Stress interactions and seismicity of non-planar faults

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Abstract

Slip on fault with fractal roughness is modeled to explore the effects of geometric complexity on earthquake nucleation, foreshocks, and aftershocks. Nucleation processes and seismicity in this model employ laboratory-based rate- and state-dependent fault constitutive properties.

Introduction

Faults in nature show significant departures from simple planar surfaces that are generally employed in simulations of earthquake processes. Natural faults have irregularities at all wavelengths and form complex networks of intersecting surfaces. Deformations, which do not occur in planar fault models, arise from interactions among these geometric complexities. The effects of fault geometry on earthquake nucleation, foreshock, and aftershock processes are currently being investigated through simulations of slip of faults with a random fractal geometry. A noteworthy characteristic of slip of non-planar faults is increasing roughening of near-fault stresses with increasing slip. In nature these stresses presumably grow with increasing slip until a yield limit is reached at which point slip on secondary faults takes place. Slip on secondary faults might occur during a mainshock, as foreshocks, or as aftershocks.

Aftershocks

Aftershock rates as functions of location and time are modeled using the formulation of Dieterich [1] for earthquakes rates together with the stress interactions arising from a mainshock slip event on the fractal fault. The earthquake rate formulation is derived from laboratory observations of rate- and state-dependent fault strength. As reported previously [1] a step-like increase of stress at the time of a mainshock results in a jump of earthquake rates followed by Omori-type aftershock decay. In planar fault models, aftershocks are restricted to regions outside of the mainshock rupture. In the fractal fault models the aftershocks within the region of fault slip arises as a consequence of the roughening of the near-fault stresses which results in localized areas of stress increase. The relative abundance of aftershocks within the rupture zone to aftershocks outside of the rupture depends, in part, on the amplitude of fault irregularities.

Foreshocks

Foreshocks may arise by two mechanisms. The first is a manifestation of the earthquake clustering that gives rise to aftershocks. In this model, the stress change of a prior earthquake increases the probabiltity of earthquakes of all magnitudes and an earthquake mainshock is simply an aftershock that is larger than the prior event. The second model assumes the accelerating nucleation phase of the mainshock, as predicted by rate- and state-dependent fault constitutive properties, induces stress changes that trigger foreshocks. Both models appear to quantitatively satisfy foreshock-mainshock statistics, but result in different spatial distributions of foreshocks. In the clustering model for foreshocks and mainshocks the regions of rupture rarely overlap. In the nucleation model for foreshocks, repeated foreshocks and the mainshock initiation may occur at the same location.

References

[1] Dieterich, J. H., 1994, A constitutive law for rate of earthquake production and its application to earthquake clustering, *J. Geophys. Res.*, *99*, 2601-2618.