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Near-real-time imaging of earthquake rupture by normalized short-period envelopes

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1. Introduction

After a great earthquake, real-time estimations of rupture area and locations of asperities are important to assess hazards due to tsunami and ground shaking. However, it takes long time to analyze source process by the waveform inversion. Aoki et al. (2010, SSJ) developed a method for near-real-time imaging of earthquake rupture by normalized short-period envelopes, and succeeded in depicting rough image of rupture process of the 2003 Off Tokachi Eq. (TKEQ). In this study, we apply our method to the 1994 Far E off Sanriku Eq. (SREQ), and evaluate the accuracy for location and timing of the rupture.

2. Method

Our method is based on the Source-Scanning Algorithm [Kao & Shan, 2007]. It is applied for identifying the rupture plane. The brightness of a grid point is calculated by summing the amplitudes of normalized envelopes with the correction of the S-wave travel times at all stations. The grid points are arranged not on the prescribed fault plane, but in the 3D source volume. The composite image of the brightness of all grid points illuminates the locations and timings of seismic rupture (e.g. asperity). The normalized short-period (5-10Hz) envelopes give us an advantage of reducing the effect of site amplification factors, radiation patterns [Kamae et al., 1990] and surface waves [Izutani & Hirasawa, 1987]. In addition, our method is robust to outliers because the brightness is defined as the average amplitude of all stations, and is suitable for real-time processing.

3. Application to the SREQ

We used 17 JMA 87-type accelerometers within 500km from the epicenter. The grid points were arranged in and around the aftershock area (200km (NS) x 400km (EW) x 90km (depth)) at 2km interval. The brightness of each grid was calculated for 120 sec after the initial rupture.

The maximum of brightness (0.89) was appeared at 54s, and its location was 129km in N83W of the epicenter, and the depth was 26km. This point was close to the high frequency source [Sato et al. (1996), 51s, 137km in N82W, and 49km depth], except for the depth with low resolution. In the brightness snapshots from 27.5s to 63.0s, the peak brightnesses exceeded 0.7. The trace of the peak brightness almost corresponded to that of large slip area estimated by the waveform inversion [Nakayama & Takeo, 1997].

In this study, data length must be more than 5 minutes after the origin time, and it took about 15 minutes of calculation by an Intel Xeon X5550 (2.66GHz). For the TKEQ, the data length must be more than 3.5 minutes, and the computation time was about 4 minutes. To reduce the computation time, we plan to investigate the proper number of the grid points and to modify the code for parallel computing.

4. Discussion

The brightness image is interpreted as a superposition of a real rupture image and a blurring effect, which is due to a gap of station distribution, rupture duration and a wave scattering. In this section, we evaluate the blurring effect on the basis of the brightness images of point-source-like aftershocks and synthetic envelopes.

We estimated the M5.0 aftershock near the asperity of the TKEQ by the same station distribution as the main shock. The maximum was appeared at 1.0s, the location was 18km from the epicenter. In the case of the M5.6 aftershock of the SREQ, the peak was appeared at 5.0s, the location was 6km away. In both cases, the grid points having more than 0.7 in the brightness were distributed within 55km in horizontal distance, and ranged from -10s to 10s in time.

We compare the images calculated by the synthetic envelopes with and without scattering effect. The scattering effect is evaluated on the basis of the theory by Saito et al. (2002). Consequently, the image with scattering effect was more similar to that of the real aftershock. These results show that our method was influenced by scattering effect and the image was broadened.

Keywords: Near-real-time processing, Source process, The 1994 Far E Off Sanriku Earthquake