Uncertainty of anticipation of seismic intensities -A study of fluctuation of anticipated seismic intensities by the method of current Earthquake Early Warning –

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Introduction

Earthquake Early Warning (EEW) started nationwide in Japan and became fully operational in October, 2007 (Hoshiba et al., 2008, Doi et al, 2008). In this method, the location of hypocenter and magnitude of earthquakes are determined as quick as possible, the seismic intensities at each place are rapidly anticipated, and a warning is disseminated if the anticipated seismic intensities surpass a certain threshold. Precise anticipation of seismic intensities, therefore, is important factor for EEW.

The seismic intensities are determined from source factor, path factor and site amplification factor. In the anticipation of the current EEW, source factor is represented by one scalar, that is magnitude, and site amplification is also by one scalar. We investigate how precise the seismic intensities are anticipated, and how large uncertainty should be expected in this situation.

Data

Seismic intensities are measured by scale of the Japan Meteorological Agency (JMA scale) in Japan, and are instrumentally observed from 1996. For JMA intensity scale, not only amplitude but also frequency and duration of the shaking are considered (Japan Meteorological Agency, 1996).The definition of seismic intensity is

$$I = 2 \log_{10}(a_c) + 0.94, \quad (1)$$

where I is JMA seismic intensity, and a_c is defined as the value which satisfies that total duration of $a(t) > a_c$ is 0.3 s. Here $a(t)$ is time series of vector amplitude of the three components of band pass filtered acceleration (measured in cm/s^2). Levels 1 and 5 on JMA scale approximately correspond to II and VIII-IX, respectively, on the modified Mercalli scale. At present approximately 4000 intensity meters are operated by JMA, local governments and National Research Institute for Earth Science and Disaster Prevention (NIED). In this analysis, we use the intensity catalog from 1996 to 2007.

For hypocenter and magnitude, the unified hypocenter catalog of JMA is used.

Analysis

Based on the method of current EEW, distributions of seismic intensities of two earthquakes are expected to be the same if the earthquakes occur at the same location with the same magnitude. In the actual data, however, the distributions are not always the same, and fluctuation of intensity is observed (Fig. 1a). The difference ranges from -1.2 to 1.5, and root mean square (RMS) of the difference is 0.80 for the event pair of Fig.1. For 100 pairs of adjacent earthquakes of the same magnitude, RMS is evaluated. Fig.2 shows the distribution of RMS, and the average of RMS is 0.41, which is an extent of the uncertainty of seismic intensity even when the earthquakes occur adjacently with the same magnitude. It suggests that we should expect this fluctuation in seismic intensity even if magnitude, path factor and site amplification factor are the same.

Differences of seismic intensities of two adjacent sites are expected to be the same for different earthquakes. In the actual data, however, the distributions are not always the same. Fig.3a shows example of distribution of the difference of seismic intensity. Even for the quite adjacent sites, fluctuation of intensity is observed. Because the average of the distribution corresponds to the difference of the site factors of the two sites, the RMS is evaluated after shifting the average. The

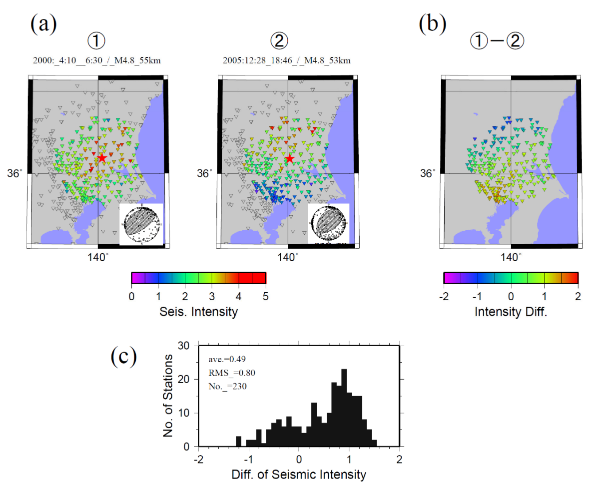

Figure 1. (a) Distribution of observed seismic intensities of two adjacent earthquakes of M4.8 occurred at Kanto, Japan, whose focal depth is 55 and 53 km, respectively. The color in the reverse triangles represents the observed seismic intensities. The open triangles without color indicate stations which are not used in this analysis. Focal mechanism obtained from polarity of P waves is also shown. (b) Distribution of the difference of the seismic intensity of the two earthquakes. The color represents the difference of the seismic intensity. (c) Histogram of the difference of the seismic intensity shown in Figure 1b. Average of the difference of the seismic intensity, RMS, and number of the data are shown in the upper left.

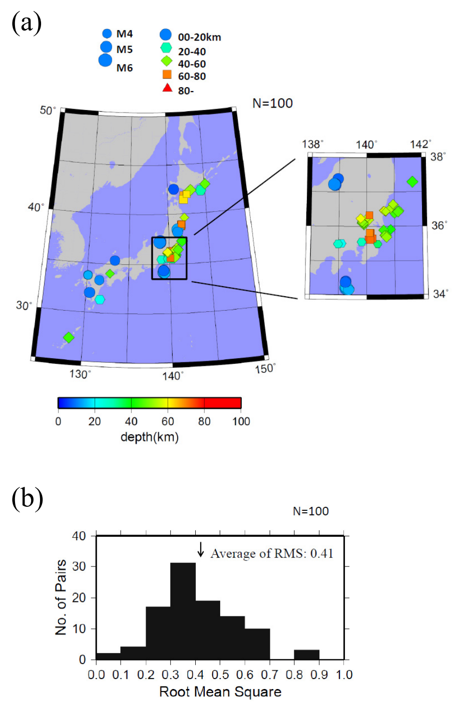

Figure 2. (a) Location of the 100 pairs of the earthquakes used in the analysis. (b) Histogram of the RMS of the intensity difference for the 100 pairs of earthquakes. The average of RMS is 0.41.

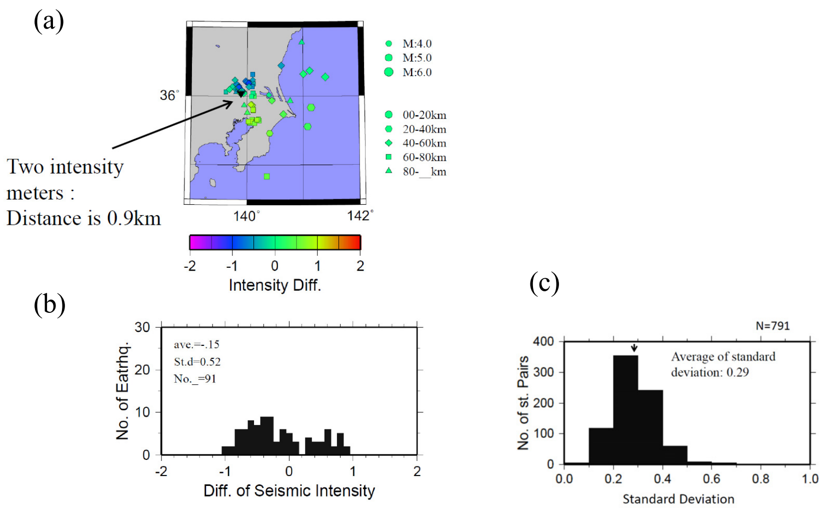

Figure 3. (a) Example of intensity difference distribution of earthquakes observed at a pair of adjacent sites at Kanto, Japan. Focal depth and magnitude of the earthquakes are represented by different symbol and its largeness, respectively. The color represents the intensity difference between the two sites. (b) Distribution of the difference of the seismic intensity of the two sites. (c) Histogram of the standard deviation of 791 pairs of sites.

standard deviation, that is RMS after substituting the average, is 0.52 for the station pair of Fig. 3a. For 791 pairs of adjacent sites, the average of the standard deviation is evaluated to be 0.29 (Fig.3b).

Conclusion

Because the RMS, or standard deviation, of the fluctuation is evaluated from the difference of two earthquakes or two sites, they should be divided by $\sqrt{2}$ for single earthquake or single site. The error of anticipated intensity is expected to be 0.29(=0.41/$\sqrt{2}$) for an event when using magnitude as the source factor. The error is expected to be 0.21(=0.29/$\sqrt{2}$) for a site. They are considered to be a limit of the anticipation of seismic intensity used in the current EEW.

Reference

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