Energy 66 (2014) 699–710

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Spatial variability of waves within a marine energy site using in-situ measurements and a high resolution spectral wave model

I. Ashton*, J.C.C. Van-Nieuwkoop-McCall, H.C.M. Smith, L. Johanning

College of Engineering, Mathematics and Physical Sciences, University of Exeter, Cornwall Campus, Penryn TR10 9EZ, United Kingdom

ARTICLE INFO

Article history:
Received 25 June 2013
Received in revised form
5 December 2013
Accepted 29 December 2013
Available online 26 January 2014

Keywords:
Marine renewable energy
Resource assessment
Spatial variability
SWAN (Simulating WAves Nearshore)

ABSTRACT

A high resolution spectral wave model is used to quantify the spatial wave climate on geographical scales relevant to intra-site variability for marine renewable energy installations. For the first time, results are compared to in-situ data from an array of four floating wave buoys, and demonstrate the ability of the spectral wave model SWAN (Simulating WAves Nearshore) to resolve spatial differences in the wave climate. Examination of the model source terms highlights bottom friction and refraction as the primary processes contributing to the observed differences across the site. Wave models for climate assessments for marine renewable energy are not commonly operated at sufficient spatial resolution to accurately resolve intra-site variability. This study demonstrates that high spatial resolution spectral wave models, nested into a larger model domain, have the potential to provide an accurate and detailed prediction of the spatial variability of wave conditions across a marine renewable energy site. As such, they could be implemented to provide a more accurate resource assessment for wave energy array deployments, but also for engineering assessments of other marine energy technologies.
© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Technologies to convert the energy within the ocean into electrical energy are underdevelopment throughout the world. Leading companies have devices that have been tested at sea and are moving toward deployment as commercial ventures [1,2]. This next phase of development is geared towards sites that are capable of providing a meaningful contribution to global electricity supply. As such, most developers envisage arrays of multiple devices, covering a site and providing increased energy yields. The deployment of multiple devices offers many new challenges to the industry, and to the research community. Amongst them is the robust assessment of hydrodynamic conditions at site, and their spatial distribution. Recent work has highlighted significant differences in the wave conditions across a potential wave energy site, based on analysis of in-situ data [3]. It follows that intra-site variability, which has the potential to change the conditions experienced by different devices within an array, is now a critical area for consideration.

Spatial variability of underlying wave conditions within a deployment site will govern both the productivity of a wave energy site and the engineering specifications for design and marine operations for other marine energy infrastructure, such as tidal devices. Furthermore, the spatial distribution and behaviour of hydrodynamic properties can be linked to environmental factors, to inform environmental impact assessment of proposed MRE (Marine Renewable Energy) developments. In particular, the small-scale attributes of habitats and feeding areas for marine species [4], and sensitive areas for downstream or down-wave impacts [5], can be predicted, based on the spatial distribution of hydrodynamic properties. This information allows project developers to minimise adverse impacts through array design and planning.

For an operational site, an accurate resolution of intra-site differences will allow a site operator to make informed assessments of device performance, potentially highlighting faults in individual devices. Furthermore, this detailed information about the physical conditions that each device is exposed to could inform control strategies [6], as well as fatigue monitoring and estimation [7,8], allowing the site operator to maximise output whilst streamlining service and maintenance schedules. With installed infrastructure, the spatial properties of the wave conditions will be affected by wave–device interactions. Prediction of this effect using a spectral wave model is an established methodology for both wave energy [9,10], and offshore wind [11,12]. Most recently, Carballo and Iglesias [13] used measurements of waves around wave energy devices from wave tank experiments to provide a realistic representation of transmission within the spectral model. In order for results to be representative of real situations, an accurate assessment of natural

* Corresponding author. Tel.: +44 (0) 1326 254188.
E-mail addresses: I.G.C.Ashton@exeter.ac.uk, iga202@ex.ac.uk (I. Ashton), Joana.vanNieuwkoop@deltares.nl (J.C.C. Van-Nieuwkoop-McCall), H.C.M.Smith@exeter.ac.uk (H.C.M. Smith), L.Johanning@exeter.ac.uk (L. Johanning).

0360-5442/$ – see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.energy.2013.12.065

intra-site variability provides an important baseline, on which the on-going impact of installed infrastructure on the propagating wave field can be quantified.

Despite its importance to MRE sites, there exists little in-situ data with which to assess spatial variability of wave conditions. Multiple point measurements have been used for the inter-comparison of wave sensors [14], although for the case of the WADIC experiment [15], these data were directly applied to examining spatial variability [16]. More recently, marine energy test sites have offered data sets from 2 simultaneous wave buoys, on scales of 500 m – 2 km. Results from these buoys indicate a significant difference in wave conditions across the EMEC (European Marine Energy Centre) test site [17–19]. Forwarding this area of research, Ashton et al. [3] analysed data from a unique deployment of four floating wave buoys, measuring simultaneously for 13 months, with a separation of 500 m. In what represents a direct precursor to work presented here, the conclusions supported the hypothesis that spatial variability is an important consideration for MRE developments, particularly arrays. It also raised the question of how physical processes influence this spatial variability, and how prediction can be integrated into established resource assessment procedures for MRE sites.

Data capture for wave energy sites has been the subject of standards and protocols designed to provide developers with a consistent methodology for resource assessment (e.g. Refs. [20–22]). These sources recommend that the spatial properties of the wave climate be defined by numerical modelling, commonly in conjunction with a campaign of site-specific point wave measurements. Following this methodology, spectral wave models developed for nearshore use are commonly combined with global models to improve the accuracy of predictive data sets in coastal regions [23:28], whilst a thorough review of this procedure is provided by Mackay [29]. Operating these models to resolve changes in a wave climate for different devices would require a particularly high spatial resolution, and a typical resolution of 1 km × 1 km means that intra-array variability for small sites would not be quantified. Plant [30] describes a high resolution spectral wave model (resolution 10 m × 40 m), highlighting that accuracy is highly dependent on input bathymetry data at a reasonable resolution, although this is a nearshore study and results are strongly linked to wave breaking. Thus, despite the preference for spectral wave models in MRE resource assessments, there exists little precedent to a developer wishing to assess spatial variability within their site using this approach.

This paper draws on the extensive measurement undertaken in the area of sea surrounding the Wave Hub wave energy test site in Cornwall, southwest UK [31], including the development of a regional phase-averaged spectral wave model [24]. In particular, the research assesses the potential for this wave model to operate at a very high, 10 m × 10 m, resolution in order to resolve intra-site variability for potential wave energy deployment sites. The work benefits from the unique deployment of four identical wave buoys in close proximity, to validate model output on a relevant scale. Furthermore, the source terms are interrogated to identify the physical processes contributing to the differences in the model. The results present an interesting case-study for the application of spectral wave models in detailed resource assessments, and as an operational tool for MRE sites.

2. Methodology

2.1. The wave buoy array

During 2009 and 2010, the University of Exeter deployed four Fugro Oceanor SeaWatch mini II directional wave buoys at a site close to the Wave Hub test site, Cornwall UK (Fig. 1). The wave buoys were operational for a period of 13 months between October 2009 and October 2010. Raw data were quality controlled in accordance with international guidelines for the analysis of oceanographic data [32]. Data processing was designed to follow the guidelines set out in Refs. [33] and [34], in accordance with manufacturer's recommendations [35]. To ensure accurate comparisons, all data were limited to records where simultaneous data from all 4 buoys were available.

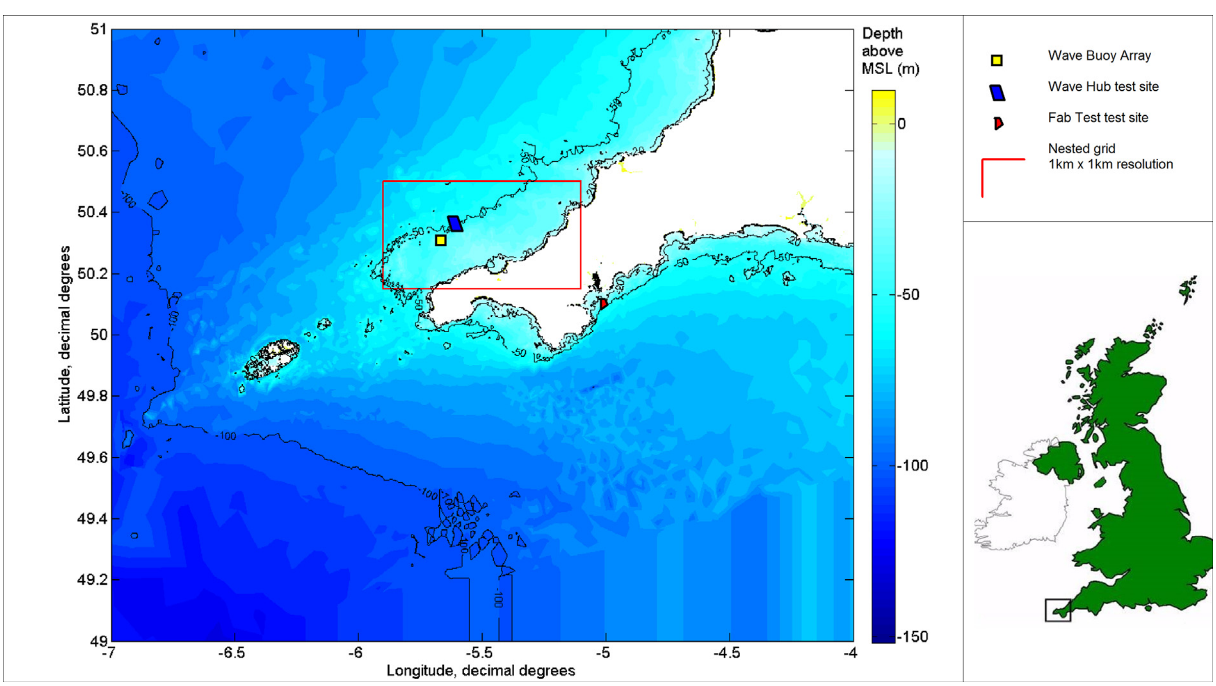

Fig. 1. An overview of the model domain showing the bathymetry in the southwest UK. Also shown is the nested 1 km × 1 km grid, within which the wave buoy array, and the Wave Hub test site are situated.

Download English Version:

https://daneshyari.com/en/article/8078546

Download Persian Version:

https://daneshyari.com/article/8078546

Daneshyari.com