Home Seismometer for Earthquake Early Warning

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1. Introduction of EEW by Hi-net data
2. Hypocenter location by single P wave data
3. Home seismometer for EEW

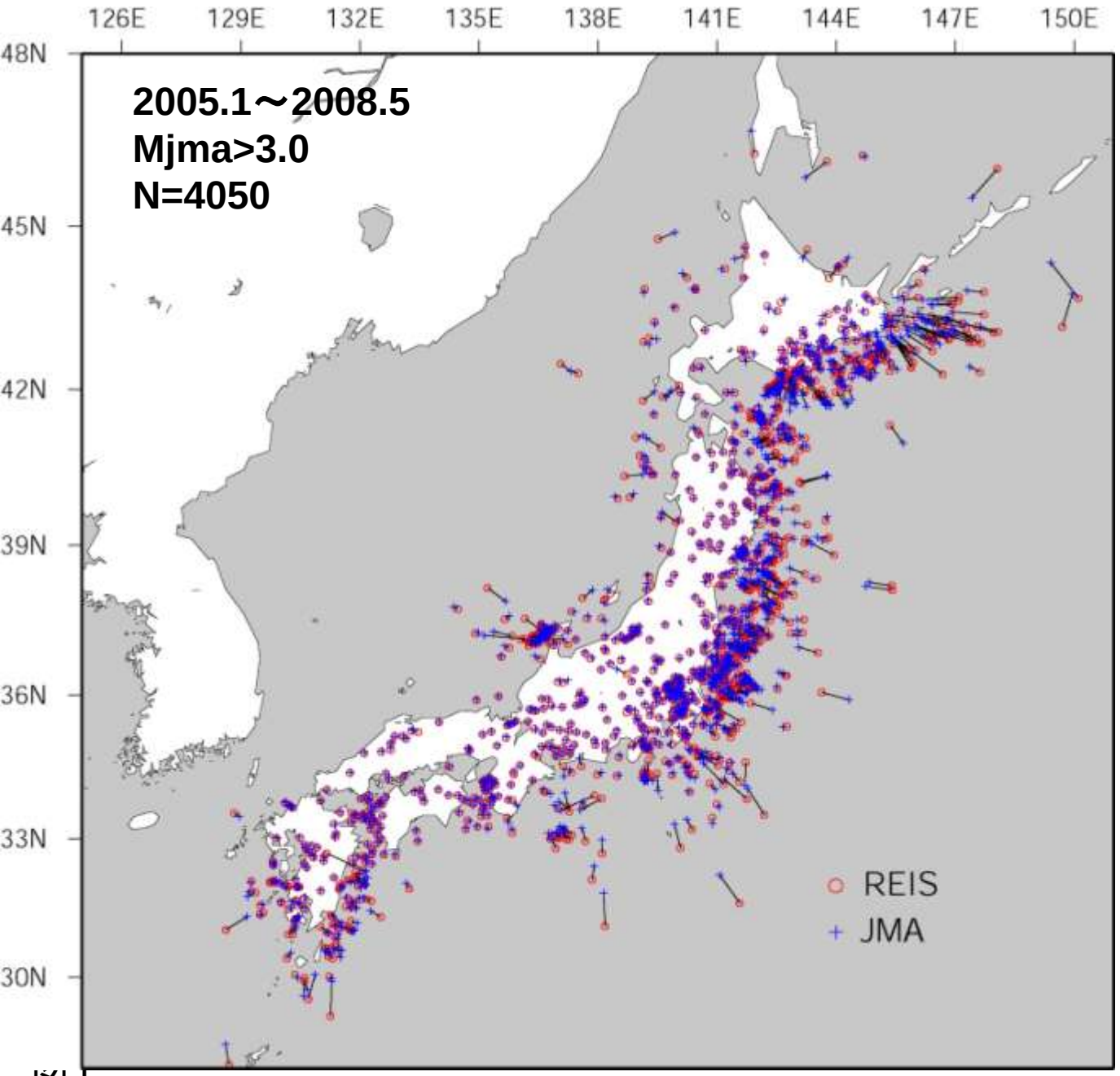


図1.

Comparison between epicenter locations obtained by the present EEWS (red) and those by JMA with using manually picked data (blue). EEWS located 4050 events larger than magnitude 3.0 in the period from January 2005 to May 2008. The present EEWS locates nearly correct epicenters for about 99 % events.

Introduction of a new parameter for the reliable shaking intensity estimation

$$M_{jma} = 1.73 \log \Delta + \log A - 0.83 \quad (1)$$

Δ; Epicentral distance

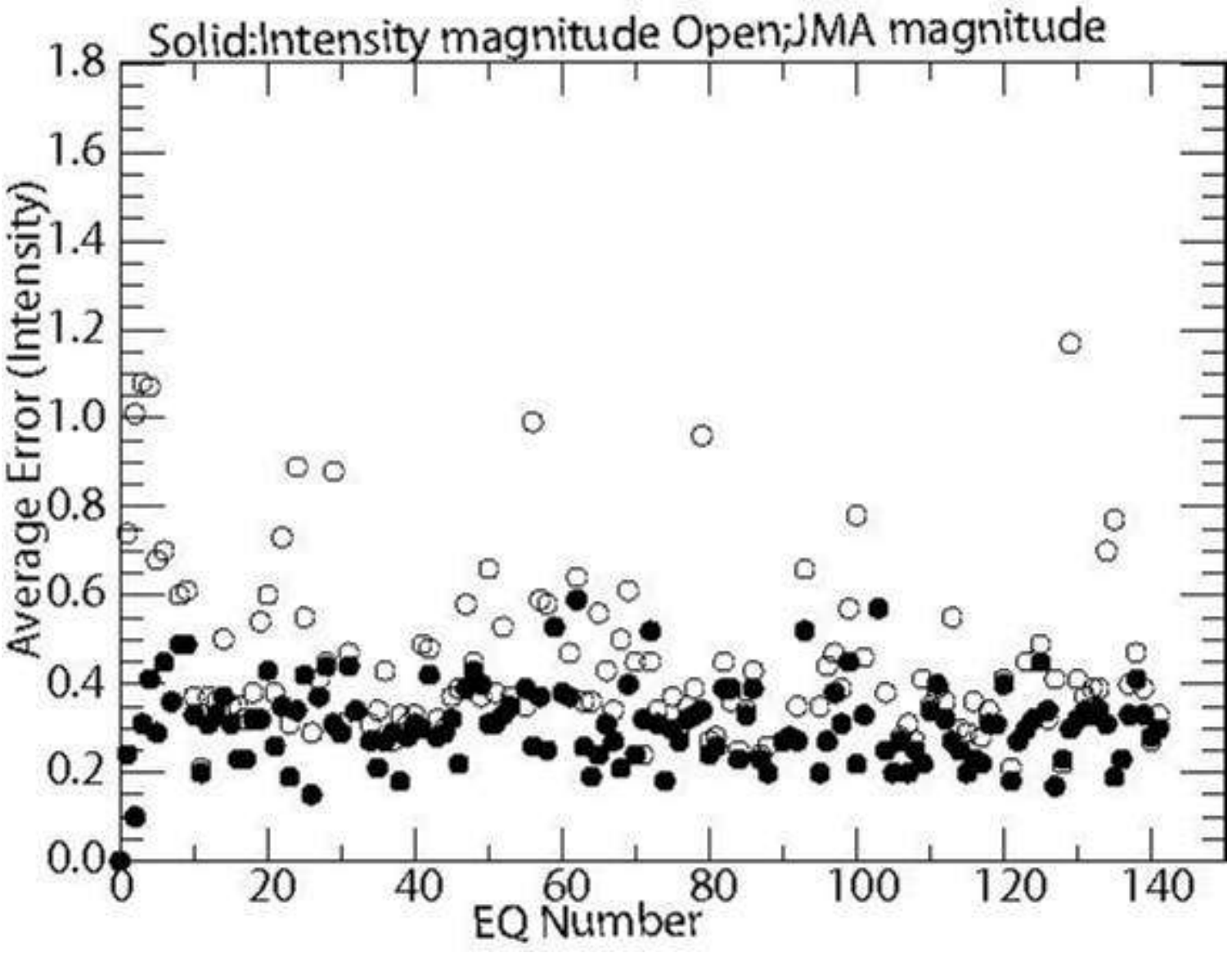
A ; Maximum displacement amplitude

$$I = 2 \log (Va) + 0.94 \quad (2)$$

I ; Shaking intensity of JMA definition

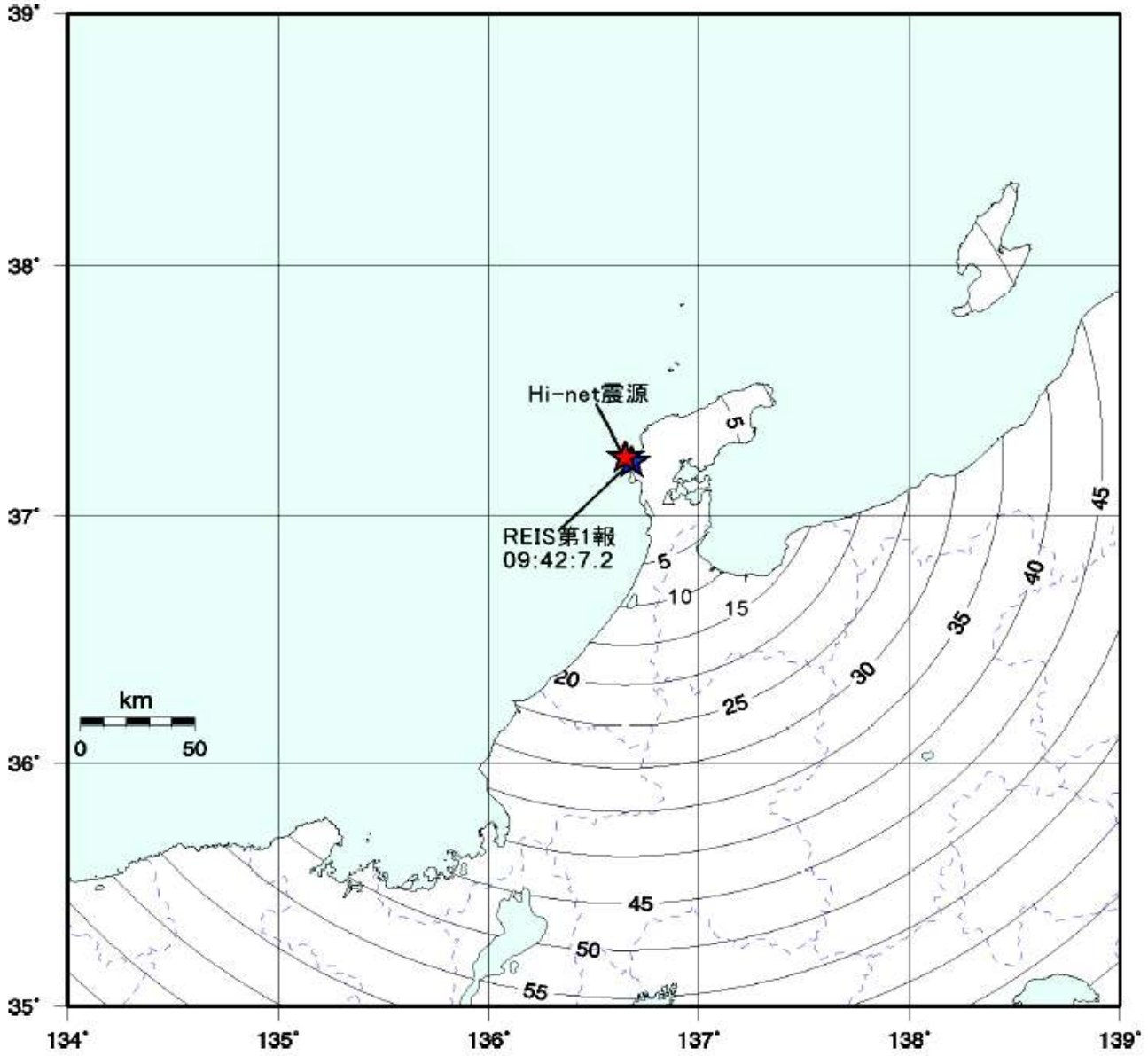
Va; Maximum amplitude(0.3sec) of filtered acceleration

The displacement and acceleration are different physical parameters. We introduce a new magnitude, which is defined directly from observed shaking intensity so as to decrease the effect of complexity of source time function of earthquakes in shaking intensity estimation.



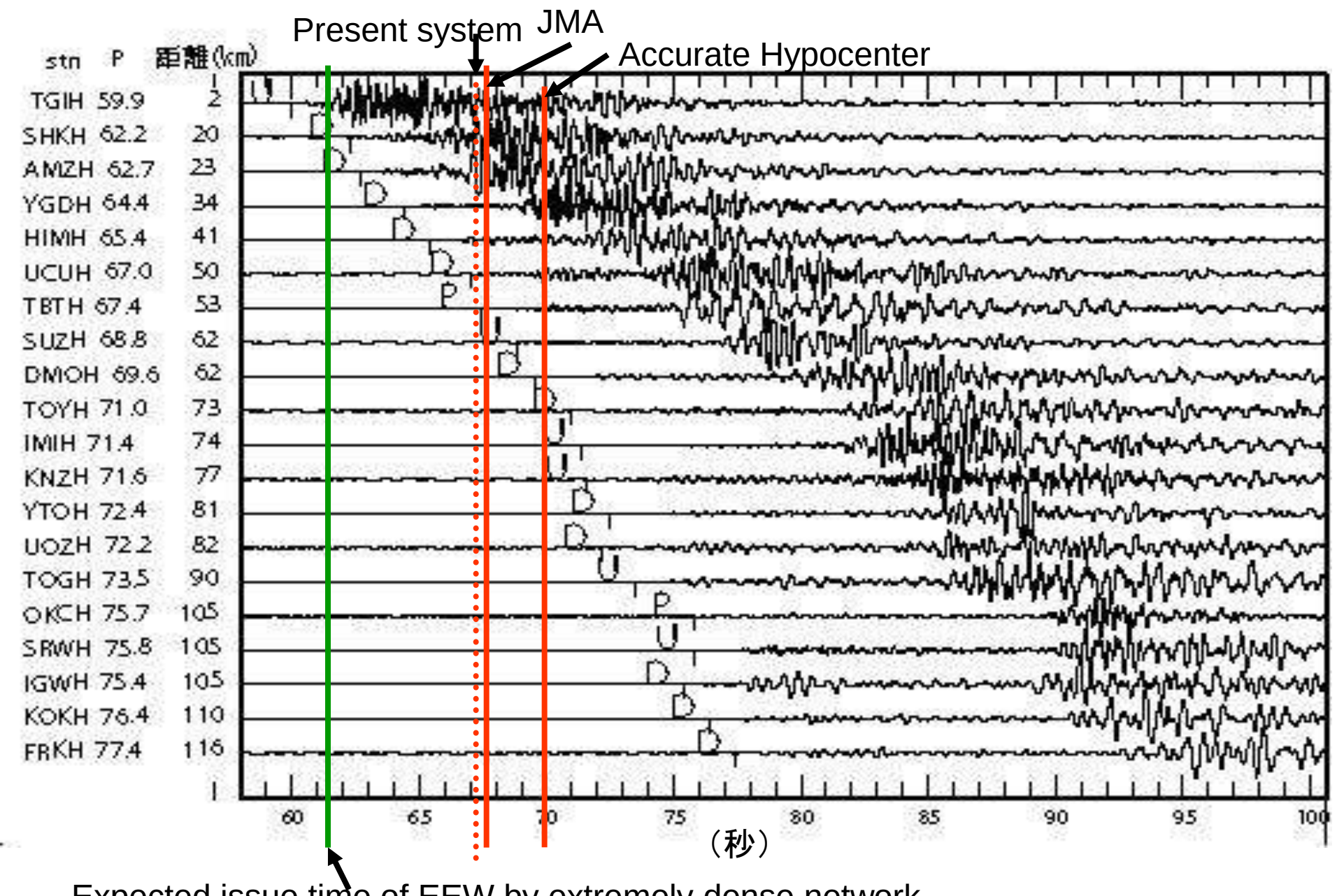
Average errors of shaking intensity estimated by using JMA magnitude (blue) and those by shaking intensity magnitude (red). It is clear that Mi can decrease estimation errors by about 22 %.

Early warning time in second for the 2007 Noto Peninsular Earthquake of M6.9



EEW is not available in areas within about 30 km.

2007 Noto Peninsular Earthquake（March 25 , M6.9)



Expected issue time of EEW by extremely dense network.

Hypocenter location using single P wave data

Target Distance: Less than several ten km

Estimate attenuation by Q

Hypocentral distance ; 50km, Q_P ;400,

Attenuation by Q becomes = 1/3 (20Hz)

1/15 (50Hz)

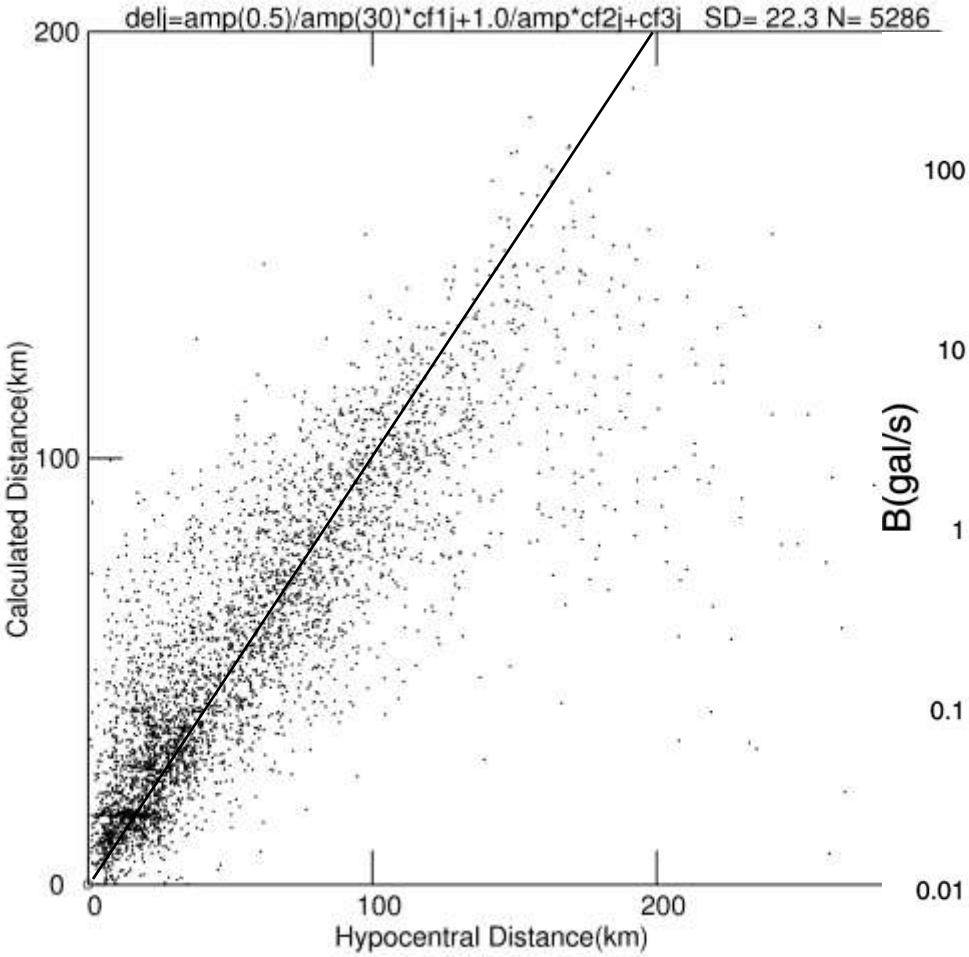
We should use amplitude data of a few ten Hz.

Empirical equation using ratios of high and low frequency amplitudes

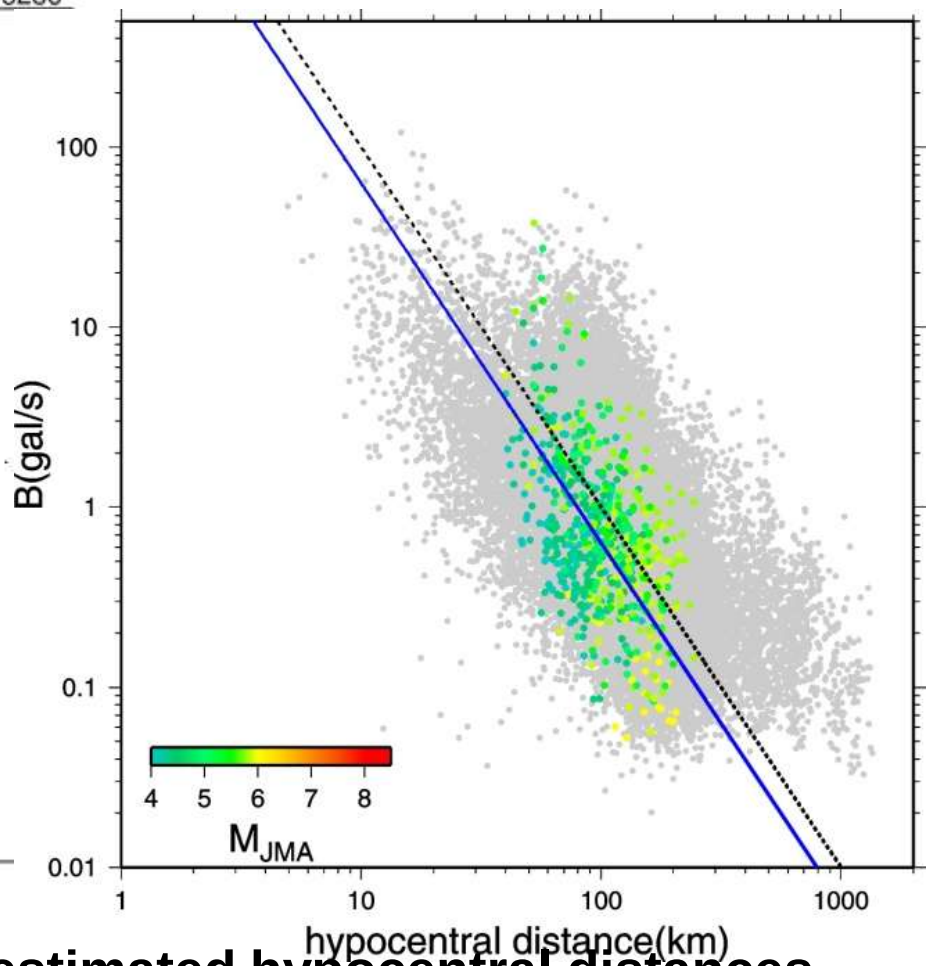
$$D = C_{1j}\,(A_L/A_H) + C_{2j}/A_M + C_{3j}$$

C_{1j}, C_{2j}, C_{3j} : Coefficients defined at each station
A_L: Amplitude at 2 Hz
A_H: Amplitude at 30Hz
A_M: Maximum amplitude of acceleration

Amplitude ratios with station correction



B-Δ method



Comparison between Observed and estimated hypocentral distances by amplitude ratio(left) and by B-Δ method (right).

Home Seismometer for Earthquake Early Warning

The GRL special section is available online.

1) **The receiving/alarm unit of EEW is equipped with a CPU and is on-line via the internet.**
2) **Addition of a seismometer and A/D converter changes this unit into a real-time seismic observatory (Home seismometer).**
3) **If the home seismometer is incorporated in the standard receiving unit of EEW, then the number of seismic observatories will be drastically increased.**
4) **Since the background noise inside a house may be very large, we have developed specialized software for the discrimination of seismic signal from noises.**

Home Seismometer

- **Receiving unit for EEW**
- **Real-time seismic observatory via internet connection**
- **On site warnig**
- **700 US $**

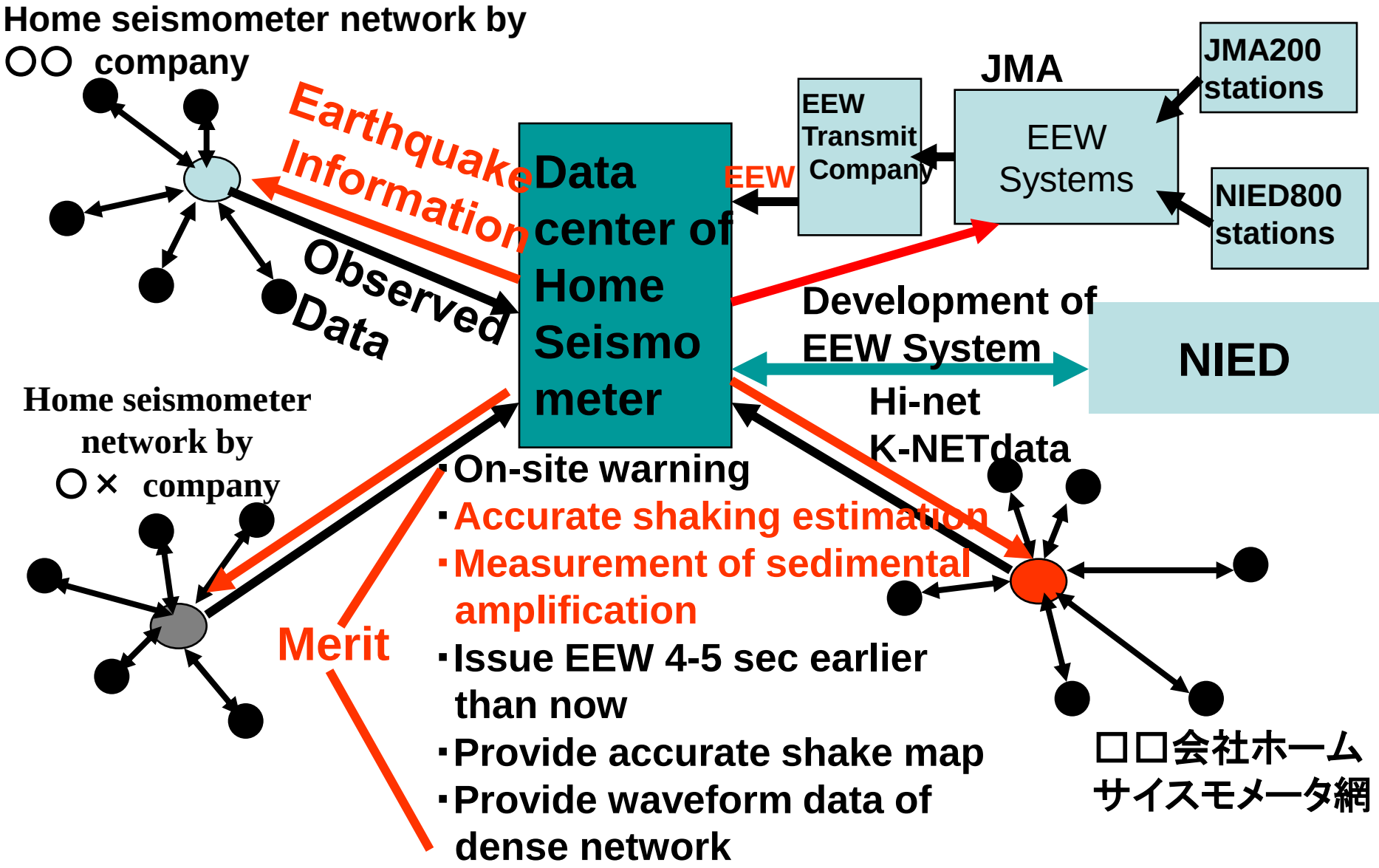
1）MEMS accelerometer

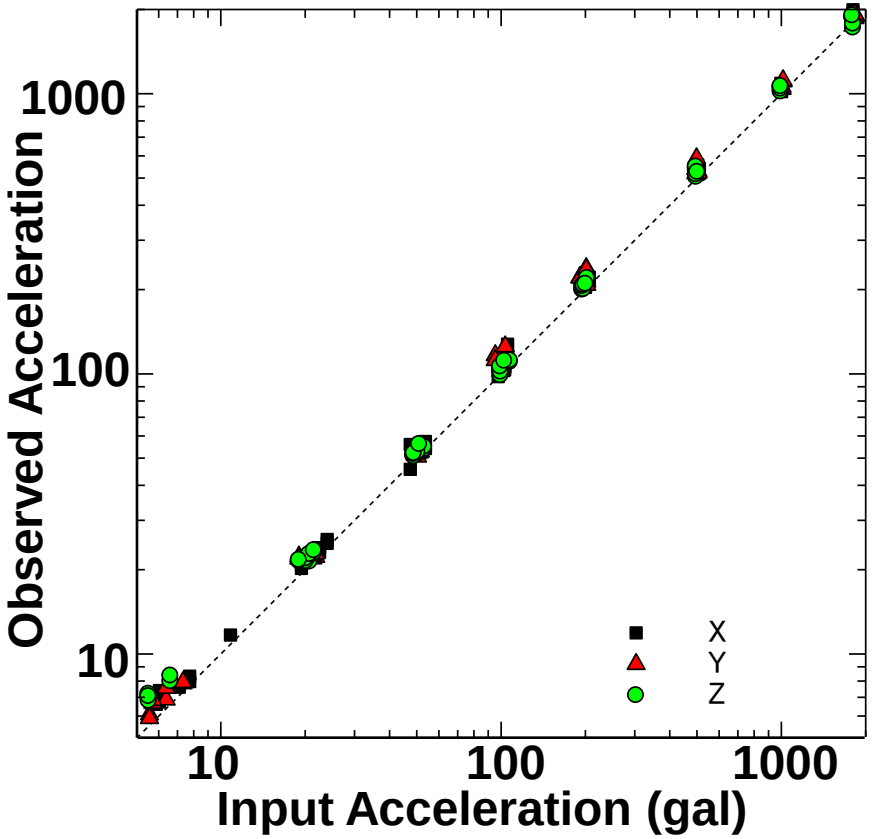
- 3 components
- observation range ±2G sensitivity 660mV/G

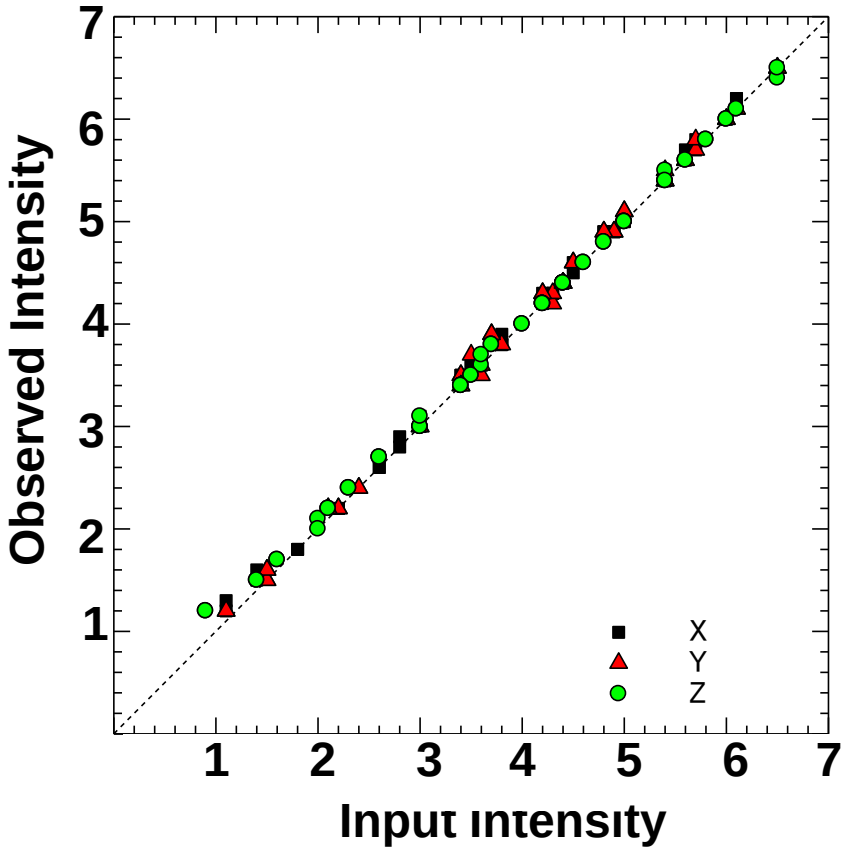
2）A/D converter

- 24bit、4channel、500Hz sampling (100 Hz for recording)

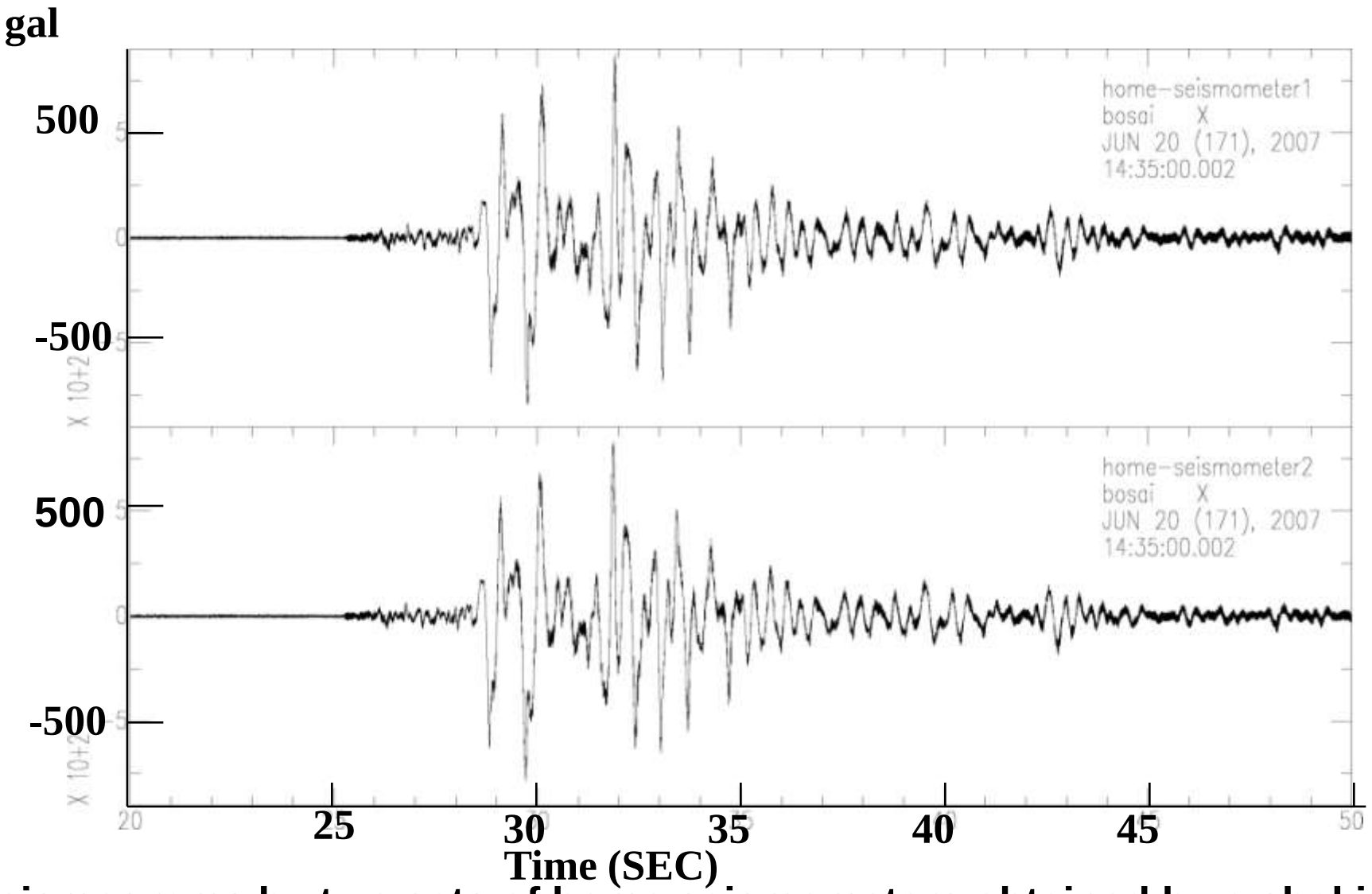
Earthquake Early Warning System Based on Home Seismometer Networks(650 sets, now).



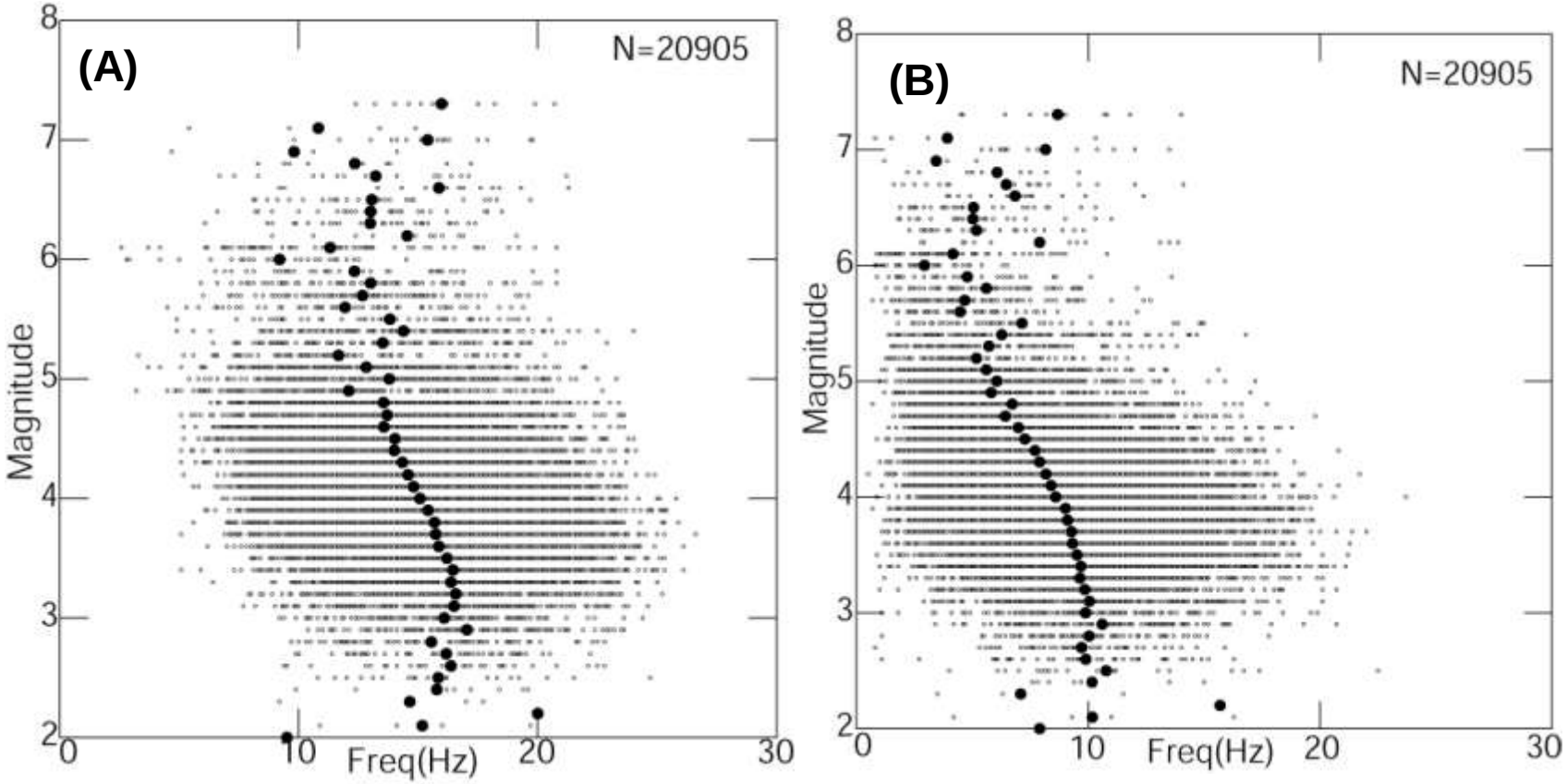




Result of shake tests on a shake table using sinusoidal oscillations. Vertical and horizontal axes in the left figure show observed and input acceleration, respectively. The right figure shows the comparison of shaking intensity.



Seismograms by two sets of home seismometers obtained by a shaking table experiment, in which NS component recorded by JMA Kobe at 1995 Kobe earthquake is reproduced. Maximum acceleration is 810 gal.



Plot of magnitude versus predominant frequency for the noise descrimination. Predominant frequency is calculated by the amplitude ratio between acceleration and jerk (A) and velocity and acceleration (B) using 2-seconds of waveform data from the P-wave onset. Large circles are the average predominant frequencies in magnitude ranges of 0.1.

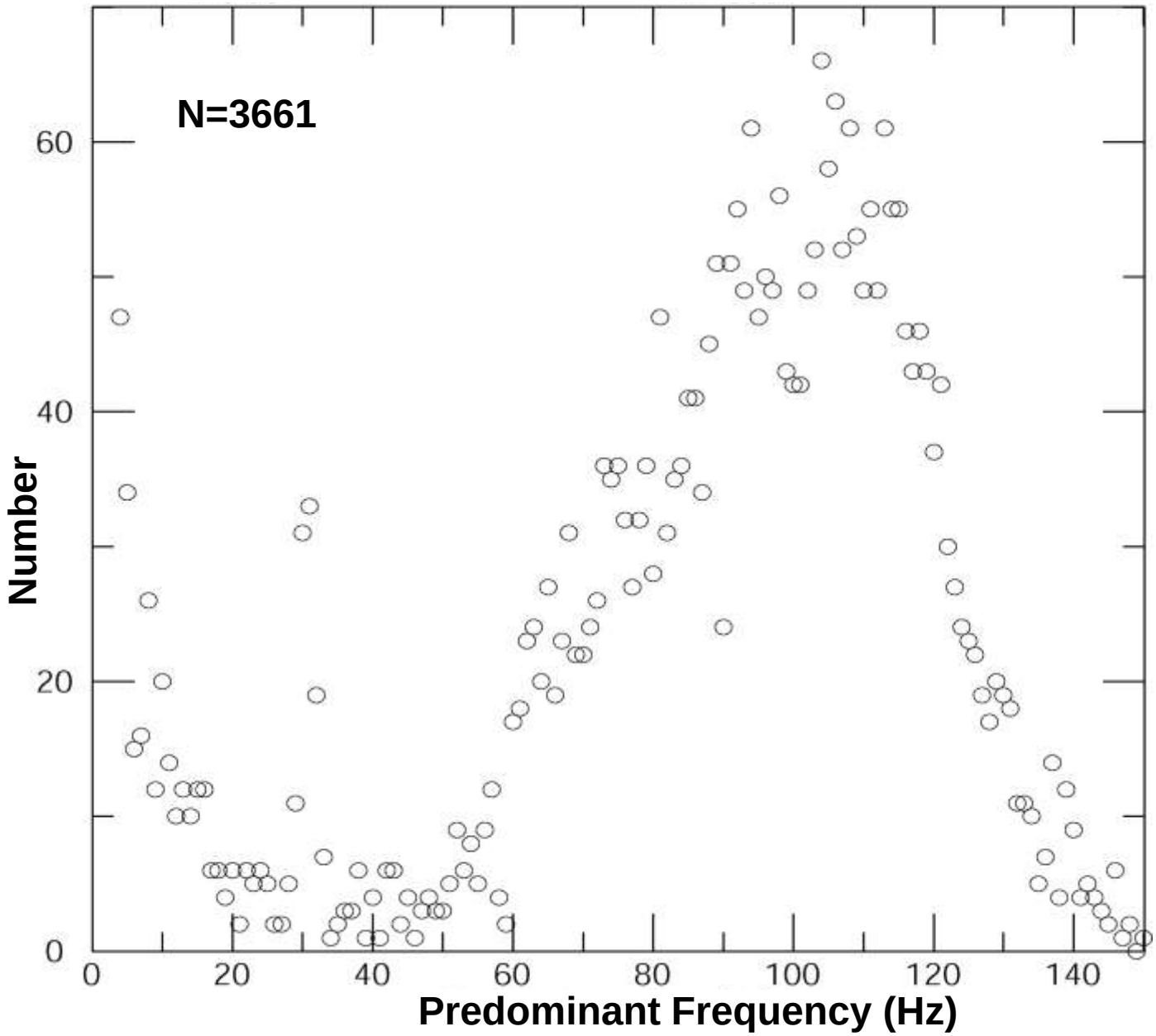
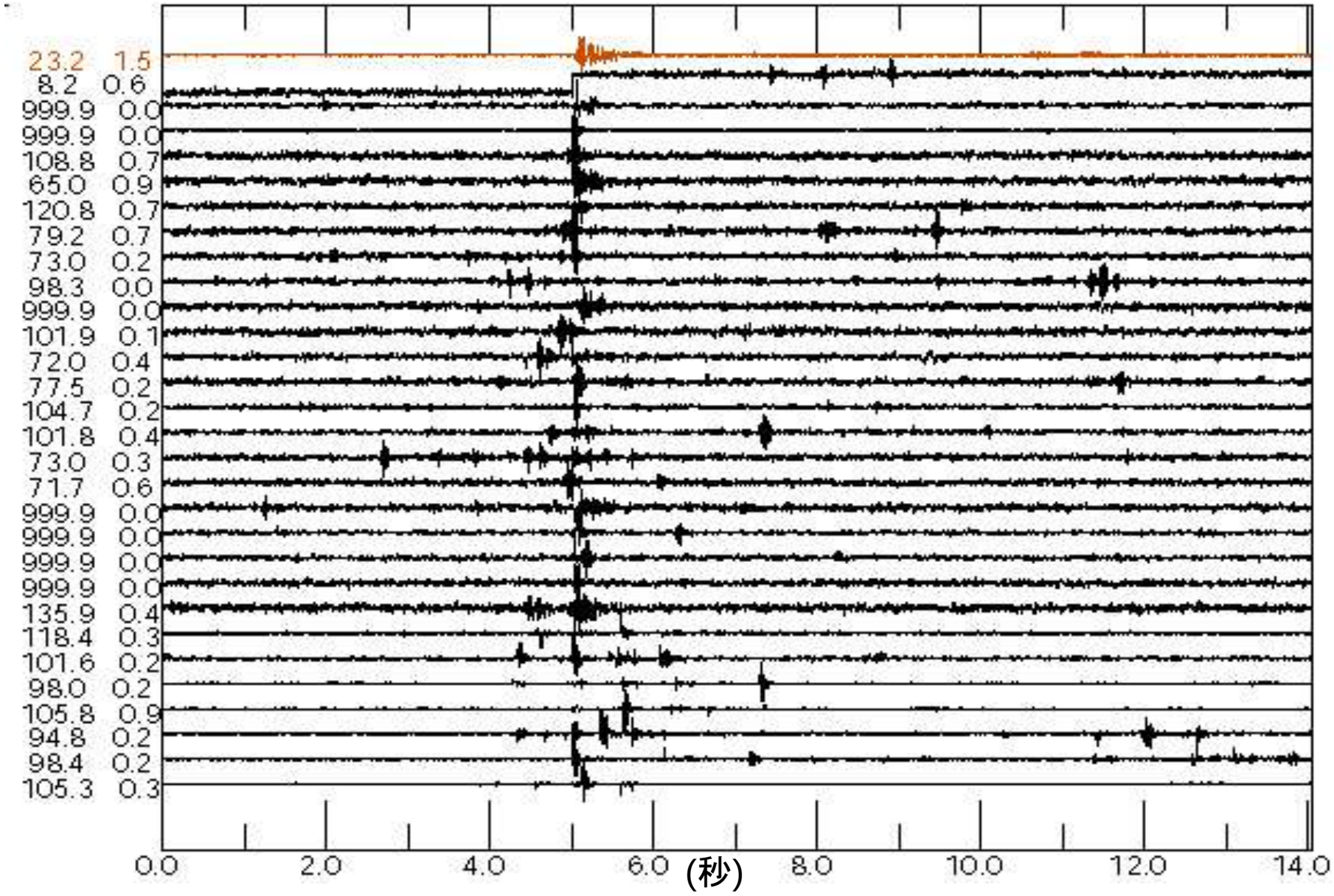
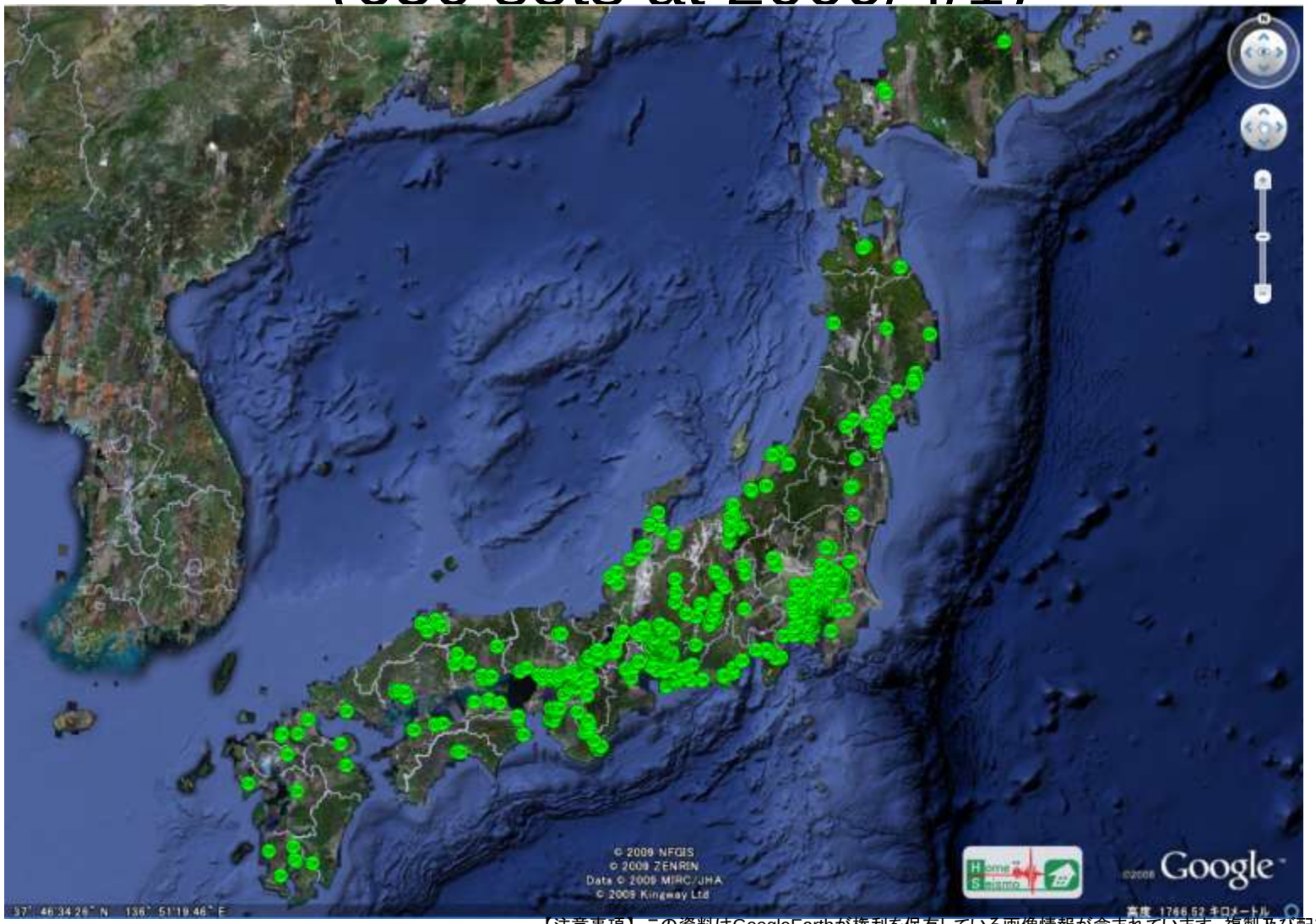

N=3661
Number
Predominant Frequency (Hz)
0
20
40
60
80
100
120
140
0
20
40
60

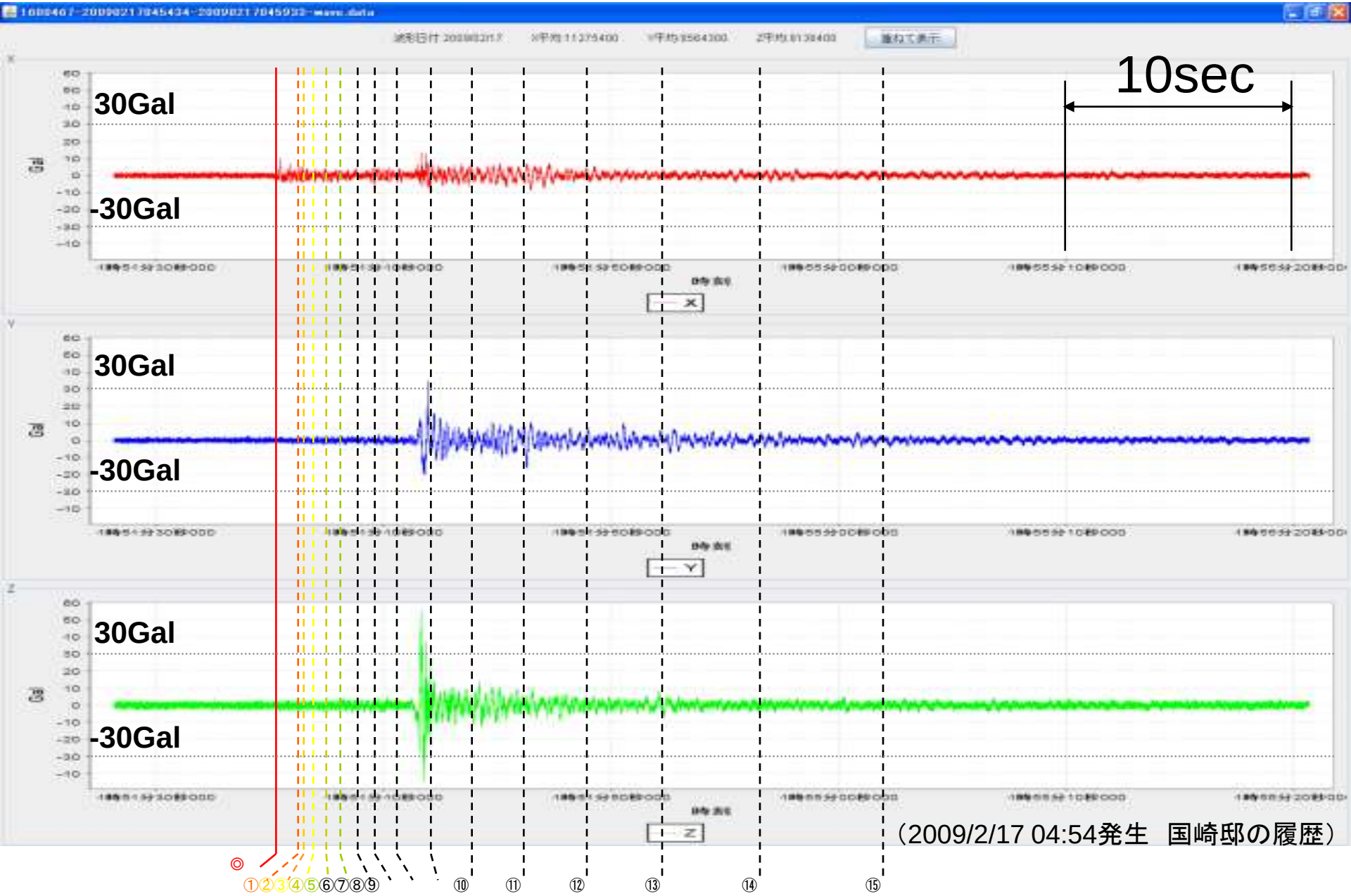
Figure 2



We developed a special software to distinguish artificial noise data from seismic data. A testing result shows that it can distinguish 444 trigger events without mistakes. Home seismometer can be available for on-site warning.

Distribution of home seismometer by A-2 Corporation(http://www.a-2.co.jp) (650 sets at 2009/4/1)





An example of data processing by home seismometer. Vertical solid line and 15 dashed lines show P wave onset and times of revisions.

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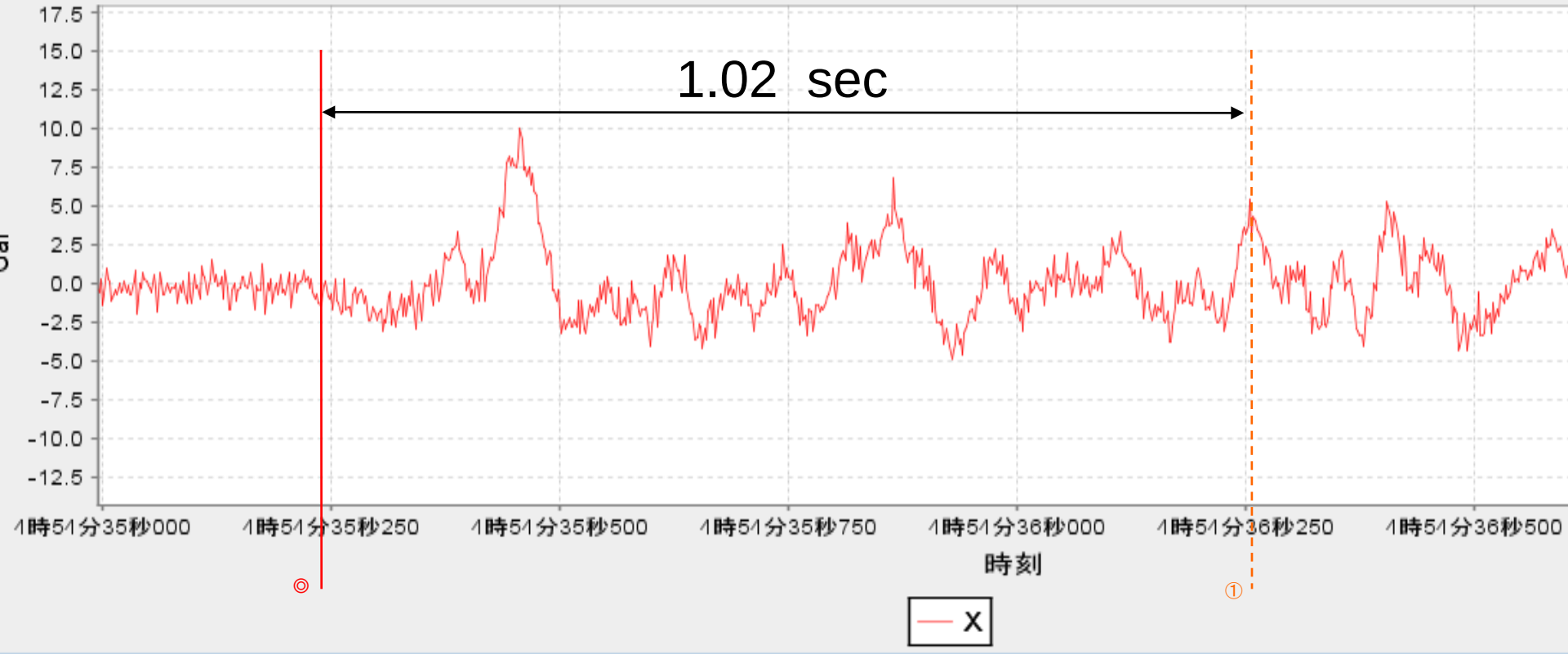
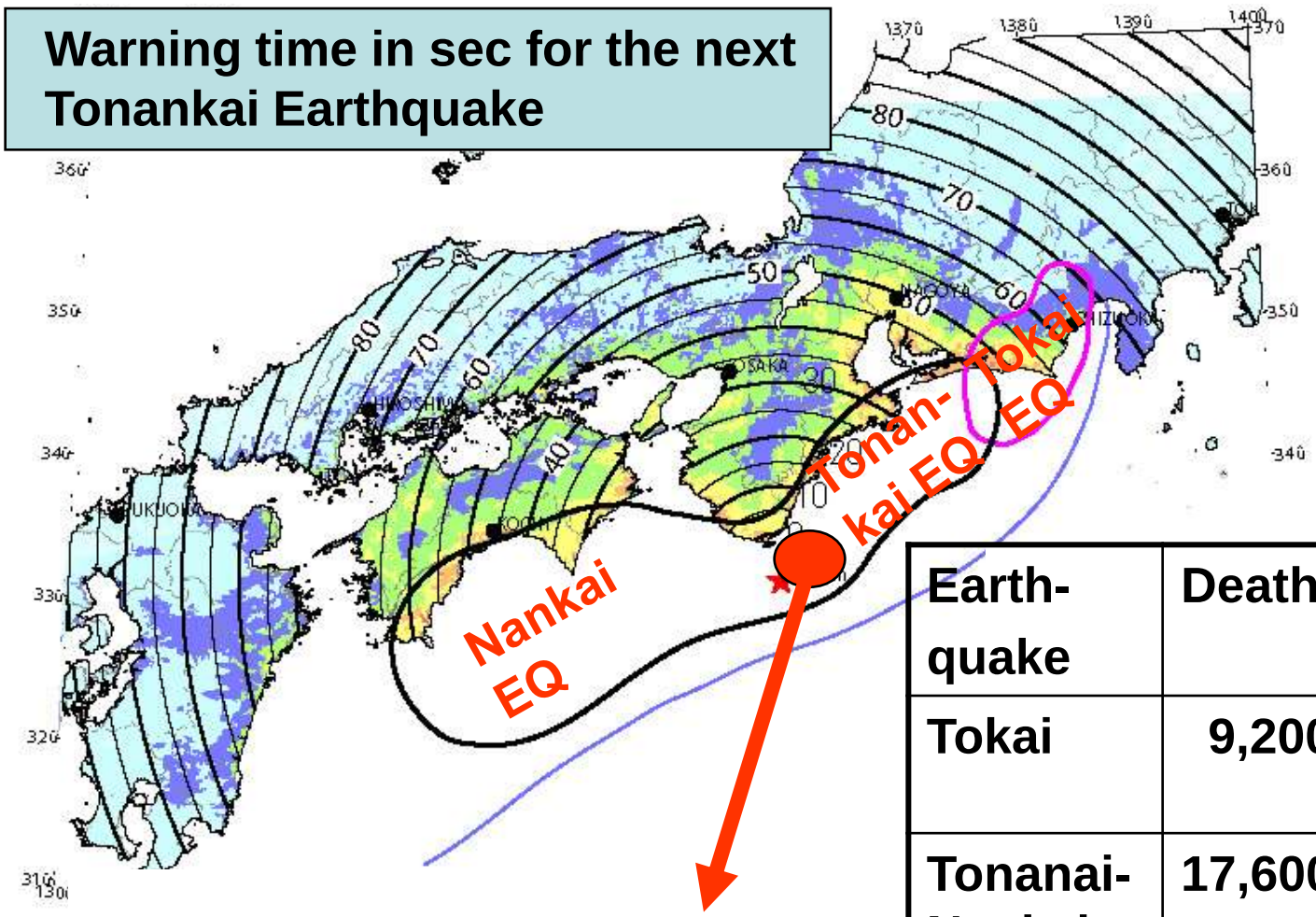


	Data receiving time (s)	P Wave intensity	Estimated intensity	Observed intensity	P wave arrival time
①	36..257	1.05	2.05	1.05	35.241

Receiving time of EEW (2009)	Time difference (sec)	Area	M	Depth
02/1806:47:17	0	North Fukui	M5.1	10km
02/20 18:17:37	−6	South Ibaragi	M4.4	70km
03/08 06:02:49	−1	North Osaka	M3.8	20km
03/13 21:22:13	−5	Tokyo Bay	M3.8	90km
03/25 15:26:32	−8	South Ibaragi	M4.0	50km

List of events with detection times earlier than those by EEW of JMA（Jan.-Mar. 2009). Event detection is made by more than three home seismometers.

Warning time in sec for the next Tonankai Earthquake



Earth-quake	Deaths	Damage (Yen)
Tokai	9,200	37 trillion
Tonanai-Nankai	17,600	57 trillion

Issue information that the Tonankai Earthquake occurs when small part of its fault area is ruptured. Its brings long warning time.

Meguro(2004) pointed out that the installation of EEW decreases death tolls by the next Tokai EQ by 82%.

Conclusion

1. **We development an automatic system for EEW, which determines nearly correct earthquake parameters for 99% of events.**
2. **Home seismometer network is effective for the EEW.**

http://www.a-2.co.jp

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