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Wave energy balance in wave models (SWAN) for semi-enclosed domains–Application to the Catalan coast

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ABSTRACT

This study has been motivated by the limited accuracy of wave models under short-duration, fetch-limited conditions. This applies particularly to the wave period, in semi-enclosed domains with highly variable wind patterns as along the Catalan coast. The wave model SWAN version 40.91A is used here in three nested grids covering all the North-western Mediterranean Sea with a grid resolution from 9 to 1 km, forced with high resolution wind patterns from BSC (Barcelona Supercomputing Center) for two study periods, the winter 2010 and the spring 2011. The results are validated in eight locations with different types of instrumentations. In order to improve the results, a modification of the whitecapping term parameters is performed. Also the appropriate frequency integral range used to calculate the integral wave parameters is tested to be sure to compare the simulation results and the measurements for the same frequency interval. The results obtained show a clear improvement of the mean wave period and the peak period for the study area, decreasing considerably the negative bias observed previously, while almost no change is observed in wave height due to the proposed modifications. These results can be generalized to the Spanish Mediterranean coast and may be applicable to study areas with similar characteristics as the ones presented here: semi-enclosed domains with fetch-limited conditions and young sea waves.

1. Introduction

It is widely known that wind and wave predictions are less precise in semi-enclosed domains than in the open ocean. Ardhuin et al. (2007) pointed that in the Western Mediterranean Sea, the winds are still the major source of errors for the wave model results. These errors, however, tend to decrease in stormy conditions or, more generally, when the meteorological situation is better defined. However, in coastal areas and enclosed basins, improving the wind quality it is not enough to improve the wave results because of the wave characteristics due to their nearly permanent local generation. Cavaleri and Bertotti (2004) considered the underestimation of wind speed and wave height dependency on fetch, and proved than fetches smaller than 100 km generate larger errors. These errors are more important and persistent in waves than in wind. The boundary layer when the air blows from land to sea and the poor description of the orography are suggested as possible reasons for the underestimation at short fetches.

Previous studies in the Catalan coast describe the wave climate controlled by (1) short fetches, (2) shadow effect for waves from the south and east due to the Balearic islands (Fig. 1), (3) complex bathymetry with deep canyons close to the coast, (4) high wind field variability in time and space, (5) wave calms during the summer and energetic storms from October to May, (6) presence of wind jets canalized by the river valleys and, (7) sea and swell waves combination that generate bimodal spectra (Bolaños, 2004; Sánchez-Arcilla et al., 2008; Alomar, 2012). These characteristics, some of them typical for a semi-enclosed basin, limit the reliability of wave predictions in the area.

More specifically, an underestimation of the significant wave height and wave period has been observed in this area by different authors. Bolaños (2004) considered that a part of the error was due to the limited spatial and time scales of the processes to reproduce, around 10 km and 12 h. He recommends using an atmospheric model nested with enough resolution to reproduce the different phenomena. Alomar (2012) presented two ways to improve the wave predictions. One option consisted in increasing the temporal and spatial resolution of the wave modeling system to capture the wind and wave gradients in the geographic dimension. She proved that using a wind input with better temporal resolution leads to improve the maximum values for a storm event, while a higher wind spatial resolution only improved the timing of the peaks but not the magnitude. The second modification

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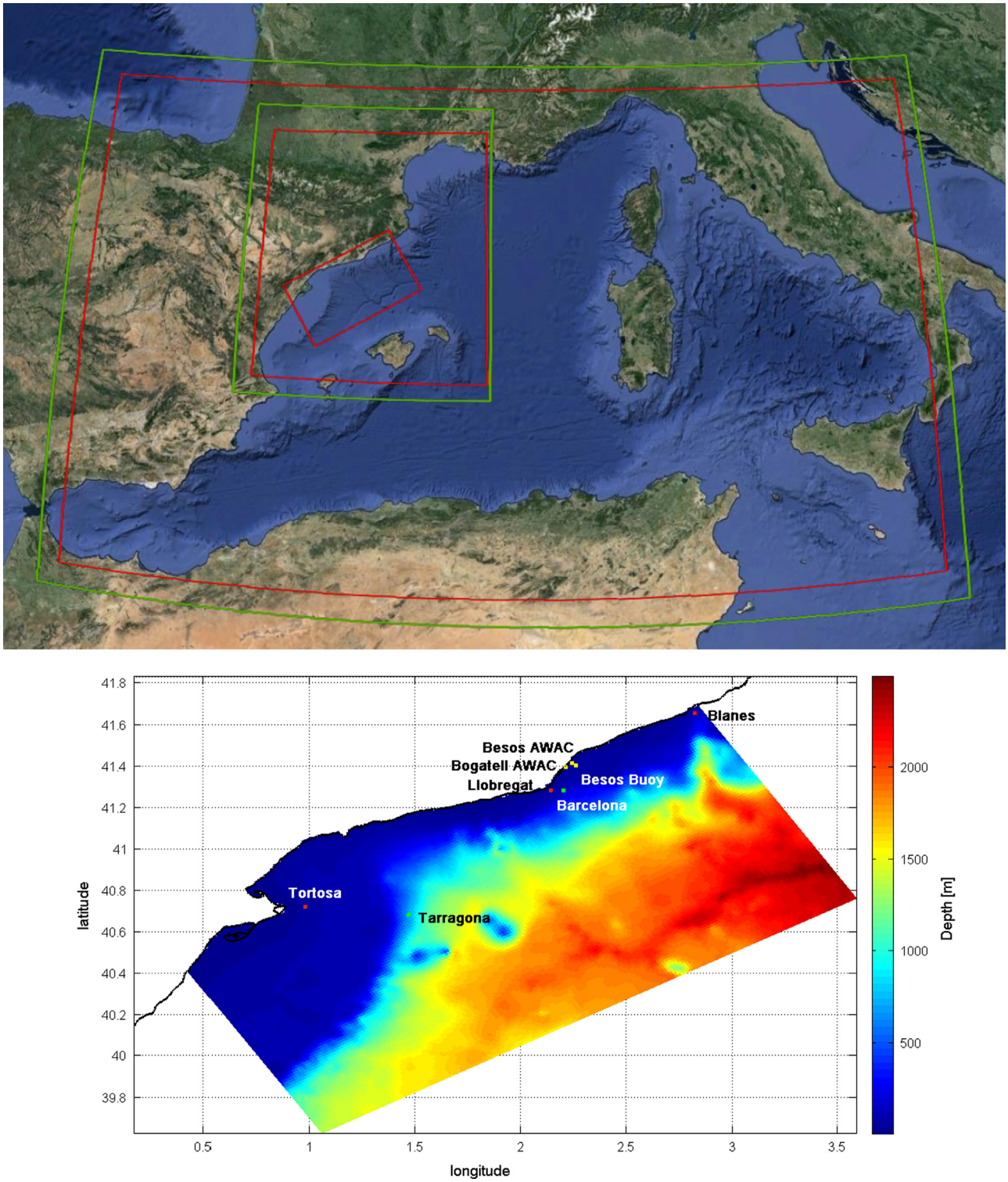

Fig. 1. On top: the Western Mediterranean Sea. The local distribution of the computational grids implemented in SWAN (in red) and the two wind fields used as a forcing (in green) are represented. At the bottom: a detailed bathymetry for the finest grid (1 km grid size in average) is presented. In yellow are represented the Field_ac campaign instruments, in green the Puertos del Estado buoys, and in red the XIOM buoys. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper.)

proposed was adjusting the wave growth rate. The author confirms that the observed rate of wave growth in the region of study was faster than the simulations and faster than the rates derived for more homogeneous wind conditions.

But this is not a local effect since in similar locations the same problems have been observed. Akpinar et al. (2012) describe an equivalent behavior, with an under-prediction of the significant wave height and period for the Black Sea. Their results show a clear similarity to the results obtained for the Catalan coast, with an under-prediction of the significant wave height, more important for the maximum values (peaks of the storms) and an important negative bias for the wave periods. Similar results have been obtained also in semi-enclosed basins and bays, as Lin et al. (2002) who demonstrate that in Chesapeake Bay (USA) the waves

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