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WIND SPEED STATISTICS AT IASI INTERNATIONAL AIRPORT

BY

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Abstract. The paper presents a case study of statistical analysis concerning long-term wind speed databases. A 40 years wind database containing data collected from Iasi airport international meteorological station was analysed, both the analysis of the parent population and of extreme values being performed. The database contains daily maximum values (1961-2015) provided by the National Meteorological Administration (ANM), as well as 10min mean hourly data (1976-2015) provided by the National Oceans and Atmosphere Administration (NOAA). Results obtained were further compared with values for Iasi from the wind hazard zonation map of the Romanian wind loading code CR1-1-4/2012.

Keywords: wind speed statistics; Weibull analysis; parent distribution; analysis of extreme values; directional analysis.

1. Introduction

Among the natural hazards, the action of turbulent wind produces each year a significant damage to both the natural as well as the built environment leading to considerable economic loss. In this context, statistical analysis of long term wind data could provide very useful information for the construction

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industry activating in a specific location. Also, short term wind data analysis is used for estimation of the potential of wind energy of a particular area (Burlando *et al*., 2013, 2014; Ozay and Celiktas, 2016; Herrero-Novoa *et al*., 2017; Katinas *et al*., 2017). These studies imply wind directional analysis together with the hourly, monthly and annual analysis of the parent population. The most commonly used model in the parent population analysis is the bi-parametric Weibull model (Torrielli *et al*., 2013; Pagnini & Solari, 2015), characterized by shape c and scale k parameters. Derived from the classical bi-parametric Weibull model, the Hybrid Weibull distributions takes into account the presence of wind calm. Weibull parameters are key parameters to be used for evaluation of wind induced fatigue of structures (Repetto & Solari, 2001), while statistic and probabilistic analysis of extreme values and classification of aeolian phenomena (Solari, 1996; Lombardo *et al*., 2009; Holmes, 2015) are important for establishing accurate loading values for structural design.

In this paper, a wind speed database collected at Iasi Airport international meteorological station over a period of 40 years (1976 to 2015) is analysed. The study includes statistical analysis, directional analysis with wind rose, Weibull distribution for population of data, isolation of extreme values >25 m/s within a 7 days window, several distributions for extreme values >20 m/s and comparison of obtained Weibull parameters c and k with those from other European stations.

In Section **1** a brief introduction is presented. Section **2** describes the climatology of Iaşi, whereas Section **3** focuses on the statistical analysis of both data population and extreme values from the long-term wind speed database. Conclusions from Section **4** present the main findings of the study.

2. Brief Description of the Local Conditions at Iaşi International Airport

Iaşi is located in the Eastern part of Romania (Fig.1 *a*), the climatology of the city being influenced by factors such as regional microrelief and local small hilly relief as well as by seasons. Historical recorded wind data corresponds mainly to cyclonic and anti-cyclonic activities. Local intense and short term meteorological events, mainly thunderstorms observed on interval 1938-1975, were also present in Iasi area, mostly during summer time, while 1,...,2 days dust storms were rare and without periodicity. Based on existing literature (Erhan, 1979), the dominant wind direction, as resulted from the analysis of a 25 years wind speed database (1951-1975, Iaşi), is North-West (23,...,24% from population of data), followed by South-East and East directions, mainly on winter time. Concerning extreme wind speeds, over 16 m/s, those were registered in average on 5 days per year (Erhan, 1979). A special attention has to be paid to the extreme event from 4^{th}-7^{th} of January

1966. Gust wind speeds of at least 55 m/s (200 km/h) were manually recorded. Despite disputes concerning recording process, meteorologist Ov. Machedon considered the event as a milestone in meteorology and very likely, the biggest gust wind speed ever recorded during winter time in Romania (Pădurariu, 2014).

a *b*

Fig. 1 – *a* – Map of Romania showing location of Iaşi; *b* – Surroundings of the Iaşi Airport and location of meteorological station.

Concerning the scientific meteorological observations, at Iasi, first observations were made by Gheorghe Asachi, Teodor Stamati, inside decade 1830-1840 (both published observations in Albina Romaneasca). Starting from 1924, aerologic measurements were made at Iasi and beginning with 1961, climatologic observations and actinometrical measurements (1963) were made regularly, four times per day. From June 29th 2000 the classical equipment was replaced by an automatic meteorological station that measured all necessary parameters. Starting June 23rd 2011, Iasi Airport International Meteorological Station is located on 30 Marginei Street, at coordinates 47º09’48” latitude and 27º37’38” longitude, at 74.29 m height and 2.5 km in North-East direction from Iasi city centre (Fig. 1 *b*). Until this date, the meteorological station was located in the vicinity of the current location, in similar climatic and landform conditions, at only 1,200 m distance from the Iasi airport passenger terminals, runway and aprons. Iaşi Airport International Meteorological Station is currently included in the international meteorological data network.

3. Statistic Analysis of Wind Speed Data Base from Iaşi Airport International Meteorological Station

For an accurate statistic and probabilistic analysis of wind speed recorded values, wind data bases have to present some essential characteristics like representativeness, reliability, or homogeneity. The wind data analysis comprises of certain stages like preliminary analysis with validation of recorded values, statistical analysis of the parent population, isolation, statistical and probabilistic analysis of yearly extreme values, graphic representation of density and distribution functions for parent population and extreme values.

Concerning statistical analysis of the parent population, the most widely used distribution is the Weibull model developed in 1951 by Swedish scientist E.H. Waloddy Weibull (Weibull, 1951). The Weibull distribution function is given by:

$$F_V(v) = 1 - \exp\left[-\left(\frac{v}{c}\right)^k\right]; v \geq 0, \tag{1}$$

while the density function is given by:

$$f_V(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} \exp\left[-\left(\frac{v}{c}\right)^k\right]; v \geq 0 \tag{2}$$

where k and c, are shape and scale parameters respectively.

The main issue in case of Weibull distribution is the treatment of wind calm (wind speed nil values). In this case, (Takle & Brown, 1978) introduced the Hybrid Weibull distribution defined by the following modified expression:

$$F_V(v) = 1 - A_0\left\{\exp\left[-\left(\frac{v}{c}\right)^k\right]\right\}, \tag{3}$$

while the density function is given by:

$$f_V(v) = (1 - A_0)\delta(v) + A_0\frac{k}{c}\left(\frac{v}{c}\right)^{k-1} \exp\left[-\left(\frac{v}{c}\right)^k\right]; v \geq 0, \tag{4}$$

where $\delta(v)$ is Dirac function and A_0 is the probability that v has value over 0.

For the analysis of extreme values, several distribution models are available. However, no single model is universally accepted. The asymptotic models type I (Gumbel), II (Frechet) and III (reversed Weibull) are well known (Gumbel, 1958). The Gumbel model, frequently used for extreme values, described by the distribution and density functions, is given by (Gumbel, 1958):

$$F_{\hat{v}}(v) = \exp\left\{-\exp\left[-a\left(v-u\right)\right]\right\};(-\infty < v < \infty) \tag{5}$$

$$f_{\hat{v}}(v) = a\exp\left\{-a\left(v-u\right)\right\}\exp\left\{-\exp\left[-a\left(v-u\right)\right]\right\};(-\infty < v < \infty) \tag{6}$$

where $F_{\hat{v}}(v)$ and $f_{\hat{v}}(v)$ are the distribution function and the probability density function, respectively.

For the statistic analysis of wind data from Iaşi Airport International Meteorological Station, two distinct databases were used: the database from the Romanian National Meteorological Administration (ANM) containing daily maximum values recorded during 1961 – 2015 and a database from the National Oceans and Atmosphere Administration (NOAA), containing 10 min mean hourly velocities (according to ANM recording procedure) recorded during the year interval 1976 – 2015. While in the ANM data base it was identified the extreme event from January 4th-7th 1966, the 40 years wind data base from NOAA was used for further analysis.

A total number of 350.640 data lines were analyzed (100%), from which 251.689 lines contained data (71.8%) and 98.951 were missing data (28.2%). A number of 27.380 data lines represented wind calm (7.8%). A number of contiguous data with same period gust wind values smaller than mean values were eliminated (Fig.2).

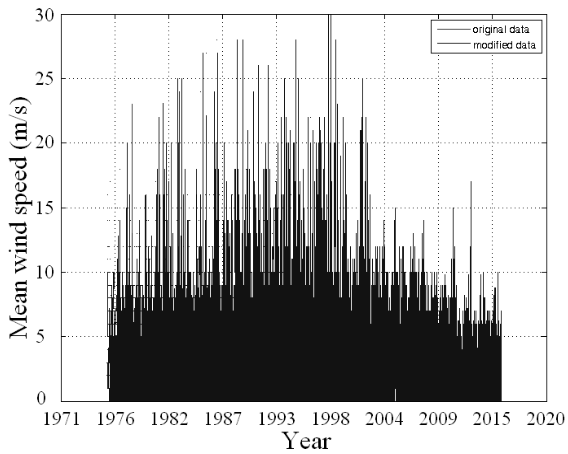


Fig. 2 − Yearly distribution of the parent population 1976-2015.

Monthly and hourly representations for entire population of recorded data are shown in Fig. 3.

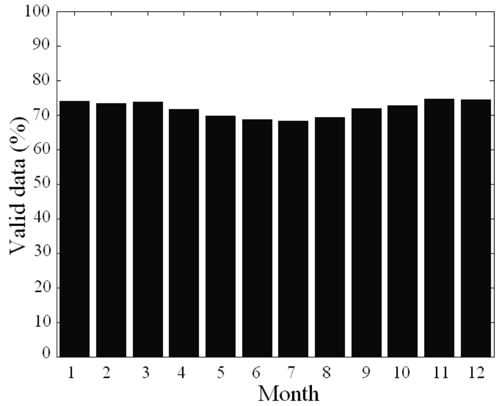


Fig. 3 – Monthly distribution of the parent population 1976-2015.

Fig. 4 shows the wind rose obtained based a directional analysis which shows that the predominant directions were North-West, followed by East. A correlation between predominant direction and extreme values ≥20 m/s was observed, about 40% from these values being recorded in the North-West direction. The directional analysis confirms the observations available in literature (Erhan, 1979).

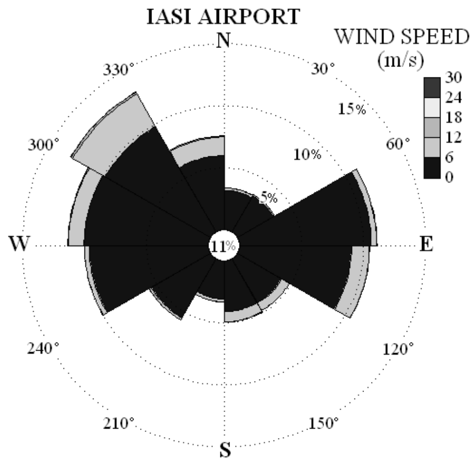


Fig. 4 – Wind Rose, 1976-2015.

Concerning extreme values, a number of 75 values ≥20 m/s were observed. From these values, 66 were recorded between 1976 and 1999 (manual recording). A number of 17 wind speed values ≥25 m/s were also observed and isolated within a 7 days window as seen in Fig. 5, with 16 recorded between 1976 and 1999 and just one by the automatic station after 2000. The maximum hourly 10 min mean wind speed value of 30 m/s was recorded in 1998 and is inferior to the reference as given by the Romanian wind loading code value for Iaşi, of 33.47 m/s (for a Mean Recurrence Interval MRI = 50 years).

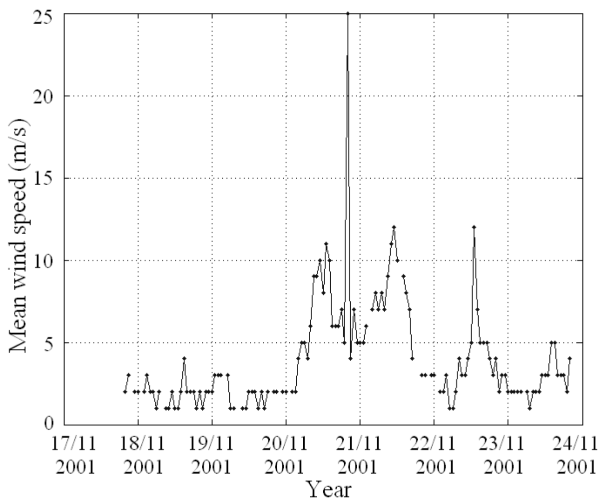
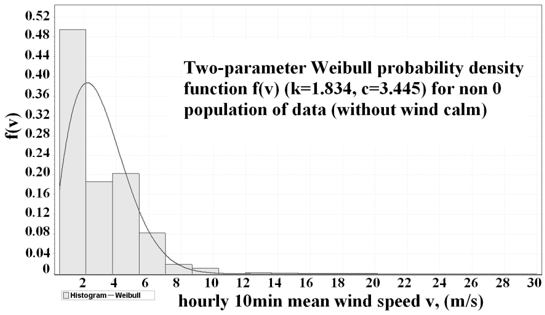
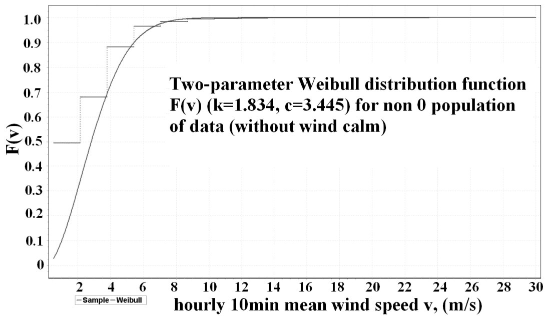


Fig. 5 − Isolation in a 7 days window of the extreme wind speed of 25 m/s, 21.11.2001.

The Weibull distribution model was applied for the valid parent population without considering wind calm. The probability density function $f(v)$ and distribution function $F(v)$ are represented in Fig. 6, the shape and scale parameters resulting k = 1.834 and c = 3.445. A similar analysis was made in the area, at Ceadir-Lunga in Rep. of Moldavia, at 150 km south-east from Iaşi, in 2015 (Rachier, 2015; Rachier 2016). The statistical analysis was made on a 22 years database of wind speeds recorded between 1990 and 2011. The obtained Weibull parameters were k = 1.91 and c = 4.8, close to those obtained at Iasi in this study. Similar recent analyses of wind speed databases were made for example in Turkey (Ozay & Celiktas, 2016), Spain for 46 meteorological stations in the northern part (Herrero-Novoa *et al*., 2017), or Lithuania (Katinas *et al*., 2017), positioned at east, west and north compared with coordinates of Romania. These were statistical analyses of data population from short term data bases, 5 to 10 years, using a Weibull model, serving for energy sector. In Turkey, the obtained Weibull parameters for data population were c = 9.16 and k = 2.05, with max wind speed of 13m/s while in Spain for around 40% from the data sets were obtained Weibull parameters c above 4 and k above 2.25.



a



b

Fig. 6 – Weibull *a* – probability density function $f(v)$ and *b* – distribution function $F(v)$.

Furthermore, the *c* and *k* Weibull parameters obtained for Iaşi were compared with a series of values obtained after analysis of wind data bases from different meteorological stations across Europe, especially from Italy, as presented in Fig. 7 (Pagnini & Solari, 2015).

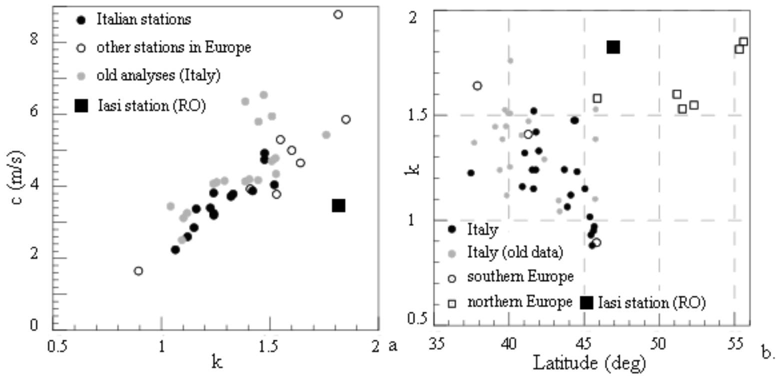
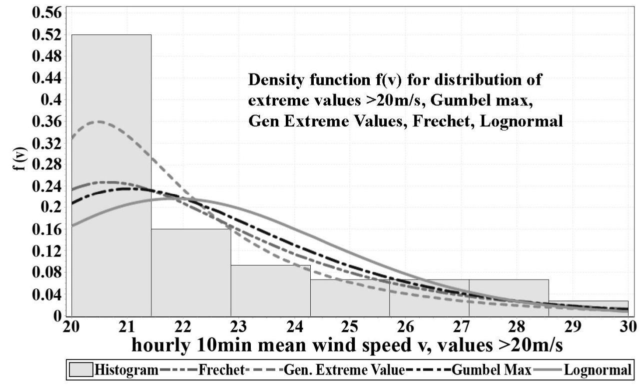
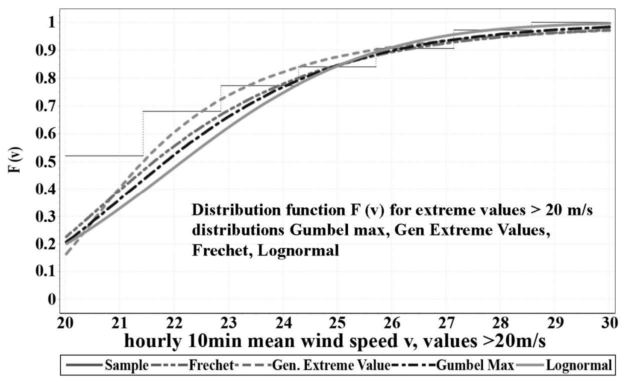


Fig. 7 – Comparative representation of c and k Weibull parameters between different locations in Europe and Iasi meteo station.



a



b

Fig. 8 − Gumbel, GEV, Frechet and Lognormal distributions for extreme values >20 m/s: *a* – probability density functions $f(v)$ and *b* – distribution functions $F(v)$.

Concerning the 75 values of mean wind speed $v \geq 20$ m/s, Gumbel max, Generalized Extreme Values, Frechet and Lognormal distribution models were applied, preliminary density and distribution functions being presented in Fig. 8.

4. Conclusions

The present paper described the statistical analysis of a 40 years (1976-2015) wind speed data base from Iaşi Airport. The Weibull *c* and *k* parameters for data population were obtained and results were compared with those from similar studies. These parameters may be used for evaluation of wind induced fatigue effects on structures in a specific location. The directional analysis has confirmed the observations presented in literature regarding the location studied within this paper. The extreme event (highest registered winter wind speed in Romania) from January 1966 was identified in ANM wind data base. A preliminary analysis of extreme values was carried out, 17 wind speed values over 25m/s being isolated on a 7 days window. The maximum recorded hourly 10min wind speed was 30 m/s, inferior to the reference value for Iasi, from CR1-1-4/2012 Code, of 33.47 m/s (MRI of 50 years). A statistic difference between standard recorded data (1976-1999) and automatic recorded data (2000-2015) was observed. In this sense, a deeper analysis of both population of data and extreme values, might prove interesting. Due to climatic changes, a recent statistic and probabilistic analysis based on automatic recorded wind speed data for most important cities where relevant constructions are concentrated might be very useful for the industry.

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ANALIZA STATISTICĂ A UNEI BAZE DE DATE PRIVIND VITEZA VÂNTULUI LA AEROPORTUL INTERNAŢIONAL IAŞI

(Rezumat)

Această lucrare prezintă un studiu de caz privind analiza statistică a bazelor de date privind viteza vântului. O astfel de bază de date privind viteza vântului, înregistrată pe o perioadă de 40 de ani, aparţinând staţiei meteorologice internaţionale a Aeroportului Iaşi a fost analizată statistic din punctul de vedere al populaţiei de date şi al valorilor extreme. Baza de date conţine valori orare mediate pe un interval de 10 minute, din perioada 1976-2015, obţinute de la National Oceans and Atmosphere Administration (NOAA), cât şi valori maxime zilnice din perioada 1961-2015, obţinute de la Administraţia Naţionala de Meteorologie (ANM). Rezultatele obţinute au fost comparate cu prevederile hărţii de zonare din codul românesc CR1-1-4/2012, privind evaluarea acţiunii vântului.