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Impact of global climate change on the surface runoff of the Chatkal River

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Abstract. Charvak reservoir is the largest reservoir in Uzbekistan. It is surrounded by the Tien Shan Mountains. The Chatkal River begins from the western part of The Tien Shan Mountains and flows into the Charvak reservoir. The average annual water discharge is 108 m^3/s and is the largest right tributary of The Chirchik River. Based on long-term observational data, intra-annual flow distribution was calculated. And trends were determined, tests for homogeneity were carried out, differential-integral curves in the observation series were evaluated. Average flow rates the error does not exceed 10%, for the coefficient of variation; the error does not exceed 15%. 4. Analysis of the difference integral curve showed since the 90s of the last century to the present time, a high water period has been observed on The Chatkal River and its tributaries. This is mainly due to the increase in annual precipitation. There is no significant change in long-term annual precipitation. However, shift happening with the type of precipitation. Namely, in the last two decades more rainy days than cold snowy days were observed.

1. Introduction

The article deals with features of the hydrological regime of the Chatkal River which is located in the territory of Uzbekistan and Kyrgyzstan [4]. Chatkal – is a mountain river and it begins from a nameless moraine lake in the territory of Kyrgyzstan [11]. It flows mainly to the west along the westernmost part of The Tien Shan Mountains. Near to the Burchmulla village (Tashkent region, Uzbekistan), it flows into The Charvak reservoir [17]. Length of the river is 217 km (until 1965 223 km) and catchment area is 6580 km^2 (7110 km^2 until 1965) [4]. The study of the hydrological regime of the Chatkal River is necessary for the effective regulation of water resources. The objective of the research is to study the hydrological regime of the Chatkal River and to evaluate the main characteristics of the intra-annual distribution of river surface runoff [3].

As observation data, we used a series of meteorological and hydrological characteristics for 8 stations and we set up a hydrological series of the average monthly, daily annual water discharge data set. All meteorological stations of the study area considered being high mountain stations in terms of altitude and all rivers surrounding The Charvak Reservoir format Charvak reservoir catchment area [16]. The nearest meteorological station to the Charvak reservoir is Chimgan and it is located on 1265 m above the sea level, the farthest station Oigaing, located on 2175 m above the sea level [9, 10].

All hydrological and meteorological stations are opened during the last century. After filling the Charvak reservoir The Chatkal River – hydrologic station at Charvak village closed. At present, the nearest hydrological station to The Charvak Reservoir is located upstream of the mouth of The Khudoydodsay River [11].

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2. Methods

2.1 Initial data

In the paper, we used the average monthly and average annual water discharge data from 4 hydrological stations of the focusing area. Locations of the hydrologic stations are given in table 2.1. The data of annual flow rates received from the department of water cadaster and meteorological measurements, Centre of Hydrometeorological Service at Ministry of Emergency Situations of The Republic of Uzbekistan and hydrologic yearbooks of the library of Russian State Hydrometeorological University [10].

Table 1. Hydrological stations of the Chatkal River.

River station	*F*, km^2	The period of observation	Observations, year
Chatkal River–at Khudoydodsay station	6580	1965-2016	52
Chatkal River–at Nayzatukay station	5520	1933-1963	26
Chatkal River–at Ters station	4090	1933-1975	39
Chatkal River–at Charvak village station	7110	1932-1963	35

2.2 Extension of the records and observations

How the various models available for filling in missing data and extension of records of the annual streamflow, corresponding to the availability and the length of data are based on the following methods commonly used methods: 1) for a long period of observations, the calculation is carried out directly from the observation data; the time period from this dataset is used in computations if its duration is 50-60 years and more; 2) if the observation is short it should be filled relatively to a longer period of observation by applying the method of hydrological analogy (river analog); 3) in the case of a series of observations very short or no data at all, annual runoff is determined by generalizations of the results of the studied river or the water balance equations are used [8, 14,15].

For design at a site where data are available the method of hydrological analogy was applied. A hydrological station, where it is necessary to fill the gaps of records of The Chatkal River, the parameters of the linear regression equation for the connection of average annual discharge is calculated. Average-flows gauged in the Khudoydodsay station are related to contemporaneous data for the Charvak village station, enabling average-flow characteristics for the Charvak village station to be transferred through the relation to the Khudoydodsay station. Fig. 2.2 shows the average flow rate relationship between two hydrologic stations. Statistically, the correlation coefficient should be at least 0.7. In our case it was 0.95.

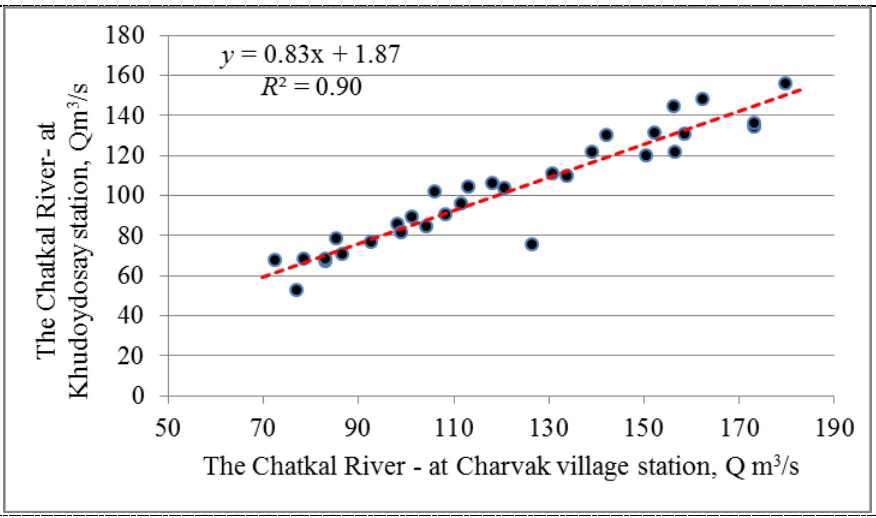

Figure 1. Average-flow correlations between two The Chatkal River streams, Khudoydodsay station and Charvak village station, 1933-1966.

Table 2. The parameters of the average-flow correlations plot of the annual discharge values between two stations of The Chatkal River – at Khudoydodsay station and The Chatkal River – at Charvak village station

Characteristics	Value
estimated river (*Y*)	Chatkal River – at Khudoydodsay station
analog-river (*X*)	Chatkal River – at Charvak village station
Observations (*n*)	32
The correlation coefficient (*R*)	0.95
Standard error of R (σ_R)	0.04
R/σ_R	23.3
the coefficient of regression (*a*)	0.83
Standard error *a* (σ_a)	0.05
a/σ_a	16.65
Independent member (*b*)	1.87
Regression Equation	$Y = 0.83 * x + 1.87$

For practical estimation, the correlation coefficient (R) ought to be at least 0.7 and in case table 2.2 this parameter is 0.95., which means we have an excellent relationship. Also for the better result it is necessary to use at least six years of simultaneous observations and in our example, it was 32 years [5].

3. Results and discussion

3.1 Extension of data set

The initial dataset for The Chatkal River – at Khudoydodsay station was from 1965 to 2014 (Figure 2). After the recovery is was extended to 32 years and became 1933-2014.

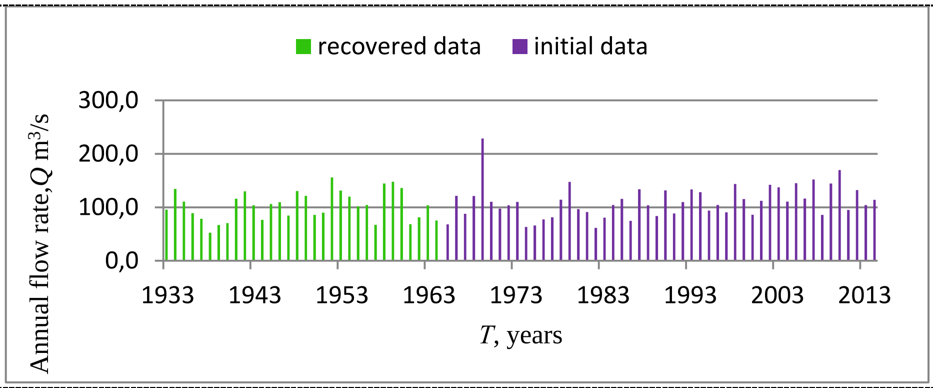

Figure 2. Histogram of annual streamflow for the Chatkal River – at Khudoydodsay station, initial with the recovered data set

3.2 Results of the estimation of main hydrological characteristics

Table 3 gives results for all analyzed hydrological stations of The Chatkal River modulus of flow (amount of water that is originating from unit area per second in liters) varies within 15-17 l/s km^2, the coefficient of variation - C_v varies between the of 0.21-0.27 [13]. At the same time, the statistical error of the average annual water flow is 8-9% and the error of C_v does not exceed 15%.

Table 3. Outcomes of the estimations of the main hydrological characteristics

Hydrological Station	Catchment area, km^2	Q_m, m^3/s	Q_m, l/s km^2	C_v	C_s	C_v/C_s	Relative error, %		
							Q_m	C_v	C_s
The Chatkal River-Nayzatukay	5520(1932-1964)	82.8	15.0	0.21	0.22	1.03	4.2	14.2	108
The Chatkal River-Ters	4090(1915-1962)	64.0	15.6	0.23	0.26	1.12	4	12	61
The Chatkal River-Khudoydodsay	6580(1965-2015)	108	16.4	0.27	0.87	3.21	8.7	8.1	32
The Chatkal River-village Charvak	7110(1933-1967)	121	17.0	0.25	0.22	0.85	4	12	85
Average value	–	–	16	0.24	0.39	1.53	5.15	11.5	71.5

3.3 The probabilistic methods of calculation of the average annual streamflow

This section provides computations of several families of distributions which are widely used in hydrology. Based on the recovered data set of The Chatkal River at Khudoydodsay Station, the mean annual streamflow is estimated and exceedance probability distribution plotted for the following families of distributions: Normal, Lognormal, Gumbel and Kritskiy-Menkel [13, 14]. For a calculated return period, the annual flow rate is given in Figure 3.

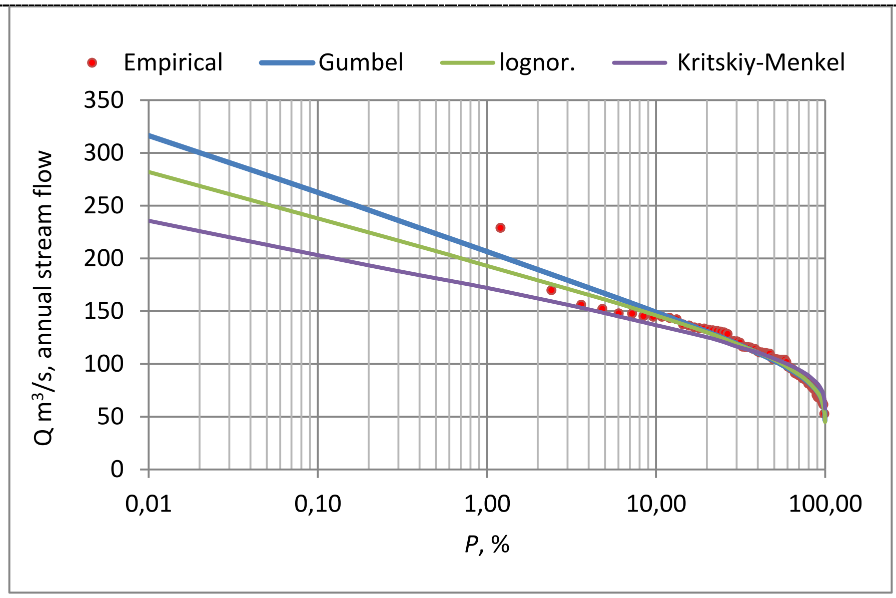

Figure 3. Comparative illustration of the average annual water flow of the exceedance probability distributions Normal, Lognormal, Gumbel and Kritskiy-Menkel

4. Conclusions

As a result of the work done, the following conclusions can be drawn: Filling gaps in observations and extension of records were carried out. For all data set, statistical characteristics and their errors are estimated, for average flow rates the error does not exceed 10%, for the coefficient of variation, the error does not exceed 15%.

For analysis of probabilities, empirical, and Gumbel distribution function were plotted. Gumbel distribution best describes exceedance probability distributions.

The impact of Global Climate Change to Tien-Shan mountains is obvious, however, this impact still keeps within the allowed interval or statistically insignificant.

As an example, it was the Gumbel (Generalized Extreme Value Distribution Type-I) was chosen. In the empirical distribution plot, one observation year strongly deviates from the others. This is the average annual water discharge for 1969, which was extremely high due to heavy snowfall and relatively long winter. The Gumbel distribution best fits because it lays more close among others to this point, hence it illustrates fits the maximum average annual flow rate.

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