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Monitoring coastal-cliff erosion processes using a novel change detection methodology for high-resolution terrestrial laser scanner data

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High-resolution terrestrial laser scanning technology is one of the primary tools for studying coastal cliff retreat processes. Commonly driven by basal wave-cut erosion and subsequent gravitational instability of the entire cliff face above, the variable physical erosional processes observed in the coastal cliff environment characteristically occur at spatial scales ranging from 0.01-100 m. Thus, laser-scanning technology, which is specifically designed to measure surface micro-topography at these scales, now offers a unique resource to study coastal cliff erosion. Furthermore, the short seasonal time scales associated with the evolution of coastal cliffs makes repeated scanning especially suitable for analyzing morphological changes and the erosional dynamics in the coastal cliff environment.

Here, we focus on selected sites along the Mediterranean coastal cliff of Israel and utilize for the first time a novel change detection model that allows us to overcome the typical 2-3 fold resolution degradation associated with conventional change detection algorithms based on rasterization of the raw laser data (which is not applicable here from the outset). Our model involves no data loss, is three- dimensional, and requires no imposition of external constraints (e.g., enforcement of a positional constraint). Using a relative 3D rigid-body-transformation relation between the datasets and utilizing a polar data representation, we reformulate the "change detection question" into a "point visibility" problem. This reformulation provides direct solution to problems associated with occlusion, multi-scale analysis between and within scans, and varying scanner positions. It, therefore, enables detecting major and minor changes within different ranges, efficiently, and at once.

Change detection, as demonstrated here, allows us to study and monitor collapse dynamics that occur at the resolution limits of existing laser systems. In particular, we can now link measured mm-scale deformation with cliff-scale collapse mechanisms in order to gain a more comprehensive understanding of the cliff erosional processes and possibly identify collapse precursors such as crack widening and mass creep. The new change detection algorithm presented here also facilitates improved geotechnical site-specific hazard monitoring.