

# ANALYSIS OF VARIABILITY OF MEAN ANNUAL AIR TEMPERATURE IN TBILISI IN 1844-2023 AGAINST THE BACKGROUND OF CLIMATE CHANGE

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**Abstract.** The article presents the results of the analysis of the variability of the mean annual air temperature in Tbilisi ( $T_{Tb}$ ) for 1844-2023 against the background of climate change. A comparison of the anomalies of the average annual air temperature in Tbilisi ( $\Delta T_{Tb}$ ) and in the zone of 24°-64° north latitude ( $\Delta T_Z$ ) in 1884-2023 is also made. The trends of the studied parameters are obtained ( $T_{Tb}$  and  $\Delta T_{Tb}$  are fourth-degree polynomials,  $\Delta T_Z$  is a seventh-degree polynomial). It is noted that in the studied locations there has been a significant increase in air temperature in the last decade.

**Key Words:** air temperature, climate change, statistical analysis.

## Introduction

The problem of climate change is well known in the world [1], including in Georgia [2], given the great diversity of climatic regions on its territory. In our latest studies, using various statistical methods, the variability of air temperature and its expected changes in the coming decades for some regions of Georgia (including Tbilisi) were studied [3-10].

This paper presents some results of the study of the variability of the average annual air temperature in Tbilisi against the background of global warming in 1844-2023, and also compares the anomalies of the average annual air temperature in Tbilisi and in the zone of 24°-64° north latitude in 1884-2023.

## Study area, material and methods

Study area – Tbilisi and zone of 24°-64° north latitude.

For the analysis, data of the National Environment Agency of Georgia [<http://www.pogodaiklimat.ru/>] and the NASA Goddard Institute for Space Studies [<https://data.giss.nasa.gov/gistemp/>] are used.

In the proposed work 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 [11, 12].

The following designations will be used below: Mean – average values; Min – minimal values; Max – maximal values; St Dev – standard deviation;  $R^2$  – coefficient of determination; R – coefficient of linear correlation;  $K_{DW}$  – Durbin-Watson statistic.

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.

Mean annual air temperature and its change rates (first derivative of the trend regression equation) in Tbilisi –  $T_{Tb}$  and  $T'_{Tb}$  respectively; anomalies of the average annual air temperature (deviations from the 1951-1980 means) in Tbilisi –  $\Delta T_{Tb}$  and in the zone of 24°-64° north latitude –  $\Delta T_Z$ ; average annual air temperature anomalies change rates in Tbilisi –  $\Delta T'_{Tb}$  and in zone (24°N-64°N) –  $\Delta T'_Z$ . Period of observations:  $T_{Tb}$  – 1844-2023 (180 years),  $\Delta T_{Tb}$  and  $\Delta T_Z$  – 1884-2023 (140 years).

The statistical programs Data Fit 7 and Excel 16 were used for calculations.

## Results

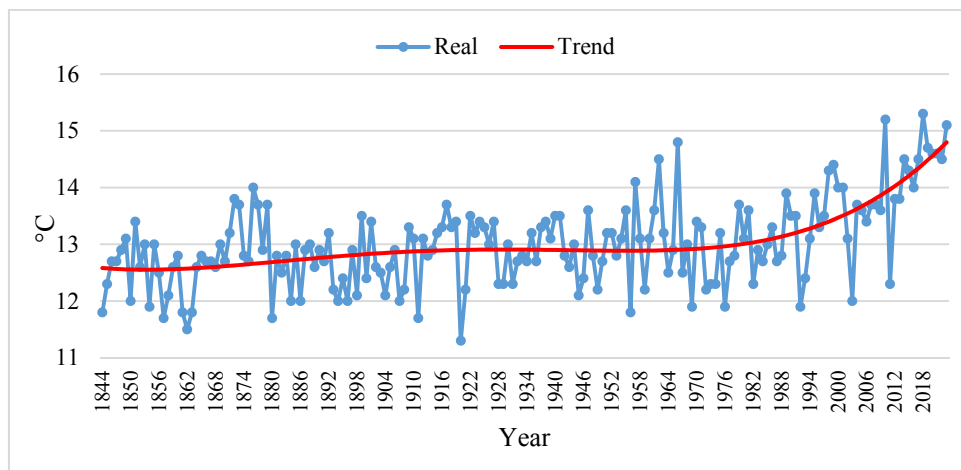
Results in Table 1-4 and Fig. 1-2 are presented.

**Table 1. Statistical characteristics of mean annual air temperature in Tbilisi in 1844-2023.**

**X – the number of years, 1...180**

Min	Max	Mean	St Dev	R <sup>2</sup>	K <sub>DW</sub>
11.3	15.3	13.0	0.76	0.38	1.82
Regression	$a \cdot X^4 + b \cdot X^3 + c \cdot X^2 + d \cdot X + e$				
Coefficient	a	b	c	d	e
Value	1.93E-08	-5.35E-06	0.00045	-0.00764	12.58688

In Table 1 statistical characteristics of mean annual air temperature in Tbilisi in 1844-2023 are presented. As follows from Table 1 value of  $T_{Tb}$  change from 11.3 °C to 15.3 °C with average value 13.0 °C. The air temperature trend in 1844-2023 has the form of a fourth-degree polynomial (Table 1, Fig. 1).



**Fig. 1. Trend of mean annual air temperature in Tbilisi in 1844-2023.**

In Table 2 data on ten-year average annual air temperature and its change rates in Tbilisi in 1844-2023 are presented. In particular, as follows from this Table, over the past thirty years, Tbilisi has seen a significant increase in the values of  $T_{Tb}$  and  $T'_{Tb}$ , with a maximum in 2014-2023 (14.6 °C and 0.73 °C/10 year respectively).

**Table 2. Ten-year average annual air temperature and its change rates in Tbilisi in 1844-2023.**

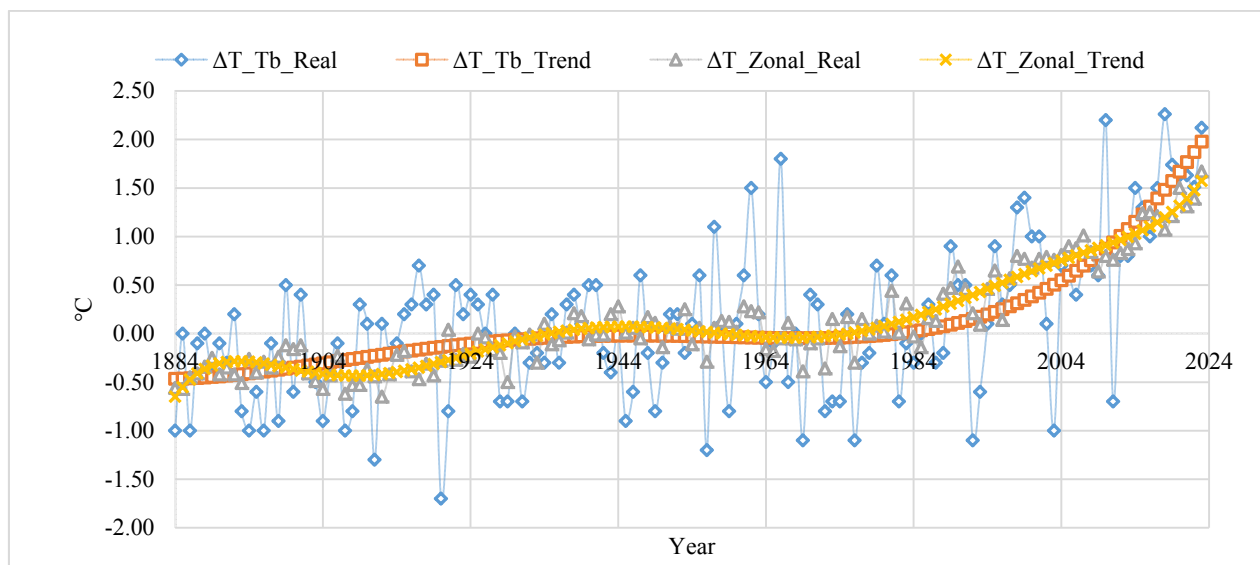
Years	$T_{Tb}$ , °C	$T'_{Tb}$ , °C/10 year	Years	$T_{Tb}$ , °C	$T'_{Tb}$ , °C/10 year
1844-1853	12.7	-0.03	1934-1943	13.1	-0.01
1854-1863	12.2	0.03	1944-1953	12.8	-0.01
1864-1873	13.0	0.06	1954-1963	13.2	0.01
1874-1883	13.0	0.07	1964-1973	12.9	0.05
1884-1893	12.7	0.07	1974-1983	12.9	0.11
1994-1903	12.6	0.06	1984-1993	13.0	0.21
1904-1913	12.6	0.04	1994-2003	13.6	0.34
1914-1923	13.0	0.02	2004-2013	13.7	0.51
1924-1933	12.9	0.00	2014-2023	14.6	0.73

Data on global air temperature changes have been available since 1880. Table 3, 4 and Fig. 2 show the results of a comparative analysis of the variability of air temperature anomalies and the rate of its changes in Tbilisi and in the zone 24°-64° of northern latitude in 1884-2023.

As follows from Table 3 value of  $\Delta T_{Tb}$  change from -1.7 °C to 2.26 °C with average value 0.09 °C, and value of  $\Delta T_z$  - from -0.65 °C to 1.67 °C with average value 0.11 °C. The air temperature anomalies trend in Tbilisi in 1884-2023 has the form of a fourth-degree polynomial, and in zone (24°N-64°N) – the form of a seven-degree polynomial (Table 3, Fig. 2).

**Table 3. Statistical characteristics of mean annual air temperature anomalies in Tbilisi and in zone (24°N-64°N) in 1884-2023. X – the number of years, 1...140.**

Location	Min	Max	Mean	St Dev	R <sup>2</sup>	K <sub>DW</sub>		
Tbilisi	-1.70	2.26	0.09	0.78	0.43	1.98		
24°N-64°N	-0.65	1.67	0.11	0.51	0.91	1.79		
Regression	$\Delta T_{Tb} = a \cdot X^4 + b \cdot X^3 + c \cdot X^2 + d \cdot X + e$							
Coefficient	a		b		c		d	e
Tbilisi	1.93E-08		-5.35E-06		0.00045		-0.00764	12.58688
Regression	$\Delta T_z = a \cdot X^7 + b \cdot X^6 + c \cdot X^5 + d \cdot X^4 + e \cdot X^3 + f \cdot X^2 + g \cdot X + h$							
Coefficient	a	b	c	d	e	f	g	h
24°N-64°N	8.99E-13	-4.60E-10	9.29E-08	-9.36E-06	0.000489	-0.01239	0.132029	-0.76999



**Fig. 2. Trend of mean annual air temperature anomalies in Tbilisi and in zone (24°N-64°N) in 1884-2023.**

**Table 4. Ten-year average annual air temperature and its change rates in Tbilisi and in zone (24°N-64°N) in 1884-2023.**

Years/Variable	$\Delta T_{Tb}, ^\circ\text{C}$	$\Delta T_z, ^\circ\text{C}$	$\Delta T'_{Tb}, ^\circ\text{C}/10 \text{ year}$	$\Delta T'_z, ^\circ\text{C}/10 \text{ year}$
1884-1893	-0.35	-0.43	0.05	0.42
1994-1903	-0.42	-0.28	0.10	-0.12
1904-1913	-0.42	-0.48	0.11	0.01
1914-1923	0.00	-0.27	0.09	0.18
1924-1933	-0.15	-0.16	0.06	0.20
1934-1943	0.08	0.04	0.02	0.09
1944-1953	-0.20	0.08	0.00	-0.04

1954-1963	0.23	0.07	-0.02	-0.07
1964-1973	-0.12	-0.11	0.00	0.02
1974-1983	-0.15	0.08	0.06	0.17
1984-1993	-0.03	0.25	0.17	0.29
1994-2003	0.56	0.64	0.34	0.30
2004-2013	0.68	0.83	0.59	0.27
2014-2023	1.62	1.28	0.92	0.61
R		0.94		0.72

Finally, in Table 4 data on ten-year average annual air temperature and its change rates in Tbilisi and in zone (24°N-64°N) in 1884-2023 are presented.

As follows from Table 4 and Fig. 2, the variability of  $\Delta T_{Tb}$  and  $\Delta T'_{Tb}$  during the studied period of time is in good agreement with the variability of  $\Delta T_Z$  and  $\Delta T'_Z$  respectively. Coefficient of linear correlation between  $\Delta T_{Tb}$  and  $\Delta T_Z$  is 0.94 (very high correlation), and between  $\Delta T'_{Tb}$  and  $\Delta T'_Z$  is 0.72 (high correlation). Maximum increase values of  $\Delta T_{Tb}$ ,  $\Delta T_Z$ ,  $\Delta T'_{Tb}$  and  $\Delta T'_Z$  in 2014-2023 are observed (Table 4).

## Conclusion

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

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