Inverse Weibull Method Application to wind Speed Modeling in Campo Grande-Ms Brazil

Razika Ihaddadene[1,3,*], Nabila Ihaddadene[1,3], Amaury de Souza[2] and Abdelhadi Beghidja[3]

[1]*Mechanical Engineering Department, University of M' Sila, Algeria*

[2]*Federal University of Mato Grosso do Sul, C.P. 549, 79070- 900 Campo Grande MS, Brazil*

[3]*Laboratory of Renewable Energy and Sustainable Development, Constantine1 University, Constantine, Algeria*

Abstract: Wind potential estimation requires an analysis of wind characteristics (wind speed density and wind direction). In this study, the applicability of two distribution models named Weibull and Inverse Weibull aiming to characterize the wind speed distribution in Campo Grande-Ms (Brazil) is investigated. The wind speed data collected from Campo Grande-Ms National Institute of Meteorology (INMET) at 10 m height for 5 years from January 2013 to December 2017, at an hour interval, are used. The method of maximum likelihood estimation is applied to calculate the parameters of the selected distributions. The best distribution function is chosen based on three goodness-of-fit statistics, namely; mean absolute percentage error (MAPE), root mean square error (RMSE), and coefficient of determination (R^2). The obtained results indicate that the Weibull distribution provides a more accurate and efficient estimation than Inverse Weibull distribution. Therefore, Weibull distribution can be used to better estimate wind speed distribution in Campo Grande-Ms (Brazil) than Inverse Weibull distribution.

Keywords: Wind speed, Weibull distribution, Inverse Weibull distribution.

1. INTRODUCTION

Electricity is an indispensable factor for the economic development of all countries in the world. Its relative importance increases with technological progress, industrialization, and the need for modern comfort. Renewable electricity comes from six energy sources, namely: geothermal, wind, solar, hydroelectric, biomass and marine [1]. Wind energy is one of the most efficient sources of renewable energies available. In 2016, China was the largest producer of electricity from the wind with 237.07 TWh (which constitutes 24.7% of world production), followed by the United States with 229.47 TWh (24% of the world production), then, Germany with 78.6 TWh *i.e*., 8.2% of world production [2].

For a given region, the wind potential estimation requires an analysis of wind characteristics (wind speed density and wind direction). They can have considerable differences between regions, even at short distances. Characterization of wind speed is complex because of the random nature of its variation. It does not follow any known statistical distribution. This is why several probability distribution functions exist in the literature, namely; Weibull distribution [3-10], Gamma distribution [3, 5, 10], Rayleigh distribution [4-6, 10], Normal distribution [6, 10], Lognormal [3, 5, 6, 10], Inverse Gaussian [6, 10], Logistic [6, 10], Generalized Extreme Values [6, 10], Nakagami [6, 10], Log-normal [6, 10], Log-logistic [6, 10], Birnbaum-Saunders distribution [6, 10]……

The quality of the adjustment of the distribution used depends on the estimation method and the region studied. The Weibull and Rayleigh distributions are the most common ones used by researchers to model wind speed data. The Weibull distribution has mostly been used to fit wind speed variation for wind energy applications. Weibull parameters are obtained using different estimation methods [6, 9, 11], namely; maximum likelihood, Modified maximum likelihood, Graphical method, Last squares method, moment method, Energy pattern factor method, Empirical method of Justus, and Empirical method of Lysen.

Recently, an alternative to the Weibull distribution is used, named as Weibull inverse distribution. Gul Akgul *et al*. [12] compared the applicability of these two distributions to two different regions in Turkey, Bursa, and Sakarya, using three parameter estimators (maximum likelihood, maximum likelihood modified and last squares). The results found showed that the inverse Weibull distribution provides a better wind estimation than Weibull distribution. In addition, Emrah Dokur *et al*. [13] have applied those two methods to Bilecik, another region in the same country, using maximum likelihood Weibull parameter estimator. They

*Address correspondence to this author at the Mechanical Engineering Department, University of M'Sila, Algeria; Tel: 00 213 778417517;
E-mail: tassekurt1@gmail.com; razika.ihaddadene@univ-msila.dz

E-ISSN: 2410-2199/19

have noted the best fit of the alternative distribution to model Bilecik wind speed distribution.

This paper aims to check the applicability of the Inverse Weibull distribution (IWD) in modeling wind speed in Campo Grande-Ms Brazil. This research document is organized as follows: in section 2, first, the wind speed distributions and the maximum likelihood estimator used to estimate their parameters are presented. Then, the data used in this study are reported. Finally, the goodness-of-fit tests are given in order to compare the two selected distributions (WD and IWD). In section 3, the results and discussion are presented. A conclusion of this work is given in section 4.

2. MATERIALS AND METHODS

2.1. Modeling Methods Forestimating Wind Speed

In this study, two distributions are used to model the wind speed in Campo Grande region located in Brazil, namely; the Weibull distribution (WD) and the inverse Weibull distribution (IWD).

2.1.1. Weibull Distribution

Weibull distribution (W) is a probability distribution function, which is usually used for describing wind speed and evaluating wind energy. In this study, we use the two-parameter probability distribution function given as follows: [5, 7, 8-10]

$$f_W(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} exp\left[-\left(\frac{v}{c}\right)^k\right] (k>0,\ c>0,\ v>0) \quad (1.a)$$

Where v, k, and c are wind speed (m/s), shape factor (dimensionless), and scale factor (m/s) respectively.

The cumulative function of Weibull distribution can be obtained by the integral of the probability distribution function.It is given as [5,7]:

$$F_W(v,k,c) = 1 - exp\left[-\left(\frac{v}{c}\right)^k\right] (k>0,\ c>0,\ v>0) \quad (1.b)$$

2.1.2 Inverse Weibull Distribution

The inverse Weibull distribution (IWD) has gained recently more interest in the research field. It is obtained by changing the variable (v) in Weibull distribution by its inverse (1/v). The shape and scale parameters (k, c) of the inverse Weibull distribution (IWD) are given as follows [10, 12, 13]:

$$f_{WI}(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{-k-1} exp\left[-\left(\frac{v}{c}\right)^{-k}\right] (k>0,\quad c>0,\quad v>0) \quad (2.a)$$

The cumulative function of the Inverse Weibull distribution has the following form [12, 13]:

$$F_{IW}(v,k,c) = exp\left[-\left(\frac{v}{c}\right)^{-k}\right] (k>0,\ c>0,\ v>0) \quad (2.b)$$

There are several methods to estimate the k and c parameters of the two distributions (W and IW) namely; Maximum Likelihood Method (MLM), Modified Maximum Likelihood Method (MMLM), Moment Method (MM), Power Density Method (PDM), Graphical Method (GM), and empirical method. During this study, the Maximum Likelihood Method (MLM) is applied.

2.1.3. Maximum Likelihood Estimator

The Likelihood function for the Weibull (W) distribution is given as follows:

$$L(k,c) = \prod_{i=1}^{n} f_w(v_i,k,c) \quad (3.a)$$

$$L(k,c) = \prod_{i=1}^{n} \frac{k}{c}\left(\frac{v_i}{c}\right)^{-k-1} exp\left(-\left(\frac{v_i}{c}\right)^{-k}\right) \quad (3.b)$$

The log-likelihood function is given by:

$$ln(L(k,c)) = n\,ln\,k - nk\,ln\,c - (k-1)\,ln(v_i) - c^{-k}\sum_{i=1}^{n} v_i^{-k} \quad (4)$$

The log-likelihood function is maximized by taking the derivatives of ln(L(k,c)) relative to the parameters k and c equal to zero, the obtained equations are given as:

$$\frac{\partial\,ln(L(k,c))}{\partial k} = \frac{n}{k} - \sum_{i=1}^{n} ln(v_i) + c^{-k}\sum_{i=1}^{n}(ln\,v_i)v_i^{-k} = 0 \quad (5.a)$$

$$\frac{\partial\,ln(L(k,c))}{\partial c} = -\frac{nk}{c} + kc^{-k-1}\sum_{i=1}^{n} v_i^{-k} = 0 \quad (5.b)$$

The same method applies to the Inverse Weibull distribution case. The following equations are obtained:

$$L(k,c) = \prod_{i=1}^{n} f_{Iw}(v_i,k,c) \quad (6)$$

$$ln(L(k,c)) = n\,ln\,k + nk\,ln\,c - (k+1)\sum_{i=1}^{n} ln(v_i) - c^k\sum_{i=1}^{n} v_i^{-k} \quad (7)$$

$$\frac{\partial \ln(L(k,c))}{\partial k} = \frac{n}{k} - \sum_{i=1}^{n} \ln(v_i) + c^k \sum_{i=1}^{n} v_i^{-k} \ln v_i = 0 \qquad (8.a)$$

$$\frac{\partial \ln(L(k,c))}{\partial c} = \frac{nk}{c} - kc^k \sum_{i=1}^{n} v_i^{-k} = 0 \qquad (8.b)$$

The solutions of these likelihood equations (5a, 5b) for Weibull distribution and the Inverse Weibull distribution (8a, 8b) are obtained by an iterative method using Newton-Raphson iteration method.

2.2. Case Study

In order to check the capability of the Weibull distribution and the inverse Weibull distribution to describe the wind speed distribution, Campo Grande-Ms province has been used as a case of study. Campo Grande is the capital of the Brazilian state of Mato Grosso do Sul. It is the largest city of the Center-West region of Brazil (Figure **1**). This region is located in a plateau region in the center of the state, with a plain landscape covering around 8,096 km². In addition, 33.4% of its area is urbanized, with less than 1% of the municipal area are under conservation units [14]. Campo Grande-Ms is located at latitude of 20°26'34'' South and longitude of 54° 38' 47'' West. This province is at an altitude of 532 m above sea level. Its climate is equatorial with two well-defined seasons, a dry winter (from April to August) and a wet summer (from September to March).

The hourly wind speed data considered in this study are taken from Campo Grande-Ms National Institute of Meteorology (INMET) at 10 m height from January 2013 to December 2017 (data recorded for five years).

Figure 1: Location of Campo Grande-Ms in Brazil [15].

2.3. Goodness of fit and Data Used

In order to compare the two selected distributions seen above in terms of the fitting ability of wind speed data, several goodness-of-fit tests have been used in the literature toanalyse wind speed. Indeed, the most widely used tests are the mean absolute percentage error (MAPE), the root mean square error (RMSE), and the coefficient of determination (R²). These latter are used in this investigation and detailed in the following.

2.3.1. Mean Absolute Error (MAPE)

The mean absolute percentage error is applied to test the predicted distribution of observed climatic variables (wind speed in this case) against the real distribution. Often, it is defined as the mean of the absolute errors derived from the observed and predicted values, mathematically expressed as [11]:

$$MAPE = \frac{1}{N} \sum_{i=1}^{N} \frac{|f_i - f_{mi}|}{f_{m,i}} \qquad (9)$$

Where f_{mi} are the frequency observed or measured values of wind speed; f_i is the predicted frequency values through Weibull distribution (or Weibull inverse distribution). N is the number of wind speed observations.

2.3.2. Root Mean Square Error (RMSE)

The root mean square error identifies the precision of the model by providing a term by term comparison between observed frequency probabilities and predicted frequency probabilities. It is given by the following formula [8, 10, 11]:

$$RMSE = \left(\frac{1}{N} \sum_{i=1}^{N} (f_i - f_{mi})^2 \right)^{1/2} \qquad (10)$$

2.3.3. Coefficient of Determination (R²)

The coefficient of determination (R²) indicates the proportional magnitude of variation in the predicted wind speed (WD or WID) relative to the measured wind speed using a linear regression model. It can be calculated as follows [8,10,11]:

$$R^2 = 1 - \frac{\sum_{i=1}^{N} (f_{mi} - f_i)^2}{\sum_{i=1}^{N} (f_{mi} - \overline{f}_m)^2} \qquad (11)$$

Where $\overline{f_m}$ is the mean frequency of the measured values.

3. RESULTS AND DISCUSSION

The knowledge of the average annual wind speed of a given site makes it possible to determine the importance of the wind energy at this site. The monthly and maximum monthly wind speeds inform us about seasonal and inter-annual wind speed variations. Average annual and monthly speeds are also used to estimate annual and monthly usable wind power. Moreover, the maximum wind speeds allow us to know the critical speed and subsequently to predict the resistance of the rotor, which is the main part of the wind generator. They are also important for the development of automatic controls that preserve the wind turbine when the wind speed reaches its critical value.

Table **1** described the monthly and annual averages wind speed in Campo Grande-Ms region for five years of study, *i.e.*; from 2013 to 2017 for twenty-four measurements per day. The maximum monthly average wind speed in this region was observed to be 4.09 m/s in July 2017, while the minimum value (2.27 m/s) was recorded in December 2017 (see Table **1**). On the other hand, the year and the month during which the wind was stable are the year 2016 and August month respectively (lower standard deviation).

As mentioned earlier, the two distributions, namely, Weibull and inverse Weibull are compared in order to determine their suitability to estimate wind speed in Campo Grande-Ms city. The empirical coefficients of these two models obtained for the monthly, seasonal, and whole years' data are listed in Table **2a** and **2b**. This estimation was performed using Excel Microsoft 2010.

Table 1: Monthly and Yearly Wind Speeds in Campo Grande-MS city, Brazil (2013-2017)

Years	2013	2014	2015	2016	2017	Mean	Standard deviation
Months	V(m/s)	V(m/s)	V(m/s)	V(m/s)	V(m/s)	V(m/s)	σ
Jan	3.06	2.44	2.48	2.71	2.37	2.61	0.28
Feb	2.65	2.67	2.31	2.34	2.29	2.45	0.19
Mar	2.84	2.59	2.40	2.52	2.65	2.60	0.16
Apr	2.95	3.02	2.73	2.66	3.07	2.89	0.18
May	3.00	3.15	3.21	3.00	2.68	3.01	0.20
Jun	2.70	3.36	3.77	3.36	3.41	3.32	0.39
Jul	3.81	3.69	3.44	3.53	4.09	3.71	0.26
Aug	3.74	3.62	3.77	3.57	3.83	3.70	0.11
Sep	4.02	3.64	3.38	3.52	3.86	3.68	0.26
Oct	3.30	3.64	3.27	3.56	3.45	3.44	0.16
Nov	3.09	2.86	2.71	3.07	2.98	2.94	0.16
Dec	2.30	2.68	2.82	2.86	2.27	2.59	0.28
Mean	3.12	3.11	3.02	3.06	3.08	3.08	
σ	0.51	0.46	0.52	0.44	0.65	0.48	

Table 2a: Weibull and Inverse Weibull Distribution Parameters of Monthly Wind Speed in Campo Grande-MS city, Brazil (2013-2017)

Dist	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<u>**WD**</u>												
k	2.391	2.342	2.546	2.515	2.431	2.510	2.860	2.720	2.593	2.305	2.457	2.308
c	3.171	3.370	3.594	3.788	3.975	4.306	4.830	4.750	4.674	4.506	3.905	3.550
<u>**IWD**</u>												
k	1.897	1.931	1.960	1.963	1.846	1.877	2.712	1.855	1.864	1.857	1.886	1.896
c	2.175	2.067	2.269	2.399	2.439	2.690	3.314	3.026	2.945	2.771	2.429	2.170

Table 2b: Weibull and Inverse Weibull Distribution Parameters of Seasonal and Annual Wind Speed in the Campo Grande-MS City, Brazil (2013-2017)

Distribution	Autumn	Spring	Winter	Summer	Whole year
WD					
k	2.396	2.438	2.342	2.622	2.367
c	4.367	3.764	3.492	4.599	4.065
IWD					
k	1.851	1.906	1.906	1.875	1.844
c	2.700	2.338	2.138	2.911	2.490

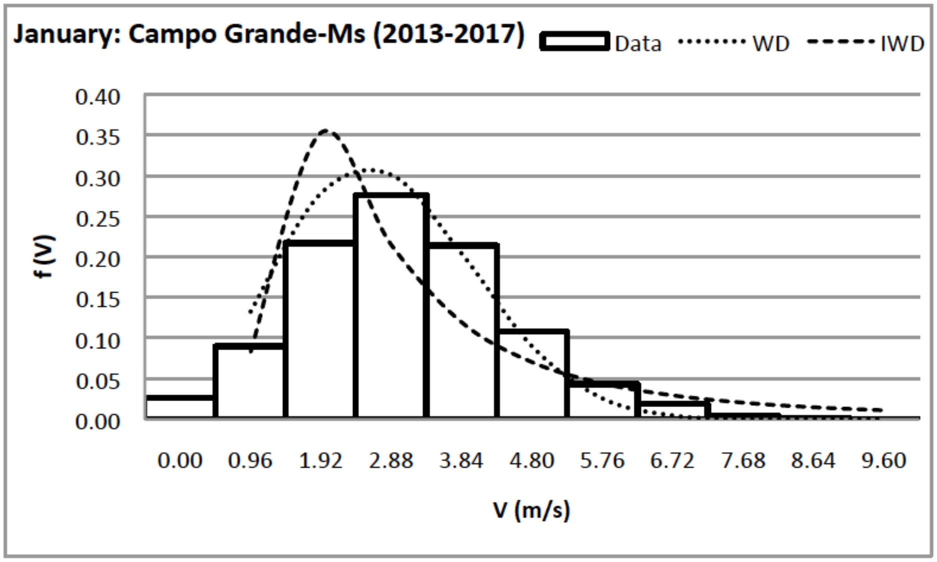
Table 3: Statistical Analysis wind Speed in Campo Grande-MS city, Brazil (2013-2017)

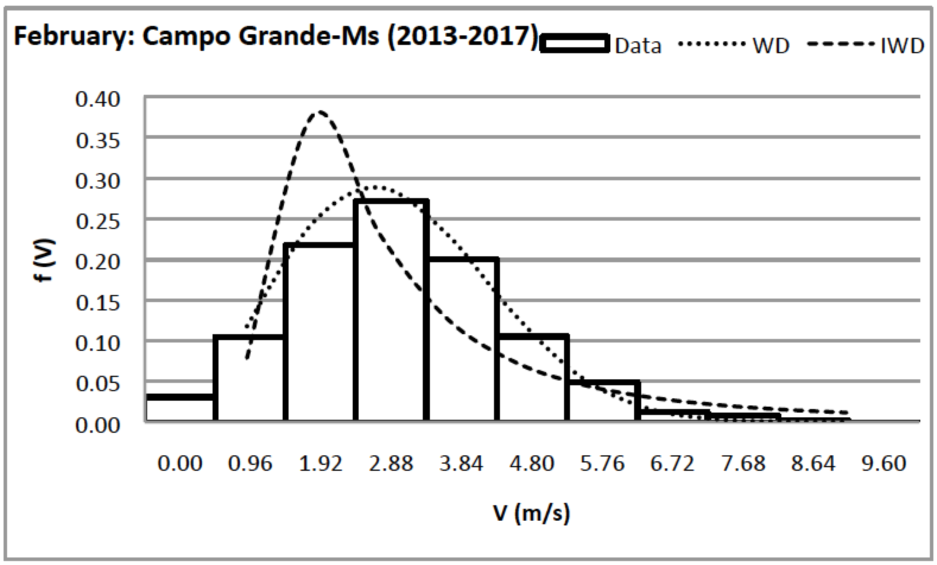
Months	MAPE		RMSE		R²	
	WD	IWD	WD	IWD	WD	IWD
Months						
Jan	0.204	0.396	0.0356	0.085	0.961	0.704
Feb	0.141	0.402	0.0240	0.087	0.994	0.727
Mar	0.116	0.463	0.0240	0.099	0.982	0.609
Apr	0.206	0.387	0.0593	0.108	0.979	0.775
May	0.094	0.434	0.0183	0.018	0.981	0.650
Jun	0.108	0.387	0.0185	0.067	0.974	0.669
Jul	0.089	0.316	0.0235	0.052	0.976	0.845
Aug	0.139	0.447	0.0217	0.062	0.953	0.526
Sep	0.105	0.447	0.0207	0.083	0.975	0.552
Oct	0.246	0.360	0.0583	0.088	0.966	0.771
Nov	0.114	0.431	0.0336	0.098	0.983	0.684
Dec	0.162	0.429	0.0460	0.104	0.899	0.701
Seasons						
Aut	0.203	0.347	0.056	0.056	0.967	0.816
Spr	0.183	0.339	0.049	0.100	0.982	0.754
Win	0.172	0.458	0.048	0.106	0.989	0.694
Sum	0.077	0.459	0.017	0.080	0.989	0.594
Whole year	0.217	0.398	0.055	0.095	0.982	0.747

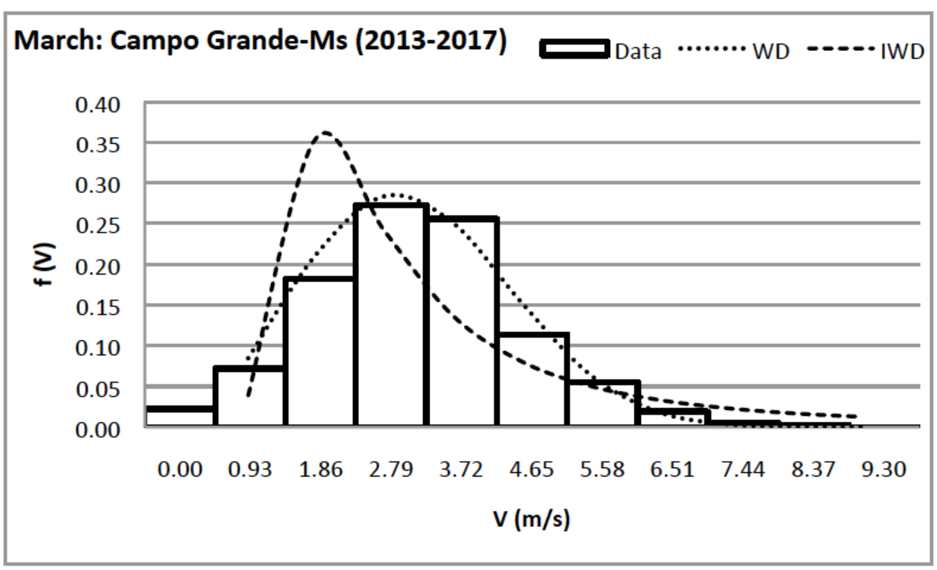
Wind speed monthly evolution according to Weibull and Inverse Weibull distributions and the corresponding measured frequency histograms are shown in Figure **2**. The seasonal and annual evolution of Weibull and Inverse Weibull distributions are illustrated in Figure **3**.

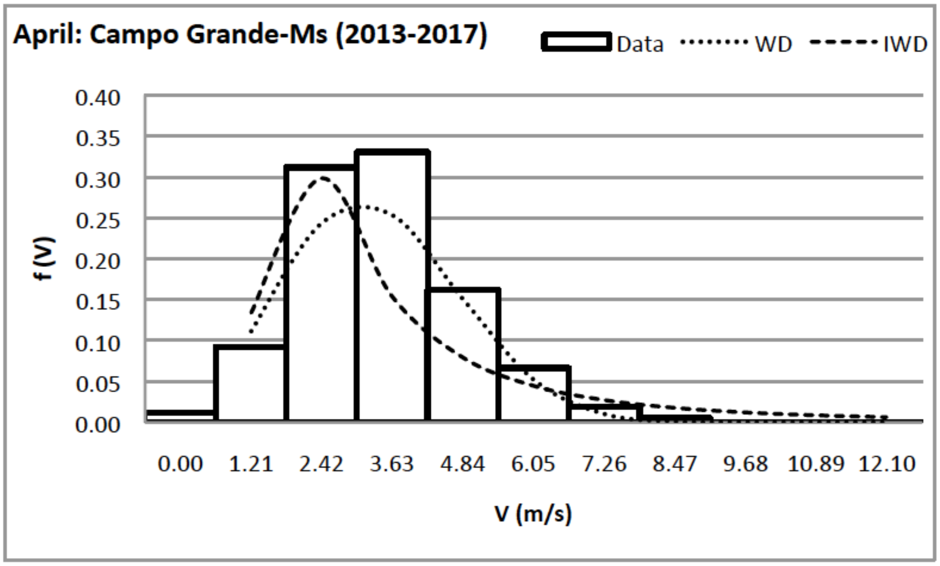
As shown in Figures **2** and **3**, the Weibull distribution is better than the Inverse Weibull distribution in all cases of study, *i.e*. months, seasons, and the whole year. This distribution fits well the evolution of frequency histograms (real values). This distribution fits well the evolution of frequency histograms (real values). To confirm this result, a statistical analysis was performed, and the results obtained are illustrated in Table **3**.

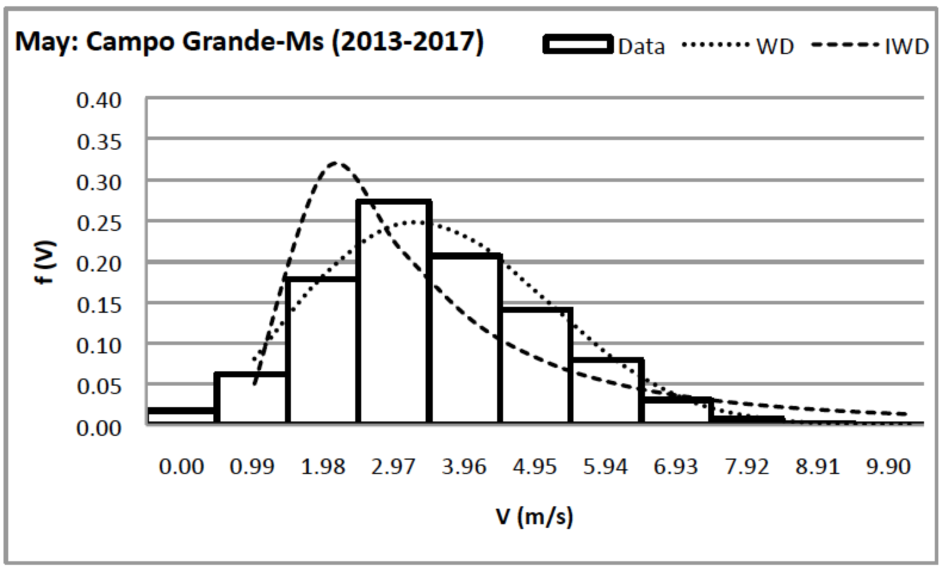
We observe that the monthly coefficient of determination (R^2) for the Weibull distribution (WD) varies between 0.899 recorded in December and 0.994 recorded in February. On the other hand, in the case of the Inverse Weibull distribution (IWD), the values of R^2 are lower than those found for the Weibull distribution. Indeed, they fluctuate between 0.526 (observed in August) and 0.845 (observed in July). On the seasonal scale, the coefficient of determination (R^2) for Weibull distribution (WD) varies between 0.967 noted in the autumn season and 0.989 recorded in the winter and spring seasons. The R^2 coefficient varies between 0.59 (in summer) and 0.816 (autumn) and takes a value of 0.747 for the annual distribution in case of Inverse Weibull distribution (Again, lowest R^2 values of inverse Weibull distribution).

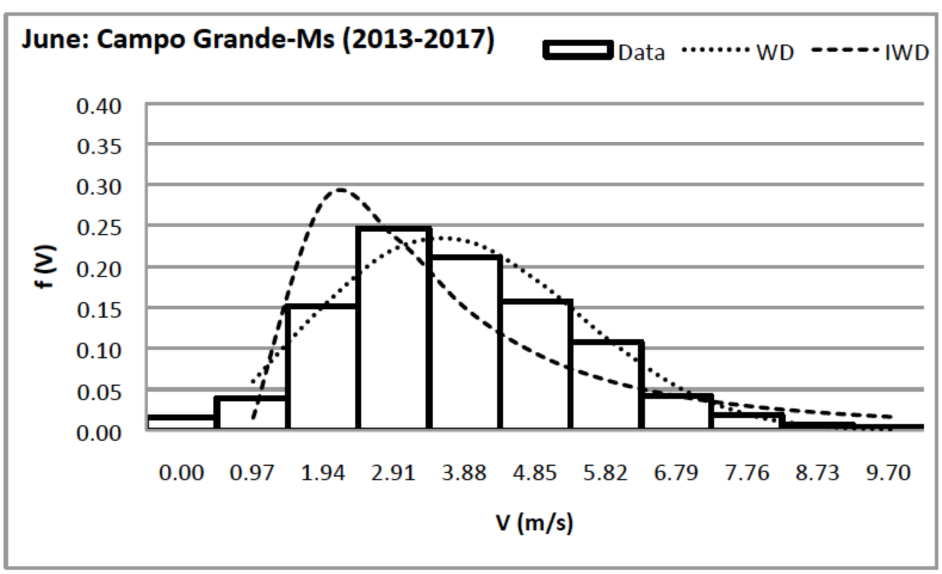

January: Campo Grande-Ms (2013-2017)
Data
WD
IWD
f (V)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00 0.96 1.92 2.88 3.84 4.80 5.76 6.72 7.68 8.64 9.60
V (m/s)

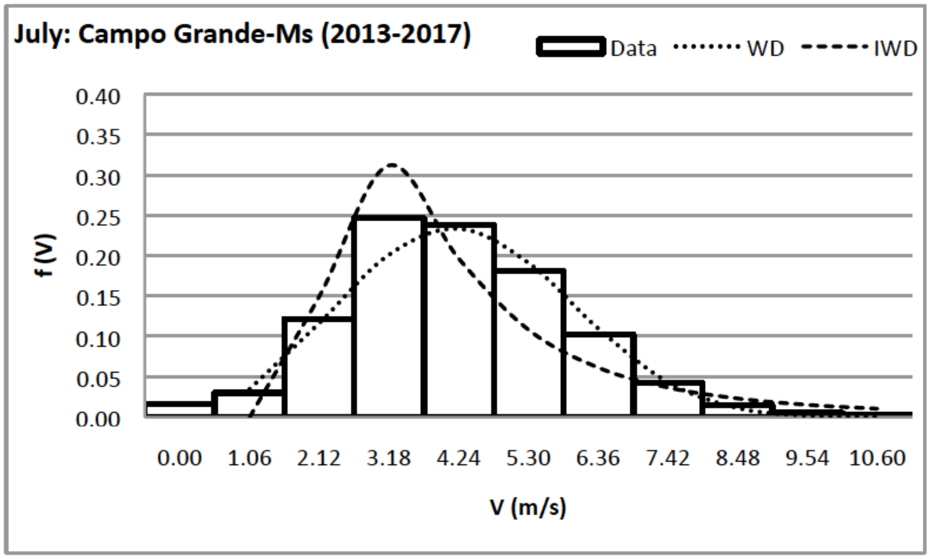

February: Campo Grande-Ms (2013-2017)
Data
WD
IWD
f (V)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00 0.96 1.92 2.88 3.84 4.80 5.76 6.72 7.68 8.64 9.60
V (m/s)

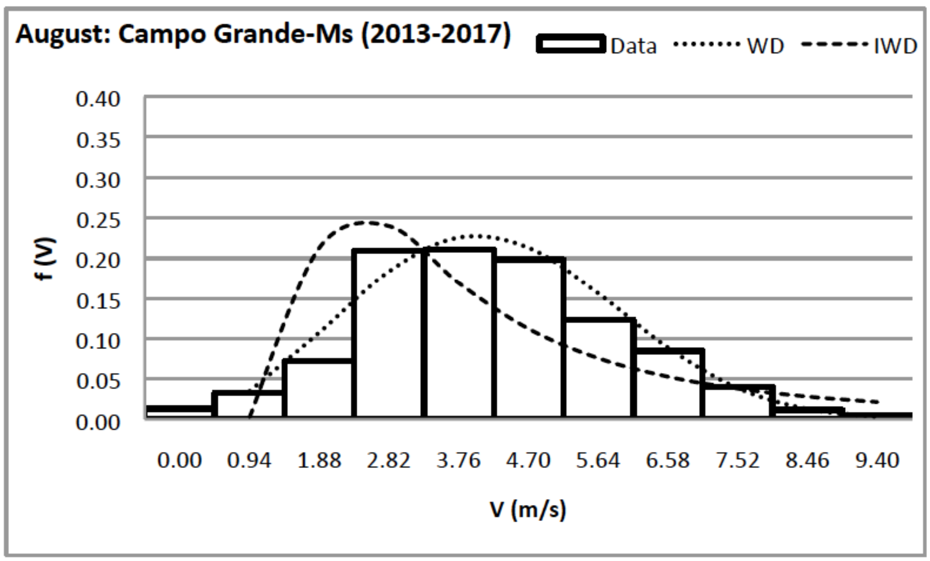

March: Campo Grande-Ms (2013-2017)
Data
WD
IWD
f (V)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00 0.93 1.86 2.79 3.72 4.65 5.58 6.51 7.44 8.37 9.30
V (m/s)

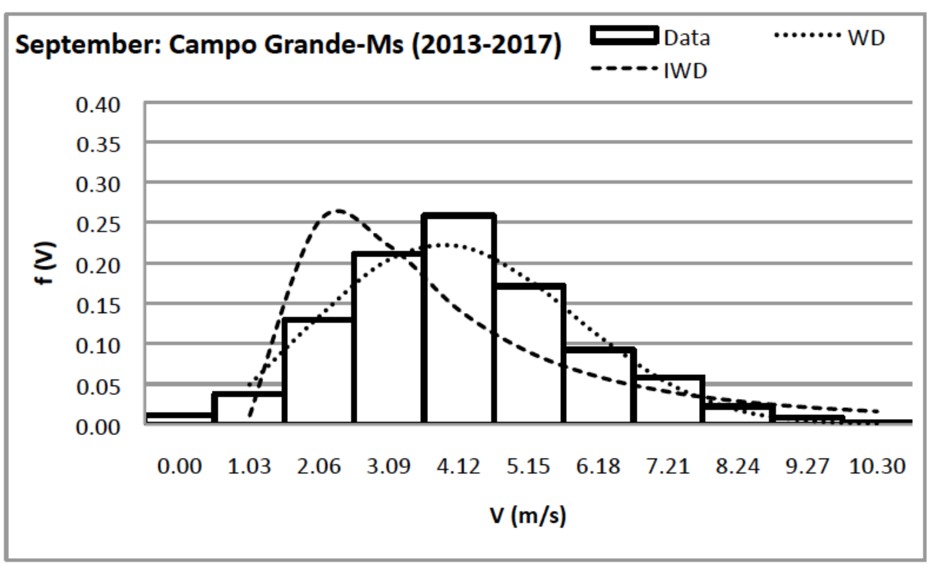

April: Campo Grande-Ms (2013-2017)
Data
WD
IWD
f (V)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00 1.21 2.42 3.63 4.84 6.05 7.26 8.47 9.68 10.89 12.10
V (m/s)


May: Campo Grande-Ms (2013-2017)
Data
WD
IWD
f (V)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00 0.99 1.98 2.97 3.96 4.95 5.94 6.93 7.92 8.91 9.90
V (m/s)


June: Campo Grande-Ms (2013-2017)
Data
WD
IWD
f (V)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00 0.97 1.94 2.91 3.88 4.85 5.82 6.79 7.76 8.73 9.70
V (m/s)


July: Campo Grande-Ms (2013-2017)
Data
WD
IWD
f (V)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00 1.06 2.12 3.18 4.24 5.30 6.36 7.42 8.48 9.54 10.60
V (m/s)


August: Campo Grande-Ms (2013-2017)
Data
WD
IWD
f (V)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00 0.94 1.88 2.82 3.76 4.70 5.64 6.58 7.52 8.46 9.40
V (m/s)


September: Campo Grande-Ms (2013-2017)
Data
WD
IWD
f (V)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00 1.03 2.06 3.09 4.12 5.15 6.18 7.21 8.24 9.27 10.30
V (m/s)

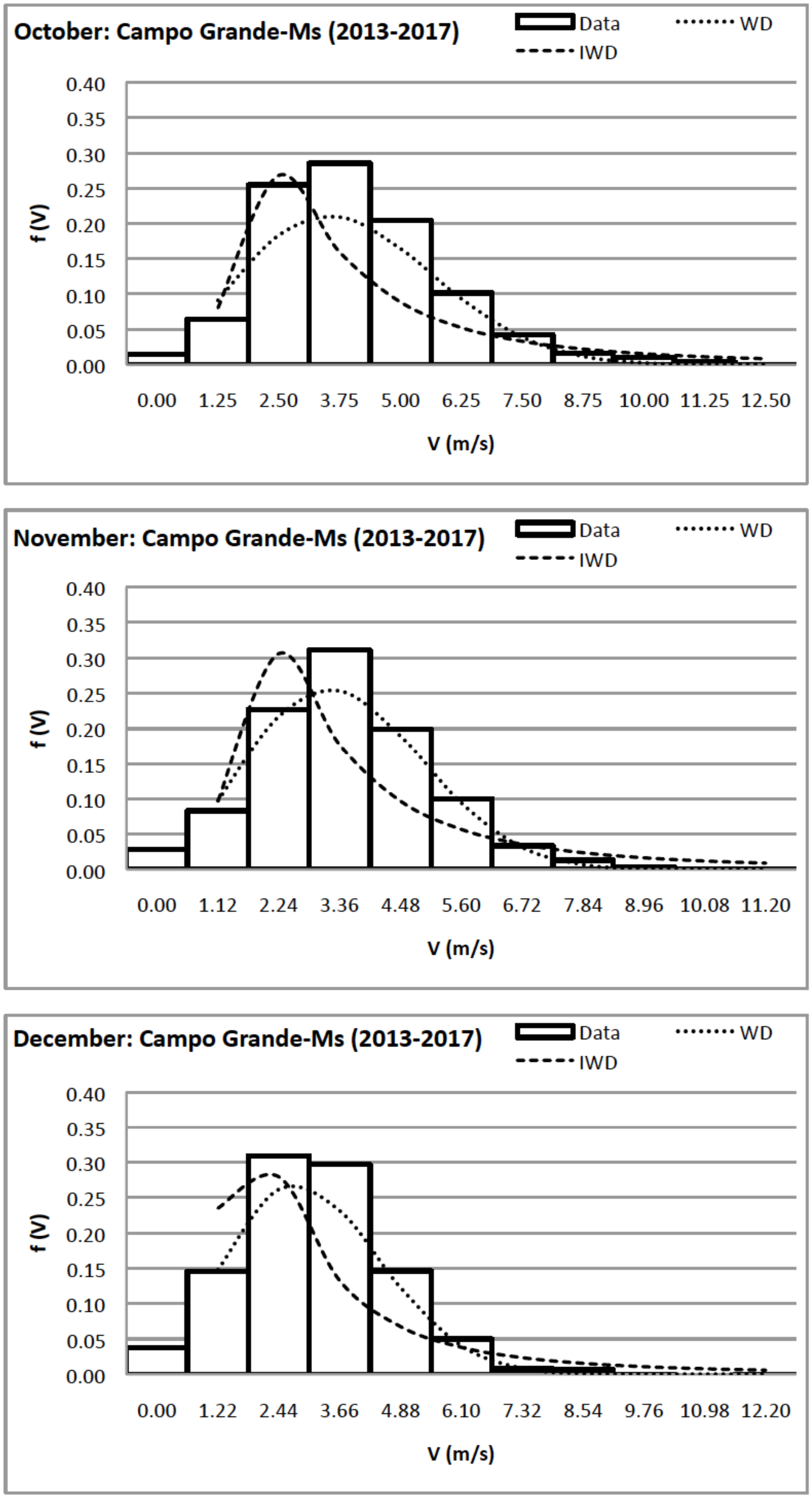
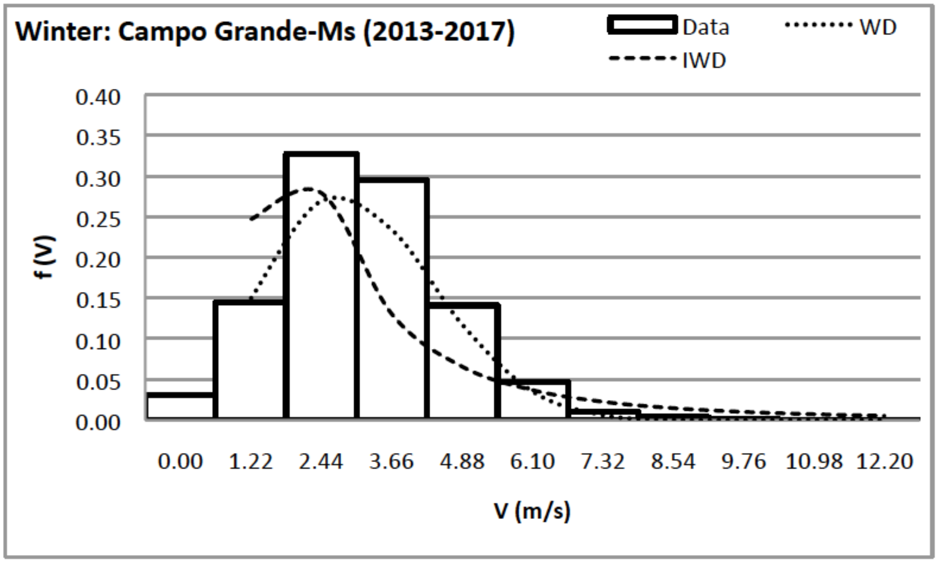
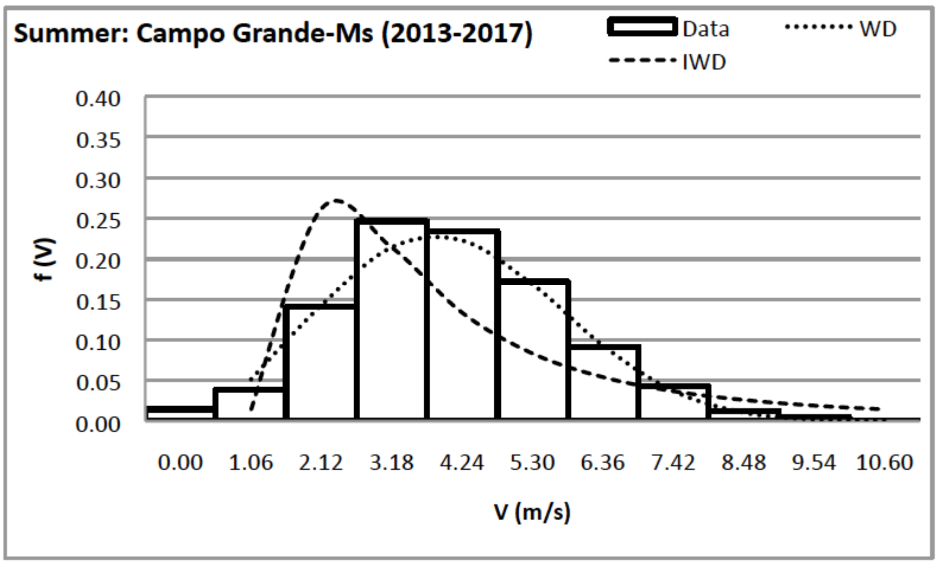
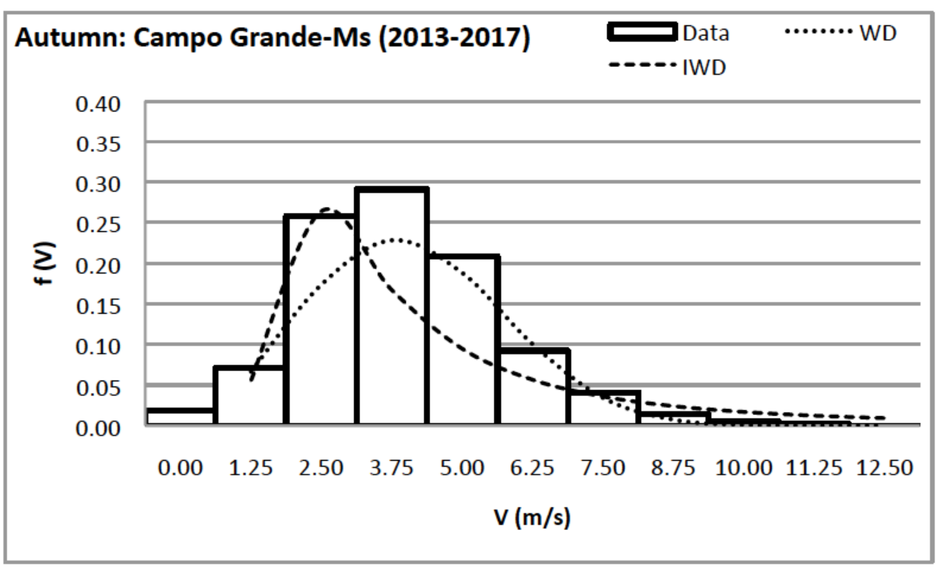
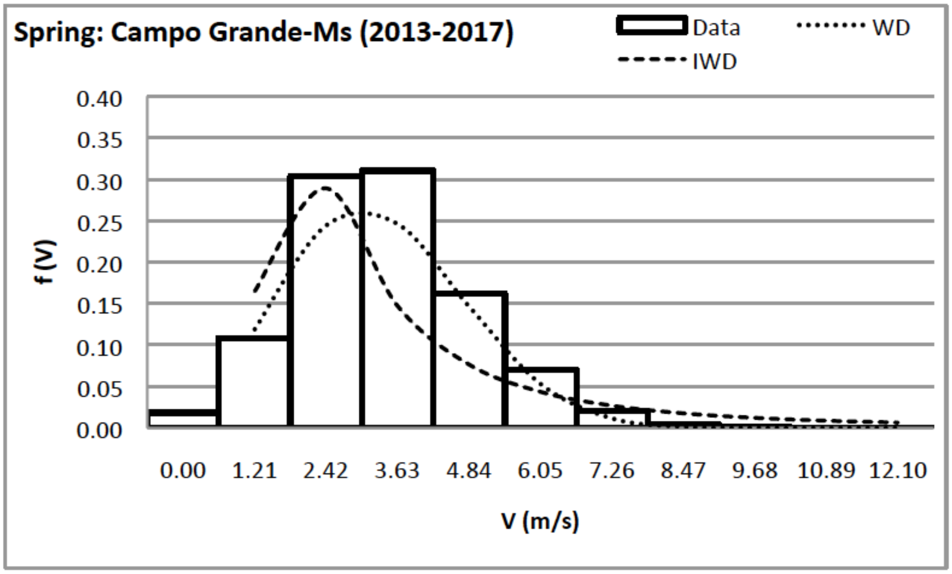


Figure 2: Monthly wind speed distributions in Campo-Grande-Ms City, Brazil (2013-2017).


Winter: Campo Grande-Ms (2013-2017)
Data
WD
IWD
f (V)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00 1.22 2.44 3.66 4.88 6.10 7.32 8.54 9.76 10.98 12.20
V (m/s)


Summer: Campo Grande-Ms (2013-2017)
Data
WD
IWD
f (V)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00 1.06 2.12 3.18 4.24 5.30 6.36 7.42 8.48 9.54 10.60
V (m/s)


Autumn: Campo Grande-Ms (2013-2017)
Data
WD
IWD
f (V)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00 1.25 2.50 3.75 5.00 6.25 7.50 8.75 10.00 11.25 12.50
V (m/s)



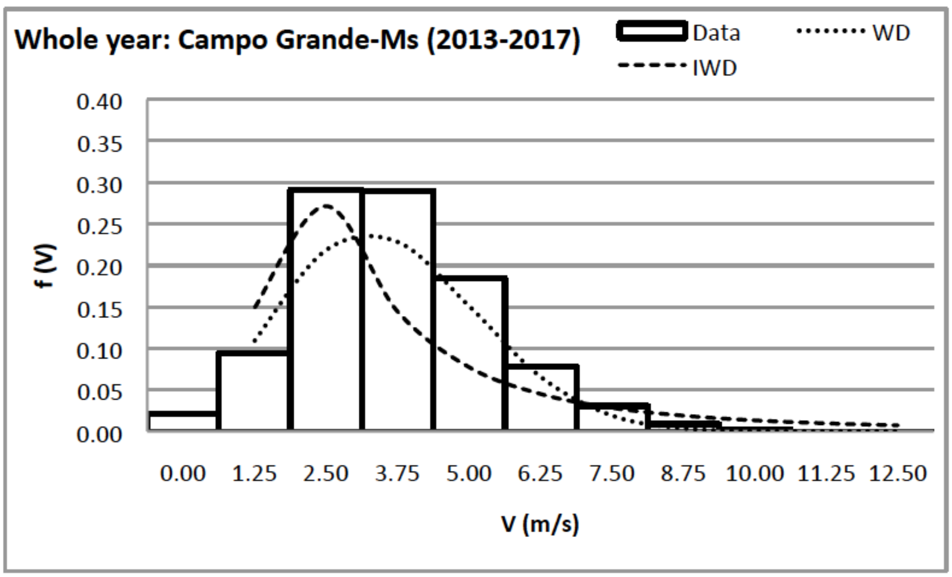


Figure 3: Seasonal and annual wind speed distribution in Campo-Grande-Ms city, Brazil (2013-2017).

The monthly root mean square error (RMSE) value of Weibull distribution varies in the interval from 0.0183 (noted in May) to 0.0593 (noted in April). In contrast, the Inverse Weibull distribution takes the highest values. Indeed, it varies between 0.052 (in July) and 0.108 (in April).

The value of the seasonal mean square error (RMSE) of the Weibull distribution varies between 0.017 (summer) and 0.056 (autumn) and that of the Weibull inverse distribution between 0.056 recorded in the autumn and 0.106 noted in the winter. For the annual mean square error value of the Weibull and inverse Weibull distributions, they take the values of 0.055 and 0.095, respectively.

The monthly mean absolute percentage error value of Weibull distribution varies between 0.049 (May) and 0.246 (October) and that of Inverse Weibull distribution between 0.316 (July) and 0.4 (August and September). In the case of seasons, the value of the mean absolute percentage error of the Weibull distribution varies between 0.077 (summer) and 0.203 (autumn) and that of the Weibull inverse distribution between 0.339 and 0.459, noted in the autumn and summer, respectively. Moreover, the annual mean absolute percentage error values of the Weibull and inverse Weibull distributions are 0.217 and 0.398, respectively.

It can be said that the values of the determination coefficient (R^2) for the Weibull distribution are higher than those of the Weibull inverse distribution of the monthly, seasonal, and whole year analysis. These values are greater than 0.967 in the case of Weibull distribution. Conversely, the inverse Weibull distribution has high values of RMSE and MAPE compared to Weibull distribution. According to these results, we can say that the distribution of Weibull is best adapted for the description of the evolution of wind speed frequency distribution in Campo Grande -Ms (Brazil).

This result is not in agreement with those found in Turkey regions, namely Barsa [12], Sakarya [12], and Bilecik [13], where Weibull Inverse distribution is the best model for the description of wind speed frequency distributions.

Therefore, we can say that the frequency distribution of the wind speed is a characteristic that depends on the region studied.

4. CONCLUSION

This study compares the adequacy of the two distributions, namely; Weibull and Inverse Weibull for the description of the wind speed frequency in the region of Campo Grande-Ms (Brazil). This investigation allowed us to retain the following points:

1. The mean value of the annual wind speed in this region is about 3.08 m/s. The mean maximum value of monthly wind speed is 3.71 m / s recorded in July and the mean minimum value of monthly wind speed is 2.45 m/s noted in February. The months of June, July, August, September, and October are the windiest months of the year,

2. The parameters of Weibull (WD) and Inverse Weibull (IWD) distributions were determined using the maximum likelihood estimator for monthly, seasonal and annual analysis. Frequency distributions evolution of the two models reveals that the Weibull distribution is the best adapted to the three cases studied (monthly, seasonal and annual),

3. This result does not agree with those of the literature (case of Turkey). Therefore, the choice of the frequency distribution strongly depends on the studied site.

REFERENCES

[1] La production d'électricité d'origine renouvelable dans le monde Collection chiffres et statistiques. Quinzième inventaire -Edition 2013. http://www.energies-renouvelables.org/observ-er/html/inventaire/fr/sommaire.asp. (accessed April 2, 2019).

[2] L'éolien en chiffres. EDF.France. https://www.edf.fr/groupe-edf/espaces-dedies/l-energie-de-a-a-z/tout-sur-l-energie/produire-de-l-electricite/l-eolien-en-chiffres. (accessed April 2, 2019).

[3] Pobočíková I, Sedliačková Z, Michalková M. Application of Four Probability Distributions for Wind Speed Modeling.. Procedia Engineering 2017; 192: 713-718. https://doi.org/10.1016/j.proeng.2017.06.123

[4] Ozay C, Celiktas MS. Statistical Analysis of Wind Speed Using Two-parameter Weibull Distribution in Alaçatı Region.. Energy Conversion and Management 2016; 121: 49-54. https://doi.org/10.1016/j.enconman.2016.05.026

[5] Alavi O, Sedaghat A, Mostafaeipour A. Sensitivity Analysis of Different Wind Speed Distribution Models With Actual and Truncated Wind Data: a Case Study for Kerman, Iran. Energy Conversion and Management 2016; 120: 51-61. https://doi.org/10.1016/j.enconman.2016.04.078

[6] Mohammadi K, Alavi O, McGowan JG. Use of Birnbaum-Saunders Distribution for Estimating Wind Speed and wind Power Probability Distributions: A Review. Energy Conversion and Management 2017; 143: 109-122. https://doi.org/10.1016/j.enconman.2017.03.083

[7] Ihaddadene R, Ihaddadene N, Mostefaoui M. Evaluation of Three Methods for Estimating Annual and Seasonal Wind Speed Distributions. In: IEEE Conferences. Proceedings of the 2 nd International Renewable and Sustainable Energy Conference (IRSEC) Ouazazate-Morocco 2014; pp.311-316. https://doi.org/10.1109/IRSEC.2014.7059761

[8] Ihaddadene R, Ihaddadene N, Mostefaoui M. Estimation of Monthly Wind Speed Distribution Basing on Hybrid Weibull Distribution. World Journal of Engineering 2016; 13(6): 509-515. https://doi.org/10.1108/WJE-09-2016-0084

[9] Ihaddadene R, Ihaddadene N, Mostefaoui M. Comparison of Three Methods for Weibull Distribution in Calculating Wind Energy Potential. Applied Mechanics and Materials 2014; 492: 574-578. https://doi.org/10.4028/www.scientific.net/AMM.492.574

[10] Jung C, Schindler D. Global Comparison of The Goodness-offit of Wind Speed Distributions. Energy Conversion and Management 2017; 133: 216-234. https://doi.org/10.1016/j.enconman.2016.12.006

[11] Mohammadi K, Alavi O, Mostafaeipour A, Goudarzi N, Jalilvand M. Assessing different parameters estimation methods of Weibull Distribution to Compute Wind Power Density. Energy Conversion and Management 2016; 108: 322-335. https://doi.org/10.1016/j.enconman.2015.11.015

[12] Akgül FG, Şenoğlu B, Arslan T. An Alternative Distribution to Weibull for Modeling the Wind Speed Data: Inverse Weibull Distribution. Energy Conversion and Management 2016; 114: 234-240. https://doi.org/10.1016/j.enconman.2016.02.026

[13] Dokur E, Kurban M, Ceyhan S. Wind Speed Modeling Using Inverse Weibull Distribution: a Case Study for Bilecik, Turkey. International Journal of Energy Applications and Technologies 2016; 3(2): 55-59.

[14] Carvalho PS, Da Silva LA, Ferreira VL. Snakes of Campo Grande Municipality, Mato Grosso do Sul State, Central Brazil. Herpetology Notes, 2018; 11: 321-328 (published online on 22 April 2018).

[15] Lucchese JR, Andreasi WA. Designing Thermally Pleasant Open Areas: The Influence of Microclimatic Conditions on Comfort and Adaptation in Midwest Brazil. Journal of Sustainable Development; 2017; 10(4): 11-21. (ISSN 1913-9063 E-ISSN 1913-9071). https://doi.org/10.5539/jsd.v10n4p11

Received on 19-5-2019 Accepted on 29-5-2019 Published on 15-7-2019

DOI: http://dx.doi.org/10.31875/2410-2199.2019.06.6