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Deviation from empirical relations - Initial several seconds and strong ground motion: tau_c, Pd, and spectrum -

Mitsuyuki Hoshiba[1*], Kazuhiro Iwakiri[1]

[1]Meteorological Research Institute

The strong ground motions were recorded at wide area of north eastern Japan. The amplitude of the Mw 9.0 is quite small for first several seconds, and its spectrum contains strong high frequency waves. For research of Earthquake Early Warning (EEW), several empirical relations are has been proposed, but large deviation is found from the empirical relations for the Mw 9.0.

Amplitude of initial several to several tens second: Pa, Pv and Pd are the maximum absolute amplitude of acceleration, velocity, and displacement, respectively, for the range between tp and tp+ tN, where tp is P wave onset time for each waveforms. For tN, 3, 4, 5, 10, 20 and 30s are used in this analysis. For tN=3-5s, Pa, Pv and Pd of the Mw9.0 are comparable to or even smaller than those of not only the Mw7.3 but also the Mw6 class earthquakes. This indicates that the initial amplitude do not suggest the large magnitude event.

Pd-PGV: Wu and Kanamori(2008) showed the correlation of Pd of first 3 sec and PGV(peak ground velocity), and proposed to use it for EEW. However, because the Pd of the first 3 sec is quite small for the Mw 9.0, it is difficult to anticipate the large PGV for the first several seconds.

tau_c-M relation: New algorisms, called tau_c, were proposed for estimates of eventual magnitude from the very early portion of waveforms using the frequency contents, and has been widely investigated by many researchers. Most of them concluded that the frequency contents are more sensitive to the magnitude than the ground motion amplitude in the initial several seconds of the P wave, and also claimed that the sensitivity is appropriate for EEW and it is possible to determine the eventual size of the events from the initial several seconds. However, there are some counterarguments against them. Discussion of the validity of the new algorisms of tau_c for estimates of magnitude is not yet well settled. tau_c of the Mw9.0 is comparable to or even smaller than that of not only the Mw7.3 but also the Mw6 class earthquakes for initial several seconds. This suggests that it is difficult to recognize to be larger than the Mw7.3 from only tau_c for initial several seconds.

Spectrum of waveform: Spectrum of Mw9.0 earthquakes contains strong high frequency waves, which is flat to the frequency of anti aliasing filter, and clear fmax is not found. Spectrum ratio of the Mw9.0 to the Mw7.3 foreshock shows that the dominant frequency is higher for the Mw9.0 than for the Mw7.3. This high frequency is the reason of the contrary to the expectation that tau_c increases with increasing magnitude.

Estimation of source rupture extent: Irikura et al.(2010) proposed a method to estimate the source rupture extent using ”more than 150cm/s/s for vertical component”, and Yamada(2010) also a method based on a criterion depending on ”f=4.36logPa+5.69logHv-19.97, in which f>0 corresponds to near source region”. For the Mw9.0, these indexes are satisfied for wide area of inland region of Tohoku and Kanto.

Summary: Our analysis indicates that updating procedure is necessary using ongoing waveforms for EEW, and we believe that the EEW should be robust even for the extraordinary case, especially for larger events.

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Keywords: The 2011 off the Pacific coast Tohoku Earthquake, Earthquake Early Warning, empirical relations, tau_c, Pd-PGV, Intitial several seconds