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# Wave resource in El Hierro—an island towards energy self-sufficiency

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ABSTRACT

The island of El Hierro (Spain), a UNESCO Biosphere Reserve in the Atlantic Ocean, aims to become the first 100% renewable energy island in the world. With a €54 million wind project already under way, the present research looks at the island's wave resource using a 44-year hindcast dataset obtained through numerical modelling. The geographical distribution of wave energy is examined on the basis of eight study sites around the island. A substantial resource is found west and north of El Hierro, with average wave power in the order of 25 kW $m^{-1}$ and total annual energy in excess 200 MW h $m^{-1}$; the resource is less abundant east and south of the island. In addition to these geographical variations, wave energy in El Hierro presents seasonal variations, with energetic winters and mild summers. After analysing the total resource and its spatial and seasonal variations, its composition in terms of sea states (significant wave heights and energy periods) is examined, and how this composition affects the selection of the Wave Energy Converters to be installed is discussed.



## 1. Introduction

El Hierro is the smallest (278 $km^2$) and least inhabited (10753 inhabitants) of the Canary Islands (Spain), a volcanic archipelago in the Atlantic Ocean (27.5° N–29.5° N, 013° W–018.5° W) (Fig. 1). Although the influence of Saharan air masses results in an arid landscape in the eastern islands, rainfall increases towards the west—so much so that El Hierro, the westernmost island, is famed for its lushness. A UNESCO Biosphere Reserve, El Hierro aims to become the first 100% carbon-free island.

Perhaps nowhere is the case for renewable energy easier to present than in El Hierro. First, the surrounding water depths are too large to allow any submarine connection, so its energy needs must be provided for locally. Second, the island is endowed with two natural commodities of the greatest interest—waves and wind. Third, its mountainous nature (with a 1501 m high peak) is an excellent basis for energy storage by means of water reservoirs. Last, but not least, there is considerable consensus among its population and policy makers in support of renewable energy. These favourable conditions have been recognised both locally and nationally, and a €54 million project combining a 10 MW wind farm with two water reservoirs is under way [1]. The present research looks at El Hierro's wave resource.

Although there are no (prior) assessments in the Canary Islands, marine energy was assessed in other regions of Spain, notably the north-western and northern coastlines of Iberia [2–7]. Wave energy assessments in other European regions include the Baltic Sea, Denmark and Sweden [8–10], among others; Europe-wide and global assessments may be found in [11–15]. As regards other Atlantic islands, wave energy was evaluated in Madeira (Portugal) [16] and, as part of a wider study, in Azores (Portugal) [17]. The combination of wave and wind power was studied by [18–20], and a 100% renewable energy system was discussed by Lund et al. [21].

This article is structured as follows. Section 2 presents the wave data and how they were obtained. Section 3 deals with the geographical and seasonal variations of wave energy; the area with the highest potential for a *wave farm* is determined. Section 4 looks at the composition of the resource in terms of sea states (wave heights and periods) and how this composition affects the selection of the Wave Energy Converters to be installed. Finally, Section 5 presents the conclusions.

## 2. Wave data

With no wave buoys in the vicinity of El Hierro, hindcast wave data obtained through numerical modelling were used in this research. The basis for the hindcast dataset was the global atmospheric reanalysis carried out by the U.S. National Center for Environmental Prediction, Washington, D.C., USA (NCEP) and the National Center for Atmospheric Research, Boulder, Colorado, USA (NCAR) integrating instrumental observations and satellite data [22]. Data from this reanalysis were used to force a regional atmospheric model, REMO [23–25]; the model grid covered the

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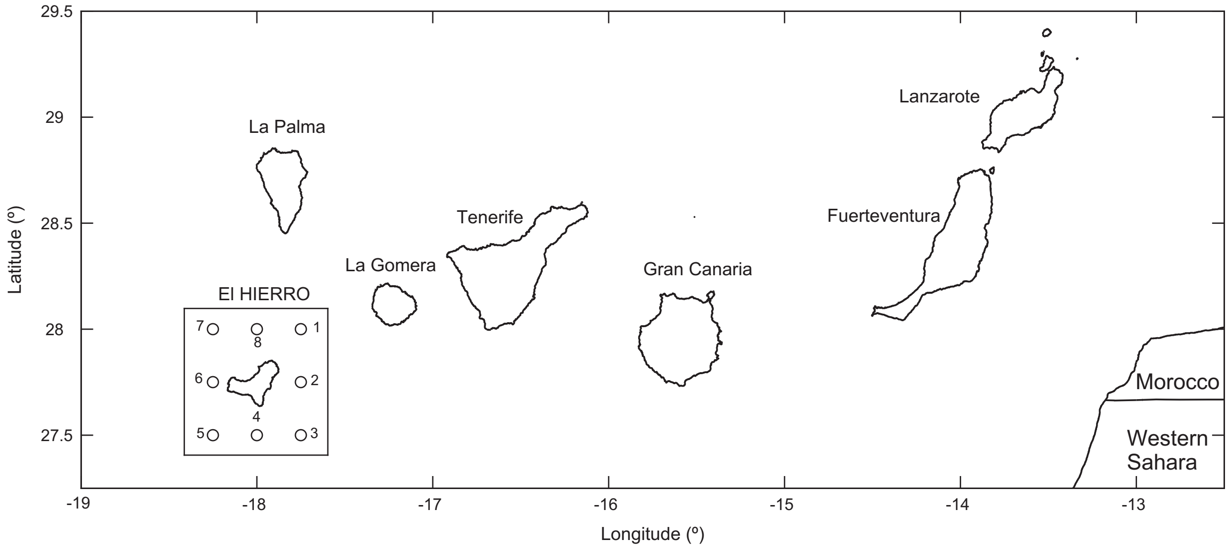


**Fig. 1.** Map of the Canary Islands showing the location of the eight study sites around El Hierro.

North Atlantic with a resolution of 30′ × 30′, enhanced near the coastline to 15′ × 15′. The effects of the interaction between the larger-scale (atmospheric) flow and smaller-scale features (topography, land uses) were included using a spectral nudging technique [23]. The high-resolution atmospheric data thus obtained were used to force the third generation wave model WAM (WAve prediction Model) cycle 4 run on the same grid (So-called third generation models are those in which the wave spectrum is free to develop without any shape imposed a priori). After running the WAM model, the hindcast wave database was obtained; it covers a 44-year period (from 1.1.1958 to 31.12.2001) with a three-hourly frequency.

Only a brief summary of the WAM model is included here—further details may be found in [26–28]. The model's formulation is based on the spectral action density rather than the spectral energy density because wave action is conserved in the presence of

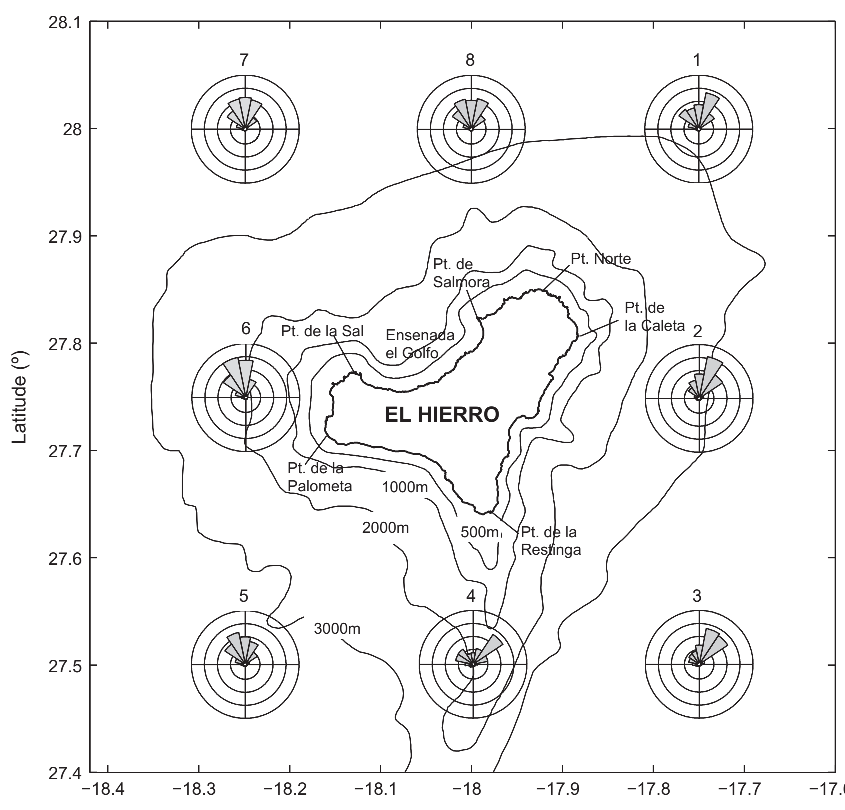


**Fig. 2.** Map of El Hierro with the annual wave roses for the eight study sites (the centre of each rose is located at the corresponding site).