Geophysical Research Abstracts, Vol. 7, 08789, 2005
SRef-ID: 1607-7962/gra/EGU05-A-08789

Combining k-square and fractal source models for modeling broadband accelerograms

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The k^{-2} kinematic model proposed by Bernard et al. (1996) is attractive because it allows generating realistic broadband accelerograms using heterogeneous slip and rupture process. Furthermore, the synthetics are valid for any distance and fault-station configuration, and the directivity effect introduced is equal to the directivity factor, C_d.

The slip velocity functions generated by the k^{-2} model (with a scale-dependent rise-time) are analyzed to define their main characteristics and are compared with the dynamic modeling solutions (decay proportional to $t^{-1/2}$, e.g. Nakamura and Miyatake, 2000). We found that the slip velocity functions are characterized by a stochastic spatial behavior with a mean slip velocity corresponding to a boxcar function. Moreover, we identified a few zones on the fault plane with unphysical behaviors (i.e. negative slip), generally related to weak slip amplitudes. In order to obtain more realistic solutions, we tested different approaches: (1) developing a new numerical scheme for the k^{-2} model, (2) adding a correction to the slip at each wavenumber k in order to obtain only positive contributions, (3) decomposing the slip using an elementary dislocation shape.

This latter approach led us to propose a new hybrid method combining the k^{-2} and fractal source models. The final dislocation is generated using a composite source model with a fractal distribution of sizes (Zeng et al., 1994). Each elementary source has a crack-type dislocation (of radius R), and is randomly located on the fault. A boxcar source time function is defined for each source considering a scale-dependent rise time $\tau(R)$, similarly to the k^{-2} model (Bernard et al., 1996). The largest rise-time, τ_{max}, is related to the width of propagating slip pulse. Assuming a constant rupture

velocity, each point of an elementary source starts radiating when the rupture front reaches it. The slip velocity is generated in each fault point by adding all the source contributions. The seismogram is obtained by convolving the slip velocity functions with the impulse Green responses. The resulting far-field acceleration spectrum follows the ω^{-2} model and the high frequency spectral amplitudes are proportional to C_d. Finally, we show that the slip velocity functions associated to this model are, to the first order, in better agreement with dynamic modeling solutions.