Applied Ocean Research 71 (2018) 20–33

Contents lists available at ScienceDirect

Applied Ocean Research

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

Blended wind fields for wave modeling of tropical cyclones in the South China Sea and East China Sea

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ARTICLE INFO

Article history:
Received 27 August 2017
Received in revised form
29 November 2017
Accepted 29 November 2017

Keywords:
Tropical cyclone
ERA-Interim
Holland model
Blended wind field
South China Sea
East China Sea
Wave modeling

ABSTRACT

Accurate tropical cyclone (TC) wind fields are crucial for modeling TC waves. Usually, reanalysis wind data, such as the ERA-Interim dataset, and parametric TC models, such as the Holland model, are widely used to generate TC wind fields. In the present work, 29 tropical cyclones (TCs) in the South China Sea (SCS) and East China Sea (ECS) of 4 years (2011–2014) are analyzed at 10 buoy locations. Among them, 9 TCs are selected as study cases due to buoys experience their whole processes of the TC passing. For the 9 selected TCs, data of the ERA-Interim and Holland model are compared with observation data of 10 buoys in the SCS and ECS. Results show that the ERA-Interim largely under-predicts wind speeds near the TC center, where the Holland model performs generally well. However, the Holland model fails to reproduce wind speeds in outer-region of the TC. After analyzing character of two sets of data, applicable ranges for the ERA-Interim and Holland model are identified with critical boundary limits, which are associated with the TC size. A formula for blended TC wind fields combining two datasets is proposed, which shows good capacity of the TC wind simulation. Then, the blended wind model is applied in TC wave simulations in the SCS and ECS, and shows a better performance than both the ERA-Interim and the Holland model. Thus, the proposed blending formula can be used to generate more accurate TC wind fields which are required in TC wave hindcasts.

1. Introduction

Tropical cyclones (TCs), which are also named as typhoons in the Pacific and hurricanes in the Atlantic, respectively, are one of the most important ocean dynamic factors. Due to their high intensities, irregular tracks and fast speeds, TCs pose great threats (e.g. high winds, strong waves and extreme water levels) to human lives and marine structures [1–3]. Among these threats, strong waves within TCs are a significant factor. For example, wave parameters with different return periods for design of coastal and marine structures are required, and their values are usually obtained through statistical analysis of historic strong waves. For this purpose, hindcast wave data are useful since long-term measurements are often absent in many areas [4–12]. Usually, reanalysis data and parametric tropical cyclone (TC) models are two basic methods to acquire wind fields required for wave simulations [13–23].

Long-term reanalysis wind data obtained from data assimilation models have been widely used as wind data products, such as the National Centers for Environmental Prediction (NCEP) [24,25], the European Centre for Medium-Range Weather Forecasts (ECMWF) [26,27], the National Aeronautics and Space Administration (NASA) [28,29], and the Japanese Reanalysis (JRA) [30,31]. Due to their accessibility and accuracy, they are widely used in many related studies, such as analysis of wind and wave characteristics [32–34], wave energy assessments [35–38], prediction of sea water levels [39], hindcasting and prediction of waves [40–43], maritime activity safety assessments [44,45]. In the other aspects, various parametric models have been proposed (e.g. Fujita [46], Jelesnianski [47,48], Wadachi [49], Jelesnianski and Taylor [50], Holland [51], Wijnands et al. [52], Olfateh et al. [53]) for generating realistic air pressure and surface wind distributions under TCs. They are used to simulate storm surges induced by TCs in the northern Bay of Bengal [54,55], forecast TCs and storm surges at the eastern coast of India [56] and forecast the TC storm surge in the Australian Sea [57]. Among these models, the Holland model and the improved Holland model [58,59] are widely used in different seas, such as

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https://doi.org/10.1016/j.apor.2017.11.012
0141-1187/

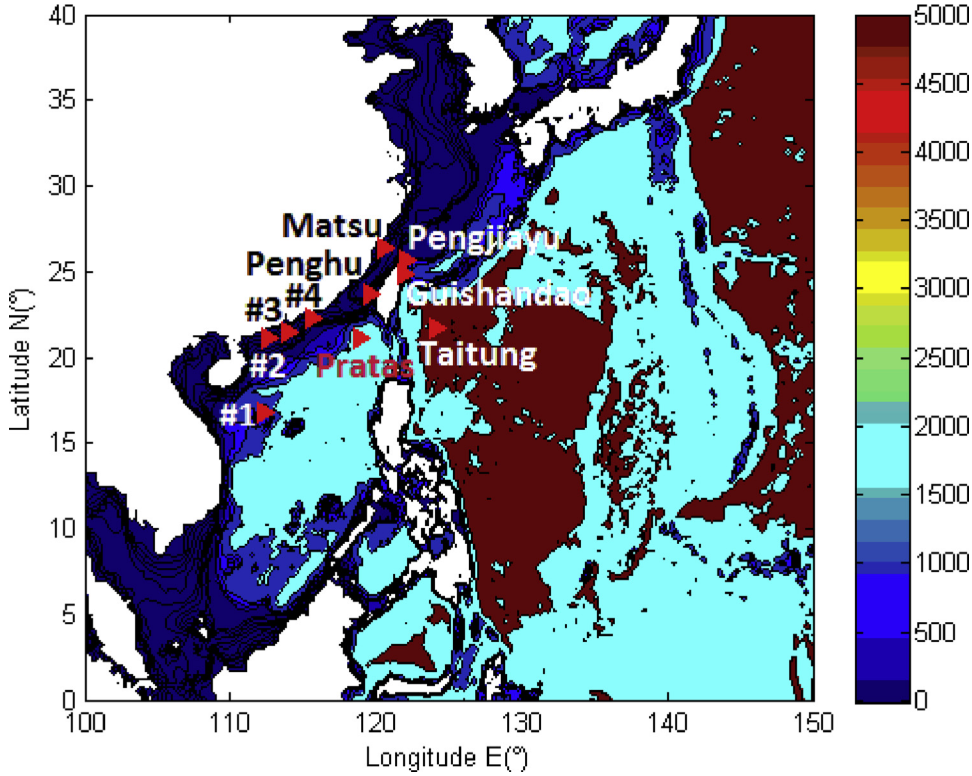

Fig. 1. The computational area bathymetry (m) and buoy locations (triangles stand for buoy locations).

Table 1
Buoy information statistics at ten locations.

Location	Longitude (°E)	Latitude (°N)	Wather Depth (m)	Time Period (Hour Day/Month/Year)	TC Number
Guishandao	121.9233	24.8469	28	17 15/06/2013–20 12/08/2013	4–10
				11 13/08/2013–10 12/09/2013	11–17
				21 24/06/2014–20 24/07/2014	8–10
Matsu	120.5361	26.3769	58	18 15/06/2013–20 12/08/2013	4–10
				11 13/08/2013–10 12/09/2013	11–17
				21 24/06/2014–20 24/07/2014	8–10
Penghu	119.5519	23.7269	26.6	07 19/06/2013–20 12/08/2013	4–10
				11 13/08/2013–10 12/09/2013	11–17
Taitung	124.0916	21.661	5522	18 15/06/2013–20 12/08/2013	4–10
Pratas	118.82	21.0683	2618	18 15/06/2013–20 12/08/2013	4–10
				11 13/08/2013–10 12/09/2013	11–17
				21 24/06/2014–20 24/07/2014	8–10
Pengjiayu	122.07	25.63	102	11 10/09/2013–10 10/10/2013	15–24
#1	112.3333	16.8333	28	00 23/09/2011–10 05/10/2011	17–19
#2	112.6167	21.1158	50	00 15/08/2012–23 19/08/2012	13
#3	113.9993	21.4988	51	00 15/08/2012–23 18/08/2012	13
#4	115.592	22.284	50	00 29/06/2012–23 30/06/2012	6

the Australia seas [60,61], the Bay of Bengal [62–64], and the China seas [65,66].

In previous studies, weaknesses in existing reanalysis wind data and TC model wind data have been found [67–69], which cannot describe wind fields accurately in total effect range of TCs. CARR III et al. [67] proposed a weight coefficient, which was used to combine reanalysis wind data and TC model wind data as blended wind data directly under TCs. For the weight coefficient, the scaling parameter is a significant factor, which can be adjusted to a desired value related to the radius of maximum wind speed empirically. Jiang et al. [68] presented two critical values as boundary limits for application of reanalysis wind data and TC model wind data. Between two critical values, a weight coefficient determined by two critical values was used to combine two wind data. For this method, two critical values are significant factors. However, they are not explicitly given, which need to be appointed empirically. Pan et al. [69] applied a similar method to simulate wind fields of TC Fanapi 2010 and TC Meranti 2010. However, two critical values were not explicitly given either.

ERA-Interim wind data [70] provided by the ECMWF and Holland model wind data are typical representative of reanalysis wind data and TC model wind data, respectively. According to buoy measurement in the South China Sea (SCS) and East China Sea (ECS) during TCs, the present work analyzes wind data of the ERA-Interim and Holland model in detail, and gives two definite critical values for their application ranges and a new method with the capacity to generate accurate wind data between two critical values. After verifying wind data of the new model, the wave modeling is conducted through inputting wind data of the ERA-Interim, Holland model