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Characterizing the near shore wave energy resource on the west coast of Vancouver Island, Canada

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ABSTRACT

Global wave energy inventories have shown that the west coast of Canada possesses one of the most energetic wave climates in the world, with average annual wave energy transports of 40–50 kW/m occurring at the continental shelf. With this energetic climate, there is an opportunity to generate significant quantities of electricity from this renewable source through the use of wave energy conversion (WEC) technologies. To help evaluate the feasibility of deploying wave energy conversion technologies along the west coast of Vancouver Island, a detailed Simulating WAves Nearshore (SWAN) model was developed to assess the wave resource. The SWAN model hindcasted wave conditions along the west coast over the 2005–2012 period, at a 3 h time resolution. Detailed sensitivity studies within this report illustrate that the Fleet Numerical Meteorology and Oceanography Centre's (FNMOC) WaveWatch 3 results exhibited superior model performance when used as wave input boundary conditions. The corresponding Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS) wind fields were used as non-stationary wind forcing functions within the computational domain. Yearly and monthly mean variations of spectral and parametric wave characteristics for two reference locations were plotted to indicate both the spatial and temporal variability of the wave climate. The mean annual wave energy transport for Amphitrite Bank was calculated to be 34.5 kW/m, while the shallower second location featured 27.8 kW/m just 500 m from shore. Wave energy resources of this magnitude are not common globally and, as a consequence, signify that the west coast of Vancouver Island may be an excellent candidate location for future wave energy development.

1. Introduction

Global wave energy inventories [1,2] have shown that the west coast of Canada possesses one of the most energetic wave climates in the world, with average annual wave energy transports of 40–50 kW/m occurring at the continental shelf. With this energetic climate, there is an opportunity to generate significant quantities of renewable electricity through the use of wave energy conversion (WEC) technologies. Despite this opportunity, efforts to quantify the resource along the coastline at a spatial and temporal resolution relevant to power project development have been limited. Little precision in regional wave energy measures is available.

Resolving the spatial distribution of the wave resource, especially near-shore, is a critical step to enable wave energy development. Utilities require this knowledge so that infrastructure expansion, such as new transmission lines, can be planned to correspond with WEC distributions. Proponents of wave energy developments require detailed temporal wave resource data to ensure demonstration sites are energetic and to accurately evaluate the performance of a WEC technology *a priori* to ensure project viability. Previous detailed studies of the western Canadian coast have focused either on the off-shore wave climate [3], or on small sections of coastline [4,5].

The present work details the development of a Simulating WAves Nearshore [6,7] wave model covering waters from the continental shelf to the shore-line of the west coast of Vancouver Island (WCVI) region, and over a 450 km stretch of British Columbia and Washington coastline (see Fig. 1). Simulating WAves Nearshore (SWAN) is a third generation wave model that computes the dynamics and propagation of ocean swells and random short crested wind-generated waves in coastal regions. The model discussed in this work is being applied within the West Coast Wave Initiative (WCWI), a federally funded endeavour to monitor and forecast wave conditions along the Vancouver Island coast on an ongoing

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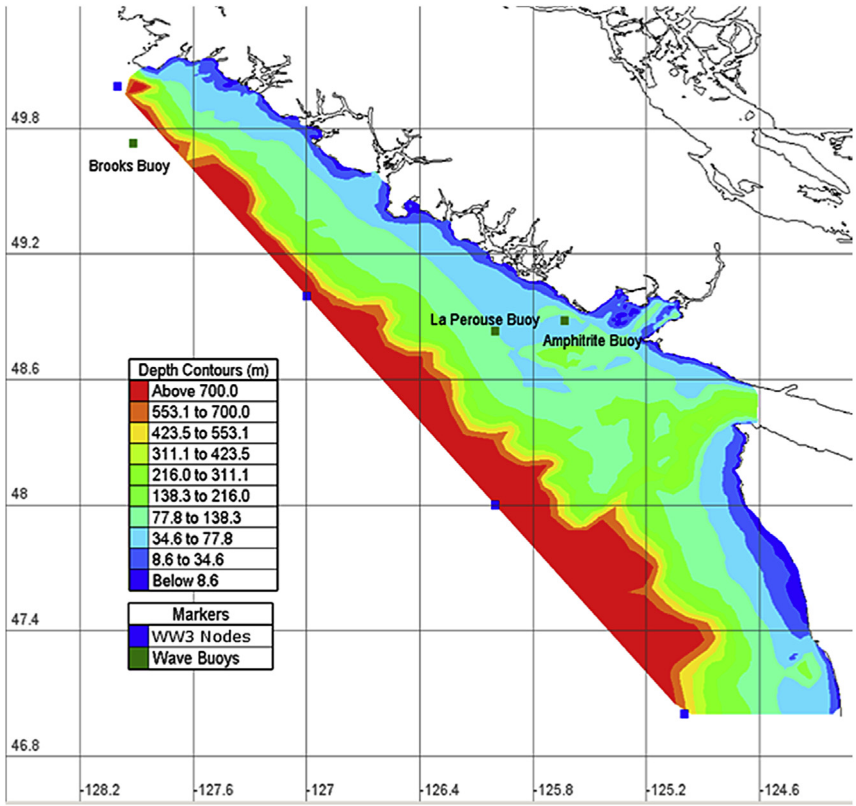

Fig. 1. Map showing BC/WA coastline. Color contours give depth throughout model domain. Green squares indicate wave buoy location. Blue squares indicate SWAN boundary condition nodes from FNMOC and NCEP WW3 model (addressed further in Sections 2.1 and 2.4). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

basis. Leveraging high resolution, publicly available off-shore wave data, the presented model hindcasts wave conditions between 2005 and 2012. The current work builds on previous resource assessment studies by Cornett [8] and Hiles et al. [9] by dramatically expanding the spatial and temporal domains considered and through tuning SWAN model parameters using WCWI and Environment Canada wave measurement buoy data sets.

The presented model computes the transformations of a full directional variance density spectrum at each of the 9945 model grid points over 8 years, or 23,360 3 h time steps. Draft standards in development by the International Electrotechnical Commission (IEC) Technical Committee 114 [10] have introduced new methods and metrics for the characterization of wave energy resources for WEC developers based on full directional spectra. This paper follows this new protocol when quantifying the wave energy transport and associated metrics over various temporal and geographic scales within the target time period (2005–2012) and WCVI region.

This paper is organized as follows: Section 2 discusses the setup of the SWAN model, the input data sources including bathymetry, wave and wind boundary conditions as well as the methods used to determine the best choice of numerical solvers for the WCVI region. Section 3 deals with the parametric and spectral validation of model predictions against buoy measurements made during 2010 and 2011. Additionally, the model input boundary conditions for the target time period (2005–2012) are validated against long term wave climate measurements to ensure they accurately represent the typical deep water conditions outside the WCVI region. Section 4 discusses the wave energy metrics adopted for the wave resource assessment. Section 5 presents the model results and discusses the temporal and spatial variability along the west coast of Vancouver Island. Finally, Section 6 presents the study's conclusions and recommendations.

2. Wave model development

Canada, the UK, Ireland and other countries have each developed wave atlases [3,11]. These studies inventory the wave resources off-shore of the respective nation based on ocean-scale wind-wave models. Ocean-scale wind-wave model results are limited in spatial resolution and are usually parameterized only in terms of the significant wave height (H_{m0}) and peak period (T_p). These parameters are convenient for many applications but full wave spectra are required for accurate estimation of WEC device performance. This spectral limitation combined with the coarse spatial resolution and lack of depth induced wave transformations necessitates a more detailed near-shore model be used for estimates of wave climates closer to shore.

Near-shore wave resource models have been developed for many regions globally, including Portugal [7], Spain [12] and Canada [8]. Each of these studies uses ocean-scale model results to calculate boundary conditions for driving a near-shore SWAN model operating in structured mode. The Portuguese model is fully transient, covers the country's coastline and has a number of nested sub-domains to provide detail in areas of interest [7]. The Spanish model covers only a small part of the coastline in the Galicia region and is used to study near-shore conditions for a small number of frequently occurring boundary conditions [12]. The Canadian model covers a small subsection of the coastline around the Ucluth Peninsula on the west coast of Vancouver Island. Near-shore wave conditions were pre-processed for an array of characteristic