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Earthquake Early Warning system combined with real-time ground motion prediction

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We introduce a hybrid method which is a combined method of the current JMA EEW system and the simplest version of real-time ground motion prediction method. We also report applications of the hybrid method to some cases in which the current JMA EEW system underestimates or overestimates seismic intensity.

The current JMA EEW system (the conventional method) forecasts seismic intensity on the basis of hypocenter parameters estimated from observed seismic waveform. When accurate hypocenter parameters are determined in an early phase, forecast values of seismic intensity in all areas are calculated quickly and long lead times are available in many areas. On the other hand, if estimated hypocenter parameters are inappropriate, the conventional method leads to underestimation or overestimation of forecast values of seismic intensity.

Hoshiba (2013) proposes real-time ground motion prediction method as a method of forecasting ground motion without the use of hypocenter parameters. The real-time ground motion prediction method predicts wave field directly from observed wave field by a boundary integral equation for displacement. This method is expected to robustly forecast accurate ground motion because it utilizes actual wave field information. Forecast of JMA seismic intensity based on the real-time ground motion prediction method can be performed easily by the following algorithm:

(1) Gather real-time pseudo seismic intensities (Kunugi et al., 2013) of observation stations within a radius R from a target station.

(2) Take the maximum value of the real-time pseudo seismic intensities as a forecasted seismic intensity of the target station.

This is the simplest version of real-time ground motion prediction method. The algorithm assumes that a ground motion which causes large seismic intensity propagates within a radius R without attenuation. In this method, a lead time tends to be short because the area where actual wave field information is available is limited to a radius R.

The conventional method and the simplest version of real-time ground motion prediction method have complementary features on earliness and robustness. Therefore, appropriate combination of these methods is expected to become a hybrid method which has both earliness and robustness. We propose a hybrid method as follows:

(1) Take the maximum forecasted value of two methods in ordinary circumstances.

(2) Reject a forecasted value of the conventional method when the conventional method is not consistent with the real-time ground motion prediction method.

We set input data as real-time pseudo seismic intensities of JMA observation stations, output data as forecasted values of seismic intensity meters in Japan and radius R as 30km and apply the hybrid method to some previous earthquake events. In the case of the 2011 off the Pacific coast of Tohoku Earthquake, whereas seismic intensity scales of Kanto region the conventional method estimates are more than one degree smaller than actual, the hybrid method estimates them appropriately with an accuracy of about one degree. In the case of multiple events on April 3, 2011, the hybrid method can avoid overestimation of seismic intensity the conventional method leads to by qualify control of estimated hypocenter parameters of the conventional method. In the case of an earthquake in the northern part of Tochigi prefecture on February 25, 2013, forecasted seismic intensities of the conventional method are one or two degrees larger than actual although the conventional method estimates hypocenter parameters appropriately. The hybrid method also overestimates seismic intensity in consequence of the overestimation of the conventional method.

Reference:
Hoshiba, M. (2013), *J. Geophys. Res. Solid Earth,* **118,** 1038-1050.
Kunugi, T., S. Aoi, H. Nakamura, W. Suzuki, N. Morikawa and H. Fujiwara (2013), *Zisin 2,* **65,** 223-230. (in Japanese)

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