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Statistical properties of strong ground motions based on the spectral inversion method

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Studies to separate strong motion properties (source, path, and site properties) from Fourier spectra of observed strong motions by the generalized spectral inversion method have been attempted for several decades (e.g., Iwata and Irikura, 1986; Kawase and Matsuo; 2004). However, there is barely any research to separate strong motion properties using response spectra because the physical meaning of these properties in the separated response spectra is not clear. However, similarities are identified between acceleration Fourier spectra and the velocity response spectra, and so investigation using response spectra seems worth attempting. In addition the data used in Kawase and Matsuo (2004) was those observed from 1996 to 2002 for three nation-wide strong motion networks, namely, K-NET, KiK-net, and Japan Meteorological Agency's seismic intensity-meter network. Since then more than ten years have passed, and vast amount of data has been accumulated. Thus we separated and analyzed strong motion properties for both the Fourier and response spectra of strong motion data between 1996 and 2011 (with Mj 4.5 and over) and summarizes findings on newly obtained strong motion properties.

Strong motion properties separated from acceleration Fourier spectra agreed well with those by Kawase and Matsuo (2004) regardless of earthquake types and regions. The Q values tend to be more linear and stable than their results. The Q values of crustal earthquakes in Hokkaido were obtained for the first time. Site amplification properties show a good match with Kawase and Matsuo (2004). The source properties represented by the so-called Brune's stress drop were also not so significantly different.

The Q values from acceleration response spectra agreed very well above 1 Hz with those from the Fourier spectra. In contrast, different trends were observed below 1 Hz, where the Q values from response spectra showed linear frequency dependence. The site amplification properties matched well with those from Fourier spectra; however, many sites below 1 Hz tend to show a flat trend with high amplitude. As for the source properties, we compared source terms of the pseudo-velocity spectra with those from acceleration Fourier spectra. Basically levels were similar for frequencies higher than 1 Hz, but again data separated from response spectra again maintained a high value below 1 Hz. The differences below 1 Hz would be due to higher response spectral values by prominent peak amplitudes in Fourier spectra in the higher frequency range.

Source properties separated from acceleration Fourier spectra were statistically analyzed. We applied t tests to the Brune's stress drop estimates before and after the Off the Pacific Coast of Tohoku Earthquake of March 11, 2011, to realize that they were not significant for all earthquake scales and types. This means that there are barely any effects of the Off the Pacific Coast of Tohoku Earthquake on the stress drops of small earthquakes including aftershocks in the source region in Tohoku.

We also compared the short-period level A, which is one of the important indicators that determine the area of asperities in the so-called empirical Green's function method, with the generally used scaling relationships by Dan et al. (2001) and Satoh (2003). The obtained data was not considered to be the same as those by Dan et al. (2001), although the regression line for subduction-zone earthquakes is close to their work. The obtained distribution of the short-period level A was also tested against those by Satoh (2003) to find that the distribution for subduction-zone earthquakes and intraslab earthquakes can be considered as the same data; however, the data was not the same for crustal earthquakes because the standard deviation in our study was larger than that by Satoh (2003). On the other hand direct comparison of short-period level A with Sato (2003)'s results showed correlation coefficients higher than 0.8 for all earthquake types.

Keywords: response spectrum, strong motion properties, Q value, stress drop, short-period level A