

CHANGES IN THE ATMOSPHERIC PRECIPITATION REGIME IN GEORGIA

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Abstract. This study examines long-term changes in the atmospheric precipitation regime in Georgia from 1960 to 2019 under the impact of temperature variations and global warming. Using daily data from 14 meteorological stations, precipitation was classified into four intensity categories: light, moderate, heavy, and very heavy. Changes were evaluated with both the difference method and dynamic norm, also probability distributions and normalized analyses were conducted to evaluate regional and temporal variations. Results indicate the reduction of light precipitation days and a slight increase in very heavy precipitation events, with average annual changes across Georgia about -0.0037 mm/year for light, $+0.0001$ mm/year for moderate, -0.0006 mm/year for heavy, and $+0.0063$ mm/year for very heavy precipitation. Regional analysis shows stronger impacts in high-precipitation areas, and polynomial approximations reveal cyclic patterns of precipitation changes. These findings demonstrate that global warming is altering precipitation regimes in Georgia, increasing the frequency of extreme events while reducing the duration of light rainfall, emphasizing the need for rational water management and climate adaptation strategies.

Keywords: Daily precipitation, Difference Method, Dynamic Norm Method

Introduction

Over the past century, the Earth's atmospheric energy potential has steadily increased, driving gradual changes in the climatic regime of near-surface air. The equilibrium of the so-called sublayer surface regime – established over millennia under the direct atmosphere influence – has been disrupted, causing variations across all climatic parameters. Consequently, the modern biosphere, long adapted to prevailing climate conditions, is experiencing gradual deterioration, bringing society closer to the adverse effects of climate change. Among the key climatic parameters, atmospheric precipitation is most critical.

The statistical structure of precipitation in Georgia has been studied for many decades and is relatively well understood [1–8]. However, recent changes related to global warming remain insufficiently investigated [9, 10]. This study aims to analyze the changes in the precipitation regime in Georgia under the influence of temperature field variations during 1960–2019. The period was purposefully selected: the initial phase exhibited cooling in western Georgia, despite the broader context of global warming, followed by pronounced warming in the latter half. Currently, temperature increases are more obvious in western Georgia than in eastern and southern regions.

Methodology

14 meteorological stations' daily precipitation data were compiled from 24 hourly measurements. Although more stations were operating during this period, incomplete or discontinuous records limited the study up to 14 stations with sufficiently reliable data.

Data quality was comprehensively assessed by decomposing the random function into natural orthogonal components. The study focused on the following: Duration of precipitation events; Frequency and variability across four intensity categories: light (<10 mm/day), moderate (10–40 mm/day), heavy (40–70 mm/day), and very heavy (>70 mm/day).

Changes in precipitation were assessed using: Difference Method: long-term data are divided into three equal subperiods; the difference between the third and first subperiod defines the change, excluding the middle period.

Dynamic Norm Method: applies linear approximation across all data points to estimate magnitude and direction of changes, converging to the mean under stable energy balance.

As the precipitation amount varies significantly across regions, normalized precipitation totals were calculated relative to the long-term mean (1960–2019) for each station and intensity group. This approach allows assessment of the direction and magnitude of changes rather than absolute amounts.

Results

Table 1 presents the mean annual precipitation totals across 14 stations, and their changes are calculated using both methods. Differences between methods are minor in trend direction, with discrepancies primarily in magnitude.

Table 1. Annual precipitation totals in Georgia and changes, 1960–2019

Observation Station	Elevation above Sea Level (km)	Mean Annual Precipitation (mm)	Change (mm/year)	
			Difference Method	Dynamic Norm
Poti	0.003	1963.1	+7.90	+6.21
Kobuleti	0.007	2404.4	+7.28	+6.53
Kutaisi	0.114	1389.4	+0.79	-0.28
Zugdidi	0.117	1832.2	+2.50	+0.85
Tbilisi	0.403	502.9	+0.71	+0.88
Bolnisi	0.534	513.8	-0.10	-0.20
Ambrolauri	0.544	1088.1	+2.96	+2.37
Telavi	0.568	760.4	-0.46	-0.58
Gori	0.588	513.9	-0.08	+0.06
Sagarejo	0.802	842.3	+4.58	+3.20
Akhaltzikhe	0.982	535.0	+0.18	+0.20
Pasanauri	1.070	980.4	+0.20	+0.21
Tianeti	1.099	750.1	-6.16	-5.81
Tsalka	1.457	679.1	-1.45	-1.34

The mean annual number of precipitation days was analyzed for two subperiods (1960–1989 and 1990–2019), considering intensity categories shown in Table 2.

Table 2. Changes in the number of precipitation days in Georgia, 1960–2019

Period	Annual number of precipitation days %	Annual number of precipitation days % of annual days			
		≤10 mm	10–40 mm	40–70 mm	≥70 mm
1960-1989	18.9	14.5	3.93	0.36	0.09
1990-2019	17.1	12.8	3.86	0.35	0.12

Global warming has led to a decrease in the duration of precipitation, mainly due to reduced low-intensity events. In contrast, the frequency of heavy and very heavy precipitation days increased slightly, highlighting the impact of energetic changes in the Earth–atmosphere system.

Probability distributions of precipitation days by different intensity classes were calculated using Gaussian functions. Figure 1 illustrates the probability changes between the two subperiods, showing a decline in light precipitation and a modest increase in very heavy precipitation events.

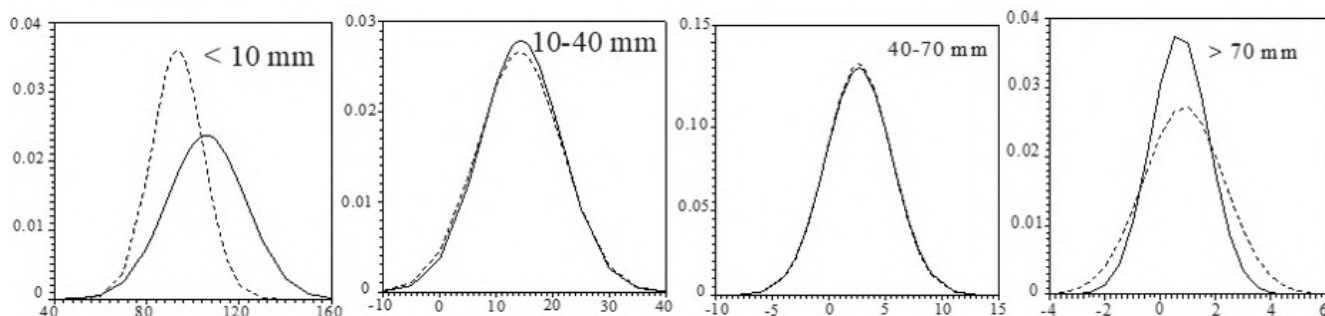


Fig. 1. Probability distribution of precipitation duration for 1960–1989 (solid curve) and 1990–2019 (dashed curve).

Normalized annual precipitation totals are shown in Fig 2. Sixth-order polynomial curves highlight cyclic variations in precipitation patterns across all intensity categories. Average annual changes (dynamic norm) were: light -0.0037 mm/year, moderate $+0.0001$ mm/year, heavy -0.0006 mm/year, and very heavy $+0.0063$ mm/year.

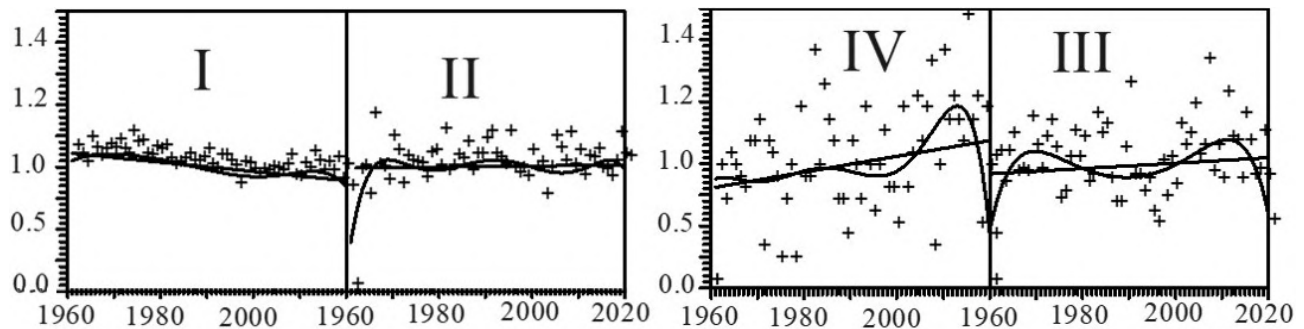


Fig. 2. Annual normalized precipitation totals in Georgia (+), dynamic norm (linear trend), and sixth-order polynomial approximation for light (I), moderate (II), heavy (III), and very heavy (IV) precipitation.

For probabilistic assessment of precipitation amounts, stations were grouped into four categories based on mean annual totals: Group 1: <600 mm (Gori, Tbilisi, Akhaltsikhe, Bolnisi), Group 2: $600\text{--}800$ mm (Telavi, Tsalka, Tianeti), Group 3: $800\text{--}1100$ mm (Ambrolauri, Sagarejo, Pasanauri), Group 4: >1100 mm (Kutaisi, Zugdidi, Poti, Kobuleti).

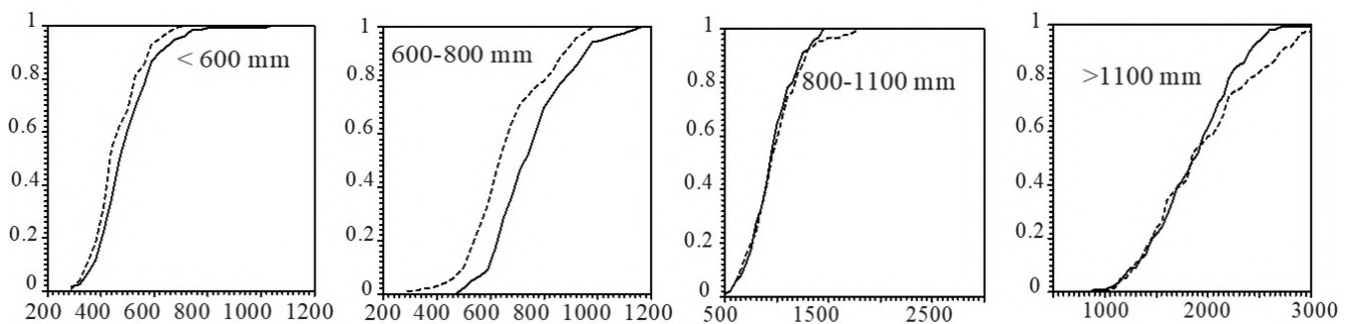


Fig. 3. Probability density distributions of annual precipitation total in Georgia for 1960–1989 (solid curve) and 1990–2019 (dashed curve), classified by annual totals.

Fig. 3 shows that Groups 1 and 2 experienced precipitation probabilities decline for all amounts, while Group 4 shows a clear shift toward higher totals.

Fig. 4 illustrates changes in the ratio of annual precipitation totals to the number of precipitation days. Linear (dynamic norm) and seventh-order polynomial approximations reveal a gradual increase of 0.027 mm per day, with cyclic variations visible in the polynomial representation.

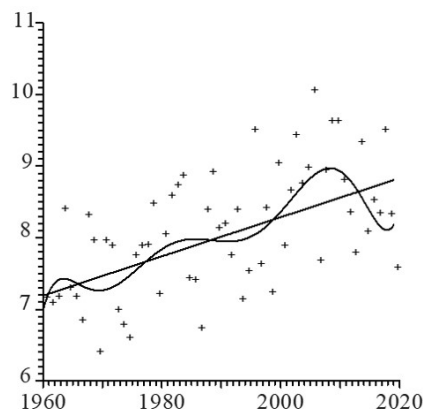


Fig. 4. Annual precipitation totals per precipitation day (+), linear (dynamic norm), and seventh-order polynomial approximation.

Conclusion

Global warming in Georgia has led to a decrease in the number of light precipitation days, whereas very heavy precipitation events have shown a slight increase. Average annual precipitation totals remain largely unchanged, in line with the physical constraint of near-constant total water content on Earth. Polynomial-based approximations highlight cyclic variations in precipitation patterns for all intensity classes. Regional analyses indicate that high-precipitation areas are most sensitive to global warming, revealing notable increases in heavy precipitation events. These results emphasize the importance of continuous monitoring of precipitation patterns to guide water resource management, agriculture, and climate adaptation strategies in Georgia.

References

1. Elizbarashvili E., Chavchanidze Z., Gvalvebi, Unaleko da Nalekiani Periodebi Sakartveloshi. // Mecniereba, 1992, p.119.
2. Gagua G., Mumladze D., Javakhishvili Sh. Klimati., Sakartvelos Geografia. // Nats.1, Mecniereba,Tb., 2000, pp. 91–103.
3. Elizbarashvili E., Papinashvili L., Atmosferuli Nalekebis Multanluri Gadmoyeneba Sakartvelos Teritoriaze. // Hidrometinstitutis Shromebi, #102, 2001 (112–116).
4. Tavartkiladze K., Sakartveloshi Nalekebis Ganasagrebis Statistikuri Struktura // Hidromet. in-tis shromebi, 105, Mecniereba, Tbilisi, 2002, pp. 117-137.
5. Kartvelishvili L., Ukleba M., Atmosferuli Nalekebis Ganatsilebis Taviseburebebi Sakartvelos Mtian Regionebsi. Vakhushti Bagrationis Geografiis Institutis Shromata Krebuli, 2(81), 2008, pp. 262-270.
6. Tavartkiladze K., Kikava A., Gvalvebisa da Gaudabnoebis Khelshemtsqobi Temperaturisa da Nalekebis Rezhimuli Struktura da Havis Tsvlilebis Gavlena Masze. Sakartvelos Soflis Meurn. // Metsn. Akad. Moambe, 28, 2010, pp. 309-317.
7. Tavartkiladze K., Kikava A., Ananidze M., Gvalvebisa da Gaudabnoebis Khelshemtskobi Nalekebis Uarkopiti Anomaliebi Sakartveloshi. Vakhushti Bagrationis Geografiis Institutis Shromata Krebuli, №6(85), 2014 pp. 128-133.
8. Tavartkiladze K., Havis Tsvlilebis Gavlenis Shesaxebs Atmosferuli Nalekebis Rezhimze. // Hidromet. In-tis Shromebi, 123, Mecniereba, Tbilisi, 2016, pp. 17-29.
9. Bolashvili N., Chikhladze V., Kartvelishvili L., Variability of Atmospheric Precipitation in Tbilisi 1844-2023, Proceedings of the International Conference “Complex geophysical monitoring in Georgia: History, Modern problems, Promoting Sustainable Development of the country”, TSU, Tbilisi, 2024, pp.150-154.
10. Tselashvili N. , Biggs T., Mu Y., Trapaidze V., Regional Precipitation Regimes and Evaluation of National Precipitation Datasets against Satellite-Based Precipitation Estimates, Republic of Georgia. // Journal of Hydrometeorology, American Meteorological Society, 2024. <https://doi.org/10.1175/JHM-D-23-0116.1>