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Development of a high resolution wave climate modelling methodology for offshore, nearshore and onshore locations of interest

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ABSTRACT

The aim of this investigation was to develop a methodology to characterise the wave climate for offshore, nearshore and onshore locations of interest. The proposed methodology was applied to a domain located off the west coast of Ireland, adjacent to Loop Head, Co. Clare, and this was an area of interest for ocean energy development. A 3rd generation spectral wave model for the domain was developed, calibrated and validated using DHI's MIKE 21 spectral wave modelling software along with sea state, met-ocean and bathymetric data obtained from a wide range of sources.

The model yielded information on a range of indices including annual mean wave power, exploitable wave power, maximum wave height, percentage occurrence of a range of sea states and wave directionality at off-shore, near-shore, and on-shore locations.

The models predictions were compared with local wave measurements for calibration and validation purposes obtained from a non-directional Datawell Waverider wave measurement buoy. The wave climate model predicted significant wave height and energy period at this location exhibiting a scatter index of less than 0.25 and a correlation coefficient greater than 0.85. The inclusion of a high resolution bathymetry dataset in the on-shore and coastal regions of the domain was the main driver in achieving this level of agreement between the data.

The spectral wave model developed in this research programme will be useful for future wave energy research. Results from this model indicate that the domain off County Clare possesses an exploitable resource with promising levels of energy for potential wave energy projects. They also show that the near-shore and on-shore environment in this domain maintains good levels of power with relative filtering of extreme waves.

1. Introduction

As the wave energy industry advances, there is a need to model the resource at locations of interest in greater detail. For the west coast of Ireland, there are existing established wave climate models with varying levels of accuracy, based on numerical grids with different resolutions. These include the European Centre for Medium-Range Weather Forecasts (ECMWF)'s operational global model [1], The National Oceanic and Atmospheric Administration's (NOAA) Wavewatch III

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north Atlantic model [2] and the Marine Institute's SWAN wave prediction model [3] with resolutions of 0.5°, 0.25° and 0.025° respectively. Although these can be used for site reconnaissance to identify preferable areas for wave energy utilisation, their levels of accuracy are inadequate as the objective shifts to project feasibility assessment and wave energy converter design.

Several detailed studies have focussed on locations of particular interest in Ireland, namely the Atlantic Marine Energy Test Site (AMETS) and quarter scale test site in Galway bay [4,5]. In addition to these sites, the west coast of County Clare has been identified by numerous investigations as a favourable location for the exploitation of marine renewables and possesses a 110 kV electrical grid [4,6,7].

This paper details the development of a 3rd generation spectral wave model applied to a domain off the west coast of Ireland adjacent to Loop Head, County Clare (Fig. 1). A hindcast study based on hourly wind, wave and tidal data sourced from the United Kingdom and North Sea (UKNS) model provided 4 years of wave data which facilitated an examination of the offshore, nearshore and onshore wave climate. Using this, the following aspects of the wave energy resource were investigated in the offshore, nearshore and onshore domain: gross and exploitable wave energy; extreme sea-states; percentage occurrence of each sea-state; and wave directionality.

2. Methodology

To predict offshore, nearshore and onshore wave climates, DHI's MIKE suite of software [8] was employed. MIKE 21 Spectral Wave is a 3rd generation spectral wave model which simulates the growth, decay and transformation of wind-generated waves and swells in offshore, nearshore and coastal areas.

There are four dominant data components recommended for the development of a 3rd generation spectral wave model. These are (i) offshore boundary conditions, (ii) metocean conditions (iii) bathymetric data and (iv) local measurements for model calibration and validation. For each of these components, the data and sources of data can vary in quality, directly impacting on the accuracy of the wave climate characterisation.

Offshore boundary conditions and metocean conditions were sourced from the UKNS model, which extends to the west of Ireland. A quality check of data from the UKNS model was carried out using physical wave and wind measurements. Tidal data sourced from the UKNS model were also compared with physical measurements recorded in the region of interest. To obtain a quantitative and objective indication of how well the UKNS model data compared with physically measured data from a point off the west coast of Ireland, industry standard statistical parameters were calculated. These were bias, root mean square error (RMSE), scatter index (SI) and correlation coefficient (r), often referred to as quality indices [9].

In order to precisely characterise the wave energy resource at nearshore and onshore locations, an accurate bathymetry is of fundamental importance. Bathymetric data for this region were sourced from UK Hydrographic Office, Geological Survey of Ireland and the Marine Institute. This was used to create a digital seabed elevation model extending from the offshore boundary, where suitable boundary conditions were available, to the region of interest for this test case, Loop Head, Co. Clare.

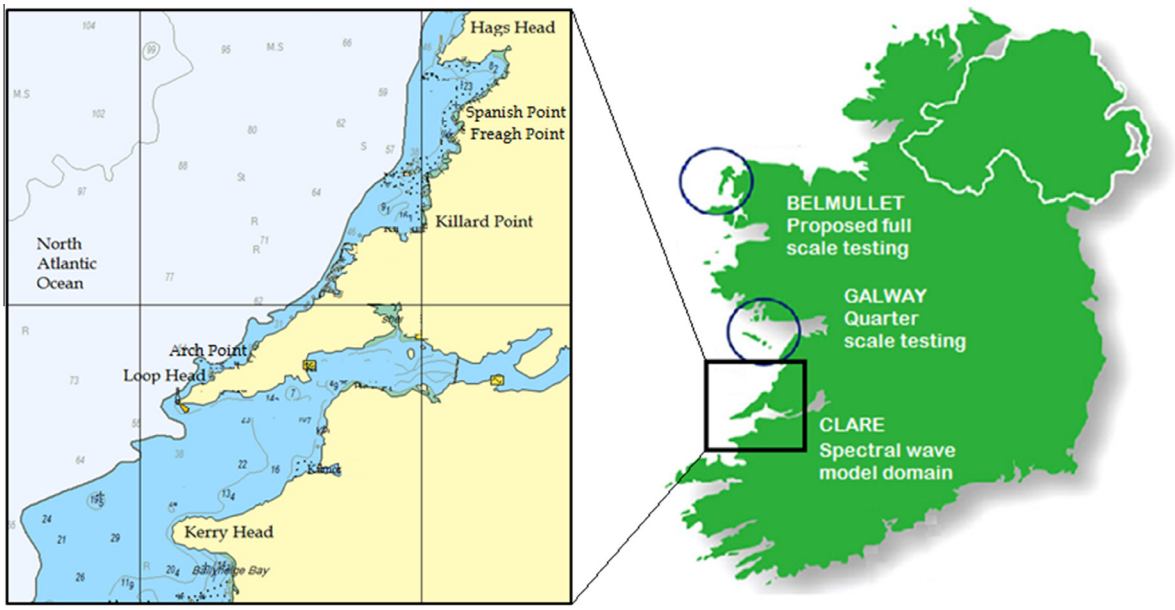

Fig. 1. Spectral wave model domain (left) relative to the Atlantic Marine Energy Test Site (AMETS) off Belmullet and the quarter scale testing facility in Galway Bay.