Abstract: The article discusses the change in river flow with glacial nutrition during global warming. It was established that on the Sokh river with a large share of glacial nutrition, a low-water period had been observed until the mid-seventies, after - during a period of global warming - a high-water period. Accordingly, in the cool period there was an increase in the area of glaciers, during the period of warming - a decrease. The latter can lead to a significant negative trend in runoff and an increase in its variation, which has been observed in recent decades in the river basin Isfayram.

Key words: global warming, rivers with glacial nutrition, rivers of glacial-snow nutrition, runoff distribution, water content, runoff modulus, annual runoff, glaciation, gauging station, hydrological year, mean long-term runoff; precipitation.

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About the reaction of the drain of rivers with glacier food to climate heating

On the basis of such conflicting forecasts, it is extremely difficult to draw any conclusions for planning the sustainable development of the Central Asian republics, especially Uzbekistan, and to develop adaptation measures to mitigate the possible negative effects of climate warming.

More or less confidently, one can say about the change in the annual distribution of runoff, since with the warming of the climate the proportion of liquid precipitation increases, snow accumulation decreases, the areas and volumes of glaciers decrease, which is noted by many authors [5].

However, there is no unanimity in this. For example, in [6] an almost ubiquitous increase in precipitation was noted, incl. and in the mountains, and [7] speaks of an almost universal decrease in them [7]. On the basis of the analysis of the runoff of the Zarafshan and Vakhsh rivers, it is concluded that the reduction in the area of glaciation does not have a noticeable effect on the water content of the rivers, since this effect, firstly, falls within the accuracy of annual runoff measurements, and secondly, runoff due to the melting of snow accumulated in the area of the
basin freed from ice is more important than ice under the measure at the ends of glaciers. Obviously, such a statement is difficult to agree with.

It contradicts the well-known estimates established on the basis of numerous studies and cited in generalizing monographs in various regions [8] that with an increase in the proportion of glaciers in the total catchment area:

- the drain modulus increases;
- the variability of annual runoff sharply decreases;
- in the annual distribution of runoff, the share of runoff increases for July-September, when there is an acute shortage of irrigation water during irrigated agriculture.

This article is devoted to the study of these differences based on the assessment of changes in the main elements of the flow of some rivers of the Ferghana Basin during global warming. For the characterization of runoff with a large share of glacial nutrition, the data on r. Sokh. Its watershed is located on the northern slopes of the Alai Range, it is characterized by a high degree of glaciation; about 10% of the catchment area, equal to 2480 km², is covered by glaciers. Therefore, the river belongs to the type of glacial-snow supply, is characterized by increased water content among the rivers of the Ferghana Valley.

**Table 1. Glacier areas in the Sokh river basin**

| Year | Glacier area, km² | Change, km² | Annual change in glacier area, km² |
|------|------------------|-------------|----------------------------------|
| 1948 | 170              | -           | -                                |
| 1968 | 258.7            | 88.7        | 4.44                             |
| 1975 | 282.7            | 24.0        | 3.43                             |
| 1981 | 244.1            | -38.0       | -6.44                            |
| 2001 | 198.3            | -45.8       | -2.20                            |

The data table 1 show an increase in the area of glaciers in the river basin. Sokh until the mid-seventies, and then reducing their area. This means that the change in the area of glaciation occurred in accordance with the periods of cooling and warming; in the cold period there was an increase in the area of glaciers, in the cold period there was an increase in the area of glaciers, in the period of warming - its decrease.

When studying the regime p. Sokh, data from observations of the only Sarykand gauging station on this river were used for the observation period from 1927 to 2018. During this period, at this gauging station in hydrological yearbooks, there are no average annual runoff values only for 1931 and 1942 due to a break in the observations for June 1931 and July 1942, attempts to calculate them according to the relationship between the runoffs of neighboring months and neighboring rivers for these months did not give the desired results.

Therefore, the possibility of accepting runoff over these months equal to their mean long-term values was checked. The check showed that with this method the average error in calculating the annual runoff is 3.6%, the maximum error in the absence of data for July can be 13%, for June - 9%. Thus, a full range of Sokh river runoff was obtained for 1927 - 2018.

For other rivers, the restoration of missing data was carried out on the basis of correlation between the flow of neighboring rivers at \( r = 0.86 \pm 0.92 \) [14].

Based on these data, the chronological course of the annual runoff, its values smoothed over five years, and the integral difference curves (Fig. 1), which indicate the presence in the runoff of the river, were
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| ISRA (India) | 4.971         |
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| SIS (USA)  | 0.912         |
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| IBI (India) | 4.260         |
| SJIF (Morocco) | 5.667        |
| ICV (Poland) | 6.630         |
| PIF (India) | 1.940         |
| OAJI (USA) | 0.350         |

compiled. Sokh of two main periods - low-water (until 1976) and high-water (since 1976).

The same figure shows for comparison the integral-difference curves of the annual runoff of the Tentaksay River, collecting its waters on the southwestern slopes of the Ferghana Range, and the river Padshaata - on the southeastern slopes of the Chatkal Range. In the basins of these rivers, the areas occupied by glaciers are insignificant - less than 1% of the catchment area. As can be seen from fig. 1, curve p. Padshaata is directly opposite to the curve p. Sokh, and r. Tentaxai, whose water collection is more favorably oriented with respect to moisture-bearing air masses, has a more frequent change in low-water and multi-water periods. It should be noted that the flow of these rivers is mainly formed due to precipitation of a given hydrological year.

Discussion

1. In hydrology, it has been established that glaciers are regulators of the annual flow of rivers - in years with low rainfall they replenish the flow of rivers; and vice versa - in snowy years, part of the precipitation falls on the replenishment of the consumed glacier reserves [8,15]. Therefore, the runoff of rivers with a large share of glacial nutrition is characterized by small coefficients of variation of $C_v$. For example, at r. Sokh $C_v = 0.13$. Comparison of the data table 1 and fig. 1 allows us to conclude that glaciers are not only regulators of the annual flow of rivers; such ability of glaciers is manifested even in thirty-year climatic periods. For example, on the river Sokh during the warming period (1975 - 2018), the average annual flow was higher than the cool period (1945-1974) by 12%, while on the river. Padshaata, in

Figura 1. Integral-difference curves of the annual runoff of the Sokh, Padshaata and Tentaxai rivers.
the catchment of which there are few glaciers, we have a 16% decrease in runoff.

2. An important feature of runoff from glaciers is its flow mainly in July - September, when the demand for irrigation water is greatest. Therefore, as the main indicator of the classification of mountain rivers by type of food V.L. Schultz [8] proposed the ratio of runoff for July - September to runoff for March - June \( \delta = \frac{W_{\text{VII}-\text{IX}}}{W_{\text{III}-\text{VI}}} \). The integral-difference curves \( W_{\text{VII}-\text{IX}} \), \( W_{\text{III}-\text{VI}} \) and \( \delta \) are shown in Fig. 2. Stock for July-September is 60%, for March-June - 23% per annum. As can be seen from fig. 2, the integral-difference curves \( W_{\text{VII}-\text{IX}} \), \( W_{\text{III}-\text{VI}} \) repeat the course of the integral-difference curve of the annual runoff: the period of their low values before 1976 and high values - during the period of warming after 1976 are highlighted. \( W_{\text{VII}-\text{IX}} \), this situation can be explained by the increased melting of glaciers during the warming period.

The increased runoff \( W_{\text{III}-\text{VI}} \), which is formed mainly due to precipitation from the previous winter-spring period, during the warming period cannot be explained by changes in the precipitation regime, since an increase in precipitation was not observed by meteorological observations. This is confirmed by data on the flow of the rivers of the Ferghana Valley, with a small proportion of glacial nutrition. In them, both \( W_{\text{III}-\text{VI}} \) and \( W_{\text{VII}-\text{IX}} \) significantly decreased during the warming period [14]. In this situation, the increased runoff for the period March-June can be explained only by the earlier onset of melting glaciers and replenishment of runoff of this period due to the melting of long-term ice reserves. For this reason, it is possible that the influence of climate warming on \( \delta \) by its integral-difference curve is clearly not detected (Fig. 2c).

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**Figura 1.** Integral-difference curves \( W_{\text{VII}-\text{IX}} \), \( W_{\text{III}-\text{VI}} \) and \( \delta \) p. Sokh.
3. It should be noted that there is a close relationship between the annual runoff of \( Q \) and \( Q_{\text{VII-IX}} \) of glacial rivers: the correlation coefficient \( r = 0.87 \pm 0.15 \), which is explained by the large share of runoff for VII-IX in the annual runoff. The relationship \( Q = f (Q_{\text{VII-IX}}) \) is slightly weaker, but also has a high \( r = 0.79 \pm 0.11 \). Moreover, the relationship \( Q_{\text{III}} = f (Q_{\text{VII-IX}}) \) is rather weak, \( R = 0.47 \pm 0.27 \).

4. Since July - September accounts for 60% of the annual flow of the river Sokh, we have the right to rely on determining the value of \( \delta \) by the drain of this period. However, the calculations showed that there is no connection between \( \delta \) and \( \Sigma Q_{\text{VII-IX}} - r = 0.13 \pm 0.01 \). And the dependence \( Q_{\text{III, VI}} = f (Q_{\text{VII-IX}}) \) has \( R = -0.75 \) From here the following conclusion suggests itself . The long-term average \( \delta \) value is determined by the share of glacier runoff in the long-term average runoff, and the annual \( \delta \) values are mainly a function of the total precipitation for a hydrological year. This is confirmed by the fact that the runoff of the river Sokh for the period July - September has a small coefficient of variation; \( C = 0.25 \), and in March \( C = 0.42 \).

5. The subsequent decrease in the area of glaciers can lead to a noticeable decrease in the flow of the corresponding rivers. This is already observed in river flows with a small fraction of glaciers in the total catchment area.

For example, in the river basin Isfayram with a catchment area of 2220 km², where in 1957 89 km² was occupied by glaciers, a decrease in their area by 25% led, starting in 1985, to a noticeable decrease in the annual flow of this river. This can be seen from the table 2, which presents data on the trend of runoff of the Sokh and Isfayram rivers.

It should be noted that the estimation of the linear trend \( \beta \) (angular coefficient of the straight line) in river flows, carried out using the criterion \( t \left( K_t = \frac{f}{\sigma_f} \right) \), where \( K_t \) is the sample size, \( \sigma_f \) is the variance of \( \beta \), showed its statistical insignificance in most cases, regardless of the length of the row. The relative contribution of trend \( \beta \) to the total variance of the series is also insignificant. Despite this, on the river in recent decades, it has become negative to Isfayram, and in the period 1995-2004 even significant at 0.95.

| Period       | Number of years | \( \beta \) | \( t(k-1) \) | \( a \) | Period       | Number of years | \( \beta \) | \( t(k-1) \) | \( a \) |
|--------------|-----------------|-------------|-------------|-------|--------------|-----------------|-------------|-------------|-------|
| r. Isfayram  |                 |             |             |       | r. Sokh      |                 |             |             |       |
| 1926-1960    | 35              | 0.15        | -0.07       | 0.005 | 1955-2018    | 50              | 0.104       | -0.346      | 0.065 |
| 1926-1970    | 45              | 0.05        | -0.08       | 0.044 | 1965-2018    | 40              | 0.198       | -0.616      | 0.129 |
| 1926-1980    | 55              | -0.02       | 0.016       | 0.009 | 1975-2018    | 30              | 0.23        | -0.219      | 0.087 |
| 1926-1990    | 65              | 0.02        | 0.115       | 0.066 | 1985-2018    | 20              | -0.23       | 0.237       | 0.038 |
| 1926-2004    | 79              | 0.06        | -0.273      | 0.085 | 1995-2018    | 10              | -1.20       | 3.78        | 0.278 |
| 1926-2018    | 92              | 0.05        | 0.163       | 0.024 | 2000-2018    | 18              | -0.28       | 1.89        | 0.087 |
| 1927-1960    | 34              | -0.005      | 0.0006      | 0.0001| 1955-2018    | 50              | 0.2         | -1.35       | 0.24  |
| 1927-1970    | 44              | 0.02        | 0.019       | 0.007 | 1965-2018    | 40              | 0.19        | 0.75        | 0.15  |
| 1927-1980    | 54              | 0.05        | 0.069       | 0.025 | 1975-2018    | 30              | 0.17        | 0.38        | 0.08  |
| 1927-1990    | 64              | 0.08        | 0.24        | 0.077 | 1985-2018    | 20              | 0.12        | 0.08        | 0.02  |
| 1927-2001    | 78              | 0.10        | 0.617       | 0.172 | 1995-2018    | 10              | 0.2         | 0.103       | 0.02  |
| 1927-2018    | 91              | 0.07        | 0.064       | 0.081 | 2000-2018    | 18              | 0.21        | 0.083       | 0.12  |
As a result of degradation of glaciers in the river basin. In Isfiram, the variability of its runoff during the thirty-year period of warming C_v increased by 78% compared with the previous thirty-year period, whereas on the river. Sox she decreased by 15%; on the river Isfayram the largest and smallest annual runoff values were recorded in the last two decades - 36 m³/s in 1994 and 14.3 m³/s in 2016, respectively.

Conclusion
Based on the foregoing, it can be concluded that glaciers are powerful regulators of not only annual runoff, but also for climatic periods, and their degradation during warming can lead to some complications in the water supply of irrigated areas.

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