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Rockfall hazard assessment by using terrestrial laser scanning. A case study in Funchal (Madeira)

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Rockfall hazard assessment in a high-relief volcanic environment is a difficult task, facing the challenge of missing standard rating systems and procedures. Likewise mountainous areas, further handicaps are a restricted accessibility to the rock faces and the high efforts in terms of time and labour force to identify and rate these problems. To develop a procedure for rockfall hazard assessment, the island of Maderia is a good research area to investigate rockfalls in a volcanic environment under sub-tropic humid climate conditions. As the entire island is characterised by high mountain ridges and steep deep valleys in lavaflows and tuff layers, the occurrence of rockfalls is a frequent and a serious problem. These hazards are the most frequent causing severe damage to infrastructure and fatalities. In this research, slopes in Funchal city have been mapped and investigated regarding their rock fall hazard potential. The analysed slopes are build-up of lava flows with column structures and intercalated breccias, pyroclatics or tuff layers. Many of the columns already lack basal support and show a wide joint spacing, threatening houses and streets in the city. TLS data acquisitions in May and December 2008 provide information for detailed structural analysis, detection of unstable areas within a slope and rockfall simulations. High resolution scans have been recorded on uncovered rock surfaces with detectable joints while in areas with dense vegetation a lower resolution has been chosen. Although it makes sense to scan an entire area with the best acquirable resolution, the resulting enormous data require powerful computing environments and will slow down data processing. To speed up the data processing, a conventional local digital elevation model (DEM) built up the geometric basic model. Its main disadvantage is that it is not possible to project overhanging parts or notches within the steep slopes which have an important influence on the accuracy of any rockfall simulations. By implantation of the high resolution scans of the TLS into the local DEM, an improvement close to a solely high-resolution digital elevation model (HRDEM) can be achieved. The rockfall hazard assessment starts by comparison of time-shifted datasets and with additional automatic jointing analysis. Based on this data 3-D displacements and associated kinematical failure mechanism can be identified. Using on this information, it becomes possible to determine specific parameters for numerical rockfall simulations like average block sizes, shape or potential sources. Including additional data like surface roughness the results of numerical rockfall simulations allow to classify different areas of hazard based on run-out distances, frequency of impacts and related kinetic energy. The analysis shows that rockfall favourable occurs in areas where notches and undercuts, due to the lesser erosionresistence of pyroclatics or tuff layers, appear. In case of a rockfall the typical blocks have a cylindrical shape, a volume of 1 m^3 and are able to hit the entire area. The results can help to provide useful information for civil protection and engineering countermeasures. Repeated TLS scans on the same area will continue the observation and the progress of instability and mass movement occurrence.