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# Application of terrestrial laser scanning for coastal geomorphologic research questions in western Greece

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Coasts are areas of permanent change, influenced by gradual changes and sudden impacts. In particular, western Greece is a tectonically active region, due to the nearby plate boundary of the Hellenic Arc. The region has suffered from numerous earthquakes and tsunamis during prehistoric and historic times and is thus characterized by a high seismic and tsunami hazard risk. Additionally, strong winter storms may reach considerable dimensions.

In this study, terrestrial laser scanning was applied for (i) annual change detection at seven coastal areas of western Greece for three years (2009-2011) and (ii) accurate parameter detection of large boulders, dislocated by high-energy wave impacts. The Riegl LMS-Z420i laser scanner was used in combination with a precise DGPS system (Topcon HiPer Pro) for all surveys. Each scan position and a further target were recorded for georeferencing and merging of the point clouds. (i) For the annual detection of changes, reference points for the base station of the DGPS system were marked. High-resolution digital elevation models (HRDEM) were generated from each dataset of the different years and are compared to each other, resulting in mass balances. (ii) 3D-models of dislocated boulders were reconstructed and parameters (e.g. volume in combination with density measurements, distance and height above present sea-level) were derived for the solution of wave transport equations, which estimate the minimum wave height or velocity that is necessary for boulder movement.

(i) Our results show that annual changes are detectable by multi-temporal terrestrial laser scanning. In general, volumetric changes and affected areas are quantifiable and maps of changes can be established. On exposed beach areas, bigger changes were detectable, where seagrass and sand is eroded and gravel accumulated. In opposite, only minor changes for elevated areas are derived. Dislocated boulders on several sites showed no movement. At coastal areas with a high surface roughness and along recent beaches, post-processing of point clouds turned out to be more difficult, due to noise effects by water and shadowing effects. A point to point comparison was used in addition to check the results.

(ii) Furthermore, it is possible to obtain highly accurate volumetric data of dislocated boulders by 3D reconstruction. Further parameters, such as inclination, elevation above sea level or the distance of the boulder to the sea can be extracted from the 3D model of the study site. Accurate maps of the geomorphological settings are established. All parameters were incorporated into selected wave transport equations, which regard the variable "mass" as a direct input parameter for the calculation of wave heights and velocities needed for boulder dislocation. Our results were compared to data based on manual measurement of boulder axes and roughly estimated rock density values, which show a combined, general overestimation of $\sim$40%.