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Assessment of wave energy in the Canary Islands

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ABSTRACT

A numerical study of the wave energy distribution around Canary Islands is presented. For this study the WAVEWATCH III model is used to generate waves for the entire North Atlantic basin and the SWAN model is used to determine the transformation of the waves in the Canary Islands.

The model results are validated with measured data from the Gran Canaria buoy, over a three-year period, and satellite data for the period of one year. The computed results show a good agreement with data from buoy and satellites. Wave energy resource climatology is evaluated and characterized in terms of probability of occurrence of sea states for the three year period.

1. Introduction

Wave energy seems to be the one of the most promising among the marine renewable resources. It is estimated that this extraction will have significant growth in the next decades as the technology will became more advanced [1–3].

The potential for the wave energy extraction can be accessed from wave climate analysis. Existing records from buoy data in coastal and offshore regions can give a general idea of the main conditions that can be found. Some limitations related with the time period of the buoy measurements can be found. Assessments can be based both in buoy data and in deep water numerical models, allowing the estimation of wave conditions offshore. An example of such study is the European Wave Energy Atlas [4] that summarises the deep-water resources off the Atlantic and Mediterranean coasts of Europe, which has been complemented by many studies of various authors that are predicting conditions in shallower coastal waters of practical interest.

Furthermore the use of numerical models that are able to take into account the physics of wave generation and propagation in the shallow waters of the coastal regions is essential. They can make more realistic assessments of the wave energy potential in the coastal areas in which developments of wave energy parks are being considered.

Different types of assessments have been implemented in different regions. They vary from the global perspective [5] to the European one [6]. In Europe several studies concerning wave energy resources using wave models were carried out [7,8]. For instance in the Swedish west coast, Waters et al. [9] used WAM [10] and SWAN [11] wave models to perform simulations. The results reveal an average energy flux of approximately 5.2 kW/m in the offshore Skagerrak, 2.8 kW/m in the nearshore Skagerrak, and 2.4 kW/m in the Kattegat. Other studies were performed for the North coast of Spain [12,13], and for Italy [14,15].

Stopa et al. [16,17] made assessments for Hawaii using the state-of-the-art spectral models, WAVEWATCH III [18] and SWAN. The results demonstrate the wave energy potential in Hawaii waters, with a consistent energy resource of 15–25 kW/m throughout the year.

Statistical studies show that although the uncertainty related to the variability in the wave climate, developments in the accuracy of historic data will improve the accuracy of predictions of future Wave Energy Converters yield [19,20].

As part of the European project MAREN, studies have been made on the assessment of the wave energy resources on the Atlantic coast of Europe, building upon the experience developed during the HIPOCAS project [21]. In that project, Pilar et al. [22] implemented the WAM model over the Atlantic area and SWAN for the coastal domain [23]. The same type of approach was adopted to assess the wave energy in some Portuguese areas [24,25].

The present studies are based on a different setup, using WAVEWATCH III covering almost the entire North Atlantic basin and providing the boundary conditions for SWAN. This

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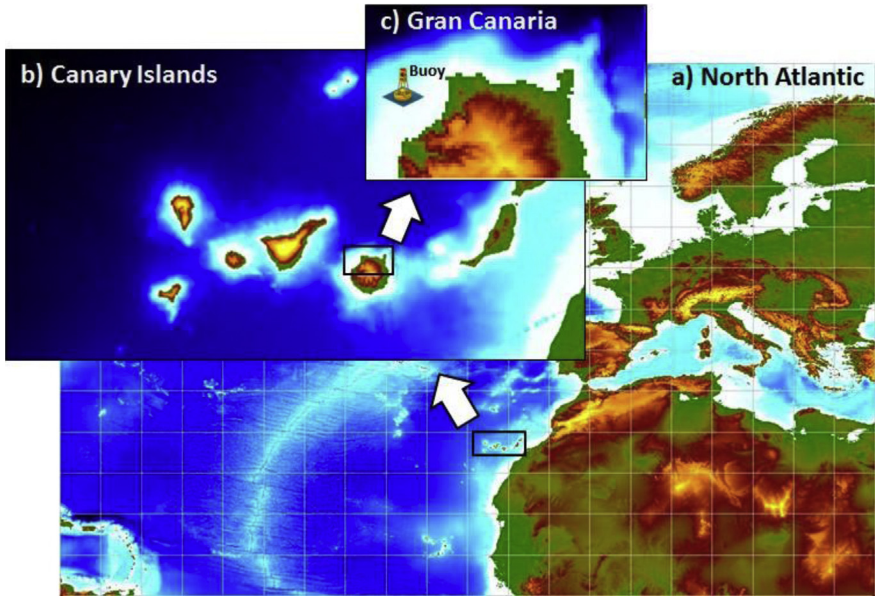

Fig. 1. Implementation area. a) WW3, b) SWAN Level I, c) SWAN Level II.

methodology have been implemented in the West coast of Ireland [26], the Southwest of UK [27], the North of Spain [28], France [29] and Portugal [30] revealing that the predicted wave conditions are in good agreement with wave measurements in those areas [31]. The prediction of wave resources is not an objective itself but is required to estimate the production of specific devices [32] and also to determine the impact that farms of wave energy converters may have in the coast [33].

Marine resources in the sea around the Canary Islands have been estimated. The main marine resources are offshore wind and waves. Wave energy resources are mainly located in the northern coast of the Islands, which 25–30 kW/m [34]. Studies concerning the wave energy have been made by Iglesias and Carballo [35,36], and Sierra et al. [37], showing the geographical distribution of the wave energy with an average wave power of 25 kW/m.

The Gran Canaria Island offers extraordinary weather conditions for the exploitation of renewable energy. The Oceanic Platform of the Canary Islands (PLOCAN) [38] is a multi-purpose service centre integrated by large infrastructures to facilitate and accelerate the research, development and innovation in the fields of ocean sciences and technologies.

In this context, the purpose of this work is to validate the present model setup comparing the SWAN simulations with satellite data and measurements from the Gran Canaria buoy. The results demonstrate the wave energy potential around the Canary Archipelago waters, in particular in the pilot area of the Gran Canaria.

2. Theoretical formulations

WAVEWATCH III (WW3) is a third-generation spectral model for wind wave development and propagation from deep to intermediate water [39]. Developed by the Marine Modeling and Analysis Branch (MMAB), of the Environmental Modeling Center (EMC), of the National Center for Environmental Prediction (NCEP), it solves the action balance equation for evolution of the wave spectrum under wind forcing, which is given by

$$\frac{DN}{Dt} = \frac{S}{\sigma} \tag{1}$$

The spectrum that is considered in most of the present wave models is the action density spectrum (N), rather than the energy density spectrum since in the presence of currents the action density is conserved whereas energy density is not. The S from the right hand side of the action balance equation represents the source terms. Source terms account for nonlinear effects such as wind–wave interactions, quadruplet wave–wave interactions, and dissipation through whitecapping and bottom friction.

SWAN is a third-generation stand-alone (phase-averaged) wave model, similar to WW3 in that it solves the action balance equation with parameterization of nonlinear processes [11]. However, SWAN is better suited for shallow water processes by including additional source terms for triad wave–wave interactions and depth-induced wave breaking as well as the JONSWAP parameterization for dissipation due to bottom friction [40]. In addition, SWAN accounts

Table 1
Computational grids for the hindcast system.

	Latitude	Longitude	Resolution
North Atlantic	10°N to 75°S	70°W to 30°E	1° × 1°
Canary Islands (A1)	27°N to 30.5°N	20°W to 13°W	0.05° × 0.1°
Gran Canaria (A2)	27.93°N to 28.33°N	15.92°W to 15.23°W	0.0083° × 0.0083°

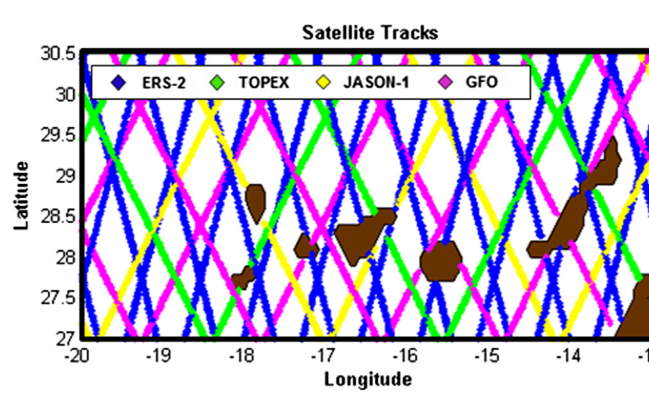

Fig. 2. Satellite tracks over the Canary Islands (ERS-2, TOPEX, JASON-1 and GFO).