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On the feedback between forearc tectonics and megathrust earthquakes in subduction zones

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An increasing number of observations suggest an intrinsic relationship between short- and long-term, elastic and plastic deformation processes in subduction zones. These include the global correlation between megathrust earthquake slip patterns with morphotectonic forearc features and the historical predominance of giant earthquakes (M > 9) along accretionary margins (e.g., Chile, Alaska, Cascadia, Sumatra). Here we explore experimentally the feedback between forearc tectonics and megathrust earthquakes. We use compressive granular wedges overlying a rate-and-state dependent frictional interface as analog models of subduction zone forearcs. We simulate and analyze seismotectonic deformation time-series with respect to the accumulation of permanent strain and the evolution of the frequency-size distributions of associated megathrust earthquakes. Over multiple seismic cycles deformation in the overriding plate localizes at the downdip limit of the seismogenic zone in form of a backthrust. A shallow velocity strengthening interface sustains strain localization near the wedge tip. This results in a structural segmentation of the wedge with an elastic domain overlying the seismogenic zone enclosed by plastically shortened domains corresponding to the accretionary wedge/outer arc high and coastal high in nature. Along with the evolution of the wedges from internally deforming wedges to segmented wedges the analog megathrust seismicity develops from random, Gutenberg-Richter like distributed events towards deterministic, periodic events. Accordingly, the frequency distribution of earthquakes becomes narrower as the models evolve from plastic to elastic. Because the width of the frequency distribution controls the length of the time window during which an event can be triggered by a nearby event, this indicates that the probability of synchronous failure of neighboring segments in a single giant event is generally higher along plastically deforming margins than along elastic margins. We thus suspect that the clustering of giant earthquakes in accretionary settings (i.e. deforming forearcs) suggested by the historic record reflects the higher probability of synchronization of seismic cycles in adjacent megathrust segments along strike of the subduction zone. Importantly, this implies that generally every subduction zone of the world produce giant M > 9 earthquakes but at different long-term rates.