



General characteristics of surface waves in Iraq marine water, Northwest of Arabian Gulf

Ali Abdulridha Lafta¹ · Adel Jassim Al-Fartusi¹

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Abstract

Understanding wave characteristics is crucial for coastal activities, coastal infrastructure, navigation safety, and coastline management policies. Although wave characteristics in several regions of the Arabian Gulf are relatively studied, until now, wave features in Iraq marine water are not well recognized. In this study, we analyzed the wave parameters measured off Iraq marine water, northwest coast of the Arabian Gulf during 2017–2021 to identify the features associated with different wind systems. However, the results indicated that the averages of wind speed are higher in summer than in winter. The peak wind speeds are generally due to the northwest wind, and the maximum wind speed recorded during the study period reaches 19.9 m/s. Additionally, the results revealed that wave heights in summer are generally lower than that in winter. The highest significant and maximum wave heights during the study period reach 0.78 and 1.95 m, respectively. The highest wave heights were recorded during the southeast wind, although its speed is generally lower than the northwest wind. This mainly could be attributed to a large fetch available for the southeast wind relative to a limited fetch available to the northwest wind. Waves with long periods were mainly recognized during winter, spring, and fall seasons. The maximum significant wave period and zero-crossing wave period reach 6.84 and 5.4 s, respectively. The results obtained could be beneficial for overall coastal and near shore activities in the region.

Keywords Wave statistics · Significant wave height · Zero-crossing wave period · Fetch limit · Arabian Gulf

Introduction

The sea state is mainly described following the dominant climatic conditions, in particular, the wind regimes, which play the main role in determining the sea state variability (Amrutha et al. 2015; Ostad-Ali-Askari et al. 2020). Surface waves are the direct result of the wind field over the sea surface, and their characteristics will be determined according to the nature of the dominant wind regime in these regions. The knowledge of wave characteristics has a high priority for several aspects of marine and coastal engineering due to their direct effect on navigation activities, coastal constructions, and coastal region stability (Vu et al. 2014; Han et al. 2019; Pao et al. 2021; Abdollahi et al. 2021).

Surface waves are very complex, as they consist of several components of varying height, amplitude, direction, and periodicity (Patra et al. 2016). In general, the ocean waves consist of locally generated waves (wind sea) and remotely generated waves (swell) (Aboobacker et al. 2009). The contribution of these two waves systems in the wave spectra depends particularly on the wind regime and the dimensions of the water basin. However, in the wind-dominated sea, the wave energy is concentrated at the high frequencies of the spectra. Meanwhile, in the swell-dominated seas, wave energy generally shifts towards the low frequencies of the wave spectra (Sorensen, 2006). Correspondingly, the wind sea is characterized by short wave periods in comparison with relatively long swell wave periods (Patra et al. 2016). Wave characteristics derived from a fixed location are generally utilized for representing the wave statics at that area. Meanwhile, temporal and spatial wave characteristics are described following the numerical model results as well as satellite observations (Kamranzad et al. 2018; Aboobacker et al. 2021). However, the most important wave parameters to be considered in all the coastal engineering operations in

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✉ Ali Abdulridha Lafta
ali.lafta@uobasrah.edu.iq

¹ Marine Science Center, University of Basrah, Basra, Iraq

both normal and severe sea states are the significant wave height and wave period. Additionally, for fixed offshore constructions, wave direction could be another parameter that must be taken into consideration (Vanem and Walker, 2013). The significant wave height represents the average height of the highest 1/3 (one-third) of waves in the wave measurements (Zounemat-Kermani and Kisi 2015). There are several techniques utilized for measuring these parameters, which are different in their measuring methods and principles. The most widely used are the directional buoys, non-directional buoys, and ADCP wave instruments (Kumar et al. 2010). Furthermore, recently, remote sensing devices and ultrasonic radars are widely utilized in conducting such marine measurements (Kumar et al. 2013; Christensen et al. 2013; Løken et al. 2021; Pirnazar et al. 2018).

Iraq marine water is located on the northwest tip of the Arabian Gulf. However, the wave patterns in the Arabian Gulf are affected by wind systems over the area. The wind regime of the region is characterized by two distinct wind climates: northwest wind and southeast wind (Reynolds 1993; Lafta 2021). The wave studies based on the real wave measurements in the Arabian Gulf are very limited, and when available, then they are limited to a fixed area or to a short period of recording (Hamza et al. 2018). Parvaresh et al. (2005) studied the wind-wave parameters in the Bush-eir, located north of the Arabian Gulf. They demonstrated that the significant wave height ranged between 0.10 and 1.02 m. Mazaheri and Ghaderi (2011) studied the spectral characteristics of sea waves in the northern Arabian Gulf. They compared the measured spectrum of the Arabian Gulf with Bretschneider, Scott, and JONSWAP spectra and illustrated that none of these spectra can adequately describe the waves of the Arabian Gulf. The maximum value of the significant wave height of 2 m was observed in front of Saadiyat beach, Abu Dhabi, southwest of the Arabian Gulf, as indicated by Hamza et al. (2018). Li et al. (2020) examined the physical response to winter shamal winds in Kuwait water located in the northwest Arabian Gulf. They mentioned that the surface wave heights and periods will increase from 0.58 to 0.82 m and from 3.6 to 4.2 s, respectively, during winter shamal events. Aboobacker et al. (2021) investigated the wave characteristics in Fuwairit, on the north coast of Qatar, on the southern coast of the Arabian Gulf. They demonstrated that the significant wave height was higher in winter than in summer, and the annual mean and maximum significant wave heights reach 0.46 m and 2.3 m, respectively. Meanwhile, despite the highest importance of Iraq marine water for the country, wave studies in this region are very scarce. To the best of the authors' knowledge, until now, wave studies in this area are not available. Consequently, and to fill this gap, the present study aims to highlight the general characteristics of surface waves in this important region of the Arabian Gulf. For fulfilling this objective, the

realistic measurements of waves that were not measured ever previously in this region were used. This investigation will be beneficial in understanding the wind and wave behavior in this region which could be used for many applied purposes such as coastal infrastructure, navigation safety, port construction, and coastal protection strategies.

Materials and methods

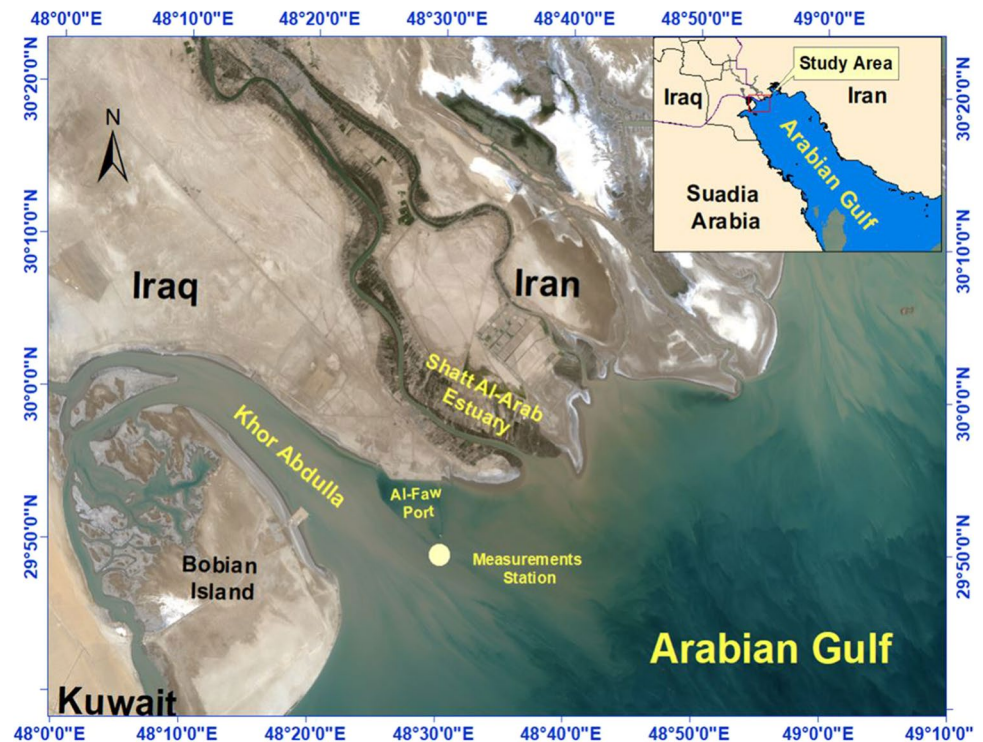
Study area

The location of Iraq marine water in the northwest tip of the Arabian Gulf has a special and major role nationally and internationally. The continuous developments in this region including the construction of a mega-port, known as Faw Grand port, are expected to change the transportation map of the world by linking eastern Asia with Europe. Additionally, the Iraq marine water is known as the way of oil transportation and oil industries for mega oil fields in southern Iraq, as well as their economic importance for the country through the shipping processes by several commercial ports.

The Iraq marine water represents the most estuarine area of the northwest of the Arabian Gulf (Lafta et al. 2020). Figure 1 displays the location of the study area and shows the wind and wave measurement site. The hydrodynamics regime of Iraq marine water is governed by tides and the dominant climatic conditions. The tidal regime of the Arabian Gulf is complex and varies spatially between diurnal, semidiurnal, and mixed. The tidal range is large and reaches 1 m in most locations in the gulf. The key tidal constituents in the area are the semidiurnal M_2 and S_2 and diurnal K_1 and O_1 (Lafta et al. 2019). There are two amphidromic points for the semidiurnal constituents and one amphidromic point for the diurnal constituents (Reynolds, 1993). However, the tidal regime in Iraq marine water displays a mixed, predominantly semidiurnal tide, and the tidal range exceeded the 4 m in the spring tidal phase (Lafta et al. 2019). The tidal currents are generally strong and exceed 1 m/s (Al-Mahdi et al. 2009; Lafta et al. 2020). The northern part of the Arabian Gulf is a generally shallow area, and the depths ranged between 10 and 20 m. The climate of the area is extremely hot summer, relatively cold winter, low precipitation, high level of evaporation, and shamal winds, enhancing occasionally the dust storms (Aboobacker et al. 2021). The climate in the Arabian Gulf can be divided into two main seasons with two transition periods: summer season (June–September), fall transition (October–November), winter season (December–March), and spring transition (April–May) (Al Senafi and Anis, 2015).

The wind regime of the Arabian Gulf is characterized by two wind systems. The northwest wind (shamal wind) is known as a predominant wind regime in the region

Fig. 1 Location map of study area showing the measurement location



throughout the seasons. The second wind regime is the southeast wind that prevails occasionally, particularly in winter (Thoppil and Hogan 2010; Lafta 2021). The northern part of the Arabian Gulf experiences higher wind speeds during shamal events, particularly in summer, and the mean wind speed reaches 5 m/s (Liao and Kaihatu 2016). The summer shamal wind is caused by a steep pressure gradient over the gulf formed between the low-pressure region in northwest India and the high-pressure region in the eastern Mediterranean. Meanwhile, the winter shamal wind in the Arabian Gulf is influenced by cold air carried into the region by the Siberian high-pressure system, and it is associated with mid-latitude disturbances moving from west to east (Al Senafi and Anis 2015). The waves in the Arabian Gulf are following the prevailing wind regimes in the region (Kamranzad et al. 2013). However, due to the semi-enclosed configuration of the gulf, as well as the narrowness of the Gulf entrance, the waves within the Arabian Gulf are predominantly considered a wind sea (Aboobacker et al. 2021).

Data sources

Wave measurements in Iraq marine water are very scarce, and when they exist, then they will be limited for short periods. Fortunately, during the construction of the western breakwater of Faw grand port, the general company of Iraq ports and DAEWOO engineering and construction company built an offshore measurement platform at a distance of about 655 m from that breakwater. Several

oceanographic and meteorological elements are recorded continuously by this platform. This data is managed under the responsibility of the General Acoustics company, Germany (<https://www.generalacoustics.com/>). However, this dataset is unique since, to the best of our knowledge, no other dataset in the region has been found previously. From this dataset, the variability in wave parameters over 5 years was estimated.

The wave measurements were conducted through the use of an ultrasonic sensor installed over the offshore platform at 4.961 m relative to the mean sea level, the reference datum in this area. The wind measurements were carried out by the weather station that was installed over the offshore platform. The wind speed and direction were measured at 10 m relative to the mean sea level. The continuous data records of the waves and wind speed and direction for the 5 years (2017 to 2021) were acquired by the general company of Iraq ports. The interval of measurements was 10 min. The hourly data were obtained by averaging the original 10-min data records. The water depth in the location of wave measurements reaches 10 m. The wave parameters were obtained by applying the zero-crossing analysis for the sea surface elevation data. The wave parameters include significant wave height $H_{1/3}$, maximum wave height H_{max} , significant wave period $T_{1/3}$, and zero-crossing wave period T_z . However, H_{max} represents the highest wave height in the wave records, $T_{1/3}$ denotes the average period corresponding to the highest one-third of wave records, and T_z is the mean period of wave records (Young 1999).

Results and discussion

Wind regimes

Several wind regimes blow over the northwest of the Arabian Gulf and from various directions. Figure 2A illustrates the hourly wind speed during the study period. The wind regime displays monthly and seasonal variability. The maximum wind speed recorded during the study period reached 19.9 m/s on 22 Oct. 2018 from the northwest direction. However, the maximum wind speed in 2017 was 19.03 m/s, in 2019 was 19.32 m/s, in 2020 was 17.1 m/s, and in 2021 was 16.4 m/s. All these winds were from the northwest direction; that is, the maximum wind speed in the northwest of the Arabian Gulf is commonly due to the winter and summer shamal. This finding is consistent with the results of Aboobacker et al. (2021), who indicated that the highest wind speed in the Arabian Gulf region is predominantly associated with summer and winter shamal events. Figure 2B illustrates the monthly averages of wind speed in the study area. According to this figure, the average wind speed increases in January, March, and April and decreases

in May. Then, the average wind speed reaches the highest value during June–July, then decrease again in September to reach the lowest value during October.

This pattern in the monthly average wind speed distribution is mainly associated with the activity of summer and winter shamal wind in the northwest of the Arabian Gulf. However, our analysis revealed that the highest monthly average wind speed was recorded during the summer season which exceeded 5 m/s (Table 1). This finding is in line with the results of both Kamranzad (2018) and Al Senafi and Anis (2015), who indicated that the average wind speed is

Table 1 Seasonal averages of wind speed and corresponding wave parameters during 2017–2021

Season	Wind speed (m/s)	$H_{1/3}$ (m)	H_{max} (m)	$T_{1/3}$ (s)	T_z (s)
Winter	4.97	0.152	0.452	2.816	2.236
Spring	4.99	0.125	0.382	2.563	2.035
Summer	5.37	0.122	0.374	2.422	1.948
Fall	4.47	0.132	0.395	2.642	2.099

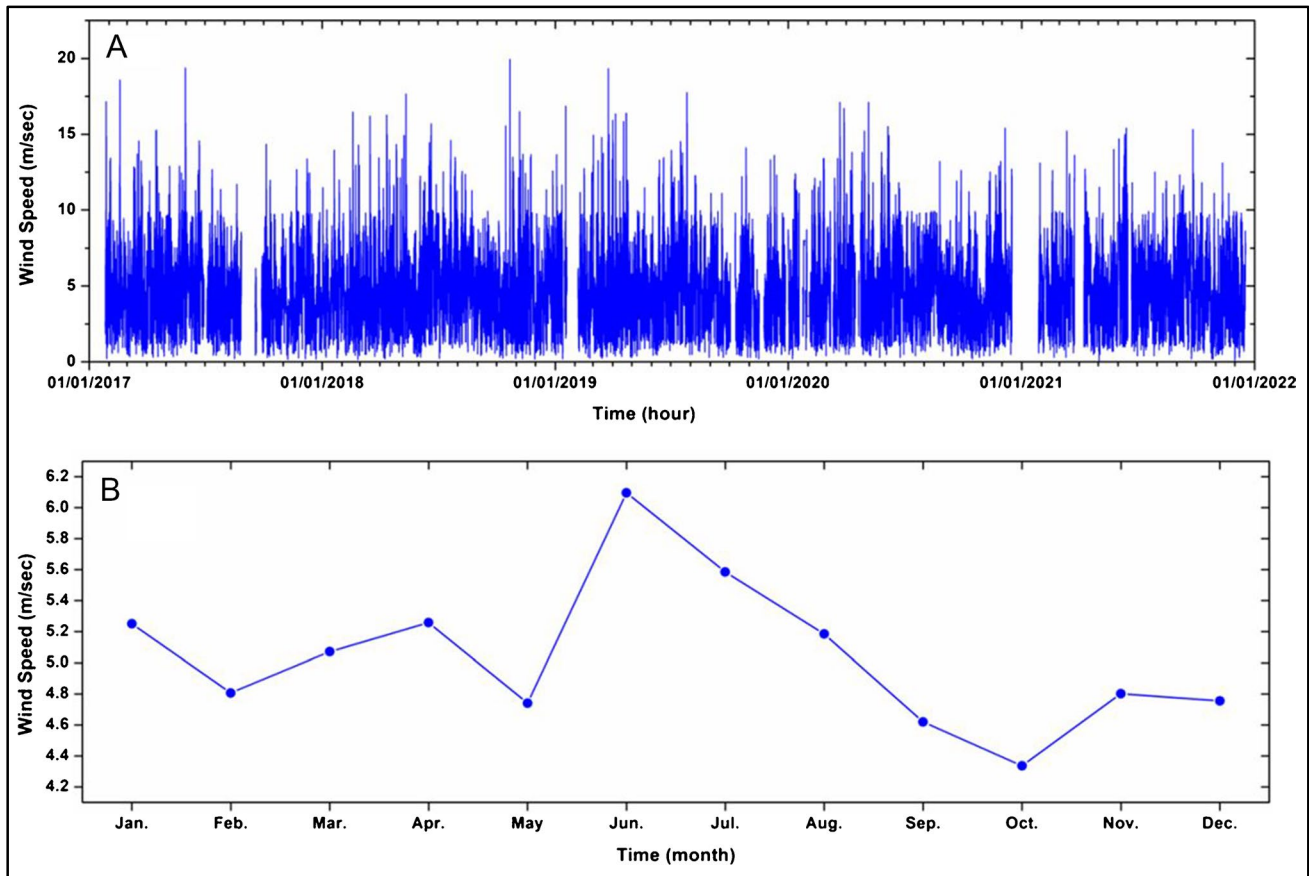


Fig. 2 Time series of wind speed (A) and monthly averages of wind speed (B)

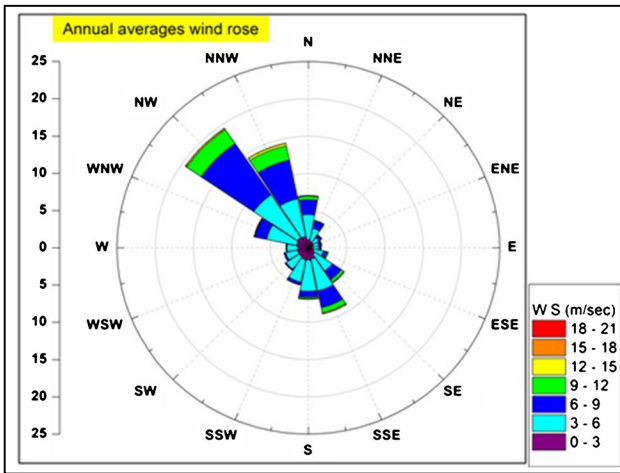


Fig. 3 Wind rose diagrams in Iraq marine water during 2017–2021

higher during the summer season in the northwestern part of the Arabian Gulf.

The percentage occurrence of winds in the area is predominately due to the northwest wind (NW/NNW/ WNW), followed by the southeast wind (SSE/SE/ESE) (Fig. 3). The highest wind is from NW (19.4%), NNW (14.3%), and WWN (7.2%). The percentage occurrence of southeast wind was the second most crucial wind regime during the study period and contributed by about 17.5%, while the lowest wind was from the east direction (1.7%). In the seasonal cycle, the results indicated that the northwest wind is higher during summer and reaches about 60% of the wind regime in the area, followed by 48%, 40%, and 35% during fall, winter, and spring seasons, respectively (Fig. 4). The highest occurrences of the southeast wind were recorded during spring and winter, with the relative contributions of 23% and 21%, respectively, while the lowest occurrence of this wind is during the summer season with a contribution not exceeding 8%.

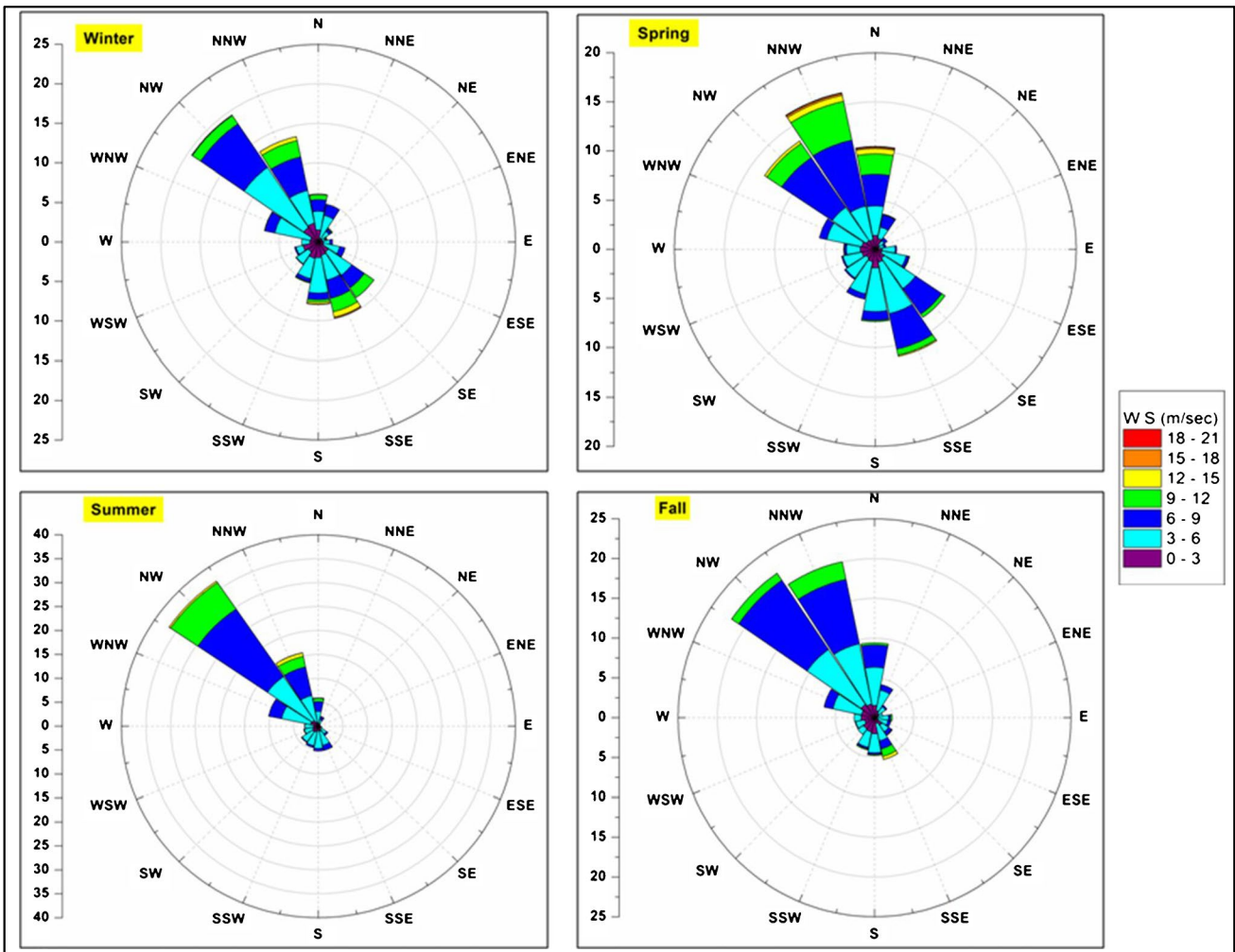


Fig. 4 Seasonal averages of wind rose diagrams in Iraq marine water during 2017–2021 (A winter, B spring, C summer, and D fall)

Wave characteristics

Generally, and based on the dominant wind regime in the Arabian Gulf, wave patterns are mainly associated with these wind conditions, that is, northwest as well as southeast winds, and somewhat with other winds that blow from various directions. The time series of the significant wave height ($H_{1/3}$) measurements indicated that this parameter displays monthly and seasonal variability. The time series of wave parameters indicated that there are several peaks with $H_{1/3}$ higher than 0.6 m (Fig. 5A). Our analysis illustrated that all of these peaks are associated with the southeast wind.

The highest $H_{1/3}$ recorded during the study period was 0.78 m on 26 March 2019. Correspondingly, the highest $H_{1/3}$ observed during 2017 was 0.76 m, in 2018 was 0.72, in 2020 was 0.71, and in 2021 was 0.71 m. When comparing the highest $H_{1/3}$ with the wind condition at that time, it appears that all these peak values of $H_{1/3}$ are associated with the southeast wind. The maximum southeast wind speed corresponding to the highest recorded $H_{1/3}$, that is, 0.78 m, does not exceed 12 m/s. Meanwhile, the maximum wind speed during the study period was observed on 16 October 2018 at 19.9 m/s, from the northwest direction with the corresponding $H_{1/3}$ recorded being 0.37 m. However, our results

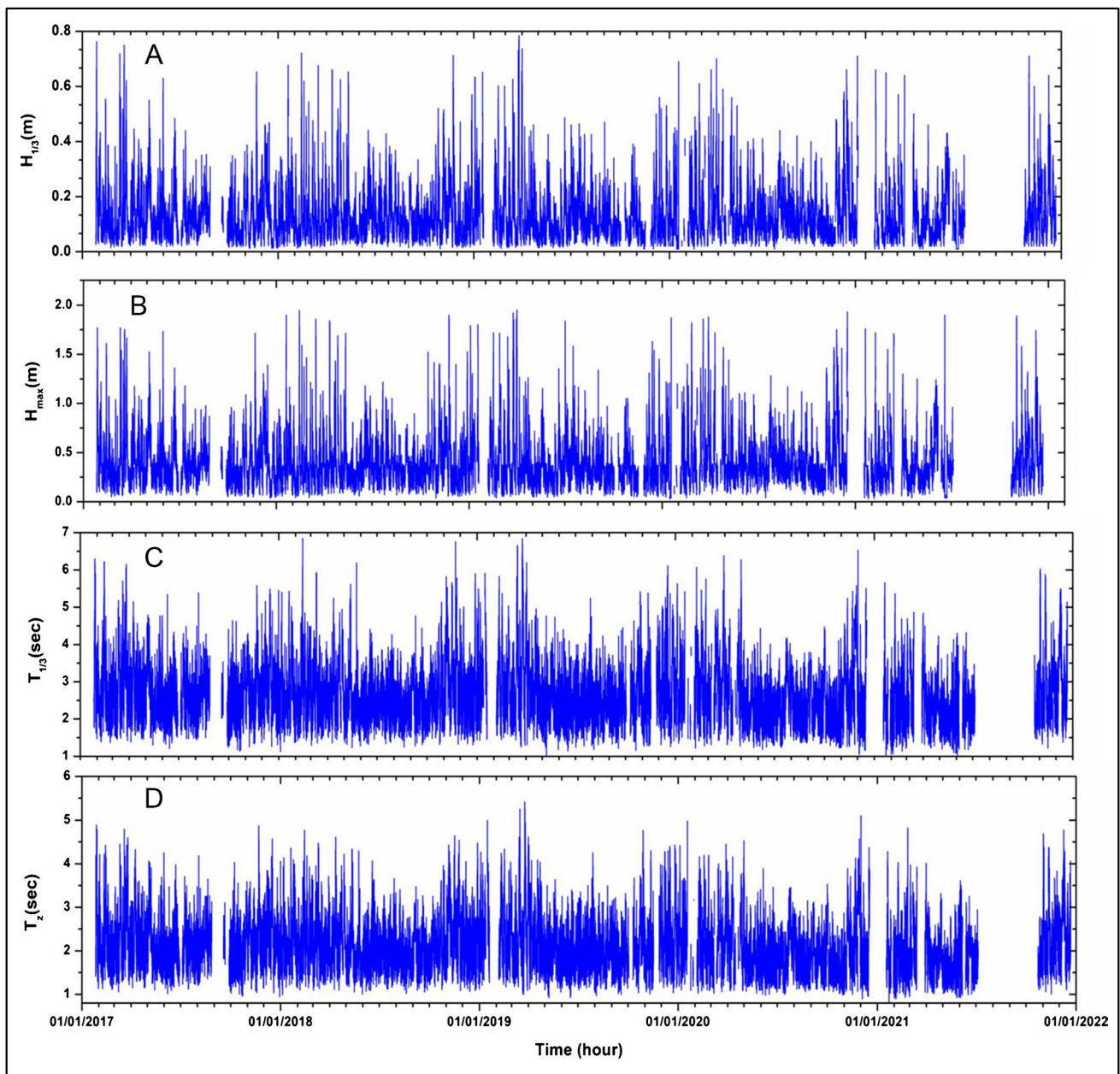


Fig. 5 Time series of wave parameters during 2017–2021 ($H_{1/3}$ (A); H_{max} (B); $T_{1/3}$ (C); T_z (D))

indicate that all the observed high $H_{1/3}$ that are greater than 0.4 m are mainly due to the southeast wind. This behavior could be mainly attributed to a large fetch available for the southeast wind relative to a limited fetch available to the northwest wind, considering the orientation of the coast of the northwest tip of the Arabian Gulf (Fig. 1).

The seasonal averages of $H_{1/3}$ indicated that wave heights are higher in winter and decrease in spring and fall to reach the lowest values in summer (Table 1). This finding is in agreement with the results of Aboobacker et al. (2021), who indicated that wave heights in winter are generally higher than in summer in the central Arabian Gulf. Figure 6A illustrates the monthly averages of $H_{1/3}$. This figure shows that the averages of $H_{1/3}$ are higher in the winter months (January, February, March, and April). Next, they experience a pronounced decrease in May. After this, there is a little increase during the summer months (June, July, and August). Then, $H_{1/3}$ starts to decrease again in late summer, that is, during September, and reaches the lowest values in the early fall season, that is, in October. This monthly distribution of averages of $H_{1/3}$ is generally associated with the

dominant wind regime in the area. For instance, the little increase in $H_{1/3}$ during the summer months is mainly attributed to the existence of stronger summer-time Shamal wind.

The highest H_{max} recorded during the study period was 1.95 m on 13 February 2018. Correspondingly, the highest H_{max} observed in 2017 was 1.77 m, in 2018 was 1.83, in 2020 was 1.93, and in 2021 was 1.9 m (Fig. 5B). The time series of H_{max} indicated that there are several peaks higher than 1.5 m (Fig. 5B). Our analysis revealed that all peak values of H_{max} exceeding 1.5 m generally coincide with the southeast wind in the northwestern Arabian Gulf.

The seasonal averages of H_{max} display the same behavior as the seasonal averages of $H_{1/3}$. They are higher in winter and decrease in spring and fall to reach the lowest values in summer (Table 1). Figure 6A illustrates the monthly averages of H_{max} . It is obvious from this figure that the averages of H_{max} are higher in the winter months (January, February, and March). Then, they experience a pronounced decrease in the summer months, particularly during early and late summer, that is, May and September, respectively. The little

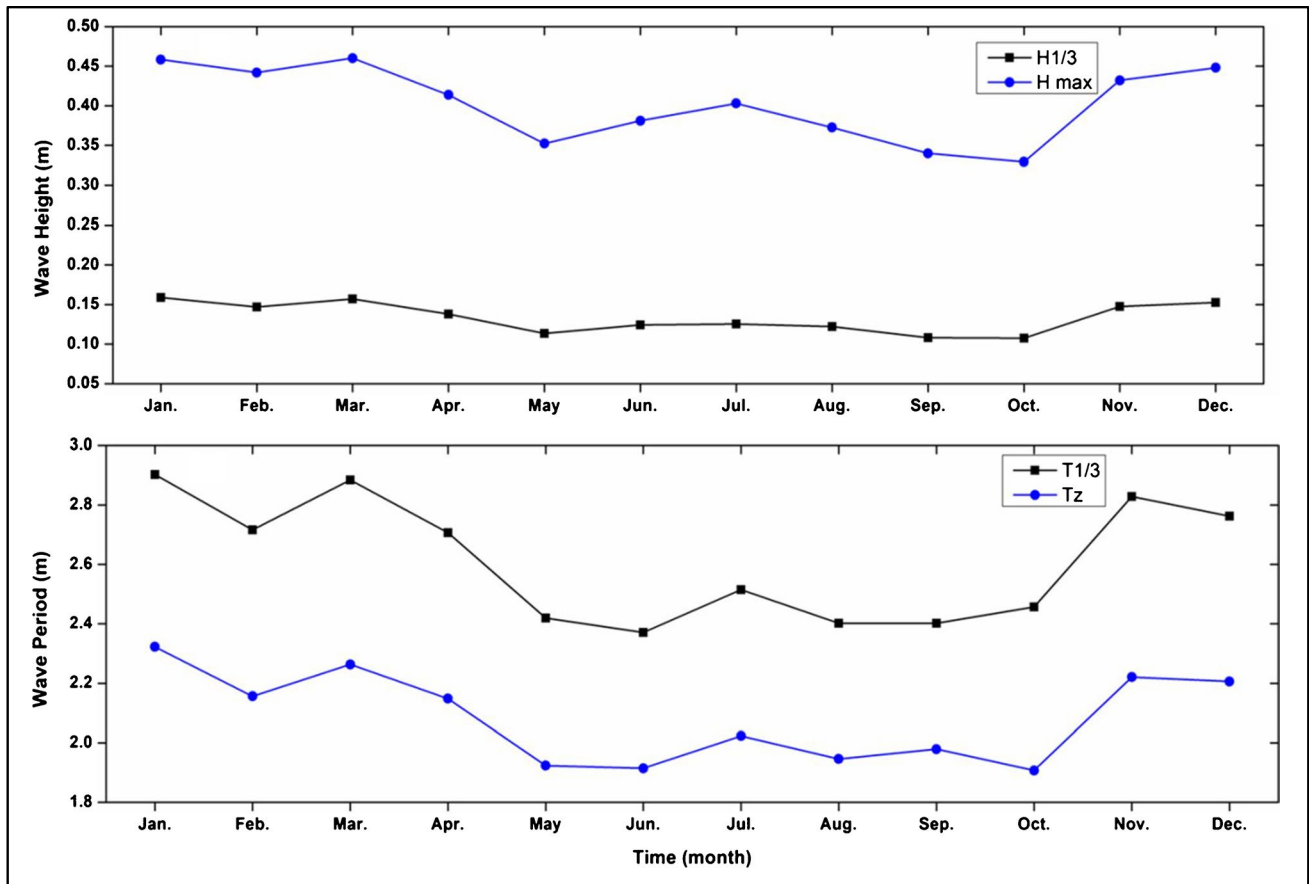


Fig. 6 Monthly averages of wave heights (A) and wave periods (B)

increase in H_{\max} averages during June, July, and August is mainly associated with the activity of stronger summer-time shamal wind.

The time series of $T_{1/3}$ indicated that waves with a long period are generally observed during the winter and fall seasons (Fig. 5C). The maximum $T_{1/3}$ observed during the study period was 6.84 s on 14 February 2018. Correspondingly, the maximum $T_{1/3}$ observed during 2017 was 6.29 s, in 2019 was 6.83 s, in 2020 was 6.53, and in 2021 was 6.01 s. The seasonal averages of $T_{1/3}$ seem to be higher during the winter season and decrease in fall and spring to reach their lowest during summer (Table 1). Meanwhile, the highest monthly averages of $T_{1/3}$ in Iraq marine water occur during January at 2.9 s, and the lowest occur during June at 2.37 s (Fig. 6B). This finding agrees with the observed high monthly averages of $H_{1/3}$ that occur also in January. However, the prevailing wind regime during the winter season is mainly responsible for generating waves with higher $H_{1/3}$ as well as $T_{1/3}$ in this region of the Arabian Gulf. Similarly, the time series of T_z illustrated that waves with a long period are generally observed during the winter and fall seasons (Fig. 5D). The maximum T_z observed during the study period was 5.4 s on 25 March 2019. Correspondingly, the maximum T_z observed during 2017 was 4.88 s, in 2018 was 4.77 s, in 2020 was 5.1 s, and in 2021 was 4.82 s. The seasonal averages of T_z display the same variation pattern as $T_{1/3}$. They seem to be higher during the winter season and decrease in fall and spring to reach their lowest during summer (Table 1). The monthly averages of T_z during the study period are generally like the behavior of $T_{1/3}$. The highest monthly averages of T_z occur during January at 2.32 s, while the lowest appear during October at 1.9 s (Fig. 6B).

Percentage of occurrence of wind and wave for different intervals

The percentage of occurrence of several ranges of wind speeds is shown in Fig. 7A. As shown in this figure, the highest percentage of occurrence in all seasons belonged to 3–6 m/s with the maximum occurrence exceeding 45% during the winter season; the same result was observed by Kamranzad (2018). The second important wind belongs to the range of 6–9 m/s with the percentage of occurrence reaching 31% during the summer season. Meanwhile, the lowest frequency of occurrence belongs to high winds. The highest frequency of high wind speed (greater than 15 m/s) can be seen during winter and spring with negligible occurrence during the summer and fall seasons.

The frequency of occurrence of the several ranges of $H_{1/3}$ is shown in Fig. 7B. It is obvious from the figure that during the winter season, 41% of the waves are less than 0.11 m, 25% are in the range of 0.11–0.2 m, and the remaining waves are more than 0.2 m. In the spring season, about 49% of the

waves range between 0.05 and 0.1 m, 30% range between 0.11 and 0.2 m, and the remaining waves are more than 0.2 m. During the summer season, the wave ranges seem to be reduced, and $H_{1/3}$ ranges between 0.01 and 0.5 m. Forty-one percent of the waves are in the range of 0.05–0.1 m, 37% are in the range of 0.11–0.2 m, 9% are in the range of 0.21–0.3 m, and the remaining waves exceed 0.3 m. During the fall season, the wave ranges return to be expanded. The wave range of 0.05–0.1 m has the dominant frequency of occurrence by 48%, the range of 0.11–0.2 m by 26%, and the range of 0.21–0.3 m by 10%, and the remaining waves are more than 0.3 m. Correspondingly, the distribution of the percentage of occurrence of H_{\max} during the winter season revealed that 29% of waves are less than 0.25 m, while about 32% are in the range of 0.25–0.5 m. The other wave ranges generally exceed 0.5 m, with only about 0.3% of these waves exceeding 1.75 m (Fig. 7C). During the spring season, the frequency of waves less than 0.25 m decreases to 24%, and the waves within the range of 0.25–0.5 m increase and reach 44% of the total ranges in this region of the Arabian Gulf. Meanwhile, during the summer season, the wave range seems to contract, and the maximum wave height does not exceed 1.25 m. About 24% of the waves in this season are less than 0.25 m, 49% in the range of 0.25–0.5 m, 13% in the range of 0.5–0.75 m, and the remaining waves in the range of 0.75–1.25 m. Correspondingly, during the fall season, 33% of the waves are less than 0.25 m, 38% range between 0.25 and 0.5 m, and the rest of the waves are generally more than 0.5 m. Waves with the highest H_{\max} (greater than 1.5 m) are more frequent in this season and reach 0.5%. The distribution of the percentage of occurrence of the significant wave period is given in Fig. 7D. $T_{1/3}$ during the winter season generally have a wide range, that is, between 1 and 7 s. The predominant ranges are 0–2 s, 2–3 s, and 3–4 s, with percentages of occurrence at 15%, 41%, and 19%, respectively. Similarly, wave periods have a wide range during the spring season. The three-period range has predominant frequencies during this season, that is, 0–2, 2–3, and 3–4 s, with the percentage of occurrence at 22%, 49%, and 18%, respectively. However, the distribution of frequencies illustrated that the waves have narrow ranges during the summer season. Wave periods range between 1 and 6 s. The predominant range was 2–3 s, with occurrence reaching 53%. In addition, there is an obvious increase in the percentage of occurrence of the waves with the lowest periods, that is, ranging between 0 and 2 s, which reaches 24% of the total occurrence of wave periods. The wave periods during the fall season range between 1 and 7 s. About 46% of the waves are in the range of 2–3. Additionally, the occurrence of waves with a high period, that is, periods more than 5 s, seems to be more frequent in this season and reaches about 2% in comparison with 1.8%, 0.4%, and 0% in the winter, spring, and summer, respectively.

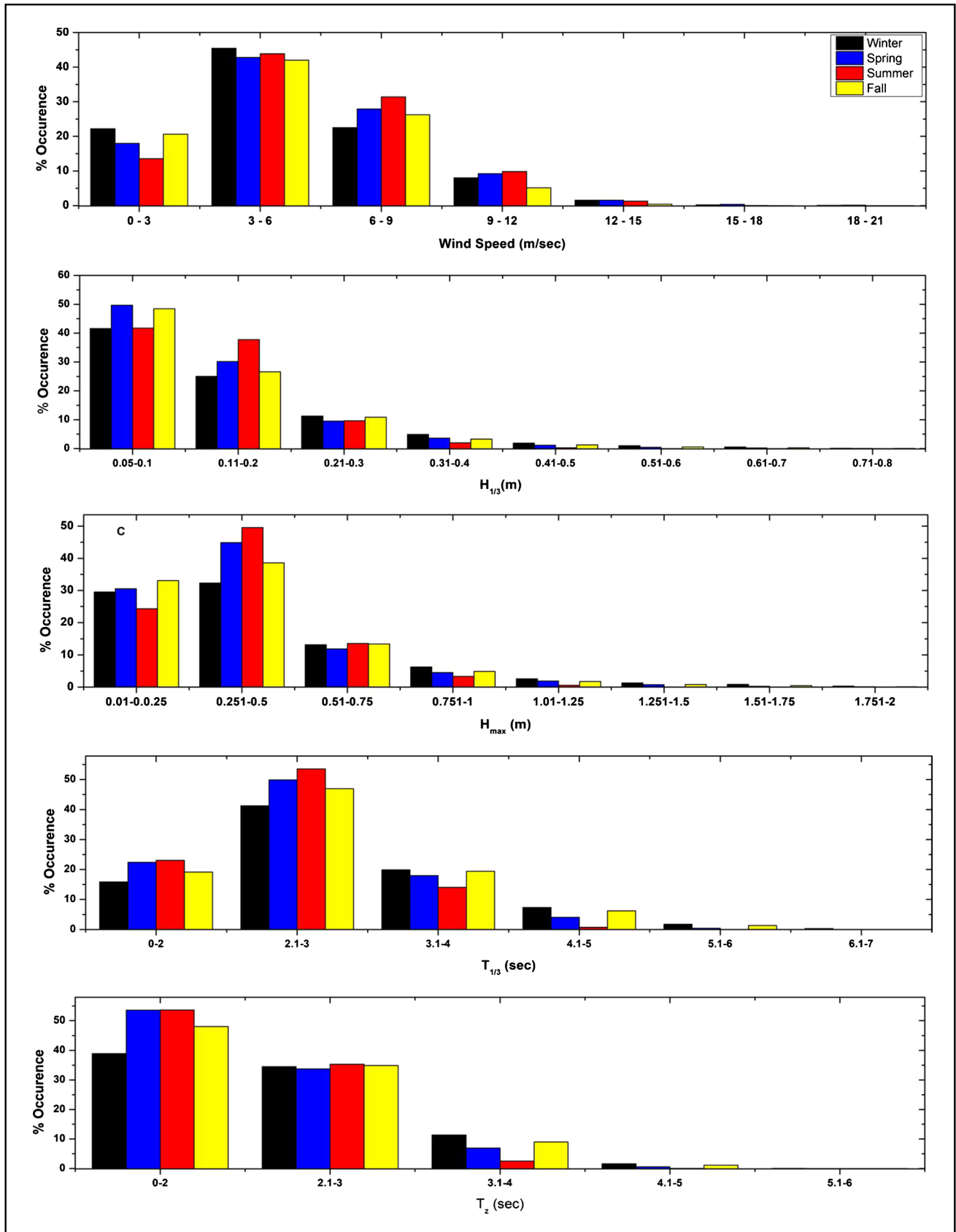


Fig. 7 Percentage occurrence of wind speed (A); $H_{1/3}$ (B); H_{max} (C); $T_{1/3}$ (D); T_z (E) during 2017–2021

Figure 7E shows the distribution of T_z . During the winter season, the frequency of occurrence of waves in the ranges of 0–2 and 2–3 s seems to have the highest percentage with 38% and 34%, respectively. The wave distribution in the range of 3–4 s participates by about 11%, and only about 1.5% is due to the waves in the range of 4–5 s. During spring, the dominant wave range is 0–2 s and reaches 53%, followed by the range of 2–3 s with 33% of the total contribution in wave periods in that time. Other wave ranges, that is, waves that belong to 3–4 s, participate by 7%, and those belong to 4–5 s participate by only 0.6% of the distribution. The periods have a narrow range during the summer season. Fifty-three percent of the waves belong to the range of 1–2 s, 35% fall within the range of 2–3 s, and only about 3% are in the range of 3–4 s. No wave periods in the range of 4–5 s were observed during this season. This is mainly due to the dominant wind patterns in the summer season and indicates that the summer waves are dominated by short-period waves. During the fall season, waves seem to have a wide range (1–5 s). Nearly 48% occur in the range of 1–2 s, 34% in the range of 2–3 s, 8% in the range of 3–4 s, and 1.1% in the range of 4–5 s

Conclusions

The wind and wave climate of Iraq marine water are studied for 5 years (2017–2021). The results revealed that the averages of wind speeds are higher during summer than in winter. The maximum wind speed recorded during the study period reaches 19.9 m/s. Additionally, our result revealed that all the peak values of wind speed are mainly due to the summer and winter shamal wind. The relative contribution of the northwest wind is higher during summer compared to the other seasons and reaches about 60% of the total wind regime in this season. Meanwhile, the highest occurrences of the southeast wind are recorded during winter and spring. The occurrence of winds below 6 m/s seems to be the most frequent during the study period.

The results indicated that wave heights in the region display seasonal variability. The wave heights in summer are generally lower in comparison with the other seasons due to the wind regimes in the region. Correspondingly, the highest wave heights are observed with the southeast winds. In contrast, although the northwest wind could exceed 15 m/s, the associated wave heights are generally less than 0.4 m. This is mainly attributed to the fetch limitation available to the northwest wind considering the measurement location at the northwest tip of the Arabian Gulf. The waves with a longer period generally occur during the winter and fall seasons. The maximum $T_{1/3}$ and T_z reach 6.84 and 5.4 s, respectively. The wave periods generally have a narrow range during the

summer season in comparison with the winter season with relatively longer waves reaching about 6.8 s.

Although the role of the general characteristics of the surface waves in Iraq marine water has been examined, the study of the directional waves needs to be explored. This can be done by installing a directional wave buoy or ADCP wave instrument. By these measurements, the interaction of multidirectional and multi frequency waves can be examined by spectral analysis to give deep insight into wave behavior in this vital region of the Arabian Gulf.

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Data availability Not applicable.

Code availability Not applicable.

Declarations

Conflict of interest The author declares that they have no conflict of interest.

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