Supplementary information of the article "Role of the forcing sources in morphodynamic modelling of an embayed beach"

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In this Supplementary Information document, two sections are included. Section A contains an extra figure with satellite images of the study site. Section B describes the methodology implemented to propagate wave conditions from the Cap Begur buoy to the AWAC location using the SWAN model.

A Satellite images

In order to visualize the changes in the dry beach during he 6 month studied, satellite images of the initial and final dates are shown in Fig. S1. These changes are not reproduced by the models, as explained in the main text, because the corresponding physical processes are not included.

B Description of the wave propagation method

One of the wave datasets used as boundary condition in the morphodynamic models was obtained by propagating wave data measured by an offshore wave buoy to a location in front of the study site using the SWAN model (AWAC position). This appendix provides additional details regarding the wave propagation model setup and validation.

B.1 Model setup

SWAN (Simulating Waves Nearshore) is a third-generation spectral wave model that computes the evolution of the 2D frequency-direction wave spectrum in coastal regions and inland waters (Team, 2019a).

The SWAN Cycle III version 41.31 code (Team, 2019b) was used to propagate the measured wave conditions by the Cap Begur wave buoy (located at 3.65°E 41.9°N at a water depth of 1200 m (Fig. S2) to the AWAC location (at 14.5 m depth), following a methodology similar to De Swart et al. (2020). The model domain consists of a main rectangular grid that stretches

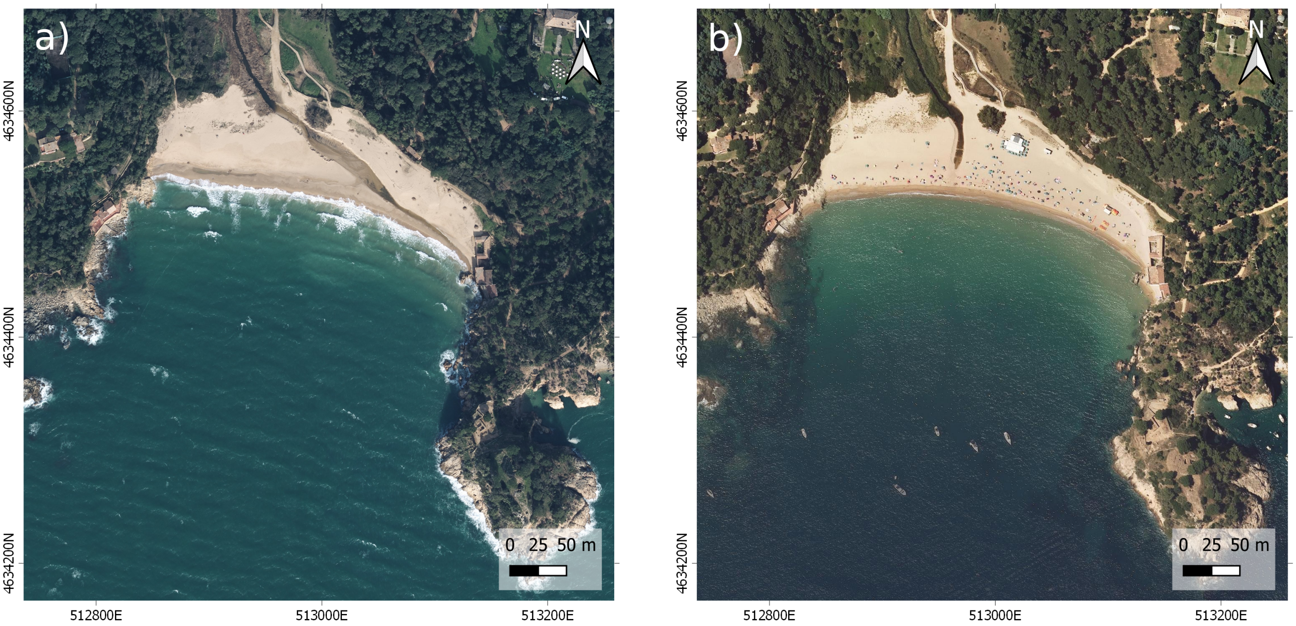

Figure S1. Satellite Images from Castell beach. Panel (a) (left) was obtained the 27th of January 2020 and the panel (b) (right) was obtained between the 27th of May to the 8th of July of 2020. Images obtained from Institut Cartogràfic i Geològic de Catalunya (ICGC).

approximately 70 km alongshore and 35 km cross-shore and has a spatial resolution of approximately 300 m (Fig. S2a). Within the main grid, three additional rectangular grids are nested to increase the resolution (each with a factor 3), resulting in a spatial resolution of approximately 10 m around Cala Castell (Fig. S2c). Bathymetric data was obtained from different surveys and has a resolution of 25m in the model domain, except in the area adjacent to Castell beach (within a radius of about 1.5 km), where the resolution is 5m (Fig. S2b, d). SWAN was used in 2D non-stationary mode and stationary computations (recommended for domains smaller than 1 deg) with a maximum of 50 iterations per computation were employed. The frequency space consisted of 38 logarithmically spaced values in the range 0.03–1 Hz, with the recommended frequency resolution of df/f = 0.1 (Team, 2019b) and the directional resolution was 5°. For bottom friction, the default JONSWAP formulation was used with a coefficient value of 0.038 m2s-3. The default third-generation physics formulation of Komen et al. (1984) was used (including wave decay due to whitecapping) with constant wave breaking (alpha = 1 and gamma = 0.73), whilst quadruplets, triad wave-wave interactions and wave growth by wind were switched off.

B.2 Boundary conditions

Following De Swart et al. (2020), full 2D frequency-direction spectra of the sea-surface elevation variance, $E(f,\theta)$, were specified as boundary conditions. Unfortunately, the Cap Begur wave buoy did not measure the full spectra $E(f,\theta)$, but it did provide the sea-surface elevation variance E, mean direction θ_m and directional spreading $\sigma\theta$ for a total of 14 spectral

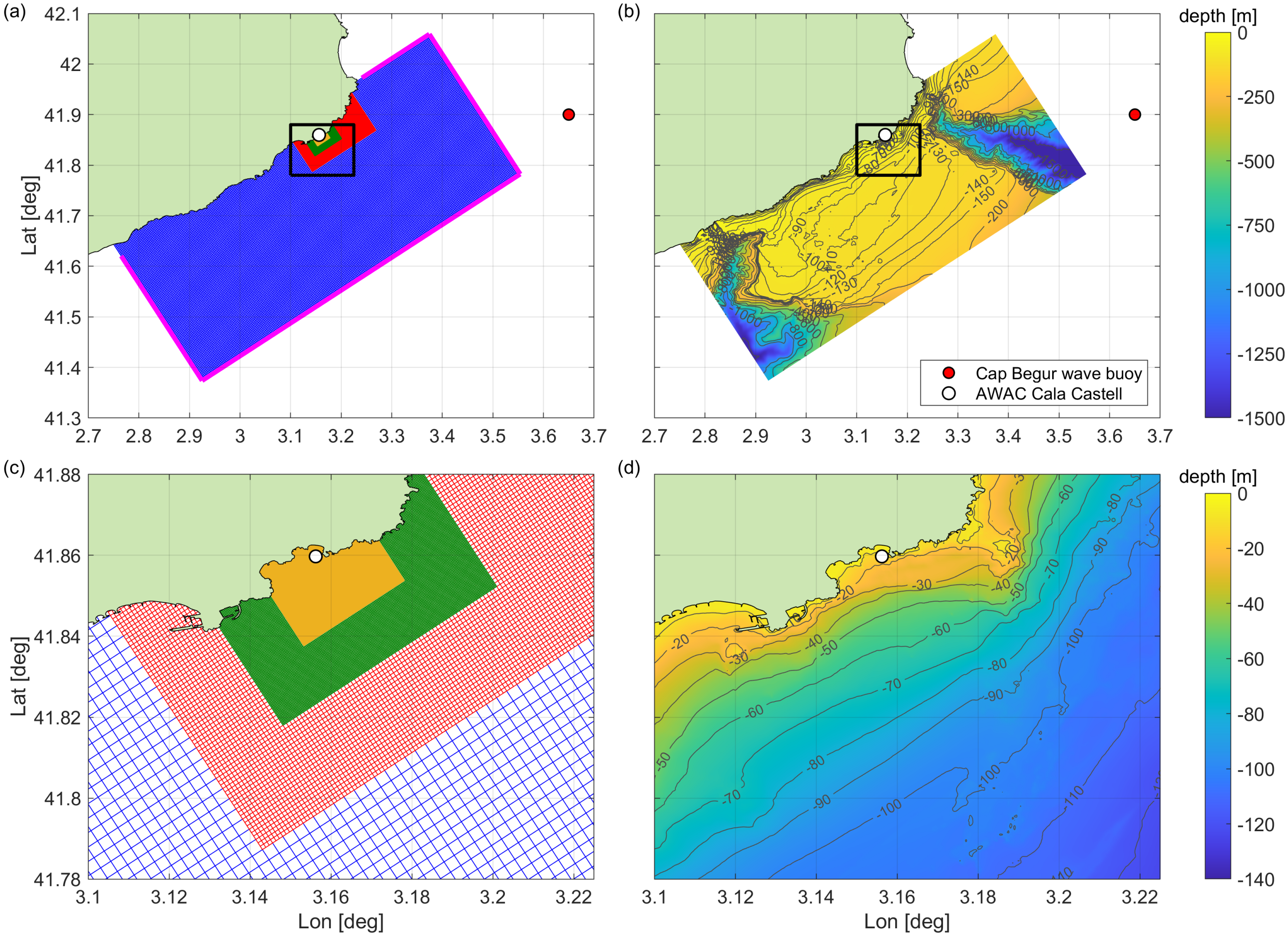

Figure S2. Overview of the model domain for the SWAN simulations including the locations of Cap Begur wave buoy and the AWAC at Cala Castell. Panel (a) shows the main grid in blue and the three nested grids in red, green and yellow, as well as the boundary sections where wave conditions were imposed in magenta. Panel (b) shows the model bathymetry in the entire model domain. Panels (c) and (d) are identical to panels (a) and (b), but show a zoom of the area around Cala Castell (displayed area is indicated by the black square in panels (a) and (b)).

Table S1. Comparison of the SWAN simulations results with the AWAC measurements for different wave parameters and wave climates. The wave climates were determined from the full 2D frequency-direction spectra of the Begur buoy.

	H_{m0} $[m]$		T_{m02} $[s]$		θ_m $[deg]$	
	RMSE	BIAS	RMSE	BIAS	RMSE	BIAS
Full period	0.15	-0.08	0.92	0.32	21.5	2.8
Northerly	0.21	-0.17	1.32	0.74	29.4	-13.6
Easterly	0.16	-0.08	0.92	0.53	12.4	8.4
Southwesterly	0.16	-0.02	0.74	0.54	18.1	12.4
Bimodal	0.11	-0.04	0.69	-0.03	20.1	6.4

bands. This data was used to reconstruct $E(f,\theta)$ using the 1D frequency spectrum $E(f)$ and the directional distribution $D(f,\theta)(E(f,\theta) = E(f)D(f,\theta))$. Here, $E(f)$ was determined directly from the buoy variance data and $D(f,\theta)$ was computed from the directional properties using the cos^{2s} method (Mitsuyasu et al., 1975). The resulting 2D frequency-direction spectra were imposed along the entire southeastern and northeastern boundaries, and parts of the southwestern and northwestern boundaries (Fig. S2a), meaning that they were assumed to be spatially constant and equal to those at the Cap Begur buoy.

B.3 Model validation

The SWAN results at Cala Castell were validated using the AWAC measurements. An overview of the statistical errors for various wave parameters and different wave climates is given in Table S1. Modelled wave height and period agree well with the measurements, whilst larger differences are found between the modelled and measured mean wave direction. The largest errors for all wave parameters are encountered during northerly waves, but fortunately these waves are not that important for studying the morphological evolution of Cala Castell. The southern orientation of the coastline at Cala Castell and the headlands' presence ensures that northerly waves undergo substantial refraction (well over $90\ ^{\circ}$) to reach Cala Castell so that their energy is considerably reduced (Fig. S3). For the other wave climates, the errors in the various wave parameters are much smaller (Table S1). In conclusion, the validation results show that the SWAN model is well-capable of propagating measured offshore wave conditions to Cala Castell that can subsequently be used as input for morphodynamic models.

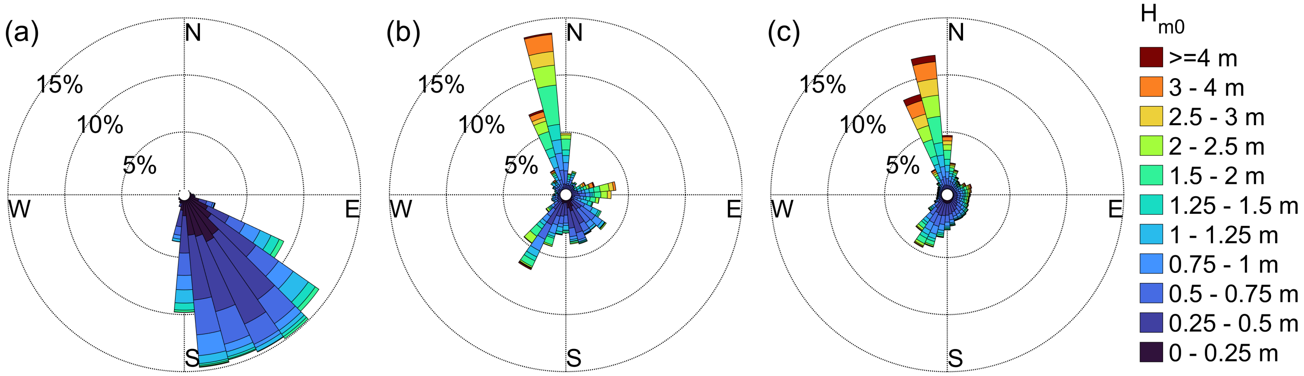

Figure S3. Wave roses of the wave climate measured by the Cala Castell AWAC between 28 January 2020 and 8 July 2020 (a), the Cap Begur wave buoy during the AWAC deployment (b) and at the Cap Begur wave buoy between April 2001 and October 2022 (c).

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