# A detection method for giant earthquake based on counting a number of seismic intensity observation stations


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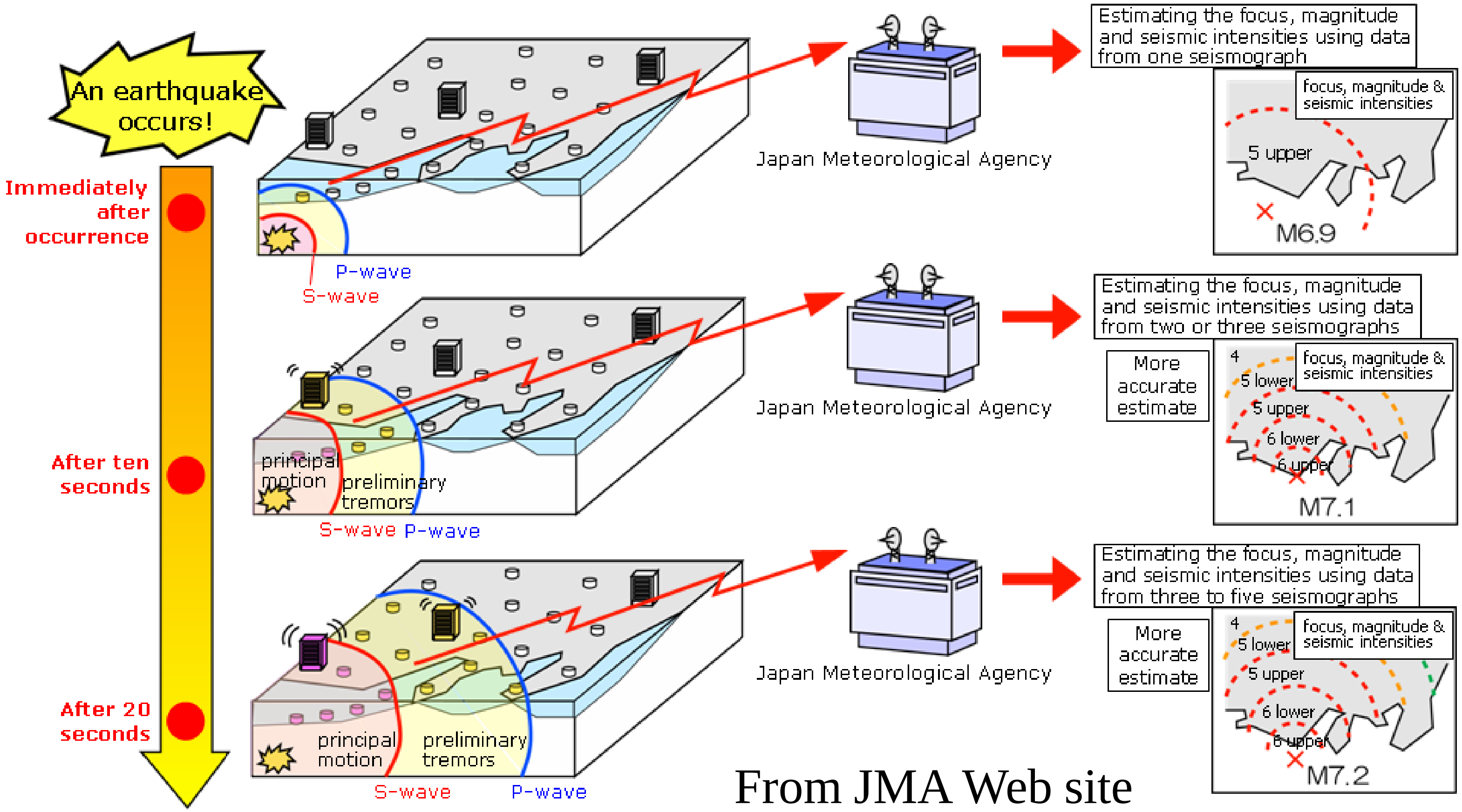
# Outline

- An overview of the earthquake early warning (EEW) during the 2011 Tohoku-Oki earthquake
- Problems of the present EEW system
- A method for the detection of giant earthquakes

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




From JMA Web site

The EEW system provides an advance warning of estimated seismic intensities and the expected arrival time of S-waves. These estimates are based on the 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 an earthquake, improving the accuracy of the warning as the amount of available data increases.

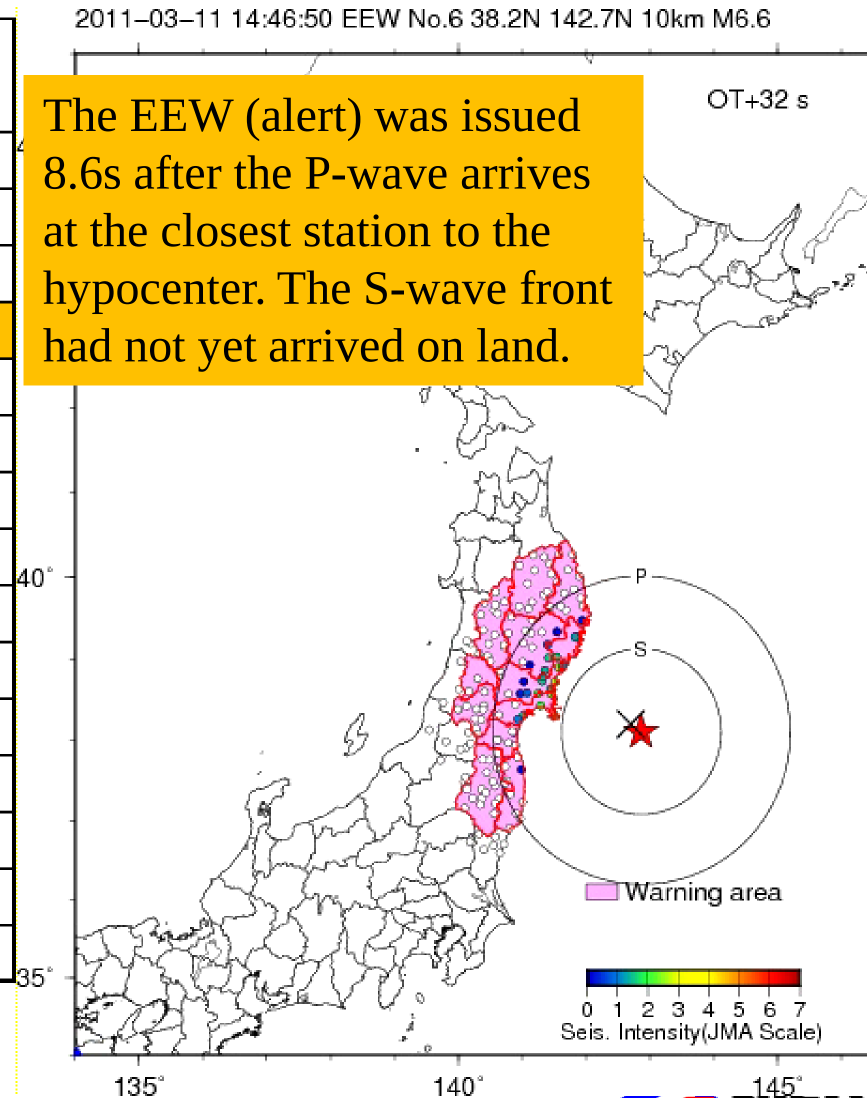
# EEW of 2011 Tohoku-Oki earthquake (M9)

Details of issued data
(warning at the 4th message)

| No. | Issuance time | Elapsed time since the E.Q. detection (s) | ° N | ° E | depth (km) | M |
|---|---|---|---|---|---|---|
| 1 | 2011/03/11-14:46:45.6 | 5.4 | 38.2 | 142.7 | 10 | 4.3 |
| 2 | 2011/03/11-14:46:46.7 | 6.5 | 38.2 | 142.7 | 10 | 5.9 |
| 3 | 2011/03/11-14:46:47.7 | 7.5 | 38.2 | 142.7 | 10 | 6.8 |
| 4 | 2011/03/11-14:46:48.8 | 8.6 | 38.2 | 142.7 | 10 | 7.2 |
| 5 | 2011/03/11-14:46:49.8 | 9.6 | 38.2 | 142.7 | 10 | 6.3 |
| 6 | 2011/03/11-14:46:50.9 | 10.7 | 38.2 | 142.7 | 10 | 6.6 |
| 7 | 2011/03/11-14:46:51.2 | 11.0 | 38.2 | 142.7 | 10 | 6.6 |
| 8 | 2011/03/11-14:46:56.1 | 15.9 | 38.1 | 142.9 | 10 | 7.2 |
| 9 | 2011/03/11-14:47:02.4 | 22.2 | 38.1 | 142.9 | 10 | 7.6 |
| 10 | 2011/03/11-14:47:10.2 | 30.0 | 38.1 | 142.9 | 10 | 7.7 |
| 11 | 2011/03/11-14:47:25.2 | 45.0 | 38.1 | 142.9 | 10 | 7.7 |
| 12 | 2011/03/11-14:47:45.3 | 65.1 | 38.1 | 142.9 | 10 | 7.9 |
| 13 | 2011/03/11-14:48:05.2 | 85.0 | 38.1 | 142.9 | 10 | 8.0 |
| 14 | 2011/03/11-14:48:25.2 | 105.0 | 38.1 | 142.9 | 10 | 8.1 |
| 15 | 2011/03/11-14:48:37.0 | 116.8 | 38.1 | 142.9 | 10 | 8.1 |

A total of 15 EEWs were issued during this earthquake, including forecasts and alerts. The 4th message was alert.

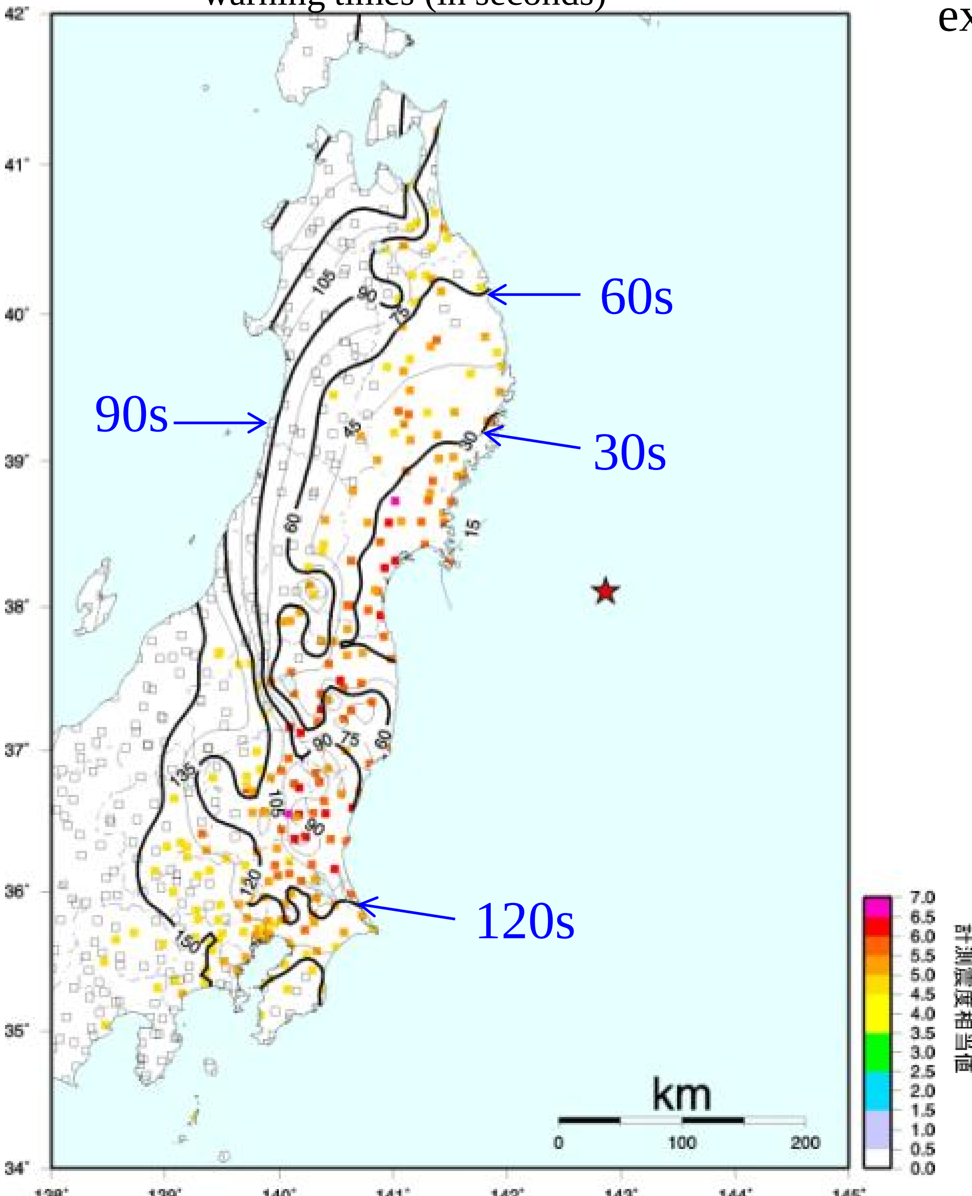
Area for which the warning was issued




The EEW (alert) 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.

# Warning times from issuing the EEW until the real-time seismic intensity exceeded 5-lower during the Tohoku-Oki Earthquake.

The contours in the map show warning times (in seconds)




■Warning times before observed seismic intensity exceeded 5-lower on the JMA scale (equivalent to VII on the MMI scale)

| | |
|---|---|
| Miyagi | 15s |
| Iwate | 20s |
| Fukushima | |
| Ibaraki | 60s |
| Tochigi | |
| Chiba | 120s |
| Saitama | |
| Tokyo | |

The EEW played an important role in providing information in terms of an "**early**" warning.

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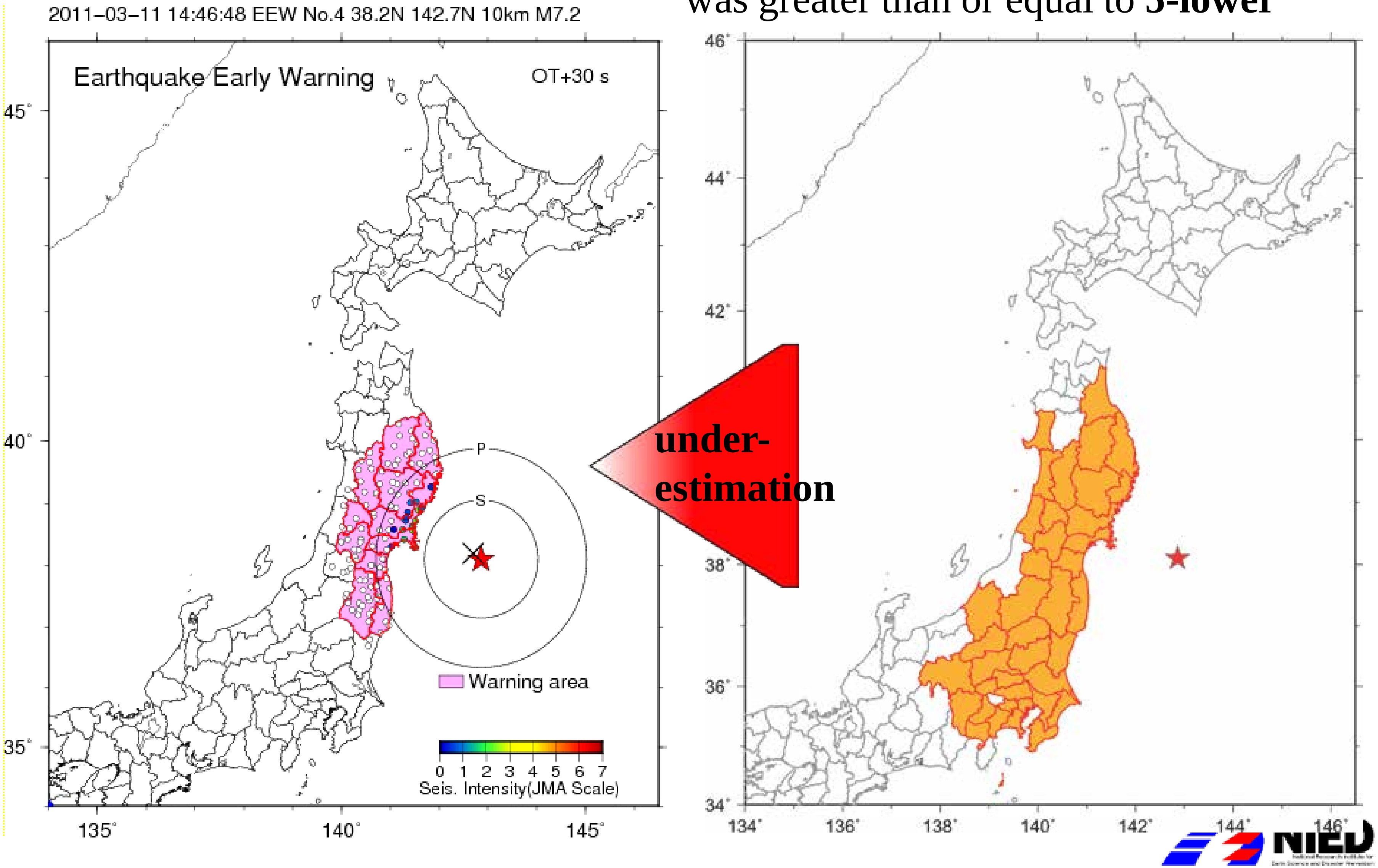
# Warning area was underestimated

EEW area

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



# Causes of the underestimation

- Warning information cannot be updated

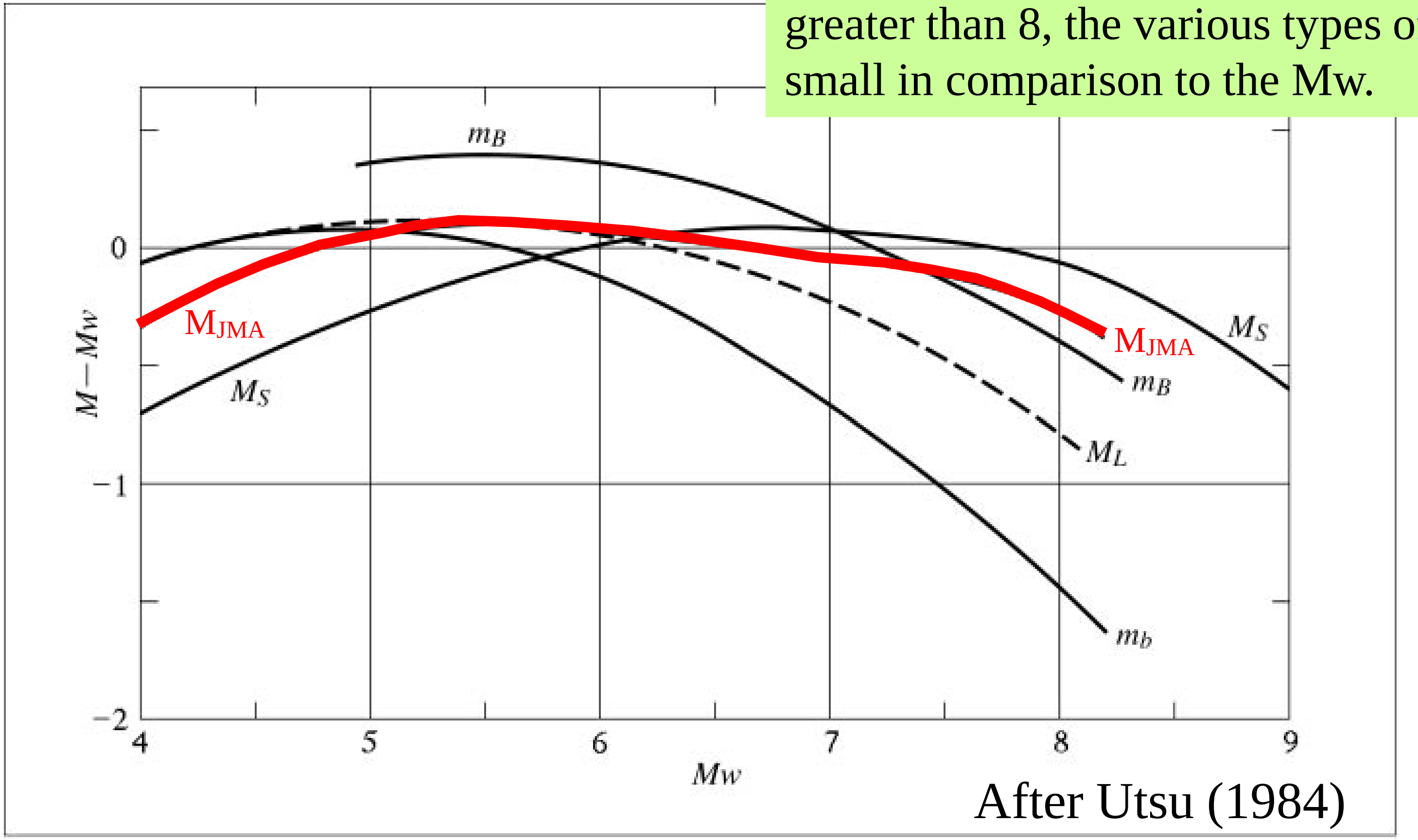
  The EEWs are updated as available data accumulates, but this is when the elapsed time is less than 60s from the first trigger.
  In this giant earthquake, the magnitude continued to increase even after exceeding the threshold (60s), and therefore the alert information could not be updated.
  This problem can be solved by increasing the threshold time.

- Amplitude-magnitude ($M_{JMA}$) saturation for events of Mw greater than 8

Fundamental problem concerning the detection of giant earthquakes

# $M_{JMA}$ saturation for events of Mw greater than 8

In the case of giant earthquakes with M greater than 8, the various types of M are small in comparison to the Mw.



After Utsu (1984)

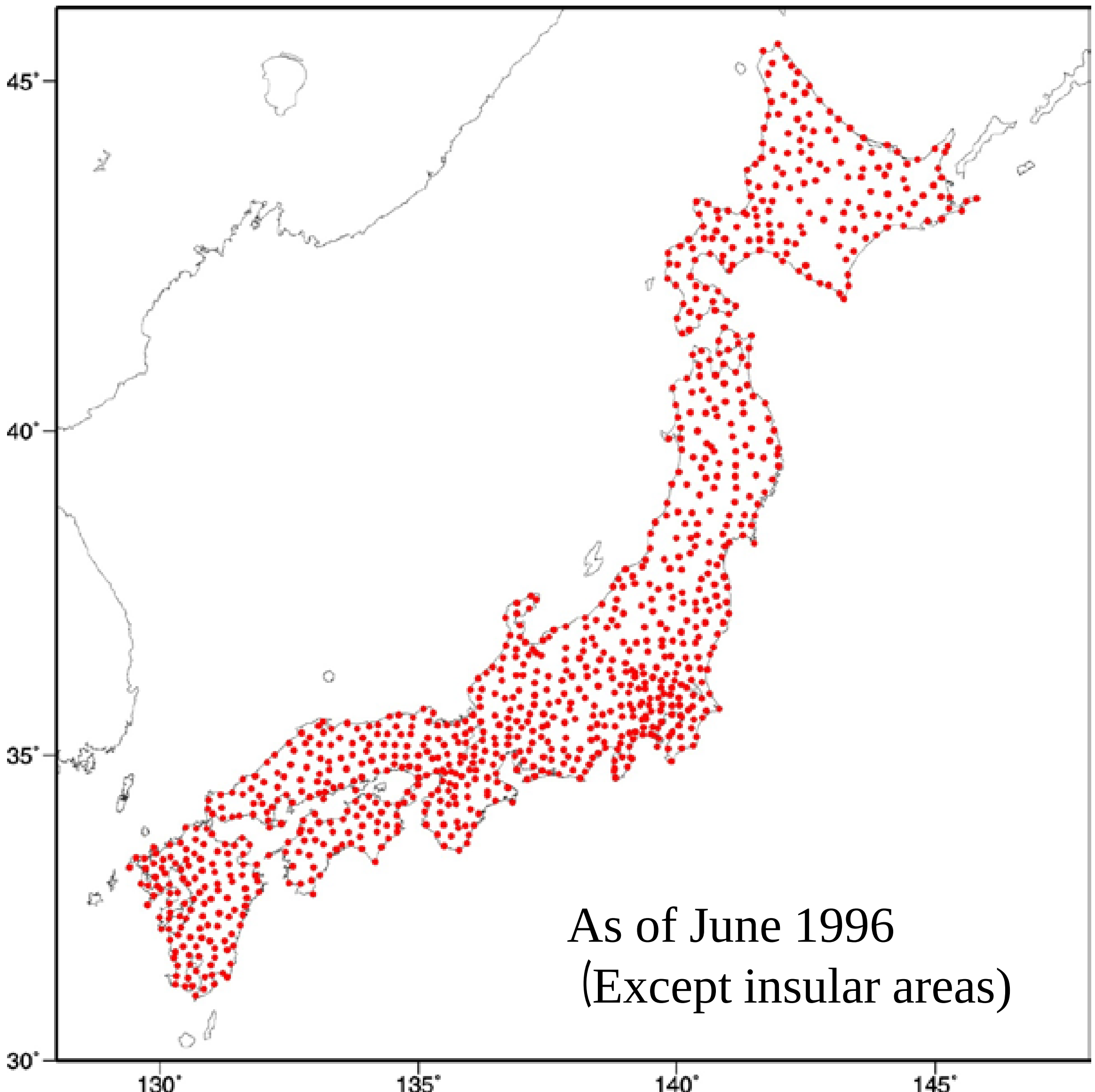
$M_{JMA}$ is estimated from the maximum displacement which corresponds to the outputs of seismometers having an eigenperiod of 6s.

# Goal

We develop a detection method for giant earthquakes based on counting a number of seismic intensity observation stations.

The advantage of this method is that it is not always necessary to have information regarding the earthquake source.

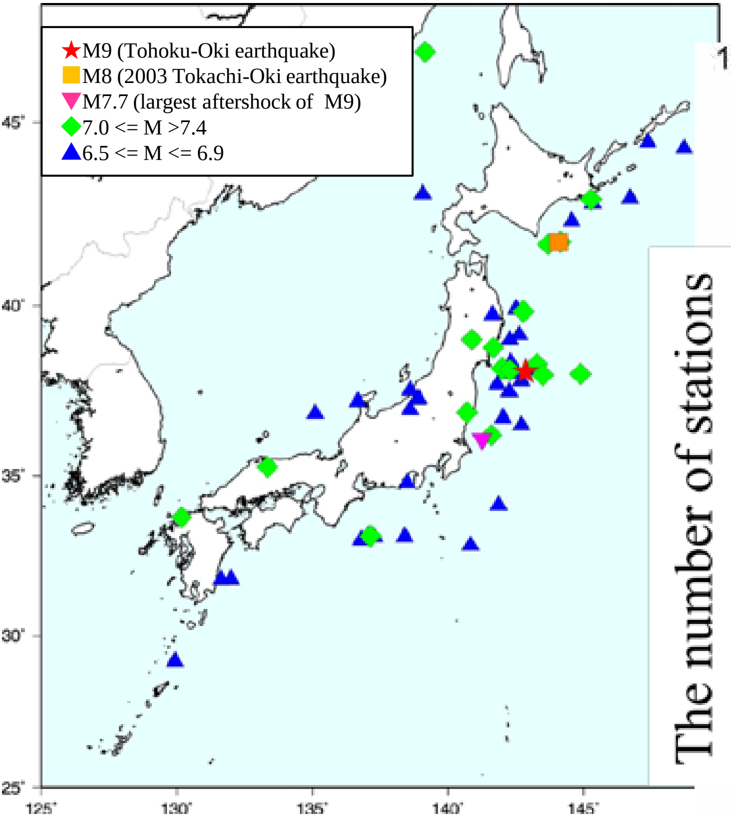
# Distribution of observation stations used for analysis

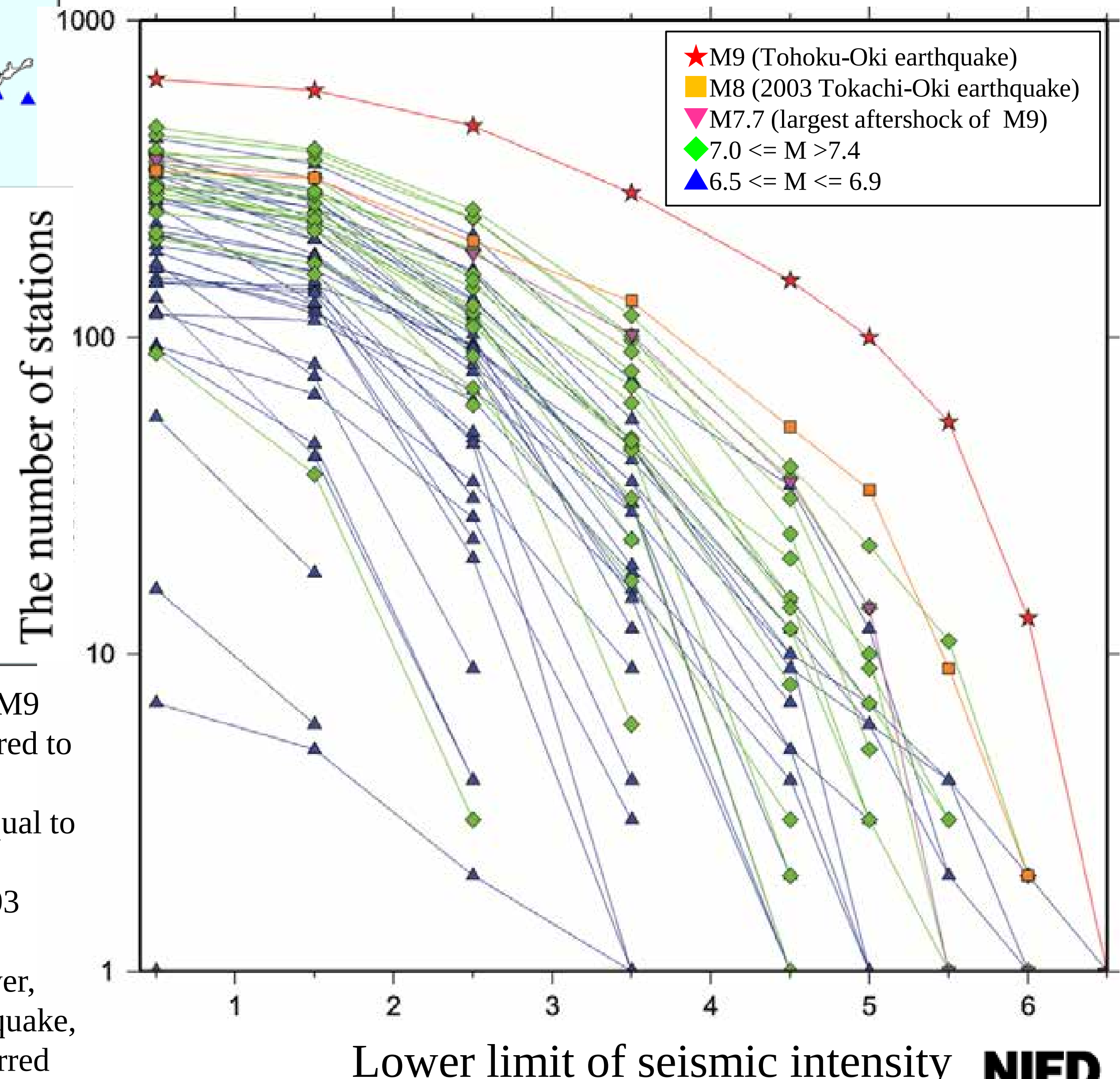



In order to make the distribution of observation stations uniform, we chose observation stations established as K-NET in 1996, with the exception of insular areas.

The spacing between stations is approximately 20 km.

# Counting results for M6.5 or greater




The number of observation stations in the M9 earthquake was exceptionally large compared to other earthquakes.

For instance, 151 stations with intensity equal to or greater than 5-lower during the M9 earthquake, compared to 52 during the 2003 Tokachi-Oki earthquake (M8).

For intensity equal to or greater than 6-lower, 54 stations were observed in the M9 earthquake, compared to 11 in the aftershock that occurred on April 7, 2011.

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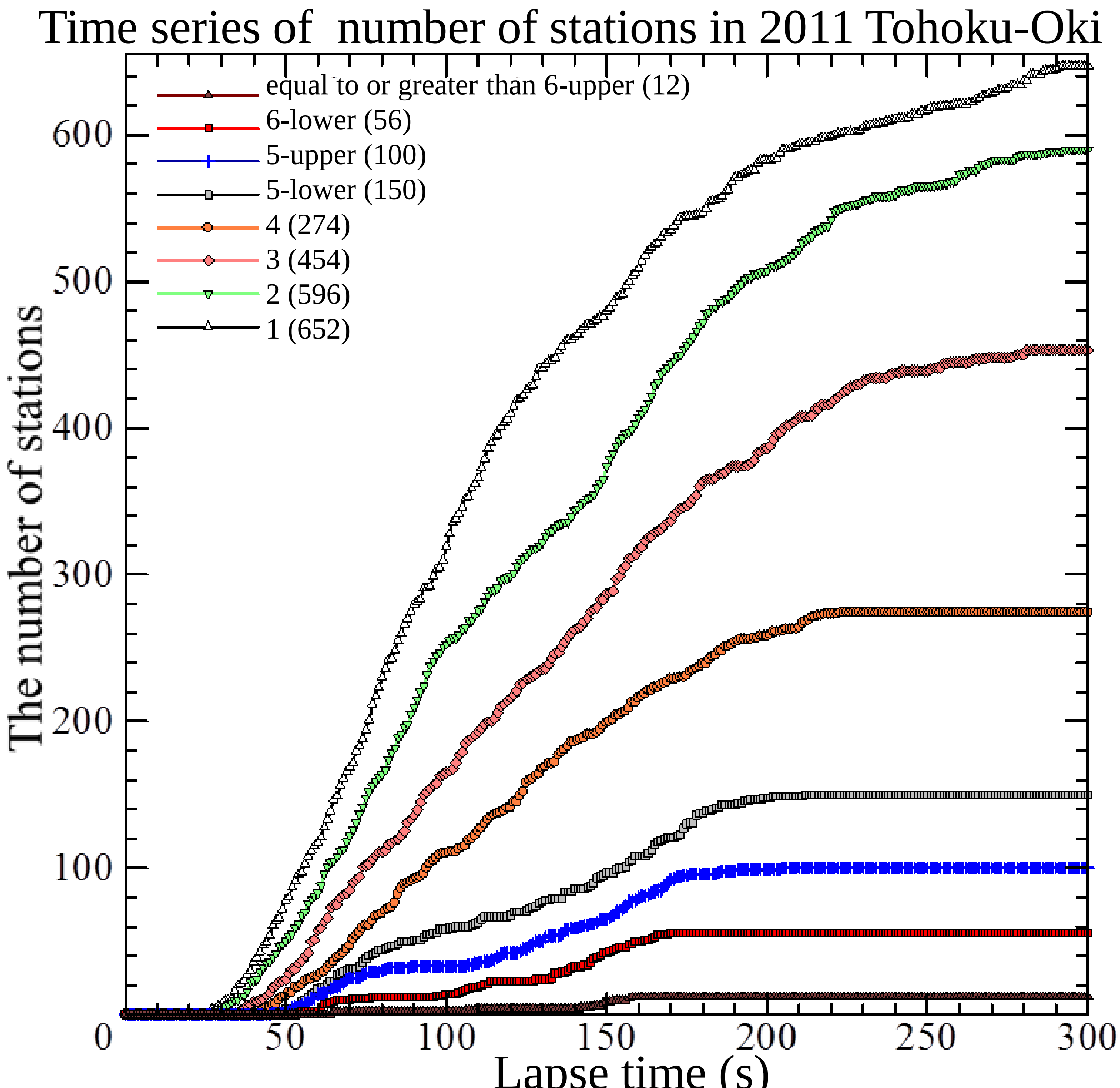
# Real-time counting is possible using real-time seismic intensity (Kunugi *et al.*, 2008)




The JMA seismic intensity is calculated based on one minute-long waveform data, so we cannot calculate intensity in real-time.

However using the real-time seismic intensity by Kunugi *et al.* (2008), it is possible to count the number of observation stations in real time.

An alert can be issued when the number of stations exceeds a threshold.

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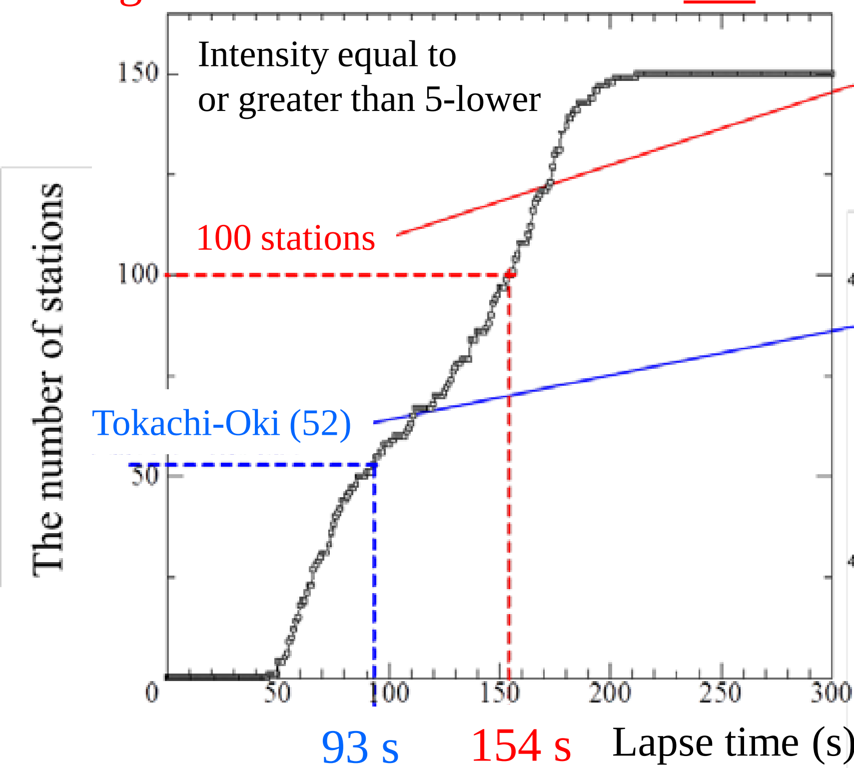
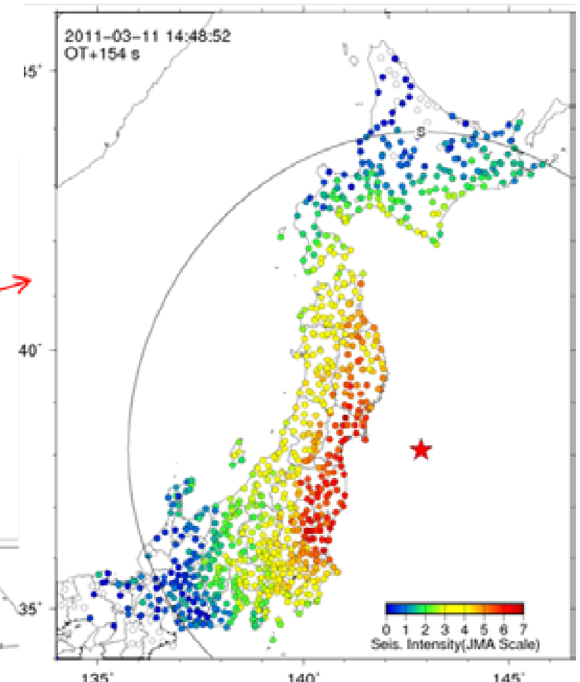
# Off-line analysis of detection based on real-time intensity monitoring

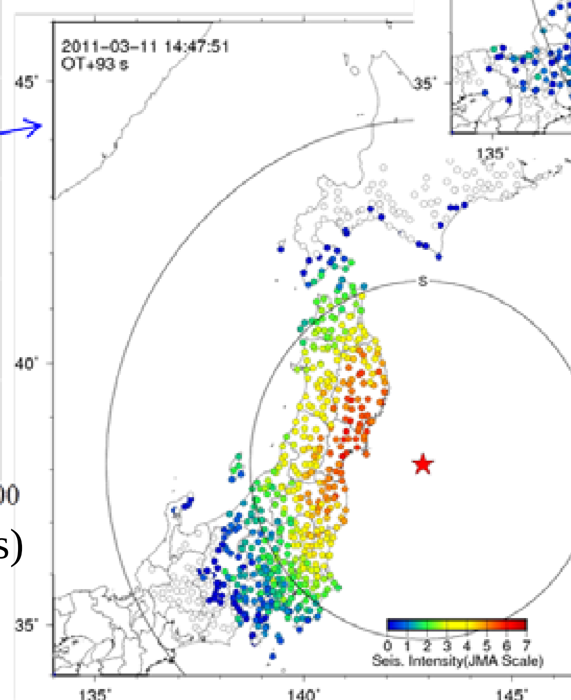
The example of the Tohoku-Oki earthquake

Detection pattern:

- If the number of observation stations with an intensity equal to or greater than 5-lower exceeds that (52 stations) of the 2003 Tokachi-Oki earthquake
- If the number of stations with an intensity equal to or greater than 5-lower exceeds 100




Since the alert is issued based on the spatial spreading of strong motions, the probability of overlooking a giant earthquake is extremely small

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# Improving warning information accuracy

## EEW

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

## Real-time monitoring of strong motion (e.g., **Counting method**)

**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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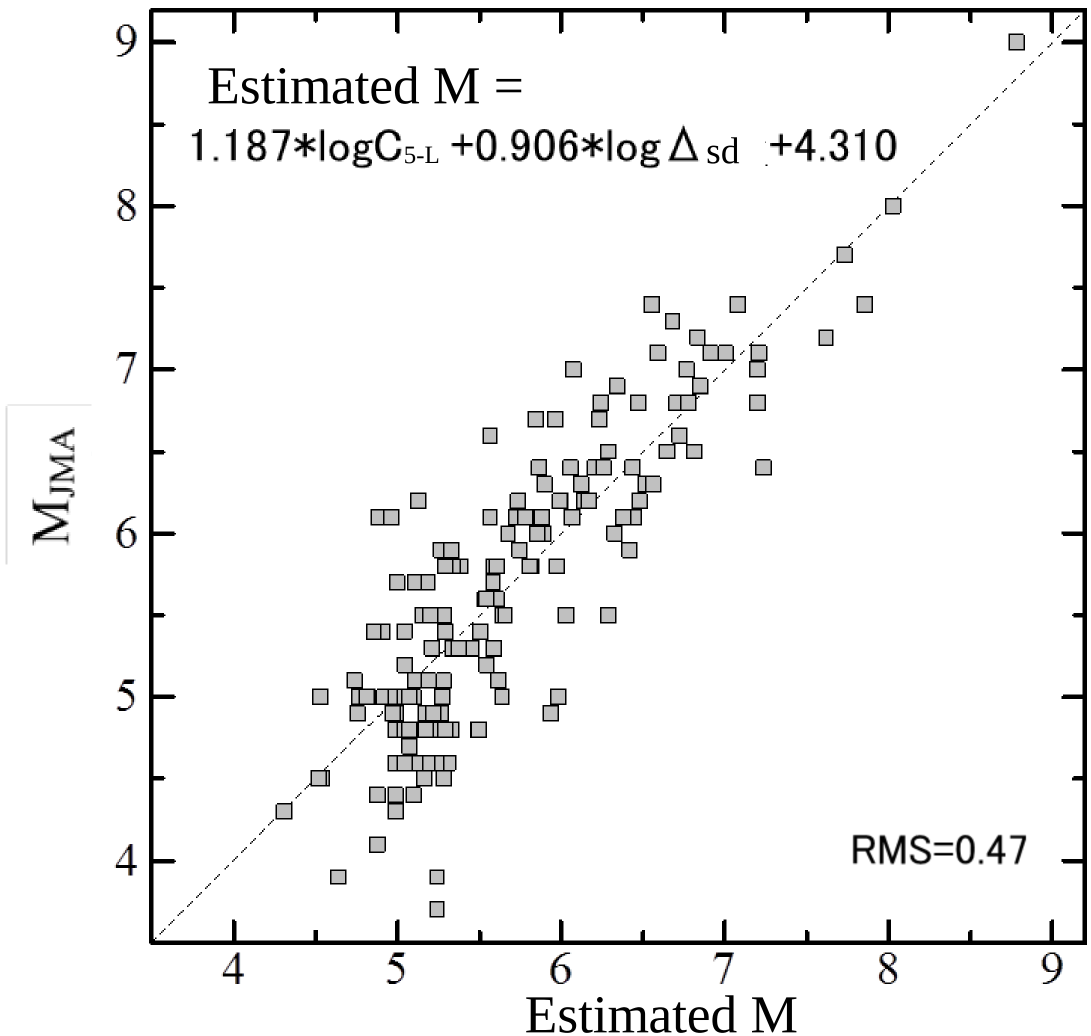
# Estimating M

- Number of observation stations with an intensity equal to or greater than 5-lower ($C_{5\text{-}L}$)
- Shortest observed epicentral distance ($\Delta_{sd}$)

For instance, using the hypocenter location information from the EEW




Data:
153 earthquakes that observed an intensity equal to or greater than 5-lower

# Conclusion

- The proposed approach is a simple method that consists of counting the number of observation stations. <u>The method is effective at detecting giant earthquakes that occur inland or relatively close to the coast.</u>
- This method is unique in <u>that it does not use any hypocenter location information.</u> <u>If the hypocenter location can be obtained</u>, however, it could be combined with the number of stations <u>to estimate the magnitude of a giant earthquake.</u>
- An additional advantage is the facility <u>to perform real-time monitoring</u> easily in combination with the real-time intensity calculation method by Kunugi et al. (2008).