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A wave farm for an island: Detailed effects on the nearshore wave climate

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A R T I C L E I N F O

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A B S T R A C T

Wave energy is of particular interest in the case of islands, and even more so if the electricity network of the island is isolated – as in many Atlantic islands. The objective of this work is to analyse the impacts of wave exploitation on the nearshore wave climate of the island through a case study: the island of Tenerife (Spain), in the NE Atlantic, and a wave farm off its north coast. Two wave conditions, typical of winter and summer, and three values of the wave transmission coefficient of the Wave Energy Converters (WECs) are used. For each of these six cases, the neashore wave conditions in the lee of the farm are compared with the baseline scenario. The impact is characterized in terms of: wave height, power, energy period, directional spreading and energy dissipation due to bottom friction. We find that the impact is relevant, in particular in some of these cases, with the value of the wave transmission coefficient playing a significant role.

1. Introduction

The importance of renewable energy in reducing carbon emissions and, more generally, the impact of human activities on the environment is well known [1,2]. Its strategic value is even greater in the case of small- and medium-size islands with isolated electricity grids, such as Tenerife (Fig. 1), an Atlantic island where local, renewable energy sources can play a significant part in achieving the energetic self-sufficiency of the community [3–5]. In addition to wind energy [6], wave energy can be put to use in Tenerife; it has the following advantages [7–16]: (i) a high power density, (ii) a relatively high utilization factor, and (iii) a low visual impact (especially in comparison with other renewables, e.g., wind energy). The objective of this work was to analyse in detail the effects of exploiting wave energy on the nearshore wave conditions of an island [17–22]. This was carried out by means of six case studies concerning a prospective wave farm off the north coast of Tenerife.

Located off the northwestern coast of Africa, Tenerife (Fig. 1) is the largest island of the Canary Archipelago. Volcanic in nature, it is surrounded by large water depths (of the order of 5000 m), which renders the laying of submarine cables unviable; therefore, its electricity network is isolated – as are those of the other Canary Islands. Furthermore, the case for exploiting wave energy and thus advancing towards a carbon-free energy system is strengthened in Tenerife by the great environmental value of the island, corroborated by its status as a UNESCO Biosphere Reserve.

Hindcast data were used to determine the offshore wave climate. A study zone was selected based on the wave resource [23], the offshore zoning prescribed by the authorities, the water depth and distance to the coastline, and the distance to a port. The assessment of the wave resource was based on the procedure followed in Ref. [24]. The wave farm considered consisted of a row of five generic Wave Energy Converters (WECs). Two wave conditions, representative of typical summer and winter scenarios, and three values of the wave transmission coefficient were considered, resulting in six case studies. The numerical model used to calculate wave propagation from deep water to the coastline was SWAN (Simulating Waves Nearshore) [25]. This model was successfully used in previous works [26,27] to assess the wave resource. In this work it was applied to establish the effects of the wave farm on the nearshore wave conditions, by contrasting the situation in each of the six case studies with the corresponding baseline scenario (without the wave farm). The interaction between the wave field and the individual WECs of the farm was characterised by means of the wave transmission coefficient, C_t, for which three values were selected based on laboratory tests representative of the current state of the technology [28] and the prospects of technological improvements in future. The effects of the wave farm on the

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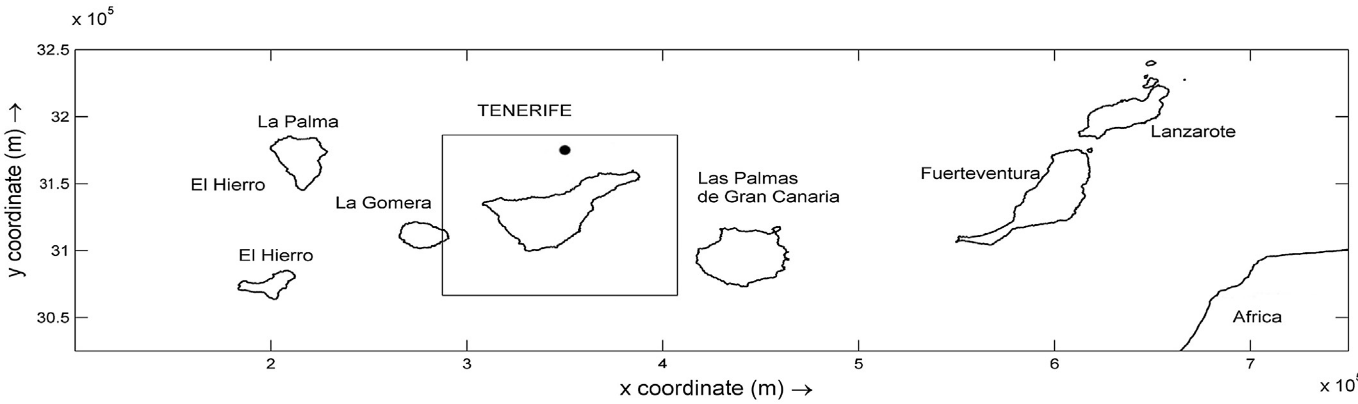

Fig. 1. The island of Tenerife in the Canary Archipelago.

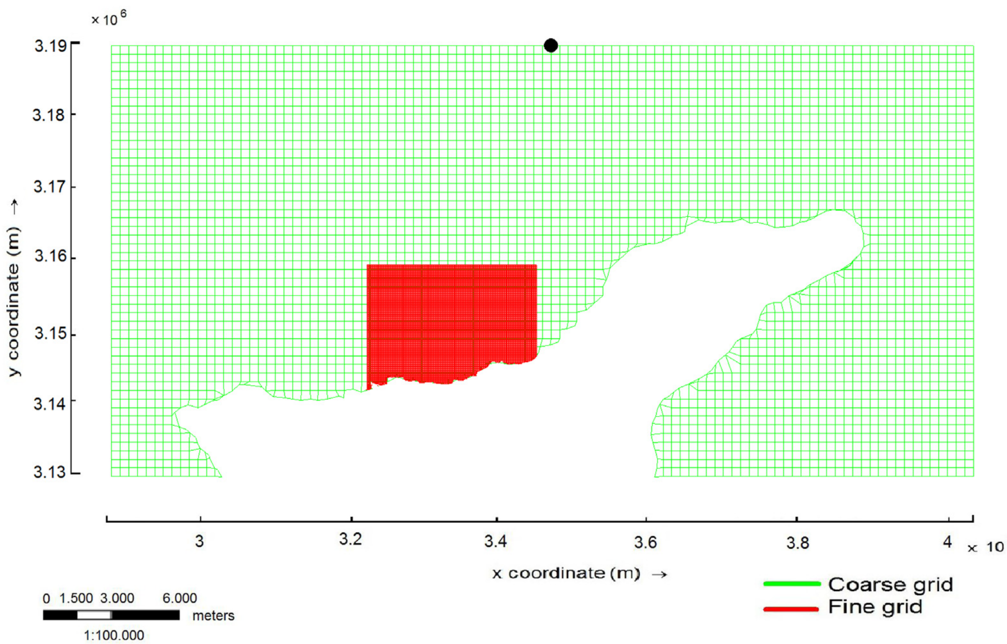

Fig. 2. Coarse and fine computational grids. The black circle indicates the position of the hindcast data point.

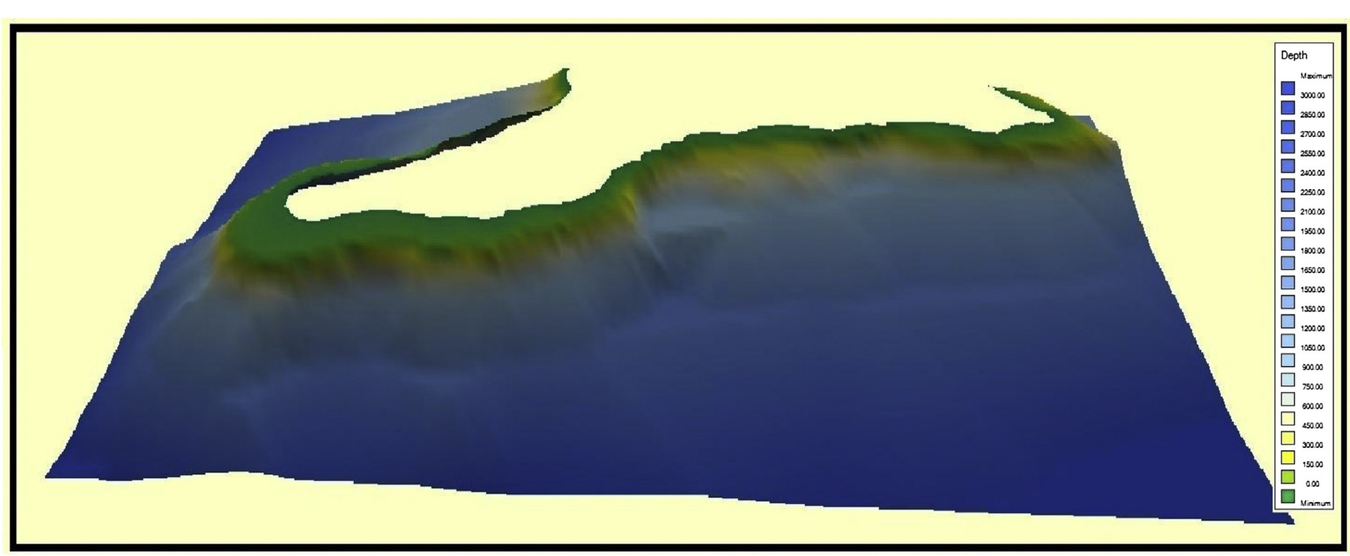

Fig. 3. Perspective of the bathymetry from the North. The absence of a continental shelf and the steep slopes characteristic of a volcanic island are apparent.