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Wave resource assessment along the Cornish coast (UK) from a 23-year hindcast dataset validated against buoy measurements

Joana C.C. van Nieuwkoop*, Helen C.M. Smith, George H. Smith, Lars Johanning

University of Exeter, Cornwall Campus, Penryn, Cornwall TR10 9EZ, UK

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ABSTRACT

Long-term knowledge of the wave climate of a potential wave energy site is essential for project planning and design, not only for an understanding of the resource variability, but also for the prediction of design wave conditions. The southwest region of the UK is at the forefront of the country's wave energy development, with two operational test sites. However, no detailed long-term resource assessment has yet been performed. This paper presents a long-term wave hindcast for southwest England, performed using the numerical wave model SWAN, with a particular focus on two energy device test facilities: 'Wave Hub' on the energetic and exposed north Cornwall coast, and 'FaB Test' on the more sheltered south coast. A high-resolution wave model suite, aimed at establishing nearshore wave hindcasts, is described and evaluated. The suite is run for a 23-year period, starting in 1989 and continuing to 2011. The hindcast is compared with measurement data and the results are analysed for the two test sites. Special attention is given to the implications of present hindcast errors and how the hindcast errors can be minimized.

1. Introduction

The UK is at the forefront of the development of wave energy as a viable renewable energy technology. Although some way behind established renewable technologies such as wind, solar and hydropower in terms of development, the potential for wave energy is vast, with a European deep water resource in the region of 320GW [1]. The UK government has set a target of 1.3GW of installed marine energy capacity by 2020 [2], of which wave energy is expected to form a significant component.

Two regions of the UK are leading the nation's wave energy development; Scotland, in particular the islands of Orkney, and southwest England. Both regions are exposed to the energetic seas of the northern Atlantic and have thus benefited from large amounts of investment in developing test sites to drive forward the emerging wave energy industry: the European Marine Energy Centre (EMEC) in Orkney and Wave Hub in Cornwall, SW England. EMEC is the world's most advanced test site, with grid connected offshore and nearshore berths which have hosted, or are currently hosting, full-scale prototypes such as Pelamis Wave Power's Pelamis device, Aquamarine's Oyster and Wello's Penguin. Testing at the site is well documented (e.g. [3,4]), and a number of resource assessment studies for the region have been published, e.g. [5,6].

Although conceived as early as 2003, the development of the 20 MW, grid connected Wave Hub site in southwest England has been slower than the progress in Scotland. However, construction was completed in 2010, and the site is awaiting its first deployment in spring 2013. It has been supported by other developments in the southwest region, notably the 'nursery' FaB Test site in the more benign Falmouth Bay off the south coast of Cornwall (see Fig. 1), a non-grid connected site designed to bridge the gap between full-scale demonstration sea trials and commercial array demonstration trials at the exposed Wave Hub site. In March 2012, the southwest's first device testing programme commenced with the deployment of the Fred Olsen Bolt2 device at FaB Test. The region also benefits from the establishment of the South West Marine Energy Park, the UK's first.

However, to date there have been no detailed long-term resource assessment studies performed for the region. Resource assessment during the development of the Wave Hub site relied on short-term buoy deployments and output from Met Office models at locations a number of kilometres from the site itself. The resource assessment process is described in [7], which highlights the difficulties of using a number of short-term datasets from varied locations to draw reliable conclusions about the resource, and recommends that a 20-year study should be performed.

* Corresponding author. Tel.: +44 (0) 1326 371837; fax: +44 (0) 1326 254243.
E-mail addresses: j.van-nieuwkoop-mccall@exeter.ac.uk, Joana.vanNieuwkoop@deltares.nl (J.C.C. van Nieuwkoop).

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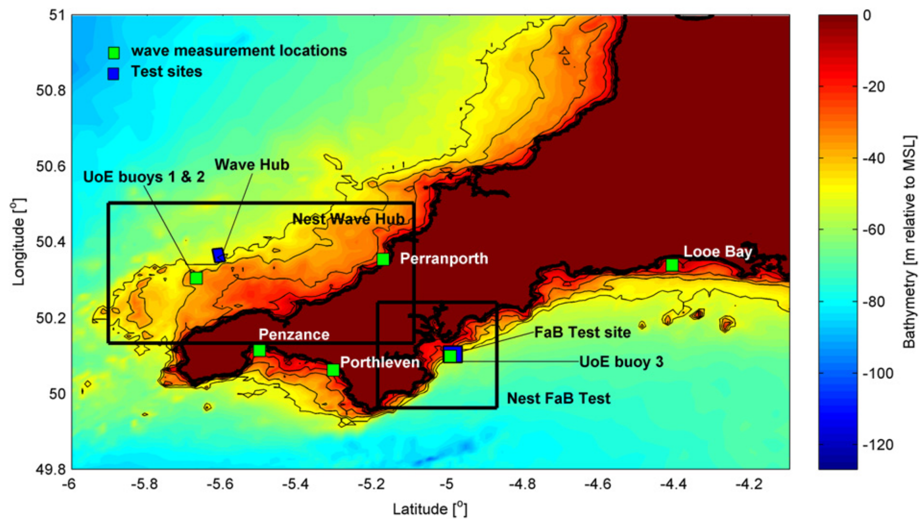

Fig. 1. Bathymetry, nests and validation points.

This paper describes the set-up and results of a 23-year hindcast wave modelling study for the region, performed with the numerical wave model SWAN, with a particular focus on the Wave Hub and FaB Test sites. The methodology, including model calibration and validation studies, is described in Section 2, and the results are presented in Section 3. The Wave Hub and FaB Test sites are used as case studies, addressing issues such as resource variation across the site, monthly and annual power variations, spectral energy distributions and prediction of extreme conditions. These results represent the most extensive study yet performed for the region and are discussed in this context in Section 4, with conclusions drawn in Section 5.

2. Methodology

2.1. Sensitivity study

This study uses the spectral wave model SWAN (Simulating WAves Nearshore) [8] in third generation mode. SWAN accounts for depth and current-induced refraction and represents processes that generate, dissipate or redistribute wave energy. These include the deep water processes of wind input, whitecapping dissipation, quadruplet nonlinear interaction and the shallow water processes of bottom friction dissipation, depth-induced breaking and triad wave-wave interactions.

The model was set-up covering the area of 4–7 degrees west and 49–51 degrees north, which means that the whole Cornwall coast, part of the Devon coast and the Isles of Scilly were included. A sensitivity study was initially carried out to determine optimal model settings. Various parameters and settings were considered, e.g.:

- physical settings: bottom friction, diffraction, directional spreading, whitecapping formulation;
- numerical settings: numerical scheme, convergence criteria;
- resolution: grid resolution, nested grid, unstructured grid, time step, directional resolution;
- wave boundary input: spectral shape, wave input source, number of input points;
- water level, current and wind input: input sources, sensitivity to increase or decrease;
- computational cluster: number of computational nodes.

The model results were compared to a reference simulation, with default SWAN settings according to the SWAN manual [9], and to measurements for two hindcast periods: a stormy period from 11 to 14 November 2009 and a period with mixed sea states, but smaller waves, 1–28 February 2010. An example of the comparison for the physical settings is presented in Fig. 2. It can be seen that changing the whitecapping settings from the SWAN default to settings proposed by Rogers [10] enhances the agreement between the computed and measured wave period significantly. In the hindcast for 1–28 February 2010 the same behaviour was found with regard to the whitecapping settings. In the modification proposed by Rogers, the weighting of the relative wave number term in the default whitecapping formulation in SWAN [9] is altered ($n = 2$ instead of $n = 1$). By increasing n, the dissipation is reduced at lower frequencies and increased at higher frequencies compared to the

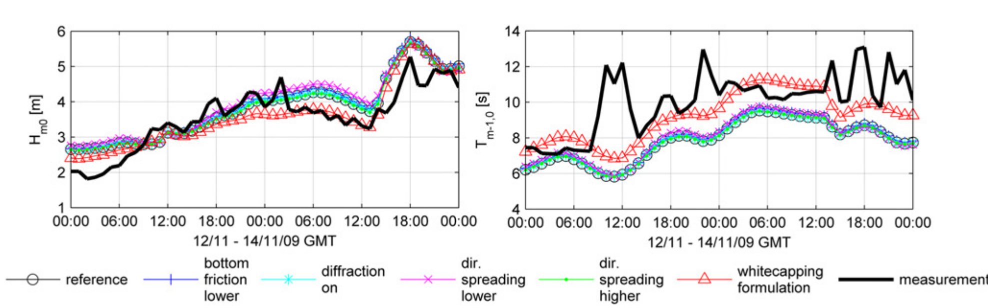

Fig. 2. Variations in physical settings compared to reference simulations and measurement.