Offshore boundary conditions for nearshore wave modeling

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Introduction

Bathymetric features, shoreline geometry and local atmospheric forcing drive significant small-scale wave transformations in the nearshore. With the aim of characterizing nearshore wave transformations, coastal scientists commonly rely on regional spectral wave models nested into global wave models. If not available from the global model (first option), the wave spectrum imposed as boundary condition (BC) of the nearshore model can be inferred either from partitioned or bulk wave parameters (second and third options). Recent work highlighted the importance of BC treatment to accurately address wave-induced nearshore processes [1] [2]. This study considers the three types of spectral BCs and assesses the model accuracy by comparing computed results with wave data collected by two coastal wave buoys (water depth ranges from 15 to 30 m) belonging to the Puertos del Estado network.

Methods

SWAN runs for the months of October and November 2021, covering two regional domains laying in the Western Mediterranean (Tarragona and Palma, see Figure 1). The computational grids have a spatial resolution of 462 m, equal to that of the GEBCO 2022 bathymetry.

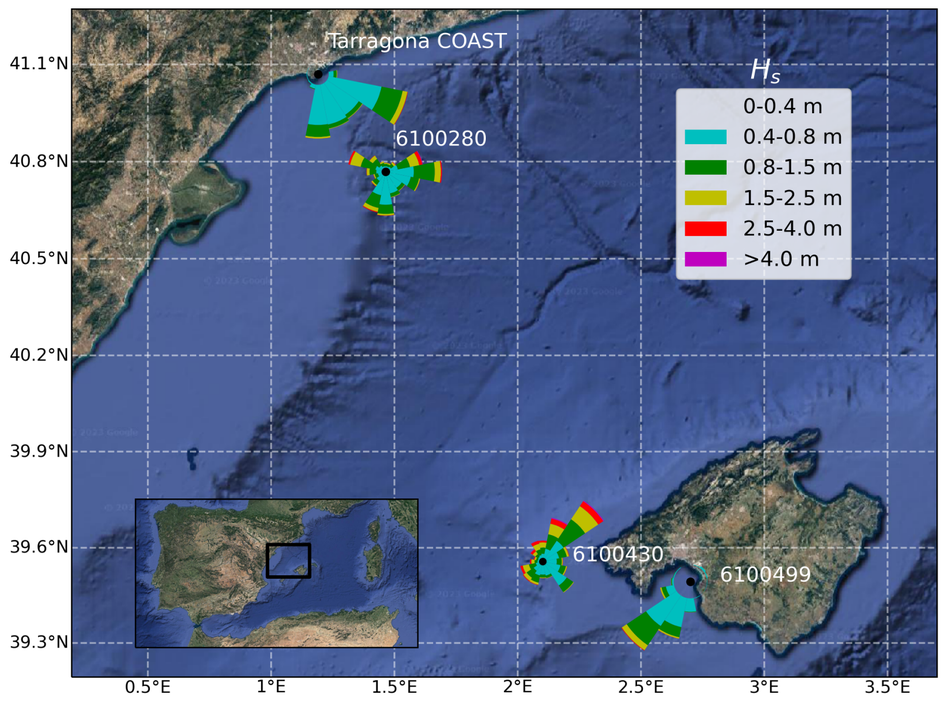

Fig. 1: Wave roses at the offshore and nearshore buoys.

ERA5 provides the wind forcing. Along the lateral boundaries, time- and space-varying wave spectra come either from the CMEMS (simulations CMEMS-X) or ERA5 (simulations ERA5-X) systems. The last letter in the simulation name indicates whether the spectra are reconstructed from bulk (B) or partitioned (P) parameters, or are the global model directional spectra (S). Figure 2 shows an example of the output of the spectrum reconstruction routine at the North-West corner of the Palma grid.

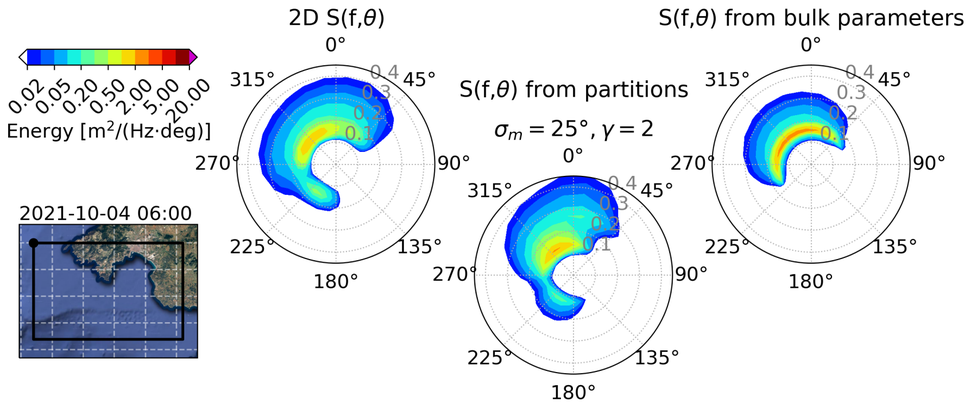

Fig. 2: Output of the spectrum reconstruction routine at the grid boundary.

Results

The accuracy of the model simulations is assessed by estimating the normalized error metrics NRMSE (root-mean-square error) and NB (bias) between computed and measured wave parameters. In deep water, CMEMS provides a higher accuracy. Nevertheless, the two datasets underestimate wave energy fluxes E_f.

	H_s		T_m		θ_m		E_f
	NRMSE	NB	NRSME	NB	NRSME	NB	NB
Tarragona 6100280- Depth = 688m							
CMEMS	0.19	-0.00	0.15	-0.11	0.20	-0.02	-0.03
ERA5	0.25	-0.18	0.21	-0.19	0.22	-0.02	-0.38
Palma 6100430 - Depth = 141m							
CMEMS	0.17	-0.03	0.12	-0.04	0.16	0.03	-0.10
ERA5	0.27	-0.23	0.19	-0.17	0.19	0.00	-0.49

The use of BCs from CMEMS improves the overall model performance in the nearshore. BCs constituted by spectra from the global model and inferred from partitions raise the accuracy of wave directions θ_m. Except for CMEMS-B and -P at Palma, computations tend to underestimate wave heights H_s and periods T_m.

	H_s		T_m		θ_m	
	NRMSE	NB	NRSME	NB	NRSME	NB
Tarragona Coast - Depth = 15 m						
CMEMS-B	0.23	-0.12	0.26	-0.04	0.12	-0.00
CMEMS-P	0.25	-0.15	0.21	-0.07	0.09	0.02
ERA5-B	0.35	-0.31	0.29	-0.11	0.18	0.02
ERA5-P	0.40	-0.36	0.27	-0.12	0.10	0.02
ERA5-S	0.38	-0.35	0.31	-0.26	0.12	0.01
Palma 6100499 - Depth = 30 m						
CMEMS-B	0.20	0.05	0.62	0.02	0.15	-0.00
CMEMS-P	0.20	0.03	0.52	0.02	0.11	0.00
ERA5-B	0.22	-0.11	0.51	-0.11	0.15	-0.00
ERA5-P	0.21	-0.08	0.47	-0.02	0.08	-0.01
ERA5-S	0.18	-0.07	0.34	-0.18	0.09	-0.01

Conclusions

Reconstructing realistic spectral shapes as BCs yields a better description of wave directions in the nearshore of two fetch-limited areas. The results show modest or no improvements for wave heights. This may be due to: (1) small occurrence of multimodal spectral shapes with significant energy in secondary partitions, (2) poor definition of spectral shape partitions due to the adoption of standard directional and frequency spread parameters, (3) underestimation of incoming wave energy fluxes at the offshore boundary.

References

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