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The role of climate change in the water regime of rivers in south-east of Kazakhstan

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ABSTRACT: The role of climatic factors in changing the intra-annual distribution of the runoff of the rivers in South-East of Kazakhstan was determined by statistical and hydrological calculations, spatial-temporal analysis. The dependence of river runoff on climatic factors was estimated by the graph-analytical method. The trends of change over the entire observation period with the annual indicators of the distribution of water flow within the year for the average year's water volume, for the main hydrological posts were determined by the linear trend method. The air temperature and atmospheric precipitation data were taken from the nearest meteorological station. In addition, the characteristics of high water with the greatest runoff in the river, and the date of the beginning of the high water, the maximum indicator, the duration and the completion date of the high water were estimated, what will allow us to estimate in more detail the trends in the hydrological regime and its dependence on climatic conditions. A conclusion about the changes in the water regime of the river flow related to climate change in the study area was made.

KEYWORDS: Air temperature, atmospheric precipitation, hydrological regime, intra-annual distribution of runoff, river runoff , flow change trend.

I . INTRODUCTION

Contemporary climate changes and the growth of anthropogenic loads in recent decades have led to serious changes in the spatial and temporal distribution of river flow resources. A lot of studies on climate deal with the intensification of climate variability within a year due to the global changes in recent years. Rivers runoff, as an integral climatic characteristic is more resistant to changes than to meteorological parameters, possibly due to the mitigating effect of the underlying surface.

The studied area covers the territory of the Ile-Balkhash basin, which is located in the southeastern part of the Republic of Kazakhstan (Figure 1). Administratively, on its territory there are Almaty region, southeastern part of Karaganda region, south-western part of East Kazakhstan region, eastern part of Zhambyl region, as well as the northwestern part of Xinjiang Province which is within the People's Republic of China [1,2].

The total length of the watershed line is about 4 thousand km. The area of the studied territory is more than 500 thousand km^2, including 400 thousand km^2 within Kazakhstan. The length of the basin from west to east is more than 900 km and from north to south is 680 km.

The recent decades studies [3-6] show that in general the annual runoff of the rivers of Kazakhstan because of climate has changed insignificantly. The long-term norms of annual river runoff in the period before 1970, when noticeable trends in climate warming began, are comparable with the present period, which cannot be done with the interannual and, especially, intra-annual variability of river flow. The observed trends in the growth of extreme hydrological phenomena are statistically significant everywhere.

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Fig 1. Geographical location of the studied area

Most modern scientific researches concerning the changes in water resources and river flow pay attention to the character of the interannual variability and cyclical nature of the annual variation of river flow of a given region in conditions of changing climate and anthropogenic impact. The annual flow indications often average out the changes that occur within a year in the distribution of the runoff and do not reflect the real picture of changes in the water regime of rivers, both in the whole for the water basin and at the regional level.

II. METHODS OF RESEARCH

The methodology for the estimation of the impact of climate on the inter-annual distribution of rivers run off is based on a comparative analysis of the long-term course of runoff of separate months, seasons and meteorological elements. To determine the dependence of river flow, the regression method was used. This method consists in constructing regression equations for rivers runoff depending on meteorological factors (precipitation, air temperature, humidity deficit, etc.) of the following type:

$$Y_i = a_1x_1 + a_2x_2 + \ldots + a_nx_n + a_0, \qquad (1)$$

where: $a_1, a_2, \ldots, a_n$ are parameters;

$x_1, x_2, \ldots, x_n$ are meteorological elements.

Some complication of the regression model is the so-called sequential complex regression. The essence of this version of the regression method is to evaluate the combined factors with the subsequent construction of the regression equation of the river run off, depending on these arguments.
Models of complex regression resemble models of factor analysis. This analysis is represented by two independent branches: component analysis (main components method) and actual factor analysis.

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Unlike the regression method, where the arguments are run off factors, the factors are unknown in the studied model, and many of their features are only known. The task is reduced to finding these factors through features and, possibly, to their interpretation. The hydrographic, orographic, geographical and climatic characteristics are the features of water resources.
From the whole set of features, the factors of Φ_i by decomposition are determined by the optimization methods:

$$x_i = \sum_{r=1}^{k} l_{ir}\Phi_r + e_i \quad (2)$$

where: *lir* - *i*-th indication on the *r*-th factor.
This expression (2) is valid for the factor model, and for the component model (principal components method), the random remains of *e* in this expansion are absent. The difference between the two branches of the same model is in the fact that in the component model, the variance of all features is gradually exhausted by the variances of the components, and in the factor model, the presence of *ei* remains is assumed.
There are a number of methods to test linear unidirectional changes. A technique widely used in hydrology and meteorology was applied in our case [7,8]. This method based on checking the statistical significance of the trend parameters calculates the following linear regression equation:

$$Y(t) = a0 + a1t, \quad (3)$$

where: *Y (t)* - indicators of the studied water resources (river basin);
t is the serial number of the observed quantity;
ao, *a1* are regressive coefficients.

The importance of the linear trend is the basis for acceptance (rejection) of the hypothesis. The simplest technique for solving this problem is to estimate the correlation coefficient of the averaged runoff indicators versus time, with respect to the standard error of the regression coefficient or with respect to the doubled or tripled standard error. If the value of the correlation coefficient is greater than twice or tripled value of the standard error of the correlation coefficient, then an alternative hypothesis of the instability of the hydro meteorological series, respectively, at the 5% or 1% significance levels is recognized, i.e. the presence of a linear trend.
To accept the hypothesis of a linear trend by the method of I.I. Polyak, it is required to meet the following conditions [8]:

$$\overline{\sigma}^2 \le \sigma^2, \qquad |a_1| \ge 2\sigma_{a_1}, \quad (4)$$

$\overline{\sigma}^2$ is the variance of the deviation of the observed values from the trend line, where the category is defined as:

$$\overline{\sigma}^2 = \sigma^2 (1-R^2), \quad (5)$$

σ_{a_1} - standard deviation of the regression coefficient *a1*, which is defined as follows:

$$\sigma_{a_1} = \sqrt{\frac{12}{n(n-1)}}\,\sigma \quad (6)$$

If conditions (6) are not met, then the linear trend is insignificant with a probability of 5%.

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III. CLIMATIC CONDITIONS FOR THE FORMATION OF WATER REGIME OF THE STUDIED AREA

According to hydrological conditions, the studied territory is divided into two areas: a mountainous area, or a zone of the formation of a runoff, and a flat, or an area of loss or dispersion of runoff. Figure 2 shows the character of the terrain of the studied area with the following physic-geographical areas: the uplands and the lowlands of the Kazakh folded country, the plains of the Balkhash-Alakol depression, the systems of the Kazakh-Dzungaria mountain area, the Shu-Ile Mountains and the eastern part of the Northern Tien Shan and Tien Shan Mountain area.

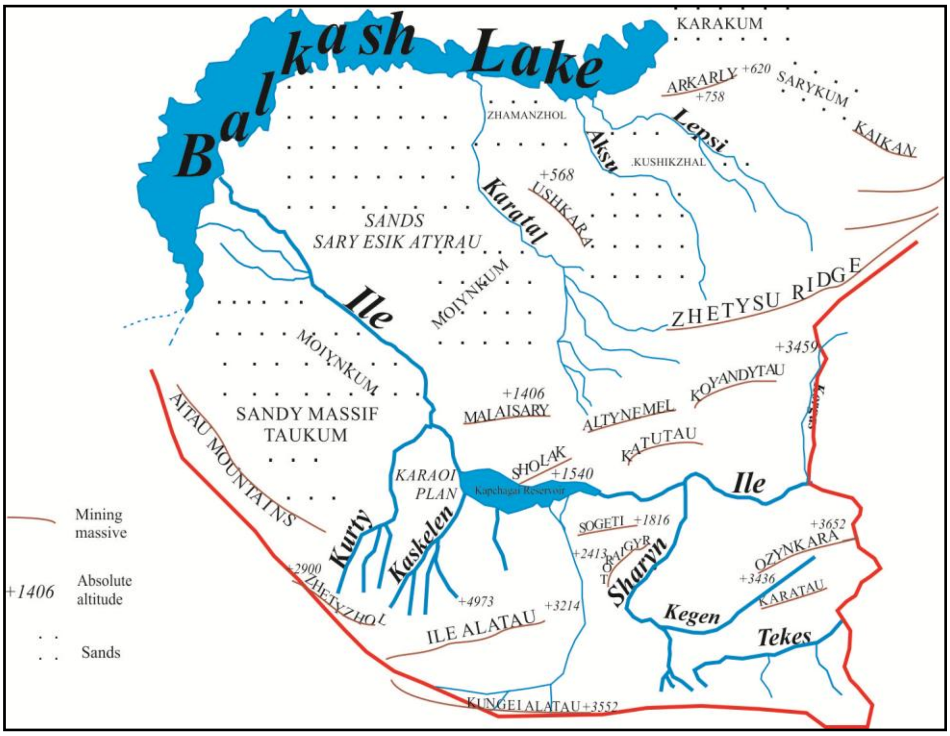

Fig 2.Scheme of the orographic structure of the basin of Lake Balkhash

In the mountains, due to considerable humidity because of atmospheric precipitation and low evaporation, numerous rivers and streams are born. Their water content along the current is rapidly increasing due to numerous tributaries and intensive draining of groundwater by deep-cut gorges. When leaving the mountains on the cones, the tributary network is replaced by a characteristic fan-shaped river branches, streams and irrigation canals. Here and in the adjacent arid plains, the runoff is quickly lost because of evaporation and replenishment of underground waters of artesian basins; only the largest rivers - Ile, Karatal, Aksu, Lepsi and others - carry their waters to the lake or flow into the main river of the basin - the Ile River.

The area of the runoff formation within the studied territory is represented by mountain ranges of the Northern Tien-Shan and Zhetysu Alatau, separated by the vast Ile depression.

The climate of the described region is mainly continental, but it is very heterogeneous due to its latitude and mountain zone. In winter, the weather is mostly cold (dry and clear) because of the West Siberian anticyclone. Spring is characterized by long variable weather with frequent polar invasions leading to light frosts and abundant rainfall. In summer, because of the development of the Central Asian thermal depression, the weather is mostly hot, slightly cloudy. Precipitation at this time is caused by the invasion of cold northern air masses.

In the fall, frontal processes and cyclonic activity intensify while the spur of the West Siberian anticyclone over Kazakhstan is gradually developing. Intensive cold snaps, leading to the snow cover and the freezing of water bodies, are caused by the November cold invasions connected with the predominance of meridian circulation [9].

In spring, the steady transition of the average daily air temperature from negative to positive values first of all occurs in the flat southeastern part in March 5-10, in the north - at the end of March, and at altitudes of about 3000 m - in the second decade of May. The studied territory is characterized by an intensive rise in air temperature in the spring. From

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March to April, the temperature rises by 10-13 degrees C in the Balkhash area, by 7-9 degrees C in the foothills and by 5-6 degrees C in the mountains. There are light frosts in the spring.

The annual amount of precipitation on the territory decreases from south to north. The greatest amount of precipitations is in the high-mountainous areas of the northwestern slope of Zhetysu Alatau (1800-2000 mm), the smallest - on the coast of Lake Balkhash - about 150 mm per year.

It is known that in latitudinal circulation in all seasons of the year, the precipitation is less than the norm (except for foothills), with a maximum indication at altitudes of 1500-1700 m. With meridian circulation, precipitation is higher than normal with a maximum at altitudes of 2000-2500 m. Snow cover in northern and foothill areas appears on November 10-15, in the mountain areas - in the last days of October, and in the high-mountainous areas - in early September. In 70-80% of cases, the first snow is not followed by the steady snow cover.

The steady snow cover in high-mountain areas is established in September-October, in foothill areas - in November-December. In the Balkhash basin, the snow cover is established in the middle of November, in the northern area – in the first decade of December, and in the second decade of December is in the southern regions. In the south, winters are often without a stable snow cover.

Relative humidity in the flat areas has a well-defined annual cycle: the maximum is in winter (60-75%), the minimum is in summer (20-40%). In the mountains up to an altitude of 1500-2000 m, the maximum relative humidity is also observed in winter, and in the area higher than 1500-2000 m, the annual relative humidity variation is reversed, with the maximum in spring and the minimum in winter.

The amount of total evaporation varies throughout the year from north to south, and in mountains - from top to bottom within large limits. In the Southern Balkhash area, the annual evaporation from the soil is 150 mm, increasing to the foothills up to 350-400 mm [9].

According to I.S. Sosedov' researches of 1984, in the Ile Alatau , the total evaporation for the warm period of the year in the middle zone varies from 275 to 350 mm, on the northern slope is from 434 and to 475 mm is on the southern slope [10]. Evaporation from snow during the cold period averages 42 mm - in the low mountains; 65 mm – in middle mountains and 71 mm - in the high mountains. Evaporation from bare sections of the slope in the Ile Alatau can reach 110 mm. In Balkhash area and intermountain hollows, evaporation from snow can be 50% of snow reserve.

IV. RESULTS AND DISCUSSION

A. The role of climatic factors in the water regime changing

The intra-annual distribution of runoff is sensitive to changes in both atmospheric precipitation and air temperature. In this case, it is important not only the indication of these changes, but also the seasons (months) of their manifestations. Both precipitation and air temperature can play a decisive role.

Flood is the most important phase of the water regime, characterized by high water content. The course of the runoff during the flood is mainly determined by snow thawing. The main elements of the spring flood are the dates of the beginning and end of the flood, its duration, the maximum (time and average daily) flow and the level and date of its occurrence, the duration of the rise and fall, the volume and the runoff layer.

The dates of the beginning and the end of the flood were established by the hydrographs of the runoff. The first day begins with a noticeable increase in water flow, which usually precedes a sharp increase in the level and flow, and the end of the flood is the day at the end of the recession curve, when the intensity of the decline has already sharply decreased as a result of the end of the runoff of the main volume of thawed water. The date of the greatest flood is considered to be the day with the highest daily average water flow. The duration of the flood is from the date of the beginning of the flood, inclusive, till its end.

Spring floods in the southeast of Kazakhstan are the main phase of the water regime of rivers, which accounts for the main amount of annual runoff and, as a rule, maximum water flow. Maximum water flow in the rivers of Lake Balkhash basin is formed because of thawing snow and glaciers. However, in some areas (the rivers of the Middle Zone - Ile and Zhetysu Alatau, as well as of the Tarbagatai Range) rain floods are superimposed on the high water, their maximum flow in some years are several times higher than those formed by thawed waters.

For the rivers of the northern slopes of the Ile Alatau, the maximum flow of snow-glacial origin are observed on the rivers of the highland zone with average reservoir heights of more than 3200 m. Cases of mixed floods on these rivers are very rare. The share of ground seasonal snow and rain components in the annual runoff with an increase in the average height of the reservoir decreases [11].

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While considering in more detail the change in the distribution of runoff within a year of the two periods of 1952-1965 and 1960-2012, it can be noted that the month of the flood peak changes from July to August in the modern period, while the month of the beginning of the high water remains May and the end of the flood is observed in September, there is a noticeable increase by 6% in the flow in June, in August, it is by 20%, and a decrease by 15% is in July for the current period of 1960-2012. From December to April, it is possible to note a 5-15% decrease in runoff for the modern period (1960-1912) (Figure 3). It should be noted that, firstly, in this case, the river run-off by months is averaged, that is why it is impossible to detect the deviations of the start of certain phases of water content, which are limited to 15-20 days. Secondly, the percentage deviation does not sufficiently reflect the water content of each separate month, but shows only the share of these months comparing to the same years. Therefore, to see a more specific change in the HRV run off, the work directly characterizes the dates of the phases of the water regime over a multi-year period. According to these parameters, the analysis of these characteristics gives a more vivid picture of the change in the water regime.

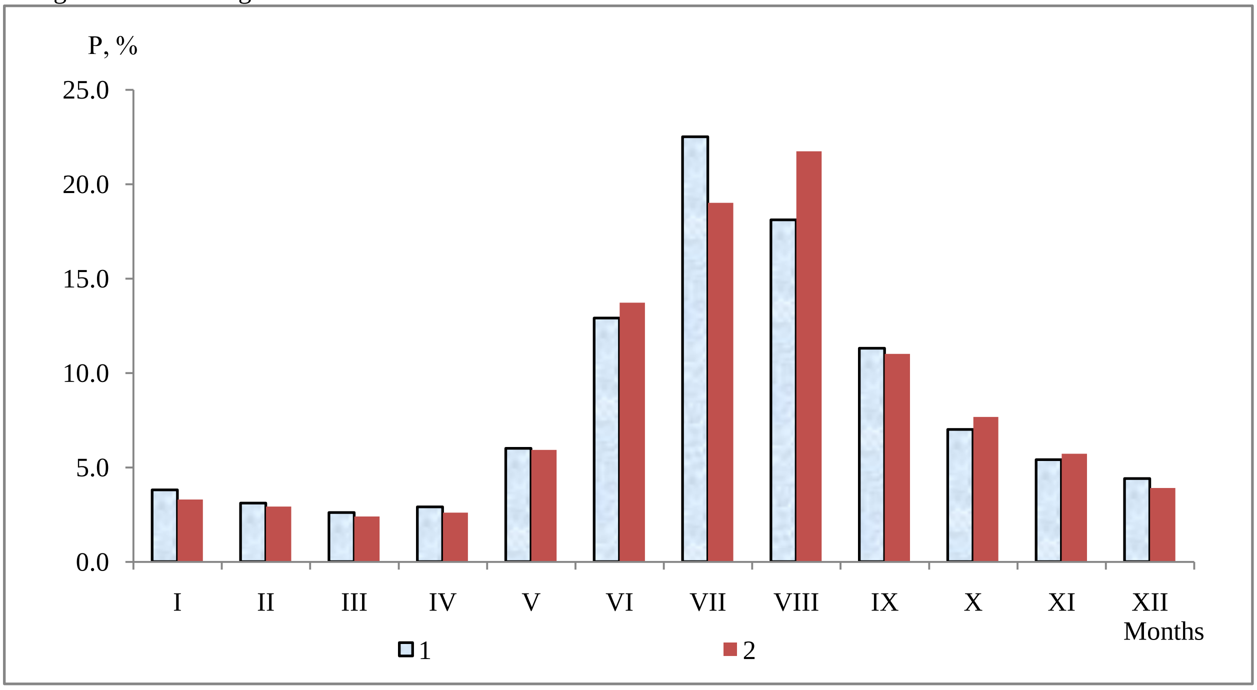

Fig 3. Intra-annual distribution of the Ulken Almaty River flow - 2 km above the lake Ulken Almaty for the years 1952-1965 (1) and 1960-2012 (2)

Figure 4 shows the dates of the beginning and ending of the flood, the duration and dates of the flood peak of the Ulken Almaty River. Flood usually passes in two stages. The first is due to the thawing of snow in the foothill zone, and the second is due to the thawing of glaciers and snowfields in the mountains. The graph shows the trend of the beginning dates and the peak of the flood in the direction of earlier periods: the dates of the beginning of the high water, on average, by 2.2 days over 10 years, the peak floods - by 2.1 days over 10 years, and the dates of the flood completion in the later terms: 4.3 days over 10 years. Therefore, the average duration of flood increased by 6.5 days over 10 years (Figure 4).

The rivers of the northeastern part of the Zhetysu Alatau Ridge originate under the glaciers of the northern slope of Zhetysu Alatau at the altitude of more than 3000 meters above sea level. The rivers of the alpine zone (at the altitude of more than 2800-3000 m) are characterized by the fact that thawed waters of high-mountain snows and glaciers play a great role in the formation of maximum flow. Some years, liquid precipitation can only slightly increase them [11,12].

On small rivers of the middle zone, there are flows of mixed (snow-rain) origin. The maximum flow on the rivers of the low mountain-foothill zone (at an altitude of less than 1000 m) is formed from the thawing of seasonal snows.

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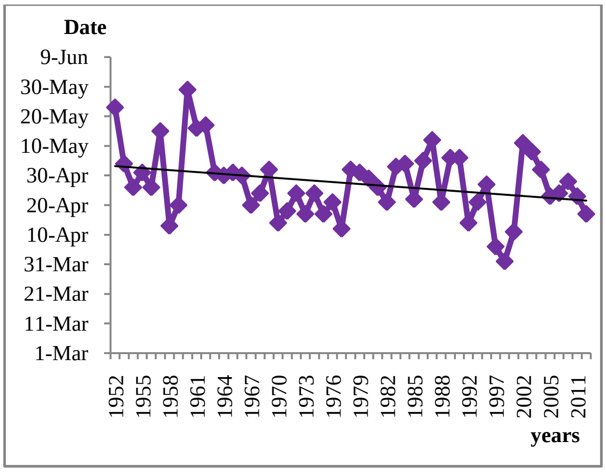
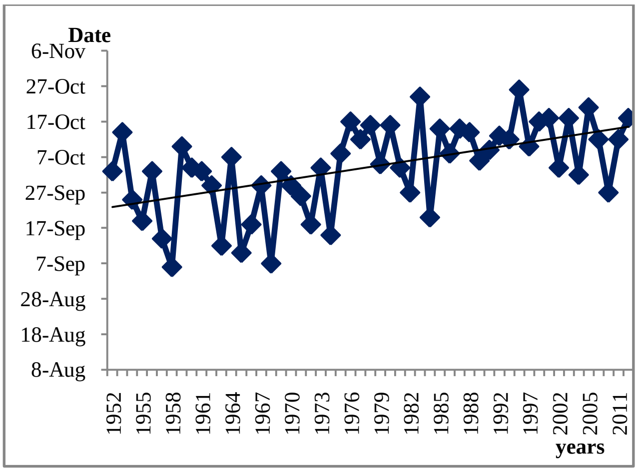


The start date of the flood



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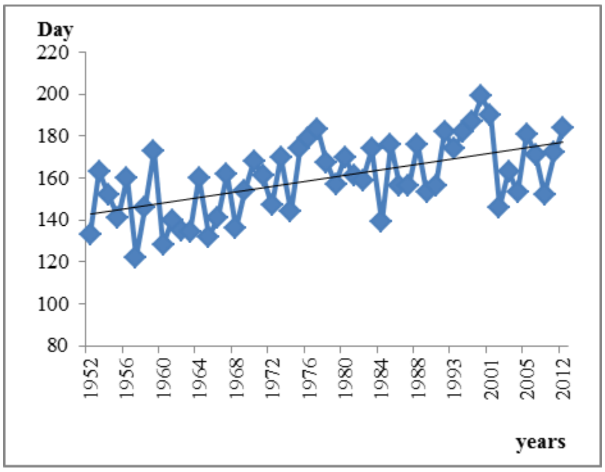

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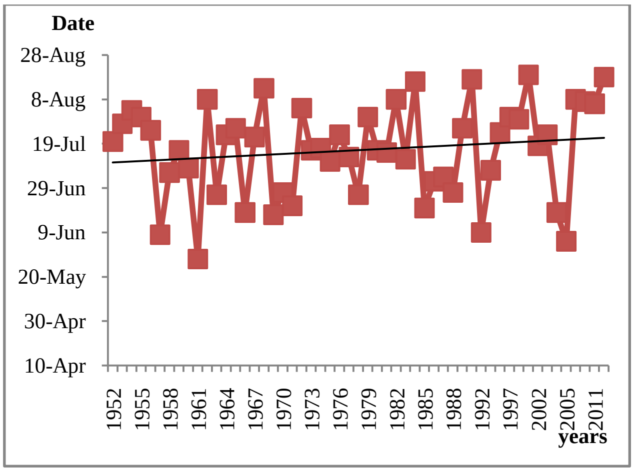

The end date of the flood

Fig 4.Changes in the characteristic of floods of the Ulken Almaty River - 2 km above Ulken Almaty lake .

The supply of the Lepsi River is mixed - snow and glacial. From mid-March to the second half of April, the first wave of snow floods takes place due to the thawing of the snow. From the second half of May to the middle of June, a new, higher wave occurs, due to the thawing snow reserves of the high-mountainous part of the basin. The flood (spring-summer) on the rivers of the region on average is about 80%, and for the limiting winter season is about 20% of the runoff (the Lepsi River - aul Lepsi). Further, the change in HRV for 1960-2012 in comparison with the period of 1935-1965 is analyzed. For the period of 1960-2012, there was a significant decrease in runoff in April and May (12% and 23%, respectively) and in October, it was 9% compared to the period of 1932-1965. (Figure 5).
A significant increase was observed in June, September and March (23%, 26%, 11%), and a slight increase in July. For the current period, the largest monthly flow for this area was observed in June, a month later than in 1932-1965.

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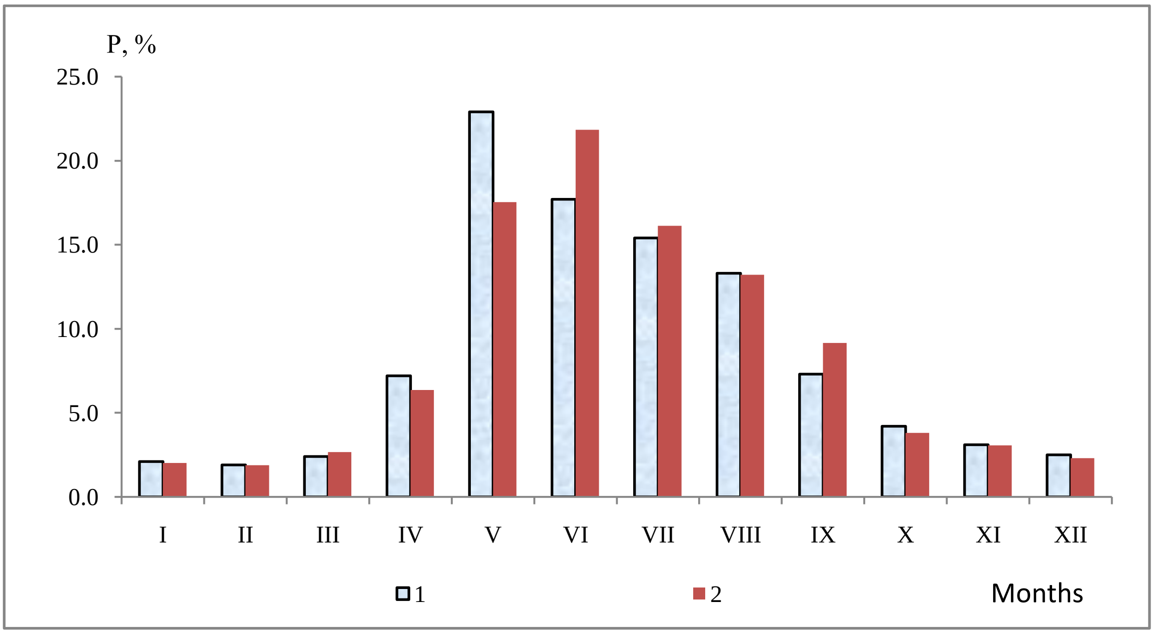

Fig 5. Intra-annual distribution of the Lepsi river run off - aul Lepsi for 1932-1965 (1) and 1960-2012 (2).

Floods on the rivers of the northeastern part of the Zhetysu Alatau Ridge begin in early April and end in mid-September. Figure 6 presents graphs of the dates of the beginning and ending of the flood, the duration and dates of the flood peak of the Lepsi River - aul Lepsi. The trend of the beginning date shifts to earlier dates: the dates of the beginning of the high water, on average, 1.1 days for 10 years, and the dates of the end of the flood to the later date: 2.4 days for 10 years. Therefore, the average duration of flood increased by 3.5 days for 10 years (Figure 6).

The terms of the beginning and the end of the high water have some nominal meaning, since the determination of the start time of high water proves to be quite a difficult task. With some degree of conventionality, it can be said that at the present moment, on the observed posts, there is a statistically significant trend in shift of the date of the beginning of the flood to earlier periods. The dates of changes in the beginning, end, and peak of the spring high water have a close connection with the change in air temperature within the year, and this indicator was considered as a conditionally objective characteristic of the flood.

According to the data obtained from the evaluation of the linear trend of the date of beginning, end and peak of the flood shown in Figures 3, 4 and 5 and air temperature, it can be concluded that the increase in air temperature in February and March, for the period from 1970 to 2012, compared with the period before 1969 at + 0.7 ... + 1.08 °C, had an effect on the dates of the beginning of the flood, shifting them to earlier ones. The start dates of high water on the studied rivers began to be observed earlier by 1.1-2.2 days, on average over 10 years. The date of the end of the flood is also a rather difficult characteristic to determine. Nevertheless, the general trend for the modern period is mainly the "delay" of dates of the end of high water. But the dates of the end of the flood may be at different terms depending on the supply of the river. On the Ulken Almaty river and the Lepsi river, where the glacial component plays the most significant role in the annual runoff, the flood completion date is observed later by 4.3-2.4 days for 10 years, and accordingly the average duration of the flood increased with a significant trend (6.6 days for 10 years), and in line of the Sharyn River – Sarytogai natural boundary, where the snow supply plays an essential role, the end of the high water shifted by 3.4 days for 10 years.

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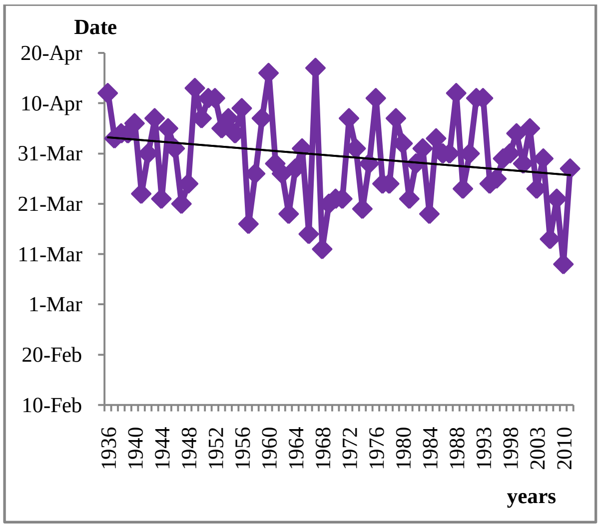
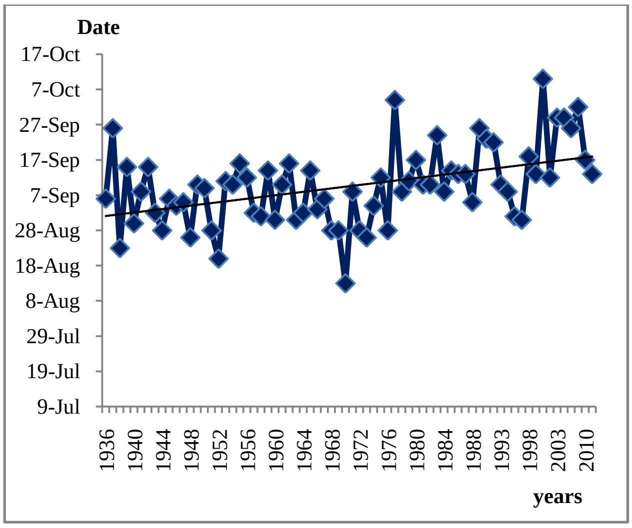


The start date of the flood



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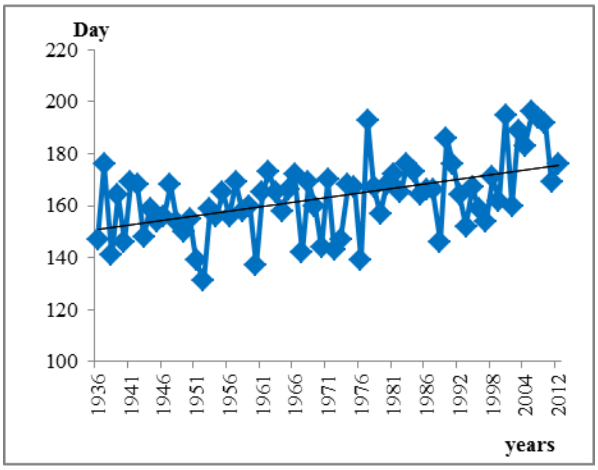

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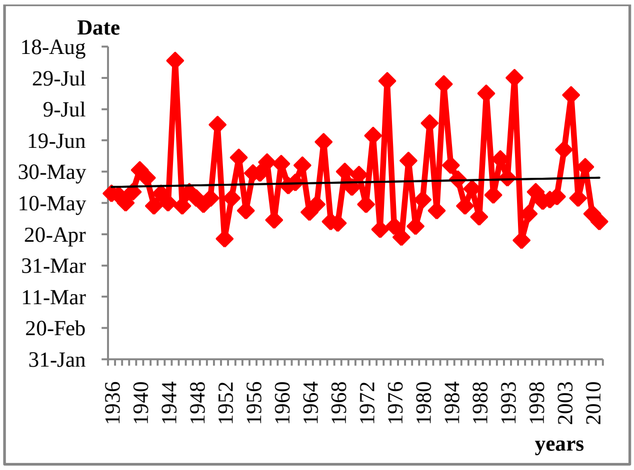

The end date of the flood

Fig 6. Changes in the characteristic floods of the Lepsi river - aul Lepsi.

To estimate the trends in monthly water flow, average monthly air temperature and monthly precipitation totals, the linear trend coefficients (a, ^{0}C per 10 years) were calculated for two periods: from the beginning of observation to 1969 and 1970-2012. The results of calculation of the coefficients of the linear trend of the river runoff, the average monthly air temperature, the monthly precipitation totals are given in Tables 1 to 3.

In the intra-annual distribution of river run off over the studied territory, for the two periods considered, there is a tendency both to increase and to reduce the river runoff (Table 1). At the same time, there is an increase in river flow at the majority of the observed stations. After 1970, the trend of increasing run-off in all months with the largest increase mainly in the summer months is observed in the line of the Ulken Almaty River - 2 km above Big Almaty Lake and in the line of the Sharyn River – Sarytogai natural boundary. On other sections during a year, in the modern period there is a change in river run off both in the direction of decrease and increase.

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Table 1. Coefficient of linear trend (a, m^3 per seconds for 10 years) of monthly water flow of rivers

River - Station	Periods	Months												yearly
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Ulken Almaty - 2 km above Big Almaty Lake	1952-1969	-0,09	-0,08	-0,07	-0,04	0,07	0,20	-0,08	-0,16	-0,32	-0,26	-0,22	-0,21	-0,10
	1970-2012	0,08	0,06	0,05	0,07	0,16	0,57	0,63	0,79	0,49	0,21	0,15	0,12	0,28
Sharyn – Sarytogai	1936-1969	0,64	0,89	2,72	7,28	0,36	4,44	0,86	1,77	2,37	2,03	1,35	1,31	2,17
	1970-2012	3,36	3,98	2,18	0,56	7,04	6,48	3,47	3,56	4,09	4,15	3,75	3,53	3,86
Lepsy - Lepsinsk	1932-1969	0,34	0,30	1,03	2,85	4,19	6,48	3,75	2,41	1,02	0,58	0,64	0,41	9,86
	1970-2012	0,18	0,22	0,06	-0,14	-0,99	1,74	0,27	1,07	0,69	-0,01	-0,16	0,10	0,26
Bizhe - Krasnogorovka	1949-1969	0,40	0,16	1,91	1,47	1,59	0,90	0,34	0,25	0,21	0,32	0,39	0,43	0,70
	1970-2012	0,36	0,28	-0,16	0,21	0,40	0,29	0,32	0,23	0,17	0,17	0,18	0,27	0,23
Ayaguz - Tarbagatay	1960-1969	-0,33	-0,27	2,73	-0,03	1,87	-0,11	-0,47	-0,38	0,14	1,25	0,69	0,24	0,71
	1970-2012	0,09	0,12	0,38	-0,62	-0,39	-0,32	-0,03	0,04	0,06	0,08	0,11	0,12	-0,03

On the Sharyn River – Sarytogai natural boundary, the greatest change comparing to the previous period is observed, i.e. if we compare river run off from the beginning of observation till 1969, in the modern period (after 1970) in the line of the Sharyn River – Sarytogai natural boundary in April, there is a decrease in river flow, while the linear trend coefficient retains its positive sign.

In the modern period, the reduction of river run off on the Lepsy River - Lepsinsk town (aul Lepsi) is observed in April, May, October and November, in the line of the Bizhe river - Krasnogorovka village - in March, in the line of the Ayaguz river - Tarbagatay village - in April-August. The decrease in water flow in the area does not exceed 1 m^3 per seconds.

In January and February in the modern period, the river runoff increases from 1 to 4 m^3 per seconds. The increase in river run off is connected with a trend of increasing precipitation with the positive trends in air temperature (Tables 2 to 3).

Table 2. Coefficient of linear trend (a, mm per 10 years) of monthly precipitation totals for MS

Meteorological Station	Periods	Months												yearly
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Big Almaty Lake	1952-1969	14,1	-8,53	18,0	-4,65	-25,8	-35,5	9,90	-12,7	13,1	19,3	5,27	-0,60	-8,00
	1970-2012	2,30	2,55	3,91	-0,08	2,26	-2,55	14,6	0,18	1,71	4,22	1,42	1,84	32,4
Kyrgyzsay	1936-1969	1,48	-2,21	8,48	2,41	-4,19	1,88	9,05	-0,43	0,60	3,00	-1,50	-1,12	17,4
	1970-2012	2,73	3,04	3,68	1,52	4,89	-4,37	6,84	-0,53	-0,74	3,69	2,83	1,38	25,0
Lepsi	1932-1969	0,64	-1,59	17,5	7,68	2,77	3,06	4,32	2,08	-2,18	8,89	5,11	-1,89	46,4
	1970-2012	7,29	4,74	5,90	-6,54	-2,45	-4,48	10,3	3,79	1,12	-2,93	-0,65	1,86	17,9
Zharkent	1949-1969	5,64	-7,52	19,7	-10,7	-0,87	-35,2	11,2	-3,70	0,30	16,9	5,90	3,16	4,87
	1970-2012	3,44	2,62	9,12	0,03	-0,61	-1,45	4,89	1,29	-5,04	2,60	-2,95	-0,71	13,2
Ayaguz	1939-1969	2,68	2,35	5,27	-2,27	-3,94	8,72	8,52	1,70	-3,48	6,60	5,04	3,70	34,9
	1970-2012	-4,88	-1,47	-0,11	-2,38	-4,72	-0,87	-0,01	-0,04	-2,44	-2,78	-2,56	-0,72	-23,0

The change in the amount of precipitation over the area during the year is not even. The increase in monthly precipitation totals in the modern period is 2-7 mm per 10 years - in winter, 2-9 mm per 10 years - in spring, 1-14 mm per 10 years - in summer, 1-4 mm per 10 years - in autumn. The change in the annual amount of atmospheric precipitation in the modern period ranges from 13 to 32 mm per 10 years. It should be noted that on the Ayaguz river - Tarbagatay village after 1970 in all the months of the year there is a decrease in the monthly precipitation amounts in comparison with the period of the beginning of observations before 1970 and it is 0.7-5 mm per 10 years.

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Table 3. Coefficient of linear trend (a, ^{0}C per 10 years) of the average monthly air temperature for MS

Meteorological Station	Periods	Months												yearly
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Big Almaty Lake	1952-1969	-0,32	-1,69	0,76	0,27	-0,10	0,51	-0,44	-0,32	-0,81	-0,63	0,99	0,75	-0,09
	1970-2012	0,37	0,71	0,84	0,03	0,22	0,23	-0,02	0,20	0,23	0,19	0,33	0,13	0,29
Kyrgyzsay	1936-1969	0,14	-0,10	0,58	-0,11	-0,28	-0,05	-0,45	-0,35	-0,17	-0,55	0,39	0,44	-0,04
	1970-2012	0,03	0,07	0,08	0,00	0,01	0,03	-0,01	0,01	0,02	0,02	0,03	0,00	0,03
Lepsi	1933-1969	0,54	-0,27	1,10	-0,01	-0,13	-0,21	-0,11	-0,26	0,12	-0,27	0,66	0,73	0,16
	1970-2012	0,54	1,07	0,91	0,07	0,15	0,26	0,16	0,16	0,15	0,29	0,64	0,41	0,40
Zharkent	1949-1969	0,61	0,004	1,62	0,34	0,01	0,75	-0,13	-0,63	-0,26	0,41	2,00	2,15	0,57
	1970-2012	0,56	1,17	1,02	0,11	0,16	0,23	0,09	0,29	0,45	0,47	0,55	0,23	0,44
Ayaguz	1939-1969	-1,05	-0,51	0,46	-0,75	-0,04	-0,17	-0,23	-0,52	-0,25	-0,41	0,56	-0,46	-0,28
	1970-2012	0,00	0,87	1,40	0,25	1,24	0,26	0,11	0,40	0,60	0,50	0,51	-0,05	0,38

The analysis of the coefficients of the linear trend of the average monthly and annual air temperature shows that in the region there is an increase in air temperature in the modern period compared with the period from the beginning of observations to 1970. The greatest increase in air temperature was in cold season. The greatest increase in air temperature was observed at the meteorological stations of Lepsy, Zharkent and Ayagoz in February and March and it was 1.1 ^{0}C per 10 years and 1.4 ^{0}C per 10 years. The least increase in air temperature was in the summer, which is consistent with the results of other researchers. In the modern period, insignificant decreases in the average monthly air temperature are observed at the meteorological stations of Kyrgyzsay and Aygoz.
Thus, in the modern period, the increase in river flow is in January, February, August, September and December, and the decrease is in the spring-summer period.
In general, the share of runoff in the winter months in all rivers of the area has a tendency to increase, except for the rivers of the Northern Balkhash and the rivers of the northern slopes of Zhetysu Alatau, where there are separate months with a negative trend. But despite this, it can be said that the runoff of the winter months has a positive trend and the runoff of the spring-summer period, when there is the flood season in these areas, is characterized with lower trends. This, to some extent, explains the general redistribution of runoff within the year for the current climatic period. Frequent winter thaws caused the greatest increase in the share of runoff in February; i.e. part of the water in the snow began to thaw in the cold period. In the high-mountain rivers, the share of runoff from summer (July-August) and pre-winter (November) months to the season of high waters (September-October) is also redistributed.

V CONCLUSION

Due to the climatic changes in the water regime of the rivers in the area, especially the characteristics those are sensitive to air temperature rise as the date of the beginning and end of the flood, have shifted in time:

- on the main rivers of the area, the beginning of high water has significant shift trends for earlier dates (from 0.3 to 2.2 days for 10 years);
- the dates of flood completion, in high-altitude catchments with glacial supply, as well as in large catchments of the midlands and highlands, has a shift trend at later dates (2.0-4.3 days over 10 years), while the remaining catchments have a trend of shifting to earlier dates (1,2-6,8 days for 10 years);

The rise in air temperature also led to changes in monthly flow and their share in the annual runoff: river runoff throughout almost all the months increased. The rivers of the northern slope of Zhetysu Alatau and the Northern Balkhash basin are exceptions, there the monthly average water flow in the spring and summer months slightly decreased. If along the Zhetysu Alatau Rivers these reductions up to 5% are insignificant, in the Northern Balkhash, they are 7-9%.
In general, in all rivers of the area the share of runoff in the winter months has a tendency to increase, except for the rivers of the Northern Balkhash and the rivers of the northern slopes of Zhetysu Alatau, where there are separate months with a negative trend. But despite this, it can be said that the runoff of the winter months has a positive trend, and the runoff of the spring-summer period, when there is the flood season in these regions, is characterized with lower trends. This, to some extent, explains the general redistribution of runoff within the year for the current climatic period. Frequent winter thaws caused the greatest increase in the share of runoff in February; i.e. part of the water in the snow

began to thaw in the cold period. In the high- mountain rivers, the share of runoff from summer (July-August) and pre-winter (November) months to the season of high waters (September-October) is also redistributed.

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