

Anatomy of Strike Slip Fault Tsunami-genesis

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On September 28, 2018, an inexplicably large tsunami devastated the Indonesian coastal city of Palu (Sulawesi). Between the tsunami and the magnitude 7.5, earthquake that caused it, some 4,340 people were killed, making it the deadliest earthquake that year, Fritz et al. 2019. The Palu earthquake rupture occurred on the *strike-slip* segment of the Palu-Koro fault system bisecting the narrow Palu bay and was *super-shear* [2]. *Super-shear*, or *Intersonic* earthquakes, are ones which involve ruptures whose speeds exceeded the shear wave speed of crustal rock. Their existence was first observed and studied experimentally by Rosakis and his coworkers [3,4,5], who also investigated their unique ground motion signatures[6]. While tsunami generation from underwater ground motions associated with *thrust-fault* earthquakes has long been recognized as a major hazard to coastal and marine areas, the ability of underwater *strike-slip* faulting to generate substantial tsunamis has been dismissed by tsunami experts. Here we discuss the results of a study [7] which shows that near-fault ground motions due to strike-slip earthquakes can indeed create large tsunamis under rather generic conditions applicable to Palu and elsewhere. We demonstrate that *super-shear*, *strike-slip* earthquake ruptures are very efficient in producing tsunamis due to the interactions of resulting unattenuated shear Mach-Cones [6] with close-by shorelines and bay boundaries [7]. To this end, we have developed a coupled computational mechanics framework that integrates fully 3-D models for earthquake rupture dynamics with fluid mechanics models of tsunami generation and propagation. The three-dimensional, time-dependent, vertical and horizontal ground motions from spontaneous dynamic rupture models are translated into a moving bathymetry of the bay that drives the 2D nonlinear shallow water-wave equations. We find that supershear ruptures propagating along underwater, strike-slip faults, traversing narrow bays, are prime candidates for tsunami generation. We also show that, the dynamic focusing effect and the large horizontal displacements, characteristic of strike-slip earthquakes (especially *super-shear* ones) on long faults, are the critical drivers for the tsunami hazard in bays. These findings point to intrinsic mechanisms for tsunami generation by strike-slip faulting that do not require us to invoke complex seismic sources, landslides, or complicated bathymetries. We identify three distinct phases in the tsunami motion; an instantaneous dynamic phase, a lagging co-seismic phase, and a classical post-seismic phase, each of which affect the coastal areas differently (see Fig-1). We conclude by emphasizing the need for re-evaluating the near-source tsunami hazard to coastal areas (e.g. the SF bay area in CA, the sea of Marmara near Istanbul, or the bay of Al Aqaba in the Red Sea) from *local* strike-slip faults.

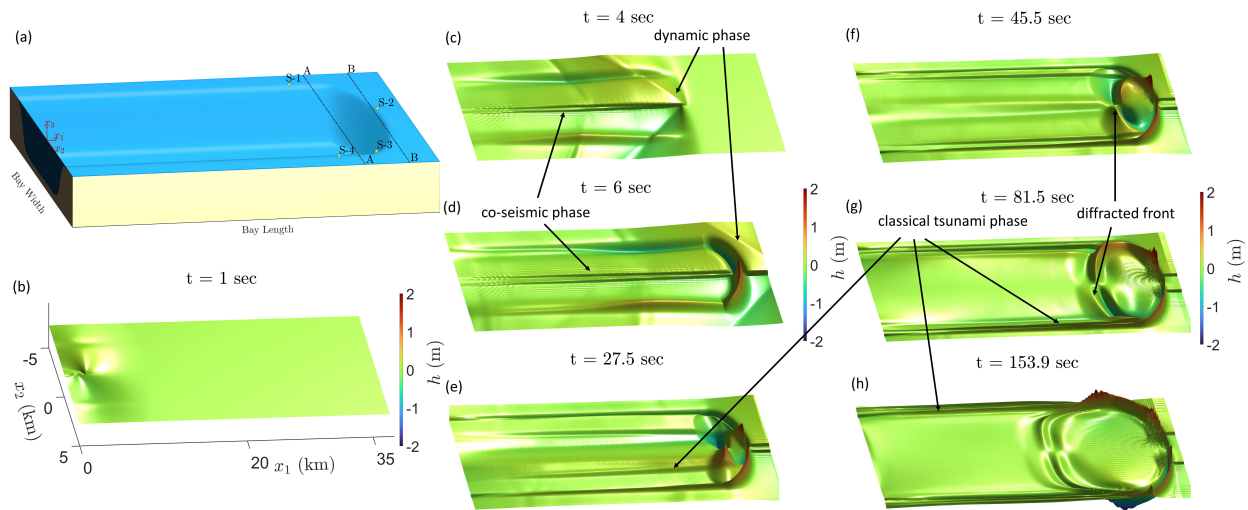


Fig. 1. Evolution of the earthquake induced Tsunami in a basin traversed, from left to right, by a super-shear rupture propagating on a strike-slip fault under it: (a) Basin bathymetry, with various measuring stations and sections marked. (b-h) Snapshots of the super-shear tsunami scenario at 1, 4, 6, 27.5, 45.5, 81.5 and 153.9 s after rupture nucleation at depth, shown sequentially from left to right. Colors indicate the sea surface height (h) relative to the undisturbed water level. Panels (b,c,d) correspond to the "dynamic tsunami generation phase", and the rest to the "post-seismic classical tsunami generation phase". The evolution of different tsunami generation mechanisms, as well as co-seismic rupture signatures are observed.

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