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A Prototype Earthquake Early Warning (EEW) System in Beijing Capital Region of China

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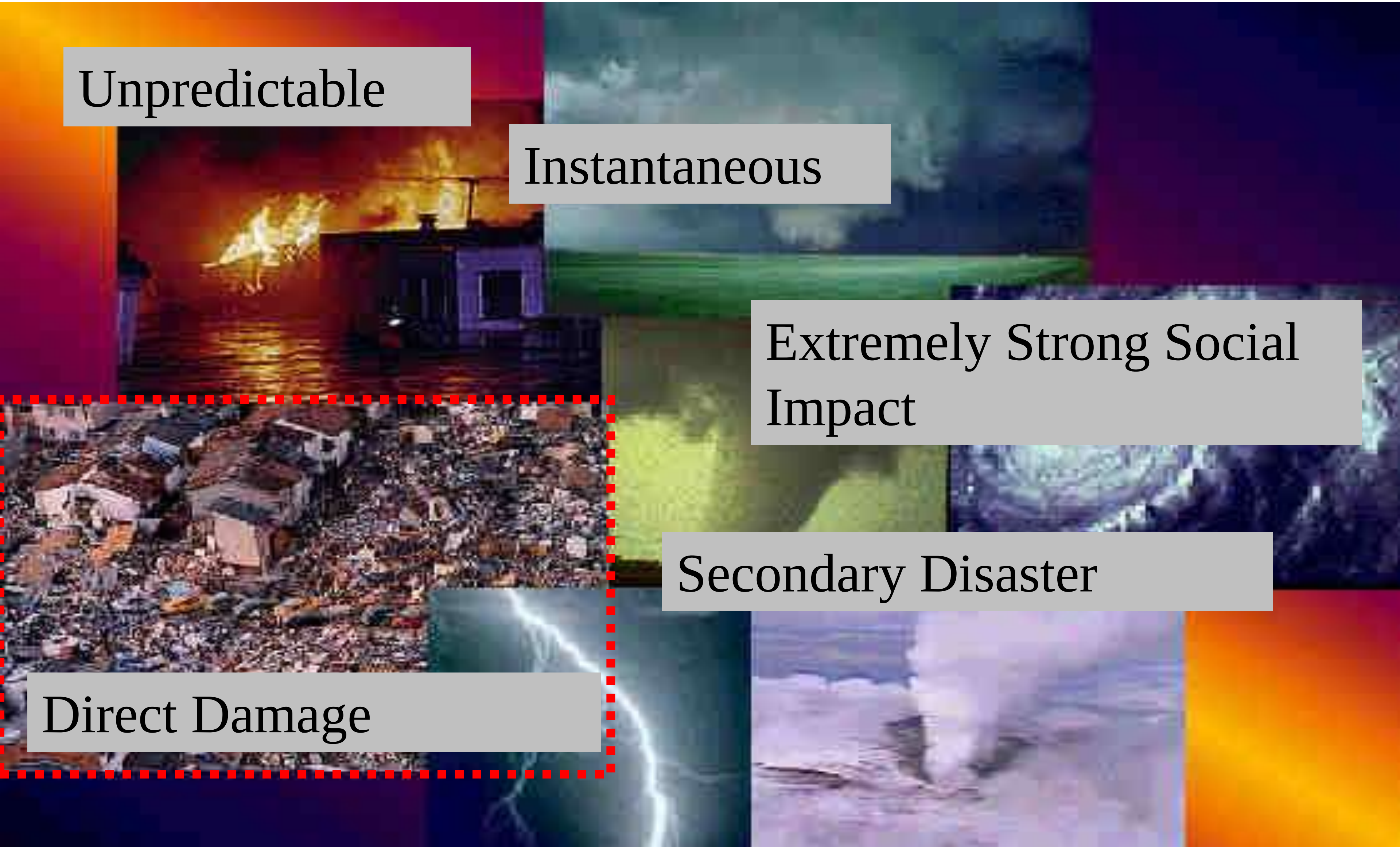
In history, earthquake has brought our world with uncountable criminals! **Is it possible to catch it?**



The Original Concept of EEW

3 November 1868

Editor, San Francisco Daily Evening Bulletin:

"... we are now obliged to look for some ... means of prognosticating [earthquakes] and I wish to suggest the following mode by which we may make electricity the means, perhaps, of saving thousands of lives in case of the occurrence of more severe shocks than we have yet experienced ... If this center happens to be far enough from [San Francisco], we may be easily notified of the coming wave in time for all to escape from dangerous buildings before it reaches us...

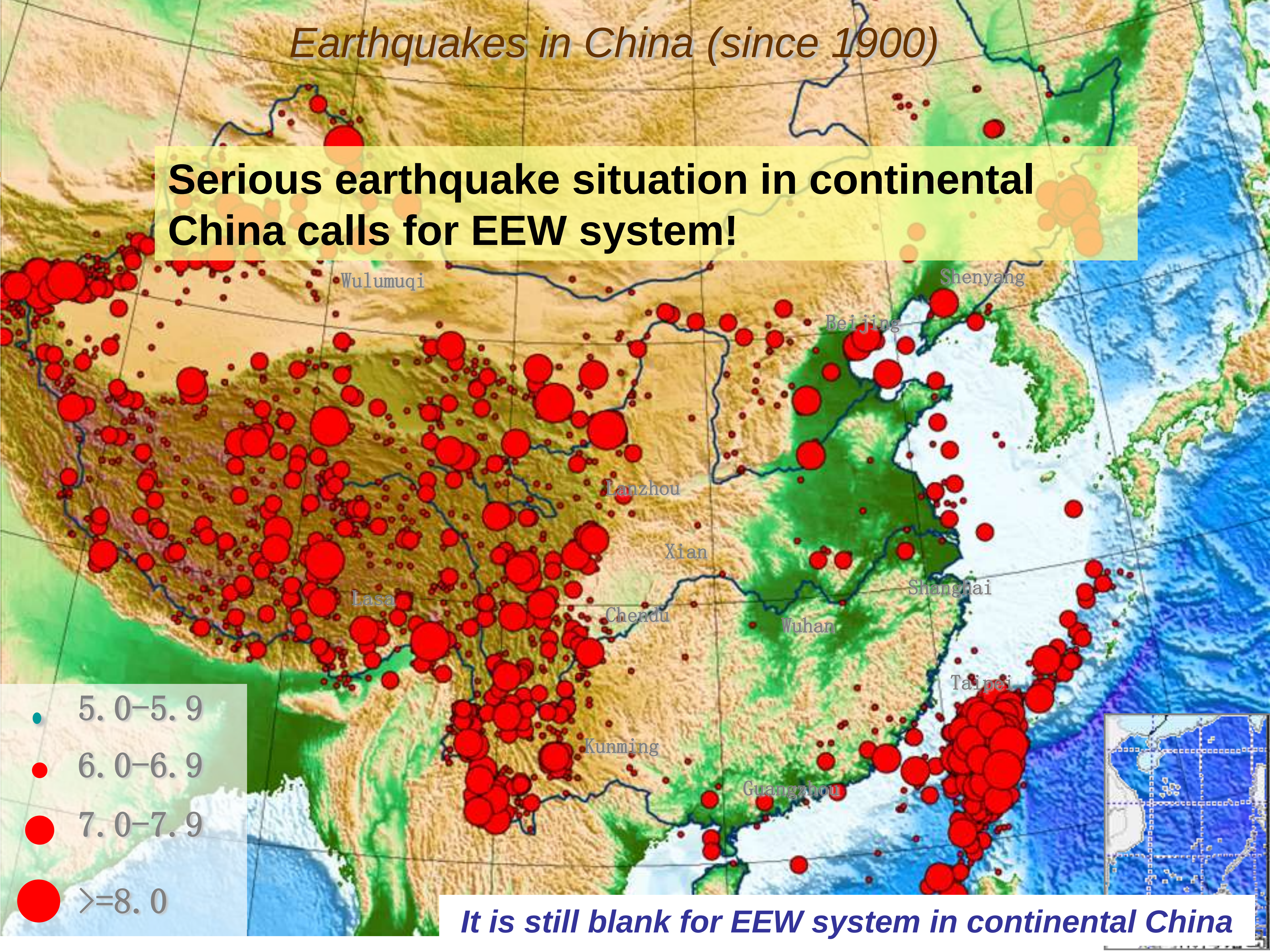
"... A very simple mechanical contrivance can be arranged at various points from 10 to 100 miles from San Francisco, by which a wave of the earth high enough to do damage will start an electric current over the wires now radiating form this city and almost instantaneously ring an alarm bell..."

J. D. Cooper, M.D.
San Francisco, California

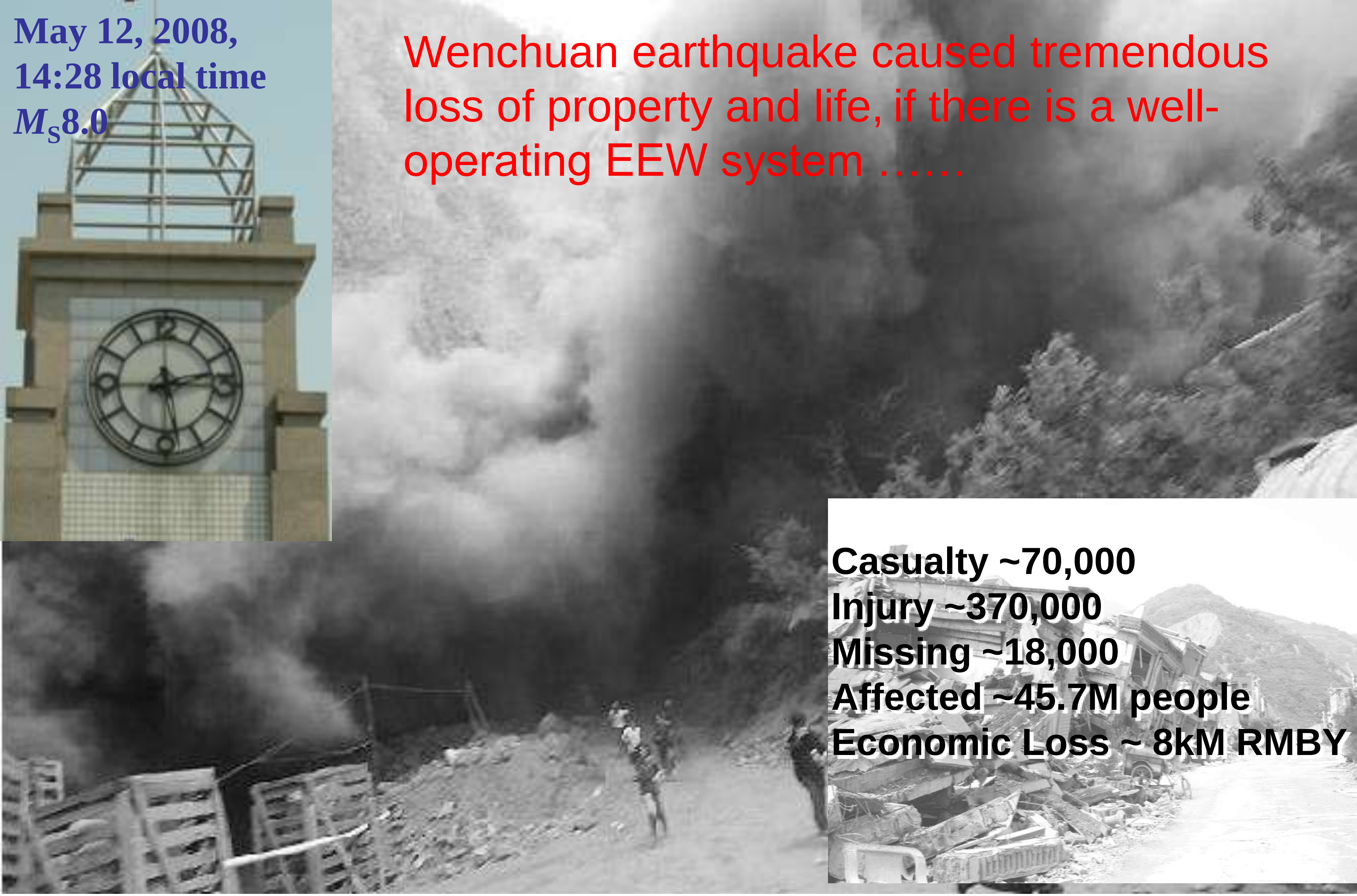
Recent 10 years

- EEW has been developed rapidly both on theory and technology.

- In Japan, California, Taiwan, Mexico, Turkey and so on, EEW systems have shown significant potential for the earthquake disaster reduction.



Earthquakes in China (since 1900)
Serious earthquake situation in continental China calls for EEW system!
Wulumuqi
Shenyang
Beijing
Lanzhou
Xian
Shanghai
Lasa
Chendu
Wuhan
Taipei
Kunming
Guangzhou
5.0-5.9
6.0-6.9
7.0-7.9
>=8.0
It is still blank for EEW system in continental China



The occurrence of 2008 Wenchuan Earthquake highlighted the importance of constructing earthquake early warning (EEW) system in continental China.

At present, it is impossible to construct EEW for all regions of China.

A famous saying "*let some people be rich first*" leads to today's prosperity of continental China.

Mr. Xiaoping Deng,

an outstanding leader of China

We should *let some regions construct EEW system first*.

As the beginning

As attempts of EEW system construction, several projects related to EEW have been conducted in continental China.

•In Fujian Province:

Fast report of earthquake parameters within 1 minute after the earthquake

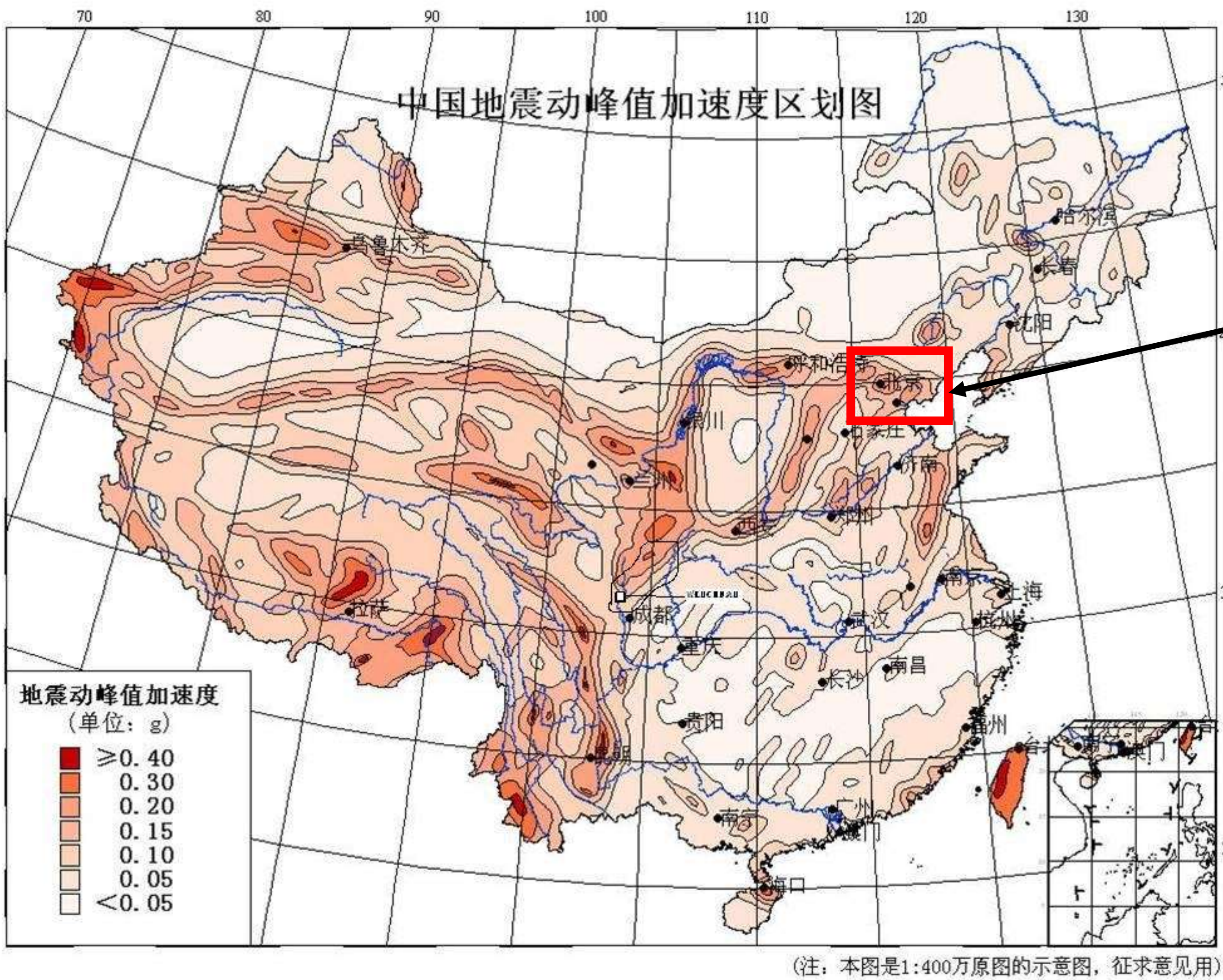
•In Beijing Capital Region：

A prototype EEW system is under construction, which will be introduced in this workshop

Prototype EEW in Beijing Capital Region

- Demand and Foundation
- Progress in theoretical problem
- Prototype system construction

Location of Beijing Capital Region (with higher peak ground acceleration)

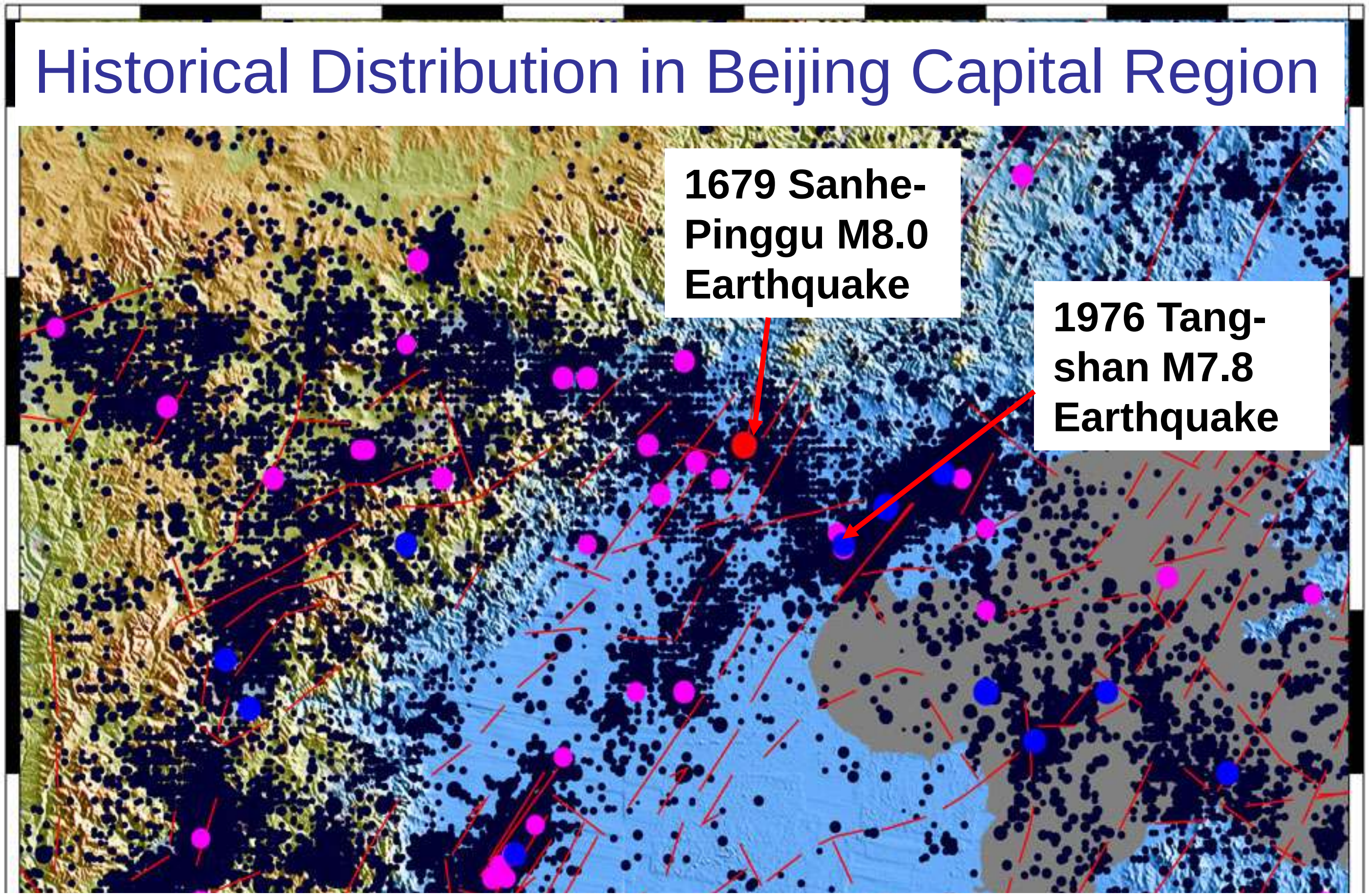


(38.5° -41.5° N, 113.5° -120° E)

Peak Ground Acceleration Zonation Map of Continental China

Demands of EEW System in Beijing Capital Region

- Pc
- Ma
- Se

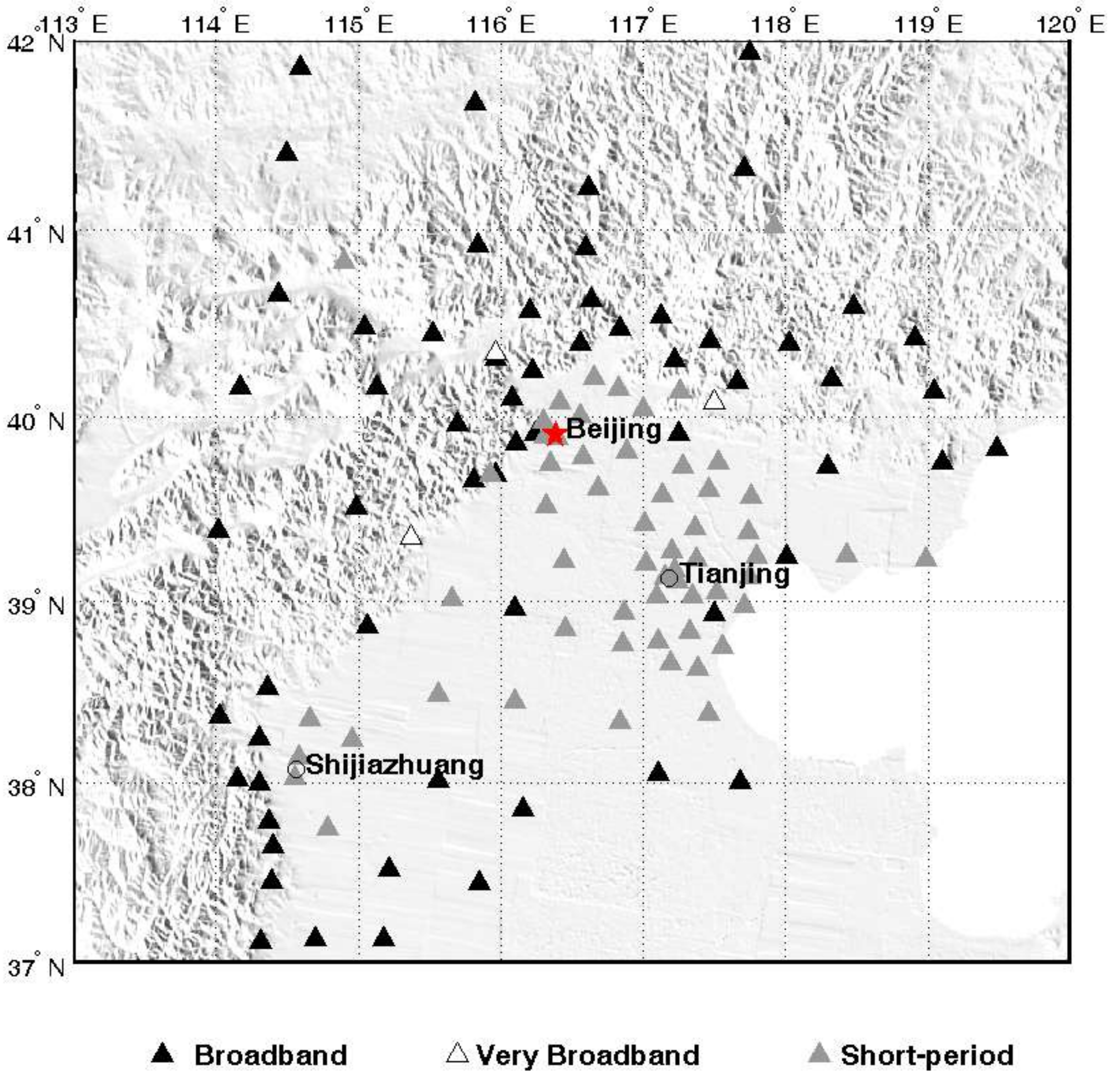


So, it is necessary and urgent to develop EEW system in this region.

Beijing Capital Seismic Network (BCSN)——Platform Foundation

Total 135 stations with average inter-station distance about 50 km, local reach to 20km.

Broadband: 74
Very Broadband:3
Short-period:58



Prototype EEW in Beijing Capital Region

- Demand and Foundation
- Progress on theoretical problems
- Prototype system construction

Theoretical Problems on EEW in Beijing Capital Region

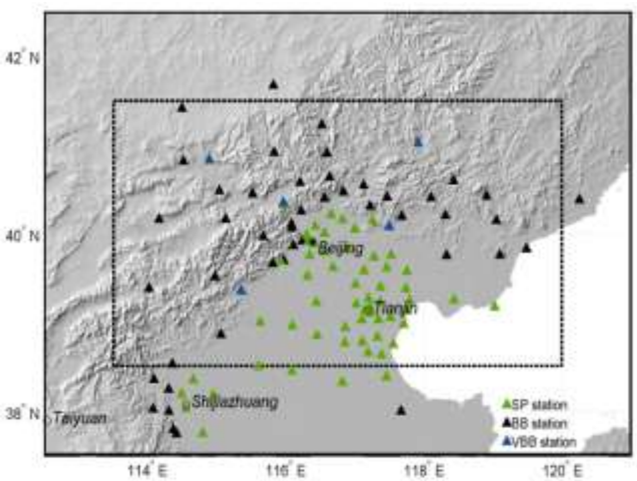
As preparatory work of EEW construction in Beijing Capital Region, we have done some theoretical research on EEW.

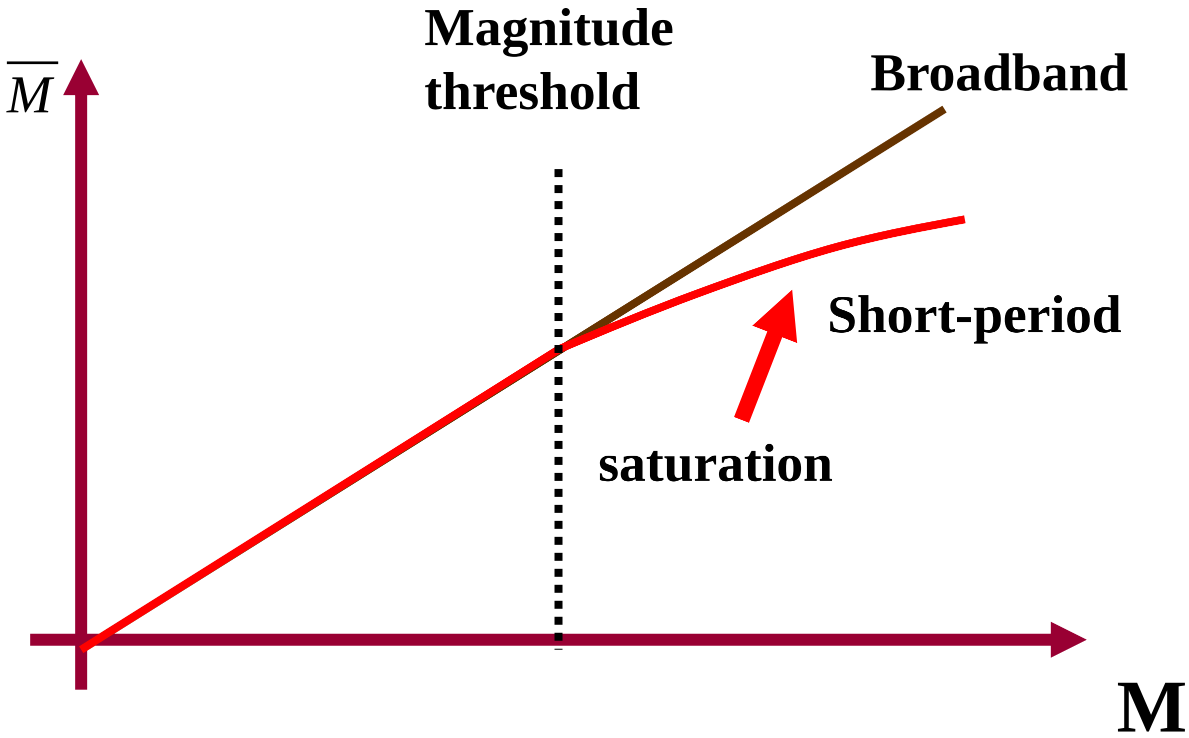
- ‘Saturation’ of magnitude estimation associated with short-period recordings

- Empirical relations for the estimation of magnitude using the first 3-second P waves

- Capability evaluation of EEW

Theoretical Problem in EEWS Construction in Beijing Capital Region： *Magnitude ‘saturation’*

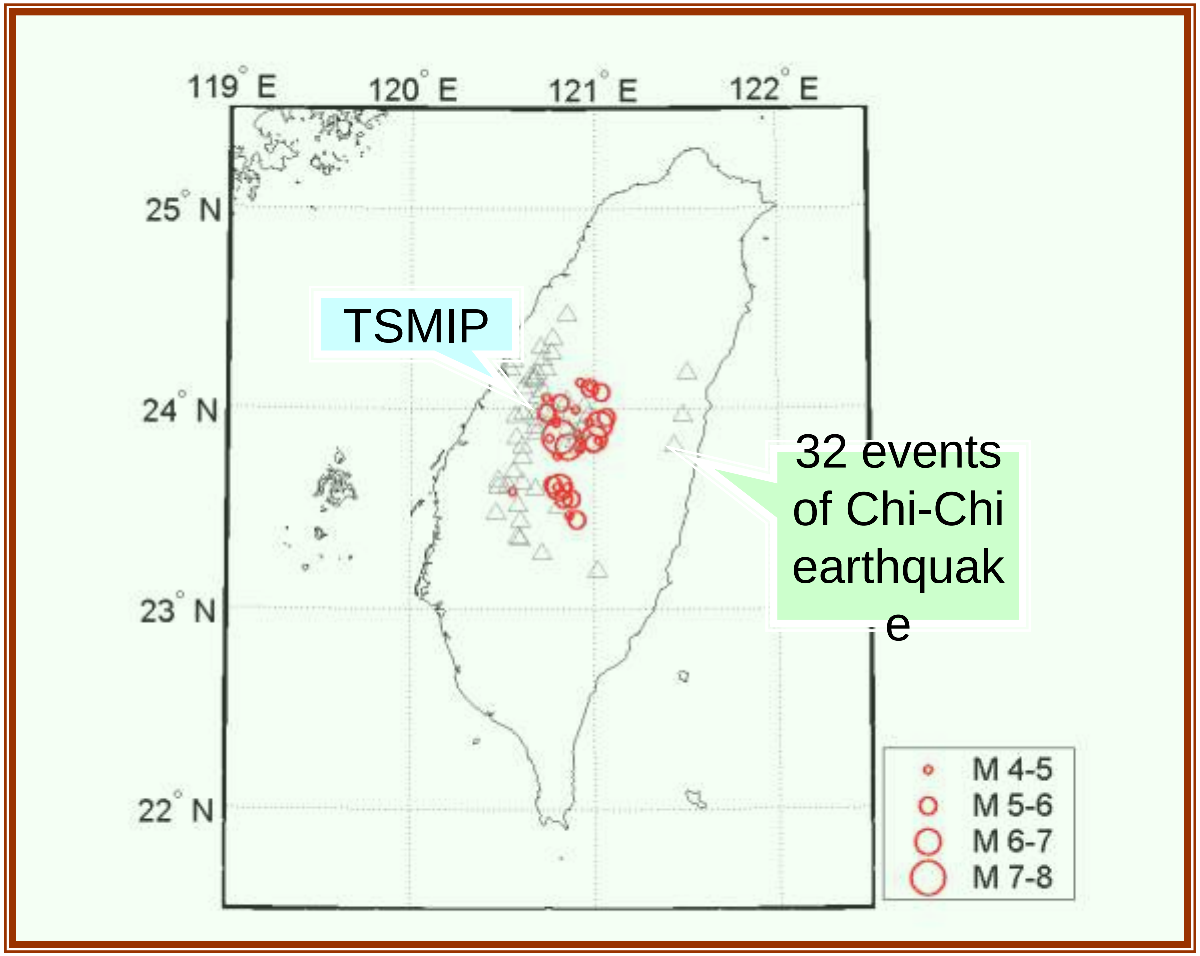




Broadband instrument is widely used to EEW due to the magnitude ‘saturation’ caused by short-period recording. But there are so many short-period seismographs deployed in BCSN.

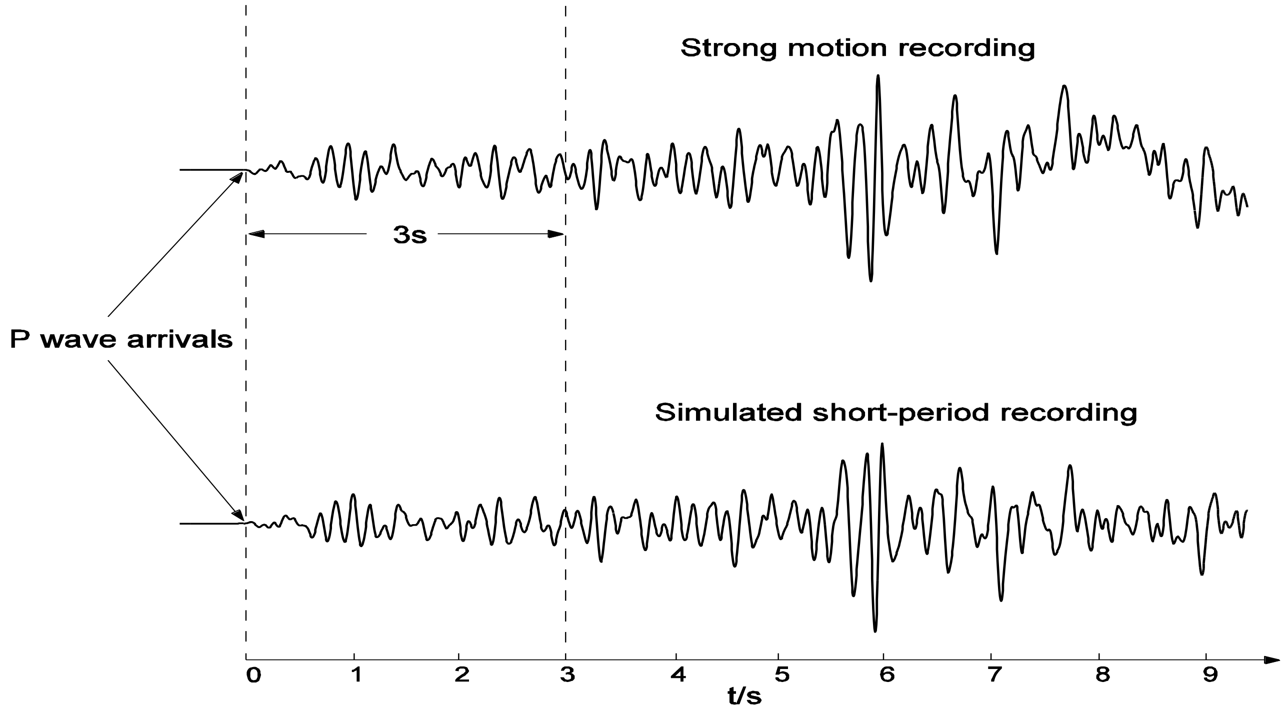
Theoretical Problem in EEWS Construction in Beijing Capital Region： *Magnitude 'saturation'*

To investigate the possibility of using short-period recording to EEW, we conducted a testing with 1999 Chi-chi earthquake and its 32 aftershocks.



Theoretical Problem in EEWS Construction in Beijing Capital Region： *Magnitude ‘saturation’*

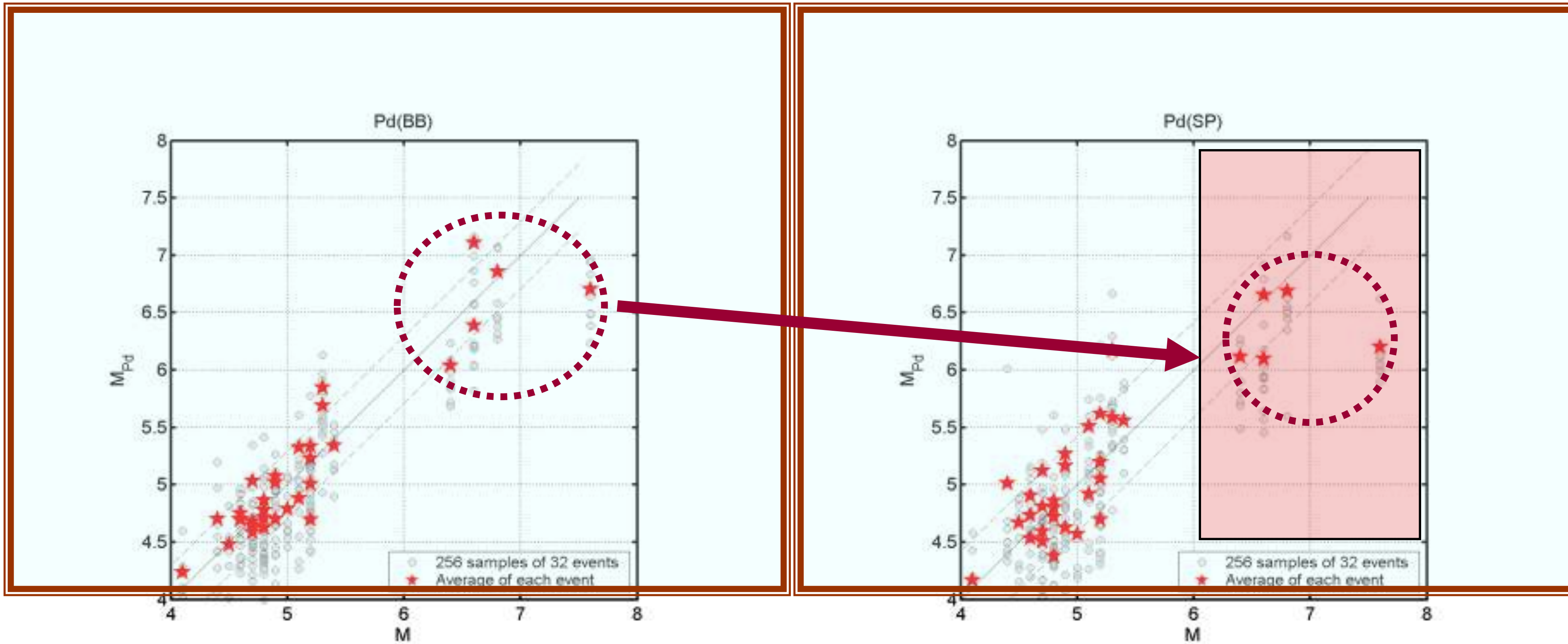
Convolving the strong motion acceleration recordings in Taiwan with the instrument response of short-period seismographs in Beijing Capital Region, we get the simulated short-period recording of Beijing Capital Region to the same event.



The first few seconds after the P-arrival, especially for the first 3 seconds, the strong motion recording and the simulated short-period one are similar to each other .

Theoretical Problem in EEWS Construction in Beijing Capital Region： *Magnitude ‘saturation’*

Comparison between Broadband Recordings and Short-period Recordings Using P_d Measurement

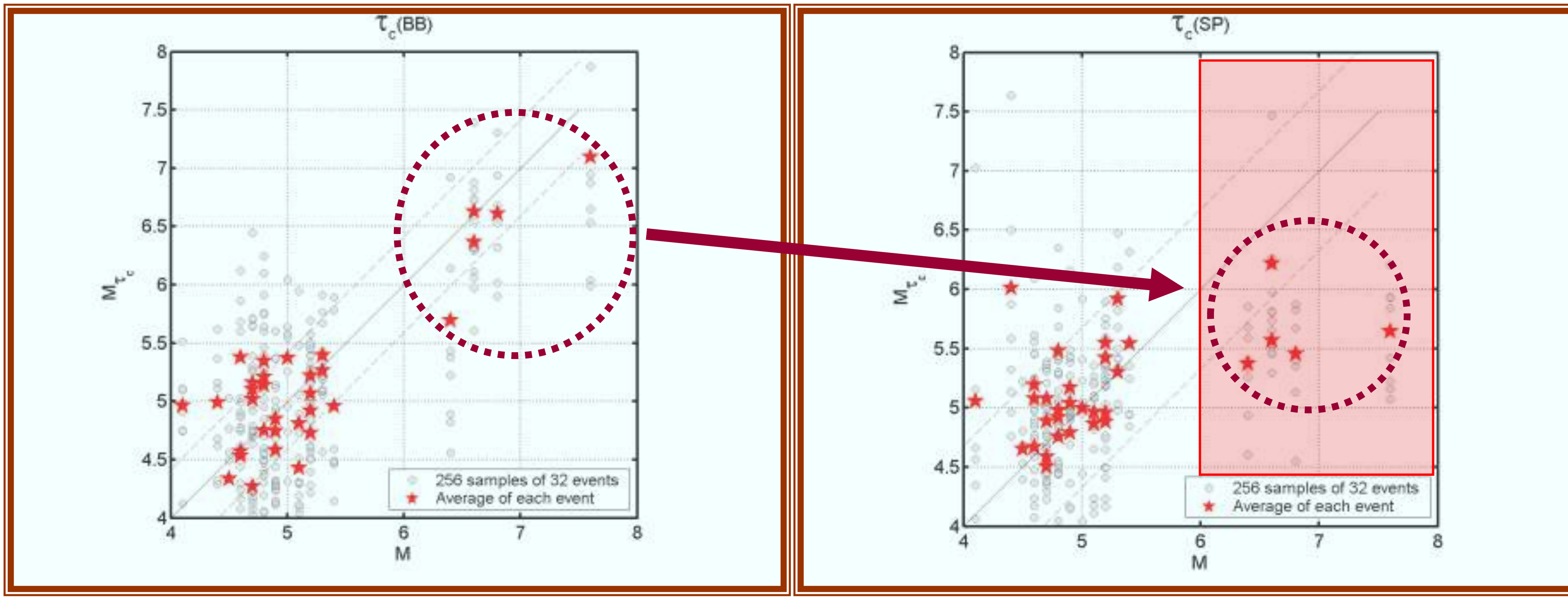


X-coordinate: Original Magnitude Y-coordinate: Estimated Magnitude

’Saturation’ appears with short-period recording for large earthquake upper 6, no obvious difference for middle earthquake.

Theoretical Problem in EEWS Construction in Beijing Capital Region： *Magnitude 'saturation'*

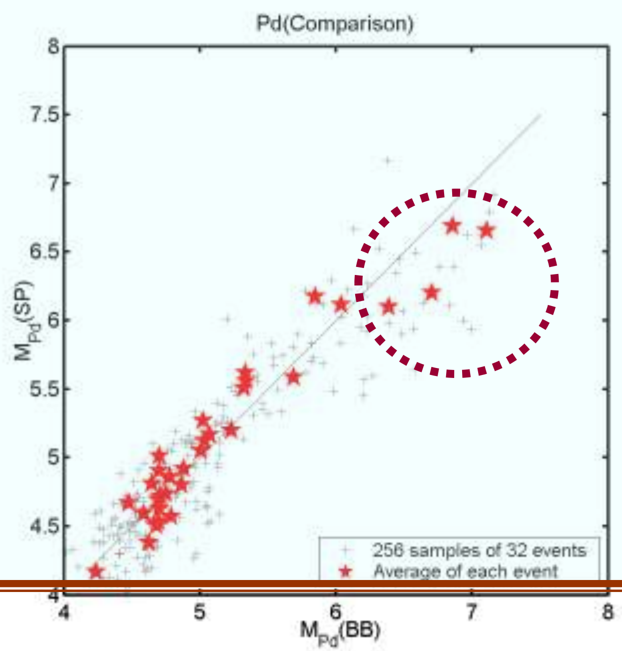
Comparison between Broadband Recordings and Short-period Recordings Using *tau_c* Measurement

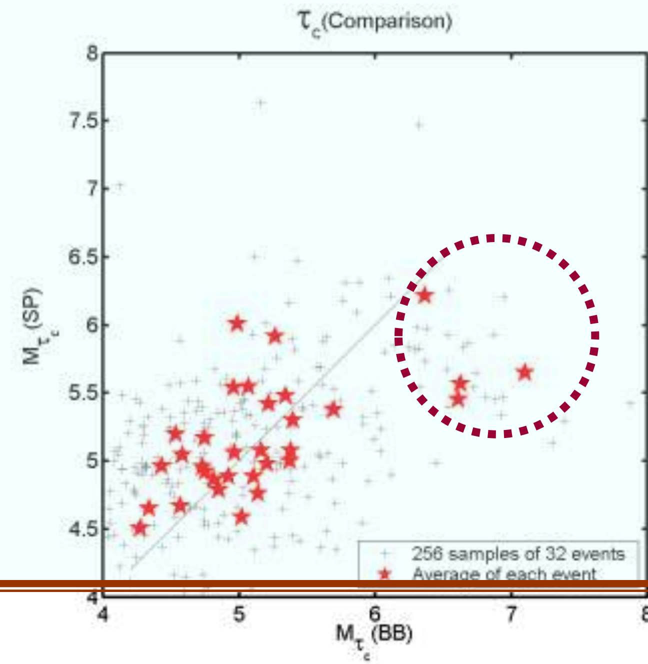


Magnitude 'saturation' can be found more obviously in the result of tau_c measurement for large earthquake.

Theoretical Problem in EEWS Construction in Beijing Capital Region： *Magnitude 'saturation'*

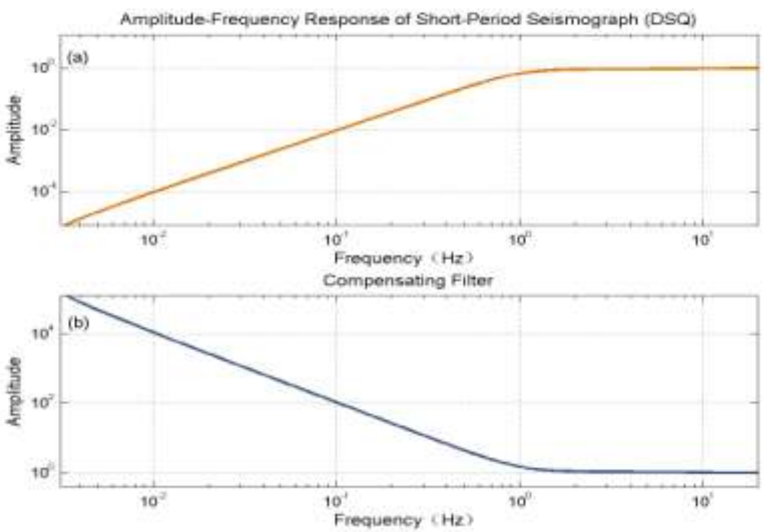
Comparison between Using *Pd* Measurement and Using *tau_c* Measurement for Short-Period Recording

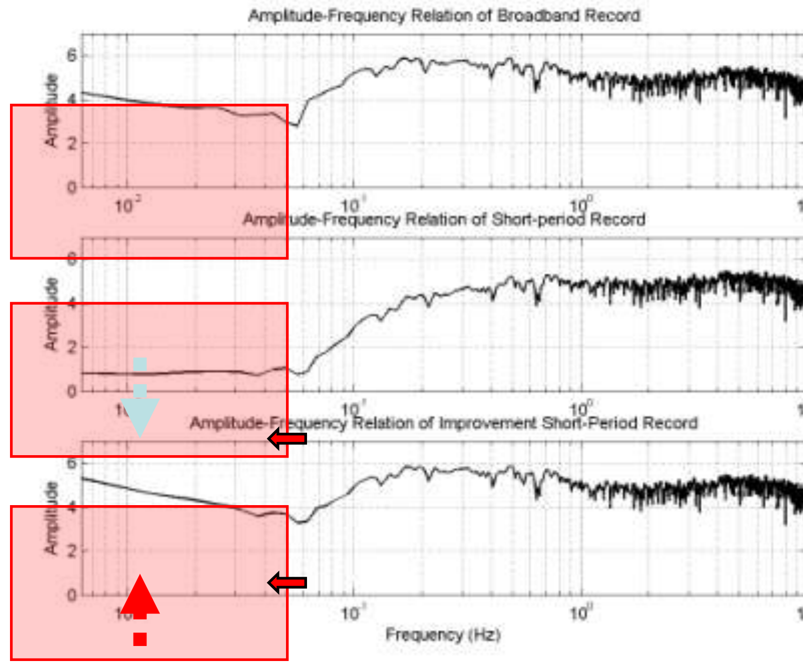




Pd measurement is more preferred than tau_c measurement due to relatively slight magnitude 'saturation' for large earthquake

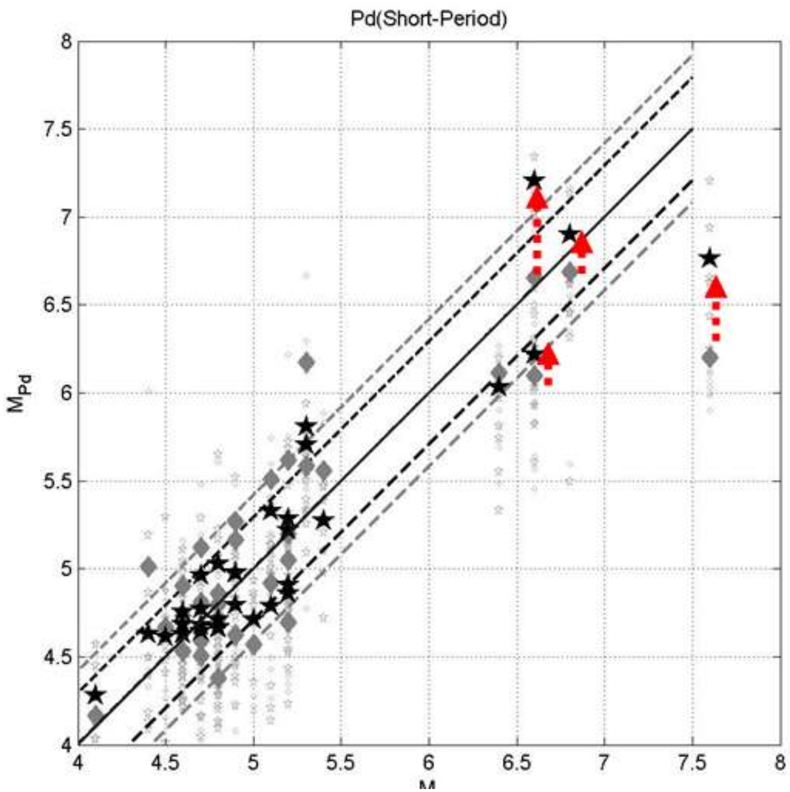
Theoretical Problem in EEWS Construction in Beijing Capital Region： *Frequency compensation*

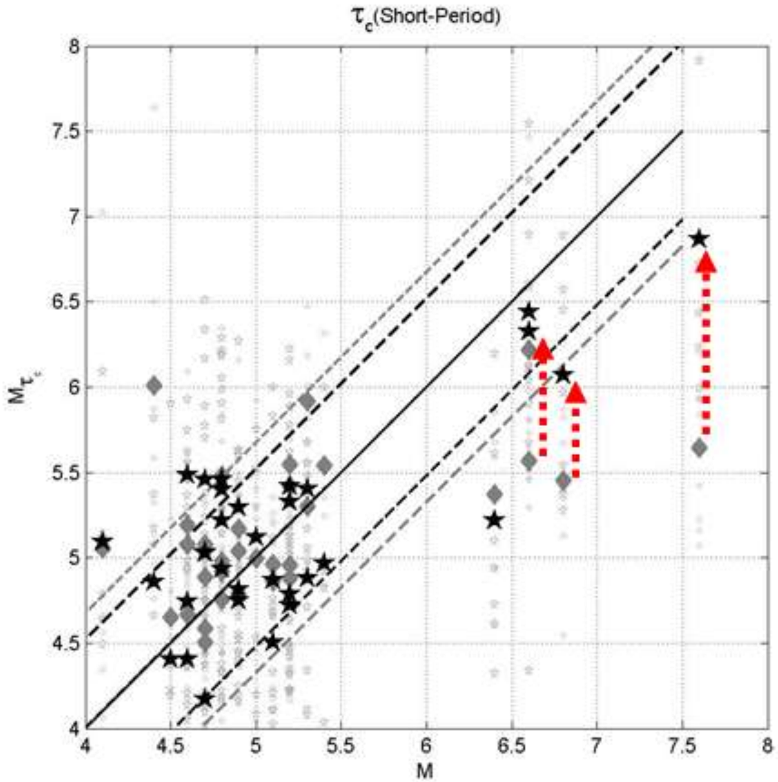




A compensation filter was designed to make up for the magnitude estimation loss with short-period recordings.

Magnitude estimation after frequency compensation

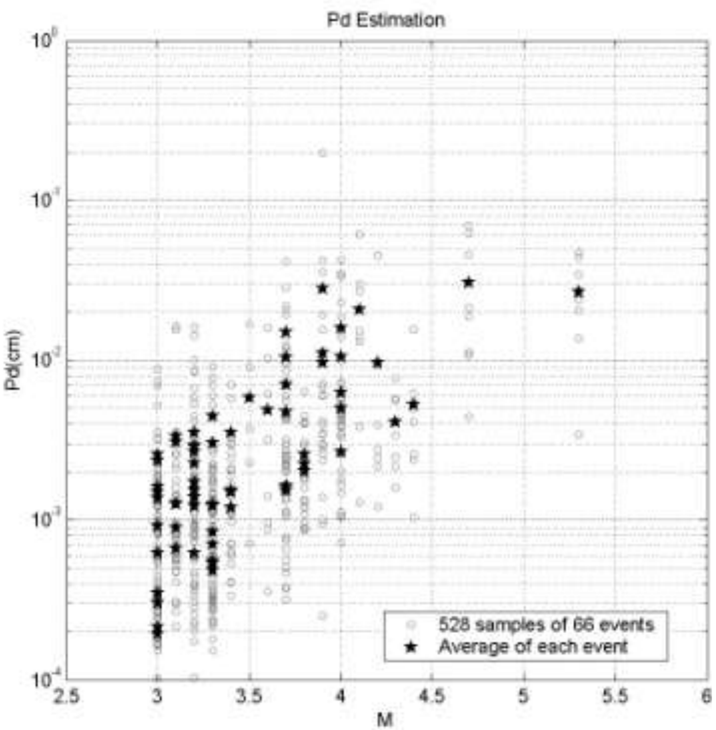


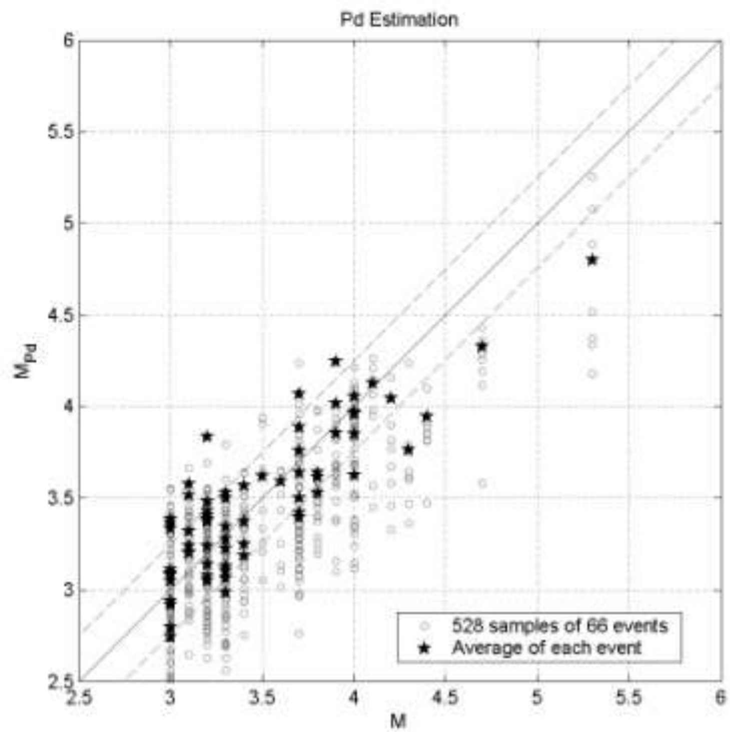


After compensation, the estimated magnitude was improved obviously for larger size event, especially to tau_c measurement

Theoretical Problem in EEWS Construction in Beijing Capital Region: *Magnitude Estimation*

Empirical magnitude relation by P_d measurement

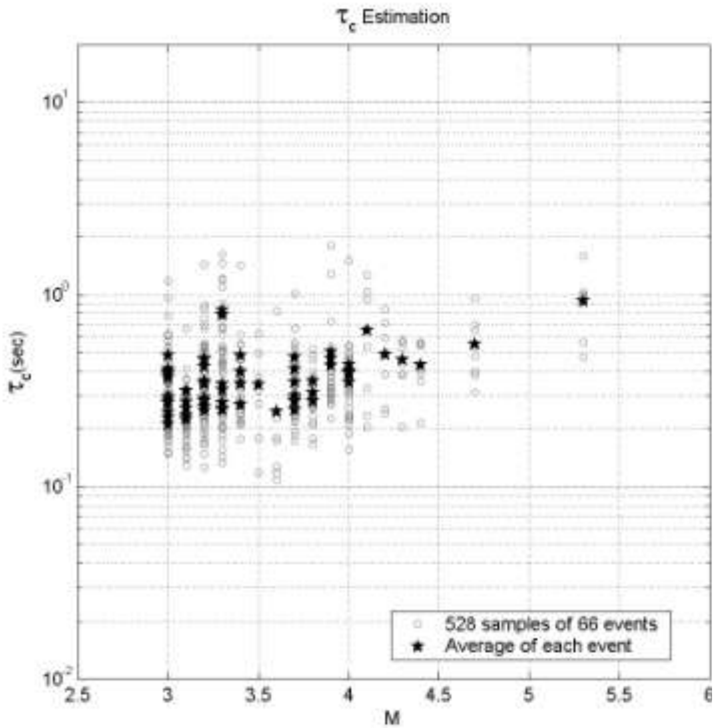


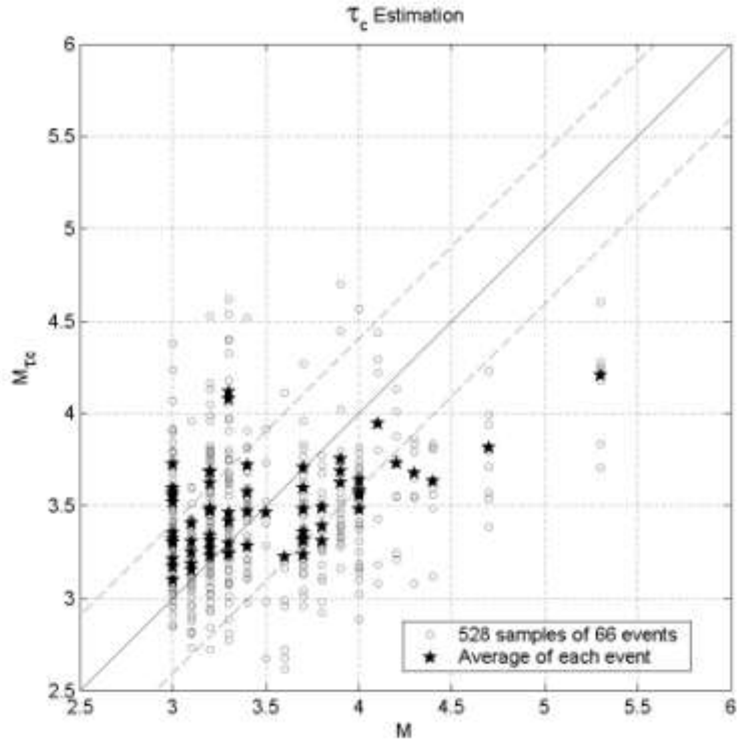


$$M = 0.72 \times \log 10(Pd) + 1.60 \times \log 10(R) + 3.34$$

Theoretical Problem in EEWS Construction in Beijing Capital Region：Magnitude Estimation

Empirical magnitude relation by tau_c measurement





$$M = 1.71 \times \log 10(\tau_c) + 4.26$$

Some conclusions

- Using the first three seconds of the P wave seismograms, short-period recordings can be applied to estimate the size of an earthquake to some extent.
- By the method of frequency compensation, the problem of magnitude ’saturation’ can be solved effectively.
- When applying short-period seismograph network in the EEW operation, P_d measurement is more preferred than *tau_c* measurement.

Zonation of EEW capability in Beijing Capital Region

Compared with the seismic network in Japan, California, and Taiwan, Beijing Capital Seismic Network is not an ideal one for its relatively low density and non-uniform distribution. It is necessary to evaluate it by…

Estimations of:

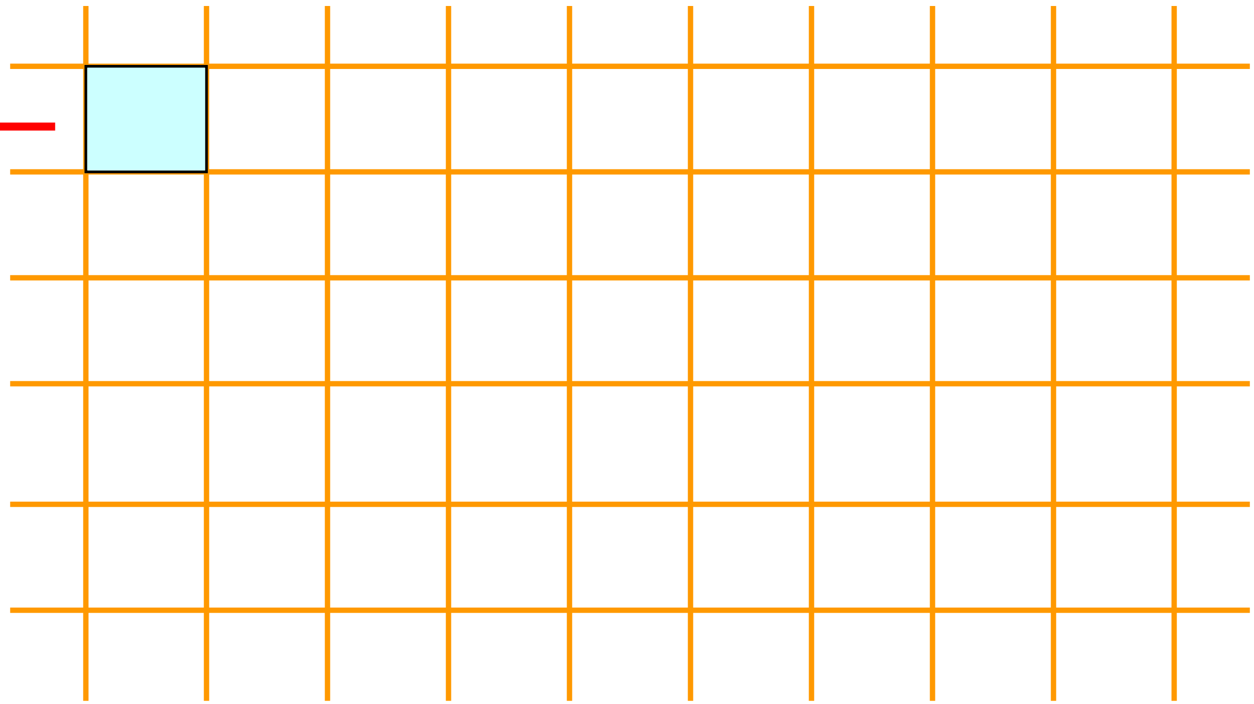
Warning reporting time

Minimum early-warning time

Area with high risk of destruction

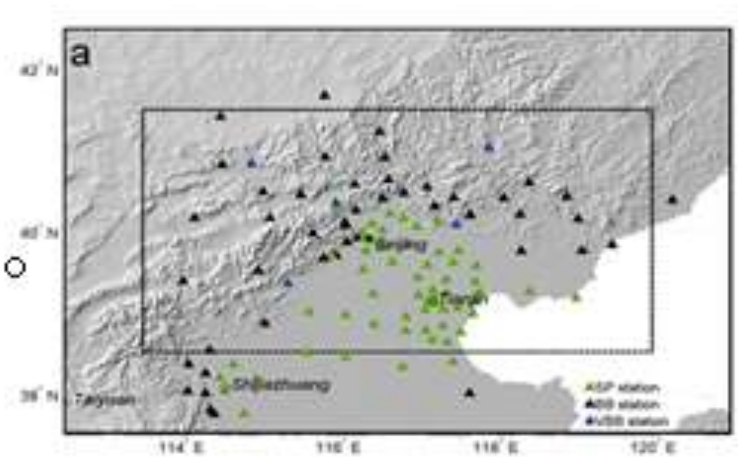
Zonation of EEW capability in Beijing Capital Region

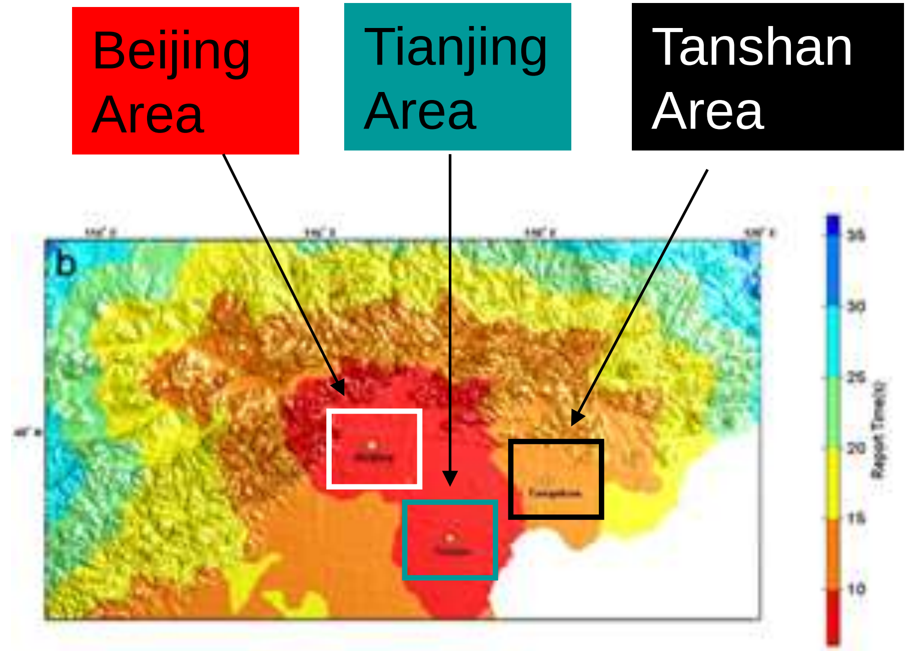
0.1° ×0.1°



Warning reporting time estimation

Supposing earthquake occurred at every grid point we considered with focal depth h=10km, and P wave velocity Vp=6km/s

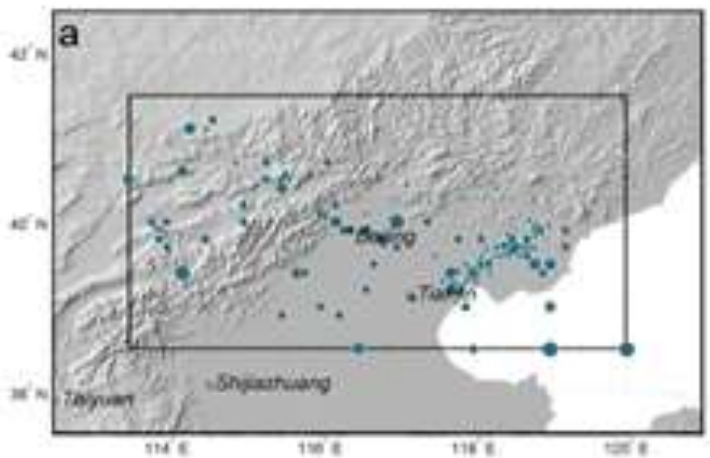


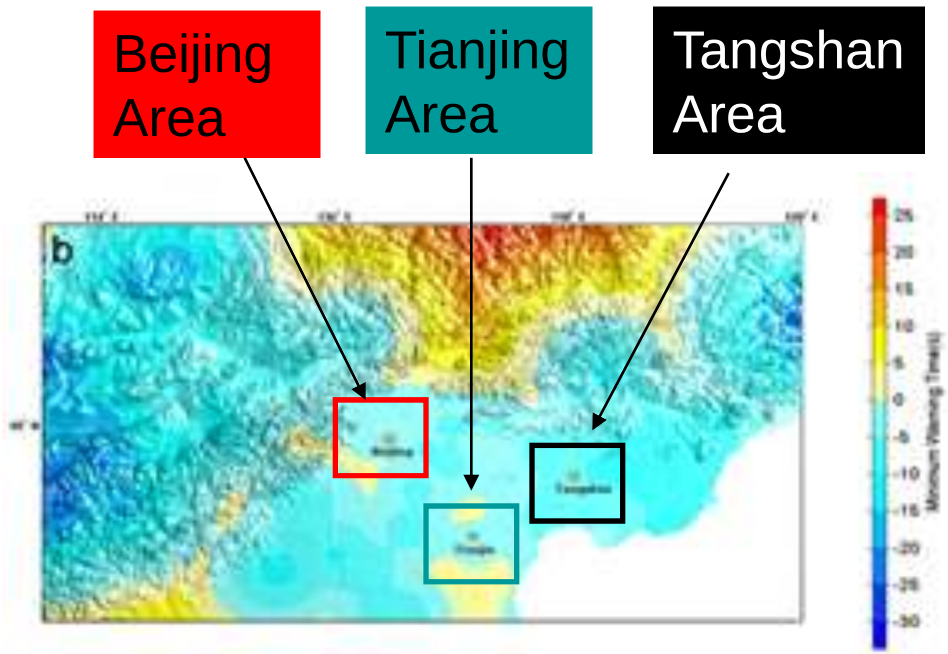


The reporting time are all less than 10 seconds in Beijing area and Tianjin area. Tanshan Area is between 10 to 15 seconds.

Minimum early-warning time estimation

Supposing earthquake occurred at its historical epicenter with focal depth h=10km, P wave velocity Vp=6km/s and S wave velocity Vs=3.5km/s

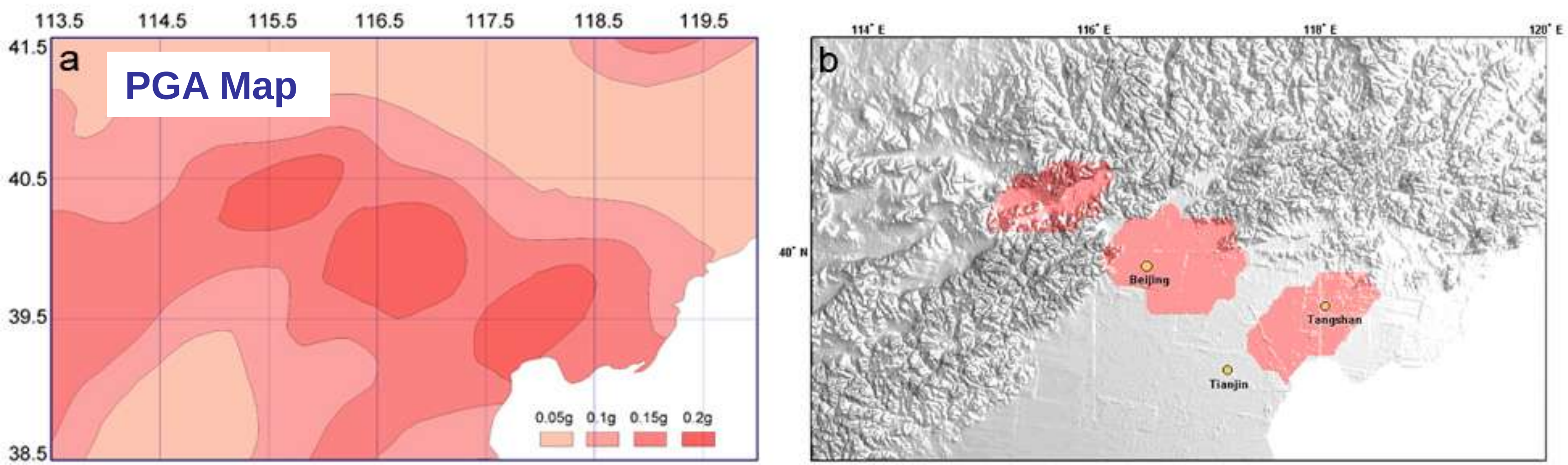




Beijing, Tianjing and Tangshan all have the possibility to have larger ‘blind zone’ of EEW when earthquake occurs, for their minimum early-warning time is less than zero.

Area with high risk of destruction estimation

Pay attention to these areas with PGA>0.2 and the early-warning time is less than zero



Huailai-Yanqing Basin, Beijing area and Tangshan area ar all with high risk of destruction.

Our present seismic network need to be upgraded ASAP.

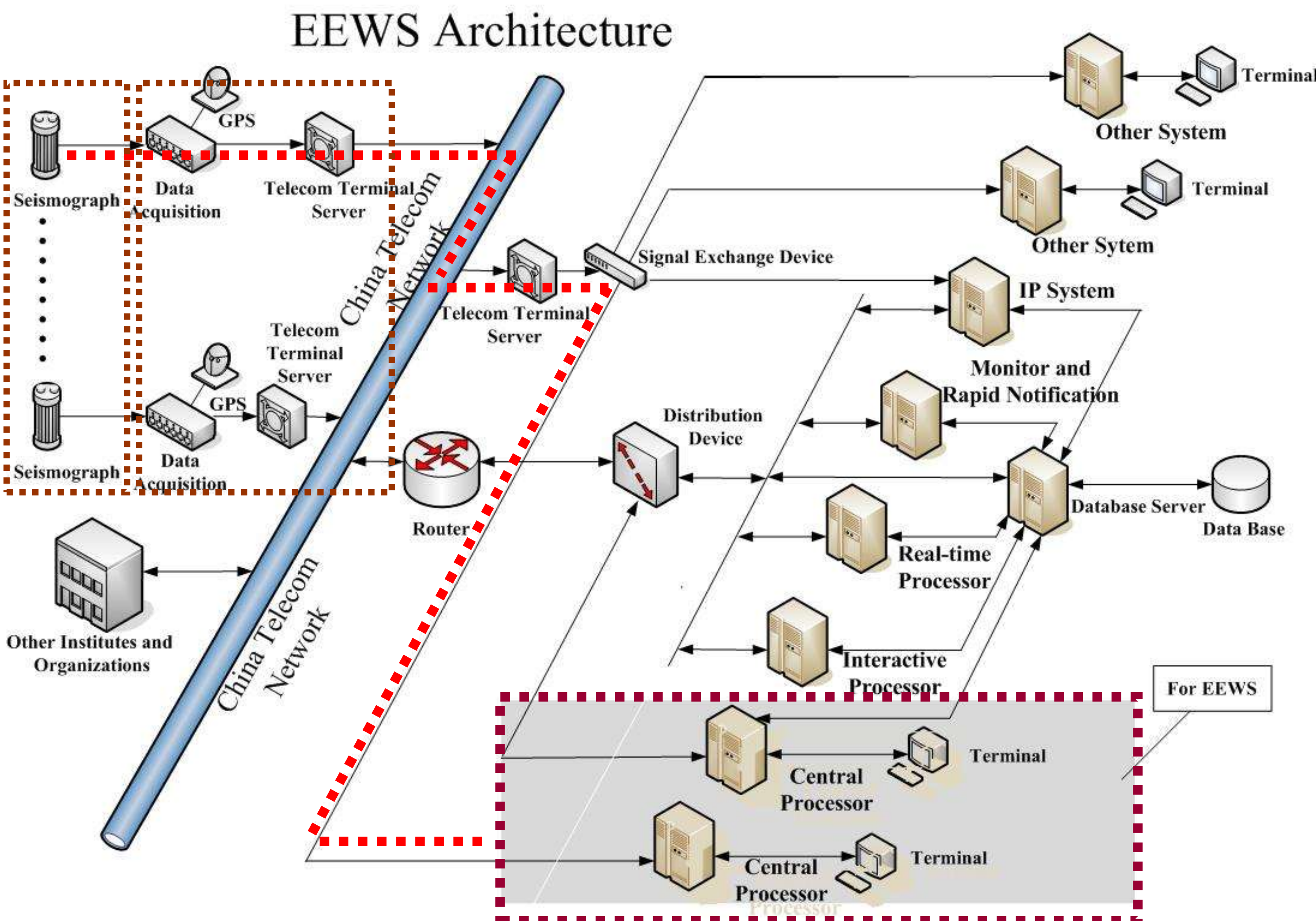
It's luck that it has been under the new five-year plan of CEA to provide a more ideal platform for EEW.

Prototype EEW in Beijing Capital Region

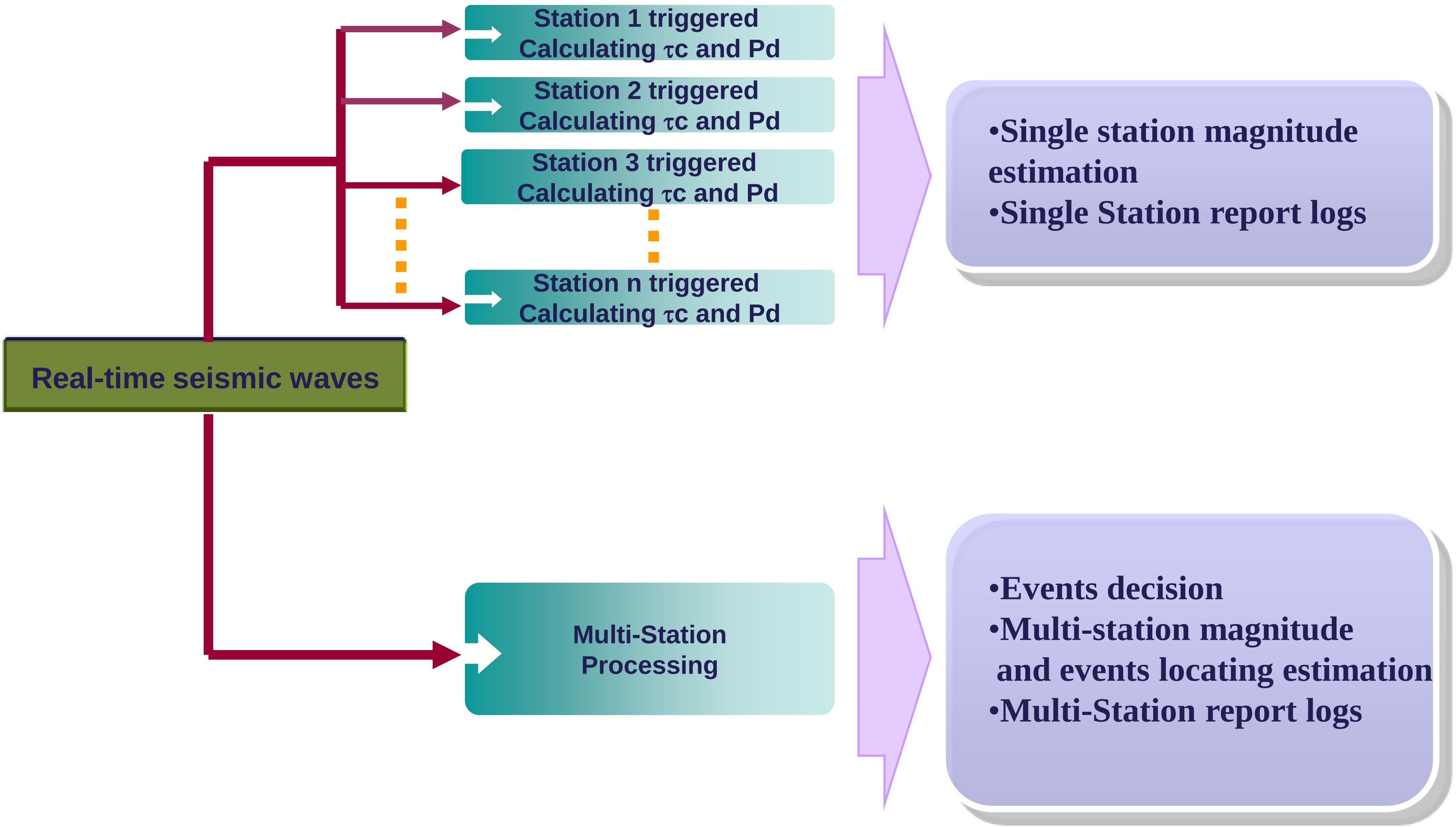
- **Demand and Foundation**
- **Progress in theoretical problems**
- **Prototype System construction**

In 2007, with the help of Prof. Yih-Min Wu, a testing EEW system was installed to process the data stream at 16 stations.Simulated experiments have been conducted.

Prototype EEWS Architecture



Data Processing Flow in the Central Processing Unit



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First station P arrive 2007/ 2/14  8:33: 5.858
Reporting time         2007/ 2/14  8:33:18.809
Centroid of stations, Lat.=  40.15140, Long.=  115.82264, Mtc=  6.50, Predicted averaged PGV=      8.222
Event origin time      2007/ 2/14  8:33: 2.977
Epicenter Lat.=  40.00069, Long.=  115.99982, Depth= 10.31 km, Mpd=  6.54, Averaged travel residuals= 0.005 sec
Revised Mtc=  6.50, Revised predicted averaged PGV=      8.222 cm/sec
Station Latitude Longitude   Parrival                 Tc(sec)    Pd(cm)      Pv(cm/sec)      ReportTime           ReportTime-Par
LQS    40.10170  116.08170 2007/ 2/14  8:33: 5.858  1.2000   0.54028614   0.50000000 2007/ 2/14  8:33: 8.642      2.784 -0.
SFS    39.66140  115.81360 2007/ 2/14  8:33:10.229  1.2000   0.11530499   0.50000000 2007/ 2/14  8:33:12.659      2.430  0.
SHC    40.44060  115.52310 2007/ 2/14  8:33:14.058  1.2000   0.06277853   0.50000000 2007/ 2/14  8:33:16.680      2.622  0.
MDY    40.39610  116.56170 2007/ 2/14  8:33:14.296  1.2000   0.06092158   0.50000000 2007/ 2/14  8:33:17.688      3.392 -0.
ZHL    40.15720  115.13310 2007/ 2/14  8:33:16.163  1.2000   0.04914043   0.50000000 2007/ 2/14  8:33:18.696      2.533 -0.

First station P arrive 2007/ 2/14  8:33: 5.858
Reporting time         2007/ 2/14  8:33:19.816
Centroid of stations, Lat.=  40.15140, Long.=  115.82264, Mtc=  6.50, Predicted averaged PGV=      8.222
Event origin time      2007/ 2/14  8:33: 2.977
Epicenter Lat.=  40.00069, Long.=  115.99982, Depth= 10.31 km, Mpd=  6.54, Averaged travel residuals= 0.005 sec
Revised Mtc=  6.50, Revised predicted averaged PGV=      8.222 cm/sec
Station Latitude Longitude   Parrival                 Tc(sec)    Pd(cm)      Pv(cm/sec)      ReportTime           ReportTime-Par
LQS    40.10170  116.08170 2007/ 2/14  8:33: 5.858  1.2000   0.54028614   0.50000000 2007/ 2/14  8:33: 8.642      2.784 -0.
SFS    39.66140  115.81360 2007/ 2/14  8:33:10.229  1.2000   0.11530499   0.50000000 2007/ 2/14  8:33:12.659      2.430  0.
SHC    40.44060  115.52310 2007/ 2/14  8:33:14.058  1.2000   0.06277853   0.50000000 2007/ 2/14  8:33:16.680      2.622  0.
MDY    40.39610  116.56170 2007/ 2/14  8:33:14.296  1.2000   0.06092158   0.50000000 2007/ 2/14  8:33:17.688      3.392 -0.
ZHL    40.15720  115.13310 2007/ 2/14  8:33:16.163  1.2000   0.04914043   0.50000000 2007/ 2/14  8:33:18.696      2.533 -0.

First station P arrive 2007/ 2/14  8:33: 5.858
Reporting time         2007/ 2/14  8:33:20.823
Centroid of stations, Lat.=  40.15140, Long.=  115.82264, Mtc=  6.50, Predicted averaged PGV=      8.222
Event origin time      2007/ 2/14  8:33: 2.977
Epicenter Lat.=  40.00069, Long.=  115.99982, Depth= 10.31 km, Mpd=  6.54, Averaged travel residuals= 0.005 sec
Revised Mtc=  6.50, Revised predicted averaged PGV=      8.222 cm/sec
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Refining of our prototype is going on……

Our goal: Constructing a "Hybrid" EEW system in Beijing Capital Region.

1

Combination of seismographs and strong motion instruments

2

Combination of front-detection EEW and onsite EEW

3

Combination of EEWS and QEDS

Finally, let's recall the tremendous loss of property and life caused by Wenchuan earthquake again…

Casualty ~70,000
Injury ~370,000
Missing ~18,000
Affected ~45.7M people
Loss ~8kM RMBY

We hope and believe that all these losses must be compensated by the advancement of earthquake science and technology and the enhancement of the capability of the reduction of seismic disasters not only in China but also all over the world

End of the talk

But no ending in EEW system construction

EEW in continental China is growing.
We are enjoying with international exchange of experiences and international collaborations during the construction of continental China's EEW system.

Thank you