SHORELINE EVOLUTION MODEL CALIBRATION AT THE PORTUGUESE WESTERN COAST

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Abstract

The notable increase in coastal erosion in the last decades has been drawing the attention of coastal managers and society to this issue. Efforts have been made on the development of tools that can help the prediction of future shoreline position to help coastal managers in planning and performing appropriate coastal interventions and improve coastal erosion risk management. In this sense, numerical models appear as useful tools to simulate different intervention scenarios: do-nothing, the advance of the shoreline (nourishments) as well as the implementation/removal of coastal structures. In this work, a one-line numerical model (ShorelineS) is calibrated in four coastal stretches (53 km) along the Portuguese western coast to obtain the appropriate longshore sediment transport and shoreline position according to historical data. Also, further implementations were performed into the model in order to better represent the local conditions and also to allow different coastal engineering solutions (e.g. shoreface nourishments).

Introduction

Efforts have been made on the development of tools that can improve the prediction of future shoreline position to help coastal managers in planning and performing appropriate coastal interventions. In this sense, one-line numerical models are the most used tools for simulating medium to long-term (months to decades) shoreline changes as a response to coastal interventions. The sediment conservation equation is usually used by these kinds of models to predict coastline evolution as a function of the gradients in the wave-induced longshore sediment transport rate. The potential longshore sediment transport is calculated by a semi-empirical formula (here the CERC formula) and the wave propagation and transformation is often based on linear wave theory.

This work aims at calibrating the newly developed one-line model ShorelineS (Roelvink, et al., 2020) in four coastal stretches along the Portuguese western coast, based on both line-to-line comparison and longshore sediment transport rate. Therefore, this works provides a contribution to future assessment of coastal interventions based on cost-benefit analysis, which will help coastal managers' decisions.

Study area

The present work focuses on the shoreline evolution of four coastal stretches along the Portuguese western coast: Esmoriz-Torrão do Lameiro (E-TL), Barra-Mira (B-M), Cova Gala – Leirosa (CG-L) and Costa da Caparica (CC). All stretches are characterized by a shoreline retreat over the last 20 years, ranging between maximum values of -8 m/yr at E-TL to -4-m/yr at CC (HAEDES, 2023).

ShorelineS numerical model

General description

The ShorelineS is an open-source numerical model developed by Deltares and IHE Institute for Water Education for predicting the evolution of the shoreline position (available at www.shorelines.nl). This is a one-line model with a spatial scale of application in the order of tens of kilometres and the temporal scale in the order of a few to hundreds of years. This model has the advantage of having a dynamic computational grid based on a vector of x, y points, allowing the description of complex geometries usually observed along the coastline, such as sandy spits. A full description of the model can be found in Roelvink et al. (2020).

Model implementations

To improve the applicability of ShorelineS to the case studies, the following changes were performed: 1) determination of *k* in CERC formula based on deep-water wavelength and breaking wave height; 2) new bypass implementation across groynes; 3) new methodology to determine sediment transport along seawalls; 4) implementation of a time-varying sea level rise rate; 5) possibility of having several beach nourishments at the same run; 6) the implementation of shoreface nourishments and; 7) space-variable nearshore orientation angle.

Model calibration

The model was forced with offshore CMEMS wave data and iteratively adjustments on the input parameters were made to improve the model performance at each coastal section. The parameters that were used for calibration, as well as their description can be found on Table *1*. For the calibration procedure at Costa da Caparica, it was also possible to consider the beach nourishment performed in 2019 (1M m^3 along a 3.8 km stretch), where it was assumed a constant nourishment rate of 1500 $m^3/m.yr^{-1}$ during 2 months. Overall, the calibration period was between 3 yr and 10 yr.

Table 1 – Specific calibration parameters by coastal stretch and the calibration period.

Parameter	Description	E-TL (2011-2018)	B-M (2011-2018)	C-GL (2011-2021)	CC (2018-2020)
dMDir [°]	Shift in wave direction	0	0	0	-50
D_c [m]	Active profile height	10	16	18	10
h_n [m]	Nearshore water depth for refraction	15	20	20	15
qs_{calc}	Sediment transport calibration factor	0.3	0.325	0.31	0.1
dx [m]	Initial space step	40	40	40	30

Model verification

The evaluation of ShorelineS model performance is done using two approaches. The first one consists of the direct comparison between the simulated and measured coastlines (+3m CD). In addition to the assessment of simulated and observed shoreline fit (qualitative approach), the associated statistical errors are presented (bias and root-mean square error). The second approach consists of the quantification of the longshore sediment transport and its comparison to the reference values available in the literature.

Results

Figure 1 and Figure 2 show the comparison between the modelled and measured shoreline positions for all the four coastal stretches. The statistical errors regarding the line-to-line comparison and longshore sediment transport rates (modelled and from literature) are shown in Table 2.

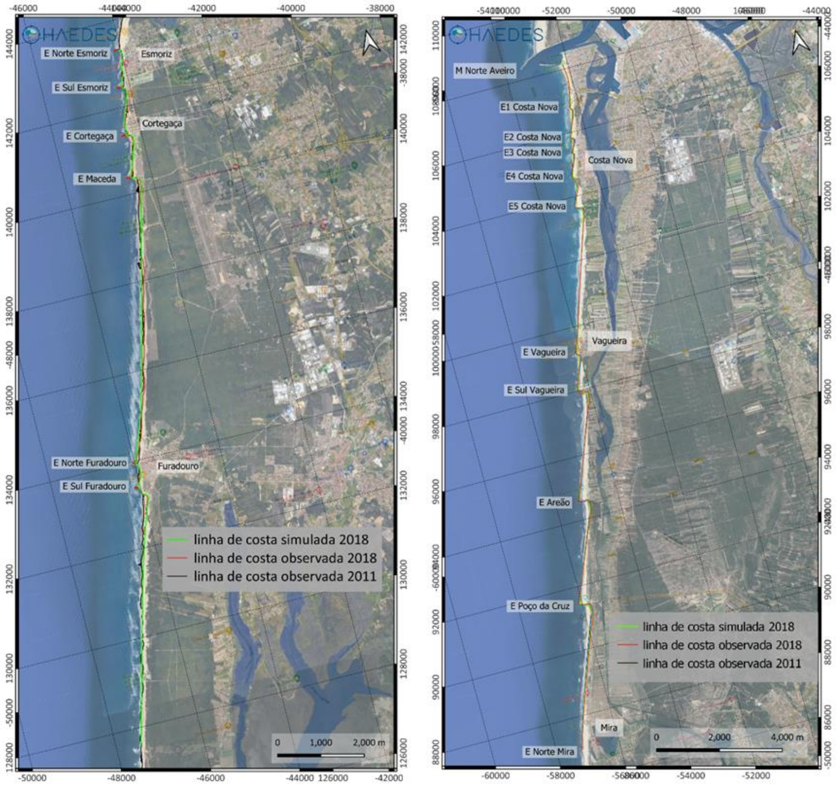

Figure 1 - Model verification at E-TL (left) and B-M (right) coastal stretches.

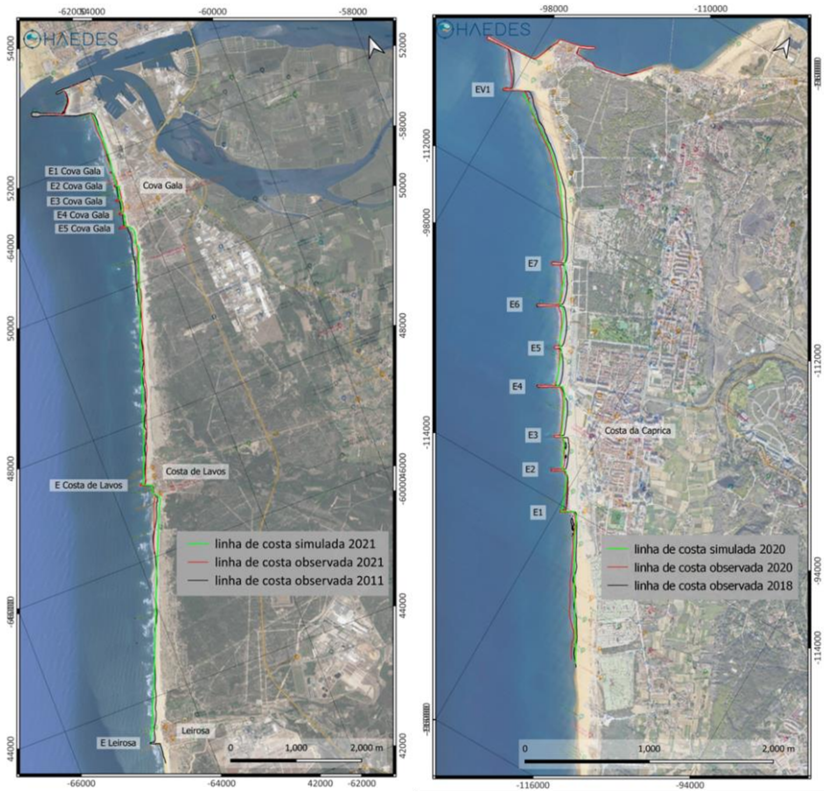

Figure 2 - Model verification at CG-L (left) and CC (right) coastal stretches.

Table 2- Statistics for the model calibration. In sediment transport rates Q_m (modeled) and Q_{ref} (reference value). Negative values represent southward transport.

Location	Coastal section	Bias [m]	RMSE [m]	Q_m(m^3/yr)	Q_{ref}(m^3/yr)
E-TL	Esmoriz/Cortegaça	-1	20	- 0.5 to -1 x 10^6	-0.5 to -3.5 x 10^6
	Furadouro	8	28		(Duarte Santos et al., 2017)
B-M	Costa Nova	-10	41	- 0.5 to - 0.8 x 10^6	-1.1 x 10^6
	Vagueira	2	47		(Duarte Santos et al., 2017)
CG-L	Cova Gala	-4	20	- 0.5 x 10^6	-1.1 x 10^6
	Costa de Lavos	-3	53		(Duarte Santos et al., 2017)
CC	S.J. da Caparica	-12	19	+ 0.1 x 10^6	+0.05 to +0.1 x 10^6
					Sancho (2023)
	Southward EC7			- 0.2 x 10^6	-0.2x10^6
					(Dodet et al., 2013)

Discussion

Results suggest that sediment transport calibration accounts for uncertainties related to the use of linear wave theory on wave propagation and transformation as well as the use of semi-empirical longshore sediment transport formulation (CERC formula). Moreover, the potential longshore sediment transport rate was reduced by a factor between three and ten, through qs_{calc} parameter to fit the actual longshore sediment transport rate. The implementations performed in ShorelineS allow a wider application of the model.The lack of quantitative information on the errors associated with shoreline modeling in similar works prevents a further comparison on model performance.

Conclusions

This work presents a calibrated shoreline evolution model for four coastal stretches along the Portuguese western coast based on both line-to-line comparison and longshore sediment transport. Also, significant implementations have been performed allowing a wider application of the model, especially regarding the coastal intervention scenarios. In future, this model can be used to assess different coastal interventions scenarios based on a cost-benefit analysis to provide useful information to coastal managers.

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