Persistence of Seismic Rupture Asperities inferred from Geodetic Data in Northern Japan

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Abstract

Inversions of interseismic geodetic data near subduction zones image the megathrust locked over spatially smooth and extensive regions, in contrast to the smaller discrete asperities estimated by earthquake source studies. Such smooth, broad regions may be a consequence of a lack of model resolution and the resulting need for regularization inherent to the use of onshore geodetic data. It is also possible that the inferred interseismically coupled regions are larger than the collective asperity sizes for known earthquakes due to an incomplete earthquake catalog. Hence, the different levels of apparent coupling implied by interseismic and seismic-source inversions have very different implications for regional seismic hazard.

Here, we focus on the Japan-Kurile megathrust off northeastern Japan. We test the hypothesis that mechanical coupling on a configuration of asperities inferred only from the locations of past earthquakes is sufficient to explain geodetic observations. The alternative is that these data require additional regions of the megathrust to be coupled. Underlying our hypothesis is the assumption that known asperities persist across multiple earthquake cycles.

We use a 3-D mechanical model of stress-dependent interseismic creep along the megathrust, considering frictional rheologies and known spatio-temporal distribution of large earthquakes (Hetland et al. 2010). Here, we apply their method to curved fault surfaces in a geo-referenced coordinate system, containing multiple asperities experiencing an arbitrary sequence of seismic ruptures. These mechanical models predict that late in the seismic cycle, there are relatively smooth, long wavelength regions of very low slip-rates on the megathrust interface surrounding these asperities, owing to the "stress-shadow" effect of seismic ruptures. Such "physical smoothing" around asperities provides a more realistic alternative to the artificial smoothing introduced by model regularization in inversions of interseismic geodetic data.

We find that most of the present horizontal components of geodetic data in northeastern Japan can indeed be explained by the stress-shadow effect following seismic ruptures on known asperities, over surrounding rate-strengthening regions of the megathrust. However, we cannot fit the vertical components of geodetic data well, because we consider ruptures only on the megathrust interface in the context of an elastic half-space. Such an approach ignores potentially important processes such as anelastic crustal deformation, surface processes, and subduction erosion, over the seismic cycle time scale.