ISSN: 2634 - 8845

Journal of Earth and Environmental Science Research

Research Article

Open Access

Analysis of the Dynamics of Atmospheric Precipitation in the Territory of Azerbaijan in the Aspect of Climate Changes

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ABSTRACT

The research is based on the preliminary data of atmospheric precipitation covering the years 1981-2023 of about 70 hydrometeorological stations operating in the territory of the Republic of Azerbaijan. Using mathematical, statistical and cartographic methods in the analysis, attention was paid to the monthly, seasonal, multi-year and surface precipitation trends. In order to determine the impact of climate changes on the precipitation regime, a comparative analysis of the precipitation amount indicators of 1981-2010 and the corresponding indicators of 2011-2022 was conducted. Studies show that the amount of atmospheric precipitation has decreased by 5% (24 mm) in the territory of Azerbaijan in 2011-2023. 60% of the 10 years with the lowest multiyear precipitation are from 1989 and later. The effects of climate changes on the air temperature and atmospheric precipitation regime in the territory of Azerbaijan include the change of the traditional climate regime, the expansion of the semi-desert and dry-desert landscape in the front mountainous areas, the shift of the green landscape, the replacement of forests with forest thickets (mainly 900-1100 m), altitude up to 1000 m causes a sharp increase in the amount of possible evaporation in the area and deepening of environmental crises such as drought.

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Received: November 18, 2024; **Accepted:** November 22, 2024; **Published:** January 15, 2025

Keywords: Climate Changes, Atmospheric Precipitation, Anomaly, Climate Norm, Altitude Zone, ArcGIS

Introduction

Atmospheric precipitation is one phase of the global circulation of water vapor on Earth. Moist air masses carried by macro and micro atmospheric circulations cause precipitation due to the physical and geographical conditions of different regions [1,2]. Cloudy, strong convective processes develop along the boundaries of macro-atmospheric circulations and thundershowers occur [3,4]. On the other hand, the warm and moist air mass formed by rapid evaporation in the high temperature weather over the water bodies in the plains and lowlands cools and turns into precipitation as it rises to the highlands [5,6].

Differentiation of ecosystems under suitable weather conditions is directly related to the water supply and precipitation regime of the area. Thus, in arid deserts, the amount of precipitation is low, and the amount of possible evaporation is high. These indicators are opposite in forest and forest-steppe landscape [7,8]. In hot seasons, strong flow on dry or saturated soil surface, which cannot inflate in a small-time phase, turns into a flood [9,10].

Glaciers, river basins and underground water resources that form water resources in the regions are also distributed depending on the amount of atmospheric precipitation. Abundant precipitation throughout the year is essential to maintain permanent glaciers. Dense distribution of river networks means good development of green landscape, diversity of ecosystem and high indicators of fresh water supply of local communities [1,2,11].

In recent times, the increase in global temperature is observed with the rapid expansion of climate changes and their effects on all regions. In the territory of the Republic of Azerbaijan, which is located in the middle latitudes, where the warming has a greater effect, the air temperature has increased by 0.80C compared to the climate norm in the last 35 years [7,12].

The multi-year dynamics of air temperature in the country shows that starting from 1961-1970, compared to the previous 10 years, the temperature of the country decreased by 0.2^{0}C (-0.024^{0}C/year) in 1971-1980. In 1981-1990, this indicator was 0.1^{0}C (0.02^{0}C/year), in 1991-2000 it was 0.4^{0}C (0.03^{0}C/year), in 2001-2010 it was 0.5^{0}C (0.06^{0}C/year), in 2011-2020 It increased by 0.4^{0}C (0.04^{0}C/year), and by 0.7^{0}C (0.06^{0}C/year) in 2021-2022. The highest temperature increases in decadal periods occurred in 2001-2010. In 2010, the increase in air temperature across the country reached a record level [7,8]. This record will last from 2016 to 2023.

The temperature observed in the country in the last 7 years has been a new record every year since 1881. The temperature observed on November 17-18, 2023 became a new record since the date of hydro meteorological measurements on the globe and exceeded the climate norm of 2.06^{0}C [13-15].

In recent times, the study of the effects of climate changes has become more popular, and the study of various characteristics of precipitation in individual regions N.Sh. U.R. Taghiyeva, Y.C. Hadiyev, C.S. Huseynov, etc. has been reflected in the researches of scientists such as All the studies were conducted on individual regions, no place has been allocated to the classification of atmospheric precipitation for the whole country in recent times. The year-by-year increase and expansion of the effects of global warming has led to the worsening of its effects on the precipitation regime. Over time, the increase in the number of observations, the determination of new climate norms, and the lack of integration of research into individual regions and countries make it necessary to redefine the regularities of the distribution of atmospheric precipitation.

Material and Methods

The research was conducted on the basis of observational data on atmospheric precipitation of more than 70 hydro meteorological stations of the National Hydro meteorological Service operating in the territory of Azerbaijan during 1961-2023 [16]. Some parameters of the hydro meteorological stations whose data are used in the analysis are given in Table 1.

All statistical data used in the study were collected from periodical statistical publications of state institutions, internet resources, satellite reanalysis and research materials of various scientists [15,17, 18]. In the analysis, monthly, seasonal, seasonal and annual total indicators of precipitation, and the average indicators of the same series for multi-year were worked out. Also, the maximum and minimum monthly indicators of atmospheric precipitation cover the years 1961-2023, taking into account the possibility of recurrence in the future, and modern distributions (month, season, year, surface) under the influence of climate changes cover the years 1991-2023.

During the study of precipitation, modern methods were used. One of them is the construction of a moving average quintile curve, which is used against the possibility that random quantities with multi-year series may mislead the cyclical trend with sharp deviations in the instantaneous time phase (individual years).

In graphs, this parameter provides graph smoothing, taking into account sudden jumps of random quintile thresholds. It is possible to determine the trend of the dynamics of the considered random quantity in separate periods [4,5]. The average sliding quantity is calculated by the following formula:

$$X_{1i} = \frac{X_1+X_2+X_3...+X_{10}}{10},\ X_{2i} = \frac{X_2+X_3+X_4...+X_{11}}{10}$$

Here, X_{1i}, X_{2i} are the moving averages of ten-year precipitation.

Table 1: Main Characteristics of Hydrometeorological Stations

№	Station	Height, m	Observation Periods used in the Work, Years	Climate Norms Amount of Precipitation (1981-2010), mm
1	Mashtaga	27	1961-2023	274
2	Bakı	2	1961-2023	263
3	Jilov	-17	1961-2023	146
4	Oilrocks	-17	1961-2023	108
5	Alat	-18	1961-2018	206
6	Sumqayit	-20	1961-2023	208
7	Pirallahi	-25	1961-2023	186
8	Shahdag	2712	1992-2014, 2017-2020	740
9	Gırız	2071	1961-2022	525
10	Khinalig	2049	1991-2021	563
11	Xaltan	1104	1970-2023	480
12	Altiagaj	1099	1961-2023	502
13	Guba	550	1961-2023	523
14	Shabran	226	2017-2023	-
15	Khachmaz	27	1961-2022	307
16	Nabran	14	1992-2021	404
17	Alibay	1786	1991-2020	1335
18	Saribaşh	1680	2015-2023	-
19	Gobustan	775	1961-2023	331
20	Shamakhi	750	1961-2023	576
21	Gabala	679	1961-2023	941
22	İsmayilli	653	1983-2023	639
23	Shaki	639	1961-2023	786
24	Oguz	582	1961-2023	889
25	Zagatala	487	1961-2023	977
26	Jeyranchol	425	1966-2023	306
27	Mingachevir	93	1961-2023	349
28	Yevlakh	13	1961-2023	297
29	Tartar	107	1996-2023	332
30	Goychay	160	1961-2023	399
31	Barda	69	1984-2023	287
32	Kurdamir	2	1961-2023	339
33	Zardab	-5	1961-2023	290
34	Beylagan	62	1961-1976, 1984-2023	274
35	Imishli	-1	1961-1976, 1984-2023	277
36	Jafarkhan	-16	1961-2023	282
37	Hajigabul	-7	1961-2022	235
38	Bilasuvar	75	1961-2023	323
39	Salyan	-21	1965-2022	246
40	Neftchala	-23	1961-2023	277
41	Goytapa	2	1961-2021	611
42	Dashkasan	1614	1961-2023	667
43	Goygol	1585	1961-1990	660
44	Gadabay	1480	1961-2023	699
45	Shamkir	404	1961-2023	298
46	Agstafa	331	1961-2023	372
47	Ganja	312	1961-1976, 1984-2023	258
48	Istisu	2294	1961-2015	509
49	Shusha	1358	1961-2015	622
50	Lachin	1152	1961-2015	567
51	Khankandi	827	1961-2015	544
52	Hadrut	725	1961-2015	510
53	Jabrayil	625	1961-2015	358
54	Asgaran	540	1961-2015	529
55	Fuzuli	439	1961-2015	481
56	Agdam	378	1961-2015	489
57	Khojavand	320	1961-2015	410

58	Minjivan	313	1961-2015	428
59	Paragachay	2218	1965-2023	550
60	Bichanak	1700	2004 -2023	521
61	Shahbuz	1205	1961-2023	340
62	Sadarak	960	2005-2023	204
63	Nakhchivan	875	1961-2023	254
64	Ordubad	861	1961-2023	261
65	Sharur	812	1966-2023	244
66	Julfa	710	1961-2023	211
67	Kalvaz	1567	1961-2023	344
68	Lerik	1115	1961-2023	561
69	Yardimli	730	1961-2022	600
70	Goytapa	2	1961-2021	611
71	Lankaran	-20	1961-2023	1178
72	Astara	-23	1961-2023	1255

X1, X2, etc. and the series is the considered year and the series limits of the last 10 years included in it. The coefficient of the average moving quantity in the considered cell is equal to the average of the next 10 years in which it is included in that year. The next limit of the sliding quantity is again the average of that year's precipitation and the next 10-year limit. Thus, the rows are completed to the end. It provides smoothing on the graph.

Mathematical-statistical, physical and cartographic methods were used to determine the time-space distribution of precipitation. From the obtained results, graphs, tables and histograms were visualized in MS Excel, the map was visualized in ArcGIS 10.8, and statistical calculations were visualized in the Statistic program. Determining the modern patterns of atmospheric precipitation was carried out for the period 1991-2023, when climate changes became more severe.

In order to investigate the effects of climate changes on atmospheric precipitation, comparative analyzes of the corresponding precipitation indicators with the climate norm (1981-2010) recommended by the World Meteorological Organization were conducted [7,19]. In this study, 1961-2023 years were considered as 10-year phases to determine the trends of atmospheric precipitation in separate decades.

Discussion

Our analysis shows that in the period 2011-2023, atmospheric precipitation in Azerbaijan will decrease to a lower level of 30-34 mm in January and February (Table 3). In March (43 mm), this indicator begins to increase, in April it is around 37 mm.

Table 3: Indicators of Atmospheric Precipitation in Physical-Geographic Provinces and Regions in Different Periods (mm)

Period	Province	Months												Year
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1981-2010	Gobustan-Absheron	18	20	20	17	12	5	3	5	17	27	30	26	199
	North-east of the Great Caucasus	22	31	35	42	51	44	36	34	54	55	41	29	472
	South of the Great Caucasus	35	47	63	85	103	84	63	62	78	88	60	36	799
	Kura depression	19	24	31	32	34	24	13	13	25	38	30	19	303
	North-east of the Lesser Caucasus	18	25	37	50	78	76	46	36	36	45	30	16	492
	South of the Lesser Caucasus	21	29	46	60	82	59	32	28	36	46	36	21	495
	Nakhchıvan	21	24	35	54	52	28	13	8	15	25	27	20	323
	Lankaran lowland	52	67	64	49	46	28	19	35	95	143	98	62	758
	Country	26	33	41	49	57	44	28	28	44	58	44	29	480

2011-2023	Gobustan-Absheron	23	22	20	15	9	6	3	3	19	25	32	23	200
	North-east of the Great Caucasus	28	31	41	33	54	46	28	26	45	43	37	28	436
	South of the Great Caucasus	40	42	68	70	110	73	52	47	78	86	56	34	756
	Kura depression	23	27	28	20	32	19	11	7	23	37	24	22	274
	North-east of the Lesser Caucasus	17	25	36	41	70	59	34	22	31	41	22	17	415
	South of the Lesser Caucasus	23	38	45	39	85	65	27	24	30	60	38	27	503
	Nakhchıvan	26	24	37	38	50	21	11	6	10	26	23	28	300
	Lankaran	60	64	67	39	45	28	22	30	106	149	108	58	777
		30	34	43	37	57	40	24	21	43	58	42	30	457

The amount of precipitation increases in May (57 mm). The amount of precipitation begins to decrease from June (40 mm), reaching the minimum level of the year in July (24 mm) and August (21 mm). During the cold period, the amount of precipitation increases and is 43 mm in this month, as cold and moist air flows from the north affect the region. The amount of precipitation in the country is 58 mm in November, and the annual maximum precipitation phase is observed. Starting from November (42 mm), the amount of precipitation decreases and decreases again to 30 mm in December. The average multi-year rainfall in the territory of Azerbaijan is around 457 mm. This indicator falls to a higher level in the southern part of the Greater Caucasus province and the Lankaran plain. The lower limit of perennial precipitation is recorded in the Kura depression and Gobustan-Absheron physical-geographic region.

In the territory of the Republic of Azerbaijan, there is a different distribution of seasonal precipitation indicators during the multi-year period (2011-2022) (Figure 1). Thus, the amount of precipitation in winter, which is the coldest season, is higher in the south of the Greater Caucasus region (116 mm) and Lankaran plain (182 mm). In other provinces, this indicator varies around 60-90 mm. Although it is around 40-80 mm in Gobustan-Absheron and Kura basin in spring, the amount of precipitation in other regions increases and varies around 130-250 mm. Summer is the hottest season, and precipitation is slightly reduced during this period. In summer, the amount of precipitation does not exceed 100 mm in the Gobustan-Absheron region, Nakhchivan, Lankaran and Kura valley regions. In this season, more precipitation falls in the southern part of the Greater Caucasus and Lesser Caucasus provinces.

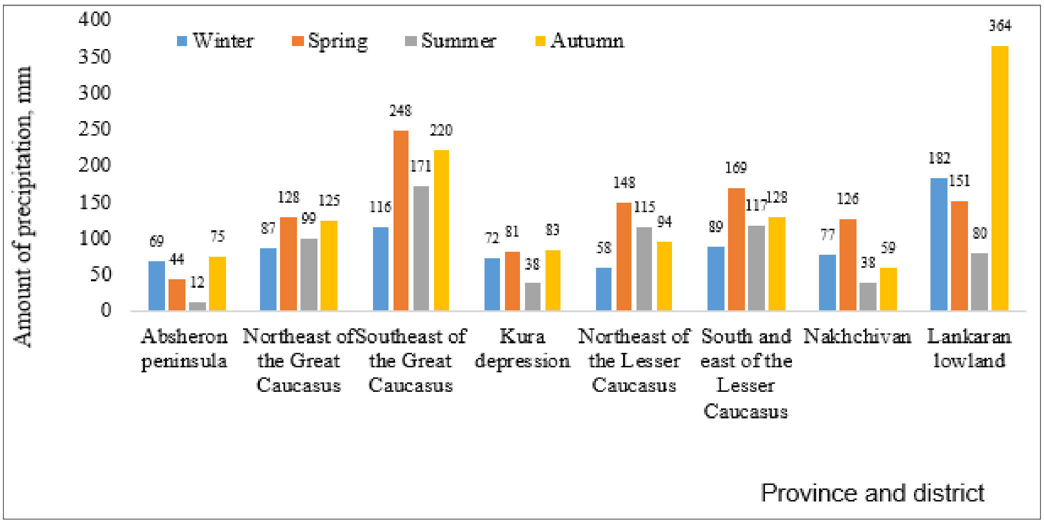


Figure 1: Seasonal Indicators of Atmospheric Precipitation in Physical-Geographic Provinces and Regions

On the territory of Azerbaijan, the amount of precipitation is higher in the southern part of the Greater Caucasus and Lesser Caucasus provinces, Lankaran lowland province in autumn. In this season, the amount of precipitation in other areas also increases relatively, but the smallness of the annual indicators does not allow it to be selected as seasonal indicators.

A graph was drawn up to monitor the dynamics of the annual amount of precipitation in the territory of Azerbaijan in 1961-2023. The country's multi-year precipitation amount, its trend line, climate norm (1981-2010) and average sliding amount are also added to the graph. If we pay attention to the graph, the multi-year indicator of annual precipitation has fluctuated around 349-695 mm in the long term. The trend of precipitation in the general period tends to decrease gradually. A straight-line trend can represent the overall trend over a period, but it does not allow determining the trend of the series in small time phases. Therefore, the moving average added to the graph shows that the country's precipitation is higher than the climate norm in 1961-1982, 2002, 2006-2009, and lower in 1983, 1986-2000, and 2010-2023 (Figure 2).

Analyzes of rainfall in individual regions show that 60% of the 10 years with the heaviest rainfall over a multi-year period occurred in 1994 and earlier. During this period, 60% of the 10 years with less precipitation occurred in 1989 and later. In the long-term period, the highest average indicators of precipitation in the territory of the Republic of Azerbaijan were observed in 1982 (673 mm) and 1963 (695 mm).

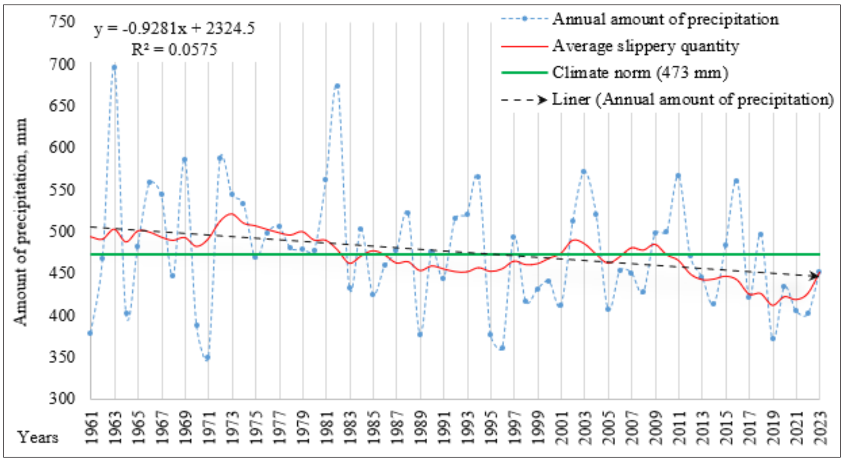


Figure 2: Multi-Year Dynamics of Average Precipitation in the Territory of Azerbaijan

The study also paid attention to the monthly changes of atmospheric precipitation in 2011-2023 compared to 1981-2010 (Figure 3). The analysis of the amount of precipitation on the surface of the country shows that although precipitation increased by 16% (4 mm) in January, 2% (1 mm) in February, 4% (2 mm) in March and 3% (1 mm) in December compared to the climate norm, in April it increased by 24%. (12 mm), decreased by 9 % (4 mm) in June, 16 % (5 mm) in July, 26 % (7 mm) in August, 4 % (2 mm) in September and 3 % (1 mm) in November. This indicator remained stable in May and October. The amount of precipitation for the whole country was 5% (24 mm) less than the climatic norm. A sharp decrease in the amount of precipitation in April, when the vegetation of the plant begins to accelerate, will lead to a decrease in productivity and damage to its root-stem system. The decrease in precipitation in April is due to the change in the characteristics of the air masses penetrating the country during this period.

Seasonal anomalies show that nationally, compared to the climate norm, winter precipitation increased by 6 mm (7 %) during 2011-2023, but by 10 mm (7 %) in spring, 16 mm (16 %) in summer, and 3 mm (3 mm) in autumn (decreased by 2%).

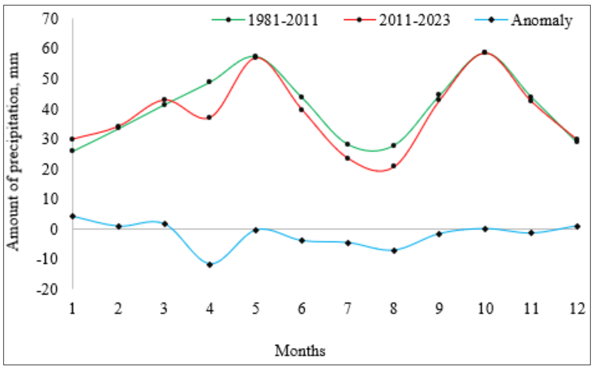


Figure 3: Monthly Trend of Atmospheric Precipitation in the Territory of Azerbaijan

Although there was a slight decrease (2%, 3 mm) in the south of the Greater Caucasus region in winter, the amount of precipitation increased in the range of 1-18 mm (1-17 %) in other regions. In spring, this indicator decreased in the range of 1-19 mm (1-18%) compared to the climatic norm across the country. More precipitation decreases were recorded in the Lesser Caucasus (10%, 17-19 mm), Nakhchivan (11%, 15mm) and Kura depression (18%, 17mm) regions. In summer, the amount of precipitation has decreased in all regions of the country. In this season, more negative precipitation anomalies were observed in the south of the Greater Caucasus region (18%, 37 mm) and in the northeast of the Lesser Caucasus region (27%, 43 mm). Although the amount of precipitation in autumn increased by 1-28 mm (2-9%) in the Gobustan-Absheron physical-geographic region, the southern part of the Lesser Caucasus (Karabakh) and the Lankaran lowland region, compared to the climatic norm, it increased by 3-25 mm (2-17%) in other stations decreased in the range.

During the multi-year period (2011-2023) across the country, the amount of precipitation increased by 1 mm (1 %) in the Gobustan-Absheron region, by 7 mm (2 %) in the south of the Lesser Caucasus, and by 19 mm (2 %) in the Lankaran plain. Compared to the climate norm during this period, 36 mm (8 %) in the northeast of the Greater Caucasus region, 49 mm (6 %) in the south, 30 mm (10 %) in the Kura depression region, 78 mm (16 %) in the northeast of the Lesser Caucasus region. The amount of precipitation decreased by 23 mm (7%) in Nakhchivan province. Also, the amount of precipitation for the whole country decreased by 24 mm (5%).

Fluctuations of atmospheric precipitation at individual stations in 2011-2023 compared to the climate norm (1981-2010) are presented in the table (Table 2). If we pay attention to the table, it is possible to see that during the last 13 years, the amount of atmospheric precipitation has decreased in April at all stations (except Mashtaga, Pirallahi, Nabran). The maximum indicators of this fluctuation were 18-34 mm at Gabala, Ismayilli, Sheki, Oguz, Jeyranchol, Dashkasan, Shusha, Khankendi, Hadrut, Askaran, Fuzuli, Aghdam, Khojavend, Paragachay, Bichenak, Shahbuz, Sadarak and Kalvez stations. In the months of July and August, we can observe the negative fluctuations of precipitation in most stations. In these months, Alibey, Dashkasan, Goygol, Gadabey and Lankaran stand out with high negative fluctuations. The analysis shows that higher increases were observed in the stations located in the plains and low mountains during the late autumn and winter months.

The highest positive anomalies across the country were 15 mm in Mashtaga, Kurdamir, Goytepe and 20 mm in Lerik in January. In February, this fluctuation was 13-14 mm in Shusha, Khankendi and Lerik. The highest positive anomaly in march is in Lerik (20 mm), in may in Minjivan (17 mm), in june in Hadrut (25 mm) and Askeran (27 mm), in august in Lankaran (16 mm), in september in Lerik and Lankaran (24-25 mm), in october it was determined in Hadrut (54 mm) and Lerik (34 mm), in november in Lankaran and Astara (37 mm), and in december in Lerik (15 mm).

The highest negative precipitation fluctuations across the country are in February in Alibey (20 mm), in March in Astara (12 m), in April in Bichenak (34 mm) and Askeran (31 mm), in May in Goygol (28 mm), in June in Dashkasan (28 mm) and Goygol (27 mm), in July in Alibey (31 mm) and Goygol (35 mm), in August in Alibey (56 mm) and Goygol (29 mm), in September in Khinalig (22 mm), in October in Khinalig and Lankaran (15 mm), in November in Zagatala (22 mm). and Goytepe (29 mm), Nabran (18 mm) and Lankaran (23 mm) in December.

In addition, the study investigated the anomalies of atmospheric precipitation in the height zones above sea level in the years 2011-2023 (Figure 4). Analyzes show that the highest precipitation reductions in the country were recorded at 1501-2000 m-altitude (99 mm).

Table 2: Fluctuations of Atmospheric Precipitation at Hydro Meteorological Stations (2011-2023)

№	Station	Months												Year
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1	Sumgayıt	3	5	4	7	-3	4	1	-1	6	1	4	0	31
2	Baku	11	11	7	-3	2	1	0	0	7	10	11	3	59
3	Mashtaga	15	2	3	0	-4	1	0	-2	0	-11	-13	0	-9
4	Pirallahi	6	0	-5	0	-6	-2	-1	-1	-3	-5	3	-4	-18
5	Chilov	0	-5	-4	-7	-4	-1	2	-2	0	-8	4	-8	-32
6	Oilrocks	-2	-1	-1	-4	-3	-1	1	-2	4	-6	-2	-2	-19
7	Alat	2	7	0	-6	-5	3	0	-5	-4	6	6	-8	-4
8	Giriz	14	-1	5	-9	15	3	-17	-13	-16	-11	-14	5	-39
9	Khınalig	5	-5	-4	-13	-5	-8	-5	-7	-22	-15	-17	-2	-99
10	Khaltan	1	-1	4	-7	7	1	1	-13	14	-9	10	-1	6
11	Altiagaj	4	0	5	-17	-8	13	-11	-8	2	-12	-2	-1	-36
12	Guba	7	3	12	-10	1	1	-10	-5	-19	-14	-5	1	-39
13	Khachmaz	0	-3	11	-9	10	2	-3	-8	-6	-10	16	15	15
14	Nabran	9	5	11	0	-2	-3	-11	-5	-19	-8	-17	-18	-58
15	Alibay	10	-20	7	-3	15	4	-31	-56	-10	1	2	-10	-89
16	Gobustan	5	4	-4	-9	4	-11	-4	-6	4	6	8	6	4
17	Shamakhi	-1	4	-2	-21	-2	-3	-2	-5	-7	-12	-5	-2	-58
18	Gabala	2	-3	13	-27	8	-7	-20	-16	-3	-4	2	0	-57
19	İsmayilli	3	0	6	-22	19	-8	-2	-2	1	3	2	-2	-2
20	Shaki	7	-7	10	-20	3	-21	-10	-11	8	-12	-14	-2	-69
21	Oguz	3	-4	4	-18	8	-21	-12	-7	-7	-8	-5	-1	-69
22	Zagatala	8	-10	7	1	6	-20	-10	-19	11	10	-22	-10	-48
23	Jeyranchöl	-5	-5	-8	-20	-10	-25	-4	-13	-8	-4	-10	-6	-118
24	Mingachevir	2	-4	0	-4	3	-17	-5	-10	-12	1	-7	-5	-59
25	Yevlakh	1	3	-2	-7	-6	-13	-11	-8	-6	7	-6	-2	-48
26	Tatar	0	4	-6	-10	1	4	3	-9	-2	-4	-6	1	-26
27	Goychay	0	7	-4	-13	-2	-3	-9	-5	1	-1	-11	2	-38
28	Barda	1	7	-3	-8	7	-4	0	-7	-10	-7	-4	-3	-30
29	Kurdamir	15	0	-4	-13	7	7	-5	-9	-11	-3	-7	0	-24
30	Zardab	7	5	-3	-11	3	-7	-3	-9	-6	-11	-3	0	-39
31	Beylagan	4	3	1	-13	-2	0	-3	-3	7	12	1	13	20

32	İmishli	11	5	-4	-17	0	-13	-1	-2	3	-4	-6	-1	-29
33	Jafarkhan	5	1	-7	-11	-9	-2	1	-3	9	-5	-8	3	-26
34	Hajigabul	3	2	-3	-12	-4	-5	2	-3	4	-6	-1	4	-21
35	Bilasuvar	8	3	-9	-18	-12	-1	6	-1	5	0	-11	6	-24
36	Salyan	8	5	-1	-14	-8	-3	-1	-5	-3	-8	-1	13	-19
37	Neftchala	3	0	2	-11	8	3	3	-2	-5	16	-4	14	27
38	Dashkasan	-3	-6	-2	-18	-10	-28	-20	-15	-5	-6	-13	-1	-128
39	Goygol	-2	-3	-1	-3	-28	-27	-35	-29	-7	-11	-1	4	-143
40	Gadabay	4	6	4	-8	8	-12	-20	-14	-2	1	-6	6	-33
41	Shamkir	-2	4	-1	-5	-3	-11	6	-9	-1	-3	-9	0	-34
42	Agstafa	-3	-4	-5	-11	-12	-18	-1	-17	-9	-6	-14	-6	-104
43	Ganja	0	5	-1	-7	-1	-5	-5	0	-2	-1	-6	-1	-23
44	Istisu	0	4	3	-10	-5	2	3	1	-5	1	1	3	-3
45	Shusha	0	14	-1	-29	9	3	-10	-8	-7	13	-3	9	-11
46	Lachin	1	7	1	-14	-7	-3	-3	-4	-7	-4	0	4	-28
47	Khankandi	-1	13	0	-29	14	2	-9	-8	-8	10	-4	8	-11
48	Hadrut	9	10	5	-24	3	25	-5	5	-11	54	18	6	95
49	Jabrayil	0	7	-4	-14	-3	0	-1	-5	-5	11	3	-1	-11
50	Asgaran	0	12	-6	-31	4	27	-13	0	-12	12	1	12	6
51	Fuzuli	1	9	-3	-20	4	6	-2	-12	-2	15	-7	6	-6
52	Agdam	0	10	2	-19	2	2	-5	-5	-6	12	-6	8	-4
53	Khojavand	11	10	-4	-29	-11	-7	-6	-4	9	15	8	9	3
54	Minjivan	5	6	4	-11	17	8	-2	2	-6	12	9	8	51
55	Paragachay	9	0	10	-20	-12	-11	-2	-4	-7	2	-3	11	-28
56	Bichanak	4	-8	-11	-34	-9	-4	-2	-8	-11	10	-11	12	-72
57	Shahbuz	8	4	0	-22	-16	-12	-5	-3	-8	-3	-5	8	-53
58	Sadarak	-1	5	11	-19	15	-7	2	-3	-6	-7	-1	9	-1
59	Naxchivan	1	-2	8	-9	3	-10	-4	-4	-1	3	-2	2	-15
60	Ordubad	8	3	-1	-9	-3	-4	0	1	-4	-2	-8	9	-10
61	Sharur	2	-1	2	-6	11	-5	-4	2	3	2	-1	2	7
62	Julfa	2	-4	2	-9	-4	-6	0	-1	0	-2	-4	7	-17
63	Kalvaz	-7	-6	-9	-18	-3	-2	-5	-1	-1	3	-8	-3	-61
64	Lerik	20	13	20	-4	12	7	3	5	24	34	29	15	177
65	Yardimli	6	4	2	-8	-6	-9	-5	0	11	16	-3	2	10
66	Goytapa	15	-15	8	-12	-1	13	4	0	-10	4	-29	-6	-29
67	Lankaran	13	-10	11	-6	-3	-4	16	-21	25	-15	37	-23	18
68	Astara	1	-5	-12	-11	-7	-3	4	-15	19	-3	37	-8	-2
Country		4	1	1	-12	0	-3	-4	-7	-2	1	-2	2	-23

This indicator is observed at a significant level in the altitude zone of 101-300 m (23 mm), 301-500 m (31 mm) and 2001-2500 m (42 mm). Smaller precipitation decreases were recorded at stations located below sea level. In addition, at an altitude of 1001-1500 m, this indicator has a positive (3 mm) anomaly for many years.

In order to analyze the trends of atmospheric precipitation in 2011-2022 compared to the years 1981-2010, the surface distribution of precipitation was analyzed by applying the IDW interpolation model in GIS (Geographic Information Systems) technology (Figure 4). If we pay attention to the map, there is a process of decreasing the amount of precipitation in the foothills of the country (low and medium highlands of the Great Caucasus Ranges) where more precipitation falls.

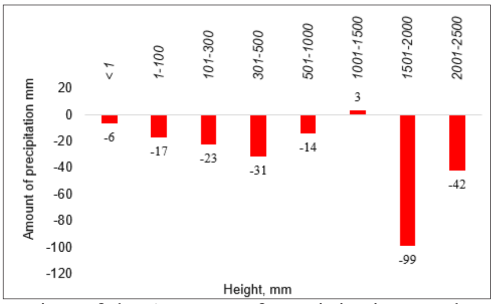
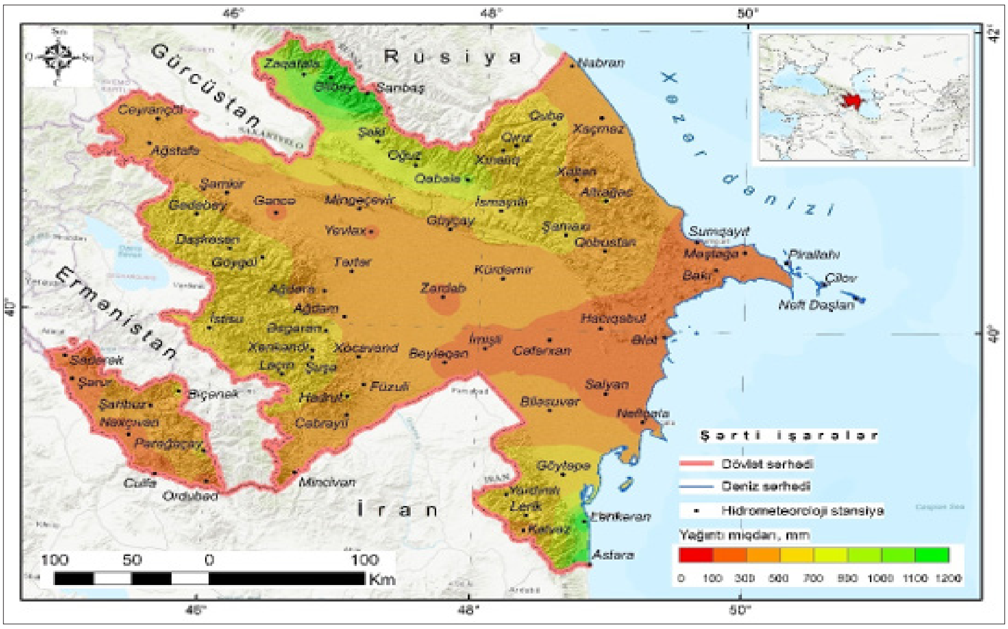
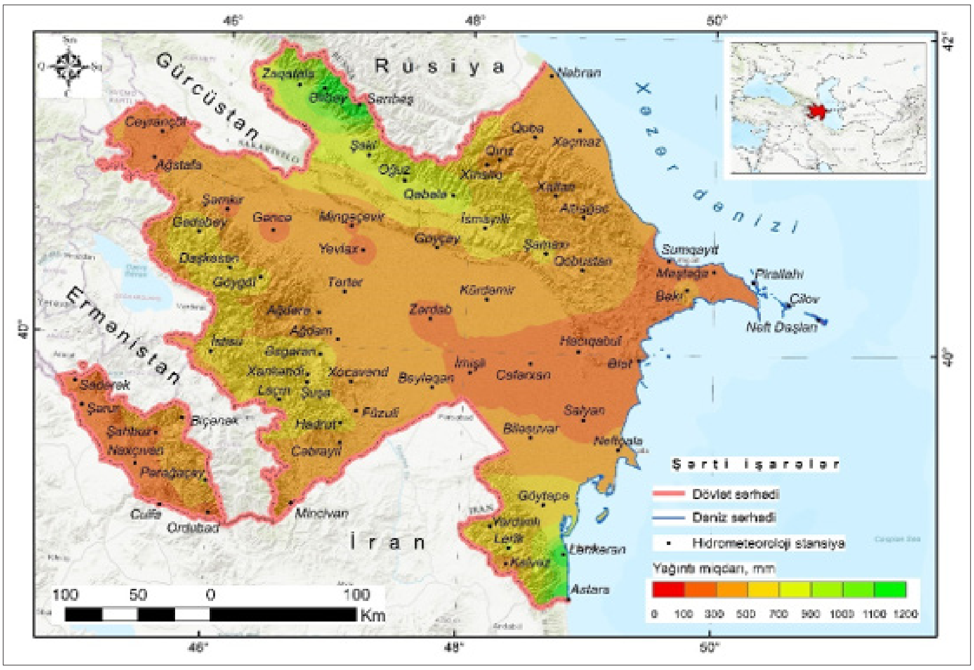


Figure 4: Fluctuation of the Amount of Precipitation on the Territory of Azerbaijan

So, as can be seen in both maps, although the 500-700 mm zones cover a large area in the first map drawn up according to the climate norm, this area has shrunk in the 2011-2023 map. In the central part of the country, the area of the 300-500 mm precipitation area in the coastal strip of the Kura-Aras plain is rapidly decreasing and the area of 100-300 mm is expanding in this zone.



(a)



(b)

Figure 5: Precipitation Map in the Territory of Azerbaijan in 1981-2010 (a) and 2011-2023

This area has also started to show itself in the western parts of the Kura depression province. As can be seen in the compiled maps, the amount of precipitation continues to decrease over time. The decrease in precipitation is associated with warming, and this process accelerates the expansion of arid and related landscape types.

The analysis of anomaly indicators in the territory of Azerbaijan raises interest in how the amount of precipitation changes in the long term. The trend of atmospheric precipitation during the period 1961-2023 was considered as 10-year periods (Figure 5). The conducted analyzes were calculated based on the data of 59 stations with intact time series. If we pay attention to the multi-year trend of atmospheric precipitation, the amount of precipitation remained almost constant in 1961-1990. However, in 1991-2000, this indicator decreased sharply (456 mm), and in 2001-2010, it slightly increased. Starting from 2011-2020, precipitation starts to decrease again across the country and has decreased to 419 mm in 2021-2023. A 3-year polynomial approximation curve has been added to the graph according to the time course of atmospheric precipitation. Here, the determination limit has a high index. This limit indicates that the 80% limit of the random variable lies above this curvilinear trend.

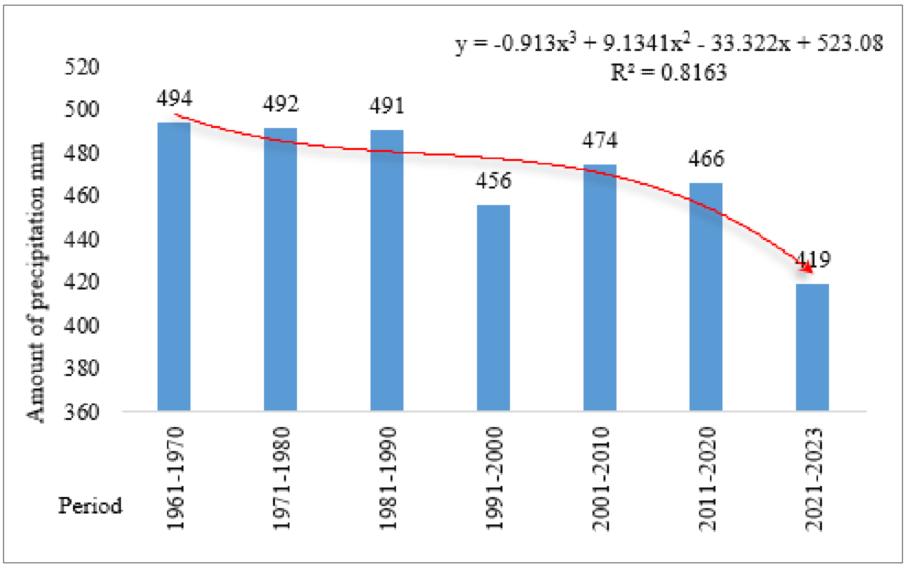


Figure 6: Tendencies of Precipitation Amount in the Territory of Azerbaijan

The Result

As a result of the comparative analysis of atmospheric precipitation in 2011-2023 compared to 1981-2010 in the territory of Azerbaijan, the following results were obtained:

- In the period 2011-2023, the amount of atmospheric precipitation decreased by 5% (24 mm) in the territory of Azerbaijan. Although this indicator increased by 6 mm (7 %) in winter, it decreased by 10 mm (7 %) in spring, 16 mm (16 %) in summer and 3 mm (2 %) in autumn. Atmospheric precipitation increased by 16% in January, 2% in February, 4% in March and 3% in December compared to the climate norm, decreased by 24% in April, 9% in June, 16% in July, 26% in August, 4% in September and 3% in November.
- 60% of the 10 years in which the heaviest precipitation was recorded in the multi-year period fell in 1994 and earlier years. During this period, 60% of the 10 years with less precipitation occurred in 1989 and later.
- Higher precipitation decreases in the country were recorded at 1501-2000 m-altitude (99 mm). This indicator is observed at a significant level in the altitude zone of 101-300 m (23 mm), 301-500 m (31 mm) and 2001-2500 m (42 mm).

The effects of climate changes on the air temperature and atmospheric precipitation regime in the territory of Azerbaijan include the change of the traditional climate regime, the expansion of the semi-desert and dry-desert landscape in the front mountainous areas, the shift of the green landscape, the replacement of forests with forest thickets (mainly 900-1100 m), altitude up to 1000 m causes a sharp increase in the amount of possible evaporation in the area and deepening of environmental crises such as drought. It is recommended to use the results of the research in the development of the alternative energy sector, in the settlement of new residential and industrial centers. The results of this study can be useful in the activities of climate atlases, glacier expeditions and ecological monitoring, which are regularly prepared for dangerous weather conditions across the country [20].

References

1. Geography of the Republic of Azerbaijan (2015) ed. RM Mammadov. - Baku: Europe, - c 1. Physical Geography 530.
2. Mammadov RM, Safarov SH, Safarov ES (2009) Current changes of the atmospheric precipitation regime on the territory of Azerbaijan. Geography and Natural Resources 30: 403-407.
3. Huseynov N Sh (2011) Synoptic meteorology / N.Ş. Huseynov. Baku: Sada 316 p.
4. Richard GT, Bridget S, Petra Döll, Matt Rodell, Rens Van Beek, et al. (2013) Ground water and climate change. Nature Climate Change 3: 322-329.
5. Mahmudov RN (2022) Regional climate changes and dangerous hydrometeorological phenomena in Azerbaijan / R.N. Mahmudov. Baku: National Aviation Academy 210.
6. Huseynov N Sh, Huseynov JS (2022) Distribution of the Contemporary Precipitation Regime and the Impact of Climate Change on it within the Territory of Azerbaijan. Journal of Geography & Natural Disasters 12: 01-07.
7. Huseynov NS, Huseynov CS (2024) Climate of Azerbaijan: Temperature regime of the air. Optimist 267.
8. Huseynov N Sh (2024) Climate change: cause, conclusion

and perspectives. Science without borders 7: 132-142.
9. Ahmadov NN (2023) Ecological impact of climate changes // Materials of the scientific-practical conference on The development of the water sector of Azerbaijan is connected with the name of national leader Heydar Aliyev. Baku 414-416.
10. Otto FEL (2023) Attribution of extreme events to climate change. Annual Review of Environment and Resources 48: 813-828.
11. Thomas D, Rachael L Sh, Cameron TW (2020) Climate Change and Society. Annual Review of Sociology 46: 135-158.
12. Huseynov JS, Tagiyev A Sh, Balammadov Sh R (2024) Characteristics of air temperature on the southern and southeastern slopes of the Greater Caucasus in the modern period. Journal of Geology, Geography and Geo Ecology 33: 475-484.
13. GISS Surface Temperature Analysis. https://data.giss.nasa.gov/gistemp/.
14. The Intergovernmental Panel on Climate Change. https://www.ipcc.ch/.
15. www.noaa.gov.
16. www.eco.gov.az.
17. www.power.larc.nasa.gov.
18. https://stat.gov.az/source/environment/.
19. World Meteorological Organization (2017) WMO Guidelines on the Calculation of Climate Normals // Geneva 1203: 29.
20. National Atlas of the Republic of Azerbaijan (2014) Baku: State Land and Mapping Committee. 444.