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Partitioning subduction deformation throughout the earthquake cycle: Why Pre-earthquake and co-earthquake deformation patterns don't agree.

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The recent Mw 9.0 Tohoku event and the suite of other great earthquakes over the past decade provide observations of the range of behaviors of partitioning of deformation through the seismic cycle for megathrust events. This set of great subduction zone earthquakes, including the 2004 Sumatra event, the Kurile Islands doublet (Mw 8.2 and 8.0), the Solomon Islands event (Mw 8.1), the Samoa-Tonga events (complex, contemporaneous normal and thrust events) and Chile (Mw 8.8), show a broad spectrum of deformational behavior ranging from inter-earthquake strain being partitioned preferentially to the subducting (lower) plate (e.g. Kuriles) to evidence of dominantly upper plate deformation (Solomon Islands). What controls this pattern of partitioning is not fully clear but has important consequences for our ability to use observations of pre- co- and post-seismic displacements and deformation to infer the nature, pattern and magnitude of moment accumulation on the megathrust plate boundary. This conceptual model of variable patterns of upper plate deformation in space and time along a subduction zone is at odds with the standard model utilized in most geophysical studies of subduction zone strain accumulation and release. To use the recent Tohoku earthquake as an example, observations (made on the upper plate) of both strain accumulation and release assume that essentially all observed variations reflect (i.e. are mapped to) variations in coupling/locking/slip on the slab interface. Thus the assumption is made that the upper plate is essentially a passive recorder of the slab interface stress/strain evolution, rather than it being another component (along with the slab itself) of the deformational system; each part of which plays an important role in terms of both our observations and also the details of earthquake rupture during great earthquakes. We are exploring this issue with a two-pronged approach. From a theoretical side we are systematically testing via elastic and visco-elastic numerical modeling the effects of variations in rheology (e.g. elastic parameters, viscosity etc.) in controlling the partitioning of deformation during the earthquake cycle. Here, we find stark differences in the overriding plate deformation field depending on whether it is mechanically weak or strong relative to the subducting lithosphere. If relatively strong, pre-seismic surface deformation may give the false impression of the subduction interface not being locked or accumulating strain at a rate a small fraction of that expected for the plate convergence rate. In a similar way the spatial distribution lithospheric strength (i.e. how it deforms in response to stress loading) can significantly bias the interpretation of the geographical extent of the locked plate interface. We can use observations from these recent great earthquakes to assess how slip and moment release on the megathrust is mapped into observed co-seismic displacements; determining the way in which the upper plate filters the observations of plate boundary slip and conversely improving our assessment of earthquake potential from pre-earthquake observations of deformation.