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Altitude regularity of climatic factors in suspended sediments flowing formation of Mountain Rivers

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Abstract. The article addresses the changing role of climatic factors in the formation of the flow of suspended sediments of Mountain Rivers in Central Asia with the height of their pools. For this purpose, multi-factor analysis of the relationship between suspended sediment runoff and climatic factors - atmospheric precipitation of winter and summer seasons and air temperature over summer - has been carried out. The division of atmospheric precipitation takes into account another climatic parameter, namely the type of precipitation - solid and liquid. Under winter are taken the amounts of precipitation falling from October to March, mainly in solid form, and behind summer - precipitation of warm half-year (April-September), which mainly fall in liquid form. It is shown that in rivers of snow-rain and snow types of nutrition paired coefficients of correlation of run-off of suspended sediments both with winter and summer precipitation have a positive sign. On the contrary, with the increase in the average height of the basins, i.e. in the rivers of the snow-ice and ice-ice types, the values of the paired correlation coefficients with the precipitation of winter and summer are low and they are always lower than the values of the paired correlation coefficients with the air temperature.

1. Introduction

The study of the patterns of flow formation of weighted sediments of rivers in Central Asia has great scientific and applied significance. In scientific terms, this problem is important for understanding the history of mountain terrain development, as a clear idea of the process of formation from the surface of river basins makes it possible to more accurately estimate the value of the denudation cut of mountain structures. The practical importance of studying river sediments is also very great. First, river sediments are the most important characteristics of the hydrological regime of rivers. Secondly, the number of sediments transported by the river and their mode largely determine the processes of river bed formation and silting of reservoirs, irrigation channels, the mode of operation of settlers, and other hydro-technical structures. Therefore, its intra-annual and multi-year variability are valuable initial data, which, along with information about the water drain mode, are necessary for the design and operation of many hydraulic structures.

The purpose of this work is to study the altitude pattern of the influence of climatic factors in the formation of Mountain Rivers.

2. Methods

Materials and methods. In the work, rivers and their catchments located in different parts of the Central Asian mountain massif and belonging to the basins of the Amudarya, Syrdarya, Chu, and Lake



Issyk-Kul Rivers are selected as the research object. The main source of information used in the work is the materials of standard observations of the river and meteorological elements. They are taken into account on the network of hydrometeorological services of the States of the Central Asian region, i.e. the studies were based on the materials of standard observations carried out according to a uniform method, hydrometeorological stations, and posts. We selected 4 hydrological observation points to solve the core methodological issues. In their selection, the main criteria were the reliability of measurements and the duration of observations of the SSR, the distribution of hydraulic solutions over the territory of the studied area and by the altitude position and, most importantly, the naturality of the process of formation of the SSR in the river basin (Table 1).

Table 1. Unfortunately, it was not possible to obtain a uniform series for all treated rivers, both due to the different timing of the beginning of systematic observations of turbidity and due to gaps in observations

Watershed	Number of ponits	Limits		
		area, km ²	height, m	years of processing
Panj	9	355-2570	1210-2680	25-38
Vakhsh	5	4190-31200	3930-4540	11-31
Kafirnigan	3	140-3040	2640-2680	32-40
Surkhandarya	2	684-2200	2570-2650	22-36
Kashkadarya	5	435-3170	1520-2550	22-41
Zeravshan	5	792-10200	3080-3700	14-39
Naryn	1	10500	3570	34
Karadarya	4	1010-10500	2110-3570	34-38
FerghanaValley	3	1240-2480	2480-3480	25-40
Ahangaran	1	1290	2370	25
Chirchik	3	869-2830	2030-2690	28-41
Issyk-Kul Lake	3	250-513	2800-3220	32-37
Choo	1	302	3220	34
Total	45	250-31200	1210-4540	11-41

The assessment of the meteorological study of the mountain part of Central Asia and the corresponding correlation analysis were carried out to select representative meteorological stations and posts. In the presence of numerous weather stations, precipitation amounts were calculated for each of the reviewed basins as average according to selected representative weather stations. In a rare meteorological network, the readings of meteorological stations and sprinkler posts operating in adjacent basins were also used to characterize watershed columbia, together with observation points located in the basin itself. Overall, 146 meteorological stations and posts were used.

Thus, the joint processing of data from selected hydrological and meteorological observation points provides an opportunity to study the impact of the whole variety of climatic, soil-geological and other conditions for the formation of SSR in the mountains of Central Asia.

In the work, the multi-factor relationship between SSR and climatic factors – atmospheric precipitation of different seasons and air temperature during the summer is calculated using the objective method of balancing and normalizing correlation links proposed by G.A.Alexeyev [1]. A detailed description of this method and its application in different fields of hydrometeorology with specific examples are quite sufficiently shown in the works of G.A. Alekseev [1], F.H.Khikmatov [12, 14], O.P.Scheglova [22] and others.

3. Results and discussion

The influence of climatic factors - atmospheric precipitation and air temperature on the formation of runoff of Mountain Rivers in Central Asia was considered in the works of MN Bolshakova, EV Petryashova, VL Shults, and others [9, 12]. The most detailed question about the influence of these factors on the runoff of the Tien Shan and Pamir-Alai rivers was investigated by M. N. Bolshakov and E. V. Petryashova [3]. As a result of research on this issue, they identified three groups of rivers. In the first group of rivers, the formation of their annual flow is determined mainly by annual precipitation. In the second group, they are determined by the combined effect of precipitation and air temperature, and in the last group, by temperature fluctuations during snowmelt [3].

The issue of climatic factors in the formation of the hydrological regime of rivers is of significant interest not only about liquid runoff but also to sediment runoff. In this regard, this work is devoted to identifying the role of climatic factors – precipitation and air temperature in the formation of annual SRI.

In the works of K.S. Kabanova, A.R. Rasulova, O.P. Shcheglova, and others noted a significant difference in the role of liquid and solid sediments in the formation of SHS rivers. Therefore, in contrast to the studies of liquid runoff carried out by M.N. Bolshakov and E.V. Petryashova, we, when studying the long-term fluctuations of solid runoff, took into account one more climatic indicator, namely, the type of precipitation. To this end, precipitation is divided into winter (October-March) and summer (April-September). In the study of the formation of SSR, the selection as a separate argument of winter precipitation is rational and in light of the possibility of identifying prognostic dependencies.

The predominant influence on the formation of the SSR of one or another climatic factor can be judged on the basis of the calculated values of pair correlation coefficients between the annual values of the SSR and three meteorological indicators: precipitation of winter, summer and average summer air temperature (Table 2).

Table 2. Values of paired and complete coefficients correlation of annual SSR with climatic factors

River	H_m км	Values of paired correlation coefficients			
		$r_{R_a X_w}$	$r_{R_a X_s}$	$r_{R_a t_s}$	$r_0 \pm \sigma_{r0}$
Watershed of Amudarya					
Gunt - Khorog	4.17	0.281	0.311	0.576	0.763±0.070
Bartang is a village. Murghab	4.41	0.117	0.287	0.621	0.713±0.100
Bartang - Shujand villages	4.33	-0.148	-0.284	0.633	0.748±0.097
Langar - mouth	4.67	-0.322	-0.232	0.764	0.811±0.060
Kudara - mouth	4.48	-0.240	-0.195	0.710	0.789±0.077
Yazgulem - Motravn village	3.92	-0.303	-0.061	0.714	0.776±0.074
Vanch - Vanch village	3.78	-0.226	-0.193	0.657	0.739±0.081
Kyzylsu - Samanchi village	1.21	0.768	0.593	-0.111	0.826±0.063
Yakhsu - Korbostanak village	2.04	0.707	0.579	-0.097	0.780±0.083
Vakhsh - town Garm	3.73	0.313	0.105	0.561	0.753±0.082
Vakhsh - Tutkaul village	3.43	0.389	0.051	0.480	0.768±0.087
Kyzylsu - the village of Dombrachi	3.54	0.210	-0.070	0.724	0.820±0.095
Muksu - Drvsear villages	4.54	-0.092	-0.082	0.878	0.935±0.034

Obihingau - Lyron village	3.75	-0.118	-0.240	0.686	0.747±0.156
Kafirnigan - Chinar village	2.64	0.811	0.603	0.118	0.841±0.048
Varzob - villages of Dagana	2.67	0.598	0.712	-0.122	0.797±0.060
Tuikutal - Takob	2.68	0.674	0.643	-0.130	0.806±0.065
Tuplang - the village of Zarchob	2.57	0.649	0.588	-0.080	0.750±0.100
Karatag - Karatag villages	2.65	0.721	0.669	-0.181	0.815±0.058
Kashkadarya - Varganza villages	1.80	0.682	0.501	-0.272	0.800±0.058
Akdarya - villages of Khazarnova	2.55	0.807	0.567	-0.319	0.860±0.043
Tanhizydarya - Kattagan village	2.21	0.658	0.617	-0.355	0.843±0.056
Yakkabagdarya - villages of Tatars	2.74	0.736	0.419	-0.164	0.795±0.061
Guzardarya - Yartepa villages	1.52	0.547	0.701	-0.226	0.840±0.048
Zeravshan - Khudgif village	3.70	-0.224	-0.385	0.671	0.836±0.083
Zeravshan is a river. Fandarya	3.33	0.112	-0.114	0.693	0.815±0.092
Zeravshan - Dupuli	3.10	0.176	-0.121	0.564	0.692±0.087
Fandarya - mouth	3.30	0.596	0.351	0.483	0.751±0.131
Kshtut - Zerifshor village	3.08	0.654	0.350	0.197	0.705±0.090
Naryn - the city of Naryn	3.57	0.221	-0.082	0.472	0.634±0.107
Watershed of Syrdarya					
Karadarya - Kamyrravat	2.60	0.777	0.520	-0.198	0.821±0.058
Iasi - Mikhailovskoye	2.59	0.696	0.516	-0.201	0.760±0.071
Kugart - the village of Mikhailovskoye	2.11	0.782	0.501	-0.240	0.848±0.047
Tentyaksay - Charvak village	2.19	0.669	0.551	-0.252	0.804±0.057
Kassansay - Urukty River	2.48	0.614	0.510	-0.175	0.733±0.099
Sokh - Sarykanda villages	3.48	0.237	-0.264	0.671	0.717±0.080
Isfara - Tash-Kurgan villages	3.17	0.231	-0.278	0.593	0.682±0.096
Ahangaran - Turk	2.37	0.606	0.497	-0.76	0.722±0.102
Chatkal - Charvak	2.61	0.690	0.452	-0.242	0.740±0.090
Pskem - mouth	2.69	0.692	0.586	-0.290	0.744±0.089
Ugam - Khodjикent	2.03	0.695	0.592	-0.314	0.786±0.062
Watersheds of Chu and Lake Issykkul					
Tyup - Sarytologai	2.80	0.428	0.518	0.102	0.683±0.099
Jyrgalan - Soviet	2.97	0.377	0.466	0.241	0.652±0.098
Chon-Kyzylsu -1 cordon	3.22	0.318	0.281	0.421	0.607±0.113
Issykat - Yuryevka	3.03	0.346	0.238	0.384	0.596±0.112

Note H mid – average weighted height of the watershed; $r_{R_a} X_w$, $r_{R_a} X_s$, $r_{R_a} t_s$. Pairwise correlation coefficients of the annual SSR, respectively, with winter and summer precipitation and average summer air temperature $r_0 \pm \sigma_{r_0}$ Full correlation coefficient and its feel.

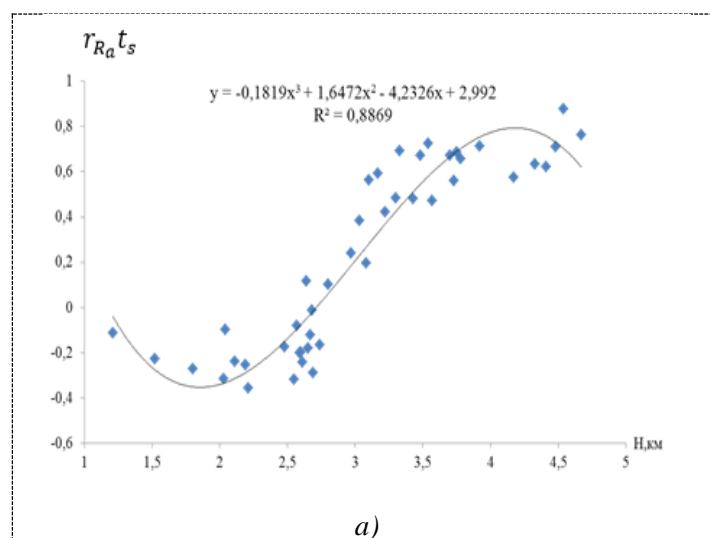
Our calculated values of pairwise coefficients of correlation of SSR with meteorological factors were compared with data of similar calculations made by M.H.Bolshakov and E.V.Petryashova for the liquid drain. In this connection, for some rivers. The paired correlation coefficients of the SSR with the annual amounts of atmospheric precipitation were calculated additionally (Table 2).

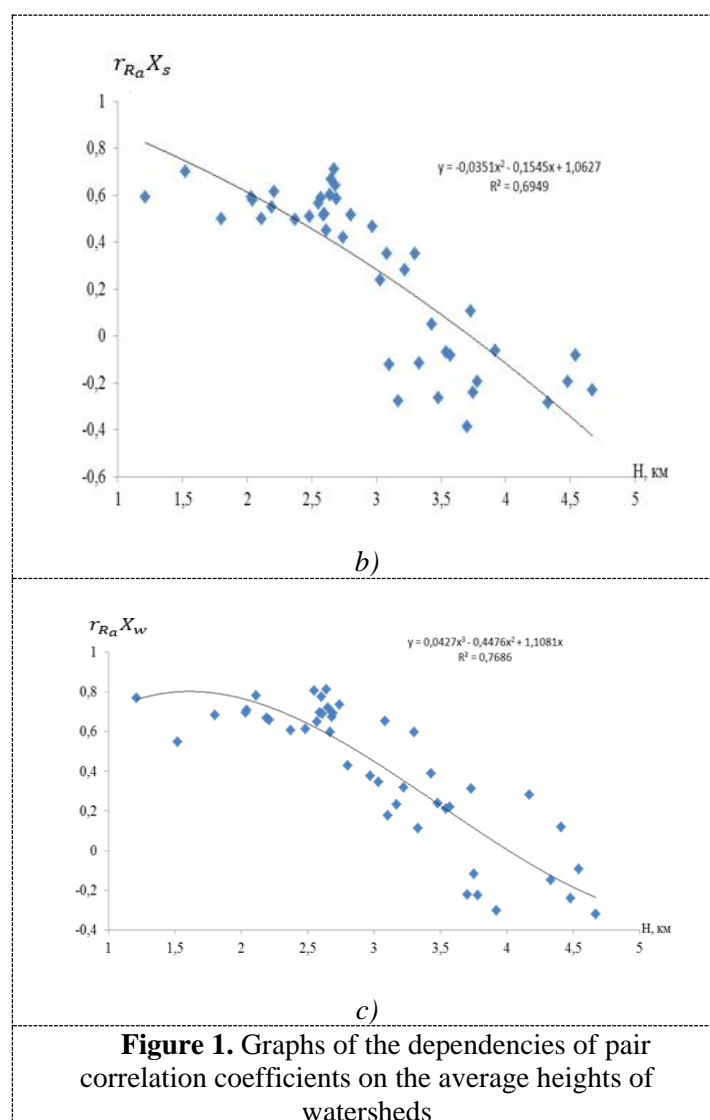
For rivers similar in the calculation and related to snow-glacier and glacial types of nutrition (except for the Issykat river), the influence of the temperature factor on long-term fluctuations of solid runoff is more pronounced than for liquid runoff. So, for the Sokh river (Sarykanda), the paired correlation coefficients with air temperature are 0.622 and 0.470, respectively. For rivers of snow and rain type of nutrition (Kugart, Tentyaksay, Tyup rivers), the relationship between the annual precipitation and liquid runoff is closer than with solid runoff (Table 3).

Table 3. Paired correlation coefficients of liquid and solid river flow with annual precipitation and summer air temperature

River	correlation coefficients	
	with precipitation	With temperature
Langar - mouth	-0.164 / -0.260	0.759 / 0.730
Cougart-s.Mikhailovskoe	0.742 / 0.850	-0.246 / -0.480
Tentyaksay - K. Charvak	0.492 / 0.900	-0.259 / -0.460
Sokh - K. Sarykanda	-0.013 / -0.300	0.662 / 0.470
Isfara - K. Tashkurgan	-0.162 / -0.090	0.593 / 0.400
Tyup - Sarytologai village	0.672 / 0.490	0.080 / -0.150
Issykat - S. Yuryevka	0.310 / 0.120	0.338 / 0.430

Based on the purpose of the work we studied changes in the values of pair correlation coefficients depending on the average weighted height of catchments. An analysis of the calculation results showed that regardless of the differences in the petrographic composition of the rocks that form the basins of the rocks and other natural factors affecting the formation of the SSR. An unambiguous hypsometric pattern can be observed: the values of the paired coefficients of the correlation of the SSR with sediments of both seasons decrease as the average height of the catchment increases (Figure 1 a, b) and the paired correlation coefficients with summer air temperature increase (Figure 1 c).





These graphs clearly show the change in the role of climatic factors in the formation of the annual SSR of rivers due to the change in the height of their catchments. That is the change in the average weighted conditions of their nutrition.

Thus the different role of individual climatic factors in the formation of SSR rivers at different altitude levels has been revealed: atmospheric precipitation (liquid and solid) plays a dominant role in the lower zones of the mountains of Central Asia and in the upper zones of the mountains, the formation of SSR is determined by the thermal regime of the warm half-year.

4. Conclusion

The main results of the study are as follows:

1. The most important of the natural factors affecting the formation of SSR mountain rivers are climatic factors-atmospheric precipitation and air temperature. They have a twofold effect on the formation of the SSR. With their participation rocks are destroyed and material for demolition is prepared. Further transport of these occurs under the influence of surface runoff forming again when they are exposed to them;
2. Atmospheric precipitation according to the predominant type of its precipitation – in solid or liquid form - is divided into winter and summer. For winter precipitation the amounts of precipitation

- accumulated in the mountains from October to March are accepted. Which fall mainly in solid form and for summer precipitation which fell from April to September mainly in liquid form;
3. The intensity of SSR formation due to melting waters of snow cover and glaciers in high-mountain catchments is mainly determined by values of positive air temperatures in their basins. As is known in the mountain part of Central Asia the increased removal of fine meat is installed in April and this continues through September. Therefore we use the average temperature of the warm half (April-September) as the temperature index;
 4. When establishing the multi-factor connection of the annual SSR with climatic elements. The sums of atmospheric precipitation of different seasons (winter and summer) and average values of air temperature for the warm half-year at selected in representative meteorological points were used. The calculations are performed using an objective method of balancing and normalizing correlation connections. This method allows you to obtain curved dependencies between many variables. This circumstance was very significant for our case. That is the distinctive feature of the bonds which include the solid drain is their crawliness;
 5. The dependence of solid runoff on atmospheric precipitation (in snow-ice and ice feed rivers) should essentially be expressed as a monotonically increasing function. That is meets the requirements of the G.A.Alexeeva method. Using this method in the future it is possible to directly estimate the contribution of atmospheric precipitation of different seasons and air temperature in the formation of SVN Mountain Rivers;
 6. The isolation, in the study of the process of formation of SSR as a separate argument of precipitation of winter is rational and in the light of the possibility of detecting prognostic connections;
 7. In general, a high-altitude pattern of changing the role of climatic factors – atmospheric precipitation of winter and summer seasons and average air temperature over the summer in the formation of SSR Rivers of Middle Asia has been revealed. In the lower zones of the mountains of Central Asia atmospheric precipitation (liquid and solid) plays a dominant role and in the upper zones of the mountains, the formation of SSR is determined by the thermal regime of the warm half of the year.

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