Source model of the 2005 west off Fukuoka prefecture earthquake estimated from the empirical Green's function simulation of broadband strong motions

Wataru Suzuki and Tomotaka Iwata

Disaster Prevention Research Institute, Kyoto University, Gokasho, Uji, Kyoto 611-0011, Japan

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We estimated strong motion generation area (SMGA) source model which is responsible for broadband (0.2, 0.3–10 Hz) strong motions of the 2005 west off Fukuoka prefecture earthquake and its largest aftershock using the empirical Green's function (EGF) method. The estimated SMGAs are almost corresponding to the large slip area deduced by kinematic waveform inversion. The SMGA rupture for the mainshock propagated mainly upward and toward the northwest with rupture velocity of 3.15 km/s. The size of the SMGA follows the self-similar empirical formula of the asperity size derived by Somerville *et al*. (1999). The stress drop of the mainshock SMGA is calculated to be 10.7 MPa, which is larger than those of the largest aftershock SMGA and the aftershocks used as EGF.

Key words: Empirical Green's function method, broadband strong motion, source model, stress drop.

1. Introduction

At 10:53 on 20 March 2005, an M_J 7.0 (magnitude determined by Japan Meteorological Agency, JMA) earthquake occurred in the off-shore of the Fukuoka prefecture, northern Kyushu island, Japan. This event, the 2005 west off Fukuoka prefecture earthquake, was a crustal earthquake with left lateral strike slip (Fig. 1). There was little seismicity before this earthquake and this is the first time to record the JMA seismic intensity 6− since the observation had started for this area. Several kinematic waveform inversion analyses have revealed the slip distributions in detail using strong motion records (e.g. Asano and Iwata, 2006; Horikawa, 2006; Kobayashi *et al*., 2006; Sekiguchi *et al*., 2006). In these analyses, the frequency band is limited to lower than 1 Hz because precise information of underground structure is necessary to construct numerical Green's function to synthesize the higher-frequency ground motions. On the other hand, the empirical Green's function (EGF) method, which uses records of a small earthquake as Green's function, is able to provide realistic ground motions including high-frequency component. In order to investigate the source characteristics that are responsible for strong motions up to higher frequency, we estimated the strong motion generation area (SMGA, Miyake *et al*., 2003) from broadband (0.2–10 Hz) strong motion simulation using the EGF method proposed by Irikura (1986).

SMGA is a rectangular area with no explicit heterogeneities of slip, stress drop and rupture velocity inside it (Miyake *et al*., 2003). This simple source model has successfully been applied to explain broadband ground motions of many large to moderate-sized earthquakes. The SMGAs roughly correspond to the large slip areas on the fault deduced by kinematic inversion in studies of the recent destructive earthquakes (e.g. the 1994 Northridge earthquake, by Kamae and Irikura, 1998a; the 1995 Hyogo-ken Nanbu earthquake, by Kamae and Irikura, 1998b; the 2000 Tottori-ken Seibu earthquake, by Ikeda *et al*., 2002). More quantitatively, Miyake *et al*. (2003) showed that the SMGA corresponds to the asperity area which is characterized from slip distribution according to the criterion by Somerville *et al*. (1999) for three moderate-sized crustal earthquakes. Since important characteristics of broadband ground motions can be explained by large slip or large slip-velocity regions on ruptured fault as shown in studies presented above, the concept of the characterized source model used for strong motion prediction has been developed. We, therefore, analyze the SMGA, not only for illustrating the source physics, but also for advancing and testing the source model for strong motion prediction.

A month after the mainshock, the largest aftershock (M_J 5.8) occurred at the southern edge of the total rupture area of the mainshock inferred from kinematic inversion and aftershock distribution. We also estimated the SMGA and compared its source characteristics with respect to the mainshock.

2. Estimation of SMGA for the Mainshock

2.1 Data and analysis procedure

For the waveforms of the 2005 west off Fukuoka prefecture earthquake, the P-wave amplitudes of the first arrival phases ($P1$) are small and larger phases ($P2$) arrived a few seconds later. Horikawa (2006) estimated that the main rupture started 3.6 km to the southeast and 4 km deeper than the hypocenter 3.3 s after the origin time from the $P2-P1$ arrival time differences. Sekiguchi *et al*. (2006) did a similar analysis and found the starting point of the main rupture was located 4 km along the strike and 1 km along the down-