Influence of Regional Tectonic and Rheological Structure on the Seismic Cycle for Northeast Japan

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The subduction zone is a natural laboratory for studying the seismic cycle. On March 11, 2011, in the central part of the Japan subduction zone, the strongest Mw=9.0 Tohoku earthquake occurred, terminating a seismic cycle that lasted about 1200 years. We analyzed two decades of GNSS observations at 1400 GEONET stations to reveal the peculiarities of the tectonic and rheological structure of the Japan subduction zone which driven such a long-term seismic cycle. We consider GNSS data within the framework of a generalized approach, including the assessment of the coupling of the interplate interface before the earthquake, the construction of a model of the distributed displacement in the source zone, and the study of postseismic processes characterizing the relaxation of elastic stresses in the vicinity of the source.

As a result, we found that in the last year before the earthquake, there was an increase in the rates of elastic deformation of the continental margin and a corresponding increase in the interplate coupling. To study the process of the release of elastic energy during the Tohoku earthquake, we built a model of the distributed slip in the source. We used different earth models during inversion of GNSS data to study the impact of the regional tectonic and rheological structure and confirm the resilience of our inversion technique. We used GNSS data to build a model of pure afterslip in the first six months after the Tohoku earthquake and a model of afterslip combined with the short-term viscoelastic relaxation to estimate the relative contributions of these postseismic processes to the observed displacement field. Long-term postseismic time series of GNSS displacements were used to build the model of viscoelastic relaxation in the asthenosphere following the Tohoku earthquake. To estimate the transition time of the subduction zone to the steady-state of elastic stress accumulation we constructed a forecast of attenuation of viscoelastic stresses in the asthenosphere on the basis of our viscoelastic relaxation model.

We also studied the possible block structure of the Japanese Islands and its impact on the seismic cycle performing cluster analysis of GNSS displacement data at different stages of the seismic cycle.
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