High-frequency earthquake radiation inferred from strong motions: Constraints from a dynamic model and empirical Green's tensors

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Simple dynamic crack models have theoretically demonstrated that strong variations of the rupture velocity at the crack boundaries (stopping phases) play a very important role in the radiation of high frequency (HF) from the source. For large earthquakes, strong heterogeneity in rupture velocity during the fault rupture progression may have a strong influence on the HF generation across the fault plane.

To address this problem we have investigated a spontaneous dynamic fault rupture process of the 2000 Western Tottori prefecture earthquake (Japan), by using a 3D-FDM scheme coupled with a slip weakening fault-friction law. The dynamic model parameters are constrained by the final slip and stress time histories obtained from a kinematic model. In order to infer the HF from our dynamic model we calculate the gradient of local rupture velocity across the fault plane and multiply it by the dynamic stress drop distribution obtained from the dynamic model. This product gives an indication of the HF radiation as it represents the flat level of far-field radiated acceleration Fourier spectra (FFS) for a crack model. Calculation of this product across the fault plane for the Tottori earthquake suggest that HF is radiated from regions where a large rupture velocity gradient is overlapped with a strong dynamic stress drop. Regions in the fault with an uniform rupture do not radiate HF, even when accompanied by an important stress drop.

In this paper we infer the source HF radiation directly from near-fault strong ground motion recordings. For this purpose we calculate HF ground motions as an incoherent rupture of cracks evenly distributed accross a finite fault plane. Rupture times of every crack are constrained by results of the dynamic model. HF ground motion contribution from each crack at every site is obtained by convolving an Empirical Greens Tensor Derivative (EGTD), to accurately account for propagation path, with the slip velocity function at each crack. For this purpose we use the slip velocity functions obtained from the dynamic model at each crack location by modifying their acceleration Fourier spectra amplitude to allow for a variable FFS and fmax. These two parameters describe the HF radiation, and are obtained by a GA inversion scheme that optimize the agreement between simulated and observed ground motions at all available nearfault KNet and Kiknet recordings. EGTD are obtained from a set of clustered weak events with known focal mechanism by solving a system of linear equations in the frequency domain. EGTD accurately describe an average propagation path between each station and a focal zone corresponding to large slip regions across the mainshock fault plane.