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ASSESSMENT OF WIND CLIMATE RESOURCES ON THE TERRITORY OF THE REPUBLIC OF MOLDOVA FROM THE PERSPECTIVE OF CLIMATE CHANGE

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ABSTRACT. – Assessment of Wind Climate Resources on the Territory of the Republic of Moldova from the Perspective of Climate Change. This paper investigates the changes in wind climate resources in the Republic of Moldova in the context of climate change. The study analyses wind speed and direction data from meteorological stations over the periods 1961-1990 and 1991-2020. Results show a decreasing trend in average wind speed, particularly in the southern and central parts of the country. Additionally, there is a slight shift in dominant wind directions. The study discusses the potential impact of these changes on wind energy utilization and emphasizes the need for updated wind resource assessments to support renewable energy planning.

Keywords: *wind speed, wind direction, climate change, wind energy, Moldova.*

INTRODUCTION

Renewable energy sources (wind, solar, hydro, ocean, geothermal, biomass and biofuels) are alternatives to fossil fuels that help reduce greenhouse gas emissions, diversify energy supply and reduce dependence on volatile and uncertain fossil fuel markets, especially oil and gas (European Parliament, 2025).

The wind climate resources of the Republic of Moldova have been studied and described in fundamental scientific publications, realized in the last decades in terms of their potential energy (T. Ambros *et al.*, 1999; P. Todos *et al.*, 2002;

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V. Rachier, 2016) or spatio-temporal characteristics (G. Mleavaia, 2016). In this paper we aimed to evaluate the changes in wind climate resources in the light of climate change, an analysis of the evolution over time of the main indicators - wind direction, wind speed and calm.

MATERIALS AND METHODS

Wind observations are performed at all meteorological stations in the country (table 1). According to the recommendations of WMO (World Meteorological Organization), the data analysis and summarization was carried out for 30-year time intervals starting from 1961 (WMO, 2017). In case of missing data for some years or some months of a year, the method of data restoration was applied by using the arithmetic mean for the analysed period of the string.

Table 1. Meteorological stations whose data were used in the study

Station	Observation period, years	Station	Observation period, years
Briceni	1961-2020	Codrii	1996-2020
Soroca	1961-1983, 1985, 1988-1993, 2007-2020	Bălţata	1961-2020
Camenca	1961-2020	Chişinău	1961-2020
Râbniţa	1963-2020	Tiraspol	1961-2020
Bălţi	1961-2020	Leova	1961-2020
Făleşti	1961-2020	Ştefan Vodă	1981-2020
Bravicea	1961-2020	Comrat	1961-2020
Cornești	1961-2020	Ceadâr-Lunga	1961-1964, 1975-2020
Dubăsari	1961-2020	Cahul	1961-2020

Source: the authors

Analysis and understanding of the basic wind characteristics are based on measurement data. The quality of measurement data is a difficult subject, which depends, on one hand, on the equipment and terms of observations, and on the other hand, on the landscape specificity of the meteorological platform location and its changes over time (V. Rachier, 2016; G. Mleavaia, 2016).

For example, until 1966 wind speed was measured 4 times daily - every 6 hours, from 1966 until today - 8 times daily, every 3 hours. Until the ′60s or ′70s, the instrument used to measure wind direction and wind speed was the wind vane fixed at 10 m above the ground, then measurements were made with an anemometer, and nowadays with specialized sensors. These issues are of importance because the probability of recording extreme wind gusts is a function of the terms of the measurements, and the values of the wind speeds measured with the gyro are overestimated compared to those measured with the anemometer.

The statistical processing and string homogeneity checks, and the calculation of basic statistical parameters was performed using the Excel mathematical package.

Spatial modeling of the parameters describing the wind regime in the country did not provide satisfactory results, mainly due to the insufficient number of stations with qualitative data. Some stations were moved during the study period (Chișinău, Ceadâr-Lunga, Tiraspol), others have large gaps in the period of operation (Soroca), some do not have long enough string with years of observations (Codrii, Ștefan-Vodă), but the biggest problem in data homogenization lies in the modification of the station terrain - vegetation cover and construction. These statements are also confirmed in recent specialized publications (V. Rachier, 2016, p. 33).

For these reasons, for the evaluation of the wind regime change trends in the Republic of Moldova, we selected only the stations where the data maximally satisfy the natural conditions or where the structure of the corresponding land has not changed substantially - Briceni, Camenca, Râbnița, Fălești, Bravicea, Cornești, Dubăsari, Bălțata, Leova, Comrat, and Cahul.

RESULTS AND DISCUSSIONS

On the territory of the Republic of Moldova, the wind regime, which is characterized by two highly variable parameters in time and space - wind direction and wind speed (G.F. Lasse, 1978; Administrația Națională de Meteorologie, 2008), is determined both by the general circulation of the atmosphere and by the underlying surface.

Wind direction. The atmospheric circulation on the territory of the Republic of Moldova during the analysed period did not undergo major changes. Meteoclimatic research indicates the major influence of the seasonal baric centres described sufficiently well in the literature (G.F. Lasse, 1978; V.M. Lipinskyi *et al.*, 2003; G. Mleavaia, 2016): the winter Mediterranean cyclone, the winter Black Sea depression and the summer South-Asian cyclone. The results of the statistical analysis indicate that these trends during the analysed period changed little. Winds prevail from two opposite directions - north-westerly and south-easterly. However, the comparative analysis of the changes in wind direction presented in table 2 shows small changes, which occur in the north, north-westerly and, at some stations, southerly directions.

Table 2. Changes in the frequency of annual mean wind direction in numbers, 1991-2020 compared to 1961-1990 (%)

Station	N	NE	E	SE	S	SV	V	NV
Briceni	*5.0*	-0.2	0.3	-0.9	4.1	-1.2	-2.8	*-7.3*
Camenca	2.0	0.8	0.2	-2.4	0.2	0.2	*2.9*	*-4.0*
Râbniţa	*-3.7*	2.3	-0.7	1.8	*-4.3*	0.0	2.0	2.9
Făleşti	*-1.0*	-0.9	0.3	0.1	-0.2	*1.4*	0.0	0.4
Bravicea	-1.0	-0.2	0.0	-0.3	*-1.8*	*2.0*	0.9	0.4
Cornești	*-1.8*	0.9	-1.5	*2.2*	-0.8	1.0	-0.6	0.6
Dubăsari	1.9	*2.7*	0.2	-0.1	*-3.3*	-0.3	0.0	-0.9
Bălţata	*-1.9*	1.8	-0.6	-0.7	-0.5	0.9	-2.3	*3.4*
Leova	*4.4*	0.2	-0.6	-2.1	-0.5	0.4	0.2	*-1.9*
Comrat	*-2.2*	-0.9	1.0	-0.7	-0.7	0.1	2.7	*0.8*
Cahul	*-1.6*	0.8	0.2	*-1.8*	0.0	1.1	1.1	0.1

Source: data from meteorological stations

Thus, the largest changes in wind frequency (years 1991-2020 compared to 1961-1990) are observed at the meteorological station Briceni, where the frequency of northerly winds increased by 5.0%, southerly - by 4.1% and those from the northwest decreased by 7.3%. At the Râbniţa meteorological station the frequency of northerly winds decreased by 3.7% and northerly by 4.3%. In the central part of the country, at the Bălţata meteorological station the frequency of northerly winds decreased by 1.9% and northwesterly winds increased by 3.4%. In the southern part of the country, the greatest changes in wind frequency were observed at the Leova meteorological station, where the frequency of northerly winds increased by 4.4%, while southerly winds decreased by 1.9% (fig. 1 and 2).

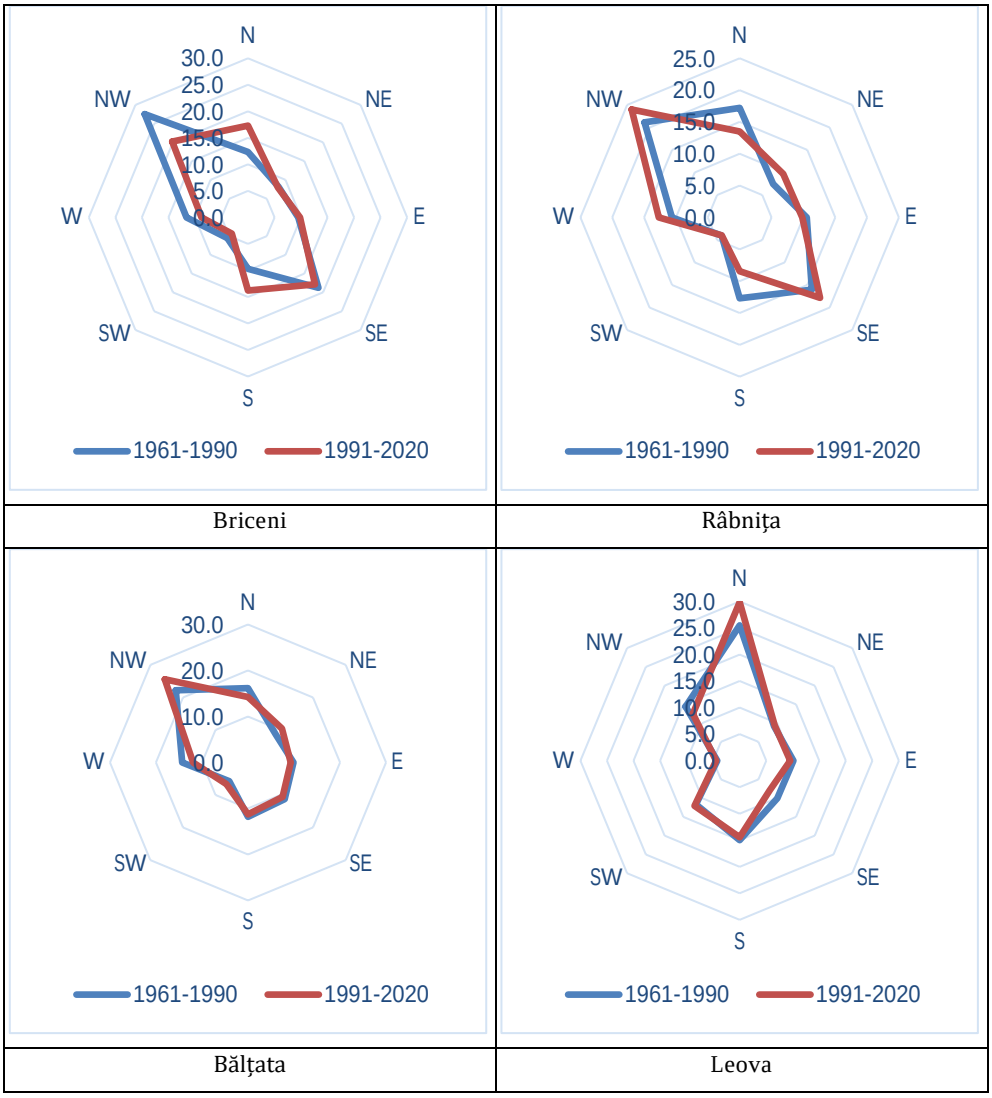

Fig. 1. Wind speed changes, 1991-2020 compared to 1961-1990.
Source: data from meteorological stations

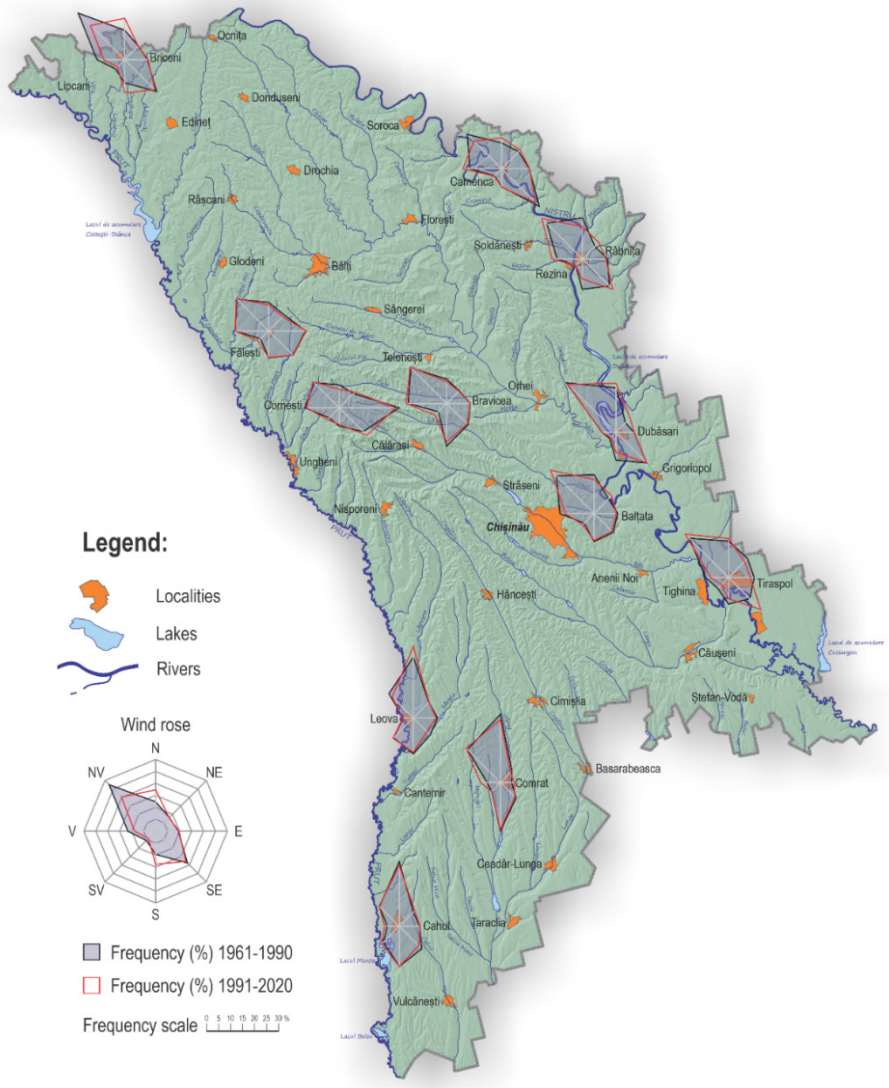

Fig. 2. Wind speed changes over the analysis periods 1961-1990 and 1991-2020.
Source: data from meteorological stations

These changes can be explained by a shift in the movement of air masses from latitudinal to meridional orientation (T. Constantinov *et al.*, 2006). This phenomenon is also confirmed in earlier scientific investigations, which find the

permutation of eastward North Atlantic fluctuations originating from the normal pressure difference between the Azorean maximum and the Icelandic minimum (U. Ulbrich and M.M. Christoph, 1999).

We consider that the atmospheric circulation is an extremely dynamic process, but it is premature only on the basis of the analysis of 60 years of observations to deduce the causes of its modification, even if some trends are noticeable.

Wind speed. It is considered (G.F. Lasse, 1978) that the mean wind speed is a stable value, varying little from year to year. However, recent research results in the literature indicate that decreasing trends in the mean wind speed in south-eastern Europe in particular and in the northern hemisphere in general are evident (A. Busuioc *et al*., 2013; J. Weber, F. Gotzens and D. Witthaut, 2019; S.B. Krasheninnikova and M.A. Krasheninnikova, 2019; R.J. Bartelmie and S.C. Pryor, 2021).

In this context, particular attention should be paid to the results of research obtained in Romania (A. Busuioc *et al*., 2013): "The linear trend of the evolution of the annual mean speed indicates mean decreases over the period 1961-2007 greater than 1 m/s for the north of the Eastern Carpathians, the Moldavian Plateau and the north of the Bărăgan Plain and the Dobrogea Plateau. The same regions have the most relevant values in terms of decrease in wind speed also on a seasonal scale, with values reaching -2...-3 m/s at several meteorological stations in the eastern half of the country".

The average annual wind speed in the country varies, predominantly, depending on the variety of landscape regions of the Republic of Moldova and due to the specific location of the meteorological station. At present, the mean annual wind speed ranges from 1.4 m/s at the Bravicea meteorological station to 3.5 m/s at the Cahul meteorological station (table 3). The highest mean wind speeds are found in the south of the country (Cahul, Comrat). The role of altitude is evident - the average annual wind speed is higher on higher landforms (Cornești, Bălțata), and lower in depressions (Bravicea).

In the cold period of the year, wind speeds are higher (from 1.5 m/s at Bravicea to 3.8 m/s at Cahul) than in the warm period (1.2 m/s and 3.2 m/s respectively). In percentage ratio, the average wind speeds in the cold period of the year for the country as a whole are 22% higher than in the warm period (10.9% at Comrat and 29.7% at Camenca). It should be noted that the gap between average winter and summer wind speeds increases latitudinally from north to south. Thus, average wind speeds in the south of the country are more stable throughout the year.

Seasonally, summer is the season with the lowest average wind speeds, ranging from 1.1 m/s (Bravicea) to 3.1 m/s (Cahul). In percentage ratio the average summer wind speeds are 14.2% lower than the annual average (7.0% in Comrat and 19.6% in Camenca).

In spring the average wind speeds are the highest: 1.7 m/s at Bravicea and 3.9 m/s at Cahul. In percentage ratio, the average spring wind speeds are higher than the annual average by 13.5% on average over the country (9.9% in Cahul and 22.3% in Bravicea).

Table 3. Average wind speed, m/s, 1991-2020

Station	Annual	Warm time of year, (V-IX)	Cold time of year, (X-IV)	Winter	Spring	Summer	Autumn
Briceni	2.2	1.9	2.4	2.4	2.5	1.8	2.1
Camenca	2.5	2.1	2.7	2.7	2.8	2.0	2.4
Râbnița	1.9	1.7	2.1	2.1	2.2	1.7	1.8
Fălești	2.2	1.9	2.3	2.3	2.4	1.8	2.1
Bravicea	*1.4*	*1.2*	*1.5*	*1.5*	*1.7*	*1.1*	*1.2*
Cornești	2.4	2.1	2.6	2.5	2.7	2.0	2.4
Dubăsari	1.9	1.7	2.1	2.1	2.2	1.7	1.8
Bălțata	2.4	2.2	2.6	2.5	2.8	2.2	2.3
Leova	2.5	2.2	2.7	2.7	2.9	2.2	2.4
Comrat	2.5	2.4	2.6	2.6	2.8	2.4	2.4
Cahul	*3.5*	*3.2*	*3.8*	*3.8*	*3.9*	*3.1*	*3.4*

Source: data from meteorological stations

The regional trend of decreasing average wind speeds was mentioned earlier. The analysis of the dynamics of these values over time confirms this statement also for the territory of the Republic of Moldova where the average wind speeds have decreasing trends (tab. 4 and 5, fig. 2). Comparing the average annual wind speeds from 1961-1990 with those from 1991-2020, we find that the average annual wind speed decreased by 0.6 m/s on average over the country or 21.6% (tab. 4, 5). Particularly dramatic is the decrease in mean annual wind speeds at the meteorological station Leova by 1.5 m/s (37,9%). Along with Leova, considerable decreases in mean annual wind speeds are recorded at Râbnița, Camenca and Cornești (0.7, 0.8 m/s or 26.9%, 34.8% and 24.2% respectively). The smallest change in average wind speed was in the south of the country: Comrat (0.2 m/s or 8.8%) and Cahul (0.4 m/s or 8.8%).

Comparison of the change in mean speeds in the warm and cold period of the year (1961-1990 vs. 1991-2020) does not show large differences - mean speeds decreased by 0.6 m/s and 0.7 m/s respectively (21.7% and 21.6%).

The speeds during the cold period of the year have decreased significantly compared to the annual averages - on average by 0.8 m/s per country (1991-2020 compared to 1961-1990) or by 24.3%. In summer the average wind speeds per country decreased by 0.6 m/s or 19.4%.

Table 4. Changes in mean wind speed, m/s, 1991-2020 compared to 1961-1990 (decreasing direction)

Station	Annual	Warm time of year, (V-IX)	Cold time of year, (X-IV)	Winter	Spring	Summer	Autumn
Briceni	0.5	0.5	0.5	0.6	0.4	0.6	0.3
Camenca	0.6	0.5	0.6	0.7	0.6	0.5	0.4
Râbnița	*0.7*	*0.6*	*0.8*	*0.9*	*0.7*	*0.6*	*0.6*
Fălești	0.6	0.5	0.6	0.7	0.6	0.5	0.4
Bravicea	*0.7*	*0.7*	*0.7*	*0.8*	*0.7*	*0.7*	*0.6*
Cornești	*0.8*	*0.7*	*0.8*	*1.0*	*0.8*	*0.6*	*0.6*
Dubăsari	0.4	0.4	0.5	0.5	0.3	0.4	0.4
Bălțata	0.6	0.5	0.6	0.7	0.6	0.5	0.4
Leova	*1.5*	*1.3*	*1.7*	*1.9*	*1.6*	*1.3*	*1.2*
Comrat	0.2	0.2	0.3	0.4	0.3	0.2	0.1
Cahul	0.4	0.2	0.5	0.6	0.4	0.2	0.2

Source: data from meteorological stations

Table 5. Changes in mean wind speed, %, 1991-2020 compared to 1961-1990 (decreasing direction)

Station	Annual	Warm time of year, (V-IX)	Cold time of year, (X-IV)	Winter	Spring	Summer	Autumn
Briceni	18.9	22.6	16.6	19.7	13.6	25.1	13.4
Camenca	18.7	18.1	19.1	21.8	18.1	19.2	13.2
Râbnița	*26.9*	*26.3*	*27.2*	*30.5*	*24.9*	*26.8*	*23.2*
Fălești	21.6	22.1	21.3	23.2	20.1	22.6	17.4
Bravicea	*34.8*	*37.4*	*33.3*	*35.0*	*29.9*	*37.7*	*34.1*
Cornești	*24.2*	*24.5*	*24.0*	*28.1*	*21.9*	*23.8*	*19.7*
Dubăsari	18.0	18.1	18.0	19.9	13.0	18.2	17.6
Bălțata	18.7	17.7	19.3	21.5	18.1	17.2	14.9
Leova	*37.9*	*37.0*	*38.4*	*41.8*	*35.2*	*36.8*	*33.8*
Comrat	8.8	8.6	8.9	12.1	9.9	9.4	3.3
Cahul	9.4	6.6	11.1	13.7	8.5	7.3	6.8

Source: data from meteorological stations

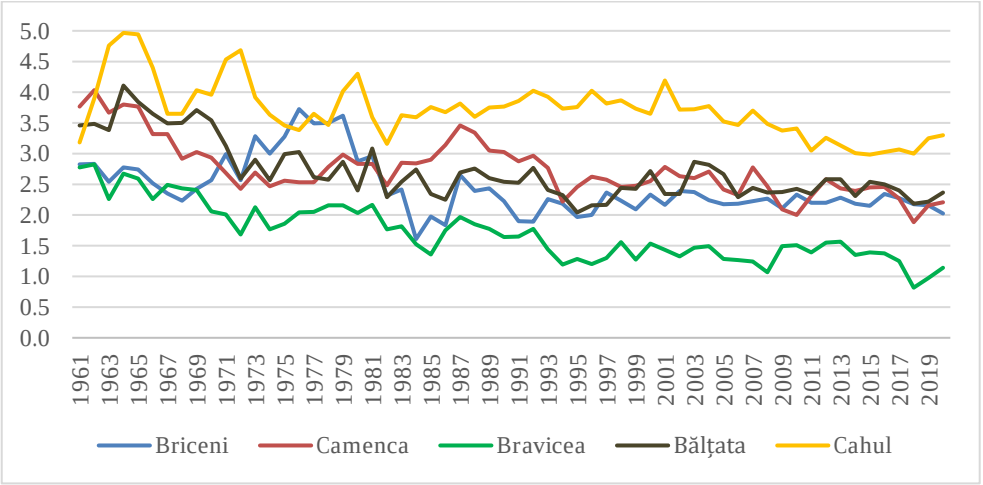

Fig. 3. Dynamics of the change in mean annual wind speeds (m/s) at some representative stations (1961-2020).
Source: data from meteorological stations

In the frequency distribution of wind speeds by gradations (table 6, Fig. 3), we note that in the Republic of Moldova, at present (period 1991-2020), on average, winds with speeds of 2-3 m/s predominate - 42.1%, followed by those with lower speeds - below 1 m/s - 35.8%. Obviously, as the speeds increase, the frequency is decreasing (table 6).

Table 6. Wind speed frequency by gradation, %, 1991-2020

Station	Wind speed, m/s											
	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-20	21-24	25-28
Briceni	37.8	44.4	13.4	3.3	0.7	0.2	0.1	0.1	0.0	0.0	0.0	0.0
Camenca	32.1	42.2	18.2	5.5	1.7	0.3	0.1	0.0	0.0	0.0	0.0	0.0
Râbnița	37.6	46.2	12.7	2.7	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Fălești	30.6	54.9	12.2	1.8	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Bravicea	58.1	32.9	7.3	1.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Cornești	29.4	49.7	16.7	3.4	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Dubăsari	45.0	40.4	11.6	2.3	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Bălțata	39.6	31.3	20.1	6.9	1.6	0.4	0.1	0.0	0.0	0.0	0.0	0.0
Leova	36.1	39.5	16.4	5.6	1.7	0.4	0.3	0.1	0.0	0.0	0.0	0.0
Comrat	32.3	41.2	19.4	5.8	1.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Cahul	15.3	40.3	28.4	11.1	3.6	0.8	0.3	0.1	0.0	0.0	0.0	0.0

Source: data from meteorological stations
Note: If '0.0' is entered, the value indicated is very small, in the order of hundredths, thousandths, etc., and is not shown in the table.

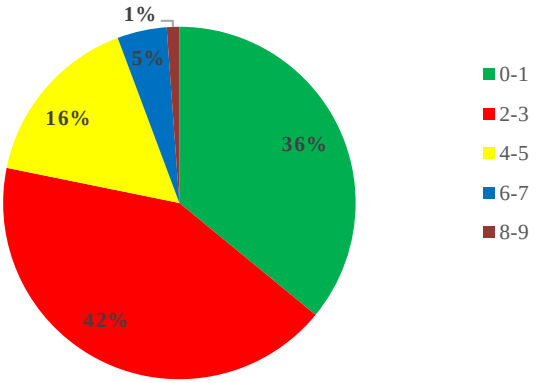

Fig. 4. Wind frequency distribution by speed gradations, %. Period 1991-2020.
Source: data from meteorological stations

The general decrease in wind speed in the Republic of Moldova can be broken down in detail over the analysed period and in terms of frequency according to the speed gradations (tables 7 and 8). It should be noted that against the background of decreasing mean wind speed, the frequency of low wind speeds is increasing. Thus, comparing the frequency of wind speeds in the period 1961-1990 with 1991-2020, it can be seen that the frequency of wind speeds below 1.0 m/s is increasing by 3.5% and the frequency in the 2-3 m/s range - by 7.4%. In percentage ratio this increase constitutes 14.6% and 21,4% respectively.

Table 7. Changes in wind speed frequency by gradation, %,
1991-2020 compared to 1961-1990

Station	Wind speed, m/s											
	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-20	21-24	25-28
Briceni	4.0	9.0	-6.2	-4.2	-1.4	-0.7	-0.3	-0.1	0.0	0.0	0.0	0.0
Camenca	1.2	8.2	-4.1	-3.3	-1.3	-0.6	-0.1	0.0	0.0	0.0	0.0	0.0
Râbnița	0.6	14.2	-6.9	-4.9	-2.0	-0.7	-0.2	-0.1	0.0	0.0	0.0	0.0
Fălești	-2.9	13.0	-4.6	-3.4	-1.1	-0.5	-0.3	-0.1	-0.1	0.0	0.0	0.0
Bravicea	7.7	4.0	-5.7	-3.8	-1.4	-0.3	-0.5	0.0	-0.1	0.0	0.0	0.0
Cornești	6.3	6.7	-6.1	-3.8	-1.8	-0.8	-0.3	-0.1	-0.1	0.0	0.0	0.0
Dubăsari	3.2	2.4	-1.8	-1.9	-0.9	-0.5	-0.2	-0.1	0.0	0.0	0.0	0.0
Bălțata	2.1	3.8	0.6	-2.6	-2.2	-0.9	-0.5	-0.1	-0.2	0.0	0.0	0.0
Leova	19.0	6.8	-7.6	-8.7	-5.0	-2.9	-0.9	-0.4	-0.2	-0.1	0.0	0.0
Comrat	-0.1	7.0	-2.1	-2.7	-1.5	-0.3	-0.2	-0.1	0.0	0.0	0.0	0.0
Cahul	-2.4	6.4	2.9	-3.2	-2.1	-1.2	-0.3	-0.1	0.0	0.0	0.0	0.0

Source: data from meteorological stations
Note: If '0,0' is entered, the value indicated is very small, in the order of hundredths, thousandths, etc., and is not shown in the table.

Starting with the range of velocities above 4 m/s the difference between the frequency of velocities in the compared periods is decreasing dramatically. The larger the velocity range, the larger the difference in their frequencies becomes compared to the period 1961-1991. Thus, in percentage ratio the frequency of velocities 4-5 m/s decreased by 20.3% on the country average, 6-7 m/s - by 48.8%, 8-9 m/s - by 65.2%, 10-11 m/s - by 75.9%, and from 21 m/s - by more than 100% (table 8).

Table 8. Percent changes in wind speed frequency by gradations, 1991-2020 compared to 1961-1990

Station	Wind speed, m/s											
	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-20	21-24	25-28
Briceni	11.7	25.5	-31.5	-56.0	-67.4	-73.6	-80.1	-63.2	-70.8	-44.3	-100	-100
Camenca	3.9	24.2	-18.3	-37.7	-44.0	-67.2	-58.4	-77.0	-73.8	-100	-100	-100
Râbnița	1.6	44.4	-35.0	-64.4	-77.5	-81.0	-93.4	-94.9	-94.7	-95.0	-100	-100
Fălești	-8.7	31.1	-27.5	-65.0	-75.3	-83.1	-98.4	-94.3	-100	-96.3	-100	-100
Bravicea	15.3	13.9	-43.9	-74.4	-84.9	-82.3	-95.6	-56.9	-100	-100	-100	-100
Cornești	27.3	15.6	-26.9	-52.8	-73.9	-88.6	-91.7	-91.4	-97.9	-100	-100	-100
Dubăsari	7.7	6.3	-13.6	-45.0	-65.7	-77.7	-84.3	-94.1	-96.5	-100	-100	-100
Bălțata	5.5	13.8	3.0	-27.0	-57.4	-66.8	-85.7	-84.2	-96.4	-91.1	-100	-100
Leova	111	20.6	-31.7	-61.0	-74.8	-88.2	-75.4	-82.8	-92.9	-97.2	-100	-100
Comrat	-0.3	20.5	-9.6	-31.6	-59.3	-66.4	-78.9	-72.4	-96.2	-100	-100	-100
Cahul	-13.7	19.0	11.2	-22.3	-36.7	-60.2	-50.0	-36.3	-52.2	-78.6	-100	-100

Source: data from meteorological stations

Spatially, the south of the country stands out because wind speeds above 4 m/s decrease less than the rest of the stations, thus confirming a relative stability in the change of wind speeds in this region. Here the meteorological station Leova again represents an exception conditioned by the specific landscape of the region.

Calms. The mean annual frequency of calms varies spatially depending on the specific physical-geographical and regional features of atmospheric circulation (G.F. Lasse, 1978; Administrația Națională de Meteorologie, 2008). The highest frequency of calms is observed in the northeastern part of the country and in depressions (Râbnița - 25.8%, Bravicea - 39.6%, table 9). The lowest frequency of calms is specific to the south of the country and high, open places (Cahul - 5.1%, Cornești - 9.7%, table 9). In the warm period of the year, the frequency of calms is slightly higher than in the cold period (4.3% on average over the country), keeping the same spatial distribution properties as in the annual average (table 9).

Table 9. Changes in calm frequency, %, 1991-2020 compared to 1961-1990

Station	Calm (an, 1991-2020)	The difference	Calm (V-IX, 1991-2020)	The difference	Calm (X-IV, 1991-2020)	The difference
Briceni	**14.3**	-5.5	**17.9**	-7.4	**14.1**	-5.8
Camenca	**18.8**	-1.8	**22.6**	-2.9	**16.0**	-1.1
Râbniţa	**25.8**	0.3	**30.9**	0.7	**22.1**	-0.2
Făleşti	**9.1**	-5.3	**10.8**	-5.7	**7.9**	-5.0
Bravicea	**39.6**	2.4	**44.4**	3.8	**36.2**	1.4
Cornești	**9.7**	2.7	**10.7**	3.1	**9.0**	2.4
Dubăsari	**18.77**	-3.5	**22.7**	-3.0	**15.9**	-4.2
Bălţata	**24.1**	0.1	**27.3**	1.2	**21.9**	-0.6
Leova	**13.1**	6.7	**13.8**	6.0	**12.6**	7.2
Comrat	**12.51**	-9.8	**12.9**	-11.1	**12.2**	-9.2
Cahul	**5.1**	-2.7	**5.4**	-4.1	**5.0**	-1.7

Source: data from meteorological stations

Compared to the period 1961-1990, the frequency of calmness undergoes visible changes in the direction of decreasing. These changes are particularly noticeable in percentage terms (table 10). Even if at some stations these changes are very small (Râbniţa – 1.1%, Balţata – 0.6%, Bravicea – 6.1% compared to the average for 1961-1990) and have an increasing character, at many stations in the country a considerable decrease in the frequency of calm is observed.

Table 10. Percentage changes in calm frequency, %, 1991-2020 compared to 1961-1990

Station	Calm (an, 1991-2020)	The difference	Calm (V-IX, 1991-2020)	The difference	Calm (X-IV, 1991-2020)	The difference
Briceni	14.3	-38.5	17.9	-41.3	14.1	-41.2
Camenca	18.8	-9.8	22.6	-12.7	16.0	-6.8
Râbniţa	25.8	1.1	30.9	2.3	22.1	-1.0
Făleşti	9.1	-58.2	10.8	-52.4	7.9	-63.8
Bravicea	39.6	6.1	44.4	8.5	36.2	3.8
Cornești	9.7	27.5	10.7	28.8	9.0	26.4
Dubăsari	18.77	-18.9	22.7	-13.3	15.9	-26.4
Bălţata	24.1	0.6	27.3	4.5	21.9	-2.9
Leova	13.1	51.1	13.8	43.4	12.6	57.2
Comrat	12.51	-78.5	12.9	-85.5	12.2	-75.5
Cahul	5.1	-53.6	5.4	-75.5	5.0	-33.3

Source: data from meteorological stations

These trends are particularly strong in the south of the country, where in Comrat the average annual frequency of calms decreased by 78.5% compared to 1961-1990, in Cahul - by 53.6%. In the north of the country these trends are also visible but less expressed - in Briceni the average frequency of calms decreased by 38.5% compared to 1961-1990. Analysis for the hot and cold periods of the year shows the same trends.

On average over the country, the average annual frequency of calm has decreased by 15.5% compared to 1961-1990, in the warm period of the year by 17.6%, and in the cold period by 14,9%.

We find that the overall decrease in calm frequency is accompanied by a decrease in mean annual wind speeds, which is confirmed by the correlation of these parameters (fig. 5). The degree of correlation, R2, ranges from 0.6-0.7, which is within the acceptable range.

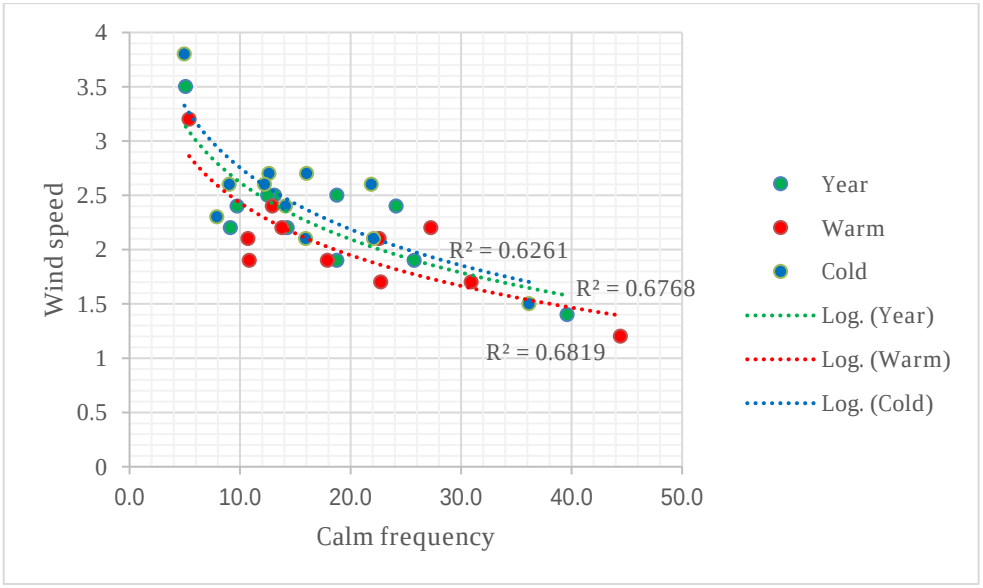

Fig. 5. Function of mean annual mean calm wind speeds, 1991-2020.
Source: the authors, based on data from meteorological stations

This is also confirmed by the frequency distribution of low wind speeds in relation to calm frequency: the higher the calm frequency, the higher the frequency of low wind speeds (below 1 m/s, fig. 4).

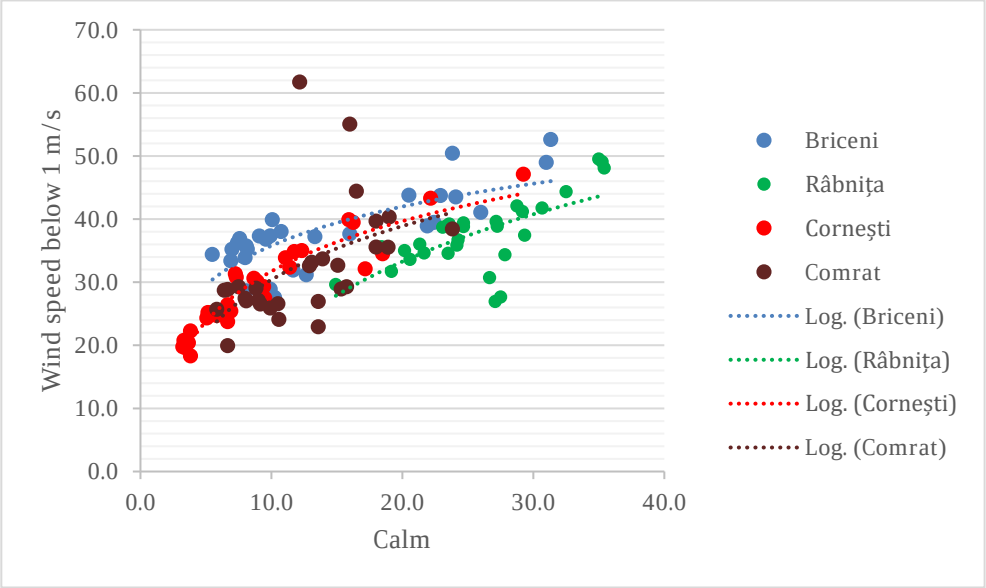

Fig. 6. Frequency function of low wind speeds (below 1 m/s) versus calm frequency, period 1991-2020

Source: the authors, based on data from meteorological stations

In general, the analysis of calm frequency, in particular its correlation with other characteristic wind indicators, requires dedicated studies.

CONCLUSIONS

1. Comparative analysis of the changes in wind direction shows small changes, which occur in the north, northwest and, at some stations, south directions. These changes can be explained by the change in the movement of air masses from latitudinal to meridional orientation. We consider that the atmospheric circulation is an extremely dynamic process, but it is premature only on the basis of 60 years of analysed observations to deduce the causes of its modification, even if some trends are noticeable.

2. For the territory of the Republic of Moldova trends of decreasing average annual wind speeds are characteristic. Comparing the average annual wind speeds of 1961-1990 with those of 1991-2020 we find that the average annual wind speed decreased by 0.6 m/s on average over the country or 21.6%.

The wind speeds in the cold period of the year also decreased compared to the annual average - on average by 0.8 m/s over the country (1991-2020 compared to 1961-1990) or by 24.3%.

3. Against the background of decreasing average wind speed, the frequency of low wind speeds is increasing. Thus, comparing the frequency of wind speeds in the period 1961-1990 with 1991-2020, the frequency of wind speeds below 1.0 m/s is increasing by 3.5% and the frequency in the 2-3 m/s range by 7.4%. In percentage ratio, this increase constitutes 14,6% and 21,4% respectively.

4. Starting with the range of velocities above 4 m/s, the difference between the frequency of velocities in the compared periods is decreasing dramatically. The larger the velocity range, the larger the difference in their frequencies becomes compared to the period 1961-1991. Thus, in percentage ratio the frequency of velocities 4-5 m/s decreased by 20.3% on average over the country, 6-7 m/s - by 48.8%, 8-9 m/s - by 65.2%, 10-11 m/s - by 75.9%, and from 21 m/s - by more than 100%. In the southern part of the country the speeds above 4 m/s decrease less, compared to the rest of the stations, thus confirming a relative stability in the change of wind speeds in this region.

5. Compared with the period 1961-1990, the frequency of calms is visibly decreasing. On average for the country, the annual average frequency of calms decreased by 15.5% compared to 1961-1990, in the warm period of the year - by 17.6%, in the cold period - by 14.9%.

6. Against the background of decreasing average wind speeds, particularly those above 4 m/s, we consider that there is an obvious trend of decreasing wind potential in the average wind on the country, because the more lulls there are, the more frequent are low wind speeds, with small exceptions in the southern part of Moldova.

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