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Surface deformation due to megathrust seismic cycles derived from analogue scale modeling

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Megathrusts form the principal plate boundary structure in both oceanic and continental collision zones, controlling the topographic evolution of the hanging wall on multiple time-scales. Here we focus on surface deformation during the short time scales (years to ka) associated with the seismic cycle of megathrust earthquakes in subduction zones.
A decade of high resolution geodetic monitoring of seismic cycle-related ground surface deformation in subduction zones around the globe has led to a better understanding of the megathrust earthquake process and its associated seismic hazard. However, little is known about the relation between our fragmentary seismic cycle observations and the long-term topographic evolution of subduction zones.
In this research, we aim at the simulation of morphotectonic evolution over multiple seismic cycles. We have set up analogue megathrust models using elastoplastic rheologies and monitored their surface deformation in 3D by means of digital image correlation. Earthquakes nucleate within pre-defined rectangular asperities for simulating co- and interseismic surface deformation over multiple seismic cycles. The surface deformation has been used as virtual GPS3 stations (Ve,Vn,Vu) to invert the distribution of coseismic slip and interseismic locking at depth. We show that analogue earthquakes and interseismic locking of the megathrust follow closely the kinematics of the natural prototype. The long-term, continuous geodetic observations simulated here illustrate the archetypical multiscale surface deformation pattern in subduction zones: (1) Coseismically, fast subsidence landward of the seismic source area and (tsunamigenic) uplift of the shelf; (2) Interseismically, slow coastal uplift and shelf subsidence; (3) Seismotectonically, a few percent of seismic cycle deformation is preserved in the morphotectonic record resulting in a segmented forearc including coastal high, shelf and slope.