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Low retreat rate sea cliff monitoring by photogrammetric methods

F. Marques (1,2), P. Redweik (1,3), R. Matildes (1), and L. Santos (1)

(1) Faculty of Sciences, Lisbon University, (2) Department of Geology, Centre of Geology (fsmarques@fc.ul.pt), (3) Department of Geographic Engineering, Geophysics and Energy

Sea cliff evolution is dominated by the occurrence of mass movements of different types and sizes, being a considerable source of natural hazard in coastal areas. Hazard assessment requires the use of substantially complete inventories of cliff failures occurred in the past, which are usually produced by multi-temporal aerial photo based studies, where photogrammetric methods still combine the advantages of high accuracy and the possibility of monitoring periods of time in excess of half a century.

However, the study of low retreat rate cliffs still involves problems, because parts of the cliff top contour remain unchanged during the monitoring period and retreat is restricted to the places where cliff failures have occurred. This situation creates problems related with the inherent difficulties of a multi-temporal processing of aerial photos (different flight directions and scales, insufficient ground control for older photos and poor radiometric quality) and requires the use of refined photogrammetric approaches to prevent the generation of false mass movements, which cannot be included in the inventories.

Because cliff retreat is discontinuous in space and time, better sampling of the process requires the widening of the monitoring time window, by use of older aerial photos, which involve further problems as unavailable camera calibration and photo distortions. To address these problems, the sea cliffs of Burgau-Lagos coast (Southwest Algarve, Portugal) were studied using digital photogrammetry methods, which involved several aerotriangulation steps, generation of pseudo-camera data for the older aerial photos, stereo plotting of the cliff top, ridges and toe and automatic generation of digital terrain models. Inconsistencies in the results were solved by systematic stereo photo interpretation, supported by oblique aerial photos.

This study enabled the detection and characterization of 137 cliff failures that occurred between 1947 and 2007 along the 13 km long cliffs, causing the loss of 10,234 m^2 of horizontal area at the cliffs top. The cliff failures identified correspond to planar slides (58%) mainly in Cretaceous alternating limestone and marls, toppling failures (17%) mainly in Miocene calcarenites, slumps (15%) in Plio-pleistocene silty sands that infill the karst in the Miocene rocks, and the remaining 10% correspond to complex movements, rockfalls and not determined cases.

The space distribution of cliff failures is quite irregular but enables the objective separation of sub sections with homogeneous retreat behavior, for which were computed mean retreat rates varying within one order of magnitude from $5x10^{-3}$m/year in strong sandstones to $5x10^{-2}$m/year in Miocene calcarenites with frequent karst sinkholes filled with Plio-pleistocene silty sands, reflecting the strength variations of the rock masses that compose the cliffs. The maximum value of local retreat of the cliff top was up to 33m, with more frequent values in the range 2m to 6m. The relation between the magnitude expressed by the maximum local retreat and frequency follows an inverse power law for values higher than 2m with exponent of 1.8, close to the values recently proposed (Marques, 2008).

The photogrammetric methods used in this study, and specially the strategies to obtain reliable information from old aerial photos, provided an accurate characterization of the cliffs evolution and supported a reliable compilation of a systematic inventory of cliff failures occurred in a 60 years period. These methods provided a confirmation and enhancement of a previous inventory made with simplified methods, providing a more detailed picture of the space and time distribution of cliff failures, but without changing substantially the general pattern of the studied phenomena.

The use of these methods requires a considerable degree of expertise and resources and, for reliable compilation of an inventory data set, a final systematic checking of each cliff retreat event is still required.

The specific topic of DDEM generation for reliable assessment of volumetric data is still in development and may provide a significant improvement of the outputs of these methods in the particular topic of low cliff retreat rate monitoring.

Reference:

Marques, F.M.S.F. (2008) Magnitude-frequency of sea cliff instabilities. Nat. Hazards Earth Syst. Sci., 8, 1161-1171.