The role of precipitation and air temperature in the formation of summer runoff

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Abstract. This article focuses on the analysis of the formation of river flow in the summer period, in which there is the greatest need for water to meet agricultural needs and there is the maximum contribution of glacier water to the total flow. To identify the influence of air temperature and precipitation in different summer months and in general for June-August, calculated were correlation coefficients between climate elements and the water content of watercourses. The steady dependence of the runoff on air temperature, both for individual months and the summer period, is generally characteristic only of the Chon and Kichi Naryn river basins.

1. Introduction
The presence of differences in the degree of glaciation of catchments and spatial heterogeneity in the mode of heat and moisture make it difficult to identify a reliable region-wide dependence of flow on air temperature and precipitation in the summer.

The research of M.N. Bolshakov [4], whose development is connected with the search for dependencies of annual runoff on annual precipitation amounts and positive temperature amounts, is rather detailed in this direction.

M.N. Bolshakov identified three groups of rivers, characterized by different leading factors in the formation of runoff: rivers, subject to fluctuations in annual precipitation amounts; rivers, the flow of which is determined by the combined effect of precipitation and air temperature; and the river, in which the flow obeys fluctuations in air temperature.

According Aizen Elena coefficient of runoff variation in Tien Shan's rivers is about 0.20, and coefficient of glacial runoff variation is about 0.15. Glacial runoff is 15–20 percent of the total volume of river runoff [13].

Aizen Elena identified two groups of hydrographs floods: one is formed from melt of seasonal snow cover, and the other is formed from melt of glacial ice [14].

2. Materials and methods
To assess the summer runoff of the Naryn River were used the hydrological and meteorological data of the archive of the Hydrometeorological Service of the Kyrgyz Republic for the period 1980-2017 [5, 7]. The methods of correlation, statistical, geographical, hydrological analyses were used.
3. Results and discussion
Differences in the altitude position of the basins, their degree of moisture, and the time of maximum precipitation fallout are reflected in the ratio of types of food and priorities of the leading climatic element on the effect on runoff. The increase in the weighted average height of the catchment was also manifested in the scale of the glaciation, the height of its lower boundary and the level of the firn (snow) line. To identify the influence of air temperature and precipitation in different summer months and in general for June-August, were calculated the coefficients of correlation between climatic elements and the water content of watercourses (Table 1).

Table 1. Correlation coefficients between costs, temperatures air (t) and precipitation (x mm).

| Hydrological posts                  | VI   | VII  | VIII | VI-VIII | Element | HMS          |
|-------------------------------------|------|------|-------|---------|---------|--------------|
| Chon Naryn - mouth                  | 0.43 | 0.39 | 0.72  | 0.31±0.14 | t       | Tien Shan    |
| Kichi Naryn - mouth                 | 0.69 | 0.39 | 0.70  | 0.62±0.09 | t       | Tien Shan    |
| Naryn – Naryn city                  | 0.23 | -0.03| 0.01  | -0.00±0.15| t       | Naryn        |
| On-Archa – On-Archa village         | 0.20 | 0.25 | -0.07 | 0.14±0.19 | t       | Naryn        |
| Kokomeren - below the mouth of the Jungal river | 0.07 | 0.24 | -0.03 | 0.17±0.16 | x       | Naryn        |
| At-Bashy – Jalgyz-Tal village       | 0.39 | -0.10| -0.53 | -0.20±0.15| t       | Naryn        |
| Chychkan - above the mouth of the river Bala-Chychkan | -0.51 | -0.52 | -0.33 | 0.53±0.14 | t       | Naryn        |

Analysis of the data in Table 1 reveals some regional and temporal features of the dependence of the flow of summer months on air temperature and precipitation. The main feature is changing in time not only of absolute values, but also of their signs. The steady dependence of the runoff on air temperature, both for individual months and the summer period, is generally characteristic only of the Bolshoi and Kichi Naryn river basins. The maximum values are in August. This month, the value of the correlation coefficient rises to 0.72. On the other tributaries, the dependence of runoff on air temperature does not differ in the closeness of the bond, and in some months it is inverse (r. Kokomeren). In general, the values of the correlation coefficients of the dependence of monthly expenditures on average monthly temperatures for the main tributaries of the Naryn River vary from 0.53 (At-Bashy, August) to 0.70 - 0.72 - along the Bolshoi and Kichi Naryn rivers.

Regional runoff dependencies on precipitation can be either direct or inverse with a wide range of values - from - 0.60 (the Chychkan River) to 0.68 (the On-Archa River) [8].

In most cases, the values of the coefficients are significantly lower than the extreme values. In this regard, the assessment of the probable error of the correlation coefficient and its significant value for various samples is of practical interest. The correlation coefficient was calculated using the formula most used in hydrometeorology:

\[ r_{xy} = \frac{\sum \Delta x \Delta y}{\sqrt{\sum \Delta x^2 \sum \Delta y^2}} \]

where: \( X \) and \( Y \), respectively, temperature and runoff, or precipitation and runoff. The probable error (Er) of the correlation coefficient (r) was determined by the formula

\[ E_r = \pm 0.674 \frac{1 - r^2}{\sqrt{n}} \]

\( n \) is the length of the row.
For the correlation coefficients presented in table 2, the probable errors are quite large — from 0.09 to 0.19 with an average value of 0.15, but given that for most cases the values of are low and the probable errors are significant, it is necessary to estimate the significance threshold correlations. Unfortunately, due to the closure of a number of hydrological posts, use homogeneous series of observations for the main tributaries of the Naryn river, was not possible.

Of the 6 considered tributary basins and the main watercourse, the 20-year observation series is represented by 4 rivers, the length of the series on two rivers is 12 years, and on one 17. With a sample of 20 years and a confidence level of 0.95 and 0.99, respectively, not less than 0.44 and 0.55, with a row length of 17 years, the threshold of significance \( r \) increases to 0.48 and 0.60, and over a period of 12 years to 0.57 and 0.70. Based on these thresholds of significance, \( r \) over the summer period, for practical use, the dependence of the flow on air temperatures for Kichi Naryn river with \( r = 0.62 \) and with some assumption in the Chychkan river basin - \( r = 0.53 ± 0.14 \). The correlation coefficients of monthly dependencies, which exceed the lower limits of dependence, revealed 7, of which 4 are related to temperature and 3 to precipitation. As a rule, significant correlation coefficients are observed only in one of the summer months, and no river has any options, when in one month there is a close dependence on air temperature, in the other - on precipitation [8, 11].

Abstracting from the quantitative value of \( r \), we draw attention to the nature of the dependence - direct or inverse. Only in two rivers - Chon and Kichi Naryn - in all summer months the dependence of the flow on air temperature is direct, the same direction of dependence, but only on precipitation, at the Atbashy and Kokomeren rivers. At the last river in June - July - August, the inverse dependence of the flow on air temperature is manifested.

Based on the postulate of A.I. Voeikova - the river is a product of climate - we should expect an increase in closeness of dependence in case of multiple correlation, in this case from two main flow-forming climatic elements - air temperature and precipitation (table 2). In this connection, calculations of the coefficients of multiple correlation between the dependence of the runoff on air temperature and precipitation and the pair correlation between the last parameters were performed. Correlation dependencies were found for the flight period.

| Station of Meteorology | Correlation coefficient  | Period          |
|------------------------|--------------------------|-----------------|
|                        | \( r_{Qtx} \)  | \( r_{tx} \)  |                 |
| Chon Naryn-Tien Shan   | 0.38±0,13     | -0.33±0,13     | 1995-2017       |
| Kichi Naryn-Tien-Shan  | 0.72±0,09     | -0.33±0,13     | 1995-2017       |
| Naryn-Naryn            | 0.24±0,14     | -0.55±0,10     | 1995-2017       |
| On-Archa-Naryn         | 0.14±0,19     | -0.63±0,12     | 1976-1987       |
| Kokomeren-Naryn        | 0.25±0,15     | -0.49±0,12     | 1980-1996       |
| At-Bashy-Naryn         | 0.55±0,10     | -0.75±0,08     | 1975-1986       |

In rivers, a decrease in flow from June to August is traced. The explanation of such an orientation of the flow regime should be sought in the joint effect of precipitation accumulated in September-June and summer temperatures in June. In July, the seasonal snow from the glaciers melts, and the formation of the runoff is due to the melting of ice due to the maximum monthly temperature. In August, the monthly amount of precipitation decreases and temperatures decrease, which immediately manifests itself in runoff volumes. Due to fluctuations in air temperature and precipitation, the nature of the spring-summer flow distribution changes. At average water levels on rivers with a small degree of glaciation (Kokomeren, Chychkan), the maximum flow is timed to June. For Chychkan river is characterized by practical equality of runoff values in June and July. On other rivers, the June (Kokomeren), July (Chon Naryn) and August (Naryn) runoffs are clearly expressed.

In years with minimal water flow, the Chychkan river reaches its maximum in May and very slowly, only by 6%, decreases by June, in August and September the decline is more intense. At Naryn river in the alignment of the city of Naryn manifests a spring and summer maximum. The first,
less significant, falls on May, the second, the main, on August. In the upper Chon Naryn river since July, the maximum flow has shifted to August.

The course of expenses of the spring-summer period per year with a minimum water content of the Kokomeren river. The largest runoff occurs in May, some decline in expenditure in June, an increase in July and a gradual decrease from September to December.

In years with maximum water content, the contrast between the flow rates of the warm and cold periods increases. On all the rivers, there is a steady increase in expenditures by the month of maximum water availability and a further decline. The greatest amplitude between the expenditures of the summer and winter months is characteristic of Kokomeren river, the smallest – Chychkan river. On these rivers, the maximum expenditure occurs in June, on the Kichi Naryn and Chon Naryn rivers in July, i.e. for the month of the greatest intensity of ice melting [1, 2, 6, 9, 10].

The shift of the months with the maximum expenditures of various rivers as a whole has a positive effect on the sustainable water supply of the region using the waters of the Naryn river.

4. Conclusion

Identified are the following features of the manifestation of dependencies and the relationship between the runoff and climate elements. Reliable, i.e. suitable for practical use, is the dependence of runoff on air temperature and precipitation only for Chon and Kichi Naryn rivers, and for preliminary assessments, such dependencies can be used for the basins of the At-Bashy and Chychkan rivers.

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