A wavefield-based ground motion prediction approach incorporating P-waves from the initial rupture: Toward the timeliness improvement of the PLUM earthquake early warning algorithm

*Yuki Kodera[1]

1. Meteorological Research Institute, Japan Meteorological Agency

Introduction

To issue accurate earthquake early warning (EEW) messages for M8+ earthquakes such as the 2011 Tohoku-Oki earthquake and the expected Nankai trough event, the Japan Meteorological Agency (JMA) has introduced and been operating the PLUM algorithm (Kodera et al., 2018) in its EEW system since March 2018. PLUM is an algorithm based on the concept proposed by Hoshiba (2013) that ground motion predictions can be made directly from observed shaking, without source characterization. The algorithm therefore exhibits high robustness for complex earthquake scenarios; on the other hand, PLUM has a shortcoming in that available lead times are short because PLUM uses intensity observations only within 30 km from a target site.

To improve the PLUM timeliness, Kodera (2018) developed an on-site algorithm that predicts S-wave intensities from the corresponding P-waves and proposed that the resulting on-site predictions can be used for PLUM' s input data. The study showed that the algorithm could detect P-waves from strong motion generation areas (SMGAs) that rupture with a certain delay and also could predict ground motions from those SMGAs if the algorithm continues trying to detect P-waves not only until the initial S-wave onset but also after that. However, the algorithm has difficulty in the implementation into an operational system because the calculation procedure requires some ideal conditions (the use of borehole sensors and the employment of a sophisticated site correction technique). Therefore, in this study, we developed and evaluated an algorithm that can be easily implemented and applied to many situations.

Proposed algorithm

We proposed an algorithm different from that of Kodera (2018) in the following points:

1) Input data: Although Kodera (2018) used borehole sensors with the site factor corrected, the proposed algorithm assumes ground-surface sensors without site correction. This modification would allow the JMA EEW system to benefit more from the proposed algorithm because the system is operated with many ground-surface stations.

2) P-wave detection: Kodera (2018) conducted the P-wave detection continuously; on the other hand, the proposed algorithm uses only the initial P-waves just after the station is triggered (i.e., when the observed intensity exceeds 3 on the JMA scale) to reduce the number of false P-wave detection.

Evaluation of the timeliness improvement by the proposed algorithm

We evaluated the algorithm mentioned above using event waveforms recorded at JMA intensity meters. Target events were earthquakes with M6.0+ and the maximum observed intensity of 5L+ in and around Japan from January 2000 to September 2019 (116 cases in total; 76 out of them were events in which a JMA station observed 5L+).

When simulated with the same parameter setting as in Kodera (2018) (i.e., a P-wave is declared if a P-filter value exceeds 0.4), the proposed algorithm improved warning issuance times for 18 events (~20%). Compared with theoretical limits of available lead times that could be provided by the perfect system (i.e., the time between the theoretical P-wave arrival and the appearance of 5L observation), the improved time

lengths were ~30% of the limits. We also quantified the prediction accuracy, the number of improved events, and the length of improved lead times, changing the P-wave detection threshold. We found that there was a trade-off relationship between the prediction accuracy and the number of improved events. With the P-filter thresholds of 0.2 to 0.6, the prediction accuracy and the number of improved events did not change drastically. The improved time lengths were almost constant and did not seem to depend on the P-filter threshold.

Conclusions

We found that the times from the earthquake detection to the warning issuance could be shorten by ~30% using the initial onset P-waves and ground-surface stations without site correction. On the other hand, the number of improved events was limited to ~20%; therefore, further studies would be needed to seek more effective algorithms that can be implemented easily and improve the timeliness substantially.

Keywords: Earthquake Early Warning, Nationwide Earthquake Early Warning in Japan, Ground Motion Prediction, Strong Motion, Wave Propagation, Automatic Detection

