High Frequency Radiation Mechanism from Dynamic Models of Fault Rupture

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The study of high frequency radiation (HF) of large earthquakes have been traditionally investigated by using kinematic models of the source. Some of these studies locate the radiation of high frequency near boundaries of large slip regions (Zeng et. al. 1993, Kakehi et. al. 1996a, 1997; Nakahara 1999, 2002), while others locate the HF radiation overlapping regions of large slip or near fault plane discontinuities (Kakehi et. al 1996b). However, a major limitation of all these studies is the over-simplification of the physical parameters involved in the rupture process such as the assumption of a nearly constant rupture velocity across the fault plane. Simple dynamic crack models have theoretically demonstrated that local variations of the rupture velocity play a very important role in the radiation of high frequency from the source (Madariaga 1977, 1983).

In the present study we investigate the HF radiation of the 2000 Tottori earthquake (Japan) in two steps: First we perform a spontaneous fault rupture dynamic simulation of the 2000 Tottori earthquake, by using a 3D-FDM scheme coupled with a slip weakening fault-friction law. Dynamic rupture parameters are constrained from results of a kinematic source model from previous studies. The dynamic model is improved by trial and error in order to optimize the agreement to the final slip of the kinematic model. In the second step we calculate the HF ground motions at target stations from a semi-stochastic approach based on a incoherent rupture of sub-events modeled as cracks. Rupture times of sub-events and the flat level of acceleration Fourier spectra are constrained by results of the dynamic model. We investigate the HF source radiation, represented by a heterogeneous stress drop distribution, by optimizing the agreement between observed and simulated near-fault acceleration waveforms (RMS envelopes) and the flat level of acceleration Fourier spectra. For this purpose we apply a parallel GA inversion scheme. In order to effectively constraint the HF inversion, we correct the observed waveforms by their respective site effects and Q, obtained from a spectral inversion technique (Moya et. al 2003), to 55 aftershocks of the Tottori earthquake.

Results from our dynamic model as well as inversion of HF near fault ground motions show that HF radiation originates within regions of large slip (asperities), where fault rupture velocity experiences a very strong change; The coincidence of a strong rupture velocity gradient and a large dynamic stress drop within asperities could be responsible for most of the HF ground motion radiation from the source (Figure 1). This mechanism could be explained because of the delayed break of a strong barrier above the hypocenter of the Tottori earthquake, that produces a sudden rupture velocity increase as well as a large dynamic stress drop. On the other hand regions in the fault plane with an uniform (smooth) rupture do not radiate HF, even if they have an important stress drop (i.e. see region south-east from the hypocenter in figure 1).

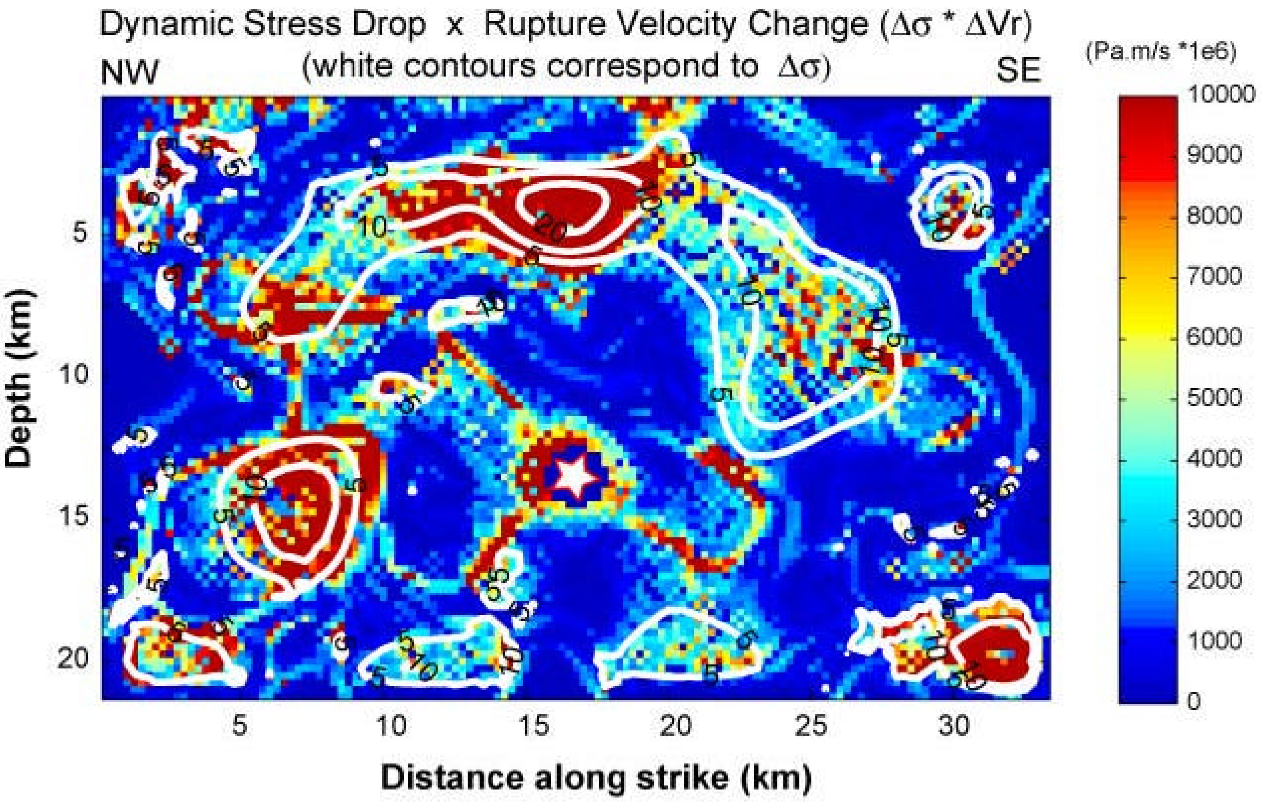

Figure 1. Product of the rupture velocity gradient and dynamic stress drop from dynamic model, as a measure of the HF radiation during the 2000 Tottori earthquake.