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I. Sh. Normatov[1], V. V.Goncharuk[2], P. I. Normatov[3],Q. N. Odinaev[1]

[1]Tajik National University, Dushanbe, Tajikistan;
[2]A. V. Dumansky Institute of Colloid and Water Chemistry, Kiev, Ukraine;
[3]Institute of Water problems, Hydropower and Ecology AS, Dushanbe, Tajikistan.
E-mail: inomnor@gmail.com,honch@iccwc.kiev.ua, norparviz89@gmail.com

HYDROLOGY OF THE VANCH RIVER THE TRIBUTARY OF THE TRANSBOUNDARY PYANJ RIVER UNDER CLIMATE CHANGE

Abstract. For the period 1958-2018, the atmospheric precipitation in the Vanch river basin remained almost unchanged, due to the free penetration of wet masses of Mediterranean and Caucasian cyclones and the relatively weak influence of orography of the mountainous area. The average annual temperature of the considered period is characterized by weak increases of 3·10-3 °C/year. The effect of climate change on river runoff was determined by comparing their values in the two periods 1940-1970 and 1986-2016, which showed a significant increase for the period 1986-2018. The Vanch river hydrograph in the corresponding periods showed the shift of maximum runoff value to the left, which indicates an early period of melting of the snow cover and glaciers on the river upstream.

Keywords: Mountain Pamir, Pyanj river basin,, snow, runoff, orography, Vanch river, climate, hydrograph.

Introduction. The modern stage of the development of mankind proceeds in the face of constant challenges caused by global climate changes that make significant changes to the functioning of ecosystem components. Now all the efforts of human thought are aimed at developing mechanisms to mitigate the negative impacts and consequences of climate change and to adapt the entire sphere of activity to its cataclysms.

Climate change has become the greatest danger of the 21st century. Climate change manifests itself in the form of irregularities and disturbances in the climate cycle because of an increase in the temperature of the Earth due to global warming. Meteorological observations confirm that between two 30-year control periods of 1942-1972 and 1973-2003, surface temperatures in Central Asia increased by 0,65 °C. The serious effects of climate change have already begun to manifest, and the latest example of this is that 2016 has overtaken 2015; It was the warmest year in history. According to the analysis of the World Meteorological Organization (WMO) of the United Nations Climate Agency, the average global temperature in 2016 was 1.1 °C above the previous period [1].

Among all the components of the ecosystem, the mountain ecosystem is the most vulnerable and particularly sensitive to climate change. The current trend in the development of natural phenomena (climate warming, emergency situations, etc.) is of particular concern to mountain countries and stimulates the adoption of drastic measures to mitigate the effects of climate change.

For example, by the Decree of the Government of the Republic of Tajikistan dated May 3, 2010 No. 209, for the continuous monitoring and study of glaciers in Tajikistan, the State Program for the Study and Preservation of Glaciers of the Republic of Tajikistan for 2010-2030 was approved. The need to approve such a program is justified by the fact that despite the small area (slightly more than 10% of the total area of Central Asia), Tajikistan has more than 11,000 km^2 of glaciation area, occupied by more than 14 thousand glaciers and forms more than 65% of the region's water resources. The main glaciation zone of the republic is in the Pamirs with a total area of 8500 km^2 [2].

The problems of water and the consequences of global climate change are relevant and priority now for Central Asia for stimulating scientific, applied, technical, and economic research. The problem of water availability in various sectors of the economy and population has been felt since 60-70 years of the 20th century and manifestations of water scarcity has led to the concept of water security. Since then, the attention of scientists and international communities to the water problem has increased rapidly. In the last decade, studies have been conducted simultaneously on more than 50 international programs, directly or indirectly aimed at solving water security problems [3].

Water resources in the Aral Sea Basin, whose territiory belongs to five states former republics of USSR in Central Asia, are mostly used for irrigation and hydropower engineering.These water users require river runoff to be regulated with different regimes. The aim of the hydropower engineering is the largest production and, accordingly, the utilization of the major portion of annual runoff of rivers in the winter, the cjldest season of the year. Irrigation requires the largest volume to be available in the summer, during the vegatation period. River runoff regulation is exercised by large reservoirs, which, along with hydropower stations are operated as part of complex-purpose hydrochemes. The largest hydropower stations have been constructed in the republics of the runoff formation zone in the upper reaches of the Amudarya and Syrdarya rivers – in Kyrgyzstan and Tajikistan, while the major land areas to be irrigated are concentrated in the repumlics in the lower reaches of the rivers-Kazakhstan, Turkmenistan and Uzbekistan. The problems of water resources use and appropriate river runoff regulation were solved in the USSR by administrative-command methods, based on nationwide interests. The situation has radically changed after collaps of the Soviet Union and the formation of five independent states in Central Asia. The conflict of interests between hydropower engineering and irrigated farming has become evident and acquired transnational significance [4].

The total surface runoff resources in the Aral Sea Basin in the average water content year are no more than 148.5 km^3/year (116.5 km^3/year is natural river runoff) and about 32.0-33.0 km^3/year is return water. Taking into account non-productive water losses, these resources do not exceed 125.0-133.0 km^3/year [5]. Natural flow resources in the Aral Sea Basin are completely exhausted and the region's economy is developing in conditions of increasing water scarcity. Their total use already is 130-150 % in the Syr Darya basin and 100-110 % in the Amu Darya basin [6,7].

Mountain watersheds serve as important water sources by providing fresh water for downstream human activities [8,9].

As a result of snow and glacier melt, the magnitude and timing of runoff from these watersheds tend to be very sensitive to changes in the climate [10,11]. Changes of melt runoff may even affect the sustainable development of downstream cities in the long run [12,13]. Geographic areas where the water cycle is dominated by snow and glacier melt hydrology are expected to be more susceptible to climate change as it affects the seasonality of runoff [14]. Changes in seasonal snow covered and glaciated regions may alter the variability of stream flow and hence water availability that sustains a large population downstream. Despite its regional importance, there is uncertainty associated with the rates and magnitude of climate change impacts on snow cover and snow and glacier melt hydrology. These climate driven responses of mountainous river hydrology when combined with potential land cover changes, population growth, and already stressed water resources may pose significant challenges for this region. Regional climate projections by IPCC (2007) indicate Central Asia to be warmed by a median temperature of 3.7°C by the end of the 21stcentury, with largest warming over higher altitudes particularly in the Tibetan Plateau and the Himalayas [15].

In the Amu Darya and Syr Darya basins, meltwater resources contribute 69% and 79%, respectively, to mean annual streamflow, and the share of seasonal snowmelt by far outweighs that of glaciers.

According to the forecast data of the Scientific Information Center of the Interstate Coordination Water Commission of the Central Asia (SIC ICWC) in the middle of XXI the water deficit in the countries of the Amu Darya basin will be 8-11 km^3 including a decrease in runoff from climate change in 1.5-3 km^3. At population growth rate of 320 Th. people, water demand will increase by 2.5 km^3 and economic growth will require 1.5 km^3 of water. Due to the melting of glaciers, the water content of transboundary Amu Darya and Syr Darya to decrease by 12-15% by the middle of the century. For the past 35 years, water supply per capita in the Aral Sea basin has decreased from 4.500 m^3 per year to 2.150 m^3. Nevertheless, the countries of Central Asia occupy the leading places in the world in terms of water consumption per capita [10].

Planning the development of agriculture and the hydropower industry in the region is largely dependent on the current state and prospects of the water resources of the formation zone.

The results of studies on the establishment of the climate-forming role of Pamir, as well as significant differences in its climatic zones, are widely presented in the work [16] on the example of snow cover formation and atmospheric precipitation on the upper parts of the Transboundary River Pyanj of Central Asia. It has been found that the formation of snow cover and the spatial distribution of atmospheric precipitation in mountain Pamir is determined by the orography of the terrain.

On the border of the Southern and Central Pamir zones, the vertical gradient is about 40 mm for every 100 m of height, which indicates foothills that are more humid and the existence of wide basins that have an open exit to the West, to meet the wet air flows. As the air current moves deeper into the mountain area and passes through the ridges, the moist air converts moisture and becomes dry [16].

The average annual amount of atmospheric precipitation in the Eastern Pamir is insignificant and varies between 40-140 mm with an average long-term value of about 76 mm [17]. The lack of precipitation in the Eastern Pamir is due to that in the Western Pamir which is characterized by high mountain ranges (5000-6000 m a. s. l.) moist air is discharged with heavy precipitation, and the air that passes through the ridges of the Western Pamir becomes dry [18].

Objects and Methodology. The object of research is Vanch river Basin.The meteorological and hydrological data presented by the Agency for Hydrometeorology of Tajikistan were used. Statistical data processing to determine the trend of changes in meteorological and hydrological parameters and Vanch river hydrograph was used.

Hydrology of the Vanch river of the tributary of the Transboundary Pyanj river. The penetration of air masses from the Mediterranean and Caspian seas is also characteristic of the Vanch River basin. The Vanch River is one of the tributaries of the transboundary Pyanj River that is formed after the confluence of equivalent rivers Kasholyakh and Abdukahor (figure 1).

www.ai.stanford.edu www.mapsofworld.com

Figure 1 – Maps of Pyanj river basin

The Vanch is a representative of river arteries, in the formation of runoff of which an important place is played groundwater, dictated by the geological structure and distribution in the basin of permeable rocks. Measurements carried out in 1965 showed that the annual runoff module in the basin of the Geographical society glacier on the upstream of Vanch River (basin area 206 km, the share of glacial runoff 62%) is 15-60 l/km^2 · sec. In the Abdukahor river basin on the upstream of Vanch river (the basin area is 329 km, the share of glacial runoff is 42%) 28.4 l/ km^2 · sec [19]. The general tendency reduction of glaciers in Central Asia in the last century also covered the glaciers of the Vanch river basin. The processing of satellite images LANDSAT ETM + and TERRA (ASTER) allowed the authors [20,21] to establish that the glacier area of the Vanch river basin for the period 1961-2000 decreased by 23.4% and throughout the basin of the transboundary Pyanj river by 32.7%.

The average annual runoff of the Vanch river in relation to the long-term for the period 1940-2018 is present on the figure 2a.

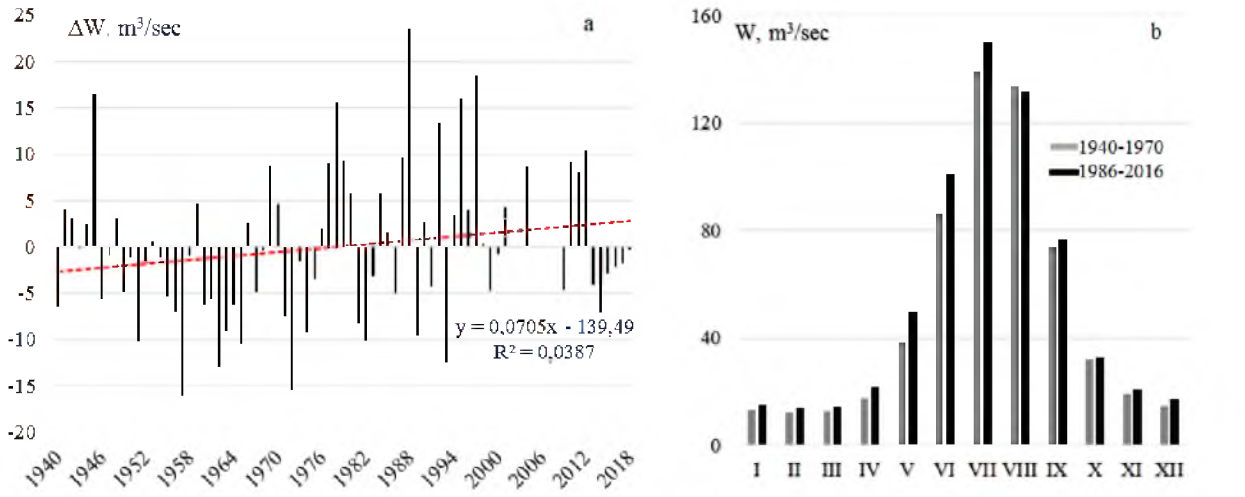

Figure 2 – The runoff (a) and hydrograph (b) of the Vanch river
in relation to the long-term for the period 1940-2018

The period is characterized by an increasing trend of river flow. In order to determine the influence of the climatic factor on the hydrological regime of the Vanch River a comparison of the dynamics of changes in the water flow of the river was made for the periods 1940-1970 and 1986-2018 (figure 2b). The hydrograph of the river for two periods (1940-1970, 1986-2018) presented on the figure 2b. It can see that the average monthly value of the water flow of the Vanch River for the period 1986-2018 exceeds the analogous values of the period 1940-1970. The nature change of river runoff in two periods indicates about the impact of climate change on the state of the ice-snow reserves of the basin on the river upstream. If take into account the low temperature changes ($3 \cdot 10^{-3}$ °C/year) for considered period, as can be seen from figure 3a and the almost constant value of atmospheric precipitation (figure 3b) then what factors contribute to the positive development trend of the river runoff.

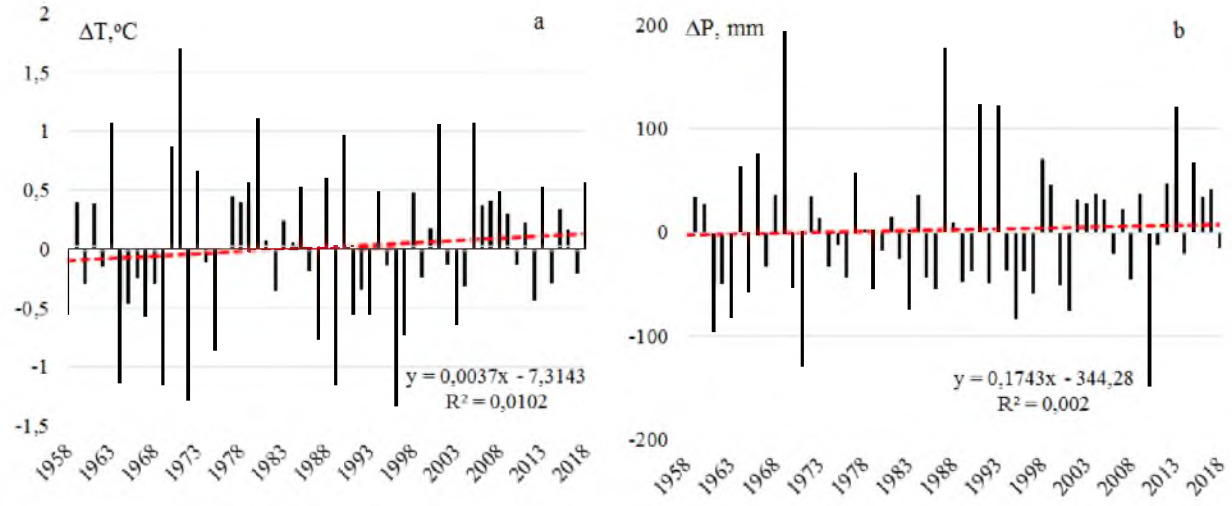

Figure 3 – A change of temperature (a) and atmospheric precipitation (b)
in relation to the long-term value in the Vanch river basin for the period 1956-2018

To receive an answer to this question the Vanch river hydrograph make up in the form shown on the figure 4a. As can see from the figure 4a the maximum of the hydrograph of the Vanch river for the period 1986-2018 is shifted to the left. Therefore, the maximum value of the water runoff is observed earlier than

the corresponding value of the period 1940-1970. The observed phenomenon can be explained in the framework of the assumption that the source of the river (glacier) is subject to degradation as a result of warming and is not a dense but loosened structure. For such structures, a small impact is sufficient to effect an aggregate transformation. Based on the obtained results it can be concluded that the glacial area of the Vanch river upstream is subject to a significant reduction. In order to establish the type of supply of the Vanch river it is sufficient to look to the figure 4b.

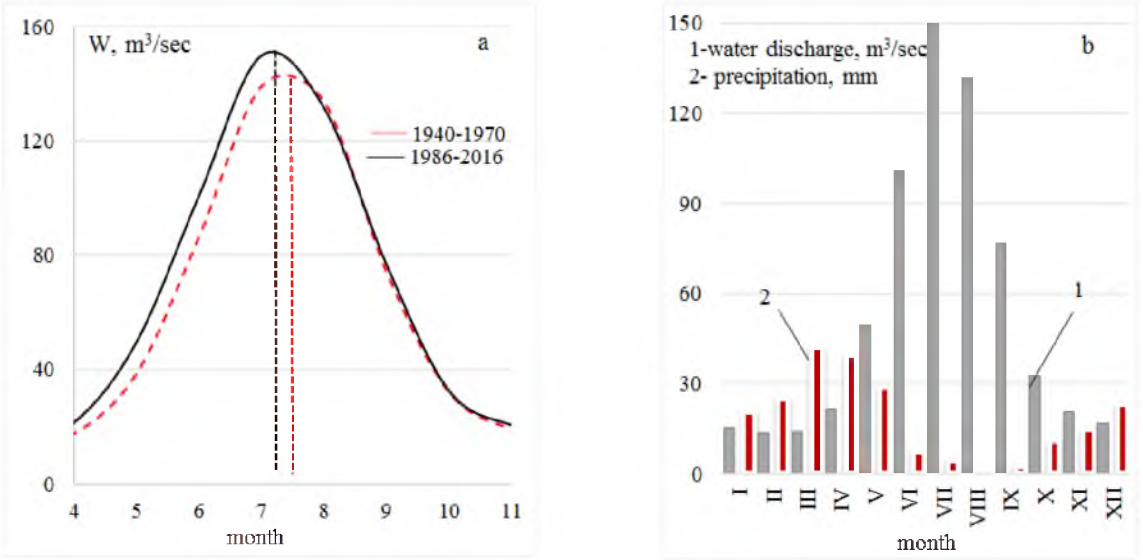

Figure 4 – Hydrograph of the Vanch river for the period 1940 -1970 (1), 1986-2018 (2) (a) and the average monthly discharge values of the Vanch river and atmospheric precipitation for the period 1940-2018 (b)

As can be seen from figure 4b, the maximum amount of precipitation in the Vanch river basin is March-April but the maximum runoff of the river is July. This means that the Vanch river is characterized by glacier feeding. Naturally, the contribution of seasonal snows to the formation of the river's water flow is not excluded. The value of water flow observing on the figure 4b indicates the predominance of the glacial feeding of the river.

Conclusion. It has been established that in the Vanch River basin, the inflow of the transboundary Pyanj River the precipitation for the period 1956-2018 remained almost constant although the temperature trend was characterized by a slight increase. Comparison river runoff in the two periods 1940-1970 and 1986-2018 was showed a significant increase for last period. The Vanch river hydrograph in the corresponding periods showed the shift of maximum runoff value to the left, which indicates an early period of melting of the snow cover and glaciers on the river upstream.

И. Ш. Норматов[1], В. В. Гончарук[2], П. И. Норматов[3], Қ. Н. Одинаев[1]

[1]Таджик ұлттық университеті, Душанбе, Тәжікстан;
[2]Думанский А. В. атындағы коллоидтық химия және су химиясы институты, Киев, Украина;
[3]Су проблемалары, гидроэнергетика және экология институты АН, Душанбе, Тәжікстан

КЛИМАТТЫҢ ӨЗГЕРУІ ЖАҒДАЙЫНДАҒЫ ТРАНСШЕКАРАЛЫҚ ПЯНДЖ ӨЗЕНІ АҒЫСЫ ВАНЧ ӨЗЕНІНІҢ ГИДРОЛОГИЯСЫ

Аннотация. Су ресурстарының проблемалары және климаттың жаһандық өзгеру салдарлары ғылыми, қолданбалы, техникалық және экономикалық зерттеулерді ынталандыру тұрғысынан қазіргі уақытта Орталық Азия үшін өзекті болып отыр. Экономиканың түрлі салалары мен халықты сумен қамтамасыз ету проблемасы XX ғасырдың 60, 70-жылдарынан бері сезіледі, ал су тапшылығының пайда болуы су қауіпсіздігі тұжырымдамасының пайда болуына алып келді. Содан бері ғалымдар мен халықаралық қоғамдастықтың су проблемасына деген қызығушылығы қарқынды түрде өсті. Соңғы онжылдықта

зерттеулер су қауіпсіздігі проблемаларын шешуге тікелей немесе жанама бағытталған 50-ден астам халықаралық багдарламалар бойынша бір мезгілде жүргізілді. Өңірде ауыл шаруашылығы мен гидроэнергетиканы дамытуды жоспарлау көп жагдайда қалыптастыру аймағының су ресурстарының ағымдагы жағдайы мен даму перспективасына байланысты.

Демек, Орталық Азияның трансшекаралық өзендері жогаргы су-мұз ресурстарының жай-күйін жүйелі түрде зерттеу және жаһандық жылыну жағдайындағы сипаттарын анықтау да, сөзсіз, өзекті болып отыр.

Жұмыстың зерттеу объектісі – Пяндж трансшекаралық өзені агынының бірі – Ванч өзенінің бассейні.

Ванч өзенінің гидрологиялық режиміне климаттық фактордың әсерін анықтау мақсатында 1940-1970 және 1986-2018 жылдары өзеннің су агысының өзгеру серпінін салыстыру жүргізілді. Егер қарастырылып отырган кезеңде температураның төмен өзгеруін ($3\cdot10^{-3}$ °С/жыл) ескеретін болса, онда атмосфералық жауын-шашынның іс жүзінде тұрақты шамасы кезінде қандай факторлар өзен ағынының оң даму үрдістеріне ықпал ететіні анықталады.

1940-1970 жылдары және 1986-2018 жылдары Өзен гидрографының құрылысымен 1986-2018 жылдары Өзен гидрографының максимумының солга ығысуы анықталды. Байқалатын құбылысты өзеннің көзі (мұздақ) жылыну нәтижесінде тозуга ұшырайды және тығыз емес, жыртылган құрылымды білдіреді деген болжам шеңберінде түсіндіруге болады. Мұндай құрылымдар үшін агрегаттық түрлендіруді жасау аз әсер етеді. Алынган нәтижелер негізінде Ванч өзенінің мұз айдыны агыс бойынша айтарлықтай қысқаруга ұшырайды деген қорытынды жасалды.

Осылайша, Ванч өзенінің бассейнінде Пяндж трансшекаралық өзені ағынының 1956-2018 жж. аралығындагы атмосфералық жауын-шашыны тұрақты болды, бірақ температуралық тренд аздаган өсумен сипатталды. Өзен ағынын салыстыру екі кезеңде – 1940-1970 және 1986-2018 жылдары жүргізілді

Түйін сөздер: Памир тауы, Пяндж өзені бассейні, қар, ағыс, орография, өзен Ванч, климат, гидрограф.

И. Ш. Норматов[1], В. В. Гончарук[2], П. И. Норматов[3], К. Н. Одинаев[1]

[1]Таджикский национальный университет, Душанбе, Таджикистан;
[2]Институте коллоидной химии и химии воды им. А. В. Думанского, Киев, Украина;
[3]Институт водных проблем, гидроэнергетики и экологии АН, Душанбе, Таджикистан

ГИДРОЛОГИЯ РЕКИ ВАНЧ ПРИТОКА ТРАНСГРАНИЧНОЙ РЕКИ ПЯНДЖ В УСЛОВИЯХ ИЗМЕНЕНИЯ КЛИМАТА

Аннотация. Проблемы водных ресуров и последствий глобального изменения климата являются актуальными и приоритетными в настоящее время для Центральной Азии с точки зрения стимулирования научных, прикладных, технических и экономических исследований. Проблема водообеспеченности различных отраслей экономики и населения ощущается с 60-70-х годов XX века, а проявления дефицита воды привели к появлению концепции водной безопасности. С тех пор внимание ученых и международного сообщества к водной проблеме стремительно возросло. В последнее десятилетие исследования проводились одновременно по более чем 50 международным программам, прямо или косвенно направленным на решение проблем водной безопасности. Планирование развития сельского хозяйства и гидроэнергетики в регионе во многом зависит от текущего состояния и перспектив развития водных ресурсов зоны формирования.

Следовательно, систематическое изучение состояния водно-ледовых ресурсов верховья трансграничных рек Центральной Азии и их поведение в условиях глобального потепления, несомненно, является актуальной.

Объектом исследования настоящей работы был бассейн реки Ванч – одной из притоков трансграничной реки Пяндж.

С целью определения влияния климатического фактора на гидрологический режим реки Ванч проведено сравнение динамики изменения водного стока реки за периоды 1940-1970 и 1986-2018 гг. Установлено, что среднемесячное значение стока воды реки Ванч за период 1986-2018 гг. превышает аналогичные значения периода 1940-1970 гг. Изменение характера речного стока в два периода свидетельствует о влиянии климатических изменений на состояние ледово-снежных запасов бассейна реки выше по течению. Если учесть низкие изменения температуры ($3\cdot10^{-3}$ °С/год) за рассматриваемый период, то при практически постоянной величины атмосферных осадков такие факторы способствуют положительной тенденции развития речного стока. При составлении гидрографа реки за периоды 1940-1970 гг. и 1986-

2018 гг. было обнаружено смещение максимума гидрографа реки за период 1986-2016 гг. влево, что указывает на ранний период таяния снежного покрова и ледников на реке выше по течению. Наблюдаемое явление можно объяснить в рамках предположения, что исток реки (ледник) подвержен деградации в результате потепления и представляет собой не плотную, а разрыхленную структуру. Для таких структур достаточно небольшого воздействия, чтобы произвести агрегатное преобразование. На основании полученных результатов был сделан вывод, что ледниковая площадь реки Ванч выше по течению подвержена значительному сокращению.

Таким образом, было установлено, что в бассейне реки Ванч – притока трансграничной реки Пяндж – атмосферные осадки за период 1956-2018 гг. оставались практически постоянными, хотя температурный тренд характеризовался незначительным повышением. Сравнение речного стока в два периода 1940-1970 и 1986-2018 гг. показало значительный рост за последний период.

Ключевые слова: Горный Памир, бассейн реки Пяндж, снег, Сток, орография, река Ванч, климат, гидрограф.

Information about authors:

Normatov Inom Sherovich, Corresponding Member of Academy of Sciences of the Republic of Tajikistan, Doctor of Chemistry, Professor, Head of the Department of Meteorology and Climatology, Tajik National University, Dushanbe, Tajikistan; inomnor@gmail.com; https://orcid.org/0000-0001-5474-584X

Goncharuk Vladislav Vladimirovich, academician of the National Academy of Sciences of Ukraine, doctor of chemical Sciences, Professor, Director of the Institute of colloid and water chemistry of the National Academy of Sciences of Ukraine, A. V. Dumansky Institute of Colloid and Water Chemistry, Kiev, Ukraine; honch@iccwc.kiev.ua; https://orcid.org/0000-0003-4594-2440

Normatov Parviz Inomovich, senior researcher at the Institute of water problems, hydropower and ecology of the Academy of Sciences of the Republic of Tajikistan; Institute of Water problems, Hydropower and Ecology AS, Dushanbe, Tajikistan; norparviz89@gmail.com; https://orcid.org/0000-0003-0322-8433

Odinaev Qodir Nodirovich, assistant of the Meteorology and Climatology Department of the Tajik National University; Tajik National University, Dushanbe, Tajikistan; muminqosim89@gmail.com; https://orcid.org/ 0000-0002-7853-2109

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