SURFACE WIND CHARACTERISTICS AND WIND DIRECTION ESTIMATION FOR "KALAR REGION/ SULAIMANI-NORTH IRAQ"

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(Accepted for publication: June 9, 2013)

Abstract:

This work is an analysis of wind characteristics and estimation of wind direction for a particular region named Kalar, located in southern Sulaimani city North/Iraq. Specific hourly wind speeds and wind directions, based on one year (2003), were used to generate monthly, seasonal and annual wind roses charts for the studied area. The summary statistics for the seasonal and annual data for the surface wind speeds at 10 meters were presented and shown that the wind roses depend on spatial wind pattern and the prevailing wind direction between north and east.

KEYWORDS**:** *wind speed, wind rose, Kalar region*

1. Introduction:

Studies of wind field characteristics have increased as wind affects heat and moisture transfer between the earth's surface and the atmosphere, this study employs wind direction analysis. The objectives are to describe and evaluate seasonal means and inter-annual variability of surface wind speed and direction. Like all other meteorological data, wind recordings have specific features that must be taken into account by the use and interpretation of them. It is well known that wind data characterize first of all the measurement site. They depend not only on the properties of the landscape but also on the particular location of the station in the landscape.(Keevallik S. et.al, 2007)

Wind-rose is a typical meteorological tool which can give an estimate of prominent flow directions and ranges for wind velocity naturally available at a wind monitoring station. It is important to know the measurement height for a given wind speed because of the variation of wind speed with height. It is also desirable to know the exposure of a particular location to the prevailing winds because nearby obstacles such as trees and buildings can reduce the apparent wind speed. On a site with rough terrain, hills or buildings it is important to know wind direction distribution to locate a wind turbine. Hills, mountains or large buildings could change wind direction significantly.

Turbulence from obstacles has different impact on power output of a turbine located upwind or downwind from it. Wind direction data could be collected from nearest weather station, collected wind data should be analyzed to make a wind rose with wind speed at prevailing directions.(Panofsky H. and Brie G.: 1965, Petrson E, et.al: 1997)

Direction of wind is an important factor in the sitting of a wind energy conversion system (WECS). Information about the distribution of wind speeds and the frequency of the varying wind directions in a combined form, can be presented in the wind roses. The wind rose is a chart which indicates the distribution of wind in different directions.

Three types of information can be presented in a wind rose,

(i) The percentage of time in which the wind blows mostly from a particular direction. (ii) The result of this percentage alongside the average of wind velocity in particular direction tells us the average strength of the wind spectra. (iii) The product of time percentage and cube of the wind velocity, helps us in identifying the average available from different directions.(Ahmed S.,Akram O.:2011)

The wind characterization in terms of speed, direction and wind power is the first step to obtain the initial feasibility of generating electricity from wind power through a wind farm, in a given region.(Rehman S. et.al:2007)

In the last decade, a lot of studies related to the wind characteristics and wind direction have been made in many countries worldwide. (Poor A.:2010. Jeromd M. et.al:2009, Yan Y.:2007, Dahmonni A. et.ai,:2009, Jaramillo O. et.al: 2004). In the Present study, the wind speed and direction of Kalar region is statistically and graphically analyzed based on one-year (2003) measured hourly time –series wind speed –direction data . The location concerned in this study is situated in south Sulaimani $34^{\circ}37'25''$

North latitude, $45^{\circ}19'11''$ East longitude and it is at an elevation of 245 meters above sea level.

There is no obstacle around wind speed measuring location as shown in figure (1). The aim of the study is to estimate the surface prevailing wind direction and characteristics of wind speed

Figure (1): Topographical image of the study area

2. Mean Wind Speed-Direction Distribution:

The wind direction distribution is often presented as a wind rose, a plot of frequency of occurrence by direction. Wind roses can also represent quantities such as the average speed or the percent of the available power for each direction (Tteimiller D.,George R.2002) The mean wind is normally computed by components.

The components of the mean wind along any orthogonal directions are equal to the simple means of the individual wind components along the same directions. The directions along which the components are taken are most commonly chosen as the West-East and South-North directions, when the wind is given to 8 points only, (N,NE,E,SE,S,SW,W,NW) the computation then becomes particularly simple. If R_x is the component of the resultant wind in the west-east direction, and R_y the component in the south-north direction, these components are given by Panofsky H., Brie G.:1965)

$$R_x = \frac{\sum W - \sum E + 0.707(\sum SW + \sum NW) - 0.707(\sum SE + \sum NE)}{N'} \quad -----(1)$$

$$R_y = \frac{\sum S - \sum N + 0.707(\sum SW + \sum SE) - 0.707(\sum NE + \sum NW)}{N'} \quad -----(2)$$

Where N' in the denominators is the number of observations. The speed of the resultant wind R is given by:

$$R = (R_x^{\,2} + R_y^{\,2})^{1/2} \quad ---------(3)$$

and the direction θ can be expressed as:

$$\theta = \tan^{-1} \frac{R_y}{R_x} \quad \text{----------(4)}$$

In these equations, W stands for the speed of each individual west wind, SE for the magnitude of each individual south-east wind, (N to north, S to south, SW to south-west) and so forth.

3. Results and Discussion:

The annual average of wind direction was obtained by finding the annual average vector direction using the computed hourly wind vector components form the reported values of wind speed and direction for period of the site, and also the monthly average of wind direction was obtained and these monthly statistics were grouped into (winter, spring, summer and autumn) seasonal values.

In this work the compass is divided into 12 sectors, one for each 30 degrees of the horizons. In order to evaluate the frequency with which the wind direction falls within each direction sector, we present the data collected in the form of wind rose.

The summary statistics for the seasonal and annual data for the surface wind speeds at 10 meters and the percentage confidence intervals for the means and standard deviations of each variables (seasonal and annual data), shown in the table (1). Tables (2 and 3) summarizes the percentage and direction of the resultant vector of the mean wind direction, and the number of the hours that the winds blowing and the percentage frequency of the clam winds of the observed time series.

Table (1) Seasonal and annual statistics summary data

	Winter	Spring	Summer	Autumn	Annual
Mean	2.133	2.530	2.247	1.912	2.133
Variance	2.348	2.671	2.380	1.664	2.348
Standard deviation	1.532	1.634	1.542	1.290	1.532
Standard error	0.026	0.027	0.026	0.022	0.026
Minimum	0.0	0.0	0.0	0.0	0.0
Maximum	12.7	12.4	10.2	8.16	12.7

Table (2) Monthly Wind rose frequency counts and frequency distribution data

Data	Resultant Vector %	Direction of the resultant Vectors		No. of the Hours	Frequency of the Calm wind	Annual mean wind speed m/s
Jan.	88	41°	NE	1019	2.00%	1.869
Feb.	97	70°	E	1233	0.99%	1.913
Mar.	94	45°	EN	1163	0.25%	2.600
April	81	48°	NE	2102	0.05%	2.544
May	97	50°	NE	1834	0.27%	2.519
Jun	92	60°	NE	2160	0.14%	2.532
July	82	53°	NE	1860	0.54%	2.239
Aug.	92	47°	NE	2220	0.05%	1.020
Sep.	92	72°	E	1801	0.06%	2.180
Oct.	97	47°	NE	2206	0.54%	1.998
Nov.	88	37°	EN	1355	2.21%	1.686
Dec.	85	43°	EN	699	0.00%	2.673

Table (3) Seasonal and Annual Wind rose frequency counts and frequency distribution data

Data	Resultant Vector %	Direction of the resultant Vectors		No. of the Hours	Frequency of the Calm wind	Annual mean wind speed m/s
Winter	91	53°	NE	3415	1.17%	2.133
Spring	89	61°	NE	6096	0.26%	2.530
Summer	86	69°	E	5881	0.24%	2.247
Autumn	92	44°	EN	4260	0.99%	1.912
Annual	89	56°	NE	19652	0.53%	2.133

The speed and velocity variances show notable seasonality, variance was generally higher in spring and lower in autumn, also the means of annual and seasonal wind speeds for the whole year exhibits the same pattern except for the autumn, this can be explained by the decrease of the temperature from summer to autumn, such a decrease causes the thermal convection and thus a fraction of the upper air momentum, which moves with higher velocities is transmitted to the surface layers causing the notice increase or decrease in the mean monthly wind speeds.

Figures [2(a, b, c, d, e,)] shows frequency histograms for the seasonal and annual wind speeds data separately. To show the information about the distribution of wind speeds and the frequency of the varying wind directions of the study area, one may draw a so-called wind rose on the basis of meteorological observation of wind speeds and wind directions. A wind rose is a polar plot which represents the percentage of time that the wind direction falls within each sector of the compass. The wind rose only tells one the relative distribution of wind directions not the actual level of the mean wind speeds (Droulhet S.:2005).

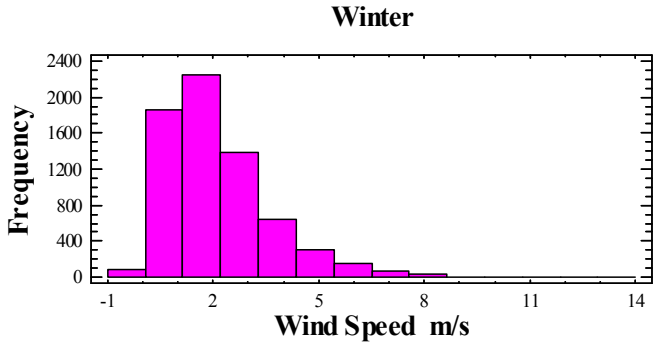


Figure (2a) a Frequency histogram for winter

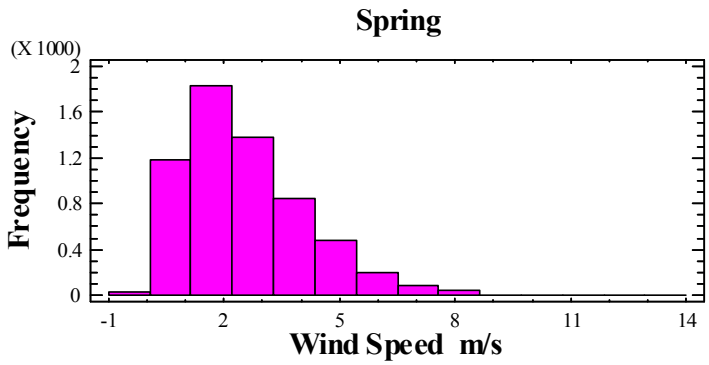


Figure (2b) a Frequency histogram for spring

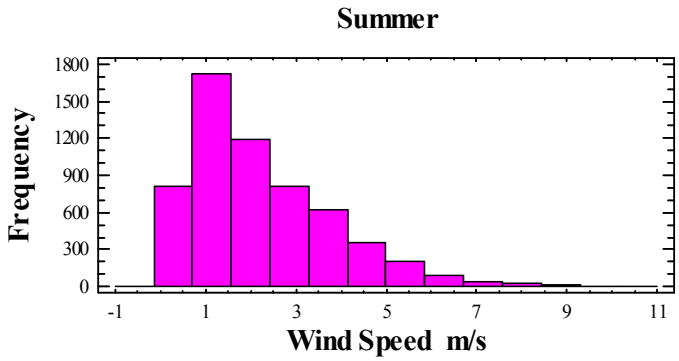


Figure (2c) a Frequency histogram for summer

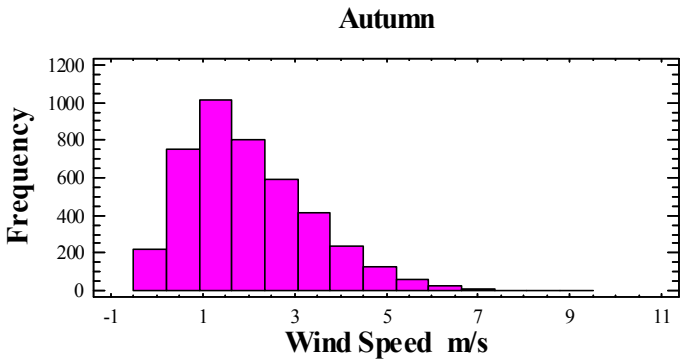


Figure (2d) a Frequency histogram for autumn

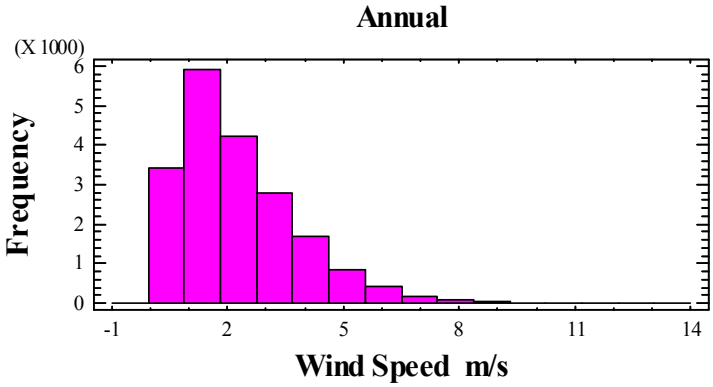
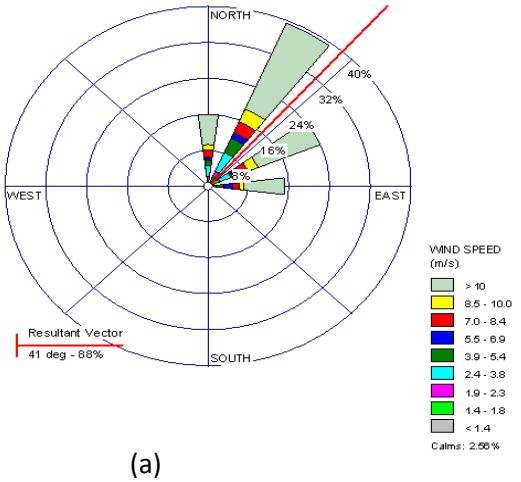
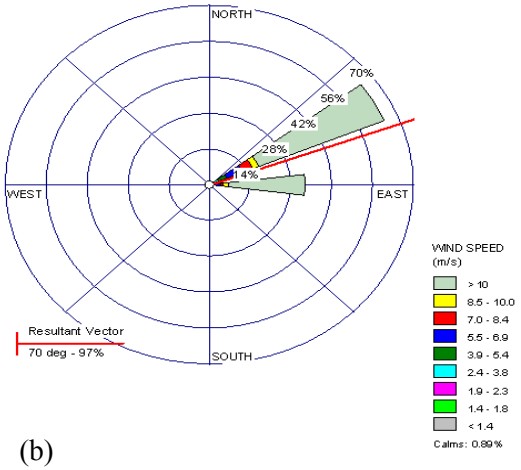


Figure (2e) annual Frequency histogram

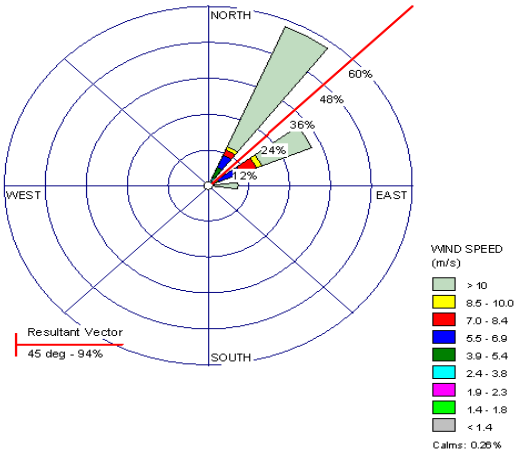
Figures (3, 4 and 5) show the monthly, seasonal and annual wind roses, respectively, recorded at the surface station of the study region for the period of one year (2003), it was shown that winds below between the two main directions North and East, while the only fluctuation is at the percentages and the resultant vectors of the directions, as shown in tables (2 and 3).


NORTH
40%
32%
24%
16%
8%
WEST
EAST
SOUTH
Resultant Vector
41 deg - 88%
WIND SPEED
(m/s)
> 10
8.5 - 10.0
7.0 - 8.4
5.5 - 6.9
3.9 - 5.4
2.4 - 3.8
1.9 - 2.3
1.4 - 1.8
< 1.4
Calms: 2.56%

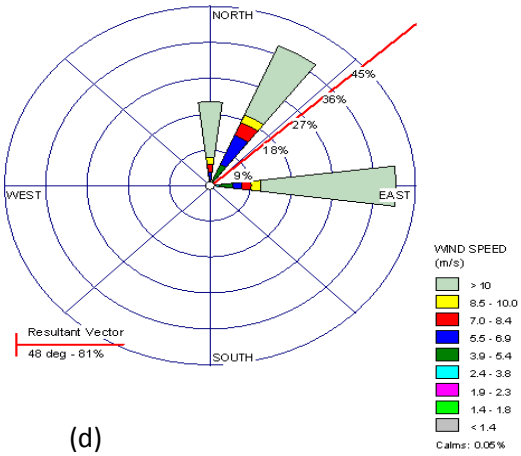
(a)


NORTH
70%
56%
42%
28%
14%
WEST
EAST
SOUTH
Resultant Vector
70 deg - 97%
WIND SPEED
(m/s)
> 10
8.5 - 10.0
7.0 - 8.4
5.5 - 6.9
3.9 - 5.4
2.4 - 3.8
1.9 - 2.3
1.4 - 1.8
< 1.4
Calms: 0.89%

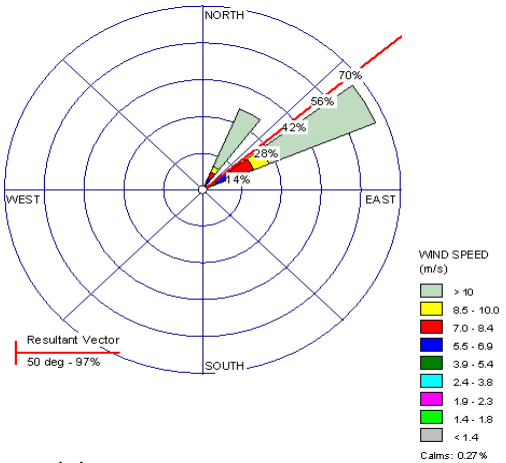
(b)


NORTH
60%
48%
36%
24%
12%
WEST
EAST
SOUTH
Resultant Vector
45 deg - 94%
WIND SPEED
(m/s)
> 10
8.5 - 10.0
7.0 - 8.4
5.5 - 6.9
3.9 - 5.4
2.4 - 3.8
1.9 - 2.3
1.4 - 1.8
< 1.4
Calms: 0.26%

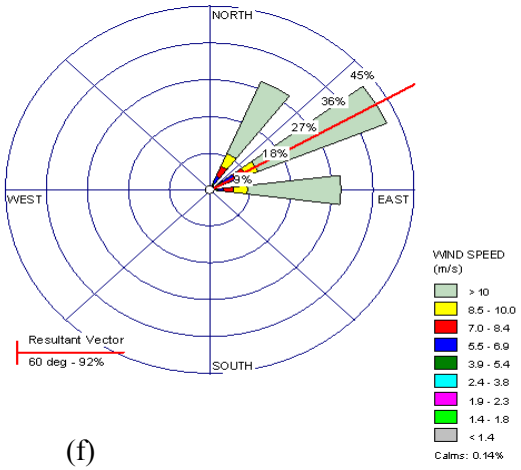
(c)


NORTH
45%
36%
27%
18%
9%
WEST
EAST
SOUTH
Resultant Vector
48 deg - 81%
WIND SPEED
(m/s)
> 10
8.5 - 10.0
7.0 - 8.4
5.5 - 6.9
3.9 - 5.4
2.4 - 3.8
1.9 - 2.3
1.4 - 1.8
< 1.4
Calms: 0.05%

(d)


NORTH
70%
56%
42%
28%
14%
WEST
EAST
SOUTH
Resultant Vector
50 deg - 97%
WIND SPEED
(m/s)
> 10
8.5 - 10.0
7.0 - 8.4
5.5 - 6.9
3.9 - 5.4
2.4 - 3.8
1.9 - 2.3
1.4 - 1.8
< 1.4
Calms: 0.27%

(e)


NORTH
45%
36%
27%
18%
9%
WEST
EAST
SOUTH
Resultant Vector
60 deg - 92%
WIND SPEED
(m/s)
> 10
8.5 - 10.0
7.0 - 8.4
5.5 - 6.9
3.9 - 5.4
2.4 - 3.8
1.9 - 2.3
1.4 - 1.8
< 1.4
Calms: 0.14%

(f)

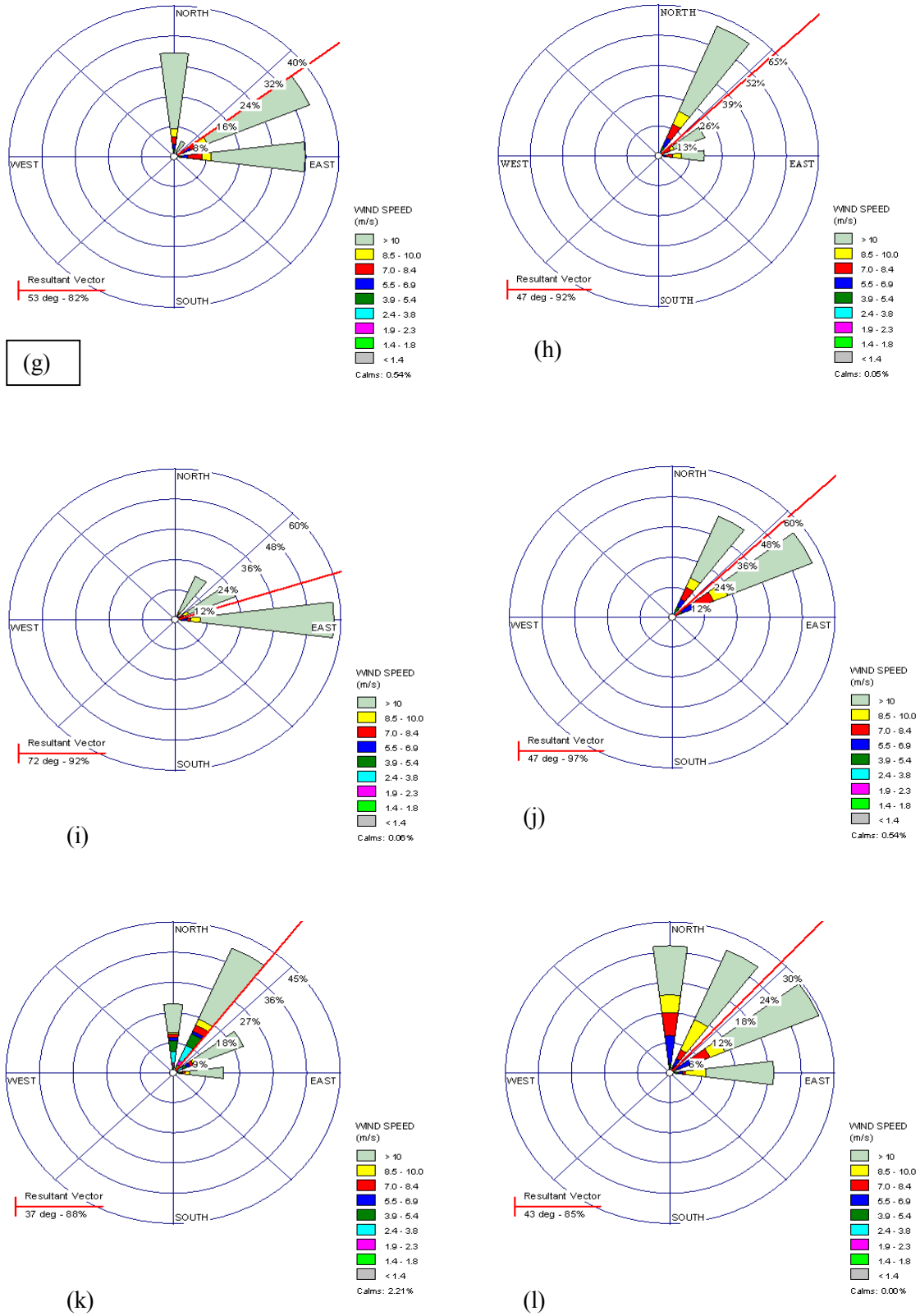


Figure (3,a,b,c,d,e,f,g,h,i,j,k and l**)** Monthly wind roses for (Jan, Feb, Mar, April, May, Jun, July, Aug, Sept, Oct, Nov, and Dec . respectively)

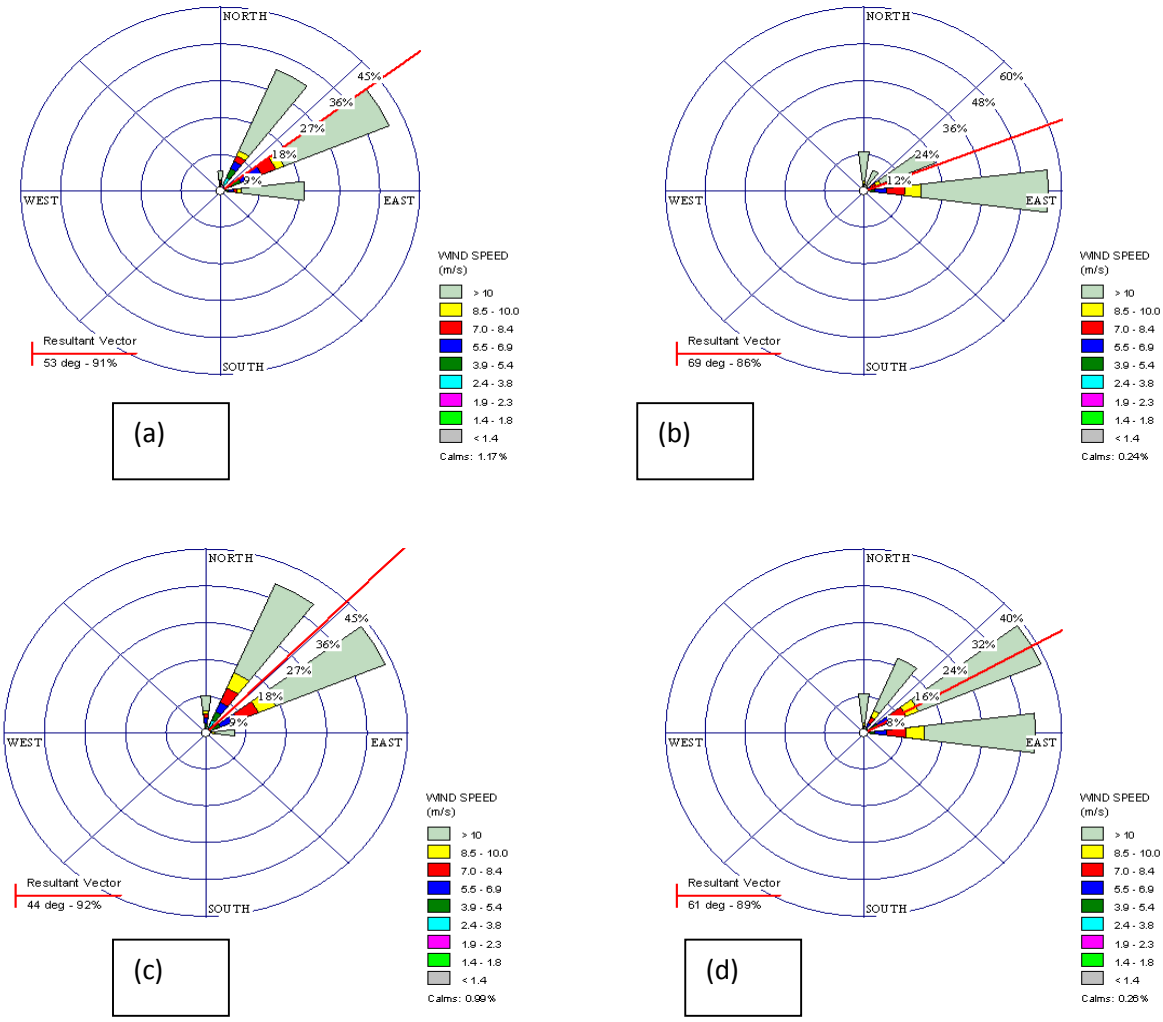


Figure (4, a, b, c, and d**)** Seasonal (Winter, Spring, Summer and Autumn) wind roses respectively.

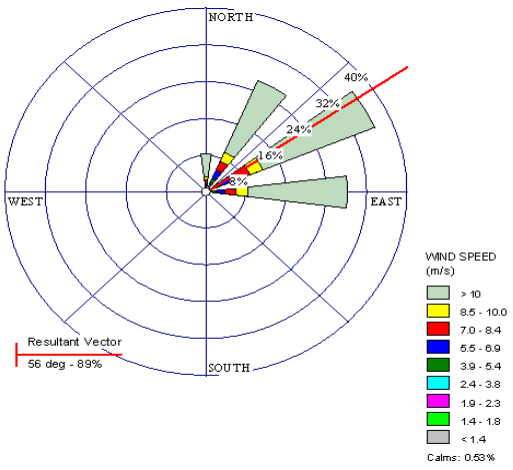


Figure (5) Annual wind rose

4. Conclusions:

The most important results obtained from this study can be summarized as follows for this particular site in north Iraq:

1- The seasonal mean wind speed and the standard deviations for the whole year exhibit the similar variation except the autumn months.

2- Wind direction data show that the maximum frequency and the dominant wind direction are between north and east.

3- The seasonal prevailing wind direction is as follows: for the winter the resultant vector wind direction is (53°) with (91%) of the time of observed wind, for the spring with the direction of (61°) and (89%) of the time of observed wind, for the summer, the prevailing wind direction is (69°) and (86%) of the time of observed wind and for the autumn with the direction (44°) of (92%) of the time of observed wind.

4- During the annual mean wind direction, the highest value of time (longer period) for which the wind blows is from the direction northeast (56°) with 19652 hours of observed wind, and 89% of the time.

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مميزات الرياح السطحية مع احتساب اتجاه الرياح في منطقة " كلار– السليمانية / شمال العراق"

الخلاصة

هذا العمل عبارة عن تحليل الرياح السطحية مع احتساب اتجاه الرياح الخاصة بمنطقة كلار الواقعة في جنوب مدينة السليمانية / شمالي العراق.

في هذا البحث استخدمت قراءة سرعة و اتجاه الرياح الساعية لسنة 2003 لرسم وردة الرياح الشهرية والموسمية و السنوية لتلك المنطقة , تم احتساب الخلاصة الاحصائية الموسمية و السنوية على ارتفاع (10) عشرة امتار , حيث ظهر ان وردة الرياح تعتمد على خريطة الرياح الموقعية و اتجاه الرياح السائده هو باتجاه الشمال و الشرق .