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Tsunami Research driven by Survivor Observations: Sumatra 2004, Tohoku 2011 and the Lituya Bay Landslide (Plinius Medal Lecture)

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The 10th anniversary of the 2004 Indian Ocean tsunami recalls the advent of tsunami video recordings by eyewitnesses. The tsunami of December 26, 2004 severely affected Banda Aceh along the North tip of Sumatra (Indonesia) at a distance of 250 km from the epicenter of the Magnitude 9.0 earthquake. The tsunami flow velocity analysis focused on two survivor videos recorded within Banda Aceh more than 3km from the open ocean. The exact locations of the tsunami eyewitness video recordings were revisited to record camera calibration ground control points. The motion of the camera during the recordings was determined. The individual video images were rectified with a direct linear transformation (DLT). Finally a cross-correlation based particle image velocimetry (PIV) analysis was applied to the rectified video images to determine instantaneous tsunami flow velocity fields. The measured overland tsunami flow velocities were within the range of 2 to 5 m/s in downtown Banda Aceh, Indonesia.

The March 11, 2011, magnitude Mw 9.0 earthquake off the coast of Japan caused catastrophic damage and loss of life. Fortunately many survivors at evacuation sites recorded countless tsunami videos with unprecedented spatial and temporal coverage. Numerous tsunami reconnaissance trips were conducted in Japan. This report focuses on the surveys at selected tsunami eyewitness video recording locations along Japan's Sanriku coast and the subsequent tsunami video image analysis. Locations with high quality survivor videos were visited, eyewitnesses interviewed and detailed site topography scanned with a terrestrial laser scanner (TLS). The analysis of the tsunami videos followed the four step procedure developed for the analysis of 2004 Indian Ocean tsunami videos at Banda Aceh. Tsunami currents up to 11 m/s were measured in Kesennuma Bay making navigation impossible. Further tsunami height and runup hydrographs are derived from the videos to discuss the complex effects of coastal structures on inundation and outflow flow velocities.

Tsunamis generated by landslides and volcanic island collapses account for some of the most catastrophic events. On July 10, 1958, an earthquake Mw 8.3 along the Fairweather fault triggered a major subaerial landslide into Gilbert Inlet at the head of Lituya Bay on the south coast of Alaska. The landslide impacted the water at high speed generating a giant tsunami and the highest wave runup in recorded history. This event was observed by eyewitnesses on board the sole surviving fishing boat, which managed to ride the tsunami. The mega-tsunami runup to an elevation of 524 m caused total forest destruction and erosion down to bedrock on a spur ridge in direct prolongation of the slide axis. A cross-section of Gilbert Inlet was rebuilt in a two dimensional physical laboratory model. Particle image velocimetry (PIV) provided instantaneous velocity vector fields of decisive initial phase with landslide impact and wave generation as well as the runup on the headland. Three dimensional source and runup scenarios based on real world events are physically modeled in the NEES tsunami wave basin (TWB) at Oregon State University (OSU). The measured landslide and tsunami data serve to validate and advance numerical landslide tsunami models.

This lecture encompasses multi-hazard aspects and implications of recent tsunami and cyclonic events around the world such as the November 2013 Typhoon Haiyan (Yolanda) in the Philippines.