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Temporal Variability of Atmospheric Elements in Iraq Marine Water, Northwest of Arabian Gulf

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Abstract

An understanding of climate variability in coastal regions is essential for several aspects of maritime activities in such systems. Even though fluctuations in atmospheric parameters have been widely recorded in a number of Arabian Gulf locations, such variations in the Iraq marine waters are not well understood. This study looked at the atmospheric parameters (atmospheric pressure AP, wind field, air temperature AT) measured between 2017 and 2022 off the coast of Iraq's marine water to estimate the temporal variation of these parameters. However, the results revealed that these parameters vary annually and seasonally. The limitations of AP are alternately at their peak and lowest throughout the winter and summer seasons, respectively. The maximum AP recorded during the study period was 1030.80, while the minimum AP was 989.04 mbar. The AT was at its lowest and highest during the winter and summer, respectively. Correspondingly, the winter wind speeds are lower than the summer wind speeds. Higher wind speeds are frequently caused by the shamal (northwest) wind. However, during the study period, the highest recorded wind speed was 19.9 m.sec^{-1}. Correspondingly, AP oscillates more notably in the winter and spring and less notably in the summer and autumn, while AT oscillates more frequently and over a larger frequency range in the autumn and spring and less frequently in the summer and winter, according to our data. These results can be useful for future developments along the entire coastline of the region in terms of coastal constructions and coastal protection strategies.

Keywords: *Atmospheric pressure, wind, Iraq Marine Water, Arabian Gulf*

Introduction

An understanding of climate variability has a high priority for coastal activities, particularly the management of harbors and ports (Almazroui *et al*., 2012; Al Senafi and Anis, 2015; Tonbol *et al*., 2019; ElBess *et al*., 2021). Additionally, the study of climate variability is essential in coastal systems due to their direct impact on the environmental stability of such areas. According to Almazroui *et al*. (2012) and Bawadekji *et al*. (2022), air temperature, atmospheric pressure, and wind field are the three most significant climatic factors that directly affect the different facets of human life. Through the ages, air temperature has appeared to be the major climate factor that affects all aspects of daily life. But even a slight shift in air temperature, especially near the coast, can cause numerous changes to other meteorological and oceanographic variables, such as wind regimes, relative humidity, sea surface temperature, water density, dissolved oxygen, etc. One of the main difficult components of climate change, for instance, is the relationship between changes in relative humidity and increases in surface air temperature. In particular, during heat wave occurrences, this mutual effect can be calamitous and may raise mortality and morbidity rates (Maia-Silva *et al*., 2020). Furthermore, changes in AP have a variety of effects on coastal areas. The sea surface can freely respond to changes in the AP in a given area. The inverse relationship is well-documented since a rise in atmospheric pressure of 1 mb causes a 1 cm drop in the sea surface (Pugh and Woodworth, 2012). Additionally, wind patterns are very important to coastal hydrodynamics. Higher wind speeds, however, will produce larger sea waves, which will generally have an impact on all elements of coastal activity, port operation, and the morphological stability of these locations. Furthermore, wind direction has a direct impact on the sea surface in coastal areas. The sea surface may rise when the flood tide and the wind are in the same direction (Zubier and Eyouni, 2020). Similarly, the port's activities and operations are heavily reliant on the wind regime. This includes the implications on ship arrival and departure safety (Rusu and Guedes Soares, 2013).

Iraq marine water is located in the northwest part of the Arabian Gulf (Mahmood *et al*., 2022; Lafta, 2021a; Lafta, 2022) (Figure 1). The Arabian Gulf is a major waterway for the oil industry and oil

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transportation around the world (Reynolds, 1993). As a result, scientists working in a variety of fields, particularly oceanography, are interested in it (Sadrinasab and Kämpf, 2004; Alothman and Ayhan, 2010; Ranjbar *et al*., 2020; Al-Fartusi *et al*., 2023a; Al-Fartusi *et al*., 2023b, Lafta and Abdullah, 2025). However, studies highlighting the characteristics of atmospheric elements, particularly in the northwestern of the gulf, are limited, due to the scarcity of meteorological records. Al-Senafi and Anis (2015) examined fluctuations in climate over a 40-year period, from 1973 to 2012, in the northern Arabian Gulf. They showed that there was a general trend toward rising temperature (0.8ºC) and falling air pressure (1 mbar) in the area. Additionally, they showed that there is 10 shamal (northwest wind) events per year, with 85% of them occurring in the summer and winter. AlOsairi *et al*. (2020) investigated the characteristics of sea temperature and climate factors (relative humidity, air temperature) from 2016 to 2020. According to them, the maximum air temperature is 45.7 (°C). The long-term (40-year) monthly and seasonal climatology of the Arabian Gulf was examined by Dasari *et al*. (2022), utilizing high-resolution regional reanalysis data created for the area. They suggested that the northwest Arabian Gulf is a temperature hotspot in the area, with extremely high summer and extremely low winter temperatures. They also showed that the winter shamal winds are highest over the central Arabian Gulf, whereas the summer shamal winds peak in the northern parts of the gulf.

There is insufficient information about atmospheric variable swings in Iraq marine water, particularly those based on relatively long-term measurements, and when accessible, it is limited to short periods. Lafta (2021b) showed, using only one-year measurements, that atmospheric pressure and air temperature in Iraq marine water display monthly and seasonal fluctuations. The current study aims to highlight the climate element variations in this key area of the Arabian Gulf in order to address and fill the knowledge gap in this region. To achieve this goal, actual measurements of these variables, which had never been measured in this region before, were used.

Materials and Method

Since it is the country's only outlet to the sea, Iraqi marine water is of particular importance. The area appears to be a natural estuarine environment situated at the northwestern of the gulf (Al-Fartusi and Al-Sayyab, 2021; Lafta, 2023). The tidal range is high in most of the gulf's areas and approaches 1 m. Correspondingly, the tidal currents are high and exceed 0.5 m.sec^{-1} (Najafi, 1997; Lafta, 2023).

According to Zakaria *et al*. (2013), the region has a desert-like climate with two notable seasons: a long, scorching summer that lasts for about 230 days, and a cold, rainy winter. Rainfall occurs during the winter season, but its average is generally low (Reynolds, 1993). The Arabian Gulf has high amounts

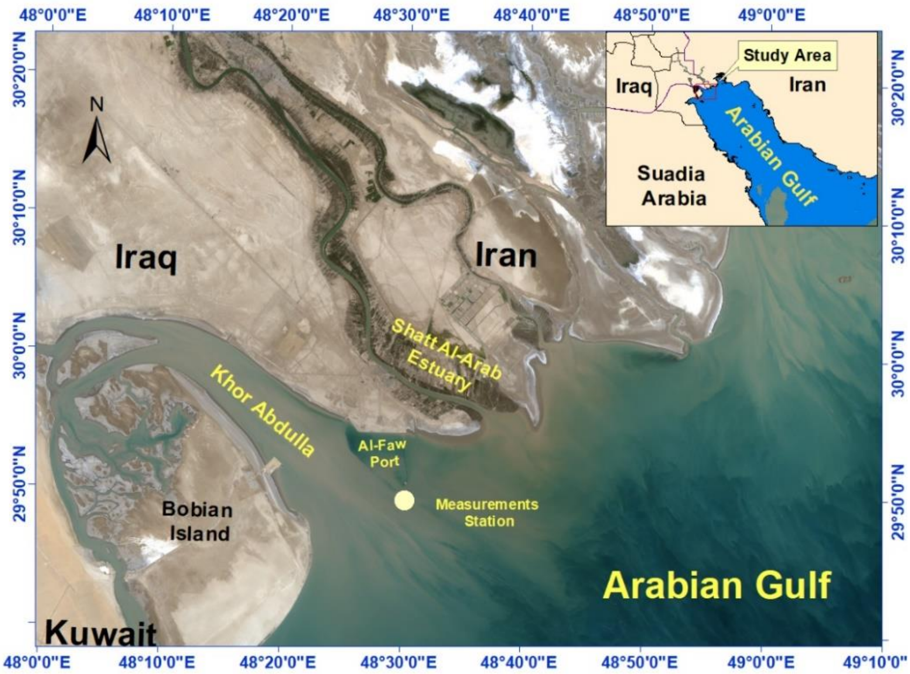

Figure 1. Map of the studied area

of AP during the winter and a low AP during the summer, with the lowest values in July (Sharaf El Din, 1990). The major wind system in the Arabian Gulf is the northwest wind, often known locally as the Shamal wind. Most of the year, this wind blows over the area, with notable seasonal fluctuations. The other most significant wind pattern in the area is the southeast wind, or Kaus wind, with periods ranging from hours to many days (Kamranzad, 2018).

Data sources

Oceanographic and atmospheric measurements in Iraqi maritime water are extremely rare. Fortunately, DAEWOO and the general company of ports of Iraq created an offshore platform roughly 655 meters from the breakwater during the construction of Faw grand port's western breakwater. This platform continuously records several oceanic and meteorological factors. However, this dataset is distinct because no other dataset was ever found in the area before. The fluctuation in atmospheric factors over 6 years was evaluated using these datasets. The Al-Faw port platform provided a continuous record of atmospheric factors (AP, AT, and wind field) for six years (2017-2022). Our analysis is based on the hourly time series of these parameters, the temporal variability was evaluated

Results and Discussion

Atmospheric pressure variability

The time series for atmospheric parameters showed substantial annual and seasonal fluctuations. In the winter and summer, respectively, the annual fluctuation of AP reaches its greatest and lowest limits (Figure 2A). Maximum of AP recorded during the study period was 1030.80 mbar, in the winter of 2020. Correspondingly, the highest AP recorded in 2017 was 1030.21, in 2018 was 1026.98, in 2019 was 1026.81, in 2021 was 1024.80, and in 2022 was 1028 mbar (Table 1). Meanwhile, throughout the study interval, the minimum of Ap was observed in the summer of 2020 at 989.04 mbar. Correspondingly, the lowest AP recorded in 2017 was 992.09, in 2018 was 991.8, in 2019 was 990.99, in 2021 was 990, and in 2022 was 990.13 mbar (Table 1). The annual averages of Ap indicated that the year 2017 exhibited the maximum average of AP during the study period at 1009.79 mbar. Correspondingly, the average of AP in 2018 was 1007.87, in 2019 was 1007.4, in 2020 was 1008.05, in 2021 was 1007.31, and in 2022 was 1008.39 mbar.

The AP seasonal changes begin to rise in early autumn and subsequently begin to fall in early spring. Based on the standard deviation, the AP time series revealed a significant increase in the oscillation range in the winter and spring and less in the summer and fall seasons (Table 2). The seasonal averages of AP reach their maximum value during winter and are then reduced to their minimum during summer at 998.88 mbar. The recorded data of AP display that during the autumn season, the AP average has a high value and is close to its range during the winter season (Table 1). However, it is well recognized that AP increases when AT decreases and vice versa. Consequently, the increment in the AP average during the autumn season could be attributed to the great decline in air temperature in this season, in particular in December (Lafta, 2021b).

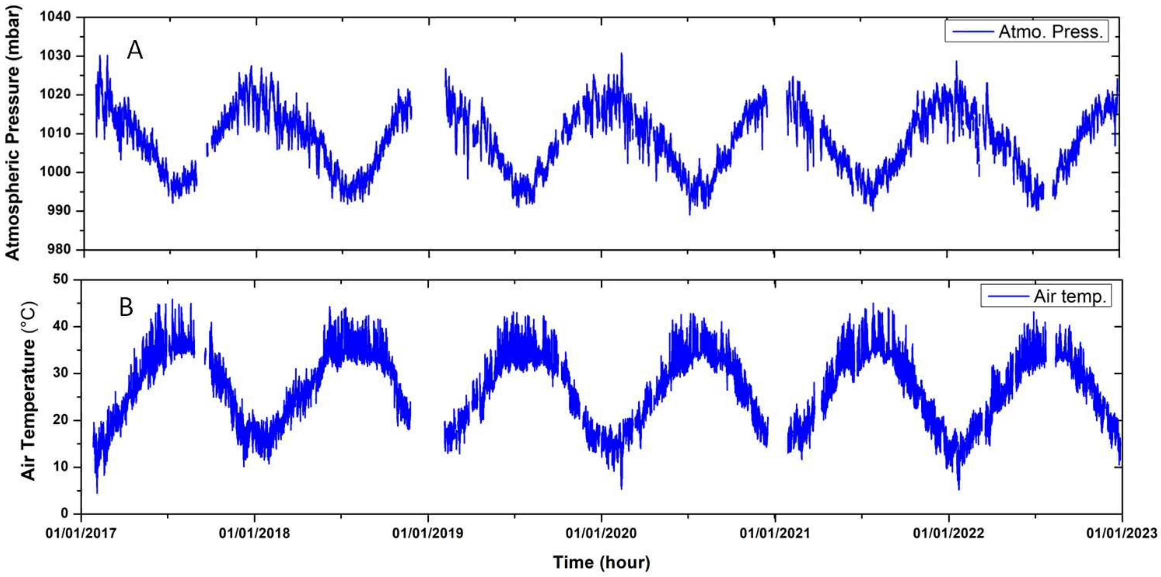

Figure 2. Time series of (A: Atmospheric pressure, B: Air Tempertuare) in Iraq marine water during 2017 to 2022).

Table 1. Seasonal statistical analysis for atmospheric parameters at Iraq marine water

Parameters	Statics	Season			
		Winter	Spring	Summer	Autumn
Atmospheric pressure (mbar)	Max	1030.80	1019.37	1011.27	1027.530
	Min	997.48	991.05	989.04	1001.730
	Mean	1015.67	1005.00	998.88	1014.468
	Stdv	4.63	4.99	3.97	4.165
Air Temperature (°C)	Max	31.029	44.85	45.87	40.925
	Min	4.489	19.06	24.86	9.660
	Mean	17.640	30.00	34.74	23.634
	Stdv	3.341	4.58	2.54	5.407
Wind speed (m.sec^{-1})	Max	19.327	19.04	17.74	19.930
	Min	0.100	0.19	0.21	0.100
	Mean	4.88	4.68	5.18	4.45
	Stdv	2.671	2.62	2.29	2.460

Table 2: Annual statistical analysis for residual water level and atmospheric parameters.

Year	Air Temperature (°C)			Atmospheric Pressure (mbar)			Wind Speed (m.sec^{-1})		
	Max	Min	Ave.	Max	Min	Ave.	Max	Min	Ave.
2017	45.86	4.49	26.64	1030.21	992.09	1009.79	19.03	0.16	5.09
2018	44.28	10.73	28.06	1026.98	991.80	1007.87	19.93	0.15	5.12
2019	43.16	12.85	27.55	1026.81	990.99	1007.40	19.33	0.19	4.96
2020	42.78	5.32	26.38	1030.80	989.04	1008.05	17.10	0.2	5.17
2021	45.01	9.66	27.26	1024.80	990	1007.31	16.50	0.1	5.34
2022	43.15	5.16	25.58	1028.73	990.13	1008.39	15.9	0.1	5.02

Air temperature variability

Unlike AP, AT reaches its highest and lowest limits in the summer and winter seasons, respectively (Figure 2B). During the study interval, a highest AT recorded was 45.87°C in the summer of 2017. Meanwhile, the highest AT recorded in 2018 was 44.28, in 2019 was 43.16, in 2020 was 45.011, and in 2022 was 43.15°C (Table 1). Correspondingly, the minimum value of the recorded AT was observed in the winter of 2017 at 4.49 C. However, the lowest AT recorded in 2018 was 10.73, in 2019 was 12.85, in 2020 was 5.32, in 2021 was 9.66, and in 2022 was 5.16°C (Table 1). The annual averages of AT indicated that the year 2018 exhibited the maximum average of AT during the study period at 28.06°C. Correspondingly, the average of AT in 2017 was 26.64°C, in 2019 was 27.55, in 2020 was 26.38, in 2021 was 27.26, and in 2022 was 25.58°C (Table 1).

The AT seasonal fluctuation begins to increase in early spring and starts drop during early Autumn season. The seasonal averages of AT reach their maximum value during the summer season at 34.74°C and then are reduced to their lowest range during winter at 17.64°C. Correspondingly, for the transition period from winter to summer, i.e., during the spring season, the average AT reaches 30°C; for the transition period from summer to winter, i.e., during the fall season, the average AT is 23.63°C.

Wind variability

Various wind patterns blow from various directions across the northwestern portion of the Arabian Gulf. The observed wind speed in the studied area between 2017 and 2022 is shown in Figure (3A). The wind pattern exhibits monthly and seasonal fluctuation. The highest velocity of the wind observed throughout 2017-2022 was 19.93 m.sec^{-1} from the northwest on October 22, 2018. Similarly, 19.03 m/sec was the highest speed in 2017, 19.33 m.sec^{-1} in 2019, 17.1 m.sec^{-1} in 2020, 16.5 in 2021, and 15.9 m.sec^{-1} in 2022. All of these winds were coming from the northwest, which means that shamal winds (winter and summer shamal) are usually to blame for the Arabian Gulf's northwest region's highest wind speeds. This result coincides with the results of Aboobacker *et al*. (2021). The study area's monthly average wind speed shown in Figure (3B). This graph indicates that wind speed increases in January, March, and April and falls in May. However, the average wind speed then peaks in June and July, declines again in September, and finally reaches its lowest point in October. However, our investigation found that the maximum monthly average wind speed, which exceeded 5 $m.sec^{-1}$, was recorded during the summer season (Table 1). This result aligns with the investigation conducted by Kamranzad (2018) and Al Senafi and Anis (2015), who showed that the northern Arabian Gulf experiences greater average wind speeds throughout the summer months.

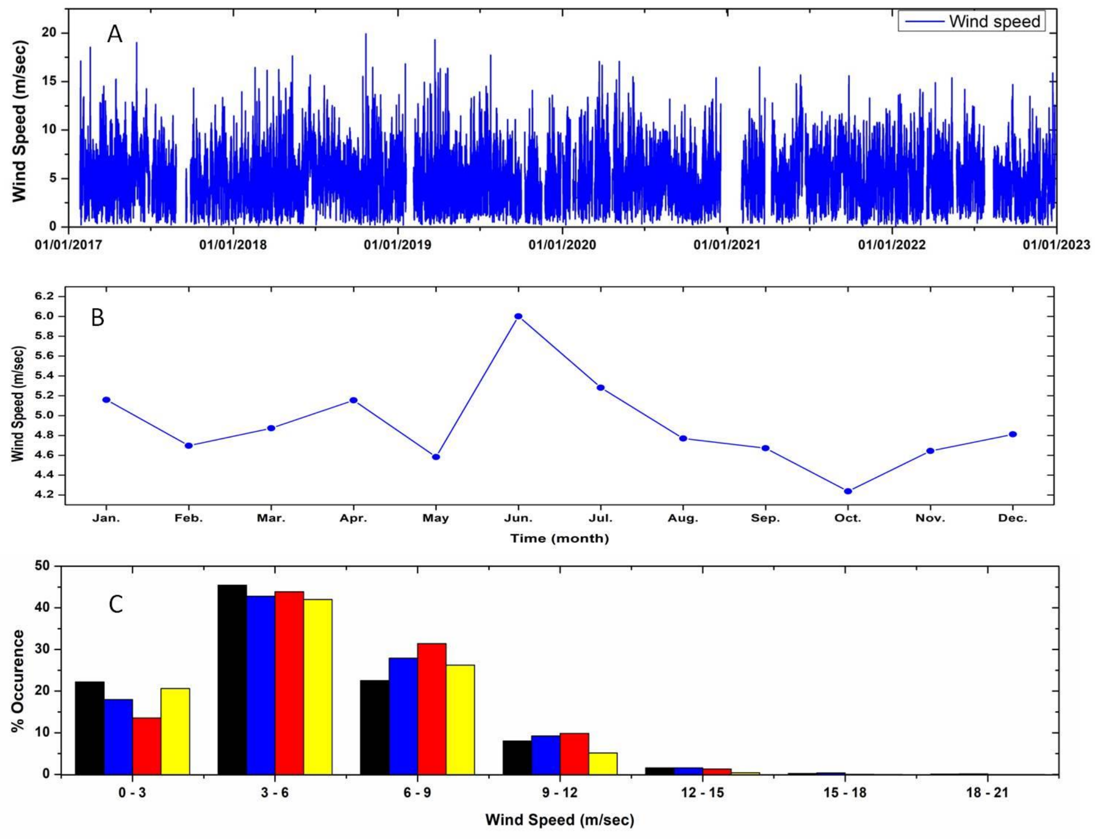

Figure 3. Hourly wind speed (A), monthly average wind speed (B), and percentage of occurrence of several wind speed (C) in Iraq marine water during 2017–2022.

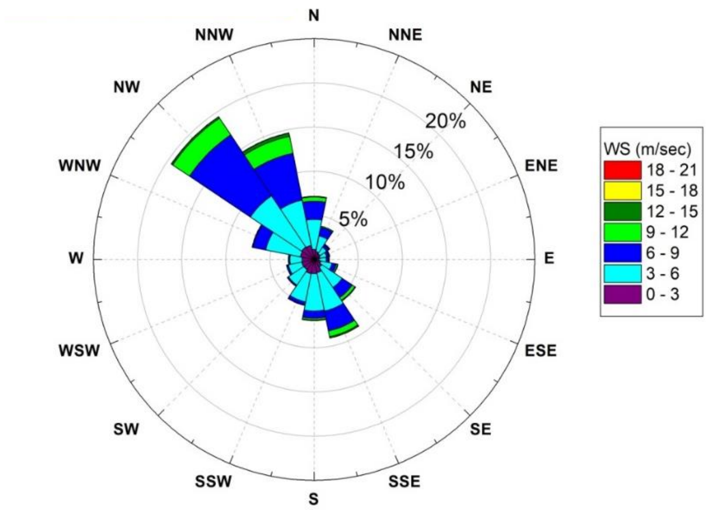

Figure 4. Wind rose diagrams in Iraq marine water during 2017–2022.

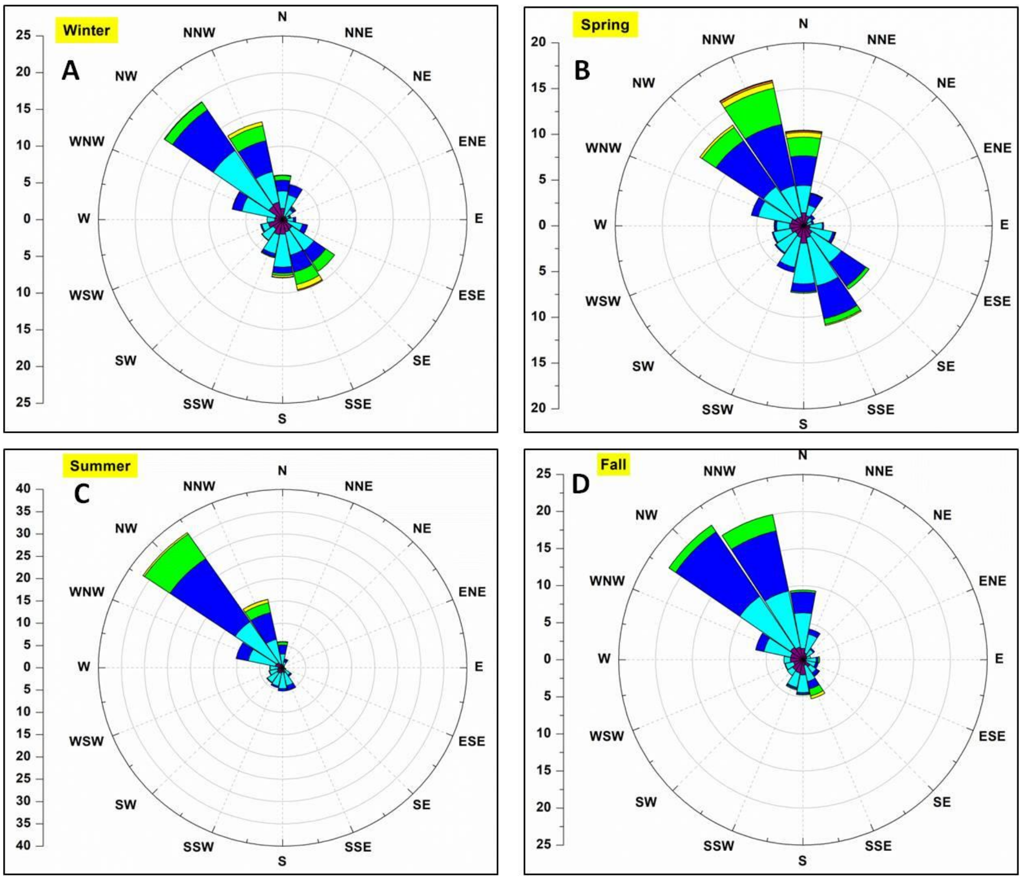

Figure 5. Wind rose (seasonal averages) during 2017–2021 (A: winter, B: spring, C: Summer, D: fall).

The area's largest frequency of wind is from the northwest, with 19.4% from NW, 14.6% from NNW, and 7.1% from WNW. With a proportion of 17.5% of the total wind, the southeast wind regime was the next most significant wind regime. While the least amount of wind (1.7%), came from the east. The findings indicated that the northwest wind contributes roughly 60% of the local wind regime during the summer, followed by 48%, 40%, and 35% during the fall, winter, and spring seasons (Figure 5). With relative contributions of 23% in the spring and 21% in the winter, respectively, the southeast wind was most frequent throughout those seasons. With a contribution of no more than 8%, the summer has the lowest frequency of this wind.

The percentage that consists of occurrence for different wind speed ranges is shown in Figure (3 C). The largest proportion of incidence in the seasons was 3-6 m/sec, with the most occurrence high at 45% through the winter, a result that Kamranzad (2018) also noticed. The second key wind speed range is 6-9 $m.sec^{-1}$, with a 31% occurrence rate throughout the summer season. Meanwhile, high winds had the lowest frequency of occurrence. High wind speeds (greater than 15 m/sec) are most common during the winter and spring seasons, with an insignificant occurrence throughout the summer and autumn months.

Conclusions

The temporal fluctuation of some atmospheric variables in Iraq marine water is explored using in situ data for six years (2017-2022). All of these factors show annual and seasonal fluctuations, according to the findings. AP reaches its peak and lowest levels through the winter and summer seasons, respectively. The maximum observed AP hits 1030.80 mbar in the winter of 2020 but drops to 1024.80 mbar in the winter of 2021. The lowest observed AP was in the summer of 2020 at 989.04 mbar. In contrast, AT reaches the highest and lowest values during the summer and winter seasons, respectively. The highest AT observed during 2017-2022 was $45.87^{o}C$ in the summer of 2017, while the lowest AT was $4.49^{o}C$ in the winter of 2017. Moreover, our investigation showed that summer and winter shamal winds are mostly responsible for all of the peak wind speed estimates. Winds of less than 6 $m.sec^{-1}$ appear to be the most common during the study period.

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