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2011 Japan tsunami observations and inundation velocity measurements from survivor videos using LiDAR

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On March 11, 2011, a magnitude Mw 9.0 earthquake occurred off the coast of Japan's Tohoku region causing catastrophic damage and loss of life. Numerous tsunami reconnaissance trips were conducted in Japan (Tohoku Earthquake and Tsunami Joint Survey Group). This report focuses on the surveys at 9 tsunami eyewitness video recording locations in Yoriisohama, Kesennuma, Kamaishi and Miyako along Japan's Sanriku coast and the subsequent video image calibration, processing, tsunami hydrograph and flow velocity analysis. Selected tsunami video recording sites were visited, eyewitnesses interviewed and some ground control points recorded during the initial tsunami reconnaissance from April 9 to 25.

A follow-up survey from June 9 to 15, 2011 focused on terrestrial laser scanning (TLS) at locations with previously identified high quality eyewitness videos. We acquired precise topographic data using TLS at nine video sites with multiple scans acquired from different instrument positions at each site. These ground-based LiDAR measurements produce a 3-dimensional "point cloud" dataset. Digital photography from a scanner-mounted camera yields photorealistic 3D images. Integrated GPS measurements allow accurate georeferencing of the TLS data in an absolute reference frame such as WGS84. We deployed a Riegl VZ-400 scanner (1550 nm wavelength laser, 42,000 measurements/second, <600 meter max range) and peripheral equipment from the UNAVCO instrument pool.

The original full length videos recordings were recovered from eyewitnesses and the Japanese Coast Guard (JCG). Multiple videos were synchronized and referenced in time (UTC). The analysis of the tsunami videos follows a four step procedure developed for the analysis of 2004 Indian Ocean tsunami videos at Banda Aceh, Indonesia (Fritz et al., 2006). The first step requires the calibration of the sector of view present in the eyewitness video recording based on visually identifiable ground control points measured in the LiDAR point cloud data. In a second step the video image motion induced by the panning of the video camera was determined from subsequent raw color images by means of planar particle image velocimetry (PIV) applied to fixed objects in the field of view. The third step involves the transformation of the raw tsunami video images from image coordinates to world coordinates. The mapping from video frame to real world coordinates follows the direct linear transformation (DLT) procedure (Holland et al., 1997). Finally, the tsunami surface current and flooding velocity vector maps are determined by applying the digital PIV analysis method to the rectified tsunami video images with floating debris clusters resulting in instantaneous tsunami velocity vector fields. Tsunami currents up to 10 m/s per second were measured in Kesennuma Bay making navigation impossible. Characterizing tsunami inundation with hydrographs and flow velocities is critically important for the preservation of world heritage cites.