Earthquake early warning using Numerical Shake Prediction based on wavefield estimation approach: Inland earthquakes and subduction earthquakes

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Earthquake early warning (EEW) is an alert of strong shaking before its arrival. Many of the present EEW systems quickly determine the hypocenter and magnitude (source parameters), and then predict strength of ground motions (peak ground acceleration, PGA; peak ground velocity, PGV; and/or seismic intensity) using ground motion prediction equations (GMPE). In this strategy, the source parameters are regarded as the causes of future strong shaking. EEW system of Japan Meteorological Agency (JMA) also had been based on the above source-parameters strategy. The 2011 Tohoku earthquake (Mw9.0), however, revealed some technical issues with such methods: under-prediction at large distances due to the large extent of the fault rupture, and over-prediction because the system was confused by multiple aftershocks that occurred simultaneously. To address these issues, we have proposed a new strategy for EEW (Hoshiba and Aoki, 2015), in which the distribution of the present wavefield is estimated precisely in real time (real-time shake-mapping) by applying a data assimilation technique, and then the future wavefield is predicted time-evolutionally by simulation of seismic wave propagation Here, we can directly monitor the propagation of ongoing ground shaking, and information on the hypocenter location and magnitude are not necessarily required. In this method, ground shaking itself is regarded as the cause of future ground shaking. We call this method, in which physical processes are simulated from the precisely estimated present condition, “numerical shake prediction” by analogy to “numerical weather prediction” in meteorology, in which present atmospheric condition (i.e., distribution of pressure, temperature, wind strength, wind direction and so on) are precisely estimated by data assimilation and then future is predicted from the time evolution of the atmosphere dynamics.

In the presentation, I will show the performances of the numerical shake prediction applied to waveform data of M6 class crustal earthquakes, the 2016 Kumamoto earthquake (Mw 7.0), and subduction earthquakes, such as the 2011 Tohoku earthquake (Mw9.0).

GMPE usually leads the prediction of concentric distribution. However, actual ground shaking is not always concentric, even when site amplification is corrected. The strength of shaking may be much different among earthquakes even when their hypocentral distances and magnitudes are almost the same, as shown in examples of M 6 crustal earthquakes occurred at central Japan. For some cases, PGA differs more than 10 times, which leads to imprecise prediction in source parameter-based EEW. In numerical shake prediction method, because future is predicted from the present condition estimated by data assimilation technique, it is possible to address the issue of the non-concentric distribution. Once the heterogeneous distribution is actually monitored in ongoing wavefield, future distribution is predicted accordingly to be non-concentric. We will indicate examples of the M 6 crustal earthquakes occurred at central Japan. We will also show the case of the numerical shake prediction for the 2016 Kumamoto earthquake (Mw 7.0), during which M 6 class earthquake was remotely triggered apart from 70 km from the epicenter (Figure 1). Many authors estimated that rupture duration of the 2011 Tohoku earthquake (Mw9.0) was more than 130 s. The numerical shake prediction predicts well the ground shaking from the late rupture which caused the under-prediction in source parameter-based algorithm.

Monitor of the propagation of ongoing ground shaking itself is a key for improving EEW technique.

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Reference:

Hoshiba, M. and Aoki, S., Numerical Shake Prediction for Earthquake Early Warning: Data Assimilation, Real-Time Shake Mapping, and Simulation of Wave Propagation, Bull. Seismol. Soc. Am., 105, 1,324-1,338, doi:10.1785/0120140280, 2015

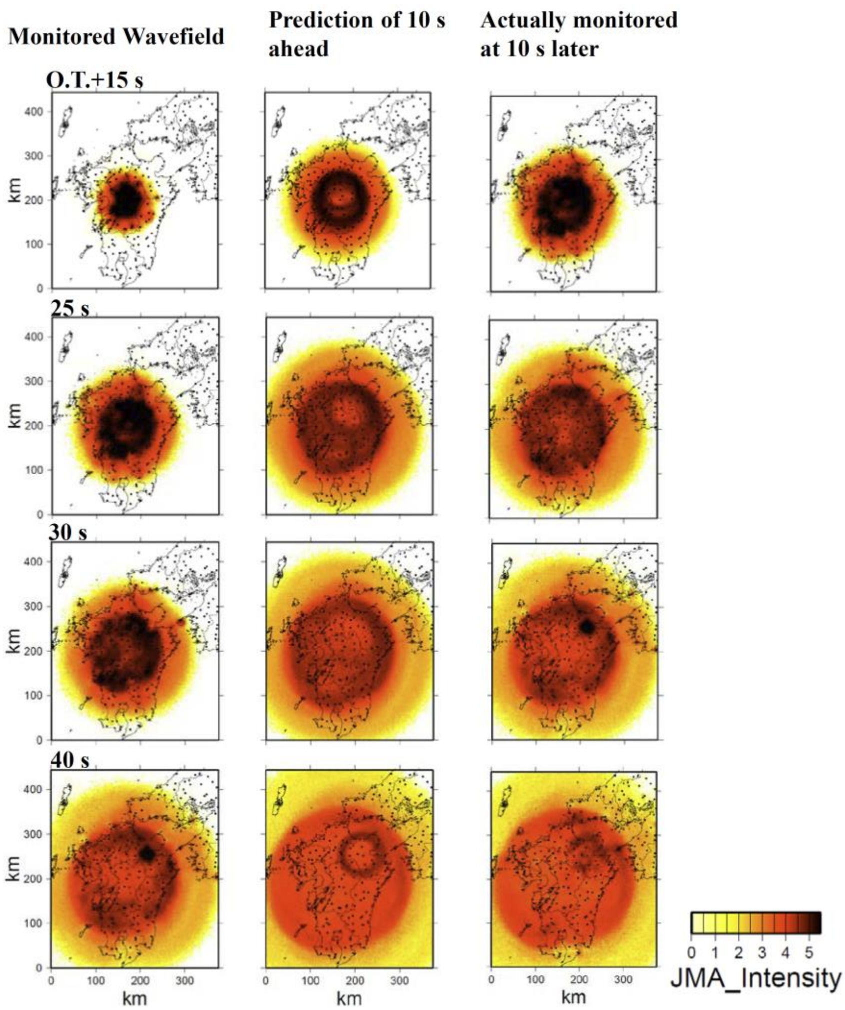

Fig. 1. Example of prediction of real-time ground motion of the M7.3 Kumamoto earthquake. During the earthquake, M6 triggered earthquake occurred at 35 s.