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Research Article

Distribution of the Contemporary Precipitation Regime and the Impact of Climate Change on it within the Territory of Azerbaijan

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ABSTRACT

The regularities of the contemporary distribution of the precipitation regime within the territory of Azerbaijan were researched in the research paper. The perennial tendency of the precipitation regime was determined using the rainfall observation data for the years between 1961 and 2020 in the conducted research. Based on the obtained results, a state-of-the-art precipitation map was compiled for the country. At the same time, the dynamics of the precipitation regime during the period 1961-2020, as opposed to the period 1881-1960, were evaluated. The research period was divided into two half-periods, namely 1961-1990 and 1991-2020, and the internal tendencies were analysed. The results of the investigation indicate that although the amount of the precipitation region underwent a downward trend across the country, the number of stations with a statistically significant decrease is small. Compared to the years 1881-1960, the amount of precipitation has decreased throughout the country. Moreover, the average annual temperature in the country increased by 0,8°C from 1991 to 2020. This indicator is the same period between 1961 and 2020 compared to the period between 1881 and 1960. In order to conduct research, mathematical-statistical and cartographic methods were used.

Keywords: Precipitation regime; Tendency; Climate change; Temperature fluctuations; Amount of precipitation; Convergence; Mitigation

INTRODUCTION

The global climate changes that have occurred in recent times on Earth are evident with their separate effects on different regions. Considering that the essential changes are observed in temperate and subpolar latitudes, a fundamental study of the climate regime in those areas is likely to play a major role in the implementation of mitigation measures in the future [1]. In this regard, one of the important issues is the assessment of the modern features of the climate regime in the Southern Caucasus region located at those latitudes. Within the territory of the Republic of Azerbaijan, which has different areas with great diversity in terms of its physical and geographical position, the precipitation forms under the influence of intra-mass and front-type processes [2]. Large morphometric units of the Greater and Lesser Caucasus Mountains are located in this area, and they play a fundamental role in the formation of synoptic conditions in the country [3]. The permanent glacier, water and forest resources of the country locate in these mountains and ranges, which receive abundant rainfall throughout the year. Furthermore, the necessary part of the large river systems supplying the country with water resources is fed from these mountains [4]. However, the changing climate has provided an avenue for increasing temperature and decreasing the amount of precipitation. Undoubtedly, the consequences of this challenge may lead to the change or destruction of all ecosystems in the following years [5]. The decrease in precipitation in the country has brought about natural disasters such as the lowering of the groundwater level, drought and salinisation in water-scarce zones [6]. In recent times, R.N. Mahmudov, S.H. Safarov, A.S. Mammadov, Y. Hadiyev, R.A. Mammadov, Kh.Sh. Rahimov, N.Sh. Huseynov and other climatologists have conducted research on the study of climate changes during different periods. In the current research paper, changes in the precipitation regime for the period 1961-2020, seasonality and modern distribution on the territory are provided. One of the essential studies belongs to S.H. Safarov. He studied the effects of climate changes on the distribution of the precipitation regime in the territory of the Republic of Azerbaijan from 1991 to 2006 [7]. During his research, the scientist found that there was an intense decrease in the amount of precipitation and an increase in the temperature regime. However, it was determined that there is no significant dependence between both parameters.

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The study of the contemporary distribution regularities of precipitation and temperature regime, the synoptic processes that create them and the modern characteristics of hazardous atmospheric phenomena in the territory of the country is connected with the name of N.Sh. Huseynov. Recently, a scientist has scrutinized climate change and its influences on air transport in detail [8].

It is a known fact that the global temperature increase is a common problem on the Earth and the average temperature has risen in almost all regions. Hence, during the last 100 years (1906-2005), the average global temperature increased by 0,74 ± 0,18°C. The global warming rate in the last 50 years (0,13 ± 0,03°C per 10 years) is more than twice that estimated for 100 years. According to the "4th National Communication to the United Nations Framework Convention on Climate Change" prepared by the Ministry of Ecology and Natural Resources of the Republic of Azerbaijan, during the last 20 years (1991-2020), the average annual temperature change of the country continues at a higher rate (MENR 2021). Thus, in the latest report, compared to 1971-2000, the average annual temperature rise of the country by regions in 2001-2020 was close to 1-0°C on average and varied between 0,5-1,5°C in various regions. The change in the statistical structure of temperature, which is one of the decisive elements of the climate, leads to the re-formation of heat and water circulation in the atmosphere. These changes in turn affect the precipitation formation process. More often than not, such effects lead to a time shift and an increase in the recurrence of natural cataclysms, namely droughts, floods, hurricanes, hail, lightning, landslides and other cataclysmic events. In this respect, it is important to study the changes in atmospheric precipitation in different regions and to find out the relationship between them, along with the evaluation of the air temperature regime by different methods.

MATERIALS AND METHODS

The characteristics of climate change during the period 1891-2020 were investigated by using precipitation and temperature observation data of 60 stations of the same period [9]. Changes in the temperature regime determine the extent of their impact on precipitation in one way or another. Moreover, the regularities of the contemporary distribution of various characteristics of precipitation on the earth's surface were determined using the cartographic method. The data used in the study were collected from the database of the National Hydrometeorological Service. Mathematical-statistical methods were used during the analysis of primary data. In order to specify the statistical importance of the obtained data, the Fisher and Student statistical criteria were used. The maps of the distribution of average annual precipitation on the earth's surface were prepared by the authors in special ArcGIS software.

RESULTS

Since the territory of the Republic of Azerbaijan has a high height contrast, its relief has a complex structure. The Greater Caucasus Mountains located in the north of the territory handicap cold and humid air masses from the north to pass through to the south [10]. In such cases, the fast winds move over the sea along the coast towards the Absheron peninsula because of air masses converge along the northern foothills. Due to such a synoptic regime throughout the year and the relief of the area, rainfall is distributed differently from the coastal areas to the highlands [11]. The zone differs from other regions due to the characteristics of the precipitation regime. Thus, there are two maximum precipitation zones in this zone. Hence, the annual amount of precipitation in the coastal plains of the Caspian Sea is 300 mm. As the altitude increases, the amount of precipitation increases up to the upper parts of the low mountains (800-1000 metres), even though the precipitation decreases again and begins to increase again at a certain height. This situation continues to increase up to 700 mm in the parts of the highlands up to 3000 metres. However, precipitation starts to decrease above the indicated zone. In the southern foothills of those mountains, orographic conditions prevail in the formation of the precipitation regime. As evaporation accelerates in the first half of the day in the plains and lowlands, the air masses cool and produce precipitation as they rise up the foothills of the mountains. 53% of the precipitation in the area falls in the warm period of the year or in late spring, summer, and early autumn.

Air masses moving along the northeastern foothills of the Greater Caucasus Mountains have a great influence on the Absheron Peninsula. These conditions continue throughout the year, and therefore windy weather prevails here 250 days a year [12]. Cold air masses from the north, semi-arid and arid climate type and proximity to the sea are the fundamental natural factors influencing the precipitation regime of the peninsula. In recent years, the transformation of the peninsula into a large urban agglomeration has culminated in the increase in the anthropogenic influence on the formation of precipitation. Since there is no hypsometric unit in the peninsula, the precipitation difference in the area is not large. Thus, during the year, 250 mm of precipitation falls on the peninsula, and 160 mm on the surrounding islands of Pirallahi, Chilov and Neft Dashlari (Oil Rocks). About two-thirds of the precipitation in the area fall during the cold period of autumn, winter, and early spring. Therefore, a semi-desert dry steppe climate type with dry summer is typical in all parts of the aquatorium (Table 1).

There is a different precipitation regime in the listed areas on the southern slopes of the Greater Caucasus Mountains [10]. Thus, as 950 mm of precipitation falls from the lowlands to higher altitudes along the slope, the amount of precipitation increases to 1400 mm up to the height of 2000-2500 metres of the middle mountains, but continues to decrease at higher altitudes. The amount of perennial precipitation decreases slightly in the southeastern part of the southern slope. So, this indicator commences from 500 mm in the foothills. The permanent glaciers, which are the essential water resources of the country, locate in the highlands. However, in recent years, global climate change has led to a sharp decrease in their areas. Generally speaking, the climatic snow line in the country starts from 3000 metres. The annual amount of precipitation in the highest parts of the Greater Caucasus Mountains is 1100 mm and falls in the form of frozen precipitation (sleet, snow and ice crystals). 57% of the region's precipitation falls in the hot season. Less precipitation is observed in late autumn, winter and partly early spring.

The Kura-Araz lowland is a plain located along the foothills of the Lesser Caucasus Mountains, starting from the southern foothills of the Greater Caucasus Mountains [13]. There are almost no large orographic units in the plain. This is the essential underlying reason for the distribution of the precipitation regime with small differences over a wide area. Here, the difference in precipitation between the coastal areas and the more western regions is not high. Nevertheless, temperature differences reach 1-2°C. The amount of perennial precipitation on the plain is 310 mm. In this region, more precipitation falls in the western and lowland border regions of the area, and less precipitation falls in the coastal areas. In the area, more precipitation falls in the cold season (52%) than in the warm season. Thus, the main part of the annual precipitation falls in late autumn, winter and early spring. The Lesser Caucasus Mountains rise along the southwest of the Kura-Araz lowland and cause a sharp change in the climate regime of the area. Thus, the amount of precipitation in the foothills of the Murov range, in the Jeyranchol plain and along the coast of the Kura River is 300 mm. In the 2000-2500 m height zone of the Lesser Caucasus, it reaches the zone where the maximum precipitation falls in the interval of 700-800 mm. In the higher parts, the precipitation becomes less and less. The area is the zone where more thunderstorm processes occur in the country. The reason for this is the transition from the plain area to the sharp mountainous zone. 64% of the precipitation in this zone falls in the warm season. There are some differences in the amount of precipitation along the Karabakh range of the Lesser Caucasus Mountains. Thus, the amount of precipitation in the foothills of the area is 500 mm, and this indicator reaches 800 mm in the 3000 m altitude zone. Precipitation decreases gradually in the higher zone. The southern part of this mountainous province is the Zangazur-Daralayaz ridges. In the low-mountain plateaus (Sharur-Ordubad plain) at the southern foothill of these ridges, the annual rainfall is close to 300 mm. As the slope increases, the amount of precipitation reaches 900 mm in the highlands. The essential part of the precipitation in the region falls in the warm period, namely in late autumn, winter and spring. The average annual precipitation in the region is 330 mm.

The precipitation regime of the Talysh Mountains, which run parallel to the coast of the Caspian Sea, is completely different from other areas of the country [14]. Hence, in this zone, the amount of precipitation decreases from the coast to the highlands. Although this indicator is 1200 mm in the Lankaran plain, 250 mm of precipitation is observed at a height of 2000-2500 mm. As the area has a fertile climate regime, the subtropical climate type is typical in wider coastal areas. 66% of the annual precipitation fall in the cold period. Despite the fact that less precipitation falls in the summer months, the amount of precipitation is plentiful from late autumn to mid-spring. The amount of perennial precipitation in the region is 770 mm [15].

Table 1: Distribution of precipitation in the territory of Azerbaijan for the years from 1961 to 2020, millimetres.

No	Station	Height, m	1891-1965	1961-2020	Winter	Spring	Summer	Autumn	Mild	Cold
1	Khachmaz	27	334	311	82	76	44	109	39	61
2	Guba	550	571	513	102	129	108	173	46	54
3	Khaltan	1104	-	516	90	152	117	157	52	48
4	Altiaghach	1099	-	518	91	172	112	143	55	45
5	Giriz	2071	580	547	65	180	179	124	66	34
6	Baku	2	247	272	94	62	19	98	30	70
7	Sumgait	-20	200	227	70	56	20	81	33	67
8	Mashtagha	27	311	283	95	62	18	108	28	72
9	Pirallahi	-25	198	196	64	51	13	68	32	68
10	Chilov	-17	197	153	52	42	9	51	33	67
11	Oil Rocks	-17	130	132	43	37	8	44	34	66
12	Alibey	1540	1394	1266	139	386	405	337	62	38
13	Zagatala	487	1036	951	121	308	273	248	61	39
14	Shaki	639	803	784	114	250	212	208	59	41
15	Gabala	679	1128	964	154	305	229	277	55	45
16	Oghuz	582	1027	886	139	281	214	252	56	44
17	Shamakhi	750	591	592	124	188	106	174	50	50
18	Maraza	775	379	364	72	120	71	101	52	48
19	Jeyranchol	419	-	309	44	102	93	69	63	37
20	Mingachevir	93	359	335	61	108	75	90	55	45
21	Yevlakh	13	323	301	53	95	71	82	55	45
22	Goychay	107	503	419	92	138	74	116	50	50
23	Zardab	-5	-	291	62	92	47	90	48	52
24	Kurdamir	2	360	345	79	106	53	107	46	54
25	Hajigabul	-7	254	241	64	78	26	72	44	56
26	Jafarkhan	-16	293	285	77	90	33	86	43	57
27	Imishli	-1	-	281	66	89	38	87	45	55
28	Beylagan	62	312	297	65	101	48	83	50	50
29	Bilasuvar	75	321	324	94	97	28	105	39	61
30	Neftchala	-24	-	288	84	77	17	110	33	67
31	Salyan	-21	283	261	75	77	25	83	39	61
32	Aghstafa	331	402	355	52	120	101	82	62	38
33	Shamkir	404	389	327	49	106	100	72	63	37
34	Ganja	312	282	271	37	91	79	65	63	37
35	Dashkasan	1655	622	635	85	216	201	133	66	34
36	Gadabay	1480	696	699	78	229	249	143	68	32
37	Goytapa	2	633	597	177	134	53	233	31	69
38	Lankaran	-20	1402	1183	293	194	104	591	25	75
39	Astara	-23	1398	1261	290	211	144	617	28	72

40	Yardimli	730	645	629	122	166	101	240	42	58
41	Kalvaz	1567	-	330	86	114	37	94	46	54
42	Sharur	812	-	267	58	112	41	55	58	42
43	Shahbuz	1205	444	343	79	146	52	66	58	42
44	Nakhchivan	875	271	254	56	108	38	52	58	42
45	Ordubad	861	307	264	60	110	38	56	56	44

***Source:** National Hydrometeorological Service, Ministry of Ecology and the Natural Resources Republic of Azerbaijan

DISCUSSION

In order to visually observe the results of the research on the territory, and to detect feasible regularities, a contemporary precipitation map was compiled by the authors in ArcGIS software. The precipitation map was compiled by the classification module on the DEM (Digital Elevation Model) file (3D) taken by a stationary satellite placed in the space around the earth from a height of 30 m above the earth's surface in GIS. At this time, the pre-obtained results and DEM-type images are divided into 9 gradations by height. As a result, according to the height, the amount of precipitation was determined. Using cartographic methods, it is possible to indicate that the amount of precipitation increases from the plains to the mountains, while less precipitation falls on the coast and islands (Figure 1).

Climate change

Changes in the amount of precipitation in the country in 1961-2020 compared to 1891-1965 are of great interest [10]. The analyses indicate that precipitation decreased in most stations during 1961-2020. The decrease in the amount of precipitation in the country is 7% in the lowland areas consisting mainly of plains, 8% in the middle highlands at a height of 1500-2000 meters, and 11% in the area of the middle highlands with a height of 1500-2000 m. In addition to this, during the research period, the central and northern parts of the Absheron peninsula had an increase in precipitation of about 11%. A slight increase (1-2%) in neft dashlari (Rock Oils), Neftchala and Bilasuvar are not statistically significant. Average annual temperature indicators in 1961-2020 also increased compared to 1881-1960 [10]. Thus, in the territory of the country, the temperature increase was equal to 0,8ºC in the plains surrounding the coastal plains of the Caspian Sea, Kura-Araz plain, Absheron peninsula, the plain areas covering Jeyranchol plain, 1,00°C in the 500-1000 m area of the foothills of large mountain ranges, and 0,7°C in all parts of the highlands.

As opposed to 1961-1990, the temperature indicators in 1991-2020 changed by 0,8°C in the country. At the same time, the primary rise was 0,9 -1,0°C, being in the upper parts of the lowlands (500-1000 m) and in the upper parts of the middle highlands (1500-2000 m). However, in plain zones, this indicator is 0,8°C. Thus, during this period, the amount of precipitation decreased by 7% in the 0-500 m altitude area where the plateau, lowland and coastal plains are located. The amount of precipitation decreased by 9% in the lowland zone of 500-1000 metres. A further decrease in precipitation is around 10% in the 1000-1500 m zone of the highlands. Although the decrease of precipitation occurred less in the higher parts of the lowlands, this fluctuation was 13% in the lower parts of the middle highlands. During a far-reaching study of climate changes, supposed that we look at the trend of perennial average temperature and precipitation for every decade, it can be seen that the amount of precipitation across the country has a decreasing trend, and the temperature has an increasing tendency. From 1961 to 2020, the average annual temperature of the Republic of Azerbaijan has increased. During this period, more precipitation fell on the territory of the country between 1961 and 1970. During this period, as less precipitation fell from 1991 to 2020, the dry areas in the area expanded. Over the past 3 decades, precipitation has been steadily decreasing. Provided that we look at the histograms, it is feasible to observe that the amount of precipitation decreases with temperature (Figures 2a and 2b).

The statistical significance of the results obtained during the research period was evaluated as well. For this purpose, temperature and precipitation series were checked according to the Student criteria. According to the results, the temperature anomaly is not homogeneous and statistically significant at the 5% level of the Student criteria. Among the precipitation anomalies, Baku, Maraza, Chilov, Oil Rocks and Goychay stations are not homogeneous. This confirms that the obtained results are statistically significant (Table 2).

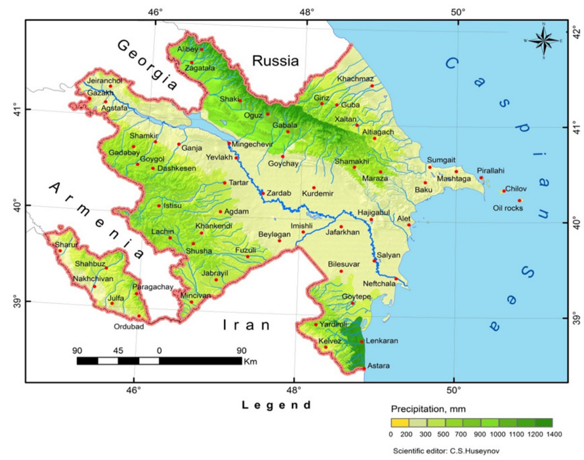

Figure 1: Map of the distribution of precipitation within the territory of the Republic of Azerbaijan. **Note:** (•) Hydrometeorological stations; (—) River; (—) State border; ( ) Water bodies.

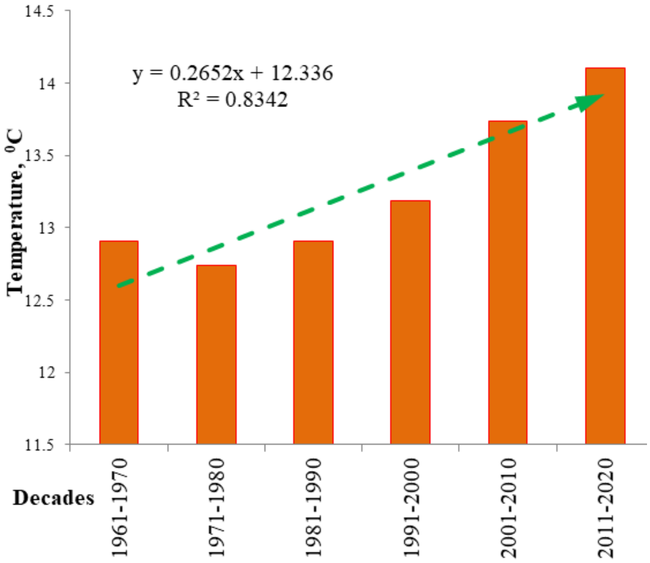

Figure 2a: The average annual tendency of temperature and precipitation.

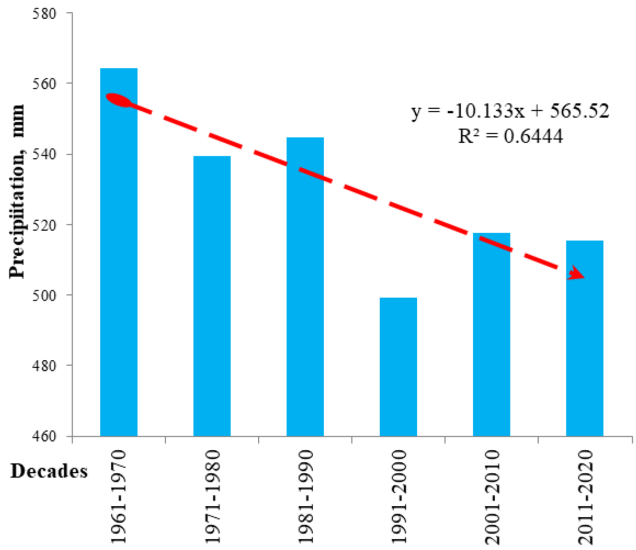

Figure 2b: The average annual tendency of temperature in the Republic of Azerbaijan.

Table 2: Fluctuations of temperature and precipitation in several periods within the territory of Azerbaijan.

No	Station	Height, m	1961-2020		1991-2020		Student, 5% (2.01)	
			t,°C	p, %	t,°C	p, %	t	p
1	Sumgait	-20	1,1	13	0,7	2	3,8	0,24
2	Baku	2	0,5	10	0,3	32	2,27	3,64
3	Mashtagha	27	1,0	-9	0,9	4	5,15	0,56
4	Pirallahi	-25	0,8	-1	0,8	2	4,52	-
5	Chilov	-17	0,7	-22	0,7	-21	4,07	2,69
6	Oil Rocks	-17	0,8	1	0,7	-30	4,42	3,33
7	Alat	-18	-	-	0,4	-16	-	-
8	Khachmaz	27	0,7	-7	0,9	3	4,97	0,48
9	Guba	550	1,1	-10	1,1	-4	5,53	0,84
10	Altiaghaj	1099	0,9	-	0,8	-11	3,49	2,07
11	Giriz	2071	0,6	-6	0,8	-13	3,9	2,75
12	Zagatala	487	0,8	-8	0,9	-2	4,9	0,34
13	Alibey	1540	0,7	-9	0,9	4	-	-
14	Shaki	639	0,6	-2	0,9	-6	4,36	1,37

15	Gabala	679	1,1	-15	1,2	-7	5,5	1,48
16	Oghuz	582	-	-14	1,1	-7	10,7	1,38
17	Maraza	775	0,6	-4	0,8	-27	3,99	4,84
18	Jeyranchol	419	-	-	0,7	-27	-	-
19	Mingachevir	93	0,7	-7	0,9	-8	4,34	1,28
20	Yevlakh	13	0,7	-7	0,8	-15	4,45	-
21	Tartar	160	-	-	0,9	-6	-	-
22	Goychay	107	0,9	-17	1,0	-20	5,44	3,38
23	Kurdamir	2	0,8	-4	1,0	-3	5,49	-
24	Zardab	-5	0,9	-	0,8	-9	4,58	-
25	Beylagan	62	0,7	-5	0,8	6	4,24	-
26	Imishli	-1	-	-	0,9	-8	-	-
27	Jafarkhan	-16	0,7	-3	0,7	-11	4,8	1,76
28	Hajigabul	-7	1,0	-5	0,8	-6	3,89	-
29	Bilasuvar	75	0,8	1	0,8	-7	3,87	-
30	Salyan	-21	-	-8	0,8	-17	-	-
31	Neftchala	-24	0,8	-	0,8	-7	3,62	-
32	Ganja	312	0,7	-4	1,0	-11	6,31	-
33	Aghstafa	331	1,0	-12	1,0	-5	4,4	0,6
34	Shamkir	404	1,3	-16	0,9	-12	5,48	1,44
35	Gadabay	1480	0,8	0	0,8	3	3,45	0,22
36	Dashkasan	1655	-	2	1,1	-7		-
37	Astara	-23	-	-10	0,9	-8		1,71
38	Lankaran	-20	0,5	-16	0,9	-4	5,22	0,79
39	Goytapa	2	-	-6	1,0	-2		-
40	Yardimli	730	-	-2	0,4	-9	1,57	1,94
41	Kalvaz	1567	-	-	-	4		-
42	Sharur	812	-	-	0,9	-12		-
43	Ordubad	861	2,3	-14	0,8	-9	3,44	1,4
44	Nakhchivan	875	0,0	-6	0,8	-1	3,36	-
45	Shahbuz	1205	0,5	-23	0,3	-23	1,23	-

***Source:** National Hydrometeorological Service, Ministry of Ecology and the Natural Resources Republic of Azerbaijan

CONCLUSION

The research conducted using the precipitation and temperature observation data in Azerbaijan indicates that the average annual temperature increased by 0,8°C in 1961-2020 compared to 1881-1961. This indicator was 0,8°C in 1991-2020 compared to 1961-1990. The amount of precipitation decreased throughout the period. Precipitation fell 7% less in 1891-1960 and 1991-2020. The increase in temperature is one of the fundamental causes of the decrease in precipitation. The alteration in the amount of precipitation is also related to the change in the characteristics of the air masses penetrating the regions as a result of the effects of global climate change on the general circulation. Providing that the climate regime proceeds to alter at this rate, the size of the area where the semi-desert and arid climates exist is likely to grow. A sharp increase in air temperature at the beginning of summer is likely to lead to the melting of glaciers and acceleration of processes such as flooding, and the desertification process is likely to begin to grow.

STATEMENT OF DECLARATION

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

COMPETING OF INTEREST

The authors have no relevant financial or non-financial interests to disclose

AUTHOR CONTRIBUTIONS

All authors contributed to the conception and design of the study. Material preparation, data collection, Map design and research analysis were carried out by Nazim Huseynov. The first draft of the manuscript was written by Nazim Huseynov, and all authors commented on earlier versions of the manuscript. All authors read and approved the final manuscript.

DATA AVAILABILITY

The data sets analyzed during the current study are not publicly available due to [REASON WHY THE DATA IS NOT PUBLIC], but are available upon reasonable request from the National Hydrometeorological Service and author Jamal Huseynov.

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