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OBSERVED WIND CLIMAT OF REPUBLIC OF MOLDOVA

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Abstract: *Increasing electricity demand and reducing the amount of fuel in the world are two reasons that led to the rapid development of renewable energy; and one of the most important and developed is wind energy. To choose where to place a wind turbine or a wind farm and to predict the amount of energy that will be produce, you need to know the wind energy resources in this region. And this because the wind power density is proportional to the cube of wind speed. Same knowing the wind energy potential leads investors to invest or not to build a wind farm in a certain region. That's why the goal of this work is to obtain the wind climatology statistics of the weather stations of Republic of Moldova as a result of historical wind processing data for a period of 22 years. Have been analyzed data of 18 weather stations located on the entire territory of Republic of Moldova for the period 1990 to 2011 and were built variations characteristics: annual, monthly, diurnal and winds rose.*

Keywords: *observed wind climate, WAsP program, wind speed, wind direction, weather station.*

1. INTRODUCTION

Extensive use of renewable energy sources (RES) is a vital necessity for Moldova, which imports about 95 percent of energy necessary resources. In our case one of the easiest and most pronounced renewable energy sources for Moldova is wind energy.

The wind energy development requires knowledge of wind potential at different levels starting with area where we want to install a turbine and finished with the country and the neighboring countries level. To estimate the production of electricity in a day, a month or a year is necessary to know the variations in wind speed measured at different heights. These variations are obtained as a result of the processing of data series measured for large periods of time either on the Hydrometeorological service (usually at a height of 10 m above ground level), either in the specialized measurement campaigns.

The main goal of the study is the

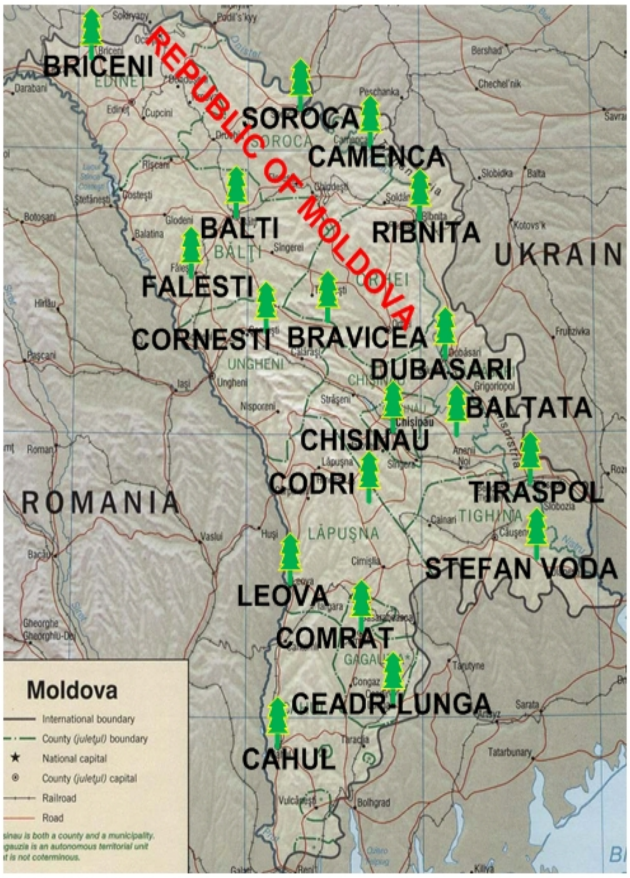


Figure 1. The location of meteorological stations

presentation of the results of measurements of characteristics of wind from eighteen whether station located on the entire territory of Republic of Moldova.

2. THE GEOGRAPHY OF MOLDOVA

Located in southeastern Europe, Moldova is bordered on the west by Romania and on the north, south, and east by Ukraine, figure 1. Most of its territory lies between the area's two main rivers, the Dniester and the Prut. It lies between latitudes 45° and 49° N, and mostly between meridians 26° and 30° E (a small area lies east of 30°).The total land area is 33,851 km^2.

The relief of the country represents a hilly plain sloping from the northwest to the southeast and having an average elevation of around 147 m above the sea level. The central part is occupied by Codrii woods, the most elevated topographical region with the maximum altitude of 429.5 m at Hill Balanesti and a terrain strongly fragmented by valleys and dales. The other important plateaus are: the plateau of Moldova situated in the Nord with maximum altitude 320 m, the plain of the South of Moldova with maximum altitude 250 m, the Tigheci heals situated in the South with maximum altitude 301 m. In the North-East is situated the part of the Podolia tableland, on the left part of the river Dniester, with maximum altitude 275 m.

3. THE CLIMATOLOGY OF MOLDOVA

Moldova's proximity to the Black Sea gives it a mild and sunny climate.

Moldova's climate is moderately continental: the summers are warm and long, with temperatures averaging about 20 °C (68 °F), and the winters are relatively mild and dry, with January temperatures averaging −4 °C (25 °F). Annual rainfall, which ranges from around 600 millimeters (23.6 in) in the north to 400 millimeters (15.7 in) in the south, can vary greatly; long dry periods are not unusual. The heaviest rainfall occurs in early summer and again in October; heavy showers and thunderstorms are common.

4. DESCRIPTION OF THE METEOROLOGICAL STATIONS

Currently in Moldova are located 18 meteorological stations, presented in Table 1. Geographical location is given in Figure 1. For each station indicate the name, geographical coordinates, altitude above sea level and average wind speed during the 22 years.

For all weather stations were used raw data during 1990-2011, stored in the Hydrometeorological Service archive.

Wind speeds are obtained as a result of systematic measurements every three hours, respectively, at 0^{00}, 3^{00}, 6^{00}, 9^{00}, 12^{00}, 15^{00}, 18^{00} and 21^{00}. Wind speed for each period of three hours is considered average speed determined within 10 minutes, i.e. between 0^{00}-0^{10}, 3^{00}-3^{10} etc.

The wind speed is measured by cups anemometers and wind direction-by vane. These data, stored in the archive Hydrometeorological Service, are called raw data. For Energy Projects purposes is recommended to analyze the raw data for a period of 20 years [2], in our case - 22 years.

Table 1. Moldova’s Historical Wind Measurement Sites

Nr.	Name	Lat	Lon	Elev	From	To	AWS
1	Briceni	48,35213	27,10206	261	01/1990	12/2011	2.19
2	Bravicea	47,37218	28,43831	78	01/1990	12/2011	1.4
3	Balțata	47,05538	29,03615	79	01/1990	12/2011	2.45
4	Bălți	47,77462	27,95065	102	01/1990	12/2011	2.7
5	Corneşti	47,36717	27,99398	232	01/1990	12/2011	2.51
6	Cahul	45,89924	28,21345	196	01/1990	12/2011	3.71
7	Comrat	46,30286	28,62947	133	01/1990	12/2011	2.52
8	Ceadîr-Lunga	46,03558	28,85220	180	01/1990	12/2011	3.98
9	Camenca	48,04352	28,69812	154	01/1990	12/2011	2.55

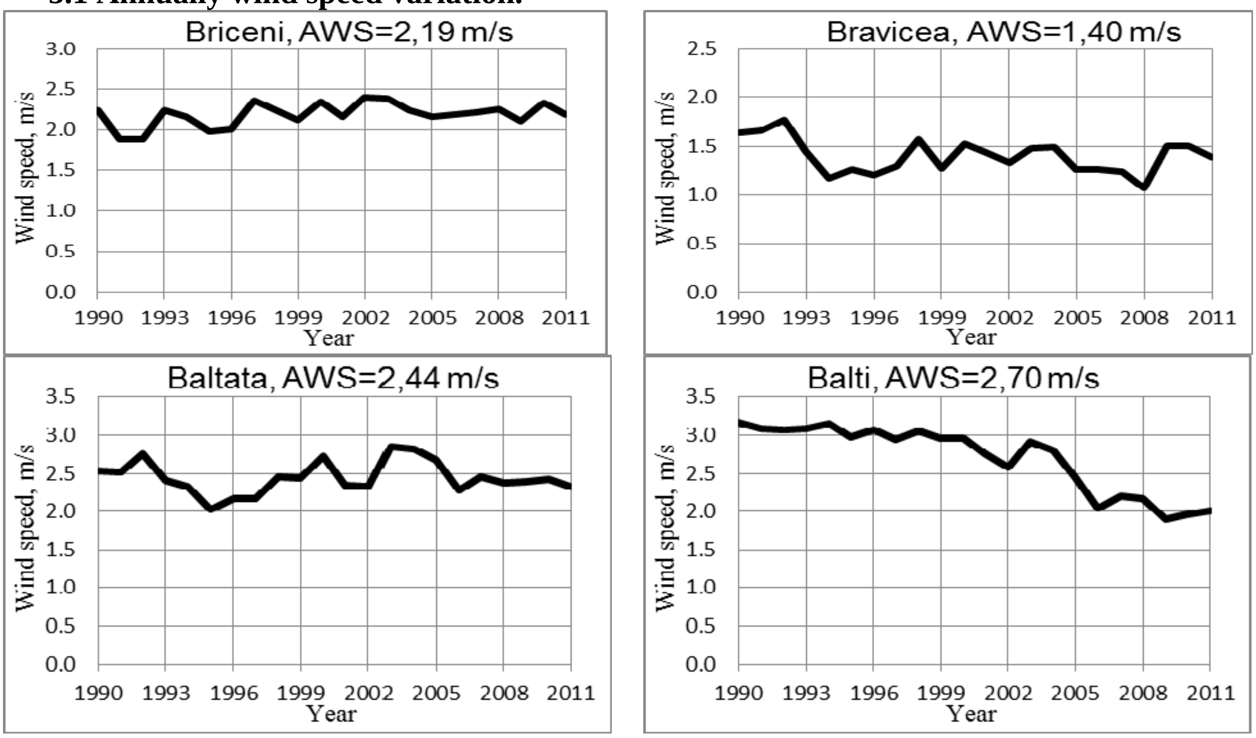
10	Chişinău	46,97169	28,84828	173	01/1990	12/2011	2.28
11	Dubăsari	47,28971	29,12363	40	01/1990	12/2011	1.94
12	Făleşti	47,58341	27,70487	162	01/1990	12/2011	2.11
13	Leova	46,48842	28,28340	156	01/1990	12/2011	2.55
14	Rîbniţa	47,77253	29,01650	119	01/1990	12/2011	2.02
15	Soroca	48,19849	28,31189	173	01/1990	12/2011	2.83
16	Ştefan-Vodă	46,52788	29,65116	173	01/1990	12/2011	2.37
17	Tiraspol	46,83431	29,61699	40	01/1990	12/2011	2.84
18	Codrii	47,1117	28,36667	157	01/1990	12/2011	1.28

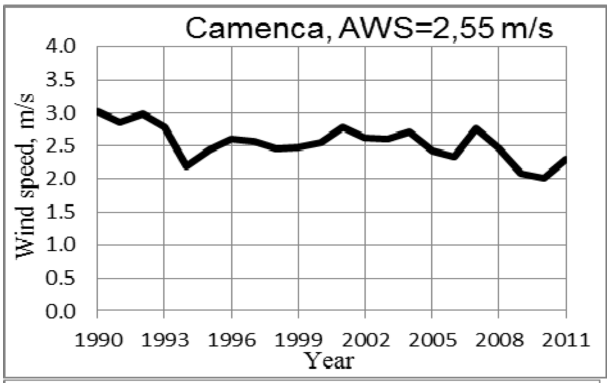
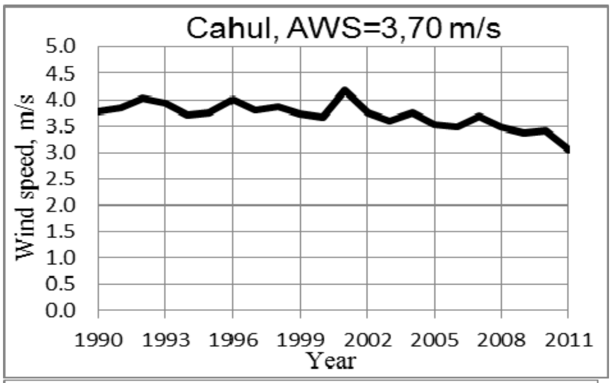
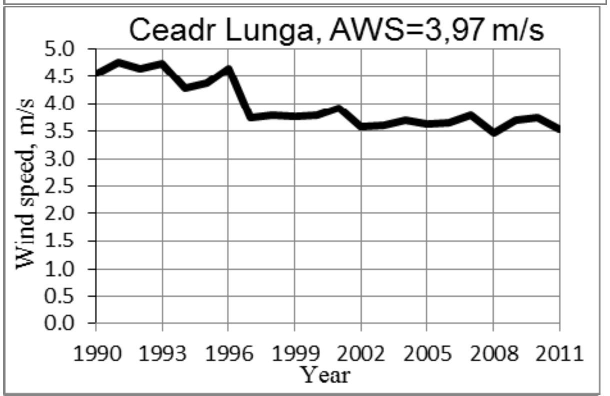
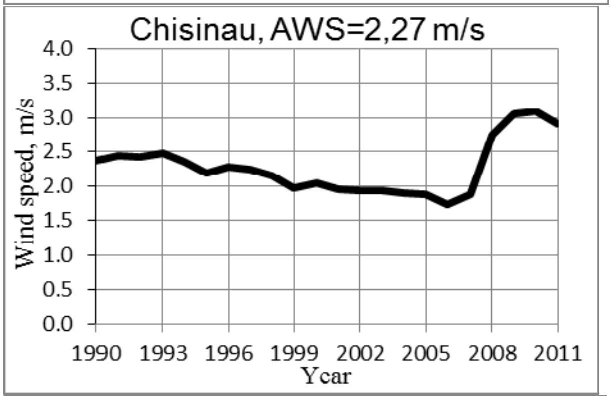
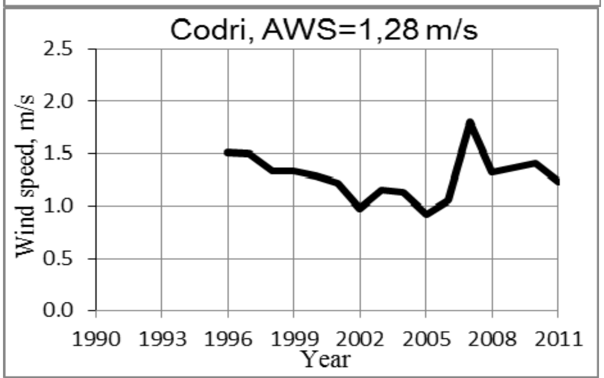
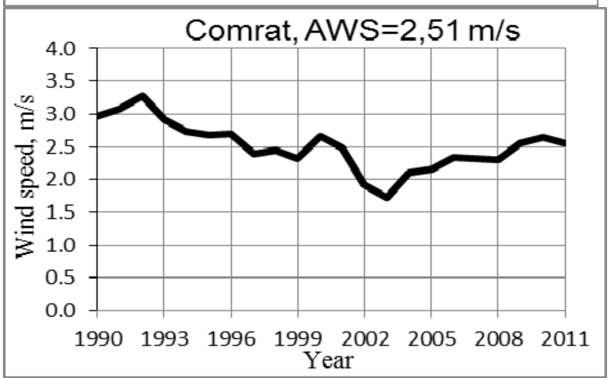
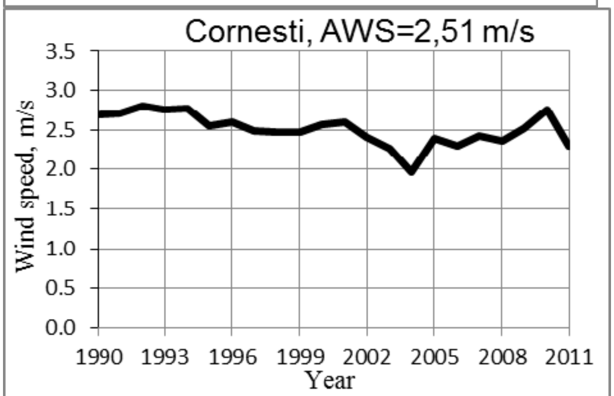
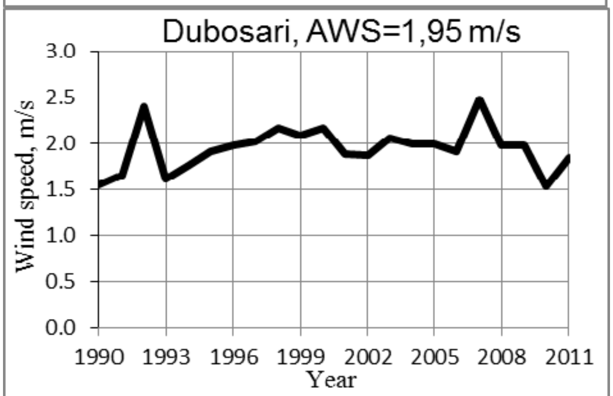
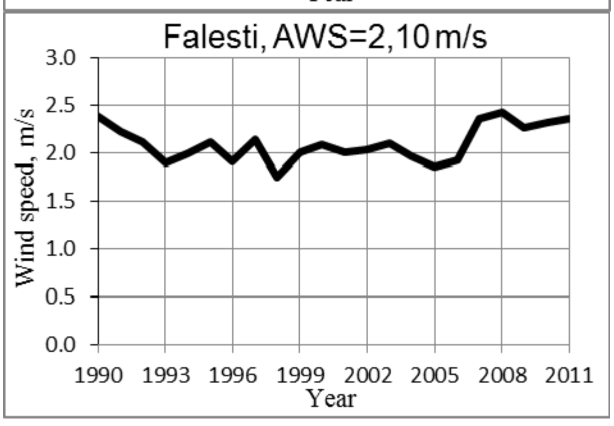
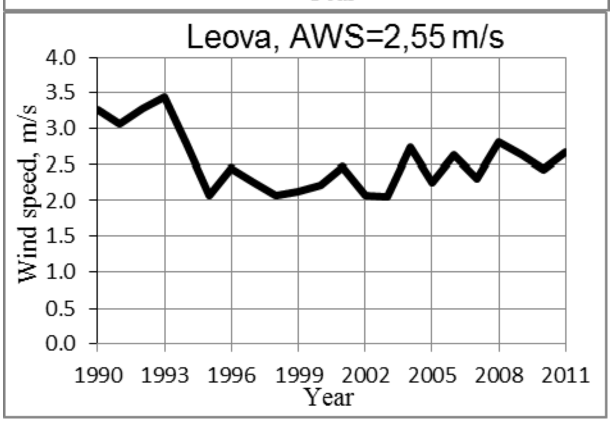
Where :
Lat is the latitude in grades, N;
Lon is the longitude in grades, E;
Elev is the elevation in meters above sea level;
From/To is the period of record in yr/mo;
AWS is the average wind speed in m/s.

5. THE OBTAINED RESULTANTS

The annual wind speed variation provides confidence in the availability of wind energy in the future because it will show as the trends of wind speed. At this stage of the study raw data were processed in Excel and were obtained the graphics presented in Figure 2. In Figure 3 is presented the average wind speed of all meteorological stations.

5.1 Annually wind speed variation.




Camenca, AWS=2,55 m/s
Wind speed, m/s
4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
1990 1993 1996 1999 2002 2005 2008 2011
Year

Cahul, AWS=3,70 m/s
Wind speed, m/s
5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
1990 1993 1996 1999 2002 2005 2008 2011
Year

Ceadr Lunga, AWS=3,97 m/s
Wind speed, m/s
5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
1990 1993 1996 1999 2002 2005 2008 2011
Year

Chisinau, AWS=2,27 m/s
Wind speed, m/s
4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
1990 1993 1996 1999 2002 2005 2008 2011
Year

Codri, AWS=1,28 m/s
Wind speed, m/s
2.5 2.0 1.5 1.0 0.5 0.0
1990 1993 1996 1999 2002 2005 2008 2011
Year

Comrat, AWS=2,51 m/s
Wind speed, m/s
4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
1990 1993 1996 1999 2002 2005 2008 2011
Year

Cornesti, AWS=2,51 m/s
Wind speed, m/s
3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
1990 1993 1996 1999 2002 2005 2008 2011
Year

Dubosari, AWS=1,95 m/s
Wind speed, m/s
3.0 2.5 2.0 1.5 1.0 0.5 0.0
1990 1993 1996 1999 2002 2005 2008 2011
Year

Falesti, AWS=2,10 m/s
Wind speed, m/s
3.0 2.5 2.0 1.5 1.0 0.5 0.0
1990 1993 1996 1999 2002 2005 2008 2011
Year

Leova, AWS=2,55 m/s
Wind speed, m/s
4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
1990 1993 1996 1999 2002 2005 2008 2011
Year

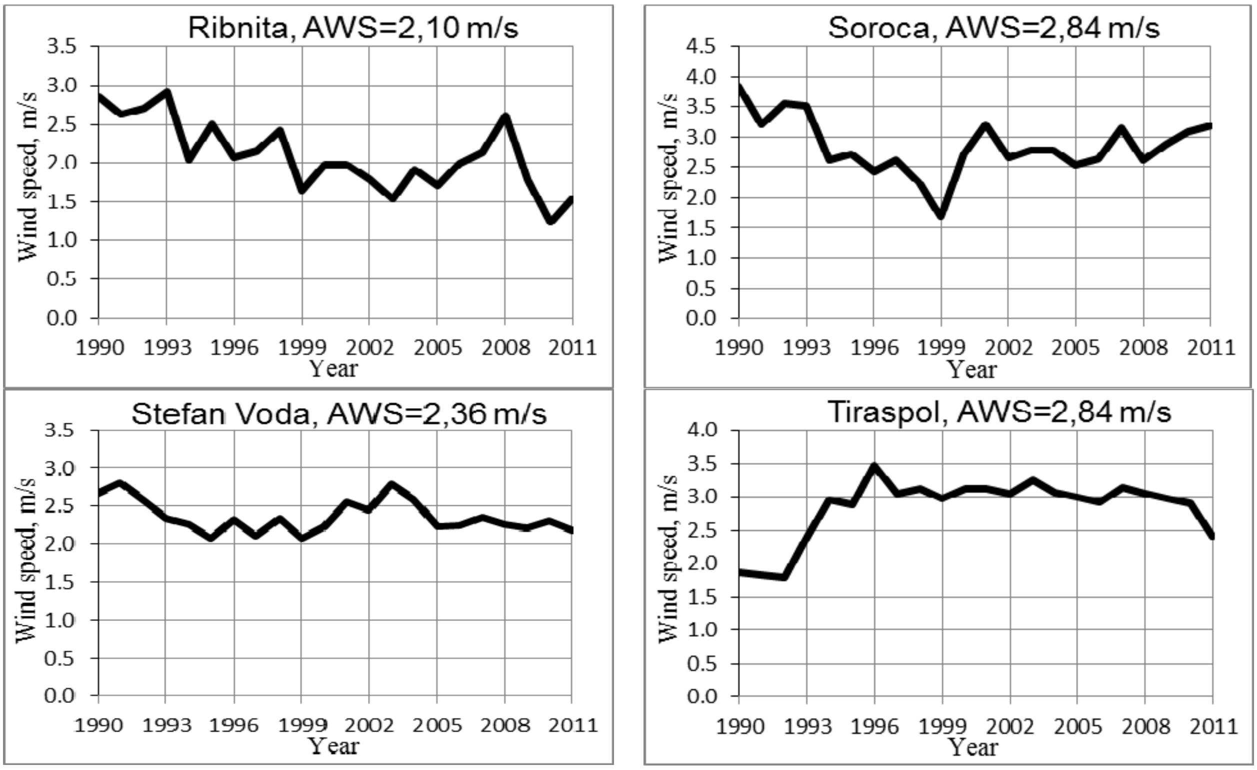


Figure 2. Annually wind speed variation

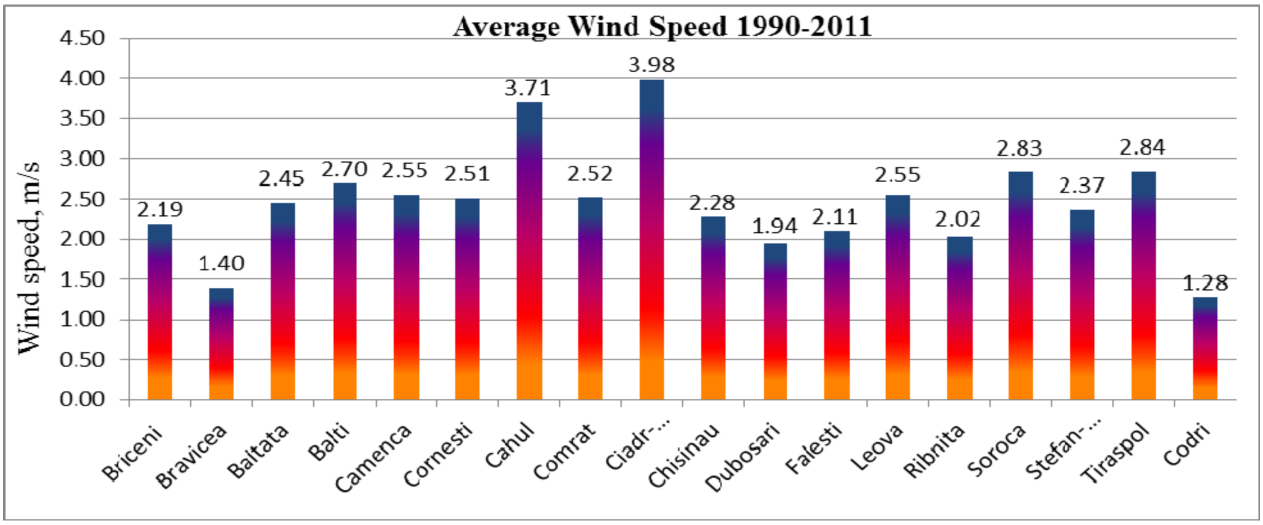


Figure 3. Annually average wind speed for all stations

From figure 2 we can easily see that practically all weather stations wind speed decreases, and this is due to the fact that in recent years around weather stations appear homes or roughness factor increase with is caused by the growth of trees and vegetation, except Tiraspol and Chisinau weather stations. The first was moved to a site with fewer obstacles in 1992 and the second - in 2008. In both cases the annual average wind speed increased by 33 %. This phenomenon is encountered in most countries and is called "death wind" [1]. Also we can see that for all whether stations the average wind speed is between 2 and 3 m/s, which is due to the shading effect of the weather station.

5.2 Monthly average wind speeds. Monthly variation of wind speed knowledge provides confidence in wind energy availability in different months. Figure 4 shows an example of monthly average wind speeds at a height of 10 m for a period of 22 years for five meteorological stations in south of Moldova. For all location the maximum speeds are in the cold season in February and March but the minimum speeds were recorded in summer in July and August [3].

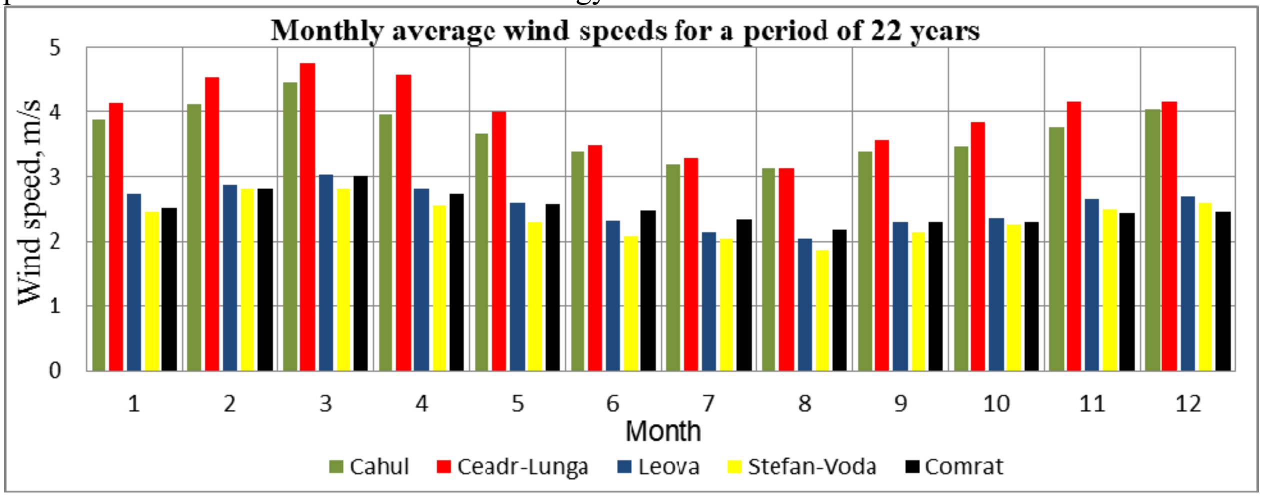


Figure 4. Monthly average wind speeds

5.3 Diurnal variation of wind speed. Wind speed is related mainly different air warming [1]. Daily and seasonal evolution can be influenced by turbulent exchanges and local orography conditions [2]. In the adjacent layer wind speed increases during the day especially since the land surface warming is more intense. Character diurnal variation, as a rule, is the one simple oscillation, with a maximum in the afternoon and a minimum night to morning. As an example, in Figure 5 is presented diurnal variation of wind speed for 4 weather stations over a period of 22 years.

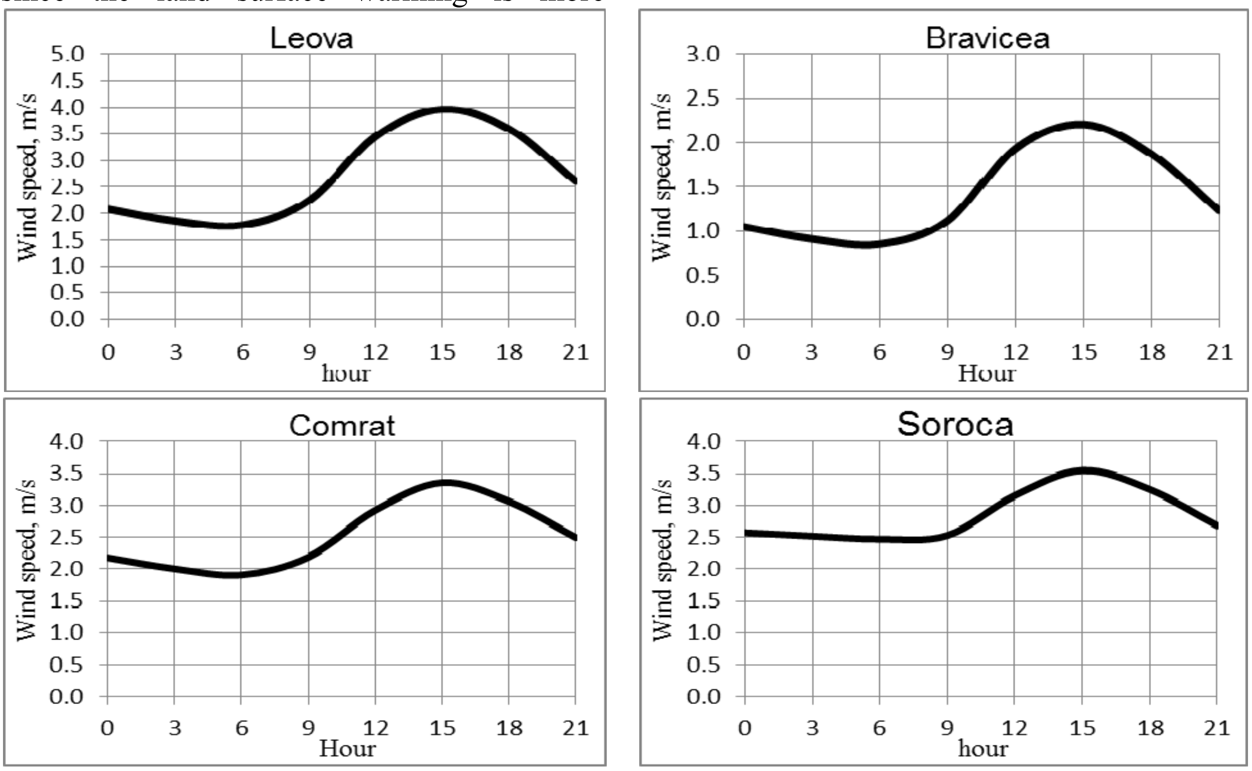


Figure 5. Diurnal variation for Leova, Bravicea, Comrat and Soroca weather stations

5.4 Weibull distribution and directions. Weibull distribution is often used to model wind speed, including the analytical approximation of the histograms of measured wind speed. In Figure 6 is shown the wind speed histograms, Weibull approximation and wind rose for 8 meteorological stations.

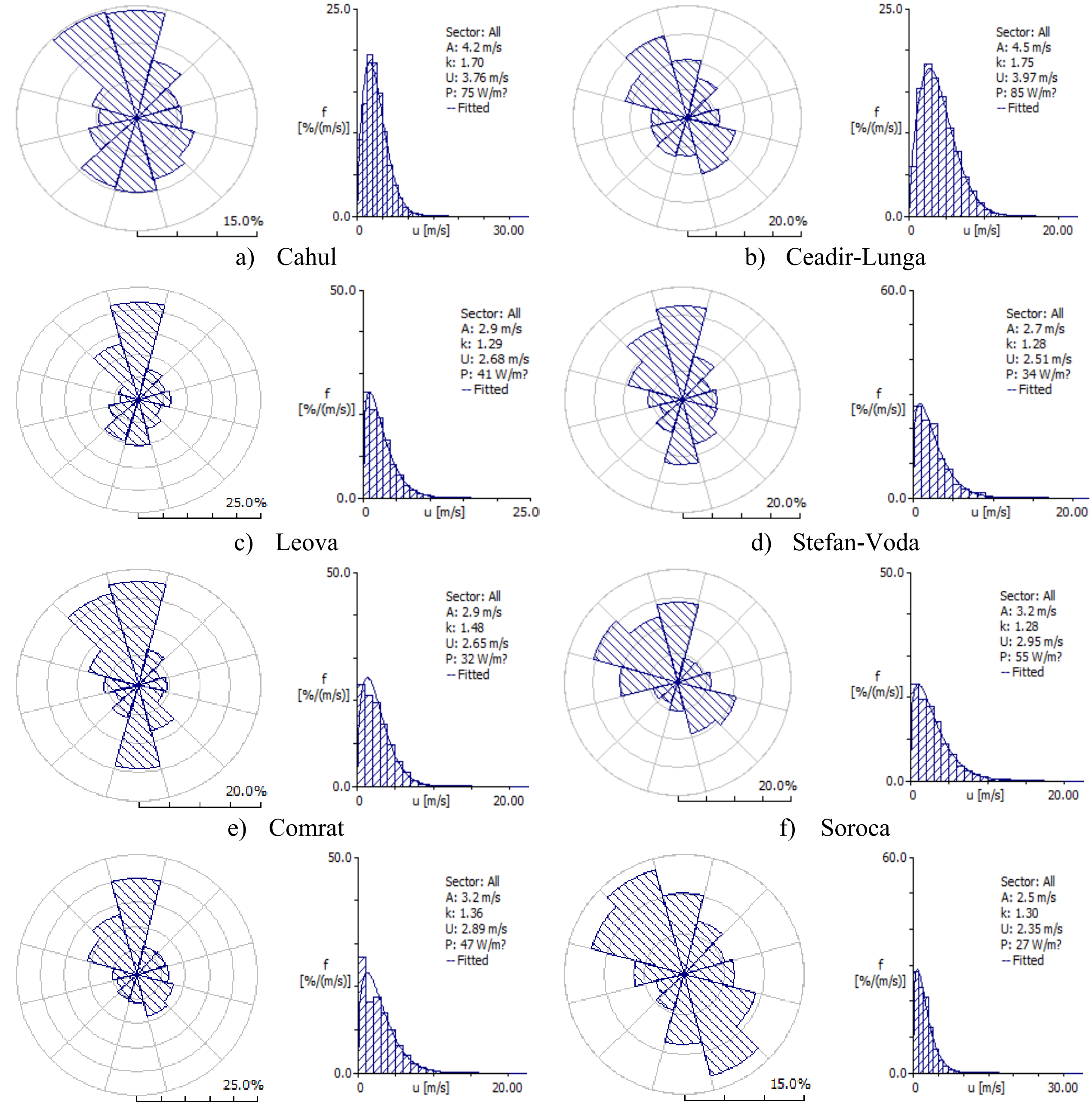


Figure 6. Wind rose and Weibull distribution

6. CONCLUSIONS

Following the analysis, the research and the processing of data from Moldova's meteorological stations were formulated the following conclusions:

1. Wind speeds are low because the height of meteorological stations, where the speeds are measured, is low and also as a result of shading phenomenon of the anemometers.
2. Practically at all weather stations (excepted Tiraspol and Chisinau) wind speed decreases and this is due to the fact that in recent years around weather stations appear obstacles or roughness factor increase with is caused by the growth of trees and vegetation. This phenomenon is encountered in most countries and is called "death of the wind".
3. For all location the maximum speeds are in the cold season in February and March but the minimum speeds were recorded in summer - in July and August.
4. Prevailing wind directions are N, NE, NW, S and SE and vary from one station to another which also tells us that it is influenced by obstacles and terrain orography.
5. The diurnal variation, have a maximum oscillation in the afternoon and a minimum in the night to morning.

References

1. D. Elliott, M. Schwartz, G. Scott, S. Haymes, D. Heimiller, R. George. Wind Energy Resource Atlas of Armenia, July 2003, NREL/TP-500-33544
2. Ib Troen, Erik Lundtang Petersen. European Wind Atlas. Directorate General for Sciance, Research and Development, Brussels, 1989.
3. Alam Md. Mahbub et al. Wind speed and power characteristics at different heights for a wind data collection tower in Saudi Arabia. Wold Rewnewable Energy Congress, 8-13 May 2011, Linkoping, Sweden.