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ОСОБЕННОСТИ ПРОЯВЛЕНИЯ ЭКСТРЕМАЛЬНЫХ МАКСИМАЛЬНЫХ РАСХОДОВ ВОДЫ РЕК В КОНТЕКСТЕ ГЛОБАЛЬНОГО ИЗМЕНЕНИЯ КЛИМАТА (НА ПРИМЕРЕ РЕК АРМЕНИИ)

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SPECIFIC FEATURES OF EXTREME MAXIMUM RIVER RUNOFFS IN THE CONTEXT OF GLOBAL CLIMATE CHANGE (CASE STUDY OF THE RIVERS OF THE REPUBLIC OF ARMENIA)

В статье рассматриваются особенности проявления экстремальных максимальных расходов воды рек в контексте глобального изменения климата. На примере сравнительно крупных рек Армении исследована, сравнена и оценена динамика изменений экстремальных максимальных расходов воды и температуры воздуха в период 1960–2012 гг. В исследуемых речных бассейнах наблюдается тенденция повышения температуры воздуха и уменьшения абсолютных максимальных расходов воды рек. Выявлено, что повышение температуры воздуха способствовало постепенному таянию снега, накопленного в речном бассейне зимой, вследствие чего весной абсолютные максимальные расходы воды рек изменились. В результате этого опасность возникновения наводнений резко снизилась.

***Ключевые слова**: изменение климата, максимальные расходы воды, абсолютно максимальный сток, температура воздуха, тенденция уменьшения максимального стока.*

The article compares and evaluates the dynamics of changes in extreme maximum water flow and air temperature in the period 1960–2012 for the relatively large rivers in Armenia.

There is an increasing tendency of air temperature and, on the other hand, decreasing tendency of the absolute maximum water flow of the rivers in all the studied river-basins. Obviously, it turns out that rising temperatures have contributed to a gradual melting of the accumulated snow in the river-basins in winter, so that the absolute maximum water flow of the rivers has changed in spring. As a result, the risk of flood occurrence has declined significantly.

***Keywords:** climate change, extreme runoff, absolutely maximal runoff, air temperature, tendency to reduce the maximum runoff.*

Introduction

The 20th century was marked by global changes in the social, political and economic spheres that had an impact on the state of environment, including water bodies. These changes in environmental components are connected with the increase of greenhouse gas concentration in the atmosphere and the growth of temperature of the sub-surface layer of the atmosphere. The studies by the IPCC experts indicate growth of the average annual air temperature on the Earth by 0,6–0,8 °C within the last century. If the greenhouse gas emissions keep growing at the same rate, the mean temperature of the sub-surface layer is likely to increase by 3–5 °C by the end of the 21st century [8].

The impact of global climate change is available throughout the world. Studies have shown that from 1929 to 2012 the average annual air temperature increased by 1,03 °C and precipitation decreased by 10 % in Armenia [7] compared with the average standard period 1961–1990 (adopted by the Intergovernmental Expert Group on Climate Change department). Moreover, the frequency and intensity of the dangerous phenomena have increased. Armenia has vulnerable mountain ecosystems, dry climate conditions and active exogenous processes of desertification and recurring natural disasters.

Floods have occurred much more frequently and they are much more dangerous than any natural disasters in the world. As a result significant areas of land found themselves under water causing numerous human victims and enormous material damage. Among different kinds of flood the ones which are formed in river basins are very common. They are extremely dangerous particularly for mountainous regions, because most of the river basins are located in residential areas. Floods occurring frequently and causing great material losses, destruction and human victims, mud runoffs and landslides are very common in the Republic of Armenia. However, unlike other natural disasters, floods are somehow predictable.

The aim of this study is to explore and evaluate the characteristics of the extreme runoff formation in relatively large rivers of the Republic of Armenia, their changes in 1960–2012 period compared with air temperature changes in the same river basins and identifying climate change impact on the observed extreme maximum runoffs of the river basins.

Research material and methods. Research materials are the features of observed extreme maximum runoffs and air temperatures in the relatively large rivers of the Republic of Armenia in the context of global climate change

Meteorological and hydrological data taken from Armstatehydromet official observations (1960–2012), from different departments, existing scientific sources, as well as climatic and hydrological atlases are used in the article.

The following methods have been used in this work: comparative analysis, synthesis, mathematical statistics, modeling, genetic theory, geographic interpolation and extrapolation, regression, analog methods etc. [2; 4–6].

Results and their analysis. The Republic of Armenia is located in the northeast of the Armenian Highlands, at the border of the Caucasus and Western Asia. In the north, Armenia borders with Georgia, in the east – Azerbaijan, in the west and southwest – Turkey, and in the south – Iran. The territory of the Republic of Armenia covers 29743 km^2. Armenia is a mountainous country: 76,5 % of the territory is in the altitudes of 1000–2500 metres above sea level.

Armenia is a country of climatic contrasts: because of intricate terrain, one can find wide climate diversity over even a small territory. The country has almost all types of climate, from arid subtropical to cold high mountainous climates.

The average annual ambient air temperature is 5,5 °C. The highest annual average temperature is 12–14 °C. The average annual temperature is below zero in altitudes above 2500 m. The summer is temperate: the temperature at the end of July is 16.7 °C, while in Ararat valley it ranges between 24–26 °C. The recorded absolute highest temperature is 43,7 °C [3].

Winters are cold. January is the coldest winter month, with an average temperature of –6,7 °C. The recorded absolute lowest temperature is –42 °C. Winters in the northeastern and southeastern parts of the country are temperate.

The average annual precipitation amounts to 592 mm. The most arid zones are the Ararat Valley and Meghri region, with annual precipitation of around 200–250 mm. The highest precipitation is observed in high mountainous areas: about 1000 mm per year. The average precipitation in the Ararat valley does not exceed 32–36 mm in summer months.

The average annual wind velocity in the territory of Armenia is unevenly distributed, in the range of 1,0–8,0 m/sec. Mountain winds are quite common for some regions, particularly for the Ararat valley. In summer their velocity reaches to 20 m/sec and over [7].

In Armenia the rivers belong to the Araks (76,4 % of the territory) and the Kur (23,6 %) rivers basins. These are 380 rivers having more than 10 km length in the country (fig. 1). The average density of the river network is 0,81 km / km^2 [1]. Hydrographic network is denser in folded-fractured mountains and sparser on volcanic plateau.

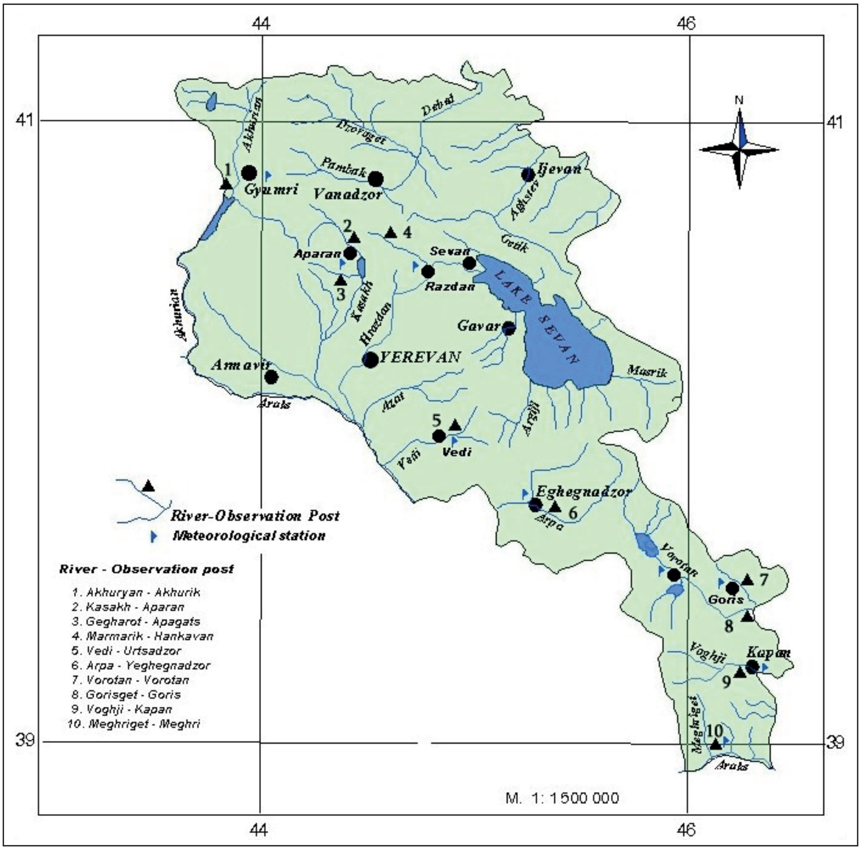

Fig. 1. Schematic map of river network of the Republic of Armenia

The hydrometric and hydrological features of the relatively large rivers of the Republic of Armenia are shown in Table 1.

Armenia's rivers generally have mixed alimentation; melting snow, rain and groundwater. The Sevjur river has only groundwater alimentation (92 %), while the Gavaraget, the Masrik rivers have mostly underground.

In general, the maximum runoffs of rivers, except in some cases, are seen during spring high-water period. As a rule, almost for all the rivers maximum runoffs are formed due to rapid snow-melting. Sometimes heavy rains are added during the spring.

Table 1

Hydrometric and hydrological features of the relatively large rivers of the Republic of Armenia

River - Observation post	Catchment area, km^2	The average height of the catchment area, m	The average annual runoff of river water, m^3/s.	Runoff module, l / sec. km^2	Absolute maximum runoff, m^3/s.	Monitoring time
1. Akhuryan - Akhurik	1060	2100	9,93	9,37	182	18.04.1968
2. Kasakh - Vardenis	441	2300	1,26	2,86	41,2	1968
3. Gegharot - Apagats	40	3100	0,96	24,0	18,7	19.07.1933
4. Marmarik - Hankavan	94	2430	1,65	17,6	31,3	26.04.1960
5. Vedi - Urtsadzor	329	2090	1,9	5,8	53,8	11.09.1974
6. Arpa - Yeghegnadzor	1220	2140	11,5	9,43	244	29.04.1969
7. Vorotan - Vorotan	2020	2280	22,6	11,0	1140	18.04.1968
8. Gorisget - Goris	85	2180	0,95	11,2	46,4	18.06.1967
9. Voghji - Kapan	685	2380	11,1	16,2	118	20.05.1976
10. Meghriget - Meghr	274	2200	3,5	12,8	87,5	12.04.1956

The studies have shown that the majority of the average annual runoff of rivers runoff (60–70 %) fall on high-water season and sometimes the runoff can exceed ten times the average annual runoff of those rivers. For instance, the absolute maximum runoff of the Vorotan and the Gorisget rivers in the Vorotan and the Goris observation post is 49–50 times more than the average annual runoff and for the Kasakh this ratio is over 32 times (tab. 1). In the case of dominance of undergroundriver alimentation the above mentioned ratio drastically decreases, which is caused by the stable alimentation regime.

Observing the changes in a relatively long period and trend equations of the absolute maximum runoffs of the four major rivers of the Republic of Armenia (fig. 2, tab. 2) it can be seen that in all the rivers the absolute maximum runoff has the tendency of reduction. In other words, it can be assumed that the level of expected hydrological disaster risk has drastically reduced. The highest observed values are for the Vorotan (–93,4 %), the Gorisget (–53,7 %) and the Gorisget (–52,4 %) rivers, and the minimum is for the Marmarik (–9 %) (tab. 2).

Comparing the observed absolute maximum runoff of the rivers with long-term changes of the air temperature in the same river basins during the same period, it is clear that the temperature has increased for all river basins (fig. 2).

Thus, it appeares that the absolute maximum air temperatures have contributed to the runoff reduction of rivers, as a result the risk of possible floods decreases.

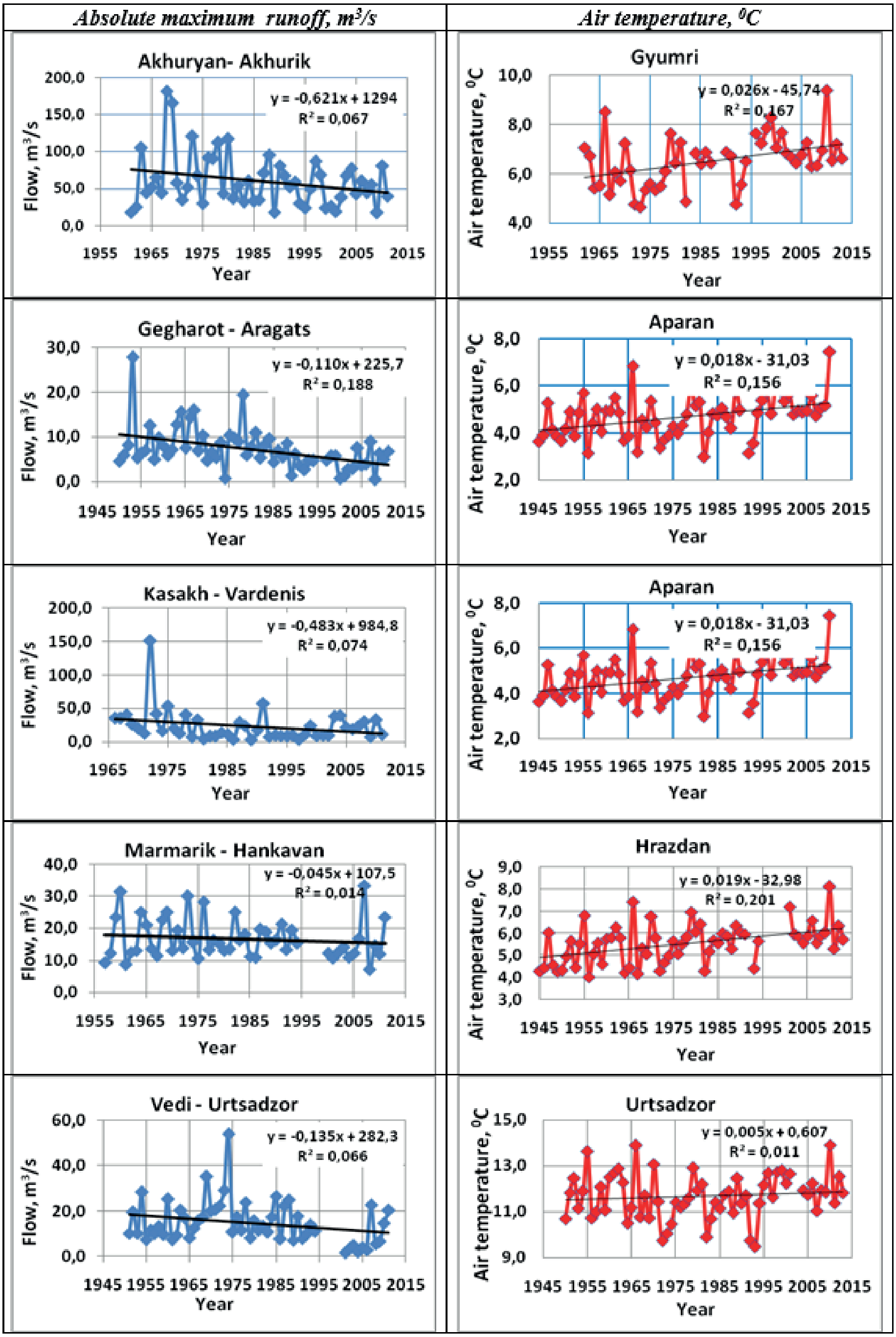

Fig. 2. Dynamics of changes of absolute maximum runoff
and average temperatures of the relatively major rivers the Republic of Armenia

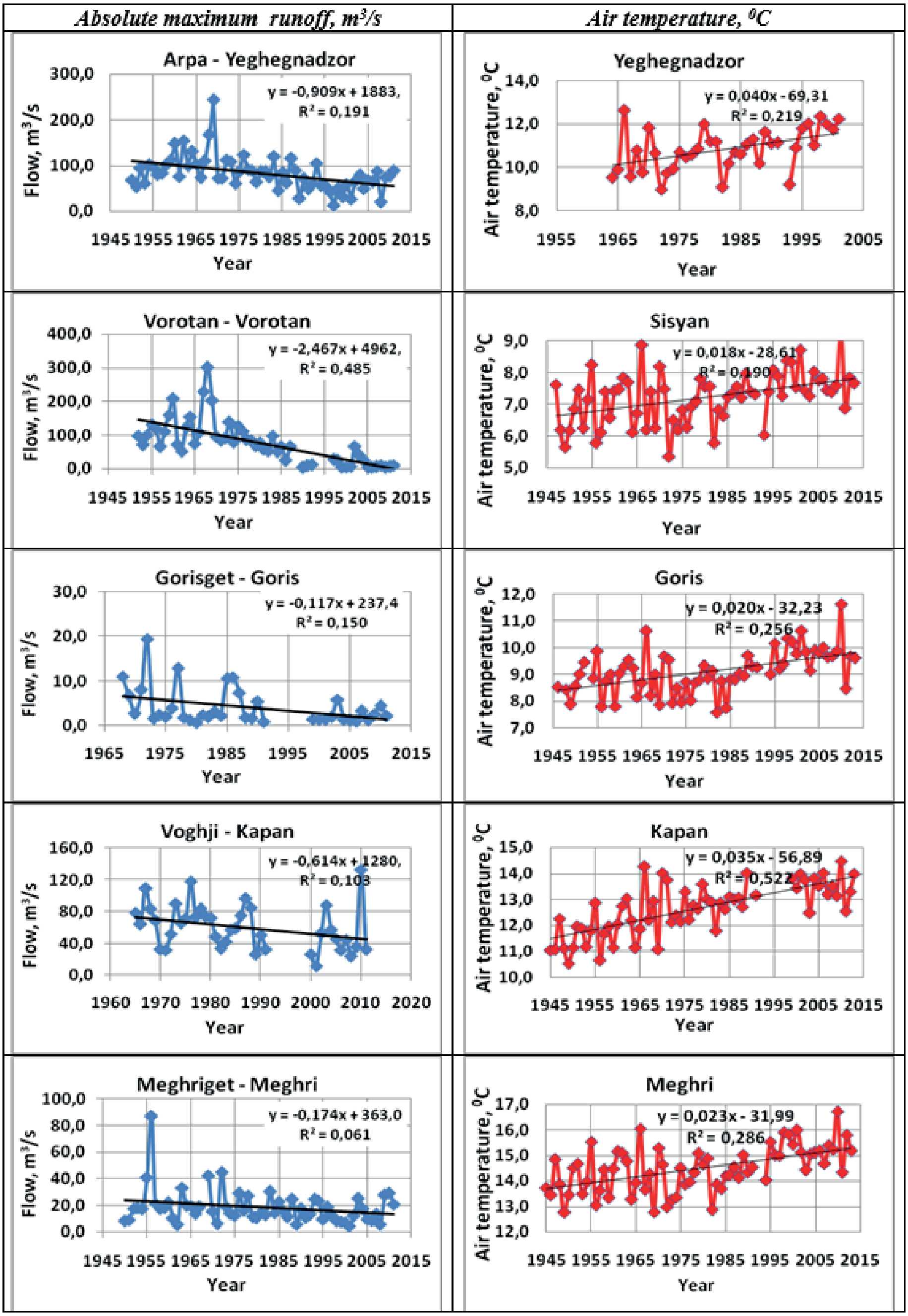

Fig. 2. Dynamics of changes of absolute maximum runoff
and average temperatures of the relatively major rivers the Republic of Armenia

This process is also observed in the rivers of Sevan lake basin [9].

In our opinion, this circumstance is explained by the fact that the snow is not completely collected in the river basins during winter because of global climate change, since from time to time it melts due to the increasing air temperature.

From early spring to late spring snow gradually melts and decreases its capacity, resulting in reduction or completely eliminates possible absolute maximum runoff, therefore, the risk of flood formation decreases.

Table 2

Change of characteristics
of absolute maximum runoff of the relatively major rivers the Republic of Armenia

River - observation post	Trendline equation	Absolute maximum runoff norm, m^3 / s	Runoff change	
			m^3 / s	%
1. Akhuryan – Akhurik	$y = -0{,}6212x + 1294$	60,2	-17,7	-29,4
2. Kasakh – Vardenis	$y = -0{,}4837x + 984{,}85$	23,1	-12,1	-52,4
3. Gegharot – Apagats	$y = -0{,}1103x + 225{,}72$	7,2	-3,2	-44,4
4. Marmarik – Hankavan	$y = -0{,}0458x + 107{,}5$	16,6	-1,5	-9,0
5. Vedi – Urtsadzor	$y = -0{,}1352x + 282{,}3$	15,1	-5,1	-33,8
6. Arpa – Yeghegnadzor	$y = -0{,}9091x + 1883{,}2$	82,7	-31,2	-37,7
7. Vorotan – Vorotan	$y = -2{,}4675x + 4962{,}4$	76,0	-71	-93,4
8. Gorisget – Goris	$y = -0{,}1174x + 237{,}47$	4,1	-2,2	-53,7
9. Voghji – Kapan	$y = -0{,}6143x + 1280{,}6$	60,3	-16,3	-27,0
10. Meghriget – Meghr	$y = -0{,}174x + 363{,}09$	18,5	-5,5	-29,7

However, in our opinion, absolute maximum runoff reduction trend is due to the fact that the average annual air temperature compared with 1961–1990 baseline period (adopted by IPCC) from 1929 to 2012 (the same studied period for the absolute maximum runoff) has increased by 1,03 °C [8]. As a result, snow has not been accumulated in many river basins and from time to time it melts due to increasing air temperature in winter. From early spring it gradually melts and the possibility of absolute maximum runoff in late spring as well as the risk of the flood occurrence decreases or completely disappeares.

In all surveyed observation points cyclic changes have been observed for the absolute maximum runoff. It consists mainly of small cycles (3–5 years of repetition). The upper parts of the basins are close to natural cycles, but in low-lying parts cycles are regulated because of human economic activity.

Conclusion. Summarizing the features of extreme maximum runoffs of the rivers the Republic of Armenia in the context of global climate change, it can be concluded that, in general, the natural and anthropogenic factors have almost similar impact on their manifestation.

There is a clear reduction potential of absolute maximum runoff dynamics in 75 % of the investigated rivers, while the average annual air temperature has increased in the same period. Consequently, we can conclude that the degree of flooding risk in the river basins drastically decreased due to the increase of average annual air temperatures in the context of global climate change.

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