A Two-dimensional Probabilistic Cell-Automaton Model for Slow Earthquakes

*井出 哲[1]、矢部 優[2]
*Satoshi Ide[1], Suguru Yabe[2]

1. 東京大学大学院理学系研究科地球惑星科学専攻、2. 海洋研究開発機構
1. Department of Earth an Planetary Science, University of Tokyo, 2. JAMSTEC

Slow slip events (SSE) discovered in subduction zones and along major faults are often accompanied with seismologically observable signals, which are named tremor or several other terms. These signals are confirmed as radiated from sources with shear slip motion similar to SSE. Thus these seismic sources can be regarded as local acceleration and deceleration of slip during an SSE. In other words, SSE is an event with spatially and temporally heterogeneous slip, radiating geodetic and seismic signals in broad frequency range, which we may call broadband slow earthquake as a whole.

Various features have been known for slow earthquakes: for example, (i) the proportionality between event duration and seismic moment, (ii) the proportionality between seismic energy rate and seismic moment rate, (iii) almost constant moment acceleration spectrum in a broad frequency band, and (iv) diffusive migration of sources. In order to explain these characteristics, Ide (2008, 2010) proposed the Brownian slow earthquake (BSE) model, where the slipping area of slow earthquake evolves stochastically based on a Langevin equation. BSE model is 1D model only for moment rate function, while Ben-Zion (2012) simulated randomly evolving slow slip process using a 2D discretized fault plane with simplified elastodynamics. He showed that slow slip propagates by nearest-neighbor interaction when local stress change is very small.

Here, we develop a probabilistic cell-automaton (PCA) model of 2D fault. Each cell has two states: "slip" or "hold", and the state of each cell changes with time steps depending on the state of itself and nearest neighbor cells.

(1) Each "slip" cell keeps slip at probability $1+(Nb-4)p$, or become "hold".

(2) Each "hold" cell starts slip at probability $(Nb)p$.

p is a constant and Nb is the number of neighboring slipping cell (0-4). The expected number of slipping cells does not change after each time step. Given that Ns cells are slipping, we can approximate the increase of the number of slipping cell dNs as standard normal distribution with zero mean and variance of $CpNsdt$, where dt means time step interval. C is slowly decreasing function of Ns, but can be assumed as a constant. This is essentially the same equation as the governing equation of the 1D BSE model, and therefore, a natural extention of the 1D BSE model.

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