Implications of loading/unloading a subduction zone with a heterogeneously coupled interface

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**Introduction**

Comparisons of co-seismic slip in three great earthquakes offshore Chile (2010 Maule, 2014 Iquique, and 2015 Illapel) to inter-seismic coupling inferred from onshore GPS prior to the events show:

- Slip propagates outside the regions of highest coupling.
- Events with greater slip areas also have larger slip magnitudes.
- Tsunamigenic slip occurs despite low inferred coupling near the trench.

**Pseudo-coupling Model**

We assume that the plates are elastic bodies, so inter-seismic slip deficit must be continuous on the plate boundary. As a result, areas outside locked asperities can accumulate slip deficit even with no friction on the boundary. We call this “pseudo-coupling” to distinguish it from mechanical coupling and quantify its effect with a new element model.

**Imaging Plate Boundary Coupling**

We fit observed horizontal GPS velocities from Chile reasonably well with a pseudo-coupling model (dip=17°, displacement=70 mm, 10° obliquity). This suggests that pseudo-coupling may provide a useful independent physical constraint for inferring the slip deficit distribution on the subduction interface.

**Surface Displacements**

Pseudo-coupling around nearby, unruptured asperities limits the maximum available slip in an earthquake. A 40-km long event bounded by locked areas can slip up to only ~50% of the accumulated slip deficit. As the earthquake grows in length, it overlaps with a lower level of pseudo-coupling and can have greater co-seismic slip. At a length of ~250 km and larger, the earthquake can release the full accumulated slip deficit.

**Loading the Shallow Interface**

The megathrust up-dip of the locked zone accumulates a large slip deficit and displacements near the trench. These displacements occur without accumulating significant elastic strain, i.e., the region moves as a block. During an earthquake, the shallow interface may have slip magnitudes comparable to the asperity, but without radiating the same characteristic seismic waves.

**Summary**

Some areas in the seismogenic zone appear partially coupled due to pseudo-coupling alone. Other regions appear partially coupled because asperities here are too small to resolve.

Fully locked asperities accumulate slip deficit at the convergence rate. Outside asperities, the interface appears partially coupled over a large area.

The eventual earthquake characteristics depend on the number and size of ruptured asperities. Large, multi-asperity ruptures release the full accumulated slip deficit, allowing the up-dip region to slip in concert with the seismogenic zone.

In smaller earthquakes, slip is reduced by unruptured asperities. Depending on the geometry, the shallow interface may also slip.