2nd EEW Workshop in Kyoto, April 22, 2009
JSPS/ DPRI

Basic study for developing the Earthquake Early Warning system for great earthquakes - case of ground motions in large crustal earthquakes-

Kojiro Irikura*, Susumu Kurahashi*, and Kazuaki Masaki*

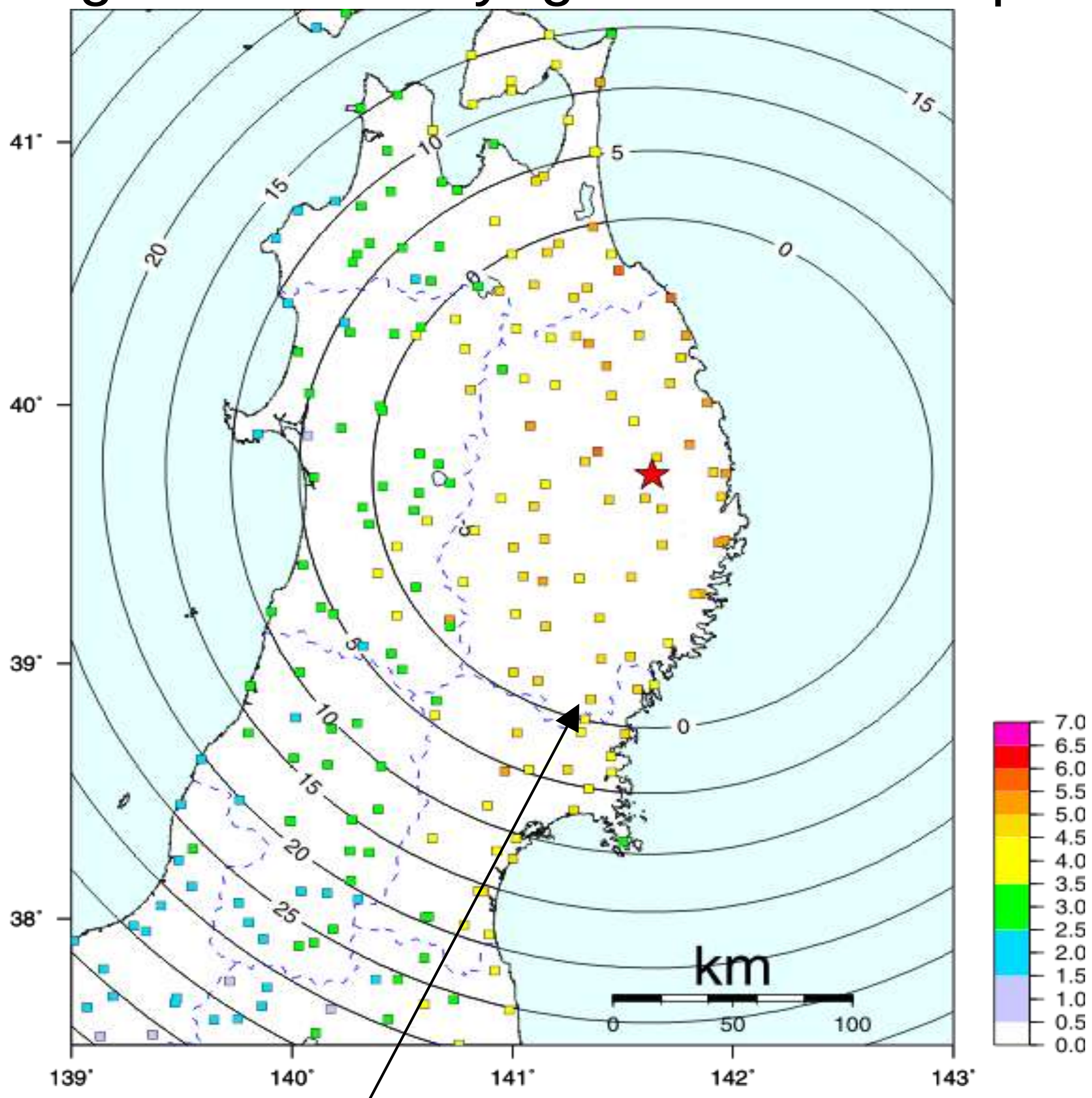
*: Aichi Institute of Technology

The EEW of JMA is successfully operating,
which provides the origin-time and location of the hypocenter and magnitude for possibly-disastrous earthquakes as quickly as possible
and then seismic intensities rapidly predicted at target sites.

Some problems to improve still remain.

1. The EEW is possibly not in time in case of near-field earthquakes.
2. The EEW is possibly underestimated in case of great earthquakes with magnitude more than 8.

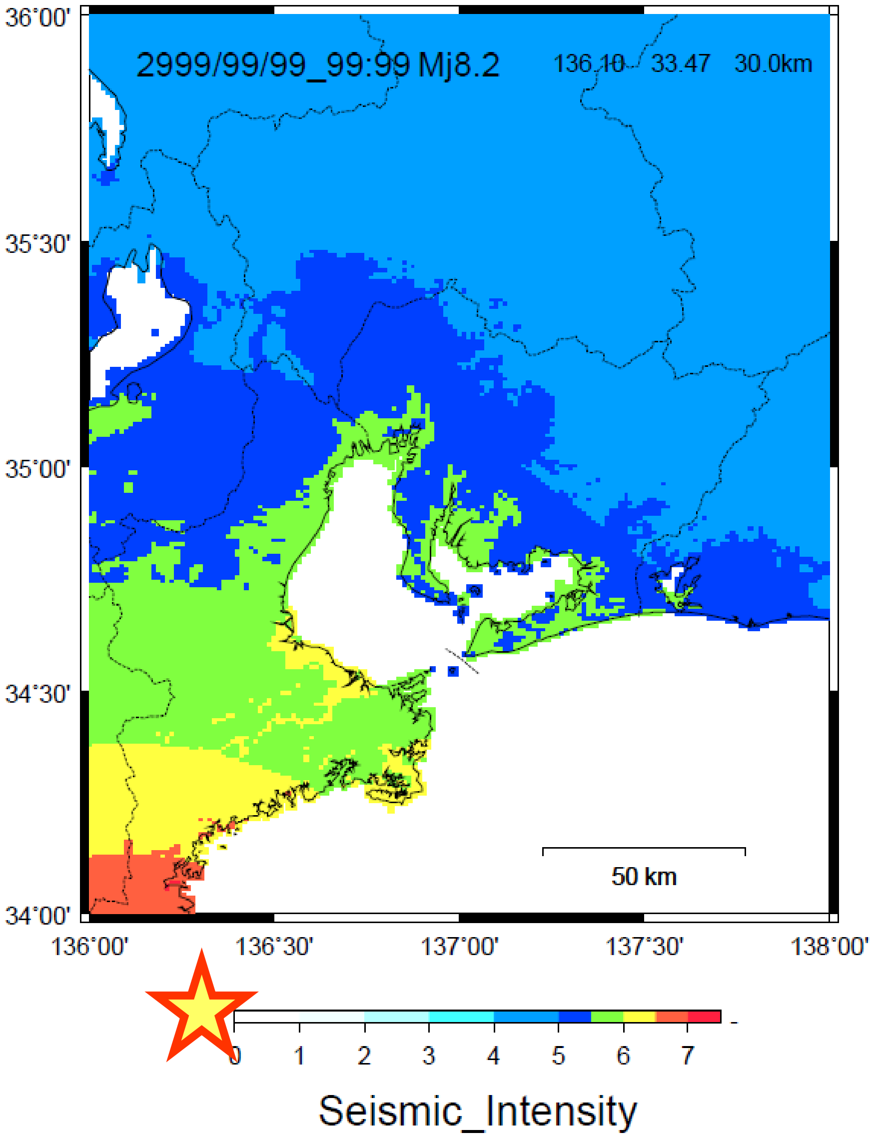
Provision of EEW by JMA during the Iwate-Miyagi Nairiku Earthquake



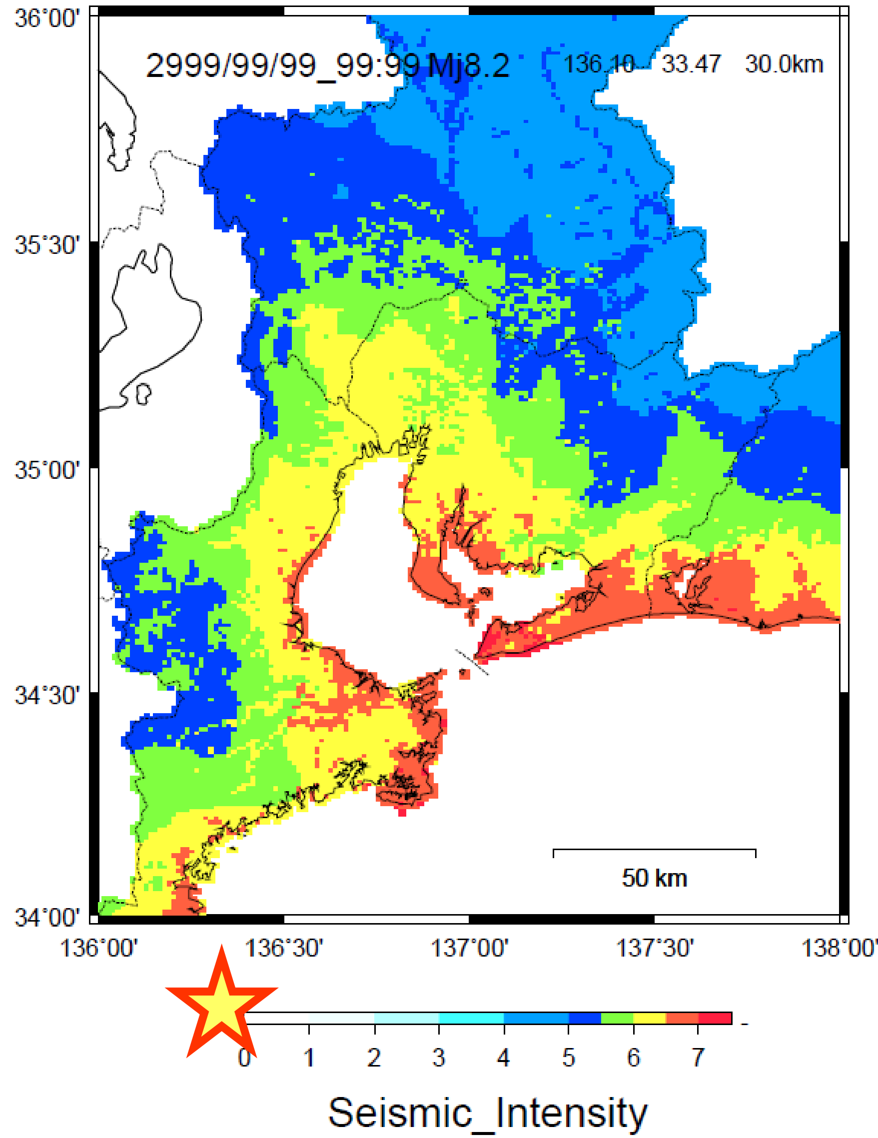
Area where the EEW was not in time

Aftter JMA (2008)

緊急地震速報および強震動予測（中央防災会議）による東南海地震発生時の予測震度



緊急地震速報による予測震度



強震動予測による予測震度

緊急地震速報および強震動予測（中央防災会議）による東南海地震発生時の予測震度差

震源近傍：

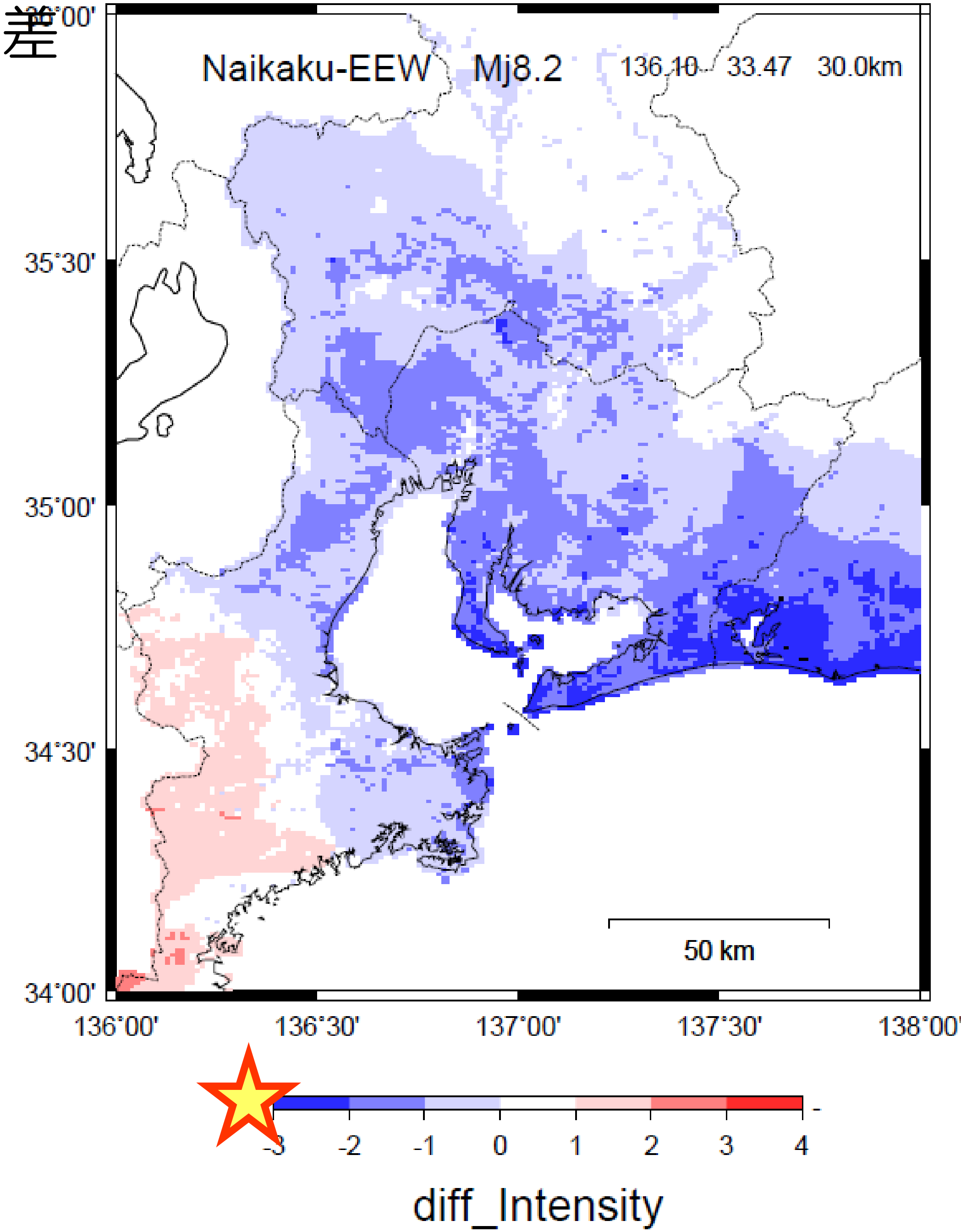
過大評価

東海地域：

震度が1～2階級過小評価

静岡県の太平洋沿岸：

震度3階級過小評価



Some solutions for the problems are already proposed.

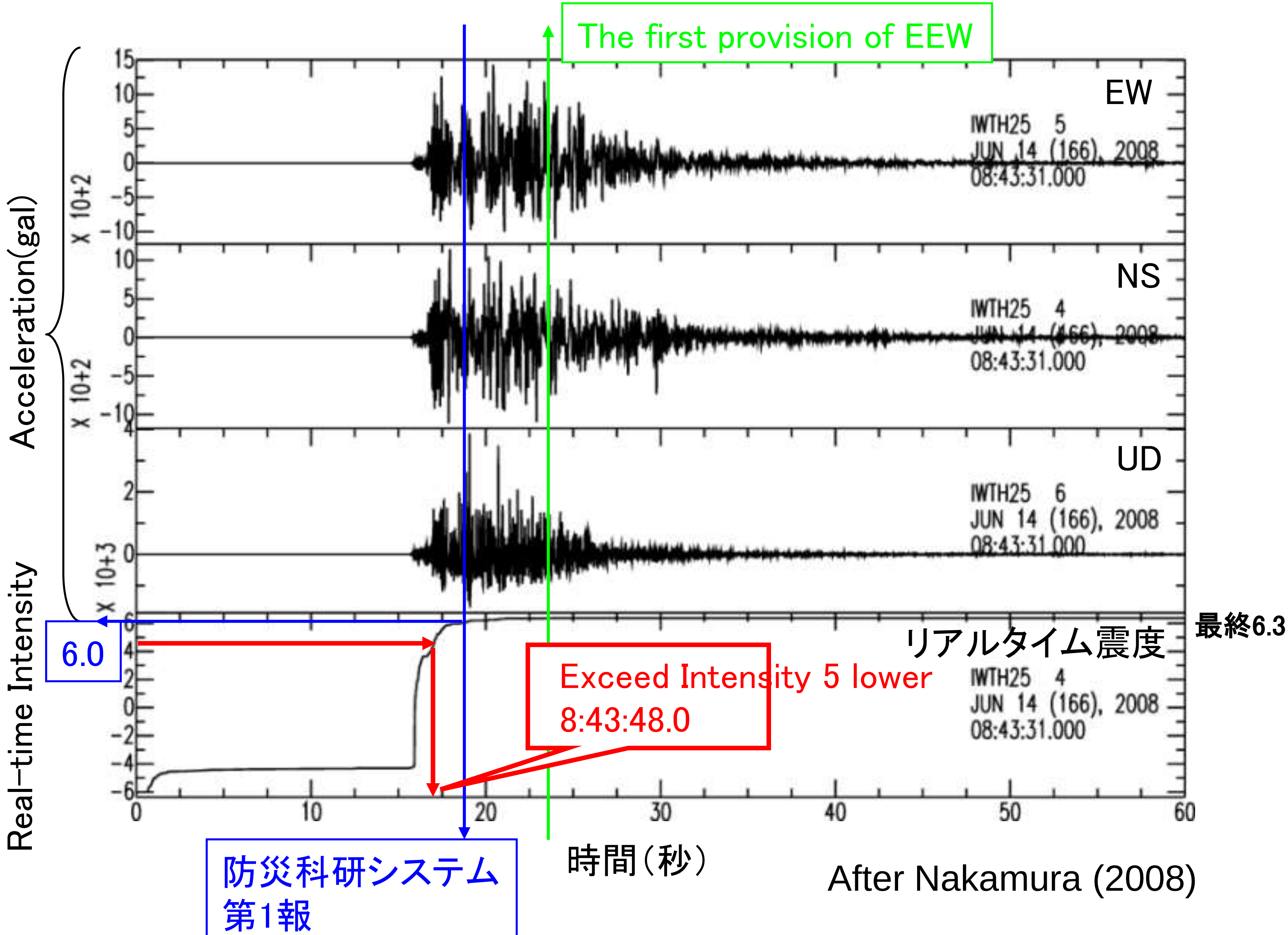
On-site warning system using the first P waves motions is one of the most effective methods.

However, there are still problems.
It is not available for sites having no seismometers.
Time to spare before strong shaking is a little even for further distance from the earthquake source.

To be more effective and efficient, the on-site warning system should be incorporated with the EEW.

Time Variation of Real-time Seismic Intensity

KiK-net Ichinoseki-nishi：surface

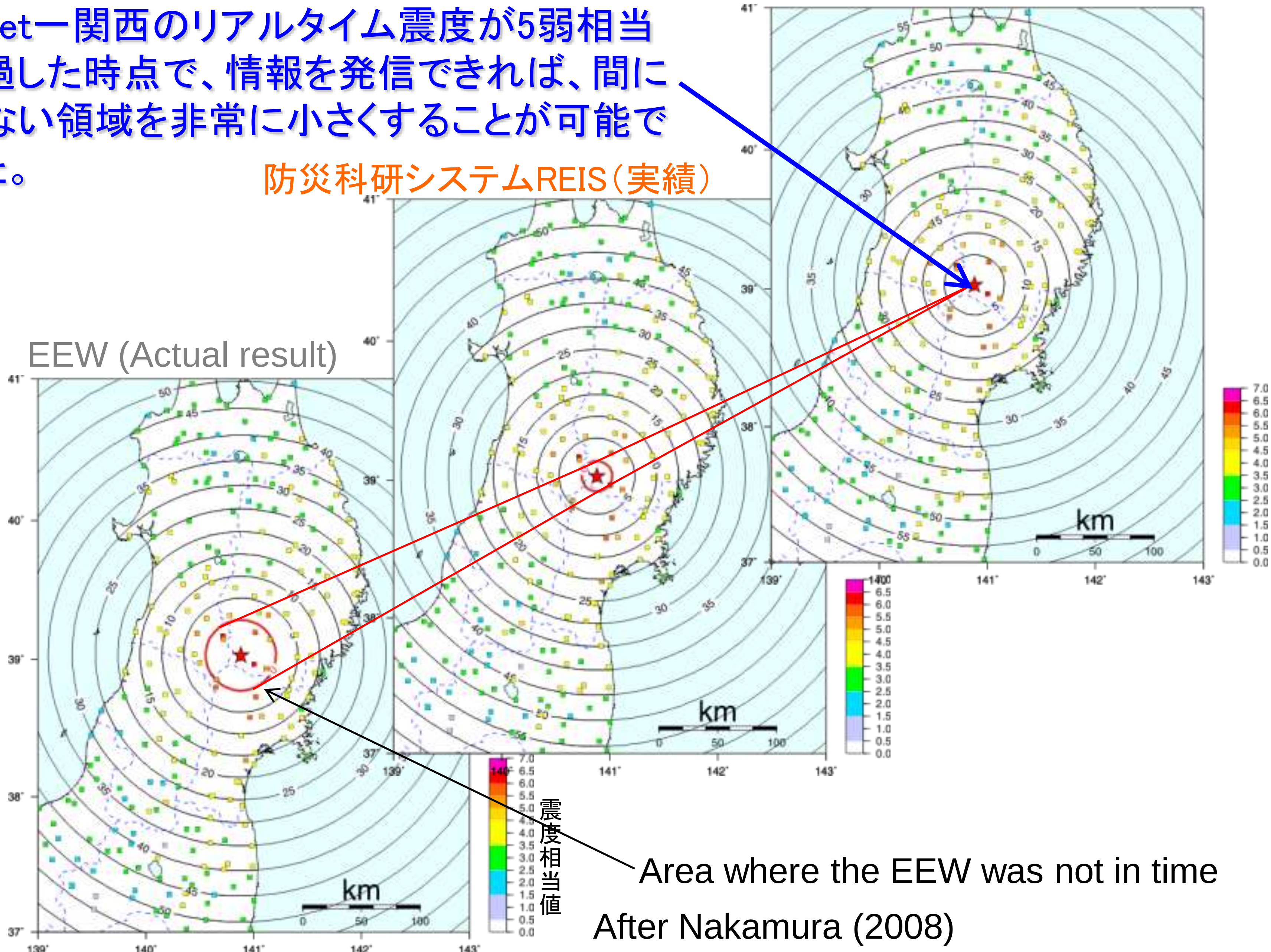


After Nakamura (2008)

Leading Time before Strong Shaking

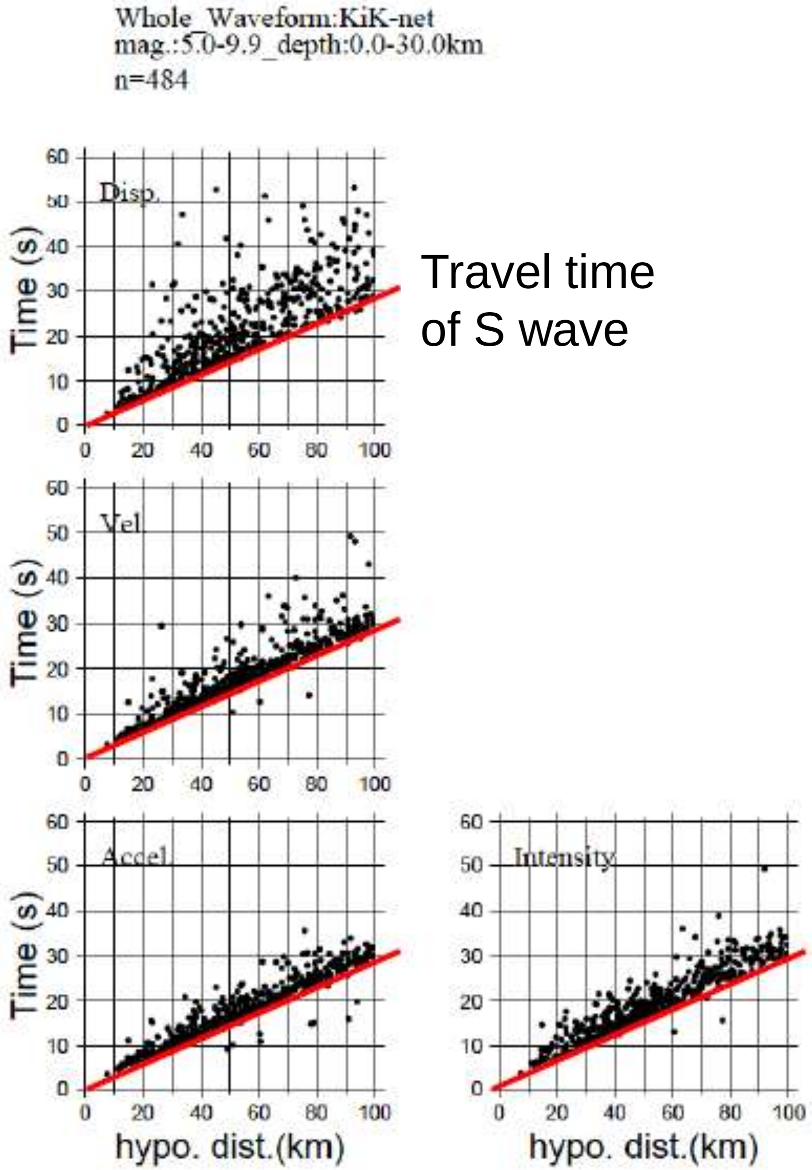
Time when ground motions exceed Intensity 5-lower at the station

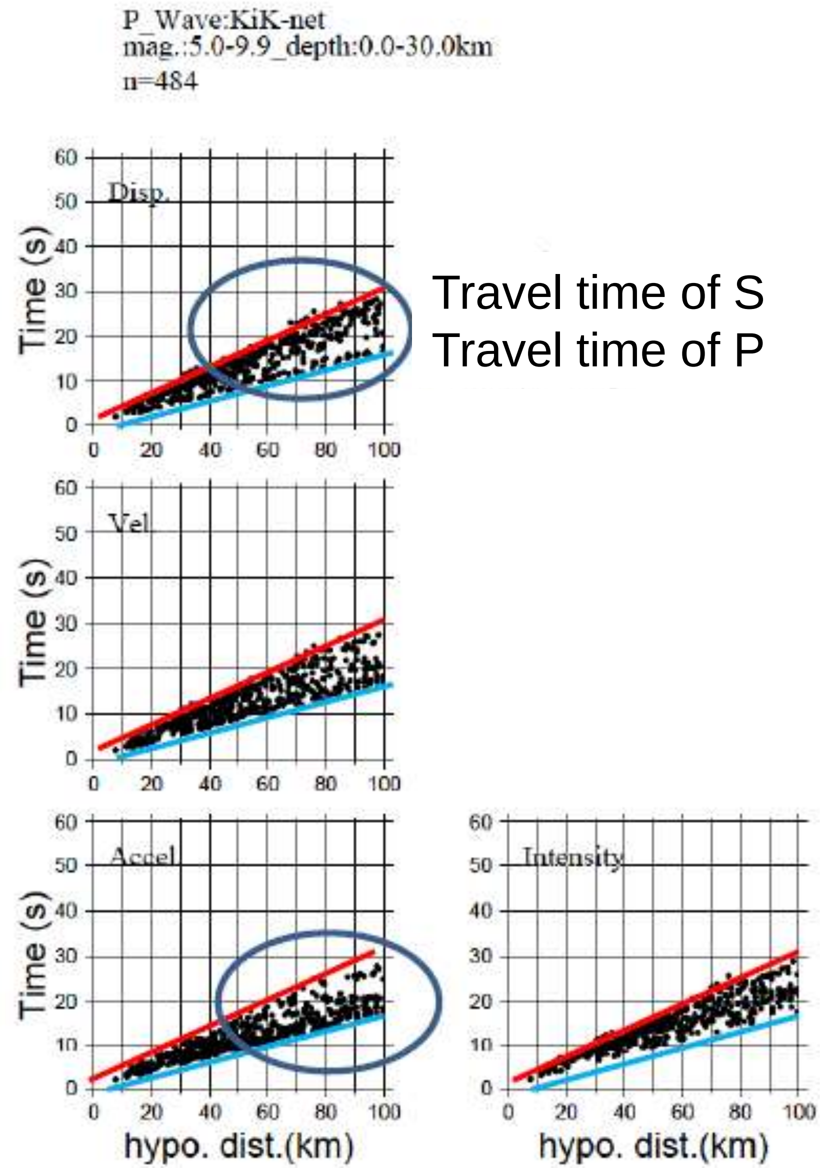
KiK-net一関西のリアルタイム震度が5弱相当を超過した時点で、情報を発信できれば、間に合わない領域を非常に小さくすることが可能であった。



After Nakamura (2008)

Appearance Time of the Maximum Amplitudes

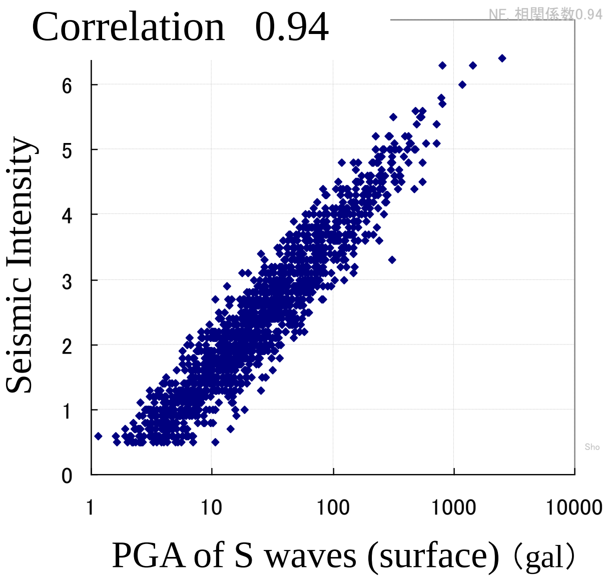




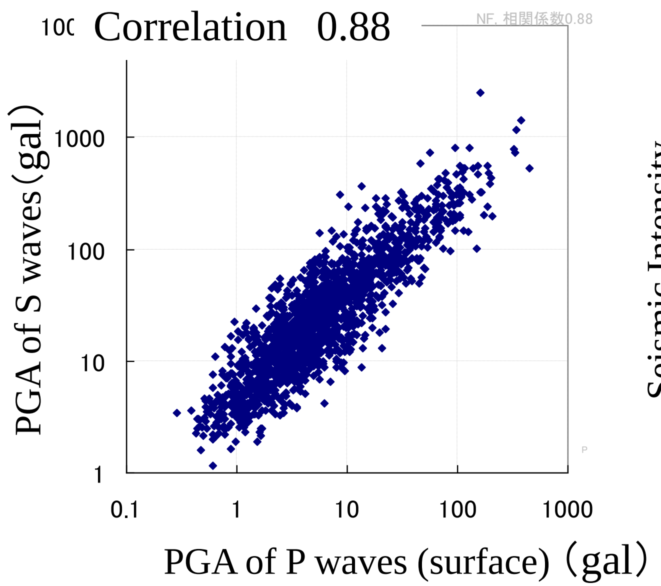
After Hoshiba (2008)

Relationships between Maximum Amplitudes of P waves and S waves and Seismic Intensity

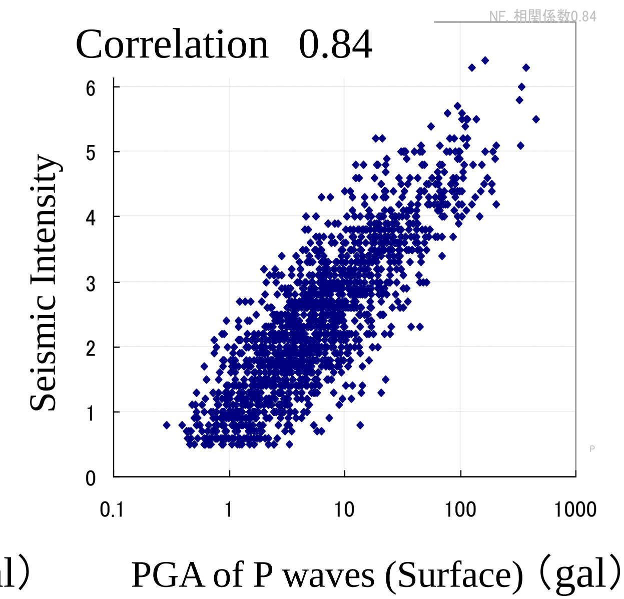
PGA of S waves vs Intensity



PGA of Pwaves vs PGA of S waves



PGA of P waves vs Intensity



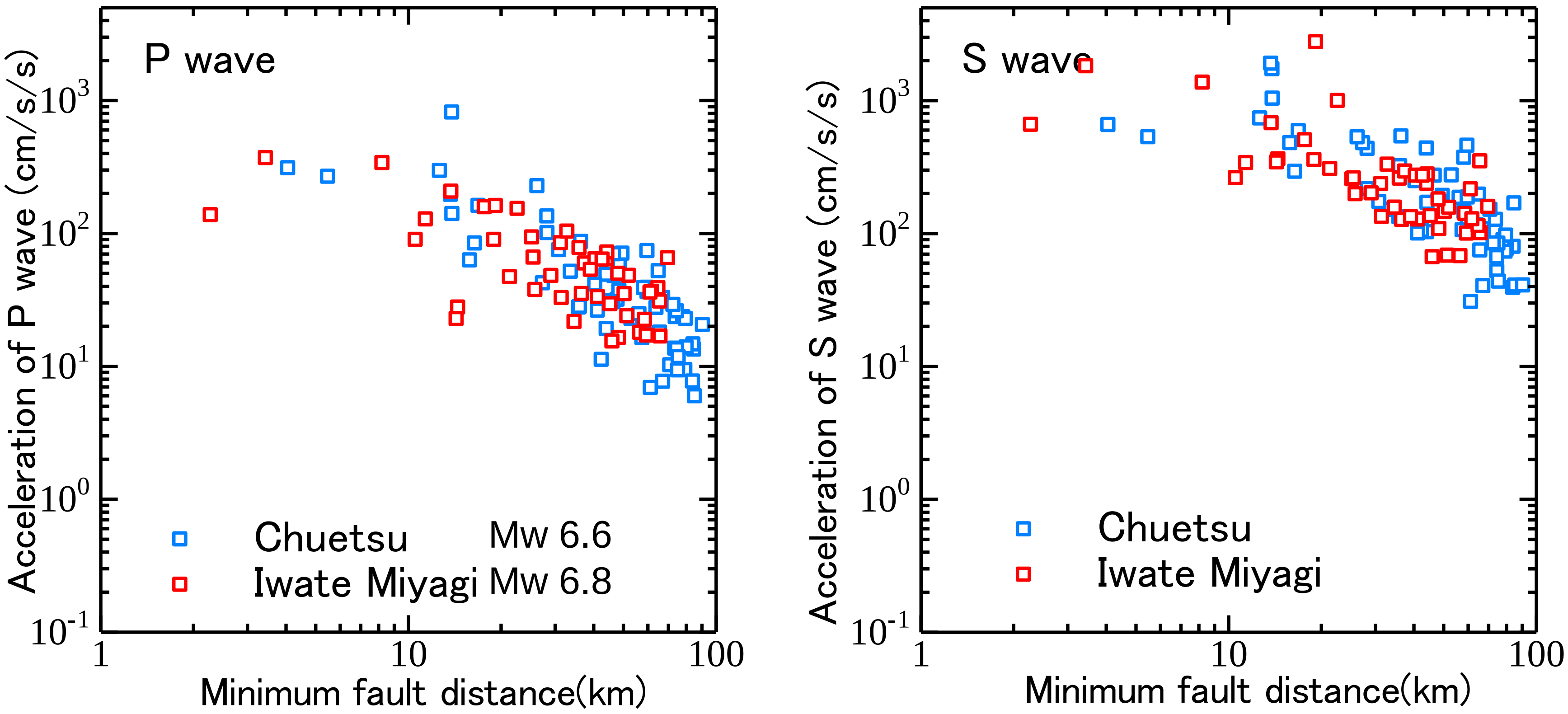
$$I = 2.18 \cdot \log P\max + 0.77$$

where

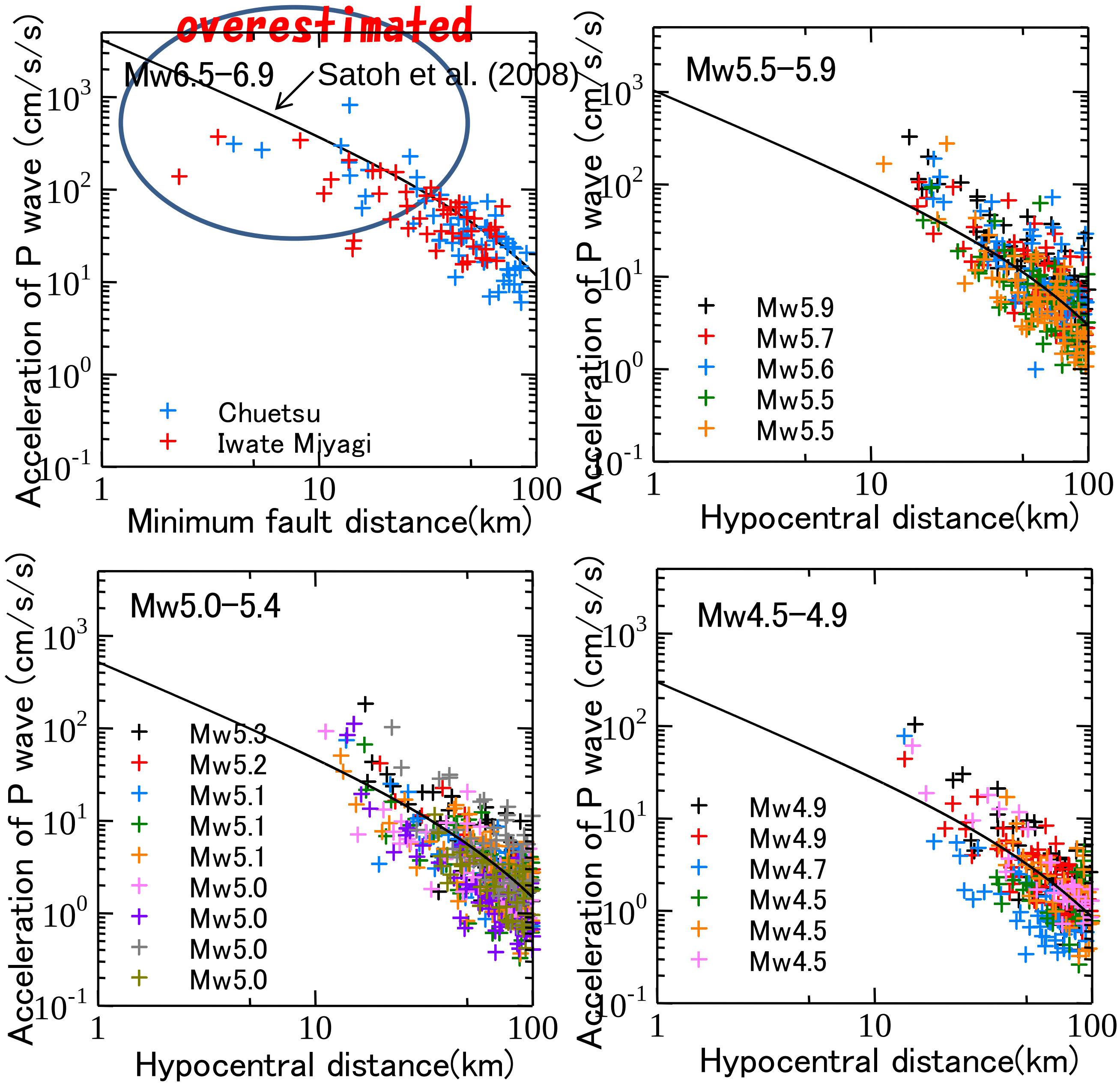
I : Seismic Intensity

P_{max} : Maximum Acceleration of P waves (Vertical) (cm/s^2)

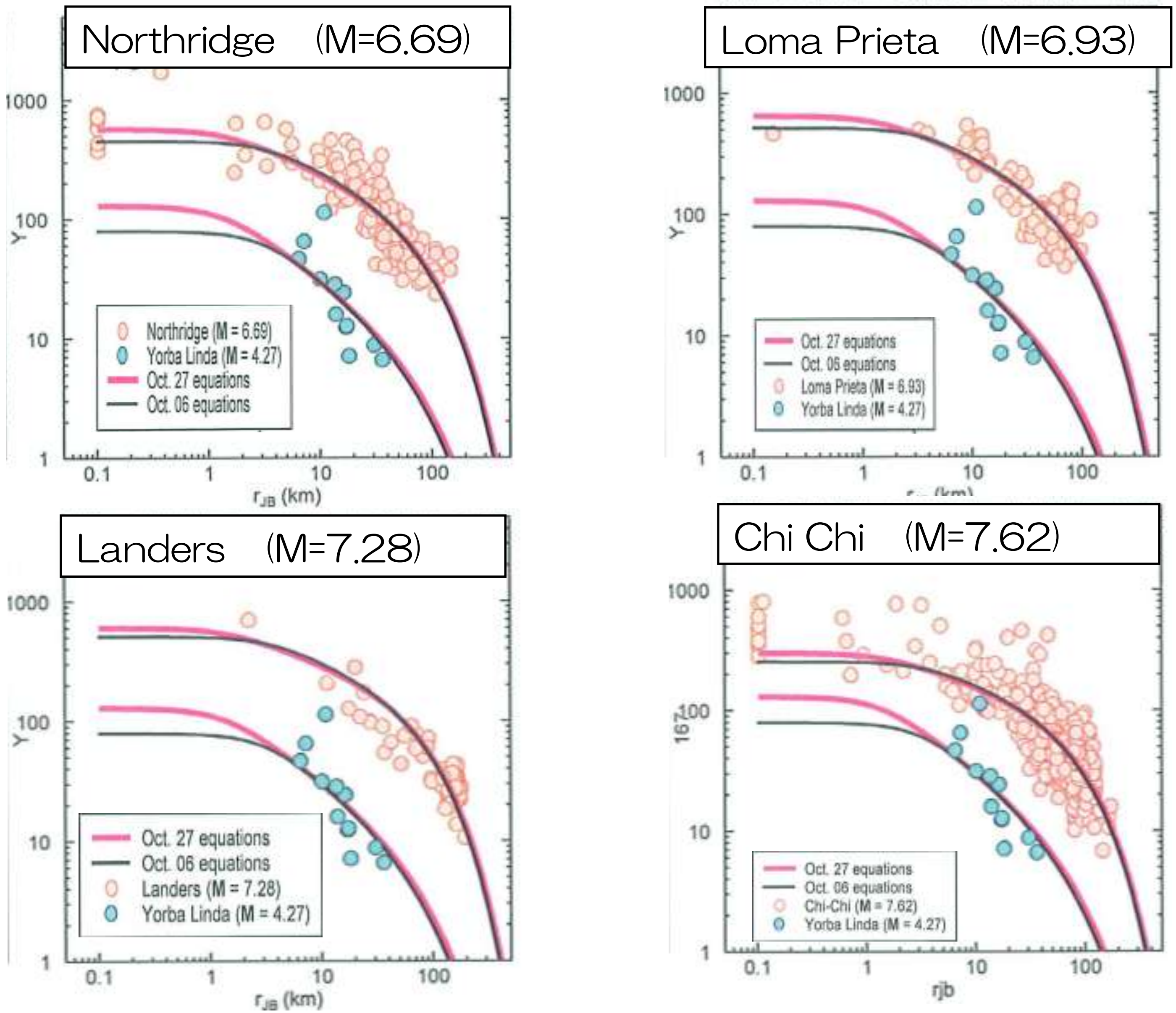
Attenuation-Distance Relationship of P waves amplitudes of Acceleration with Shortest Distance to Fault



Comparison between Observed and Calculated PGA using the empirical relationship by Satoh et al. (2008)



NGA（Next Generation of Ground Motion Attenuation Model） project　PGAの距離減衰式

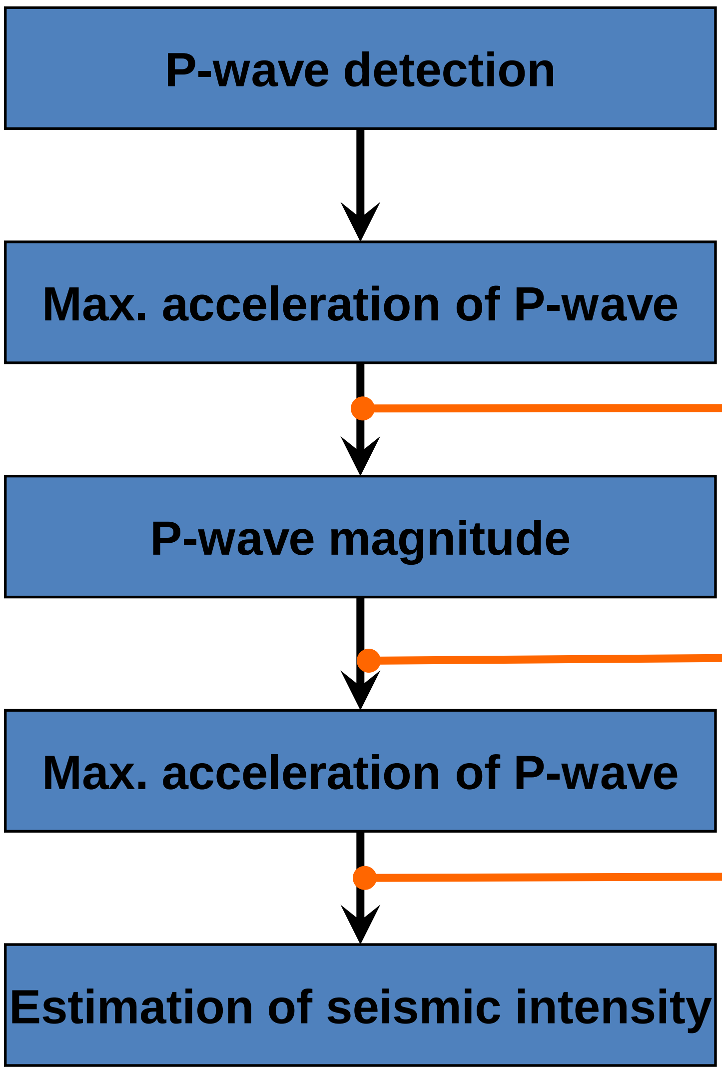


Ｓ波のPGAは、震源近傍で飽和する。

Our Idea

1. The fastest method to anticipate seismic intensity is to use the maximum vertical motions of acceleration (PGA) of the P waves.
2. The PGAs of the P waves well correlate the instrumental seismic-intensities of later-arriving strong shakings.
3. Then, the seismic intensity at target sites are estimated at earliest based on the P waves magnitude Mp which is evaluated from the maximum acceleration of the P waves.
4. The Mp has a saturation for earthquakes beyond magnitude (Mw) of about 6. It is caused by saturation of the maximum motions of acceleration (PGA) of the P waves in near-fields of the large earthquakes.

Procedure of Determining Mp



We decided equations (①~③).

We can calculate estimated seismic intensity by these equations.

① Definition of P-wave magnitude

$$Mp=\{\log(P_{max}\cdot r)+0.0055r+0.338\}/0.600$$

② Attenuation relationship of P-wave max. acceleratio

$$\log P_{max}=0.600Mp-\log r-0.0055r-0.338$$

③ Relationship between P-wave max. acceleration and seismic intens

$$I=2.18\cdot\log P_{max}+0.77$$

Estimation of P waves Site Effects

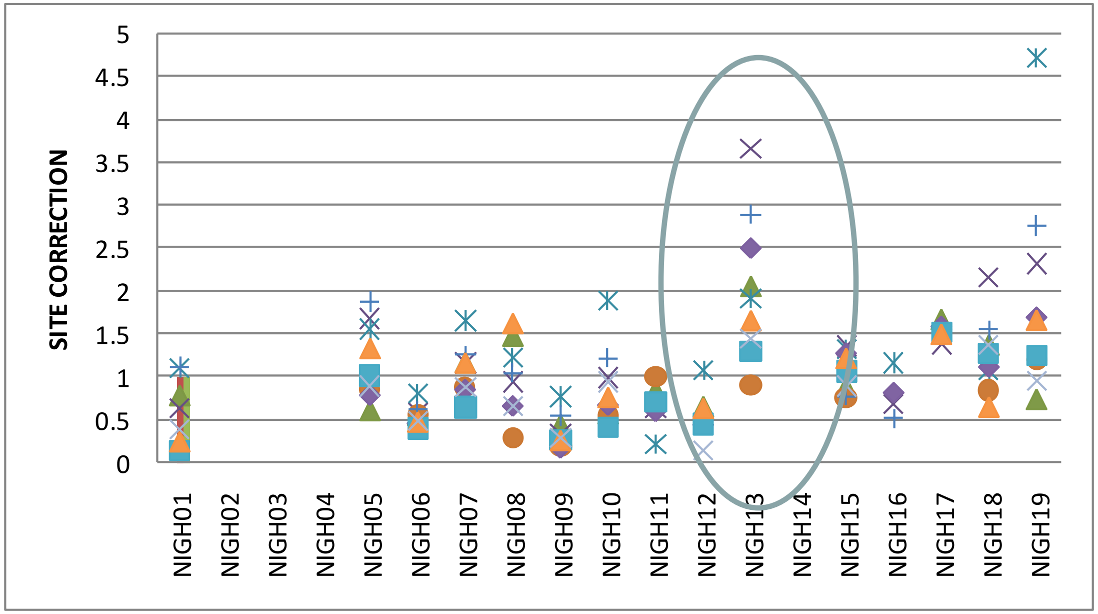
$$G_i = \frac{Obs(r)_i}{Cal(r)_i}$$

Cal(r) is estimated using an empirical relation for P waves' amplitude by Satoh et al (2008)

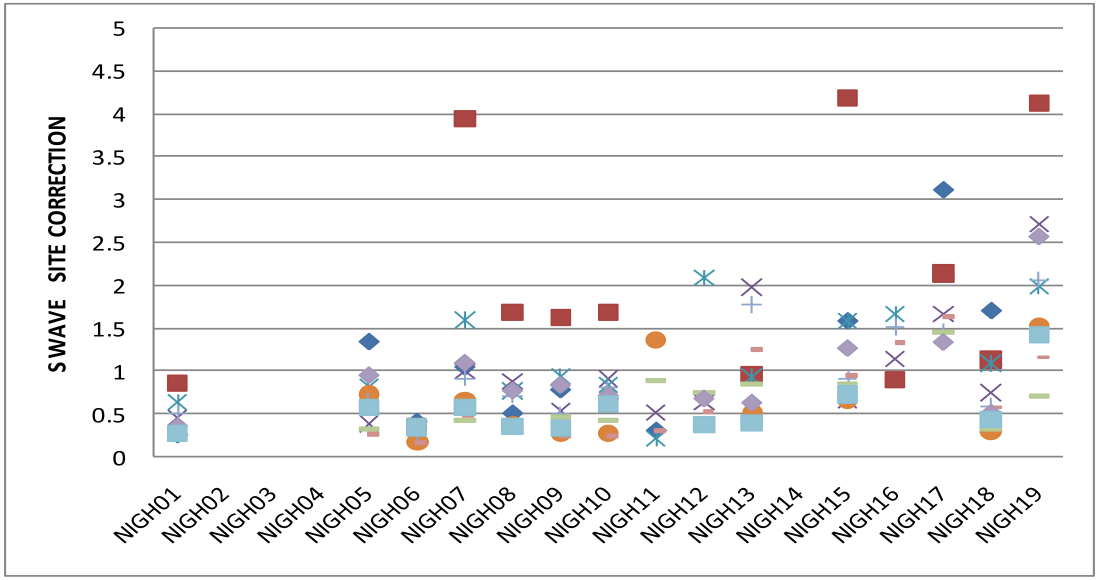
$$G_{ave} = \frac{1}{N}\sum_{i=1}^{N}\frac{Obs(r)_i}{Cal(r)_i}$$

Comparison between P waves site effects and S waves site effects

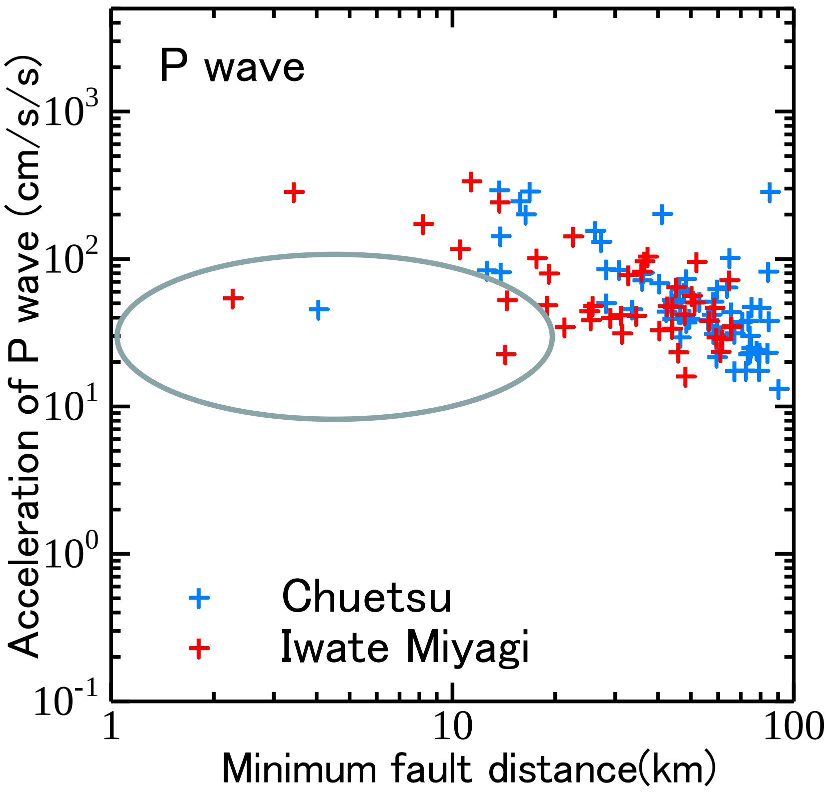
P waves site effects

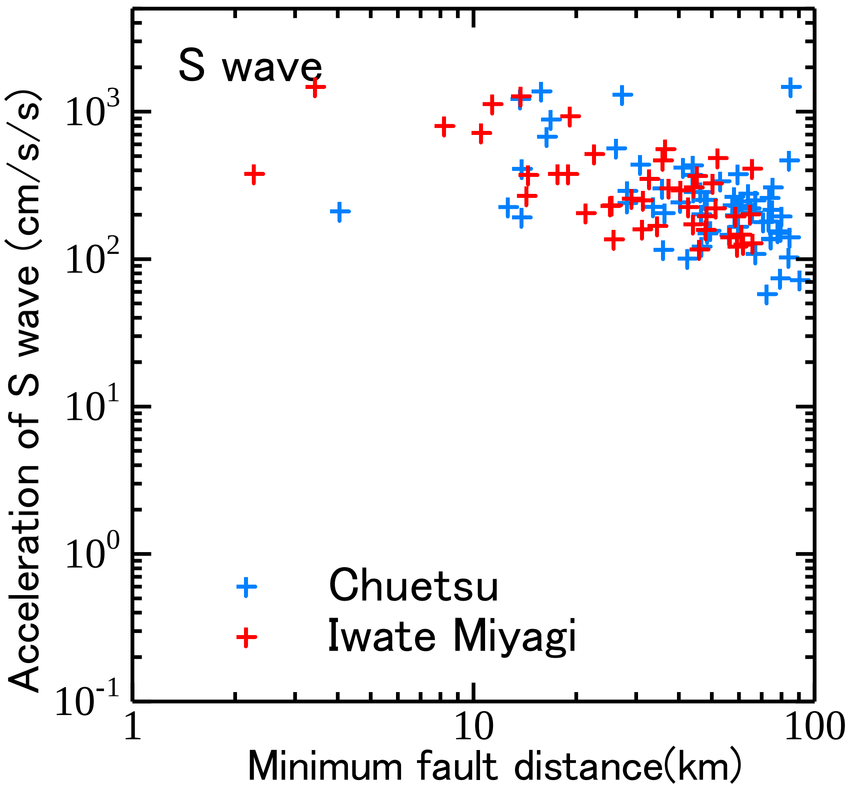


S waves site effects

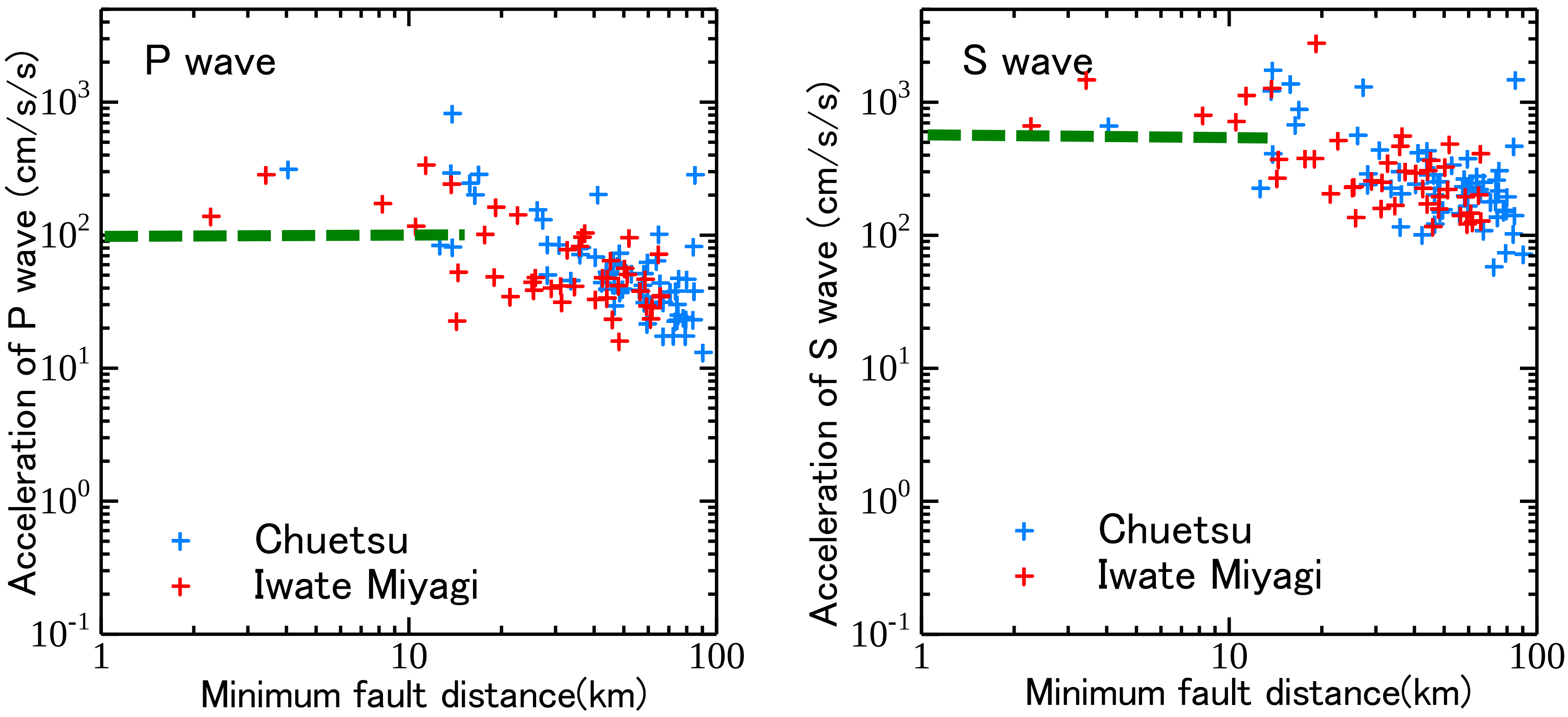


Attenuation-Distance Relation
(Site effects are Removed)



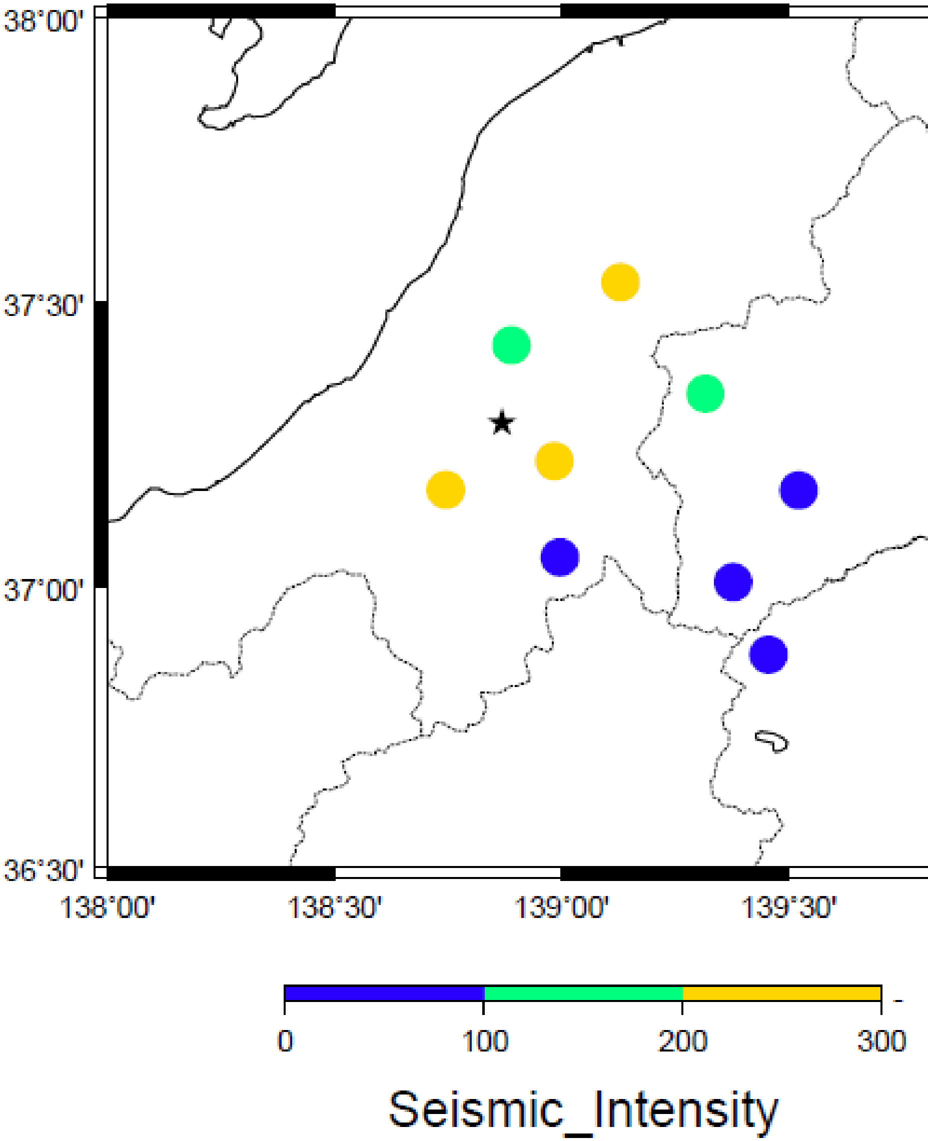


Attenuation-Distance Relation
(Site effects are removed except near-source area)

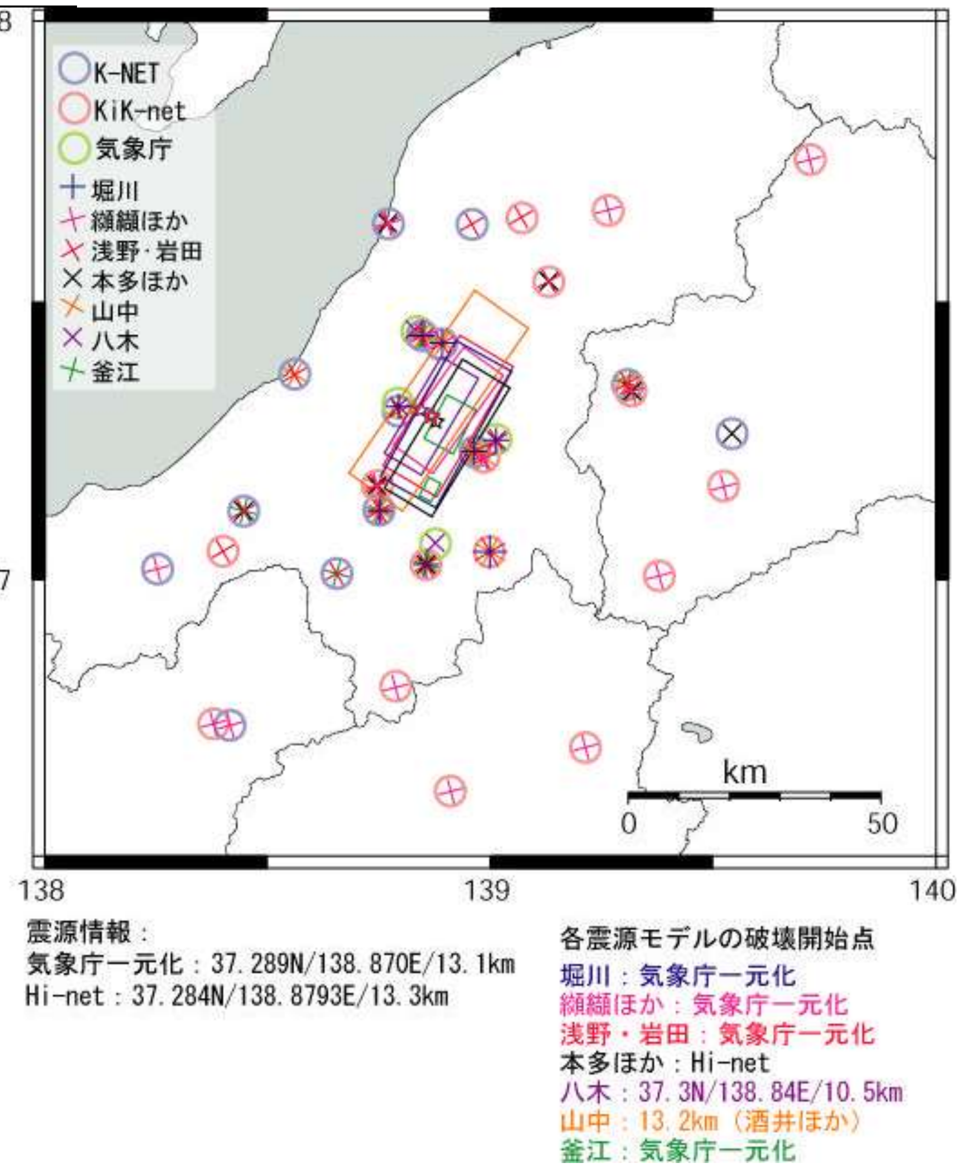


Saturation level of acceleration of P waves is roughly 100 gals.

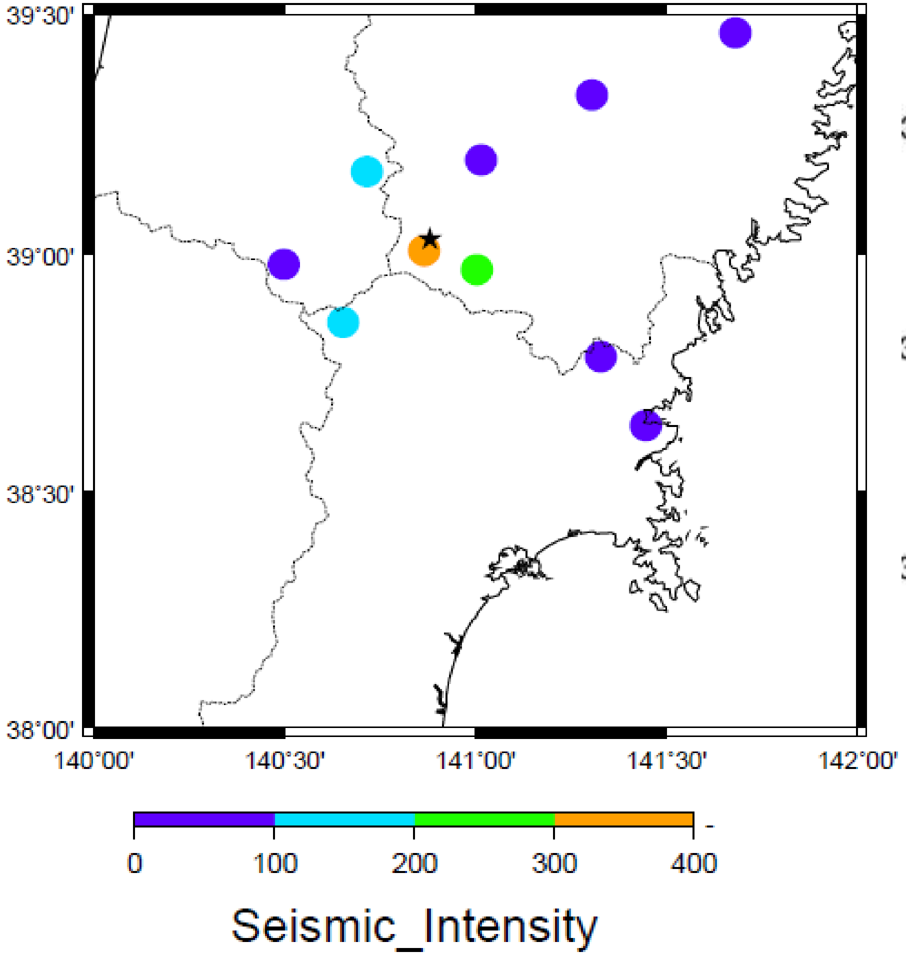
Sites with more than 100 gals
During the Chuetsu-oki earthquake
(Mw 6.6)



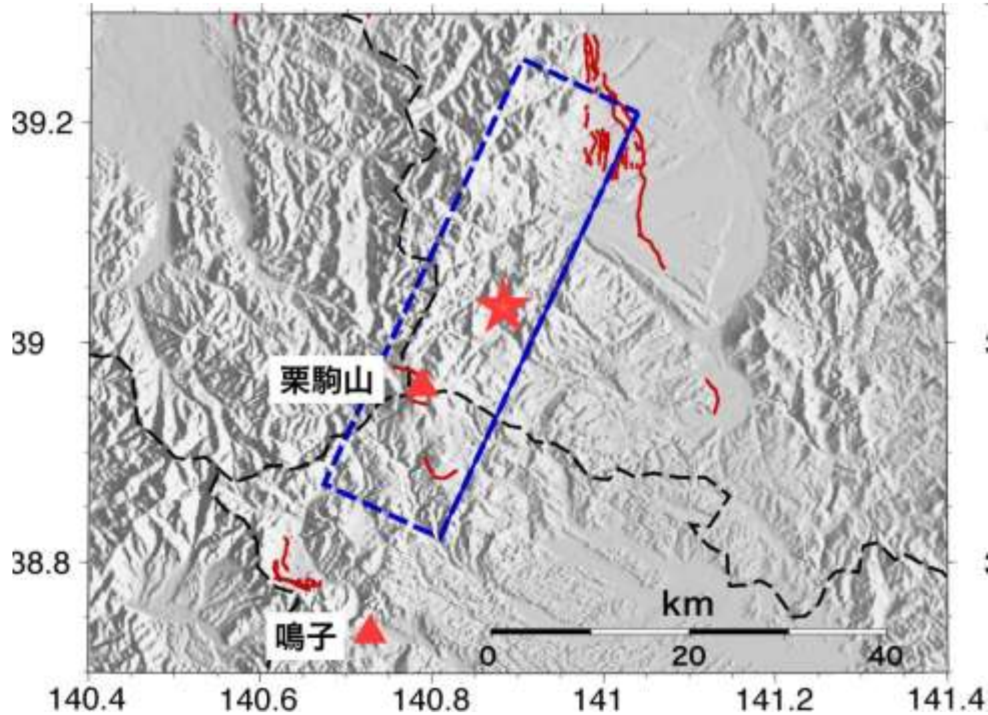
Rupture Area estimated
by the waveform inversion



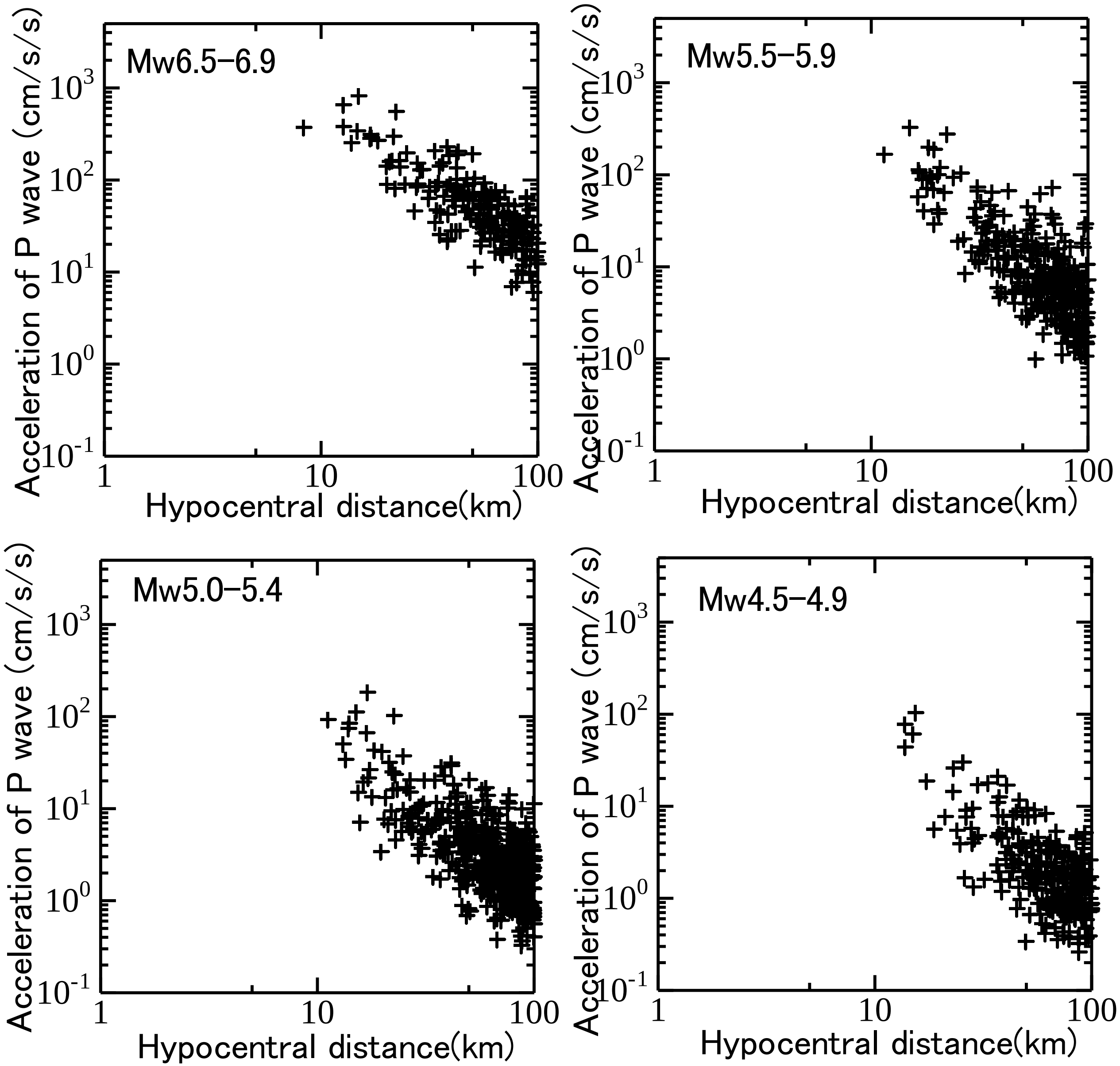
Sites with more than 100 gals During the Iwate-Miyagi Nairiku earthquake (Mw 6.8)



Rupture Area estimated by the waveform inversion



Attenuation-Distance Relationships Dependent on Magnitude



Conclusion

1. The maximum motions of acceleration (PGA) has a certain saturation level near the source area.) of the P waves. The saturation levels depend on geological conditions of the sites.

2. The extent of the sites beyond the saturation level is related to the magnitude and rupture area of the earthquakes.

3. The seismic intensities at the sites outside the rupture area should be estimated using a function of shortest distance to the rupture area as well as magnitude.