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Dynamic Fault Rupture constraints to High Frequency Radiation of Crustal Earthquakes : The role of Rupture Velocity and Dynamic Stress Drop

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Abstract

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 (Kakehi et. al. 1996a, 1997; Nakahara 1999, 2002, Zeng et al. 1993), while others locate the HF radiation overlapping regions of large slip or near fault plane discontinuites (Kakehi et al. 1996b). However a major limitation of all this 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).

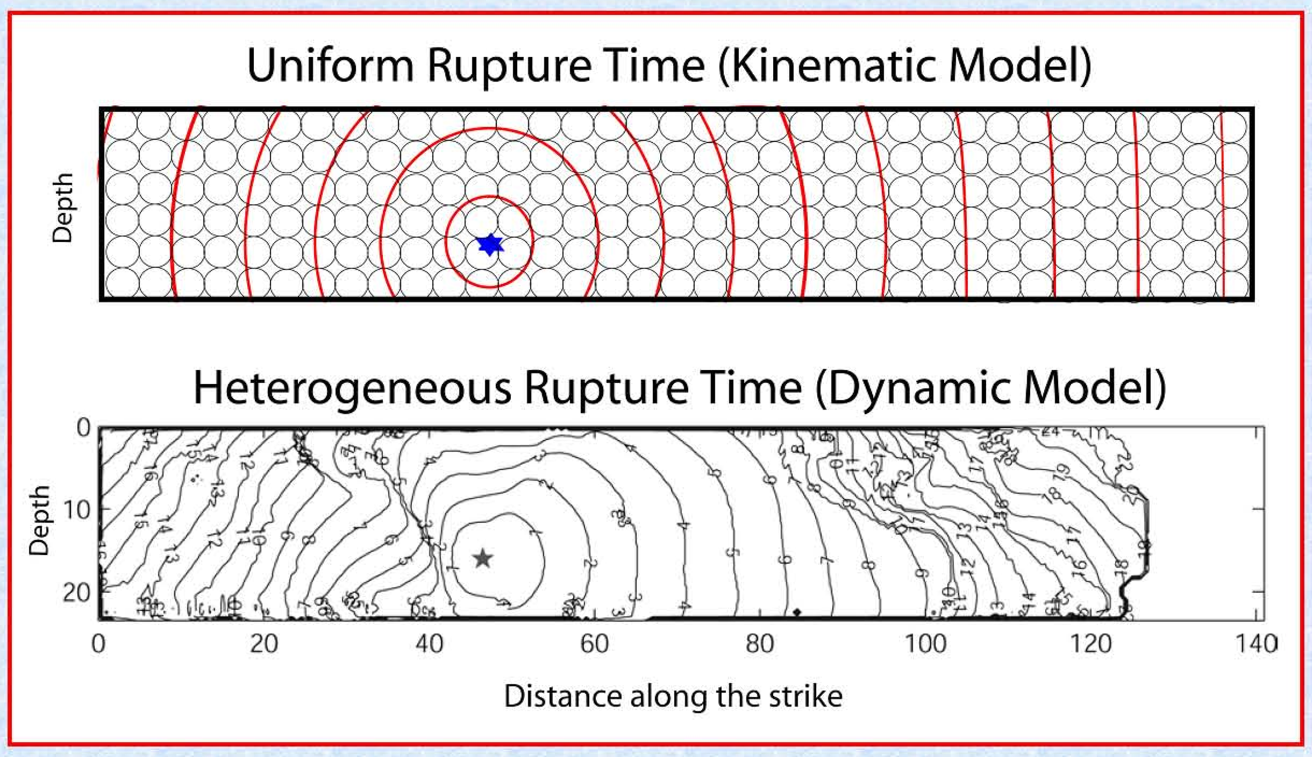
In the present study we investigate the HF radiation of the 2000 Tottori earthquake (Japan) in two steps: First we perform a spontaneous fault rupture dynamic simulation of the 2000 Tottori earthquake, by using a 3D-FDM scheme coupled with a slip weakening fault-friction law. Dynamic rupture parameters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

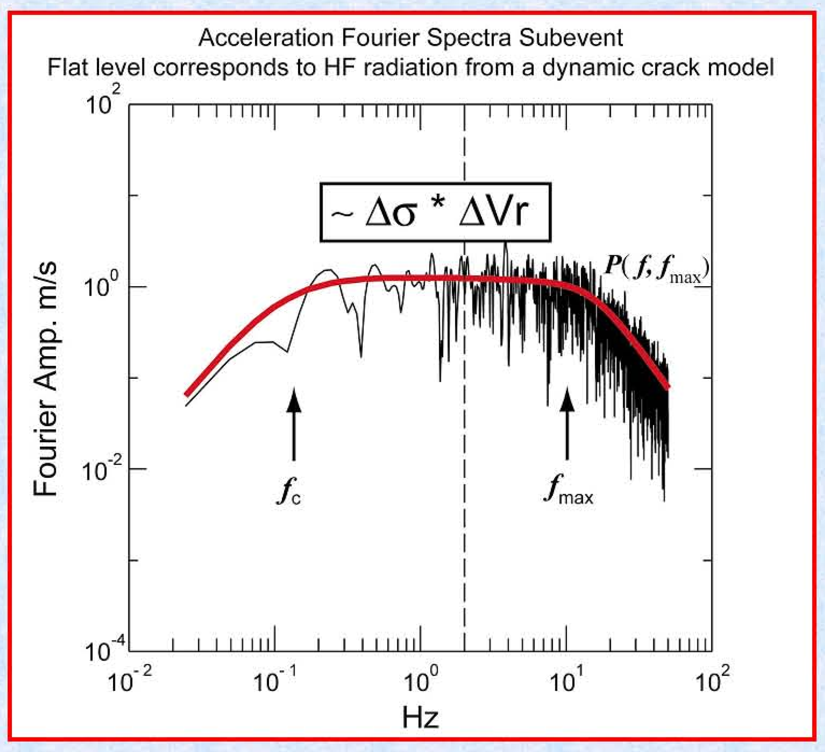
Preliminar results show that the high frequency radiation from the source is determined by a complex relationship between the rupture velocity change, and the dynamic stress drop. In our model HF radiation is mainly radiated from inside asperities, in regions with a strong rupture velocity gradient and moderate to high dynamic stress drop.

I Ground Motion Simulation Methodology

The high frequency ground motion (2 to 32Hz) is obtained by an incoherent summation of point sources (sub-events) (Irikura 1986) to obtain the ground motion from a finite fault.

Rupture time and flat level of acceleration Fourier spectra of sub-events are constrained by a dynamic fault rupture model





Acceleration Fourier spectra of subevents (HF radiation from a dynamic crack model)

$$a_{ij\theta\phi}(f) = \frac{R_{pij}(\phi_s, \delta, \lambda, \theta, \phi, f) F_s \Delta V_r \Delta\sigma \, r_c P(f, f_{\max})}{\rho \beta^2 R_{ij}}$$

Decay of high frequencies above *fmax*

$$P(f, f_{\max}) = \frac{1}{\left[1 + \left(f / f_{\max}\right)^c\right]^d}$$

- **Δσ** : Dynamic stress drop (model parameter of HF inversion)
- **ΔVr** : rupture velocity change (from dynamic model)
- **Rc** : radius crack

Attenuation and Site Effect terms are not included

Rupture Velocity Gradient

The spatial change in rupture velocity can be obtained by calculating the gradient of the inverse of slowness (***u***), which can be obtained as the gradient of the rupture time from the dynamic model as follows:

$$u = \nabla t = \frac{\partial t}{\partial x}\hat{i} + \frac{\partial t}{\partial z}\hat{k}$$

$$\nabla V_r = \nabla(1/u)$$

Modified Empirical Green's function method

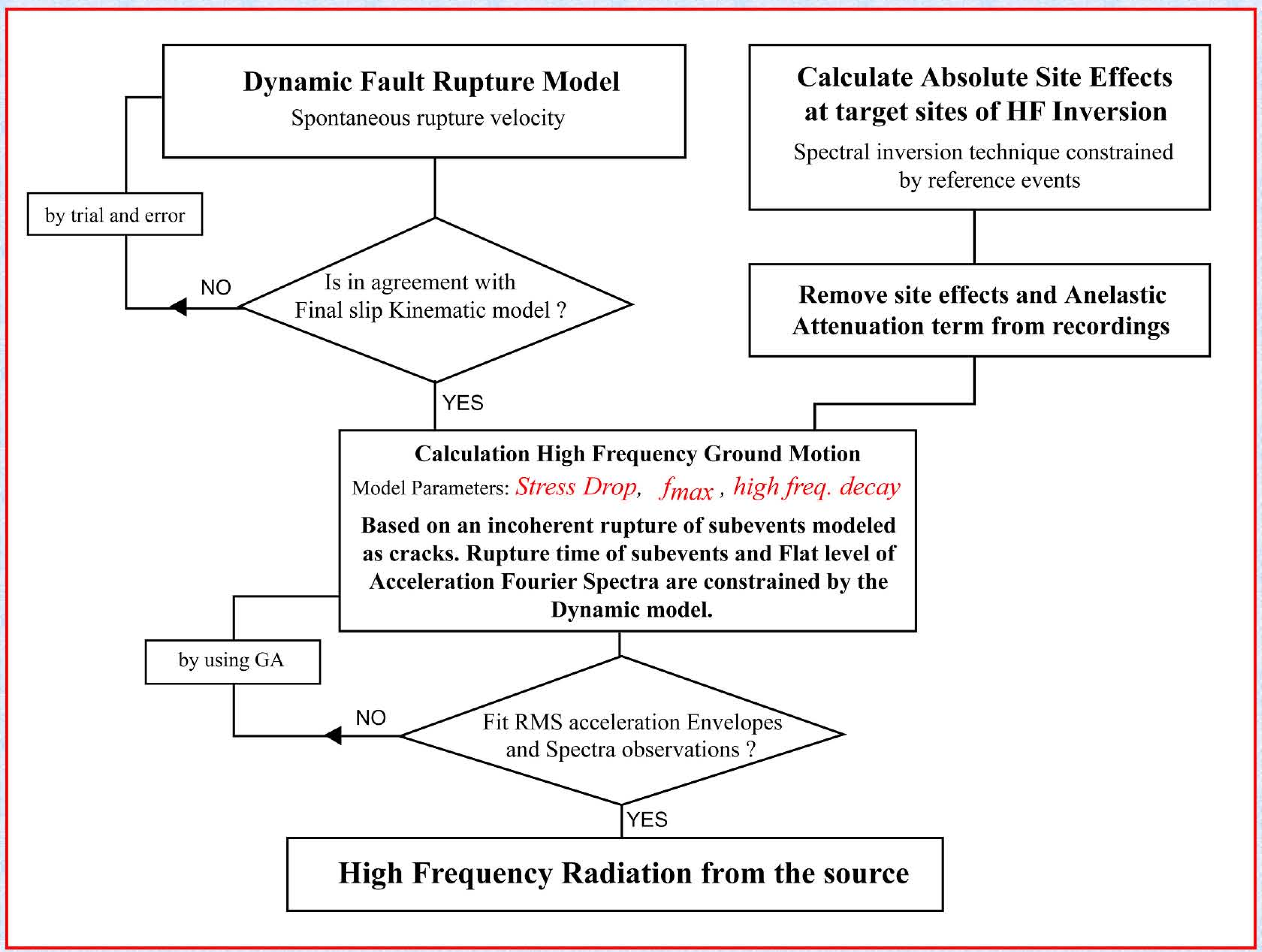
A specific green's function for every subfault and site is calculated. The rupture time of subevents t_{rup} is provided by a dynamic model.

$$A(t) = \sum_{i=1}^{N}\sum_{j=1}^{N} F(t - t_{ij}) * a_{ij\theta\phi}(t)$$

$$t_{ij} = \frac{r_{ij} - r_0}{\beta} + t_{rup}$$

$a_{ij\theta\phi}$: point source acceleration waveform at subfault (ij) and site θϕ.

II High Frequency Radiation Estimation Flow Chart



Dynamic Fault Rupture Model

Dynamic simulation is implemented by a 3D-FDM scheme combined with a slip weakening fault friction law. Dynamic model parameters are constrained by a kinematic model of the source.

Site Effects

We calculate site effects and Q by applying a spectral inversion technique that provide "absolute site effects and do not require the assumption of a reference site. The inversion is constrained by assuming an omega square model and providing the seismic moment for a group of aftershocks.

High Frequency Inversion

We apply a GA scheme to optimize the agreement to observed rms acceleration envelopes and flat level of acceleration Fourier Spectra.

High frequency Parameters for Inversion

Stress Drop distribution: $\Delta\sigma_i$ of subevents

High frequency decay: f_{max}, c, d $1 / [1+(f/f_{max})^c]^d$