

THE POTENTIAL WIND POWER RESOURCE IN CENTRAL-SOUTH OF THE CONSTANTA COUNTY

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Abstract: Usually, wind turbine generator's structures or radio masts are located in wind exposed sites. The paper aims to investigate the wind conditions in the nearby area of Cobadin Commune, Constanta County, Romania at heights of 150-200m above the surface using global reanalysis data sets CFSR, ERA 5, ERA I and MERRA 2.

Using the extreme value theory and the physical models of the datasets, the research focuses on the assessment of the maximum values that are expected for the wind speeds, but the wind statistics created can be used for a further wind or energy yield calculation.

Without reaching the survival wind speed for wind turbine generators, with mean wind speed values higher than 7 m/s and considering the cut-in and cut-out wind speeds of 3 m/s, respectively 25 m/s, the site can be exploited in more than 90% of the time to generate electricity, thus, the paper is addressed to the investors in the energy of renewable sources. At the same time, the insights of the wind characteristics and the knowledge of the extreme values of the wind speed can be useful, not just for the designers, in the rational assessment of the structural safety of wind turbines, but also those evaluating the insured losses.

Keywords: wind energy, extreme values, wind Constanta County, wind turbine generators

1. Introduction

The objective of this paper was to evaluate the maximum values that are expected for the wind speeds in the Constanta County, area of Cobadin Commune.

Lately, to identify, estimate and to take into consideration the natural hazards has become a common practice not only when human life or the environment are in danger, but also when it is the case to mitigate the economical losses of commercial activities.

Also, an accurate prediction of the wind speed extremes can be useful in the process of evaluating the insured loss and also for an accurate assessment of the wind turbines structural safety.

Being aware of the aspects presented above and motivated by the international trend of developing renewable energy technologies that will form the backbone of the energy system the paper uses wind data series that describes the wind conditions at a height of 150m above the surface. The wind data series are build using satellites observations, surface observations, rawinsondes, buoys and other in situ measurements from ships and aircraft [9]. This approach is limited by the transversal aspect of the work, a further and deeper study can bring out a result with a higher interdisciplinary impact. A significant barrier to research across this field is the lack of historic data [6]. This affects the renewable energy market where the wind characteristics need to be understood in depth at regional scale, rather than a national and continental scale. Wind data series were used in industry for modeling wind power [6], [8] but due to commercial confidentiality, the academic research can not take advantage; nevertheless, in academia, for both offshore and onshore, studies based on the use of reanalysis data began to proliferate in 2014 for broad continental regions [5], [11], or limited to a single country [2], [3], [7], [10].

While the paper outlines in the next section (Wind data and Site location) the characteristics of the investigated site as well the attributes of the wind data series used; the results of the analyses performed using the extreme value theory and the physical models of the datasets (provided by the company Vortex S.L., with headquarters in Barcelona, Parc Tecnologic Barcelona, Carrer Marie Curie 8-14, 08042, Spain) are presented in Section 3 (Results) and discussed under the Section 4

(General Discussion) using rose wind charts, data histograms and probability density functions, exceedance probabilities and return periods for Gumbel and Fréchet distributions. Section 5 concludes and considers further applications.

2. Wind data and Site location

The studied area was chosen having in mind the favorable conditions for implementing wind farm projects with respect to accessibility to the location, access to the electrical grid, soil conditions, the existing telecommunication infrastructure, existing commercial activities, designated use of the area and population density.

Cobadin Commune is located in the southern region of the Constanta County, in the south eastern part of Romania. It is located at approximately 35 km southwest of the city of Constanta and approximately 40 km northwest from Mangalia town.

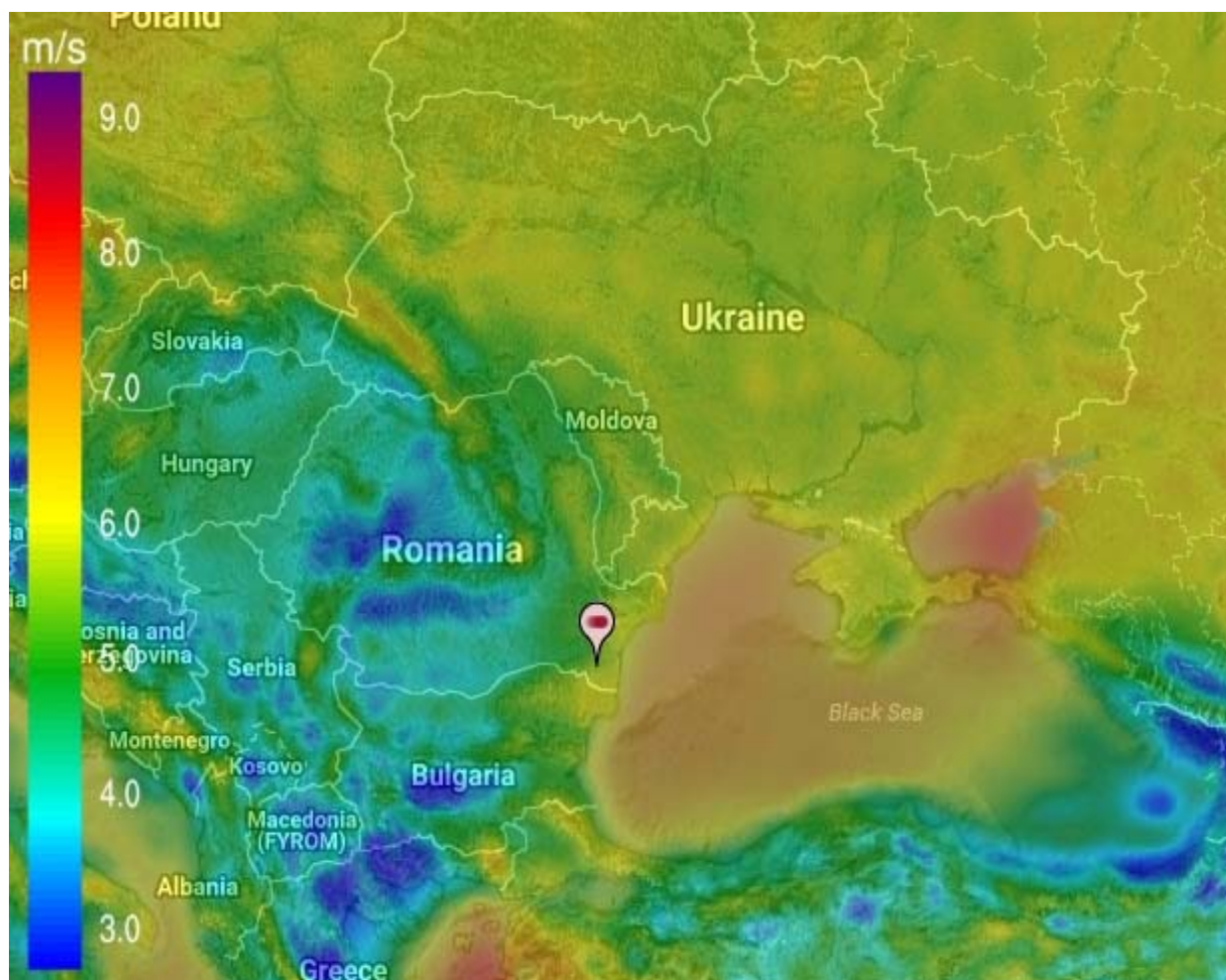


Fig. 1 - The region and the mean wind speed; <http://www.vortexfdc.com/>

The terrain conditions in the location and its vicinity are characterized by an almost flat orography, with height differences around 30 m and very low slope values.

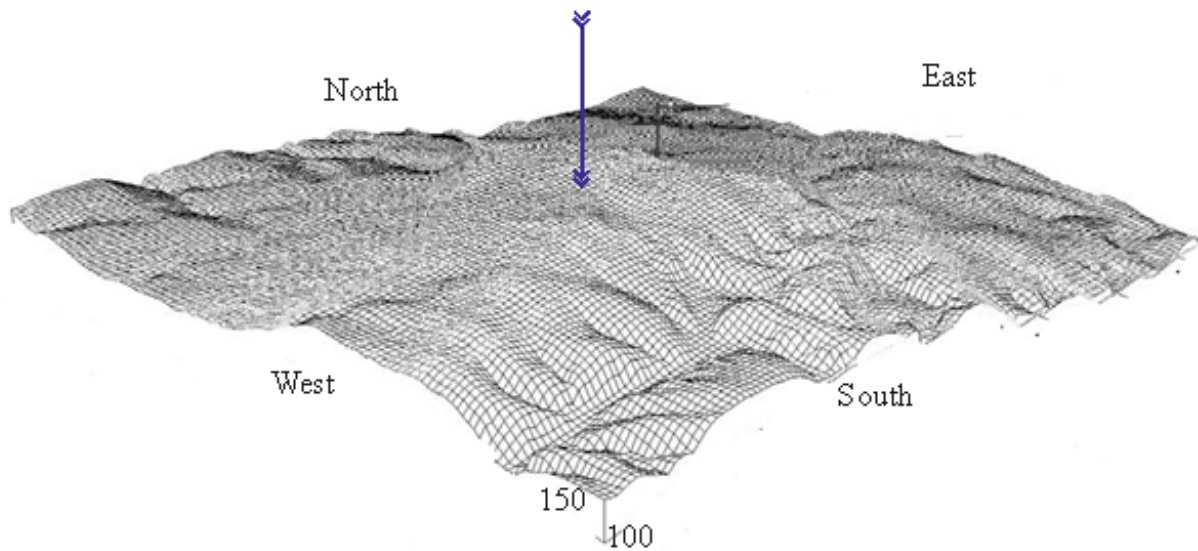


Fig .2 - Orography around the point with coordinates 44.050337 lat, 28.18285 long Cobadin (12 km x 12 km), indicating a moderate height excess in the views from the South and West directions

The orography and elevation was reconstructed around the point with the coordinates 44.050337 lat., 28.18285 long. The vegetation data set was represented on a regular 10 arc second lat./long. grid (about 300 m) and a combined global data set on a regular lat/long grid of 30 arc sec resolution.

The topography of the investigation area is governed by agricultural land (crop fields and pastures), with an open character. Only in the north eastern part there are some forested areas. No major city is located in the nearby areas but several villages, from which Cobadin and Viisoara are the closest, are to be found in the surroundings.

Since the first space observation of solar irradiance and cloud reflection was made with radiometers onboard the Vanguardsatellite in 1959 [14], satellite remote sensing has gradually become a leading research method in climate change studies.

Observations using satellites have seen a strong development in recent years because the high degree of fidelity of in-situ calibration has led to a high level of accuracy and reliability of cross-satellite calibration.

Even though there are surface recordings, rawinsondes, buoys and other in situ measurements from ships and aircraft, the observations are limited in global coverage. Satellite observations play a crucial role filling the gaps in the data for sparse regions [9].

In recent years, global reanalysis datasets with high spatial and temporal resolution have been used to compensate for the lack of direct observations [1], [4], [9], [13]. In this research four reanalysis datasets were used: CFSR (Climate Forecast System Reanalysis), ERA I (The European Centre of Medium-range Weather Forecasts Interim), ERA 5 (fifth generation of ECMWF atmospheric reanalyzes), MERRA 2 (the Modern Era Retrospective – Analysis for Research and Applications by the National Aeronautics and Space Administration).

The temporal resolution is 1 hour for the period: February – July 2017.

Having in mind the above, the uncertainty given by the physical models used in reanalysis methods it is considered to have the values of 9,9% for CFSR, 10,3% for ERA I, 6,8% for ERA 5, 9,6% for MERRA 2.

3. Results

The topography of the investigation area is governed by agricultural land (crop fields and pastures), with an open character. Only in the north eastern part there are some forested areas. No major city is located in the nearby areas but several villages, from which Cobadin and Viisoara are the closest, are to be found in the surroundings.

The nearby forests located nearby Cobadin village are usually composed by false acacia trees, with heights not exceeding 10 m. In accordance with the *European Windatlas*, the equivalent roughness class is 2 at reference height 150 m above ground for the site (cumulating the effects of roughness, orography and obstacles).

The time series have been classified according to wind direction and wind speed. The wind rose diagram is developed for all sectors over the entire studied time period and for each representative sector for periods where extreme events were recorded. In the first situation, the chart was divided into 36 cardinal and inter-cardinal directions, with eight wind speed classes being highlighted and the results as shown in Fig. 3, 5, 7, 9 for each dataset, *CFSR*, *ERA 5*, *ERA I*, respectively *MERRA 2*.

For further mathematical processing, the distributions are approximated by the Gumbel and Fréchet distributions (Fig. 4, 6, 8 10).

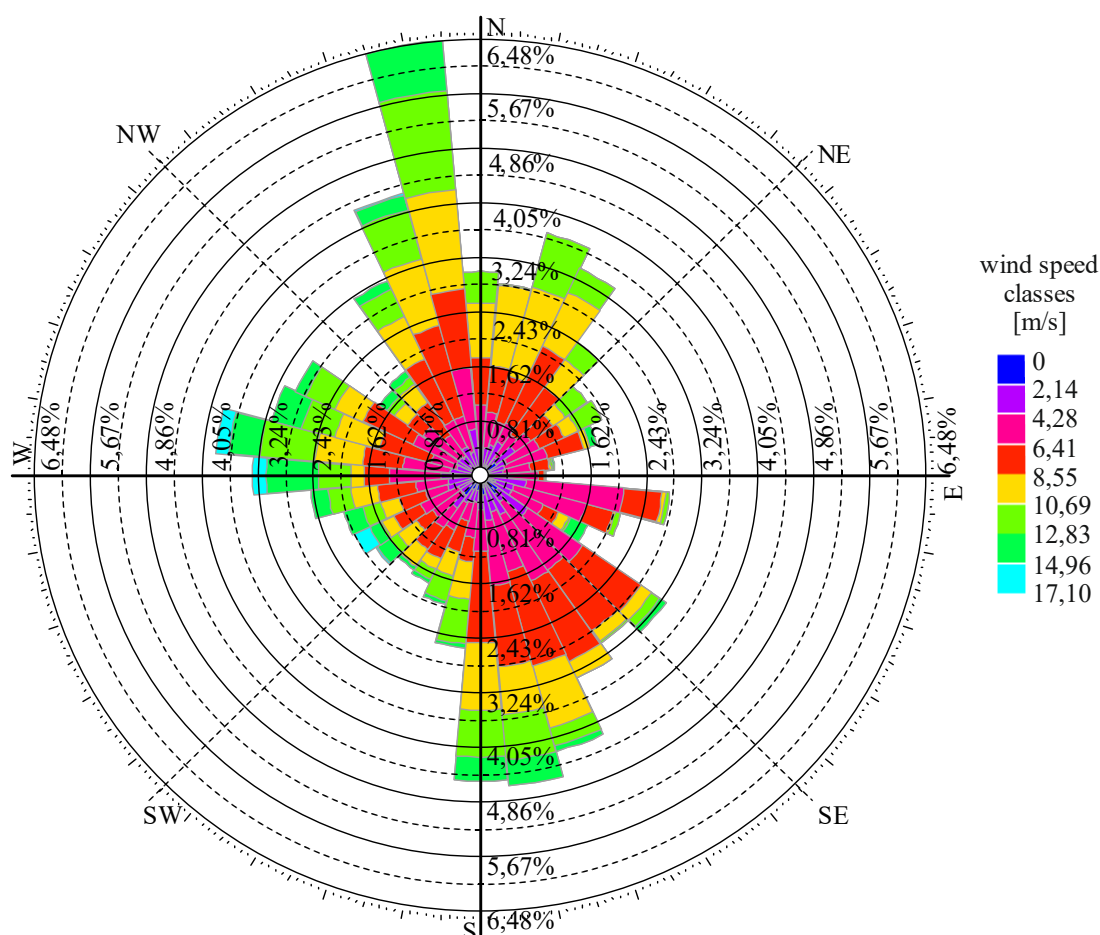


Fig. 3 - Wind Rose Chart CFSR 150 m

Sectors number:	36
Analysed sectors:	all
Period:	February ÷ June 2017
Mean speed value; azimuth	7,5 m/s; 305,6°
Speeds ratio below threshold	3 m/s 9,3 %
	3,5 m/s 12,1 %
	4 m/s 15,7 %

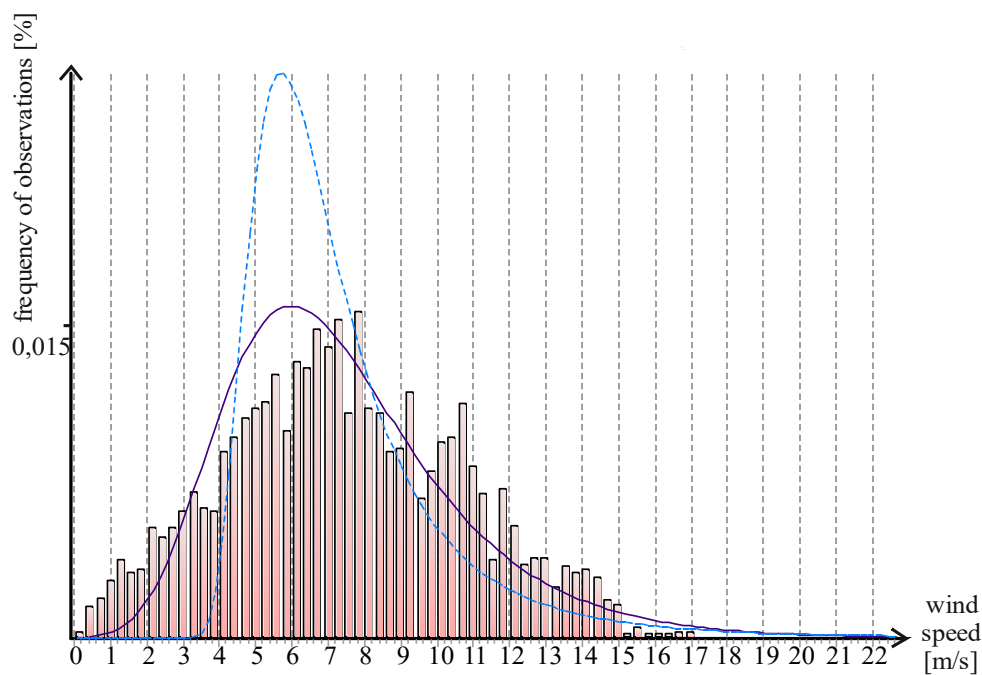


Fig. 4 - Probability Density Function *CFRS* 150 m

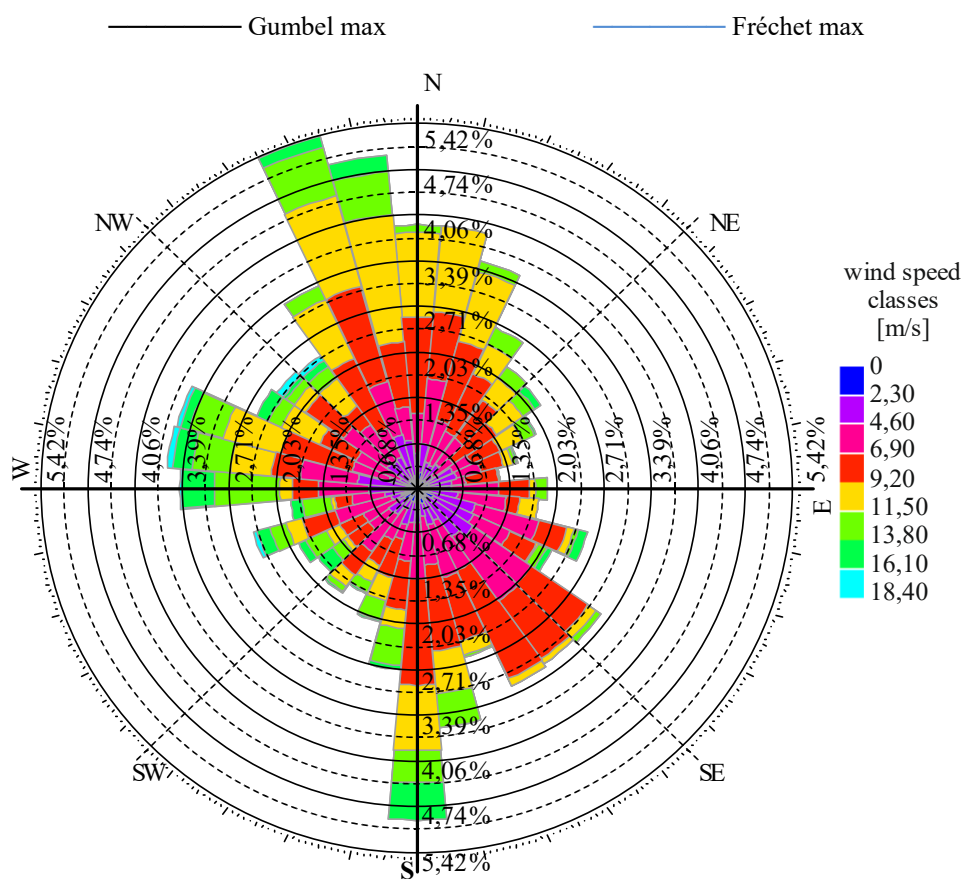


Fig. 5 - Wind Rose Chart *ERA 5*, 150 m

Sectors number:	36
Analysed sectors:	all
Period:	February ÷ June 2017
Mean speed value; azimuth	7,6 m/s; 313,4°
Speeds ratio below threshold	3 m/s 8,5 %
	3,5 m/s 11,5 %
	4 m/s 14,6 %

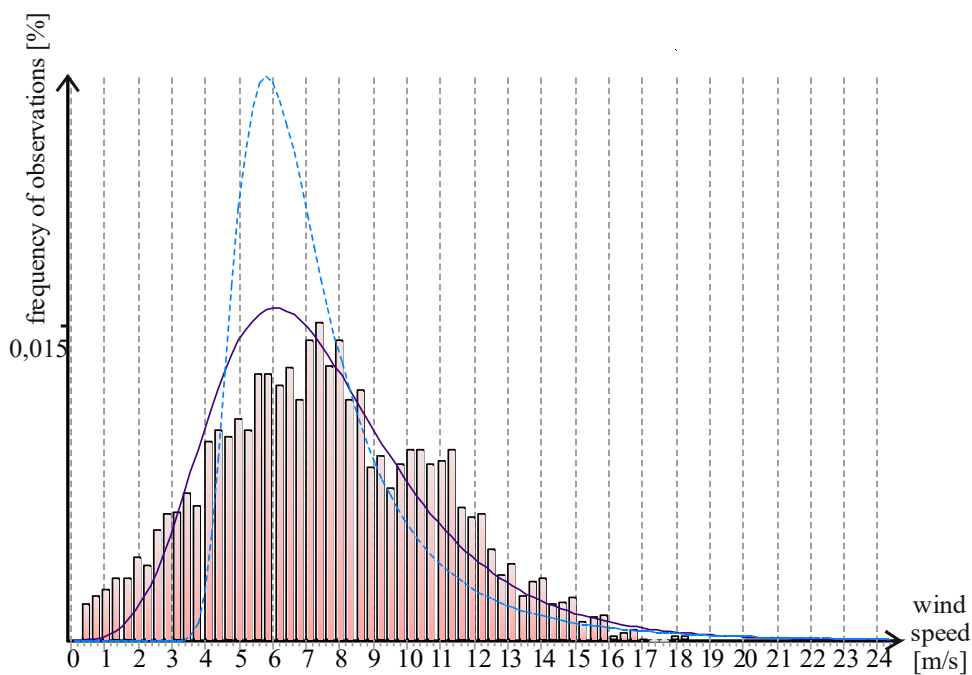


Fig. 6 - Probability Density Function *ERA 5*, 150 m

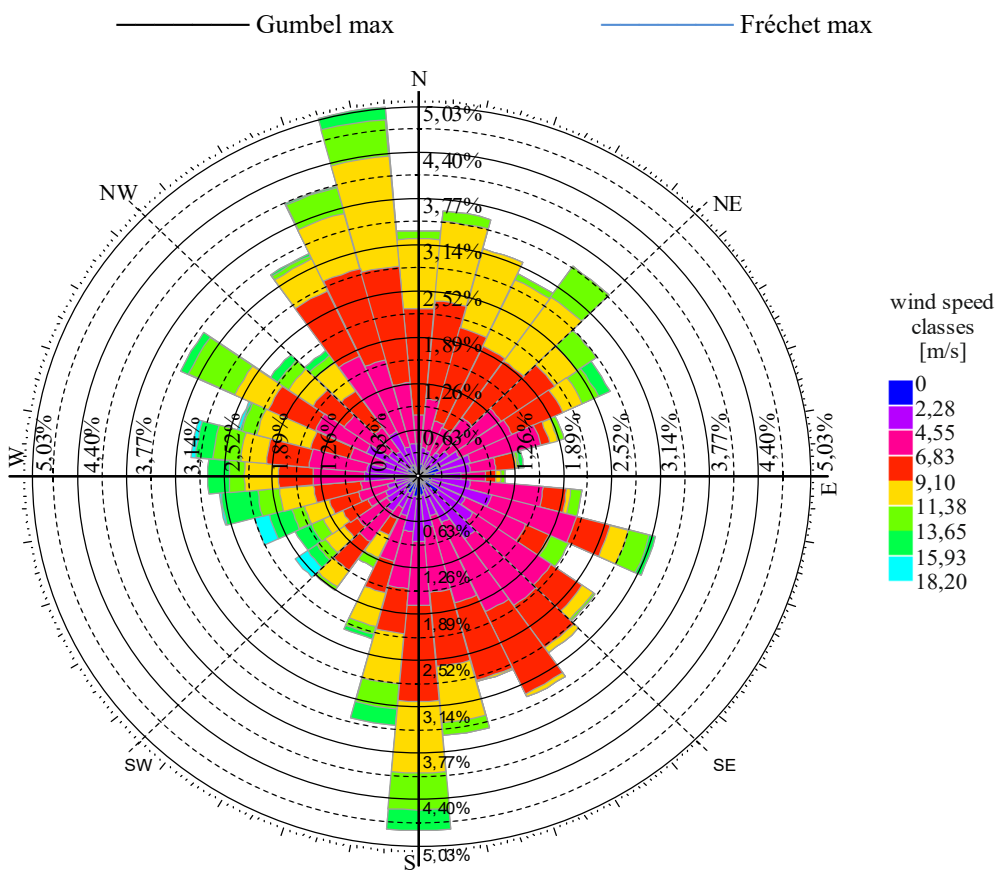


Fig. 7 - Wind Rose Chart *ERA I*, 150 m

Sectors number:	36
Analysed sectors:	all
Period:	February ÷ June 2017
Mean speed value; azimuth	7,3 m/s; 328,2°
Speeds ratio below threshold	3 m/s 9 %
	3,5 m/s 12,9%
	4 m/s 17,1%

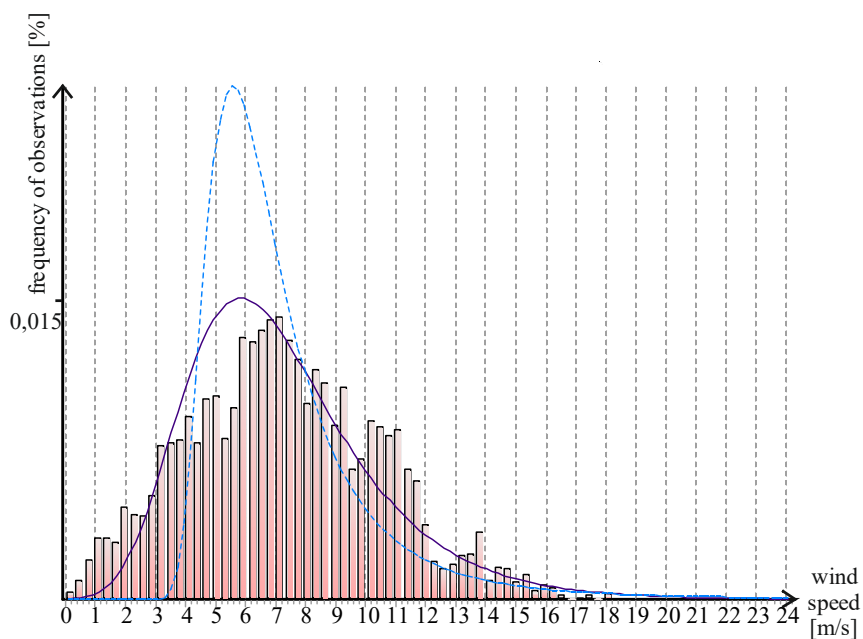


Fig. 8 - Probability Density Function ERA, 150 m

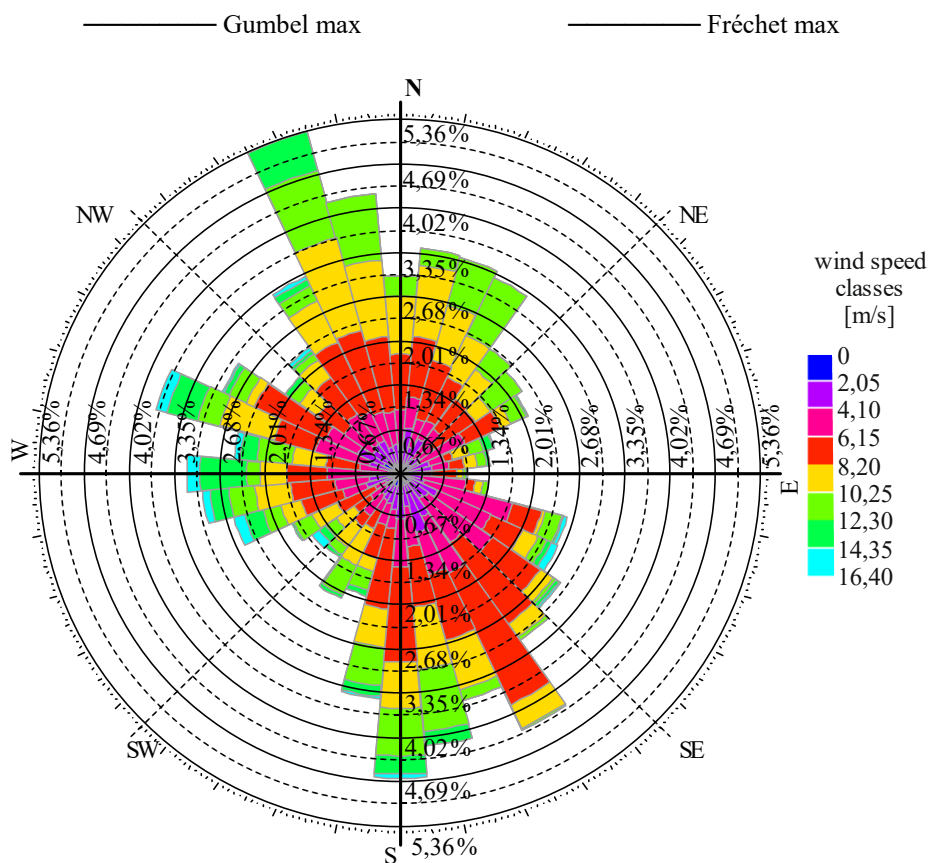


Fig. 9 - Wind Rose Chart MERRA 2, 150 m

Sectors number:	36
Analysed sectors:	all
Period:	February ÷ June 2017
Mean speed value; azimuth	7,3 m/s; 296,4°
Speeds ratio below threshold	3 m/s 8,6%
	3,5 m/s 11,9%
	4 m/s 16,3%

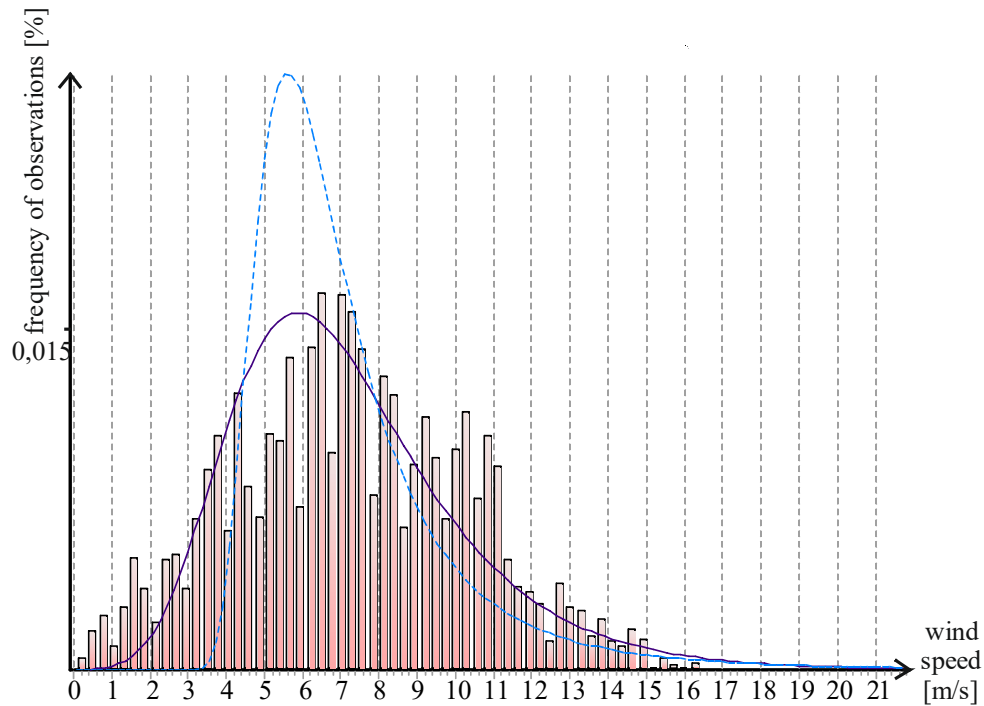


Fig. 10 - Probability Density Function MERRA 2,150 m

———— Gumbel max

----- Fréchet max

The weight of speeds lower than the usual cut-in wind speed for wind turbine generators are given in Table 1.

Table 1

Speed ratio below threshold				
Speed threshold	CFRS 150 m	ERA 5, 150 m	ERA I, 150 m	MERRA2 150 m
3 m/s	9,3 %	8,5 %	9 %	8,6%
3,5 m/s	12,1%	11,5%	12,9%	11,9%
4 m/s	15,7 %	14,6 %	17,1%	16,3%

After dividing the wind rose chart into equal sectors, for the CFRS series the extreme value it is given by the sector 25 in February when the estimated probability of having a wind speed value less than 25 m/s is 98,81 % in Gumbel distribution and 98,44 in Fréchet. The smallest probabilities can be found during February in the sector 29 for ERA 5 (98,98% Gumbel, 98,51% Fréchet), during the February in sector 26 for ERA I (99,12% Gumbel, 98,60% Fréchet) and in sector 30 for the MERRA 2 series during April (99,76% Gumbel, 99,29% Fréchet).

The mean wind speed values are shown in Table 2.

Table 2

Mean speed value and azimuth				
	CFRS 150 m	ERA 5, 150 m	ERA I, 150 m	MERRA 2, 150 m
Mean speed value	7,5 m/s	7,6 m/s	7,3 m/s	7,3 m/s
Azimuth	311,1°	323,4°	356,2°	294,8°

The data of the wind direction do not show significant deviations (wind directions of $\pm 30^\circ$ being quite common).

Table 3

The return period for maximum values of the wind speed					
Return period	Series	CFSR	ERA 5	ERA I	MERRA-2
	Distribution				
1000 years	Gumbel	34,94 m/s	33,54 m/s	31,85 m/s	27,59 m/s
	Fréchet	55,81 m/s	50,96 m/s	43,67 m/s	40,97 m/s
100 years	Gumbel	25,7 m/s	25,07 m/s	24,60 m/s	20,76 m/s
	Fréchet	28,49 m/s	27,77 m/s	26,83 m/s	22,95 m/s
50 years	Gumbel	22,90 m/s	22,50 m/s	22,40 m/s	18,70 m/s
	Fréchet	23,24 m/s	23,10 m/s	23,16 m/s	19,26 m/s

In respect of the return period for maximum values the results are shown in *Table 3*.

4. General Discussion

On the basis of the series a local wind statistics has been created, which can be used for a further wind and/or energy yield calculation (by linking the statistics of the wind conditions with the power curve the expected energy production may be determined) for the indicated reference point - considered as being representative for the location, at the proposed height.

Also, an accurate representation of the observations is provided thru the use of histograms.

The comparison of the recorded time series revealed both for wind speed and direction almost the same temporal evolution, confirming the plausibility of observations at the site. With a fraction of about 40% the north to western winds (combined sector N, NNW, WNW and W), are the most frequent winds during the regarded measurement period. The second importance in the wind frequency distribution is provided by the southern and SSE sectors (around 20 % from the total).

Productivity is the crucial driver for the profitability of wind energy industry.

There are many different types of wind turbine models available in the renewable energy market. At very low wind speeds, there is insufficient torque exerted by the wind on the turbine blades to make them rotate. However, as the speed increases, the wind turbine will begin to rotate and generate electrical power. The wind speed at which the turbine first starts to rotate and generate power is typically between 3 m/s and 4 m/s. As the speed increases, the forces acting on the wind turbine generator's structure continue to rise and, at some point, the risk of structural damage is build. To avoid such instances, a braking system is employed to bring the rotor to a standstill. This action is taken usually at a wind speed above 25 m/s.

In Fig. 3, 5, 7 and Fig. 9, the weight of speeds lower than the usual cut-in wind speed for wind turbine generators is easily observed. The *CFSR* series for the 3 m/s wind speed threshold and the *ERA I* series for the 3.5 m/s and 4 m/s thresholds have the biggest shares (*Table 1*).

Thus, in the site the wind can be used to generate electricity using wind turbine generators in more than 80% of the time. By choosing a technology capable to enter into production at a wind speed of 3 m/s, the wind can be exploited in more than 90% of the time.

The chosen site proves to be well suited for the technical use of wind energy considering the mean wind speed values higher than 7 m/s (*Table 2*). The data of the wind direction do not show significant deviations, with wind directions (wind directions of $\pm 30^\circ$ being quite common) that varies quickly causing periods with extraordinary misalignment of the wind generators to the wind direction.

The extremes values distributions for the *CFSR* series, denote that the probability of having wind speed values less than 50 m/s is encountered in 99.99% of cases using the Gumbel distribution for maximum values and 99.97% for the Fréchet distribution. The safety value of 99.99%, in the first case, is obtained at a wind speed of 35 m/s.

Usually, structures as wind turbine generators or radio masts are located in wind exposed sites. Because the chosen study area is characterized by a flat terrain, without an extreme seasonal cycle of wind speeds, the threat to the integrity of such structures, produced by very high wind speeds, is mitigated. The safety considerations of structures or of the maintenance teams plays an important role not only in the development and implementation of the buildings, but also to the cash-flow during the operational phase. An accurate estimation of the occurrence of extreme wind speeds is an essential factor in obtaining a harmonized result between the costs and the incomes.

It can be seen, in *Table 3*, that the upper quantiles of the Fréchet distribution for maximum values have higher values than those obtained from the Gumbel distribution.

Most wind turbine generators have a specified survival wind speed above 50 m/s, value exceeded only for a return period of 1000 years, obtained using the Fréchet distribution.

The prediction of the periods with low and high wind speed values, when the wind energy cannot be used in commercial activities, together with the knowledge of the occurrence of extreme wind speeds, can prove useful for the process of evaluating the insured loss from the wind speed.

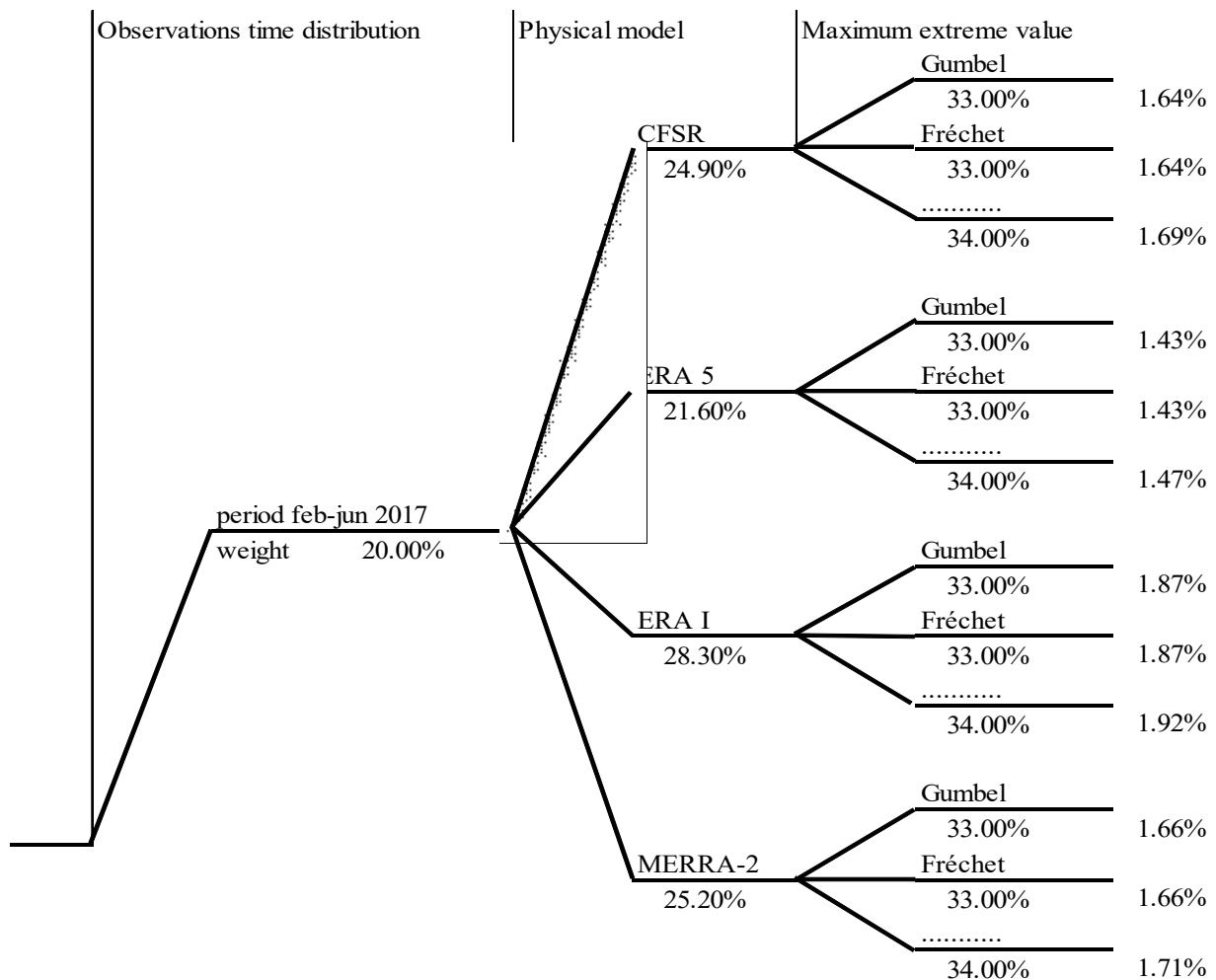


Fig. 11 - Event tree

The region has been evaluated under good viewing conditions in January, 2018. For the area examination, information regarding topographical features of the surroundings has been gathered to verify the applied data base regarding the ambient topography and the applied calculation model. Together with the data of the *Shuttle Radar Topography Mission (SRTM)* and topographic maps on scales of 1: 25,000 for an area of 1,480 km² (40 x 37 km) around the referenced point a cross

comparison of the measured digitized used as input data for the computational models was realised showing no semnificative differences.

The probabilistic approach is best suited if hazard analysis aims to establish the level of hazard for design and to achieve the site assessment, providing details to the insurance industry, or estimating the wind energy potential in order to implement renewable energy projects.

In order to incorporate in the analysis the effects of the uncertainties given by the modeling methods used in obtaining the series of data, the logical trees analysis can be used [12].

As shown in Fig. 11, uncertainties are expressed as weights, representing the degree of confidence in the applicability of the models. This method combines the contribution of all sources, all branches of the logical tree starting from an intersection representing a complete set of mutually exclusive events, and each complete combination of alternative models ultimately leading to an assessment of the average annual rate of exceeding some particular wind speeds values.

This research may be part of a branch of the logical tree that covers only a short period, a further and deeper extension of the study, through future observations using the same sources, and expanding the database used by adding data from earlier periods, can bring out a result with a higher reliability.

5. Conclusions

The studied area was chosen having in mind the favorable conditions for implementing wind farm projects with respect to accessibility to the location, access to the electrical grid, soil conditions, the existing telecommunication infrastructure, existing commercial activities, designated use of the area and population density.

In the site the wind can be used to generate electricity using wind turbine generators in more than 80% of the time. By choosing a technology capable to enter into production at a wind speed of 3 m/s, the wind can be exploited in more than 90% of the time.

On the basis of the series a local wind statistics has been created, which can be used for a further wind and/or energy yield calculation (by linking the statistics of the wind conditions with the power curve the expected energy production may be determined) for the indicated reference point - considered as being representative for the location, at the proposed height.

This research may be part of a branch of the logical tree that covers only a short period, a further and deeper extension of the study, through future observations using the same sources, and expanding the database used by adding data from earlier periods, can bring out a result with a higher reliability. To increase not only the number of available measurement data in the indicated location, but also the standard quality of the collected data an wind measuring system that meet the local requirements of climate and landscape should be installed (traditional lattice or telescope wind mast or remote sensing devices).

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