# Earthquake Early Warning in Japan: Warning the General Public and Future Prospects

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## INTRODUCTION

The earthquake early warning (EEW) information provided by the Japan Meteorological Agency (JMA) is designed to enable public officials, key safety personnel, and the general public to take advance countermeasures against the effects of earthquake strong motion. The goal of the early warning system is to provide the maximum expected seismic intensity and the earliest *S*-wave arrival time in each subprefectural area (about a quarter to a third of one prefecture) before the strong motion arrival. For the system to be effective, it is essential that JMA publicize the principle and purpose of the warning messages, the technical limits of EEW, and the proper actions to be taken when a warning is received. This is particularly important given the very short warning times (a few to a few tens of seconds) so that EEW can be used effectively without causing unnecessary confusion. In this article we outline the design of the EEW system in Japan and the necessary preparatory process to start providing EEW information to the general public, summarize the performance of the system since it was launched nationwide in October 2007, and discuss future prospects for the system.

## DESIGN OF THE EEW SYSTEM

The parameters that the EEW must determine are the estimated origin time, the hypocenter location, the magnitude of the earthquake, the expected maximum seismic intensity (in the JMA intensity scale, http://www.jma.go.jp/jma/en/Activities/earthquake.html#S_I), and earliest arrival time (in seconds) of the strong motion for each subprefectural area.

In Japan, seismic intensity has been recorded by instruments designed specifically for this task (called "seismic intensity meters") since 1996. Seismic intensity meters observe seismic intensity at representative sites for the purposes of disaster mitigation (*i.e.*, in the middle of populated areas); the data they collect are not used for hypocenter and magnitude calculation. Seismic intensity is calculated from the maximum amplitude of the acceleration after a filter with $(1/f)^{1/2}$ amplitude response is applied in the frequency range from 0.5 to 10 Hz (JMA 1996). Physically, seismic intensity is proportional to the logarithm of maximum kinematic energy flow into the observation site per unit time. JMA has been issuing seismic intensity reports on the maximum seismic intensity distribution in each subprefectural area within two minutes after the earthquake occurrence when seismic intensity of 1 or over (in JMA scale) is observed. More detailed information (seismic intensity at each observation site) promptly follows this report. Although these are "post-disaster" reports, they have been used as trigger information to start emergency responses such as directing rescue resources to an area where strong motion was observed. To integrate strong motion disaster mitigation, EEW was developed to enable countermeasures *in advance* of the strong motion arrival. For EEW, seismic intensities are evaluated at about 4,000 seismic intensity meter installation sites throughout Japan. Estimation of the seismic intensity has three steps: 1) estimation of hypocenter, 2) estimation of magnitude, and 3) estimation of seismic intensity. The third step is itself composed of three steps: 1) estimation of the maximum velocity amplitude on engineering bedrock (Si and Midorikawa 1999), 2) multiplication by the amplification coefficient to account for the surface layer (Matsuoka and Midorikawa 1994), and 3) conversion from velocity to seismic intensity (Midorikawa *et al.* 1999).

The hypocenter is the starting point of the rupture and is fixed at the time the rupture starts. Whether the final size of the earthquake, *i.e.*, the magnitude, is predictable at the starting time of the rupture is controversial (*e.g.*, Iio *et al.* 1999; Nakatani *et al.* 2000; Mori and Kanamori 1996). Furthermore, a method that is applicable in the real-time processing environment to forecast the final size of the earthquake so that seismic intensity can be estimated to a socially acceptable precision has not been developed. Therefore, JMA does not "forecast" the final size of the earthquake by using the onset part of the seismic waveform. Instead, the growth of the rupture is monitored using the maximum amplitude in real time. To provide the

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