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Regional Climate Changes and River Runoff in Azerbaijan

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Abstract—Urgent current problems, namely, the climate change and its effects on river runoff are considered. The regional climate change at different altitudes and in separate regions of Azerbaijan is studied using long-term data of hydrometeorological observations. The trend towards the decrease in annual river runoff and peak flood discharge as well as towards the increase in winter (low-water) runoff is observed due to the influence of regional climate change.

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INTRODUCTION

According to the data of World Meteorological Organization (WMO), 80–85% of natural hazards in the world are related to hydrometeorological processes [1]. Since the climate of the Republic of Azerbaijan is a component of the global climate system, processes in this system affect the climate conditions in the country with different intensity in different time periods. So, the dynamics of various natural hazards associated with hydrometeorological processes increased on the territory of the republic that has complex climate conditions. This corroborates that climate changes are real natural hazards and require the integrated approach of scientists, politicians, and related international organizations.

At present the average long-term air temperature rise as compared with the norm (computed for the 30-year period of 1961–1990 recommended by WMO) is about 1.0 C. However, this rise is different for the Northern and Southern hemispheres and is specific in different regions of the world.

REGIONAL CLIMATE CHANGES

To investigate the regional climate change in Azerbaijan, the data of 55 weather stations are used which are located in different physiographic regions and have long-term observation series including 21 Vaisala weather stations. Three of these stations, namely, Shahdag (2712 m), Kabash (3700 m), and Tufandag (4172 m) are among the highest-altitude weather stations in the world [5].

The estimation of the anomalies of major indicators of climate change (air temperature and rainfall) in Azerbaijan for the long-term period was carried out for different altitude zones (below the sea level, 1–200 m, 201–500 m, 501–1000 m, and >1000 m above the sea level) and for the separate physiographic regions (the Greater Caucasus, Lesser Caucasus, Nakhichivan, Lankaran–Astara, Kura-Aras Lowland, and Apsheron–Gobustan) as compared with the norm for 1961–1990. Of course, data from the weather stations located in the mentioned regions and at the mentioned altitude are used.

Table 1 presents the values of average annual temperature for the periods of 1991–2006 and 2007–2014 and its anomalies as compared to the norm for the quantitative estimation of air temperature rise in different periods and at different altitudes. As compared with the first period (1991–2006), the air temperature rise in the second period (2007–2014) is more significant at all levels. The increase in average annual temperature in the whole republic was 0.6 C in 1991–2006, whereas it was equal to 0.8 C in 2007–2014. The most significant temperature rise was observed in 2010 and 2012 (1.3 C in both cases), and the minimum one

Table 1. Variations in average annual air temperature (C) at different altitudes in Azerbaijan

Parameter	Desig-nation	Period	Altitude, m					Average for the country
			0	1–200	201–500	501–1000	>1000	
Norm	N	1961–1990	14.6	14.3	13.3	11.9	7.8	12.3
Average long-term value	T_1	1991–2006	14.8	14.8	13.5	12.0	8.0	12.9
Difference $T_1 - N$			0.2	0.5	0.2	0.1	0.2	0.6
Average long-term value	T_2	2007–2014	15.4	15.3	14.2	12.4	8.8	13.1
Difference $T_2 - N$			0.9	1.0	0.9	0.5	1.0	0.8
Average long-term value	T_3	1991–2014	15.1	15.4	13.8	12.3	8.5	13.0
Difference $T_3 - N$			0.5	1.1	0.5	0.4	0.7	0.7

Table 2. The amplitude of temperature variations (C) at different altitudes and its trends in Azerbaijan in 1991–2014

Amplitude of temperature	Altitude, m					Average for the country
	<0	1–200	201–500	501–1000	>1000	
Actual	2.3	2.2	3.1	2.6	3.6	2.4
Trend	1.3	1.1	1.7	1.6	2.2	1.1

(0 C) was registered in 2011. The temperature anomaly is positive at all levels; however, the maximum rise is observed at the altitude of >1000 m above the sea level (Fig. 1).

The analysis of temperature trends at different altitudes revealed that the air temperature rise was observed in all altitude ranges in 1991–2014. The maximum amplitude of temperature was registered at the altitude of >1000 m (Table 2). The analysis demonstrates that in 1991–2014 the minimum value of annual temperature at all levels was observed in 1993 and the maximum value was registered in 2010 and 2012. At the same time, as clear from Table 2, the highest amplitude of actual values of air temperature for that period was observed at the altitude of 201–500 m (3.1 C) and >1000 m (3.6 C). The estimate of the trend indicating the temperature rise is, of course, smaller than the amplitude of actual temperature, and its maximum value for the period under consideration is registered at the same altitudes of 201–500 m (1.7 C) and >1000 m (2.2 C).

Table 3 presents variations in air temperature in 1991–2014 as compared with the norm (1961–1990). Several regions of Azerbaijan differing from each other in climate conditions are described. As clear, the maximum increase in air temperature was observed in the Lesser Caucasus (1.2 C) and Nakhichivan (0.9 C) located in the continental climate zone, and the minimum increase in air temperature in these years was registered in the Greater Caucasus (0.4 C).

Table 4 presents variations in average long-term rainfall (1991–2014) as compared with the norm (1961–1990) at different altitudes in Azerbaijan. The rainfall variations as compared with the norm are insignificant for the whole republic territory: in 1991–2014 the observed rainfall increase is 11.0 mm only. The maximum decrease in rainfall (–71 mm) was registered at the altitude of 201–500 m, and the maximum increase (77 mm) was observed at 501–1000 m. During the flood in 2010 which caused great economic damage in the lower reaches of the Kura River, the rainfall exceeded the norm by 232 mm in the same altitude range of 501–1000 m.

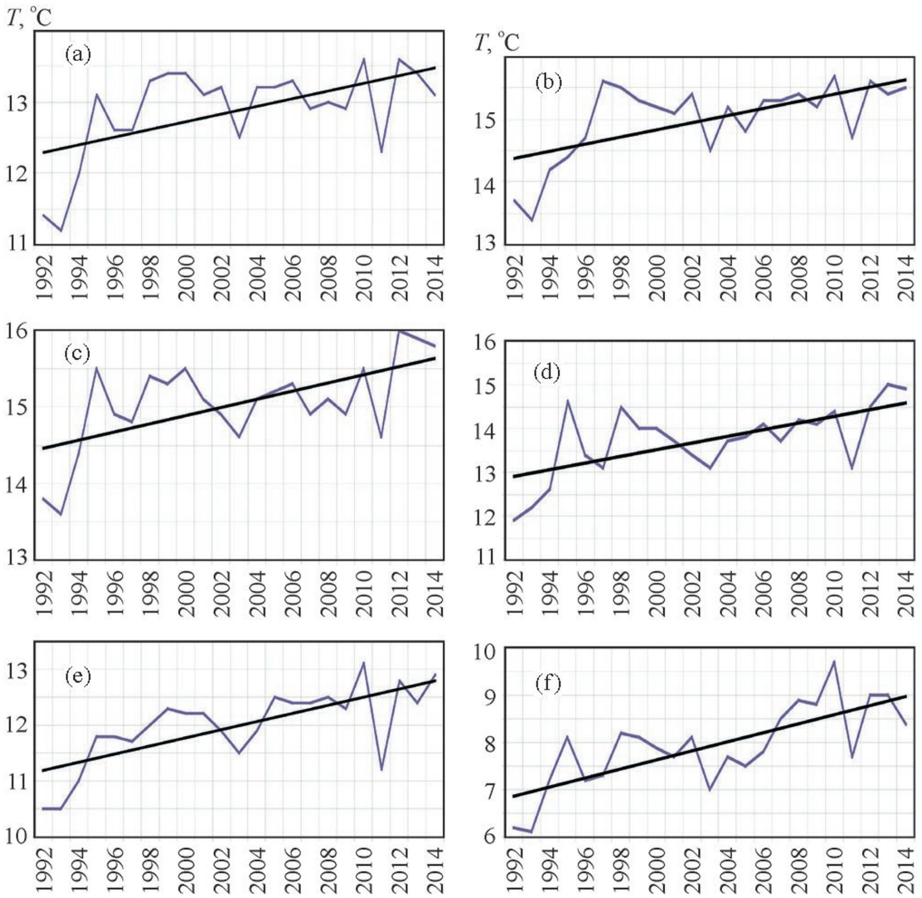

Fig. 1. Long-term variations in average annual air temperature at different altitudes in Azerbaijan in 1991–2014. The straight lines are trends. (a) Average for the country; the trend equation: $y = 0.0533x + 12.243$; (b) altitude of <0 m; $y = 0.0577x + 14.312$; (c) 0–200 m; $y = 0.0531x + 14.411$; (d) 201–500 m; $y = 0.0763x + 12.824$; (e) 500–1000 m; $y = 0.0727x + 11.119$; (f) >1000 m; $y = 0.0956x + 6.7708$.

Table 3. Temperature variations (C) in different natural regions of Azerbaijan

Parameter	Designation	Period	Region						Average for the country
			Apsheron–Gobustan	Lankaran–Astara	Greater Caucasus	Lesser Caucasus	Kura–Aras Lowland	Nakhichivan	
Norm	N	1961–1990	14.5	12.9	10.7	9.2	14.3	12.4	12.3
Average long-term value	T_3	1991–2014	15.1	13.4	11.1	10.4	14.8	13.3	13.0
Difference $T_3 - N$			0.6	0.5	0.4	1.2	0.5	0.9	0.7

EFFECTS OF CLIMATE CHANGES ON RIVER RUNOFF

To study the effects of regional climate changes on the river runoff in the republic and on its major characteristics (the maximum Q_{max}, minimum Q_{min}, and annual Q_{an} water discharge), the data were analyzed of long-term observations on the main rivers located in different physiographic regions. The long-term analysis of trends in the maximum, minimum, and annual values of river water discharge

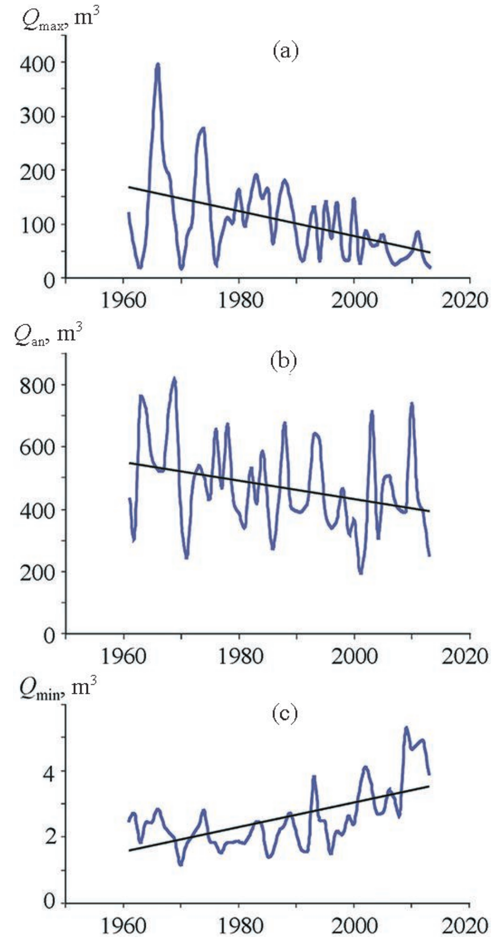

Fig. 2. Temporal variations and trends (the straight lines) in (a) the maximum Q_{max}, (b) annual Q_{an}, and (c) minimum Q_{min} river discharge in Azerbaijan. (a) the Vilyashchai River–Shykhlar; (b) the Kura River–Surra; (c) the Kudialchai River–Kyupchal.

Table 4. Rainfall variations (mm) at different altitudes in Azerbaijan

Parameter	Desig-nation	Period	Altitude, m					Average for the country
			0	1–200	201–500	501–1000	>1000	
Norm	N_X	1961–1990	334	327	478	534	639	462
Average long-term value	X	1991–2014	369	336	407	611	644	473
Difference $X - N_X$			35	9.0	–71	77	5.0	11.0

demonstrates that the maximum and annual runoff values decrease and the winter minimum runoff increases for the majority of Azerbaijan rivers (Fig. 2).

The analysis of different climatic scenarios demonstrates that the observed decrease in annual runoff of the rivers in Azerbaijan will continue [4, 5]. Such trend is registered for a number of rivers in the world including the southern rivers of Russia. The decrease in spring flood peak discharge (by about 20–40%) is observed on Western Europe rivers [2].

The increase in minimum river runoff in winter is particularly related to the origin of current climate change [3]. The most significant temperature rise is observed in winter; it increases the contribution of meltwater to the water inflow to the rivers and, at the same time, affects spring flood runoff: flood duration, runoff volume, and the peak discharge decrease.

CONCLUSIONS

Thus, the analysis of the observational data revealed the following.

In Azerbaijan in 1991–2014 the average long-term air temperature rose by 0.7 C as compared with the norm for 1961–1990. The maximum increase in temperature occurred at the altitude of 1–200 and >1000 m above the sea level. In 2007–2014 the temperature anomaly increased still more and was 0.8 C. The analysis of seasonal variations demonstrated that temperature rises in all seasons except spring. The warmest years in the republic were 2010 and 2012. In both cases the temperature anomaly as compared with the norm was equal to 1.3 C.

As to the regions, the maximum temperature rise in 1991–2014 was observed in the Lesser Caucasus (1.2 C) and the minimum one was registered in the Greater Caucasus (0.4 C).

The decrease in annual river runoff is observed. The flood peak discharge decreases and the winter minimum runoff increases.

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