3.6 Aftershock simulation

Simulated earthquake catalogue using Monte Carlo method is useful for various purposes. It can be used to test statistical algorithms for seismicity analysis. The Monte Carlo method is powerful for examining statistical properties of a real earthquake catalogue. In order to generate a simulated earthquake catalogue, the magnitudes, times and location of each simulated aftershock are randomly chosen according to the following empirical distributions:

(1) Gutenberg-Richter for magnitudes:

(2) Omori's Law for times

(3) Distances between main-aftershocks following (Felzer and Brodsky, 2002).

To generate aftershock magnitudes and times in the Monte Carlo simulations, the inverse transform method [e.g., Rubinstein, 1981] is used for choosing sample values from an arbitrary probability distribution. If G_X (x) is the cumulative distribution function (CDF) of a random variable x (such a magnitude, time and distance of aftershock from its main shock), then

$$G_X(x) = P(X \le x) \quad (3.6\text{-}1)$$

where P(X≤x) is the probability that a randomly chosen value from the population of X will be x and thus must be uniformly distributed between 0 and 1. This allows us to set GX (x) equal to r, where r is a uniform random number 0 < r≤ 1, and then invert the equation to obtain sample values for x in terms of r:

$$x = G_X^{-1}(r) \quad (3.6\text{-}2)$$

Since $P(X \ge x) = 1 - P(X \le x)$, we have

$$1 - G_X(x) = P(X \ge x) = r \quad (3.6\text{-}3)$$

Random magnitudes from the Gutenberg-Richter distribution cab be obtained by:

$$r = 1 - G_M(m) = P(M \ge m) = 10^{-b(m-M_c)} \quad (3.6\text{-}4)$$

which gives

$$m = M_c - \log_{10}(r)/b \quad (3.6\text{-}5)$$

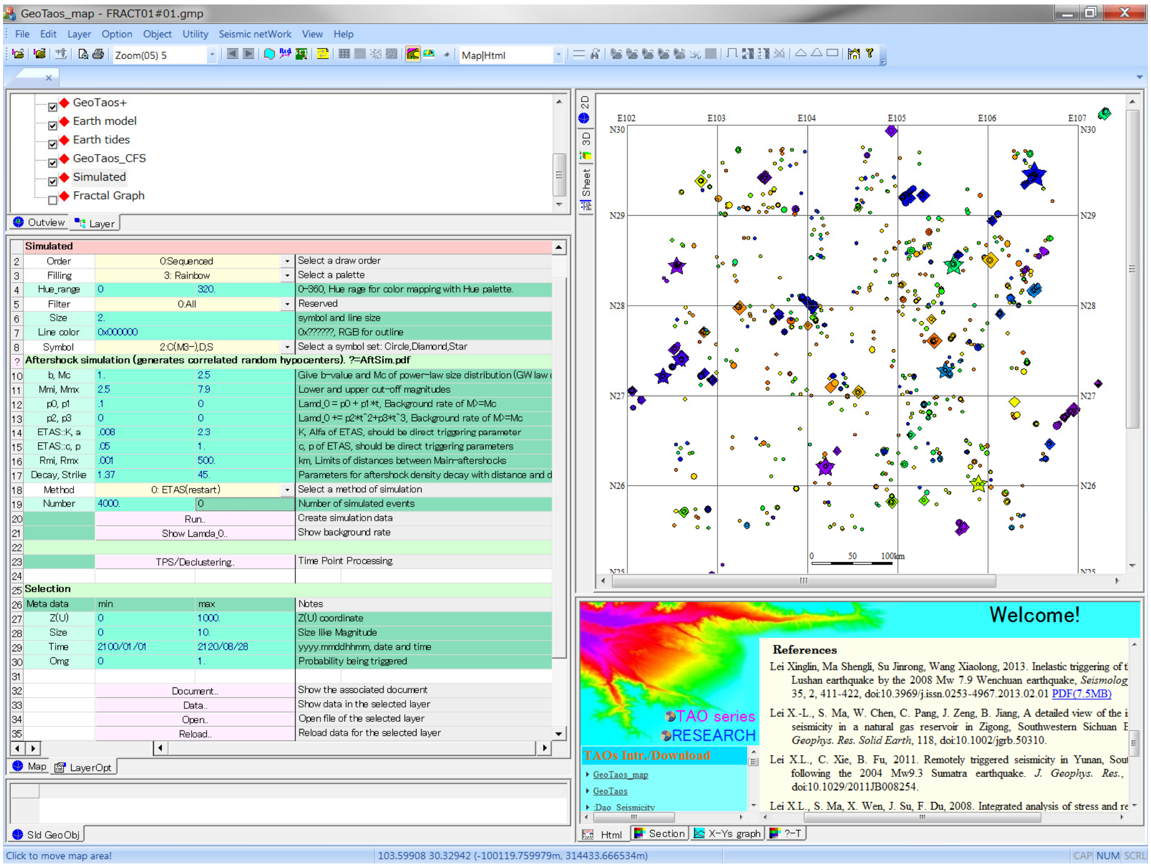
For the timing of each aftershock from the modified Omori law distribution, we have:

$$r = 1 - G_{T_2}(t_2) = P(T_2 \ge t_2) = \exp\left(-\int_{t_1}^{t_2} A(t+c)^{-p}\,dt\right) \quad (3.6\text{-}6)$$

where t_1 is the time of the last aftershock and t_2 is the time of the next aftershock. The time is obtained by

$$t_2 = r^{-1/A} t_1 + c\left(r^{-1/A} - 1\right), p = 1$$
$$t_2 = \left(t_1 + c\right)^{1-p} - (1-p)\left[\frac{\ln r}{A}\right]^{1/(1-p)} - c, p \ne 1, r > \exp(A/(1-p))(t_1+c)^{1-p} \quad (3.6\text{-}7)$$

Update: 10/27/2013



An example of simulated earthquake hypocenters

Felzer K.R., T.W. Becker, R.E. Abercrombie, G. Ekstrom, J.R. Rice (2002), Triggering of the 1999 MW 7.1 Hector Mine earthquake by aftershocks of the 1992 MW 7.3 Landers earthquake, J. Geophys. Res., 107, B9, 2190, doi:10.1029/2001JB000911.