Geophysical Research Abstracts
Vol. 20, EGU2018-7355, 2018
EGU General Assembly 2018

On the relationship between interseismic coupling and earthquake slip pattern

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Predicting the characteristics of earthquakes (e.g., rupture extent, average slip) is one of the great scientific challenges due to the close link with seismic hazard assessment. In this sense, interseismic coupling ISC maps provide useful information. These maps define locked patches of a given fault where stress is built up during the observation period and, according to the elastic rebound theory, will be released in future earthquakes. Recent investigations revealed that areas of high ISC host both high and low slip and that they have a low informative power for constraining the lateral extent of future earthquakes and, consequently, the maximum magnitude. However, this picture is based only on a limited amount of events and incomplete observations (i.e. geodetic timeseries span years to tens of years while a seismic cycle may last hundreds-thousands of years).

To test whether ISC maps may provide useful information for constraining the slip pattern of future earthquakes we use analog models of subduction megathrust seismicity. The models feature a flat subducting plate driven at a constant velocity and underthrusting a viscoelastic gelatin wedge analog of the overriding plate. Stress build up is episodically released via spontaneous ruptures that propagate along the analog megathrust. Monitoring is performed with the Particle Image Velocimetry, a technique that allows describing model surface deformation similarly to geodetic data in the prototype. Despite the simplicity of the models with respect to natural subduction zones, our approach has the fundamental advantage of a dense, homogeneously spaced monitoring network covering also the seismogenic zone, for multiple seismic cycles. We selected a timeseries of 20 analog seismic cycles from a model embedding two asperities eventually capable of rupturing simultaneously, as imaged at several subduction megathrusts worldwide. We quantified the matching between ISC and slip by means of their spatial correlation computed either above the whole seismogenic zone Rsz (i.e. including two asperities and the barrier between) or limited to the slip area Rhs. Accordingly, Rhs is >0.8 suggesting that high slip occurs in concomitance of high locking. On the contrary, Rsz is uniformly distributed from 0 to 1 suggesting that ISC maps represent a weak proxy for the lateral extent of the next rupture, similarly to what is observed for recent megathrust earthquakes. The variability of Rsz derives mainly from non-failed locked asperities. We further stressed this argument by investigating whether a long timeseries spanning multiple seismic cycles may improve the correlation between ISC and slip pattern. We found that, while Rhs is generally high and constant over increasing number of seismic cycles, Rsz oscillates without converging to a fixed value. This oscillation may derive from chaotic interaction of the two asperities as suggested based on previous numerical simulations. Earthquake slip pattern prediction based on ISC will be therefore unsuccessful if such chaotic behavior occurs also in nature and a different indicator should be used.