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THE CHANGES OF THE AİR TEMPERATURE CHARACTERİSTİCS İN THE AZERBAİJAN TERRİTORY DURING GLOBAL CLİMATE CHANGES PERIOD

(Представлено членом редакційної колегії д-ром геол. наук, ст. наук. співроб. О. Л. Шевченком)

Background. *Air temperature observation data covering the years 1981–2022 of about 70 hydrometeorological stations operating in the territory of the Republic of Azerbaijan were used in the study. In order to determine the influence of climate changes on the air temperature regime, the results of 1981–2010 were compared with the corresponding results of 2011–2022.*

Methods. *In the study, the trend of monthly, seasonal and multiannual changes in air temperature was considered using mathematical, statistical and cartographic methods.*

Results. *Studies show that the air temperature has increased by 0.9^{0}C at the country level. The positive anomaly has been reached to 1.3° C at the belt with an altitude of 2001–2500 m. The main high indicators were noted in highland regions. The temperature anomaly is in the range of 1.5–1.7° C, mostly in May and June months. Long-term temperature dynamics show that in 2001–2010 the temperature increase (0.057° C / 1 year) is observed. It was the warmest time during 1961–2022 comparing with previous decade.*

The results of the study can be used in the protection against climate changes, mitigation and studying the modern temperature regime. In addition, solar radiation can be used as an alternative energy source in flat areas where high air temperature indicators are observed. The results will be announced at the conference on climate change COP 29 (Conferences of the Parties), which will be held in Baku on November 11–22, 2024.

Conclusions. *The influence of climate changes in the air temperature regime in the territory of Azerbaijan will lead to the disruption of the traditional climate regime, the disappearance of the green landscape and expansion of semi-desert and arid landscape in the front mountainous areas, the increase of possible evaporation and the increasing of environmental crises such as drought at the 1000 m elevations. An increase in the radiation balance in Nakhchivan province may worsen the continentality of the climate type here. The increase in temperature in the Kura depression province will create conditions for the expansion of the semi-desert-arid climate in the piedmonts of the Greater Caucasus Mountains.*

Keywords: *mathematical, statistical and cartographic methods, temperature indicators, greenhouse effect, flat areas, alternative energy source, climate norm, altitude zone, ArcGIS.*

Background

The Earth has undergone climate changes several times during the geological eras in which it was formed. Such processes have been observed with millennia of "warming" and "glaciation" (Mahmudov, 2022; Richard et al., 2013). Long-term changes were formed as a result of natural factors. However, during the last 200–250 years, the Earth's temperature has been continuously increasing, and this process continues rapidly, although it sometimes slows down (Huseynov, 2020). Since 1860, when hydrometeorological measurements were made, the global temperature has increased by 1.5–2.0° C (Rzaeva, Tagiyev, & Zeynalova, 2022; Rzaeva, Guseynov, and Tagiyev, 2023). Researchers consider that modern climate changes are caused by anthropogenic influences (Huseynov, 2022; Thomas, Rachael, & Cameron, 2020).

According to a continuous temperature analysis by NASA's of Goddard Institute for Space Studies (GISS), the average global temperature on Earth has increased by at least 1.1° C since 1880. Most of the global 'warming' has occurred in recent times, amounting to about 0.15–0.20° C per decade since 1975 (Goddard Institute for Space Studies, 2023).

In the middle of the 20th century, the temperature was in a stable phase with small amplitudes, which can be explained by natural variability and the cooling effect of aerosols created by factories, electric plants and motor vehicles during the years of rapid economic growth after World War II. After the war, the increase in fossil fuel use (5 % per year) increased the amount of greenhouse gases in the atmosphere, which in turn formed the greenhouse effect. Rapid cooling occurred due to aerosol pollution of the atmosphere. Unlike aerosols, greenhouse gases accumulate in the atmosphere more slowly, but they remain there for a longer time (Ahmadov, 2023).

According to the Special Science Report on Climate Change of US for 2017, if annual emissions continue to rise as fast as they have done since 2000, models predicted that global temperatures will be at least 1.2°C higher than the average indicators of 1901–1960 at the end of this century, as well as 2.5°C is predicted. If average annual emissions increase more slowly and begin to decrease significantly by 2050, model-predicted temperatures will still be at least 0.6^{0}C and possibly as much as 1.4°C warmer than the first half of the 20th century (Mammadov, 2015; Fel, 2023).

Observations show that the last 10 years from the beginning of these measurements until today are the years when the highest air temperature indicators were recorded. In particular, the air temperature indicators of 2016–2023 broke all historical records (Goddard Institute for Space Studies, 2023).

One of the regions most affected by climate change is the South Caucasus region located in Azerbaijan. İn recent times, the reduction of glacier areas, floods, floodings, lightning, hail, torrential rains, changes in the level of the Caspian Sea, and other dangerous natural manifestations are developed (Abdullayev, & Rzayev, 2023; Kazimova, 2015).

Before that, R. Mahmudov, F. Imanov, N. Huseynov, A. Mammadov, S. Safarov, U. Taghiyeva, H. Nabiyev, C. Huseynov, and other scientists have conducted various studies related to climate changes in the country. The

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studies of the researchers show that air temperature increases in the range of 0.7–1.0° C and atmospheric precipitation decreases in the range of 26–31 mm (7 %) (Huseynov, & Ismayilova, 2023; Mahmudov, 2022; Huseynov, 2022). The constant change of meteorological elements in the territory of Azerbaijan, the increase of time series necessitates the constant study of climate changes.

Methods

The study is based on the temperature observation data of 68 continuously operating hydrometeorological stations of the National Hydrometeorological Service covering the years 1981–2022. In addition, periodical publications, electronic resources and satellite data were also referred to in the study (Annual meteorological station data, 2020). Since there is no data about the southern and eastern part of the Lesser Caucasus region, satellite data was used. Mathematical, statistical and cartographic methods were used in the study. With these methods, the mathematical expectation of the ranks, the statistical significance was checked, and the regularities of the distribution on the earth's surface were investigated. As record indicators have been observed since the last 10 years of temperature measurements until today, a comparative analysis of the air temperature indicators of 1981–2010 and 2011–2022, recommended by the General World Meteorological Organization as the last norm, was carried out.

Purpose of work. The purpose of the study is to determine the influence of global climate changes on the air temperature regime in the territory of the Republic of Azerbaijan in 2011–2022, comparing with the climate norm (1981–2010). For this, time-space variations of air temperature were investigated. In order to detect any regularity in the obtained results, the distribution of air temperature indicators on the earth's surface was mapped using cartographic methods for both periods (1981–2010, 2011–2022).

Results

As the territory of the country has a complex relief, it is impossible to conduct complex research. Therefore, regions with similar physical-geographical and climatic characteristics should be studied individually. Also, global circulations constantly show the effects of climate changes in the synoptic conditions of the country located in complex conditions (State Land and Mapping Committee, 2014; Mammadov, 2015).

Our research shows that, compared to 1961 & 1990, during 2013–2022, the area of large glaciers in Azerbaijan decreased by 25 % in Tufandag, 21.3 % in Bazarduzu, and 15.7 % in Shahdag. In all glaciers, the ice line retreated 95–100 m in just 6 years (2016–2022). In the rivers fed by snow and glacier waters in the Greater and Lesser Caucasus, as a result of rapid melting in the spring months (end of March-April), the volume of water in the rivers increases leading to waterflood sharply, and this is accompanied by landsides and the periodic recurrence of floods. As a result, in river basins such as Gobustan-Absheron, water consumption decreases sharply in summer months, and the drought extends for a long time.

The negative impact of climate change on water resources is manifested in both quantitative and qualitative parameters. Thus, a sharp increase in the degree of water mineralization is observed in the lower reaches of the rivers in the mountainous areas of Azerbaijan. The level of underground water decreases, piezometric pressure in geological wells and water consumption decrease sharply. The quality of groundwater, especially the degree of mineralization, increases, and this, in turn, negatively affects the quality indicators of pressurized water.

Conducted analysis shows that in 2011–2022, depending on the regions in Azerbaijan, the air temperature varies in the range of –1–6° C in January, 0–6° C in February, and 3–9° C in March (Tab. 1). During these months, the minimum average monthly temperature was observed in the north-east of the Greater Caucasus region and Nakhchivan province, and the maximum average monthly temperature was observed in the Absheron water area and Kura depression (Huseynov, & Ismailova, 2023) located within the Gobustan-Absheron region of the Greater Caucasus province. In spring, the air temperature increases, in April it is in the range of 9–14° C, in May it is 14–21° C, in June it is in the range of 19–26° C. In these months, the minimum average monthly temperature is observed in the northeastern piedmonts of the Greater and Lesser Caucasus mountains. Air temperature reaches its maximum in July (21–28° C) and August (20–28° C). In these months, the maximum values are recorded in the Absheron water area (27° C) and Kura depression (28° C).

Starting from September (16–23° C), the temperature decreases in all provinces. Air temperature is 10–17° C in October, 4–11° C in November and 1–8° C in December.

Table 1

Indicators of air temperature in physical-geographic provinces and regions in different periods

Periods	Province	Months												y.
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1981–2010	Absheron water area	5.1	4.8	6.9	11.5	17.0	22.5	25.7	26.1	22.2	16.9	11.3	7.0	14.8
	northeastern of Greater Caucasus	–1.7	–1.2	2.1	7.6	12.1	16.6	19.2	19.0	14.8	9.8	4.2	0.4	8.6
	South, southeast of Greater Caucasus	0.3	1.0	4.6	10.3	15.0	20.0	23.0	22.6	18.0	12.2	6.4	2.2	11.3
	Kura depression	3.5	4.6	8.1	13.7	19.1	24.4	27.1	26.7	22.2	16.2	9.7	5.0	15.0
	northeastern of Lesser Caucasus	0.2	0.7	4.3	9.9	14.1	18.6	21.4	21.3	17.1	11.6	6.2	2.0	10.6
	south and east of Lesser Caucasus	0.2	1.1	5.1	11.2	16.1	21.1	23.8	23.3	18.9	12.8	6.4	1.9	11.8
	Nakhchivan	–3.0	–0.2	5.5	11.9	16.5	21.8	25.3	25.2	20.6	13.7	6.4	–0.1	12.0
	Lankaran	2.8	3.0	6.0	11.3	16.8	20.7	24.6	22.9	20.3	14.0	8.7	4.6	12.7
2011–2022	Absheron water area	5.8	5.6	7.7	12.1	18.6	24.1	26.8	27.0	23.1	17.2	11.2	7.5	15.6
	northeastern of Greater Caucasus	–0.5	0.0	3.1	8.6	14.1	18.6	20.5	20.1	15.6	10.2	4.3	1.0	9.6
	South, southeast of Greater Caucasus	1.6	2.3	5.7	11.0	16.9	22.0	24.2	24.0	19.0	12.6	6.6	2.9	12.4
	Kura depression	4.3	5.6	9.0	14.3	20.7	26.0	28.0	27.5	23.0	16.4	9.8	5.4	15.8
	northeastern of Lesser Caucasus	1.6	2.0	5.8	10.8	16.0	20.6	22.9	22.5	18.0	11.8	6.2	2.3	11.7
	south and east of Lesser Caucasus	0.9	1.9	6.1	11.4	17.7	22.3	24.5	23.6	19.2	12.6	6.0	2.2	12.4
	Nakhchivan	–1.2	1.8	7.0	12.8	17.8	23.5	26.6	26.3	22.1	14.4	6.7	1.0	13.2
	Lankaran	3.8	4.0	7.1	11.7	17.2	22.1	24.1	23.7	19.8	14.1	8.4	4.8	13.4

The average annual air temperature indicators in the country is 13° C, 15.6° C in the Absheron water area of the Greater Caucasus region, 9.6° C in the northeastern regions of the Greater Caucasus province, 12.4° C in the south and southeast of the Greater Caucasus province, 15.8° C in the Kura depression province, 15.8° C in the northeast of the Lesser Caucasus province. It is 11.7° C, 12.4° C in the south and east of Lesser Caucasus province, 13.2° C in Nakhchivan province, 13.4° C in Lankaran province. Seasonal indicators are different in 2011–2022 in the territory of Azerbaijan (Fig. 1). Thus, in winter, which is the coldest season, the air temperature is lower in the northeastern part of the Greater Caucasus province.

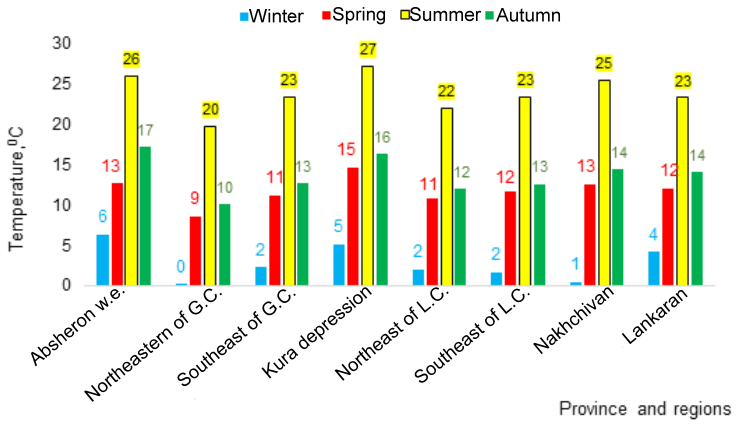

Fig. 1. Seasonal indicators of air temperature in physical-geographic provinces and regions

In this season, high temperature indicators are in the range of 5–6°C in the Kura depression province and Absheron water area. In spring, air temperature is higher in Kura depression and Nakhchivan province, Absheron physical-geographic region (13–15° C). In the summer season, higher temperature indicators are 25–27° C, in Absheron water area, Kura depression (Huseynov, Hajiyev, Huseynov, 2023) and Nakhchivan province. This temperature indicator in autumn is about 14–17° C along the country, except of the northeastern regions of the Greater Caucasus (10° C) and Lesser Caucasus (13° C). In autumn, lower temperature indicators in the north-east of the Greater Caucasus and in the Lesser Caucasus provinces are observed. The average air temperature in the country is 2–3° C in winter, 11–12° C in spring, 23–24° C in summer, and 13–14° C in autumn.

The study also paid attention to changes in air temperature in 2011–2022 compared to 1981–2010 (Fig. 2). Fluctuations in different months in the country show that the increasing air temperature in January (1.1° C), February (1.2° C), March (1.1° C), May (1.5° C), June (1.7° C), July (0.9° C) and August (0.9° C) is observed and is in the range of 0.9–1.5° C.

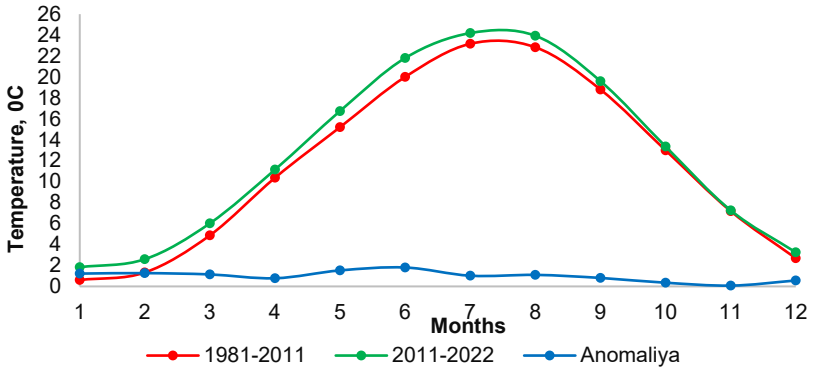

Fig. 2. Air temperature trend in Azerbaijan territory

In April and in September 0.7° C is noted, in October (0.3° C) and December (0.5° C) although less than 0.7° C, so there is no change in November (0.0° C). The increase in air temperature was higher in June (1.7° C). In these years, the 0.9° C increase in air temperature along the country is observed.

Seasonal anomalies show that the temperature increase was 0.9° C (0.6–1.6° C) in winter, 1.1° C (0.9–1.4° C) in spring, 1.2° C (0.8–1.5° C) in summer and 0.4° C (–0.1–0.4° C) in autumn. In winter, higher indicators were recorded in Nakhchivan (1.6° C), lower ones in the south and east of the Lesser Caucasus, Absheron water area (0.5–0.6° C). In spring, the maximum limits of the anomaly were in the north-eastern regions of the Greater and Lesser Caucasus provinces (1.4° C), and the minimum indicators were in the south, east and Lankaran of the Lesser Caucasus (0.9° C). The temperature increase in the summer was 1.0–1.5° C in all regions, except of the south and east of the Lesser Caucasus (0.8° C). In autumn, the air temperature in the south and east of the Lesser Caucasus was slightly less than the climatic norm (0.1° C). The maximum increase in Nakhchivan province is observed up to 0.9° C. Higher temperature indicators the whole year were repeated in the highlands of the Greater Caucasus province, the north-east of the Lesser Caucasus and Nakhchivan.

Air temperature anomalies in individual stations in the 2011–2022 years compared to the climate norm (1981–2010) are given in the table (Tab. 2). If we pay attention to the table, it is possible to see that the air temperature has

increased in May and June at all stations during the last 11 years. The maximum indicators of these increases are 2–3° C in Kiriz, Khinalig, Guba, Gabala, Sheki, Oguz, Zagatala, Mingachevir, Hadrut, Agstafa, Ganja, Paragachay stations. The analysis shows that higher temperature increases were observed in the low and mid-mountain zone.

Table 2

The temperature fluctuations in the hydrometrological stations (2011–2022)

№	Stations	Months												y.
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1	Kiriz	1.2	1.3	0.9	0.9	1.9	2.4	0.9	0.9	0.2	0.0	–0.4	0.5	0.9
2	Khinalig	1.9	1.3	1.6	1.6	3.1	2.8	2.1	1.6	1.3	0.9	0.6	0.4	1.6
3	Altiagach	1.4	1.0	0.7	0.8	1.7	1.5	0.8	1.4	1.1	0.2	0.1	0.5	0.9
4	Khaltan	0.6	1.5	1.0	1.1	2.1	1.4	1.3	0.4	0.6	0.1	0.0	0.3	0.9
5	Guba	1.0	1.0	1.1	1.0	2.3	2.1	1.2	1.5	0.7	0.4	0.1	0.8	1.1
6	Khachmaz	0.9	1.0	1.0	0.5	1.4	1.5	1.5	0.9	1.2	0.4	0.1	1.0	0.9
7	Mashtaga	0.7	0.9	0.9	0.5	1.6	1.7	1.2	0.7	1.0	0.5	0.1	0.7	0.9
8	Baku	0.7	1.0	1.0	0.7	1.7	1.7	1.1	1.1	0.9	0.2	–0.2	0.7	0.9
9	Chilov	0.7	0.6	0.6	0.5	1.4	1.5	0.9	0.8	0.5	0.2	0.0	0.3	0.7
10	Neft Dashlari	1.1	0.8	0.9	0.8	1.5	2.2	1.4	1.3	1.1	0.5	0.8	0.6	1.1
11	Sumqayit	0.8	0.9	0.7	0.9	1.6	1.5	1.2	1.0	0.9	0.6	0.0	0.8	0.9
12	Pirallahi	0.7	0.7	0.7	0.8	1.8	1.7	1.3	1.1	1.1	0.3	–0.2	0.5	0.9
13	Alibey	1.5	2.1	1.9	1.0	2.1	1.8	1.5	1.3	0.8	0.7	0.7	1.1	1.1
14	Gobustan	1.1	1.3	0.8	0.7	1.8	2.1	1.1	0.9	0.9	0.4	0.5	0.2	1.0
15	Shamakhi	1.2	0.8	0.5	0.4	1.5	1.6	0.7	1.2	0.5	0.3	–0.5	0.6	0.7
16	Gabala	1.5	1.4	1.1	1.1	2.2	2.2	1.5	1.9	1.4	0.7	0.3	1.0	1.4
17	Sheki	1.1	1.3	1.0	0.9	2.0	2.2	1.3	1.6	1.2	0.4	0.1	0.2	1.1
18	Oguz	1.5	1.4	1.4	1.0	2.0	2.5	1.7	2.0	1.5	0.6	0.5	0.9	1.4
19	Ismayilli	0.9	1.0	0.8	0.2	1.4	1.3	0.8	0.3	0.6	0.1	–0.3	0.9	0.7
20	Zagatala	1.1	1.4	1.1	0.8	2.1	2.3	1.3	1.8	1.2	0.3	0.5	0.6	1.2
21	Ceyrançöl	0.5	0.6	0.8	0.0	1.3	2.3	0.7	1.3	1.0	–0.1	0.2	–0.2	0.7
22	Tərtər	0.8	0.3	0.6	0.8	1.6	1.6	0.8	0.3	0.7	–0.4	0.0	–0.3	0.6
23	Goychay	0.8	0.9	1.0	0.5	1.7	1.6	0.9	0.9	0.9	0.3	0.1	0.4	0.8
24	Mingachevir	1.1	1.5	1.3	0.9	2.2	2.2	1.3	0.8	1.2	0.6	0.0	0.5	1.1
25	Bilasuvar	1.0	1.5	1.1	0.7	2.1	1.8	1.1	1.1	1.2	0.6	0.4	0.9	1.1
26	Barda	0.8	0.9	0.7	0.8	1.5	1.4	0.6	0.5	0.4	0.1	0.0	0.3	0.7
27	Beylagan	1.1	1.9	1.2	0.8	1.8	1.8	1.3	1.0	0.8	0.9	0.3	1.0	1.2
28	Yevlakh	0.5	1.0	0.9	0.4	1.6	1.7	0.7	0.7	0.8	0.3	0.1	0.1	0.7
29	Kurdamir	0.5	0.7	0.4	0.3	1.3	0.9	0.6	0.6	0.6	–0.2	–0.3	0.3	0.5
30	İmishli	0.9	1.1	1.0	0.7	1.6	1.4	0.9	0.8	0.8	0.0	0.1	0.6	0.8
31	Zardab	0.6	1.0	0.7	0.3	1.2	1.2	0.7	0.6	0.5	0.3	–0.4	0.4	0.6
32	Hacigabul	0.8	1.0	0.8	0.5	1.9	1.8	1.1	1.0	0.9	0.3	0.1	1.0	0.9
33	Jafarkhan	0.5	1.0	0.7	0.4	1.5	1.4	0.7	0.6	1.0	0.0	0.1	0.9	0.7
34	Salyan	0.7	1.1	0.7	0.7	1.8	1.5	1.1	0.8	0.5	0.3	0.1	0.8	0.9
35	Neftchala	0.9	1.1	0.8	0.7	1.7	1.7	1.3	0.9	0.8	0.2	0.0	0.7	0.9
36	Dashkasan	0.9	1.5	1.1	0.7	1.8	2.1	1.4	1.4	1.5	0.5	–0.3	0.8	1.1
37	Goygol	3.0	2.0	3.3	1.4	2.1	1.6	1.8	1.7	0.9	–0.8	–0.7	–0.2	1.3
38	Gadabay	1.4	1.3	0.9	0.5	1.4	1.5	0.8	0.7	0.8	0.3	0.1	0.2	0.8
39	Shamkir	0.8	0.8	1.2	0.6	1.7	1.8	1.3	0.9	0.9	0.2	0.1	–0.3	0.8
40	Agstafa	1.4	0.9	1.3	1.4	2.0	2.9	2.2	1.1	0.8	0.6	0.7	0.8	1.3
41	Ganja	1.1	1.2	1.1	0.8	2.0	2.1	1.3	1.0	0.6	0.0	0.3	0.4	1.0
42	İstisu	0.7	–0.3	0.3	0.6	1.0	0.9	0.1	0.2	0.4	–0.4	–0.8	–0.3	0.2
43	Shusha	0.8	–0.6	0.6	0.4	1.4	1.0	0.6	0.5	0.6	–0.2	–0.6	–0.5	0.3
44	Lachin	0.7	–0.7	0.2	0.5	1.2	0.9	0.2	0.2	0.3	–0.6	–1.2	–0.6	0.1
45	Khankendi	0.6	–0.7	0.5	0.4	1.4	1.1	0.6	0.6	0.6	–0.3	–0.7	–0.5	0.3
46	Hadrut	1.1	0.5	0.9	2.0	2.0	0.2	–0.4	–0.9	–0.2	–0.9	–0.3	0.6	0.4
47	Jabrayil	0.7	–0.7	0.5	0.4	1.6	1.0	0.5	0.5	0.6	–0.3	–0.7	–0.5	0.3
48	Asgaran	0.8	–0.7	–0.5	0.3	1.7	1.2	–0.1	0.4	0.8	–0.3	–0.4	–0.4	0.2
49	Fuzuli	0.5	–0.8	0.5	0.4	1.4	1.1	0.4	0.4	0.5	–0.3	–0.7	–0.4	0.2
50	Agdara	1.7	–0.1	–0.6	0.9	1.9	0.5	–0.5	0.1	0.3	–0.4	–0.4	0.1	0.3
51	Adam	0.5	–0.6	0.4	0.3	1.4	1.0	0.5	0.4	0.5	–0.3	–0.7	–0.5	0.2
52	Khojavand	0.7	–0.7	0.5	0.4	1.4	1.1	0.5	0.4	0.5	–0.2	–0.4	–0.3	0.3
53	Minjivan	0.7	–0.7	0.6	0.3	1.3	1.0	0.4	0.3	0.4	–0.2	–0.6	–0.5	0.2
54	Astara	0.8	1.0	1.3	0.7	1.5	1.5	1.0	0.8	0.9	0.4	0.0	0.6	0.9
55	Lankaran	0.9	1.1	0.8	0.5	1.3	1.3	0.6	0.5	0.7	0.2	–0.1	0.3	0.7
56	Goytepe	0.7	0.6	0.9	0.5	0.8	1.2	0.9	0.9	0.7	–0.1	–0.2	0.3	0.6
57	Yardimli	1.0	1.0	1.3	0.5	1.4	2.0	1.4	1.0	0.7	0.2	–0.5	0.4	0.9
58	Lerik	1.1	1.0	0.8	0.5	1.7	1.6	0.8	0.9	1.3	0.3	–0.8	–0.3	0.7
59	Kalvaz	1.6	1.2	1.1	–0.1	1.4	0.8	0.9	0.6	0.5	–0.3	–0.7	–0.5	0.5
60	Paragachay	2.3	2.7	3.2	2.1	2.6	3.0	2.4	1.7	1.9	1.6	0.8	2.9	2.3
61	Shahbuz	0.9	1.1	0.2	–0.4	0.5	1.1	0.4	0.4	0.4	–0.8	–1.1	–0.4	0.2
62	Naxchivan	1.6	1.5	1.6	0.8	1.1	1.7	1.7	1.2	1.2	0.0	–0.1	0.6	1.1
63	Ordubad	1.6	1.9	1.1	0.7	1.3	1.9	1.7	1.8	2.4	0.8	0.7	0.8	1.4
64	Sharur	2.5	2.1	1.3	1.0	1.1	1.4	0.8	0.7	1.2	1.1	0.3	0.5	1.2
65	Julfa	1.6	2.5	1.1	1.2	1.0	1.1	0.9	0.6	1.9	1.6	1.4	2.0	1.4
Country		**1.0**	**0.9**	**0.9**	**0.7**	**1.6**	**1.6**	**1.0**	**0.9**	**0.9**	**0.2**	**–0.1**	**0.4**	**0.8**

In all remaining stations, the increase in air temperature was around 1–2° C in May and June. The second highest phase of air temperature increase was registered in January. So, although there is a slight increase in Khaltan, Kurdamir, Zardab, Yevlakh, Jeyranchol, Aghdam, Fuzuli, Khankendi, Jafarkhan (0.5–0.6° C), the limit of increase in other stations rises to 0.7–3.0° C. In February, in some stations (Alibey, Beylagan, Goygol, Paragachay, Ordubad, Sharur, Julfa), the temperature increase was 2–3°C. The analysis shows that the stations where the air temperature increases more in the winter months are located in Nakhchivan province, low and mid-mountains areas.

In 2011–2022, low indicators of air temperature anomalies were recorded in October and November. Thus, in these months, the highest anomaly index was not higher than 1.6° C (Paragachay, Julfa). During these months it was even observed that the air temperature was slightly below than the climatic norm in others stations.

Besides, air temperature anomalies in altitude belts along the country were investigated in the study (Fig. 3). The analysis shows that the highest temperature increase in the territory of the country was recorded in 2001–2500 m altitude (1.3° C). At the altitude zone of 501–1000 m and 1501–2000 m, this indicator is 1.0° C. This indicator does not exceed 0.8° C at an altitude of 0–500 m (also below sea level) and 1001–1500 m.

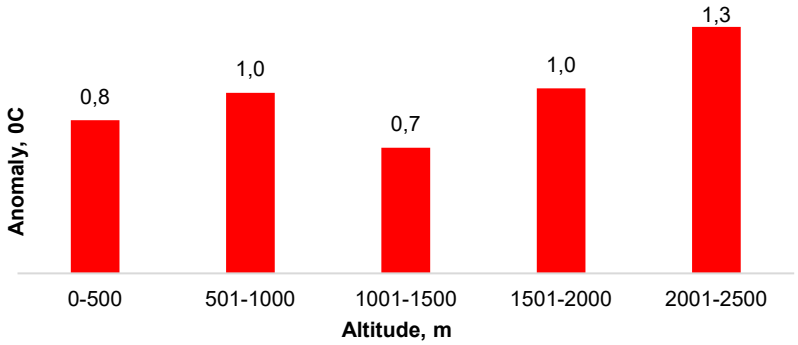

Fig. 3. Anomaly of air temperature by altitude in Azerbaijan territory

In order to analyze the trend of air temperature in 2011–2022 by territory compared to 1981–2010, the temperature distribution was given by applying the IDW model of interpolation in the GIS (Geographic Information Systems) environment (Fig. 4).

If we pay attention to the map, the Kura-Araz lowland, Absheron Peninsula, Arazboyu plains, Lankaran lowland are with higher, Greater and Lesser Caucasus, Talysh mountains and the highlands of their ridges are with lowest air temperature aerials (Huseynov, & Ismailova, 2023; Huseynov, & Huseynov, 2022; Nasibova et al., 2023). Analyzes in GIS technology show that in the country in 1981–2010, high air temperature indicators prevailed in smaller areas, more precisely, in zones up to 500 m, compared to 2011–2022. In 2011–2022, high temperature indicators, i. e. 15° C and above, have shifted slightly higher (Gulmammadov, Mammadova, & Tagiyev, 2022). This shift manifests itself in the higher parts of the lowland. Thus, temperature fluctuations were determined at an altitude of 2001–2500 m, where long-term hydrometeorological measurements were made.

The analysis of anomaly indicators in the territory of Azerbaijan attracts interest in how the air temperature changes in the long term. Air temperature trends during 1961–2022 were viewed as 10-year periods (Fig. 5).

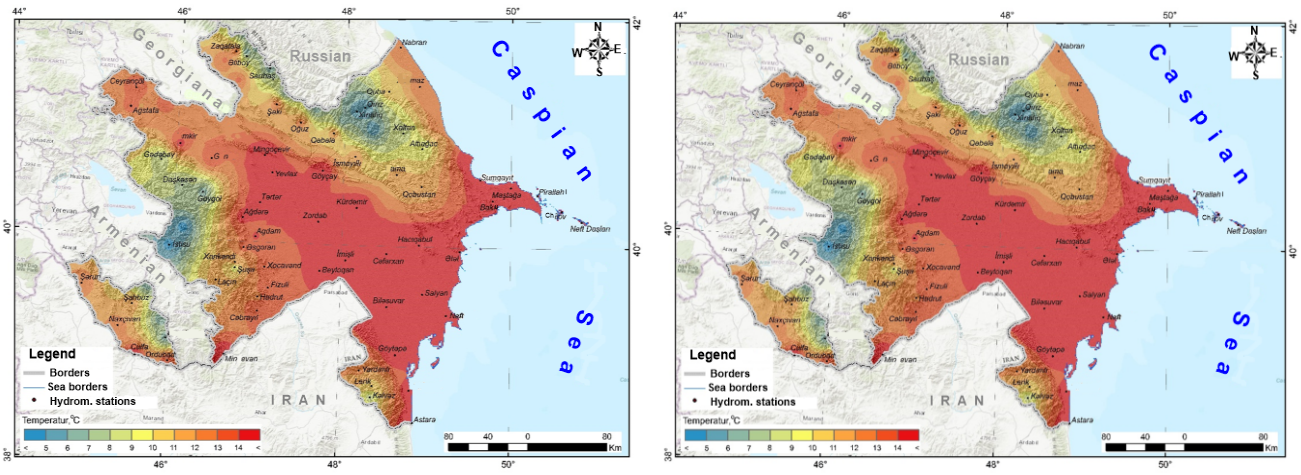

Fig. 4. Map of air temperature in the territory of Azerbaijan in 1981–2010 (a) and 2011–2022 (b)

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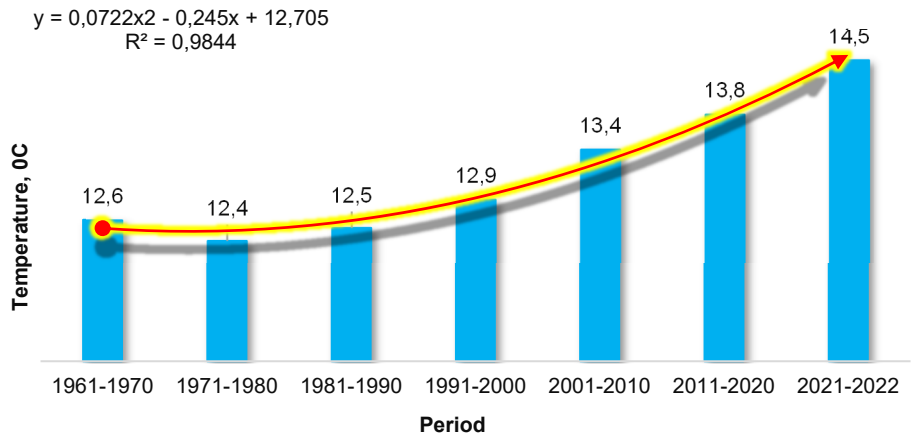

Fig. 5. Trend of air temperature in the territory of Azerbaijan by decades

If we pay attention to the multi-year dynamics of temperature, starting from 1961–1970, compared with previous decade, the temperature of the country decreased by 0.2° C (-0.024^{0}C/1 year) in 1971–1980. In 1981–1990, this indicator increased by 0.1° C (0.015° C/1 year), in 1991–2000 by 0.4°C (0.032° C/1 year), in 2001–2010 by 0.5° C (0.057° C/1 year), in 2011–2020 by 0.4° C (0.040°C/1 year), and in 2021–2022 by 0.7°C (0.062^{0}C/1 year). The highest temperature increase in decadal periods occurred in 2001–2010. In 2010, the increase in air temperature along the country reached a record level. This record is updated every year from 2016 to 2023. The temperature observed in the country in the last 7 years has been a new record every year since 1881.

Discussion and conclusions

As a result of the comparative analysis of air temperature in 2011–2022 compared to 1981–2010 in the territory of Azerbaijan, the following results were obtained:

1. The air temperature in the territory of Azerbaijan increased by 0.9°C in 2011–2022. This indicator was 0.9° C in winter, 1.1° C in spring, 1.2° C in summer and 0.4° C in autumn.

2. The highest increasing rate was 1.6° C in May and June.

3. The highest indicator of temperature anomaly was recorded at an altitude of 2001–2500 m.

4. The highest temperature increase in the long-term period was 0.5°C in 2001–2010. This indicator reached 0.7° C in 2021–2022.

The influence of climate changes in the air temperature regime in the territory of Azerbaijan will lead to the disruption of the traditional climate regime, the disappearance of the green landscape and expansion of semi-desert and arid landscape in the front mountainous areas, the increase of possible evaporation and the increasing of environmental crises such as drought at the 1000 m elevations. An increase in the radiation balance in Nakhchivan province may worsen the continentality of the climate type here. The increase in temperature in the Kura depression province will create conditions for the expansion of the semi-desert-arid climate in the piedmonts of the Greater Caucasus Mountains. Replacement of the snowing climate to a higher altitude (15 m / 1 year), melting of permanent glaciers creates conditions for the lack of drinking water, accelerates the decrease in the level and volume of underground water sources.

At the same time, the results of the study show that the hydrometeorological elements and manifestations should be re-examined such as solar radiation, albedo, precipitation, glacier volume, river and groundwater flow balance, wind, radiation balance, etc. The results of the increase in air temperature should be taken into account in new designs in tourism, energy, agriculture, construction industry. Thus, it is possible to increase the use of solar energy as an alternative energy source within the framework of mitigation measures in the country.

Authors' contribution: Jamal Huseynov – conceptualization, methodology, writing (original draft), formal analysis; Allahverdi Tagiyev – data validation, writing (review and editing).

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ХАРАКТЕРИСТИКА ВПЛИВУ ЗМІН КЛІМАТУ НА ТЕМПЕРАТУРУ ПОВІТРЯ НА ТЕРИТОРІЇ АЗЕРБАЙДЖАНУ В ПЕРІОД ГЛОБАЛЬНИХ КЛІМАТИЧНИХ ЗМІН

В с т у п . ***У дослідженні було використано дані спостережень за температурою повітря за 1981–2022 рр. близько 70 гідрометеорологічних станцій, що діють на території Азербайджанської Республіки. З метою визначення впливу змін клімату на температурний режим повітря проведено порівняння результатів 1981–2010 рр. з відповідними результатами 2011–2022 рр.***

М е т о д и . ***У дослідженні за допомогою математичних, статистичних і картографічних методів розглянуто тренд місячних, сезонних і багаторічних змін температури повітря.***

Р е з у л ь т а т и . ***Дослідження показують, що температура повітря в країні підвищилася на 0,9° С. Позитивна аномалія досягла 1,3° С на поясі з висотою 2001–2500 м. Основні високі показники відзначені у високогірних районах. Температурна аномалія коливається в межах 1,5–1,7 ° С, переважно в травні та червні місяці. Багаторічна динаміка температури показує, що у 2001–2010 рр. спостерігається підвищення температури (0,057° С / 1 рік). Це був найтепліший період протягом 1961–2022 рр.***

Результати дослідження можуть бути використані для захисту від змін клімату, пом'якшення наслідків та вивчення сучасного температурного режиму. Крім того, сонячне випромінювання можна використовувати як альтернативне джерело енергії на рівнинних ділянках, де спостерігаються високі показники температури повітря. Про отримані результати буде повідомлено на конференції зі зміни клімату COP 29 (Конференції сторін), яка пройде в Баку 11–22 листопада 2024 р.

В и с н о в к и . ***Вплив кліматичних змін на температурний режим повітря на території Азербайджану призведе до порушення традиційного кліматичного режиму, зникнення зелених ландшафтів і розширення напівпустельних і посушливих ландшафтів у передових гірських районах, можливе збільшення випаровування та посилення екологічних криз, таких як посуха на висоті 1000 м. Підвищення радіаційного балансу в Нахічеванській області може погіршити тут континентальність клімату. Підвищення температури у провінції Куринської западини створить умови для поширення напівпустельно-посушливого клімату в передгір'ях Великого Кавказу.***

К л ю ч о в і с л о в а : ***математичні, статистичні та картографічні методи, температурні показники, парниковий ефект, рівнинні території, альтернативне джерело енергії, кліматична норма, висотна зона, ArcGIS.***

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