Numerical modelling of infragravity waves in a tidal inlet during storm conditions

Diogo MENDES[1], Alphonse NAHON[2], Kévin MARTINS[3], André B. FORTUNATO[2], Xavier BERTIN[3], Baptiste MENGUAL[4], Laura LAVAUD[4], Marc PEZERAT[5], António A. PIRES-SILVA[1]

[1] CERIS, Instituto Superior Técnico, Portugal
diogo.silva.mendes@tecnico.ulisboa.pt; antonio.pires.silva@tecnico.ulisboa.pt
[2] National Laboratory for Civil Engineering, Portugal
anahon@lnec.pt; afortunato@lnec.pt
[3] UMR 7266 LIENSs, CNRS—La Rochelle Université, France
kmartins@univ-lr.fr; xbertin@univ-lr.fr
[4] BW-CGC (Benoit Waeles - Consultant Génie Côtier), France
baptiste.mengual@bw-cgc.fr; laura.lavaud@bw-cgc.fr
[5] SHOM, France
marc.pezerat@shom.fr

ABSTRACT

During storm conditions, infragravity (IG) waves with periods between 25 s and 300 s can dominate the sea-surface oscillations near the shoreline. Through processes like wave run-up, overwash and wave overtopping, IG waves can hence become major drivers of coastal hazards. Although IG dynamics are relatively well understood in open beaches, their contribution of the hydro-sedimentary dynamics of more complex coastal settings, such as tidal inlets characterized by their ebb and flood deltas connected through a transitional channel, is not well understood. Here, we assess the performance of the widely used XBeach numerical model to predict IG wave dynamics through a comparison against field observations collected on an ephemeral tidal inlet (Albufeira Lagoon) during storm Leslie (2018). XBeach accurately predicted the observed IG significant wave heights reaching up to 1 m over a 2-day period. This performance is assessed at both the nearby beaches and the flood-delta.

1. Introduction

During storm conditions, coastal hydrodynamics change mainly due to due to incident short waves, with periods between 4 s and 20 s. The width of the surf zone increases relative to mild wave conditions, which has important implications for swash dynamics, wave set-up and the generation and dissipation of infragravity (IG) waves, with periods between 25 s and 300 s, near the shoreline (e.g., Fiedler *et al*., 2015).

The morphology of tidal inlets is usually more complex than open sandy beaches, where the flood delta is connected to the ebb delta by a transitional channel. This morphological complexity modifies the wave and current patterns, and their interaction. Moreover, field observations during storm conditions in these coastal environments are scarce in the literature. Therefore, the performance of a numerical model to forecast the IG wave dynamics in a tidal inlet during such conditions remains poorly understood.

Here, we use the XBeach numerical model to forecast IG dynamics at the Albufeira Lagoon tidal inlet during storm Leslie (2018). The assessment was performed against field observations specifically collected during this event, covering a region extending from the surf zone to the inner lagoon (Bertin *et al.*, 2019).

2. XBeach model application

XBeach is applied in surfbeat mode over a 2DH domain. The grid resolution ranged between 30 m offshore and inside the lagoon and 3 m near the inlet channel. Offshore wave conditions were obtained from a hindcast simulation with the WWIII model implemented as described in Mengual *et al*. (2022). The tidal level was specified based on the 6-min recorded time series by a tidal gauge located about 20 km north of the study site.

After several sensitivity simulations, we used the *roelvink_daly* formulation (Daly *et al*., 2012) to compute short wave dissipation by depth-induced breaking. The free model parameters were specified as follows: *gamma* = 0.40; *gamma2* = 0.30; *alpha* = 1.5. Regarding bottom friction, the accurate representation of tidal currents at the flood delta required a Manning friction coefficient n = 0.028 $m^{-1/3}s$ with a maximum friction coefficient of 0.0077. Both short wave dissipation by depth-induced breaking and bottom friction impact IG characteristics, thereby contributing to the generation or dissipation of IG waves.

3. Results and discussion

Fig. 1. displays the comparison between simulated and observed significant IG wave height (Hm0,ig). In general, the overall agreement both at the nearby beach (left) and at the flood-delta (right) is very good. This can be assessed by the values of error metrics (Bias and RMSE) that are within the range published in the literature (Bertin and Olabarrieta, 2016). The adequate reproduction of Hm0,ig time series suggests an accurate simulation of short-wave transformation, which affect the generation and dissipation of IG waves.

In more details, the model accurately captures the observed decay of Hm0,ig that occurs at the flood-delta (right) between high-tide and mid-tide (i.e. during ebb). This suggests the interaction between incoming infragravity waves and tidal currents is well reproduced by XBeach during storm events. Moreover, the model simulates the correct value of Hm0,ig at the nearby beach (left), with a slight underestimation during the maximum observed Hm0,ig value (at 4am on 14 October).

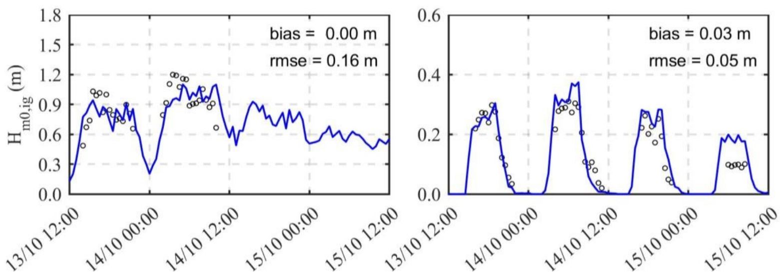

Fig. 1. Comparison between simulated (lines) and observed (circles) significant IG height on the nearby beach (left) and at the flood-delta (right). Bias and root-mean square error metrics are also shown.

Overall, the small differences between simulated and observed values of Hm0,ig, both at the nearby beaches and at the flood-delta, supports the use of XBeach to forecast the morphological evolution of this ephemeral tidal inlet during storm conditions.

Acknowledgements

The first author acknowledges Foundation for Science and Technology's (FCT) support through funding UIDB/04625/2020 from the research unit CERIS. This research was carried out in the scope of the collaborative project INLEX, funded by the French ANR and the FCT (project 40791ZC).

References

Bertin X, Mendes D, Martins K, Fortunato AB, Lavaud L (2019) The Closure of a Shallow Tidal Inlet Promoted by Infragravity Waves. Geophys Res Lett 46, 6804–6810

Bertin X, Olabarrieta M (2016) Relevance of infragravity waves in a wave-dominated inlet. J Geophys Res Oceans 121, 5418–5435.

Daly C, Roelvink D, van Dongeren A, van Thiel de Vries J, McCall R (2012) Validation of an advective-deterministic approach to short wave breaking in a surf-beat model. Coastal Eng 60, 69-83

Fiedler JW, Brodie KL, McNinch JE, Guza RT (2015) Observations of runup and energy flux on a low-slope beach with high-energy, long-period ocean swell. Geophys Res Lett 42, 9933–9941

Mengual B, Bertin X, Place F, Pezerat M, Coulombier T, Mendes D, Fortunato AB (2022) Wave-current interactions at the Tagus Estuary Mouth (Portugal) under storm wave conditions. Ocean Model 175, 102035