An investigation of wind characteristics on the campus of Izmir Institute of Technology, Turkey

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Abstract

The European Wind Atlas shows a very high wind energy capacity over the Aegean Sea and its coastal regions. Therefore, the western region of Turkey, which has a long coast along the Aegean Sea, appears to have high potential of wind energy. As a result of this fact, several studies have been performed to estimate the wind potential, especially, in western Turkey. However, due to the absence of a reliable and accurate Wind Atlas of Turkey, further studies on the assessment of wind energy in Turkey are necessary. In this study, the characteristics of wind on the campus of Izmir Institute of Technology, located in Cesme peninsula which has long coastline along the Aegean Sea, were studied over a period of one year. Measured data set and its evaluation showed that Izmir Institute of Technology campus area has a considerable wind energy potential. The study presented here is an attempt to promote wind energy in Turkey and to bridge the gap in order to create prospective Turkish Wind Atlas.
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Keywords: Wind energy; Wind site; Wind characteristics; Wind measurement mast; Weibull parameters

1. Introduction

Renewable energy resources have gained great importance, due to limited fossil fuel resources and their negative environmental impacts such as air pollution, acid rain and greenhouse effects. Increased cost of conventional energy resources, also,

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have helped renewable energy resorces to receive attention from all over the world. Among many renewable energy resources, wind energy seems to be the most suitable and cost effective power source for electricity production.

Detailed knowledge of the characteristics of wind is necessary for the design of wind energy systems. This is accomplished by using wind speed measurements. But this is a very difficult task, due to transitions in direction and speed of wind at most sites. Many studies have been completed to estimate the wind potential in different parts of the world. An example of these studies is the European Wind Atlas [1]. The European Wind Atlas shows a very high wind energy capacity over the Aegean sea and its coast regions. Therefore, the western region of Turkey which has a long coast along the Aegean Sea, appears to have high potential of wind energy.

The population increase and industrialization effort have created an awareness of the renewable energy resources in Turkey . As a result, several studies have been performed to estimate the wind potential, especially, in western Turkey. The assessments of wind power are studied by Tolun et al for Gökçeada [2]; Incecik and Erdoğmus [3], and Şen and Şahin [4] for western Turkey; Türksoy [5], and Dündar and Inan [6] for Bozcaada. However, due to the absence of a reliable and accurate Wind Atlas of Turkey, further studies on the assessment of wind energy in Turkey are necessary. The present study is an attempt to bridge this gap.

2. Materials and methods

2.1. Description of the site

Izmir Institute of Technology campus, which occupies 3500 ha area, is located in a county called Urla of Izmir province. Izmir province is right by the Aegean Sea and has a hilly topography. Urla is one of the main county in Cesme peninsula. The campus includes several hills with 15–25% incline. These hills are covered with typically Mediterranean bushes. Soil depth is very low and not suitable for vegetation. Fig. 1 shows the site on Izmir map.

2.2. The wind data measurement mast

Before installation of the mast, an aerial search was made by a helicopter in order to find the most appropriate site location. The site with coordinates of 465684E and 4243843N (in UTM coordinate system) at 460 m height, from sea level, was found to be the most suitable mast location in the area. There were no obstacles around the measurement area. The site was directly open to the Aegean Sea at north direction. The south and northwest directions were covered with hills. The wind data measurement mast was 30 m tall tubular tower which was erected in July 2000. The mast is shown in Fig. 2. It had two cup anemometers which were at 10 and 30 m heights, and one wind vane at 30 m height. Temperature, relative humidity, and atmospheric pressure data were obtained from a thermometer, a hygrometer and a barometer, respectively. A data logger was connected with all sensors on the mast
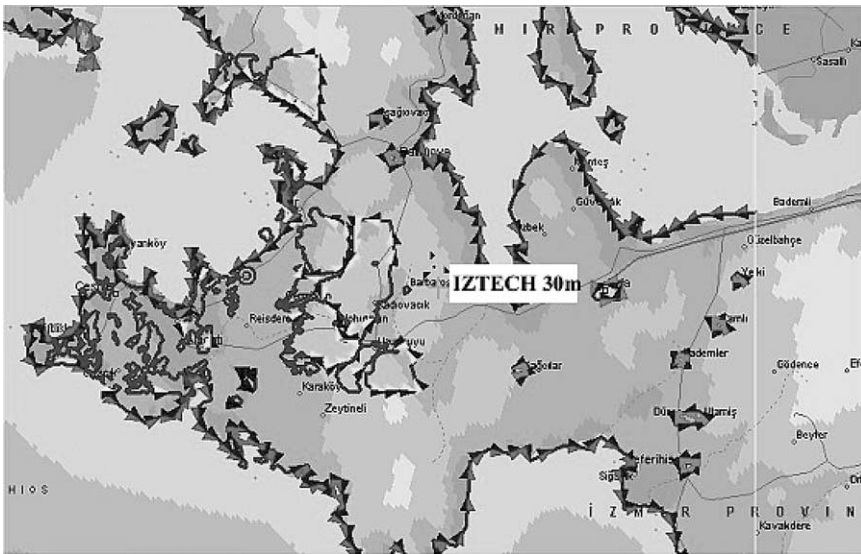
Fig. 1.   Location of the site.

to collect data in time series. Power for the equipments was supplied from an external battery charged by a solar panel. The mast was, also, equipped with a GSM modem system which was used by the data logger to achieve remote data transferring. The technical specifications for the equipments are shown in Table 1.

2.3. Data collection and evaluation

The data were collected for 16 months between July 2000 and November 2001. In the year of 2000 the data were collected with a rate of 24 observations per day using 1 h time intervals . But in 2001 time interval rate was changed to 144 observations per day using 10 min time intervals.The missing data should not exceed 10% according to the standards [7]. In this study, the missing data were 3.7% in the total collected data. The time interval configuration change was done to gain more precise results. The 'CALLaLOG' software was used for remote data transferring. The 'wind-PRO' software played a key role to evaluate all collected data in order to make wind analysis considering orography and topography at the site.

The collected data included date and time stamp, wind direction, maximum, minimum, average and deviation values of wind speeds at 10 and 30 m heights of the mast, relative humidity, temperature and barometric pressure.

Commercially available 'Encarta Digital Atlas' compact disc was used for area map. Digital height counter map which covers area within 5 km radius and surface roughness map which covers 20 km radius around measurement point were created and loaded into 'windPRO' software. There were no obstacles around measurement point in 12 sectors.
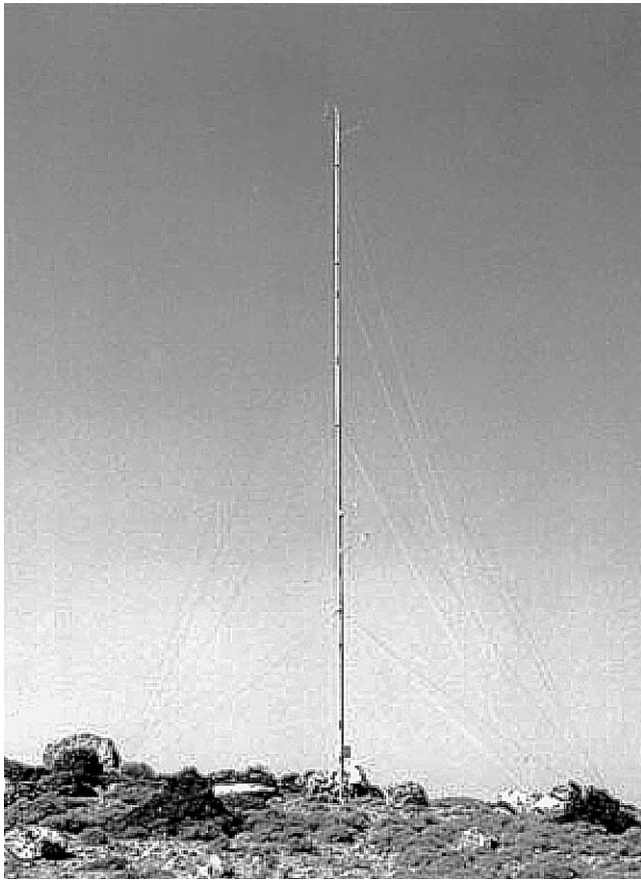
Fig. 2.   Mast erected on the campus.

Table 1
Nominal specifications of the equipments

Specification	Anemometer	Wind vane	Thermometer	Hygrometer	Barometer
Measurement range	0.3–50 m/s	0–360°	(−30)–(+70) °C	0–100% RH	800–1600 hPa
Accuracy	±2%	±2%	±2 K	±2% RH	–
Resolution	0.05 m/s	1°	0.1°C	1%	1 hPa

3. Results and discussion

3.1. Analysis of atmospheric parameters

Table 2 shows monthly averages of the temperature, relative humidity and atmospheric pressure for one year. The temperature average was 16.3°C. The maximum

Table 2
Monthly average values of atmospheric parameters

Months	Relative humidity (%)	Temperature (°C)	Barometric pressure (hPa)
Jul-00	42	26.3	955
Aug-00	49	23.2	957
Sep-00	56	20.5	958
Oct-00	75	14.2	961
Nov-00	73	13.8	962
Dec-00	82	8.2	967
Jan-01	74	10.6	995
Feb-01	75	10.9	994
Mar-01	71	12.5	958
Apr-01	75	17.2	974
May-01	68	15.9	961
Jun-01	46	21.9	960

and minimum monthly average temperatures were 26.2°C in July 2000 and 8.2°C in December 2000. The atmospheric pressure average was 967 hPa. The maximum average value of 995 hPa and minimum average value of 955 hPa were observed, respectively, in January 2001 and in July 2000. The annual average of relative humidity was 65% with maximum value of 82% and minimum value of 42% observed, respectively, in July 2000 and December 2000.

3.2. Wind speed analysis of monthly mean speed

The wind speeds were measured by two anemometers located at 10 and 30 m height on the mast. The reason for measuring wind speeds at two different heights was to calculate wind shear value. Figs. 3 and 4 show monthly mean speed variations at 10 and 30 m, respectively. The average speeds were 7.03 m/s at 10 m, and 8.14 m/s at 30 m. It can be noted that monthly average speeds were always higher than cut-in speeds of the most horizontal axis wind turbines.

3.3. Wind direction analysis

Figs. 5 and 6 show wind speed, wind direction and turbulence intensity variations for 10 m and 30 m, respectively. The prevailing wind directions are north and north–northeast sectors. There were strong winds blowing from southern sectors too. But their frequencies were quite low. Weibull histograms are determined for 12 sectors at 10 and 30 m heights separately. Tables 3 and 4 show Weibull data, respectively, for 10 and 30 m heights. Histograms for each separate sector can be seen in Figs. 7 and 8 for 10 m measurements and in Figs. 9 and 10 for 30 m measurements. These figures show that 78.6 and 74.9% of the wind blew from north, respectively, at 10 and 30 m height. NNE sector is another main sector, but its frequencies are only
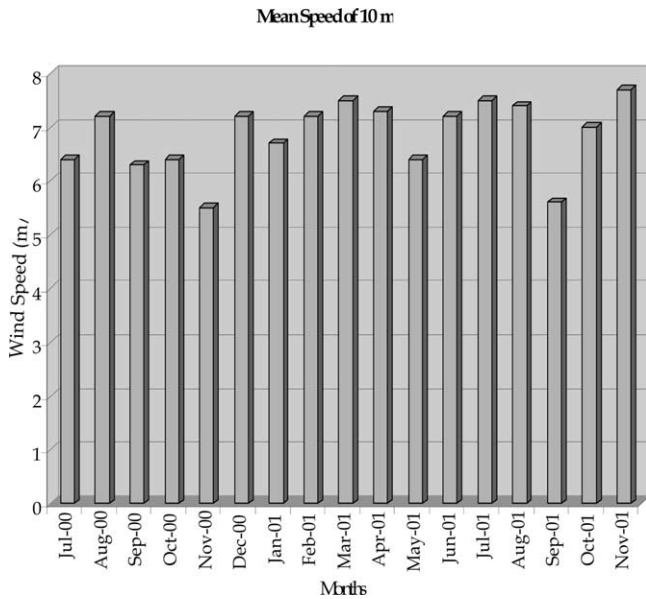
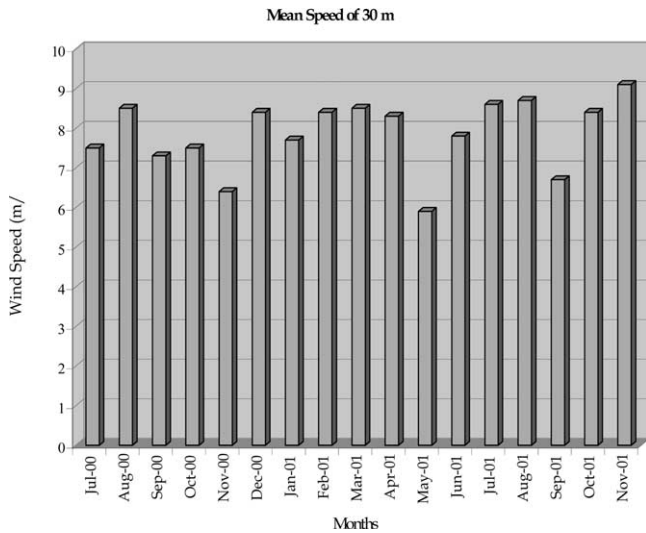Fig. 3.   Variation of monthly mean speeds at 10 m height.

Fig. 4.   Variation of monthly mean speeds at 30 m height.

4.7 and 5.3%, respectively, for 10 and 30 m measurements. Frequencies for other sectors are not higher than 3.9%.
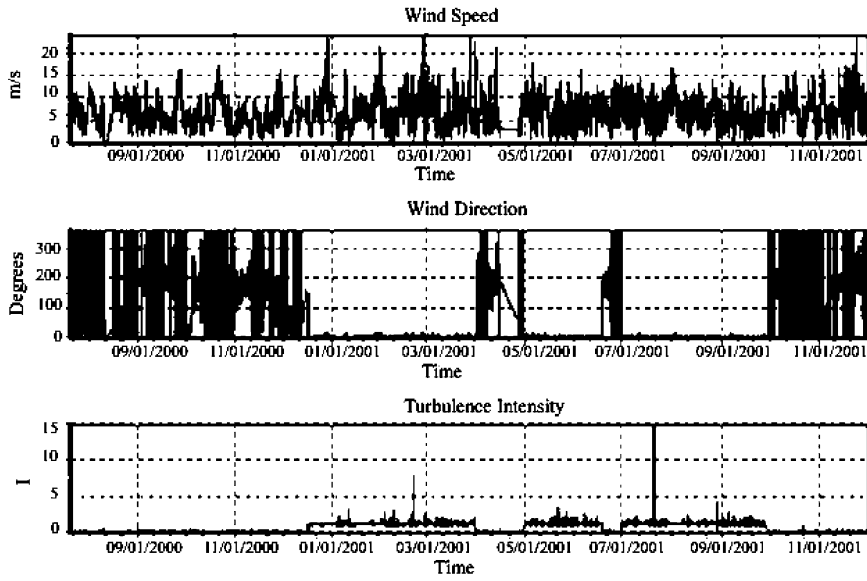
Fig. 5. Wind speed, wind direction and turbulence intensity variations at 10 m height.
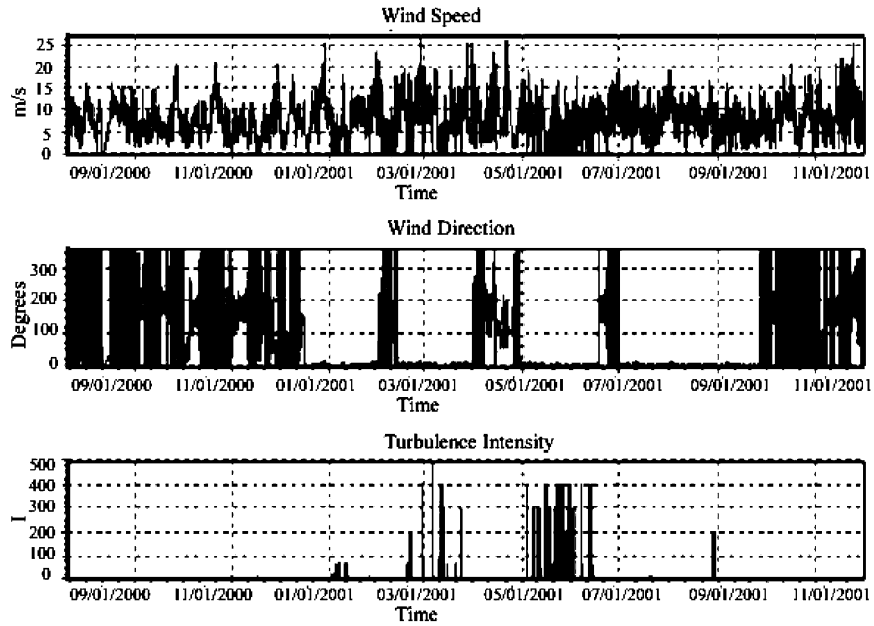

Fig. 6. Wind speed, wind direction and turbulence intensity variations at 30 m height.

Table 3
Weibull parameters for 12 sectors according to measured data at 10 m height

Sector	A-parameter (m/s)	Mean wind speed (m/s)	k-parameter	Frequency	Wind shear
N	8.08	7.17	2.470	78.61	0.14
NNE	8.41	7.56	1.575	4.65	0.14
ENE	4.10	3.66	1.692	0.66	0.09
E	4.37	3.88	1.925	0.69	0.07
ESE	8.70	7.71	2.059	1.53	0.13
SSE	8.07	7.21	1.648	3.19	0.13
S	6.77	6.10	1.542	2.57	0.13
SSW	6.39	5.66	2.272	2.30	0.21
WSW	7.24	6.47	1.683	0.94	0.10
W	5.97	5.54	1.278	0.88	0.05
WNW	5.94	5.28	1.837	1.56	0.07
NNW	7.85	6.99	2.888	2.42	0.13
Mean	7.94	7.03	2.228	100.00	0.14

Table 4
Weibull parameters for 12 sectors according to measured data at 30 m height

Sector	A-parameter (m/s)	Mean wind speed (m/s)	k-parameter	Frequency	Wind shear
N	9.41	8.35	2.473	74.86	0.14
NNE	9.77	8.74	1.633	5.25	0.13
ENE	4.45	3.99	1.596	0.80	0.08
E	4.73	4.20	1.820	0.81	0.07
ESE	10.09	8.94	2.111	1.70	0.13
SSE	9.31	8.31	1.693	3.92	0.13
S	7.87	7.03	1.690	3.48	0.13
SSW	8.08	7.16	2.052	2.86	0.21
WSW	8.10	7.23	1.668	0.99	0.10
W	6.29	5.88	1.235	0.92	0.05
WNW	6.40	5.68	1.886	1.66	0.07
NNW	8.99	8.04	3.082	2.75	0.13
Mean	9.19	8.14	2.211	100.00	0.13

3.4. Wind turbulence analysis

Weibull parameters listed in Tables 3 and 4 show that mean wind speeds of north sector are 7.17 m/s at 10 m height and 8.35 m/s at 30 m height. Shape factor (k) for 30 m height is 2.473 which means that measured data differ from the Rayleigh distribution. Eight sectors out of 12 sectors have mean speeds higher than 7 m/s at 30 m height. This is an excellent result in the name of high wind energy potential.

Turbulence intensity is very high in the north sector at 10 m height as shown in
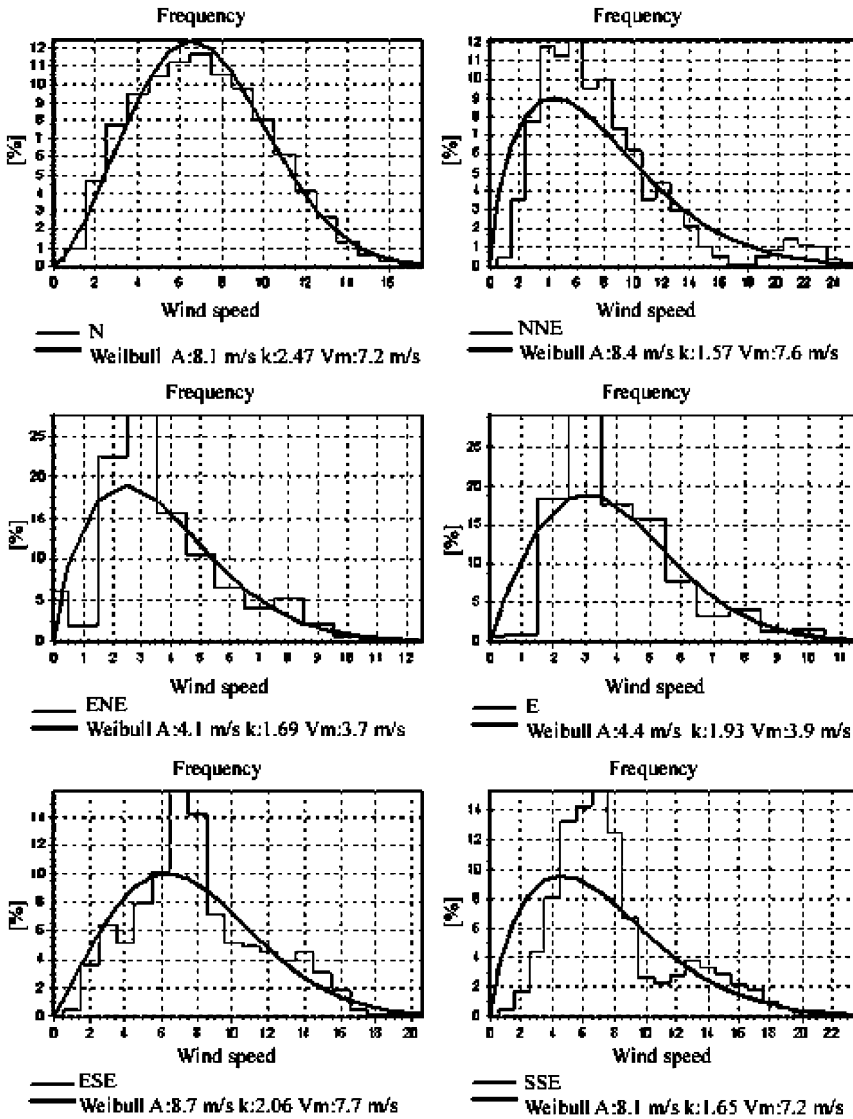
Fig. 7.   Weibull and turbulence histograms of the easterly six sectors at 10 m height.

Fig. 11. But, Fig. 12 which depicts evaluation of the data measured at 30 m height, shows very low turbulence in north direction. These two contradictory results are not unexpected, because of surface roughness influence at 10 m height. Measurements at 30 m height show turbulence-free characteristic which should be considered as the more realistic graph of the site. Complex terrain and the hills with different heights cause turbulence at other sectors.
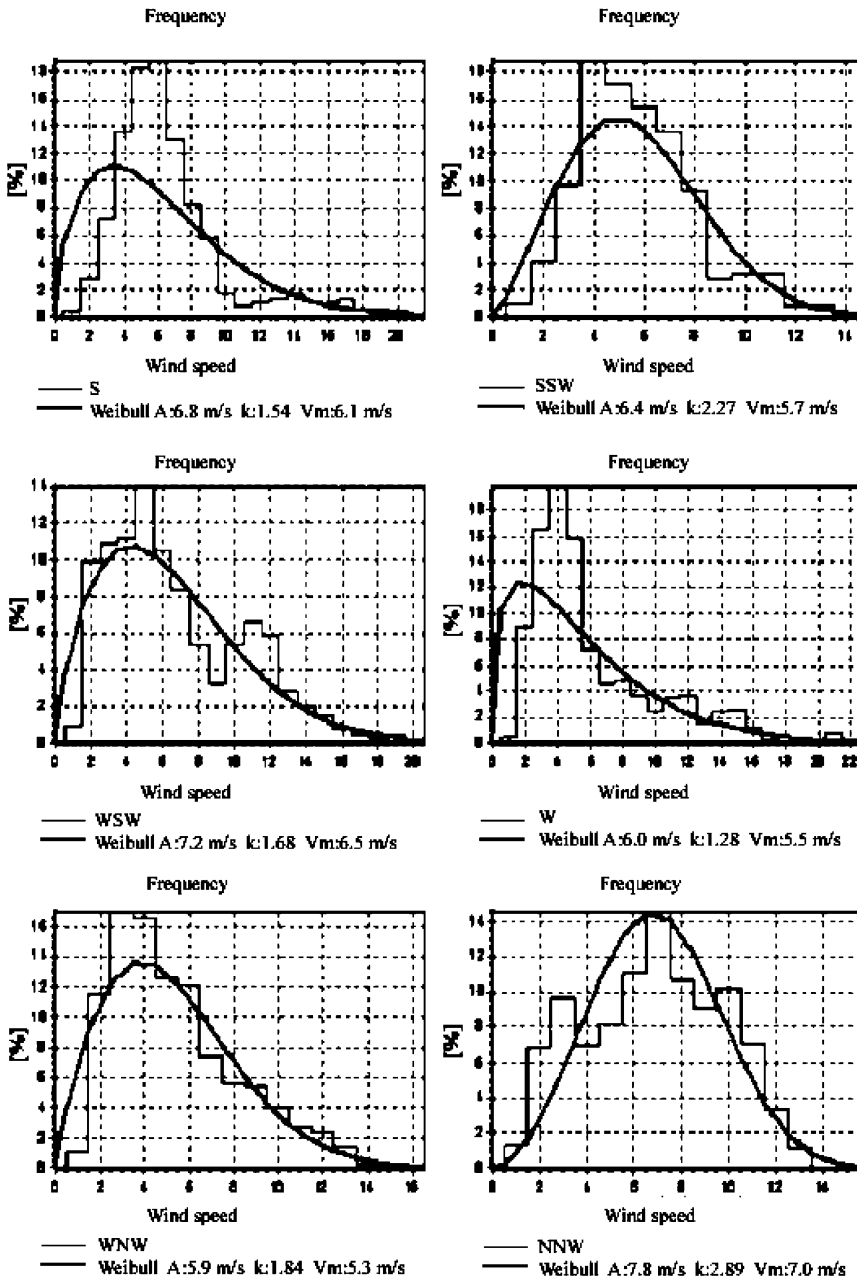
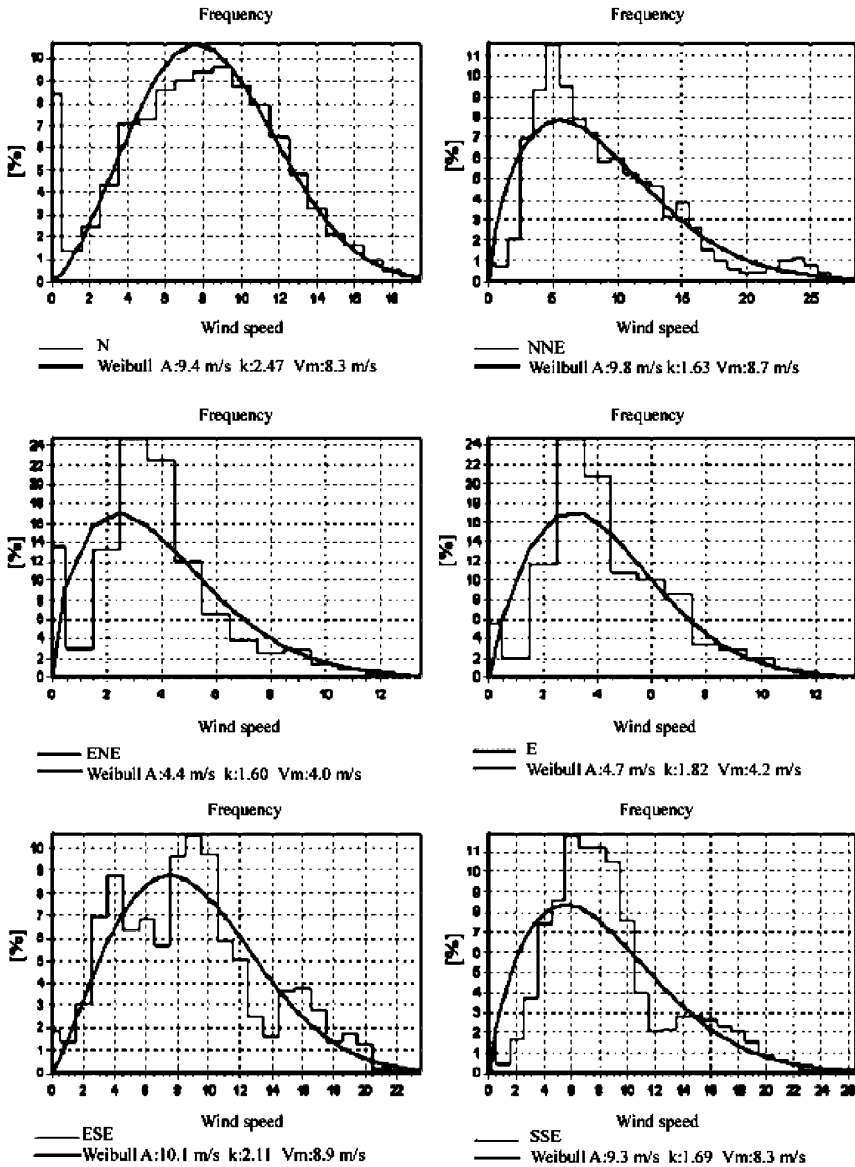Fig. 8.   Weibull and turbulence histograms of the westerly six sectors at 10 m height.

Fig. 9.   Weibull and turbulence histograms of the easterly six sectors at 30 m height.

3.5. Mean wind speed map

Collected data have been evaluated by 'windPRO' and 'WASP' softwares to create mean wind speed map of the campus. Roughness map of the measurement site with 20 km radius and orography map with 5 km radius have been used by 'WASP' to
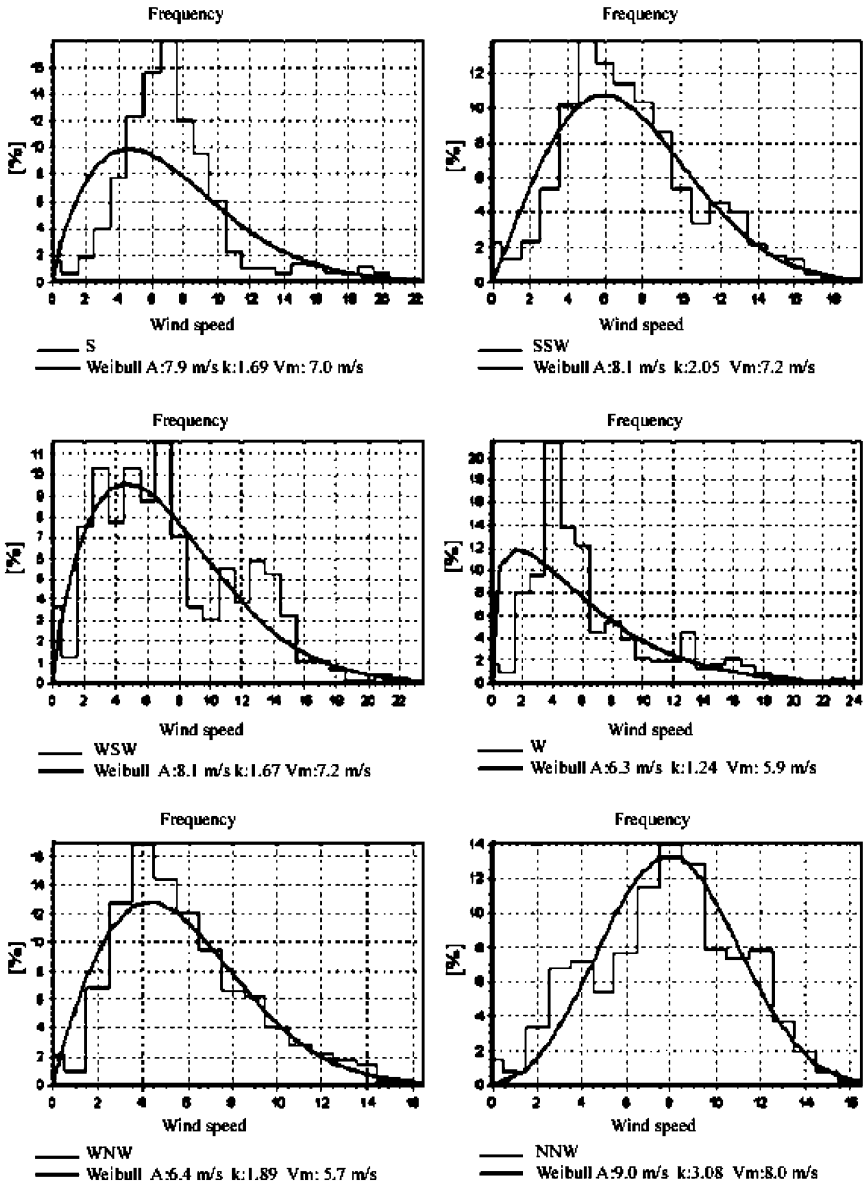
Fig. 10.   Weibull and turbulence histograms of the westerly six sectors at 30 m height.

predict mean speeds of other locations of the campus. Created map covers 177.7 km² area with a resolution of 50 m. Fig. 13 shows mean wind speed zones.
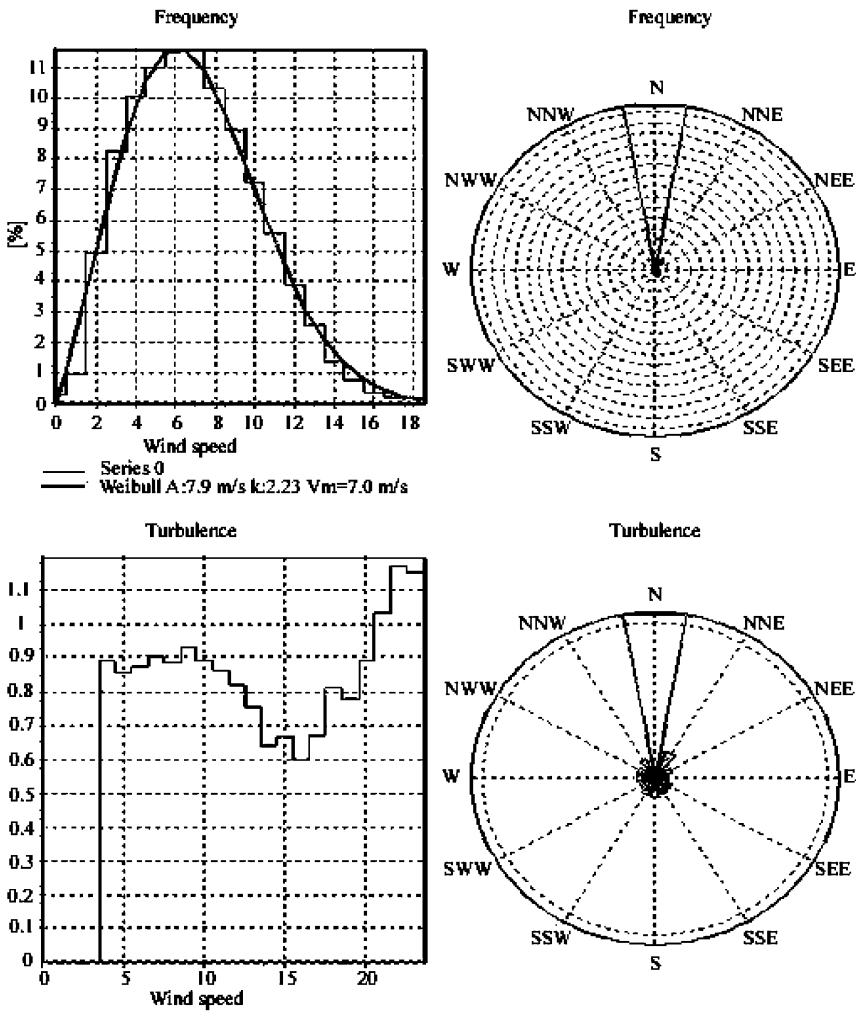
Fig. 11.   Wind rose and histograms of wind speed and turbulence at 10 m height.

4. Conclusion

   The study presented here is an attempt to promote wind energy in Turkey and to bridge the gap in order to create prospective Turkish Wind Atlas. A standard wind measurement mast was erected on the campus in order to investigate wind character-istics. 'WASP' and 'WINDPRO' softwares used for evaluation of measured data were generally representative of the area. Weibull approximation was found to be better than that of Rayleigh model. Turbulence-free character of the wind, especially at prevailing direction, was one of the most important results of the study. The result derived from this study encourages the utilization of wind energy potential on the
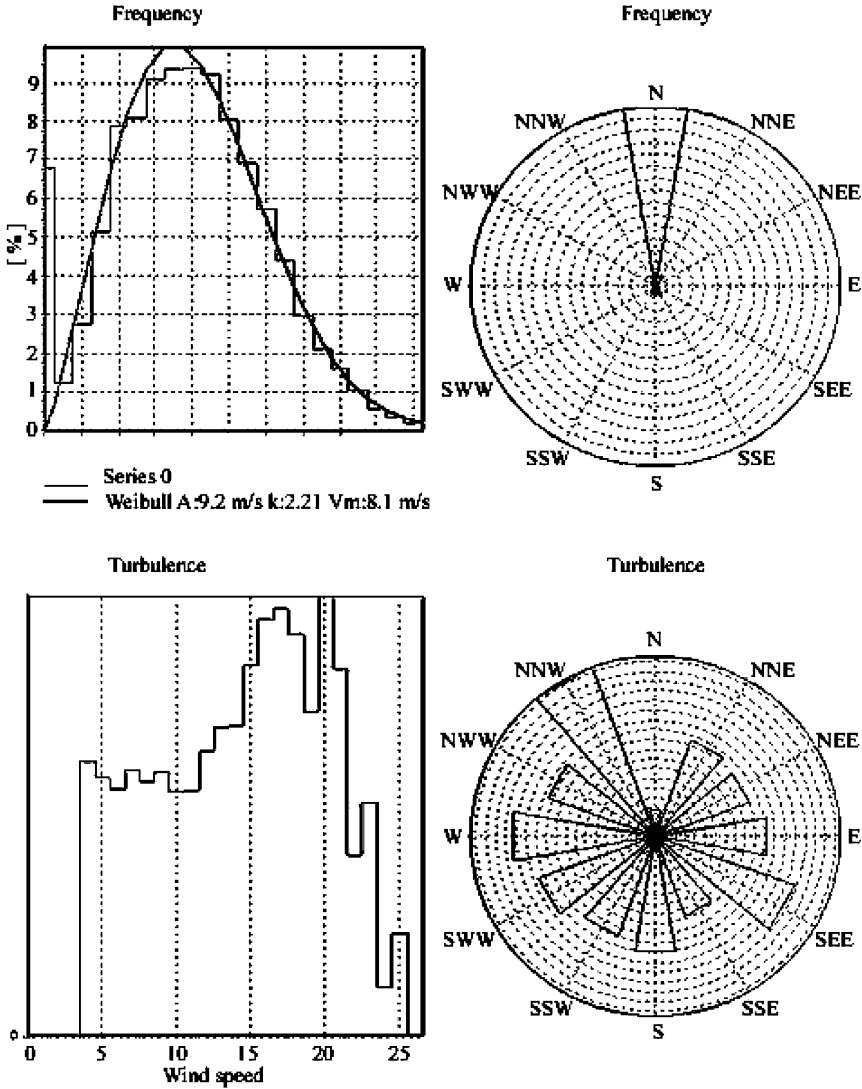
Fig. 12.   Wind rose and histograms of wind speed and turbulence at 30 m height.

Izmir Institute of Technology campus area. The presence of high wind potential in the area is explicitly demonstrated.
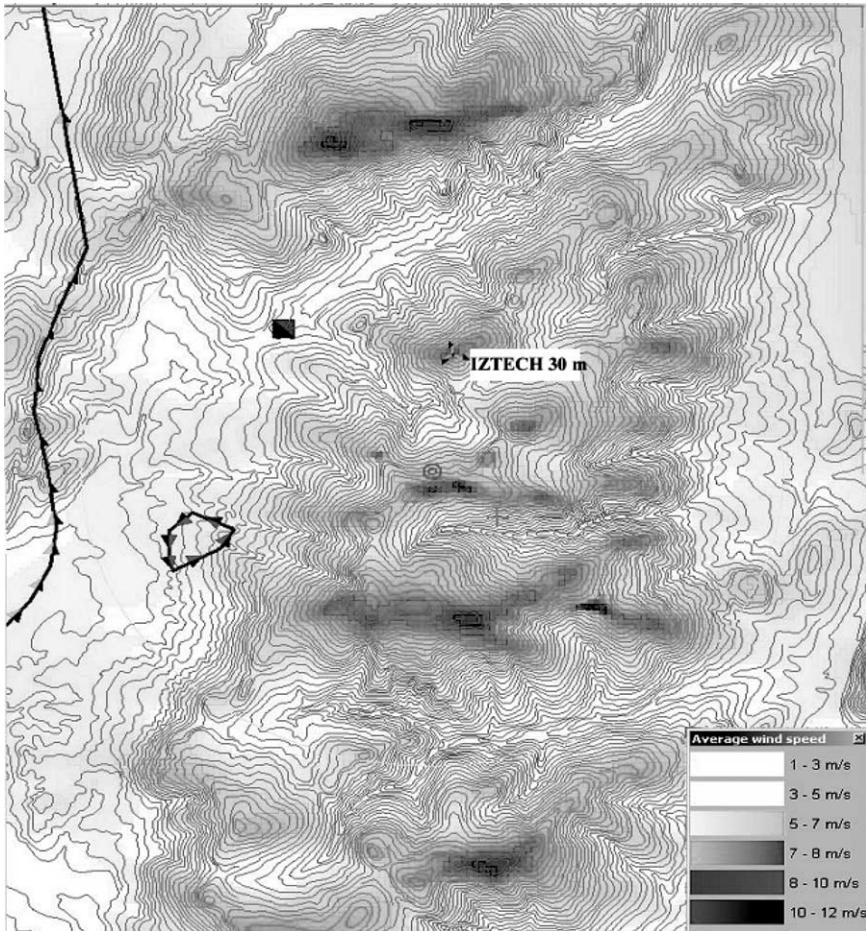
Acknowledgements

Fig. 13.   Average mean speed map of the area.

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