Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SCG058-07 Room:302 Time:May 22 12:15-12:30

Generation mechanism of slow earthquakes: Numerical analysis based on a dynamic model

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Various characteristics have been discovered for small, slow earthquakes occurring along subduction zones, which are deep nonvolcanic tremor, low-frequency earthquakes (LFEs), and very low-frequency earthquakes (VLFs). For example, the velocity spectra of seismic waves from tremor, LFEs, and VLFs are almost flat in a broad frequency range of 0.01 to 10 Hz [Ide et al., 2008]. The tremor sources migrate with a velocity of roughly 10 km/day in the strike direction of the subducting plate [Obara, 2002], and 100 km/h in the dip direction [Shelly et al., 2007]. The slow along-strike migrations of tremor episode are sometimes accompanied by the rupture propagation of slow slip events (SSEs) [Rogers and Dragert, 2003; Obara et al., 2004]. So far, there is no physical model available that encompasses all of the above characteristics. Ando et al. [2010] proposed a model that explains the anisotropy of the tremor source migration speed and the spectral property of small slow earthquakes in which dynamic ruptures occur on frictionally unstable patches triggered by a passing stress pulse of an SSE. In this study, we model these slow earthquakes using a dynamic model consisting of a cluster of frictionally unstable patches on a stable background by using slightly modified version of the model by Ando et al. [2010]. The key parameters in our model are related to the patch distribution and the viscosity of both the patches and the background.

By decreasing patch density or increasing viscosity, we observed the transition in rupture propagation mechanism, that is, from fast elastodynamic interactions characterized by an elastic wave propagation to slow diffusion-limited by viscous relaxation times of traction on fault patches and/or background. In addition, some parameter sets correctly explain observed characteristics such as moment rate functions, spectral properties, parabolic migration, and the scaled energy. Therefore, the characteristics derived from observations may provide information about the source structure and frictional properties of our dynamic model of tremor, LFEs, and VLFs, and potentially, SSEs. This model will be a powerful tool to understand the generation mechanism and various aspects of slow earthquakes in a simple framework engaging source structures and frictional properties of brittle-ductile transition zones along plate boundaries.

Acknowledgments

This work was partly supported by the project ”Evaluation and disaster prevention research for the coming Tokai, Tonankai and Nankai earthquakes” of the Ministry of Education, Culture, Sports, Science and Technology of Japan.