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Variations Lithospheric Scale Strain Accumulation in Mega-thrust Subduction Zones: Implications for Earthquake rupture

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Although the general plate tectonic model of subduction zone deformation and its relationship to the earthquake cycle for mega-thrust earthquakes is well known, there are in fact significant differences in terms of how inter-earthquake strain accumulation is considered by different communities. Most seismologic studies of mega-thrust earthquakes assume that the co-seismic slip is essentially symmetric across the fault surface – that is both the upper and lower plates moved equal amounts (but in opposite directions) during the rupture – implying s similar symmetric pattern of strain accumulation. Implicit in many geologic studies along convergent margins is the assumption that most permanent deformation is within the upper plate and the subducting slab basically transits the seismogenic zone with little permanent deformation. Based on the analyises of two recent great earthquakes, we conclude that the pattern of strain accumulation during the inter-earthquake period ranges from situations (akin to the 'geologic' model) where most strain accumulates in the upper plate to situations where the subducting plate undergoes most of the recoverable elastic strain during the period between great earthquakes. Two subduction zone locales, the Kuriles and Solomon Islands, that have hosted recent Mw 8+ earthquakes demonstrate these two end-member styles of subduction zone processes. The November 2006 (thrust) and January 2007 (normal) earthquake pair in the Kuriles provide an opportunity to quantify the deformation within the subducting Pacific slab during the interseismic period. Based on the correspondence in slip during these events, we are able to both estimate the deformation (dominantly in the subducting slab and not in the overriding plate) and place a constraint on the static frictional strength of the megathrust interface of approximately 2-5 MPa. The 2007 Solomon Island Mw 8+ earthquake shows a distinctly different pattern of interseismic deformation. During this event, the propagating rupture traversed an active transform plate boundary between the separately subducting Australia and Solomon Sea plates. We interpret this to represent a situation in which interseismic deformation is primarily in the upper (Pacific) plate allowing the rupture to jump the fundamental barrier of a plate boundary. These two subduction regimes indicate that there is likely a full continuum in how deformation is accommodated during subduction, and implies that attempts to determine the megathrust (and associated tsunami) potential of subduction zones using solely observations of upper-plate deformation is problematic.