Life in the stress shadow: Stress-constrained inversion for interseismic coupling on shallow megathrusts

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Abstract

The potential for large coseismic slip on the shallow part of megathrusts represents a significant tsunamigenic and earthquake hazard, but remains poorly known due to the difficulty of observing interseismic deformation in the subduction zone wedge. We use a stress-driven boundary element model to separate the concept of frictional locking (a mechanical parameter) from the geodetic slip deficit or coupling ratio (a kinematic parameter). Our method greatly reduces the resolution problem in kinematic inversions of slip deficit, and we show that the shallow megathrust is required to be highly coupled whenever the down-dip portion of the fault is locked. For an extreme case of a subduction zone which is frictionally unlocked (and thus freely slipping) from the surface down to half the maximum seismogenic depth, we find that the slip deficit ratio will typically be higher than _˜0.7 or 0.8 at the trench. For a narrower zone of up-dip unlocking, the slip deficit ratio should be even higher. This result indicates that published kinematic models predicting low interseismic coupling at the trench likely underestimate the hazard and need to be reevaluated. We demonstrate the method for the case of the Sumatran megathrust, which has dense GPS and coral geodetic observations, and a highly complex pattern of seismic and aseismic slip over the past decade. The results show that the shallow interseismic slip deficit is much higher than reported in previous models, and this highly coupled zone contains both areas of shallow postseismic slip (e.g. following the 2005 Mw 8.6 Nias-Simeulue earthquake) and coseismic slip (e.g. the 2010 Mw 7.8 Mentawai earthquake). These results highlight the difficulty of distinguishing frictionally locked areas from frictionally unlocked areas during the interseismic period with geodetic data, and suggest the need for new types of in-situ observations that can help resolve this ambiguity.

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