Compliant prisms often, but not always, enhance shallow slip and tsunami height

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Subduction zones exhibit great diversity in the size and structure of their frontal prisms, elastically compliant regions of the hanging wall extending a few to more than 30 km inboard from the trench. Many researchers have suggested, based on intuition derived from static elasticity and the assumption of constant stress drop along the plate interface, that compliant prisms would enhance shallow slip, seafloor uplift, and tsunami height during megathrust events. However, the complex rupture dynamics of megathrust events, together with the possibly of different frictional properties, such as rate-strengthening sediments, beneath the prism, motivates more detailed investigation of this problem. We present 2D dynamic rupture simulations of megathrust ruptures that account for compliant prisms, rate-and-state fault friction, and the response of a compressible ocean with gravity. Drawing upon constraints from seismic imaging, ocean drilling projects, and laboratory experiments, we explore a three-dimensional parameter space of prism size, compliance, and sub-prism friction. We find that large, compliant prisms enhance shallow slip and tsunami height when the fault beneath the prism is velocity-weakening. However, when sub-prism friction is velocity-strengthening, large, compliant prisms actually diminish shallow slip and tsunami height. In all cases, the rupture dramatically slows down to a velocity close to the prism shear wave speed as it passes beneath the prism. We also find that small prisms (less than about 10 km width) provide only a local enhancement of shallow slip and relatively little effect on tsunami height. Our study highlights the importance of the detailed prism structure and sub-prism frictional properties on megathrust ruptures and tsunami generation, and motivates subduction-zone-specific models to quantify earthquake and tsunami hazards.

Keywords: subduction zone, earthquake, tsunami, rupture dynamics, frontal prism

