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Deep assessment of wind speed distribution models: A case study of four sites in Algeria

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ABSTRACT

The aim of this study is to assess the accuracy of different probability functions for modeling wind speed distribution at four locations, distributed over Algeria, to minimize the uncertainty in wind resource estimates. Despite mixture models perform better results, their complexity induced us to use in this work eight distributions with a maximum of three parameters, namely Weibull, Gamma, Inverse Gaussian, Log Normal, Gumbel, GEV, Nakagami and Generalized Logistic distribution to model the wind speed, fitted with four parameter estimation methods. In addition to the methods of moments and the maximum likelihood which are commonly used, the power density method and the L-moments method are developed and utilized for the first time in wind resource assessment field, to estimate the parameters of most distributions used in this work. Moreover, two goodness-of-fit tests based on the coefficient of determination and the root mean square error, are conducted in order to select good fitting probability distribution functions. According to the coefficient of determination and the root mean square error, the GEV and Gamma are the most appropriate, compared to the others used distributions. Furthermore, the L-moments method is the most effective one, among the used parameter estimators, followed by the maximum likelihood method. On the other hand, in term of power density error, different results were found, where the Power Density Method gave the best results with the Gamma, Inverse Gaussian and Log Normal distributions. Otherwise, owing to the difference in the wind characteristics for each studied site, it can be stated that to minimize the uncertainty in wind resource estimates, it is important to determine the method that gives the best parameters for each distribution.

1. Introduction

The knowledge of the wind characteristics at a particular location leads to the effective utilization of wind energy. Since the distribution of wind speeds is one of the most important aspect in wind resource assessment, the wind farms operating performance depends on the robustness of the wind speed distribution used for the selected site by investigating detailed knowledge of the wind characteristics [1,2].

A review of the literature showed that a large number of studies have been published on the use of a variety of probability distribution to describe the frequency distributions of wind speed. It appears that the two-parameter Weibull function has been the most commonly used distribution in wind energy assessment [3–5]. For instance, the two-parameter Weibull distribution has been used in the analysis of wind potential for different regions in countries such as Turkey [6,7], Algeria [8,9], Malaysia [10], Taiwan [11], Pakistan [12] and Canada [13]. Moreover, this popularity is highlighted by several well-known commercial software, such as WAsP and WindSim, which give their wind statistics results using Weibull distribution [5,14]. However, beside its flexibility, simplicity and relative accuracy, numerous comparative analyses assert that the Weibull distribution may not be always appropriate for representing all the wind regimes [15,16]. Therefore, several analyses have been carried out to identify the best distribution that models the wind speed data in a particular location [16–19].

Nevertheless, all the conventional distributions are not enough to describe some wind regime where there is evidence of bimodality [20]. Thereby, several studies claim that in this case of wind regime, mixture distributions show a significant superiority in results than those given by the conventional nonmixture distributions [21,22]. Otherwise, with a more increased number of parameters and an obvious complexity model, the use of different mixture distributions is not easy, nor even advantageous in some cases [23].

On the other hand, several efforts should be conducted to select the right parameter estimation method. In fact, it is considered as a critical topic due to the accuracy of feasibility and reliability analysis [7].

Thus, in this paper, several efforts were conducted by complex

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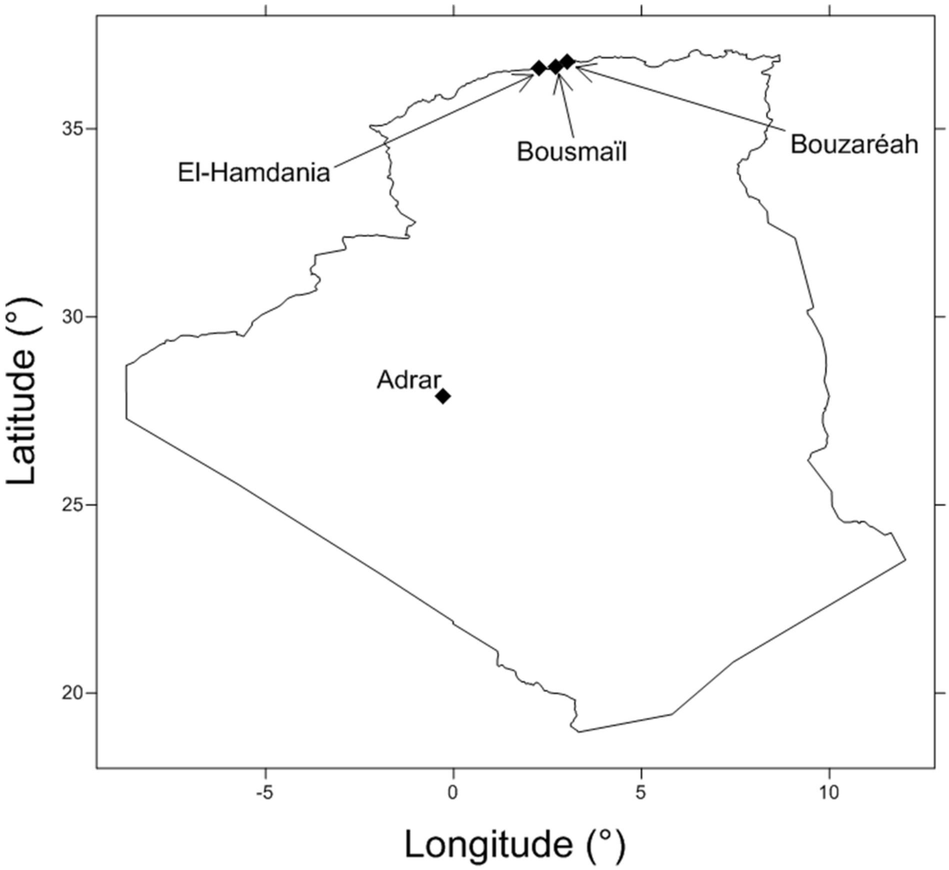

Fig. 1. Geographical location of the meteorological stations over Algeria map.

manipulations to provide explicit formulas, for selecting the best estimation method employed in the best probability distribution in order to minimize the uncertainty in wind resource estimates. For this purpose, our work focus on the use of eight distributions, namely, Weibull (W), Gamma (G), Inverse Gaussian (IG), Log Normal (LN), Gumbel (Gum), Generalized Extreme Value (GEV), Nakagami (Nak) and Generalized Logistic (GL). By other hand, another purpose of this study consists in the performance comparison of four parameter estimation methods. Two commonly used methods are used, which are robust and efficient, namely the Method of Moments (*MM*) and the Maximum Likelihood Method (*MLM*). In addition, two other methods, which are the Power Density Method (*PDM*) and the L-Moments Method (*L-MM*) applied previously only for the Weibull distribution, are developed for the first time in this paper for wind resource assessment, to the rest of used distributions with a maximum of three parameters.

2. Description of the location and the data used

This work is based on wind speeds collected from four stations belonging to the network of our research center (CDER) [24] distributed over Algeria (Fig. 1), with three stations in a coastal area (Bouzaréah, El-Hamdania and Bousmaïl), open to the Mediterranean sea, and the fourth one (Adrar) in a desertic zone in the south. The geographical coordinates of these meteorological stations, measurement periods and the recording intervals are given in Table 1.

These locations were selected as a case study in our work for different reasons, primarily because of data quality, given by our own institution, where the recorded interval data are between 5 and 30 min. In addition, the data collected at these four measuring masts have never been used in previous studies.

Some important descriptive statistics including min, max, mean values and central moments as well as skewness (γ_1) and kurtosis (γ_2) of the measured data are presented in Table 2. It is important to note that the Skewness is a measure of the asymmetry, defined as the third central moment. More explicitly, a negative (positive) skew is when the long tail is on the negative (positive) side of the peak. Regarding the kurtosis, it's is a measure of tailedness, defined as the fourth central moment, if the data have higher (lower) kurtosis it means that the curve of the data have fatter tails (middles) or more (fewer) extreme values. In other words, the skewness and the kurtosis give a way to connect numerical values to the asymmetry and thickness or heaviness of the tails of a distribution, respectively. For the four studied stations, it is seen that for the used data, the mean wind speeds vary from 2.41 m/s to 3.68 m/s. The coefficients of variation are moderately low, ranging from 0.51 to 0.74. All coefficients of Skewness are positive, which indicate that all distributions are right skewed.

Table 1
Geographical coordinates elevations from sea level, measurement periods and recording intervals of the four stations.

Site	Longitude (°)	Latitude (°)	Altitude (m)	Recording interval (min)	Measurement period
Bouzaréah	3.033187	36.797440	330	5	06-04-2011 to 21-06-2015
El-Hamdania	2.275343	36.627262	12	30	14-12-2015 to 27-03-2017
Bousmaïl	2.719466	36.661768	13	5	23-09-2014 to 04-05-2016
Adrar	-0.273581	27.879698	262	10	01-01-2014 to 30-09-2015