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Morphodynamic modelling of an embayed beach: role of the forcing sources

Modelado morfodinámico de una playa encajada: rol de las fuentes para el forzado

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Resumen: Modelizar la respuesta de las playas de arena al aumento del nivel del mar es un importante reto científico y existen para ello varios tipos de modelos. Debido a las largas escalas de tiempo involucradas, se deben combinar diferentes fuentes para el forzamiento del modelo (olas y nivel del mar, p.ej., de boyas o modelos "hindcast"). En este trabajo se aplica el modelo morfodinámico basado en procesos XBeach y el modelo de complejidad reducida Q2Dmorfo a El Castell, una cala situada en la costa catalana (Mar Mediterráneo occidental). Los modelos se calibran primero con datos medidos durante 161 días con un AWAC a 14 m de profundidad frente a la playa. XBeach predice razonablemente bien la evolución batimétrica mientras que Q2Dmorfo sólo reproduce la evolución de la línea de costa. Después, las versiones calibradas de los modelos se aplican utilizando otras posibles fuentes de forzamiento. La fuente para el nivel del mar no afecta los resultados, pero ambos modelos son sensibles a la fuente usada para el oleaje.
Palabras clave: morfología de playas; Modelado morfodinámico; Playas encajadas; Mar Mediterráneo.

Abstract: *Modelling the response of sandy beaches to sea level rise is a major scientific challenge and several types of models can be applied. Given the long-time scales involved, different sources for model forcing must be combined (wave and sea-level, e.g., from buoys or hindcast models). We here apply the XBeach process-based morphodynamic model and the Q2Dmorfo reduced-complexity model to El Castell, a Mediterranean embayed beach. The models are first calibrated with data measured during 161 days with an AWAC at 14 m depth in front of the beach. XBeach*

predicts reasonably well the bathymetric dynamics while Q2Dmorfo can only reproduce the shoreline evolution. The calibrated versions of the models are then applied using other potential forcing sources. The source for sea level does not affect the results but both models are sensitive to the wave forcing source.
Keywords: *beach morphology; Morphodynamic modelling; Embayed beaches; Mediterranean Sea.*

1. Introduction

The response of sandy beaches to sea level rise during the XXI century is a major scientific challenge. Process-based 2DH morphodynamic models are useful tools to understand beach response to storms but, besides their high computational cost, they tend to accumulate errors in resolving the many short-term processes they contain. Reduced-complexity models are then an interesting alternative for long-term modelling for being computationally more robust. Applying these models is not a simple task. First, they need to be calibrated and validated on the site of interest. Moreover, given the long-time scales involved, the information from different forcing sources must be combined (wave and sea level from, e.g., instruments or hindcast models).

The aim of this contribution is to quantify the effect of using different sources for the forcing conditions in morphodynamic modelling. We apply the XBeach process-based model and the Q2Dmorfo reduced-complexity model to a Mediterranean embayed beach. We first use data from nearly 6 months to calibrate both models and then we make a comparison of their accuracy using several sources for the forcing.

2. Methods

El Castell is a microtidal embayed sandy beach at the Catalan Costa Brava (Western Mediterranean Sea) about 300 m wide, bounded by rocky headlands of 160 m length and facing roughly to the South. The grain size is $d50 \approx 0.23$ mm and dominant waves come from the East and Southeast. Bathymetric surveys were conducted on 28-Jan and 8–Jul-2020 and, during those months, an AWAC was deployed at 14 m depth in front of the beach, measuring mean sea level and wave height, period, and direction.

XBeach is a process-based model (Roelvink *et al.*, 2009) that solves the full 2DH nearshore hydrodynamics and the corresponding bed evolution. Q2Dmorfo is a reduced-complexity model (Arriaga *et al.*, 2017) that computes sediment fluxes in a parametric way directly from the wave field without resolving the currents. They use different parameterizations and thereby require of a detailed calibration and validation before they can reproduce the physical processes of a particular beach. This is done by running the model from the Jan-2020 bathymetry and tuning the main parameters to optimize the Brier Skill Score (BSS) of the predicted bathymetry (XBeach) or shoreline (Q2Dmorfo) in Jun-2020. Finally, alternative forcing sources are used, including instruments and outputs from a storm surges and wind-waves 72-years hindcast generated with the hydrodynamic-wave coupled SCHISM model (Zhang *et al.*, 2016).

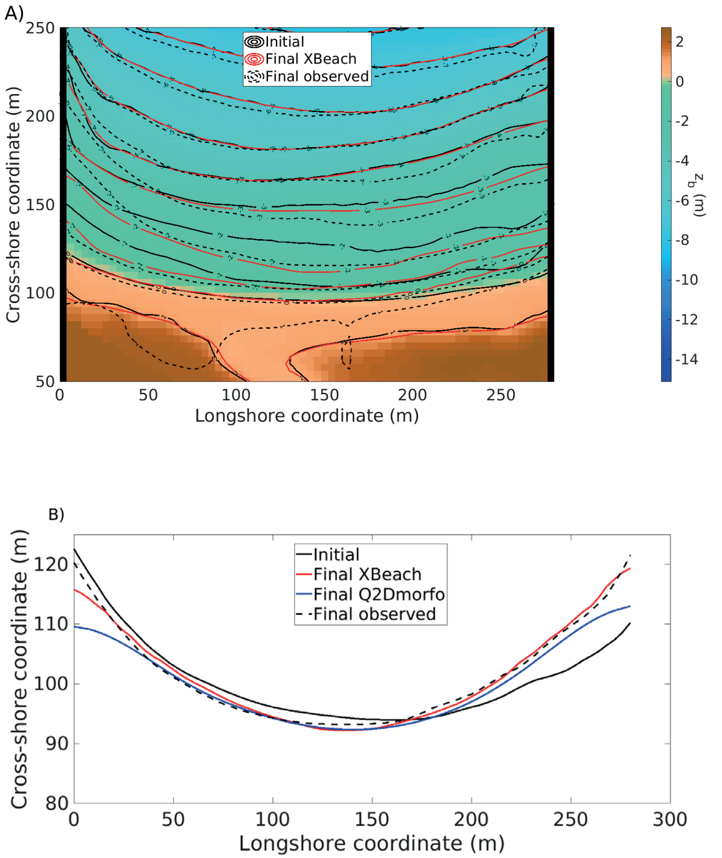

Figure 1. *A) Initial bathymetry in Jan-2020 with contour lines in black solid, and measured (black dashed) and XBeach modelled (red) contour lines in Jul-2020. B) Initial (black solid) and final (black dashed) measured shorelines, and final modelled shorelines (red and blue). In both panels, southward direction is to the top and eastward direction is to the left.*

3. Results and discussion

The models are first calibrated with the best data source for the forcing: waves and sea levels measured during the period with the AWAC. XBeach predicts reasonably well the surf-zone bathymetry (BSS=0.44, Figure 1A) from which the shoreline can be extracted (Figure 1B). Q2Dmorfo can only reproduce well the shoreline dynamics (BSS=0.64, Figure 1B) because it is not designed to accurately model the bathymetric evolution. Both models capture the observed eastward beach rotation. However, the shoreline modelled with the Q2Dmorfo model near the headlands deviates significantly from the observed one (Figure 1B). The most influential parameters for the calibration in both models are related to the cross-shore sediment transport parameterizations.

To test the sensitivity to the forcing sources, the calibrated versions of the models are applied using four other sea level time series and a second set of wave conditions. The two alternative sources for sea level (for which long-time data is available) are the tidal gauge at Barcelona harbour (BCN2) and the simulated sea level with the hindcast model SCHISM. We have also tested the effect of performing a 5-day running average in the sea level time series (Figure 2c) to test the role of the fast sea level variability, which can contain more local effects. Varying the sea level source and using the waves from the AWAC does not change the results of both models (Table 1). Regarding waves, the second tested source used are those simulated with SCHISM model (Figure 2a,b) and they worsen the Q2Dmorfo skill significantly (Table 1). The reason is that, for southern waves, SCHISM predicts wave angles biased to the west (Figure 2b), so that Q2Dmorfo model under-predict beach rotation to the east. Preliminary results show that this occurs even after Q2Dmorfo recalibration using SCHISM waves. This result gives confidence on the calibration procedure of the model as the parameter choice cannot improve the model skill if wave forcing is not correct. The role of the wave source in XBeach is not yet clear, because the skills show a significant variability so further research is needed. Future work will include improving XBeach simulations and obtaining more reliable long-term data sets of wave conditions.

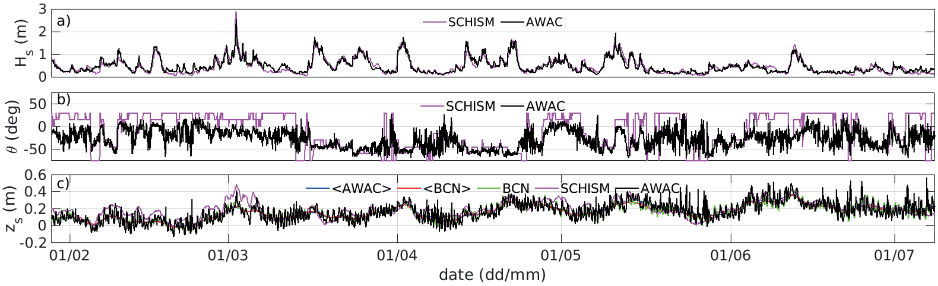

Figure 2. *Significant wave height (panel a), wave direction with respect to the shore normal (positive are waves from the west, panel b) and sea level (panel c) obtained from different sources (see the main text for details).*

Waves	Sea level	XBeach bathymetry BSS	Q2Dmorfo shoreline BSS
AWAC	AWAC	0.44	0.64
AWAC	<AWAC>	0.42	0.65
AWAC	BCN2	0.52	0.65
AWAC	<BCN2>	0.44	0.65
SCHISM	BCN2	0.31	-0.58
SCHISM	<BCN2>	-0.55	-0.52
SCHISM	SCHISM	0.48	-0.50

Table 1. *Brier Skill Score (BSS) for the two models and the different forcing sources (see the main text for details), where <> means a time average with a 5-day running average.*

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