ASSESSMENT OF THE IMPACT OF CLIMATE CHANGE ON THE PRECIPITATION REGIME IN THE SOUTHERN SLOPE OF THE GREATER CAUCASIAN PROVINCE

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Abstract

The study examines the influence of modern climate changes on the precipitation and temperature regime in the southern and southeastern regions of the Great Caucasus natural region. Also, determining the multi-year trends of the temperature and precipitation regime in 1991-2020 and investigating their change regularities is the goal. At the same time, in the article, the variability of monthly, seasonal and annual indicators was studied in the multi-year period. The impact of global climate changes on the perennial precipitation regime in the southern part of the Greater Caucasus region was studied. In the analysis, the precipitation observation data of 8 meteorological stations during the years 1991-2020 were used. Multi-year (1991-2020) various indicators of precipitation were compared with the base quantities. In the study, the multi-year period was considered for 2 periods (1991-2005, 2006-2020) and the monthly, seasonal and annual trends of precipitation were compared. The study found that the multi-year average temperature in the province for the last 30 years was 11-14^{0}C in the lowlands and 6-7^{0}C in the mid-mountains. However, compared to 1961-1990, the perennial temperature has increased by 1.0^{0}C. The amount of annual precipitation was in the interval of 300-1300 mm, depending on the stations. A decrease in the amount of precipitation has been recorded for many years, and in some places this amount has even increased to 27%.

Keywords: Greater Caucasus Mountains, water supply, hydrodynamic regime, aquifer, percent of mineralization, natural hazards, climate change, meteorological station, precipitation

I. İntroduction

Destructive effects of global climate changes have recently expanded the area of occurrence in different regions of the Earth [2,13]. The frequent recurrence of dangerous events such as floods, hurricanes, hail, droughts, landslides, and avalanches showed the extreme importance of studying the effects of global climate changes. As a result of natural disasters, it is inevitable that millions of people will suffer every year, and the economy of countries will suffer a large amount of damage [3]. It is considered important to carry out research in the direction of revealing the characteristics of climate changes in the South Caucasus. The complexity of the relief of the Republic of Azerbaijan and the diversity of the climate regime do not allow the study of the region as a whole. Therefore, the separate study of the physical-geographic regions that make up the territory or regions with the same climate regime is considered indispensable. For this purpose, it is necessary to reveal the effect of multi-year climate anomalies on the precipitation regime in the southern part of the Greater Caucasus region. Although various features of the climate regime were investigated in the previous studies, none of them included a comprehensive analysis of fluctuations in precipitation and temperature regime for the years 1991-2020 [1, 2, 3, 14].

In the southern and southeastern parts of the Great Caucasus natural region, the emergence of mild-warm, cold, mountainous tundra climate types with dry winters and evenly distributed precipitation, abundant precipitation in all seasons, is spread precisely on the basis of the physical-geographical position, complex relief and the influence of air masses [1, 7]. As the air masses from the north cannot cross the high mountain ranges, the impact on the area is very weak. However, this area is affected by local, mild, warm, humid air masses coming from the west, the Caspian Sea and the Kura-Araz plain throughout the year. The hot air masses coming to the region convect as they rise along the mountain slopes and fall to the earth's surface in the form of precipitation in the second half of the day. Such processes are observed with dangerous atmospheric phenomena (hail, lightning) in the hot season of the year [5,6,7].

II. Methods

The study was carried out on the southern slope of the Great Caucasus in Alibey (1540 m), Meraza (775 m), Shamakhi (750 m), Gabala (679 m), Ismayilli (653 m), Sheki (639 m), Oguz (582 m) and Zagatala (487 m) meteorological stations of the National Hydrometeorological Service were conducted on the basis of precipitation observation data. Multi-year (1991-2020) series of observations were analyzed using mathematical, statistical and cartographic methods. Also, the 1991-2020 annual period was reviewed for 2 half-periods (1991-2005 - first period, 2006-2020 - second period), and the trend of multi-year internal changes was revealed. The comparison and trend of monthly, seasonal and annual precipitation data of 8 meteorological stations located on the southern slope of the Greater Caucasus region during the period 1991-2020 with the corresponding indicators of 1961-1990 recommended by the World Meteorological Organization (WMO) as a norm [4,7,10]. The table, histogram, graphs in the description of the obtained results were prepared in Microsoft Excel, and electronic maps were prepared in ArcGIS software. The homogeneity of the precipitation observation series and the statistical significance of the obtained results were checked, multi-year anomaly indicators, correlation and difference integral coefficients were calculated.

Alibey (1540 m), Zagatala (487 m), Sheki (639 m), Oguz (582 m), Gabala (679 m), Ismayilli (653 m), Shamakhi (750 m) and Maraza (775 m) meteorological stations are included in the study. rainfall observation data were used. The average indicators of monthly, seasonal and annual precipitation data of 8 hydrometeorological stations during 1991-2020 were compared with the corresponding indicators of 1961-1990 [4,8,11]. The homogeneity of the series of precipitation observations and the statistical significance of anomalies were checked by Fisher and Student tests.

In this part of the province, the emergence of the climate types of temperate-warm, cold with abundant precipitation in all seasons, mountainous tundra climate types with dry winters and evenly distributed precipitation are spread on the basis of the influence of the complex relief. Since the air masses coming from the north cannot cross the high mountain ranges, they converge and move along the northern foothills. However, the southern slope is affected by local, mild, warm, humid air masses coming from the west, the Caspian Sea and the Kura-Araz plain throughout the year. The hot air masses coming to the region convect as they rise along the mountain slopes and fall to the earth's surface in the form of precipitation in the second half of the day. Such processes are observed with dangerous atmospheric phenomena (hail, lightning) in the hot season of the year [7,8,9,12].

The average annual temperature during the multi-year period (1991-2020) was 13.8^{0}C in Zagatala, 13.3^{0}C in Oguz, 13.1^{0}C in Shaki, 12.3^{0}C in Gabala, 11.9^{0}C in Ismayilli, 11.4^{0}C in Maraza, 6.9^{0}C in Alibey station. While the average annual temperature increase in this part of the province was 0.5^{0}C in the first period, it increased 2.8 times to 1.4^{0}C in the second period. The average anomaly in 1991-2020 was 1.0^{0}C.

There have been changes in the precipitation regime along with the temperature over many years. Thus, in 1991-2020, the amount of annual precipitation on the southern slope of the Greater Caucasus region was 786 mm (306-1292 mm) on average. On average, 45% (38-52%) of the annual precipitation fell in the cold and 55% (48-62%) in the warm half-cycle. This shows that the precipitation is close to the regularity of equal distribution from west to east (Table 1).

Table 1: *Seasonal and half-year distribution of precipitation in the south part of the Greater Caucasus region in 1991-2020*

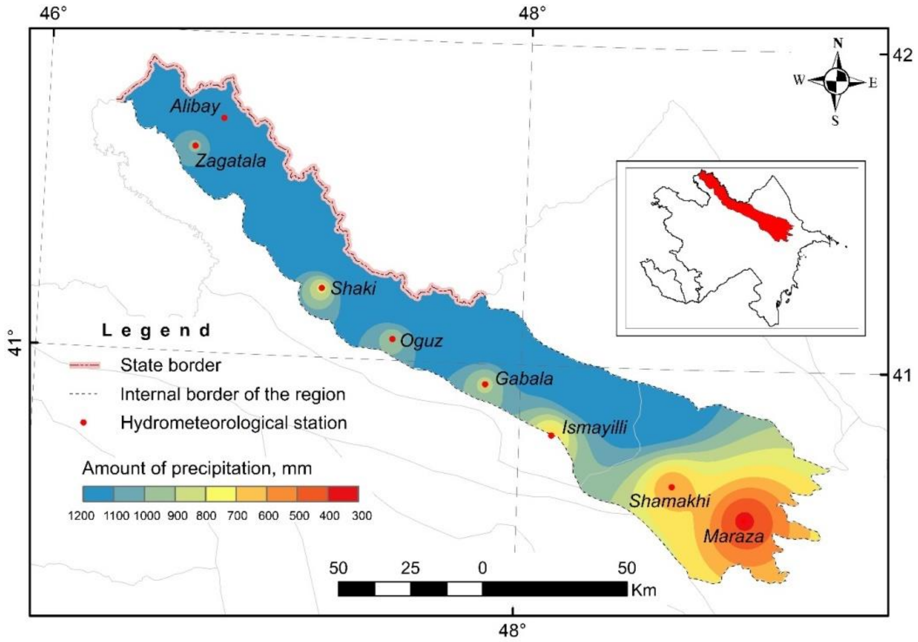
Station	Precipitation rate, mm							Precipitation rate, %	
	Winter	Spring	Summer	Autumn	Year	First period	Second period	cold	hot
Zagatala	120	316	266	242	943	977	909	38	62
Alibey	136	399	396	361	1292	1323	1261	38	62
Sheki	111	241	207	201	760	761	760	41	59
Oguz	147	296	201	282	927	925	929	46	54
Gabala	138	277	184	257	855	865	846	46	54
Ismayilli	111	202	136	205	654	629	679	48	52
Shamakhi	111	165	100	177	553	501	605	52	48
Maraza	60	95	63	87	306	280	332	48	52

As can be seen from Table 1, the main part of precipitation in this region falls in spring and autumn. Also, compared to the first and second periods, an increase was observed at Ismayilli, Shamakhi and Maraza stations, while a decrease was observed at Zagatala, Alibey and Gabala stations.

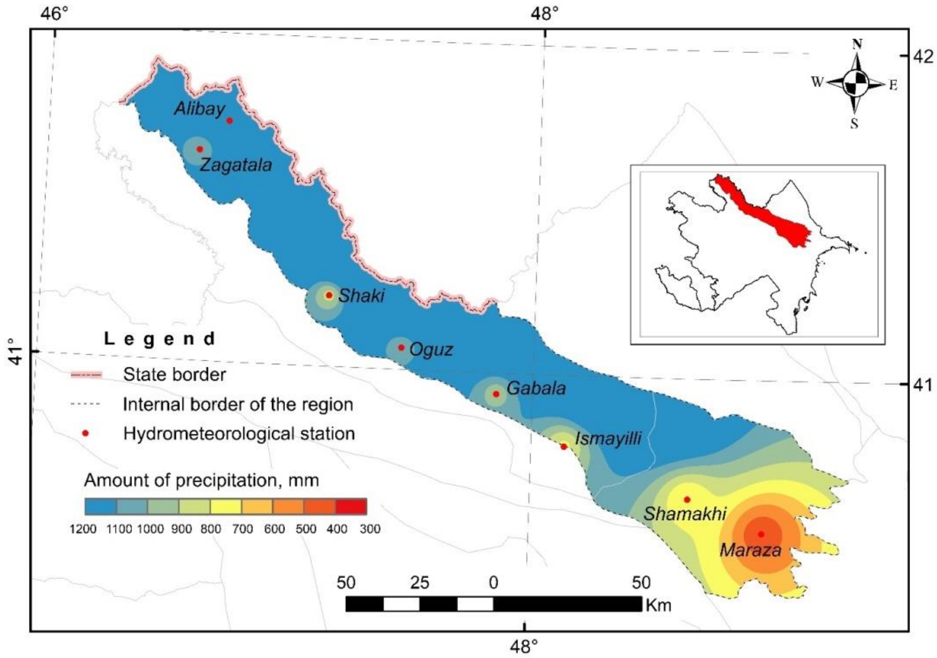
The distribution of perennial precipitation in the south of the Greater Caucasus Mountains has changed depending on the terrain characteristics. For this purpose, the results of mathematical-statistical analysis were interpolated in the IDV model for the area in the ArcGIS (Geographical Information Systems) program. If we look at the picture, in comparison with the I period, in the II period, despite the decrease of precipitation in the previous mid-mountain belt, an increase was observed in the southeastern part of the area (Fig. 1).

The change of the amount of monthly precipitation compared to the norm (1961-1990) in 1991-2020 attracts special attention. As it can be seen, in 1991-2020, the amount of precipitation decreased significantly (27%, 115 mm) throughout the year, except for July and September, at Maraza station, in contrast to other stations. The precipitation amount of other stations had weak fluctuations in January and February. In March, the amount of precipitation increased by 1-8% (0.4-7 mm) in Zagatala, Sheki and Alibey, and decreased by 7-25% (6-11 mm) in other stations. In April, except for Zagatala and Alibey, a decrease of 6-39% (6-19 mm) was observed in other stations. A decrease of 9-36% (9-19 mm) is typical in May Sheki and Meraze, and an increase of 1-8% (1-10 mm) in other areas. In June, precipitation decreased by 6-39% (11-47 mm) at all stations. In July, there was an increase of 3-38% (2-6 mm) in Zagatala and Maraza, and a decrease of 0.3-18% (0.2-13 mm) in other stations (Table 2).

Although there was an increase of 7-11% (4-8 mm) in Zagatala and Sheki in August, there was a decrease of 1-27% (2-16 mm) in other areas. In September, there was an increase of 7-25% (2-30 mm) in all stations. In October, the amount of precipitation decreased by 2-35% (2-22 mm) in other stations, except for an increase of 4% (5 mm) in Alibey. In November, an increase of 0.5-20% (0.3-14 mm) was recorded in Alibey, Sheki and Gabala, and a decrease of 2-33% (212 mm) was recorded in the remaining stations. In December, the amount of precipitation decreased by 5-37% (2-13 mm) in the region.



a)



b)

Fig. 1: *Precipitation fluctuations in 1991-2005 (a) and 2006-2020 (b)*

During 1991–2005, the precipitation anomaly decreased by 34% (142 mm), with an increase of 7% (82 mm), while during 2006–2020, it decreased by 21% (89 mm), increasing by 2% (20 mm). weakened in the range. In 1991-2020, compared to the norm, an increase of 4% (51 mm) was recorded in Alibey, and a decrease in the range of 2-27% (16-115 mm) in other stations. Looking at multi-year half-cycles, during 1991-2005 there was an average decrease of 7% (36 mm) in the south of the province, while the decrease increased to 8% (52 mm) during 2006-2020. In 1991-2020, there was a decrease of 7% (44 mm) in the indicators of precipitation.

The change in the average monthly rainfall in the area has a great impact on the seasonal indicators. Figure 2 shows the variation of seasonal rainfall anomaly indicators. If we look at the histogram, the amount of precipitation compared to the norm is 0.4-29% (1-24 mm) in winter at all stations, 3-34% (10-49 mm) in spring (except Zagatala and Alibey) and 4-25% (10 -61 mm) there was a decrease. In autumn, an increase of 4-16% (9-49 mm) was recorded in all stations, except for Maraza (23 %, 27 mm), Zagatala (5 %, 13 mm) and Sheki (6 %, 13 mm) stations. In all seasons, the amount of precipitation in Meraza station has decreased to a high level. The maximum decrease was observed in the spring season at the Maraza station (34%, 49 mm), and the maximum increase was observed in the fall (16%, 49 mm) in Alibey (Fig. 2).

Table 2: *Average monthly and annual precipitation anomalies (mm), (**dark black**-%) for 1991–2020*

Period	Station	Month												İl
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1991-2005	Zagatala	-7	1	4	-9	6	2	17	19	19	-43	1	8	18
		-18	**2**	**6**	**-9**	**5**	**2**	**22**	**26**	**22**	**-43**	**1**	**20**	**2**
	Alibey	-6	6	7	4	-1	2	-4	25	47	-11	11	1	82
		-12	**11**	**9**	**3**	**0**	**1**	**-3**	**21**	**39**	**-9**	**16**	**3**	**7**
	Sheki	-4	-2	-1	-12	-9	10	-12	5	8	-28	6	-7	-47
		-12	**-5**	**-2**	**-13**	**-9**	**10**	**-20**	**8**	**12**	**-32**	**10**	**-18**	**-6**
	Gabala	-7	5	-11	-7	17	-20	-18	-16	23	-38	6	-11	-76
		-14	**10**	**-12**	**-7**	**14**	**-17**	**-25**	**-23**	**29**	**-30**	**9**	**-20**	**-8**
	Oguz	-3	2	-2	-17	18	-36	-12	-9	28	-15	-6	-1	-53
		-6	**5**	**-3**	**-17**	**17**	**-30**	**-18**	**-15**	**38**	**-15**	**-9**	**-2**	**-6**
	Maraza	-7	-11	-9	-23	-17	-13	2	-3	-1	-28	-19	-12	-142
		-30	**-36**	**-21**	**-47**	**-33**	**-29**	**11**	**-19**	**-2**	**-59**	**-52**	**-42**	**-34**
2006-2020	Zagatala	6	-3	1	15	14	-52	-13	-3	2	-2	-4	-12	-50
		16	**-7**	**1**	**15**	**11**	**-40**	**-17**	**-5**	**2**	**-2**	**-6**	**-29**	**-5**
	Alibey	8	-10	6	16	19	-24	-6	-28	14	21	16	-11	20
		18	**-20**	**7**	**13**	**11**	**-13**	**-5**	**-24**	**12**	**17**	**23**	**-25**	**2**
	Sheki	8	-4	2	-5	-10	-39	11	4	8	-15	-5	-4	-47
		23	**-8**	**3**	**-5**	**-9**	**-38**	**19**	**7**	**12**	**-17**	**-9**	**-10**	**-6**
	Gabala	5	-1	-12	-6	-15	-33	-9	-17	12	9	10	-16	-71
		9	**-1**	**-13**	**-6**	**-13**	**-29**	**-11**	**-24**	**15**	**7**	**15**	**-29**	**-7**
	Oguz	7	2	-10	2	-11	-57	-4	-4	8	10	-7	-8	-71
		17	**3**	**-11**	**2**	**-11**	**-47**	**-5**	**-7**	**11**	**10**	**-9**	**-18**	**-8**
	Maraza	-4	-4	-12	-16	-20	-21	11	-6	5	-5	-5	-10	-89
		-15	**-14**	**-29**	**-31**	**-40**	**-47**	**66**	**-35**	**16**	**-11**	**-15**	**-32**	**-21**
1991-2020	Zagatala	0	-1	3	3	10	-25	2	8	10	-22	-2	-2	-16
		-1	**-3**	**3**	**3**	**8**	**-19**	**3**	**11**	**12**	**-22**	**-2**	**-5**	**-2**
	Alibey	1	-2	7	10	9	-11	-5	-2	30	5	14	-5	51
		3	-4	8	8	5	-6	-4	-1	25	4	20	-11	4
	Sheki	2	-3	0	-8	-9	-14	0	4	8	-22	0	-5	-47
		5	**-7**	**1**	**-9**	**-9**	**-14**	**0**	**7**	**12**	**-24**	**0**	**-14**	**-6**
	Gabala	-1	2	-11	-6	1	-26	-13	-16	18	-14	8	-13	-74
		-2	**4**	**-12**	**-6**	**1**	**-23**	**-18**	**-23**	**22**	**-11**	**12**	**-24**	**-7**
	Oguz	2	2	-6	-7	4	-47	-8	-6	18	-2	-7	-5	-62
		5	**4**	**-7**	**-8**	**3**	**-39**	**-12**	**-11**	**25**	**-2**	**-9**	**-10**	**-7**
	Maraza	-5	-8	-11	-19	-19	-17	6	-5	2	-17	-12	-11	-115
		-23	**-25**	**-25**	**-39**	**-36**	**-38**	**38**	**-27**	**7**	**-35**	**-33**	**-37**	**-27**

Fig.3 shows the dynamics of difference integrals for several typical stations. If we pay attention, the trend of precipitation in all stations increased until 1994, decreased in 1995-1996, and increased again in 1997 (Fig. 3).

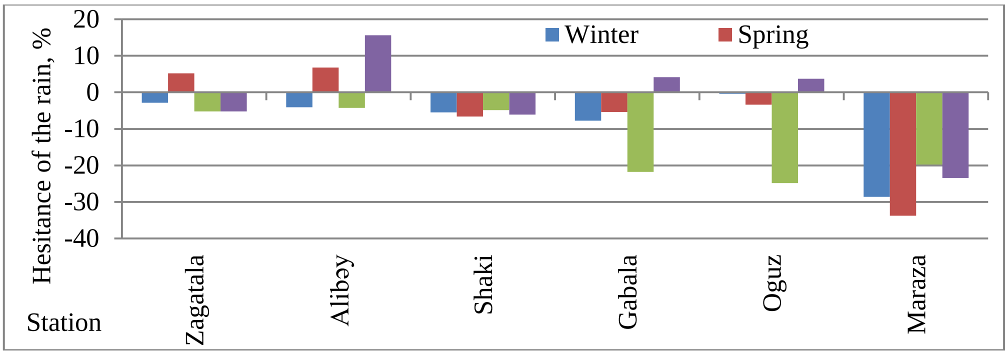


Fig. 2: *Seasonal distribution of precipitation anomalies*

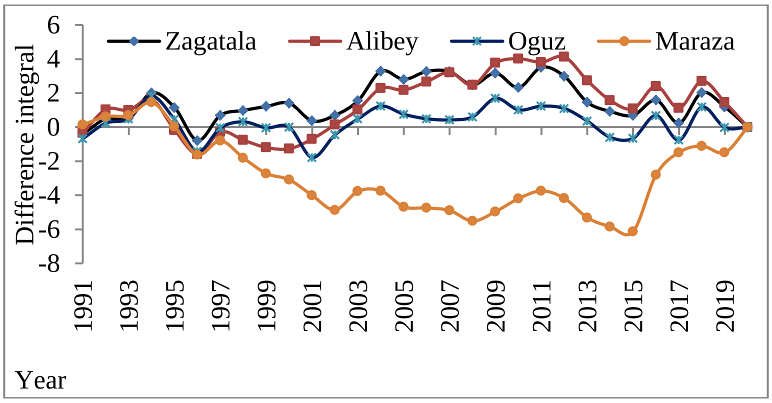


Fig. 3: *Dynamics of the difference integral of precipitation anomalies for the period 1991-2020*

The amount of precipitation in Alibey, Zagatala and Oguz stations continued to increase until 2011, despite occasional fluctuations, starting from 1997. In 2012-2020, although there was an occasional increase, it decreased for the entire period. Precipitation at Maraza station decreased sharply in 1994-2015, but increased in 2016-2020. Thus, in 1991-2020, the amount of precipitation increased in the low highlands and high highlands, while it decreased in the middle highlands of the southeastern end of this slope.

In addition, the correlation coefficients between the multi-year indicators of temperature and precipitation were calculated. The result shows that the correlation coefficients of all stations do not meet the significance coefficient of -0.5. At the stations, this relationship (-0.1 ÷ -0.4) is weaker and there is an influence of other factors besides temperature on the change of the amount of precipitation.

According to previous researchers, the rise in temperature at the beginning of summer will lead to permafrost in the mountainous belt of the province and the sudden increase in water consumption in the rivers that take the source of premature melting of glaciers from these mountains, and in summer, the melting zone will decrease, and the drought will spread with the increase of evaporation [5, 6, 10].

III. Conclusions

The following several results were obtained in the studies conducted to detect the temperature and precipitation variations of the hydrometeorological stations located on the southern slope of the Greater Caucasus physical-geographical region:

1. The average annual temperature for many years was 6.9⁰C in the middle highlands (Alibey) and 12.5⁰C (11.4-13.8⁰C) in other stations in the lowlands. In 1991-2020, the average temperature increased by 1.0⁰C (0.9-1.2⁰C) compared to the norm. .

2. The annual amount of precipitation was 1292 mm in the highlands, and 714 mm (306-943 mm) in the low highlands.

3. In 1991-2020, precipitation fluctuations were observed with an increase in Alibey station (4%) and a decrease in the range of 2-27% compared to the norm in other stations.

4. In the south of the Greater Caucasus region, 55% of the precipitation fell in the warm half-period, and 45% in the cold half-period.

Depending on the hypsometric features of the terrain, strong convection processes develop especially in the warm half-year in the region where we study the climate, but the continuation of temperature anomalies can lead to the acceleration of the recurrence of dangerous atmospheric events such as lightning and hail, as well as the shift in the time of occurrence during the year. If the fluctuations continue at this pace, the increase in air temperature in March will accelerate the vegetation, the sharp cold in April will damage the roots and stems of the plants, and the crop will be destroyed during the harvesting period in regions with constant rainfall. Drought will continue to expand in warming areas.

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