Analysis of S. João da Caparica beach vulnerability to a maritime storm event

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ABSTRACT

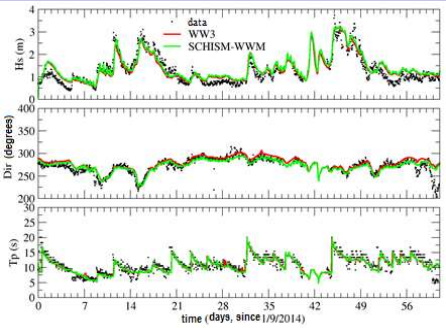
The morphological response of the S. João da Caparica beach, Almada, to the maritime storm Hercules that occurred in January/2014, was studied through mathematical modelling, for three of twelve topo-bathymetric configurations surveyed between 2008 and 2017: the two with the lowest and the one with the highest volume of sediment in the topographic part. This study aimed to quantify indicators of beach vulnerability, such as sand volume above three reference vertical levels, average and maximum retreat of two reference isobaths and maximum topo-bathymetric lowering, in order to provide guidance for future nourishment interventions. Hydrodynamic models at regional and intermediate scales were used to determine the forcing of the morphodynamic local model applied, XBeach. Besides the beach vulnerability indicators, the results revealed that the morphological configuration of the submerged zone plays an important role in the beach response when submitted to a storm with the characteristics of Hercules.

STUDY ZONE

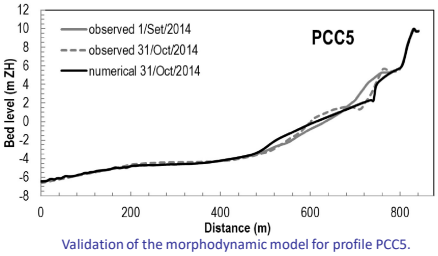
Aerial photograph of S. João da Caparica beach between groynes EV1 and EC7. Location of profiles PCC3, PCC5 and PCC7, used in the calibration of XBeach. Points P2, P3 and P4 of hydrodynamic data (© Google Earth).

MODELS VALIDATION

Topo-bathymetric evolution during the calibration period, set-out/2014.

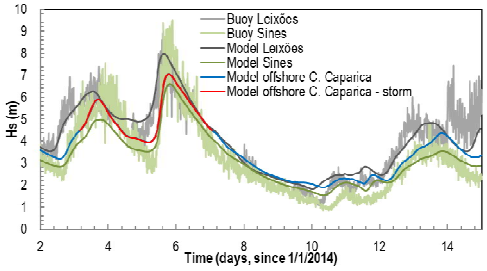


Validation of the wave climate models: hindcast values against buoy data (Hs, above; Dir, middle; and Tp, below).

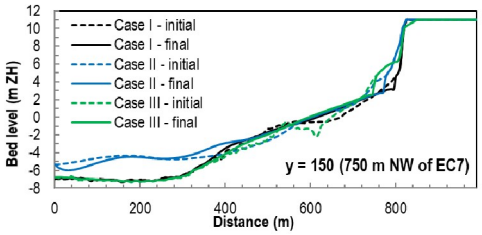


Validation of the morphodynamic model for profile PCC5.

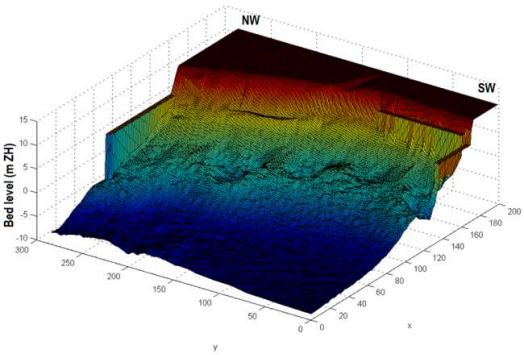
RESULTS

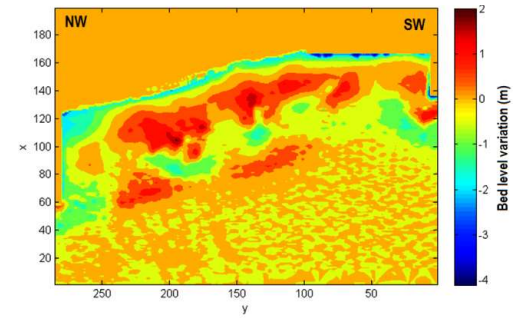


Significant wave height, Hs, in the first fortnight of Jan/2014: Leixões and Sines buoys data and WW3 model results, and offshore Costa da Caparica SCHISM-WWM model results.



Morphodynamic model results for Cases I, II and III: morphologic variation at a profile located in the central beach sector (750 m NW of EC7).





Morphodynamic model results for Case I: pre-storm topo bathymetry (above); and morphologic variation (accretion > 0 and erosion < 0, below).

- The storm caused morphological variations in all the alongshore beach extension. It smoothed out the bed irregularities by filling local depressions.
- The largest lowerings of the beach occurred in front of the alongshore defence located at the SW sector and at the NW extreme of the beach. Large values of lowering were also observed at the head's toe of EC7 and at the toe of the offshore half of EV1.
- Despite the absence of a correlation between favorability of the morphological state and the erosion or the residual volumes, Case III remains as the one with larger sand volume above levels -1 and +2 m ZH after the storm.
- The erosion and residual volumes above the -1, 0 and +2 m ZH levels were larger in Case III than in Case I. Since the lower part of the beach is similar in both cases, the cause of the different morphological beach response was the larger volume of sand available in the upper part of the beach in Case III that was provided by the 1 million m^3 nourishment of Aug/2008.
- The erosion and residual volumes above -1 m ZH in Case II are the highest of all cases. However, the erosion is predominantly located between level -1 and 0 m ZH. Above +2 m ZH the residual volume is the lowest of all cases. When comparing with Case I it can be concluded that this is due to two factors: the smoothest slope of the active zone, which slows down the energy dissipation (spilling breaker type), and the highest sand volumes above -1 and +2 m ZH levels of Case II.
- The erosion of the upper beach caused a generalised retreat of the isobath +2 m ZH, with maximum value 21 m in Case III, and a generalised advance of the isobath 0 m ZH, with maximum value of 27 m in Case II.

Erosion, sedimentation and residual area and volume above levels -1, 0 and +2 m ZH in Cases I, II and III.

Zone	Case	Area (m^2)	Sedimentation volume (m^3) (a)	Erosion volume (m^3) (b)	Residual volume (m^3) (a-b)
Above -1 m ZH	I	605 020	71 737	78 913	-7 176
	II	644 503	64 212	112 122	-47 910
	III	628 999	65 688	91 841	-26 153
Above 0 ZH	I	504 795	35 159	66 055	-30 896
	II	555 759	40 195	76 930	-36 735
	III	547 729	28 767	80 491	-51 724
Above +2 m ZH	I	407 121	817	56 910	-56 093
	II	403 569	795	37 524	-36 729
	III	431 710	303	66 726	-66 423

CONCLUSIONS

- The residual erosion volume above the +2 m ZH level was 56, 37 and 66 x 10^3 m^3 of sand for Cases I, II and III. These values agree with the measured 50 x 10^3 m^3 caused by the storm that occurred on 19/Jan/2013.
- The results also revealed that the morphological features of the active zone, such as the slope of the submerged zone, which affects the rate of the energy dissipation, play an important role in the beach response.

Acknowledgements
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