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Spatial and temporal evolution and morphodynamic zonation of the Ravenna shoreface

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Abstract:
The knowledge of the shoreface morphodynamic zonation is essential for coastal zone management, to support a large set of planning decisions and in the field of engineering. To have a real knowledge of the shoreface and its evolution, repeated bathymetric surveys on the same zone for several years should be done in order to quantify the sea bottom change.
To confront this problem, an assessment of principal limit depths was conducted, adopting well-known methods in literature on the basis of the local wave climate. The closure depth was estimated for typical and extreme values, based on the considered timescale.
Keywords: Shoreface zonation, Closure depth, Coastal management, Coastal environment, Extreme value analysis.

1. Introduction

On a wave-dominated coast, such as that of Ravenna, a basic driver of shoreface morphological change is the incoming waves and their capacity to move sea bottom sediment at different depths (wave base). Generally, in shallow water (upper shoreface) there is high movement of sediment and fast morphodynamic adaptation (bars and troughs) occurring over small time-scales (events, seasons, one year); in deeper water (middle-lower shoreface) only extreme storm waves are capable of moving sediments and the progressive evolution of cross-shore profile is slow (decades to century); beyond the deepest wave base there is a transition zone towards the inner shelf where morphological change occurs over geological time-scale (NICHOLLS *et al.*, 1998; STIVE & DE VRIEND, 1995). "Closure depth is a fundamental morphodynamic boundary separating a landward active zone from a seaward less active zone over the period defined" (NICHOLLS *et al.*, 1996). This limit depth is the edge of the zone involved in a sediment exchange system that thus involves the submerged part of the coastal system. Closure depth is a statistical concept, because over a greater period of

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observation there is greater possibility of having an event capable of moving sediment at larger depth (PRANZINI & WETZEL, 2008).
The study area in Ravenna coast (Emilia-Romagna Region, Italy), is about 50 km of sandy and low gradient beaches located in the NW Adriatic Sea. Ravenna's coast is affected by many natural and anthropoghenic factors that increase the coastal vulnerability and at the moment it has segments with an erosive trend caused principally by anthropization (MARTINELLI *et al.*, 2011). The Ravenna coastal plain presents a low elevation above mean sea level (MSL) (REGIONE EMILIA-ROMAGNA, 2010), the mean height is 1.45 m above MSL and the dune crests elevations are between 1.5 to 3 m. The mean backshore/foreshore width is 70 m with mean slopes of 0.03 (tanβ); the beaches may be classified as very dissipative beaches and the zone is characterized by a microtidal regime (ARMAROLI *et al.*, 2012). According to ARMAROLI *et al.* (2012), storms are mainly generated by the “Bora” winds, which are strong winds from ENE; the "Scirocco” wind is another important wind from SE.

2. Materials and method

In order to identify the shoreface zonation for the Ravenna's coast, meteo-marine conditions are defined for the area and different values of closure depth were calculated according to the well-known relationship of HALLERMEIER (1978):

$$D_c = 2.28\,H - 68.5\,H^2/(gT^2) \qquad (1)$$

where: H and T are respectively the local significant wave height and wave period and *g* is the acceleration of gravity. Data used for the analysis cover a period from May 2007 to March 2015 and were obtained from Nausicaa, a wave buoy managed by Emilia-Romagna environmental regional agency (ARPA-ER), from Venezia buoy (national wave metric network) and from Angelina platform.
Following the method described in PRANZINI & WETZEL (2008), typical and extreme values of closure depths are estimated. Typical closure depths are associated with small-medium temporal scale assessment. Extreme closure depths are associated with medium-large temporal scale assessment and were calculated on the basis of the value of significant wave height (Hs) and peak periods (Tp) for different return period (Tr) obtained by Extremes Value Analysis (EVA) carried out on the wave data. The EVA was conducted according to BRACA *et al.* (2013a), with the *Anabasi* Excel sheet (BRACA *et al.*, 2013b), a series of “macro” implemented for helping the user in the analysis. For both parameters, the EVA was conducted on pre-selected events of storms identified according to MICORE criteria (ARPA-ER, 2011). The Peak Over Threshold (POT) series of data was therefore analyzed with a Generalized Pareto Distribution (GPD). Extreme values for Hs, Tp and the respective extreme Dc were calculated for 5, 10, 20, 50, 100 years of Tr.

3. Results

In order to calculate the typical Dc values, a complete distribution of Dc was calculated considering each value of the wave dataset. Starting from Dc data series, the values of interest were calculated: Dc_{MEAN} is the average value of the series; $Dc_{95\%}$ is the value at 95% in a cumulative frequency distribution; Dc_{MAX} is the maximum value of the series in association with the maximal Hs (3.9 m) registered in the investigated period; Dc_H is the value in association with Hs that exceeded 12 hours per year, according to HALLERMEIER (1978).

To calculate the extreme Dc value, EVA is necessary to obtain the value of Hs and T for different Tr. This analysis was carried out with the *Anabasi* Excel sheet (BRACA *et al.*, 2013b). On the basis of extreme values, extreme Dc values were calculated.

Table 1. Typical and Extreme closure depth (Dc) values.

	Dc [m]	Hs [m]	Dir_{MEAN} [°N]	Tp [s]
Dc_{MEAN}	-0.9	0.4	101.9	4.3
$Dc_{95\%}$	-2.7	1.3	64.4	6.6
Dc_{MAX}	-7.6	3.9	59.1	9.1
Dc_H	-4.4	2.2	55.2	7.2

	Dc [m]	Hs [m]	Tp [s]
Dc_{5y}	-8.2	4.1	10.2
Dc_{10y}	-8.7	4.3	10.6
Dc_{20y}	-9.1	4.5	10.9
Dc_{50y}	-9.7	4.8	11.3
Dc_{100y}	-10.0	5.0	11.6

4. Conclusions

Shoreface morphodynamic zonation and evolution are important factors that need to be considered in integrated coastal zone management and monitoring applications, especially because it is in the submerged beach that coastal erosion starts. In this work was applied a practical method to estimate the principal limit depths between upper shoreface, lower shoreface and transition zone towards the inner shelf. The upper shoreface is the "active zone" and its depth limit, over a period of 8 years of available data, is about Dc_H – 4 m; this depth is determinated by a wave of 2.2 m. The lower shoreface is the zone where a cross-shore sediment movement occurs during storms; obviously this limit is closely linked to a singular event; in this analysis the Dc_{MAX} is about -8 m associated with the highest Hs of the dataset, that is 3.9 m.

The extreme Dc at 50 years return period, which is about -10 m, could be considered the effective one from an engineering point of view.

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