Statistical Characteristics of the Daily Max of Wind Speed in Kakheti in 2017-2019

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ABSTRACT

The statistical analysis of the daily maximum speed of wind (W) for 13 points of Kakheti in the period from 1 January 2017 through 31 December of 2019 is represented.

In particular, the following results are obtained: mean monthly and seasonal (warm and cold half-years, year) values of W for all stations during entire period of observations are calculated; it is shown that the distributions of mean monthly values of W in the territory of Kakheti has the uneven nature and changes from 0.7 m/sec (Tsnori, November) to 9.5 m/sec (Sagarejo, June); the map of the distribution of mean annual values of W in the territory of Kakheti is given; repetition of daily values of W for all points of Kakheti in accordance with the Beaufort Wind Scale is studied; it is shown that the value of the linear correlation coefficient R between the stations in terms of all daily values of W on the average compose 0.45 and change from 0.15 to 0.83, for the cold half-year - 0.54 (it changes from 0.26 to 0.87), for the warm half-year - 0.36 (it changes from 0.03 to 0.78); the dependence of the linear correlation coefficient between the stations by values of W from the distance between them is studied (with an increase in the distance between the stations value of R diminishes in the correspondence with the power function); the dependence of W on the height of the stations arrangement on the average in the year, into the cold and warm half-years is studied.

Key words: Local climate, max wind speed.

1. Introduction

Wind is one of the most important climate-forming factors. Therefore in Georgia, as in other countries, to studies of the wind regime is paid special attention. Significant number of works is devoted to the climatology of wind, changeability of its regime [1-4]. Information about the wind regime is important for the development wind-power engineers, agrarian sector of economy [1,3], etc. High wind frequently it leads to the destruction of habitable and production units, the stoppage of the work of airports, the appearance of blizzards, the intensification of the negative consequences of other dangerous hydrometeorological phenomena (intensive precipitations, hail, etc.), human victims, etc. [5-9]. On wind speed depends the level of the air pollution [10-12]. Wind is also one of the most important bioclimatic factors. Therefore information about the wind regime is important for the development of health resort - tourism sector of economy [13-14] by the estimations of different simple and complex bioclimatic indices for the specific territories [15-20].

Since 2015 in Kakheti region of Georgia is restored the work of anti-hail service [21,22]. During the estimation of damage from the hail damages frequently is also necessary the information about other associated extreme meteorological elements, including wind speed [9]. In addition to this, the data about the regime of extreme wind are necessary for the optimum distribution of the points of action on clouds, etc. [22,23].

In connection with that indicated was set the task of investigating the regime of maximum daily wind speed in Kakheti, the special features of its distribution in the investigated territory, the comparison of the wind regime in the days with the hail with the non hail days, developments the possible connection between the data about the extreme wind on the earth's surface with the data of the radar measurements of the wind speed on 2-2.5 km [24]. In this stage of these studies is carried out the detailed statistical analysis of the

daily maximum wind speed for 13 points of Kakheti in the period from 1 January 2017 through 31 December of 2019, whose results are represented below.

2. Study area, material and methods

Study area – 13 locations of Kakheti region of Georgia. Coordinates of these locations of wind speed measurements points in table 1 are presented. Distance from these meteorological stations in table 2 are presented.

The data of Georgian National Environmental Agency about the daily max values of wind speed (W) on 13 indicated stations are used. Period of observation: January 1, 2017- December 31, 2019.

In the proposed work the analysis of data is carried out with the use of the standard statistical analysis methods [25]. Missed data of time-series of observations were restored in the correspondence with the standard methods [25].

The following designations will be used below: Mean – average values; Min – minimal values; Max - maximal values; Range – Max-Min; Median – median values; St Dev - standard deviation; Cv – coefficient of variation, %; R^2 – coefficient of determination; R – coefficient of linear correlation; 99%_L and 99%_U - accordingly, 99% upper and lower levels of the confidence interval of average; α - the level of significance. Cold period: October-March, warm period: April-September. The following rule of thumb for interpreting the size of a correlation coefficient is used [26] : $0 \leq R < 0.3$ - Negligible correlation, $0.3 \leq R < 0.5$ - Low correlation, $0.5 \leq R < 0.7$ - Moderate correlation, $0.7 \leq R < 0.9$ - High correlation, $0.9 \leq R \leq 1.0$ - Very high correlation.

Table 1. Coordinates of 13 meteorological stations in Kakheti.

Location	Location (Abbrev.)	Long., E˚	Lat, N˚	Height (H), m (a.s.l.)
Tsnori	Tsn.	45.993	41.612	501
Kindzmarauli- Khareba	Kindz.	45.810	41.612	360
Telavi (Wine Cellar)	Tel.	45.603	41.959	378
Saniore	San.	45.489	42.051	550
Vachnadziani-Khareba	Vachn.	45.657	41.867	496
Ruispiri	Ruisp.	45.401	41.964	550
Dzveli Anaga	Dz. An.	46.068	41.559	395
Bakurtsikhe	Bakur.	45.935	41.733	236
Zemo Kedi	Z. Kedi	46.381	41.421	681
Sagarejo	Sagar.	45.368	41.650	580
Khornabuji	Khorn.	46.181	41.513	251
Naendrovali	Naendr.	46.068	41.760	230
Kistauri	Kist.	45.269	42.005	519

Table 2. Distance from 13 meteorological stations in Kakheti between itself (km).

	Tsn.	Kindz.	Tel.	San.	Vachn.	Ruisp.	Dz. An.	Bakur.	Z. Kedi	Sagar.	Khorn.	Naendr.	Kist.
Tsn.	0	15	50	64	40	63	9	14	39	52	19	18	74
Kindz.	15	0	42	56	31	52	22	17	52	37	33	27	63
Tel.	50	42	0	14	11	17	59	37	88	40	69	44	28
San.	64	56	14	0	25	12	73	51	102	46	83	58	19
Vachn.	40	31	11	25	0	24	48	27	78	34	59	36	36
Ruisp.	63	52	17	12	24	0	71	51	101	35	82	60	12
Dz. An.	9	22	59	73	48	71	0	22	30	59	11	22	83
Bakur.	14	17	37	51	27	51	22	0	51	48	32	11	63
Z. Kedi	39	52	88	102	78	101	30	51	0	88	20	46	113
Sagar.	52	37	40	46	34	35	59	48	88	0	69	59	40
Khorn.	19	33	69	83	59	82	11	32	20	69	0	29	93
Naendr.	18	27	44	58	36	60	22	11	46	59	29	0	72
Kist.	74	63	28	19	36	12	83	63	113	40	93	72	0

3. Results and discussion

Results in the fig. 1-8 and table 1-9 are presented.

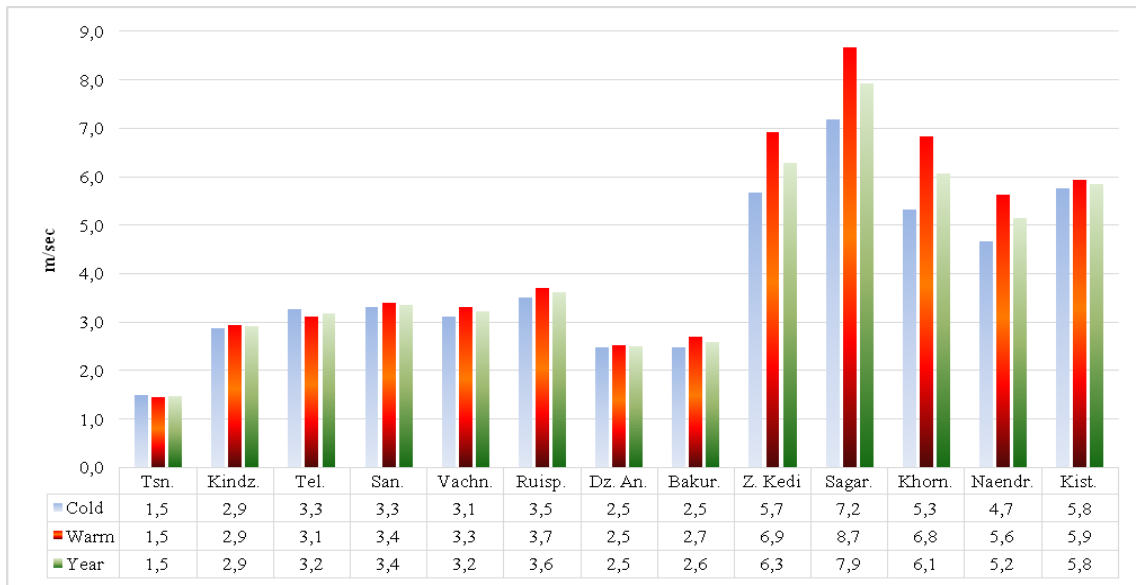|	Tsn.	Kindz.	Tel.	San.	Vachn.	Ruisp.	Dz. An.	Bakur.	Z. Kedi	Sagar.	Khorn.	Naendr.	Kist.
Cold	1,5	2,9	3,3	3,3	3,1	3,5	2,5	2,5	5,7	7,2	5,3	4,7	5,8
Warm	1,5	2,9	3,1	3,4	3,3	3,7	2,5	2,7	6,9	8,7	6,8	5,6	5,9
Year	1,5	2,9	3,2	3,4	3,2	3,6	2,5	2,6	6,3	7,9	6,1	5,2	5,8

Fig. 1. Mean values of daily max of wind speed in Kakheti in 2017-2019 in three periods of year.
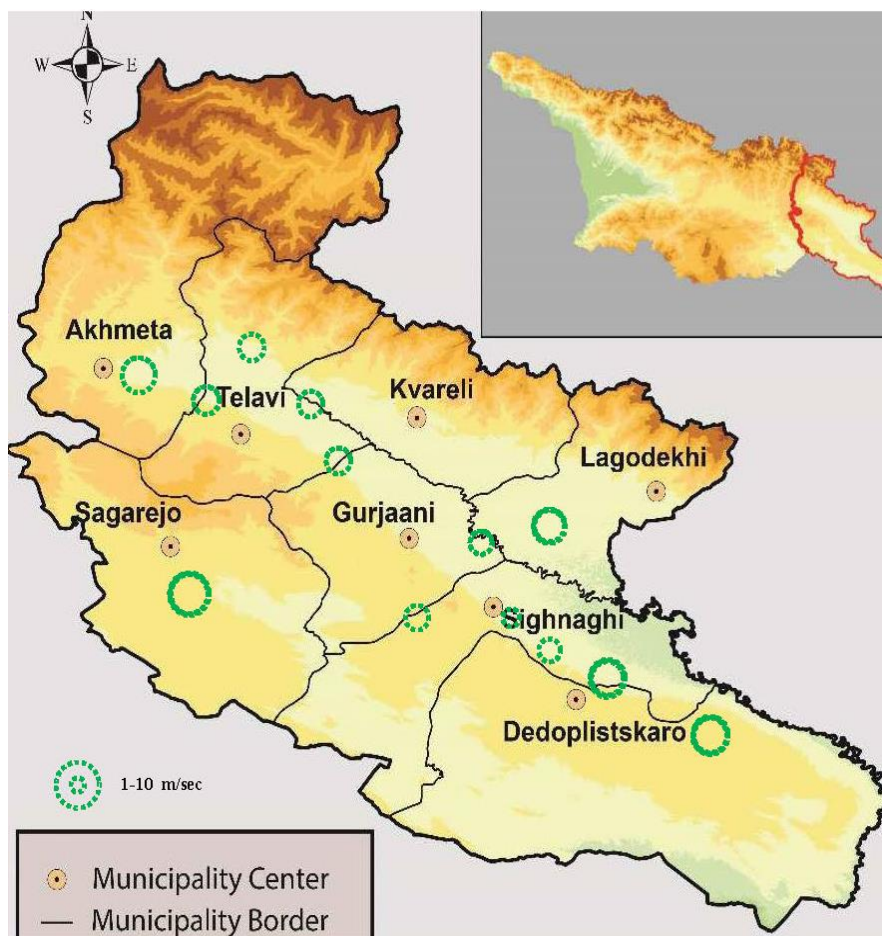

Fig. 2. Distribution of mean annual values of daily max of wind speed in Kakheti in 2017-2019.

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As it follows from fig. 1, the smallest and greatest mean values of W in the year, into the cold and warm half-years in Kakheti change from 1.5 m/sec (Tsnori) to 7.9, 7.2 and 8.7 m/sec (Sagarejo). On the stations Tsnori, Kindzmarauli- Khareba, Telavi (Wine Cellar), Saniore, Vachnadziani-Khareba, Ruispiri, Dzveli Anaga, Bakurtsikhe and Kistauri the mean values of W during the three indicated periods of year either identical or differ little from each other.

At the stations Zemo Kedi, Sagarejo, Khornabuji and Naendrovali into the warm half-year mean values of W on 20.8-28.0 % are higher than into the cold and by 9.4-12.3 % higher than on the average in the year. It also follows from fig. 1 that the distribution of W values on the territory of Kakheti has heterogeneous nature. For the clarity fig. 2 gives the map of distribution of mean monthly values of W on the investigated territory.

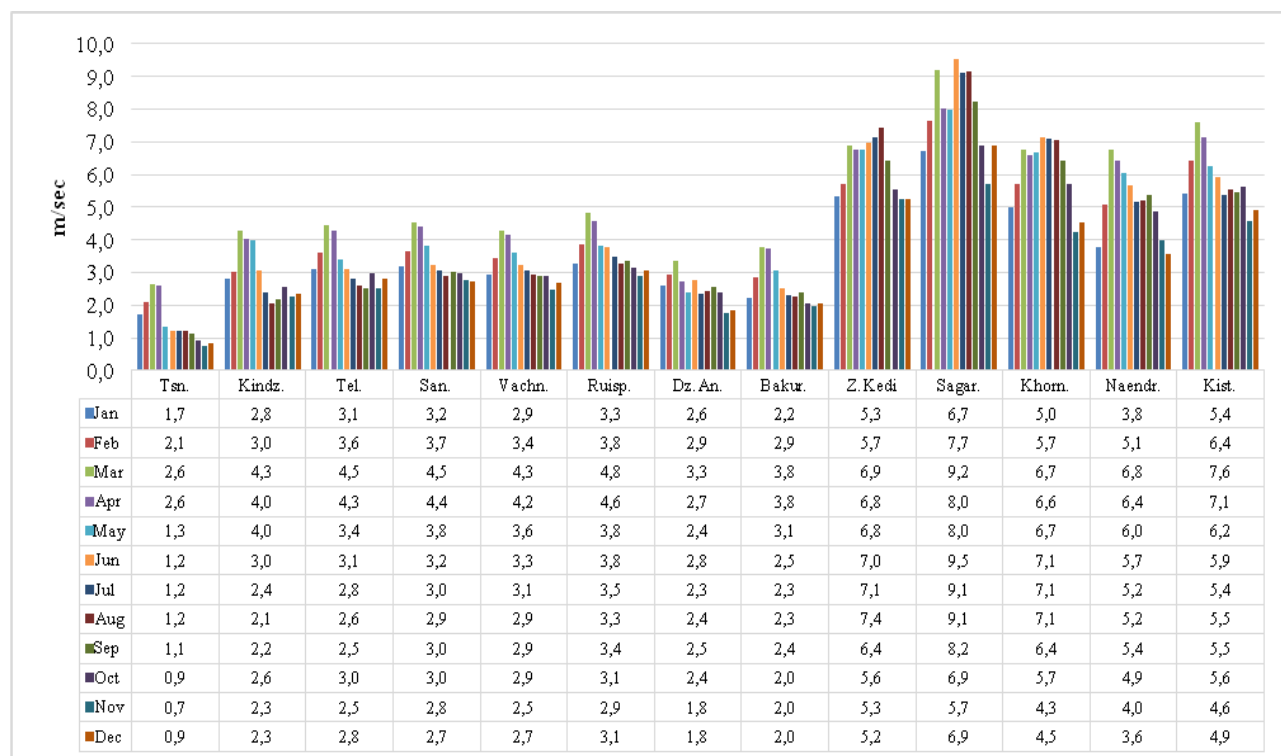|	Tsn.	Kindz.	Tel.	San.	Vachn.	Ruisp.	Dz.An.	Bakur.	Z.Kedi	Sagar.	Khorn.	Naendr.	Kist.
Jan	1,7	2,8	3,1	3,2	2,9	3,3	2,6	2,2	5,3	6,7	5,0	3,8	5,4
Feb	2,1	3,0	3,6	3,7	3,4	3,8	2,9	2,9	5,7	7,7	5,7	5,1	6,4
Mar	2,6	4,3	4,5	4,5	4,3	4,8	3,3	3,8	6,9	9,2	6,7	6,8	7,6
Apr	2,6	4,0	4,3	4,4	4,2	4,6	2,7	3,8	6,8	8,0	6,6	6,4	7,1
May	1,3	4,0	3,4	3,8	3,6	3,8	2,4	3,1	6,8	8,0	6,7	6,0	6,2
Jun	1,2	3,0	3,1	3,2	3,3	3,8	2,8	2,5	7,0	9,5	7,1	5,7	5,9
Jul	1,2	2,4	2,8	3,0	3,1	3,5	2,3	2,3	7,1	9,1	7,1	5,2	5,4
Aug	1,2	2,1	2,6	2,9	2,9	3,3	2,4	2,3	7,4	9,1	7,1	5,2	5,5
Sep	1,1	2,2	2,5	3,0	2,9	3,4	2,5	2,4	6,4	8,2	6,4	5,4	5,5
Oct	0,9	2,6	3,0	3,0	2,9	3,1	2,4	2,0	5,6	6,9	5,7	4,9	5,6
Nov	0,7	2,3	2,5	2,8	2,5	2,9	1,8	2,0	5,3	5,7	4,3	4,0	4,6
Dec	0,9	2,3	2,8	2,7	2,7	3,1	1,8	2,0	5,2	6,9	4,5	3,6	4,9

Fig. 3. Mean values of daily max of wind speed in Kakheti in 2017-2019 in different months of year.

Fig. 3 presents the data about mean monthly values of W on the Kakheti territory. As it follows from this figure, the intra-annual distribution of W values for all stations as a whole takes the single-modal form. The range of changes in the values of W for the separate stations is the following:
Tsn.: 0.7 m/sec (Nov) – 2.6 m/sec (Mar, Apr); Kindz.: 2.1 m/sec (Aug) – 4.3 m/sec (Mar); Tel.: 2.5 m/sec (Sep, Nov) – 4.5 m/sec (Mar); San.: 2.7 m/sec (Dec) – 4.5 m/sec (Mar); Vachn.: 2.5 m/sec (Nov) – 4.3 m/sec (Mar); Ruisp.: 2.9 m/sec (Nov) – 4.8 m/sec (Mar); Dz. An.: 1.8 m/sec (Nov, Dec) – 3.3 m/sec (Mar); Bakur.: 2.0 m/sec (Oct-Dec) – 3.8 m/sec (Mar-Apr); Z. Kedi: 5.2 m/sec (Dec) – 7.4 m/sec (Aug); Sagar.: 5.7 m/sec (Nov) – 9.5 m/sec (Jun); Khorn.: 4.3 m/sec (Nov) – 7.1 m/sec (Jun-Aug); Naendr.: 3.6 m/sec (Dec) – 6.8 m/sec (Mar); Kist.: 4.6 m/sec (Nov) – 7.6 m/sec (Mar).

In the season of anti-hail works (April- October) the range of changes in the values of W for the separate stations is following:
Tsn.: 0.9 m/sec (Oct) – 2.6 m/sec (Apr); Kindz.: 2.1 m/sec (Aug) – 4.0 m/sec (Apr,May); Tel.: 2.5 m/sec (Sep) – 4.3 m/sec (Apr); San.: 2.9 m/sec (Aug) – 4.4 m/sec (Apr); Vachn.: 2.9 m/sec (Aug-Oct) – 4.2 m/sec (Apr); Ruisp.: 3.1 m/sec (Oct) – 4.6 m/sec (Apr); Dz. An.: 2.3 m/sec (Jul) – 2.8 m/sec (Jun); Bakur.: 2.0 m/sec (Oct) – 3.8 m/sec (Apr); Z. Kedi: 5.6 m/sec (Oct) – 7.4 m/sec (Aug); Sagar.: 6.9 m/sec (Oct) – 9.5 m/sec (Jun); Khorn.: 5.7 m/sec (Oct) – 7.1 m/sec (Jun-Aug); Naendr.: 4.9 m/sec (Oct) – 6.4 m/sec (Apr); Kist.: 5.4 m/sec (Jul) – 7.1 m/sec (Apr).

Table 3 presents the data about statistical characteristics of daily max of wind speed in Kakheti in 2017-2019 in different months of year. The range of changes in the daily values of W for the separate stations is following: Tsn.: 0.0 m/sec (Feb, Apr, May, Jun) – 9.3 m/sec (Apr); Kindz.: 0.6 m/sec (Nov) – 12.5

m/sec (Apr); Tel.: 0.5 m/sec (Nov) – 10.3 m/sec (Mar); San.: 0.0 m/sec (Jan, Feb) – 13.4 m/sec (Apr); Vachn.: 0.6 m/sec (Jan) – 10.9 m/sec (Jan, Apr); Ruisp.: 0.0 m/sec (May, Oct) – 11.6 m/sec (Mar); Dz. An.: 0.0 m/sec (May, Jul, Aug, Dec) – 9.0 m/sec (Sep); Bakur.: 0.2 m/sec (Dec) – 11.0 m/sec (May); Z. Kedi: 1.6 m/sec (Feb) – 16.3 m/sec (Aug); Sagar.: 1.5 m/sec (Dec) – 31.2 m/sec (Jun); Khorn.: 1.7 m/sec (Feb) – 18.6 m/sec (Dec); Naendr.: 1.4 m/sec (Dec) – 20.8 m/sec (Oct); Kist.: 1.2 m/sec (Nov) – 22.1 m/sec (Jan).

Table 3. Statistical characteristics of daily max of wind speed in Kakheti in 2017-2019 in different months of year.

Month	Param.	Location											
		Tsn.	Kindz.	Tel.	San.	Vachn.	Ruisp.	Dz. An.	Bakur.	Z. Kedi	Sagar.	Khorn.	Naendr.
Jan	min	0.4	0.9	0.6	0.0	0.6	1.4	0.1	0.6	2.6	2.1	2.2	1.5
Jan	max	5.0	7.5	9.5	9.8	10.9	8.3	8.4	7.1	12.6	18.8	15.1	11.4
Jan	99%_L	1.4	2.4	2.7	2.8	2.6	2.9	2.1	1.9	4.9	5.8	4.4	3.3
Jan	99%_U	2.0	3.2	3.5	3.6	3.3	3.6	3.0	2.5	5.8	7.7	5.6	4.2
Feb	min	0.0	1.0	1.3	0.0	1.4	1.4	1.1	0.5	1.6	2.2	1.7	2.4
Feb	max	7.7	8.5	8.1	7.1	8.4	8.9	6.7	6.5	14.2	21.0	17.2	14.6
Feb	99%_L	1.7	2.5	3.2	3.3	3.0	3.3	2.5	2.5	5.0	6.3	4.8	4.4
Feb	99%_U	2.5	3.5	4.0	4.1	3.9	4.4	3.3	3.2	6.4	9.0	6.6	5.7
Mar	min	0.8	1.1	1.6	2.3	2.0	2.0	1.5	1.4	4.0	3.1	2.6	3.0
Mar	max	7.1	12.3	10.3	9.0	9.5	11.6	8.4	9.8	14.8	19.4	14.7	16.2
Mar	99%_L	2.3	3.6	4.0	4.1	3.8	4.2	3.0	3.4	6.3	8.2	6.0	6.0
Mar	99%_U	3.0	4.9	4.9	5.0	4.7	5.4	3.7	4.2	7.5	10.2	7.5	7.6
Apr	min	0.0	1.5	1.9	2.4	2.6	2.0	1.1	1.1	3.7	3.9	3.4	2.9
Apr	max	9.3	12.5	10.1	13.4	10.9	11.3	6.8	10.4	15.3	17.9	15.0	18.5
Apr	99%_L	2.1	3.3	3.8	4.0	3.8	4.0	2.4	3.3	6.1	7.1	6.0	5.6
Apr	99%_U	3.1	4.7	4.7	4.9	4.6	5.1	3.1	4.2	7.4	9.0	7.2	7.2
May	min	0.0	1.6	1.2	1.9	2.0	0.0	0.0	1.2	3.9	3.6	3.2	2.4
May	max	7.1	9.9	8.9	7.0	10.4	7.6	5.6	11.0	13.5	18.3	13.5	15.0
May	99%_L	0.9	3.5	3.1	3.5	3.3	3.4	2.1	2.7	6.2	7.1	6.0	5.3
May	99%_U	1.8	4.5	3.7	4.2	3.9	4.3	2.7	3.5	7.4	8.8	7.3	6.8
Jun	min	0.0	1.3	1.3	1.8	1.7	2.0	1.4	0.8	4.3	3.2	4.1	2.5
Jun	max	2.6	8.9	8.2	6.8	8.3	7.8	6.8	6.1	13.3	31.2	16.8	14.7
Jun	99%_L	1.1	2.6	2.7	2.9	2.9	3.4	2.4	2.2	6.5	8.2	6.6	5.0
Jun	99%_U	1.4	3.5	3.5	3.5	3.6	4.1	3.1	2.8	7.5	10.8	7.7	6.3
Jul	min	0.5	1.1	0.8	1.7	1.8	2.1	0.0	1.0	4.1	4.1	2.0	2.3
Jul	max	2.6	6.7	7.5	5.6	7.0	7.2	8.9	6.5	13.7	29.4	15.8	12.9
Jul	99%_L	1.1	2.1	2.5	2.8	2.8	3.2	1.9	2.0	6.7	8.0	6.4	4.6
Jul	99%_U	1.3	2.7	3.1	3.3	3.4	3.8	2.8	2.6	7.6	10.2	7.7	5.7
Aug	min	0.5	1.0	0.6	1.1	1.7	1.5	0.0	1.1	4.7	3.8	3.6	3.0
Aug	max	2.1	4.9	6.3	4.6	7.1	6.0	4.4	6.5	16.3	28.5	14.2	13.7
Aug	99%_L	1.1	1.9	2.4	2.7	2.7	3.0	2.2	2.0	6.8	8.0	6.5	4.7
Aug	99%_U	1.3	2.2	2.8	3.1	3.2	3.5	2.7	2.5	8.0	10.2	7.6	5.7
Sep	min	0.4	0.7	0.8	0.8	1.4	1.3	1.0	1.0	2.9	3.0	2.8	2.7
Sep	max	3.2	6.8	7.9	6.3	10.0	9.8	9.0	5.9	16.1	19.1	15.1	15.9
Sep	99%_L	1.0	1.9	2.2	2.8	2.5	2.9	2.2	2.0	5.9	7.2	5.8	4.7
Sep	99%_U	1.3	2.4	2.9	3.2	3.3	3.8	2.9	2.7	7.0	9.2	7.1	6.1
Oct	min	0.3	1.1	1.2	1.4	1.4	0.0	1.1	0.9	3.3	2.5	2.4	2.0
Oct	max	2.3	8.5	7.4	7.2	9.0	10.4	7.3	6.6	15.3	18.8	16.6	20.8
Oct	99%_L	0.8	2.2	2.5	2.7	2.5	2.7	2.0	1.7	5.0	5.8	5.0	4.1
Oct	99%_U	1.0	2.9	3.5	3.3	3.3	3.6	2.8	2.4	6.1	7.9	6.4	5.7
Nov	min	0.1	0.6	0.5	1.3	1.1	1.1	0.3	0.9	3.0	2.0	2.1	1.8
Nov	max	2.0	9.8	8.2	6.7	7.7	9.7	4.9	6.6	11.9	19.1	13.9	13.1
Nov	99%_L	0.6	1.9	2.1	2.5	2.2	2.5	1.5	1.7	4.7	4.8	3.7	3.4
Nov	99%_U	0.8	2.6	2.9	3.1	2.8	3.3	2.1	2.3	5.8	6.6	4.8	4.6
Dec	min	0.1	0.7	1.3	1.1	1.3	0.8	0.0	0.2	2.3	1.5	1.8	1.4
Dec	max	3.3	8.0	7.6	6.1	7.2	7.7	7.8	5.3	12.0	19.5	18.6	10.4
Dec	99%_L	0.7	2.0	2.4	2.4	2.3	2.6	1.5	1.8	4.7	5.8	3.7	3.2
Dec	99%_U	1.0	2.7	3.2	3.0	3.0	3.5	2.2	2.3	5.8	7.9	5.3	4.0

In the season of anti-hail works (April- October) the range of changes in the daily values of W for the separate stations is following: Tsn.: 0.0 m/sec (Apr-Jun) – 9.3 m/sec (Apr); Kindz.: 0.7 m/sec (Sep) –

12.5 m/sec (Apr); Tel.: 0.6 m/sec (Aug) – 10.1 m/sec (Apr); San.: 0.8 m/sec (Sep) – 13.4 m/sec (Apr); Vachn.: 1.4 m/sec (Sep) – 10.9 m/sec (Apr); Ruisp.: 0.0 m/sec (May, Oct) – 11.3 m/sec (Apr); Dz. An.: 0.0 m/sec (May, Jul, Aug) – 9.0 m/sec (Sep); Bakur.: 0.8 m/sec (Jun) – 11.0 m/sec (May); Z. Kedi: 2.9 m/sec (Sep) – 16.3 m/sec (Aug); Sagar.: 2.5 m/sec (Oct) – 31.2 m/sec (Jun); Khorn.: 2.0 m/sec (Jul) – 16.8 m/sec (Jun); Naendr.: 2.0 m/sec (Oct) – 20.8 m/sec (Oct); Kist.: 1.9 m/sec (Oct) – 15.2 m/sec (Apr).

Table 4. Repetition of daily max of wind speed in Kakheti in 2017-2019 according to Beaufort Wind Scale (BWS) in three periods of year.

Location	Season	Beaufort Wind Scale (Force)											
		0	1	2	3	4	5	6	7	8	9	10	11
		Wind Spead, m/sec											
		0 - 0.2	0.3 - 1.5	1.6 - 3.3	3.4 - 5.4	5.5 - 7.9	8.0 - 10.7	10.8- 13.8	13.9- 17.1	17.2- 20.7	20.8- 24.4	24.5- 28.4	28.5- 32.6
		Repetition, %											
Tsnori	Cold	1.6	65.0	24.7	7.1	1.5	0.0						
	Warm	7.3	67.9	18.0	4.6	2.0	0.2						
	Year	4.5	66.5	21.4	5.8	1.7	0.1						
Kindzmarauli-Khareba	Cold		13.7	60.8	14.7	8.2	2.2	0.4					
	Warm		8.6	66.8	16.0	5.8	2.0	0.7					
	Year		11.1	63.8	15.3	7.0	2.1	0.5					
Telavi (Wine Cellar)	Cold		8.2	56.9	21.7	12.0	1.2						
	Warm		5.8	61.4	25.1	6.7	0.9						
	Year		7.0	59.2	23.5	9.3	1.0						
Saniore	Cold	0.4	3.3	52.0	36.3	7.3	0.7	0.0					
	Warm	0.0	0.7	57.0	36.2	5.6	0.2	0.2					
	Year	0.2	2.0	54.5	36.3	6.5	0.5	0.1					
Vachnadziani-Khareba	Cold		5.1	63.0	21.6	9.0	1.1	0.2					
	Warm		0.2	65.8	26.6	6.6	0.7	0.2					
	Year		2.6	64.4	24.1	7.8	0.9	0.2					
Ruispiri	Cold	0.4	2.6	58.4	22.9	11.7	3.8	0.2					
	Warm	0.9	0.5	49.0	37.9	9.5	2.0	0.2					
	Year	0.6	1.6	53.7	30.4	10.6	2.9	0.2					
Dzveli Anaga	Cold	0.4	26.3	51.7	16.2	4.7	0.8						
	Warm	3.2	11.2	64.1	19.0	2.0	0.6						
	Year	1.8	18.7	57.9	17.6	3.4	0.7						
Bakurtsikhe	Cold	0.2	25.5	51.3	18.7	4.0	0.4	0.0					
	Warm	0.0	13.1	63.6	17.3	5.3	0.5	0.2					
	Year	0.1	19.3	57.4	18.0	4.7	0.5	0.1					
Zemo Kedi	Cold			6.2	52.6	27.5	10.1	3.1	0.5				
	Warm			0.2	27.6	48.1	18.5	5.1	0.5				
	Year			3.2	40.1	37.8	14.3	4.1	0.5				
Sagarejo	Cold		0.2	11.5	33.5	22.2	13.2	10.4	7.1	1.6	0.2	0.0	0.0
	Warm		0.0	0.4	21.1	30.8	24.0	14.6	4.7	2.9	0.5	0.4	0.5
	Year		0.1	5.9	27.3	26.5	18.6	12.5	5.9	2.3	0.4	0.2	0.3
Khornabuji	Cold			26.1	38.6	21.3	7.4	4.8	1.5	0.4			
	Warm			0.7	29.2	48.1	15.0	5.2	1.8	0.0			
	Year			13.5	33.9	34.7	11.2	5.0	1.7	0.2			
Naendrovali	Cold		0.5	37.0	38.8	13.0	7.3	2.0	1.1	0.0	0.2		
	Warm		0.0	8.9	52.6	24.2	9.5	2.7	1.8	0.2	0.0		
	Year		0.3	22.9	45.8	18.6	8.4	2.4	1.5	0.1	0.1		
Kistauri	Cold		0.4	20.7	41.2	15.6	13.4	6.0	2.4	0.2	0.2		
	Warm		0.0	4.9	45.5	34.1	10.6	4.0	0.9	0.0	0.0		
	Year		0.2	12.8	43.4	24.8	12.0	5.0	1.6	0.1	0.1		

In table 4 data about repetition of daily values of W in Kakheti in 2017-2019 according to Beaufort Wind Scale [https://www.kakras.ru/interesn/wind.htm; https://www.spc.noaa.gov/faq/tornado/beaufort.html] in three periods of year are presented.

The analysis of table 4 shows the following.

1 station - Tsn.: The greatest repetition values of W (65.0-67.9%) comes on Force 1 (Light Air) of BWS (Smoke drift indicates wind direction, still wind vanes). Repetition of greatest values of W (0.1-0.2%) comes on Force 5 (Fresh Breeze) of BWS (Small trees in leaf begin to sway).

7 stations - Kindz., Tel., San., Vachn., Ruisp., Dz. An., Bakur.: The greatest repetition values of W (49.0-66.8%) comes on Force 2 (Light Breeze) of BWS (Wind felt on face, leaves rustle, vanes begin to move). Repetition of greatest values of W for Tel. and Dz. An. (0.6-1.2%) comes on Force 5. Repetition of greatest values of W for Kindz., San., Vachn., Ruisp. and Bakur. (0.1-0.7%) comes on Force 6 (Strong Breeze) of BWS (Larger tree branches moving, whistling in wires).

3 stations - Z. Kedi., Sagar. and Khorn.: The greatest repetition values of W in cold period and in year (27.3-52.6%) comes on Force 3 (Gentle Breeze) of BWS (Leaves and small twigs constantly moving, light flags extended). The greatest repetition values of W in warm period (30.8-48.1%) comes on Force 4 (Moderate Breeze) of BWS (Dust, leaves, and loose paper lifted, small tree branches move).

Repetition of greatest values of W for Z. Kedi. (0.5%) comes on Force 7 (Near Gale; Whole trees moving, resistance felt walking against wind); for Sagar. (0.3-0.5%) – on Force 11 (Violent Storm; Seldom experienced on land, trees broken or uprooted, "considerable structural damage"); for Khorn. (0.2-0.4%) – on Force 8 (Gale; Twigs breaking off trees, generally impedes progress).

2 stations - Naendr. and Kist.: The greatest repetition values of W (38.8-52.6%) comes on Force 3. Repetition of greatest values of W (0.1-0.2%) comes on Force 9 (Strong Gale) of BWS (Slight structural damage occurs, slate blows off roofs).

Table 5-7. presents data about values of linear correlation coefficient R between meteorological stations on the max wind speed in Kakheti in 2017-2019 for three periods of year. In all - 77 pairs of stations. Critical value for R with $\alpha \approx 0.35$ is 0.30 (upper level of negligible correlation).

In the correspondence with table 5 values of R between 13 station on mean annual values of W changes from 0.15 (negligible correlation, pair: Z. Kedi - Dz. An., distance – 30 km) to 0.83 (high correlation, pair: Ruisp. - Tel., distance – 17 km). Mean value of R is 0.45 (low correlation).

Values of R between 13 station on values of W in cold period (table 6) changes from 0.26 (negligible correlation) to 0.87 (high correlation). Pair the same as for annual data. Mean value of R is 0.54 (moderate correlation)

In warm period (table 7) values of R changes from 0.03 (negligible correlation, pair: Dz. An. – Tsn., distance - 9 km and Dz. An. – Sagar., distance – 59 km) to 0. 0.78 (high correlation, pair: Ruisp. - Tel.).

Table 5. Linear correlation between meteorological stations on the max wind speed in Kakheti in 2017-2019 (annual data).

Year	Tsn.	Kindz.	Tel.	San.	Vachn.	Ruisp.	Dz. An.	Bakur.	Z. Kedi	Sagar.	Khorn.	Naendr.	Kist.
Tsn.	1	0.57	0.37	0.60	0.54	0.32	0.22	0.36	0.37	0.25	0.34	0.36	0.41
Kindz.	0.57	1	0.40	0.73	0.76	0.35	0.19	0.36	0.48	0.29	0.37	0.49	0.51
Tel.	0.37	0.40	1	0.42	0.38	*0.83*	0.49	0.79	0.22	0.36	0.43	0.55	0.59
San.	0.60	0.73	0.42	1	0.78	0.40	0.28	0.37	0.46	0.32	0.37	0.44	0.52
Vachn.	0.54	0.76	0.38	0.78	1	0.41	0.23	0.38	0.58	0.39	0.47	0.55	0.58
Ruisp.	0.32	0.35	*0.83*	0.40	0.41	1	0.46	0.76	0.29	0.44	0.51	0.58	0.65
Dz. An.	0.22	0.19	0.49	0.28	0.23	0.46	1	0.45	*0.15*	0.21	0.31	0.30	0.35
Bakur.	0.36	0.36	0.79	0.37	0.38	0.76	0.45	1	0.29	0.33	0.49	0.64	0.54
Z. Kedi	0.37	0.48	0.22	0.46	0.58	0.29	*0.15*	0.29	1	0.36	0.55	0.48	0.42
Sagar.	0.25	0.29	0.36	0.32	0.39	0.44	0.21	0.33	0.36	1	0.53	0.42	0.59
Khorn.	0.34	0.37	0.43	0.37	0.47	0.51	0.31	0.49	0.55	0.53	1	0.66	0.58
Naendr.	0.36	0.49	0.55	0.44	0.55	0.58	0.30	0.64	0.48	0.42	0.66	1	0.62
Kist.	0.41	0.51	0.59	0.52	0.58	0.65	0.35	0.54	0.42	0.59	0.58	0.62	1
Statistics													
Min		Max		Mean		Range		St Dev		Cv, %		Median	
0.15		0.83		0.45		0.68		0.15		33.2		0.43	

Table 6. Linear correlation between meteorological stations on the max wind speed in Kakheti in 2017-2019 (cold season).

Cold	Tsn.	Kindz.	Tel.	San.	Vachn.	Ruisp.	Dz. An.	Bakur.	Z. Kedi	Sagar.	Khorn.	Naendr.	Kist.
Tsn.	1	0.57	0.36	0.63	0.57	0.32	0.39	0.35	0.47	0.37	0.45	0.40	0.46
Kindz.	0.57	1	0.39	0.76	0.81	0.38	0.27	0.38	0.65	0.48	0.49	0.55	0.56
Tel.	0.36	0.39	1	0.44	0.44	*0.87*	0.57	0.83	0.35	0.57	0.63	0.66	0.65
San.	0.63	0.76	0.44	1	0.82	0.43	0.37	0.41	0.61	0.49	0.51	0.52	0.56
Vachn.	0.57	0.81	0.44	0.82	1	0.47	0.34	0.44	0.69	0.54	0.52	0.56	0.60
Ruisp.	0.32	0.38	*0.87*	0.43	0.47	1	0.58	0.80	0.37	0.63	0.64	0.66	0.70
Dz. An.	0.39	0.27	0.57	0.37	0.34	0.58	1	0.53	*0.26*	0.39	0.52	0.42	0.45
Bakur.	0.35	0.38	0.83	0.41	0.44	0.80	0.53	1	0.37	0.50	0.63	0.73	0.58
Z. Kedi	0.47	0.65	0.35	0.61	0.69	0.37	*0.26*	0.37	1	0.45	0.54	0.53	0.49
Sagar.	0.37	0.48	0.57	0.49	0.54	0.63	0.39	0.50	0.45	1	0.67	0.55	0.82
Khorn.	0.45	0.49	0.63	0.51	0.52	0.64	0.52	0.63	0.54	0.67	1	0.69	0.71
Naendr.	0.40	0.55	0.66	0.52	0.56	0.66	0.42	0.73	0.53	0.55	0.69	1	0.67
Kist.	0.46	0.56	0.65	0.56	0.60	0.70	0.45	0.58	0.49	0.82	0.71	0.67	1
Statistics													
Min	Max		Mean		Range		St Dev		Cv, %		Median		
0.26	0.87		0.54		0.62		0.14		26.5		0.53		

Table 7. Linear correlation between meteorological stations on the max wind speed in Kakheti in 2017-2019 (warm season).

Warm	Tsn.	Kindz.	Tel.	San.	Vachn.	Ruisp.	Dz. An.	Bakur.	Z. Kedi	Sagar.	Khorn.	Naendr.	Kist.
Tsn.	1	0.57	0.40	0.57	0.52	0.33	*0.03*	0.37	0.32	0.15	0.24	0.33	0.35
Kindz.	0.57	1	0.41	0.70	0.71	0.32	0.09	0.34	0.36	0.12	0.25	0.46	0.44
Tel.	0.40	0.41	1	0.39	0.30	*0.78*	0.39	0.77	0.14	0.18	0.26	0.46	0.52
San.	0.57	0.70	0.39	1	0.73	0.36	0.16	0.32	0.33	0.14	0.20	0.36	0.47
Vachn.	0.52	0.71	0.30	0.73	1	0.33	0.09	0.31	0.47	0.22	0.41	0.54	0.54
Ruisp.	0.33	0.32	*0.78*	0.36	0.33	1	0.30	0.72	0.21	0.22	0.34	0.49	0.57
Dz. An.	*0.03*	0.09	0.39	0.16	0.09	0.30	1	0.37	0.05	*0.03*	0.05	0.18	0.21
Bakur.	0.37	0.34	0.77	0.32	0.31	0.72	0.37	1	0.21	0.15	0.33	0.55	0.50
Z. Kedi	0.32	0.36	0.14	0.33	0.47	0.21	0.05	0.21	1	0.20	0.48	0.39	0.37
Sagar.	0.15	0.12	0.18	0.14	0.22	0.22	*0.03*	0.15	0.20	1	0.32	0.26	0.31
Khorn.	0.24	0.25	0.26	0.20	0.41	0.34	0.05	0.33	0.48	0.32	1	0.60	0.42
Naendr.	0.33	0.46	0.46	0.36	0.54	0.49	0.18	0.55	0.39	0.26	0.60	1	0.59
Kist.	0.35	0.44	0.52	0.47	0.54	0.57	0.21	0.50	0.37	0.31	0.42	0.59	1
Statistics													
Min	Max		Mean		Range		St Dev		Cv, %		Median		
0.03	0.78		0.36		0.75		0.18		50.1		0.34		

Number of pairs of stations with the significant value of R (α≈0.35) is following: Annual data (table 5) – 76, Cold season (table 6) – 67, Warm season (table 7) - 53.

Distribution of number of pairs of stations with values of R according to [26] is following.

Annual data: Negligible (or absence) correlation – 14.1% (α≥0.35), Low correlation – 51.3% (0.08≤α<0.35), Moderate correlation (0.008≤α<0.08) – 26.9%, High correlation (0.0004≤α<0.008) – 7.7%.

Cold season: Negligible (or absence) correlation – 2.6%, Low correlation – 39.7%, Moderate correlation – 44.9%, High correlation – 12.8%.

Warm season: Negligible correlation (or absence) – 32.1%, Low correlation – 46.1%, Moderate correlation – 14.1 %, High correlation – 7.7%.

As a whole level of linear correlation between meteorological stations on the max wind speed in Kakheti are low or moderate.   The highest level of this correlation in cold half-year is observed
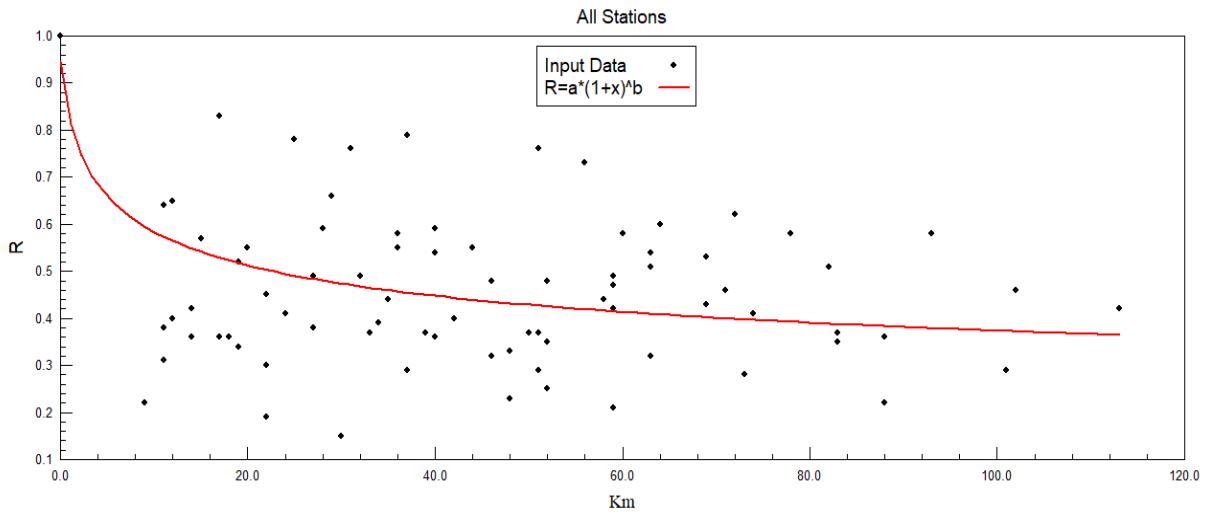
Fig. 4. Dependence of the correlation coefficient by the max wind speed on the distance between 13 meteorological stations in Kakheti (annual data).
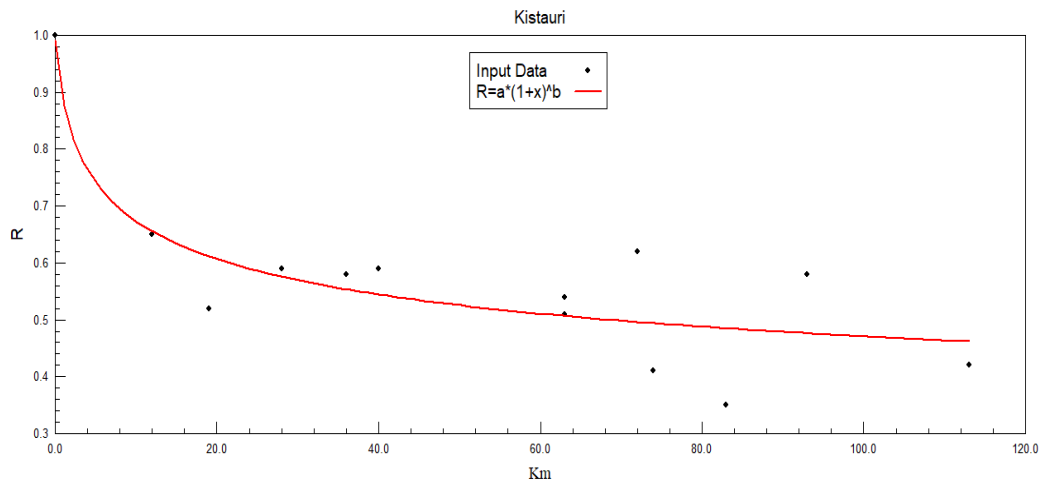

Fig. 5. Dependence of the correlation coefficient by the max wind speed on the distance from Kistauri to 12 meteorological stations in Kakheti (annual data).
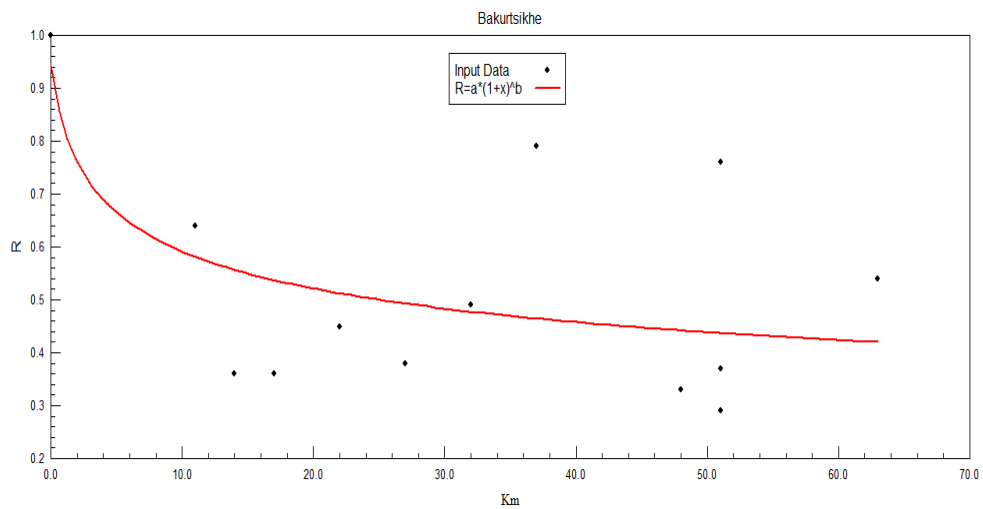

Fig. 6. Dependence of the correlation coefficient by the max wind speed on the distance from Bakurtsikhe to 12 meteorological stations in Kakheti (annual data).

In fig. 4 the example of curve of dependence of the correlation coefficient by the max wind speed on the distance between 13 meteorological stations in Kakheti according to annual data is presented. In fig. 5-6 the examples of curves of this dependence from Kistauri and Bakurtsikhe to 12 meteorological stations in Kakheti are presented.

As follows from fig. 4-6 these dependence have form of power function. Analogous dependence is observed for all seasons of year and separate stations. The values of the corresponding coefficients of the equation of regression in the table 8 are represented.

Table 8. Values of the coefficients of the equation of regression of dependence of the correlation coefficient by the max wind speed on the distance from separate metheorological station to 12 meteorological stations in Kakheti in 2017-2019 in three periods of year.

Location	Year			Cold season			Warm season		
	Equation of Regression: R = a·(1+x)^b; X – distance, km; α(R²) ≤0.06								
	a	b	R²	a	b	R²	a	b	R²
Tsn.	0.900	-0.240	0.480	0.911	-0.206	0.540	0.885	-0.271	0.373
Kindz.	0.948	-0.204	0.372	0.930	-0.159	0.299	0.963	-0.250	0.383
Tel.	0.986	-0.198	0.460	0.963	-0.149	0.339	0.993	-0.244	0.478
San.	0.946	-0.184	0.443	0.911	-0.134	0.337	0.975	-0.244	0.474
Vachn.	0.952	-0.178	0.374	0.944	-0.142	0.331	0.958	-0.225	0.377
Ruisp.	0.990	-0.187	0.490	0.980	-0.147	0.374	0.999	-0.242	0.544
Dz. An.	0.914	-0.318	0.564	0.911	-0.215	0.525	0.953	-0.552	0.633
Bakur.	0.943	-0.195	0.367	0.930	-0.152	0.281	0.958	-0.245	0.403
Z. Kedi	0.976	-0.226	0.611	0.955	-0.166	0.485	0.986	-0.298	0.692
Sagar.	0.995	-0.251	0.727	1.005	-0.160	0.570	0.997	-0.426	0.880
Khorn.	0.895	-0.172	0.445	0.880	-0.106	0.343	0.917	-0.280	0.493
Naendr.	0.945	-0.172	0.506	0.942	-0.135	0.452	0.954	-0.220	0.526
Kist.	0.991	-0.161	0.780	0.987	-0.126	0.581	0.991	-0.209	0.743
All Points	0.947	-0.201	0.447	0.933	-0.149	0.363	0.959	-0.270	0.464

Depending on the level of the coefficient of determination, it is accepted to divide design models into three groups: 1) 0.8 < R² ≤ 1 - model of a good quality; 2) 0.5 < R² ≤ 0.8 - model of acceptable quality; 3) 0 < R² ≤ 0.5 - model of poor quality.

As it follows from fig. 4-6 and table 8 the quality models of dependence values of R from distance X for seperation station is different. Model of a good quality – only for Sagarejo, in warm season; model of acceptable quality – 5 stations for annual data, 4 stations for cold season and 5 stations for warm season; model of poor quality –8 stations for annual data, 9 stations for cold season and 7 stations for warm season.
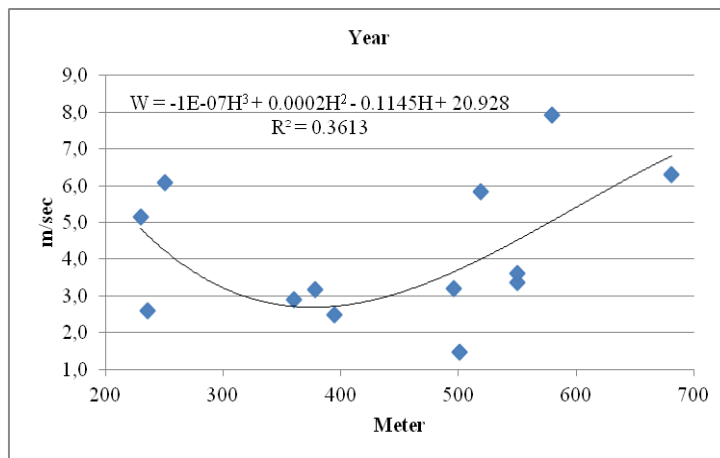

Fig. 7. Vertical distribution of mean annual max wind speed in Kakheti for all 13 stations (α(R²) = 0.03).

In fig. 7 data about vertical distribution of mean annual max wind speed in Kakheti for all 13 stations is presented. As follows from this figure dependence of W from H has form of third power of polinomial and as a whole with an increase of altitude of locality wind speed grows.
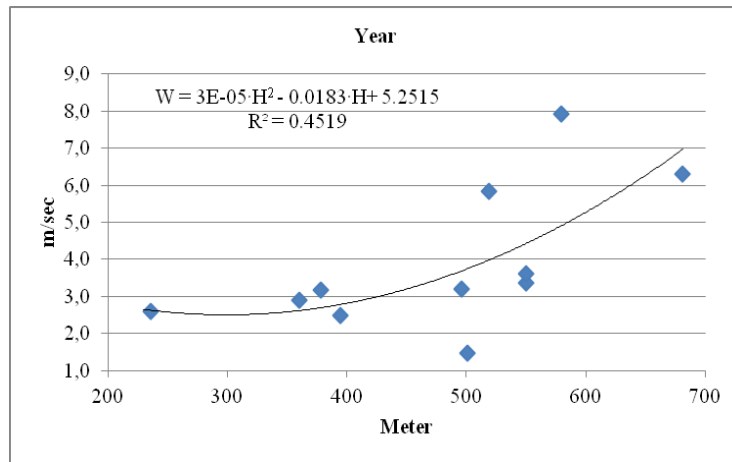

Fig. 8. Vertical distribution of mean annual max wind speed in Kakheti for 11 stations without Khornabuji and Naendrovali ($\alpha(R^2) = 0.03$).

Table 9. Values of the coefficients of the equation of regression of dependence of mean half-year max wind speed in Kakheti with height stations

	All 13 stations				11 stations without Khornabuji and Naendrovali		
	$W = a \cdot H^3 + b \cdot H^2 + c \cdot H + d$	R^2	α		$W = a \cdot H^2 + b \cdot H + c$	R^2	α
	Cold period				Cold period		
a	-1E-07	0.3271	0.04	a	2E-05	0.4139	0.04
b	0.0002			b	- 0.0125		
c	-0.0962			c	4.1908		
d	17.726						
	Warm period				Warm period		
a	-1E-07	0.3873	0.025	a	4E-05	0.4806	0.02
b	0.0003			b	- 0,.241		
c	-0.1325			c	6.098		
d	24.095						

However, it should be noted that at stations Khornabuji and Naendrovali, located on heights 251 and 230 m, the high speeds of wind are observed. This specifies the presence of the minimum in calculated curve of values of W in the range of hight of locality 300-400 m, with further increase value of W with an increase of H.

Without taking into account these stations the dependence W from H takes the form of the second power polynomial (Fig. 8). In this case, more or less a permanent increase in wind speed with an increase in altitude of locality is observed. Similar pattern is observed for the cold and warm seasons (table 9).

Conclusion

The detailed statistical analysis of the daily maximum wind speed W for 13 points of Kakheti in the period from 1 January 2017 through 31 December of 2019 is carried out.

Distribution of W on the territory of Kakheti has the complex, heterogeneous nature, depending on area relief and its height above sea level. The analysis of correlation and regression connections between the

meteorological stations in terms of the values of wind speed showed that frequently the regime of wind has local special features and little it is connected with the adjacent locations. Therefore for the larger detailing of wind regime on the territory of Kakheti should be increased the number of observation points.

In the near future it is planned to draw the comparison of the wind regime in the days with the hail with the non hail days, developments the possible connection between the data about the extreme wind on the earth's surface with the data of the radar measurements of the wind speed on hight 2-2.5 km.

Acknowledgments

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კახეთში 2017-2019 წწ. ქარის დღე–ღამური მაქსიმალური სიჩქარის სტატისტიკური მახასიათებლები

ა. ამირანაშვილი, ვ. ჩიხლაძე, გ. გვასალია, დ. ლოლაძე

რეზიუმე

წარმოდგერნილია ქარის მაქსიმალური დღეღამური სიჩქარის (W) სტატისტიკური ანალიზი კახეთის 13 პუნქტისათვის 2017 წლის 1 იანვრიდან 2019 წლის 31 დეკემბრამდე დროის პერიოდისათვის.

მიღებულია კერძოდ შემდეგი შედეგები: გამოთვლილია W–ს საშუალო თვიური და სეზონური (თბილი და ცივი ნახევარწელი, წლიური) მნიშვნელობები ყველა სადგურისთვის დაკვირვების მთელ პერიოდისათვის; ნაჩვენებია, რომ კახეთის ტერიტორიაზე W – ს საშუალოთვიური მნიშვნელობების განაწილებას აქვს არათანაბარი ხასიათი და იგი იცვლება 0.7 მ/წმ–დან (წნორი, ნოემბერი) 9.5 მ/წმ–დე (საგარეჯო, ივნისი); მოყვანილია კახეთის ტერიტორიაზე W –ს საშუალო წლიური მნიშვნელობების განაწილების რუკა; შესწავლილია W–ს დღეღამური მნიშვნელობების განმეორადობა კახეთის ყველა პუნქტისთვის ბოფორტის სკალის შესაბამისად; ნაჩვენებია, რომ კორელაციის წრფივი კოეფიციენტის R–ს მნიშვნელობები სადგურებს შორის W–ს ყველა დღეღამური მნიშვნელობებით შეადგენს საშუალოდ 0.45 და იცვლება 0.15–დან 0.83–დე, ცივ პერიოდისთვის 0.54 (იცვლება 0.26–დან 0.87–დე), თბილ პერიოდისათვის 0.36 (იცვლება 0.03–დან 0.78–დე); შესწავლილია კორელაციის წრფივი კოეფიციენტის დამოკიდებულება სადგურებს შორის W–ს მნიშვნელობებით მათ შორის მანძილისგან (სადგურებს შორის მანძილის ზრდასთან ერთად R –ს მნიშვნელობა მცირდება ხარისხობრივი ფუნქციის მიხედვით); შესწავლილია W–ს დამოკიდულება სადგურის განლაგების სიმაღლეზე წლის განმავლობაში, წლის თბილ და ცივ ნახევარწლებისთვის.

Статистические характеристики суточной максимальной скорости ветра в Кахетии и 2017-2019

А.Г. Амиранашвили, В.А. Чихладзе, Г.Д. Гвасалия, Д.А. Лоладзе

Резюме

Представлен статистический анализ суточной максимальной скорости ветра (W) для 13 пунктов Кахетии в период с 1 января 2017 по 31 декабря 2019 гг.

В частности, получены следующие результаты: рассчитаны среднемесячные и сезонные (теплое и холодное полугодия, год) значения W для всех станций за весь период наблюдений; показано, что распределений среднемесячных значений W на территории Кахетии имеет неравномерный характер и меняется от 0.7 м/сек (Цнори, ноябрь) до 9.5 м/сек (Сагареджо, июнь); приводится карта распределения среднегодовых значений W на территории Кахетии; изучена повторяемость суточных значений W для всех пунктов Кахетии в соответствии со шкалой Бофорта; показано, что значения линейного коэффициента корреляции R между станциями по всем суточным значениям W в среднем составляет 0.45 и меняется от 0.15 до 0.83, для холодного полугодия – 0.54 (меняется от 0.26 до 0.87), для теплого полугодия – 0.36 (меняется от 0.03 до 0.78); изучена зависимость линейного коэффициента корреляции между станциями по значениям W от расстояния между ними (с ростом расстояния между станциями значение R убывает по степенному закону); изучена зависимость W от высоты расположения станций в среднем за год, в холодное и теплое полугодия.