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The role of the fault-block structure of the continental margin in the generation of the strongest subduction earthquakes

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Modern seismotectonic studies are aimed at obtaining a self-consistent explanation of fault zone heterogeneity, the rupture process, recurrence times and rupture mode of large earthquake sequences. In subduction regions large earthquakes are often characterized by very long source zones and complex long-term postseismic processes following the coseismic release of accumulated elastic stresses. A set of mechanical models was proposed to describe the generation of strongest earthquakes based on the idea of the synchronous failure of several adjacent asperities.

In this study we propose a model which is based on verified numerical schemes, which allows us to quantitatively characterize the process of generation of strong earthquakes. The model takes into account the fault-block structure of the continental margin and combined the ideas of a possible synchronous destruction of several adjacent asperities, mutual sliding along a fault plane with a variable coefficient of friction and subsequent healing of medium defects under high pressure conditions.

The applicability of the proposed model is shown by the example of the recent seismic history of the Kuril subduction zone. Kuril island arc is one of the most tectonically active regions of the world due to very high plate convergence rate. Heterogeneities in the mechanical coupling of the interplate interface in this region lead to the formation of the block structure of the continental margin, which is confirmed by various geological and seismological studies.

GPS observations recorded at different stages of seismic cycle related to the 2006–2007 Simushir earthquakes allow us to model geodynamic processes of slow strain accumulation and its rapid release during the earthquake and the subsequent postseismic process. We use parameters describing the regional tectonic structure and rheology obtained from the inversion of geodetic data to construct a 2D model of generation of large earthquakes in central Kurils. Analysis of paleoseismic data on dates and rupture characteristics of previous major earthquakes shows a good agreement between the modeled and observed seismic cycle features. The predicted horizontal displacements of the seismogenic block at the coseismic stage are consistent with satellite geodetic data recorded during the 2006 Simushir earthquake.

The proposed model provides new insights into the geodynamic processes controlling the occurrence of strong subduction earthquakes.