MECHANICAL MODELS FOR INTERSEISMIC DEFORMATION IN SUBDUCTION ZONES

Thesis by

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ABSTRACT

Traditionally, interseismic deformation in subduction zones has been modeled using simple elastic dislocation models (EDMs). Such models have been extensively used over the past couple of decades as geodetic networks were being established around the world. However, with the availability of 3D (vector) velocity data with dense spatio-temporal coverage during the past decade, it becomes possible to explore more complex models of deformation. Such models may allow us to infer higher-order properties of the megathrust interface or the subducting plate from the observed deformation field. For instance, we show that it may be possible to infer the elastic plate thickness of the subducting plate (over the seismic cycle timescale) under certain conditions, especially if ocean-bottom geodetic measurements become routinely available in the near future. The plate thickness can affect surface deformation on the overriding plate if only a small fraction of the flexural stresses at the trench are continuously released over the seismic cycle time-scale. Another problem we address here is how the rheology of the megathrust interface affects the evolution of slip over the seismic cycle, and therefore, the seismic hazard inferred from geodetic data. We model such slip evolution on a realistic 3D fault surface having a frictional rheology. Assuming that seismic rupture zones (or "asperities") persist across several seismic cycles, we test the hypothesis that mechanical coupling on such asperities alone is sufficient to explain currently available geodetic observations in northern Japan. We find that it is not necessary to lock large portions of the megathrust between ruptures – unlike recent EDM predictions for northern Japan – resulting in potentially large future earthquakes. Instead, post-seismic slip around asperities immediately following seismic rupture can result in large "stress-shadow" regions, which experience negligible slip late in the cycle. Such stress-shadow regions can mimic the long-wavelength "locked" zones inferred from EDMs for the interseismic period, and account for most of the present day GPS velocities in northern Japan. The approach developed here can be extended to more complex models of deformation that include heterogeneities in crustal properties, multiple fault surfaces, and perhaps, even multiple rheologies over a single fault.

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