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Assessment and prediction of coastline erosion using airborne Lidar: an example from the East Sussex, UK

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Approximately 53% of the 6250 km length of coastline in England and Wales is characterized by cliffs. Much of the chalk cliff coast line of southeast England suffers from erosion processes, often manifested in the form of episodic slope failure, threatens public safety as well as public and private property.

The study area (about 11 km length) extends between Brighton Marina (Black Rock) and Newhaven (West side) in East Sussex (UK). It is representative of a protected and unprotected large sections of Cretaceous chalk cliff, where rock failures have occurred in the past. The main impact of coastal changes on which this paper focuses, is the recession process, which, in the study area, could influence resident's safety and critical infrastructures. The need to have reliable information about the cliff spatial variation retreat is vital to accurately evaluate and manage future risk, therefore, the objective of this study is to quantify cliff retreat and to predict coastline position scenarios in 2-5-10 and 20 years.

For the study area, the most of the available erosion rates were derived from historic mapping approaches (Cleeve and Williams, 1987; May, 1971; May and Heeps, 1985; Thorburn, 1977; Dornbusch et al., 2008a). The technique of manually tracing and overlaying cliff lines introduces errors associated with the accuracy of tracing the line, the pencil width and expansion or contraction of the paper. These errors are further aggravated by the necessity of enlarging or reducing maps to facilitate the comparison of maps of different scale (Dornbusch et al., 2006).

The use of Light Detection and Ranging (LiDAR) for airborne topographic mapping began in the 1970's (Ackermann, 1999), but its accuracy was limited by poor determination of aircraft position and orientation. Over the last decades, the application of airborne LiDAR in the coastal zone for quantifying cliff erosion greatly increased. Many reasons led researchers to LiDAR use: sufficient accuracy for monitoring and planning, dense coverage, rapid survey, cost-effective, comparable to traditional survey and to future LiDAR, etc.

In order to evaluate the topographic change of the cliffed coast, two airborne LiDAR data sets flown in November 2007 and November 2009 were used. For each site, the tiles were compared with corresponding aerial photographs using Global Mapper 15. The purpose of this was to be able to 'mask' the cliff data, at the cliff toe and the cliff top, so differences unrelated to cliff processes (e.g. due to beach change) could be excluded, and only changes to the cliff toe, face and top were considered. Also, during the mask step, the cliff was divided in sections according to the geological and morphological characteristics, and to the mitigation work realized on the cliff face (nails and steel mesh) and at the cliff toe (seawall). In this way, the study area was divided in 16 sections that were grouped in three main areas considering the sea influence: 1) AREA 1 (about 960.5m length), corresponding to the cliff protected by the Brighton Marina harbour and the seawall; 2) AREA 2 (about 6407.8m length), is the cliff protected by the seawall, and 3) AREA 3 (about 3543.2m length), which corresponds to the unprotected cliff.

The masked sections were converted into ASCII format to be exported for analysis. For each section, the changes in elevation (Zchange) were evaluated by subtracting the 2009 grid from the 2007 grid. Negative cells indicate erosion and positive cells indicate accretion. In the next step, the accretion cells are deleted and some statistical analysis are conducted on the erosion values. Also, the slope values, extrapolated for each

section from the most recent LiDAR (2009), were subject to statistical analysis.
Young and Ashford 2006, calculated the rates of retreat using the following equation: R= V / (Hc * Lc * T) where: R= linear rate of retreat (m yr^{-1}), V= net volumetric erosion (m^3), Hc= average cliff height (m), Lc= longshore length of cliff (m) and T= time interval between consecutive years (yrs). In the current study, a new approach to the rate o retreat equation was used as follow: R= Zchange * cotanα where: α = cliff slope value (°). For each section the retreat value was calculated considering the mean, median and mode values but the most representative retreat results seems to be those calculated considering the mean according to the comparison with the retreat values calculated by other authors as shown in Tab. 1.
AREA 1, the more protected from the sea influences, shows the lowest annual average retreat ranging between 0.02 m y^{-1} and 0.09 m y^{-1}. The harbour extension (more than 500m wide), the seawall and other mitigation works, are a great solution to decrease the cliff retreat that was 1.3 m y^{-1} during the period 1899-1908/1910 (Dornbusch et al., 2008a). The results measured by other authors (Tab. 1), respect to those evaluated in the current project, generally tend to change in a limited range; to explain these differences, the different approaches used in the retreat calculation, differences in terms of annual rainfall or storms and other events or modifications along the cliff face should be considered.

Table 1. Retreat values calculated in different locations and different periods between Black Rock and Newhaven.

Location	Average rate of retreat (m y^{-1})*	Author and Reference Period	Average rate of retreat (m y^{-1})
Black Rock-Portobello	0.05	Stavrou et al. (2011): 1980-2005	0.05
Black Rock-Portobello	0.05	Stavrou et al. (2011): 1873-2005	0.22
East Saltdean-Portobello	0.11	Stavrou et al. (2011): 1873-2005	0.32
Black Rock–Rottingdean	0.05	Dornbusch et al.(2008a):1873-1925/1929	0.47
Saltdean–Newhaven	0.12	Dornbusch et al.(2008a): 1973-2001	0.2
Saltdean–Newhaven	0.12	Dornbusch et al.(2008a): 1873-2001	0.29
Peacehaven-Newhaven	0.26	Thorburn (1977): 1924-1955	0.3-0.9
Telscombe cliffs	0.08	Thorburn (1977): 1973-1975	0.45
Peacehaven	0.03	Howe (1967): 1875-1967	0.427
Roedean	0.05	May and Heeps (1985): 1826-1884	0.76
Rottingdean	0.04	May and Heeps (1985): 1873-1951	0.66
Rottingdean	0.04	May and Heeps (1985): 1951-1962	0.13

In the end, according to calculated retreat values and the current cliff top edge position, some projections were estimated by multiplying the average recession rates with the time period (2, 5, 10 and 20 years). This approach shows that along the 11 km studied, some buildings and infrastructure will suffer partial losses due to the coastline retreat process. This is a useful tool for local authorities for management plans to avoid economic losses to private or public properties. However, the coastal evolution is difficult to predict due to spatial and temporal pattern of coastal changes and more detailed analysis should be carried out.

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