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The Ob River Water and Sediment Runoff Under Changing Climate Conditions

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Abstract: Changes in the Ob River sediment runoff caused by current climatic and socio-economic changes in Russian Federation have a multidirectional character in the middle and lower courses of the watercourse. According to meteorological observations, the air temperature in the studied region increased by 2 °C, and annual precipitation layers by more than 80 mm/yr, while the area of agricultural land in the middle reaches of the river decreased by 40% compared to the period before 1990. A decrease in acreage in the catchment area of the middle stream caused a three-fold decrease in sediment runoff during the high water period, while the activation of thermal erosion processes in the lower reaches led to a two-fold increase in sediment runoff during the same period. As a result of water and sediment runoff modeling according to climate forecasts, it was found that by the end of the 21st century, the average annual water runoff of the Ob River for the RCP 2.6 scenario increases by 20% relative to the period 1991–2020, while sediment runoff almost does not change. At the same time, the RCP 8.5 scenario provides a decrease in water and sediment runoff.

Keywords: watercourse, sediment runoff, Arctic, climate change, anthropogenic influence, thermal erosion, forecast.

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Introduction

Current climatic changes along with socio-economic activities ambiguously influence the conditions of water and sediment runoff formation in the catchments. For large rivers located in different physiographic and climatic zones, this ambiguity is aggravated by regional peculiarities of private catchment areas. The most significant changes in the conditions of sediment runoff formation in recent decades have occurred in the catchments of the rivers located in the cryolithozone, as well as in the catchments characterized by large variability in agricultural land areas. For example, the reduction of the agricultural fields area in the north-western region in the late 1990s and early 2000s [*Aparin and Matinyan*, 2005] determined the decrease in sediment river runoff by an average of 36% [*Shmakova*, 2021]. At the same time, the intensification of economic activity in the catchment area, associated with extensive development of the underlying surface of catchment areas, in its turn leads to a significant increase of the sediment runoff. For example, the expansion of gold mining in the Kolyma basin between 1942 and 1989 led to a 147% increase of sediment runoff [*Walling*, 2008], while sediment discharge in the Yazgulem River (Tajikistan) increased by 154% due to agricultural development in the region between 1950 and 1986 [*Walling*, 2008]. The melting of glaciers caused by global warming on our planet is also changing the water and sediment runoff regime of the glacier-fed Arctic rivers. As noted [*Mernild et al.*, 2007; *Overeem and Syvitski*, 2008; *Wegner et al.*, 2009], a small increase in the sediment load of such watercourses can be expected in the short term. However, if there is a significant reduction in the area of glacial cover in the catchment, the amount of sediment load will decrease too. Also, the changes in the sediment runoff regime of the Arctic rivers are currently caused by the intensification of soil, coastal and channel erosion

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processes due to the thawing of soil and bedrock in the northern regions [*Moskalik et al.*, 2015]. On the whole, the factors determining the direction of sediment runoff dynamics and its intensity can mutually compensate for the amount of sediment matter entering the river channel from different sources. For example, an increase in sediment load due to soil erosion caused by anthropogenic activities in a catchment is offset by a reservoir retaining sediment runoff and so on [*Syvitski and Kettner*, 2008; *Syvitski et al.*, 2005].

The purpose of this study is to assess the spatial and temporal variability of water and sediment runoff of the Ob River in the middle and lower courses of a river.

Object of Study

The Ob River, 3,650 km long, flowing through Western Siberia, is one of the largest rivers in the world, the first in terms of catchment area and the third in terms of water content in Russia. The total area of its catchment basin is 2,990 million km^2. The Ob originates at the confluence of the Biya and the Katun rivers in the foothills of the Altai Mountains and flows into the Kara Sea. The semi-mountainous course of the upper Ob (up to the confluence of the Tom River) changes to a plain course in its middle (up to the confluence of the Irtysh River) and lower parts. The upper course are characterized by snow (40%), glacial (22%), rain (19%) and groundwater (15%) feeding. Whereas in the taiga zone the river feed is distributed as follows: snow – 55%, rain – 25%, ground – 20% [*Surface water...*, 1972, 1973]. The overall gradient of the river is 0.046 ‰, in the upper course – 0.09 ‰, in the middle and lower courses – 0.03 and 0.02 ‰ respectively.

The highest values of water and sediment runoff in the studied targets occur during the spring flood period in May–June for the Ob River – Kolpashevo Town and for June – July for the Ob River – Salekhard City. In total, the values of the studied quantities for the two months of high water range from 39 to 67% of their annual values.

The entire catchment area of the Ob River crosses several natural zones and temperate and subarctic climatic zones and its main part is located on the West Siberian plain. The main composition of the sedimentary cover of the plain is represented by marine clayey-siltstone greenish-gray carbonate clays, clayey opaque rocks, lagoonal red-colored sandy-clayey and other sediment [*Alpatiev et al.*, 1973]. At the same time, in the plain part of the Ob River basin, the above mentioned bedrock is overlain by Quaternary sediment. The northern part of the studied watercourse catchment is characterized by intermittent and insular permafrost [*Afanasiev et al.*, 2000]. All this determines the development of thermokarst processes, solifluction, and also determines the peculiarities of underground feeding of the Ob River and its tributaries. Vast wetlands of Western Siberia represent huge water flow regulating capacities, among other things influencing the conditions of the sediment runoff formation at the catchment area [*Chalov et al.*, 1994].

Created in the late fifties of the last century, the Novosibirsk Reservoir, located in the upper reaches of the Ob River, solves the issues of hydropower, fisheries and water supply in the region. This reservoir belongs to the valley type with seasonal regulation [*Long-term dynamics...*, 2014]. The reservoir is filled during the spring-summer floods, and the decrease of storage takes place during the autumn-winter low water period [*Long-term dynamics...*, 2014; *Trizno et al.*, 2000]. In addition to redistributing water runoff, the Novosibirsk Reservoir also retains sediment matter from the upper reservoir [*Ivanov and Chalov*, 2021; *Vörösmarty et al.*, 2003]. The hydrological regime of the Ob River below the Novosibirsk reservoir is characterized by a spring-summer flood lasting several months, a deep autumn low-water and a stable winter low-water [*Magritskiy et al.*, 2019].

In this study, Hydrological Yearbooks used as sources of data on water and sediment discharges. Meteorological observation data (average monthly air temperature and monthly precipitation amounts with elimination of systematic errors of precipitation measuring instruments) were obtained from a database publicly available on the website of the Russian Scientific Research Institute of Hydrometeorological Information– the Global Data Center [*Global Data Center. Specialized datasets*, 2025].

Table 1 lists the discharge sites located on the Ob River, their catchment areas, the mean annual suspended sediment load and annual sediment runoff rates for the period 2008–2021. In general, as the water content of a watercourse increases, the sediment load increases accordingly. However, the upper reaches are characterized by an increased rates value. This is explained by the semi-mountainous flow of the upper Ob and, as a consequence, its increased transport potential. In the Ob River – Dubrovino Village discharge site, the values of suspended sediment discharge and annual sediment discharge rates decrease significantly due to the influence of the Novosibirsk reservoir, which acts as a settling basin. According to [*Gorshkov*, 1982], the reservoir retains up to 97% of the river sediments entering it. The reduced sediment runoff in the lower reaches of the Novosibirsk reservoir can be traced over a fairly long area, up to the mouth of the Ket River (Kolpashevo) [*Chalov*, 2020]. In turn, an increase in sediment runoff downstream of the watercourse below Kolpashevo to Salekhard is fairly uniform and proportional to the catchment area.

Table 1. Studied gauging stations, their main characteristics and the mean annual suspended sediment load and annual sediment runoff rates for the period 2008–2021.

Gauging stations	F, km^2	Distance from the mouth, km	Sediment discharge, kg/s	Sediment runoff rate, t/(yr km^2)
Ob River – Barnaul Town	169,000	3,404	182	33.9
Ob River – Kamen-na-Obi Town	216,000	3,168	264	38.6
Ob River – Dubrovino Village	258,000	2,876	46	5.6
Ob River – Kolpashevo Town	486,000	2,422	270	17.5
Ob River – Aleksandrovskoe Village	765,000	1,830	179	7.4
Ob River – Belogorye Village	2,690,000	1,152	513	6.0
Ob River – Salekhard City	2,950,000	287	917	9.8

Methods

To assess the dynamics of sediment and water runoff of the Ob River based on observational data, methods of parametric statistics were used. The forecast of average annual water and sediment runoff of the Ob River – Salekhard City is based on the climate change scenarios RCP 2.6 and 8.5 for the period 2091–2100 calculated as per the PSL–CM5A–MR climate model [*Copernicus...*, 2021]. RCP 2.6 and RCP 8.5 are the best and worst climate scenarios in terms of environmental impact, respectively. The RCP 2.6 scenario assumes that carbon dioxide (CO_2) emissions to decline steadily and reach zero by 2100. In the RCP 8.5 scenario the emissions continue to grow throughout the 21st century at the same rate as they are now. For the period 2091–2100, based on the calculated parameters of the distribution of forecast meteorological values (according to two climatic scenarios) using the stochastic weather model (SMW), long series (100 yr) of meteorological values were generated, which provided input to the ILHM runoff formation model developed by S. A. Kondratyev [*Kondratyev*, 2007; *Kondratyev and Shmakova*, 2015]. The discharges of the water obtained at the exit from the model were recalculated into the discharges of the sediment according to the sediment discharge formula by *Shmakova* [2022]:

$$G = \frac{\rho_s}{\rho_s - \rho_w} Q\left[\frac{c}{hg} - (1-f) I_\rho w\right], \tag{1}$$

where Q is the water discharge, m^3/s; ρ_s and ρ_w is the densities of soil and water, respectively, kg/m^3; g is the acceleration of gravity, m/s^2; I is the bottom slope, dimensionless;

h is the average flow depth, m; f is the coefficient of internal friction, dimensionless; and c is the parameter of adhesion of soil particles during shear, $kg/(m\,s^2)$. Equation 1 is a consequence of the water motion basic equation and solid matter in a watercourse, expressing the balance of forces that act in the "water flow – bottom sediments – sediments" system [*Shmakova*, 2022]. The formulas have been tested on a sufficiently large number of watercourses lying in different physical and geographical zones with different hydraulic and morphological characteristics [*Shmakova*, 2022]. The physically justified parameters f and c depend on the phase of the water content (low water, high water, average water content) and the bottom sediments size. The dependencies given in [*Shmakova*, 2022] can be used to determine the values of these parameters. The ILHM catchment runoff model is designed to calculate hydrographs of melt and rain runoff from the catchment. The model has a conceptual basis and describes the processes of snow accumulation and snowmelt, evaporation and soils moistening in the aeration zone, the formation of runoff, as well as the regulation of runoff by the reservoirs within a homogeneous catchment area, the characteristics of which are assumed to be constant for its entire area.

Calculations and Discussion

Private catchments of the Ob River in the middle and lower courses are located in different physical and geographical zones and correspond to different conditions for the formation of sediment and water runoff. At the same time, current climate changes lead to changes in the water content of the river and the redistribution of its flow throughout the year, and the conditions for the formation of runoff fundamentally change in the catchment area located in the permafrost zone. Over the entire observation period, according to linear trends (Figure 1), the air temperature at weather stations Kolpashevo Town and Salekhard City has increased by 2 °C in more than a hundred years, annual precipitation layers have increased by 96 and 81 mm/yr over a half-century period, respectively; the rates of change in average annual water and suspended sediment runoff of the Ob River – Kolpashevo Town discharge site are $-9\,m^3/(s\,yr)$ and $-6\,kg/(s\,yr)$, respectively; at the Ob River – Salekhard City discharge site – $+11\,m^3/(s\,yr)$ and $+1\,kg/(s\,yr)$, respectively. The maximum average monthly suspended sediment discharge in the Kolpashevo decreases at a rate of 46 kg/(s yr) and practically does not change in the Salekhard (a slight decrease was 1 kg/(s yr)).

The decrease in Ob River runoff observed in the second half of the 1970s and in the 1980s is due to increased water consumption, mainly from the river network [*Frolova et al.*, 2018]. During this period, there was also a critical decrease in the flow of some watercourses in the south of the Ob-Irtysh basin, which led to a shortage of freshwater in the region [*Frolova et al.*, 2018].

However, for the second climatic period (1991–2020) in comparison with the base period (1961–1990), the runoff of Ob River – Kolpashevo Town practically has not changed, while the suspended sediment discharge has decreased by 55% (Table 2). The runoff Q of the Ob River – Salekhard City in the second climatic period also did not undergo significant changes (1%), and the suspended sediment discharge Gsuspend increased by 12% (Table 2). At the same time, the number of annual precipitation at the Kolpashevo and Salekhard weather stations increased by about 10%, and the air temperature increased by more than 1 oC. The reduction of the maximum average monthly suspended sediment discharges Gmax in the second climatic period in relation to the base one for the Ob River – Kolpashevo Town was 64%, and for the Ob River – Salekhard City – 1%. At the same time, the revealed change for the Ob River - Salekhard City is significantly less accurate than the estimation of sediment runoff in a watercourse and can be considered an error.

Such a pronounced decrease of the suspended sediment discharge in the middle course of the Ob River is explained by a significant decrease in agricultural activity in the catchment area occurring at the turn of the millennia. Thus, in 2000, arable land in the region was sown by 40% less than in 1991 [*Ilyinykh*, 2018], while the increase in sediment runoff in the lower reaches of the studied watercourse is determined by increased thermal

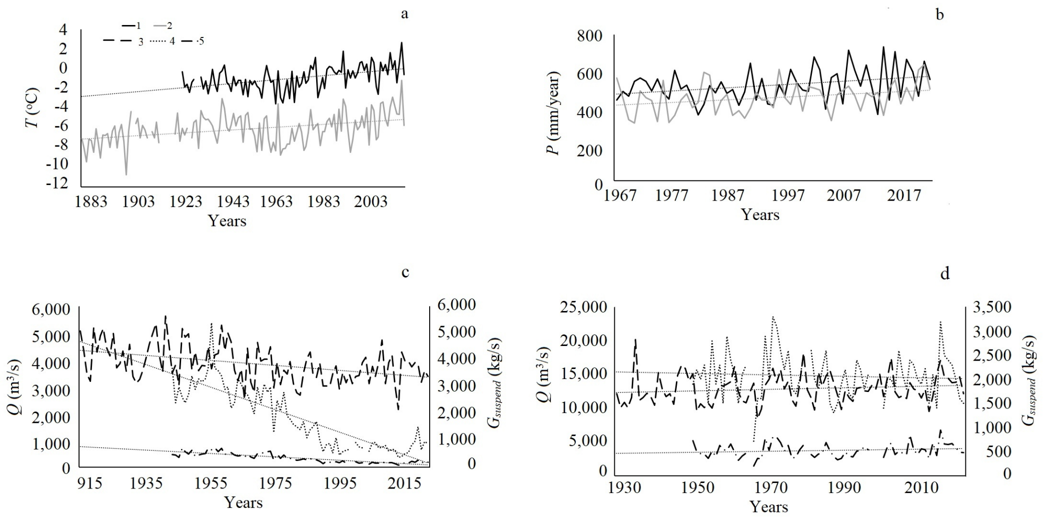

Figure 1. The timeline: average annual air temperature (a) and annual precipitation (b), weather stations Kolpashevo Town (1) and Salekhard City (2); the average annual water discharge Q (3), maximum monthly average G_{max} (4) and average annual (5) suspended sediment G_{suspend} discharge, the Ob River – Kolpashevo Town (c) and the Ob River– Salekhard City (d).

Table 2. The average annual values of meteorological values, water and suspended sediment discharges for two climatic periods.

the Ob River – Kolpashevo Town				
	1961–1990	1991–2020	Deviation	
			abs.	rel., %
T, °C	–1.21	–0.05	1.16	—
P, mm/yr	498	542	45	9
Q, m^3/s	3,585	3,571	–14	0
G_{max}, kg/s	2,064	735	–1,329	–64
G_{suspend}, kg/s	372	168	–204	–55
the Ob River – Salekhard City				
	1961–1990	1991–2020	Deviation	
			abs.	rel., %
T, °C	–6.60	–5.05	1.55	—
P, mm/yr	428	474	46	11
Q, m^3/s	12,982	13,148	166	1
G_{max}, kg/s	2,079	2,049	–30	–1
G_{suspend}, kg/s	491	548	57	12

erosion processes of the catchment area. The latter is confirmed by a slight change in water runoff against the background of pronounced dynamics of suspended sediment runoff [*Magritskiy*, 2010; *Magritskiy et al.*, 2023; *Turutina*, 2022].

The series of the studied values obey the normal distribution law (according to the Kolmogorov-Smirnov criterion at a significance level of $\alpha = 0.10$), therefore, parametric statistical methods were used in further estimates [*ISO 16269-4:2010*, 2017; *ISO 2602:1980*, 2005; *World Meteorological Organization*, 2017]. Table 3 shows the results of checking the series of average annual air temperature, annual precipitation layers, average annual water and suspended sediment discharges for two climatic periods for uniformity. According to calculations, only the series of average annual air temperature and annual precipitation for the Kolpashevo weather station are heterogeneous in the dispersion (Fisher's criterion) for the significance level $\alpha = 0.10$. According to the average values (Student's criterion), the series are heterogeneous for all meteorological values at both weather stations and the average annual suspended sediment discharge g/m of the Ob River – Kolpashevo Town for the same level of significance (Table 3). At the same time, for the significance level of $\alpha = 0.10$, according to the Student's criterion, the trends of annual precipitation at two weather stations, as well as average annual water and sediment discharges for Ob River – Salekhard City are insignificant (Table 3).

Table 3. Testing statistical hypotheses*

Value	H_0 (I)	H_0 (II)	H_0 (III)
the Ob River – Kolpashevo Town			
T, °C	$t > t_{\alpha=0.10}$	$F > F_{\alpha=0.10}$	$t > t_{\alpha=0.10}$
P, mm/year	$t > t_{\alpha=0.10}$	$F > F_{\alpha=0.10}$	$t < t_{\alpha=0.10}$
Q, m^3/s	$t < t_{\alpha=0.10}$	$F < F_{\alpha=0.10}$	$t > t_{\alpha=0.10}$
$G_{suspend}$, kg/s	$t > t_{\alpha=0.10}$	$F < F_{\alpha=0.10}$	$t > t_{\alpha=0.10}$
the Ob River – Salekhard City			
T, °C	$t > t_{\alpha=0.10}$	$F < F_{\alpha=0.10}$	$t > t_{\alpha=0.10}$
P, mm/year	$t > t_{\alpha=0.10}$	$F < F_{\alpha=0.10}$	$t < t_{\alpha=0.10}$
Q, m^3/s	$t < t_{\alpha=0.10}$	$F < F_{\alpha=0.10}$	$t < t_{\alpha=0.10}$
$G_{suspend}$, kg/s	$t < t_{\alpha=0.10}$	$F < F_{\alpha=0.10}$	$t < t_{\alpha=0.10}$

* H_0 (I) and H_0 (II) – hypotheses about the equality of sample means and variance (Student's and Fisher's criteria); H_0 (III) – the hypothesis of the significance of the trend (Student's criteria); α – significance level; t and F – Student's and Fisher's statistics; t_α and F_α – Student's and Fisher's statistics critical values.

Analysis of the intra-annual distribution of air temperature and precipitation for two climatic periods (Figure 2) showed that the average monthly temperature most significantly increases in winter and spring, while monthly precipitation increase evenly throughout the year. The exception is a decrease in the monthly precipitation by weather station Salekhard in July. At the same time, water runoff increases in winter and decreases in summer for all calculated discharge sites (Figure 3). Sediment discharge in the Ob River – Kolpashevo Town discharge site decreases significantly in the spring-summer period, whereas for the Ob River – Salekhard City discharge site has a significant increase in sediment discharge during the spring flood.

Table 4 shows the average annual air temperature and annual precipitation obtained for the series of observed meteorological values (1991–2020) for the Salekhard weather station and for the forecast period 2091–2100, calculated according to scenarios 2.6 and 8.5. According to scenario 2.6, the air temperature will increase by 1 °C by the end of the century (2091–2100), and the annual precipitation by 5%. Whereas scenario 8.5 assumes an increase in air temperature in the studied region by 8.7 °C, and an annual precipitation by 13%.

Table 4. Observed and forecast values of meteorological quantities, Salekhard City

Period	T, °C	P, mm/yr	$\Delta(T)$	$\delta(P)$,%
1991–2020	−5.0	474	—	—
2091–2100 RCP 2.6	−4.0	500	1.0	5
2091–2100 RCP 8.5	3.7	538	8.8	13

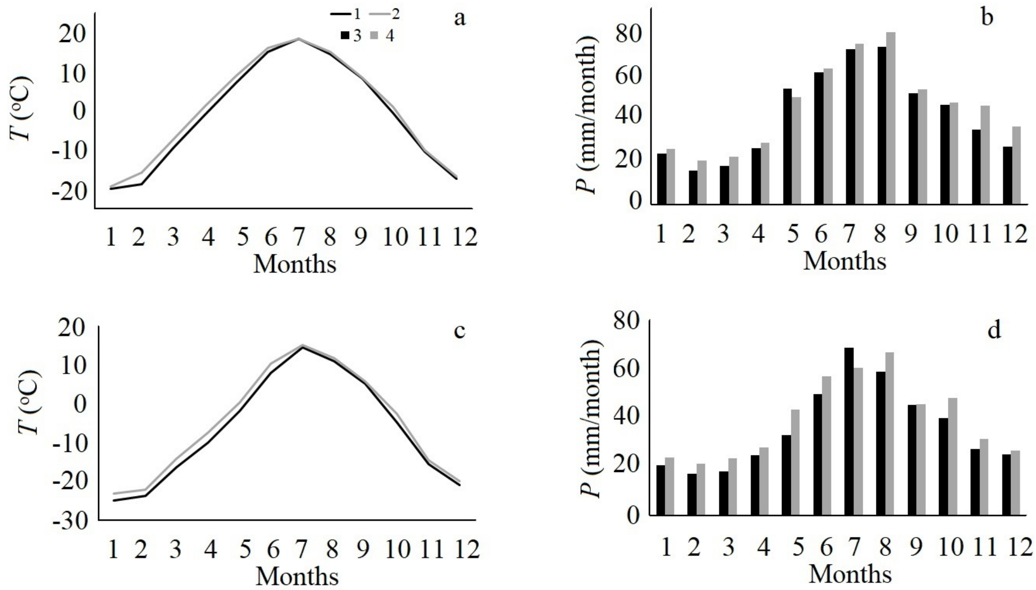

Figure 2. Intra-annual distribution of the average annual air temperature T (°C) and monthly precipitation P (mm/month) for the weather stations of Kolpashevo Town (a, b) and Salekhard City (c, d) for two climatic periods: 1961–1990 (1, 3) and 1991–2020 (2, 4).

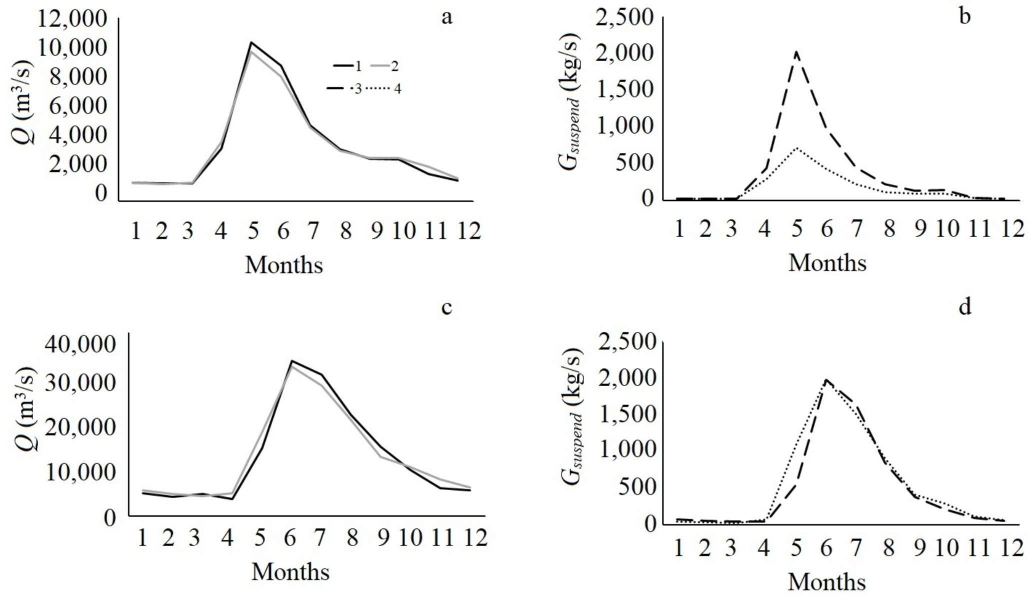

Figure 3. Intra-annual distribution of average monthly water Q, m/s^2 and suspended sediment G discharges, the Ob River – Kolpashevo Town (a), (b) and The Ob River – Salekhard City (c), (d) for two climatic periods 1961–1990 (1, 3) and 1991–2020 (2, 4).

Table 5 shows the distribution parameters of the average annual water and sediment discharges for the Ob River – Salekhard City, and Figure 4 presents the distribution curves of the studied values. An increase in precipitation and a slight increase in air temperature in the RCP2.6 scenario led to a 20% increase in river runoff by the end of the century. At the same time, a significant increase in air temperature according to the RCP8.5 scenario led to an increase in evaporation and, as a result, a decrease in runoff by 13%.

At the same time, for the period 2091–2100, according to the forecast of RCP 2.6, there is a slight decrease in sediment runoff (by 5%), whereas for the RCP 8.5 scenario,

Table 5. Water and sediment discharges distribution parameters, the Ob River – Salekhard City

Value	Average	σ	C_v	C_s	C_s/C_v	$X_{1\%}$	$X_{5\%}$	$X_{25\%}$	$X_{75\%}$	$X_{95\%}$	$X_{99\%}$
Q_{obs}, m^3/s	12,879	2,086	0.16	59	366	17,740	16,320	14,280	11,480	9,437	8,018
$Q_{2.6}$, m^3/s	15,408	1,891	0.12	16	128	19,810	18,530	16,670	14,140	12,290	11,000
$Q_{8.5}$, m^3/s	11,165	2,092	0.19	30	161	16,040	14,620	12,570	9,764	7,713	6,291
G_{obs}, kg/s	519	140	0.27	44	162	845	750	613	425	287	192
$G_{2.6}$, kg/s	495	181	0.37	55	150	917	794	616	373	196	72
$G_{8.5}$, kg/s	237	88	0.37	262	710	441	381	296	178	92	33

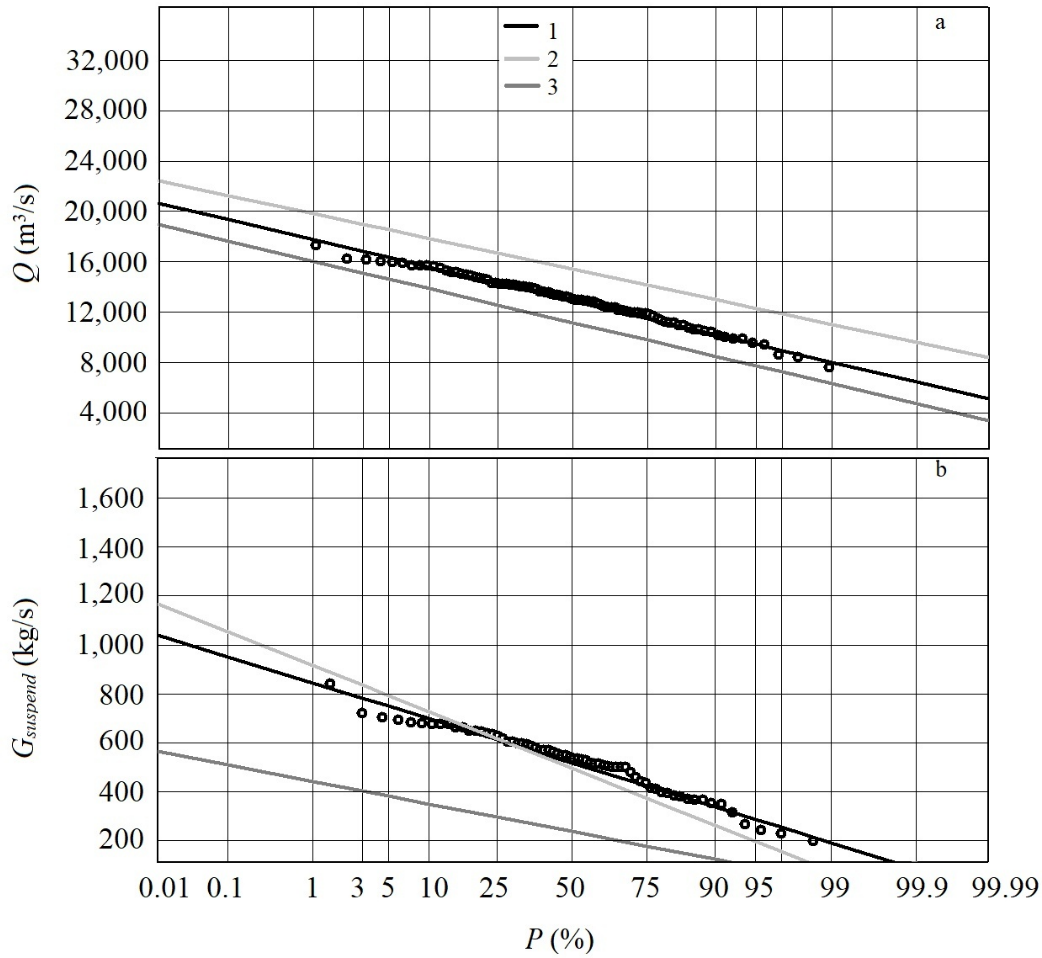

Figure 4. Average annual water (a) and sediment (b) discharges distribution curves, the Ob River – Salekhard City. 1 – observed data, 1991–2020; 2 – RCP 2.6, 2091–2100; 3 – RCP 8.5, 2091–2100.

sediment runoff will decrease by more than half. This is due to the redistribution of the water content of the Ob River – Salekhard City within a year (Figure 5). According to the calculation results based on the RCP 8.5 climate forecast, the runoff of the studied river will become more uniform throughout the year. The low water will become more full-flowing, however, the water discharge in high water will reduce by almost 40%. Due to the fact that the main part of the annual sediment runoff for the Ob River is formed during high water, such a significant decrease in water content during this period caused a significant decrease in sediment runoff.

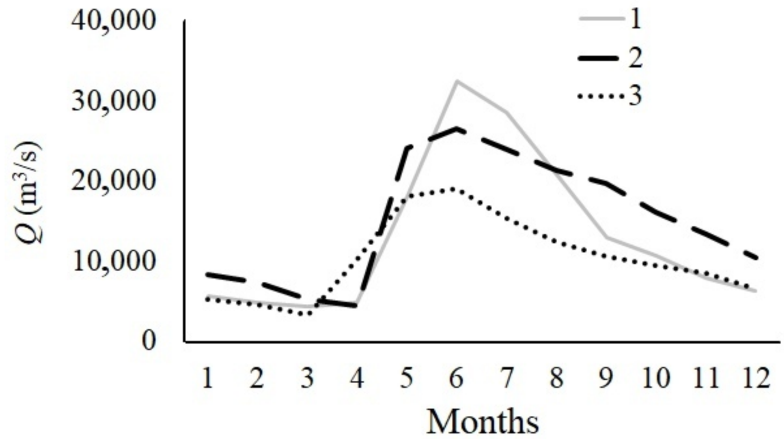

Figure 5. Intra-annual distribution of average monthly water discharge, the Ob River – Salekhard City. 1 – 1991–2020; 2 – 2091–2100, the forecast RCP 2.6; 3 – 2091–2100, the forecast RCP 8.5.

Conclusions

Based on the deterministic-stochastic modeling system developed at Institute of Limnology RAS, the order of possible changes in the values of solid runoff is shown under the condition of exclusively climatic changes without taking into account possible anthropogenic influence.

Thus, the distribution of sediment runoff along the length of the Ob River showed increased values of the annual sediment runoff rates in the upper semi-mountainous course, a decrease in sediment runoff in the lower reaches of the Novosibirsk reservoir and a uniform increase in sediment runoff downstream, according to the growth of the catchment area.

An increase in air temperature and an increase in precipitation in the basin of the middle and lower Ob River did not lead to a significant change in the river's water runoff. However, the sediment runoff of the middle course during the flood decreased almost three times in the second climatic period compared to the first (from 2,024 to 717 kg/s), whereas in the lower course, on the contrary, the sediment runoff doubled (from 540 to 1,090 kg/s) at the beginning of the flood. At the same time, the sediment runoff for other periods of water content within the year for the studied discharge sites practically did not change. This is explained by the fact that high water is characterized by the most active processes of removal of solid matter from the surface of the catchment area, and the erosive activity of the territory, due to the degree of soil erosion, is largely determined by the agricultural development of the catchment area. Thus, the area of agricultural land in the middle course of the Ob River in the nineties of the last century, due to socio-economic reasons, decreased in comparison with the previous period. For example, the area of agricultural land in Tomsk region decreased from 9,199 hectares in 1975 to 5,391 hectares in 2019, or by 41% [*Ivanov*, 2020]. Thus, at present the area of territories allocated for agriculture has not yet reached the size of the pre-perestroika period areas.

In its turn, permafrost which previously restrained the processes of removal of soil particles is retreating due to current warming. And as a result of thermal erosion, an increasing amount of solid material with surface runoff enters rivers. Thus, the increase in sediment runoff in the lower course of the Ob River may be due to the thawing of permafrost rocks and, as a result, the weakening of adhesion between soil particles, which contributes to the intensification of soil erosion processes in the catchment area.

At the same time, the numerical implementation of the forecast scenarios of climate change in the studied region showed a significant decrease in sediment runoff for the RCP 8.5 scenario. This is explained by the redistribution of the water content in the Ob river during the year and, as a result, the cutting of the high water discharges during high water.

This, in turn, leads to a significant decrease in the transporting potential of the river and a reduction of the sediment discharges by more than half.

The multi directional dynamics of sediment runoff in the middle and lower reaches of the Ob River is determined by various natural and anthropogenic factors. At the same time it should be noted that the sediment runoff of Arctic rivers is more susceptible to changes as a result of climatic influences than the water runoff of these watercourses [*Knight and Harrison*, 2009]. However, due to the multifactorial nature of the processes of formation of water and sediment runoff in the catchment area, there is currently insufficient understanding of the impact of climate change on geomorphological systems and their sensitivity to such changes [*Lu et al.*, 2013].

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References

Afanasiev A. N., Bogoyavlenskaya G. E., Varnakova G. M., et al. Section "Snow.Ice. Congelation" // National Atlas of Russia. Chapter 2 "Environment (Nature). Ecology". — Government of the Russian Federation, 2000. — (In Russian).

Alpatiev A. M., Arkhangelsky A. M. and Podoplelov N. Ya. Physical geography of the USSR. — Moscow : Vysshaya Shkola, 1973. — 334 p. — (In Russian).

Aparin B. F. and Matinyan N. N. Landscape structure of the North-West of Russia and typology of agricultural lands // Vestnik of Saint Petersburg University. Series 3. Biology. — 2005. — Issue 2. — P. 132–141. — EDN: RTSYQF ; (in Russian).

Chalov R. S. Riverbed science: theory, geography, practice. Volume 3: Human impacts, dangerous expressions and management of channel processes. — Moscow : KRASAND, 2020. — 640 p. — (In Russian).

Chalov R. S., Evstigneev V. M., Zaitsev A. A., et al. Riverbed regime of the rivers of Northern Eurasia (within the former USSR). — Moscow : MSU, 1994. — 335 p. — (In Russian).

Copernicus Climate Change Service. Climate Data Store: In situ total column ozone and ozone soundings from 1924 to present from the World Ozone and Ultraviolet Radiation Data Centre. — ECMWF, 2021. — https://doi.org/10.24381/cds.99842490.

Frolova N. L., Magritskiy D. V., Kireeva M. B., et al. Runoff and Ice Phenomena Dynamics on the Rivers of Russian Arctic Due to Anthropogenic and Climate Changes // Problems of Geography. — 2018. — P. 233–251. — EDN: XNFPMD ; (in Russian).

Global Data Center. Specialized datasets. — URL: http://meteo.ru/data/ (visited on 03/06/2025) ; (in Russian).

Gorshkov S. P. Exodynamic processes of the developed territories. — Moscow : Nedra, 1982. — 286 p. — (In Russian).

Ilyinykh V. A. Agriculture of Eastern Siberia in the late 1980s - 1990s: Dynamics, industry and organizational and production structure // Journal of Economic History & History of Economics. — 2018. — Issue 1, no. 19. — P. 59–78. — https://doi.org/10.17150/2308-2588.2018.19(1).59-78. — (In Russian).

ISO 16269-4:2010. Statistical interpretation of data - Part 4: Detectionand treatment of outliers, IDT. — Moscow : StandartInform, 2017. — 53 p. — (In Russian).

ISO 2602:1980. Statistical interpretation of test results - Estimation of the mean - Confidence interval (MOD). — Moscow : StandartInform, 2005. — 11 p. — (In Russian).

Ivanov V. Dynamics of landscapes of the floodplain segment of the middle course of the Ob River over 200 years. — SAE Siberian Institute of the Future of the National Research Tomsk State University, 2020. — 76 p. — (In Russian).

Ivanov V. A. and Chalov S. R. Sediment budget assessment of the Ob and the Yenisei // Geomorfologiya. — 2021. — Vol. 52, no. 3. — P. 79–89. — https://doi.org/10.31857/S0435428121030056. — (In Russian).

Knight J. and Harrison S. Sediments and future climate // Nature Geoscience. — 2009. — No. 2. — https://doi.org/10.1038/ngeo491.

Kondratyev S. A. Formation of external load on reservoirs: modeling problems. — Saint-Petersburg : Nauka, 2007. — 253 p. — EDN: QKHCVD ; (in Russian).

Kondratyev S. A. and Shmakova M. V. Calculation of runoff formation in a catchment area based on the ILHM model. Certificate of registration of a computer program RU 2015614210. — Federal Service for Intellectual Property, 2015. — EDN: KIHVJC ; (in Russian).

Long-term dynamics of the water-ecological regime of the Novosibirsk reservoir / ed. by O. F. Vasiliev. — Novosibirsk : SB RAS, 2014. — 393 p. — (In Russian).

Lu X. X., Ran L. S., Liu S., et al. Sediment loads response to climate change: A preliminary study of eight large Chinese rivers // International Journal of Sediment Research. — 2013. — Vol. 28, no. 1. — P. 1–14. — https://doi.org/10.1016/S1001-6279(13)60013-X.

Magritskiy D. V. Annual runoff of suspended sediment from Russian rivers in the Arctic Ocean catchment area and its anthropogenic changes // Vestnik Moskovskogo Universiteta. Seria 5, Geografia. — 2010. — No. 6. — P. 17–24. — EDN: NCSYLL ; (in Russian).

Magritskiy D. V., Chalov S. R., Agafonova S. A., et al. Hydrological Regime of the Lower Reaches of the Ob River. Factors and Features of Its Long-Term Changes // Modern problems of hydrometeorology and sustainable development of the Russian Federation. Collection of abstracts of the All-Russian scientific and practical conference. — 2019. — P. 258–260. — EDN: VXWQQG ; (in Russian).

Magritskiy D. V., Chalov S. R., Garmaev E. Zh., et al. New Data on the Transformation of Water and Sediment Runoff into the Lena River Delta Based on the Results of Expedition Measurements in August 2022 // Arctic and Antarctic research. — 2023. — Vol. 69, no. 2. — P. 171–189. — https://doi.org/10.30758/0555-2648-2023-69-2-171-190. — (In Russian).

Mernild S. H., Sigsgaard C., Hasholt B., et al. Climate, river discharge and suspended sediment transport in the Zackenberg River drainage basin and Young Sound/Tyrolerfjord, Northeast Greenland, 1995-2003 // Meddelelser om Grønland. Bioscience. — 2007. — Vol. 58. — P. 24–43. — https://doi.org/10.7146/mogbiosci.v58.142638.

Moskalik M., O'Regan M., Promińska A., et al. Variability in transport of terrigenous material on the shelves and the deep Arctic Ocean during the Holocene // Polar Research. — 2015. — Vol. 34. — P. 1–12. — https://doi.org/10.3402/polar.v34.24964.

Overeem I. and Syvitski J. Changing Sediment Supply in Arctic Rivers // Sediment dynamics in changing environments. — IAHS publication No 325, 2008. — P. 391–397.

Shmakova M. V. The River's Sediment in the North-West Russian Federation // Geographical Bulletin. — 2021. — Issue 2, 2(57). — P. 65–74. — https://doi.org/10.17072/2079-7877-2021-2-65-74. — (In Russian).

Shmakova M. V. Sediment transport in river flows: New approaches and formulas // Modeling of Sediment Transport. — IntechOpen, 2022. — https://doi.org/10.5772/intechopen.103942.

Surface water resources of the USSR. Volume 15. Altai and Western Siberia. Issue 2. Middle Ob / ed. by N. A. Panina. — Leningrad : Gidrometeoizdat, 1972. — 351 p. — (In Russian).

Surface water resources of the USSR. Volume 15. Altai and Western Siberia. Issue 3. Lower Irtysh and Lower Ob / ed. by V. E. Vodogretsky. — Leningrad : Gidrometeoizdat, 1973. — 426 p. — (In Russian).

Syvitski J. P. M. and Kettner A. J. Scaling sediment flux across landscapes // Sediment dynamics in changing environments. — IAHS publication No 325, 2008. — P. 149–156.

Syvitski J. P. M., Vörösmarty C., Kettner A. J., et al. Impact of humans on the flux of terrestrial sediment to the global ocean // Science. — 2005. — Vol. 308, no. 5720. — P. 376–380. — https://doi.org/10.1126/science.1109454.

Trizno A. K., Glodenis M. N. and Makhaeva N. M. Novosibirsk reservoir, water management complex and it's problems // Water Sector of Russia: Problems, Technologies, Management. — 2000. — Vol. 2, no. 5. — P. 423–430. — (In Russian).

Turutina T. V. Changes in the intensity of erosion processes in the riverbeds of the cryolithozone (on the example of the rivers of Central Yamal) // The thirty-seventh plenary interuniversity coordination meeting on the problem of erosion, riverbed and estuarine processes. — Ryazan : Ryazan State University named after S. A. Yesenin, 2022. — P. 157–158. — EDN: KQMXVT ; (in Russian).

Vörösmarty C., Meybeck M., Fekete B., et al. Anthropogenic sediment retention: major global-scale impact from the population of registered impoundments // Global and Planetary Change. — 2003. — Vol. 39, no. 1/2. — P. 169–190. — https://doi.org/10.1016/S0921-8181(03)00023-7.

Walling D. E. The changing sediment loads of the world's rivers // Annals of Warsaw University of Life Sciences - SGGW, Land Reclamation. — 2008. — No. 39. — P. 3–20. — https://doi.org/10.2478/v10060-008-0001-x.

Wegner C., Bennett K.E., Vernal A. de, et al. Sediments and future climate // Nature Geoscience. — 2009. — Vol. 2.

World Meteorological Organization. WMO Guidelines on the Calculation of Climate Normals. — WMO-No. 1203, 2017. — 29 p.