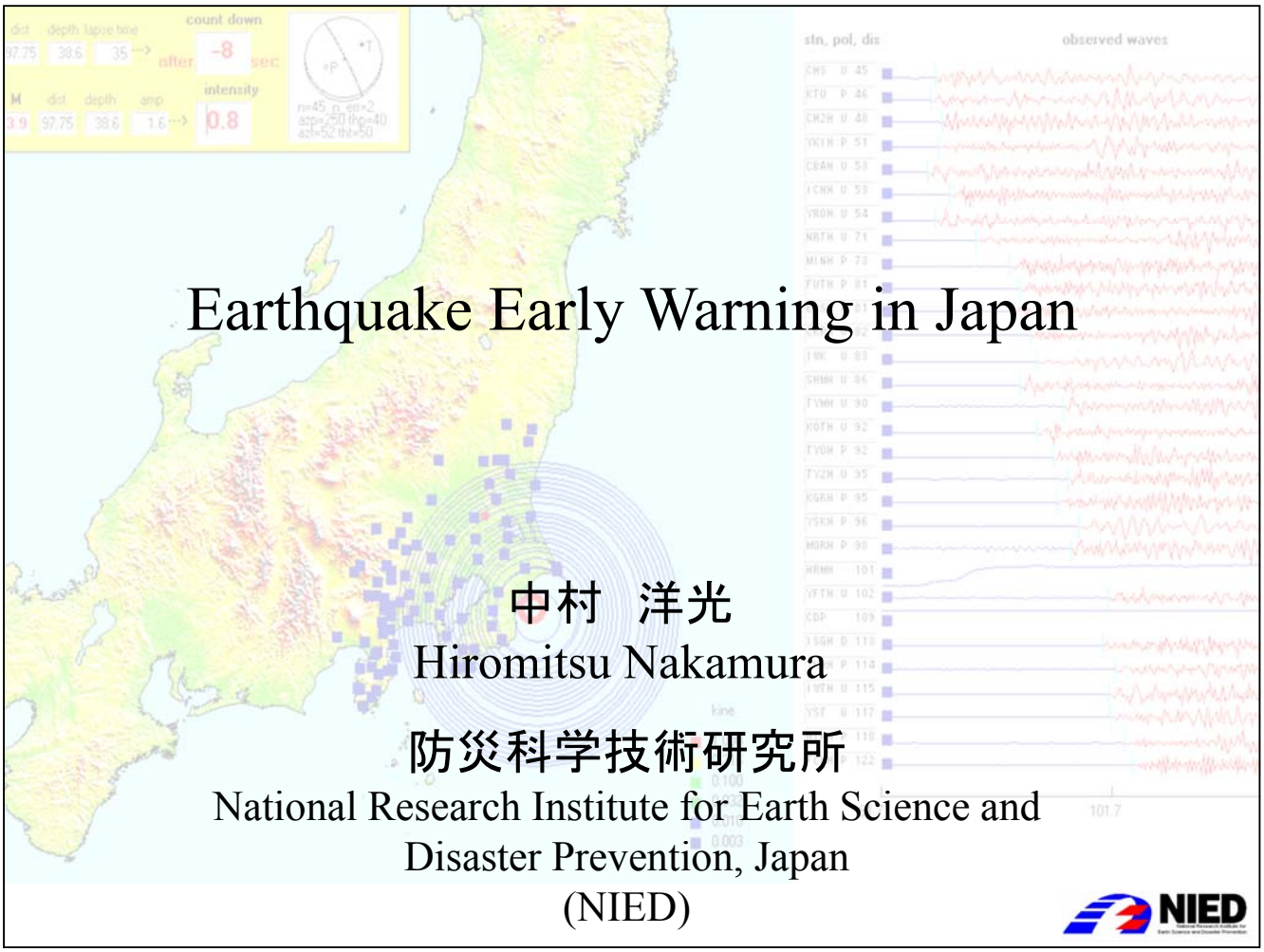

Earthquake Early Warning in Japan

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(NIED)

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Outline

- Overview of the earthquake early warning (EEW) system in Japan
- Transmission and utilization of the EEW
- Problems of the present EEW system

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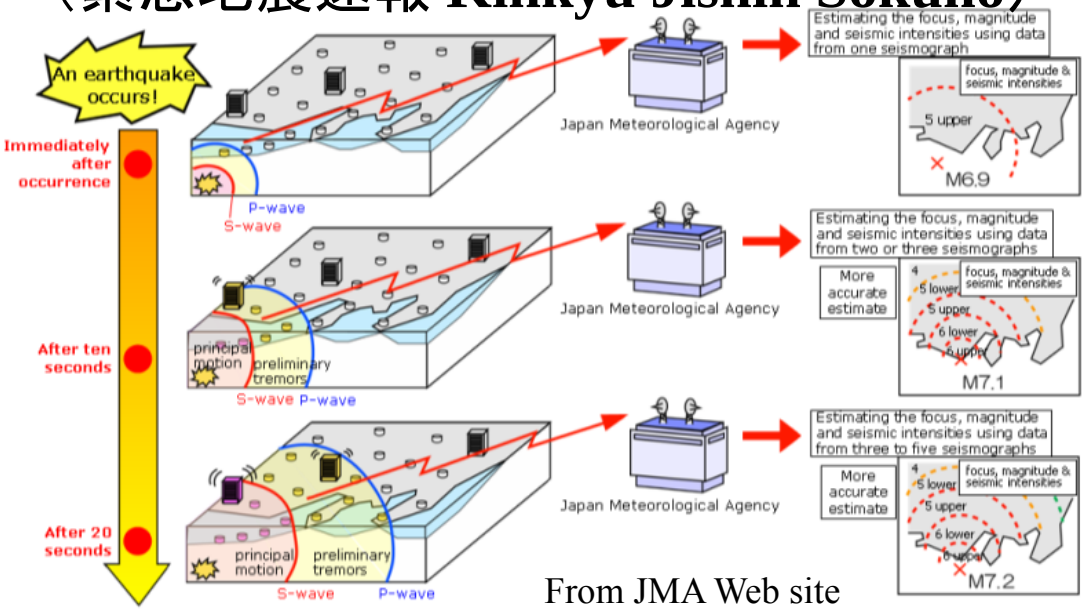
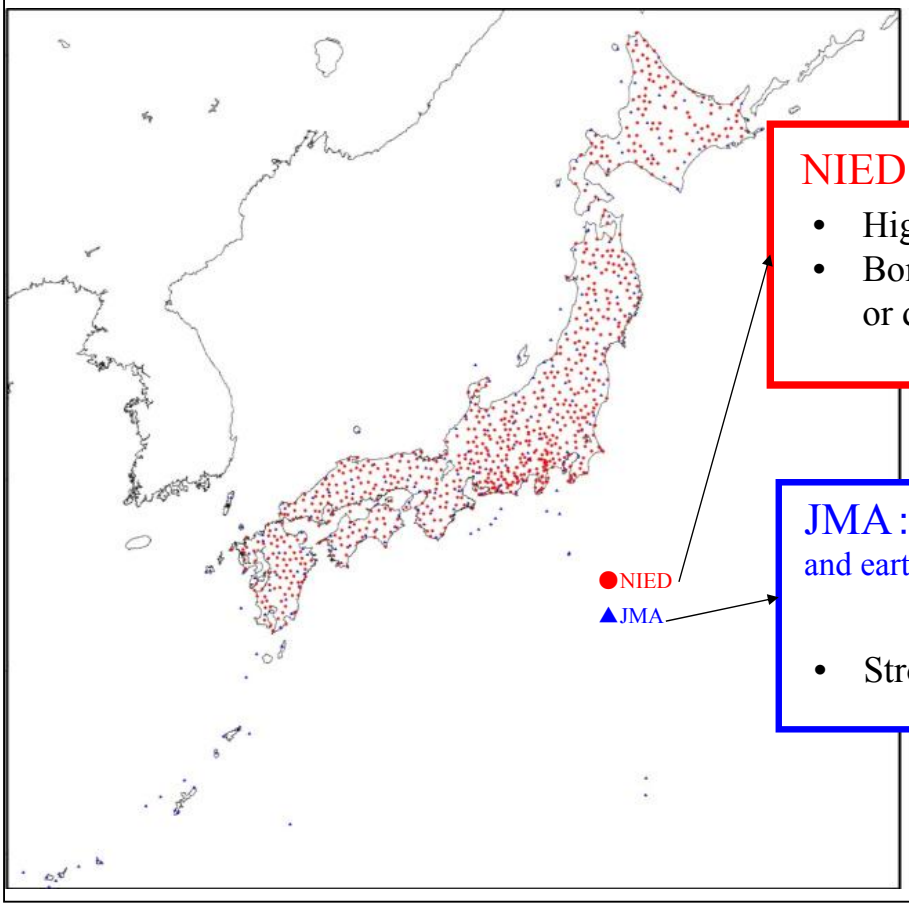
Earthquake Early Warning
（緊急地震速報 **Kinkyu Jishin Sokuho**）



From JMA Web site

The EEW system provides advance warning of estimated seismic intensities and expected arrival time of S-waves. These estimates are based on prompt analysis of hypocenter location and earthquake magnitude using data observed by seismographs near the epicenter. The system issues several EEW messages during the course of one earthquake, improving the accuracy of the warning as the amount of available data increases.

Seismic stations for EEW



NIED：Hi-net（800 stations）

- High-sensitivity seismograph
- Borehole with depth of 100 m or deeper

JMA：network for tsunami warning and earthquake information services（200 stations）

- Strong-motion seismograph

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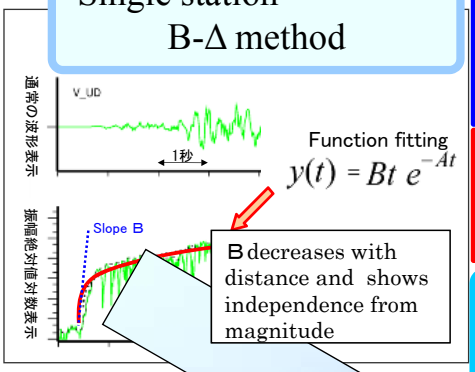
Method for determining hypocenter location

JMA uses several methods to determine hypocenter location, each optimized to the number of stations available. These methods are applied to the data observed at 200 JMA stations.

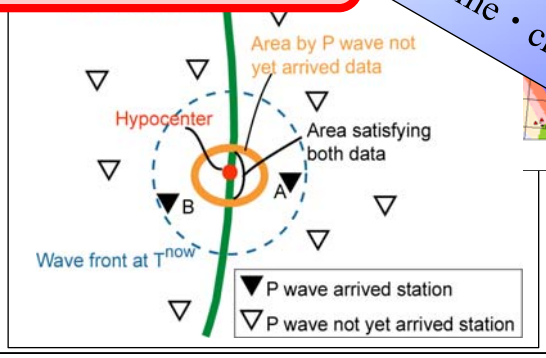
The not-yet-arrived method developed by NIED is applied to the data observed at about 800 Hi-net stations.

Single station
B-Δ method



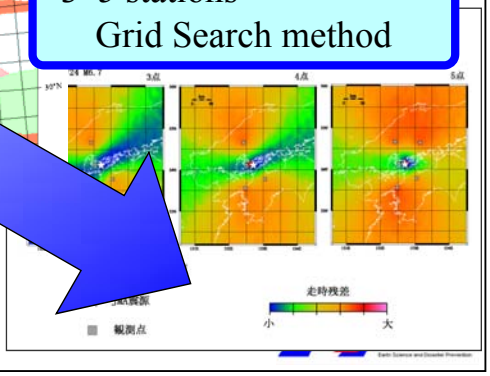
1–2 stations
Territory Method

2 or more stations
Not-yet-arrived method

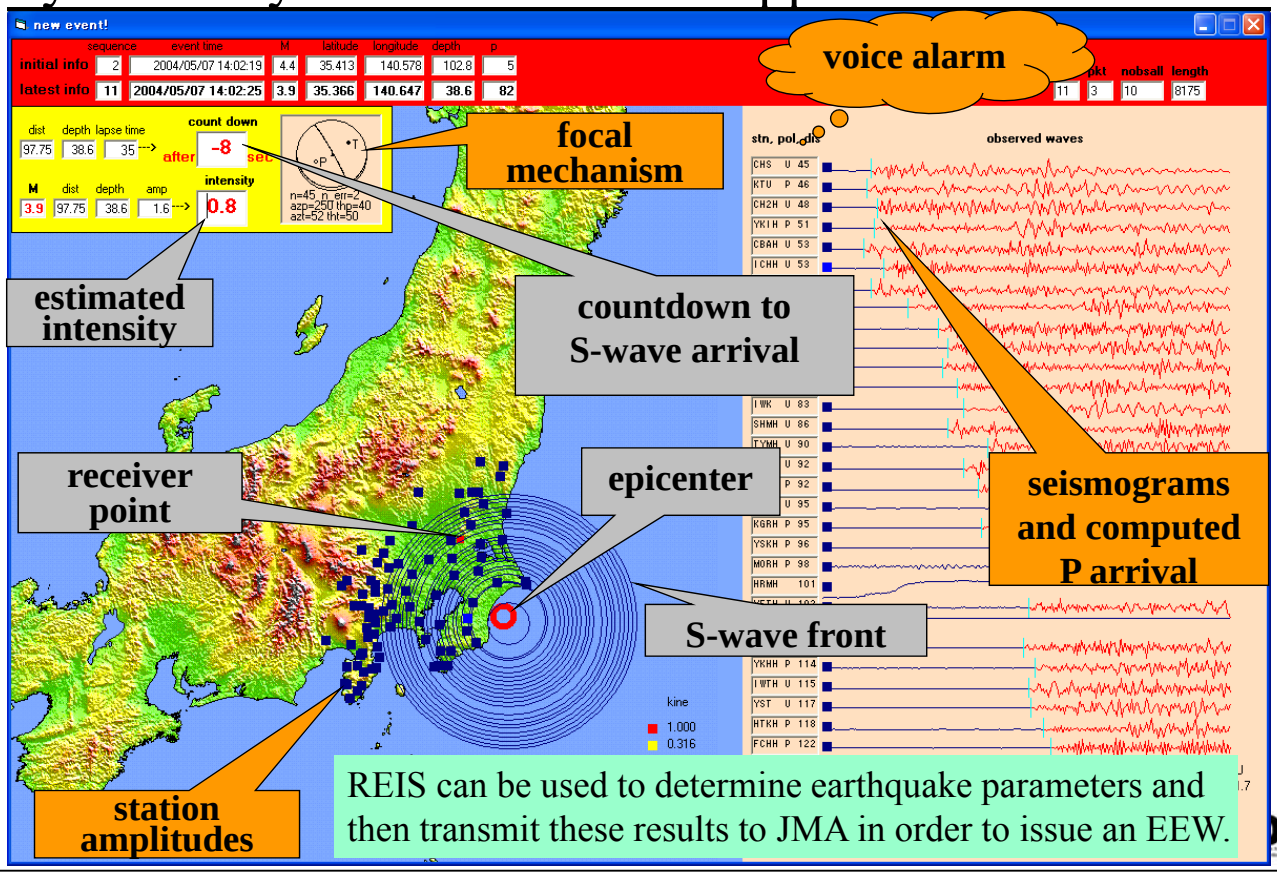


time・credibility

3–5 stations
Grid Search method

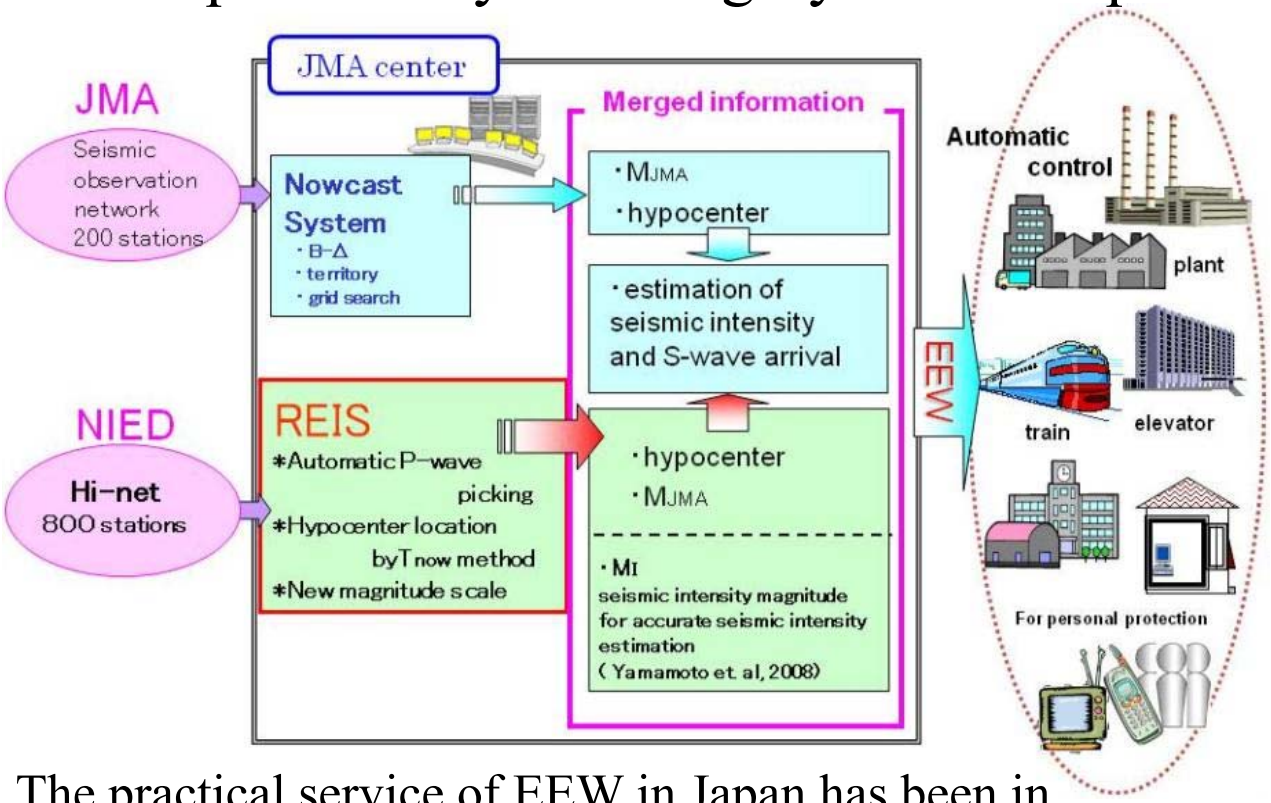


Real-Time Earthquake Information System (REIS) by the not-yet-arrived method applied to Hi-net data



REIS can be used to determine earthquake parameters and then transmit these results to JMA in order to issue an EEW.

Earthquake Early Warning System in Japan



The practical service of EEW in Japan has been in operation since Oct. 2007.

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Utilization of EEW

Cell-phone

cell-phone alert consists of an alarm and text.

Tens of millions

Personal safety

Receiving terminal

PC software

hundreds of thousands

Automatic control

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Problems of the present EEW system

(1) Sometimes EEW is issued after S-wave arrival

Warning times become negative within an area about 30km from the epicenter. When a large earthquake occurs, the closer to the hypocenter the greater the likelihood of damage.

(2) Underestimation of seismic intensity during a massive earthquake

In the 2011 Tohoku-Oki earthquake (M9), the EEW was issued to the area close to the hypocenter earlier than the S-wave arrival. But the EEW cannot be issued to areas further away from the hypocenter, where the observed seismic intensity is greater than 5-lower.

(3) False alarm

Earthquakes sometimes occurred simultaneously over the entire fault region, such that the EEW system became confused, and didn't always determine the hypocenter location and earthquake magnitude correctly.

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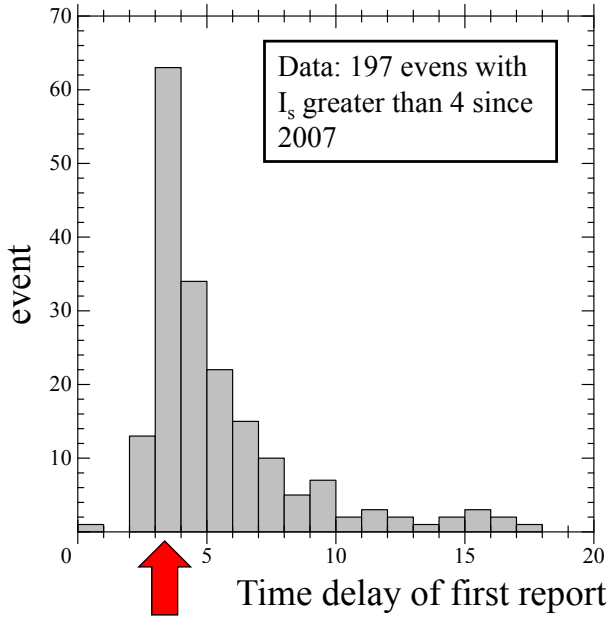
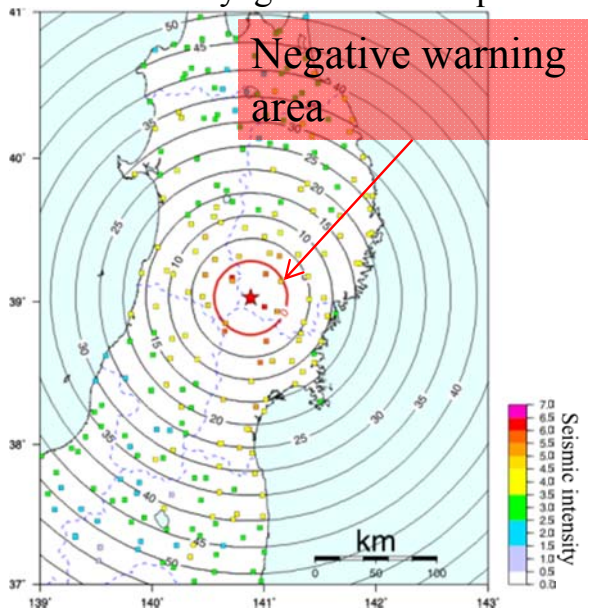
Time delay of first EEW reports and negative warning area -problem(1)-

Histogram of the time delay in issuing the first report after P-wave arrives at the closest station



Warning time before S-wave arrivals 2008 Iwate Miyagi inland earthquake



peak at 3 to 5 seconds that roughly corresponds to an area within 30 km of the epicenter where warning time is negative.

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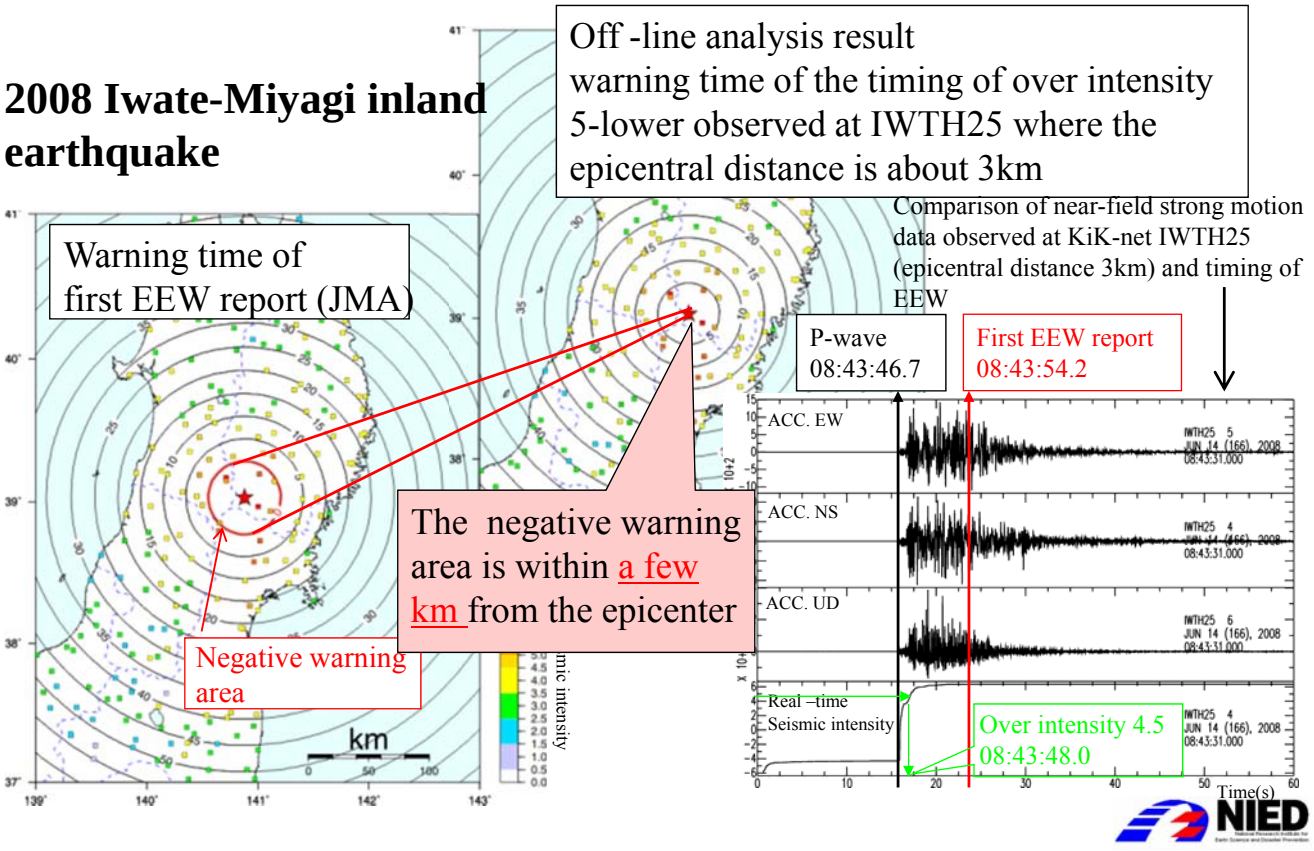
Importance of Near-field Strong Ground Motion Data for EEW

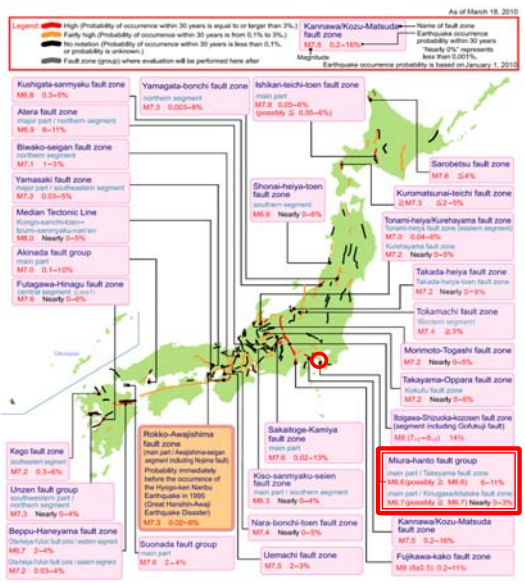
2008 Iwate-Miyagi inland earthquake

Off -line analysis result
warning time of the timing of over intensity 5-lower observed at IWTH25 where the epicentral distance is about 3km

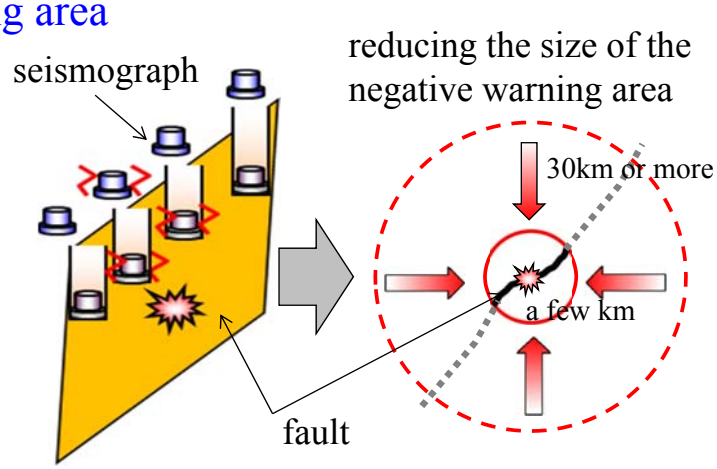


Strong-motion real-time monitoring system for a specific active fault earthquake

Near-field strong ground motion data are very effective in reducing the size of the negative warning area



110 Major active fault zones, that have a high level of activity and great social and economical influence, were selected and have been evaluated as the targets of fundamental surveys and observations by HERP.



- Observation system is installed closed to a specific active fault.
- The seismograph calculates various strong-motion parameters in real-time

Development concepts

Monitoring system must accurately observe extreme strong-motion near active fault zone.

- The full scale of the accelerometer is up to 8 G
- Each observatory has two strong-motion accelerometers on the surface and at a depth of 50 m to produce reliable on-site information
- Borehole-type accelerometer is downsized for installing in urban area.

For decreasing the area of negative warning

- Recording data in high sampling rate of 400Hz
- The seismograph calculates various strong-motion parameters in real-time (B-delta, PGA, PGV, PGD and real-time intensity etc.)
- The packet length used for transmission is shortened to 0.1 s to reduce delays in transmission

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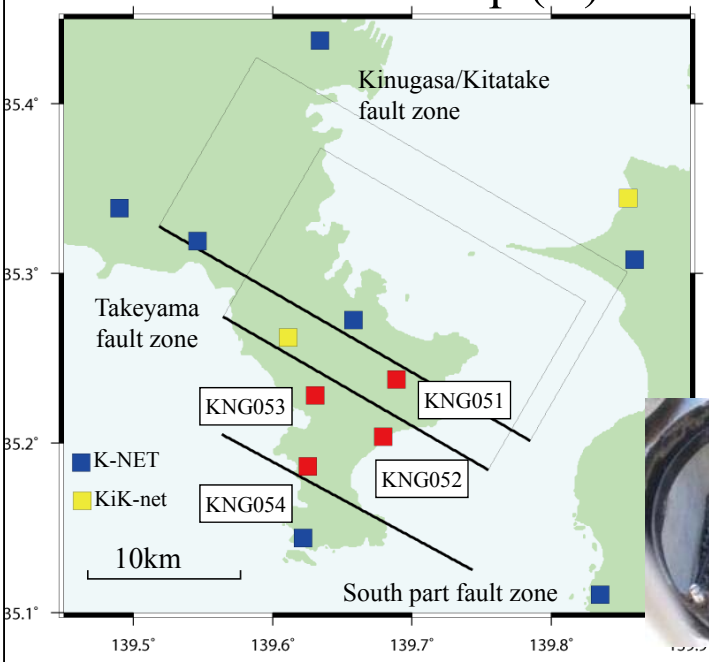
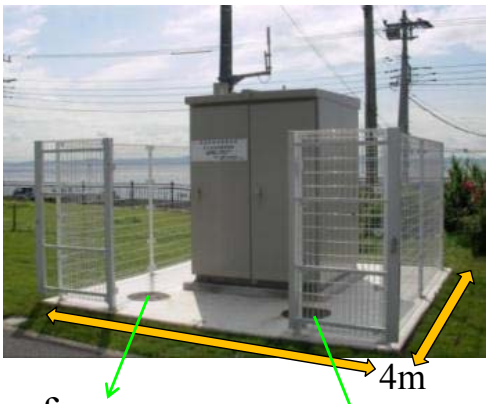
Strong-motion observation network closed to the Miura-hanto fault group

Distribution map (■)





surface

borehole (50m)

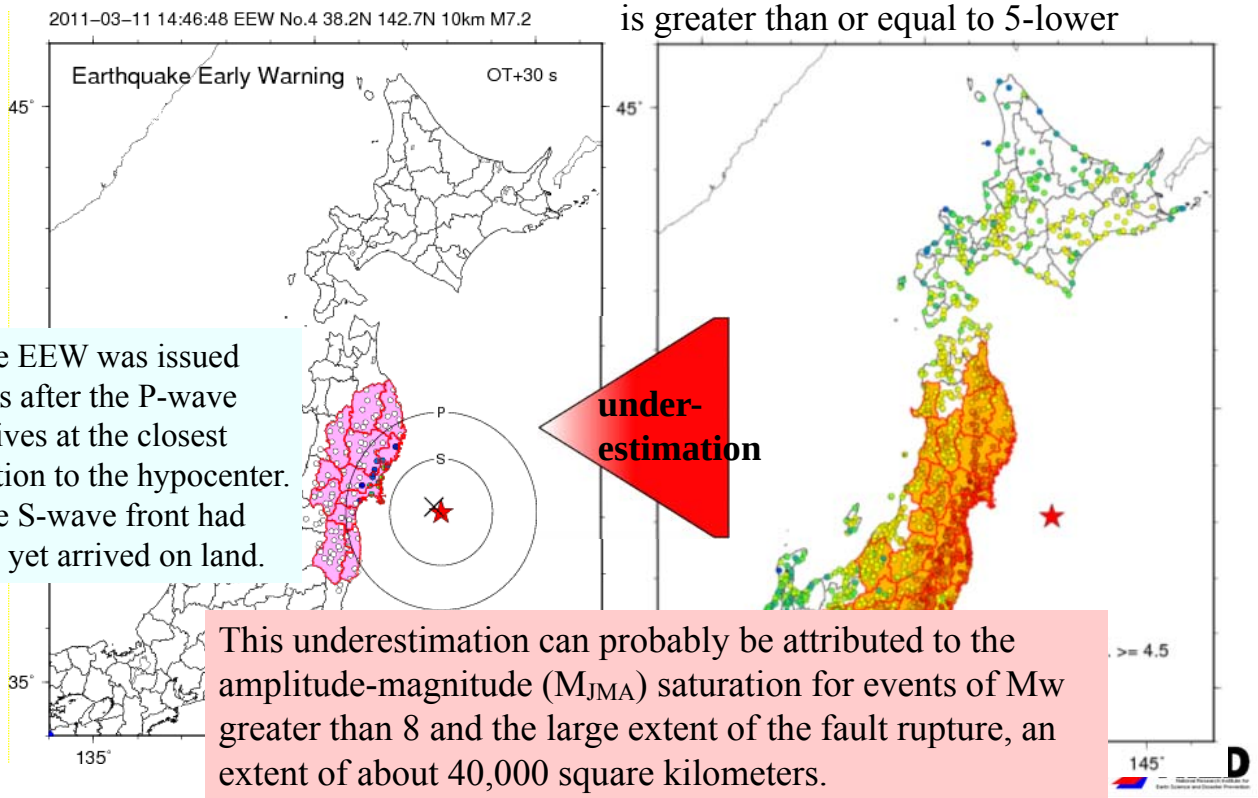
Observed data (waveform and calculated intensity) is transmitted to NIED center in real-time

The EEW of the 2011 Tohoku-Oki earthquake

-problem(2)-

Warning area

Area where the **observed** seismic intensity is greater than or equal to 5-lower



The EEW was issued 8.6s after the P-wave arrives at the closest station to the hypocenter. The S-wave front had not yet arrived on land.

under-estimation

This underestimation can probably be attributed to the amplitude-magnitude (M_{JMA}) saturation for events of Mw greater than 8 and the large extent of the fault rupture, an extent of about 40,000 square kilometers.

What should we do?

EEW

Prediction of strong motion by determination of hypocenter location and earthquake magnitude using P-wave data.

Real-time monitoring of strong motion

Live monitoring of strong motion is independent of the estimation of EEW.

The use of both types of data will improve the accuracy of warning information.

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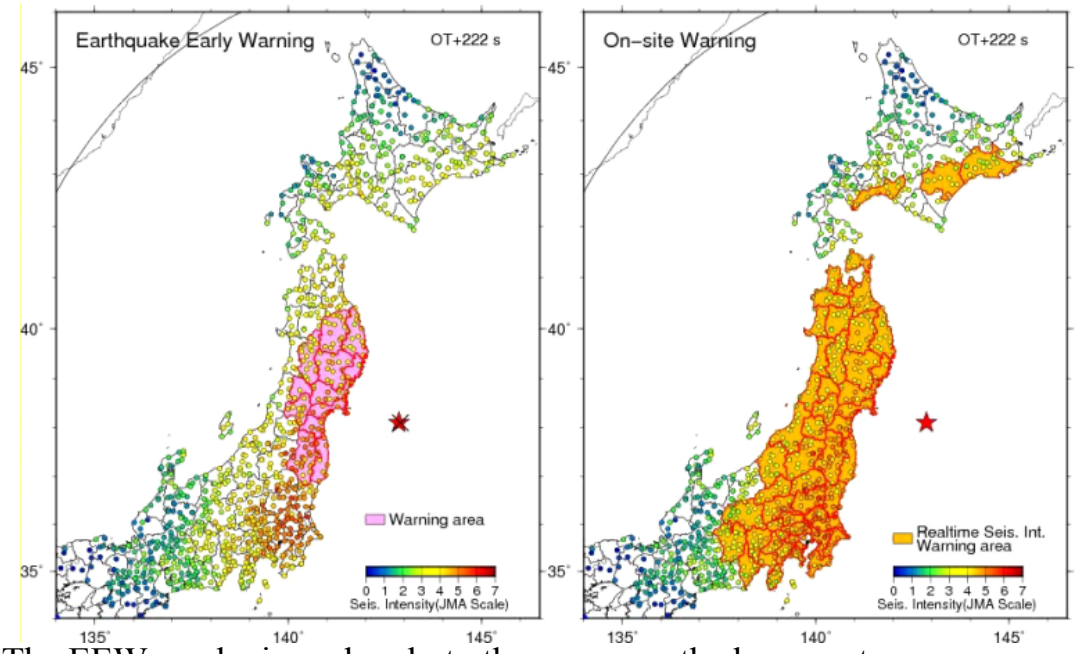
Warning test of the 2011 Tohoku-Oki earthquake

EEW

Off-line analysis of on-site warning

using K-NET & KiK-net data



- The EEW can be issued early to the area near the hypocenter.
- The on-site warning can be issued to the area where the EEW can't be sufficiently responded.

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Conclusions

- The NIED has developed the real-time earthquake information system (REIS) which is able to determine hypocenter locations and earthquake magnitude within a few seconds.
- The JMA has been issuing EEW, which contain the results of REIS, to the general public since October, 2007.
- The EEW is transmitted to many kinds of devices and used for personal safety and automatic control.
- It is very important to observe strong motion in real-time using a dense network in order to improve the EEW system.

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