Three-dimensional physical modeling of granular landslide tsunami generation in various scenarios

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Tsunamis generated by landslides and volcanic island collapses account for some of the most catastrophic events. Major tsunamis caused by landslides or volcanic island collapse were recorded at Unzen in 1792, Krakatoa in 1883, Tafjord, Norway in 1934 (Harbitz et al., 1993), Lituya Bay, Alaska in 1958 (Fritz et al., 2009), Papua New Guinea in 1998 (Synolakis et al., 2002), and Haiti in 2010 (Fritz et al., 2010). The 50th anniversary of the Vajont disaster highlights an extreme landslide tsunami in a narrowly confined reservoir behind a 265.5 m high double curved arch dam (Müller, 1964). A maximum water depth of 250 m was reached by early September 1963 during the third filling attempt of the reservoir, but as creeping on the southern flank increased a third reservoir draw down was initiated. By October 9, 1963 the water depth was lowered to 240 m as the southern flank of Vajont reservoir catastrophically collapsed on a length of more than 2 km. The lateral spreading of the surge overtopped the dam crest and sent a flood wave into the Piave Valley resulting in 2000 fatalities. The wave runup in direct prolongation of slide axis reached the lowest houses of Casso 270 m above reservoir level before impact corresponding to the second largest tsunami runup in recorded history behind only the 524 m runup at Lituya Bay in 1958 (Figure 1).

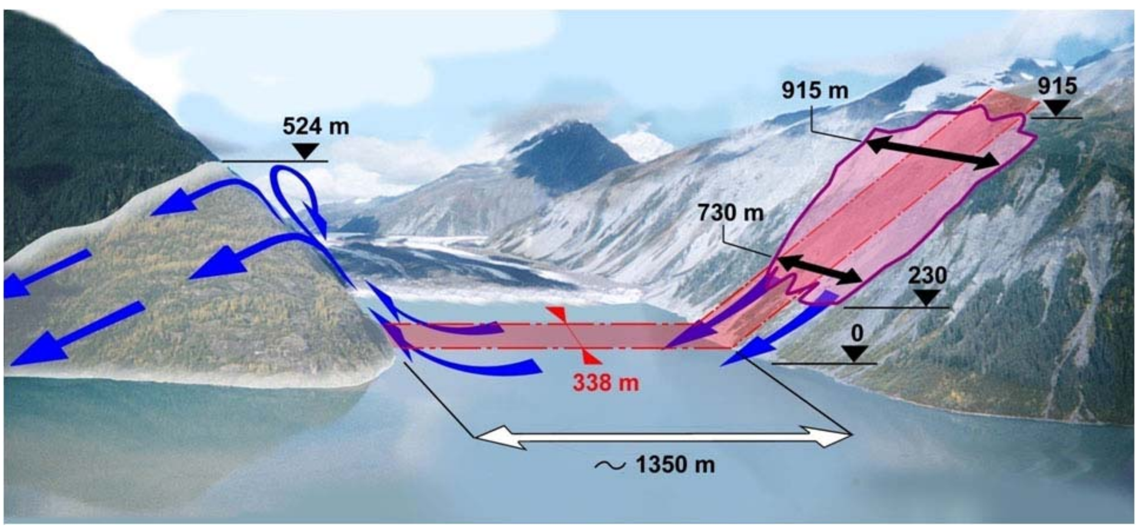

Figure 1. Landslide generated mega-tsunami in Lituya Bay, Alaska in 1958: Tsunami generation zone in Gilbert Inlet with rockslide dimensions, impact site and 524 m wave runup on opposing spur ridge (Fritz et al., 2004, 2009).

Source and runup scenarios based on real world events are physically modeled in the three dimensional NEES tsunami wave basin (TWB) at Oregon State University (OSU). A novel pneumatic landslide tsunami generator (LTG) was deployed to simulate landslides with varying geometry and kinematics. The LTG consists of a sliding box filled with up to 1,350 kg of naturally rounded river gravel which is accelerated by means of four pneumatic pistons down the 2H: 1V slope, launching the granular landslide towards the water at velocities of up to 5 m/s resulting in corresponding landslide Froude numbers at impact in the range $1 < F < 4$ (Mohammed and Fritz, 2012). Topographical and bathymetric features can greatly affect wave characteristics and runup heights. Landslide tsunamis are studied in different topographic and bathymetric configurations: basin wide propagation and runup, a narrow fjord and curved headland configurations, and a conical island setting representing landslides off an island or a volcanic flank collapse (Figure 2). Water surface elevations were measured by an array of resistance wave gauges. The granulate landslide shape and front velocity were measured using above and underwater cameras. Three-dimensional landslide surfaces with surface velocities were reconstruction using a stereo particle image velocimetry (PIV) setup. The speckled pattern on the surface of the granular landslide allows for cross-correlation based PIV analysis. Wave runup was measured by combining resistance wave gauges along the slope and video image processing. The measured landslide and tsunami data serve to validate and advance 3-dimensional numerical landslide tsunami and prediction models.

Figure 2. Conical Island setup with tsunami generation by granular landslide impact at h = 1.2 m.

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