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Detection and volume estimation of earthquake-triggered landslides from multitemporal LiDAR and tri-stereo satellite 3D remote sensing

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In mountain areas, extreme events, like earthquakes and typhoons, can trigger thousands of landslides. In addition of representing a major threat to local populations, landslides also contribute actively to surface erosion and thus can help to better understand landscape evolution. Efficient and robust methods to assess landslide location and volume are crucial to map their spatial distribution and to estimate induced erosion. Classical methods are based on a manual or automatic detection of landslide extent and area from 2D satellite images and on an area-to-volume conversion using empirical scaling laws. Yet, these 2D methods are prone to major issues such as landslide amalgamation. Here, we develop a new method that directly compares pre- and post-event 3D topographic surfaces obtained from point cloud data to measure erosion by landslides.

We apply this method to the landslides triggered by the 14 November 2016 Mw 7.8 Kaikoura earthquake in New Zealand, using point clouds derived from both LiDAR data and satellite images by photogrammetry using MicMac. Pre-earthquake LiDAR data used are dated March 2014 and post-earthquake LiDAR and satellite data from December 2016 to January 2017. To compare pre- and post-event points cloud, we remove surface displacement due to the earthquake by applying a translation with an Iterative Closest Point. We first compare these different datasets in terms of point cloud quality and landslide detection capability. A detection threshold is defined on stable areas as twice the standard deviation of the distance calculation. Then, point clouds differencing was performed by the M3C2 algorithm at 1 meter resolution in 3D in order to detect points subjected to significant erosion or sedimentation. Co-seismic landslides are then individualized by a segmentation step with connected component.

The detection threshold is about 0.4 m for LiDAR data, and 2 m for tri-stereo satellite data. This method allowed to detect 183 landslides with LiDAR data, ranging from 10 to 37 812 m2 over a 5.2 km^2 area on the Conway segment of the Hope fault. Due to the higher detection threshold, only 143 landslides were detected using tri-stereo satellite point clouds. Except for this lower limit, satellite and lidar data volume estimates are similar for large landslides. With this dataset, we found an exponent of γ = 1.25 in the area-volume relationship which is consistent with previous studies. While landslide volume is commonly estimated using area-to-volume scaling laws, this method allows a direct 3D measurement, avoiding issues such as landslide amalgamation, interpolation through DEM generation or reactivated landslides scars leading to an overestimation of the total volume. Uncertainties are provided on each measured landslide volume which allows a better precision in total volume prediction. Moreover, landslide scars and deposits can be assessed independently, and the geometry of each landslides and their associated mass redistribution can be investigated in a robust framework.