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Do magnitudes of great subduction earthquakes depend on strength of mechanical coupling between the plates?

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The common thinking is that the magnitude of a great subduction earthquake correlates with the strength of mechanical coupling between slab and overriding plate. Based on this idea, Ruff and Kanamori (1980) suggested that maximum earthquake's magnitude is controlled by two parameters: age of subducting plate and plate convergence rate, when the youngest and the fastest slabs generate the largest earthquakes. This view was supported by many researches since then. However, since 1980 a number of great earthquakes, and particularly two largest earthquakes of the last 12 years, i.e. Great Sumatra/Andaman 2004 Earthquake and Tohoku 2011 earthquake, have violated the suggested correlation.

We address the relation between strength of mechanical coupling and earthquake magnitude directly by cross-scale geodynamic modeling of seismic cycles of great subduction earthquakes. This modeling technique employs elasticity, non-linear transient viscous rheology, and rate-and-state friction at slab interface. It generates spontaneous earthquake sequences, and, by using an adaptive time-step algorithm, recreates the deformation process as observed naturally over single and multiple seismic cycles.

We model seismic cycles for the great subduction earthquakes with different geometries of subducting plates, different static friction coefficients in subduction channels and different subduction velocities. Under the assumption that rupture length scales with the rupture width, our models demonstrate that maximum magnitudes of the earthquakes are exclusively controlled by the factors that increase rupture width. These factors are: low slab's dipping angle (the largest effect), low friction coefficient in subduction channel (smaller effect) and high subduction velocity (the smallest effect).

Models suggest that maximum magnitudes of earthquakes do not correlate significantly with the magnitudes of normal and shear stresses at subduction interface. In agreement with observations, our models suggest that the largest earthquakes should occur in subduction zones with neutral (most frequently) or moderately compressive deformation regimes of the upper plate. This is a consequence of the low dipping angles and low static friction coefficients in the subduction zones with largest earthquakes, rather than a reason for the largest earthquakes.

Our models predict maximum earthquake magnitudes for the subduction zones of different geometries and these predictions are consistent with the observed magnitudes for all observed events and estimated historical events.