Earthquake Early Warning

- Information before strong ground motion -

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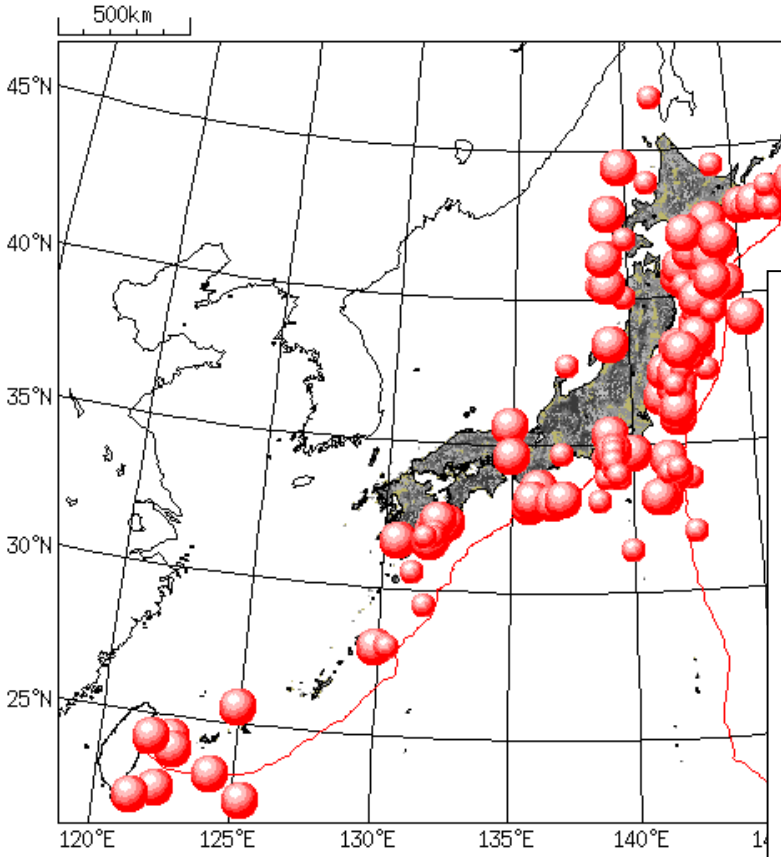
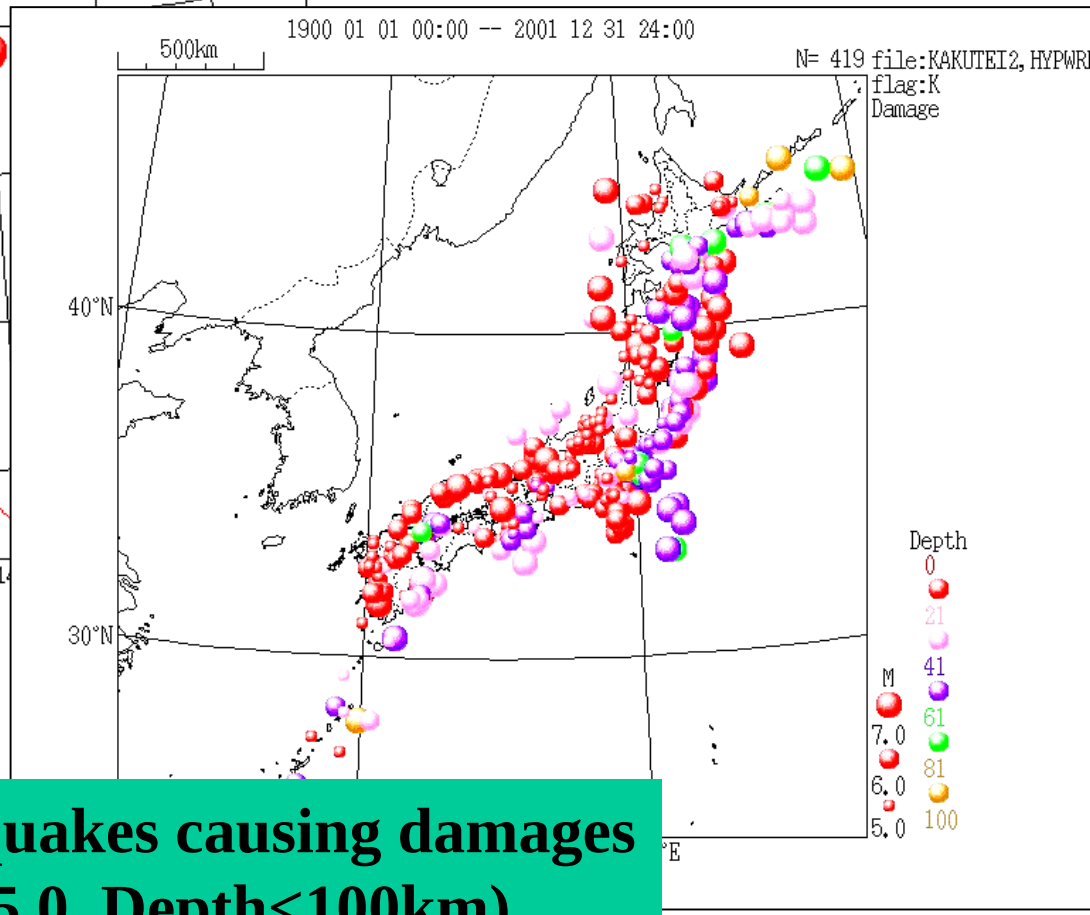
Japan Meteorological Agency

January 12 , 2007

Distribution of Earthquakes Causing Tsunami (1896~2004) in Japan





Distribution of Earthquakes causing damages (1900~2001, M>=5.0, Depth<100km)

Earthquake Information *at present*

- **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)

Before explanation of EEW, current earthquake information is briefly explained.

JMA Seismic Intensity Scale

0

1

2

3

4

5 lower

5 upper

6 lower

6 upper

7

Measurement of Seismic Intensity

Strong Motion

Earthquake

Amplitude
Duration
Frequency

Seismic Intensity

Seismic Intensity Meter

Strength of ground motion

Index of damage

Seismic Intensity Measurement Stations

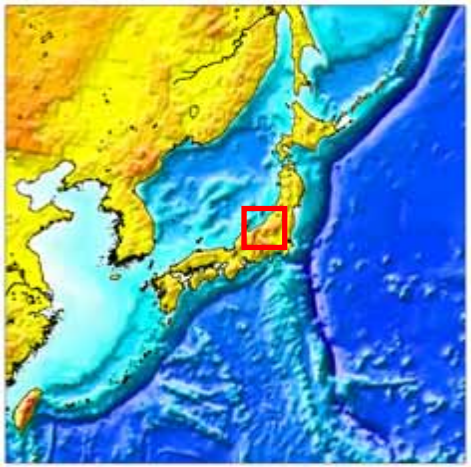
JMA （600）

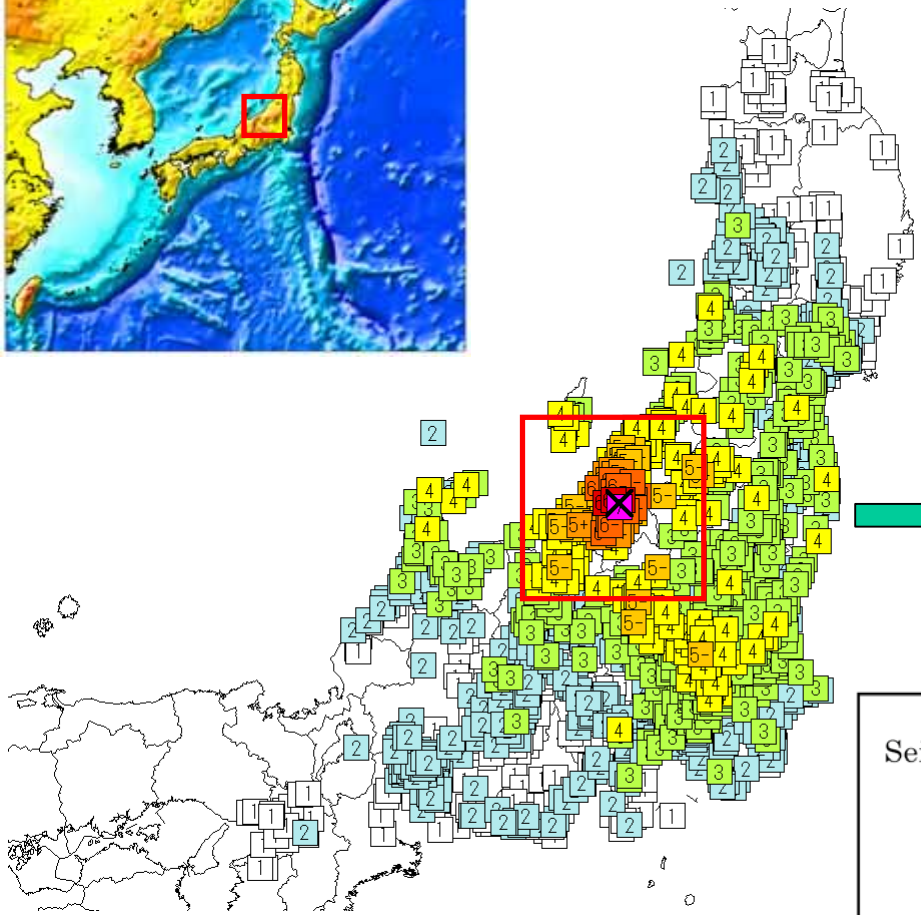
Municipalities （2,849）

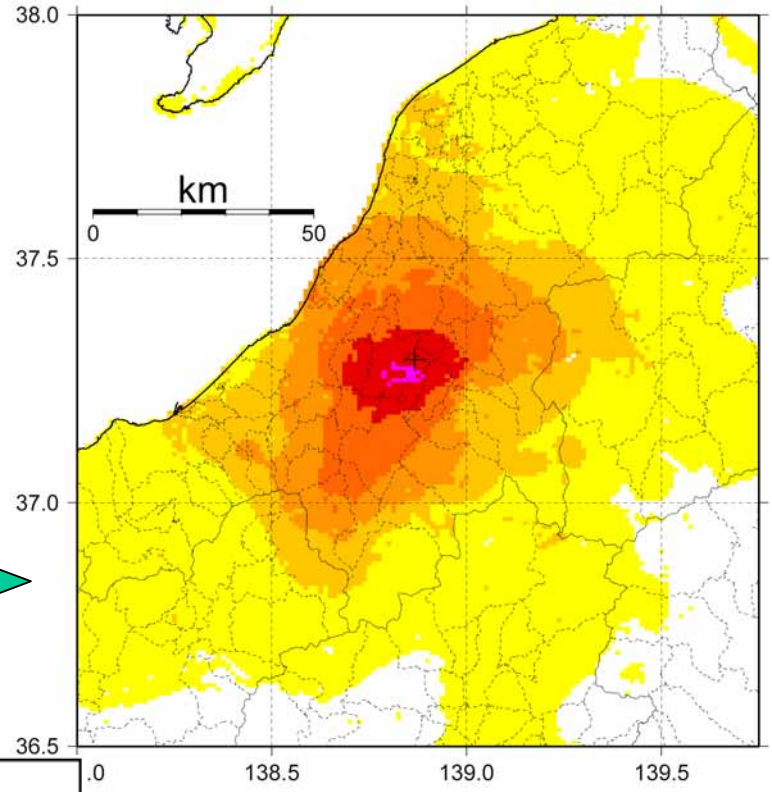
NIED(K-NET) （667）

Total : about 4,000

The Mid Niigata Prefecture Earthquake (M6.8, Oct., 23, 2004)







Notes
Seismic Intensity

7	7
6 +	6upper
6 −	6lower
5 +	5upper
5 −	5lower
4	4
3	3
2	2
1	1

Max. Intensity = 7

Seismic Intensity Distribution

Emergency Operation by Seismic Intensity Information

EQ.

2min — **Seismic intensity information**

3min — **Tsunami Warning**

5min — **Earthquake information**

Seismic intensity are used as trigger of emergent operations

Prime Minister's Official Residence

6lower(5upper for Tokyo) → Emergency Assembly team Conference

Cabinet Office → (4) Estimation of damages

Defense Agency → Investigation of damages

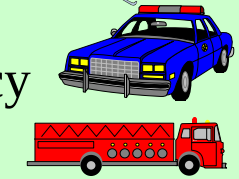
5lower

Japan Coast Guard → Investigation of damages

5lower

Metropolitan Police Department

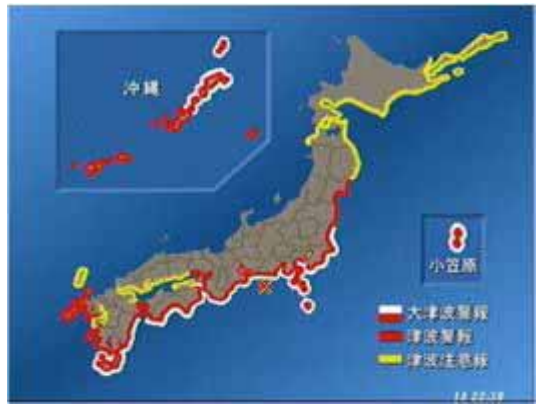
Fire and Disaster Management Agency → (4) Investigation of damages



NHK, a broadcast organization

→ Announcement with TV or Radio

When the Earthquakes occurs in Japan .....



© NHK

For more mitigation of earthquake disaster

If we can be aware of earthquake occurrence in advance, it is useful to take appropriate procedures to avoid dangerous situation for prevention of disasters.

However, earthquake prediction is still quite difficult.

Earthquake Early Warning

If we can be aware of earthquake occurrence very quickly, especially before strong shaking , it is useful to take appropriate procedures to avoid dangerous situation for mitigation of disasters.

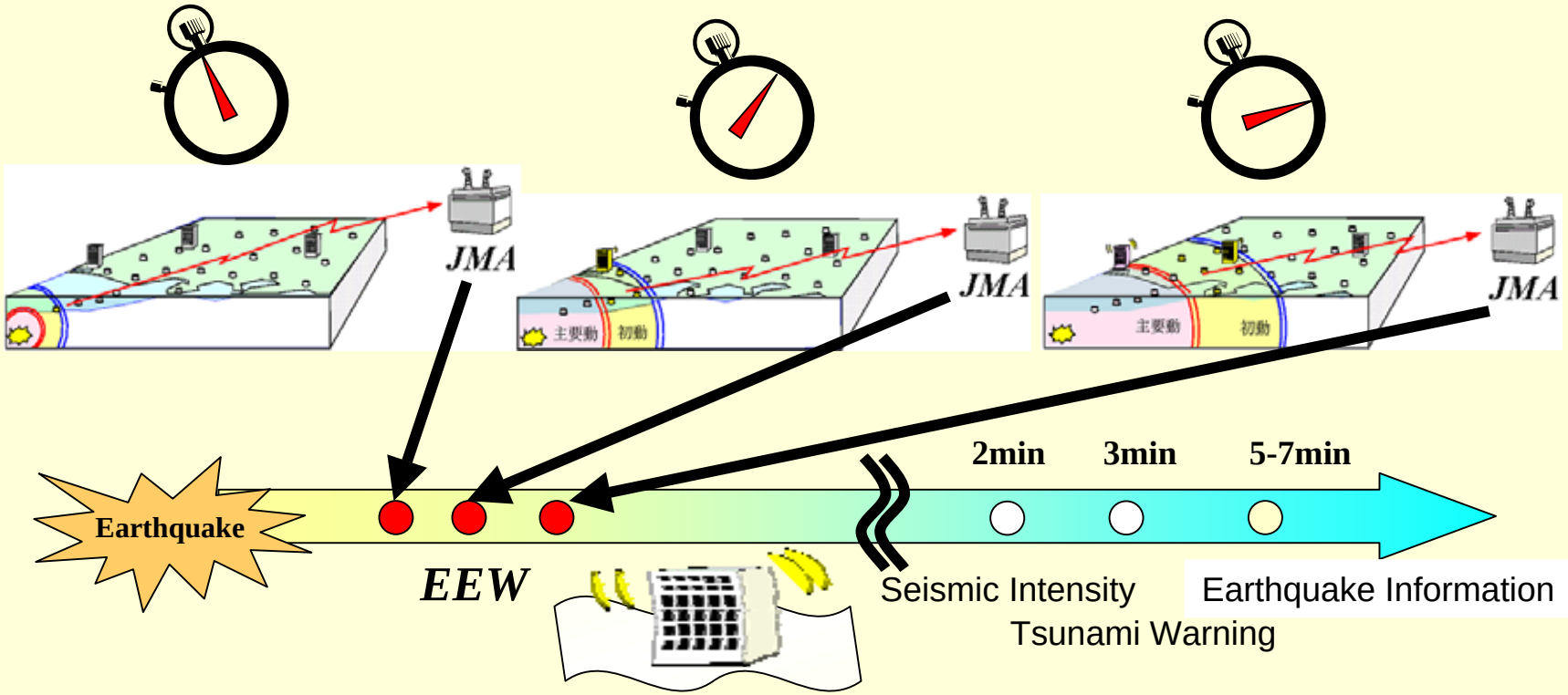
JMA intends to start a new service on earthquake information

- Earthquake Early Warning -

Information before strong ground motion of earthquake

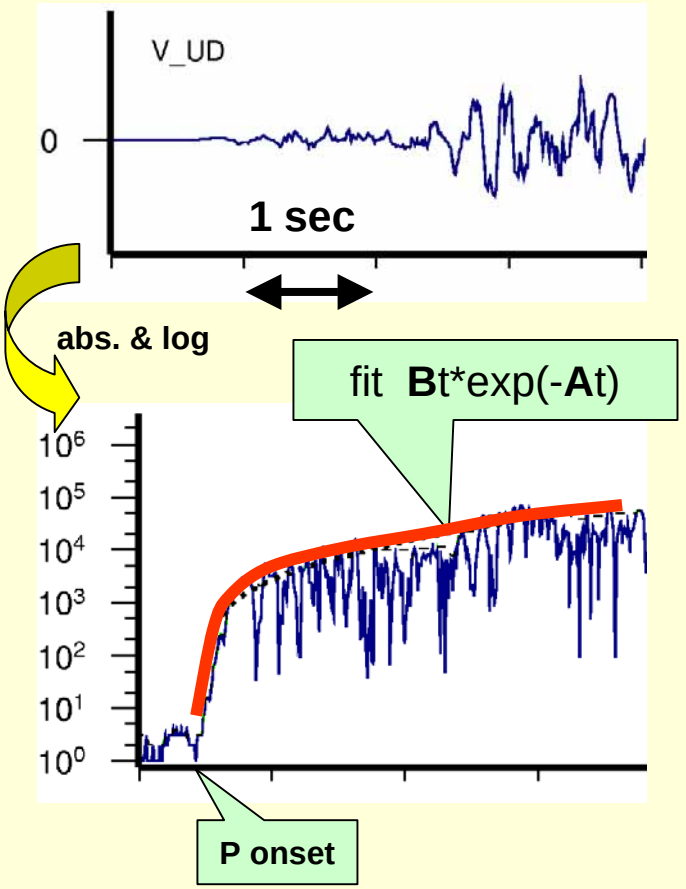
EEW Methods
(Hypocenter,Magnitude,Seismic Intensity)

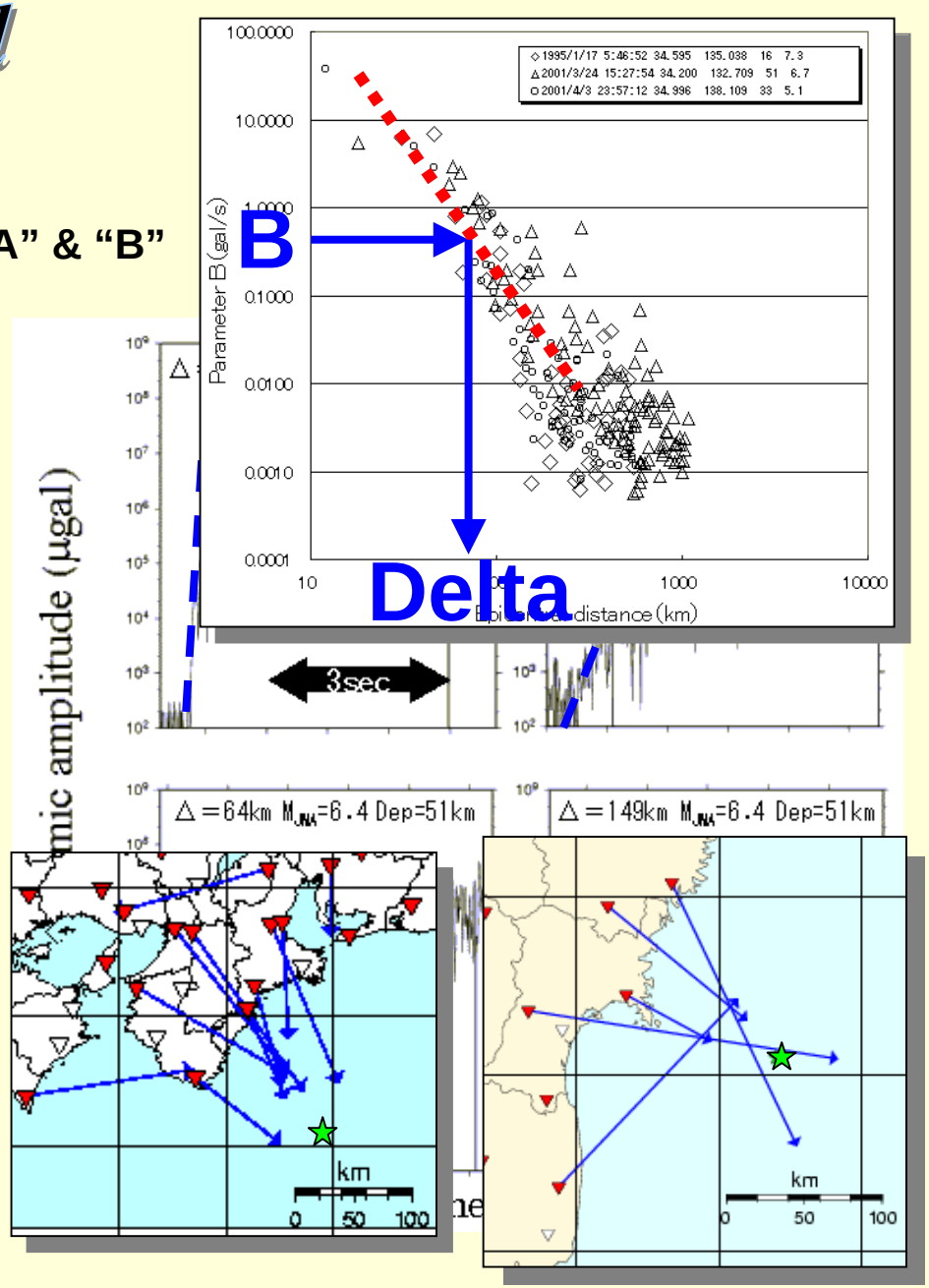
1. Hypocenter estimation
   1) Single station method　　2) Network method
2. Magnitude estimation
3. Seismic intensity estimation



Single Station Method

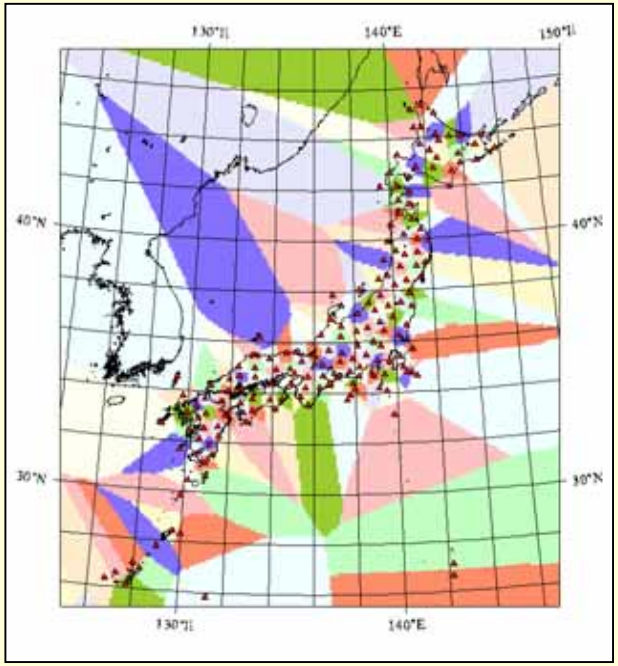
Extraction of waveform character -> “A” & “B”





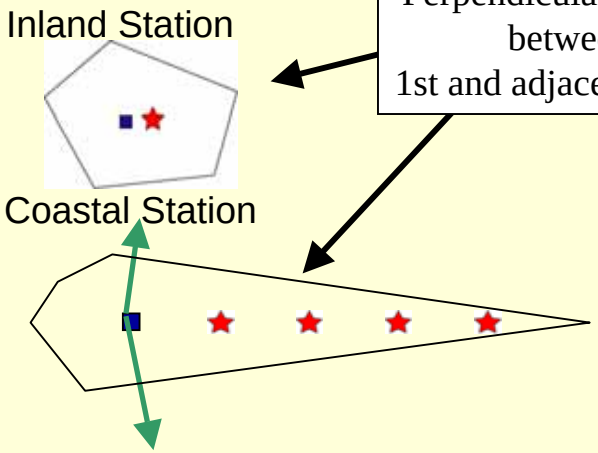
Network Method(1) - Territory

Territory status

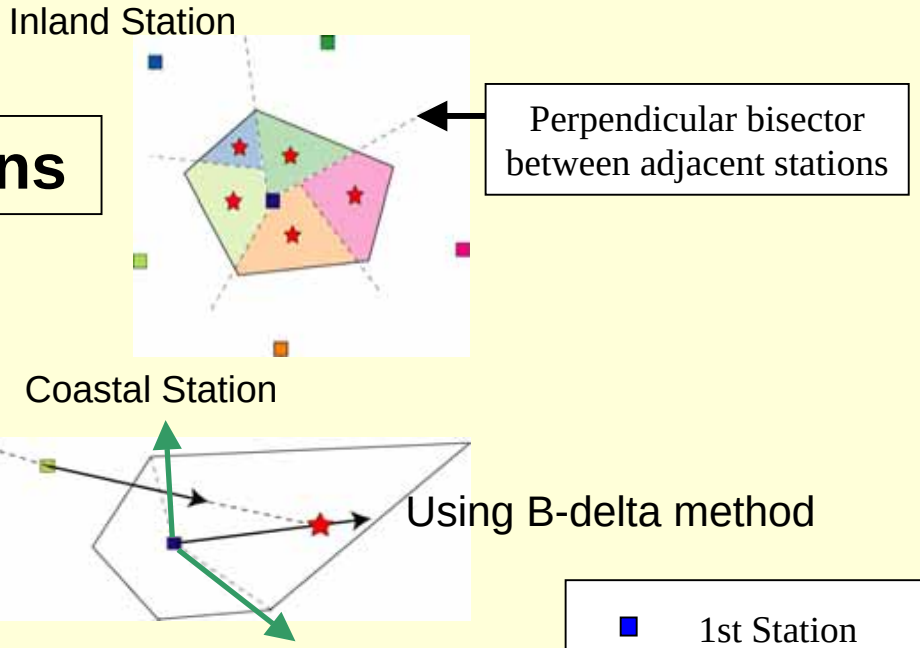


Updated every time "dead or alive" at about 200 stations

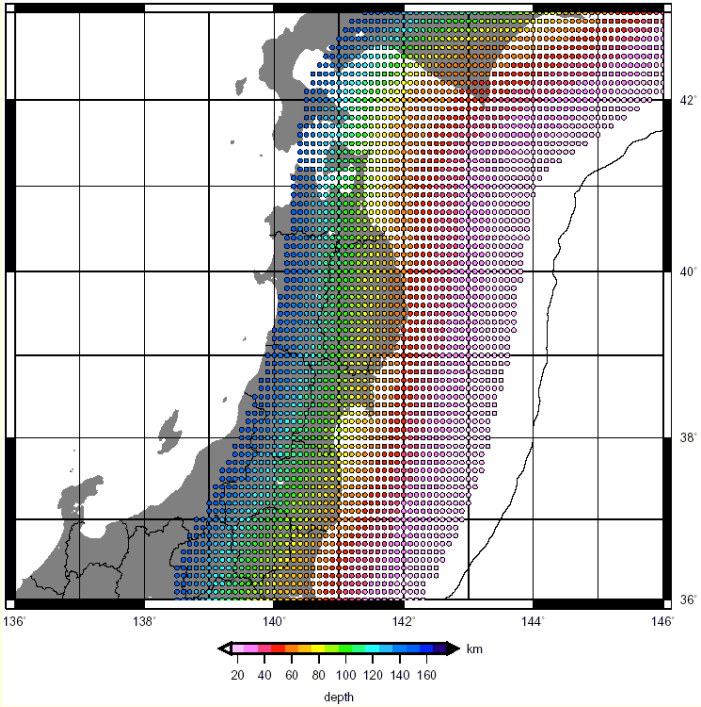
1st station



2 stations

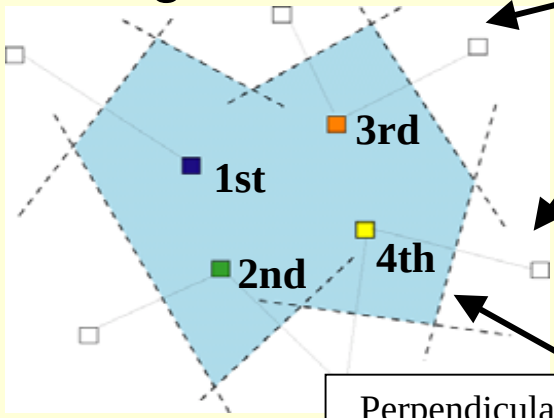


Network Method(2) - GridSearch



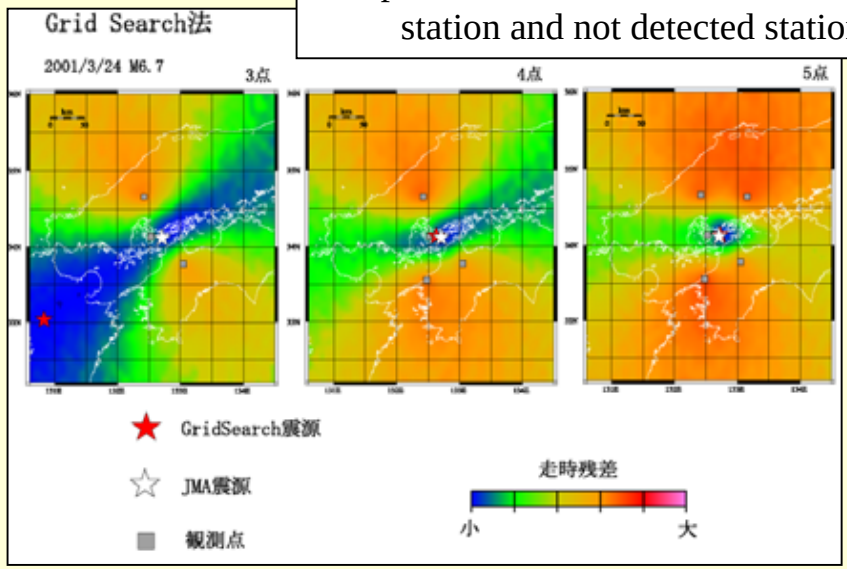
at every 0.1 degree horizontally and 10km vertically

Region limitation of grid search



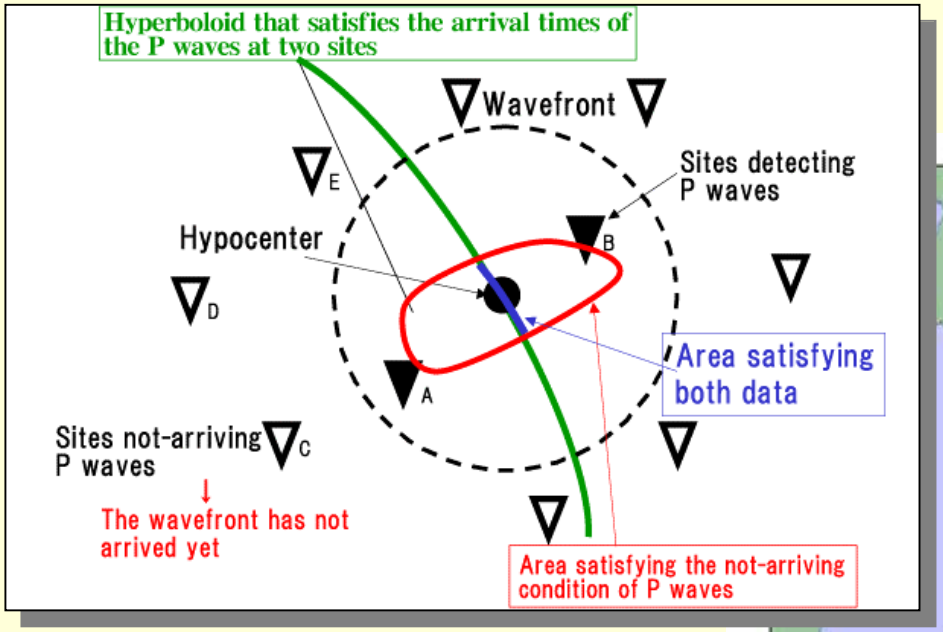
Station that is not detected P-arrival

Perpendicular bisector between detected station and not detected station

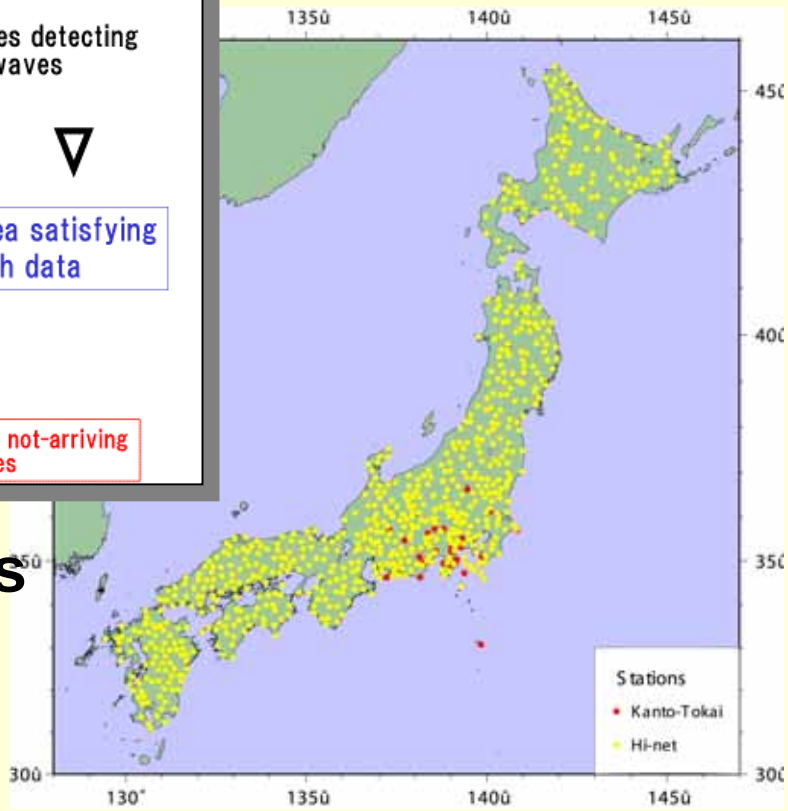


Network Method(3) - Not Yet Arrived Data

Developed by Horiuch et al., NIED



More than 2 stations

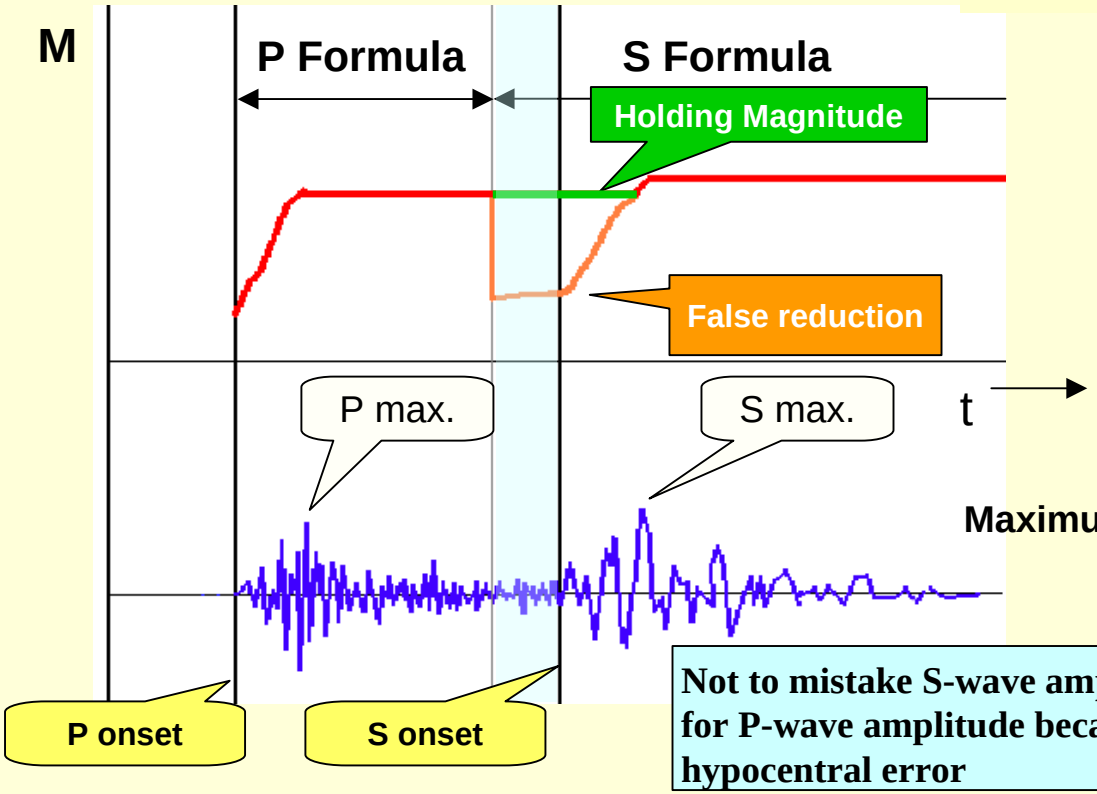


Use Hi-net (NIED)

Integrate from Jun. 2005

Magnitude Estimation

Event magnitude is average of station magnitude



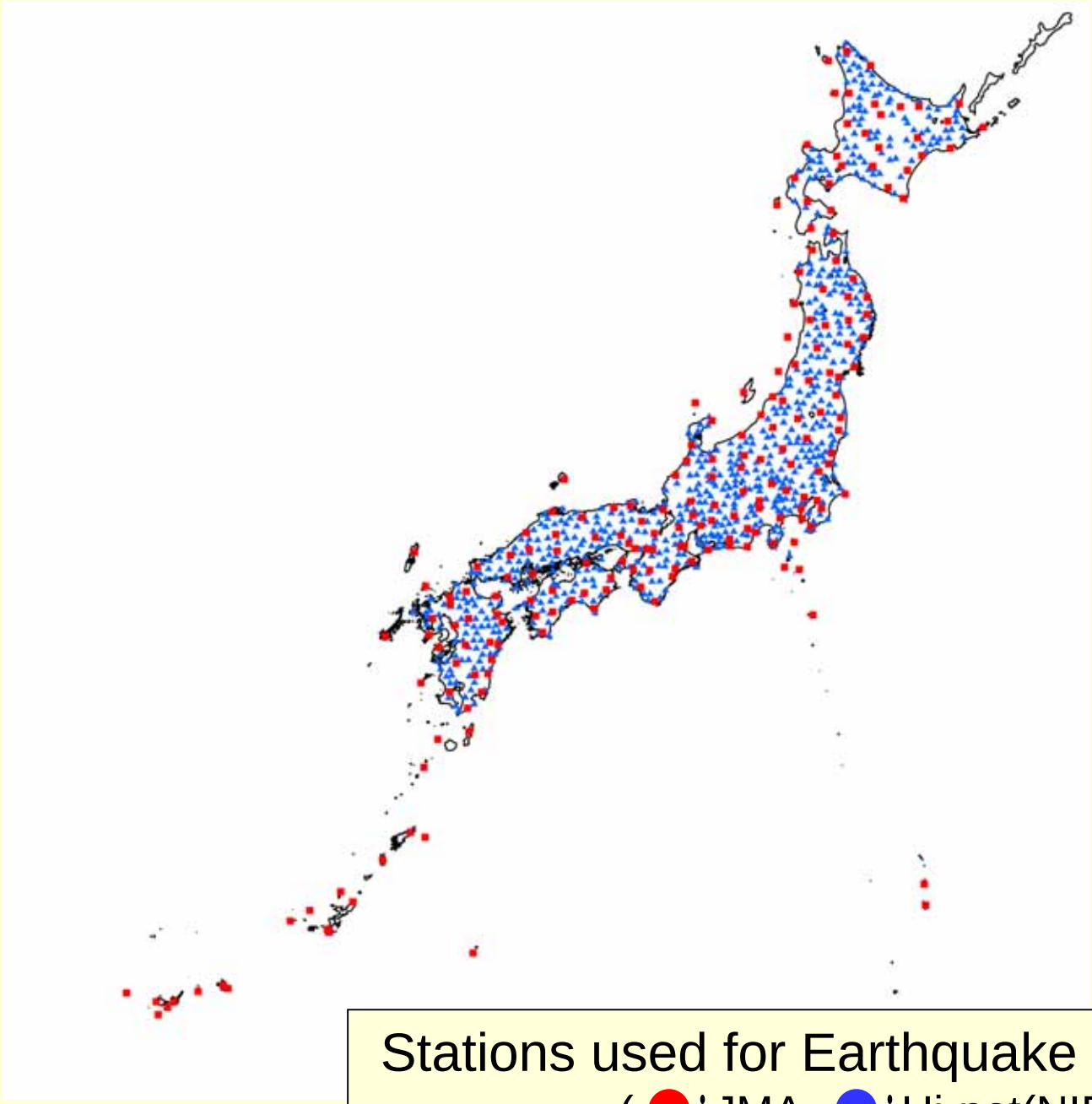
Maximum Displacement Amplitude

Not to mistake S-wave amplitude for P-wave amplitude because of hypocentral error

P Formula $M = \log D_{max} + \log R + 6.12 \times 10^{-4} \times R + 2.58$

S Formula $M = \log D_{max} + \log R + 9.53 \times 10^{-4} \times R + 1.74$

Dmax : 3-dimensional vector summation of displacement
R: hypocentral distance



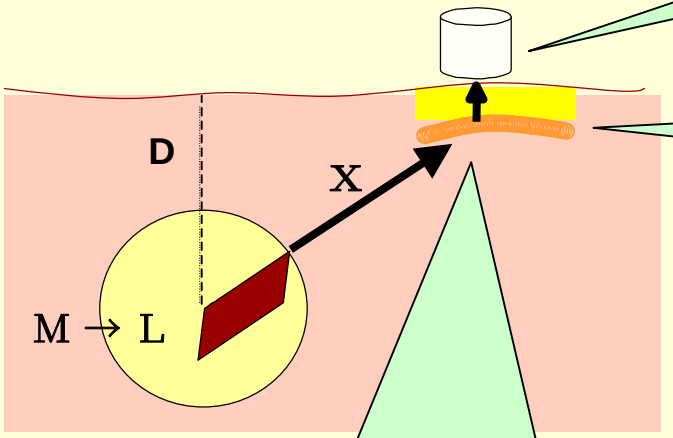
Stations used for Earthquake Early Warning

(●：JMA、●：Hi-net(NIED))

Seismic Intensity Estimation

3) Conversion of maximum velocity amplitude to JMA seismic intensity

Midorikawa, 1999

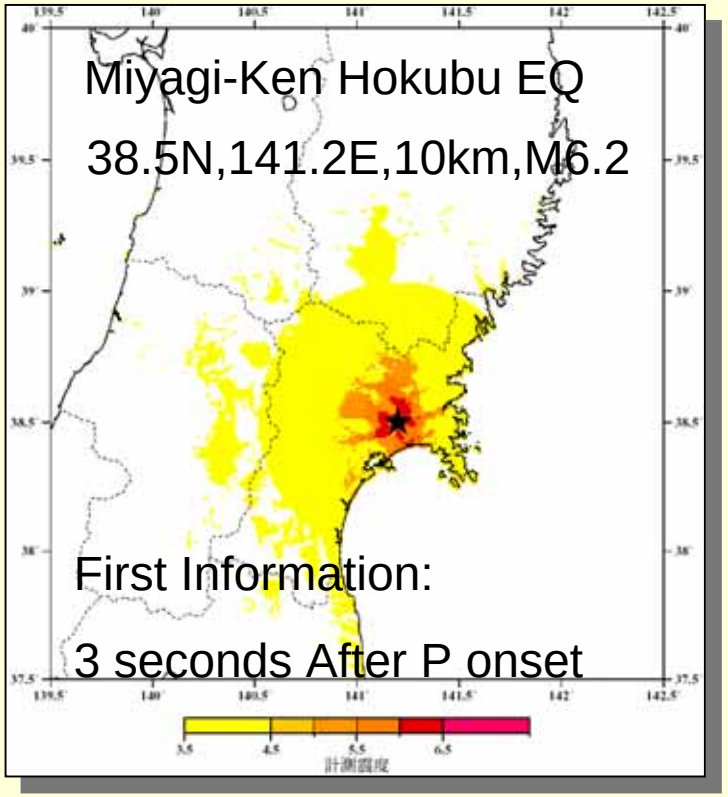


2) multiplying amplification coefficient

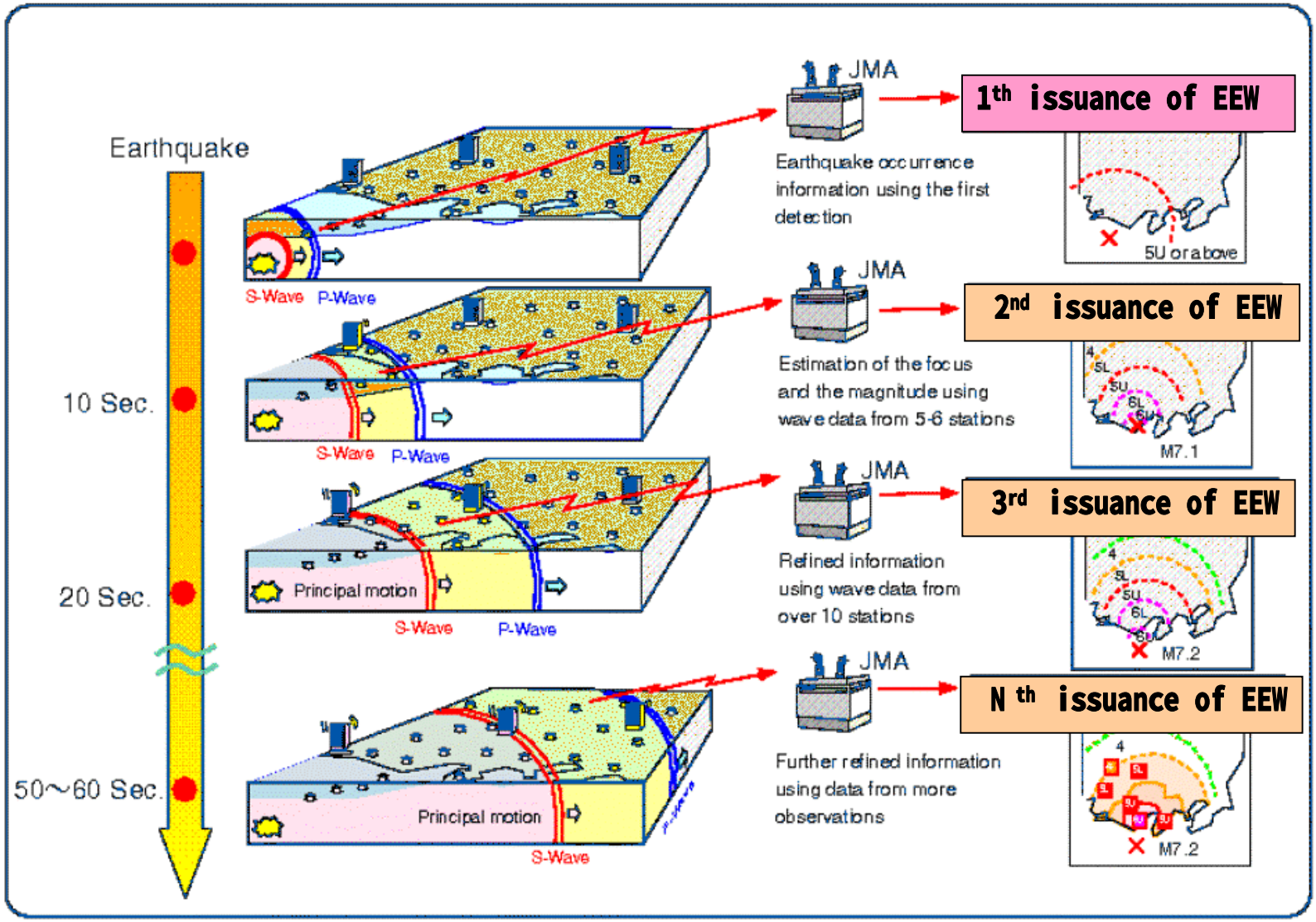
Matsuoka and Midorikawa, 1994

1) Maximum velocity amplitude at the engineering bedrock **= f (M,X,D)**

Si and Midorikawa, 1999



Conceptual Image of Seismic Wave Propagation and Earthquake Early Warning



Dissemination

Dissemination Criteria

Over 3.5 for magnitude or 3 for JMA seismic intensity scale.

1) The first warning

The result using 2seconds waveform or
Onsite warning over 100cm/s/s (without hypocenter information)

2) The cancel report

There is no following P phase detection at the closest station.

3) The updated warnings

Threshold Change 0.2 degrees for latitude and longitude,
20km for hypocentral depth,
+0.5, -1.0 for event magnitude
+0.5, -1.0 for maximum seismic intensity.

4) The final warning

when the estimated magnitude value converged, or when the pre-set time has passed after the first detection of the P phase.

Feb., 2004 to July, 2006

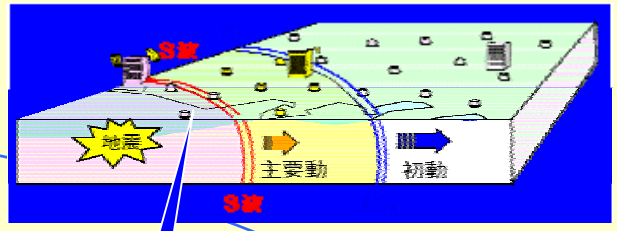
Total: 855 alarms

➡ 26 cases are false alarms

For the cases that more than 2 stations are used :

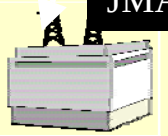
➡ No false alarms

Earthquake Early Warning (EEW)



Detection of seismic wave near the epicenter

JMA



Issuance of EEW

Transmission

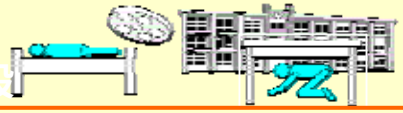
Usage

Public transportations, elevators and others

Avoiding dangerous situation by automatic suspension

防災関係機関

Emergency services against disaster



公共施設

Safety at hospitals and schools

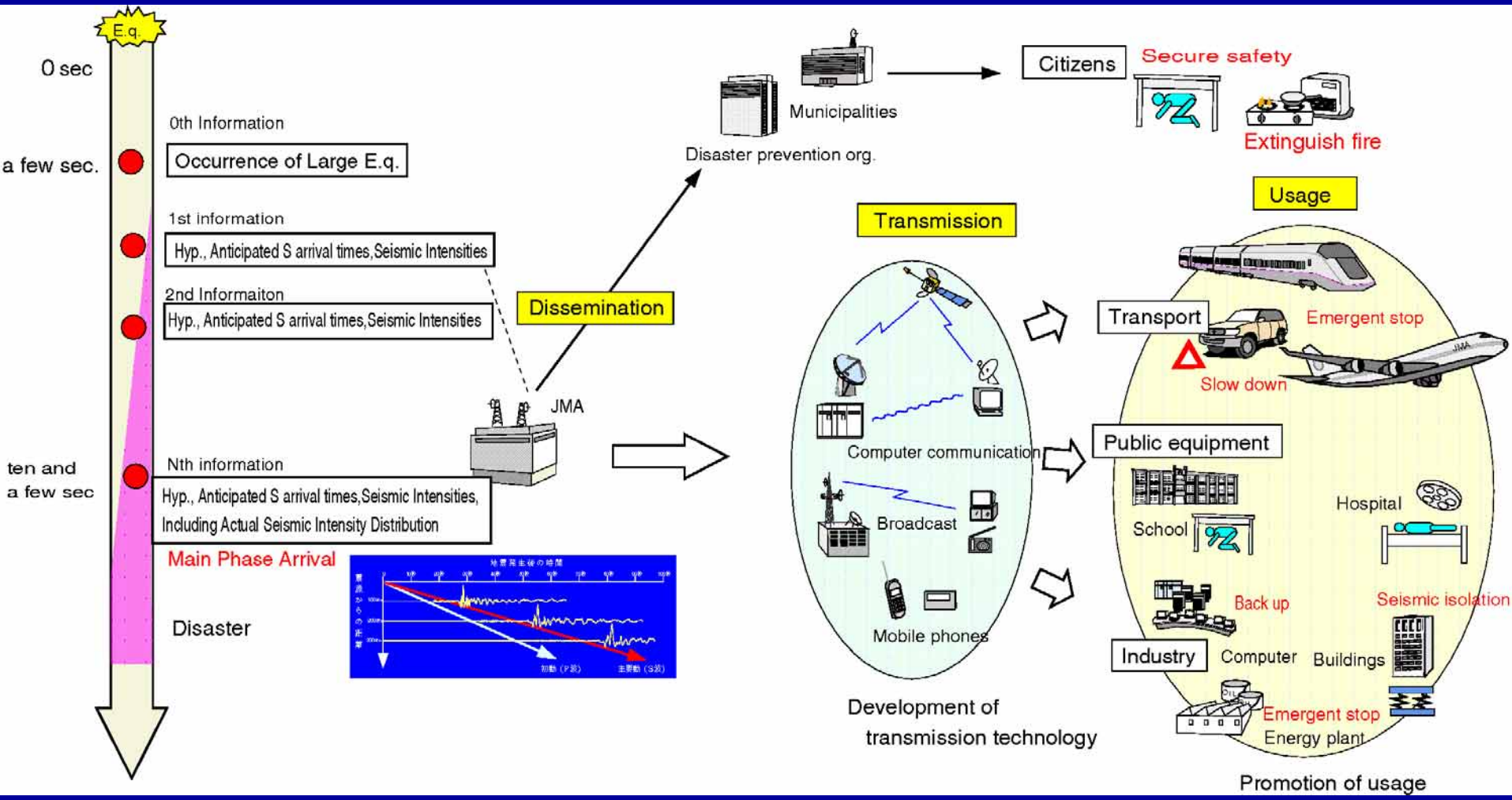
住 民

Automatic cut-off gas, heating equipment etc., Evacuation

Factories and offices

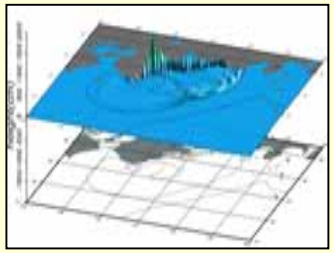
Mitigation of damage to facilities,
Emergent suspension,
Automatic backup of important data,
Safety of workers

Example of Application of Earthquake Early Warning



Application of Earthquake Early Warning

Tsunami warning



Closing of the slide Against Tsunami

Early Evacuation from Tsunami

Precaution measures for home / school / hall / shopping mall / etc.

Train Control System

Control Traffic Signals, Regulation of Traffic

Lift Control System

Hospital →Prevent Mistake in the Operation

Vibration Control Engineering

Person in Dangerous Place →Make Safe

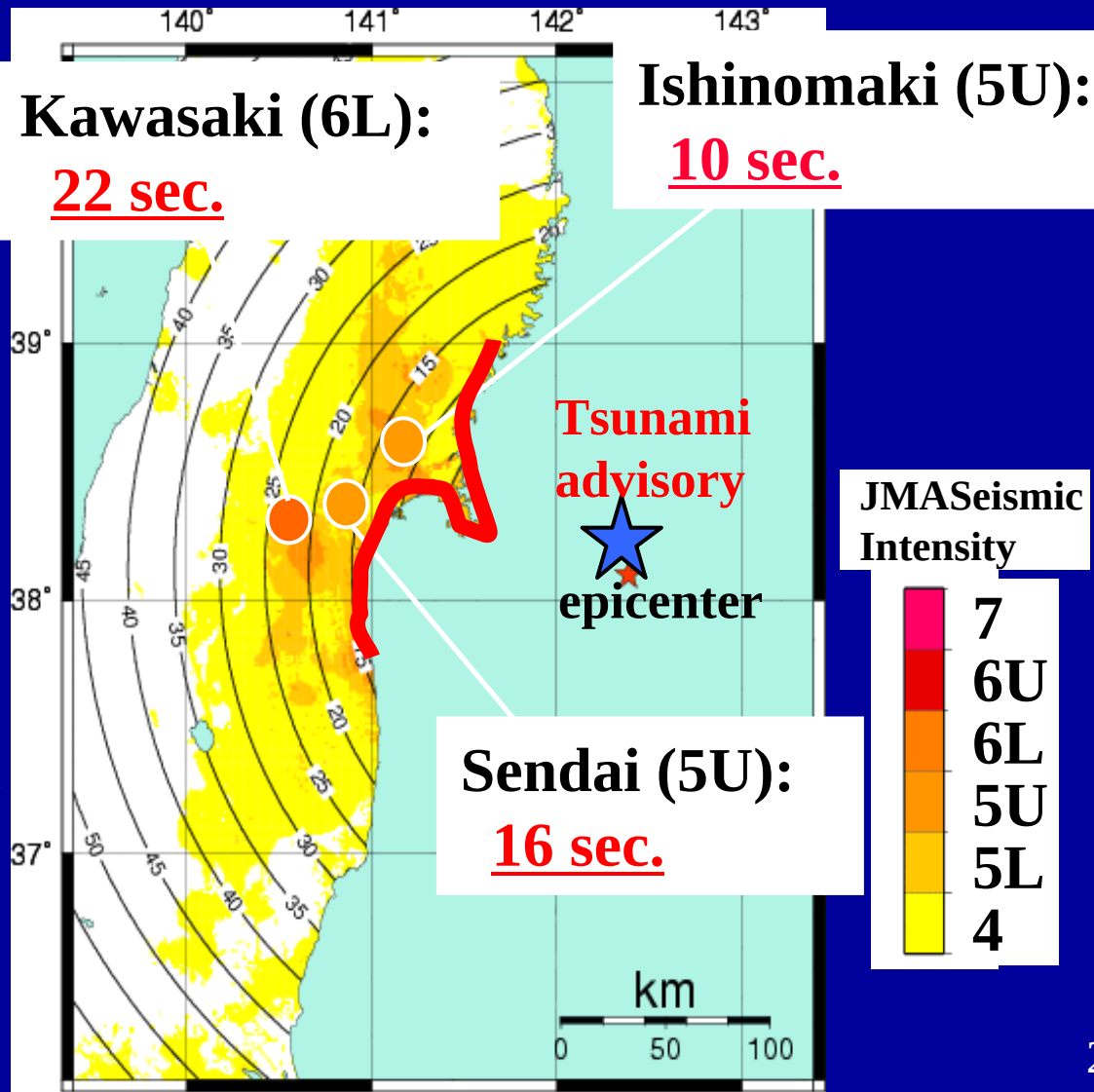
Broadcast

Lead Time to Strong Motion by EEW
M7.2 (16 August 2005, Off Miyagi Pref.)

11:46:26 Origin Time
11:46:41 First Detection
11:46:45 1st EEW
Hypocenter,Magnitude,and Seismic Intensity
11:46:45 2nd EEW
updated EEW
……
11:47:51 Final EEW(8th)

11:48 *Seismic Intensity Information*
11:50 ***Tsunami Advisory***
11:54 *Earthquake Information*
12:12 *13cm tsunami*
(at Ayukawa)
13:15 ***Tsunami Cancellation***

Lead Time



Lead Time to Strong Motion
M6.8 (23 October 2004, Mid Niigata Pref.)

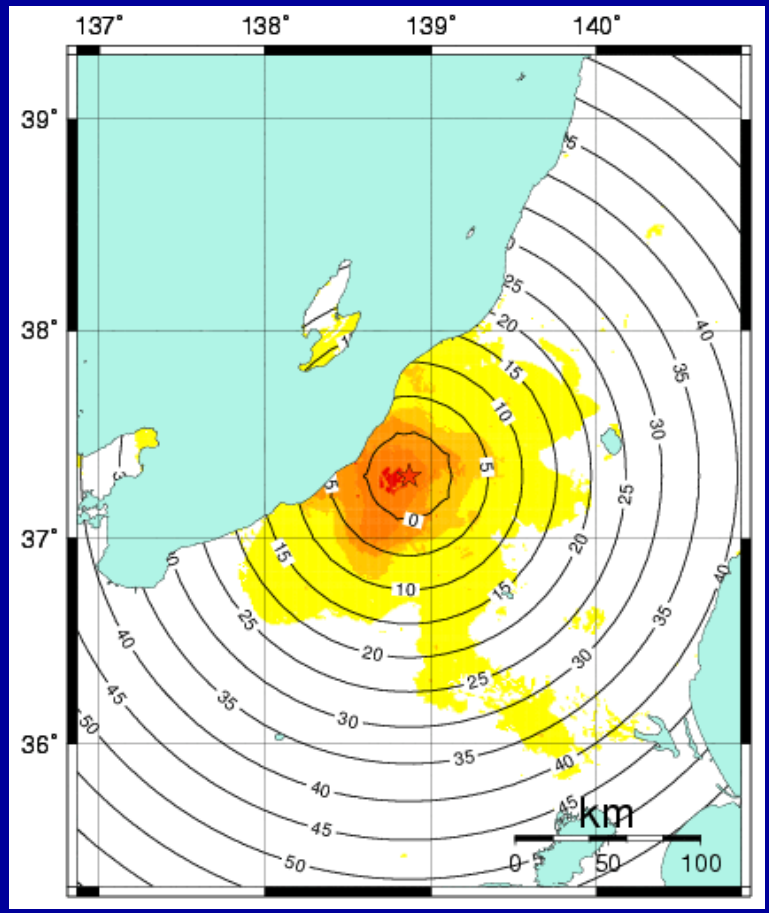
17:56:00 Origin Time
17:56:03 First Detection
17:56:04 1st EEW
Onsite warning(over 100cm/s/s)
17:56:07 2nd EEW
Hypocenter,Magnitude,and Seismic Intensity

……

17:57:03 Final EEW(8th)

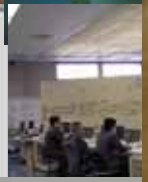
17:58 *Seismic Intensity Information*
18:02 *Earthquake Information*

Lead Time



JMASeismic Intensity
7
6U
6L
5U
5L
4

Examples of Application of EEW



Progress of EEW Project

2000-	Development of EEW Technology (with Railway Technical Res. Inst.)
25 Feb 2004	Start of Trial Provision (For Kanto-Tokai-Nankai Area)
28 Mar2005	Expansion of Trial Provision Area (For Hokkaido-Tohoku Area)
Jun 2005	Integrated use of 'Not Yet Arrived Data Method' (Algorithm Developed at NIED into EEW)
31 Mar 2006	Expansion of Trial Provision Area (For Whole Country)
1 Aug 2006	Start of Interim Provision to **Registered Corporations**
? ? 2007	Start of Provision to **the Public**

855 times (including 26 times false alarms)

Number of Registered Corporations

JMA started official service for limited fields of application in August, 2006.

Field	Number
Local governments	17
Universities, Institutes	16
Railway companys	8
Elevator companies	3
Power companies	7
Construction companies	10
Manufacturing industries	51
Communication	12
Broadcast	23
Information	10
Finance companies	7
Real estate agents	10
Medical institutions	5
Others	45
Total	224

As of November 2, 2006

- The purpose is for the control of their own facilities.
- The actions are already determined when EEW is received.

- EEW are Issued several times for each earthquake

Earthquake Early Warning for the Public

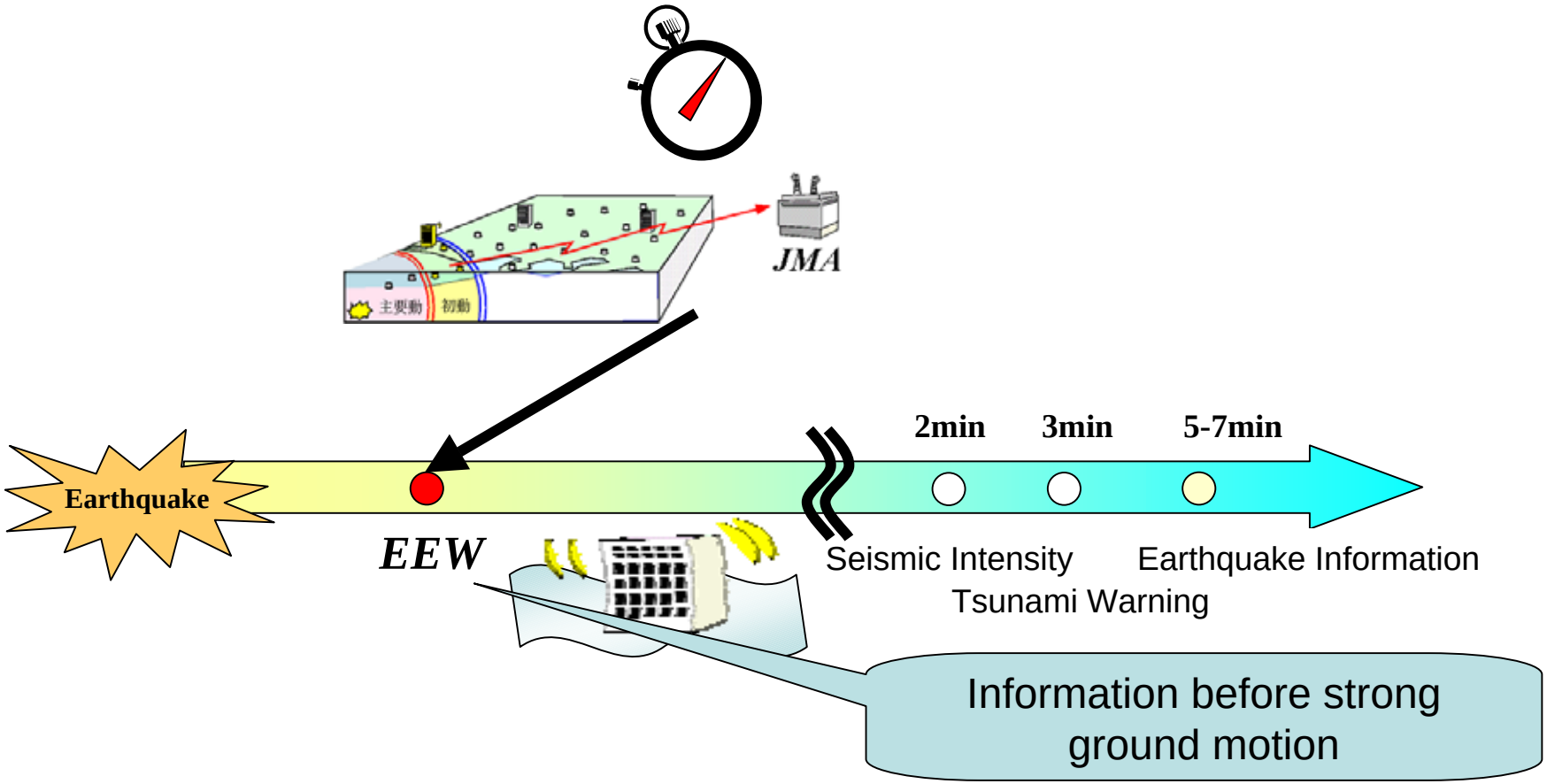
○ Criterion for Issuing
- Estimated Maximum Seismic Intensity ≧ 5 lower

○ Contents
- Origin Time (Time of Earthquake Occurring)
- Epicenter (Area of Earthquake Occurring)
- Area where Strong Shaking are Expected (Seismic Intensity ≧ 4)

From ??? in 2007

- **Basically EEW are Issued once for each earthquake.**

EEW Methods
(Hypocenter,Magnitude,Seismic Intensity)



Thank you very much for your kind attention.