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# Rupture and creep behaviours of subduction interface controlled by fault zone heterogeneity

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The behaviour of fault slip varies tremendously, ranging from seismic rupture to aseismic creep. We explore the role of fault zone heterogeneity in controlling large-scale (> 100 km in strike dimension) rupture and creep behaviours of subduction faults. Geometrically smooth subduction faults can (although not always) provide relatively homogeneous structural and stress conditions to allow large fault patches to be locked over prolonged periods and then rupture in great earthquakes. During the rupture, however, frictional heterogeneities arising from lithological changes, pore-fluid pressure variations, and low-amplitude geometrical irregularities always cause a very heterogeneous distribution of stress drop. Although some parts of the fault may undergo high or complete stress drop (local weakening), many other parts undergo very low stress drop or stress increase (local strengthening). The mixing of stress drop and increase in different parts of the rupture zone makes the average stress drop in each great earthquake very small, of the order of a couple of MPa, as widely observed in seismological studies. We use the 2011 Mw=9 Tohoku-oki earthquake to demonstrate this averaging effect. Geometrically extremely rough subduction faults, such as those featuring multiple subducting seamounts, provide very heterogeneous structural and stress conditions that promote creep and numerous small earthquakes. A global inspection of geodetically constrained locking and creeping states of subduction zones indicates that these extremely rough faults all tend to creep (Wang and Bilek, 2014). Depending on the degree of roughness and other geological conditions (e.g., sediment and fluid), some of the rough faults may host a mixture of seismic and aseismic patches and may exhibit a variety of creep behaviour ranging from steady creep to transient creep pulses (i.e. slow slip events) of different time scales. It can be envisioned that the heterogeneity in these rough faults is generally in the form of 3D deformation in a complex zone of damage along the interface and cannot be adequately approximated by heterogeneous rate-state friction. It is also important to recognize that these creeping rough faults are not "weakly coupled", nor are the highly seismic smooth faults "strongly coupled". A global examination of frictional heating of subduction faults indicate that the creeping rough faults dissipate more heat and are statically stronger, that is, they creep against greater resistance (called strong creep) than the stress required to cause a smooth fault to rupture in great earthquakes (Gao and Wang, 2014). This observation supports the notion that these faults creep as a result of geometrical irregularities forcing through a damage zone, very different from frictional creep due to the presence of week fault gouge (called weak creep).

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