საერთაშორისო სამეცნიერო კონფერენცია „კომპლექსური გეოფიზიკური მონიტორინგი საქართველოში: ისტორია, თანამედროვე პრობლემები, ქვეყნის მდგრადი განვითარების ხელშეწყობა“, შრომები, თბილისი, საქართველო, 17-19 ოქტომბერი, 2024 წ.

International Scientific Conference “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

VARIABILITY OF ATMOSPHERIC PRECIPITATION IN TBILISI IN 1844-2023

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Abstract. *A statistical analysis of time series of observations of monthly and seasonal (year, cold and warm seasons) values of precipitation amounts in Tbilisi from 1844 to 2023 was carried out. A comparison of monthly and seasonal average precipitation values was carried out for two ninety-year and thirty-year time periods (1844-1933 and 1934-2023, as well as 1844-1873 and 1994-2023). To assess the compatibility of these observation time series, a linear correlation analysis was carried out between them for the specified time periods.*

Key Words: *Climate change, atmospheric precipitation, statistical analysis.*

Introduction

The problem of observed and expected climate changes on our planet has become especially relevant in recent years. This problem is of great importance in Georgia, due to the diversity of climatic regions on its territory [1]. Atmospheric precipitation is one of the most important components of the climate and special attention has always been paid to its research in Georgia [1-4]. In particular, a large number of studies have been conducted on the climatology of seasonal, monthly and daily precipitation amounts [1-4]; the role of precipitation in the formation of bioclimatic conditions of areas [1]; the impact of precipitation deficiency and excess on the provocation of droughts [5], floods [6], landslides [7] and other negative phenomena, etc. As new information accumulated, data on the variability of the precipitation regime in various regions of Georgia were constantly updated [8-12].

In Tbilisi regular meteorological observations were begun into 1844. In [12] standard statistical analysis of changeability of atmospheric precipitations in Tbilisi in 1844-2018 was carried out.

In this work comparison of monthly and seasonal mean values of precipitations for two ninety-year and thirty-year periods of time (1844-1933 and 1934-2023, as well as 1844-1873 and 1994-2023) was carried out. A linear correlation analysis was also carried out between the studied time-series of precipitation observations to assess the monthly and seasonal compatibility of these series in the specified time periods.

Study area, material and methods

Study area – Tbilisi. Data of the Georgian National Environment Agency about monthly sum of precipitation in Tbilisi in the period from 1844 to 2023 are used. The standard statistical methods are used [13,14]. The following designations will be used below: Mean – average values; Min – minimal values; Max – maximal values; St Dev – standard deviation; St Err – standard error; R^2 – coefficient of determination; R – coefficient of linear correlation; C_v – coefficient of variation, % ; α – level of significance; Low and Upp – lower and upper levels of confidence interval of average values with probability 99.999%; P – sum of precipitation, mm (monthly, seasonally: October – March, April – September, January – December – P_{cold}, P_{warm},

P_{year}). Missing observational data using standard methods were recovered [13] . Comparison of mean values of precipitation in two ninety-year and thirty-year periods of time (1844-1933 and 1934-2023, as well as 1844-1873 and 1994-2023) was produced with the use of Student's criterion with the level of significance α not worse than 0.15. The dimension of atmospheric precipitation (mm) is often omitted from the text below.

Results

Results in Fig. 1-3 and Table 1 are presented.

Fig. 1 shows data on the variability of seasonal sum of precipitation in Tbilisi in 1844-2023. As follows from this Fig., the values of the linear correlation coefficient P_{cold}, P_{warm} and P_{year} with the years, respectively, are: 0.14 (negligible correlation), 0.024 (lack of correlation) and 0.062 (lack of correlation). Thus, only in the cold half of the year is a weak positive trend in precipitation observed in the specified period of time.

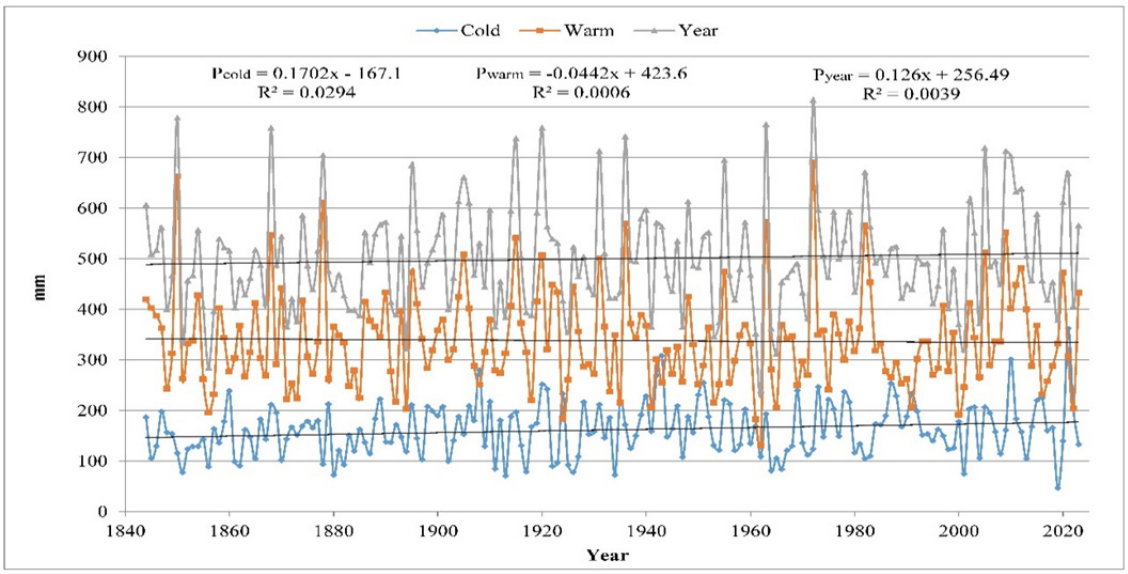


Fig. 1. Trend of precipitations in Tbilisi in three period of year in 1844-2023.

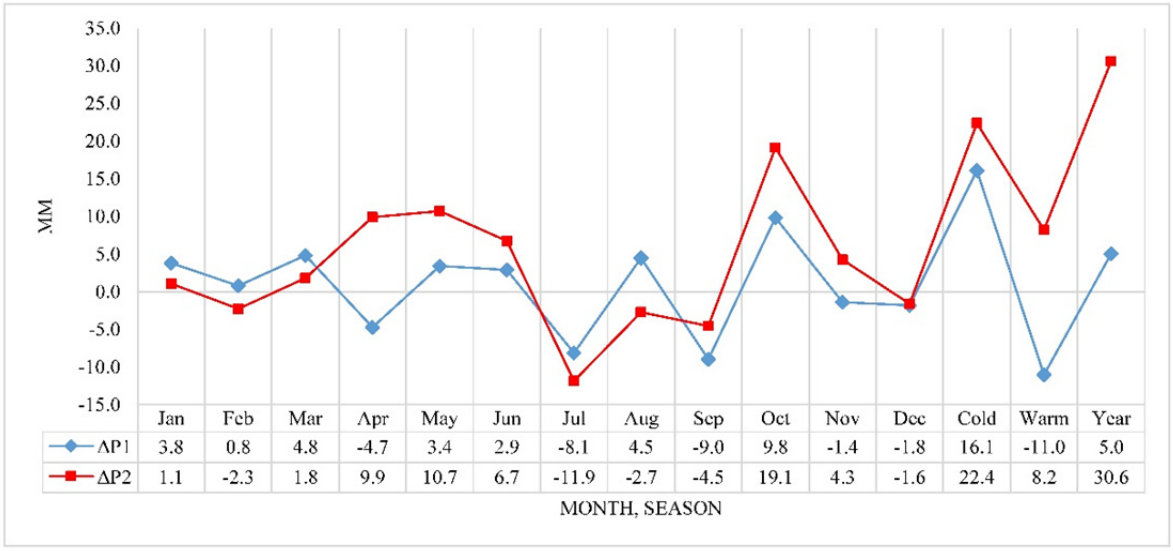
Table 1 presents data on the statistical characteristics of monthly, semi-annual and annual precipitation amounts in Tbilisi in 1844-2023. It also presents data on the significance level of the difference between the average precipitation amounts for two time periods: 1934-2023 and 1844-1933, as well as in 1994-2023 and 1844-1873 (Fig. 2).

Table 1. Statistical characteristics of monthly, annual and half-year sum of atmospheric precipitations in Tbilisi in 1844-2023.

Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Cold	Warm	Year
Min	0	0	0	5	0	3	0	0	0	0	0	0	47	131	240
Max	68	87	140	187	267	265	175	203	221	257	126	84	362	690	814
Average	16	21	31	52	82	73	48	40	44	42	32	21	162	338	500
St Dev	13	16	21	30	46	43	35	34	35	34	24	17	52	95	105
St Err	1.0	1.2	1.6	2.3	3.4	3.2	2.6	2.5	2.6	2.5	1.8	1.3	3.9	7.1	7.8
C_v,%	83	75	69	58	56	59	73	85	81	82	75	80	32	28	21
Low	12	16	24	42	67	59	36	28	32	30	24	16	145	307	466
Upp	20	26	38	62	97	87	59	51	55	53	39	27	179	369	535
Level of Significance of Difference: ΔP1 = P(1934-2023) – P(1844-1933)															
α(t)	0.05	No	0.12	No	No	No	0.12	No	0.09	0.05	No	No	0.04	No	No
Level of Significance of Difference: ΔP2 = P(1994-2023) – P(1844-1873)															
α(t)	No	No	No	No	No	No	0.15	No	No	0.08	No	No	0.10	No	No

In particular, as follows from Table 1, the monthly precipitation amounts in the studied period of time vary from 0 to 267. The average amounts – from 16 (January) to 82 (May). The smallest variations in monthly precipitation amounts are observed in May (56%), the largest – in August (85%).

The range of precipitation amounts in the cold half of the year is from 47 to 362, in the warm – from 131 to 690, according to annual data – from 240 to 814. On average, in the warm half of the year in Tbilisi there is approximately 2.09 times more precipitation than in the cold half of the year.

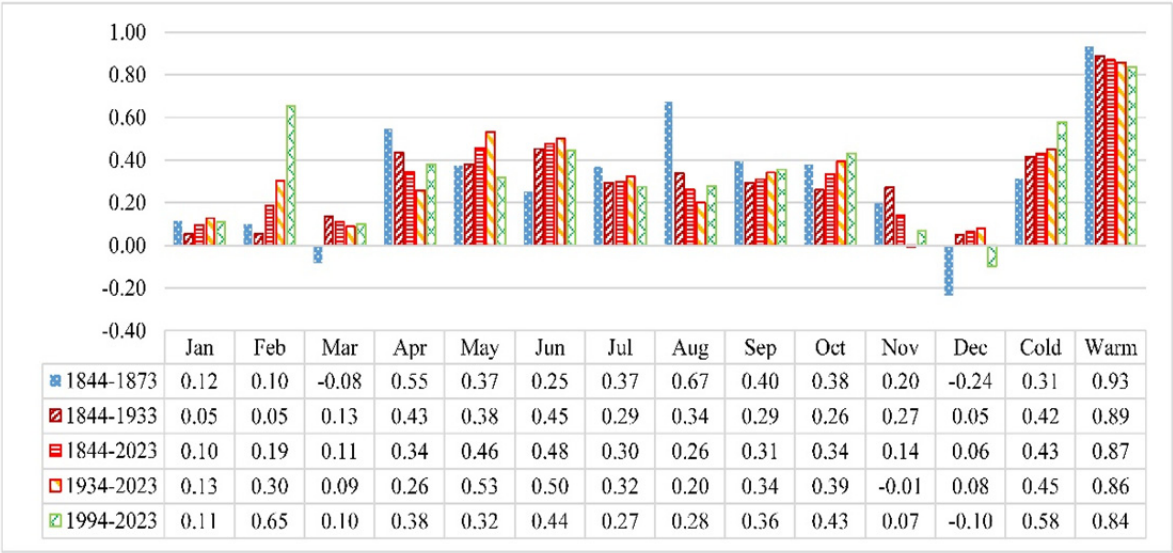


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Cold	Warm	Year
ΔP1	3.8	0.8	4.8	-4.7	3.4	2.9	-8.1	4.5	-9.0	9.8	-1.4	-1.8	16.1	-11.0	5.0
ΔP2	1.1	-2.3	1.8	9.9	10.7	6.7	-11.9	-2.7	-4.5	19.1	4.3	-1.6	22.4	8.2	30.6

Fig. 2. The difference between precipitation in Tbilisi in 1934-2023 and 1844-1933, as well as in 1994-2023 and 1844-1873.

Significant variability of the difference ΔP1 (Table 1, Fig. 2) is observed in January (increase by 3.8 mm), March (increase by 4.8 mm), July (decrease by 8.1 mm), September (decrease by 9.0 mm), October (increase by 9.8 mm) and in the cold half of the year (increase by 16.1 mm). Significant variability of the difference ΔP2 is observed in July (decrease by 11.9 mm), October (increase by 19.1 mm) and in the cold half of the year (increase by 22.4 mm).

In Fig. 3 data about coefficients of linear correlation between P_{year} and P_{cold}, P_{warm} and monthly sum of precipitation in different periods of time are presented. Note: R_{min} with $\alpha = 0.05$ for different periods of time are: 180 years – ± 0.14, 90 years – ± 0.21 and 30 years – ± 0.36.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Cold	Warm
1844-1873	0.12	0.10	-0.08	0.55	0.37	0.25	0.37	0.67	0.40	0.38	0.20	-0.24	0.31	0.93
1844-1933	0.05	0.05	0.13	0.43	0.38	0.45	0.29	0.34	0.29	0.26	0.27	0.05	0.42	0.89
1844-2023	0.10	0.19	0.11	0.34	0.46	0.48	0.30	0.26	0.31	0.34	0.14	0.06	0.43	0.87
1934-2023	0.13	0.30	0.09	0.26	0.53	0.50	0.32	0.20	0.34	0.39	-0.01	0.08	0.45	0.86
1994-2023	0.11	0.65	0.10	0.38	0.32	0.44	0.27	0.28	0.36	0.43	0.07	-0.10	0.58	0.84

Fig. 3. Linear correlation P_{year} with P_{cold}, P_{warm} and monthly sum of precipitation in different periods of time.

In particular, as follows from Fig. 3, the best correlation is observed for the pair $P_{year} - P_{warm}$ and varies from 0.84 (1994-2023, high correlation) to 0.93 (1844-1873, very high correlation). Moreover, in the last thirty-year period, compared to the first, the level of correlation weakens.

For the pair $P_{year} - P_{cold}$ in the last thirty-year period compared to the first, the level the correlation, on the contrary, grows: 0.31 (low correlation) and 0.58 (moderate correlation).

The best correlation for pairs P_{year} – P(Monthly) varies from 0.65 (1994-2023, pair $P_{year} - P_{Feb}$, moderate correlation) to 0.67 (1844-1873, pair $P_{year} - P_{Aug}$, moderate correlation also).

Finally, we note that, as the analysis of the correlation links between monthly precipitation amounts has shown, the best correlation is observed for the first and last thirty-year periods and varies from -0.52 (pair $P_{Jun} - P_{Sep}$, moderate correlation) to 0.44 (pair $P_{Apr} - P_{Oct}$, low correlation) and from -0.43 (pair $P_{Feb} - P_{Dec}$, low correlation) to 0.42 (pair $P_{Feb} - P_{Apr}$, low correlation also). For all other time intervals this correlation is negligible.

In general, the level of compatibility of the studied observation time series is quite weak.

Conclusion

In the future, it is planned to continue these studies, including forecasting changes of atmospheric precipitation in various regions of Georgia for several decades.

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