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Variability of high-frequency excitation patches estimated by strong-motion data for the 2011 Tohoku-Oki earthquake

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Using K-net and KiK-net strong-motion seismograms along the Tohoku-Kanto costal area, we characterize several notable high-frequency excitation patches for the 2011 Tohoku-Oki earthquake. We first obtained displacement seismograms with static offsets from the original acceleration waveforms recorded at K-net and KiK-net stations. For a baseline offset, we attempted several approaches, finding the correction scheme of Iwan et al. (1985) to provide us with stable and reliable displacement seismograms in all the three components.

The resulted seismograms show very large static components or steps over 5 m in some cases. For a given seismogram, there are several isolated steps in displacement, implying that there are patches to radiate these static or very low-frequency waves over the fault plane of this earthquake. The ratio of a static component to the strength of accelerations in each section of record in time (i.e., wavelet), however, varies significantly.

Considering the static component corresponding to the seismic moment (zero-frequency limit) at each patch, we measured its ratio of high-frequency and static components. We adopted the root-mean-square amplitude as a parameter for the strength of each record section, then it was divided by its static component or offset. We compared this ratio of one patch to that of the other.

The second large wavelet in each acceleration seismogram gives very low ratios, that is, static components are abnormally large, compared with the other wavelets, about one third in the radiation of high-frequency waves. Yoshida et al. (2011) located this wavelet in acceleration in the east of the epicenter, that is, a shallow part of the fault plane near the axis of the Japan Trench. Our result supports the idea that very smooth fault slips took place there, although it should not have been tsunami-earthquake type anelastic fault motions because there are still large excitations of high-frequency waves as high as 1 Hz.

We find a weak but clear delayed wavelet in acceleration only at the northernmost stations (north Iwate Prefecture) in our analysis. The ratios of high-frequency versus static component are as high as those of the first large wavelet in record, which was estimated in the location near the epicenter (Yoshida et al. 2011). That is, this northernmost patch radiates large high-frequency, suggesting strong local plate coupling in this area.

One additional wavelet that has not ever been analyzed in previous studies is a delayed one (nearly 2 minutes of the origin time) observed only in the southernmost stations in Fukushima and north Ibaraki prefectures. The ratios of high-frequency versus static components are even higher than the first patch by a factor of over 5. This implies a very strong patch that dominantly excited high-frequency waves without much total seismic moment there. This wavelet, which is composed of at least two separated parts in some records, seem to correspond to a spot off Fukushima coast identified by strong-motion array studies (e.g., Honda et al., 2011), which might be related to the asperities of a series of M7 Shioya-Oki earthquakes in 1938 (Abe, 1977).

In summary, there are various ratios of patches on the fault of the 2011 Tohoku-Oki earthquake, implying very complex nature of fault motions from place to place over the fault plane.

Keywords: 2011 Tohoku-Oki earthquake, excitation of high-frequency seismic waves, strong-motion accelerograms, static displacement