THE ASSESSMENTS OF WIND CHARACTERISTICS AT THIEN NGA - HAI AU FIELD AREA FOR OIL EXPLOITATION

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Received: 4 August 2023; Accepted: 29 August 2023

Abstract: *The paper aims to identify wind characteristics at the Thien Nga - Hai Au field area using high resolution data generated by the WRF-ARW model. The results indicate that Northeast and Southwest winds are the most frequent, as compared to other directions. The highest wind speed values are observed during the winter monsoon. These findings exhibit reasonable consistency with those of climate survey in the Southern Bien Dong Sea. In addition, the study calculates the return period for extreme wind values, comparing between the cases of monsoon activity and storm activity. The extreme wind speed values are higher in winter (32.0 - 34.0 m/s) compared to summer (29.0 - 30.0 m/s), corresponding to return periods of 50 - 100 years. It is found that highest extreme wind speeds are associated with storm events (40.0 - 46.0 m/s).*

Keywords: *Wind characteristics, Extreme wind, WRF, Thien Nga - Hai Au.*

1. Introduction

The Bien Dong Sea, located in the Western part of the Pacific Ocean, is a large, enclosed and warm sea that belongs to Viet Nam's sovereignty. The Bien Dong Sea is rich in resources, biodiversity, convenient for maritime traffic, along with thousands of coastal islands and two offshore archipelagos that have an important strategic position for Viet Nam. Therefore, research on the climate of the Bien Dong Sea, including research on wind characteristics and regimes, plays a very important role in asserting our country's sovereignty and developing marine economy.

Researches on wind characteristics and wind regimes in Viet Nam have been conducted for a long time through projects, state programs and international cooperation projects (Tran (1990), Nguyen (2003, 2011)). In particular, many researches focus on the wind regime in the Bien Dong Sea area (Le 2002, 2003). Some typical results have pointed out the monsoon regimes, and the changing characteristics of the wind field in the Bien Dong Sea such as Vlasova et al (2010), Le (2003), Nguyen and Bui (2003) and Nguyen (1997). Pham (2013) has gathered wind data at coastal stations and islands near the coast of Viet Nam to find out the statistical characteristics of the wind, coefficient of variation, and wind roses at these stations. In the research "Climate characteristics of the Bien Dong Sea", Mai et al (2014) thoroughly studied the wind regime in the Bien Dong Sea. This study stated that the distribution of average wind speed over the Bien Dong Sea and coastal areas of Viet Nam follows the following basic rules: The wind gets stronger from the coastal area to the sea and from the South to the North. Wind characteristics also change with the time of year with two main wind seasons: The Northeast monsoon in winter and the Southwest monsoon in the summer, which directly affect the distribution of average wind speed over the Bien Dong Sea.

In order to study metocean conditions in service of oil and gas exploration and exploitation in the coastal areas and continental

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shelf of Viet Nam, VIETSOVPETRO signed many scientific research contracts with scientific research centers in order to find out the meteorological, hydrological, hydrographic and environmental characteristics for specific mine areas. These studies focus on meteorology, extreme metocean criteria, fatigue and operational metocean criteria, monsoon timing analysis, etc. In which wind characteristics are studied in detail for non-cyclonic and cyclonic conditions, gusty winds in different periods of 10 min, 1 min and 30 s, wind speed extremes and return periods of 1, 10, 20, 50 and 100 years Center of Technology Application and Training for Hydrometeorology and Environment (2008) calculated marine hydrometeorological conditions of Hai Su mine. Hoang Long Joint Operating Company (2010) calculated wind characteristics for the months of the year for Te Giac Trang Filed Development (Block 16-1: Cuu Long Basin - Viet Nam). Fugro Global Environmental and Ocean Sciences (2010) researched for Block 01/97 and 02/97 Viet Nam (including Thang Long - Dong Do mines). OceanMetriX Ltd (2010) studied the Metocean Criteria and Statistics for the Thien Ung field. The Southern Regional Hydrometeorological Center (2007) studied the metocean and environmental design criteria for the Dai Hung field.

The Thien Nga - Hai Au field area (Figure 1) is located in the Southern Bien Dong Sea, 320 km from the Southeastern coastline of Viet Nam or the Vung Tau Port, which has the potential for oil and gas exploitation. Although there are some studies to evaluate the characteristics of wind fields in the Southern Bien Dong Sea as mentioned above, few specifically calculate for that at the Thien Nga - Hai Au field area. Thus, understandings of wind features and wind-related extreme events (e.g., tropical storms, and the return period of wind extremes) as well are not comprehensive. Besides, the lack of observational data in the Bien Dong Sea can result in limited research results. Thus, it is necessary to have an evaluation for this area.

As far as the station network over the East Sea is relatively coarse, it is not enough for assessing meteorological fields (e.g., wind, humidity). This research, thus, employs the Numerical Weather Model (WRF) to re-generate high-resolution wind field for the Thien Nga - Hai Au field area, and then analyzes the statistical features of wind in this area, in order to find characteristics such as wind roses, joint frequency of wind, extreme wind speeds corresponding to the givenreturn periods over the area.

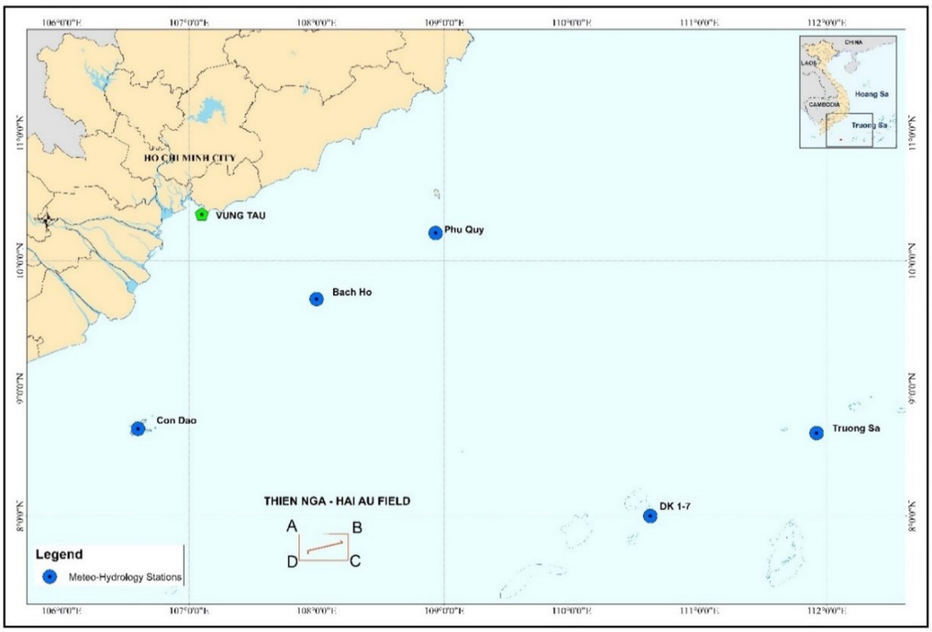

Figure 1. The research area of Thien Nga - Hai Au

2. Data and methodology

2.1. Data

a) Observational data

The wind datasets from some observed stations in the vicinity of the research area (Thien Nga - Hai Au) are used to integrate with simulated data by the numerical model. The lists of observed stations are represented in Table 1.

Table 1. The list of observational stations

TT	Stations	Longitude	Latitude	Period	Observed
1	Con Dao	106.6 E	8.7 N	1978 - 2020	4 obs/day
2	Phu Quy	108.9 E	10.5 N	1980 - 2020	4 obs/day
3	DKI-7	110.6 E	8.0 N	1996 - 2020	4 obs/day
4	Truong Sa	111.9 E	8.6 N	1978 - 2020	4 obs/day
5	Bach Ho	108.0 E	9.7 N	2004 - 2020	24 obs/day

b) Reanalysis data (ERA5)

The data ERA5 is the 5th version of global climate and weather data derived from the European Center for Medium-Term Forecasting (ECMWF). Horizontal resolution of the data is 0.25 x 0.25 degree during 1979 - 2022. Temporal resolution is every one hour. The 4-dimensional variables data assimilation system is applied during the process of building data.

2.2. Methodology

a) Numerical Weather Modelling

The Weather Research and Forecasting Model (WRF) is applied to generate high-resolution meteorological data which provides more detailed information rather than re-analysis data. The WRF has been built and developed by National Center for Atmospheric Research (NCAR; https://www. mmm.ucar. edu/weather-research-and-forecasting-model), which involves full physical processes to well represent the state of a realistic atmosphere. With high-resolution performance, the model allows to simulate local phenomena driven by lots of mesoscale processes, such as, convection, topography, and land-use. This model has been modified to be relevant to weather/climate conditions in Viet Nam and Southeast Asia.

The re-analysis data from ERA5 is used as input for the WRF model to generate high-resolution data (Hersbach et al., 2020, Bell et al., 2021). The simulation domain covering the whole Bien Dong Sea is limited to 5 - 25°N and 100 - 120°E (on the right of the Figure 2). The high-resolution data is downscaled from the horizontal resolution of 27 km x 27 km to the horizontal resolution of 9 km x 9 km, 280 x 280 grid points, 36 vertical levels (Figure 2), and temporal resolution of 1 hour for output. Physic selections are shown in Table 2. For quality verification, the high-resolution data is then compared with the re-analysis source and observed data at the research area.

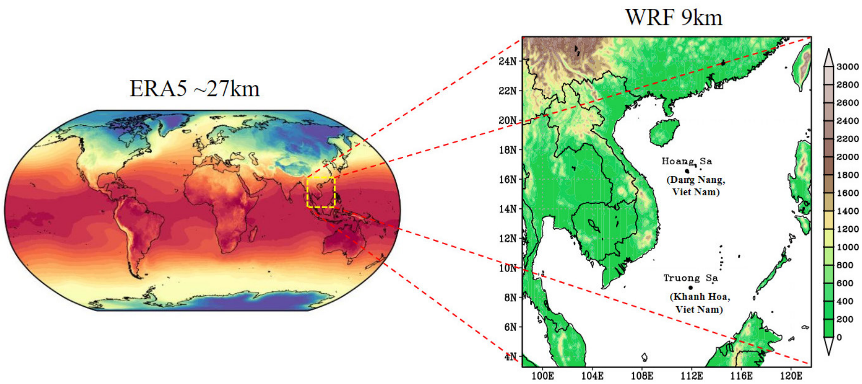

Figure 2. The domain and downscaled description of WRF simulation

Table 2. Physic selections for the model

No.	Type	Selections	Reference
1	Micro-physics	WSM6	Hong and Lim (2006)
2	Short and long wave radiation	RRTMG	Lacono et al. (2008)
3	Land surface	Noah Land Surface Model	Unified NCEP/NCAR
4	Boundary conditions	YSU	Hong et al. (2006)
5	Convection	Betts-Miller-Janjic	Janjic (1994, 2000)

b) Data assessment

To verify the quality of the data, some statistical mathematical indices are applied such as mean absolute error (MAE), mean error (ME), root mean squared error (RMSE), correlation coefficients (CC), Taylor diagram (Taylor, 2005).

c) Vertical Extrapolation of Wind Speed (Wind Profile)

In real measurement, the wind speed tends to increase with height in most locations and depends mainly on atmospheric mixing and terrain roughness. Wind speeds at different heights can be calculated by using a wind profile logarithmic law relationship (Tennekes, 1973, Troen and Peterse, 1998):

$$U(Z_2) = U(Z_1)\left[\frac{\ln\left(\frac{z_2}{z_o}\right)}{\ln\left(\frac{z_1}{z_o}\right)}\right]$$

Where z_2, z_1 are elevations above ground level and U(z) is the wind speed at z_2 and z_1 heights, respectively. z_o is the roughness length (z_o = 0.0002 for the water areas, Dalila et al, 2014).

d) Extreme value analysis method

The generalized extreme value (GEV) distribution is a family of continuous probability distributions developed within extreme value theory. By the extreme value theorem, the GEV distribution is the only possible limit distribution of properly normalized maxima of a sequence of independent and identically distributed random variables (Smith, 1984).

3. Results

3.1. Simulation assessment

The climatology of wind fields in the Bien Dong Sea, compared between the re-analysis and the simulated high-resolution data generated by WRF, is represented in Figure 3 and Figure 4. It can be seen that during the seasons of December-January-February (DJF), the North-Easterly flows are predominant. Meanwhile, during the seasons of June-July-August (JJA), the South-Westerly flows are prevailing in the Bien Dong Sea thoroughly.

The Bien Dong Sea is mainly governed by two alternating monsoon systems: Summer and winter monsoons. During the winter monsoon, the Northeast wind derived from the penetration of cold surge is predominant in most of the Bien Dong Sea, but its control is much stronger in the Northern Bien Dong Sea than in the Southern part. The results obtained from the simulated high-resolution data (Figure 3b and Figure 4b) show that, the wind fields during DJF and JJA in the high-resolution data also reflect winter (North-Easterly flows) and summer (South-Westerly flows) monsoons, respectively.

Table 3 presents the statistical errors of simulated ERA5 and WRF for surface wind speed at five observation stations. It can be observed that the simulated results tend to be higher than the observed data, except for the DK1-7 station, where the observed data is higher (ME index). The evaluation results also indicate that WRF model simulation errors are generally higher than those of ERA5. This is because the resolution domain of WRF is higher, leading to more significant differences in its simulation errors, except for CONDAO. Besides, Table 3 also indicates that the largest error is at CONDAO, with MAE of 4.25 for ERA5. The smallest error is at BACHHO, with MAE of 0.7 for both simulations. There is not a substantial difference between the MAE and RMSE values for the simulations, implying that the errors are stable and systematic. Regarding correlation, the simulations exhibit quite high correlation coefficients, exceeding 0.7. The highest value is observed at the BACHHO station, with a correlation coefficient of 0.97 for both simulations.

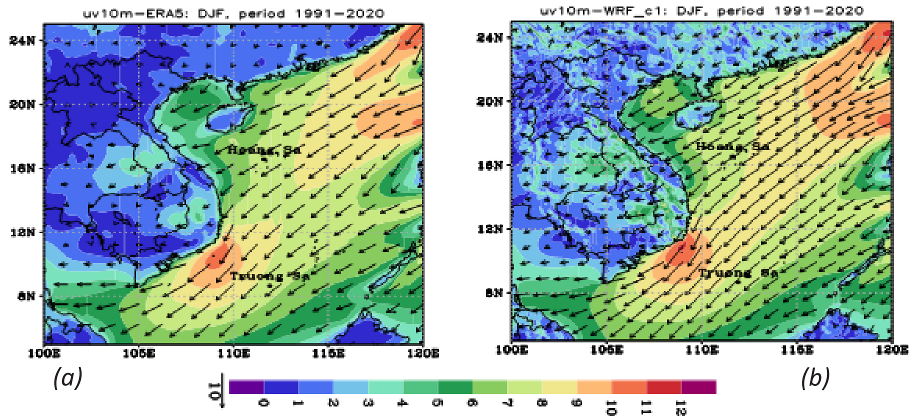

Figure 3. 10 m-height mean wind speeds for the winter: (a) ERA5, (b) WRF simulation

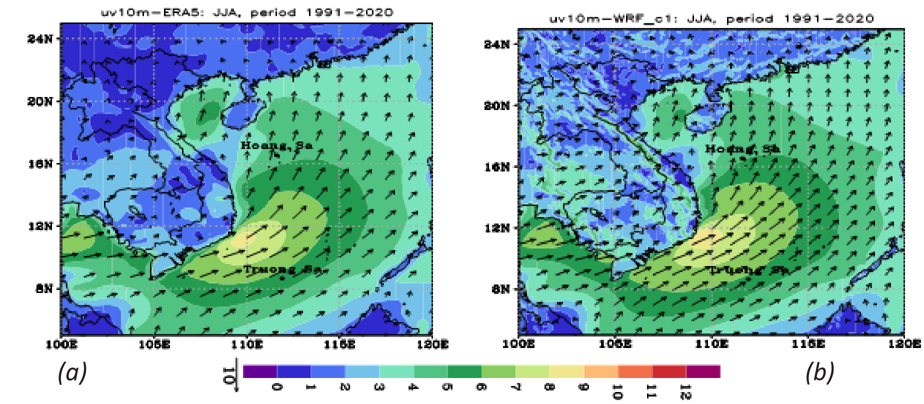

Figure 4. 10 m-height mean wind speeds for the summer: (a) ERA5, (b) WRF simulation

Table 3. Statistical errors of the simulated data compared to observed data

No.	STATION	DATA	ME	MAE	RMSE	CC
1	CONDAO	ERA5	4.25	4.25	4.53	0.86
	CONDAO	WRF	3.08	3.08	3.32	0.86
2	PHUQUY	ERA5	2.72	2.86	3.66	0.71
	PHUQUY	WRF	3.00	3.11	3.97	0.70
3	DK1-7	ERA5	-0.57	1.09	1.38	0.93
	DK1-7	WRF	-0.50	1.09	1.39	0.92
4	TRUONGSA	ERA5	1.08	1.36	1.70	0.89
	TRUONGSA	WRF	1.16	1.43	1.78	0.88
5	BACHHO	ERA5	0.07	0.71	0.94	0.97
	BACHHO	WRF	0.30	0.72	0.95	0.97

The Taylor diagram shows the simulation skills of ERA5 and WRF at selected stations. It is clear that WRF simulation skill is better than ERA5 at CONDAO and BACHHO stations while slightly worse than ERA5 at the remaining stations (Figure 5).

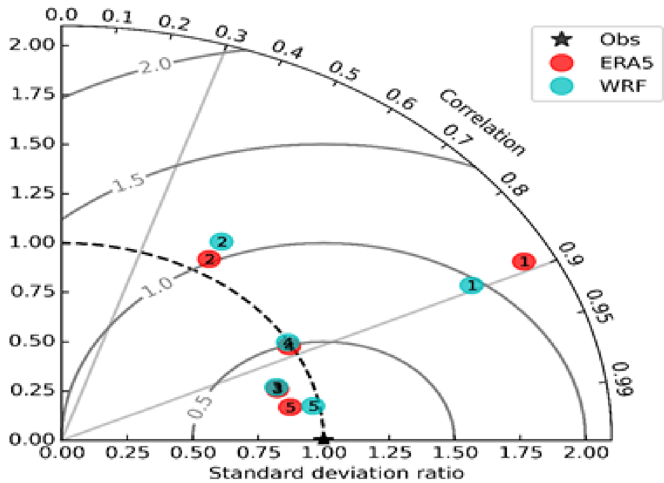

Figure 5. Taylor diagram for two model simulations at chosen stations

3.2. Statistical features of wind at Thien Nga - Hai Au

Figure 6 and Table 4 show the statistical characteristics of wind speed and direction in Thien Nga - Hai Au area. The results show that the Thien Nga - Hai Au area is mainly affected by two wind systems: The winter monsoon with Northeastern direction from October to March and the summer monsoon with the SouthWestern direction from May to September. Specifically, the frequency of occurrence of Northeast and Southwest directions accounts for 38.3% and 26.3%, respectively. The remaining proportion belongs to other directions with the highest values are for the East (11.6%) and West directions (12.1%). Table 5 shows the statistical characteristics (maximum, minimum, mean, standard deviation) for the months of the year. It can be seen that the maximum values of the maximum, standard deviation and mean factors fall in the months of October to March of the following year, corresponding to the active season of the Northeast monsoon. Specifically, the maximum wind speeds in December and January are about 18.0 - 20.0 m/s. While the months in association with the summer monsoon, the maximum wind speeds are only about 13.0 - 15.0 m/s.

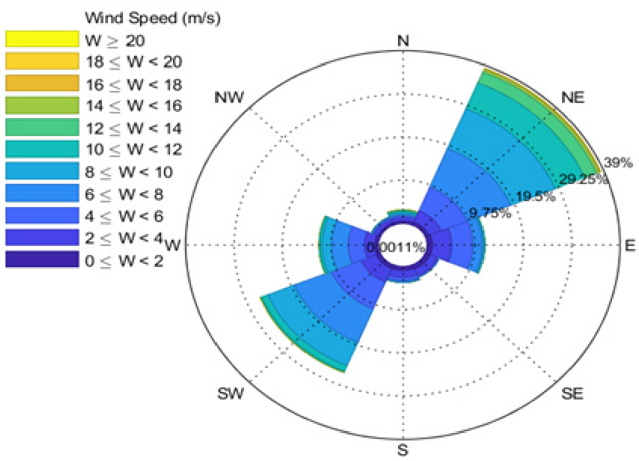

Figure 6. Wind rose at Thien Nga - Hai Au

Table 4. Joint frequency distribution (the counts of occurrence in the sample) of wind speed and direction at the Thien Nga - Hai Au

1 hr Wind Speed at 10 m (m/s)	N	N-E	E	S-E	S	S-W	W	N-W	Total (%)
Total	3.1	38.3	11.6	2.99	3.59	26.3	12.11	1.99	100.0
20									
18	0.02	0.03							0.05
16	0.08	0.5						0.01	0.59
14	0.25	2.55				0.08	0.04	0.01	2.93
12	0.38	6.42	0.02		0.01	1.32	0.51	0.04	8.7
10	0.37	9.92	0.34	0.01	0.07	5.86	1.95	0.07	18.59
8	0.32	9.62	1.89	0.03	0.29	8.18	3.41	0.18	23.92
6	0.4	5.74	4.32	0.31	0.75	6.64	3.35	0.39	21.9
4	0.8	2.76	4	1.66	1.62	3.33	2.14	0.8	17.11
2	0.48	0.76	1.03	0.98	0.85	0.89	0.71	0.49	6.19
0	N	N-E	E	S-E	S	S-W	W	N-W	Total (%)

Table 5. Monthly wind statistics comprising the maximum, mean and minimum value of 01-hour mean wind speed at 10 meters above MSL with associated to prevailing wind directions

	Statistics				Main Direction
	1 hr Wind Speed at 10 m ASL [m s^{-1}]				
	Min	**Mean**	**Max**	**StdDev**	
January	0.13	9.11	18.42	2.59	NE
February	0.11	7.88	16.08	2.90	NE
March	0.15	6.03	16.03	2.66	NE
April	0.11	4.43	12.92	2.12	E
May	0.10	4.23	14.92	2.03	SW
June	0.10	5.53	13.08	2.31	SW
July	0.17	6.42	15.25	2.50	SW
August	0.16	6.87	15.01	2.45	SW
September	0.16	6.09	14.33	2.53	SW
October	0.11	4.89	14.13	2.47	NE
November	0.15	6.82	17.15	2.78	NE
December	0.21	9.19	20.72	2.81	NE
All-Year	0.10	6.45	20.72	2.97	NE

3.3. Extreme value analysis

Tables 6, 7 show the extreme wind speeds corresponding to the given return periods under normal and extreme conditions (e.g., tropical storm). The results show that, with an average wind speed of 3 seconds at 10 m height, the values of extreme wind speed are about 25.0 - 26.0 m/s with a return period of 50 - 100 years, while at 100 m, the extreme wind speeds corresponding to a return period of 50 - 100 years have values of 31.0 - 32.0 m/s. Table 7 compares the extreme wind speeds in the case of monsoon activity and tropical storms. The extreme wind speeds of average wind speeds during 3 seconds with return periods of 50 - 100 years for the Northeast direction are 32.7 - 33.7 m/s, which is higher than the Southwest wind speeds (29.1 - 30.0 m/s). In the case of storm activity, the extreme wind speeds corresponding to the return of 50 - 100 years are about 40.7 - 46.2 m/s.

Table 6. The extreme wind speeds corresponding to the given return periods at Thien Nga - Hai Au

Height Above Sea Level [m]		Extreme Wind Speed [m s^{-1}]			Height Above Sea Level [m]		Extreme Wind Speed [m s^{-1}]		
		1-hr	1-min	3-sec			1-hr	1-min	3-sec
1-year	10	11.3	12.2	14.3	25-year	10	19.3	21.0	24.6
	20	12.0	13.0	15.3		20	20.6	22.3	26.1
	30	12.4	13.5	15.8		30	21.3	23.1	27.0
	40	12.7	13.8	16.2		40	21.8	23.6	27.7
	50	13.0	14.1	16.5		50	22.2	24.1	28.2
	60	13.2	14.3	16.7		60	22.5	24.4	28.6
	70	13.3	14.4	16.9		70	22.8	24.7	29.0
	80	13.5	14.6	17.1		80	23.0	25.0	29.3
	90	13.6	14.7	17.3		90	23.3	25.2	29.5
	100	13.7	14.8	17.4		100	23.4	25.4	29.8
5-year	10	16.5	17.9	21.0	50-year	10	20.2	21.9	25.7
	20	17.6	19.1	22.3		20	21.5	23.3	27.3
	30	18.2	19.7	23.1		30	22.3	24.1	28.3
	40	18.6	20.2	23.7		40	22.8	24.7	29.0
	50	19.0	20.6	24.1		50	23.2	25.2	29.5
	60	19.3	20.9	24.5		60	23.6	25.6	29.9
	70	19.5	21.1	24.8		70	23.9	25.9	30.3
	80	19.7	21.4	25.0		80	24.1	26.1	30.6
	90	19.9	21.6	25.3		90	24.3	26.4	30.9
	100	20.0	21.7	25.5		100	24.5	26.6	31.1
10-year	10	17.9	19.4	22.7	100-year	10	21.0	22.7	26.6
	20	19.0	20.6	24.2		20	22.3	24.2	28.3
	30	19.7	21.4	25.0		30	23.1	25.0	29.3
	40	20.2	21.9	25.6		40	23.7	25.7	30.1
	50	20.6	22.3	26.1		50	24.1	26.1	30.6
	60	20.9	22.6	26.5		60	24.4	26.5	31.0
	70	21.1	22.9	26.8		70	24.7	26.8	31.4
	80	21.3	23.1	27.1		80	25.0	27.1	31.8
	90	21.5	23.3	27.3		90	25.2	27.4	32.0
	100	21.7	23.5	27.6		100	25.4	27.6	32.3

Table 7. The extreme wind speeds corresponding to the given return periods under monsoon and tropical storm cases at Thien Nga - Hai Au

		Summer Monsoon (SW)		**Winter Monsoon (NE)**		**Storm**	
Return period		50	100	50	100	50	100
10 min. mean speed	U10	23.6	24.3	26.5	27.4	33.1	37.5
1 min. mean speed	U1	24.8	25.6	27.9	28.8	34.7	39.5
3 sec. gust	Ug	29.1	30	32.7	33.7	40.7	46.2

4. Conclusions

By using the high-resolution data generated by the WRF digital model, the paper analyzed and evaluated the wind field characteristics of the Thien Nga - Hai Au field and drew the following conclusions:

- Over the Thien Nga - Hai Au area, the Northeast and Southwest winds are the most frequent compared to other directions. The frequency of occurrence of Northeast directions accounts for 38.3% occurring during the winter monsoon season from October to March. Whereas the frequency of occurrence of Southwest directions accounts for 26.3% occurring during the summer monsoon season from May to September.

- The highest wind speeds occur during the winter monsoon period with value of about 18 - 20 m/s in December and January, while the months in association with the summer monsoon, the maximum wind speed is only about 13.0 - 15.0 m/s. The results are relatively consistent with the results of the climate survey in the Southern part of the Bien Dong Sea.

- For wind extreme values corresponding to the given return periods, the study shows that in normal condition the extreme value of wind speed in winter (32.0 - 34.0 m/s) is greater than in summer (29.0 - 30.0 m/s) for the return period of 50 - 100 years. However, the maximum extreme wind speeds belong to the case of storms (40.0 - 46.0 m/s).

The results of the paper make an important contribution to understanding the wind field characteristics of the Thien Nga - Hai Au area and provide useful information for oil exploitation.

Acknowledgments: *This article is extracted and edited from a part of the product of the scientific research contract "Provision of Supply and Proccesing of Metocean and Environmental Data for Thien Nga - Hai Au Field Development Block l2/11, offshore Viet Nam" signed between the Viet Nam Academy of Science and Technology, Vietsovpetro and Viet Nam Institute of Meteorology, Hydrology and Climate Change (IMHEN). Sincere thanks for the support of IMHEN and Vietsovpetro, especially thanks to IMHEN staff: Nam Quang Pham, Tran Duy Thuc, The Thi Doan for running the model and analyzing for the article.*

References

1. Bell, B. et al. (2021), *"The ERA5 global reanalysis: Preliminary extension to 1950", Q. J. R. Meteorol.* Soc. 2021, 147, 4186-4227. [Google Scholar] [CrossRef]
2. Center of Technology Application and Trainning for Hydrometeorology and Environment (2008), *Calculate Marine Hydrometeorological Conditions of HAI SU Mine and Block 15-2/01 for Exploration and Exploitation of Oil and Gas.* Hanoi 2008.
3. Dalila, K. et al (2014) *"Evaluation of the adequacy of the wind speed extrapolation laws for two different roughness meteorological sites", American Journal of Applied Sciences* 11 (4): 570-583, 2014 ISSN: 1546-9239 ©2014 Science Publication doi:10.3844/ajassp.2014.570.583 Published Online 11 (4) 2014 (http://www.thescipub.com/ajas.toc).
4. Fugro Global Environmental and Ocean Sciences, (2010), *Block 01/97 and 02/97 Viet Nam.*

Metocean Criteria Study. Report Number: C50631/5751/R1.
5. Goda, Y., (1992), *"Uncertainty of Design Parameters from Viewpoint of Extreme Statistics", J. Offshore Mech. Arct.* Eng., May 1992, vol. 114, issue 2, pp. 76-82.
6. Hersbach, H. et al (2020), *"The ERA5 global reanalysis", Q. J. R. Meteorol.* Soc. 2020, 146, 1999-2049. [Google Scholar] [CrossRef].
7. Hoang Long Joint Operating Company, (2010), *Metocean Report. Te Giac Trang Filed Development (Block 16-1: Cuulong Basin - Viet Nam).*
8. Le Phuoc Trinh, (2003), *Hydro-meteorological characteristics of the continental shelf of Southeast Viet Nam. Bien Dong Sea, Volume II, Hydro-meteorology of marine dynamics. State-level marine survey and research program KHCN-06 (1996-2000).* Hanoi National University Publishing House, pp. 357-376.
9. Le Van Luu et al. (2002), *"Wind speed profile according to height, in the atmosphere close to the ground, Phuoc Hoa-Binh Dinh area", Journal of Earth Sciences*, 24(2), 233-238.
10. Mai Van Khiem et al (2014), *"Assesements on climate characteristics of the Bien Dong Sea", Sea Magazine Viet Nam*. Pp70-76.
11. Nguyen Manh Hung và Bùi Xuân Thông, (2003), *Basic wind fields in the Bien Dong Sea. Bien Dong Sea, Volume II, Hydro-meteorology of marine dynamics. State-level marine survey and research program KHCN-06 (1996-2000).* Hanoi National University Publishing House, pp. 33- 54.
12. Nguyen Manh Hung, (2011), *Potential of wind and wave energy in Viet Nam and neighboring waters. Collection of major results of the Marine Science and Technology program for sustainable socio-economic development, code: KC.09/06-10. Book III: Marine Technology and Engineering.* Hanoi- 2011, pp. 373-466.
13. OceanMetriX Ltd, (2010), *Metocean Criteria and Statistics, 8 to 9ºN, 107 to 109ºE, Offshore South Viet Nam. V1.0. for the Thien Ung Project Feed Design.*
14. Pham Sy Hoan, (2013), *"Variation of wind field in coastal waters of Viet Nam", Proceedings of the International Conference "Bien Dong Sea 2012"*, Nha Trang, September 12-14, 2012, pp. 45-52.
15. Smith, R.L., (1984), *"Threshold Methods for Sample Extremes. In Statistical Extremes and Applications", Springer: Dordrecht, the Netherlands,* pp. 621-638.
16. Southern Regional Hydrometeorological Center, (2007), *Final Metocean and Environmental Design Crireria For DAIHUNG Field. Prepared for Petrovietnam Exploration and Production Company.*
17. Tran Viet Lien (2007), "*Wind energy potential in Viet Nam", National Conference on Hydrometeorology and Environment,* 2007.
18. Tran Thuc, Hoang Duc Cuong, Mai Van Khiem (2016), *Climate characteristics of the Bien Dong Sea.* Science and Technology Publishing House
19. Tran Viet Lien, (1990), *Zoning of strong wind and stormy winds in the territory of Viet Nam.* State-level Science Program, Code 42A.03.05.
20. Vlasova G.A., et al (2010), *Background data on the South China Sea.* Russia, Vladivostok: POI FEBRUS. 2010. 55p.
21. https://www.mmm.ucar.edu/weather-research-and-forecasting-model.
22. Lacono, M. J., et al (2008), *"Radiative forcing by long-lived greenhouse gases: Calculations with the AER radiative transfer models", Journal of Geophysical Research: Atmospheres*, 113(D13).
23. Hong, S. Y., & Lim, J. O. J. (2006), *"The WRF single-moment 6-class microphysics scheme (WSM6)", Asia-Pacific Journal of Atmospheric Sciences*, 42(2), 129-151.
24. Taylor, K.E., (2005), *Taylor diagram primer.* Work. Pap, pp.1-4.
25. Tennekes, H., (1973), *"The logarithmic wind profile", J. Atmos.* Sci., 30: 234-238. DOI: 10.1175/1520-0469(1973)030 <0234:TLWP>2.0.CO;2.
26. Troen, I. and E.L. Petersen (1998), *European Wind Atlas*. 1st Edn., Risoe National Laboratory, ISBN-10: 8755014828. Danemark, pp: 656.