Data assimilation for real-time prediction of earthquake ground shaking: “Numerical shake prediction” for Earthquake Early Warning

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Real-time prediction of earthquake ground shaking is a strong tool for prevention/mitigation of earthquake disaster, and it has been applied for earthquake early warning (EEW). EEW has been operated for general public in Japan since 2007 and in Mexico since early 1990s, and possible use of such systems has been investigated in the United States, Taiwan, EU, Turkey, and other countries. Many of the present EEW systems first quickly determine the earthquake hypocenter and magnitude, and then they predict the strengths of ground shaking at various locations using the hypocenter distance and magnitude. The 2011 Tohoku earthquake (M_w 9.0), 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 propose a new concept for EEW, 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. 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. By applying the proposed method to the 2011 Tohoku Earthquake and the 2016 Kumamoto Earthquake (M_w 7.0), we show that numerical shake prediction can precisely and rapidly predict ground shaking in real time manner.
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Keywords: data assimilation, earthquake early warning, real-time prediction of ground shaking

