ახალგაზრდა მეცნიერთა საერთაშორისო კონფერენცია „დედამიწის შემსწავლელი მეცნიერების თანამედროვე პრობლემები“
შრომები, ISBN 978-9941-36-044-2, თბილისი, საქართველო, 21-22 ნოემბერი, 2022 წ.
**International Conference of Young Scientists "Modern Problems of Earth Sciences"
Proceedings, ISBN 978-9941-36-044-2, Tbilisi, Georgia, November 21-22, 2022**

STATISTICAL ANALYSIS OF THE DAILY WIND SPEED IN TBILISI IN 1971-2016

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Abstract: *The results of the detailed statistical analysis of the daily mean and max wind speed for Tbilisi from January 1, 1971 to December 31, 2016 are presented. In the studied period of time, the range of changes in the average daily wind speed was 0 - 14.9 m/s, and the maximum - up to 41.0 m/s. The repeatability of the average daily and maximum wind speed in Tbilisi on the Beaufort Wind Scale was obtained. In particular, it was found that the repeatability of the maximum wind speed covers the entire Beaufort scale. At the same time, the scale range of 8 and more (17.2-20.7 m/s, gale and above, the onset of destructive processes in the environment and their intensification) accounts for about 6.5% of cases (about 24 days a year). During the entire period of research with hurricane wind 3 cases were recorded (Beaufort scale range - 12, hurricane, wind speed >32.6 m/s, devastating destruction). For separate months and according to annual data, correlation and regression relationships between daily and average monthly values of the mean and max wind speed were studied.*
Key Words: *Wind speed,* ***Beaufort Wind Scale, statistical analysis.***

Introduction

Wind is one of the most important climate-forming factors. Therefore, special attention is paid to the study of the wind regime everywhere, including in Georgia. A large number of studies are devoted to the climatology of the wind, the variability of its regime [1-7]. Strong wind often leads to the destruction of residential and industrial facilities, the shutdown of ground and air transport, the appearance of snowstorms, and the strengthening of the negative consequences of other dangerous hydrometeorological phenomena precipitation, hail, etc.), human casualties, etc. [4,7-10]. Data on the wind regime are important for the development of wind energy, the agricultural sector of the economy [2,11], etc. Wind speed largely determines the level of air pollution [12]. Since the wind is one of the most important bioclimatic factors, information about it is important for the development of the resort and tourism industry by assessing various simple and complex bioclimatic indicators for specific areas [13,14].
This work is a continuation of previous studies [3,5,6-10,14]. The results of the detailed statistical analysis of the daily mean and max wind speed for Tbilisi from January 1, 1971 to December 31, 2016 are presented below.

Study area, material and methods

Study area – Tbilisi. The data of Georgian National Environmental Agency about the daily mean and max wind speed for Tbilisi from January 1, 1971 to December 31, 2016 (16802 days) are used. Coordinates of meteorological station in Vashlijvari: Lat - 41.75785° N, Long - 44.755184° E, Elevation – 427 m a.s.l.
In the proposed work the analysis of data is carried out with the use of the standard statistical analysis methods [15]. The following designations will be used below: Mean – average values; Max - maximal values; Min – minimal values; St Dev - standard deviation; σm - standard error; Cv – coefficient of variation = 100·St Dev/Mean, %; R – coefficient of linear correlation; 95%(+/-) and 99%(+/-) - 95% and 99% confidence interval of the mean; Wmean - mean wind speed (m/s); Wmax - max wind speed.

The degree of correlation was determined in accordance with [15]: very high correlation ($0.9 \leq R \leq 1.0$); high correlation ($0.7 \leq R < 0.9$); moderate correlation ($0.5 \leq R < 0.7$); low correlation ($0.3 \leq R < 0.5$); negligible correlation ($0 \leq R < 0.3$).

Wind speed repeatability was determined in accordance with the Beaufort Wind Scale (Table 1).

Table 1. Beaufort Wind Scale [https://www.spc.noaa.gov/faq/tornado/beaufort.html; https://www.kakras.ru/interesn/wind.htm].

Force	Wind, (m/s)	WMO Classification	Appearance of Wind Effects on Land
0	**0-0.2**	**Calm**	**Calm, smoke rises vertically**
1	0.3-1.5	**Light Air**	**Smoke drift indicates wind direction, still wind vanes**
2	1.6-3.3	**Light Breeze**	**Wind felt on face, leaves rustle, vanes begin to move**
3	3.4-5.4	**Gentle Breeze**	**Leaves and small twigs constantly moving, light flags extended**
4	5.5-7.9	**Moderate**	**Dust, leaves, and loose paper lifted, small tree branches move**
5	8.0-10.7	**Fresh Breeze**	**Small trees in leaf begin to sway**
6	10.8-13.8	**Strong Breeze**	**Larger tree branches moving, whistling in wires**
7	13.9-17.1	**Near Gale**	**Whole trees moving, resistance felt walking against wind**
8	17.2-20.7	**Gale**	**Twigs breaking off trees, generally impedes progress**
9	20.8-24.4	**Strong Gale**	**Slight structural damage occurs, slate blows off roofs**
10	24.5-28.4	**Storm**	**Seldom experienced on land, trees broken or uprooted, "considerable structural damage"**
11	28.5-32.6	**Violent Storm**	It is observed very rarely. Accompanied by large destruction over large areas
12	>32.6	**Hurricane**	Devastating destruction. Separate gusts of wind reach speeds of 50-60 m/s. A hurricane can happen before a big thunderstorm

Results and discussion

Results in Fig. 1-4 and table 2,3 are presented.

In Fig. 1 repetition of daily mean and max wind speed in Tbilisi according to Beaufort Wind Scale are presented.

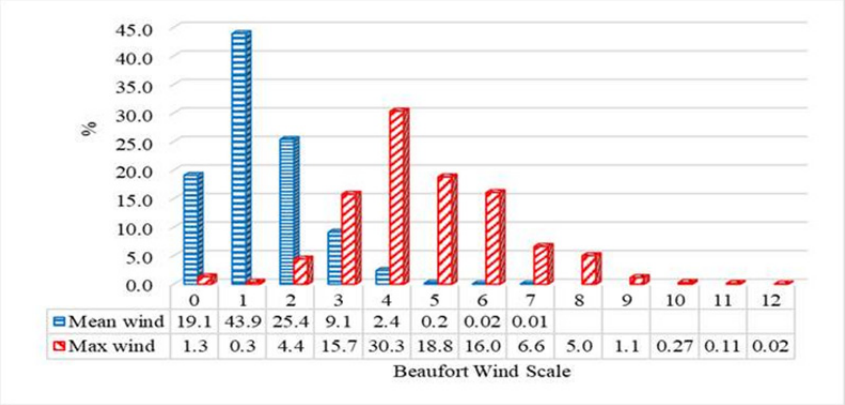

Fig. 1. Repetition of daily mean and max wind speed in Tbilisi according to Beaufort Wind Scale.

As follows from Fig. 1 Wmean values cover the Beaufort scale from 0 to 8, while Wmax covers the entire scale. The maximum repeatability of Wmean values falls on number 1 of the Beaufort scale (43.9%, smoke drift indicates wind direction, still wind vanes), and Wmax - on number 4 of this scale (30.3%, dust, leaves, and loose paper lifted, small tree branches move). The scale range of 8 and more (17.2-20.7 m/s, gale and above, the onset of destructive processes in the environment and their intensification) accounts for about 6.5% of cases (about 24 days a year). During the entire period of research with hurricane wind 3 cases were recorded (Beaufort scale range - 12, hurricane, wind speed >32.6 m/s, devastating destruction).

In Table 2 statistical characteristics of daily mean and max wind speed (m/s) in for separate months and on the whole from January to December are presented. In Fig. 2 for clarity intraannual distribution of monthly average of daily mean and max wind speed Tbilisi is presented.

Table 2. Statistical characteristics of daily mean and max wind speed (m/sec) in Tbilisi in 1971-2016 (min wind speed = 0).

Month	Parameter	Mean	Max	St Dev	σm	Cv, %	95%(+/-)	99%(+/-)
Jan	Wmean	1.2	11.0	1.5	0.04	127.2	0.08	0.10
	Wmax	7.9	33.0	5.0	0.13	63.2	0.26	0.34
Feb	Wmean	1.5	11.3	1.6	0.05	112.2	0.09	0.12
	Wmax	9.0	34.0	5.4	0.15	59.2	0.29	0.38
Mar	Wmean	1.8	14.9	1.8	0.05	99.8	0.09	0.12
	Wmax	10.1	33.0	5.3	0.14	53.0	0.28	0.36
Apr	Wmean	1.7	10.4	1.6	0.04	90.4	0.08	0.11
	Wmax	10.3	34.0	4.7	0.13	45.4	0.25	0.32
May	Wmean	1.7	9.0	1.5	0.04	86.9	0.08	0.10
	Wmax	9.9	27.0	4.2	0.11	42.5	0.22	0.29
Jun	Wmean	1.8	9.1	1.6	0.04	90.2	0.09	0.11
	Wmax	10.3	29.0	4.3	0.12	41.7	0.23	0.30
Jul	Wmean	1.8	7.8	1.4	0.04	78.7	0.07	0.09
	Wmax	9.9	26.0	3.7	0.10	37.1	0.19	0.25
Aug	Wmean	1.6	12.0	1.4	0.04	85.6	0.07	0.10
	Wmax	9.6	24.0	3.8	0.10	39.7	0.20	0.26
Sep	Wmean	1.5	8.3	1.3	0.04	86.3	0.07	0.09
	Wmax	9.4	30.0	4.1	0.11	43.6	0.22	0.28
Oct	Wmean	1.2	7.5	1.3	0.03	104.3	0.07	0.09
	Wmax	8.4	27.0	4.3	0.11	50.9	0.22	0.29
Nov	Wmean	1.1	8.4	1.3	0.04	121.7	0.07	0.09
	Wmax	7.8	30.0	4.7	0.13	60.8	0.25	0.33
Dec	Wmean	1.1	9.0	1.4	0.04	126.3	0.07	0.09
	Wmax	7.7	41.0	5.0	0.13	65.2	0.26	0.34
Jan-Dec	Wmean	1.5	14.9	1.5	0.01	100.3	0.02	0.03
	Wmax	9.2	41.0	4.7	0.04	50.8	0.07	0.09

As follows from Table 2 and Fig. 2 in the studied period of time the max daily values of Wmean changed from 7.5 m/s (October) to 14.9 m/s (March), the max daily values of Wmax changed from 24.0 m/s (August) to 41.0 m/s (December).

Variations of Wmean values are higher than Wmax. Values of Cv for Wmean values changed form 78.7% (July) to 127.2 % (January), and for Wmax - form 37.1 % (July) to 65.2 % (December).

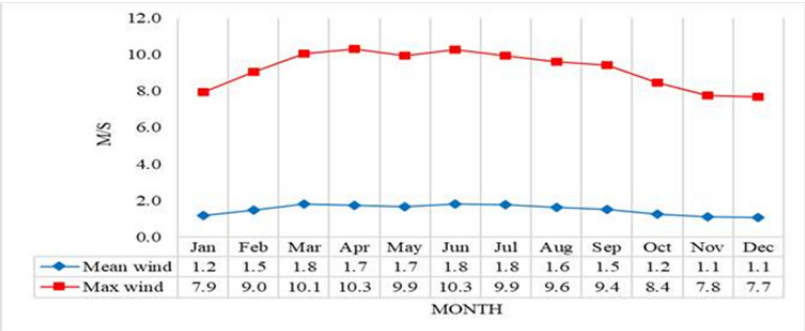

Fig. 2. Intraannual distribution of monthly average of daily mean and max wind speed Tbilisi.

The lowest average monthly values of Wmean (1.1 m/s) are observed in November and December, the largest (1.8 m/s) - in March, June and July. The lowest average monthly values of Wmax (7.7 m/s) are observed in December, the highest (10.3 m/s) - in April and June.
In Fig. 3 data about linear correlation between daily mean and max wind speed in Tbilisi in separate months and from January to December are presented.

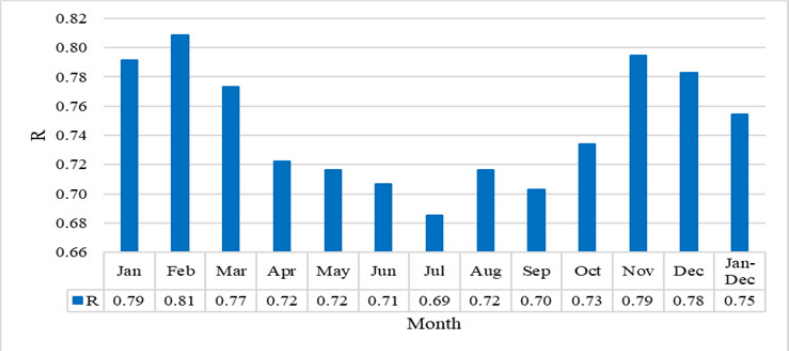

Fig. 3. Linear correlation between daily mean and max wind speed in Tbilisi in separate months and from January to December in 1971-2016.

As follows from Fig. 3 values of R changed from 0.69 (July, moderate correlation) to 0.81 (February, high correlation). For January-December value of R between daily mean and max wind speed is 0.75 (high correlation).

In Table 3 information about coefficients of linear regression equation (Y= a·X + b) between daily mean and max wind speed in Tbilisi in separate months and from January to December in 1971-2016 are presented.

Table 3. Coefficients of linear regression equation (Y= a·X + b) between daily mean and max wind speed in Tbilisi in separate months and from January to December in 1971-2016. Y - daily max wind speed, X - daily mean wind speed.

a	b	a	b	a	b	a	b	a	b
Jan		**Feb**		**Mar**		**Apr**		**May**	
2.67	4.81	2.65	5.18	2.29	5.93	2.16	6.57	2.08	6.45
Jun		**Jul**		**Aug**		**Sep**		**Oct**	
1.86	6.91	1.82	6.73	1.96	6.41	2.20	6.07	2.42	5.42
		Nov		**Dec**		**Jan-Dec**			
		2.79	4.68	2.85	4.57	2.34	5.69		

Finaly in Fig. 4 data about linear correlation and regression between monthly average daily mean and max wind speed in Tbilisi is presented.

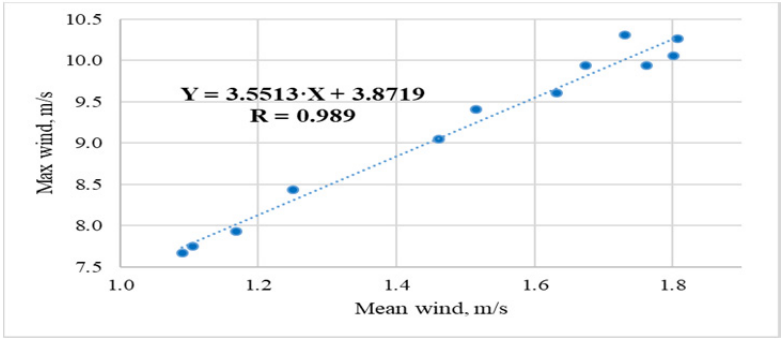

Fig. 4. Linear correlation and regression between monthly average daily mean and max wind speed in Tbilisi. Y – monthly average of daily max wind speed, X - monthly average of daily mean wind speed.

As follows from Fig. 4 value of R between monthly average values of Wmean and Wmax is 0.989 (very high correlation).

Conclusion

In the future, we plan to continue similar studies for other locations in Georgia. Part of the data from this work will be used to compile a Natural Hazards Catalog of Georgia [16].

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