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# Determination trends and abnormal seasonal wind speed in Iraq

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**Abstract**
Monthly observed wind speed data at four weather stations (Baghdad, Mosul, Basra, Rutba) at 10m above surface were used to explore the temporal variations of the wind speed (1971–2000) in Iraq. There are different methods to analyze wind speed variation data, but the time series are one of the powerful analysis methods to diagnose the seasonal wind speed anomaly. The results show most high abnormal data is found in summer seasons in all the stations of study, where it concentrated at 1975, 1976, 1978,1996-1995, 2000. Rutba station is different where its high deviation about annual average at nearly all the seasons, in this station there are trends in seasonal wind towards decreases in all the seasons, for example in winter it reached to about 0.046m/s.a$^{-1}$, while in other stations Mosul and Basra there increases in annual seasonal wind speed trends in seasons spring, summer, autumn where its reached higher value at summer in Basra about 0.0482m/s.a$^{-1}$. The second method to determine abnormal annual seasonal wind speed is through comparison seasonal average wind speed, where the average wind speed at the seasons summer and spring in Baghdad and Basra station have very high averages at nearly all years, this cannot see in Mosul and Rutba, in Rutba the seasonal average is intersected with each other, summer and spring is not have greater seasonal average in this station.


**Keywords:** Seasonal wind speed ; Iraq; Abnormal wind speed; Wind trends.

## 1. Introduction
Heat and moisture are so important in environmental systems that most investigations of climatic variability have focused on temperature and precipitation, but other elements of the climate, including wind, also vary over time. Wind transports particulates, heat and moisture between the earth's surface and the atmosphere [1], affects engineering design and construction and is a source of energy generation [2, 3]. Reductions in wind speed would lead to less effectively ventilate pollutants in urban areas, and would decrease available wind energy. Fewer days with high wind speeds would be particularly problematic for wind energy generation because wind power varies as the cube of the speed. Lower wind speeds reduce the efficiency of heat and moisture transfers between the earth's surface and the atmosphere, which could enhance any increases in near-surface temperatures. On the other hand, reduced moisture transfer might be a benefit to ecosystems if precipitation were to decrease [4].
although complex changes in surface wind speeds could be expected as the greenhouse effects on general atmospheric circulations and also the quality of observed records of near-surface wind run being generally too poor for assessing changes in the wind climate [5]. However, numerous studies have documented systematic changes in wind speed on the basis of station observations in Australia, Europe,

and North America [6]. One of these reported a significant negative trend in the number of winter storms in Switzerland, north of the Alps between 1864 and 1994 [7]. And other reported a decrease in wind activity for the central Mediterranean and Adriatic region between 1951 and 1970 and an increase from 1970 onwards [8]. The Australian-averaged wind speed trend for (1975–2006) was −0.009 $ms^{-1}a^{-1}$ with stilling over 88% of the land-surface. The overall observations of near-surface wind speed trends measured by terrestrial anemometers have shown declines between −0.004 $ms^{-1}$ $a^{-1}$ and approximately −0.017 $ms^{-1}a^{-1}$ (with an average of approximately −0.010 $ms^{-1}a^{-1}$) over the last 30 to 50 years for a range of mid-latitude regions [9].
Several studies have documented the wind speed trends in China last 50 years, these studies focus on the decrease of dust storm frequency in northern China for the last 50 years and attributed it to the decline of wind speed and days with strong wind [10]. While Some other showed a magnitude −0.011 ms−1a−1 of annual mean wind speed during 1954–2001 for mainland China as a whole by using a dataset of 740 national weather stations, and that wind speed trend magnitudes in winter and summer were larger than those in spring and fall seasons. In spatial distribution, north China had a relatively larger wind speed decreasing trend magnitude than south China, and west China had a relatively larger magnitude than east China. Decreasing wind trend in China can linked to the winter and summer monsoons, where we can concluded that the decreasing wind speed in winter for China was related to global climate warming and the decreasing wind speed in summer was associated with the weakening East Asia monsoon since the 1970s [11, 12]. In other hand Xu et al. [13] showed that the surface wind speed associated with the East Asian monsoon has significantly weakened in both winter and summer in the recent three decades. From 1969 to 2000, the annual mean wind speed over China has decreased steadily by 28%, and the prevalence of windy days (daily mean wind speed >5 m/s) has decreased by 58%. The temporal variations of the wind speed for 1961–2007 in China from used 597 weather stations and NCEP wind speed data at 10m above surface that the annual wind speed in China has experienced four phases: two relatively steady periods from 1961 to 1968 and 1969 to 1974 with a sharp step change in 1969, a statistically significant decline stage from 1974 to 1990s, and another relatively steady period from 1990s to 2007 [14].
In Iraq there is needed to know the change of seasonal and annual wind speed, this paper examine records of up to nearly 30yr in length of near-surface wind speeds at stations located in different parts of Iraq. The objectives of this research is describe the expected annual distribution of mean daily wind speeds, and to evaluate the interannual variability of wind speed distributions, and also to identify any longer-term trends. My emphasis in this paper is not specifically on wind energy production, but the variability of wind speed over time, this is also important for evaluating the reliability and predictability of wind as an energy resource.

## 2. Materials and methods

In This study we used the wind speeds that observed by Iraqi Meteorological Organization and Seismology, through the years (1971-2000). We selected certain stations (Baghdad, Mosul, Basra, Rutba) from seven possible where we excluded three stations because of incomplete histories or large amounts of missing data. The wind speed of these data sets was measured by anemometers 10m above the ground. Mosul station represents the north zone of Iraq, while Basra represents south zone, Baghdad represents east and middle area. Rutba represents the west zone, show Figure 1. From daily data of these stations we extracted mean monthly, seasonally, and annually average and we used different methods to explain seasonal and annual abnormal winds.
One of these methods, we find the deviation of the season about annual average one, this can be done by selected the seasonal months for example: (January, February, December) is used to represent the winter season and (March, April, May) to represent the spring season, (June, July, August) represent the summer season, and (September, October, November) to represent the autumn season, all these three months is averaged to extract the average seasonal for wind speed and these averaged season is also averaged through the period of (1971-2000) to extract average annual season.
The average annual season is subtracted from the average season, we can obtain the seasonal deviation about the average annual. This can be shown by the equation below:

$$u' = u - u_{av} \tag{1}$$

where: $u'$: represents deviation of seasonal average wind speed that taken abnormal value, $u$: represents seasonal averages of wind speed, $u_{av:}$ represents annual average seasonal wind speed.

If the value of u' is large (positive or negative) this means that there is high abnormal seasonal wind speed in this year, that is out of the general average, if the values u' is nearer to zero this means that there are small season deviation values in wind speed through this year.
The Second method to find abnormal seasonal wind speed, is from a comparison of all averages seasonal wind speed during the period of study and for the station of study.

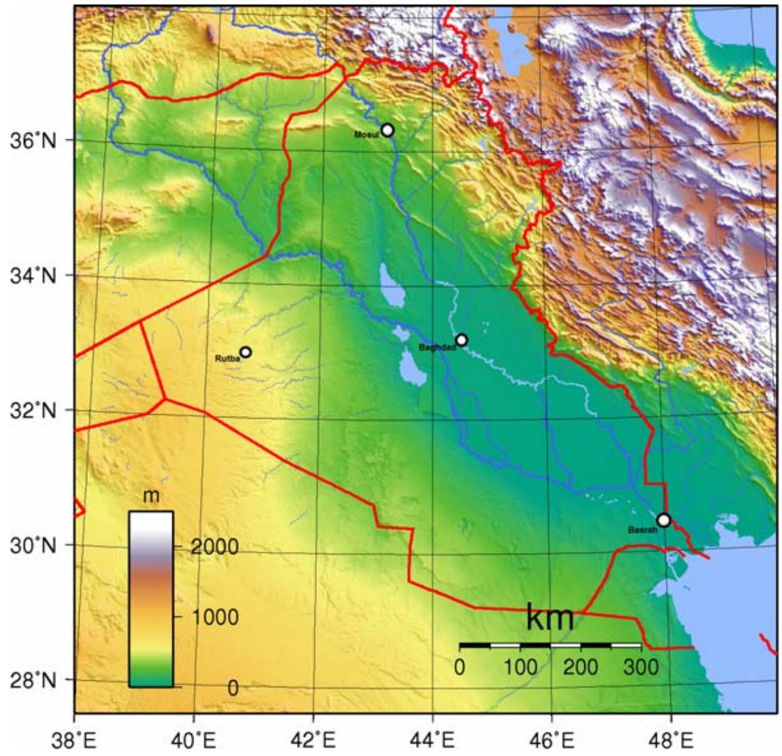


Figure 1. Stations of study in Iraq

**3. Results and discussions**

First and second method to find abnormal seasonal average wind speed can be applied on data of the four stations, that is taken to represent all the location zones of the area of Iraq. The results of these methods applied are different according to station location and season, the text below is overviews the results of each method and for each station.

*3.1 Baghdad station*

This station is about 31 meters above sea level, and has $33.3^0$ north and $44.4^0$ east, the annual average wind speed during the period from 1971-2000 was about 3.15 m/s this taken amount about 83.8%,104%,1.27%,74% respectively from the average seasonal wind speed during the seasons winter, spring, summer, autumn respectively. Winter has higher frequency average wind speed concentrated in the range (2.5-2.6)m/s, while in spring ranged (3.2-3.6)m/s, but at the summer its reached to the rate 91% at the range (4-4.5)m/s, this range at autumn is decreases to about (2.6-2.8)m/s, see Figure 2. From applied the first method to find abnormal wind speed we find that in winter the highest positive and negative deviation about the average seasonal wind 2.6m/s is concentrated at years 1985,1987, (Figure 3) the higher frequency of this deviations taken the range (0-(-0.2))m/s (Figure 4). In spring the highest negative deviation about the seasonal average (3.3m/s) is in the year 1985, but higher frequency of this deviation is concentrated at the positive side at the range (0-(-0.2)) m/s. In summer and at the period 1971-2000, the positive deviation about the average season (4m/s) was greater then negative deviation where its reached to 1.4m/s at the year 1976, this can be lead also to higher frequency of this deviation concentrated at the positive side about the range (0-(-0.5)) m/s. In autumn we recorded that the higher negative deviation.
about average 2.6m/s is greater than positive about 0.9m/s at 1984, but the frequency distribution of this deviation was greater at negative side at the range (0-(-0.2)) m/s, we can return to Figures 3, 4 and Table 1 to see abnormal deviation of wind speed and its frequency distribution.

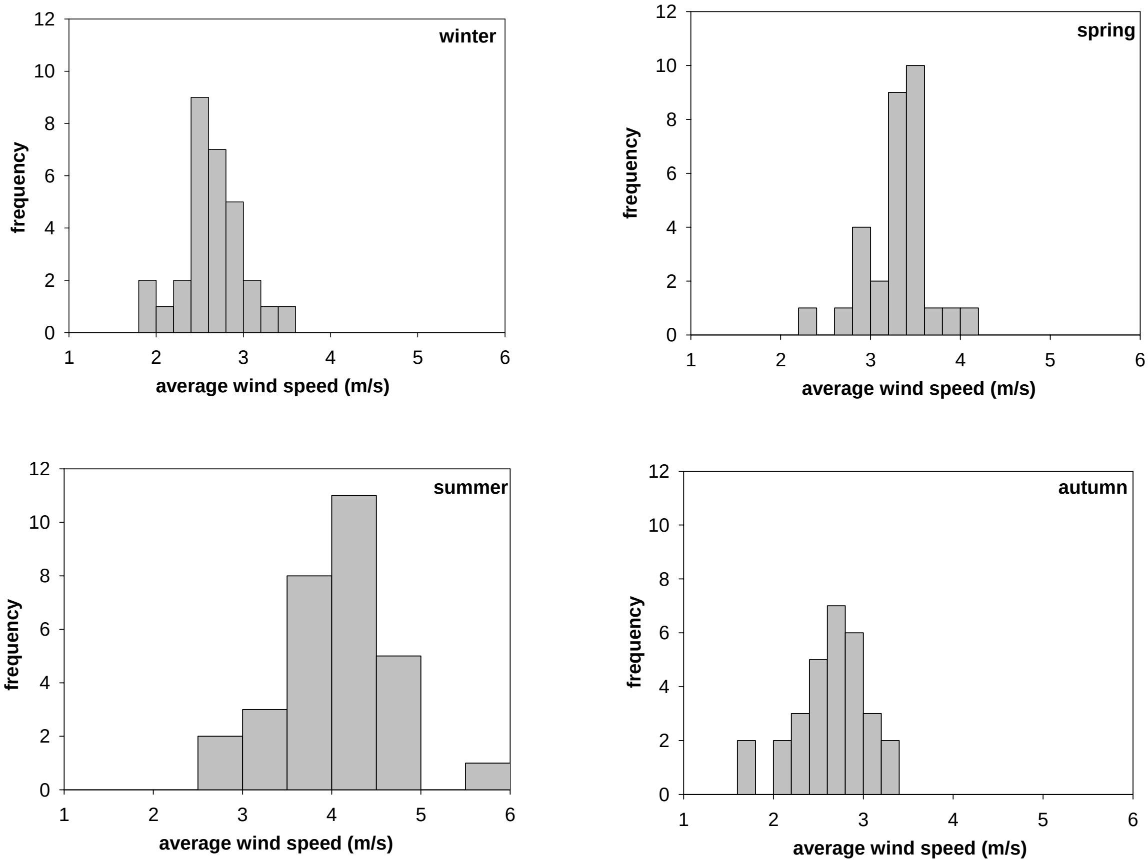


Figure 2. Average wind speed frequency at Winter, Spring, Summer, Autumn seasons for Baghdad station

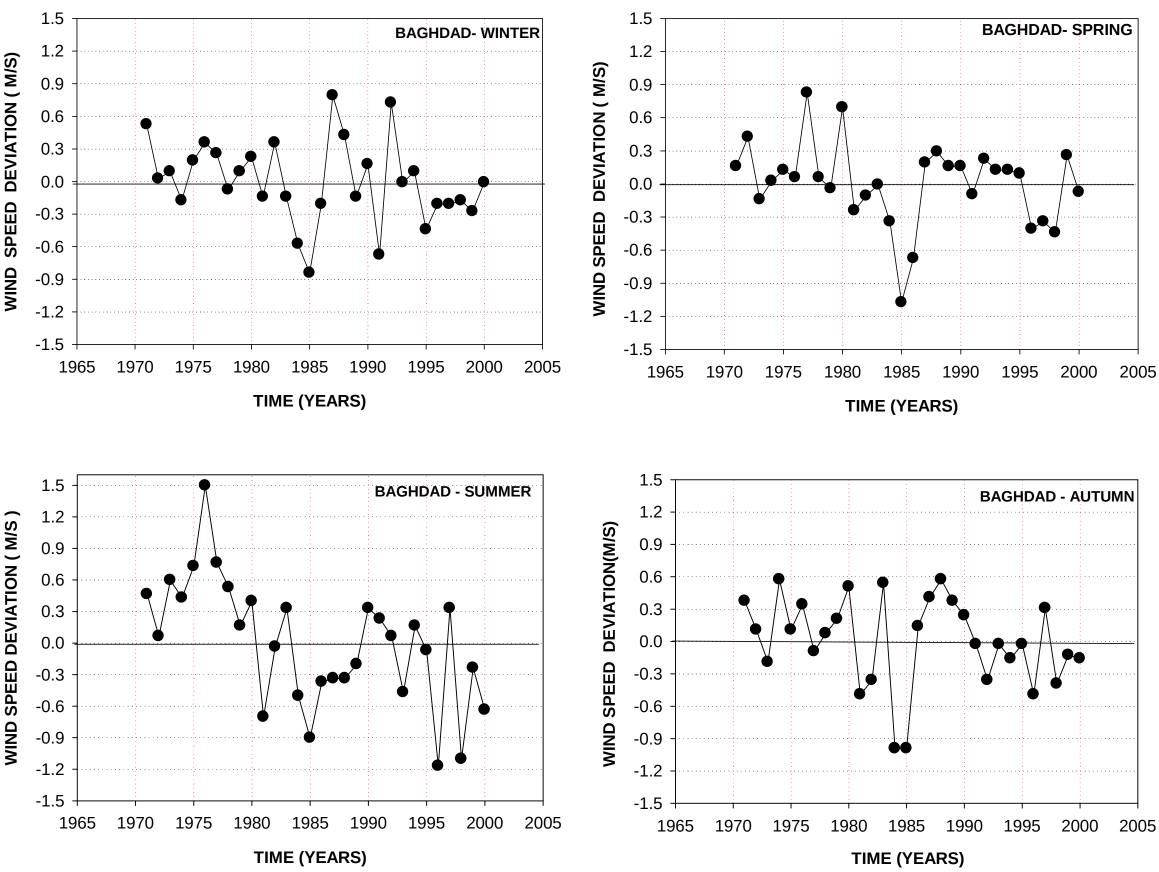


Figure 3. Wind speed deviation at Winter, Spring, Summer, Autumn seasons for Baghdad station

 

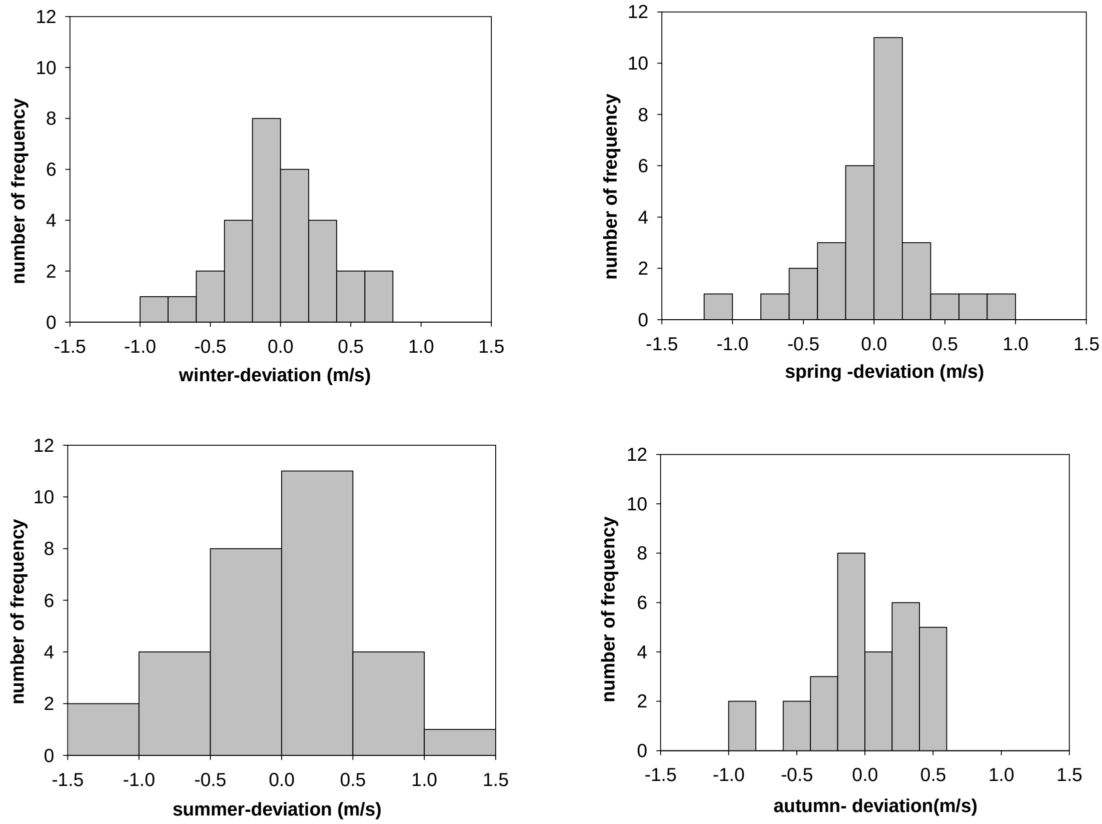


Figure 4. Average wind speed deviation frequency at Winter, Spring, Summer, Autumn seasons for Baghdad station

Table 1. Maximum and minimum wind speed deviation about average annual wind speed

| Stations | | Winter | | | Spring | | | Summer | | | Autumn | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | u’ | $u_{av}$ | years | u’ | $u_{av}$ | years | u’ | $u_{av}$ | years | u’ | $u_{av}$ | years |
| Baghdad | max | 0.7 | 3.4 | 1992 | 0.8 | 4.1 | 1977 | 1.5 | 5.5 | 1976 | 0.6 | 3.2 | 1974 |
| | min | -0.8 | 1.8 | 1985 | -1.0 | 2.2 | 1985 | -1.2 | 2.9 | 1996 | -0.9 | 1.6 | 1984 |
| Mosul | max | 0.9 | 1.9 | 1992 | 0.7 | 2.2 | 1986<br>1987 | 0.7 | 2.3 | 1986<br>2000 | 0.7 | 1.6 | 1986 |
| | min | -0.7 | 0.4 | 1981 | 0.9 | 0.6 | 1985 | -0.5 | 1.1 | 1985 | -0.5 | 0.3 | 1980 |
| Basra | max | 0.5 | 3.6 | 1994 | 0.8 | 4.5 | 1991 | 1.63 | 6.3 | 1995 | 0.9 | 3.8 | 1987 |
| | min | -0.5 | 2.5 | 1986 | -0.8 | 2.8 | 1986 | -1. | 3.6 | 1978 | -0.9 | 2 | 1982 |
| Rutba | max | 1.2 | 4.1 | 1985 | 1 | 4.6 | 1980 | 1.5 | 5 | 1975 | 1.8 | 4 | 1974 |
| | min | -2.1 | 0.8 | 1999 | -1.9 | 1.5 | 2000 | -2.6 | 0.9 | 2000 | -1.8 | 0.5 | 1998 |

Overall there is decreases in the seasonal wind speed in linear regression trend at the winter from 2.9m/s at 1971 to 2.25m/s at 2000 about 0.013m/s $a^{-1}$ decreases every year, in summer the trends is stronger than, and the wind speed decreases about 0.022m/s.$a^{-1}$, this mean wind speed decreases from 4.6m/s at 1971 to 3.46m/s at 2000. But in the spring and autumn the case is normal and there is no clear decrease or increases trends in seasonal wind speed, (Figure 5).

*3.2 Mosul station*

This station lies in the city center of Mosul (396 km north of Baghdad city) (lat. 36.19$^0$ and lon. 43.09$^0$) and rises 223m above sea level. The average annual wind speed of period study is 1.26 m/s, while seasonal average wind speed for winter, spring, summer, autumn is 0.82, 1.52, 1.66, 0.86 m/s respectively. The average seasonal frequency distribution for winter and spring is nearly distributed overall range of seasonal averages wind speed, but in summer and autumn the case is different, at summer larger frequency distributed through the range (1.6-2 m/s), in autumn the wind speed range (0.8-1.2 m/s) represents domain wind at that season, (Figure 6).

 

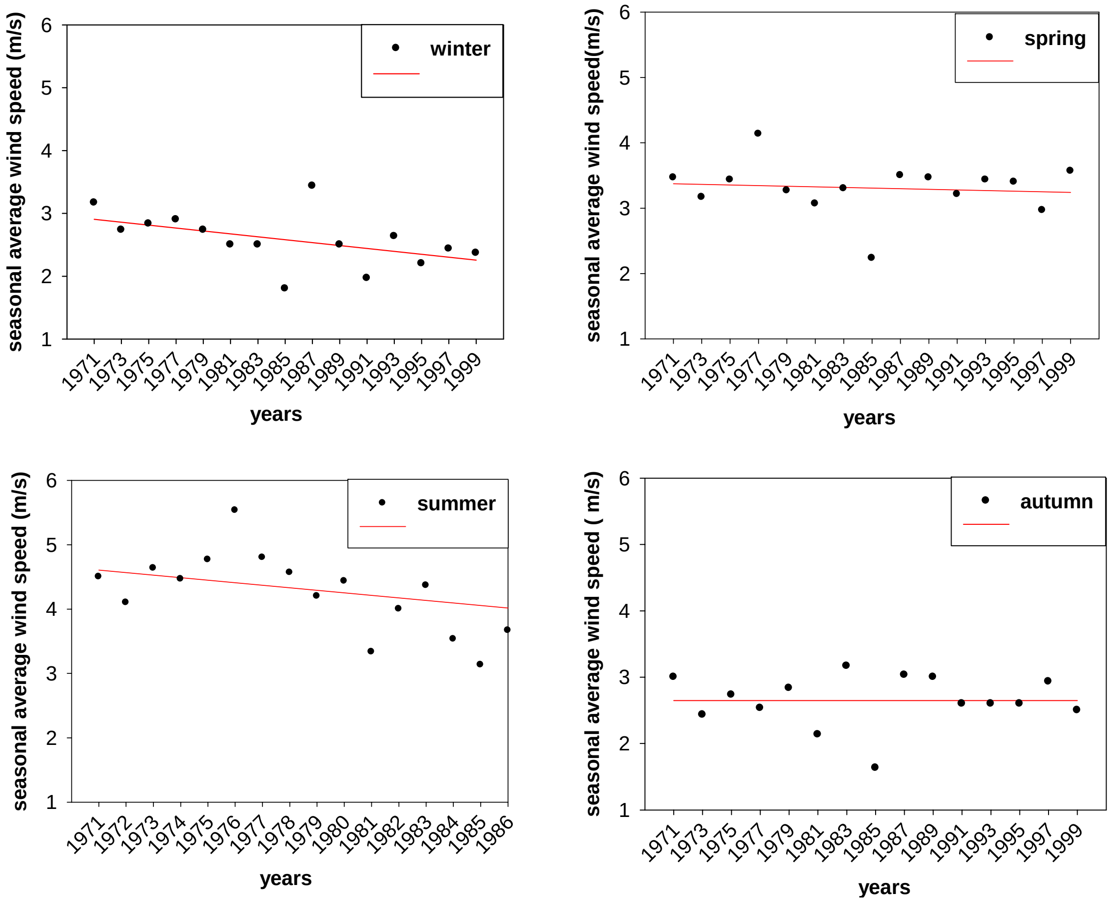


Figure 5. The trends of average seasonal wind speed for Baghdad station

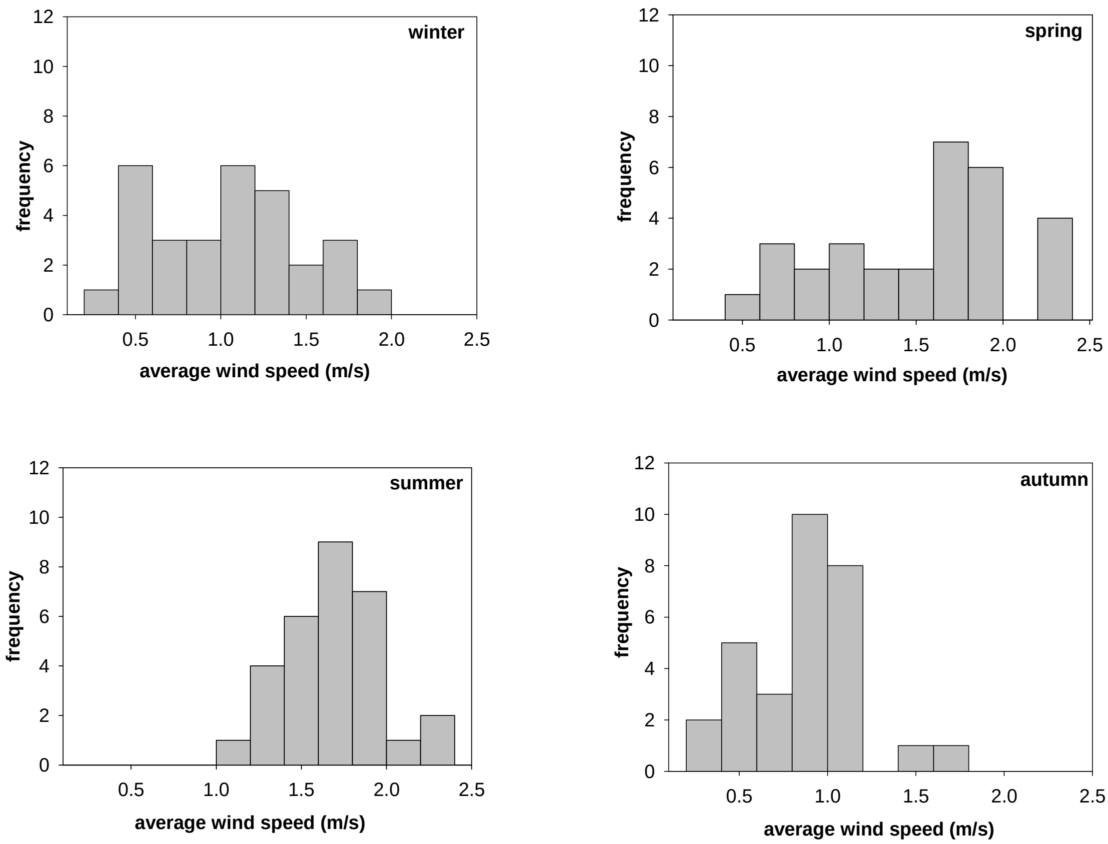


Figure 6. Similar as Figure 2 but for Mosul station

The highest positive deviation of the average seasonal wind speed about the average seasonal annual in winter season is 0.9m/s at 1992, in the same year there is highest average seasonal wind 2 m/sec. On the other hand the higher negative deviation in spring reached 0.92m/sec in 1985, higher average season is 2.23m/sec in 1986. In summer and autumn the deviation is not important and reached 0.7m/s and concentrated in years 1985 and 1986, (Figure 7).

The frequency seasonal average deviation in winter and spring is cover all the range of frequency deviation from about -1 to +1, but in the summer the frequency reached higher value and the range of positive and negative deviation from (0.2-(-0.2)m/s), on the other hand, the higher frequency deviation in autumn is concentrated in positive side (0-0.4m/s), (Figure 8).

The linear regression trends of wind speed at the winter is weaker, but at the other season there is increases in these trends and its largest in spring season about 0.52m/s through the period 1971-2000, the increase was about 0.01m/s.a$^{-1}$ for every year. In the autumn and summer the increase is about (0.18, 0.17m/s) respectively through this period, (Figure 9).

In all seasons there is a decreases in average wind speed after 1970 from above annual average until reached 1983 to under annual average, after 1985 there is increases in seasonal average wind speed to over annual average of these period, (notes Figure 7). The maximum deviation above annual average in this station was 0.9m/s in winter this value higher than Baghdad station about 0.7m/s at the same season, (Table 1), but the maximum seasonal average was 2.2m/s in spring, this is smaller than Baghdad station about 4.1m/s at the same season, Figures 3 and 7.

*3.3 Basra station*

This station is located south of Baghdad city about 549km, at latitude 30.31$^0$ north and longitude 47.47$^0$ east, and 2m above sea level. The annual average wind speed though the period study is 3.56m/s, this value is greater than the average seasonal wind speed through winter and autumn, (3.02, 2.93 m/s) respectively, but lower than the seasonal average of wind speed in spring and summer (3.66, 4.66 m/s).

The average seasonal frequency distribution through the winter and autumn is concentrated at the range (2.5–3.5) m/s and (2.8–3.4) m/s respectively, the frequency wind speed distribution of winter is very high and reached to 93.7% at the range (2.5-3) m/s, while in summer the frequency distribution extend from (3.5-6.5 m/s) Figure 10.

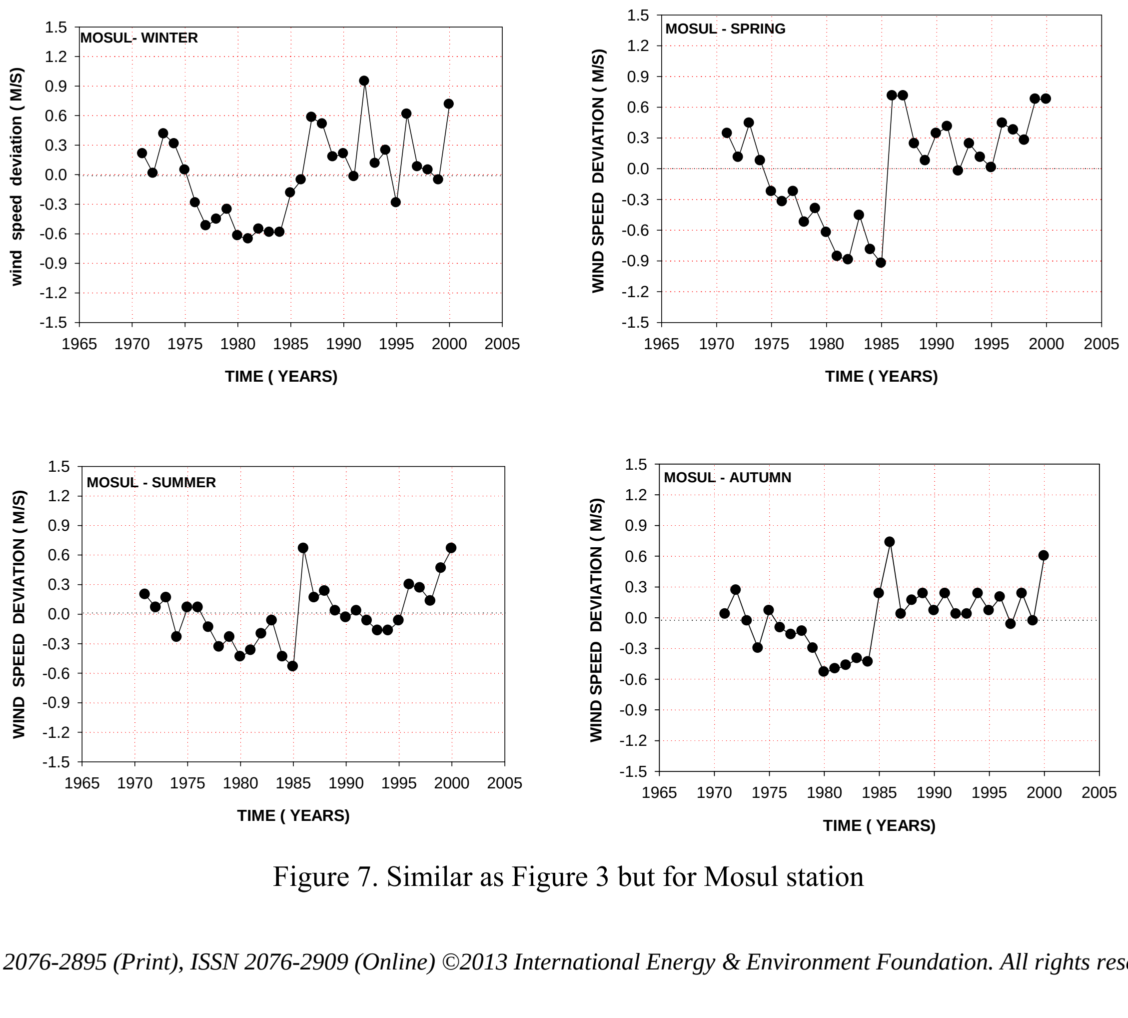


Figure 7. Similar as Figure 3 but for Mosul station

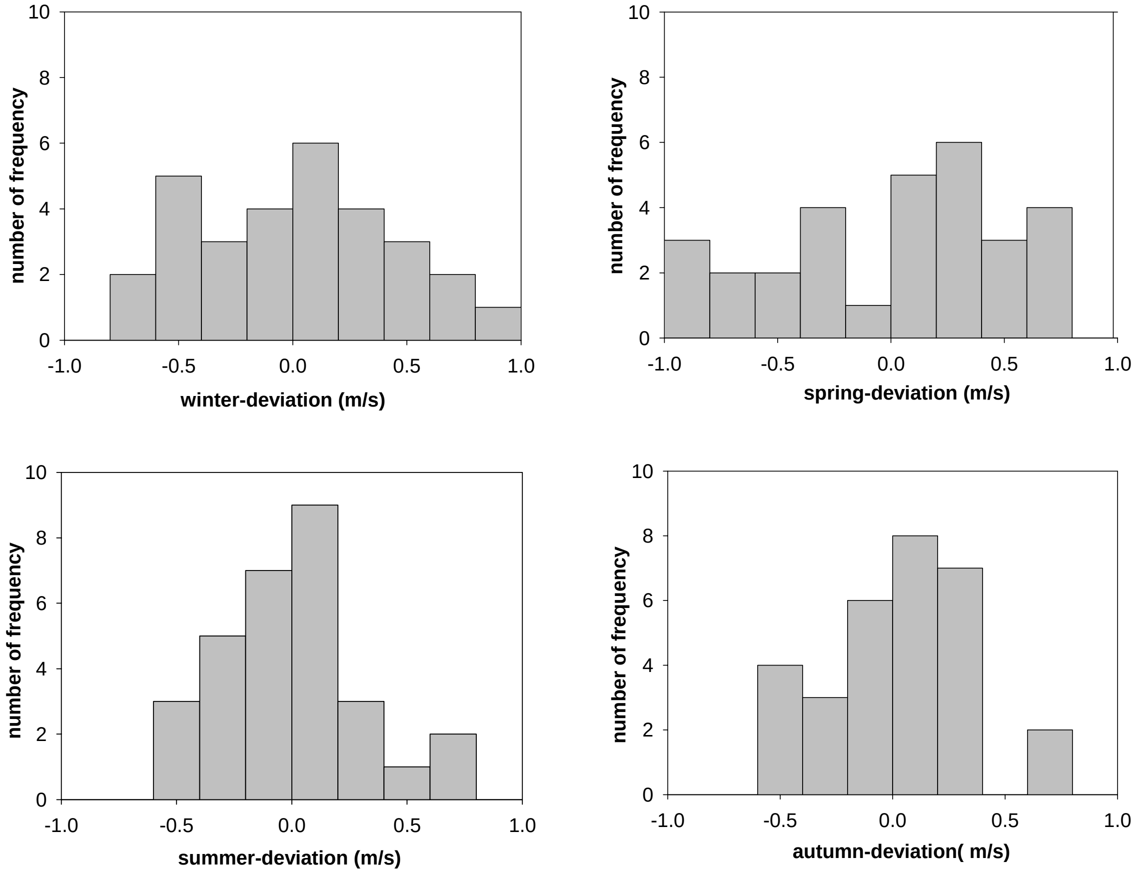


Figure 8. Similar to Figure 4 but for Mosul station

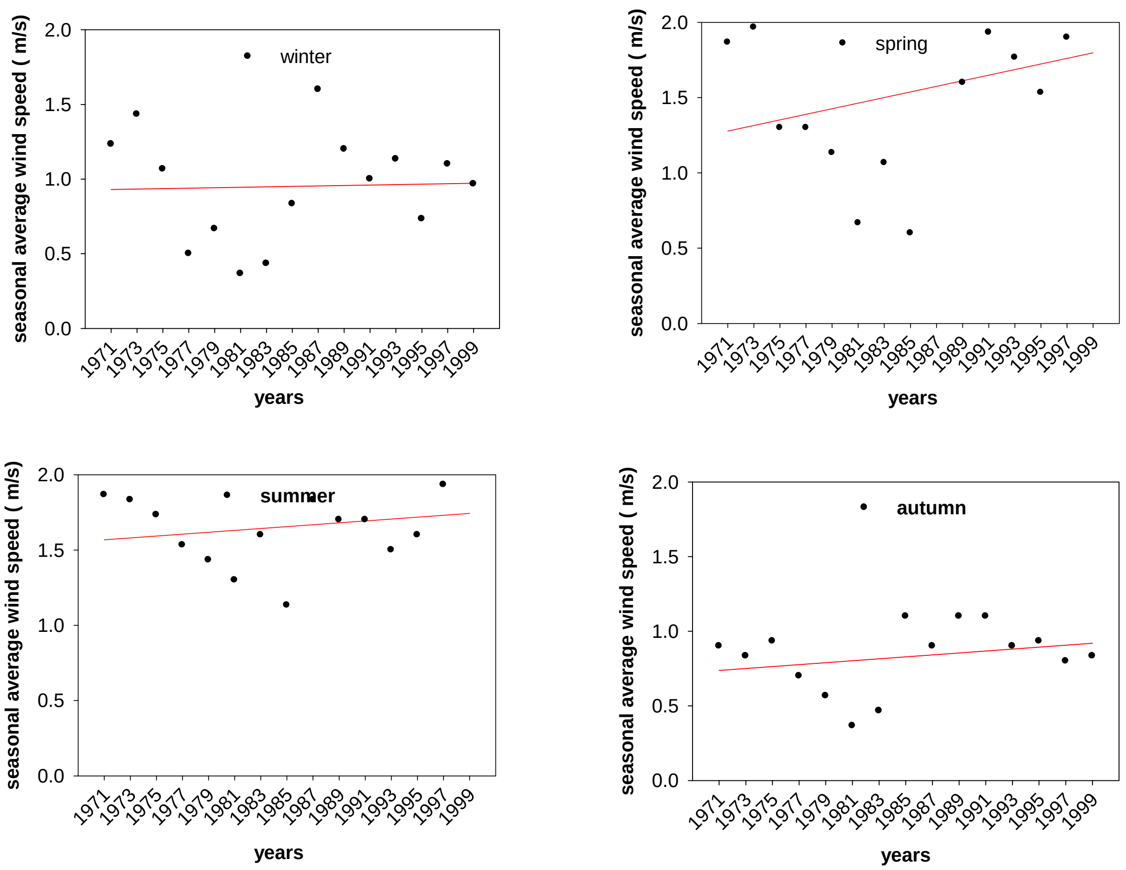


Figure 9. Similar to Figure 5 but for Mosul station

 

The highest positive deviation about yearly average was in summer 1995 about 1.6m/s, in this year there was also the largest seasonal average about 6.3m/s. While the highest negative averages was also in summer in 1978, about 1.0 m/s, Figure 11, and the higher frequency distribution concentrated at the range (0-(-0.5)) m/s (see Figure 12). In winter we don't have any large deviation above or below annual average wind speed, (see Figure 11), but higher frequency of this deviation concentrated at negative side (0-(-0.2)m/s) see Figure 12. In the spring and autumn we see that negative deviation is greater than positive deviation even after 1985 where the positive deviation becomes greater than negative, frequency distribution of this seasons is low and concentrated over large range, Figure 12.

*3.4 Rutba station*

This station is located west of Baghdad city, at latitude $33.02^0$ north and longitude $40.17^0$ east, and about 630m above sea level. The average annual seasonal wind speed is about 3.07m/s, while the average seasonal in winter, spring, summer, autumn is 2.89, 3.5, 3.52, 2.3 m/s these concentrated at the, range (3-4), (3.5-4.5), (3.5-4.5), (2-3) m/s respectively, Figure 13.

The range of variation in this station is greater than other studied stations from 2m/s above annual average to 3m/s below annual average. In winter higher deviation is 1.2 m/s at average wind speed 4.1m/sec in 1985, while higher deviation below annual average in 1999 about 2.1m/sec, positive and negative deviation at this station is higher than Baghdad station Figures 3, 14, and also higher than the spring season. In the same station positive and negative deviation in spring have 1, 1.9 m/s at years 1980 and 2000, but average seasonal wind is greater in this season. Summer in this station taken greater deviation during all years, where its 1.5m/s above the annual average at 1975 average wind at this year is 5m/s. While the deviation below annual average is 2.6 m/s at 2000. In autumn the higher deviations were equal to magnitude about 1.8m/s, but the positive deviation concentrated in 1974, and negative deviation concentrated in 1998, Figure 14 and Table 1.

All the higher frequency of this deviation is concentrated at the negative side, while the highest deviation at the ranged (0-0.5)m/s is found in winter, summer, autumn but in spring the highest deviation is concentrated at the range (0-1)m/s, Figure 15.

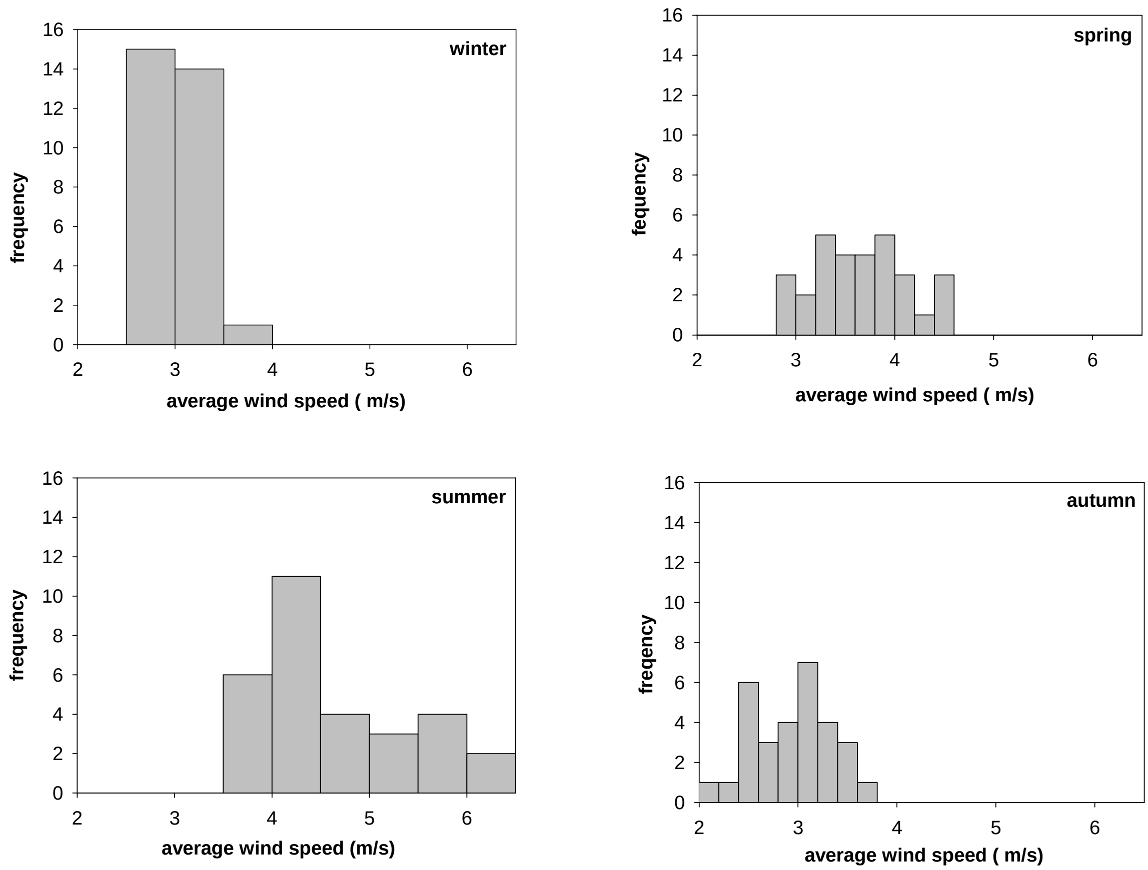


Figure 10. Similar to Figure 2 but for Basra station

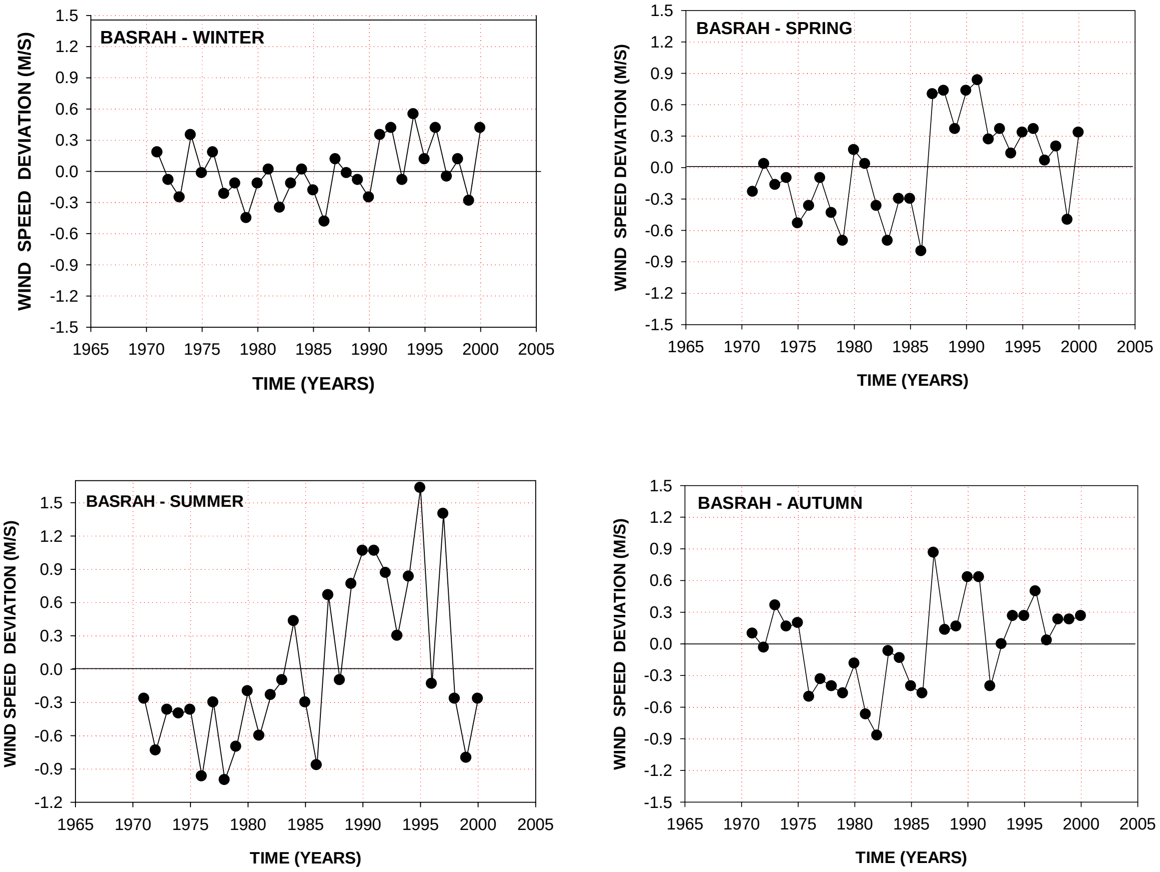


Figure 11. Similar as Figure 3 but for Basrah station

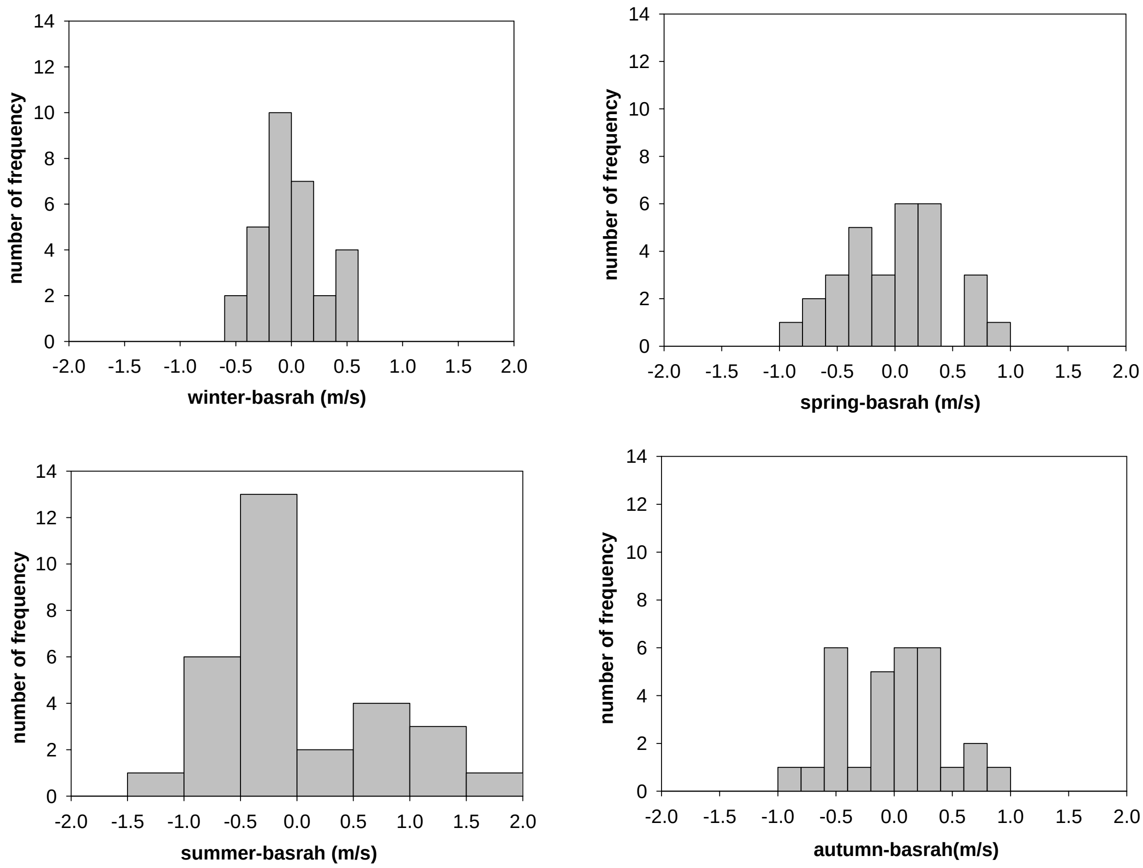


Figure 12. Similar as Figure 4 but for Basrah station

 

Overall there is a decrease in the trend of the seasonal average wind speed to go below annual average in all seasons after the 1995, where its decreases in winter 0.0465 m/s.a$^{-1}$ about 2.33 m/s and 0.0402 m/s.a$^{-1}$ at spring about 2.01 m/s decreases in wind speed at this period, and 0.0385m/s.a$^{-1}$, 0.033m/s.a$^{-1}$ at summer and autumn, we show the largest decreases trends is in the winter from average wind speed 4.1 m/s at 1971 to 1.77 m/s at 2000. this can be show in Figure 14 and Figure 16.

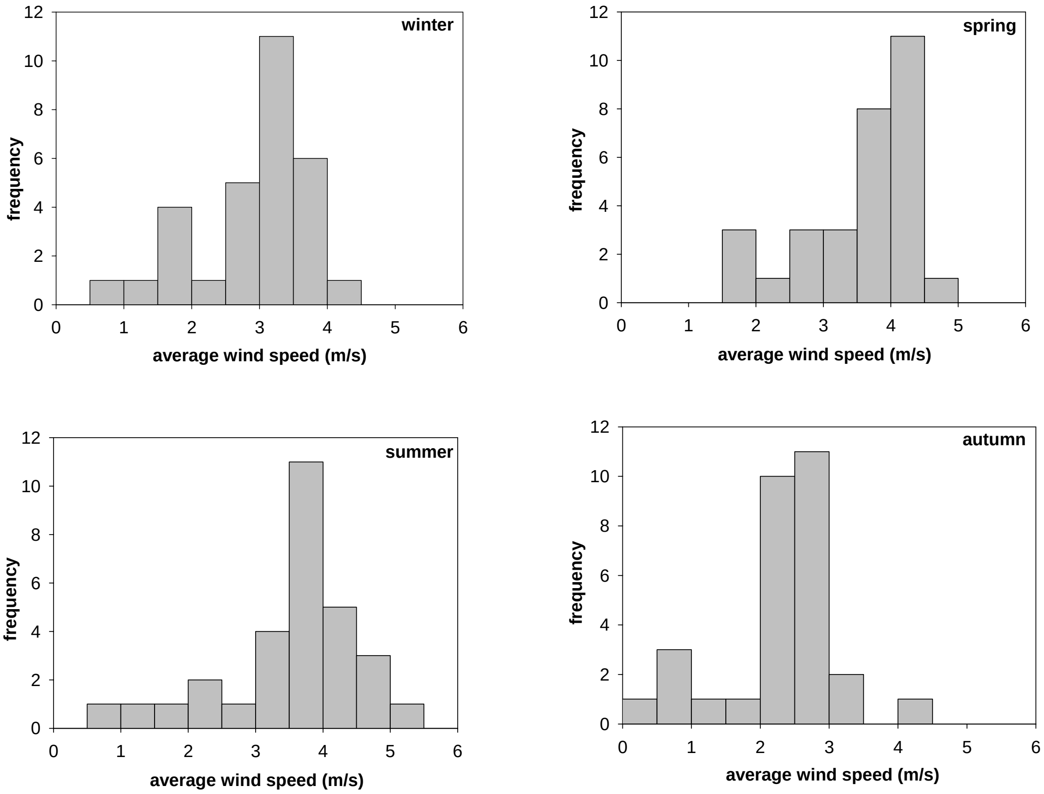


Figure 13. Similar as Figure 2 but for Rutba station

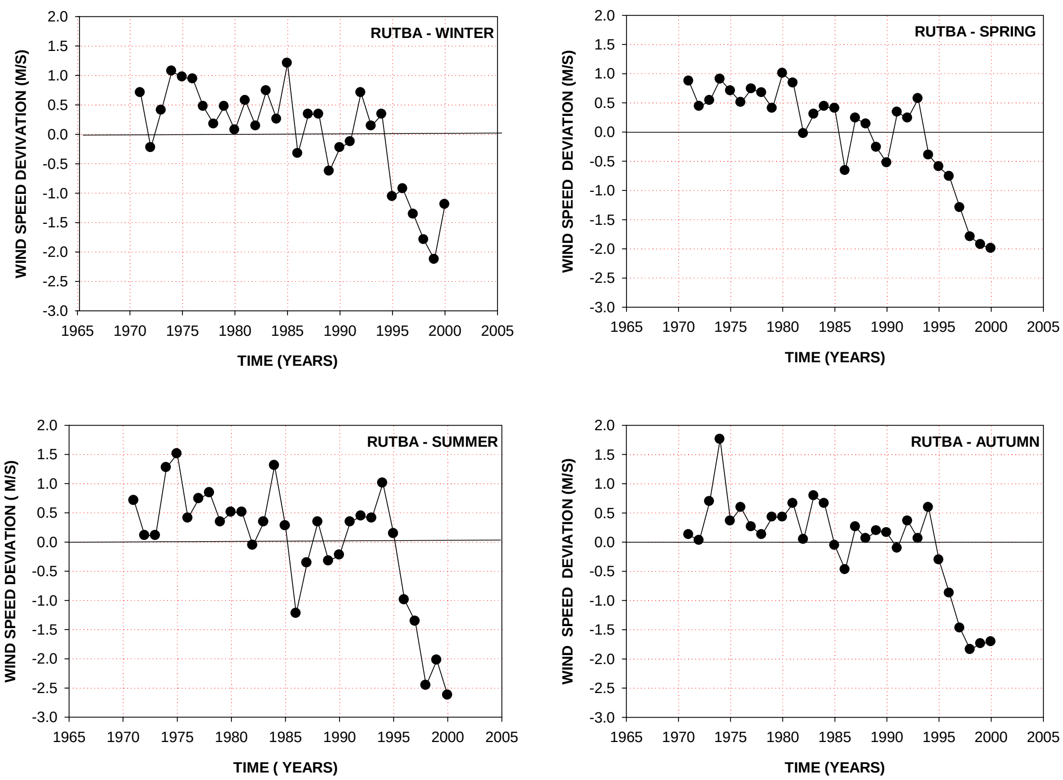


Figure 14. Similar as Figure 3 but for Rutba station

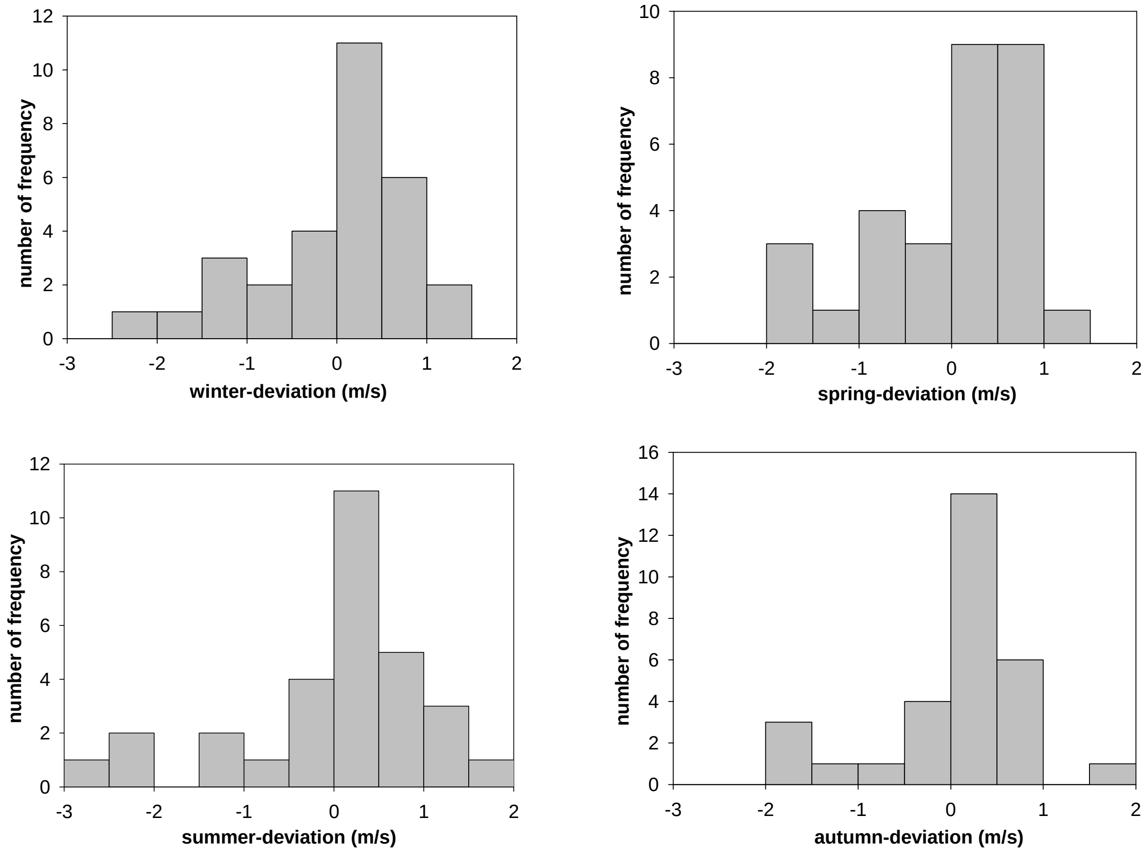


Figure 15. Similar as Figure 4 but for Rutba station

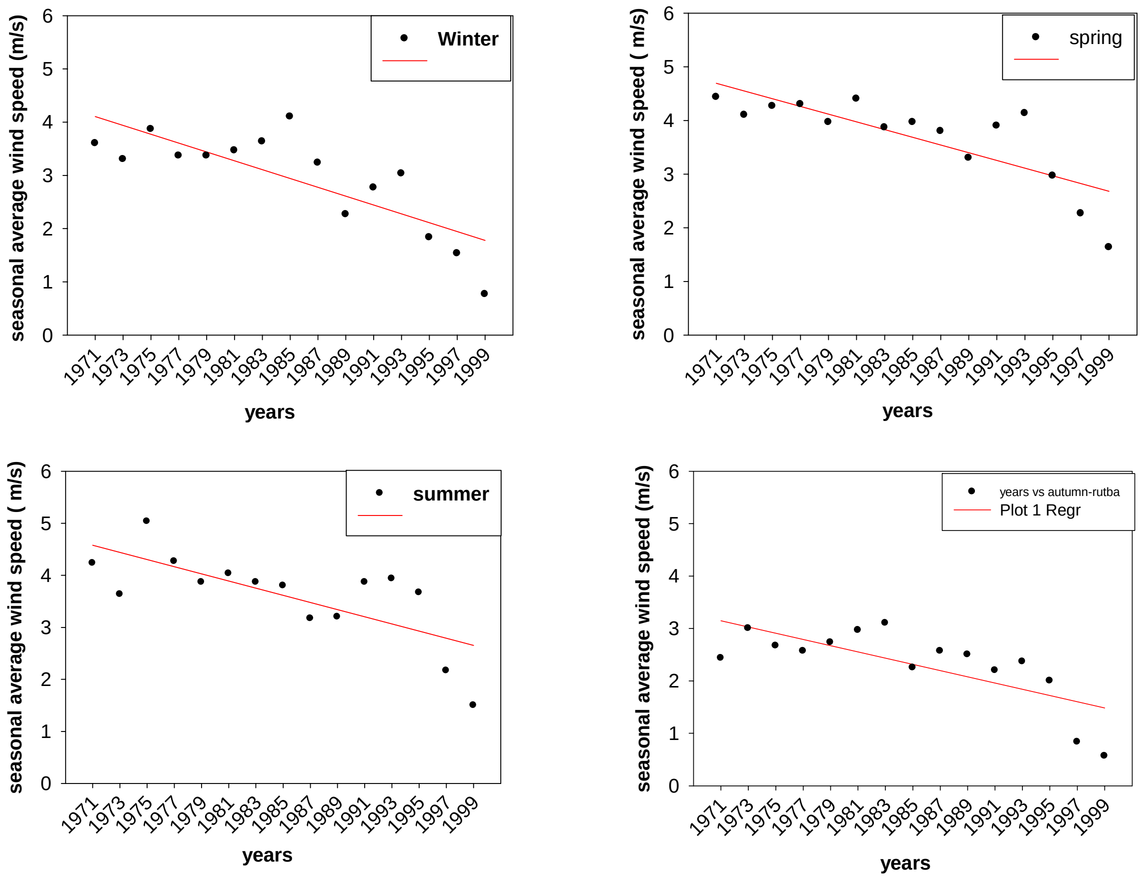


Figure 16. Similar as Figure 5 but for Rutba station

## 4. Seasonal averages comparison at duration 1971-2000

We can also determine the years that have abnormal wind speed (under or above annual average) through comparing the seasonal average wind speed at the period study, the seasonal average can be obtained from the monthly average taken for the seasons winter, spring, summer and autumn. From plotting these averages we note that average wind speed at the seasons summer and spring for Baghdad station has very high averages at nearly every year. This case can't be seen in Mosul station where there is nearly homogenous in the plotting data average but there is a decrease in the curved of data toward 1985 and after that increase in this trend after this year. The averages wind speed at summer is high also at period (1974-1985). And generally the averages seasons for Mosul station is less than Baghdad station for all years nearly. The seasonal averages of wind speed at Basra station is similar to Baghdad station where we show that summer and spring have higher average wind speed from other seasons, and greater that also from the Baghdad station, we see in this station also increase in the seasonal average wind speed in all season at the period 1971-2000. In Rutba station the averages seasonal wind speed is interested and intersected with each other and summer and spring is not the greater in this station. We also note that the trend of these averages is decreases towards the year 2000. Overall we note that the Baghdad and Rutba station have the direction toward decreases in wind averages, but the Mosul and Basra have the opposite direction there is increase in the wind seasonal averages show Figure 17.

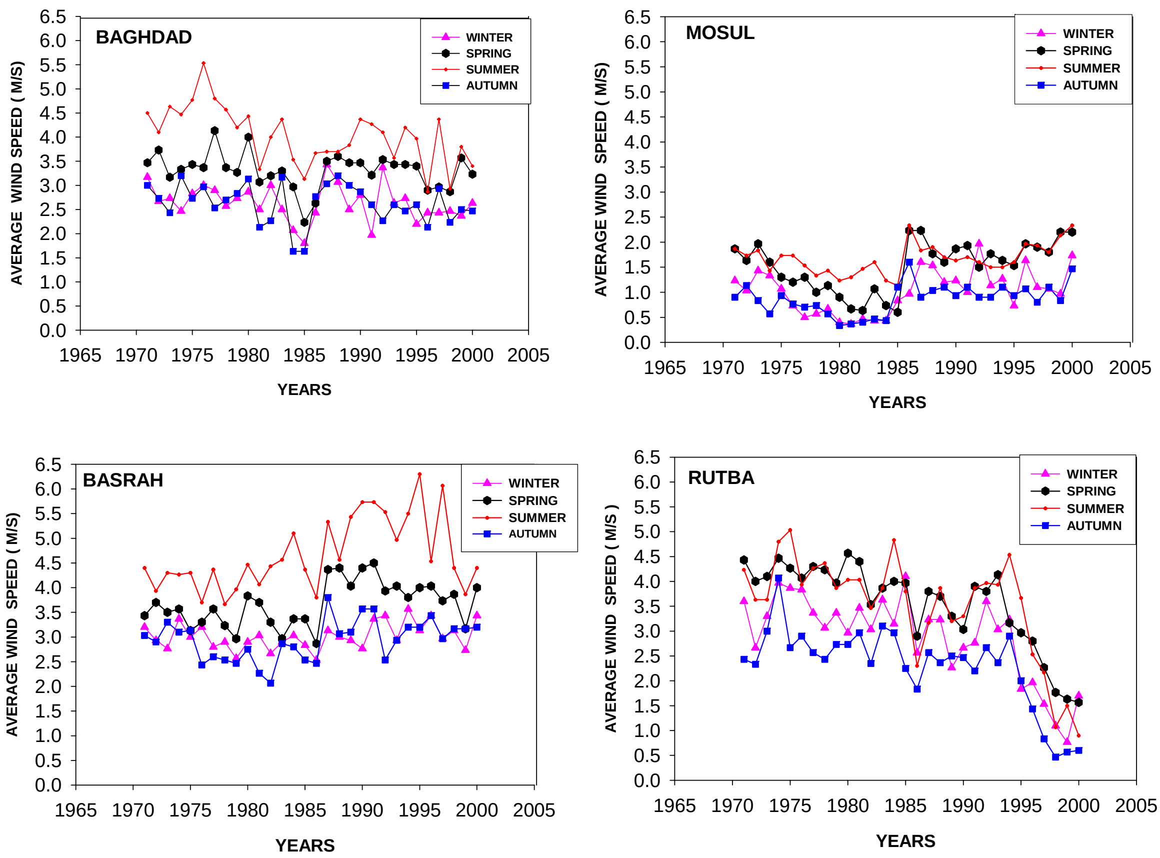


Figure 17. Average seasonal wind speed for stations (Baghdad, Mosul, Basra, Rutba)

## 5. Conclusion

The seasonal wind speed in Iraq has changed for many causes, for example the greenhouse effect and human activity, this study determines that change through many decays, the selected station allocated in all parts in Iraq, and we can abstracted the important steps that may be concluded as follow:

1. The higher positive seasonal deviation in Baghdad station is 1.5m/s in summer 1976, also taken abnormal seasonal wind in this year 5.5m/s.
2. Mosul station doesn't have any abnormal deviation about annual average though the studies period.
3. Basra station liked Baghdad station have large positive deviations in summer in the year 1995 reached to 1.6m/s, this followed by large abnormal average wind speed at the same year 6.3m/s. In the other hand large negative deviation also happened in the summer season about 1m/s in the year 1978.

4. The large positive deviation in Rutba station was 1.8m/s in autumn season in the year 1974. While greater abnormal seasonal average is 5m/s in the summer season.
5. overall we note that the Baghdad and Rutba station have the direction toward decreases in wind averages, but the Mosul and Basra have the opposite direction there is increase in the wind seasonal averages.

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