Renewable Energy 80 (2015) 454–470

Contents lists available at ScienceDirect

Renewable Energy

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

Wave energy potential assessment in the central and southern regions of the South China Sea

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ARTICLE INFO

Article history:
Received 11 February 2014
Accepted 3 February 2015
Available online

Keywords:
South China Sea
WAVEWATCH–III™
Wave power
Seasonality
WEC

ABSTRACT

Wave energy potential in the South China Sea was assessed and analysed based on a 31-year simulation of wave characteristics using the third generation spectral WAVEWATCH–III™ model. The model was forced by Climate Forecast System Reanalysis (CFSR) winds and ETOPO2 bathymetry data. The highest annual wave power can be found in the northern region of the study area with amplitudes exceeding 20 kW/m. The values decrease gradually towards the Sunda Shelf and reach to their minimum at coastal regions due to bathymetry complexity, shadowing and island obstruction effects. However, the wave power is strongly influenced by seasonality and inter-annual fluctuation. Nine sites representing different sub-regions were selected for further analysis on eligibility of wave farming. Various wave energy statistics including estimated electric power for a number of Wave Energy Converter (WEC) devices showed some stations (Hameau Mo in Vietnamese east coast, Spratly Island, Palawan and Cape Bolinao in west coast of Luzon) have greater eligibility for wave power farming. The estimated electric power that can be produced from these sites using Wave Dragon, an intermediate depth WEC device, ranges from 712 to 1211 kW and 935–1680 kW for annual and a six-month period from September to February, respectively.

1. Introduction

Most countries in the world still heavily rely on coal, oil and natural gas for their energy needs. The use of fossil fuel has been identified as the major source of CO_2 emission causing the climate system to warm up [1]. For long-term sustainability, the use of fossil fuels would have to be replaced with clean and renewable energy. Additionally, non-renewable fossil fuels are gradually becoming more expensive and will eventually dwindle. Renewable energy can be sourced naturally from the components of the Earth's system such as wind and solar and ocean waves, which constantly replenish and never wane. However, the availability and viability in harvesting renewable energy depend on the types as well as geographical locations. For ocean waves, the harvestable energy varies temporally and spatially.

The energy produced by ocean waves is considered as the cleanest and safest energy that can be harvested. Additionally, according to the International Energy Agency (IEA), the capacity of global oceans is about 93,100 TWh/year [2]. Therefore, in recent decades this type of energy has attracted researchers' attention [3]. In order to assess economic viability, and to identify the potential locations for wave energy converters and optimally harvest the wave energy, long-term wave data are a pre-requisite. Long-term wave records provide seasonal and long-term fluctuations of harvestable wave energy. However, sufficiently long-term series of wave measurement is often lacking and limited in spatial coverage. Hence, numerical modelling fills the gaps in understanding wave characteristics.

A number of wave numerical models have been developed and employed in many parts of the globe. The WAM, WAVEWATCH-III (WW3) and SWAN are three well known third generation wave models that have been used worldwide. The first two models are mostly used for large area and globally, whereas SWAN is adopted for shallow waters and coastal areas. Various studies have

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http://dx.doi.org/10.1016/j.renene.2015.02.005
0960-1481/

examined the eligibility of these models for simulating the wave characteristics under different sea states. Arinaga and Cheung [3] implemented a WW3 model using surface winds from the Final Global Tropospheric Analysis (FNL) to provide 10-year spectral wave data for a thorough examination of the wave resource globally. Based on their study, southern Australia and New Zealand have been identified as regions of high potential wave power. Prior, Lenee-Bluhm et al. [4] also highlighted higher latitudes of the southern hemisphere (between 40°S and 60°S) as regions of potential harvestable wave power. In addition, various other regions have been identified for wave energy harvesting. A series of comprehensive investigations along the northwest coastal region of Spain (including El Hierro Island) indicated the viability of this region for harvesting wave power [5–11]. In a similar study, Rusu and Soares [12] evaluated the wave conditions using WAM and SWAN models and calculated the wave energy in the Portuguese nearshore. In their study the application of SWAN model nested within WAM provided a better means of resolving nearshore complexity [12].

In a more recent study, Stopa et al. [13] identified some sections of the coastline of Hawaiian Island chain as having greater potential for harvesting wave energy. The Hawaiian Island chain is situated in the mid-Pacific where trade wind waves provide significant energy. In the western Pacific region a number of studies have shown the eligibility of some areas in capturing higher wave energy [14,15]. While in open ocean the wave energy is higher and expected to have greater economic viability for wave energy harvesting [13–15], in sheltered or semi-enclosed seas the level of wave energy can be much lower. In the Mediterranean Sea, a semi-enclosed sea, a number of studies have been carried out in assessing wave energy potential [16–19]. However, despite relatively lower wave energy compared with open ocean, some studies indicated economic viability of wave power harvesting in this region [16–19]. Nevertheless, in the South China Sea (SCS), the region of interest in this study, the evaluation of wave power potential is limited.

The SCS is a semi-enclosed marine basin that covers an area from the Taiwan Strait in the north to Karimata Strait in the south. The basin is shared by many nations including China, Vietnam, Philippines, Malaysia, Brunei, Thailand, Indonesia and Cambodia. The weather and climate of the SCS is strongly influenced by the Australian–Asian monsoon system that has two dominant components, summer monsoon (southwest monsoon) and winter monsoon (northeast monsoon). The existence of a monsoon system strongly modulates the wave characteristics in this region in addition to the inter-annual variability associated with the El Niño-Southern Oscillation (ENSO) [20]. Presumably, the wave

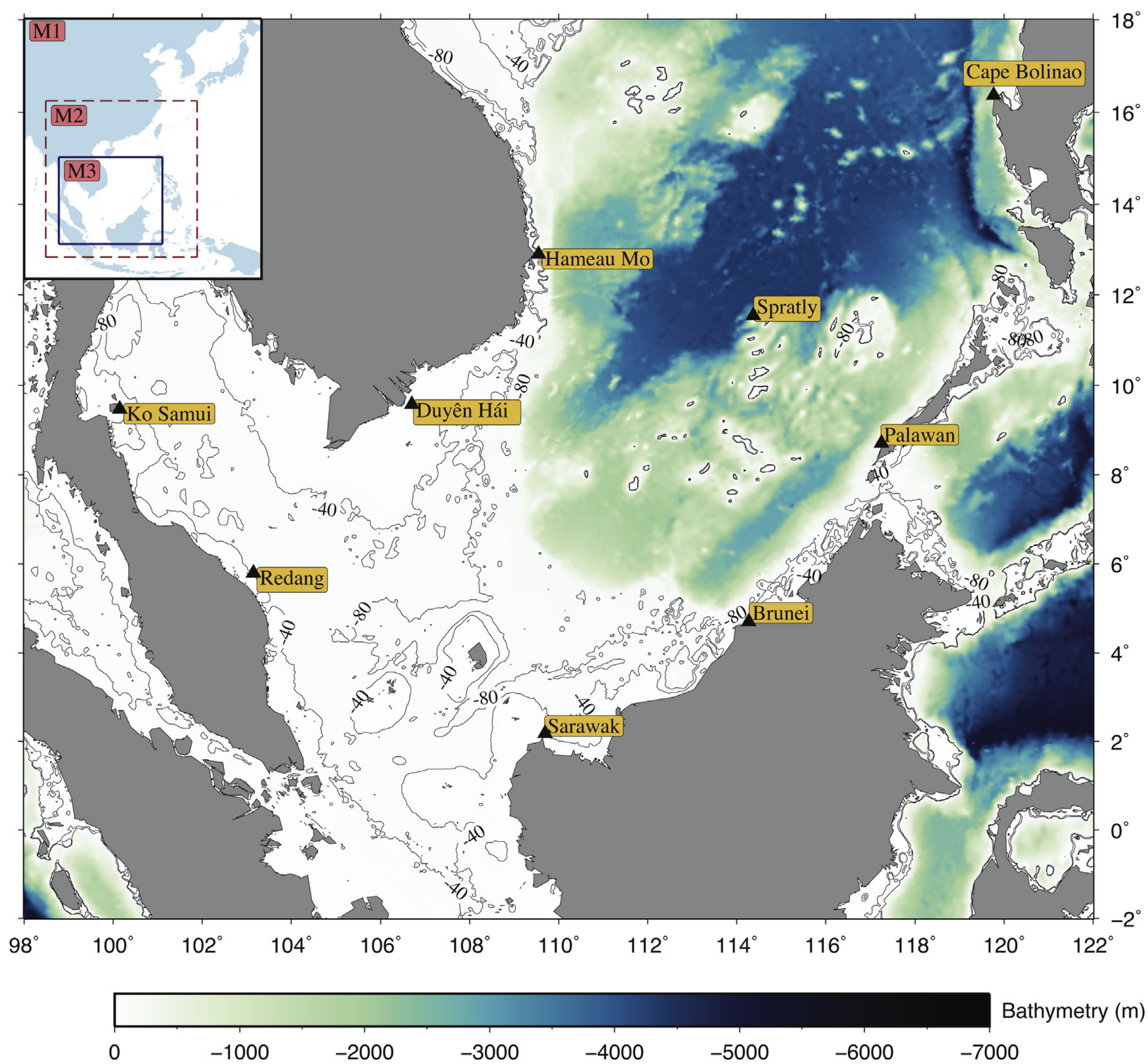

Fig. 1. Bathymetry of study area including geographical location of nine selected sites and three embedded nested domains (M1, M2 and M3).