

China offshore Wind Energy Resources Assessment With the QuikSCAT Satellite Data and Numerical Simulation

Xu Jingwei^{1,2}, Luo yong^{1,2}, Zhang Xiuzhi², Zhu Rong², Xu Min^{1,2}

1 Nanjing University of Information Science & Technology, Nanjing, China.

xujw@cma.gov.cn

2National Climate Center of CMA , Beijing, China. yluo@cma.gov.cn

ABSTRACT: Applying NASA remote sensing data from Quick Scatterometer (QuikSCAT) wind observations with the 12.5km resolution twice a day (1999 – current, 105-135° E, 15-45° N). And with the help of meteorological observation station wind data on an oil platform in west Bohai bay, and another on a small islet in South China Sea, we compare these two sets data and find out the QuikSCAT data is reliable. Then we interpolate QuikSCAT data into 0.1° grid, we calculate and analysis China offshore wind resources effective density of wind energy (EDWE) at 10 meters high above the sea level. And find that EDWE is rich in offshore area. The highest EDWE is in Taiwan Strait and North and South of the strait, with the EDWE 600-800W/m², the next highest is East China Sea and South China Sea. The lowest EDWE is Yellow Sea and Bohai bay, less than 400W/m². At the same time, The PSU/NCAR meso-scale model (known as MM5) is applied to simulate the wind speed in China Sea (12 km resolution) a year. And the wind resources maps at several heights (10m etc) come out. Compared the MM5 and satellite results in China Sea with the historical ships observation data, it is showed that the distribution of wind speed from satellite remote sensing and MM5 results are similar, but needs revised. To sum up numerical simulation and satellite inversion are effective methods for wind resources assessment on the sea.

Keywords:

QuikSCAT, wind energy resources assessment, numerical simulation, data comparison

INTRODUCTION

Because the limit of energy and globe warming effect, people search for the clean and renewable energy. The wind energy seems to be one of answers to this question.

However there are two main problems facing the wind energy resources assessment on the sea: 1) the lack of observation data, 2) obtaining the observation data cost too much. So some people turn to remote sensing for help. It is interesting to find that someone

use the remote sensing data (QuikSCAT) directly without do some work on the data exam and comparison. S. C. Pryor, and Christophe Accadia have done some work on the quantifying uncertainty and comparison with the buoy measurements. In China this kind of work is more needed, for scientists begin applied QuikSCAT data in their research, however not enough work has been down in this area. Only Liu Chunxia do comparison test in the North China Sea, with the 0.5° data (2003) and Fang Xiang has done some compare work with the boat observation use the 25km resolution data (2007). No new data quality research work has been done in China. So the data compare work is quite meaningful for the use of satellite data.

The online of this paper is as follows. Section 1 introduces the applied data and model. Section 2 compares the QuikSCAT data with the observation station data. Section 3 calculates the satellite data in China Sea following some analysis. Section 4 simulates China Sea wind field and does the statistic analysis. A summary is given in Section 5.

1. Applied Data and Model

1.1 Meteorological observation data

To tell the differences from the satellite data with the meteorological observation data, one set of meteorological observation data is applied to compare and understand the quality of the satellite data. And the China Meteorological Administration's observations station data is used. These data are 10minutes mean wind speed on islet. Station ID are 59985(north of south China sea 16.53°N, 111.62°E. the observation sensor installed on 10.4m above the sea level. (2000,

1-2007, 7), and the 54646 (located in west of Bohai bay 38.45°N, 118.42°E. (2000, 1,-2007, 12,) Observation sensor installed 40.3m above the sea level).

1.2 QuikSCAT Data

The QuikSCAT wind data is distributed by the Physical Oceanography Distributed Active Archive Center of the Jet Propulsion Laboratory. In this work we used data with spatial resolution of about 12.5*12.5km (level 2B). According to the sensor specifications, the QuikSCAT winds have an accuracy of 1.01m/s, and 23 deg. in direction when compared with the global buoy [1].

1.3 Numerical Model

The PSU/NCAR mesoscale model (known as MM5) is a limited-area, non-hydrostatic, terrain-following sigma-coordinate model designed to simulate or predict mesoscale atmospheric circulation. And it is one of classic mesoscale model with authentic in the world.

2. Compare the QuikSCAT Data with the Observation Station Data

In order to figure out the QuikSCAT data's accuracy in China off-shore area, we select two meteorological observation station data, one on oil platform in Bohai bay, and the other on a small islet in South China Sea. Then pick out the data at the same hour from station and QuikSCAT. For the wind sensor on different high, we correct the different observation data. After that we get 54646 data at 10 meters above the sea level, which is satellite observation high as the use guide says [2]. We select the time matched data in 5km around the 54646 location, and the best quality, which is on the conditions of no rain and speed between 3~30 m/s. There are

two satellite inversion methods. One is the ambiguity remove (AR) and the other DIRTH Algorithms. The Ambiguity Removal algorithm uses a modified median filter technique to select a unique wind vector out of a set of ambiguous wind vectors at each wind vector cell. Tests of this algorithm with simulated wind data show that it selects the vector closest to the true wind 96% of the time, on average [3]. The other one, The DIRTH Algorithms, two algorithms were developed to address these issues: direction interval retrieval (DIR) to address the nadir performance issue; and threshold nudging (TN) to improve ambiguity removal at far swath [3]. These two data sets are compared with observation data. The wind speed standard deviation, the speed correlation, weibull_K, weibull_C [4],[5],[6] and year mean wind speed are calculated. (See the table below)

Table I: the comparison results 54646 and satellite data of speed standard deviation, speed correlation, mean speed and Weibull_k and C

54646		Speed standard deviation(m/s)	Speed correlation	Mean speed	Weibull _K	Weibull _C
2004	(A. R.)	2.39	0.38	6.93	2.87	7.78
(142	DIRTH	2.41	0.37	6.75	2.91	7.80
samples)	Station			6.87	2.12	7.75
2005	(A. R.)	2.92	0.21	6.66	2.88	7.47
(157	DIRTH	2.93	0.20	6.70	2.94	7.51
samples)	Station			7.39	2.12	8.35
2006	(A. R.)	2.92	0.16	6.93	2.77	7.78
(149	DIRTH	2.89	0.14	6.96	2.83	7.81
samples)	Station			6.51	2.30	7.35
2007	(A. R.)	2.94	0.14	7.31	2.04	8.25
(123	DIRTH	2.95	0.14	7.38	2.22	8.34
samples)	Station			6.54	2.44	7.38

About the 59985 station, for the station's

similar observation high we do not use the high correct method. See the results below, when do the comparison with the satellite data.

Table II: Same as table I for 59985 station.

59985		Speed standard deviation(m/s)	Speed correlation	Mean speed	Weibull _K	Weibull _C
2004	(A. R.)	3.50	0.82	8.51	4.09	9.38
(179	DIRTH	3.47	0.83	8.48	4.32	9.32
samples)	Station			5.04	3.98	5.56
2005	(A. R.)	3.66	0.70	9.48	2.99	10.62
(151	DIRTH	3.64	0.74	9.51	3.00	10.65
samples)	Station			5.95	2.52	6.70
2006	(A. R.)	3.62	0.70	9.13	3.48	10.15
(140	DIRTH	3.42	0.70	8.95	3.61	9.93
samples)	Station			5.64	2.98	6.31
2007	(A. R.)	3.17	0.76	7.97	4.08	8.79
(123	DIRTH	3.13	0.79	7.93	4.34	8.71
samples)	Station			4.85	3.82	5.37

Compare the table I, the speed correlation result passing 0.001 significance test (at $\alpha=0.001$ level) in 2004, and 0.05 significance test (at $\alpha=0.05$ level) in 2005. About the table II, all year's speed passing 0.001 significance test (at $\alpha=0.001$ level). Considered all year data's weibull_k, weibull_c, and speed standard deviation, the A. R. method is a little more reliable in most years, so we chose A. R. method results to do the calculation. And the QuikSCAT data is reliable for the wind energy resources assessment.

3 Wind Energy Resources Assessment Results form Satellite

In this paper, we use 8 years satellite data from 2000 to 2007, in the area (15°N- 45°N, 105°E- 135°E). As the satellite orbits drift, the location of the observation point is not fixed. So 0.1° grid is used to interpolate all

the data into grid, and calculate the daily speed mean. And we calculate all the data by the same way to get the monthly mean of all years. Then the effective wind energy density, the wind energy density when wind speed between 3 m/s and 25 m/s, is calculated in the same way.

China's off-shore wind resources distribution characteristics can be seen from the figures of effective density of wind energy (EDWE) atlas, which mainly used among the wind farm developers.

We select the wind energy density of Jan. Apr. Jul. and Oct. to represent the four seasons to discuss the EDWE's distribution and evolutions through a year.

January is the highest wind speed month (see figure 1.). In Bohai bay the maximum effective wind energy density area is in the northeast of Bohai Sea about 600 w/m^2 , and descends to the west and south. The lowest value center is in the southwest of this area below 300 w/m^2 . In the Yellow Sea, the maximum effective wind energy density of this area is between Shandong peninsula and Korea peninsula. The lowest part in Shandong coast area and north of Jiangsu coast area, less than 400 W/m^2 . In East China Sea, EDWE is high in the south of the area, and increases towards the north, however, decrease to the coastline, where the minimum value is about $300\text{-}400 \text{ w/m}^2$. The high value appears in the north of Taiwan Island and the center and northern Zhejiang's coast area. The highest value of China's off-shore EDWE is in the Taiwan Strait above 1200 W/m^2 . This is mainly due to the Fujian and Taiwan formed a narrow 'tube' that converges airflow. The EDWE gradually reduces towards the south and north. It

reaches $300\text{-}400 \text{ w/m}^2$ in Hainan Island. Hainan Island and the mainland formed another narrow tube, so the EDWE of Beibu Gulf region increases and a high value center appears there. Away from China's coastline there is another high value area of EDWE in Bashi Channel; its centre is located at the southern part of the Bashi Channel. This is mainly the narrow Strait effect of Bashi Channel. Wind speed distribution is roughly the same as the EDWE distribution.

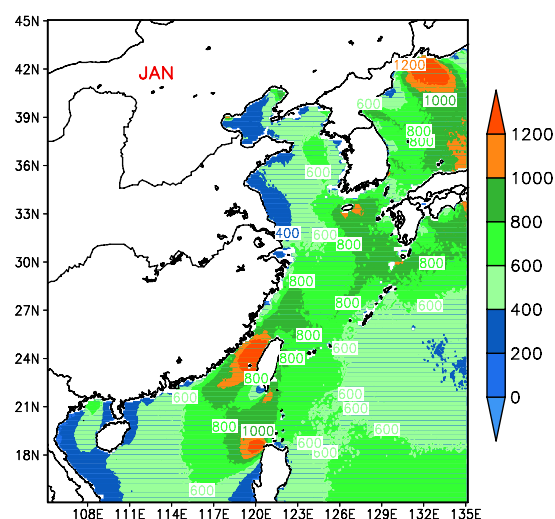


Fig. 1. Mean EDWE of Jan. in 2000-2007

April (see figure 2.) is the transition month from winter to summer, the wind speed of the study area reduces significantly, at the same is the EDWE. In Bohai Sea, Yellow Sea and EDWE dropped to $200\text{-}300 \text{ w/m}^2$. Only northern Bohai Sea has the higher value of Bohai. There are high EDWE between the Shandong peninsula and Korea peninsula, EDWE increases from the southern East China Sea to the Taiwan Strait. The highest regional centre is over 700 W/m^2 in the Taiwan Strait. Then EDWE declines towards west from Taiwan Strait, till the west of Hainan Island and the South China Sea area. A high EDWE center is in Beibu Gulf. The wind speed distribution is similar to EDWE.

However in the south of Jiangsu the EDWE value higher than the observation data, maybe for its rough sand beach magnifies the actual wind speed, where needs further study.

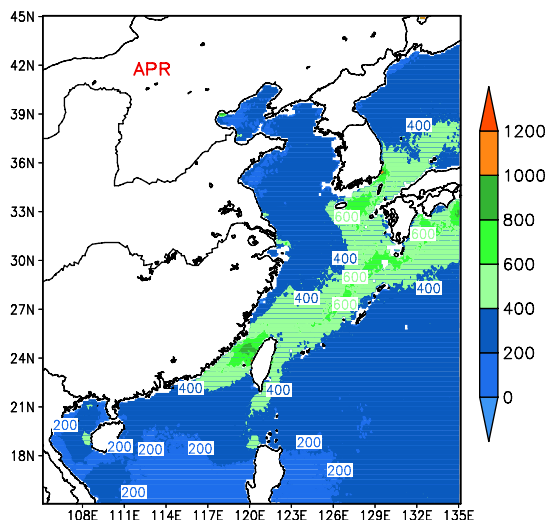


Fig. 2. Mean EDWE of all years' Apr. in 2000-2007

July, the southwest summer monsoon strengthened in this month (see figure 3.). And the large area's EDWE increases. In Bohai sea the EDWE maintains at the same level as April. EDWE increases in Yellow Hai and East China Sea. The Taiwan Strait is still the region's high-value center, but the center moves to the north, on the northwest of the Island. EDWE is relatively high in the north of Taiwan. The South China Sea's EDWE increases higher than it in April. EDWE of Beibu Bay area increases significantly. Another high EDWE value centre appears in the west of Bashi Channel. The wind speed distribution is similar to EDWE.

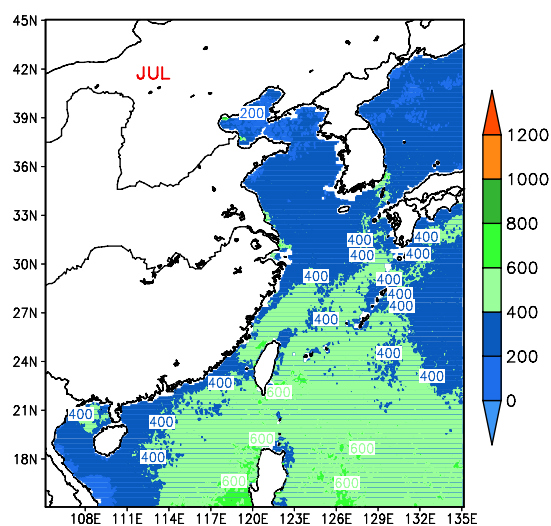


Fig. 3. Mean EDWE of all years' Jul. in 2000-2007

In September and October (see figure 4.), the summer begin to switch to the winter, and wind speed increase in most region. The Bohai Sea region is rich in wind energy, high in the northeast low in the southwest. The northern region is still the high-value center. In the Yellow Sea, EDWE is higher in the north than the central and south. EDWE is lowest in the Jiangsu coastal areas. This mainly due to Shandong peninsula blocks the prevailing wind. EDWE of the East China Sea area have increased significantly. Taiwan Strait is still one of the highest regional centers; the value increased noticeably at this time, and moved to the south inside the Strait. And EDWE decreases towards the west south.. Beibu Bay region have a high EDWE, slightly smaller than in January. Wind speed distribution is the same.

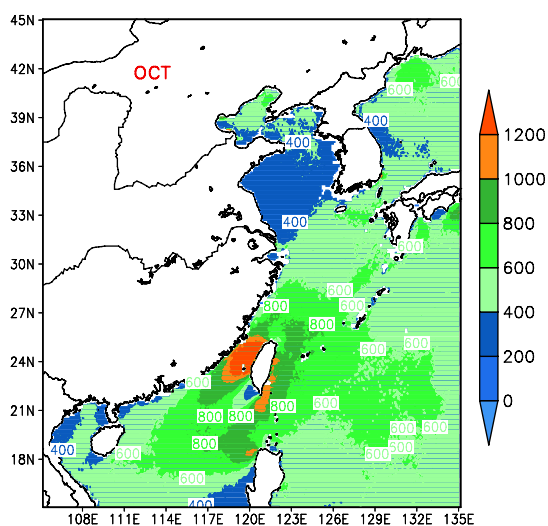


Fig. 4. Mean EDWE of all years Oct. from 2000-2007

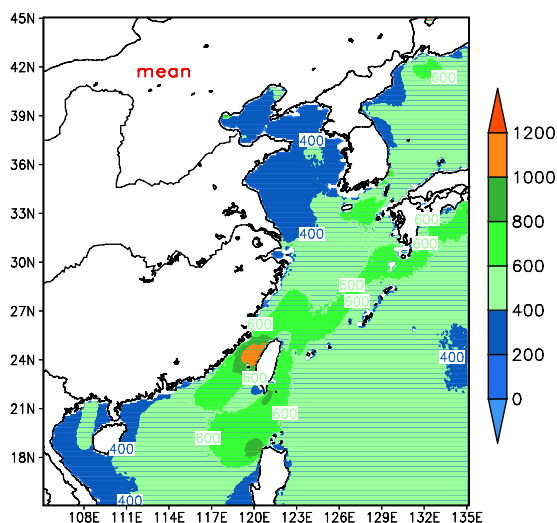


Fig. 5. All years mean EDWE

From the all data mean figure (see figure 5.) we can see two high-value centers, the Taiwan Strait and the Bashi Channel, which are subject to the narrow tube effect and the prevailing wind. EDWE decrease from Taiwan Strait to north and west. And the three smallest centers: 1) south-west of Bohai Bay, 2) the northern part of Jiangsu coast area, 3) the western part of Beibu Bay. EDWE is high in the line of Taiwan and Japan.

4 Wind Energy Sources Assessment Results from Model

In this paper, we applied a mesoscale model to simulate the wind speed at 10m above the sea level. The meteorological observation data from CMA is assimilated into the model every 6 hours. Then the object analysis (OA) is followed to make the model more reliable than without. We use 12km resolution simulating the whole China offshore sea area. For this big area we separate the region into two domains. Then combine the results. The chosen time is from Oct., 2003 to Sep., 2004, when we have the masts mach data on Hailing Island to do the comparison. And we calculate the QuikSCAT data during the same time, to compare these two results.

The results (see figure 6.) we can see that in both model and satellite results the highest value centers are in Taiwan Strait, and Bashi Channel. The trend of Bohai bay, northeast high southwest low; low value on the Jiangsu coast line and south of Shandong peninsula; a high center in the center of Beibu bay, are the same. The back ground field is similar. However the model has a lower value in the north of Taiwan. The values are lower compared with the station observation data especially in the Northeast of Taiwan. Maybe it is for the reason that the model's wind speed during the simulation is lower than the satellite's, so Taiwan Island, the high terrain, has higher effect on the model wind. The trend of the wind energy is the same compared with the satellite wind atlas, boat observation data [7], and WEST simulation [8].

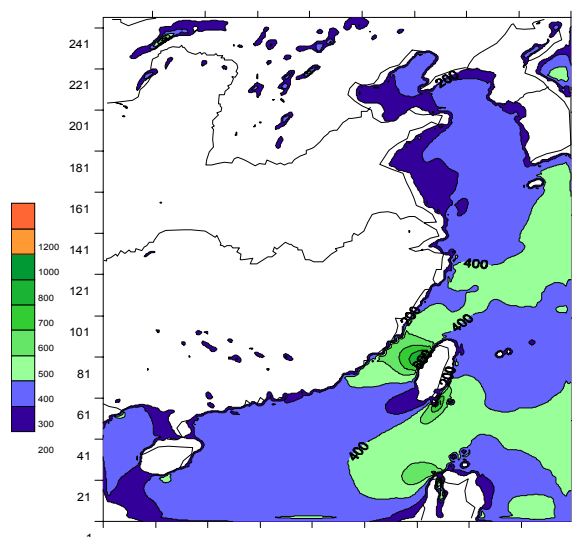


Fig. 6. Mean EDWE of model results from Sep.,2003 to Oct.,2004 (12km) and the 3km simulate area

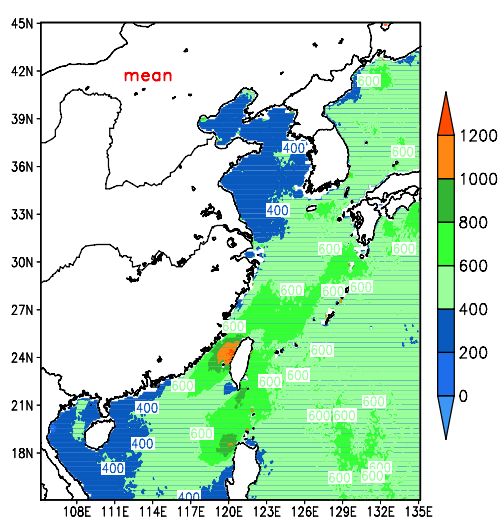


Fig. 7. Satellite mean EDWE on the China Sea from Sep., 2003 to Oct., 2004

5 CONCLUSIONS

1) Through the comparison of satellite with two meteorological observation station wind data. QuikSCAT is reliable in China offshore area.

2) From the results of all year mean effective wind energy density (EDWE), January is the highest EDWE time, the center of the highest area is Taiwan Strait, and the EDWE

decrease towards the south and the north. April is the transition time from winter monsoon to summer monsoon, and the wind speed drops in that time.

3) In July the summer monsoon is established, the high center in the west of Taiwan moves to the north, and the average wind speed of China Sea is the lowest in the whole year. October is another transition period from summer to winter. The whole area's wind speed increases, but not as high as the one in Jan.

4) The highest EDWE is in Taiwan Strait and North and South of the strait, with the EDWE $600-800\text{W/m}^2$, the next highest is East China Sea and South China Sea. The lowest EDWE is Yellow Sea and Bohai bay, less than 400W/m^2 .

5) The mesoscale model simulation results show that the trend of wind energy in China Sea is similar to the satellite data and other observation data. The further work can be done with other resources of data. Compared the MM5 and satellite results in China offshore area, with the historical ships observation data, it is showed that the distribution of wind speed from satellite remote sensing and MM5 results are reliable, but need revised. To sum up, numerical simulation and satellite inversion are effective methods for wind resources assessment on the sea.

ACKNOWLEDGMENTS

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