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Shocks in a box: An analogue model of subduction earthquake cycles with application to seismotectonic forearc evolution

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We introduce and test an experimental approach to simulate elastoplastic megathrust earthquake cycles using an analogue model and apply it to study the seismotectonic evolution of subduction zones. The quasi-two-dimensional analogue model features rate- and state-dependent elastic-frictional plastic and viscoelastic material properties and is scaled for gravity, inertia, elasticity, friction and viscosity. The experiments are monitored with a high-resolution strain analysis tool based on digital image correlation (particle imaging velocimetry, PIV) providing deformation time-series comparable to seismologic, geodetic and geologic observations. In order to separate elastic and non-elastic effects inherent the experimental deformation patterns, we integrate elastic dislocation modeling (EDM) into a hybrid approach: We use the analogue earthquake slip and interseismic locking distribution as EDM dislocation input and forward model the co- and interseismic elastic response. The residual, which remains when the EDM prediction is subtracted from the experimental deformation pattern, highlights the accumulation of permanent deformation in the model. The setup generates analogue earthquake sequences with realistic source mechanisms, elastic forearc response and recurrence patterns and reproduces principal earthquake scaling relations. By applying the model to an accretionary type plate margin we demonstrate how strain localization at the rupture peripheries may lead to a seismotectonically segmented forearc including a tectonically stable shelf and coastal high (< 20 % of plate convergence accommodated by internal shortening) overlying the area of large megathrust earthquake slip. 50 – 75 % of plate convergence is accommodated by internal shortening in the slope region where earthquake slip tapers out towards the trench. The inner forearc region remains undeformed and represents a basin.