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WATER RESOURCES OF CENTRAL ASIA AND THEIR USE

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О-72 Орта Азия су ресурстары және оларды пайдалану: БҰҰ жариялаған «Су – өмір үшін» онжылды-дығының қорытындысына арналған Халықаралық ғылыми-тәжірибелік конференциясының мате-риалдары (22–24 қыркүйек, 2016 ж.) = Водные ресурсы Центральной Азии и их использование:мат-лы междунар. научно-практ. конф., посвященной подведению итогов объявленного ООН деся-тилетия «Вода для жизни». = Water resources of Central Asia and their use: materials International Scientific-Practical Conference devoted to the summing-up of the "Water for Life" decade declared by the United Nations. – Алматы, 2016. – 285 с. – каз., рус., англ.

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БҰҰ жариялаған «Су – өмір үшін» онжылдығының қорытындысына арналған «Орталық Азияның су ресурстары және оларды пайдалану» атты Халықаралық ғылыми-практикалық конференция баяндамаларының жинағында климаттық өзгерістер жағдайында Орталық Азияның су ресурстарын бағалау және болжам жасау; су ресурстарын басқару әдістерін жасау; су шаруашылықтық кешен дерінің геоақпараттық жүйелерін құру және математикалық үлгісін жасау; жерасты және жер беті суларының трансшекаралық алаптарындағы ынтымақтастық; экстремалдық гидрологиялық құбылыстар сияқты маңызды бағыттар бойынша материалдар ұсынылған. Аталған мәселелерді шешу ұлангайыр Орталық Азия аймағының әлеуметтік-экономикалық дамуы мен саяси тұрақтылығы және экологиялық қауіпсіздігін қамтамасыз ету стратегиясында ерекше маңызды рольге ие.

Жинақ су ресурстарын бағалау, болжам жасау, пайдалану және басқару салаларындағы мәселелермен айналысатын мамандардың ширек тобына арналған.

В сборнике докладов Международной научно-практической конференции «Водные ресурсы Центральной Азии и их использование», посвященной подведению итогов объявленного ООН десятилетия «Вода для жизни», предоставлены материалы по важным направлениям: оценка и прогноз водных ресурсов Центральной Азии в условиях изменения климата; разработка методов управления водными ресурсами; создание геоинформационных систем и математическое моделирование водохозяйственных комплексов; водное сотрудничество в трансграничных бассейнах подземных и поверхностных вод; экстремальные гидрологические явления. Решения перечислен ных проблем имеет исключительно важное значение в стратегии социально-экономического развития и обеспечения политической стабильности и экологической безопасности обширного Центрально-Азиатского региона.

Сборник предназначен для широкого спектра специалистов, занимающихся решением широкого спектра проблем в области оценки, прогноза, использования и управления водными ресурсами.

In reports of the International scientific-practical conference "Water Resources of Central Asia and their use", dedicated to summing up of the UN Decade "Water for Life", are provided materials on the following issues: evaluation and forecast of water resources in Central Asia in the context of the climate change; development of water management; creation of geoinformation systems and mathematical modeling of water systems; water Cooperation in transboundary basins, groundwater and surface water; hydrological phenomenon. Solutions to the above issues are of crucial importance in the strategy for socio-economic development and political stability as well as an environmental safety of Central Asian region as a whole.

The collection is designed for a wide range of professionals involved in the decision of significant issues in the field of assessment, forecasting, use and management of water resources.

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IMPACT OF CLIMATE CHANGE ON RUNOFF IN THE REPUBLIC OF KAZAKHSTAN

The dynamics of surface runoff in Kazakhstan under the impact of climate change temperature and precipitation analyzed. It is shown that in the absence of synchrony and coherence in the climate changes in temperature and precipitation throughout the territory of the Republic for the forecast of climatic changes in surface runoff it is necessary to analyze the climatic changes and the dynamics of runoff for each basin separately. For example the analysis of the dynamics and the constructed scenario runoff changes for the period up to 2040 for basin Ural River (Zhaiyk) was fulfilled. The high sensitivity of surface runoff of rivers of the arid zone to climate change was received.

Introduction. The Republic of Kazakhstan is situated in the center of Eurasian continent and ranked ninth in the world in the area of its territory (about 2.72 million km^2) and approximately the sixteenth largest in terms of surface runoff on square unit only [1]. The cause of this is a significant distance from the oceans, primarily from the Atlantic (over 5000 km), and particularities of the General atmospheric circulation, promoting the removal of dry tropical air during the warm period and the influence of the Siberian anticyclone during winter, it is also not conducive to the cloud and precipitation.

Figure1 – Location of the Republic of Kazakhstan in the Northern hemisphere.

As a result, only in the extreme North-West and the North of the territory the rainfall reaches 400 mm/y or more, the some time evaporation exceeds 800 mm/y throughout all territory of the Republic. Only for the foothill and mountain areas of the South-East of the territory and the Kazakhstan Altai is characterized precipitation exceeding 400 mm/y [2]. As a result of shortage of rainfall and regular movement to the territory of the Republic of dry tropical air masses, the share of deserts and semi-deserts accounts for up to 58% of the territory. About 10% of the territory is occupied by mountain systems: Altai in the East, Zailiyskiy and Dzungarian Alatau in the South - East. The Central part of the territory is occupied by the Kazakh low hills, and in the North-West South Ural is located with its continuation to the South as Mugodzhary ridge with a maximum elevation of 700 m [1].

The total average annual surface runoff amounts to 100.5 km³. Of these, only 56.5 km³ are formed on the territory of the Republic, and the remaining 44 km³ come from neighboring areas of China, 18.9 km³, from Uzbekistan-14.6 km³, Kyrgyzstan 3.0 km³, Russia 7.5 km³ [3]. Interannual variability of surface runoff is large. It is in wet years can be two times higher than normal, while in the dry year is three times below the norm. In addition, there is a large intra-annual and asymmetry in the distribution of runoff. Up to 90% of runoff of steppe rivers refers to spring, while 70% of the runoff of mountain rivers - to the summer. The specific water availability in Kazakhstan is about 6 thousand m³ per one citizen per year. This is the lowest supply among all the countries on the territory of the former USSR. In fact, all branches of economic activity in the Republic lack of the water, and for some, e.g. for agriculture, water scarcity is a limit to development. Security of the population, agriculture and industry by water of required quality is a strategic priority for the state.

According to estimates made by the Russian science hydrological institute at the beginning of the nineties of the last century, average long-term runoff was estimated at 126.0 km³, of which the local runoff accounted for 66.8km³ and 59.8 km³ as cross border runoff. Consequently, surface runoff has decreased over this time by approximately 25.3 km³, of which the local flow has decreased by 10.3 km³ and transboundary – by 15.2 km³[3]. The reason for this change of flow is considered as the intensification of economic activity, especially in foreign countries, and climate change. This shows that the assessment of possible changes in runoff in the coming decades on the territory of the Republic in connection with climate change is very important. Our study problem is devoted to this problem.

Seemed most expedient to adhere to the following order of studies:

- on the example of the Ural river basin to analyze climate variability time series of temperature and precipitation over the past century and to assess the sensitivity of surface runoff to such oscillations, find the matching quantitative relationships;
-then to build a scenario of climate change temperature and precipitation for the coming decades for the basin of the Ural river, as an example of similar calculations for the other basins;
- further, to construct scenarios of changes in temperature and precipitation for the whole territory of the Republic;
- to assess in principle the possibility of predicting surface runoff for the whole territory of Kazakhstan;
- based on expected climatic changes in temperature and precipitation to draw General conclusions regarding the dynamics of surface runoff under climate change.

Materials and methods. *Data.* Used in the work, first of all, official data of the National hydro meteorological service of Kazakhstan on the average monthly temperatures and rainfall for the stations in Kazakhstan during the twentieth century to the present. In General when we studied problems in addition to Kazakhstan data were used data for the South of Western Siberia and the southern Urals. All inputs are passed strict technical and critical controls. Were also used data from several field studies performed in the basin of the Ural River on the territory of Kazakhstan, and kindly provided to us.

Methods. In the study of the temporal dynamics of temperature and precipitation we have approximated our ranks by a polynomial of the sixth degree, which is good on the one hand smoothes the time series, retaining, however, climatic extremes, and on the other, the polynomial is quite sensitive to the sign change of the dynamics in just several years.

Simultaneously approximating a time series by a polynomial of the sixth degree, we widely used harmonic analysis of series, which, as we know, involves the decomposition of the original time series into trigonometric functions [4].

If a sixth-degree polynomial smoothes a time series, quickly responding to trends in dynamics, harmonics characterize the internal structure of the series. Each of the harmonics, at least basic ones, usually interpreted as the result of exposure to a particular group of factors. There is no reason to believe that the factors that existed during the formation of climate before, suddenly disappears.

The coincidence of the directions of the approximating lines and the dynamics of the sums of the amplitudes of the main harmonics shows whether the approximated changes random or they are caused by the major harmonics.

The results of studies in the Ural river basin. *The hydrological regime.* In recent decades, when determining natural runoff of the Ural River and its components, the challenges are considerable, due to the influence of the magnitude of human economic activity. Therefore, the restoration of natural runoff of the Ural River on the border with the Russian Federation represents to the Republic of Kazakhstan of critical importance in addressing issues of joint use of water resources of transboundary rivers under consideration [5-7].

Restoration of the natural runoff of the Ural River in the Orenburg station was carried out by us by adding to the observed domestic flow values of water intake for economic needs in the basin, in the amount of 25 m^3/s per year according to [5], etc.

The total water inflow from Russia by the Ural River is estimated as the sum of runoff of the river Ural – Orenburg, Sakmara – S. Keragala (Sakmara), Shagan and others. Average value of the discharge of these tributaries is still 8674 million m^3, of which 4510 million m^3 act on the Ural River and 3312 million m^3 on the river Sakmara, respectively. During the period of global warming, i.e. since 1980, water resources of the study area increased to an average of 10.8 km^3/year or 10% compared to the period of 1936...1977. On the territory of Russia is formed about 8.5 km^3/year of runoff, and within the Republic of Kazakhstan – up to 1.6 km^3/year.

The flow period of 1974...2007 is not very different from many years value. In slow runoff years 75 % probability the flow of water from the territory of Russia is reduced to 6024 million m3 respectively. In very dry years (97 % availability) these resources are at these points in time are 2349 and 3280 million m^3 respectively [5, 6].

On untributary 587 –kilometer strip from post Kushumto post Makhambet runoff value with probability 50% reduced 24%, i.e. on average by 4% per 100 km, and an average of 6500 million m^3. In dry years, the runoff decreases with the availability of 75 % to 5456 million m^3, and security 97 % –3006 million m^3 [7]. On the 118-kilometer stretch from post Makhambet, to post Guryev (Atyrau) runoff decreases by only 3...4%.

In regulated river flow to establish the relationship between the amounts of precipitation falling in her watershed and runoff is very difficult. Reservoirs smooth out the natural fluctuations of the flow. Therefore, a thorough analysis was subjected to a period of not regulated flow. Over a period of runoff of the Ural River is considered to be a series until 1958, when it started filling the Irikla reservoir of long term regulation, which ended in 1966.The total reservoir capacity is about 3.26 km^3 and useful is 2.8 km2. Long-term flow regulation is ensured with a guaranteed return of water to 0.5 km^3/year or 15.1 m^3/s. Later were built also Verkhneuralsk and Magnitogorsk reservoirs of smaller capacity. In numerous reservoirs on the territory of Russia accumulates up to 3.5 km^3.

We have found that in the context of global warming there has been a marked intra-annual redistribution of runoff and increased runoff in autumn and winter, which significantly reduced the annual variability of its values. The variability of runoff in the district of Orenburg was previously estimated C_v=0.86, and now we got a value of 0.55.

In the alignment post Kushum average of the annual maximum discharges has decreased by about half, and the standard deviation is almost 2.5 times. The presence of Iriklia reservoir is not the only reason for the decrease of maximum runoff. From the middle of the seventies of the twentieth century global warming has begun and it affected the runoff of the rivers of the Ural Mountains.

With the introduction of Irikla reservoir, the transformation of the maximum water flow has become even greater. Calculations show that in the period after 1974, i.e., the filling of the reservoir, the maximum flow security 1% on the strip Kushum-Topoli is declining at a rate of approximately 11% per 100 km of channel. On the strip from the post Topoli to Atyrau (118 km) average decrease of maximum of runoff is only 3.3%.

After 1974, the maximum water levels along the river declined, in some areas the reduction is greater than 2 m, and the valley was inundated much less frequently. To estimate the width of the river was used the data of gauging stations and data of number of forwarding surveys of the floodplain. The width of the flooding depends on the morphology of the floodplain. Below Atyrau, the river-bed widens from 200 m to 300...500 m at the present time, although according to the data obtained up to the seventies, in the lower reaches, the floodplain was flooded for 6-8 km, and sometimes up to 15 km [7].

The creation of Irikla reservoir has significantly changed the maximum levels and water flows in the lower reaches of the Ural River, reducing the threat of flooding. The maximum water flow rates with decreased 1.5...2.0 times. It has also been affected by the warming climate, manifested mainly through evaporation loss and infiltration along the river, and also in increasing water intake and subsequent losses.

Analysis of climatic factors. *Temperature and precipitation.* In the study of the dependence of runoff from climatic conditions seem necessary to first try to find a link between the precipitation falling on the areas of runoff formation and runoff. For this, we tried to attract data stations of Ufa, Sverdlovsk (Yekaterinburg), Magnitogorsk, etc. located in areas of runoff formation. Such data, i.e. time series of temperature and precipitation for the twentieth century are available, but for various reasons they contain gaps. Therefore, for analysis we used data from two stations Uralsk and Kostanay, located on the territory of Kazakhstan, but close to the regions of runoff formation. Ural station is situated close to the Western catchment and the station Kostanay – to the East one. Since the station Uralsk and Kostanay are close enough to areas of the watershed, they should be good enough to reflect large-scale meteorological conditions of runoff formation to the West and East of the southern Urals. For the analysis we chose the period from 1932 to 1958, when the drain of the Ural River has not been regulated. Then calculated the annual amount of precipitation at the two stations, after which was built the correlation graph of the relationship between total rainfall and runoff of the Ural River in the area of post Kushum (Uralsk), i.e. on the territory of Kazakhstan, below the confluence of the right tributary of Sakmara (Figure 2).

From figure 2 we can see that between the curves of cumulative rainfall and runoff of the Ural River there is a good agreement, especially in the years of maximum runoff. Therefore, the selection of stations for precipitation, which we studied processes in both areas of runoff formation, was successful.

The maximum flow occurs when at both stations the greatest amount of precipitation. The rule works that after a small amount of precipitation in the basin, and their sharp growth it does not lead to the same increase of runoff because of the precipitation goes into soil moisture, the filling of lakes, depressions etc [8].

It is also noticed that the sharp decrease in precipitation after max leads to the same decrease in runoff, because accumulated earlier water supportsrun off. The linear trend of the total precipitation at the stations Uralsk and Kustanai indicates that there is a noticeable growth (regression equation shown in Figure 2). This is consistent with studies [5], according to which the drain is also increased.

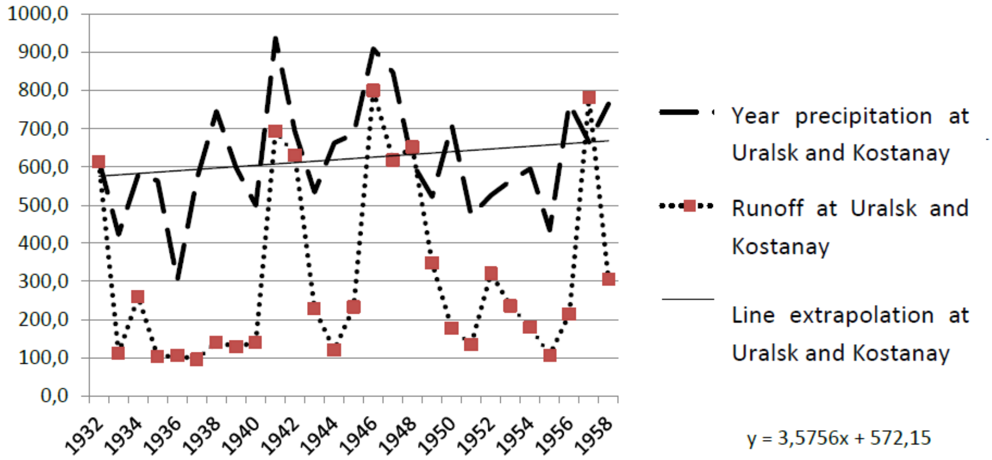
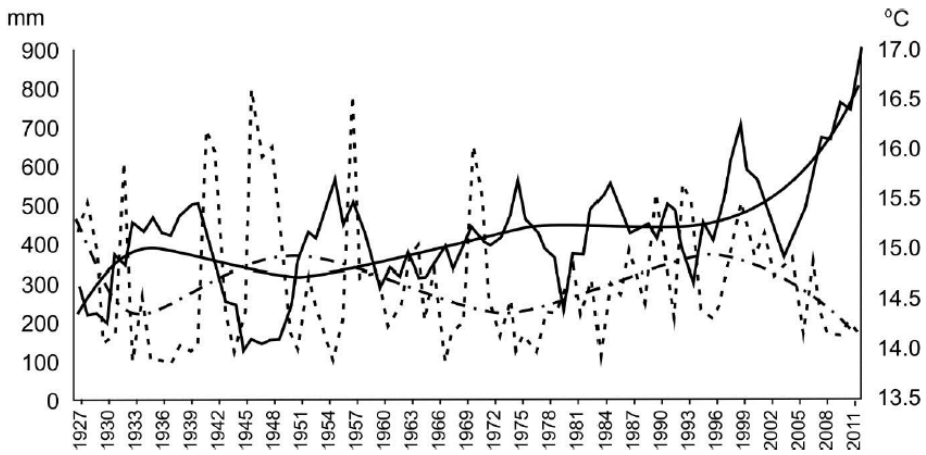


Figure 2 – Comparison of total annual precipitation values article Uralsk and Kostanay and water flow of the river Ural (Kushum post).

The dynamics of the flow It was further investigated the relationship between the time series of precipitation and temperature in the Uralsk region, on the one hand, and fluctuations of the runoff of the Ural River on the other.

The time course of water flow at the station Kushum, located almost at the entrance of the Ural River on the territory of Kazakhstan shows that during the period 1921...2007 values, the annual consumption of water varied from 89.1 to 800.0 m³/s (Figure 3 and 4).



– – – – the flow waters of the Ural River; - the average air temperature in warm period in station Uralsk, calculated over a rolling five- year period; —— the trend line of average temperatures during the warm period; –––– the trend line of water flow.

Figure 3 – The time course of the water flow of the Ural River and the average air temperature for the warm period in meteorological station Uralsk, calculated over a rolling five-year period.

We can notice a large variability from year to year, especially before 1973, while the polynomial trend shows that about 1930 and 1977 took place the climatic minima of precipitation, and about1950 and 1998 - climatic maximums. In the period from 2003 to 2007 there was a decrease in water consumption.

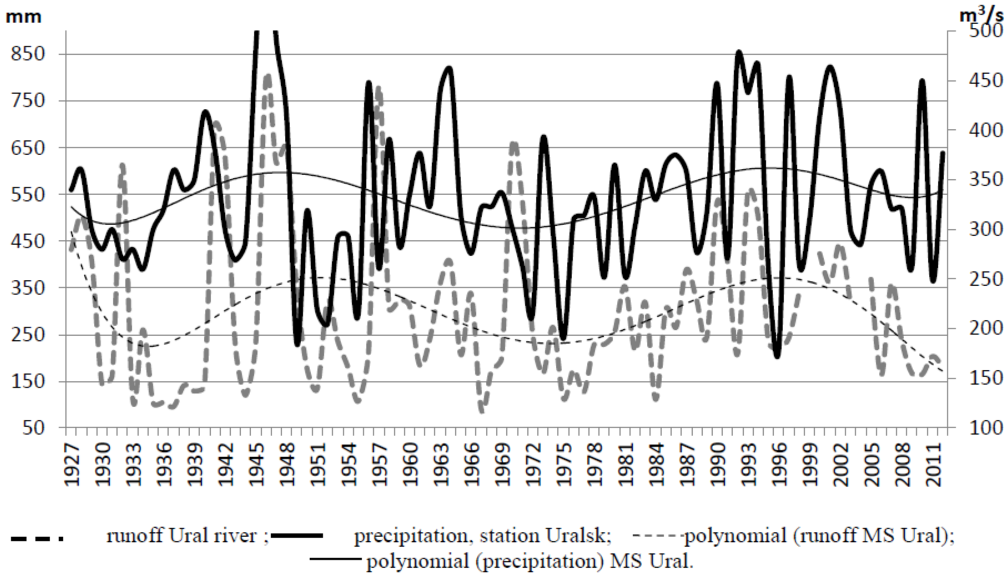


Figure 4 – The time course of the water flow of the Ural River and the annual amount of precipitation for the meteorological station Uralsk, calculated over a rolling five-year period.

Excluding the beginning and end of the rows, we can conclude that throughout the range of water flow replicates the time course of rainfall. Therefore, we can conclude that the time series of rainfall, as well as time series of temperature reflects the time course of the drain and tasks for the assessment of runoff changes under the influence of global climate change, at least at the level of General assessments, these data can be used without recourse to other information.

Purely qualitatively analyzing the time course of water flow and temperature (figure 3), as well as water flow and precipitation (figure 4), it should be noted that in the first case, there is a good negative, and the second positive connection. In this regard we tried to assess the correlation between the smoothed time series of water flow and temperature and flow of water and precipitation.

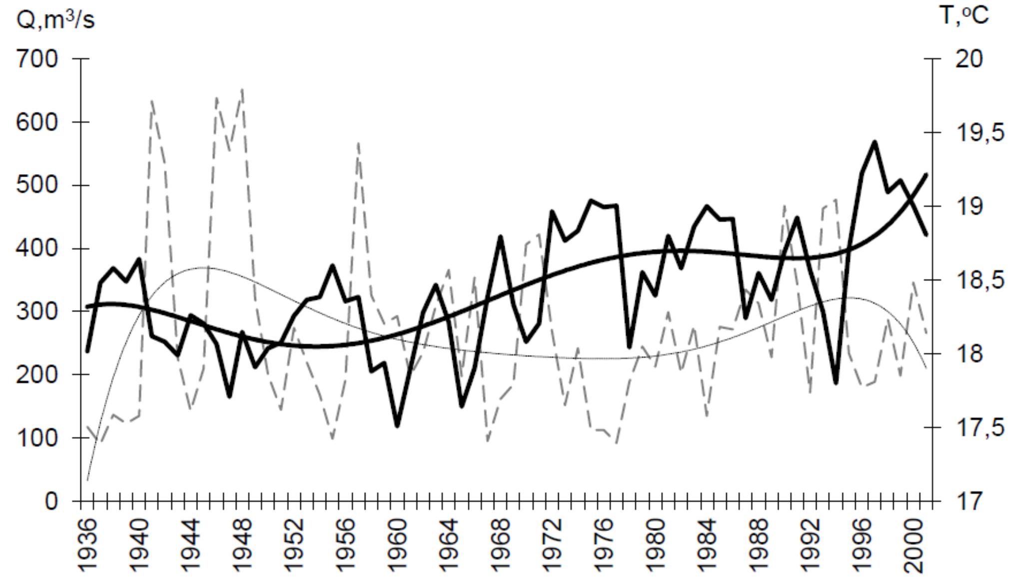
Corresponding values of parameters were taken us with smooth curves. In this case, the coefficient of negative correlation between water flow rate and temperature of the air in Uralsk increased to – 0.68, and the coefficient of positive correlation between water consumption and precipitation increased to 0.87. The coefficients of determination equal to 0.46 and 0.66, respectively. So at the decreasing (increasing) of climate temperature on 0.5°Cthe water consumption increases (decreases) by approximately 60 m3/s, and at the decreasing (increasing) rainfall at 10mm/year water consumption decreases (increases) by 20 m^3/s.

Thus, it is possible to see that, despite the relatively low correlation of annual water discharge, with annual values of air temperature and precipitation, the correlation of the smoothed speed of the water flow temperature and especially precipitation in Uralsk is high.

Since climate variations is considered to be smoothed deviations from the average within 8...10 years that we have received thus quite suitable for use in climate assessments.

Obvious, therefore, there is high sensitivity of runoff, even from weak climatic fluctuations of temperature and precipitation. It was possible to calculate quantitatively the value of communication: when decrease (increase) climate temperature 0.5°C the water consumption increases (decreases) by approximately 60 m^3/s, and decreasing (increasing) rainfall at 10mm/year water consumption reduced by 20 m^3/s. the Extreme in the averaged time series of precipitation and runoff in the zone of its formation are observed almost simultaneously.

A similar analysis of the relationships between air temperature and runoff, rainfall and runoff, we performed also for the station Atyrau, located in the delta of the Ural River, but this water consumption was assumed at the Makhambet station located near Atyrau (Figure 5).

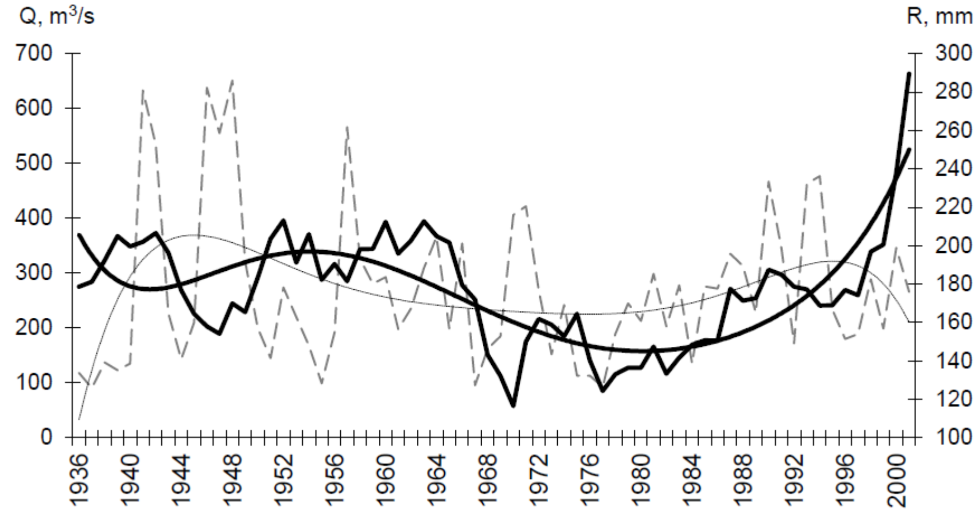


– – ·the flow waters of the Ural River; ▬▬ the average air temperature, calculated over a rolling five year period; ----- the trend line of average temperature; ——the trend line of water flow.

Figure 5 – the time course of the runoff of Ural River water and average air temperature for the warm period for the Atyrau station, calculated over a rolling three year period

We can see that the time series of annual runoff in Atyrau is very similar to the course of flow in Uralsk. This confirms the thesis that in the area from Uralsk to Atyrau are only some of the flow losses through seepage and evaporation, estimated by us above, without impacting significantly on the time course of the flow.

A joint analysis of the time course of temperature and precipitation in Atyrau and Uralsk shows that the extreme they are not the same, especially precipitation (Figure 6). The maximum rainfall took place in Uralsk in 1948, 1965 and 1994. In Atyrau, the maximums barely visible ware in 1942, 1952, 1963. So in Atyrau time series of temperature and precipitation do not correlate with the magnitude of runoff. It was interesting to find out why.



the flow waters of the Ural River; the annual rainfall, calculated over a rolling five-year period; the trend line of rainfall, the trend line of water flow

Figure 6 – The time course of the runoff of Ural River and annual amounts of precipitation for station Atyrau, calculated over a rolling five-year period

In [9-11] was done typification of the whole territory of Kazakhstan on the specifics of the temporary speed climate temperature. Northwest referred to the second type, and the South-West, where is Atyrau to fourth. Thus, there were fundamentally different changes in climatic temperature in these areas. A similar result was obtained in [12] for Almaty.

From the theory of the General circulation of the atmosphere [13, 14] it is known that the precipitation to the North and to the South of 50 ° N.L. varies greatly, as along this latitude the axis of the ridge the climate pressure is situated. Accordingly, to the north of 50 ° N.L. the maximum precipitation occurs in summer and to the South (Atyrau) – in the spring [4]. Secular variations of the position of the axes of troughs and ridges form the position of the temperature extreme in the time course, but these extremes in different regions occur at different times, and recorded in the division of the territory into types in [9-11]. Thus, climatic variations in temperature and precipitation to the South of the fiftieth latitude on the runoff of the Ural River have virtually no effect because areas of its formation located to the north of the 52 North latitude to the East and West of the Southern Urals.

The connection of the runoff of the Ural River with the forms of circulation. We carried out the search of relationships between runoff and types of macro-processes using typification of G. J. Vangengeim [13].

Analysis of the extreme of water flow of the Ural River have shown that a minimum flow in the thirties was at the prevailing macro-processes W(9) + E(15),the type C(-26) had the lowest repeatability (table 1).

High runoff in the fifties took place at prevailing processesC (+9) + E(18). The frequency of occurrence of type W(-19) was very low. The fact that the East of the southern Urals with the increased frequency of occurrence of type E is formed the conditions for precipitation above the norm was reported in [14].

Second minimum of flow in the 70-ies – 80-ies took place in the epoch of E when there was the predominant frequency of this type of E(64), with about the same frequency type(-25). Type W(-37) was expressed too weakly. Hence, having two minimal runoff of the Ural River was observed at quite different combinations of types.

Table 1 The relationship of the magnitude of the runoff of the Ural river with the forms of circulation (days)*

Extremums	Years	Types of circulation	
		Types for extremums of runoff	Types on Wangenhaim (epochs)
min	1928-30	W (9), C(-26), E(15)	E
max	1949-58	W (-19), C(+9), E(18)	E+C
min	1970-1984	W(-37), C(-25), E(64)	E
max	1998-2002	W(41), C(-14), E(-26)	W
Remark: in brackets is done the average deviation of days from norm during a year			

A maximum at two-thousand years occurred during the prevalence of the type W(41), low-frequency types C (-14) and E(-26). Consequently, the maximum runoff of the Ural River can take place at a rather different combination of types of circulation (table 1).

We can see therefore that the conclusions obtained [8], and our in general have a good agreement. Since there are essentially two catchments, one on the East and the other on the West of the Southern Urals, and the loss conditions of extreme rainfall in each watershed different, the combination of two types of macro-processes that provide the extremes of the precipitation and flow, is the expected situation. The minimum flow with maximum frequency of occurrence of type E with a low frequency of occurrence of type C and type W. High runoff occurs in type C or W with a fairly high frequency and low frequency of occurrence of type E. However, the relationship between the annual fluctuations of runoff and number of days per year a certain type of circulation was often weak, that we noted during the analysis. The years of highest and lowest water content are prepared for a long period and come usually at the end of the epoch, which determines the most favorable or unfavorable conditions for the formation of runoff in the area. These terms are formed including in the dynamics of the frequency of values and combinations of types of macro-processes

Expected changes in temperature, precipitation and runoff of the Ural River in the future. *Temperature*. We have performed the harmonic analysis of time series of temperature, precipitation in the river basin and the runoff of the Ural River. Figure 3 shows the time course of temperature approximated by a polynomial of the sixth degree for the station Uralsk, and Fig.7 - the results of harmonic analysis of the same number respectively

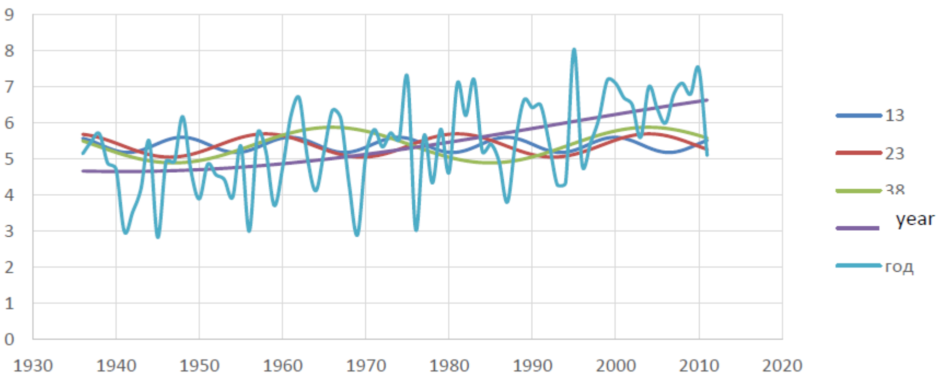


Figure 7 – Ural station. Harmonic series of temperature.

The fitted curve is, in fact, the result of the addition of the main harmonics of the time series of temperature for the observation period. We can see (figure 3) that during the analyzed period was as warming and climate cooling. Harmonic analysis of a time series (figure 7) shows that the main harmonics are secular (208y), as well as harmonics of the 38, 23 and 13 years. The addition of the main harmonics selection and trend records carried out by the method of Babkin A.V., which is widely used in hydrology for the construction of scenarios of runoff changes [15].

The amplitude of first three harmonics is about the same in both stations Uralsk and Kostanay: 1.2-1.4, 0.8-1.2 and 0.5°C, respectively.

Analyzing the time course of the harmonics of the temperature, we can see that since 2005-2006, 38 - and 23-year-old harmonics reaching a maximum, started to decrease in amplitude. Their minimum is expected in 11 to 19 years, i.e. from 2016 to 2024 consequently, until approximately 2016, a temperature reduction will occur pretty quickly under the influence of two harmonics, and then, to 2024, under the influence of only one 38-year-old harmonica.

The total temperature decreasing will be approximately 2.1°C, i.e. it will be equal to the sum of the amplitudes of the two harmonics. Eight-year-old harmonica had the max in 2013, after which its amplitude decreases to a minimum in 2017, however, the amplitude of this harmonic does not exceed 0.41°C and its contribution to the temporal course of the temperature is weak.

It is similar to the analysis of time series of temperature for the station of Kustanay. In view of the similarities of the results drawings are not given. Because in Kostanaj the amplitude of the fundamental harmonic is the same as in Uralsk, and the time of occurrence of their maxima (2005) coincide, we should expect the same speed of temperature lowering as in Uralsk, i.e. decreasing in the next one or two decades at 1-1.5°C and 1.0°C, respectively.

Therefore, the background temperature in the catchment area of 15-25 years will be lower than at present and the loss of moisture evaporation will also be lower than at present.

Precipitation We next consider the time series of precipitation and its harmonics for station Uralsk (Figure 4 and 8) and for station Kostanay.

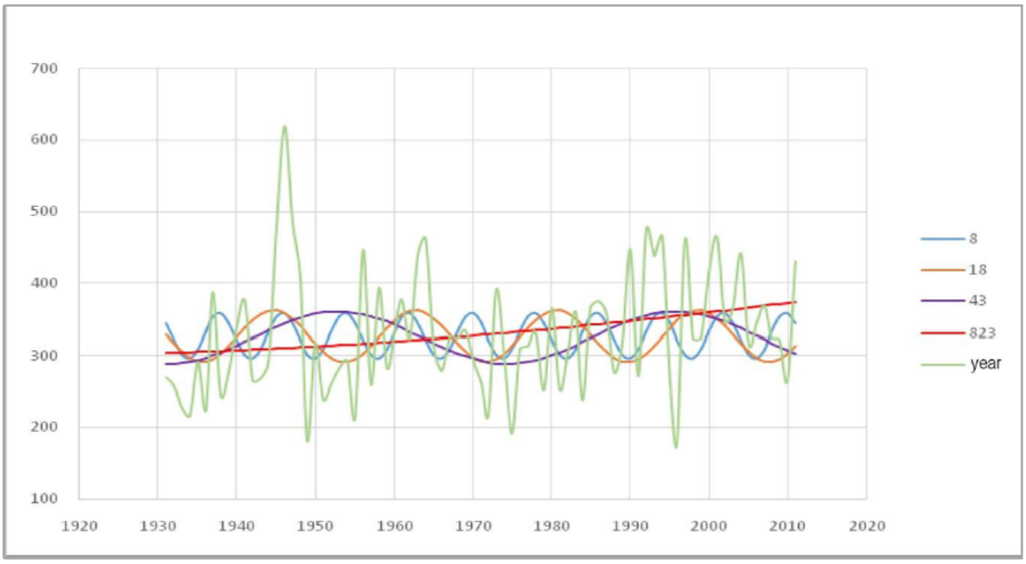


Figure 8 – Uralsk. The results of harmonic analysis of time series of precipitation

Figure 4 shows that in the time series of precipitation were the climatic extremes. In the time series of precipitation of station Uralsk there are harmonics with duration of 43, 18 and 8 years, the amplitude of the 100, 70 and 45 mm, respectively (Fig.8). In the time series of precipitation in Kostanay 38-, 23-, and 8-year-old harmonics with amplitudes of 55, 50 and 25 mm have a place respectively. However, the amplitude of the main harmonics in Uralsk almost two times more than in Kostanay [11, 16]. Accordingly, the conditions of runoff formation in the regions will be different.

Harmonic analysis series showed that in precipitation at stations Uralsk, Kostanay and almost the entire territory of Kazakhstan there is no a century harmonic, so it is difficult to build scripts. To the West of the southern Ural (the station Uralsk) the maximum 43-year-old harmonica took place about 1998 and 2020, its amplitude will decrease. Its decline from 2008 largely compensates growth of 18-year-old harmonica, and since 2013 – and 8-year-old harmonica. As a result, to the end of the decade, the amount of precipitation can fall in the range of 10 mm, and in the next decade we should expect a growth up to 50 mm due to the growth of the main 43-year-old harmonica, which will start at the beginning of the third decade.

At the station Kostanaj a maximum of 38-year-old harmonica took place about 1998 and 2020, its amplitude will decrease. This decreasing from 2012 largely will compensate rising of 23-year-old harmonica, and since 2013 – 8-year-old harmonica. As a result, to the end of the decade, the amount of precipitation can fall in the range of 10 mm. At the same time, due to the expected decreasing in air temperature, evaporation from the surface of the catchment will decrease, which should compensate decreasing in precipitation. Accordingly, the runoff of the Ural River should remain near the present values.

In the next decade we should expect a growth of precipitation up to 50 mm due to the growth of the main 38-year-old harmonica, which will start at the beginning of the third decade. Comparing the amplitude of harmonics and the time of occurrence of the extreme, we can see that the decreasing in precipitation in the current and next decade will be about 25 mm. After 2030, the precipitation will begin to increase.

According to the calculations for two catchments it is follows that in the third decade it should be expected to increasing of rainfall in the Eastern part of the catchment area to 25-30 mm and in the West area to 40-50 mm at the reduced temperature background compared with the present period. As a result, the runoff of the Ural River should increase.

Our analysis of recent temperature trends, however, showed that the climate warming trend in the region ceased. This result will be test in nearest three to five years and if the trend is confirmed, then no adaptive steps will be required. However, since this region, including its Northern part, belongs to the zone of risky agriculture, adaptation steps not to climate change, and to the great interannual variability of precipitation and drought, would be very desirable.

How can you apply the results obtained for the basin of the Ural river, to the assessment of the expected changes in surface runoff throughout the territory of Kazakhstan? You need to know how climate change temperature and precipitation throughout. In [9-11] we have shown that synchrony in change these settings there. We therefore consider more specifically how these parameters have changed in the past and what changes are expected in the coming decades.

Climatic variations of temperature and precipitation in the past century on the territory of Kazakhstan and a scenario of expected changes to 2050. The problem is quite thoroughly described in the work of one of the authors [11]. We restrict, therefore, only a summary of the result based on the data of the table 2.

Century harmonica has the maximal amplitude - 2.7 – 1.5°C. The amplitude of the second harmonic is everywhere less. The time of occurrence of the extreme of the century harmonics are remarkably different.

There were settle links for each of the cases of climatic cooling and warming with characteristics of the General atmospheric circulation [11].

It was interesting to consider intra-annual structure of the current cold snap. The first signs of cooling appeared in December 1995 and to the end of 2010, the total cooling of this month was 3°C. In January, the cold came just a year later, in 1996, but by 2010 it was 9°C. In February, the cold start recorded only since 2000, i.e. five years after its first appearance in December, and to 2010 amounted to 6°C. In March, the cold began only in 2006 and made up 2.5°C to deadline. In April, the cold began to report only from 2007 and up to 2010 only 0, 2°C.

Table 2 – The amplitude of the climatic fluctuations of temperature (°C)

Stations	Years of exstremums						
	max 30-40	min 40-50	max 65-75	min 80-90	max 2003	Century harmonica	0.5 cent. harm., years
Uralsk	0,7	0,8	0,3	0,3	1,2	2,2	60
Irgiz	0,3	0,5	0,1	0,3	0,7	2,0	54
Karaganda	0,3	0,4	0,4	0,4	1,1	1,5	51
Dzhezkazgan	0,6	0,6	0,2	0,3	0,1	2,4	53
Semipalatinsk	1,0	1,0	0,1	0,1	1,5	1,5	51
U-Kamenogorsk	1,2	1,0	0,3	0,2	1,0	1,2	50
Kzylorda	0,9	0,9	0,1	0,2	0,3	2,3	50
Aral Sea	0,6	0,5	0,1	0,1	1,0	2,7	50
Pavlodar	0,2	0,3	0,1	0,1	1,3	1,9	42
Balchash	0,3	-	0,3	-	0,1	1,4	-
Kostanay	0,8	0,9	0,3	0,3	0,7	2,4	54
Astana	0,2	0,3	0,2	0,3	0,8	2,1	54
Taldykorgan	0,4	0,5	0,3	0,2	0,7	2,2	52
Chimkent	1,0	0,6	03	04	0,3	1,8	50
Fort Shevchenko	1,0	0,9	04	0,6	0,3	1,7	60

Thus, in the period from December to April cold, first appeared in December 1995, gradually extended to subsequent months up to April inclusive for 12 years. During this time, the most significant temperature drop occurred in the winter months in December (3°C), January (9°C) and February (6°C). In the remaining months of the year, the cold was distributed without the expressed laws.

Scenario of expected temperature changes for the period up to 2050. According to the results of harmonic analysis of time series of temperature and precipitation at stations of Kazakhstan identified the most significant amplitude of harmonics with periods exceeding 10 years, and based on them built scenarios of changes in temperature and precipitation by 2050. The temperature will fall almost throughout the 1.1-:3.0°C, down to the level of the sixties of the XIX century.

Using the information contained in our [11], we performed such calculations based on the harmonic analysis under the assumption that detected in time series of temperature and precipitation are the main harmonics will remain.

In Figure 9 presents a map of the spatial distribution of average annual values of temperature (the numerator) and the expected value of changes in average annual temperature since the start of the cooling, i.e. in about 40 years (denominator). It is constructed by the method of [15], which is based on the assumption that having the harmonics will continue in the future.

You can see that in all the territory of the Republic the temperature decreases. Downside should be expected in the range of from 1.0 to 3.0°C. Values correspond roughly to the cold snap in recent decades the warming [11]. This is natural because the main contribution to the temperature fluctuation makes the age-old harmonic (about 110 years), the maximum of which took place about 2000. Accordingly, the most significant cold up to 3°C expected in the area of Turkestan and in the South-East of the Republic, 1,5-1,8°C. The same size of the cold expected in the North-East in the district of Astana-Pavlodar-Semipalatinsk. Over the Central and Western regions is expected to be less temperature decrease 1.1-1.3°C.

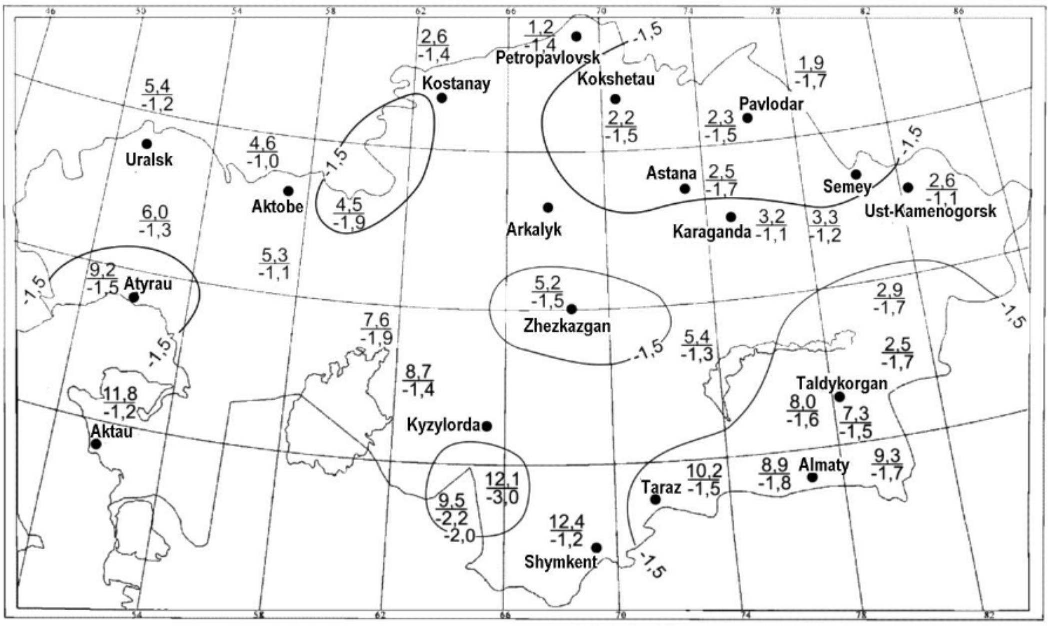


Figure 9 – The script changes the temperature field on the territory of Kazakhstan by 2050

Average annual air temperature 2050y to fall to the norm calculated for the observation period preceding the rising temperatures in the late twentieth century.

Climatic variations in precipitation in the past century and a scenario of expected changes to 2050. Table 3 presents the time of occurrence of precipitation extremes in comparison with the extremes of temperature.

From table 3 we can see that the extremes of temperature and precipitation for the territory of the Republic among themselves not associated with time of onset of any trend.

Table 4 shows the results of harmonic analysis of time series of rainfall for some stations in Kazakhstan. Data is given for the three main harmonics. First of all, you can see that in time series precipitation century harmonic is missing. For the first harmonic the characteristic period of 33 to 48 years which is known as Brickner's cycle. The period of the second harmonic is equal to 23 years. The amplitudes of the first and second harmonics close, from 20 to 90 mm of precipitation. The period of the third harmonic is unstable through the territory and varies from 8 to 18 mm, the amplitude of this harmonic is slightly less than the first two.

Table 3 – The alternation of extremes of temperature (t) and precipitation (Q) (years of the last century)

Stations	Extremums								
	Maxt	MinQ	min t	MaxQ	Maxt	MinQ	min t	MaxQ	Maxt
Pavlodar	39	-	54	64	74	-	85	98	0,2
Uralsk	35	48	44	48	68	72	88	99	98
Turkestan	37	37	52	59	69	84	84	05	06
Dzharkent	42	41	57	58	76	78	91	92	06
Astana	39	-	49	60	72	85	88	03	05
Kuigan	42	40	58	70		88		06	
Samarka	42	36	59	56	-	82	88	98	03
Atyrau	38	37	51	51	72	76	89	02	06
Karaganda	40	39	51	59	73	81	88	04	04
Dzhambul	40	38	54	58	74	82	88	03	06
U-Kamenogorsk	42	37	58	68	77	92	92	07	06
Kostanay	35	42	43	56	66	76	84	00	04

Table 4 – The main harmonics (period, years) in the ranks of precipitation and their amplitude (mm)

Stations	The first harm.		The second harm.		The third harm.	
	period	amplitude	period	amplitude	period	amplitude
Kuigan	43	10	23	20	13	18
Almaty	42	25	27	30	18	18
Dzharkent	68	20	28	40	18	40
Taldykurgan	33	30	23	35	-	-
Dzhambul	38	105	23	30	13	30
Turkestan	-	-	-	-	-	-
Shimkent	38	65	-	-	-	5
Kazalinsk	36	15	21	10	15	20
Aral Sea	-	-	28	30	8	40
Kzylorda	33	25	-	-	13	30
Samarka	53	60	23	40	13	30
Katon-Karagai	48	100	23	90	8	90
U-Kamenogorsk	-	-	23	35	-	-
Ajaguz	33	50	-	-	18	40
Karaganda	--	80	-	-	13	55
Martuk	38	60	-	-	13	40
Novosibirsk	43	120	23	65	8	20
Temir	33	60	-	-	18	40
Aktobe	38	35	-	-	-	75
Fort Shevchenko	48	30	28	30	8	35
Atyrau	33	30	-	-	18	20
Uralsk	43	65	-	-	18	65
Bajanaul	38	45	-	-	8	15
Pavlodar	-	-	-	-	15	38-50
Shcher,bakty	33	30	-	-	8	20
Astana	43	50	23	40	8	40
Kokchetav	-	-	28	65	18	65
Kostanay	38	35	23	35	8	15

Let us make a brief conclusion. For the time series of precipitation are characteristic harmonics of half a century, in a half and a third of half a century. The century harmonic with a period of 100-120 years for the time series of precipitation, in contrast to the time series of temperature, is not typical.

The amplitude of the harmonics can be analyzed basing on the data of table 4. The highest amplitude has only 50% of the first harmonics of the stations. In the remaining 50% stations the largest amplitude has the second harmonic or the third one. This fact significantly reduces the accuracy of predictive scenarios for the future.

The connection of fluctuations in precipitation rows with the types of macro-processes and harmonics in their ranks was settled [9-11].

Scenario precipitation change fields for the future Changes in precipitation to 2050 is ambiguous (Figure 10).

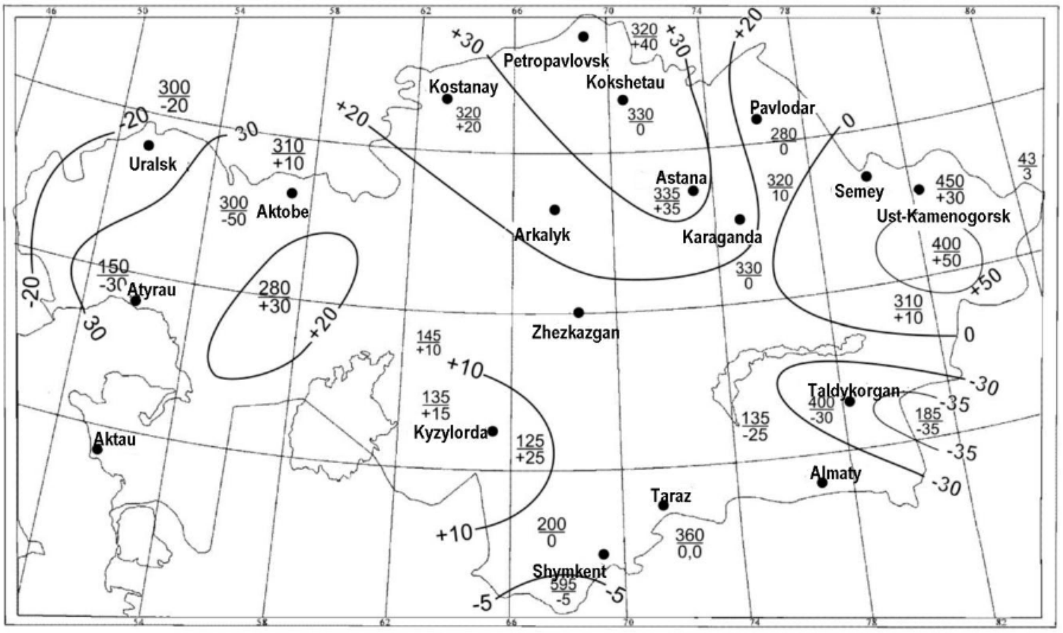


Figure 10 – Scenario precipitation change field by the 2050

Here in the numerator the norm of precipitation is given, and in the denominator - the expected changes by 2050. As can be seen from fig. 20, the amount of precipitation will undergo opposite changes. To the North, East and South-West of the Republic precipitation will increase by 20-30mm and in the West and South-East of the territory they are about the same will decrease. On the East of the country rainfall will increase by 10-50mm,approximately the same increasing in precipitation is expected over Northern Kazakhstan, 20-40mm. In the area of the Aral-Kzylorda precipitation will also increase by 10-25 m.

In the band Pavlodar-Shymkent changes in precipitation are not expected. In the West of the Republic and in the South-East is expected decreasing in precipitation by 20-35mm/year.

Only not great part of the territory of Kazakhstan amount of precipitation to 2050 will change by more than 10% of normal. In the North-West of the Republic of the expected decline will exceed this share. In the main agricultural area, Northern Kazakhstan, precipitation will even increase. Thus, the conditions for agricultural activity will remain as currently, they will not deteriorate.

Discussion. The result is that on the territory of Kazakhstan began cooling, is not entirely unexpected. At least since 2011 the national weather service of the Russian Federation fixes the beginning of the cold snap in the North of the European part of Russia, and also in the South of Western Siberia and South-East of Eastern Siberia in winter [17]. A few less cooling noted on these same areas in spring and summer, only in autumn there was no it. We noted, and this is confirmed by most researchers that the bulk of warming occurred in winter. The beginning of a noticeable cooling in this season compensates for the occurring warming.

In our research we excluded from the analysis of the mountain areas, as it requires other approaches. However, in [18] it is shown that the glacier Tuyuksu in the Zailiyskiy Alatau Mountains (South-Eastern Kazakhstan) also started cold. The some time there was an increasing in the amount of precipitation in the solid phase there.

In studies of Zandi Rahman, a thesis which we have acted as opponents, it is shown that in Iran in the Khuzestan province, in the cold season temperature rising is stopped [19]. There are a number of other studies, confirming the tendency to cooling on the Eurasian continent.

As we have shown, the onset of the cooling occurs mostly in winter and against the background of rising secular zonal harmonic transfer (type W). It is known that strengthening a zonal transfer usually leads to the outflow of warm masses from the ocean to the continent, which should contribute to warming. In fact, the zonal migration leads to the intensification of cyclogenesis, but the cyclones move along the 65th parallel, carrying out the removal of warm air in the Arctic and Siberia. In the rear of these cyclones, however, comes the cold air in temperate latitudes, where it settles down Kazakhstan [20]. Specific mechanisms for the implementation of wave fluctuations are not considered. As stated in the same [20], "the Question of the physical causes of these fluctuations remains open".

The sensitivity of the rivers in the arid region to climate changing is very high. Runoff is highly sensitive to minor climatic fluctuations of temperature and precipitation in the zone of runoff formation. Human impact on environment components in the river basin can give it the most adverse effects.

In [21], the authors, studying the climatic changes in air temperature and precipitation on the territory of the Middle and southern Urals in the twentieth century, concluded «the ambiguity of trends of changes of climatic characteristics in the twentieth century in the Urals. Installed features rhythmic changes in air temperature and precipitation". To the authors the results are similar to our own; we can only add that on the territory of Kazakhstan, adjacent to the watershed of the Ural River, and in the Kazakh part of the basin up to the Caspian Sea, we recorded also only fluctuations of climate. We and authors of [21] used different methods of analysis so we fixed the "rhythms" of different durations: a century, close to half a century (Brickner's), and shorter. The century cycle which has the greatest amplitude, over, and in the analyzed area ends, but due to the shorter harmonics and here the climatic temperature trend has become negative. In other regions of Kazakhstan climate cooling started earlier [11 and others].

In [22] using modeling techniques they studied the effect of global climate change on the hydrological system of the Aral Sea, located essentially in the center of Eurasia. Despite the fact that the area of flow formation is at a distance of about a thousand km from the sea, and the metering system of the consumed water in this area is unreliable, the authors have shown that the impact of climate change on the processes in the Aral Sea basin is significant. The water objects of the arid zone are sensitive to the slightest climatic changes in temperature and precipitation.

In [23], the authors studied the effect of climate change on underground rivers in the UK. And, although the UK is outside the arid zone, they are received, that such dependence exists. This indicates a rather strong dependence of surface runoff due to climate variability of temperature and precipitation regardless of the natural area. Existing balance between precipitation and temperature on the one hand and surface runoff on the other, being sufficiently stable for the time interval from one to several years, is very sensitive to climate change, i.e. to changes in the time period up to 10 years.

In [24] analyzed not only the temporal but also the spatial variation of the rainfall to the runoff of the Yangtze River over a period of 40 years. The obtained results confirm that the sensitivity of water systems to climate change high even outside the arid zone. There are a number of other works dealing with the problem, but with similar patterns.

Our results for the basin of the Ural River in broad outline confirm obtained for other river basins General conclusions. However, due to the presence of several features in addition to the aridity of the climate, such as the existence of two regions of runoff formation, separated by mountains, are fundamentally different conditions for the formation of extreme precipitation in each of them. We got their special connection and the expected scenarios of runoff changes in the future.

Currently, there are enough reliable data on water consumption by hydrological posts along the Ural River, and virtually no data on the abstraction of water for agricultural and household needs. Basin-wide accounting of water used and its quality control, in fact, missing. It is difficult to assess the anthropogenic impact on the runoff. At the same time, it is obvious that the system is sensitive to such influences. The solution of this problem is ahead yet.

Conclusions. As a result of the studies of the dynamics of flow in the context of climate change in Kazakhstan obtained the following:

1. *Climatic fluctuations of temperature and precipitation*:

-climatic fluctuations of temperature and precipitation that generates surface runoff, was not only currently, but in the last century. Such changes never occur simultaneously on the entire territory of the Republic. They appear anywhere on its border, and then gradually over several years spread to the entire territory;

- between the climatic fluctuations of temperature and precipitation not detected synchronism or coherence. Therefore, the construction of scenarios of change for the whole territory of the Republic is possible only individually and quotas by region;

- for the reasons stated above,the construction of scenarios of impact of climate change on runoff is possible only for each river, i.e., watershed;

- observed in recent decades, the temperature increasing at the beginning of the twenty-first century have ceased. The cooling started in the North-East at 2010, has covered the whole territory;

- in time series of temperature have taken place a century and half-century and quarter-century harmonics, which select up to 95% of the dispersion. The maximum amplitude up to 2.1°C, the amplitude of successive harmonics decreases rapidly. These harmonics can serve as a basis for developing scenarios of temperature change for the future;

- ahalf of century harmonicas, and harmonics of a shorter durationtake placein time series of precipitation. The amplitude of the first harmonic does not depend on the length. The first four harmonics choose to 90% of the variance and can serve as a basis for developing scenarios;

- while maintaining the basic harmonic series of temperature and precipitation constructed scenarios of expected changes in temperature and precipitation to 2050. The temperature will drop and it will reach by the time the level of the minimum observed near the thirties of the last century. The amount of precipitation will fluctuate, remaining on most of the territory around the norm. Interannual variability of precipitation will remain significant.

Our results, primarily the results of harmonic analysis and analysis of spatial-temporal shifts in climatic extremes in temperature and precipitation are in good agreement with the results of studies of the General circulation of the atmosphere and also with the results of analysis of atmospheric dynamics on spectral models.

2. *Basin of the Ural River:*

-by us as an example evaluated the sensitivity of flow in the Ural River basin to climatic changes in temperature and precipitation obtained the following:

-water flow of the Ural River is very sensitive to even small climate variations. At the decreasing (increasing) climate temperature on 0.5°C the water consumption increases (decreases) by approximately $60m^3/s$, and decreasing (increasing) rainfall at 10mm/year water consumption reduced by 20 m^3/s. For this reason, it is possible to speak about a particular relationship of temperature and precipitation on runoff value;

- the presence of reservoirs on the territory of Russia while in any way does not impair the flow of water to Kazakhstan. Moreover, in dry years is supported by relatively high water consumption. This flow over the years the reservoir has never dropped to the minimum, which often took place before the construction of reservoirs in the 20-ies – 50-ies of the last century;

- our analysis of recent temperature trends have shown that climate temperature rising in the region ceased. In the coming decades we should expect a gradual lowering of the temperature at 2.1°C. The Amount of precipitation may decrease up to 2025 within 10 mm. At the same time, due to the expected decreasing in air temperature, evaporation from the surface of the catchment will decrease, which should compensate for the decreasing in precipitation. Accordingly, the drain of the Ural River should remain near the present values. By the end of the third decade is expected increasing ofprecipitation up to 50 mm/year and the increasing in flow on the background of decreasing air temperature.

3. *The forecast runoff for the territory of the Republic as a whole*:

-despite the fact that the prediction of surface runoff is only possible in specific basins, some General conclusions on the basis of this work possible:

- as climatic variation and temperature and precipitation for the territory of the Republic do not occur synchronously and at the same time to expect the simultaneous climate fall or rise of runoff should not be;

- onset of climatic temperature drop throughout the territory of Kazakhstan will contribute to a slight increase in climatic runoff;

since climatic variations of temperature and precipitation at the site is small, the inter-annual variability of runoff would be significantly greater than the climatic one. So the forecast of annual runoff in a particular basin will be the main task in this area for hydrologists.

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