Review of Earthquake Early Warning Operation in Japan for eight years from 2007

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It has been about eight years since the Japan Meteorological Agency (JMA) launched a nationwide Earthquake Early Warning (EEW) service for the general public on October 1, 2007. We describe details of the JMA EEW system and review its performance and improvements.

 In the JMA EEW system, JMA seismic intensities in about 200 areas across the nation are predicted with hypocenter and magnitude estimated from several methods. EEW announcements are issued mainly based on predicted JMA seismic intensity. In order to assess EEW prediction accuracy, JMA reports annual EEW scores calculated from a percentage of areas where an error of predicted seismic intensity is within one degree (Figure 1).

 The EEW operation started with about 200 seismometers of a JMA network and 800 of a National Research Institute for Earth Science and Disaster Prevention (NIED) network. In fiscal 2007 to 2009, the EEW scores remained at a high level (Note that fiscal year begins in April and ends in March in Japan). On June 14, 2008, JMA issued EEW announcements for the Iwate-Miyagi earthquake (M7.2), which contributed to disaster mitigation in various sites such as an airport and a kindergarten. Until March 1, 2011, 12 new stations, most of which were installed in islands, and five new ocean-bottom seismometers (OBS) in Tonankai were incorporated in the system.

 On March 11, 2011, the 2011 off the Pacific coast of Tohoku Earthquake (the Tohoku earthquake) (M9.0) happened. An EEW warning was successfully issued for the Tohoku district, the nearest region from the epicenter, before S-wave arrival. The JMA EEW system worked well in Tohoku district, whereas the EEW system under-predicted seismic intensities of the Kanto district due to large extension of the rupture. After the Tohoku earthquake, highly-active aftershocks occurred and the system issued many warnings including false alarms. The score lowered down to 28% in fiscal 2010. Major causes for the false warnings fell into two factors: (1) confusion of multiple simultaneous earthquakes and a single large earthquake (2) lack of data from seismometers in disaster areas subject to blackout or disconnection of communication lines. JMA conducted improvement of an earthquake identification logic and reinforcement of the JMA seismometer network infrastructure. Owing to the countermeasures and decrease of the number of aftershocks, the number of false alarm decreased and the EEW score turned into an upward trend in fiscal 2011.

 In fiscal 2012, JMA introduced site amplification factors estimated from actual observation. The score reached 79%. However, on August 8, 2013, a false warning was issued for very wide range of areas due to contamination of abnormal data from one of the Tonankai OBS. It caused serious impact on economic activities such as stopping trains. JMA took some actions for its measures. The score temporarily fell to 63% in fiscal 2013.

 On March 31, 2015, the EEW system started to use 15 deep borehole seismometers (more than about 500 meters depth) of NIED, two OBS in DONET1 of Japan Agency for Marine-Earth Science and Technology (JAMSTEC) and 50 new JMA seismometers. JMA plans to utilize about 180 OBS of JAMSTEC and NIED and about 410 seismic intensity meters of JMA in the future after checking data quality New prediction methods are going to be implemented within a couple of years for measures of multiple

simultaneous earthquakes and a large rupture. Integrated Particle Filter (IPF) method is a new hypocenter determination algorithm with Bayesian estimation that can recognize occurrence of multiple simultaneous earthquakes more robustly. Propagation of Local Undamped Motion (PLUM) method is a new seismic intensity prediction algorithm based on wave field prediction with real-time observed seismic intensity instead of hypocenter determination.

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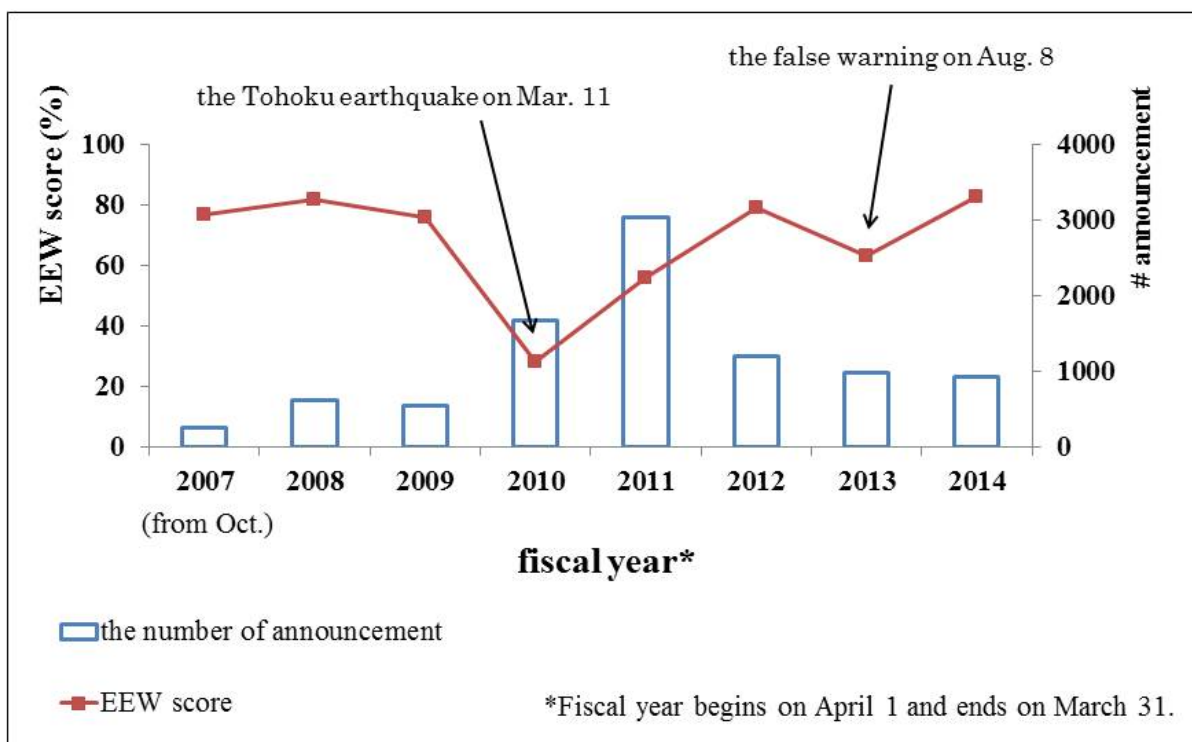   Undamped Motion method

Figure 1. A time series graph of JMA EEW scores and the number of EEW announcement from fiscal 2007 to 2014.