

# STATISTICAL ANALYSIS OF ATMOSPHERIC PRECIPITATION IN THE RACHA-LECHKHUMI AND KVEMO SVANETI REGION OF GEORGIA IN 1936-2023

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## Abstract

*Atmospheric precipitation is one of the most important components of the climate. Therefore, its study in Georgia, as in other countries, is of great importance, particularly in light of global climate change. Given that Georgia is a mountainous country with extremely heterogeneous terrain, the study of climate change in its individual regions is of particular scientific and practical interest. This study presents the results of research into the precipitation regime and its variability in the Racha-Lechkhumi and Kvemo Svaneti region, based on observational data from the Ambrolauri, Lentekhi and Shovi stations between 1936 and 2023. A detailed statistical analysis was carried out on the sum of monthly, annual and seasonal (cold and warm periods of the year) precipitation for individual stations, as well as for all stations combined. Linear correlations were established between the specified parameters for different months and seasons of the year. Regression equations were obtained for the intra-annual variation of the specified parameters' monthly values, which are of the form of a polynomial of the eighth degree. The variability of the precipitation regime from 1984 to 2023 was studied in comparison to the period from 1936 to 1974. It was found that the variability for individual points is ambiguous. In Ambrolauri, there is a tendency for precipitation to increase in the year and in the warm half-year. In Lentekhi, there is a tendency for precipitation to decrease in the year and in the cold half-year. In Shovi, annual and seasonal changes in the precipitation regime are of little significance. Trends in the annual and seasonal sums of precipitation in Ambrolauri, Lentekhi and Shovi, as well as their averaged amounts at the three stations between 1936 and 2023, were found to follow a third-degree polynomial trend. Data on the average rate of change over eight decades for the specified parameters is presented.*

**Keywords:** climate change, atmospheric precipitation, statistical analysis, trend

## I. Introduction

The problem of climate change is very relevant for many countries of the world, including Georgia, which has a significant diversity of climatic regions on its territory [1]. Considering that atmospheric precipitation is one of the most important components of the climate, special

attention has always been paid to its study in Georgia [1-3]. Over many decades, a large number of studies have been conducted on the climatology of annual, seasonal, monthly and daily precipitation amounts [1-5]; identifying the role of excess and deficit of precipitation in provoking landslides [6], mudflows [7], floods [8], droughts [9], as well as their impact on the agricultural sector [10], bioclimatic conditions of territories [11], etc. A number of studies have compared data from satellite and ground-based measurements of precipitation regimes [12,13]. Work has begun on long-term precipitation forecasting using modern models [14].

The accumulation of new information allows us to constantly update data on the variability of the precipitation regime in various regions of Georgia [1,4,8] against the background of climate change. Below are presented some results of the studies of the precipitation regime and its variability in the Racha-Lechkhumi and Kvemo Svaneti region based on observations at the Ambrolauri, Lentekhi and Shovi stations in the period from 1936 to 2023.

## II. Study area, material and methods

Study area – Racha-Lechkhumi and Kvemo Svaneti region of Georgia, three meteorological stations (Fig. 1): Ambrolauri (42.52° N, 43.15° E, height H = 544 m a.s.l.), Lentekhi (42.78° N, 42.73° E, H = 760 m a.s.l.) and Shovi (42.70° N, 43.68° E, H = 1507 m a.s.l.). Data of the Georgian National Environment Agency about monthly sum of precipitation in the period from 1936 to 2023 are used. The analysis of data is carried out with the use of the standard statistical analysis methods of random events and methods of mathematical statistics for the non-accidental time series of observations [15-17]. The following designations will be used below: Mean – average values; Min – minimal values; Max - maximal values; St Dev - standard deviation;  $\sigma_m$  – standard error;  $R^2$  - coefficient of determination; R – coefficient of linear correlation;  $C_v$  – coefficient of variation, %;  $K_{DW}$  – Durbin-Watson statistic;  $\alpha$  - level of significance; P – sum of precipitation, mm (monthly; seasonally: October - March, April – September, January – December –  $P_{cold}$ ,  $P_{warm}$ ,  $P_{year}$ ). Ambrolauri – Am, Lentekhi – Len, Shovi – Sh, Av – data, averaged over three stations. Distance between meteorological stations: Ambrolauri - Lentekhi: 45 km, Ambrolauri - Shovi: 48 km, Lentekhi - Shovi: 78 km. Missing observational data using standard methods were recovered [15]. Comparison of mean values of precipitation in two forty -year periods of time (1936-1975 and 1984-2023) was produced with the use of Student's criterion with the level of significance  $\alpha$  not worse than 0.25. The degree of correlation was determined in accordance with [16]: 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 ( $0 \leq R < 0.3$ ). The curve of trend is equation of the regression of the connection of the investigated parameter with the time at the significant value of the determination coefficient and such values of  $K_{DW}$ , where the residual values are accidental. The dimension of atmospheric precipitation (mm) and word “correlation” are often omitted from the text below.



Figure 1: Location of meteorological stations Ambrolauri, Lentekhi and Shovi.

### III. Results

Results in Table 1-4 and Fig. 2-5 are presented.

In Tables 1,2 statistical characteristics of monthly sum of precipitation in Ambrolauri, Lentekhi and Shovi, as well as their amounts averaged over three stations, from January to June and July to December in 1936-2023 are presented.

**Table 1:** Statistical characteristics of monthly sum of precipitation in Ambrolauri, Lentekhi and Shovi, as well as their amounts averaged over three stations, from January to June in 1936-2023.

Month	Jan				Feb				Mar			
Location	Am	Len	Sh	Av	Am	Len	Sh	Av	Am	Len	Sh	Av
Mean	85	114	80	93	72	91	69	77	77	109	90	92
Min	0	10	0	9	0	0	0	7	0	5	0	9
Max	452	556	444	484	199	269	212	200	251	341	258	283
St Dev	62.5	86.7	62.5	65.6	43.3	56.9	41.3	42.1	46.8	63.9	53.1	46.9
$\sigma_m$	6.7	9.3	6.7	7.0	4.6	6.1	4.4	4.5	5.0	6.9	5.7	5.0
$C_v, \%$	73.9	76.3	78.5	70.8	60.5	62.6	59.4	54.5	60.6	58.6	58.7	50.8
	Correlation Matrix				Correlation Matrix				Correlation Matrix			
Am	1	0.76	0.86	0.93	1	0.59	0.70	0.84	1	0.66	0.69	0.90
Len	0.76	1	0.78	0.93	0.59	1	0.79	0.91	0.66	1	0.48	0.86
Sh	0.86	0.78	1	0.93	0.70	0.79	1	0.92	0.69	0.48	1	0.82
Av	0.93	0.93	0.93	1	0.84	0.91	0.92	1	0.90	0.86	0.82	1
Month	Apr				May				Jun			
Location	Am	Len	Sh	Av	Am	Len	Sh	Av	Am	Len	Sh	Av
Mean	80	108	107	98	94	98	122	105	95	106	124	108
Min	10	18	10	15	20	19	25	37	23	21	0	36
Max	259	272	242	217	203	229	235	196	228	269	225	215
St Dev	39.4	56.0	47.7	41.8	41.0	41.7	43.4	35.9	41.5	55.8	41.2	36.4
$\sigma_m$	4.2	6.0	5.1	4.5	4.4	4.5	4.7	3.8	4.5	6.0	4.4	3.9
$C_v, \%$	49.0	51.8	44.7	42.5	43.8	42.7	35.5	34.3	43.6	52.4	33.3	33.6
	Correlation Matrix				Correlation Matrix				Correlation Matrix			
Am	1	0.68	0.70	0.88	1	0.57	0.55	0.83	1	0.45	0.57	0.82
Len	0.68	1	0.59	0.88	0.57	1	0.65	0.87	0.45	1	0.30	0.79
Sh	0.70	0.59	1	0.86	0.55	0.65	1	0.87	0.57	0.30	1	0.75
Av	0.88	0.88	0.86	1	0.83	0.87	0.87	1	0.82	0.79	0.75	1

In particular, as follows from these tables, the range of changes in the mean, minimum and maximum monthly values of P for individual points and their amounts averaged over three stations is as follows.

Mean values - Am: 72 (Feb) - 112 (Oct), Len: 88 (Sep) - 119 (Dec), Sh: 69 (Feb) - 124 (Jun), Av: 77 (Feb) - 112 (Oct).

Min values - Am: 0 (Jan-Mar, Jul, Aug, Oct-Dec) - 23 (Jun), Len: 0 (Feb) - 21 (Jun), Sh: 0 (Jan-Mar, Jun, Nov, Dec) - 25 (May), Av: 6 (Oct) - 37 (May).

Max values - Am 198 (Aug) - 452 (Jan), Len: 229 (May) - 556 (Jan), Sh: 212 (Feb) - 444 (Jan), Av: 196 (May) - 484 (Jan).

The range of changes in the coefficient of variation is as follows.

Am: 43.6 % (Jun)- 73.9% (Jan), Len: 42.7% (May) - 76.3% (Jan), Sh: 33.3% (Jun) - 78.5% (Jan), Av: 33.6% (Jun)- 70.8% (Jan).

The range of change in the correlation coefficient between meteorological stations for the monthly sum of precipitation by month is as follows.

Jan: 0.76 (Pair: Am - Len, high) - 0.86 (Pair: Am - Sh, high), Feb: 0.59 (Pair: Am - Len, moderate) - 0.79 (Pair: Len - Sh, high), Mar: 0.48 (Pair: Len -Sh, low) - 0.69 (Pair: Am - Sh,

moderate), Apr: 0.59 (Pair: Len - Sh, moderate) - 0.70 (Pair: Am - Sh, high), May: 0.55 (Pair: Am - Sh, moderate) - 0.65 (Pair: Len - Sh, moderate), Jun: 0.30 (Pair: Len - Sh, low) - 0.57 (Pair: Am - Sh, moderate), Jul: 0.30 (Pair: Len - Sh, low) - 0.65 (Pair: Am - Sh, moderate), Aug: 0.60 (Pair: Len - Sh, moderate) - 0.71 (Pair: Am - Sh, high), Sep: 0.44 (Pair: Am - Len, low) - 0.61 (Pair: Am - Sh, moderate), Oct: 0.70 (Pair: Len - Sh, high) - 0.85 (Pair: Am - Sh, high), Nov: 0.63 (Pair: Len - Sh, moderate) - 0.75 (Pair: Am - Sh, high), Dec: 0.73 (Pair: Len - Sh, high) - 0.83 (Pair: Am - Sh, high).

**Table 2:** Statistical characteristics of monthly sum of precipitation in Ambrolauri, Lentekhi and Shovi, as well as their amounts averaged over three stations, from July to December in 1936-2023.

Month	Jul				Aug				Sep			
Location	Am	Len	Sh	Av	Am	Len	Sh	Av	Am	Len	Sh	Av
Mean	76	101	106	94	75	100	105	93	86	88	99	91
Min	0	13	23	19	0	1	21	20	11	2	12	8
Max	209	506	218	225	198	258	306	222	202	281	235	217
St Dev	41.9	69.0	45.8	40.7	43.8	66.6	55.5	48.3	39.1	50.1	43.5	36.3
$\sigma_m$	4.5	7.4	4.9	4.4	4.7	7.1	6.0	5.2	4.2	5.4	4.7	3.9
$C_v, \%$	55.4	68.6	43.1	43.3	58.7	66.6	53.0	51.9	45.5	57.2	44.1	40.0
	Correlation Matrix				Correlation Matrix				Correlation Matrix			
Am	1	0.33	0.65	0.77	1	0.63	0.71	0.87	1	0.44	0.61	0.81
Len	0.33	1	0.30	0.79	0.63	1	0.60	0.88	0.44	1	0.48	0.81
Sh	0.65	0.30	1	0.77	0.71	0.60	1	0.87	0.61	0.48	1	0.84
Av	0.77	0.79	0.77	1	0.87	0.88	0.87	1	0.81	0.81	0.84	1
Month	Oct				Nov				Dec			
Location	Am	Len	Sh	Av	Am	Len	Sh	Av	Am	Len	Sh	Av
Mean	112	109	115	112	90	107	80	93	97	119	76	97
Min	0	1	7	6	0	17	0	15	0	9	0	10
Max	283	275	338	254	252	301	242	250	390	346	288	341
St Dev	60.7	66.3	64.1	58.5	57.1	69.6	51.8	53.2	64.8	75.8	51.2	59.4
$\sigma_m$	6.5	7.1	6.9	6.3	6.1	7.5	5.6	5.7	6.9	8.1	5.5	6.4
$C_v, \%$	54.0	61.0	55.6	52.2	63.3	64.8	64.4	57.4	67.0	63.7	67.3	61.1
	Correlation Matrix				Correlation Matrix				Correlation Matrix			
Am	1	0.76	0.85	0.94	1	0.72	0.75	0.91	1	0.82	0.83	0.95
Len	0.76	1	0.70	0.89	0.72	1	0.63	0.90	0.82	1	0.73	0.93
Sh	0.85	0.70	1	0.92	0.75	0.63	1	0.87	0.83	0.73	1	0.90
Av	0.94	0.89	0.92	1	0.91	0.90	0.87	1	0.95	0.93	0.90	1

The range of change in the correlation coefficient between meteorological stations for the monthly sum of precipitation and their amounts averaged over three stations, by month is as follows.

Jan: 0.93 (Pair: Av - All Stations, very high), Feb: 0.84 (Pair: Av - Am, high) - 0.92 (Pair: Av - Sh, very high), Mar: 0.82 (Pair: Av - Sh, high) - 0.90 (Pair: Av - Am, very high), Apr: 0.86 (Pair: Av - Sh, high) - 0.88 (Pair: Av - Am, Len, high), May: 0.83 (Pair: Av - Am, high) - 0.87 (Pair: Av - Len, Sh, high), Jun: 0.75 (Pair: Av - Sh, high) - 0.82 (Pair: Av - Am, high), Jul: 0.77 (Pair: Av - Am, Sh, high) - 0.79 (Pair: Av - Len, high), Aug: 0.87 (Pair: Av - Am, Sh, high) - 0.88 (Pair: Av - Len, high), Sep: 0.81 (Pair: Av - Am, Len, high) - 0.84 (Pair: Av - Sh, high), Oct: 0.89 (Pair: Av - Len, high) - 0.94 (Pair: Av - Am, very high), Nov: 0.87 (Pair: Av - Sh, high) - 0.91 (Pair: Av - Am, very high), Dec: 0.90 (Pair: Av - Sh, very high) - 0.95 (Pair: Av - Am, very high).

In Table 3 statistical characteristics of annual and seasonal sum of precipitation in Ambrolauri, Lentekhi and Shovi, as well as their amounts averaged over three stations for 1936-2023 are presented.

In particular, as follows from table 3, the range of changes in the mean, minimum and maximum seasonal values of P between individual points is as follows.

Mean values. Year: 1038 (Am) - 1249 (Len), Cold Season: 511 (Sh) - 649 (Len), Warm Season: 506 (Am) - 662 (Sh).

Min values. Year: 550 (Len) - 700 (Sh), Cold Season: 73 (Am) - 242 (Len), Warm Season: 161 (Len) 354 (Sh).

Max values. Year: 1443 (Am) - 1989 (Len), Cold Season: 942 (Am) - 1243 (Len), Warm Season: 765 (Am) - 1034 (Len).

The range of changes in the coefficient of variation is as follows.

Year: 16.8% (Sh) - 24.0% (Len), Cold Season: 27.7% (Am) - 32.2 (Len), Warm Season: 16.9% (Sh) - 28.1% (Len).

**Table 3:** Statistical characteristics of annual and seasonal sum of precipitation in Ambrolauri, Lentekhi and Shovi, as well as their amounts averaged over three stations for 1936-2023.

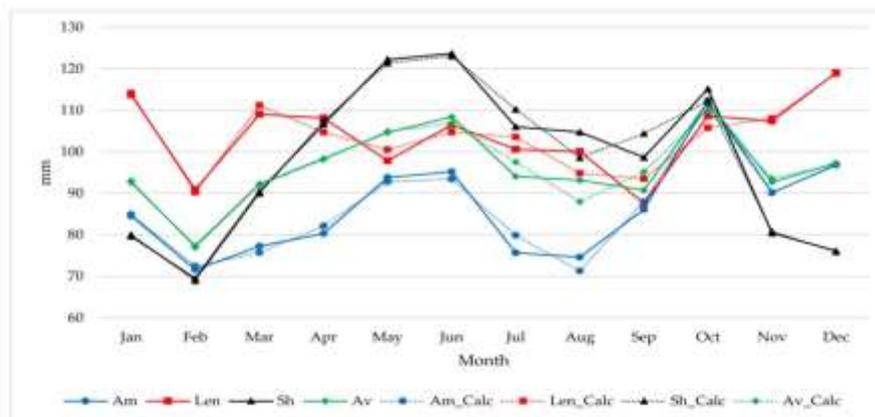
Season	P <sub>year</sub>				P <sub>cold</sub>				P <sub>warm</sub>			
	Am	Len	Sh	Av	Am	Len	Sh	Av	Am	Len	Sh	Av
Mean	1038	1249	1173	1154	533	649	511	564	506	601	662	589
Min	621	550	700	792	73	242	222	230	245	161	354	345
Max	1443	1989	1816	1732	942	1243	1026	1070	765	1034	1018	845
St Dev	185.5	300.1	197.4	195.8	147.8	208.7	141.6	148.0	102.7	168.8	111.8	106.3
$\sigma_m$	19.9	32.2	21.2	21.0	15.8	22.4	15.2	15.9	11.0	18.1	12.0	11.4
C <sub>v</sub> ,%	17.9	24.0	16.8	17.0	27.7	32.2	27.7	26.2	20.3	28.1	16.9	18.0
	Correlation Matrix				Correlation Matrix				Correlation Matrix			
Am	1	0.57	0.73	0.85	1	0.65	0.79	0.89	1	0.52	0.65	0.82
Len	0.57	1	0.55	0.87	0.65	1	0.65	0.90	0.52	1	0.46	0.86
Sh	0.73	0.55	1	0.85	0.79	0.65	1	0.89	0.65	0.46	1	0.80
Av	0.85	0.87	0.85	1	0.89	0.90	0.89	1	0.82	0.86	0.80	1

The range of change in the correlation coefficient between meteorological stations for the seasonal sum of precipitation and their amounts averaged over three stations, by seasons is as follows.

Year: 0.55 (Pair: Len - Sh, moderate) - 0.73 (Pair: Am - Sh, high), 0.85 (Av - Am, Sh, high) - 0.87 (Av - Len, high).

Cold Season: 0.65 (Pair: Am - Len, moderate) - 0.79 (Pair: Am - Sh, high), 0.89 (Av - Am, Sh, high) - 0.90 (Av - Len, very high).

Warm Season: 0.46 (Pair: Len - Sh, low) - 0.65 (Pair: Am - Sh, moderate). 0.80 (Av - Sh, high) - 0.86 (Av - Len, high).



**Figure 2:** Intra-annual variation of monthly sum of precipitation in Ambrolauri, Lentekhi and Shovi, as well as their amounts averaged over three stations (measured and calculated data).

In Fig. 2 intra-annual variation of monthly sum of precipitation in Ambrolauri, Lentekhi and Shovi, as well as their amounts averaged over three stations (measured and calculated data) are presented. In Table 4 coefficients of the regression equation (polynomials of the eighth degree) for the intra-annual variation of monthly sum of precipitation in Ambrolauri, Lentekhi and Shovi, as well as their amounts averaged over three stations, based on data from 1936 to 2023.

**Table 4:** Coefficients of the regression equation for the intra-annual variation of monthly sum of precipitation in Ambrolauri, Lentekhi and Shovi, as well as their amounts averaged over three stations, based on data from 1936 to 2023.

Regression	$Y = a \cdot x^8 + b \cdot x^7 + c \cdot x^6 + d \cdot x^5 + e \cdot x^4 + f \cdot x^3 + g \cdot x^2 + h \cdot x + i$ , $x$ – number of month, 1...12			
Location	Am	Len	Sh	Av
R <sup>2</sup>	0.971	0.889	0.974	0.933
a	0.001072	0.00115	0.000957	0.001044
b	-0.05193	-0.06126	-0.04705	-0.05261
c	1.035133	1.361883	0.957919	1.101379
d	-11.0067	-16.3896	-10.5033	-12.4425
e	67.83332	115.7414	67.67775	82.51051
f	-247.312	-485.499	-262.678	-327.163
g	521.9025	1162.667	599.6971	751.7874
h	-582.249	-1419.7	-715.591	-896.207
i	334.7955	755.9773	400.5	493.4773

As follows from Fig. 2, all cases of intra-annual distribution of P have a multimodal form. The extreme and minimum values of P are as follows.

Am: Extremes: Jan (85), May (94), Jun (95), Oct (112), Dec (97); Min: Feb (72), Jul (76), Aug (75). Len: Extremes: Jan (114), Dec (119); Min: Feb (91), May (98), Sep (88). Sh: Extremes: May (122), Jun (124), Oct (115); Min: Feb (69), Dec (76). Av: Extremes: Jun (108), Oct (112); Min: Feb (77), Sep (91), Nov (93).

The correlation coefficient between meteorological stations for intra-annual distribution of P is as follows. R = 0.39 (Pair: Am – Len, low); R = 0.35 (Pair: Am – Sh, low); R = 0.80 (Pair: Am – Av, high); R = -0.14 (Pair: Len – Sh, negligible); R = 0.40 (Pair: Len – Av, low); R = 0.78 (Pair: Sh – Av, high). The intra-annual distribution of P for all cases, with a high degree of reliability, it is approximated by a polynomial of the eighth degree ( $R^2 \geq 0.889$ ; Fig. 2, Table 4).

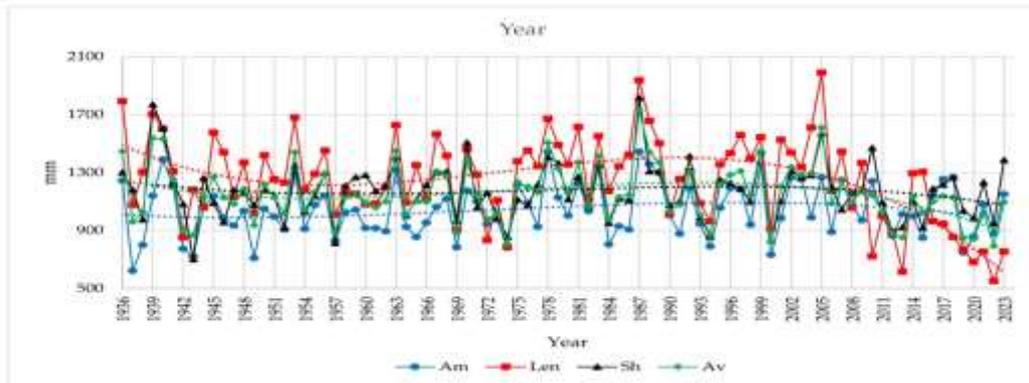


**Figure 3:** Difference between monthly, annual and seasonal sum of precipitation in Ambrolauri, Lentekhi and Shovi in 1984-2023 and 1936-1975 (ntegers without a comma refer to the difference with a level of significance  $\alpha > 0.25$ ).

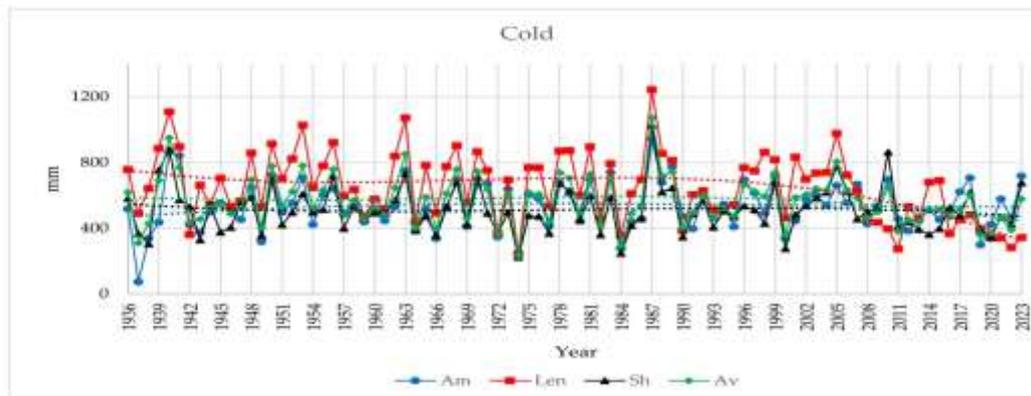
In Fig. 3 data on difference between monthly, annual and seasonal sum of precipitation in Ambrolauri, Lentekhi and Shovi in 1984-2023 and 1936-1975. The significant changes over two forty-year time periods for average monthly, annual, and seasonal values of P for individual stations and on average per station are as follows.

Am: increase in Apr (10.8), May (11.6), for the year as a whole (58.1), and in the warm season (36.3). Len: increase in Apr (27.2), May (13.4), and Jun (24.5); decrease in Jan (-33.7), Feb (-19.1), Mar (-20.0), Sep (-24.5), and in the cold season (-100.1). Sh: increase in Apr (14.9) and Jun (12.1); decrease in Aug (-24.3). Av: increase in Apr (17.6) and Jun (12.3); decrease in Feb (-11.3).

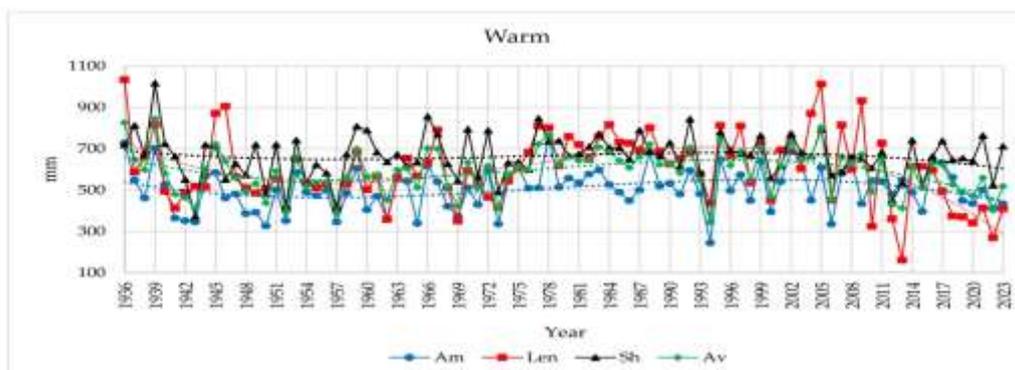
Fig. 4-6, as examples, show the trends of mean annual and seasonal sum of precipitation in Ambrolauri, Lentekhi and Shovi, as well as their averaged amounts at three stations in 1936-2023.



**Figure 4:** Trends of mean annual sum of precipitation in Ambrolauri, Lentekhi and Shovi, as well as their averaged amounts at three stations in 1936-2023.



**Figure 5:** Trends of mean sum of precipitation in cold season in Ambrolauri, Lentekhi and Shovi, as well as their averaged amounts at three stations in 1936-2023.



**Figure 6:** Trends of mean sum of precipitation in warm season in Ambrolauri, Lentekhi and Shovi, as well as their averaged amounts at three stations in 1936-2023.

In Table 4 the coefficients of the regression equation for the trend of annual and seasonal sum of precipitation in Ambrolauri, Lentekhi and Shovi, as well as their averaged amounts at three

stations in 1936 - 2023, are presented.

**Table 4:** The coefficients of the regression equation for the trend of annual and seasonal sum of precipitation in Ambrolauri, Lentekhi and Shovi, as well as their averaged amounts at three stations in 1936 - 2023.  
 $x$  – number of year, 1...88;  $\alpha(R^2) \leq 0.22$ ,  $\alpha(K_{Dw}) = 0.05$ .

Parameter	R <sup>2</sup>	K <sub>Dw</sub>	a	b	c	d
Regression	Y = a·x <sup>3</sup> +b·x <sup>2</sup> +c·x+d					
Point/Season	Year					
Am	0.0434	2.15	-0.00173	0.1934	-4.023	1011.61
Len	0.337	1.89	-0.00916	1.0620	-32.816	1518.62
Sh	0.0221	2.00	-0.00210	0.2682	-9.270	1247.85
Av	0.141	1.98	-0.00433	0.5079	-15.370	1259.31
Point/Season	Cold					
Am	0.017	2.19	0.0004	-0.0799	4.666	465.53
Len	0.211	1.89	-0.0030	0.3121	-9.227	763.13
Sh	0.018	2.00	-0.0009	0.1191	-4.366	550.45
Av	0.056	2.06	-0.00117	0.1168	-2.967	592.96
Point/Season	Warm					
Am	0.092	2.19	-0.00213	0.2735	-8.685	546.01
Len	0.294	1.93	-0.00615	0.7486	-23.545	755.29
Sh	0.023	2.14	-0.00119	0.1487	-4.887	697.29
Av	0.178	2.05	-0.00316	0.3901	-12.368	666.17

Finally, in Table 5 data on ten-year average change rate (tenfold value of first derivative of the trend regression equation) for the specified parameters are presented.

**Table 5:** Ten-year average change rate of annual and seasonal sum of precipitation in Ambrolauri, Lentekhi and Shovi, as well as their averaged amounts at three stations (mm/10 year).

Season	Point	1936-1945	1946-1955	1956-1965	1966-1975	1984-1993	1994-2003	2004-2013	2014-2023	Mean
Year	Am	-2.1	0.7	2.4	3.1	1.7	-0.5	-3.7	-8.0	-0.8
	Len	-22.2	-6.7	3.2	7.7	1.9	-9.0	-25.5	-47.4	-12.2
	Sh	-6.6	-2.5	0.3	1.8	1.3	-0.7	-4.0	-8.5	-2.4
	Av	-10.3	-2.9	2.0	4.2	1.7	-3.4	-11.1	-21.3	-5.1
Cold	Am	3.8	2.5	1.4	0.5	-0.5	-0.7	-0.6	-0.3	0.8
	Len	-6.1	-1.8	0.8	1.5	-1.7	-6.0	-12.1	-20.0	-5.7
	Sh	-3.2	-1.3	-0.1	0.6	0.6	-0.2	-1.5	-3.4	-1.1
	Av	-1.8	-0.2	0.7	0.9	-0.5	-2.3	-4.7	-7.9	-2.0
Warm	Am	-5.9	-1.8	1.0	2.6	2.2	0.2	-3.1	-7.7	-1.6
	Len	-16.0	-4.9	2.5	6.2	3.6	-3.1	-13.4	-27.4	-6.6
	Sh	-3.4	-1.2	0.3	1.1	0.7	-0.5	-2.4	-5.1	-1.3
	Av	-8.4	-2.6	1.3	3.3	2.2	-1.1	-6.3	-13.4	-3.1

In particular, the analysis of Fig. 4-6 and Table 5 shows the following. In 1936-1945 in general, there are tendencies of decreasing annual and seasonal amounts of precipitation (with the exception of Ambrolauri in the cold half-year). A similar situation is observed for the periods 1946-1955 (except Ambrolauri, according to annual data and in the cold season) and 1994-2003 (except Ambrolauri, warm season).

From 1956 to 1993, a general tendency towards increasing precipitation was observed: 1956-1965 - except Shovi in the cold season, 1966-1975 - all points, 1984-1993 - except Ambrolauri and Lentekhi in the cold season.

From 2004 to 2023, a tendency towards decreasing annual and seasonal sum of precipitation were observed for all points. Moreover, the greatest tendencies towards a decrease in precipitation amounts are observed in Lentekhi.

## IV. Conclusion

A detailed statistical analysis of time series of observations of monthly, annual and seasonal (cold and warm periods of the year) precipitation amounts for the Ambrolauri, Lentekhi and Shovi stations (Racha-Lechkhumi and Kvemo Svaneti region of Georgia) for the period from 1936 to 2023 was carried out.

It was found that the values of the linear correlation coefficient between the three points and average for these points monthly, annual and seasonal sum of precipitation are significant. At the same time, for monthly data, the values of the correlation coefficient are in the range of 0.30 – 0.95 (9.7 % of cases - low correlation, 19.4 % - moderate correlation, 52.8 - high correlation, 18.1 % -very high correlation; total 72 pairs of correlation coefficients). For annual and seasonal data, the correlation coefficient values are in the range of 0.46 – 0.90 (5.6 % of cases - low correlation, 33.3 % - moderate correlation, 55.6 % - high correlation, 5.6 % -very high correlation; total 18 pairs of correlation coefficients).

Intra-annual distributions of precipitation amounts have a multimodal form and are well approximated by an eighth-degree polynomial.

The variability of the precipitation regime in the specified time period was studied by comparing monthly, annual and seasonal data for 1984-2023 and 1936-1974, as well as analyzing the trends in annual and seasonal precipitation amounts. It was found that the specified variability for individual points is ambiguous.

In particular, the analysis of trends in annual and seasonal precipitation showed that in certain decades there were both decreasing and increasing tendencies in precipitation for different points. However, from 2004 to 2023, a tendency towards decreasing annual and seasonal sum of precipitation were observed for all points. Moreover, the greatest tendencies towards a decrease in precipitation amounts are observed in Lentekhi.

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### CONFLICT OF INTEREST.

Authors declare that they do not have any conflict of interest.

### References

- [1] Kartvelishvili L., Tatishvili M., Amiranashvili A., Megrelidze L., Kutaladze N. Weather, Climate and their Change Regularities for the Conditions of Georgia. Monograph - Tbilisi, 2023, 406 p., Publishing House "Universal". <https://doi.org/10.52340/mng.9789941334658>
- [2] Alibegova D., Elizbarashvili E. Statisticheskaya struktura atmosferikh osadkov v gornikh raionakh. Leningrad, 1980, 136 p., (in Russian).
- [3] Bliadze T., Gvasalia G., Kirkitadze D., Mekoshkishvili N. Changeability of the Atmospheric Precipitations Regime in Kakheti in 1956-2015. Proceedings – Int. Sc. Conf. "Natural Disasters in Georgia: Monitoring, Prevention, Mitigation". ISBN 978-9941-13-899-7, December 12-14, Tbilisi, 2019, pp. 74-77, Publish House of Iv. Javakhishvili Tbilisi State University.
- [4] Bolashvili N., Chikhladze V., Kartvelishvili L., Tatishvili M. Variability of Atmospheric Precipitation in Tbilisi in 1844-2023. Proceedings – Int. Sc. Conf. "Complex Geophysical Monitoring in Georgia: History, Modern Problems, Promoting Sustainable Development of the Country", ISBN 978-9941-36-272-9, Tbilisi, Georgia, October 17-19, 2024, pp. 150 – 154, Publish House of Iv. Javakhishvili Tbilisi State University. [http://dSPACE.gela.org.ge/bitstream/123456789/10620/1/38\\_MM-180.pdf](http://dSPACE.gela.org.ge/bitstream/123456789/10620/1/38_MM-180.pdf)

[5] Amiranashvili A.G. Special Features of Changeability of Daily Sum of Precipitation in Tbilisi in 1957-2006 // Journal of the Georgian Geophysical Society, Issue B. Physics of Atmosphere, Ocean and Space Plasma, v.18B, Tbilisi, 2015, pp.81-91.

[6] Chelidze T., Amiranashvili A., Svanadze D., Tsamalashvili T., Tvauri G. Terrestrial and Satellite-Based Assessment of Rainfall Triggered Landslides Activity in Georgia, Caucasus - Bull. Georg. Nat. Acad. Sci., ISSN: 0132-1447, vol. 17, no. 2, 71-77, 2023, <http://science.org.ge/bnas/vol-17-2.html>

[7] Amiranashvili A., Chelidze T., Svanadze D., Tsamalashvili T., Tvauri G. Study of the Relationship Between the Mean Annual Sum of Atmospheric Precipitation and Re-Activated and New Mudflow Cases in Georgia - Journal of the Georgian Geophysical Society, e-ISSN: 2667-9973, p-ISSN: 1512-1127, // Physics of Solid Earth, Atmosphere, Ocean and Space Plasma, v. 26(1), 2023, pp. 19–29. <https://ggs.openjournals.ge/index.php/GGS/article/view/6958>

[8] Beglarashvili N., Janelidze I., Pipia M., Varamashvili N. Heavy Rainfall, Floods and Floodings in Kakheti (Georgia) in 2014-2018. / Proceedings – Int. Sc. Conf. „Modern Problems of Ecology“, ISSN 1512-1976, v. 7, Tbilisi-Telavi, Georgia, 26-28 September, 2020, pp. 180-184.

[9] Tatishvili M., Kapanadze N., Mkurnalidze I., Palavandishvili A. Drought Evaluation in Georgia using SPI and SpEI Indices. / Proceedings – Int. Sc. Conf. “Complex Geophysical Monitoring in Georgia: History, Modern Problems, Promoting Sustainable Development of the Country”, Proceedings, ISBN 978-9941-36-272-9, Tbilisi, Georgia, October 17-19, 2024, pp. 96 – 100, Publish House of Iv. Javakhishvili Tbilisi State University.

[10] Meladze M., Meladze G., Kapanadze N., Pipia M. Impact of Droughts on the Agricultural Sector of the Eastern Georgia Regions. Proceedings – Int. Sc. Conf. “Complex Geophysical Monitoring in Georgia: History, Modern Problems, Promoting Sustainable Development of the Country”, / Proceedings, ISBN 978-9941-36-272-9, Tbilisi, Georgia, October 17-19, 2024, pp. 72 – 75, Publish House of Iv. Javakhishvili Tbilisi State University, (in Georgian).

[11] Amiranashvili A.G., Kartvelishvili L.G., Kutaladze N.B., Megrelidze L.D., Tatishvili M.R. Changeability of the Meteorological Parameters Associated with Holiday Climate Index in Different Mountainous Regions of Georgia in 1956-2015 - Journal of the Georgian Geophysical Society, e-ISSN: 2667-9973, p-ISSN: 1512-1127. // Physics of Solid Earth, Atmosphere, Ocean and Space Plasma, v. 24(2), 2021, pp. 78-91. DOI: <https://doi.org/10.48614/ggs2420213326>

[12] Amiranashvili A., Chelidze T., Svanadze D., Tsamalashvili T., Varamashvili N. Comparison of Satellite and Ground-Based Data on Semi-Annual and Annual Sum of Atmospheric Precipitation for 26 Points in Georgia in 2001-2020. / Proceedings – Int. Sc. Conf. “Complex Geophysical Monitoring in Georgia: History, Modern Problems, Promoting Sustainable Development of the Country”, Proceedings, ISBN 978-9941-36-272-9, Tbilisi, Georgia, October 17-19, 2024, pp. 159 – 163, Publish House of Iv. Javakhishvili Tbilisi State University. [http://www.openlibrary.ge/bitstream/123456789/10618/1/40\\_MM-180.pdf](http://www.openlibrary.ge/bitstream/123456789/10618/1/40_MM-180.pdf)

[13] Tselashvili N., Biggs T., Ye Mu, Trapaidze V. Regional Precipitation Regimes and Evaluation of National Precipitation Datasets against Satellite-Based Precipitation Estimates, Republic of Georgia // Journal of Hydrometeorology, Vol. 25, 2024, pp. 591-600, DOI: 10.1175/JHM-D-23-0116.1

[14] Elizbarashvili M., Amiranashvili A., Elizbarashvili E., Mikuchadze G., Khuntselia T., Chikhradze N. Comparison of RegCM4.7.1 Simulation with the Station Observation Data of Georgia, 1985–2008 // Atmosphere, ISSN: 2073-4433, 15, 369, 2024, 19 pp. <https://doi.org/10.3390/atmos15030369>

[15] Kobisheva N., Narovlianski G. Climatological processing of the meteorological information. Leningrad, 1978, 294 p., Gidrometeoizdat, (in Russian)

[16] Hinkle D. E., Wiersma W., Jurs S. G. Applied Statistics for the Behavioral Sciences. Boston, 2003, MA, Houghton Mifflin Company

[17] Kendall M.G. Time-series. Moscow, 1981, 200 p., (in Russian).