P-wave-based earthquake early warning without P-wave detection: Investigation of a P-wave-based PLUM algorithm

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Earthquake early warning (EEW) algorithms that predict ground motions directly from observation of the ongoing wavefield have been proposed to improve the ground motion prediction performance for complex scenarios such as large earthquakes (M>8) with non-negligible finite faults and multiple earthquakes that occur simultaneously (e.g., Kodera et al., 2018). The Japan Meteorological Agency (JMA) has introduced and been operating the Propagation of Local Undamped Motion (PLUM) algorithm (Kodera et al., 2018) in its EEW system since March 2018, and the PLUM implementation has led to several improvements such as the reduction of missed warnings. PLUM, which predicts future ground motion assuming that ongoing strong motions will propagate without attenuation within a short distance (30 km), has an advantage in that the algorithm can be implemented easily for an actual operational system; however, PLUM has a technical issue in that the algorithm would not provide long lead times because high seismic intensities could not be predicted until strong motions caused by S-waves are observed within 30 km from prediction points. To improve the PLUM timeliness, Kodera (2018) proposed a P-wave-based PLUM algorithm that uses S-wave intensities predicted from the corresponding P-waves. The proposed algorithm provides S-wave intensity predictions by (1) detecting P-waves continuously with the ground motion polarization and (2) predicting S-wave intensities if the detection algorithm declares P-wave, adding a constant value (1.0) to the UD-component of the real-time seismic intensities (assuming that the UD-component real-time intensity corresponds to the P-wave intensity). The prediction performance was influenced strongly by the P-wave detection capability. On the other hand, there were events where overprediction did not occur when the strong motion prediction with the UD real-time intensity was applied to entire time windows including S-waves. This implies that the strong motion prediction based on the UD real-time intensity could skip the P-wave detection process. In this study, we investigated an algorithm that predicts future strong motions using the UD real-time intensity without the P-wave detection process.

We tested the proposed algorithm with KiK-net stations for earthquakes from 2012 to 2019 with M>=6 and the maximum observed JMA intensity of >= 5-lower (~30 events in total). First, constant values added to the UD real-time intensity were obtained on a station-by-station basis, calculating the differences between the maximum UD and three-component intensities. The obtained values ranged from 0.5 to 1.5, and the majority were ~1.0. The standard deviation ranged from 0.1~0.3 for many stations, which means that the maximum intensities could be predicted within an error of 0.1~0.3 from the UD intensity. We found that the constant values were corelated well with the ratio of vertical and horizontal site amplification factors. We also evaluated available lead times by actually adding the constant values to the UD intensity.

If the intensity threshold was set to 4.5, the available lead times were ~1 to 3 s; for the intensity threshold of 3.5, the lead times were ~1 to 10 s. Those results indicate that future ground motions could be predicted effectively from the UD intensity by the proposed algorithm. For future tasks, we will conduct further investigation with other earthquake events and evaluation of more precise prediction accuracy and timeliness.

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