Real-time P-phase discriminator for earthquake early warning based on wavefield-estimation methods

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To improve prediction accuracy of earthquake early warning for large earthquakes (M>~8), wavefield-estimation methods have been recently proposed that predict ground motion directly from observed ground-motion wavefield without hypocenter estimation (e.g., numerical shake prediction (Hoshiba and Aoki, 2015); PLUM method (Kodera et al., 2014)). These methods, however, have room for improvement in rapid warning issuance since their prediction processes rely only on strong motion by S phase and do not utilize P-phase information available before the S-phase arrival. In this study, we introduce a simple real-time P-wave discriminator using on-site V/H to extract P-phase information and discuss the effectiveness of P- phase discrimination by simulating the PLUM method combined with the P-phase discriminator.

1. P-phase discrimination

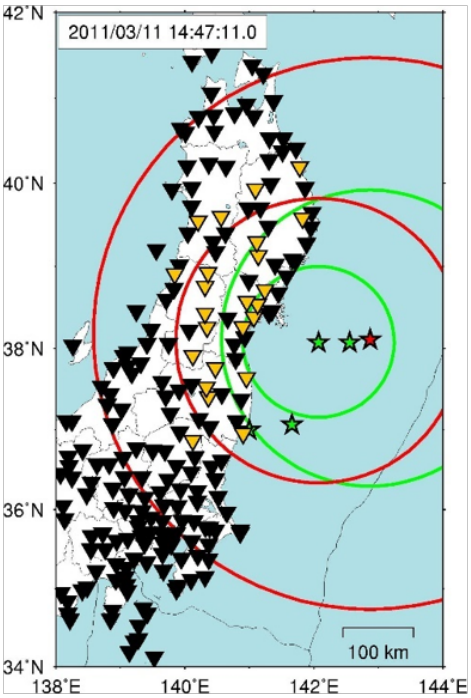
Many previous studies on P-phase discrimination use the polarity of particle motion (e.g., Ross and Ben-Zion, 2014). In this study, we focused on V/H (ratio of vertical to horizontal components of acceleration), which is easy to implement in a real-time system. The discriminator continuously calculates V/H independently of earthquake occurrences and declares P-phase arrivals when V/H reaches 1.0 or more. We tested this simple P-phase discriminator, applying to (1) the Tohoku-oki earthquake (Mw 9.0), (2) the Kumamoto earthquake (Mj 6.5), and (3) the Kumamoto earthquake (Mj 7.3). Results showed that the discriminator can clearly detect P phase of the initial part of the ground shaking in the all three events. Additionally, in (1), the discriminator recognized the P phase of strong motion generation areas (SMGAs) near the initial rupture point at some observation stations (Fig. a). In (3), the discriminator detected the P phase of the induced earthquake (Mj ~5.7) in Oita prefecture (Fig. b). On the other hand, there were some cases where the discriminator declared P-phase arrivals just after theoretical S wave arrivals, and the discriminator could not clearly recognize the P-phase of southern SMGAs near Fukushima prefecture, which may indicate the discriminator needs to be improved.

2. PLUM method with P-phase discriminator

We modified the PLUM method by combining with the P-phase discriminator. We used a statistical relationship reported by Yamamoto et al. (2008), which states that seismic intensities of P phase are roughly 1.0 less than those of S phase. The calculation processes of the modified PLUM method are as follows: (i) (on-site S-phase prediction using P phase) add 1.0 to real-time seismic intensities at observation stations where V/H is 1.0 or more. (ii) (prediction based on the original PLUM method) take the maximum of real-time seismic intensities among observation stations within 30 km from a target point. We applied the modified PLUM method to earthquakes (1)–(3), mentioned in section 1. The modified method provided longer warning times by 5 s in (1) and 1 s in (2) and (3) at the first warning issuances, compared with the original method. The final predicted seismic intensities of the modified method were comparable to those of the original method, which implies the on-site S-phase prediction did not cause serious adverse effects on prediction accuracy.

Keywords: earthquake early warning, P-phase discrimination, PLUM method, numerical shake prediction, SMGA, induced earthquake

(a) Tohoku-oki earthquake (Mw 9.0)



: initial rupture point (JMA hypocenter)

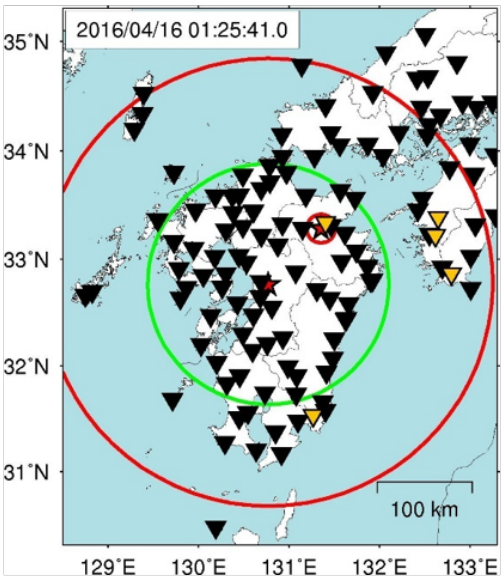
: SMGA (Asano and Iwata, 2012)

: theoretical P wave

: theoretical S wave

: station where $V/H \geq 1.0$

(b) Kumamoto earthquake (Mj 7.3)



: JMA hypocenter

: theoretical P wave

: theoretical S wave

: station where $V/H \geq 1.0$