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Tsunami Warning, Earthquake Information, and Earthquake Early Warning in Japan

- Development of recent 15 years -

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Meteorological Research Institute

Japan Meteorological Agency

World Observatories Forum at Istanbul ; September 4-6, 2008

Distribution of Earthquakes Causing Tsunami (1896~2007) in Japan

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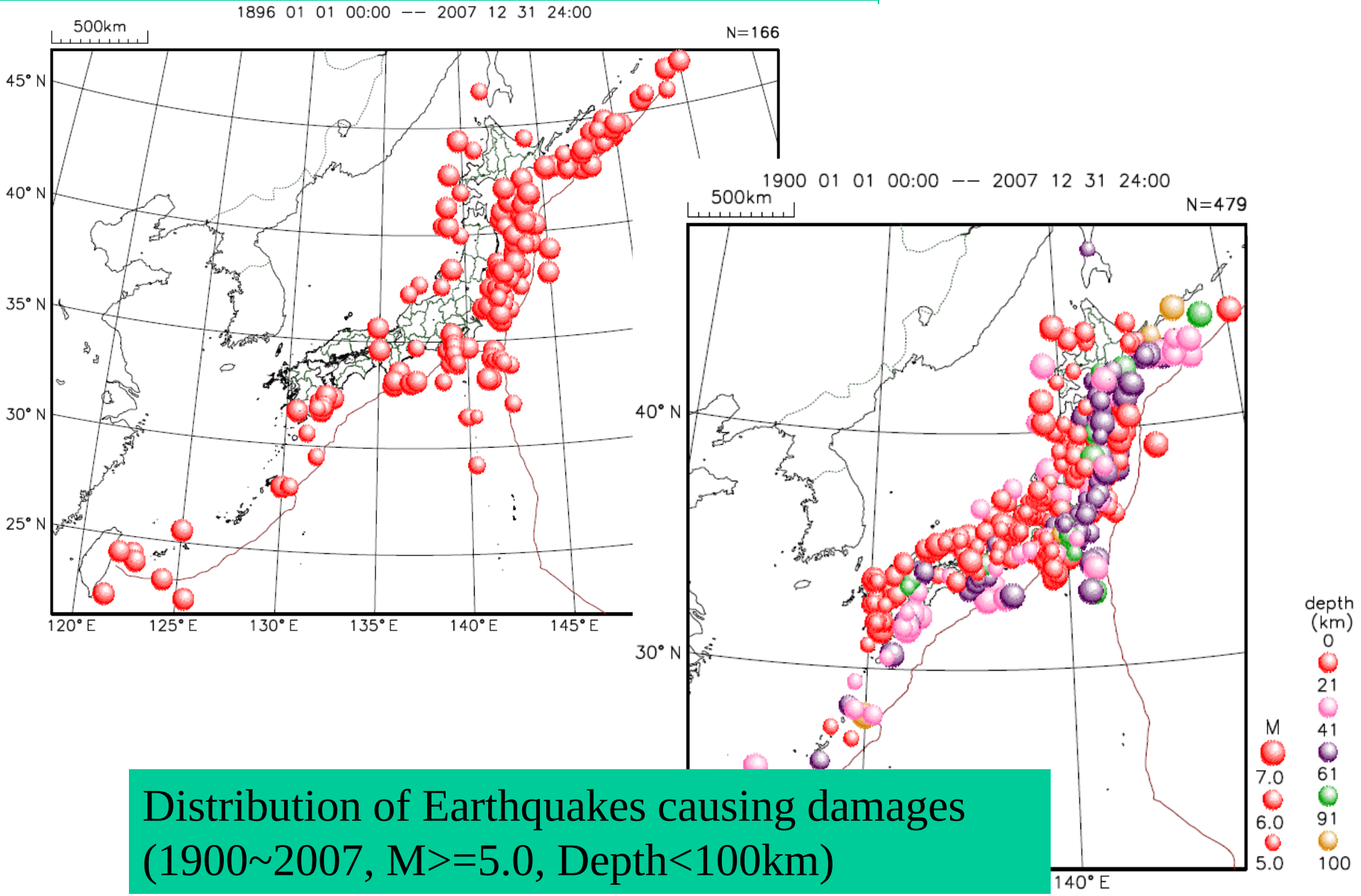
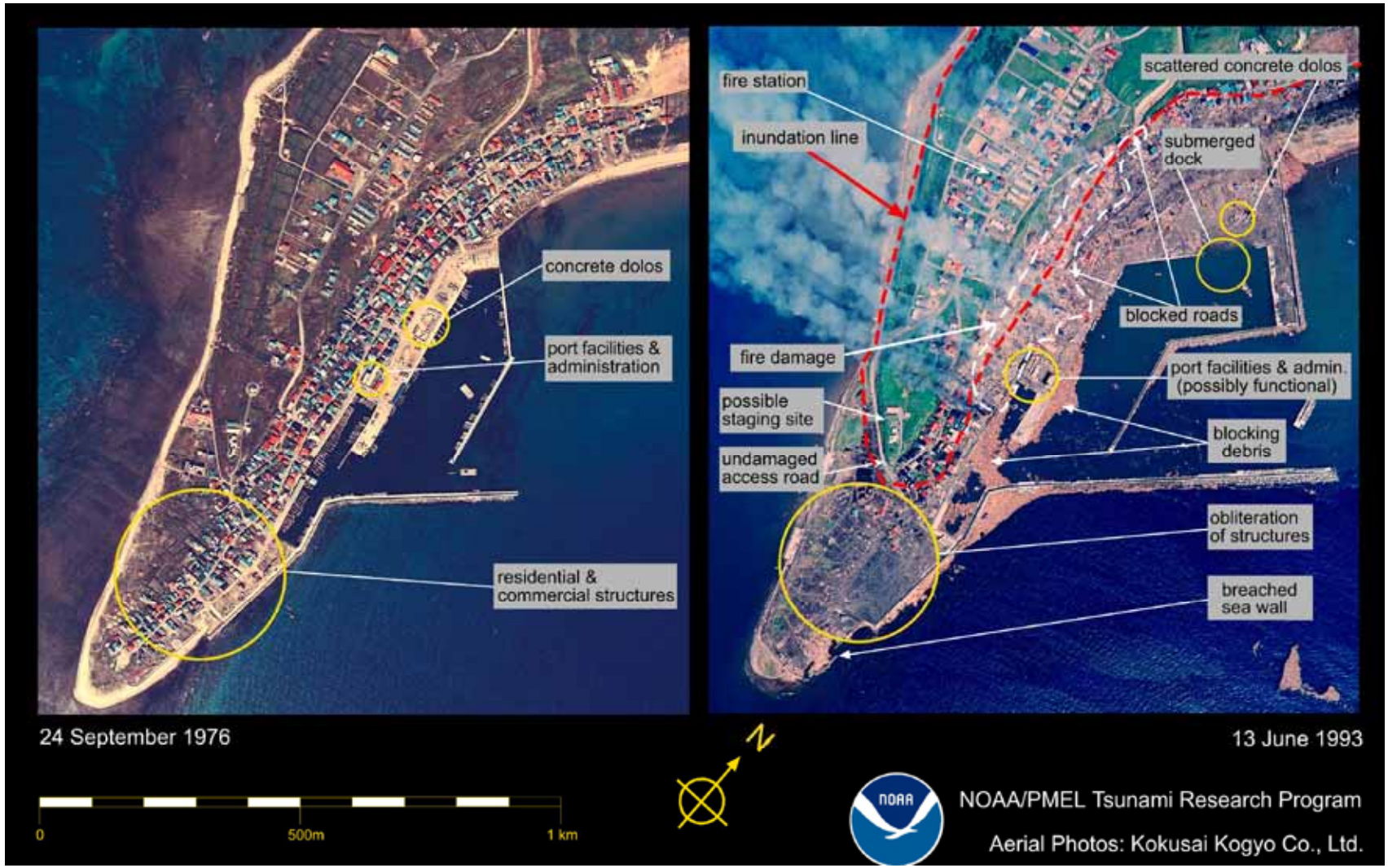


Distribution of Earthquakes causing damages (1900~2007, M>=5.0, Depth<100km)

Okushiri, Japan: July, 12, 1993 :M7.8(Tsunami disaster)

229 persons were killed or missed

Before the Tsunami (1976) *After (1993)*



The South Hyogo Prefecture Earthquake (Kobe Earthquake) in 1995

(January 17, 1995, M7.3)

more than 6000 persons were killed

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Tsunami Warning

Recent 15 years;

- Improvement of Computer System (1995 and 2003)
- Replacement of Seismic Observation Network (1994)
  - At Observatory → Remote
  - Installation of Broadband Seismometers(STS-2)
- Introducing Numerical Simulation Technique for Tsunami Propagation (1999) ： Empirical Method → Quantitative forecast
- Applying Earthquake Early Warning Technique (Full Automatic Hypo. Determination) (2006)

Time Sequence to Issue Tsunami Warning and Earthquake Information

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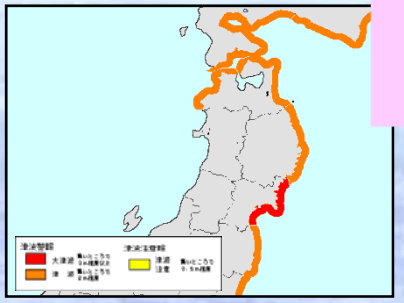


Tsunami Warning

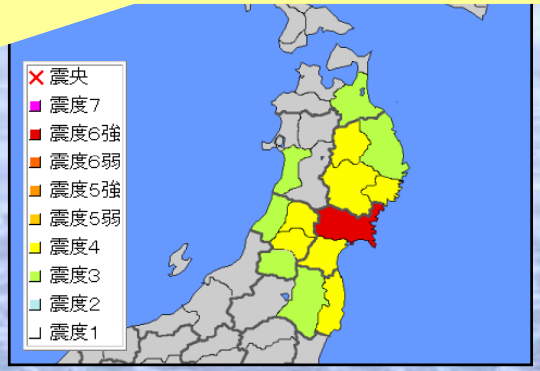
Earthquake

From Oct. 2006

2min.

3min.

Seismic Intensity Information

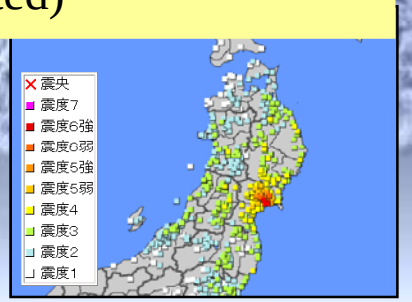


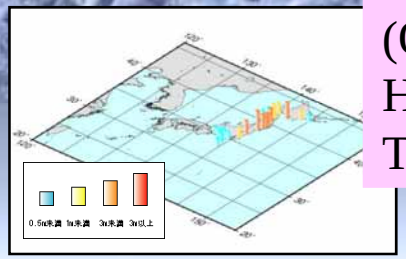
Tsunami Information (Estimated Tsunami Heights and Arrival Times)

Earthquake Information (Hypocenter and Magnitude)

5min.

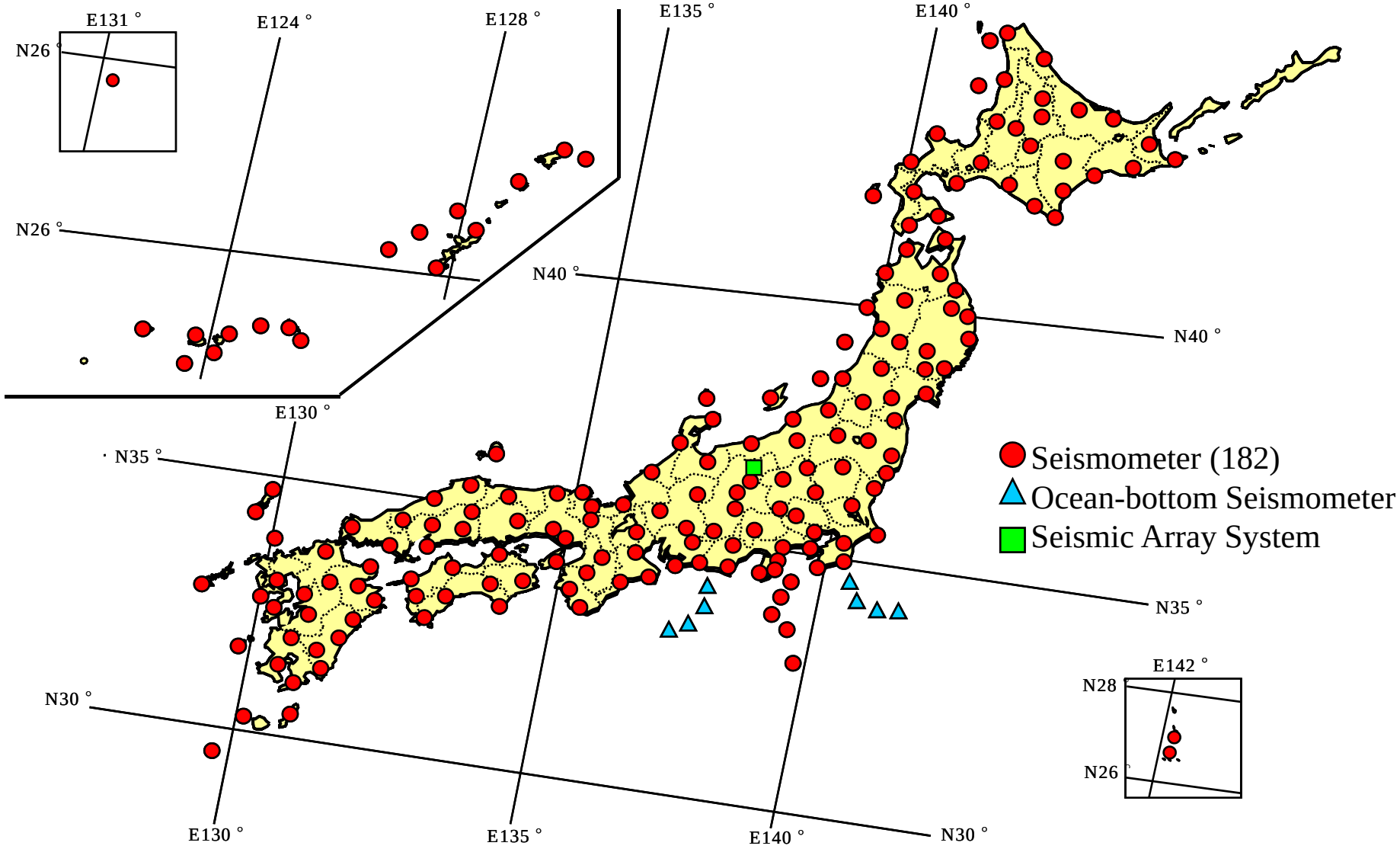
Earthquake and Seismic Intensity Information (Updated)





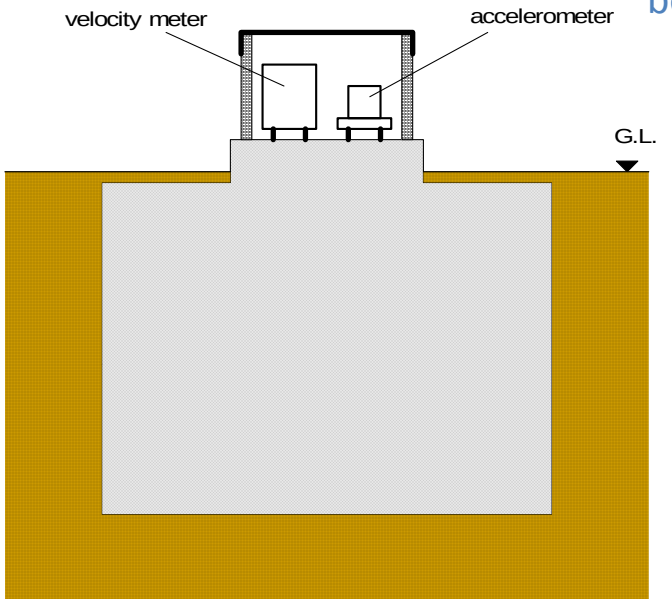
Tsunami Information (Observed Tsunami Heights and Arrival Times)

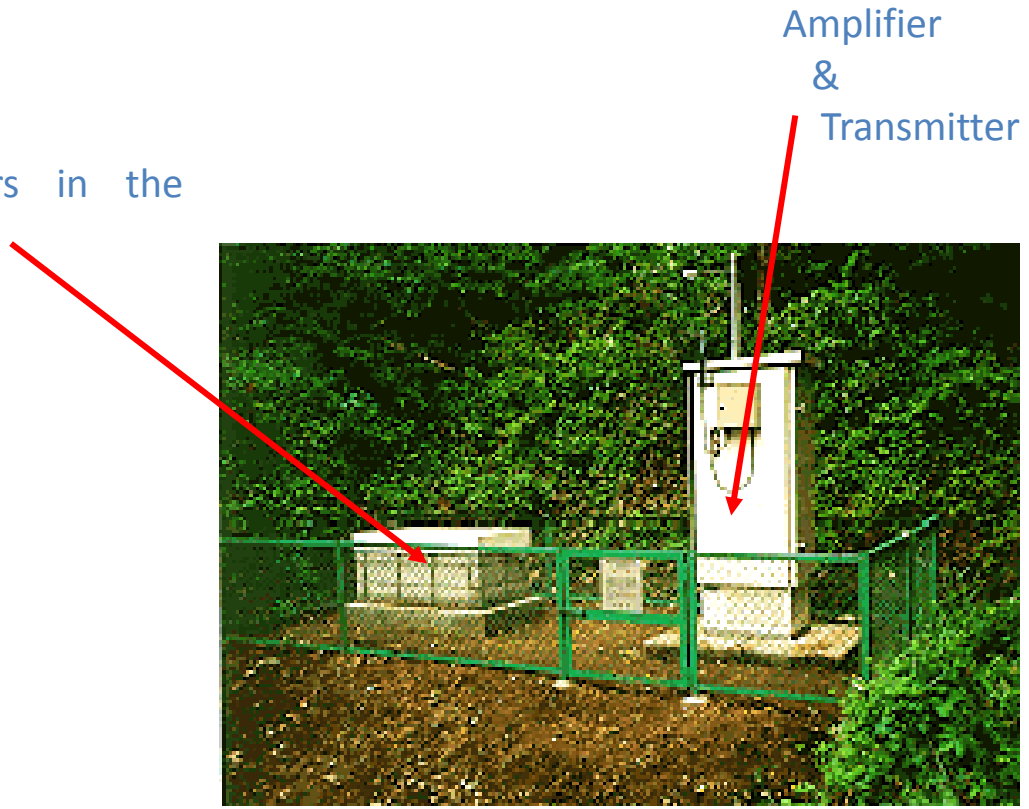
Seismic Network for Tsunami Forecast in Japan



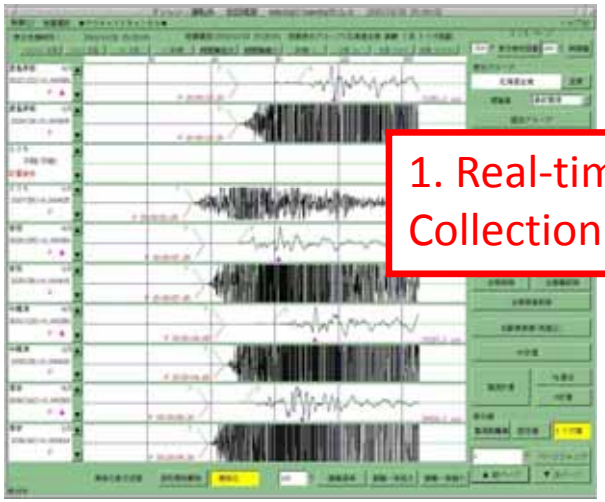
Seismometers used in JMA's Network

- **Velocity type seismometer with 3 components**
- **Strong motion accelerometer with 3 comp.**



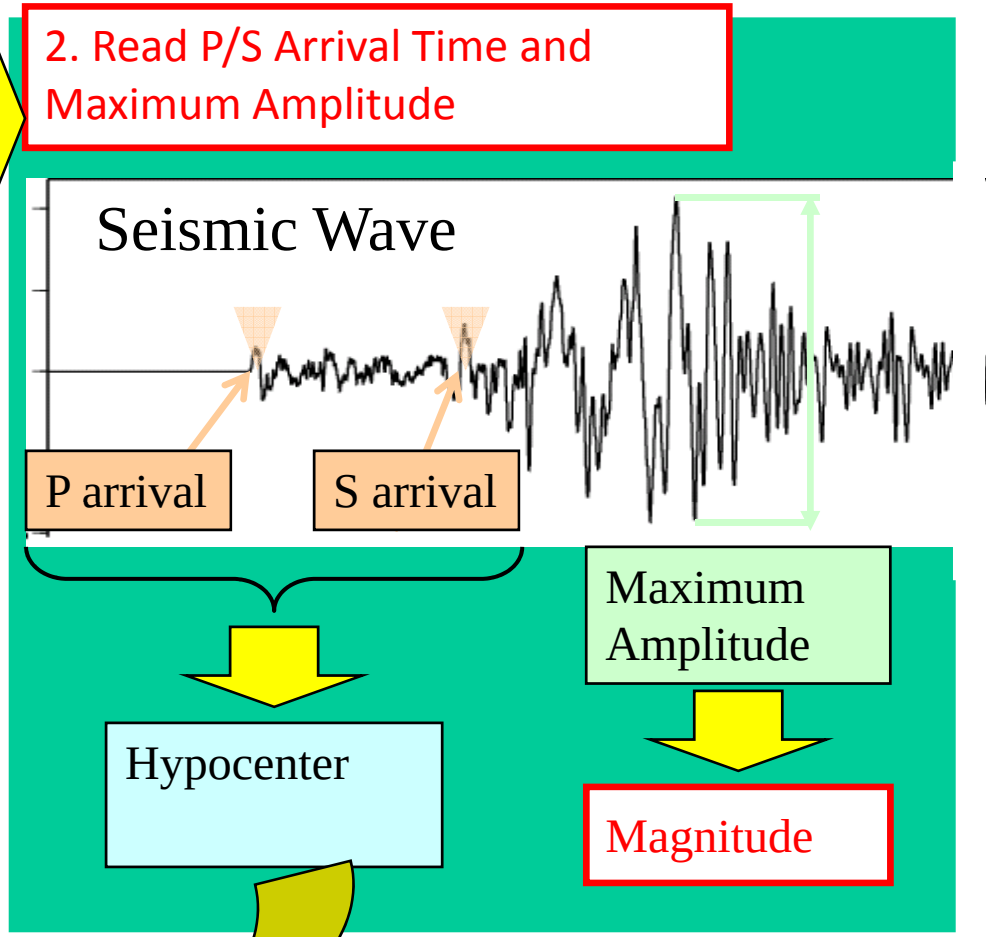


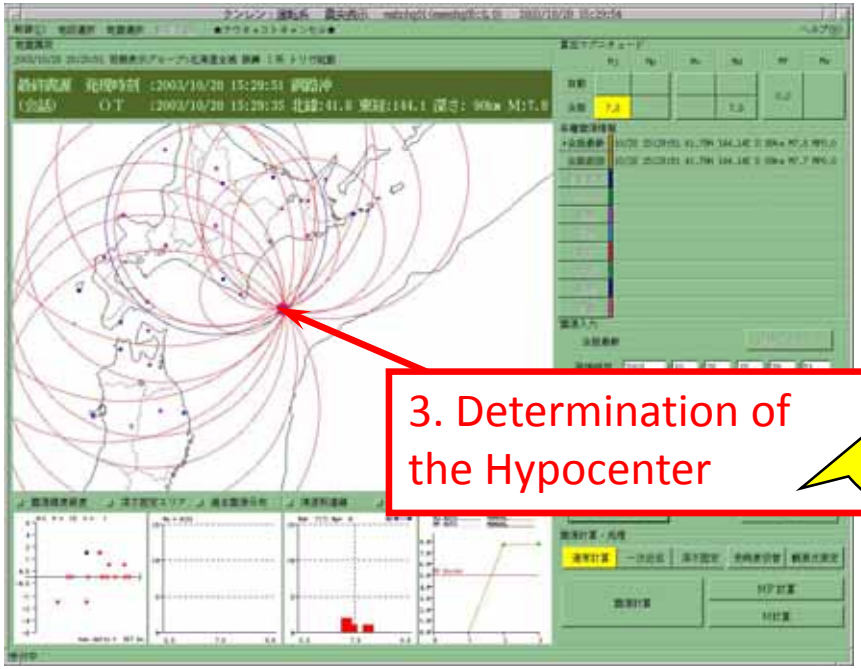
Determination of Magnitude and Hypocenter



1. Real-time Data Collection

2. Read P/S Arrival Time and Maximum Amplitude





3. Determination of the Hypocenter

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Example of Tsunami Simulation

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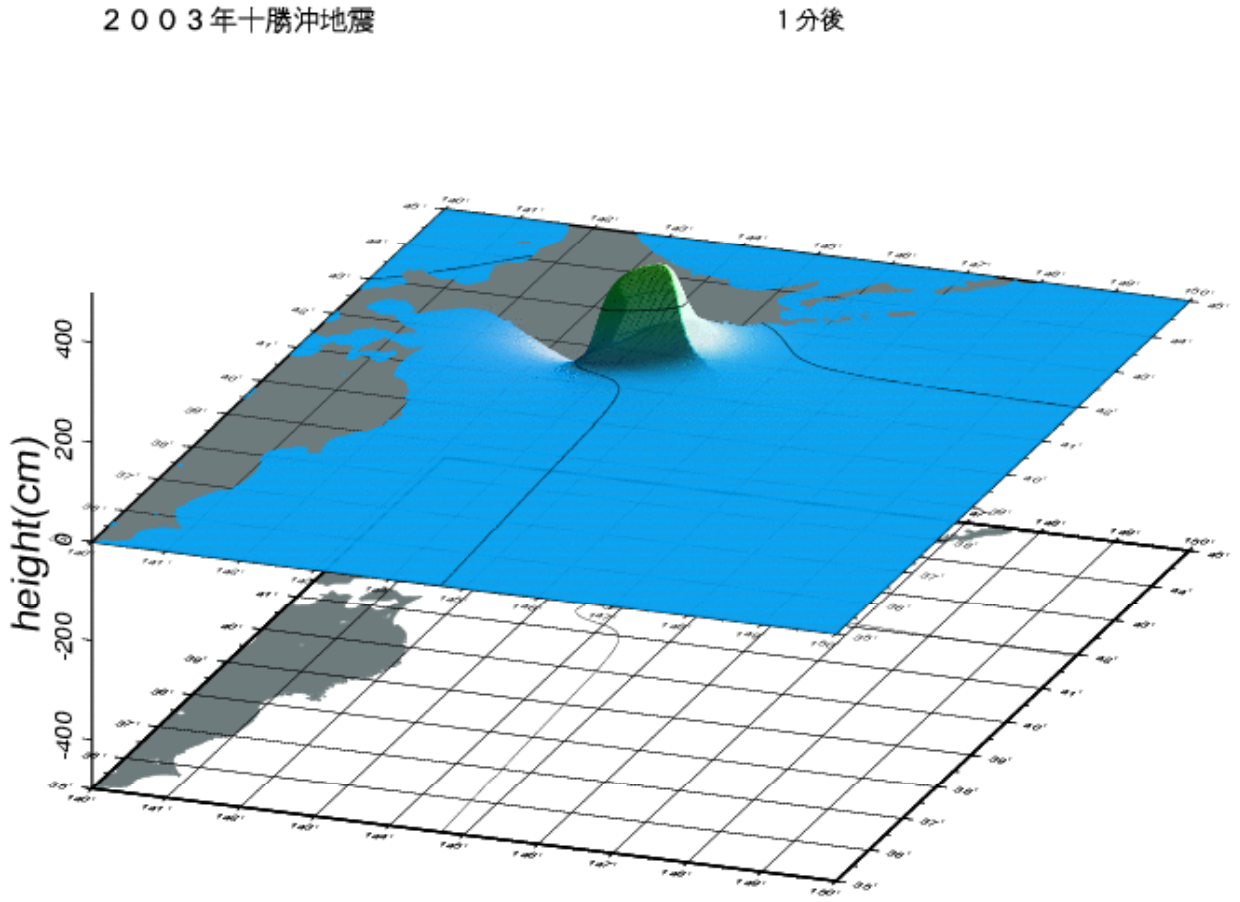
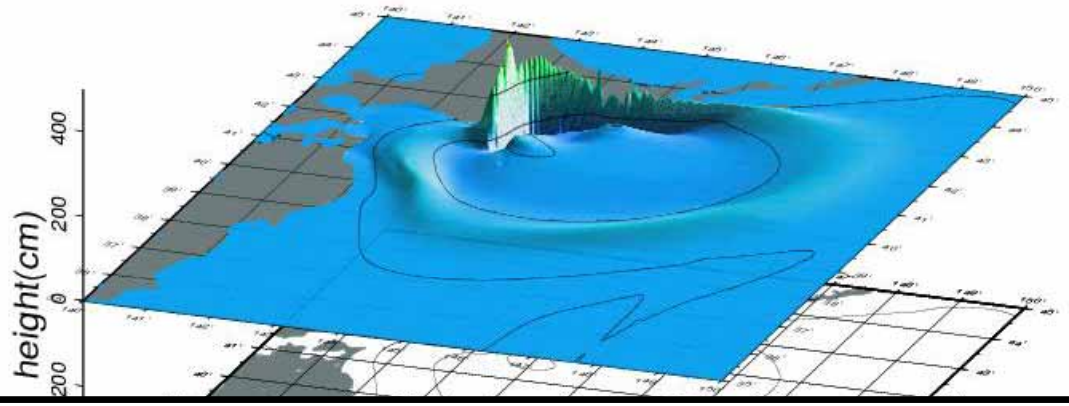
For forecast of Tsunami Height



Numerical simulation technique is a very powerful tool for precise and detailed tsunami estimation.

Tsunami Forecast (1)

But... numerical simulation takes a long time. If we run the simulation after the occurrence of an earthquake, tsunami would arrive at coasts before tsunami warning is announced.



Computer simulation of tsunami generation and propagation is conducted IN ADVANCE.

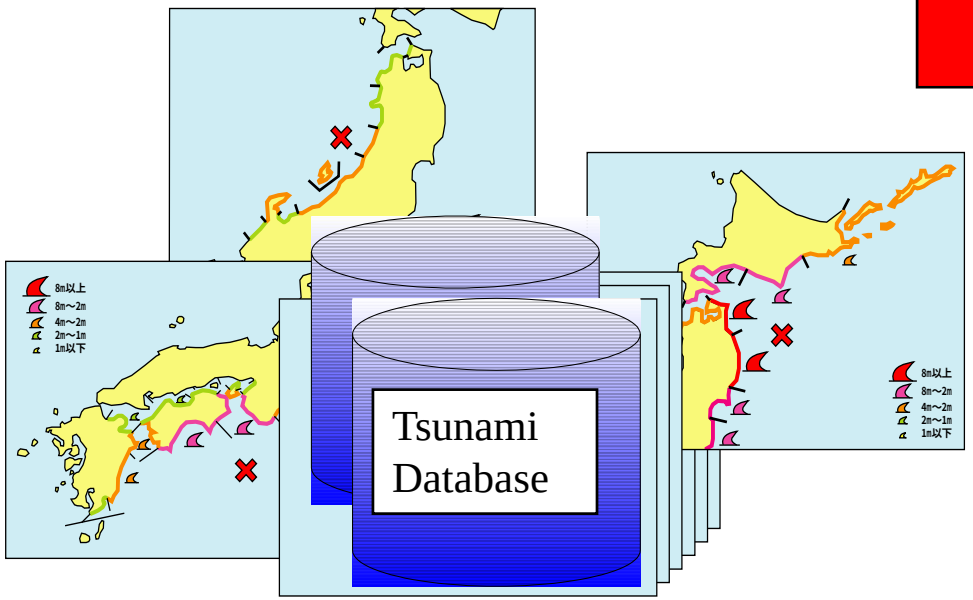
Scenarios of tsunami arrival time and amplitude corresponding to 100,000 different tsunamigenic earthquakes

Tsunami Database

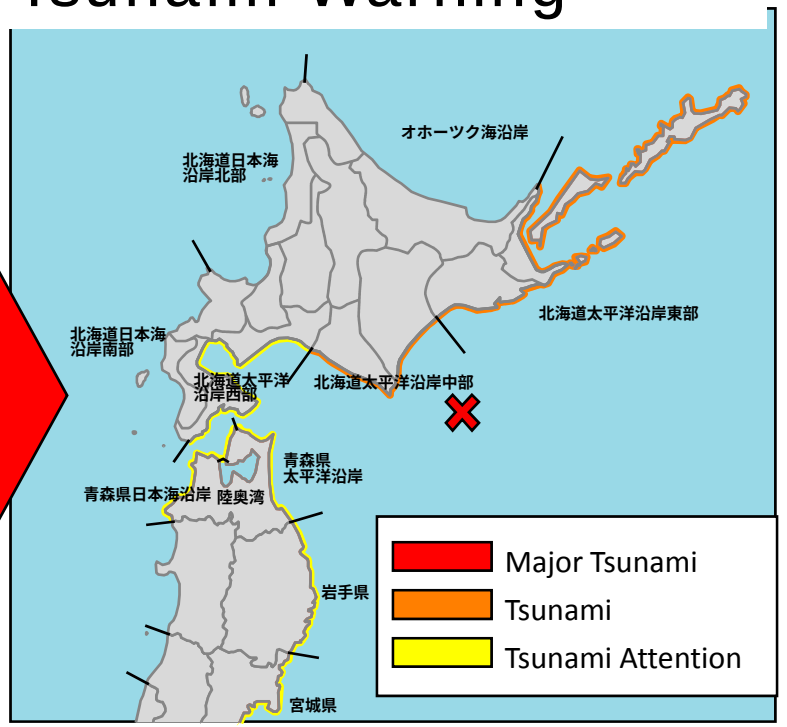
Tsunami Forecast (2)

Tsunami Forecast Operation

Referring to the determined location and magnitude of the earthquake, the system searches tsunami database and picks up the most appropriate scenario from the database.



Tsunami Warning



Issuance of tsunami warning at each coastal region (66 regions in Japan) with the grade determined from estimated tsunami height.

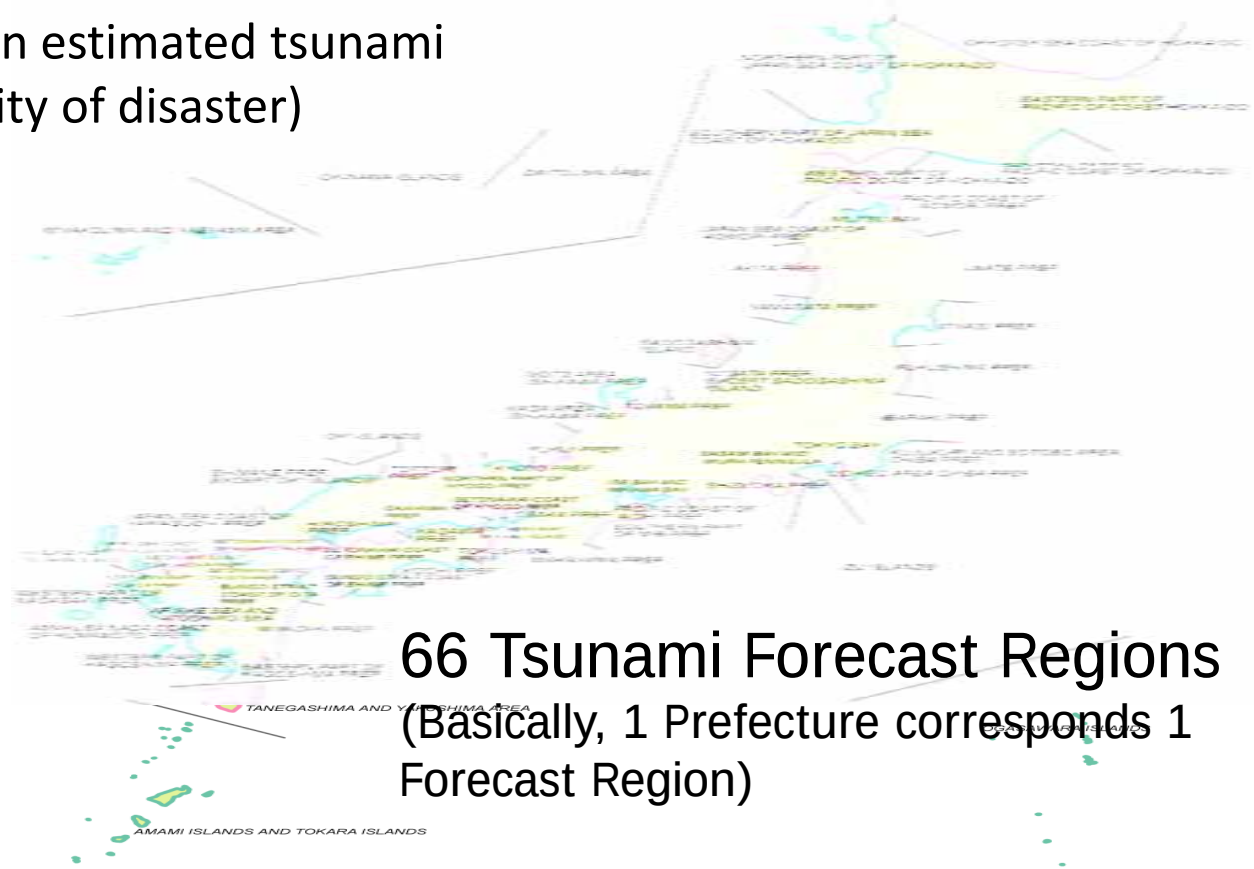
Tsunami Forecast (3)

Category		Estimated Tsunami Height to be shown in the Forecast Message
Tsunami Warning	Major Tsunami	"3m", "4m", "6m", "8m", "10m or higher"
	Tsunami	"1m", "2m"
Tsunami Advisory	Tsunami Attention	"0.5m"

People in Tsunami Hazard Zone (designated by municipalities) should evacuate

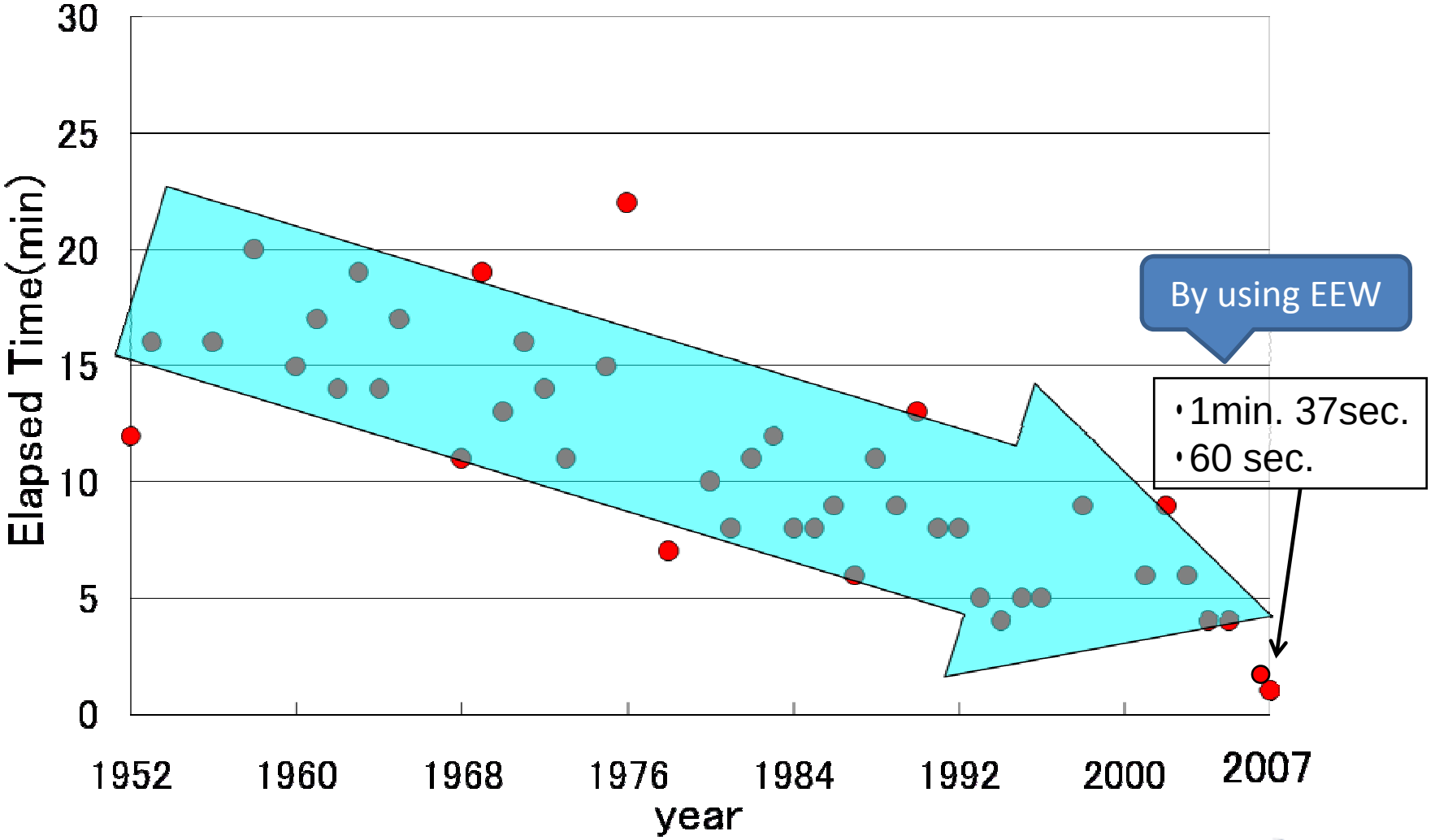
People on a beach, or swimming should go to a high place

3 grades : depending on estimated tsunami height (severity of disaster)



66 Tsunami Forecast Regions
(Basically, 1 Prefecture corresponds 1 Forecast Region)

Issue time for Tsunami Warning after occurrence of an earthquake



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Earthquake Information

- Seismic Intensity

At 150 places by human feeling or damage (1993) → More than 4000 places by seismic intensity meter (2008)

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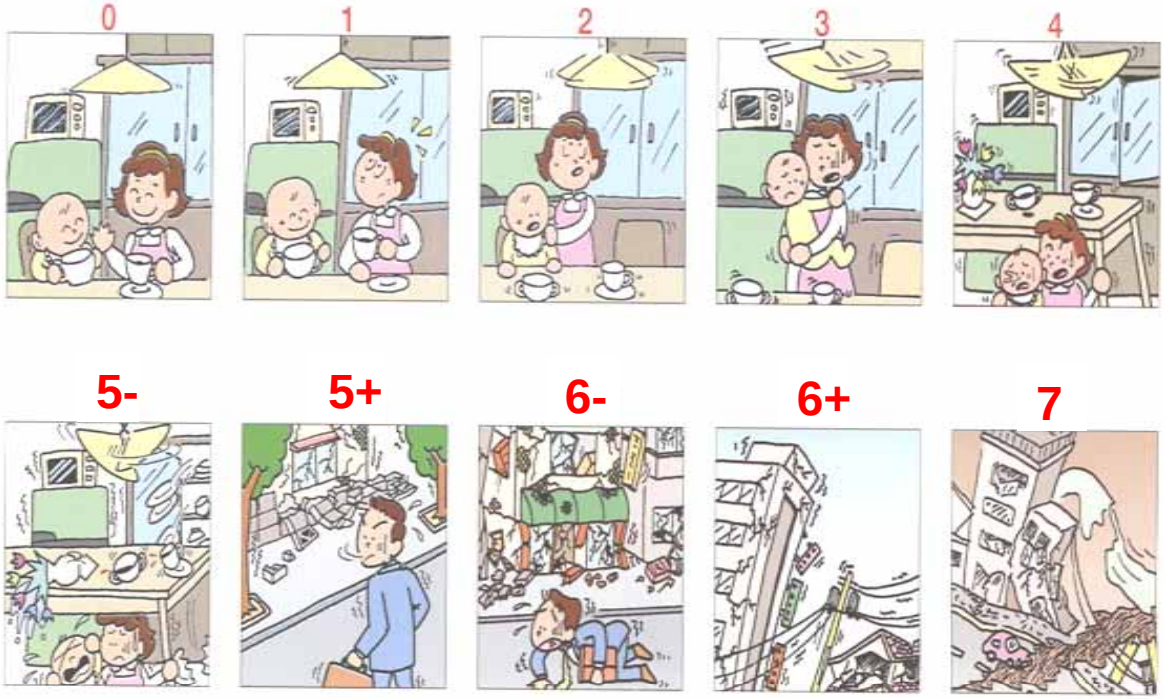
JMA Seismic Intensity Scale



JMA	0	1	2	3	4	5-	5+	6-	6+	7

MM	1	2	3	4	5	6	7	8	9	10	11 12

MSK	1	2	3	4	5	6	7	8	9	10	11 12

Measurement of Seismic Intensity

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Strong Motion

Earthquake

Amplitude
Duration
Frequency

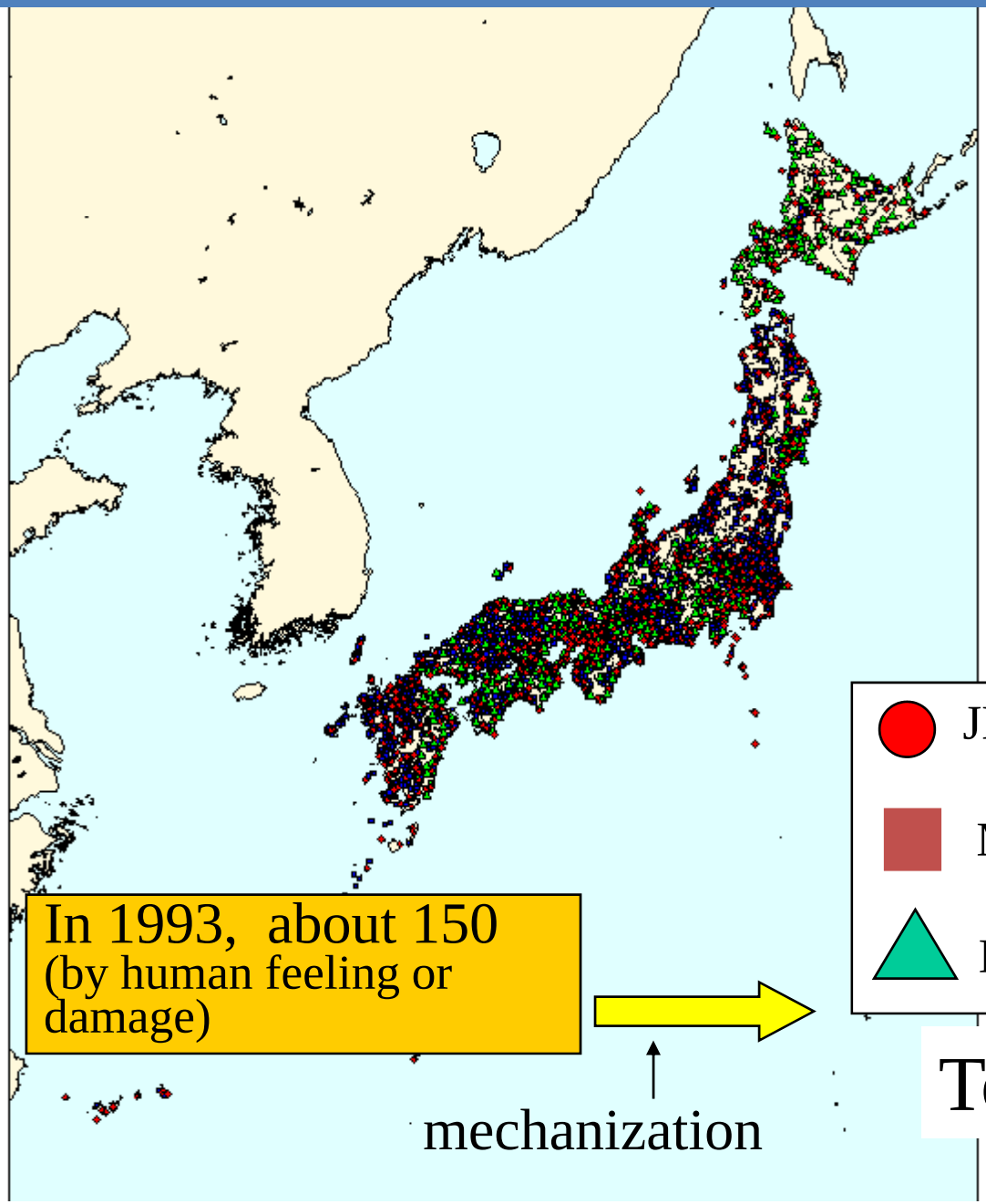
Seismic Intensity

Seismic Intensity Meter

Strength of ground motion

Index of damage

Seismic Intensity Measurement Stations



In 1993, about 150
(by human feeling or damage)

mechanization

JMA （619）

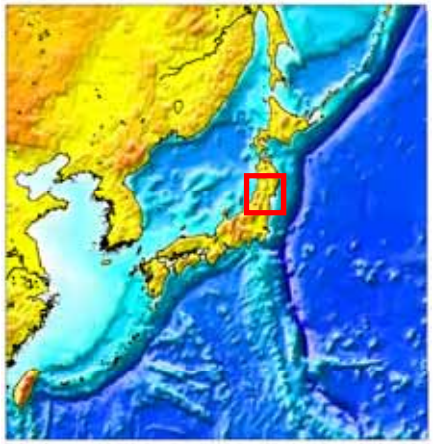
Municipalities （2,842）

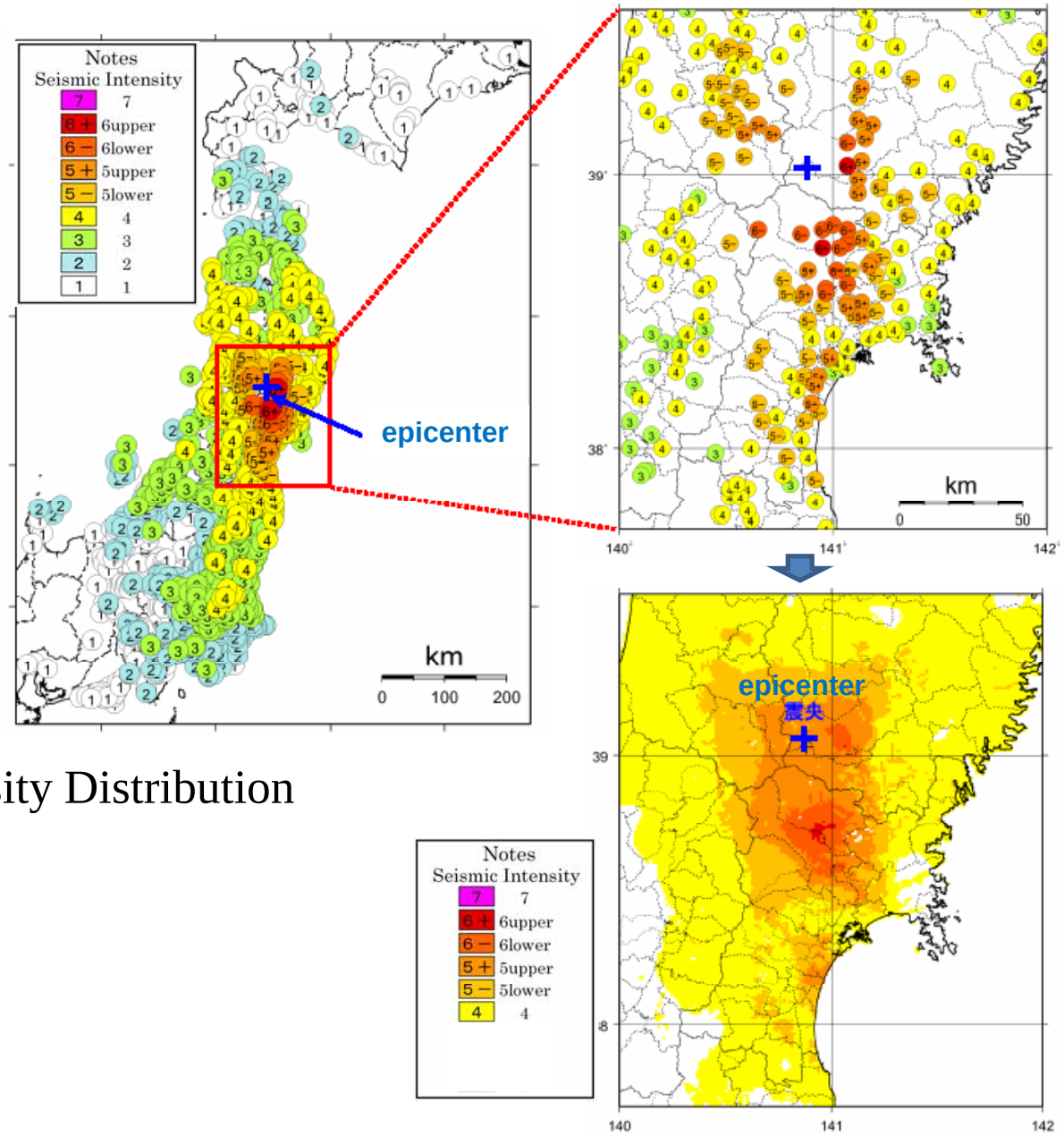
NIED(K-NET) （781）

Total : 4,242

as of Jul., 1, 2008

Iwate-Miyagi Nairiku Earthquake (June, 14, 2008); M7.2





Seismic Intensity Distribution

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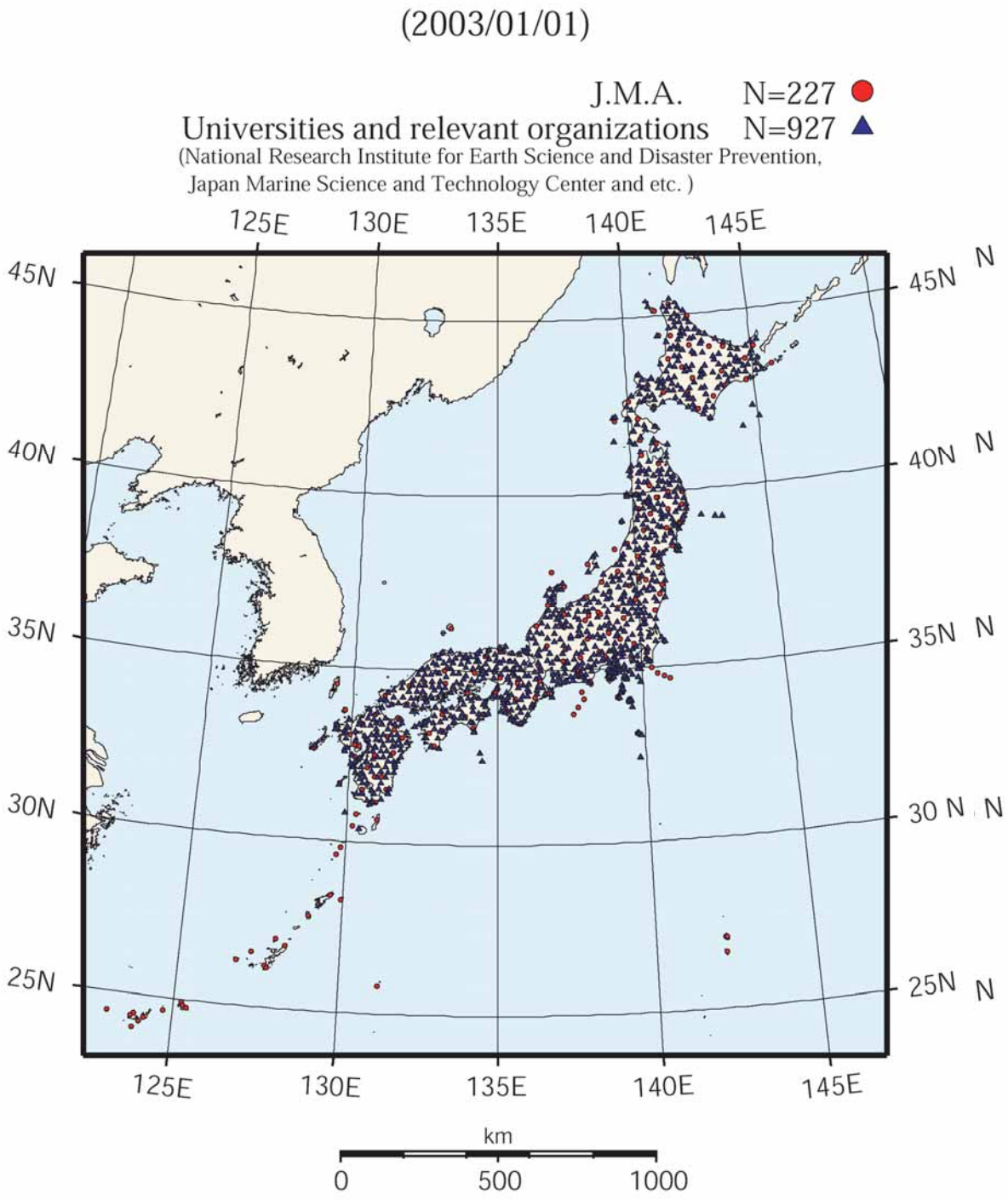
Precise determination of hypocenter and magnitude for research purpose

- Integrated Analysis of Seismic Data-

JMA Universities NIED Independently (Before 1997)	→	JMA Universities NIED Integrated Analysis (After 1997)



Seismic Data Concentration and Integrated Analysis at JMA

- Seismic Stations
  - JMA
  - Universities
  - NIED
- Comprehensive Analysis
  - JMA

Seismic Activity around Japan

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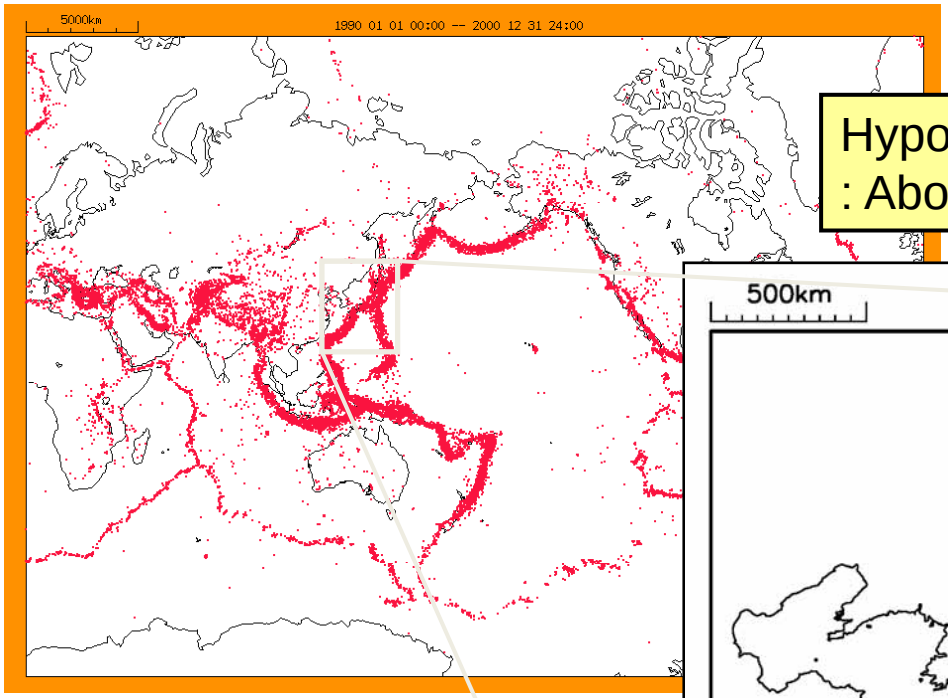
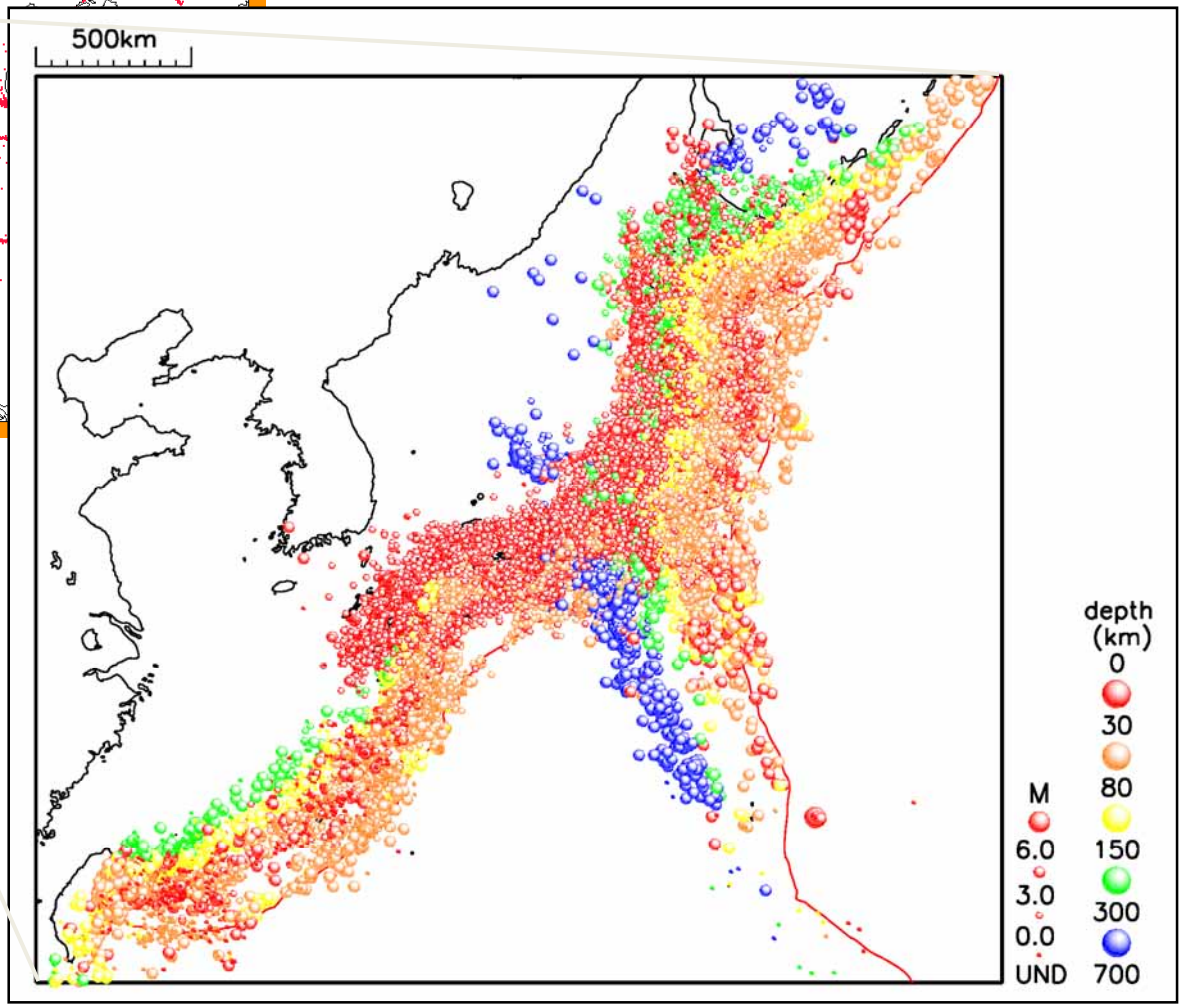
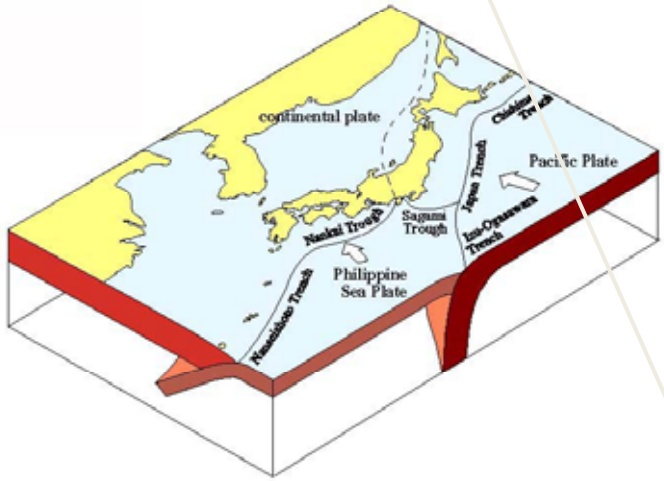


Hypocenter Determined by JMA
: About 130,000 events/year (~300 events/day)





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Earthquake Early Warning

"Information Before Strong Ground Shaking"

- Nationwide
- Issue to General Public (started in 2007) as well as Specific Users (in 2006)

Same kind of project is at
Mexico, Taiwan, California, Istanbul, Romania, Naples,….
SAFER project at Europe

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Earthquake Information

- Seismic Intensity Information
- Location of the Earthquake, and Magnitude
- Tsunami Warning / Advisory

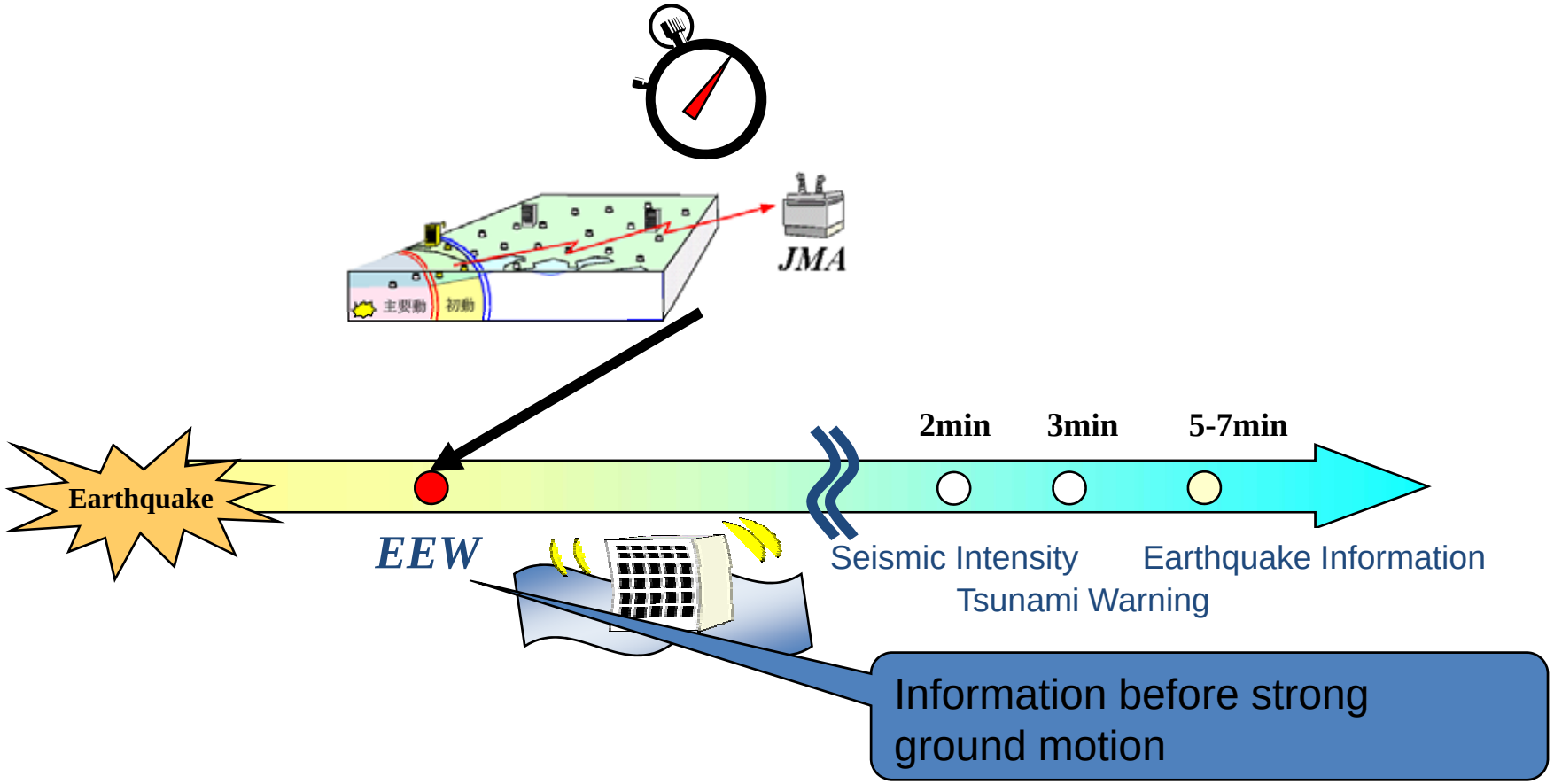
From JMA

Information after the disaster (post-disaster information)

Information *before* the strong ground motion => Earthquake Early Warning (EEW)

Earthquake Early Warning Methods

- Rapid determination of Hypocenter,Magnitude
- Quick anticipation of Seismic Intensity



Two-step provision of EEW

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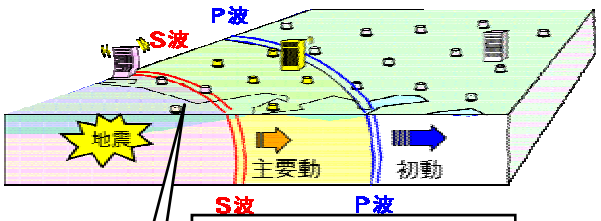


Detect seismic wave

JMA

EEW

For specific users from Aug., 2006.

For general public from Oct., 2007 after conducting public relations activities.

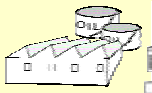
Specific Users

Disaster Mitigation Organizations

Rapid emergent countermeasure

Transportation, Lift

Emergent Stop



Factory, Construction

Line control, Safety action

Public Place

Broadcast

House, Building

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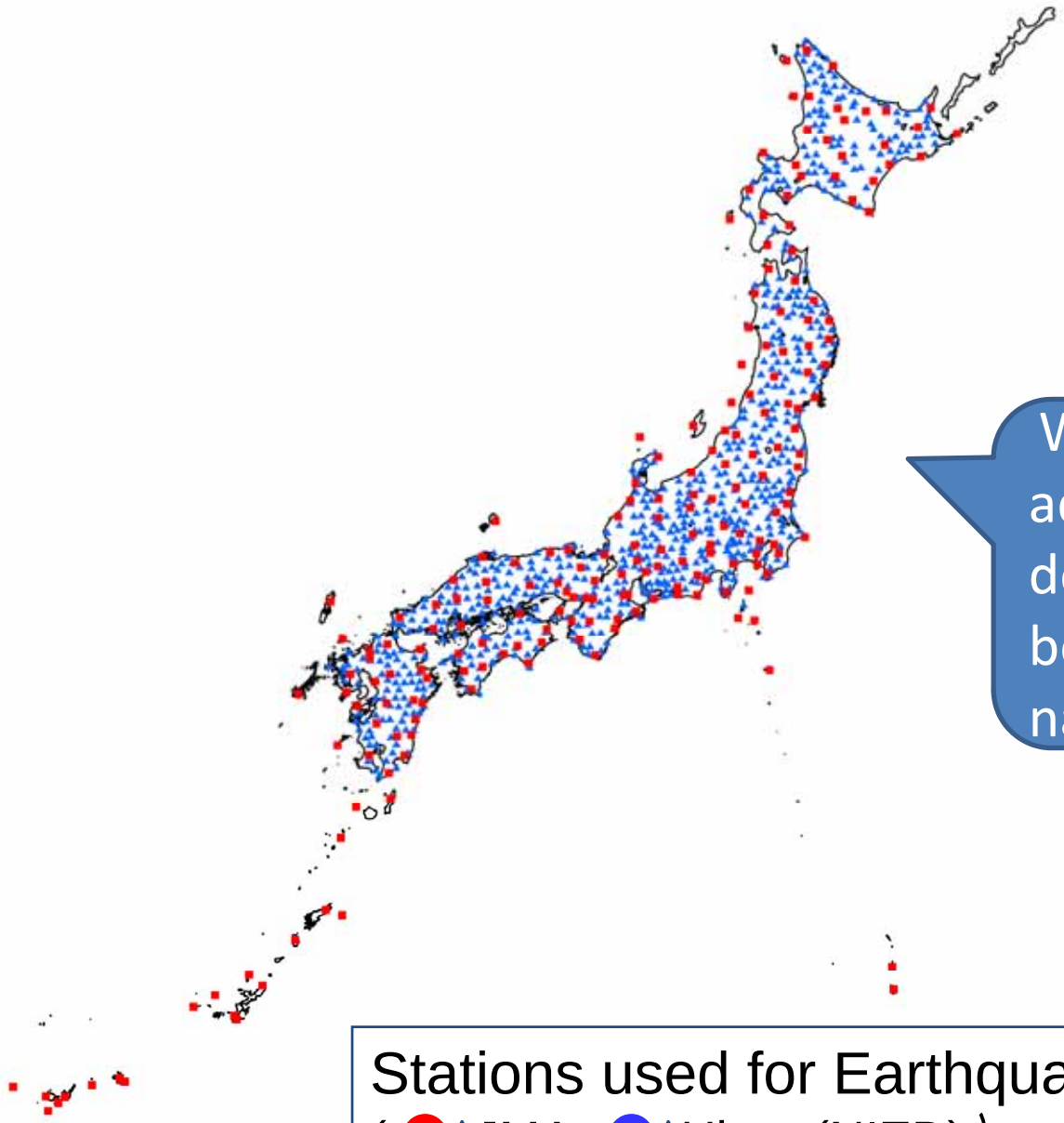

With the advancement of the dense network, EEW becomes available nationwide

Stations used for Earthquake Early Warning
(●：JMA、●：Hi-net(NIED))

More than 1000 stations → spacing of 20km

Conceptual Image of Seismic Wave Propagation and Earthquake Early Warning (EEW)

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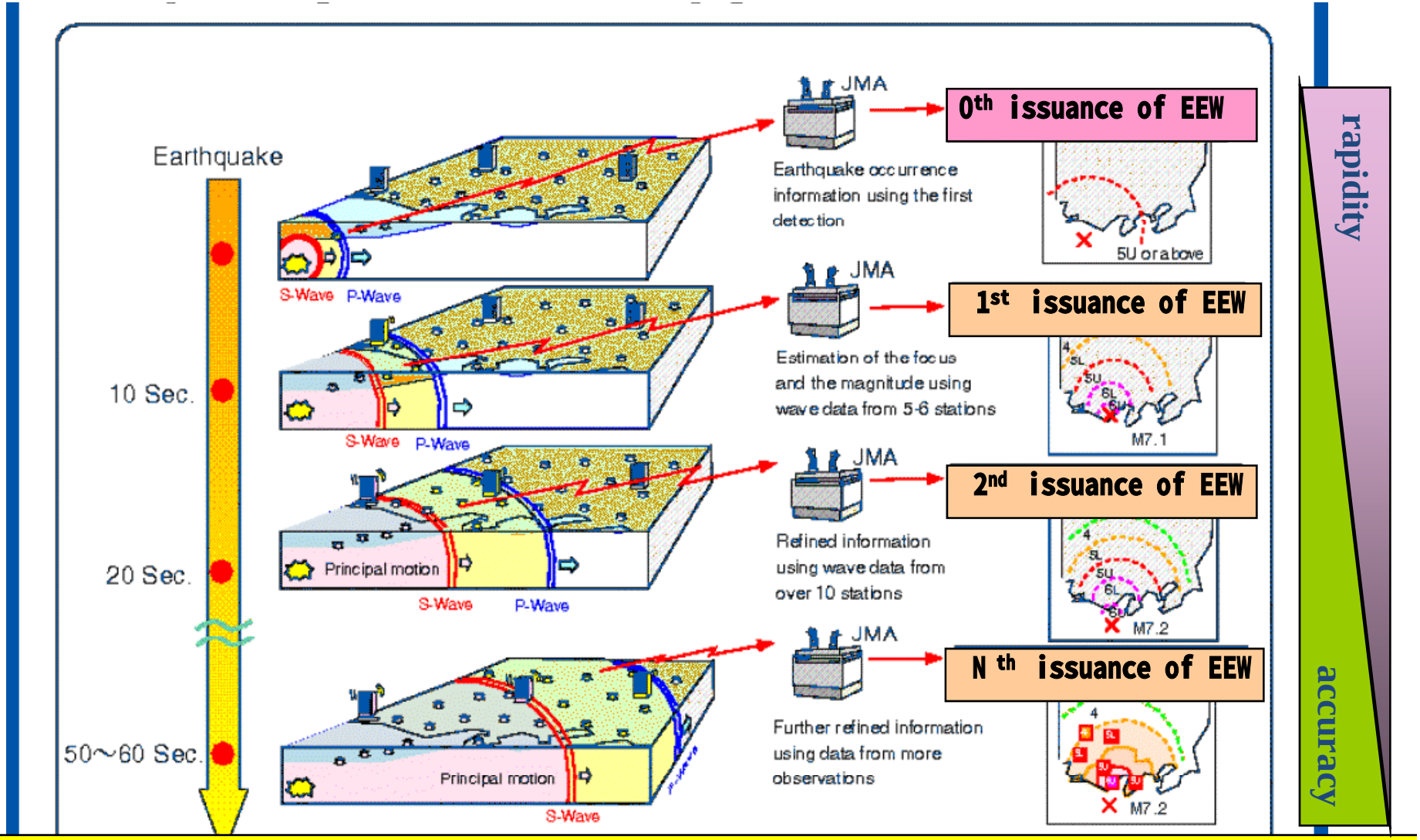

When EEW is issued to the general public, its timing and contents must be carefully designed

Example of application

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Train operation control

School children's immediate action for safety

Furnish from Prof. Motosaka

Home electronics control

© JEITA

Immediate action/measures for avoidance of danger

© KAJIMA CORPORATION

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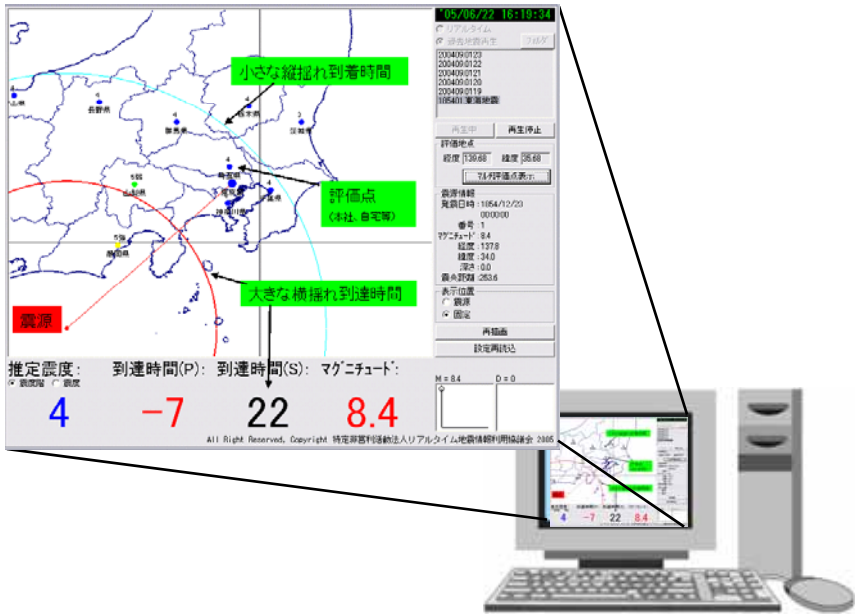
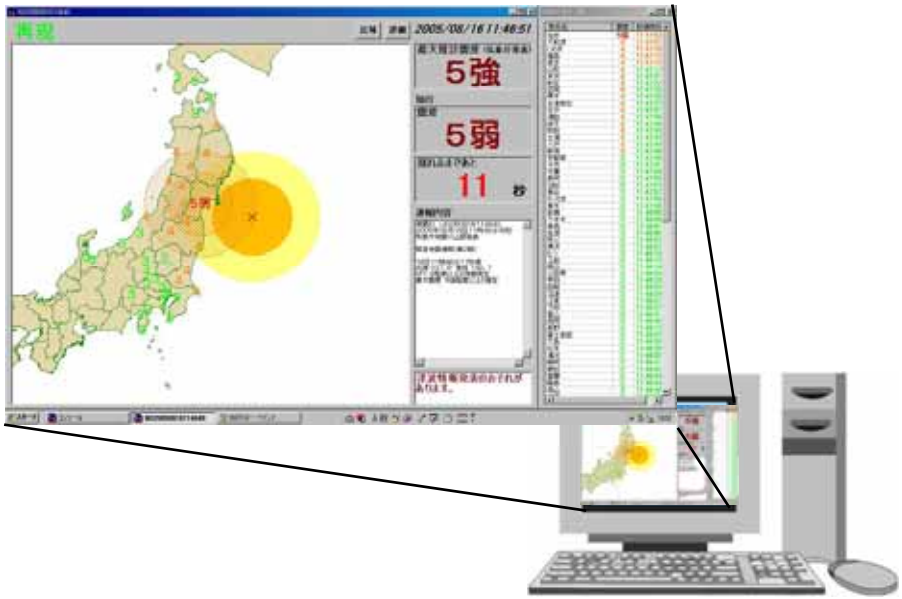
Examples of EEW Receivers





Time available for taking action
M7.2 earthquake *(June 14, 2008, Iwate-Miyagi)*

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hh:mm:ss

08:43:45 Origin Time

08:43:51 First Detection

08:43:54 1st EEW

Hypocenter,Magnitude,and Anticipated Seismic Intensity

08:43:55 2nd EEW

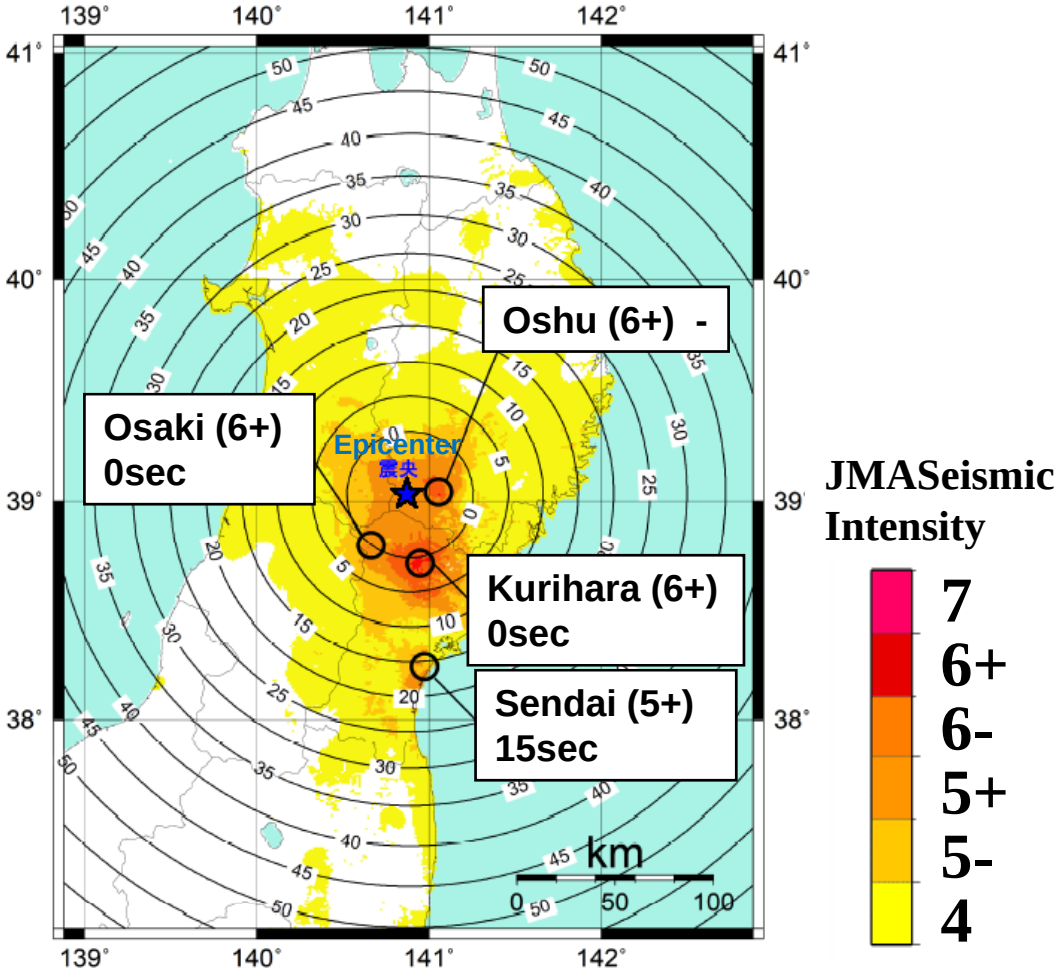
updated EEW

……..

08:44:53 Final EEW(10th)

08:45 *Seismic Intensity Report*

08:47 *Earthquake Information*



How can general people get EEW?

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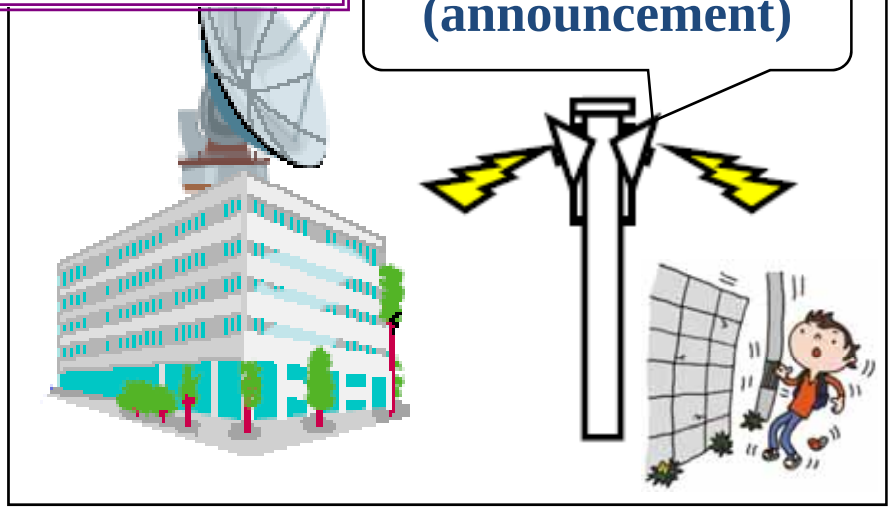
TV screen image of NHK-TV

TV & Radio

Municipalities



Public Place

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Summary

Since 15 years ago,

(1) Tsunami warning system has been developed for more rapid and precise warning.

(2) Earthquake Information has been improved by increasing seismic intensity meters.

(3) Hopocenter and magnitude have been determined by integrated analysis of networks of JMA, NIED, universities and others. (from 1997)

(4) Earthquake Early Warning started nationwide to issue to general public users. (from 2007)