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Estimates of stress drop in the focal area of the 2008 Iwate-Miyagi nairiku earthquake

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Earthquakes release the deviatoric stress in the earth by slip on faults. We can estimate the magnitudes of the shear stress reductions (stress drops) on the faults through frequency analysis of seismic wave. Stress drop is an important parameter in earthquake cycle. However, it is generally difficult to accurately determine the stress drop. This is because it depends on many assumptions, and the estimates are largely affected by the errors of the corner frequency. Therefore, meanings of stress drop variations are not well understood. One possibility is that stress drops may related to frictional strengths on the fault planes. Determinations of absolute frictional strengths are very difficult. However, we can estimate the relative strengths from fault plane orientations of focal mechanisms in homogeneous stress regions. In this study, we investigate the relationship between stress drop and frictional strength. For that, we apply a multi-window spectral ratio method of Imanishi and Ellsworth [2006] to data from the dense aftershock observation network in the aftershock area of the 2008 Iwate-Miyagi nairiku earthquake. In the focal area, the stress orientations were estimated by Yoshida et al. [2014a and b]. Furthermore, the deviatoric stress tensors in the focal area were also estimated based on the rotations of principal stress axis after the mainshock [Yoshida et al., 2014b].

We estimated stress drops for earthquakes listed in JMA catalogue with magnitudes greater than 1.0. First, velocity spectrums of S-wave were calculated for three time windows, whose lengths are 2s moving in steps of 1s from 0.2s before the S-wave arrivals. Also, the velocity spectrums of noise were computed from time windows before the P-wave arrivals. We omitted data with S/N $<$5.0 near their expected corner frequencies. Second, spectral ratios were calculated between events within 1 km. For the hypocenters, we adopted those determined by double-difference methods to arrival time data from the temporary stations above the focal area [Yoshida et al.,2014b]. Third, corner frequencies were estimated by fitting the stacked spectral ratios with omega-square source model by Boatwright [1978]. Again, we omitted the results for which we could not constrain the corner frequencies enough due to high residuals. Finally, we estimated the stress drops using the circular crack model of Sato and Hirasawa [1973] and Eshelby [1957].

The number of estimated stress drops was 761. The mean and median values are 5.1 and 4.5 MPa, respectively. Although estimated values of them scatter, we found a positive correlation between the stress drop and the focal depth. For comparisons with frictional strengths, we estimated the relative frictional strengths based on the four stress orientations estimated by Yoshida et al. [2014a and b] in various spatial scales. For the estimations, we assumed the uniform differential stress magnitude within the focal area. In all cases, we see the positive correlation between the stress drops and the relative frictional strengths. In addition, we compared the results with the absolute frictional strengths estimated by Yoshida et al. [2014b] based on the spatially variable deviatoric stress tensors. Again, we found a positive correlation of the stress drops with the frictional strengths. These suggest that static stress drop released by earthquakes is related to the absolute stress level on fault plane.

Keywords: stress drop, stress tensor inversion, frictional strength, focal mechanism