A COMPOSITE SOURCE MODEL WITH FRACTAL SUBEVENT SIZE DISTRIBUTION

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Abstract

A composite source model, incorporating different sized subevents, provides a possible description of complex rupture processes during earthquakes. The number of subevents with characteristic dimension greater than R is proportional to R^{-2}. The subevents do not overlap with each other, and the sum of their areas equals to the area of the target event. The subevents are distributed randomly over the fault. Each subevent is modeled either as a finite source using kinematic approach, or as a point source. The synthetic Green's functions are calculated by the discrete-wavenumber method in a 1D horizontally layered crustal model in a relatively coarse grid of points covering the fault plane. The Green's functions in a fine grid are obtained by cubic spline interpolation. The composite source model described above allows interpretation in terms of a kinematic model with non-uniform final slip and rupture velocity spatial distributions.

Fundamental assumptions

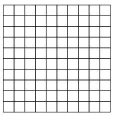
Constant stress drop scaling
$$\frac{L}{l}=\frac{W}{w}=\frac{\bar{D}}{\bar{d}}=\left(\frac{M_o}{m_o}\right)^{\frac{1}{3}}=const.$$

squared model
$$\ddot{U}\left(f\right)\propto\frac{M_o f^2}{1+\left(\frac{f}{f_c}\right)^2}$$

Subevents with equal sizes

Summation made following Frankel (1995), low-frequencies are boosted up by appropriate linear filtering.

$$\boldsymbol{u}^{main}\left(\boldsymbol{x},t\right)=S(t)*\sum_{i=1}^{N}\boldsymbol{u}_i^{small}\left(\boldsymbol{x},t-t_i^r\right)$$

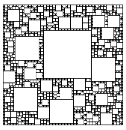


Produces wrong spectra!

Fractal Subevent Size Distribution

Theory of FSSD was taken from Frankel (1991). Practical realization of FSSD follows the one outlined by Irikura (1994).

$$\boldsymbol{u}^{main}\left(\boldsymbol{x},t\right)=\sum_{j=1}^{M}S_j(t)*\sum_{i=1}^{N_j}\boldsymbol{u}_{ij}^{small}\left(\boldsymbol{x},t-t_{ij}^r\right)$$



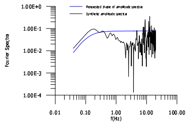
Produces good spectra!

Fortran code, which generates such distributions, is available on demand. !

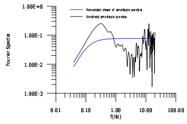
Synthetic test

Modelling Mw=6.2 event, using subevents with equal sizes. Subevent's seismogram is generated as a tapered white noise. The result is an average of 100 realization's

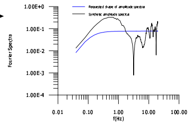
Mw=3.0 subevent, total number of subevents is 1600 (40x40)



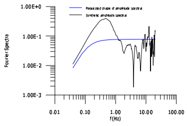
Mw=3.6 subevent, total number of subevents is 400 (20x20)



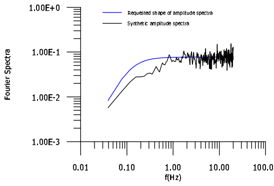
Mw=4.2 subevent, total number of subevents is 100 (10x10)



Mw=4.8 subevent, total number of subevents is 25 (5x5)



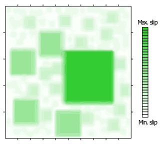
6 types of subevents with Mw within a range (2.4-5.4), total number of subevents is 1516.



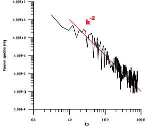
FSSD produces k^{-2} slip distribution

Using scaling laws proposed above, one can see, that FSSD produce spatial variations of final slip.

Spatial variations of final slip



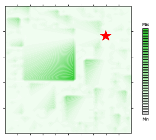
Slice (ky=0) of appropriate amplitude spatial spectra



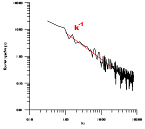
FSSD can be used to produce random spatial distribution of rupture times

When subevents are modelled kinematically, nucleation point of each subevent is taken closest to the mainshock's hypocentrum. Prescribing radial rupture on both subevent and mainfault produces k^{-1} spatial distribution of rupture times.

Rupture time deviations from radial rupture



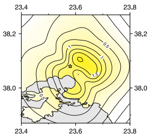
Slice (ky=0) of appropriate amplitude spatial spectra



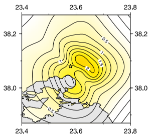
Results for Athens earthuake

- 7,5 x 6 km fault
- subevents are modelled as point sources

Average PGA (ms^{-2}) from 100 realizations of FSSD

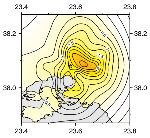


Maximum expectable PGA (ms^{-2}) from 100 realizations of FSSD

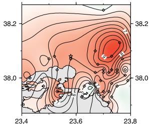


Comparable!

PGA (ms^{-2}) for 1 realization of FSSD



Macroseismic intesities published by NOA



Conclusions:

- **A composite model with FSSD gives more realistic results compared to composite model with equal subevents.**
- **FSSD generates spatial variation of the slip on the entire fault which follows k^{-2} distribution**
- **Athens earthquake:**
  - **The results are similar to the kinematic source modeling (see SE5.01 - SE120)**
  - **FSSD source model provides the PGA map explaining main features of the macroseismic field**

References:

Frankel, A., High-frequency spectral fall-off earthquakes, fractal dimension of complex rupture, b value, and the scaling strength on faults, J. Geophys. Res., 96, 6291-6302,

Frankel, A., Simulating strong motions of large earthquakes using recordings of small earthquakes: the Loma Prieta mainshock as a test case, Bull. Seism. Soc. Am., 85,

Irikura, K., and K. Kamae, Estimation of strong ground motion in broad-frequency band based on seismic source scaling model and an empirical Green's function technique, Annali Di Geofisica 37, 1721-1743, 1994.