Modelling 2DH beach morphodynamics in XBeach: model versions and hydrodynamic modes performance

João Nuno C. Oliveira[1,2,]*
Filipa S.B.F. Oliveira[2]
António A. Trigo-Teixeira[1]

[1]CERIS, Instituto Superior Técnico
[2]Laboratório Nacional de Engenharia Civil
*joao.c.oliveira@tecnico.ulisboa.pt. Lisboa, Portugal.

1.INTRODUCTION

This study investigates the differences and implications of using the Surfbeat (SB) and Non-hydrostatic (NH) modes of the two latest XBeach-2DH versions, Kingsday (2015) and XBeachX (2018), in modelling morphological evolution tendencies for a setup of reference.

The objective is to analyse the differences in the morphological evolution patterns obtained for the same conditions, and relate them with the improvements and the processes accounted for in the respective version-mode to better understand how to optimize the implementation of XBeach in morphological evolution modelling.

2.DATA AND METHODS

Hydrodynamic conditions

Simple stationary erosive scenario considered during 48 hours of morphological evolution: Hs=2.15 m and Tp=11.5 s, average values characteristic of the study site for the period 1952 to 2010 (Oliveira *et al.*, 2016).

Wave angle of 45º of incidence to maximize longshore sediment transport, according to the CERC formulation.

Mean sea level (SL) set at 2 m above ZH.

Topo-bathymetry and sedimentology

Topo-bathymetric (Fig. 1) and sediment characteristics based on representative conditions for Cova-Gala (Oliveira *et al.,* 2016).

Computational domain: 800x1100 m^2, uniform dx=dy=5 m grid, limited by a sandy dune at the landwards boundary. Centered 260 m long and 20 m wide groyne: uniform crest level at 5 m above ZH, bottom of the structure head at 2 m below ZH.

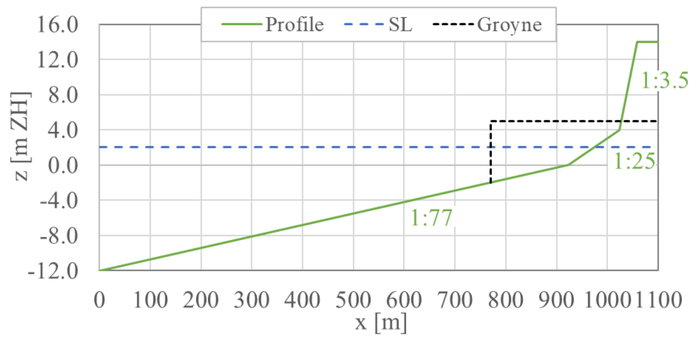

Fig. 1. Morphodynamic model initial bottom configuration: representative beach profile, groyne and sea level (SL).

Numerical modelling

Hydrostatic XBeach Surfbeat mode (SB) - solves the short-wave variations on the wave group scale and the associated long waves separately. Focus on swash zone processes. Extensively validated for the morphological evolution modelling of dissipative beaches.

Wave-resolving Non-Hydrostatic mode (NH) - computes both short and long waves but with greater computational demand. Accounts for the wave diffraction and reflection processes. Originally developed towards hydrodynamic modelling, subsequent formulation improvements.

Four different version-mode scenarios using a setup of reference were considered (Table I): the XBeach *1.22.4867 Kingsday* version was used in simulations 1, SB mode, and 2, NH mode; and the *1.23.5526 XBeachX* version was used in simulations 3, SB mode, and 4, NH mode.

Table I. XBeach model version and mode used in the numerical modelling.

Simulation	Model-version	Mode
sim1	Kingsday	Surfbeat
sim2	Kingsday	Non-Hydrostatic
sim3	XBeachX	Surfbeat
sim4	XBeachX	Non-Hydrostatic

3.RESULTS AND DISCUSSION

The results for the version-mode combinations of XBeach (Fig. 2) reveal the following morphological evolution features: a) retreat of the coastline; b) erosion of the beach face; c) formation of a submerged longshore sandbar in the upper profile at the updrift side of the groyne; d) accretion at the base of the groyne at the downdrift side; e) erosion hotspot near the groyne head; and f) formation of a longshore oblique sandbar downdrift of the groyne head.

Features a), b) and c) are observed in the results of both versions and modes, and are characteristic of the short-term beach response when subjected to an erosive wave, as the erosion of the upper beach leads to the subsequent seawards sediment transport and deposition. Features d), e) and f) can also be found in the presence of a groyne but reduced knowledge is available on the hydro-morphological conditions under which they are formed – Hs, Tp, Dir, d_{50}, bottom slope. The main reason is the difficulty to keep track of the location of these features, for being in a permanent wave breaking zone.

The erosion of the beach face (b) is similar in both Kingsday modes, as the sandbar in the upper profile (c) and the overall erosion pattern. The sandbar accretion is less intense in the NH mode, probably due to the reflection and diffraction processes accounted for in this mode that can cause the seawards deflection of the sand that was extracted from the beach face and deposited in the alongshore bar, as can be seen in Fig. 2d. These features are much more intense in the XBeachX SB mode, as is the coastline retreat (a). This can be due to the *single_dir* option introduced in XBeachX: the wave group does not spread as much and diffusion is slower, leading to better defined (involving greater volumes) erosion/accretion patterns. In the XBeachX NH mode, features a), b) and c) are more irregular than the observed in the other simulation results, and d) is not predicted.

The accretion near the groyne base (d) and the erosion hotspot near the head (e) are similarly predicted in both Kingsday modes and are more intense in the XBeachX SB mode. In XBeachX NH the erosion hotspot (e) is considerably wider and the maximum erosion predicted is four times higher than in the other simulations, most likely due to wave reflection and diffraction associated with the two-layer hydrodynamic model. These processes play a relevant part in supplying the submerged sandbar (f), already predicted in the SB mode of the same version, with the eroded sediments. The account of these processes results in the formation of a longer, more pronounced oblique sandbar in the groyne head with similar alignment to the incident wave direction.

The results indicate that the NH mode can be used for morphological evolution modelling in the same way as the SB mode, despite the limited number of parameters available for a real case study calibration in this mode. The most recent version, XBeachX, enables the model to predict physical features not predicted in the previous Kingsday version for the same conditions, such as the groyne head oblique sandbar.

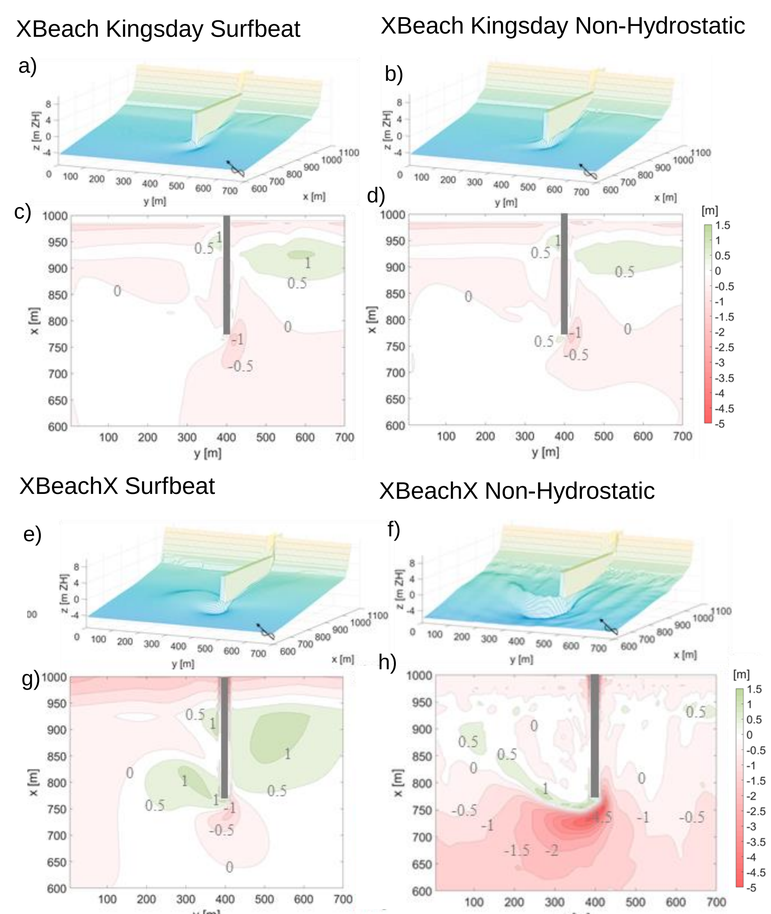

Fig. 2. Bottom configuration of the morphodynamic model after 48 hours of morphological evolution for simulations 1 (a), 2 (b), 3 (e) and 4 (f). Map of morphological differences (48 hours) for simulations 1 (c), 2 (d), 3 (g) and 4 (h): accretion in green, erosion in red. The arrows in (a), (b), (e) and (f) indicate the incident wave direction.

4.CONCLUSIONS

i) The NH mode predicts similar morphological changes as the morphology-oriented SB mode;

ii) The latest version (XBeachX, 2018) modifications and updates to the existing formulations, numerical schemes and default values, enable the model to predict physical features not identifiable in the previous version (Kingsday, 2015), such as the formation of a submerged sandbar downdrift of the groyne head;

iii) The NH XBeachX mode estimates a significantly higher overall erosion than the other version-mode model combinations.

The selection of the appropriate XBeach version-mode combination to model a specific scenario must be done according to the topo-bathymetry and structure characteristics, and the hydro-morphological parameters available for the model calibration.

REFERENCES:

Oliveira, J.N.C., Oliveira, F.S.B.F., Teixeira, A.A.T. (2016). Coastline evolution south of the Mondego river inlet: modelling the impact of the extension of the north jetty. *4th Hydrographic Institute Scientific Journeys,* Lisbon, 245-248.

Roelvink, D., Reniers, A., Dongeren, A., Vries, J.T., McCall, R., Lescinski, J. (2009). Modelling storm impacts on beaches, dunes and barrier islands. *Coastal Engineering*, 56, 1133-1152.

Roelvink, D., McCall, R., Mehvar, S., Nederhoff, K., Dastgheib, A. (2018). Improving predictions of swash dynamics in XBeach: The role of groupiness and incident-band runup. *Coastal Engineering*, 134, 103-123.

ACKNOWLEDGEMENTS:

FCT Ph.D. Grant PD/BD/128508/2017

MOSAIC.pt

CYTED Grant 2017-PE-PROTOCOL.