地区	6±	时空强	● ● ●		
6	南天山中东段	6±	时空强	● ● ●		
7	新疆乌恰至塔什库尔干	6.5±	时空强		● ●	

采用 R 值评分方法对上述预测效果进行检验（图 3.2），2007 年的 R 值为 0.594。

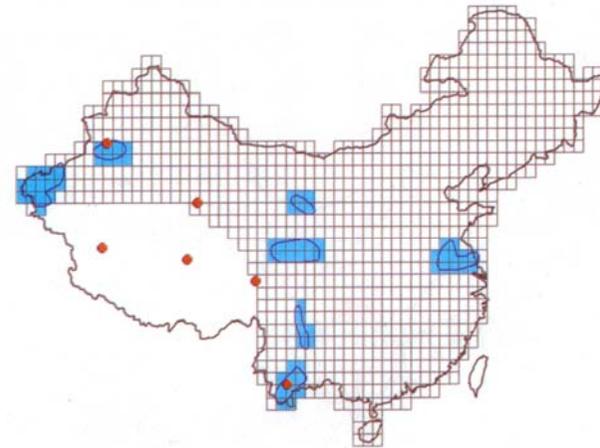
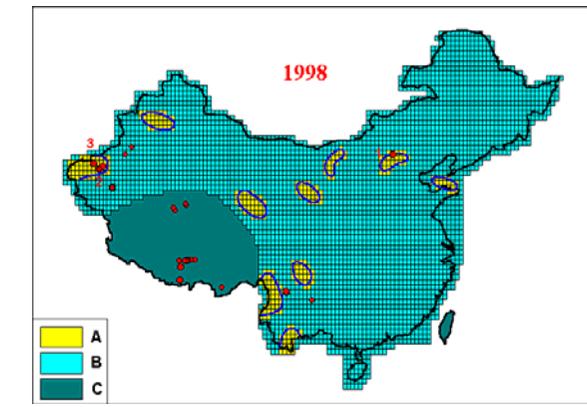
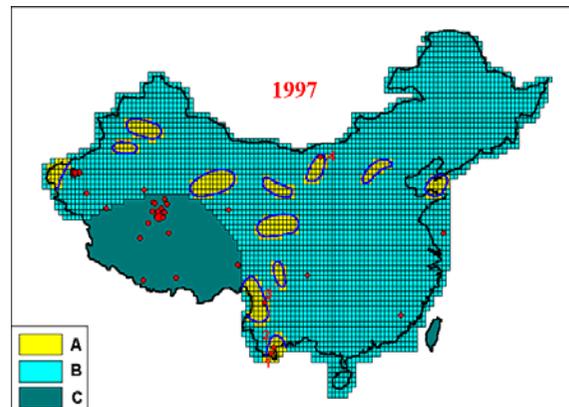
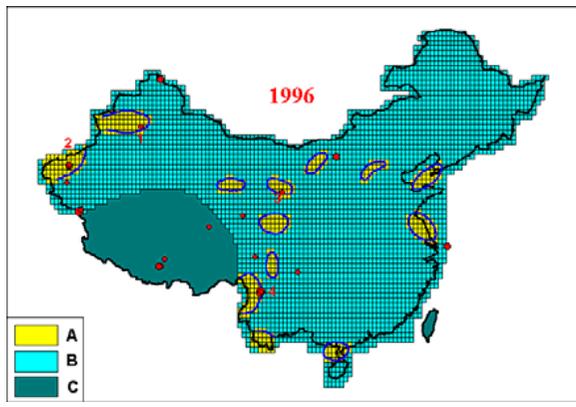
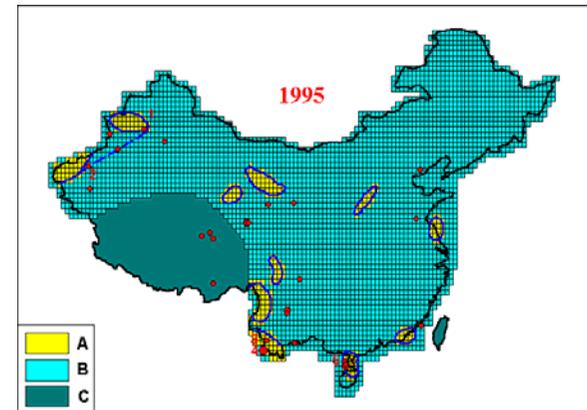
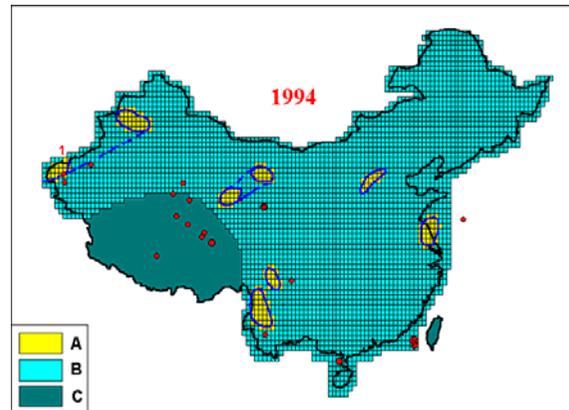
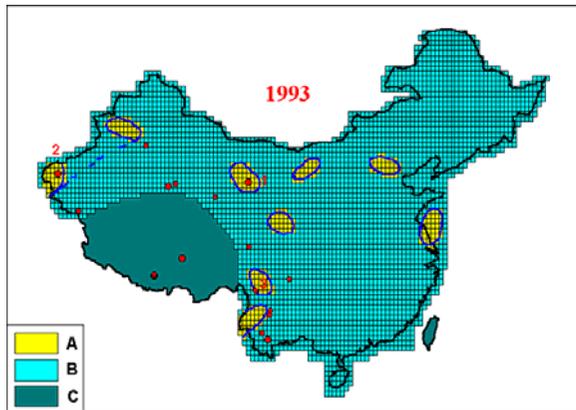
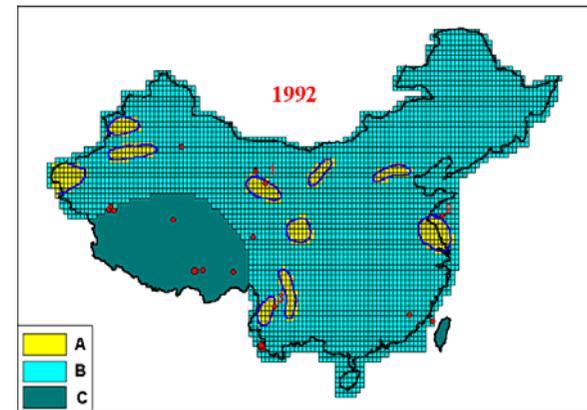
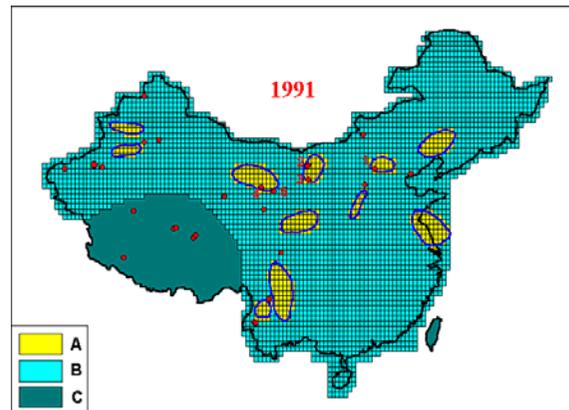
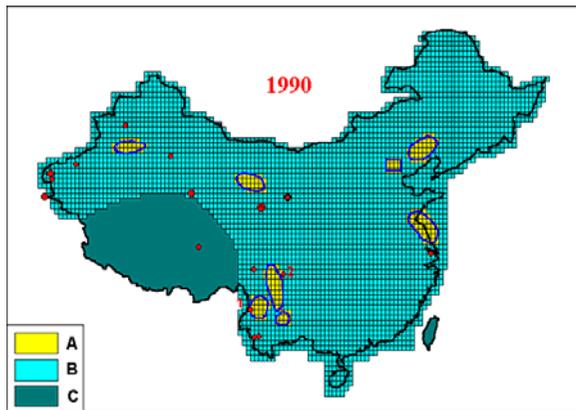


图 3.2 2007 年度危险区 R 值评分检验



***R* value from 1990 to 1998 is 0.18 on average significantly larger than 0 (for random guess) but ... the forecast is to much extent based on the knowledge of seismicity**

From Shi, Y. L., et al. (2000)

capabilities of earthquake forecast or time-dependent seismic hazard assessment

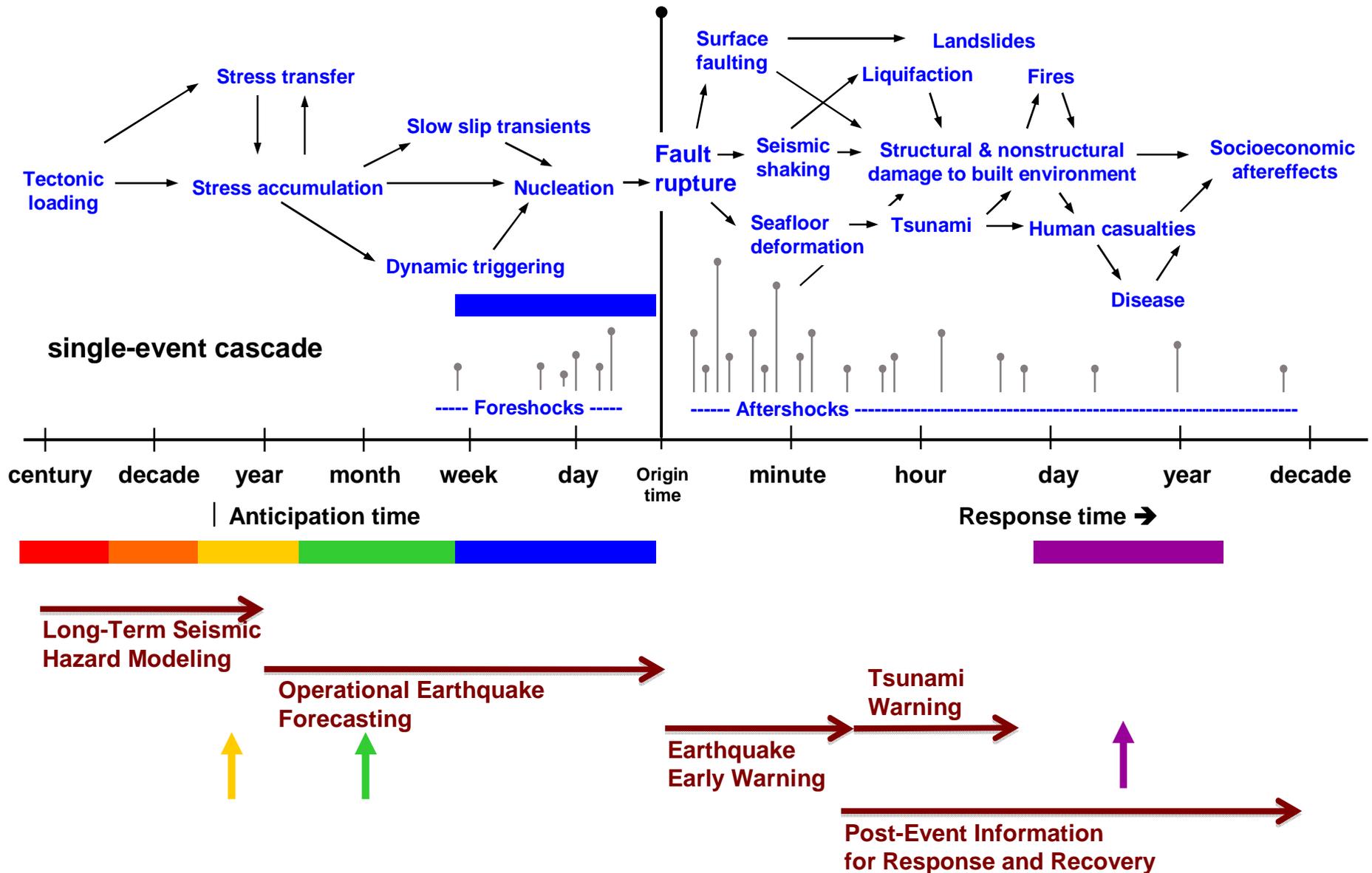
- long term and intermediate-term forecast
 - significantly outperforming random guess
 - potentially useful for earthquake preparedness
 - no plans yet for the *Zhongdian Jianshi-Fangyu Qu*
(the key region for enhanced monitoring and preparedness)
- annual consultation
 - real forward forecast test
 - successful cases for several M~6 earthquakes
 - mechanism of gathering information problematic
- short-term forecast
 - hit rate 40% for M~6 earthquakes
 - 'new parameter earthquake catalogues' may be interesting
 - problematic for M~5 earthquakes
 - very few experiences for M~7 earthquakes
- evaluation and test
 - R-value and evaluation committee
 - lack of public understandings

what are needed

firstly, doing the best for deepening the understandings of earthquake predictability at the time scales of century, year, and even months

secondly, making full use of the present knowledge of earthquake predictability for the preparedness of seismic risk

T. Jordan: tracking earthquake cascades



a few words about strong aftershocks

what can we do to serve the public

aftershocks: what we have known

- Gutenberg-Richter's law: $\log N = a - b M$
- Omori's law: $N(t) \sim (t + t_0)^{-p}$
- Båth's law: $M_{\text{mainshock}} - M_{\text{strongest aftershock}} \approx 1.2$
- Coulomb's law: for most of aftershocks $\Delta CFS > 0$

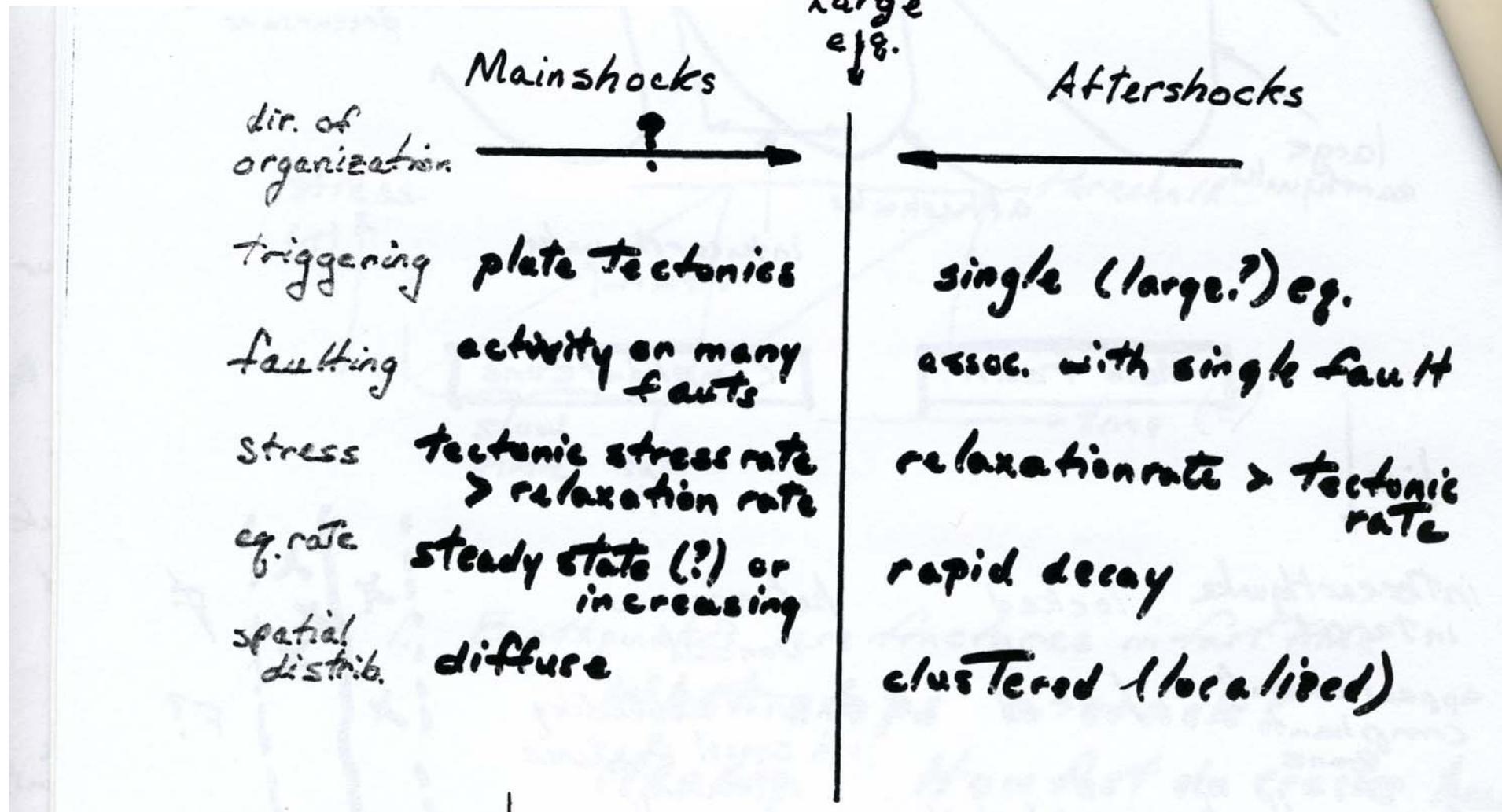
QUESTIONS ADDRESSED about the strong aftershocks:

Time – how long

Place – where

Size – how big is the maximum

Rate – how many



lecture notes of Prof. Leon Knopoff showing the present understanding of aftershocks

Today's Map

[What Is This Map?](#)

[How Do We Make This Map?](#)

[What Are Aftershocks, Foreshocks and Earthquake Clusters?](#)

[How Can I Use This?](#)

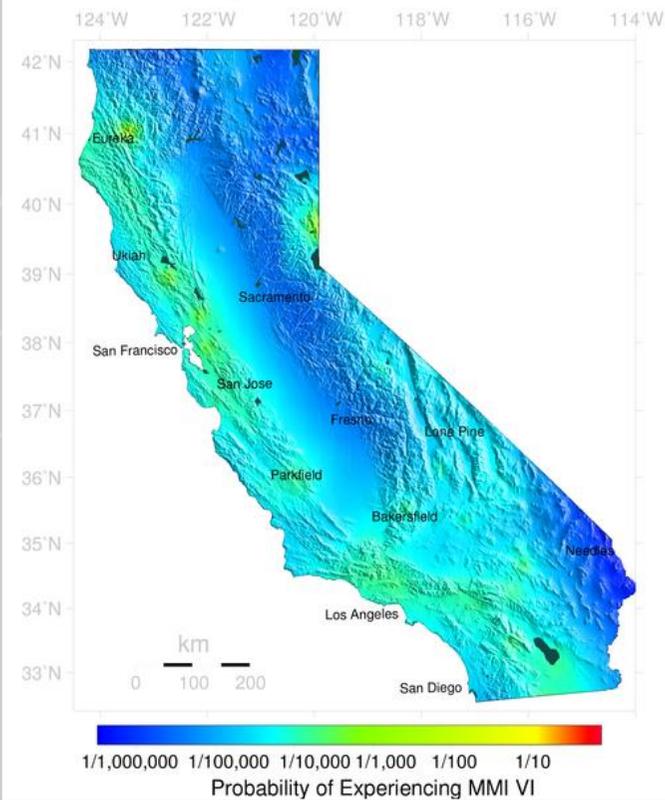
[Map Archive](#)

These maps are made with contributions from ETH-Zurich, Switzerland, and the Southern California Earthquake Center



24-Hour Aftershock Forecast Map

Forecast for 06/09/2008 05:30 AM PDT
through 6/10/2008 05:30 AM PDT



<http://pasadena.wr.usgs.gov/step/>

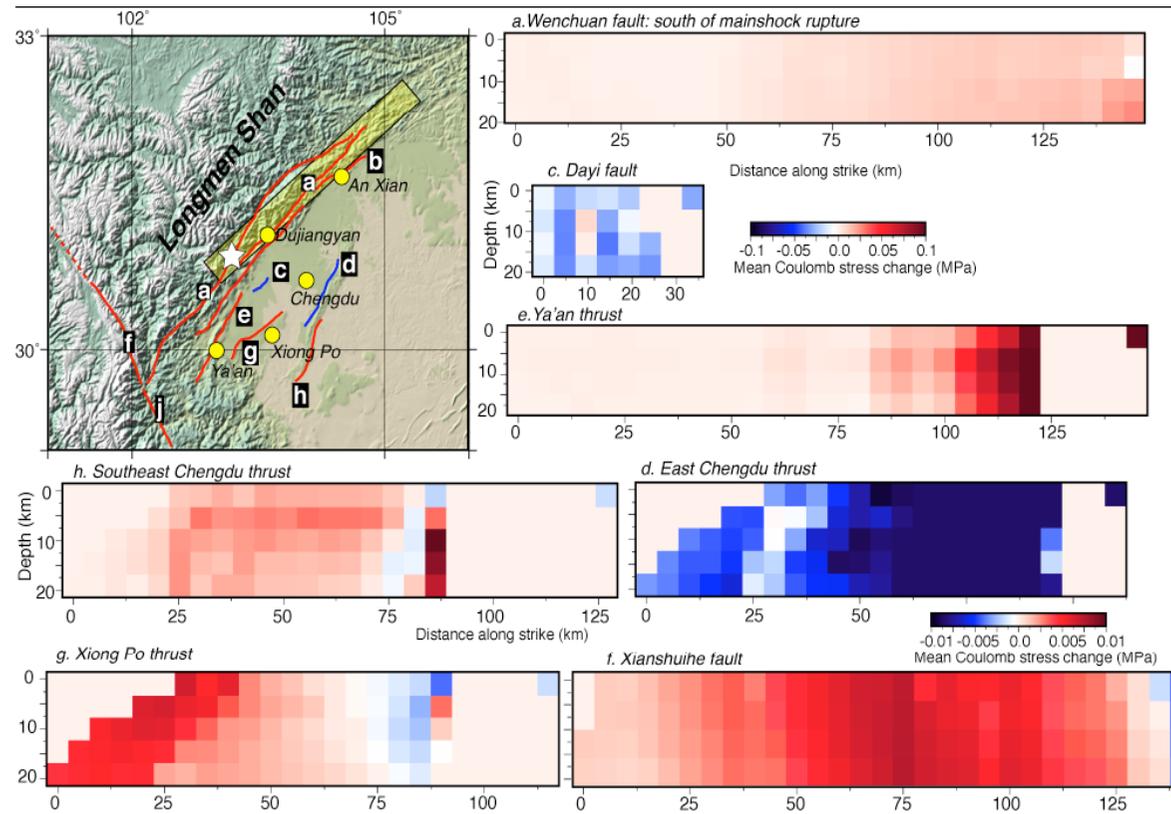
the USGS Aftershock Forecast Map project

forecast by Jiancang Zhuang (Japan) based on ETAS model

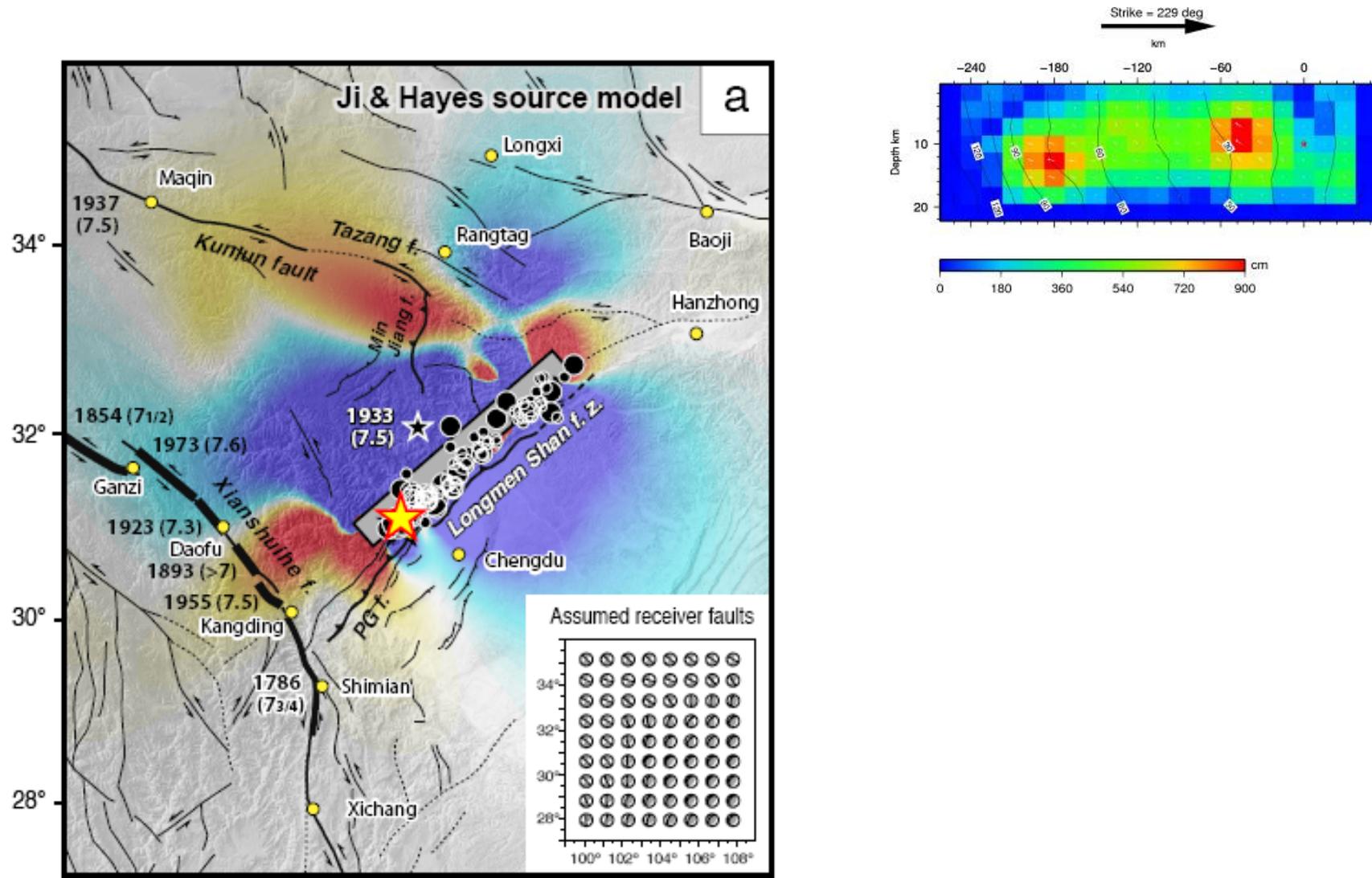
- Here are the probability forecasts for the 18th day after the mainshock

	Expected #	Prob.	Waiting time	quantile (1% 5% 50% 95% 99%)				
• $M \geq 4.0$	2.17	0.89	0.44	0.004	0.022	0.298	1.296	1.934
• $M \geq 4.5$	1.03	0.64	0.89	0.010	0.048	0.605	2.655	4.061
• $M \geq 5.0$	0.36	0.30	2.40	0.024	0.125	1.677	7.472	11.92
• $M \geq 5.5$	0.12	0.11	6.53	0.058	0.339	4.306	20.08	32.89
• $M \geq 6.0$	0.07	0.07	10.01	0.087	0.460	6.466	31.15	49.15

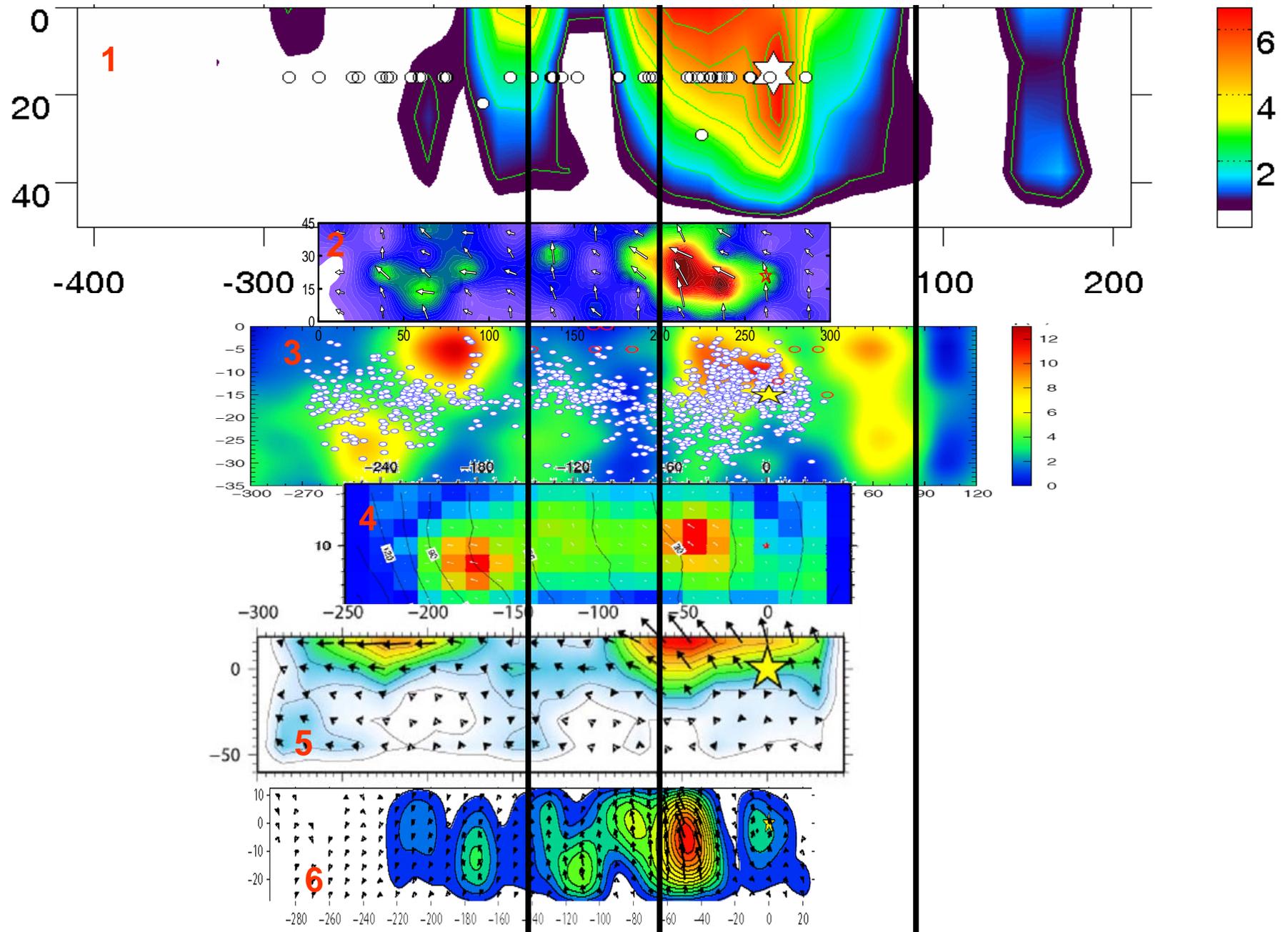
stress changes from the 12 May, 2008 $M=7.9$ earthquake calculated for major faults beneath the Sichuan basin, China by Tom Parsons and Chen Ji



Wenchuan earthquake promotes failure on major strike-slip faults, by Shinji Toda, Jian Lin, Mustapha Meghraoui, and Ross S. Stein



from Department for Monitoring and Prediction, CEA





the abduS salam
international centre for theoretical physics

summary

"Scientific thought is the common heritage of mankind" – AbduS Salam

firstly
a few words about China and about the
2008 Wenchuan earthquake

what did we see before the earthquake



the abduS salam
international centre for theoretical physics

summary

**secondly
monitoring and modeling for
forecast/prediction/preparedness**

what could be learnt from Wenchuan



the abduS salam
international centre for theoretical physics

summary

"Scientific thought is the common heritage of mankind" – AbduS Salam

thirdly
why some of the worldwide-valid algorithm
failed to indicate the approaching of the
Wenchuan earthquake

importance of the consideration
of local situations



the abdu salam
international centre for theoretical physics

summary

"Scientific thought is the common heritage of mankind" – Abdus Salam

**at last
serving the society within the present limit
of scientific capability**

**be prepared so as to avoid the
next Wenchuan disaster**

earthquakes provided valuable lessons

Robert Hooke, CEIIOSSOTTUO
In 1686 the English Physicist published a treatise entitled the True

the 1755 Lisbon earthquake

November 1, 1755 Lisbon, with a population of more than a quarter of a million was one of the largest cities in Europe. About 9:30 a.m. a great earthquake was felt 200 km to the southwest beneath the Atlantic coast. The city shook for nearly 10 minutes and 30 minutes after the event a tsunami struck the Algarve coast which ran through the center of the city. The Lisbon earthquake was the first event to be studied scientifically. J. Milne's proposed the shaking was caused by wave propagation from a distant source, and that the waves were very similar to those produced by sound in air.

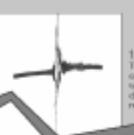


Robert Hooke, CEIIOSSOTTUO
In 1686 the English Physicist published a treatise entitled the True

It not only the inventor of the word seismology, also considered the "father" of seismology. Born in an era of enlightenment, Hooke was an engineer of considerable skill and his work in seismology marks the birth of the science. He is credited with the first comprehensive earthquake catalog and world seismicity map. In the late 1680s Hooke spent his time in London, where he proposed the idea that seismic waves travel at different speeds in different rock types. Following the 1667 Japanese earthquake, Hooke traveled to Italy and using the orientation of cracks and other in situ produced geological maps for the event. The maps identified areas of low intensities of shaking.

THE HISTORY OF SEISMOLOGY

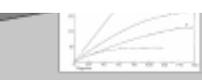
John Milne in 1855 a 25 year old student received a grant from the British Association for the Advancement of Science to study the geology of the Imperial University of Tokyo. Milne organized a seismic survey of Japan and back recognized the importance of recording the seismograms. Milne was a great promoter of establishing a world wide seismic network, designed several types of seismometers, and built the first Japanese seismograph (1880) that still exists.



1883, The First Teleseism
The first teleseism was recorded with a distant earthquake in 1883. The record shows a deep Japanese earthquake as recorded in Potsdam, Germany.

the 1906 San Francisco earthquake

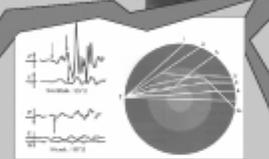
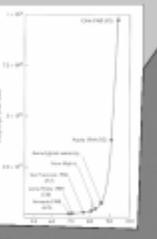
Lohess: The inner Cone
Lohess discovered the great cone, a cone of solid material at a depth of 1500 km in the early 1900s. Lohess worked at the Copenhagen Observatory and carefully measured the arrival times of seismic phases from distant earthquakes. He noted that the only way to explain the cone phase was to have a boundary where the cone was in a medium of lower velocity. He hypothesized that the inner cone was solid, which was later proved on the basis of the seismology.



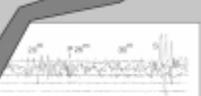
1906, A nearly 300 km long section of the fault slipped with others as great as 6 meters. Many of the structures in the city were destroyed, but much of the damage was caused by the resulting fire that burned out of control for days. The state of California set up a commission, headed by H.H. Wood and G.E. Gilbert, to study the earthquake and the resulting report laid out the theory of "elastic rebound" which forms the core of understanding earthquakes today.



1935, The Richter Scale in the early 1930s Charles Richter was analyzing a catalog of California earthquakes. Richter wanted to publish the catalog with the "size" of the earthquakes instead of the intensity. He developed a measure of earthquake size based on two fundamental principles: the level of shaking experienced at a distant site will depend on the size of the earthquake, and the level of shaking will decrease the further the distance traveled by the seismic waves. Richter used these principles to develop a logarithmic scale (each unit of the scale corresponds to a 10 fold increase in shaking which becomes known as the Richter Scale). Although Richter's early work was only applicable to southern California, it served as the basis for modern magnitude scales.



September 1, 1923 Tokyo One of the deadliest earthquakes of this century struck the heavily populated Kanto province in east central Japan. The death toll in Tokyo exceeded 100,000, and nearly 2 million people were left homeless. Seismology was a developed science in Japan in the first part of the 20th century. Professor Taishiro Inoue had studied earthquakes in Japan and in 1912 concluded that regions around Tokyo were "seismically quiet" and predicted that an earthquake would strike the region in the future. After the 1923 earthquake the legend of earthquake "prediction" completely was formed and produced the vastness of scientific and engineering studies which ultimately improved earthquake-resistant Japan.



the 1923 Tokyo earthquake

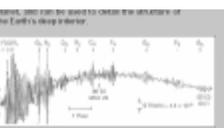
Wadati: The Discovery of Deep Earth
All earthquakes with the same apparent focal mechanism occur at different depths below the earthquake "source" (which proved conclusively occurred, and showed that the depths of the new benefit Japan, which has now recognized conventional had a profound effect on what the first 211 years that suggest plate tectonics in 1903.

1905, J. Tuzo Wilson and Transform Faults
The spatial distribution of earthquakes may be fundamental in developing the theory of plate tectonics. J. Tuzo Wilson made a major contribution with the discovery of Transform Faults, which are shear faults with significant strike-slip that are oblique to mid-oceanic ridges or collision zones.



the 1960 Chile earthquake

July 16, 1960 at 3:34 a.m. an immense earthquake struck the first nuclear reactor in central Chile. The first nuclear reactor TRISTITY had an explosive yield of approximately 15 kt equivalent to 15 thousand tons of TNT. The closest atomic attack was in Nagasaki, and the nearest atomic bomb was used in Nagasaki. The scientists at the University of California used the record to determine the origin time of the explosion. The ability to accurately record time and other explosion parameters for the field of "Nuclear Seismology".



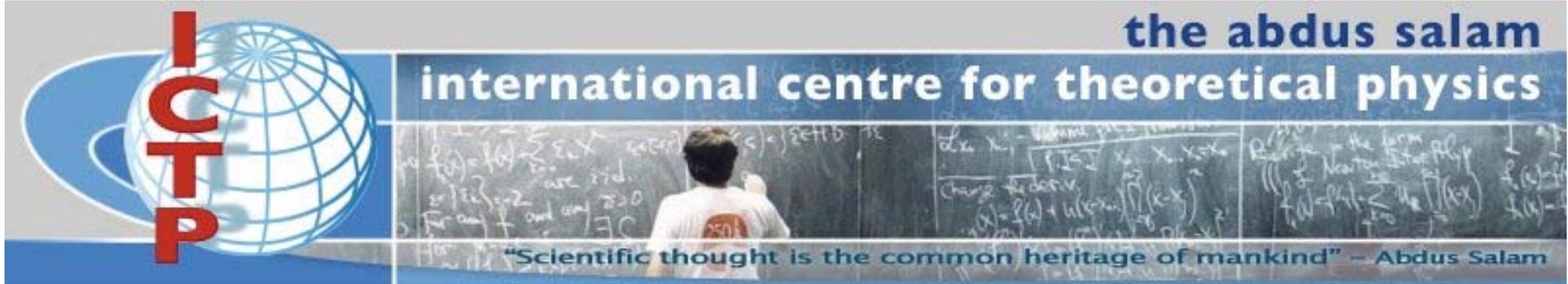
July 26, 1976 the deadliest earthquake of the 20th century struck the city of Tangshan, China on July 26, 1976. The death toll lay in excess of 500,000. The city was totally destroyed when a 7.5 magnitude earthquake struck through the population of 7 million.



the 1992 Landers earthquake

Earth Velocity Structures
Using a very large number of seismographs it is possible to map changes in velocity throughout the interior of the Earth, known as tomographic slices. These slices can show subsurface slabs and

T. Wallace, A. Paquette, and M. Hall-Wallace
University of Arizona



thank you

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wuzl@cea-igp.ac.cn

appendix: related publications of the lecturer – just for your reference

- Wu, Z. L., Liu, J., Zhu, C. Z., Jiang, C. S. and Huang, F. Q., 2007. Annual consultation on the likelihood of earthquakes in continental China: Its scientific and practical merits. *Earthquake Research in China*, 21: 365~371.
- Jiang, C. S. and Wu, Z. L., 2008. Retrospective forecasting test of a statistical physics model for earthquakes in Sichuan-Yunnan region. *Science in China, Series D: Earth Sciences*, 51: 1401~1410.
- Zhao, Y. Z. and Wu, Z. L., 2008. Mapping the b -values along the Longmenshan fault zone before and after the 12 May 2008, Wenchuan, China, $M_{S8.0}$ earthquake. *Nat. Hazards Earth Syst. Sci.*, 8: 1375~1385.
- Jiang, C. S. and Wu, Z. L., 2009. Seismic moment release before the May 12, 2008, Wenchuan earthquake in Sichuan of southwest China. *Concurrency Computat.: Pract. Exper.*, Wiley InterScience (www.interscience.wiley.com), DOI: 10.1002/cpe.1522.
- Zhao, Y. Z., Wu, Z. L., Jiang, C. S. and Zhu, C. Z., 2010. Reverse tracing of precursors applied to the annual earthquake forecast: Retrospective test of the Annual Consultation in the Sichuan-Yunnan Region of southwest China. *PAGEOPH*, 167: DOI 10.1007/s00024-010-0077-1.
- Jiang, C. S. and Wu, Z. L., 2010. PI Forecast for the Sichuan-Yunnan region: Retrospective test after the May 12, 2008, Wenchuan earthquake. *PAGEOPH*, 167: DOI 10.1007/s00024-010-0070-8.
- Zhao, Y. Z., Wu, Z. L., Jiang, C. S. and Zhu, C. Z., 2010. Is the deformation rate of the Longmenshan fault zone really small? Insight from seismic data at the two-decade time scale. *Earth, Planets and Space*, 62: in press.

Earthquake Prediction Experiment Site: Design, Performance Evaluation, and Implementation

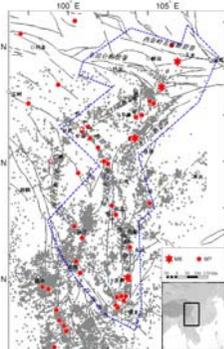
Working Group NEPTUNE, China Earthquake Administration, 100036 Beijing, China

Presented at the International Symposium on Earthquake Seismology and Earthquake Predictability, July 5-9, 2009, Beijing

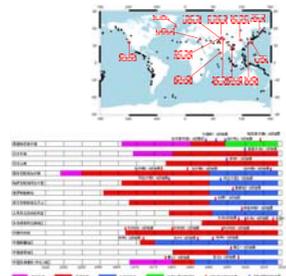
Introduction

Since the beginning of 2009, the Department for Earthquake Monitoring and Prediction of China Earthquake Administration (CEA) has been organizing the planning of the Earthquake Prediction Experiment Site in the southern part of the Central North-South Seismic Zone. Working Group 'National Earthquake Prediction Test-site with Unified Networking and Experiment' (Working Group NEPTUNE) has been working on this planning. This presentation briefly introduces the planning works and the strategies for the planning.

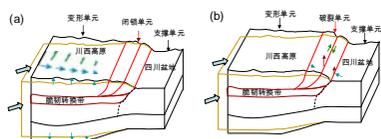
Location of the experiment site, its tectonics, and seismic activity



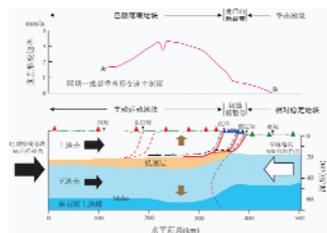
Historical background of earthquake prediction experiment site: what are their experiences, and what are their lessons?



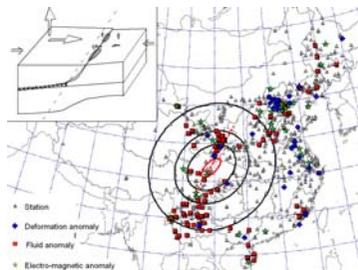
Lessons of Wenchuan



A model of earthquake preparation (left: inter-seismic, right: co-seismic, Zhang et al., 2009)



'Expected anomalies' (triangles are scenario observation stations. red: long-to intermediate-term anomalies expected; blue: short-term anomalies expected; green: few anomalies expected)



Precursors observed before the Wenchuan earthquake (Liu et al., 2009) and its relation with the earthquake preparation model

Lesson: the importance of the concept Modeling and Monitoring for Prediction

Scenario rupture Expected anomalies

For a certain segment of active fault or block boundary zone which accommodate future earthquakes, a 'scenario rupture' is considered to provide different versions of the earthquake preparation model. Based on the earthquake preparation model, detection programs and monitoring systems are designed. The system is to be oriented at the effective constraint of the earthquake preparation model, the effective monitoring of 'expected' anomalies, and the effective test of the forecast/prediction schemes.

**Effective constraint
Effective monitoring
Effective testing**



Key regions subject to the risk of strong earthquakes (2006-2020) and the distribution of tectonic block boundaries

Scientific problems associated with the earthquake prediction experiment site:

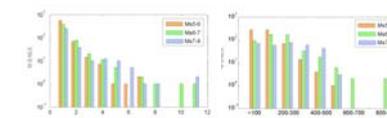
How to deploy monitoring systems for the prediction of a geologically imminent earthquake?

How to test new technologies potentially useful for capturing earthquake precursors?

Playing game with earthquakes

Considering the usefulness and uncertainties of intermediate-term medium-range earthquake forecast, region-specific models of seismic activity and seismotectonics are considered in the design of the monitoring and experiment system. That is to ask:

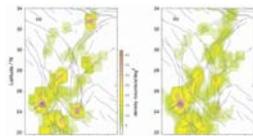
*How long should be the observation?
How far away should be the station?*



Statistics from earthquake cases in China (Jiang et al., 2009)

How many M>6.5 earthquakes are expected during the experiment?

Earthquake rate: total (Left) & background (Right)



Earthquake prediction experiment site as a big-science device

In the perspective of technology, the experiment site is treated as a 'big-science' device, emphasizing the robustness of the performance of the system with complex multi-layer and multi-component structures, and the sustainable functioning of the system ensuring the effective 'close-in contact' with earthquakes and 'standard testing norms' of predictive models and schemes.