Geophysical Research Abstracts
Vol. 20, EGU2018-8003, 2018
EGU General Assembly 2018

Overprinting the signal of inter-seismic coupling on subduction megathrusts throughout the earthquake cycle

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The inter-seismic slip deficit accumulation rate on the subduction plate interface due to frictional locking is a key parameter in estimating the hazard posed by large magnitude megathrust earthquakes. Geodetic observations of surface motions in between large events are typically used to infer the slip deficit accumulation rate; however, these datasets also record other deformation processes, such as apparent partial coupling, afterslip, and viscous relaxation. The surface motions produced by these processes overlap with the signal produced by locked asperities and may therefore bias interpretations of the slip deficit on the plate interface. We demonstrated in a previous modeling study how partial slip deficit accumulates at $\geq$50% of the convergence rate in the regions between fully locked asperities, which helped to resolve the actually locked parts of the megathrust. In this study, we use 3D geodynamic models to quantify how motions associated with post-seismic afterslip and viscous relaxation affect the ability to resolve this distribution of (partial) coupling on the megathrust.

We find that earthquakes under a threshold magnitude (Mw $\sim$6.5-7.0), produce essentially negligible post-seismic surface displacements compared to the locking signal. As the magnitude of the event increases, its post-seismic effects overprint the coupling signal over a larger area and for a longer time. We use the central Chile subduction zone (which includes the 2010 Mw 8.8 Maule and 2015 Mw 8.3 Illapel events) as a case study, modeling inter-seismic loading as well as the co- and post-seismic effects of earthquakes dating back to the 19th century. Irrespective of magnitude, no event prior to 1900 has an effect on modern surface observations, whereas great (Mw 8.0+) earthquakes in the past $\sim$50 years are still associated with reduced landward velocities relative to the full locking velocity. Near the rupture zones of the 2010 Maule and 2015 Illapel earthquakes, post-seismic motion currently produces oceanward surface velocities, and these regions may not reflect the locking signal for several decades.