Dynamics of changes in surface air temperature in the North Caucasus

Kesheva Lara Asirovna
Candidate of Physical and Mathematical Sciences, Senior Researcher
High-Mountain Geophysical Institute
Teunova Nataliya Vyacheslavovna
Senior Researcher
High-Mountain Geophysical Institute

Annotation. Climate warming studies are attracting a lot of attention from researchers around the world. In recent years, warming has been noted both throughout Russia and in some of its regions. This article analyzes temperature changes in the North Caucasus region. The research was carried out on the basis of data from 16 weather stations in the region. Changes are considered both at individual w/stations and in the region as a whole.

It was found that in the region as a whole, since 1976, there has been an increase in the rate of growth of the average annual temperature to 0.41°C/10 years. The maximum growth rate is observed in the summer season, while since the mid-90s of the XX century, exceptionally positive anomalies of the average summer temperature have been observed.

The highest growth rate of average annual temperatures is observed in the foothill zone, followed by a plain zone, then a mountain zone. The high-mountain zone is distinguished by the stability of average annual temperatures, where the rate is 0.09°C/10 years.

Keywords: average annual temperatures, absolute maximum, absolute minimum, rate of change, weather stations, North Caucasian region.

Climate change is a factor that has a significant impact on atmospheric processes, on the natural and climatic characteristics of almost all regions of our planet and is the main cause of many extreme weather events. The problems of modern climate changes, especially the rapid ones in recent decades, are of increasing concern to the world community. They are constantly discussed in scientific publications, at international forums and in the media [1-3].

Climate change studies, as well as the determination of possible consequences, have long been scientific problems that attract a lot of attention of researchers around the world. Along with the general trend of increasing average temperatures, there is an increase in the amplitude of

short-term temperature fluctuations and the recurrence of anomalous phenomena associated with severe frosts and high positive temperatures, storm winds, snowfalls, heavy rains, etc. [4].

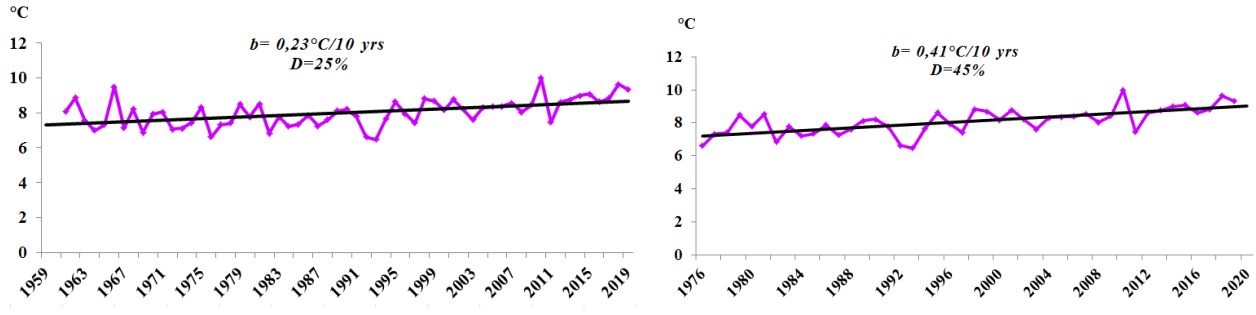
In recent years, warming has been noted both throughout Russia and in some of its regions.

This paper examines the change in the temperature regime on the territory of the North Caucasus region for the period 1961-2019. The North Caucasus is a region rich in diverse natural landscapes and climatic diversity in the south of the Russian Federation.

Based on the data from the series of climatic variables of the 16 weather stations (w/stations) studied, averaged series of average temperatures were obtained for the territory of the North Caucasus region.

Characteristics of linear trends for the full study period from 1961 to 2019 and from 1976 to 2019 are presented in terms of the slope *b* and characterize the rate of change of the investigated meteorological parameter (°C/10 years). Significance of the trend for the studied period 1961-2019 was determined by the value of the contribution to the explained variance (*D*,%). In the course of the study, the stability of climatic changes was assessed. An indicator of fractal properties of time series, the so-called Hurst exponent (*H*), was used as its integral characteristic [5,6].

According to our estimates, the warming trend in the territory of the North Caucasian region of Russia corresponds to the general direction of the global temperature change in the second half of the 20th century and the beginning of the XXI century. The growth rate of the average annual air temperature since 1961 was 0.23°C/10 years, since 1976 the growth rate of the average annual temperature increased to 0.41°C/10 years (Fig. 1 and Table 1). The value of the contribution to the explained variance increased from *D*=13% (1961-2019) to *D*=45% (1976-2019). The Hurst exponent *H*=0.91, obtained for the series of average annual temperatures in the period 1961-2019, demonstrates the high trend stability of the series.



a) 1961-2019 b) 1976-2019

Figure 1 – The rate of growth of the average annual air temperature in the North Caucasus.

Table 1 shows the seasonal characteristics of the average air temperature in the North Caucasus region.

Table 1. Characteristics of the dynamics of the average air temperature in the North Caucasus

Temperature, °C	Year	Winter	Spring	Summer	Autumn
Average temperature 1961-2019	8.0	-2.1	7.3	18.1	8.7
Climatic norm 1961-1990	7.7	-2.3	7.1	17.5	8.5
Standard deviation 1961-2019	0.8	1.5	1.0	1.0	1.0
Anomalies 1961-2019	0.3	0.3	0.3	**0.6**	0.2
Slope of the trend 1961-2019, *b*, °C/10 yrs. (*D*%)	0.23 (25%)	0.2 (4.7%)	0.2 (12%)	**0.38 (23%)**	0.15 (6.2%)
Slope of the trend 1976-2019, *b*, °C/10 yrs. (*D*%)	0.41 (45%)	0.36 (11.7%)	0.35 (21%)	**0.58 (53%)**	0.34 (16%)

On the time interval 1961-2019 there is an increase in the average air temperature in all seasons and the year as a whole. Table 1 show that the average winter temperature has increased since 1961 by 0.2°C/10 years, and since 1976 its growth rate has reached 0.36°C/10 years. The growth rate of the average spring air temperature increased from 0.2°C/10 years in the period 1961-2019, to 0.35°/10 years in the period 1976-2019. The rate of increase in air temperature in the summer season at these time intervals was 0.38°C/10 years and 0.58°C/10 years, respectively. The rate of increase in air temperature in the autumn season also increased significantly: from 0.15°C/10 years to 0.34°C/10 years for the corresponding periods.

Thus, the maximum value of the averaged anomalies in the considered time interval is observed at summer temperatures (0.58°C/10 years). Since the mid-90s of the 20th century, extremely positive summer temperature anomalies have been observed (Fig. 2).

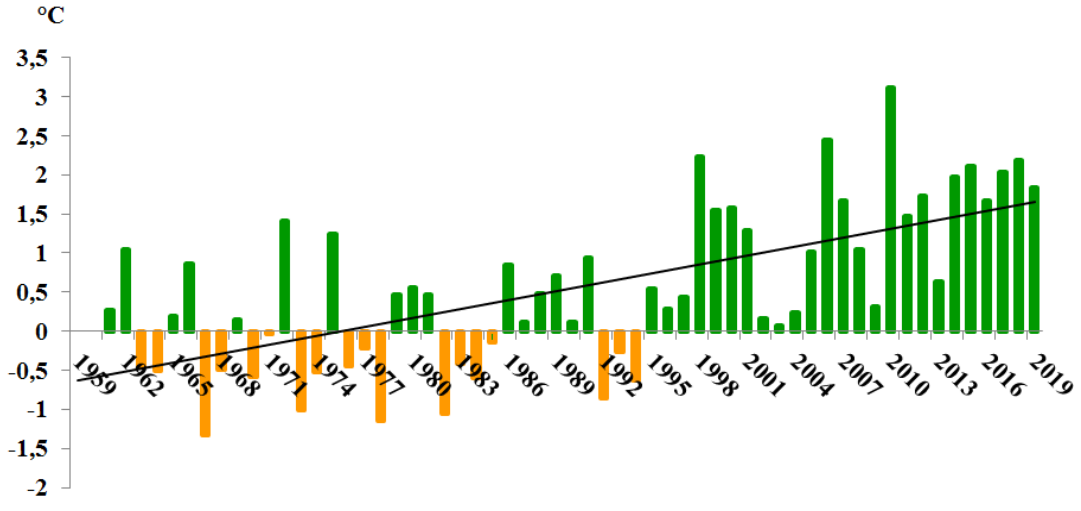


Figure 2 – Average-summer anomalies in the North Caucasus for the 1961-2019

It should be noted that the North Caucasus region is rich in various natural landscapes and climatic diversity. According to climatic conditions, the region is subdivided into plain (<500 m above sea level), foothill (from 500 to 1000 m above sea level), mountain (> 1000 m above sea level) and high mountain (> 2000 m above sea level) climatic zones.

The analysis of the temperature regime of different climatic zones of the region showed approximately the same (synchronous) changes in average annual temperatures. Apparently, this can be explained by the influence of one dominant factor, namely, the same large-scale atmospheric circulations.

The magnitude of the range of air temperature values obtained at meteorological stations of different climatic zones and the rate of their change are determined by the regional features of the air temperature regime. Table 2 shows that the average annual temperature is maximum in the plain zone, t_{av}=11.8°C and minimum in the high-mountain zone (Terskol), t_{av}=2.6°C.

Table 2. Average climatic parameters of the region 1961-2019

Weather stations	Average annual temperature,°C	Absolute maximum temperature, °C	Absolute minimum temperature, °C
Plain stations (<500 m a. s. l.)			
Izobil'nyi (Stavropol region)	11.0	36.2	-18.7
Mozdok (Republic of North Ossetia - Alania)	10.8	37.7	-20.9
Prokhladnaya (Kabardino-Balkaria)	10.6	37.0	-19.4
Derbent (Dagestan)	13.2	33.8	-8.4
Kizlyar (Dagestan)	12.1	36.4	-18.5
Makhachkala (Dagestan)	12.4	35.0	-14.3
Izberg (Dagestan)	12.5	32.6	-10.9
Foothill stations (500-1000 m a. s. l.)			
Stavropol (Stavropol region)	9.6	35.0	-19.5
Cherkessk (Karachay-Cherkessia)	9.4	34.1	-20.5
Kislovodsk (Stavropol region)	8.3	32.0	-18.4
Nalchik (Kabardino-Balkaria)	9.8	34.1	-18.9
Vladikavkaz (Republic of North Ossetia - Alania)	9.1	33.5	-19.0
Buinaksk (Dagestan)	10.5	35.9	-16.5
Mountain stations (1000-2000 m a. s. l.)			
Teberda (Karachay-Cherkessia)	6.9	34.7	-19.4
Akhty (Dagestan)	9.6	32.9	-15.9
Alpine station (>2000 m a. s. l.)			

Terskol (Kabardino-Balkaria)	2.6	23.9 (2006-2019)	-16.8 (2006-2019)

In the plain zone, the highest value of average annual temperatures was observed at w/station Derbent (Caspian) 13.2°C, and the minimum value of average annual temperatures at w/station Prokhladnaya was 10.6°C. The largest scatter of the absolute maximums and minimums of annual temperatures was noted at weather station Mozdok with values of 37.7°C and -20.9°C, respectively.

In the foothill zone, the highest value of the average temperature and absolute maximums for the entire study period from 1961 to 2019 took place at weather station Buinaksk 10.5°C and 35.9°C, respectively. The smallest values of the absolute minima for the period under study were observed at w/station Cherkessk -20.5°C.

In the mountainous zone, the maximum value of the average temperature was noted at w/station Akhty 9.6°C. The highest values from the absolute maximums and minimums at the Teberda w/station with values of 35.9°C and -19.4°C, respectively.

The alpine zone is represented only by the 1st meteorological station Terskol, where the average annual temperature is 2.6°C. Data on absolute maximums and minimums have been available only since 2006. During this period, the average value of the absolute maximum and minimum was 23.9°C and -16.8°C, respectively.

The average annual air temperature according to the data of the mountain station Akhty (1054 m above sea level, t_{av}=9.6°C) and the stations of the foothill zone are approximately the same. Apparently, this can be explained by the fact that the mountainous climate of Akhta is mitigated by the proximity of the Caspian Sea.

Further, Table 3 shows the characteristics of the temperature regime of the surface air and the rate of their change in the climatic zones of the North Caucasus region.

Table 3. Characteristics of the temperature regime of surface air in the climatic zones of the North Caucasus

Average annual temperature, 1961-2019	Plain zone	Foothill zone	Mountain zone	High-mountain zone
Average temperature, °C	11.8	9.5	8.3	2.6
Standard deviation, °C	0.9	**1.0**	0.8	0.7
Upper limit*	13.6	**11.4**	9.8	4.0
Bottom line*	10.0	**7.4**	6.6	1.2
Slope of the trend *b*, °C/10 yrs. (*D*,%)	**0.27** (27%)	**0.32** (33%)	0.25 (27%)	0.09 (4.8%)

* Upper (lower) limit of average temperature (t_{av} ± 2 sigma) at 95% confidence interval

In all climatic zones of the region, with the exception of the high mountain (Terskol), for the period 1961-2019 an increase in the average annual air temperature was observed: in the plain zone by 0.27°C/10 years, in the foothill zone by 0.32°C/10 years, in the mountain zone by 0.25°C/10 years, in the high-mountain zone (Terskol) 0.09°C/10 years.

Table 3 shows the upper and lower boundaries of the intervals of the mean annual air temperature; at a 95% significance level, its values are in the range of ± 2σ. The lower and upper boundaries of the ranges of the confidence intervals of the average annual temperature according to the data of the plain, foothill and mountain weather stations intersect. The average annual temperature in Terskol is significantly lower than the rest (2.6°C, taking into account the interannual variability from 1.2°C to 4.0°C), which is explained by the altitudinal zonality. This station is also distinguished by the stability of changes in the annual temperature (0.09°C/10 years).

References

1. Report on the peculiarities of the climate in the territory of the Russian Federation for 2020. Roshydromet. Moscow, 2021. - 97 p.

2. Budyko M.I., Efimova N.A., Strokina L.A. Empirical estimates of climate change by the end of the 20th century // Meteorology and Hydrology. - 1999. - No. 12. - Pp.5-12.

3. Ashabokov B.A., Tashilova A.A., Kesheva L.A., Teunova N.V., Taubekova Z.A. Climatic changes in mean values and extremes of near-surface air temperature in the south of the European territory of Russia. Fundamental and Applied Climatology. No. 1, 2017. - Pp. 5-19.

4. Akimov V.A., Vladimirov V.A., Izmalkov V.I. Catastrophes and safety. - M .: Business Express, 2006. - 392 p.

5. Hurst H.E., Black R.P., Simaika Y.M. 1965, Long-termstorage: An experimental study. L.: Constable, 1965. -145 p.

6. Mandelbrot B. Fractal geometry of nature. - Moscow: Institute for Computer Research, 2002 .- 656 p.