INTERNATIONAL JOURNAL OF HYDROGEN ENERGY 41 (2016) 15805–15811

Available online at www.sciencedirect.com

ScienceDirect

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

Assessment of wind energy and wave energy resources in Weifang sea area

Zhifeng Wang, Sheng Dong, Xiangke Dong, Xin Zhang*

College of Engineering, Ocean University of China, Qingdao 266100, China

ARTICLE INFO

Article history:
Received 24 March 2016
Accepted 1 April 2016
Available online 17 May 2016

Keywords:
Weifang sea area
Wind hindcast
Wave hindcast
Wind power assessment
Wave energy assessment

ABSTRACT

Wind fields in the Bohai Sea are continuously simulated by wind model WRF in order to determine the wind energy resources from 1995 to 2014. And then, wave hindcasting data are simlated by SWAN in the same time range. Comparisons of wind speeds and significant wave heights between simulations and observations show good agreement. The results show that wind and wave energy are validated with measured data. Then, wave and wind energy of Weifang sea area are assessed by 20 years wind data and the wave data. The assessment results showed that Weifang sea area possesses huge wind and wave energy potentialities. Annual average wind energy density reaches up to 429 W/m^2, wave power density reaches up to 1.3 kW/m. The combined exploiting of wind energy and wave energy is suggested.

Introduction

At present, environmental problems caused by energy consumption centered on coal consumption has become the important problems that economic and social development faces, while wind energy and wave energy is renewable clean energy and publicly recognized important renewing energy and strategic substitutive energy in new energy development. In order to make full use of and develop wave energy resources, many scholars of countries and regions evaluate wave energy resource distribution [1]. Arinaga et al. [2] evaluate wind energy and wave energy using 10 years reanalysis data. Gallagher et al. [3] evaluate wind energy and wave energy in surrounding waters of Ireland with hindcast data of wind energy and wave energy of 14 years. Veigas et al. [4] evaluate wind energy on Fuerteventura of Spain. Rusu et al. [5] evaluate coastal wind energy and wave energy of Caspian Sea using remote data and hindcast data of wind energy and wave energy. Kamranzad et al. [6] evaluate wave energy of the Persian Gulf using hindcast data of wave energy of 25 years. Robertson et al. [7] evaluate wave energy of West Coast of Vancouver Island with hindcast data of wave energy of 8 years. Appendini et al. [8] evaluate wave energy of Caribbean Sea with hindcast data of wave energy of 30 years.

For wave energy resource distribution in China, wave energy resources are rich in southeast coast. Compared with land wind energy, the wind energy at sea has the advantages of high speed, good stability and small limit by noise. Zheng et al. [9] evaluate Chinese coastal sea wave energy according to hindcast data of 22 years (from 1988 to 2009) by WAVEWATCH III wave mode. Wu et al. [10] evaluate wave energy of East China Sea based on float observed data from 2011 to 2013. Wang et al. [11] evaluate wave energy of the Bohai Sea based on hindcast data of 26 years (from 1985 to 2010). Yaakob et al. [12] evaluate wave energy of the South China Sea with altimeter data from 2001 to 2010.

Weifang locates at west bottom of Laizhou Bay. The specific geographic position is shown in Fig. 1. Wind energy and wave energy in Weifang sea area cover a wide range. The

* Corresponding author.
E-mail address: dongsh@ouc.edu.cn (S. Dong).

http://dx.doi.org/10.1016/j.ijhydene.2016.04.002
0360-3199/

construction condition of Weifang sea area is good and it is the ideal sea area for energy development. The wind energy and wave energy along Weifang sea areas are evaluated in this paper. The paper includes two parts. The first is wind simulation in the Bohai Sea by WRF mode and wave simulation by SWAN model. The second is to evaluate wind energy and wave energy in Weifang sea areas with the 20 years hindcast data.

Wind and wave simulation

Wind field is one of important factors for wave driven and correct wind simulation is the basis of wave hindcast. Weather Research and Forecasting (WRF) mode is chosen for wind field simulation in this paper. WRF is a mesoscale forecasting mode and assimilation system. It is a non-static mode, integrating numerical weather forecast, atmosphere simulation and data assimilation with Arakawa C grid. It can improve the simulation and forecasting of mesoscale weather better. The mode includes dynamic process and physical process of climate change. It is a planetary boundary layer (PBL) model with 2-order turbulence close or non-local K close scheme It includes an atmosphere radiation mode considering long-wave radiation scheme and short-wave radiation scheme as well as cloud and ground surface layer.

For vertical direction, η is definition as:

$$\eta = (p_h - p_{ht})/\mu \tag{1}$$

where $\mu = p_{hs} - p_{ht}$, p_{hs} and p_{ht} are pressures. The equation of euler form can be written as:

$$\frac{\partial U}{\partial t} + (\nabla \bullet Vu) - \mu_d \alpha \frac{\partial p}{\partial x} + (\alpha/\alpha_d)\frac{\partial}{\partial \eta}\left(\frac{\partial p}{\partial \eta}\frac{\partial \Phi}{\partial x}\right) = F_U \tag{2}$$

$$\frac{\partial V}{\partial t} + (\nabla \bullet Vv) - \mu_d \alpha \frac{\partial p}{\partial y} + (\alpha/\alpha_d)\frac{\partial}{\partial \eta}\left(\frac{\partial p}{\partial \eta}\frac{\partial \Phi}{\partial y}\right) = F_V \tag{3}$$

$$\frac{\partial W}{\partial t} + (\nabla \bullet Vw) - g\left[(\alpha/\alpha_d)\frac{\partial p}{\partial \eta} - \mu_d\right] = F_W \tag{4}$$

$$\frac{\partial \Theta}{\partial t} + (\nabla \bullet V\theta) = F_\theta \tag{5}$$

$$\frac{\partial \mu}{\partial t} + (\nabla \bullet V) = 0 \tag{6}$$

$$\frac{\partial \varphi}{\partial t} + \frac{1}{\mu}[(V \bullet \nabla\varphi) - gW] = 0 \tag{7}$$

$$\frac{\partial Q_m}{\partial t} + (\nabla \bullet Vq_m) = F_{Qm} \tag{8}$$

Where, Φ is potential, F is external force; μ is friction coefficient; θ is potential temperature; q_m is specific humidity.

The paper take NCEP historic reanalysis weather data as ambient field to assimilate all acquired observation data, such as air sounding data, ground weather data, sea surface temperature and so on. The grid setup in WRF is shown in Fig. 2. The horizontal resolution of D1 is 30 km and time step is 180 s. The horizontal resolution of D2 is 10 km and time step is 60 s. There are 35 layers in the mode and the results of wind field in Bohai is 1/12° × 1/12°. The wind data is 20 years from 1995 to 2014 with time interval 1 h.

The observance data ata station BZ35 and W0101 are used for simulation validation. The position of two observance stations is shown in Fig. 1. The comparision results between simulation data and measured data is shown in Fig. 3 and Fig. 4. The results show that wind fields produced by the simulation method are in good agreement with the observations.

In this study, the SWAN spectral wave model is used for wave simulation. The SWAN model is a numerical wave model that provides realistic estimates of wave parameters in coastal areas, lakes, and estuaries from given wind, bottom, and current conditions. The model is a third-generation fully spectral model and Zijlema & van der Westhuysen [13] described the theoretical background.

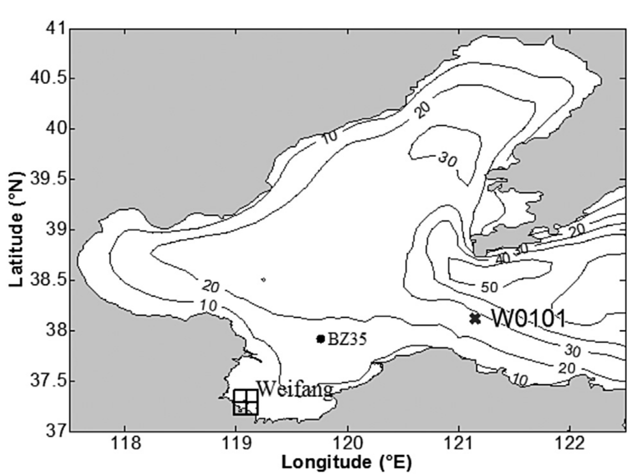

Fig. 1 – The geographical location, bathmatry and observation stations.

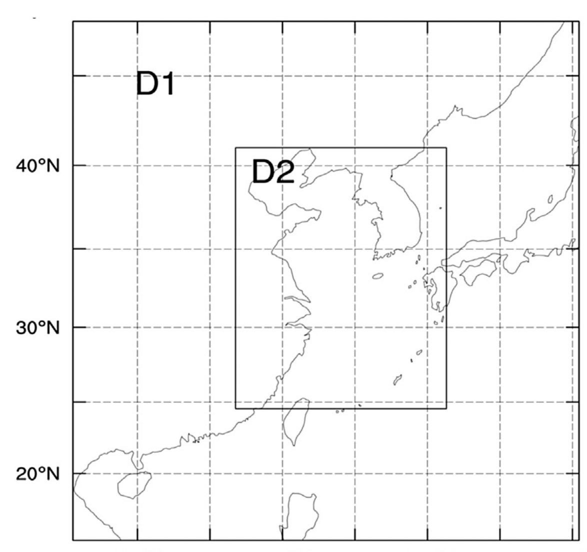

Fig. 2 – Computational domain of WRF.