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TEMPORAL FLUCTUATIONS OF WATER RESOURCES OF SOUTH AND SOUTH-EAST KAZAKHSTAN

Abstract. Analysis of publications on a global scale forces us to admit that the world is undergoing global changes in climate, water resources, and also there are significant changes in geographic environment. Over the past 25–30 years, Kazakhstan has experienced the most severe changes in the main factors that determine the fluctuations of water resources and their changes in time and territory, which include the drastic alterations in socio-economic sphere and the observed climate change.

The present studies are devoted to urgent problems of the current state and the change in the patterns of formation and distribution of surface water resources of South and South-East Kazakhstan.

Water resources of the southern region of the country are considered in view of the changing factors in formation of water resources: the hydrological regime, economic activities in the catchment basins and the possible global and regional climate change.

In the long-term dynamics of the water resources of *South and South-East Kazakhstan*, there is some tendency to increase all over the place. As for total water resources of the region for the modern period, they are slightly higher than this characteristic for the long-term period. Analysis of data shows that there are no existing significant trends of water resources of the river basins under consideration. Though some increase in water content, substantiated by quantitative values of the runoff, takes place.

The conducted studies of the distribution of water resources over the territory and changes over time can provide a secure basis for long-term planning and development of large-scale activities for the integrated management and protection of water resources and for solving the complex problems of water supply in the southern regions of river basins of Kazakhstan.

Keywords: runoff, river basin, water resources, long-term fluctuations, dynamics of the water resources.

Introduction. The environmentally tense situation in all regions of Kazakhstan, formed nowadays, is aggravated due to problems of water supply for the areas and because water basins and major waterways are transboundary. Timely specification of the existing water resources in our country, as well as their use, is one of the first tasks in the modern hydrology of Kazakhstan. Problems of study of modern fluctuations and changes in the course of river runoff are becoming more urgent due to ongoing changes in the climatic system of the Earth and the strengthening of anthropogenic impact on water resources.

Distinguished in studies of long-term fluctuations of river runoff. Basins of rivers of South and South-East Kazakhstan were relatively well studied in hydrological aspect, this include the Aral-Syrdariya, Shu-Talas and Balkhash-Alakol water-economic basins (figure 1). First glimpse of the norm of river runoff of the south region of Kazakhstan were performed by Schultz V.L. (Schulz V.L., 1965) and Zaikov B.D. (Zaikov B.D., 1946), more detailed studies were conducted before 70-ies of the last century Sosedov

et al. (Sosedov I.S. et al. 1984; Surface water resources of the USSR. Central Asia. Basin of the Syrdariya river, 1969; Surface water resources of the USSR, 1973; Surface water resources of the USSR, 1970; Lavrentyev P.F. et al. 1963; Korovin V.I., 1966; Boldyrev V.M., 1965). The analysis of the hydrological study of rivers shows that while large and medium rivers are characterized by systematic and rather long-lasting observations, for small rivers there are only separate scattered data.

The study of temporal patterns of fluctuations of river runoff in time and space is one of the most complicated problems. The following main trends can be distinguished in studies of long-term fluctuations of river runoff:

1) the study of century-long and intra-century runoff fluctuations to identify groupings of low-water and high-water years, their duration and repeatability, as well as identification of areas with synchronous and asynchronous runoff fluctuations;

2) study of the links between runoff fluctuations, synoptical and heliophysical processes (types of atmospheric circulation, cycles of solar activity and others, etc.);

3) study of long-term runoff fluctuations in time and space with the help of differential integral curves;

4) study of long-term runoff fluctuations in time with the help of Markov's A.A. discrete chains.

The point of the first trend is modeling, i.e. artificial reconstruction of long runoff series through one of the variants of the Monte-Carlo method. The fundamentals and calculating techniques of that method with regard to hydrological and water-economic objectives were developed by Svanidze [30] and the idea and a principal scheme of modeling of the level of drainage basins on the basis of the Monte-Carlo method was suggested by Khomeriki (Khomeriki I.V., 1979). Monte-Carlo method allows to obtain information about the selective distribution in such cases when the common theory of selective distributions is helpless. But this method does not take into account the difference in a calendar sequence of members of sampling and the general population.

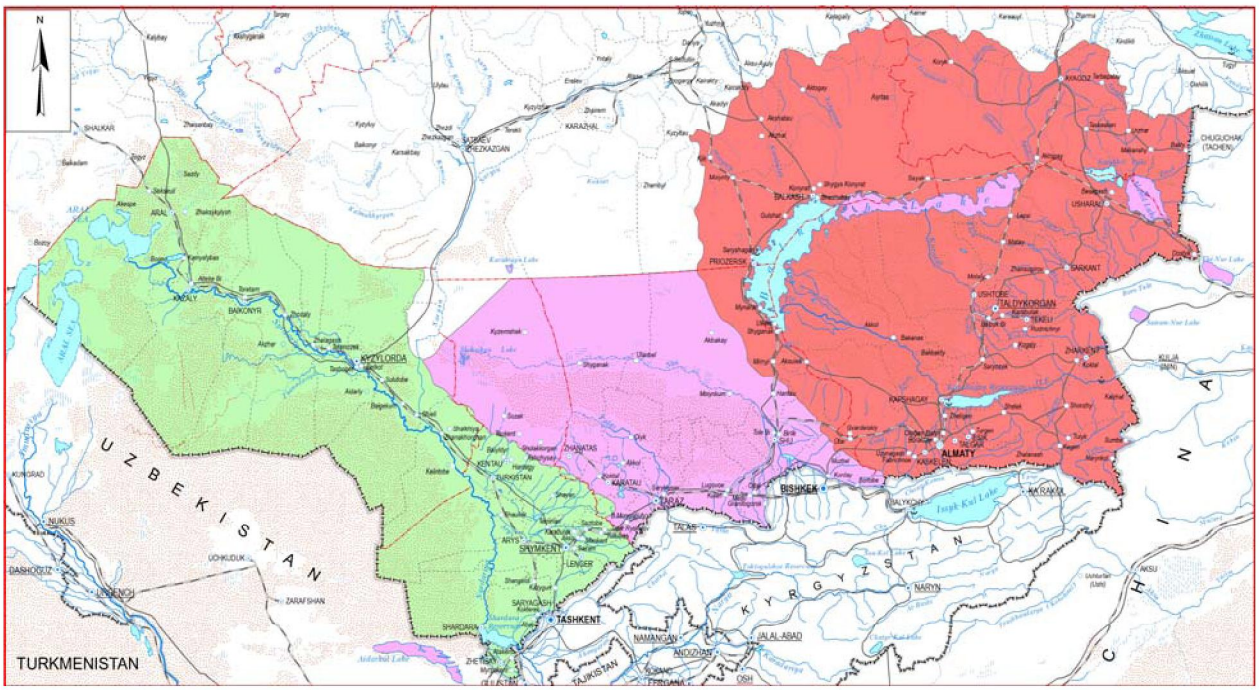

Figure 1 – Hydrographic scheme of river basins of South and South-East Kazakhstan

1. In the second trend, numerous studies on availability of links between runoff fluctuations, synoptic and heliophysical processes were conducted. In order to clarify physical reasons of formation of low-water and high-water periods on the territory of the northern hemisphere, many researches (Belinskiy N.A, Kalinin G.P., 1976; Smirnova K.I., 1974; Girs A.A., 1987; Afanasyev A.N., 1967; Shnitnikov A.V.,1950; Baidal M.Kh., 1964; Korovin V.I., 1964; Kurdin N.D., 1990; Andreyanov V. G., 1959; Aniksina N.A., 1970; Giorgio Z.V., 1957; Druzhinin I.P., 1966) tried to find a connection between fluctuations of annual

runoff and W, C, E (western, meridional, eastern) types (forms) of atmospheric circulation on Wangenheim, Girs or on B.L. Dzerdzeyevskiy (Girs A.A., 1987; To study the dynamics, 2005).

Despite the dependence of river runoff fluctuations on the types of atmospheric circulation and indices of solar activity, described in a number of studies, its definition is very difficult. Fluctuations in annual river runoff over long periods of time in some cases repeat changes of fluctuations of indices with the types of atmospheric circulation and solar activity, in others they are opposite and in the third case they have an independent character.

2. However, the researchers of the Institute of Geography of the RK made an attempt to find the interrelationship of hydrological characteristics and repeatability of ECM (elementary circulation mechanisms) on B.L. Dzerdzeyevskiy, measured by numbers of days, based on the direct accounting of the nature of atmospheric circulations; though this method has yet to be considered not as a forecast but rather an evaluation of influence and illustration of scenarios of synchronous development of natural processes in atmosphere and hydrosphere (Druzhinin I.P. et al, 1966).

3. The third trend – a way of differential integral curve to evaluate the cyclical fluctuations of many natural phenomena was for the first time proposed (Andreyanov V.G., 1959) for the first time started to make a comparative analysis of heterogeneous material on the basis of normalization of differential integral curves of modular coefficients. The differential integral curves are widely used to identify the phases of high and low water content of rivers, the points of change of phases. The comparison of the course of the study characteristic on different rivers is ideal only in case of the same composition of years of original series, which is not always possible in the practice of hydrological observations. In case of super-century course the marked inaccuracies will be exacerbated depending on the value of changeability of the element. Thus, the calculation of ordinates from the middle and the construction of differential integral curve on them does not always reflect the actual conditions of the full cyclic process.

4. The forth trend in the study of long-term fluctuations of river runoff with the use of Markov's discrete chains allows discovering the patterns of transition of runoff phases and their difference in various basins. Markov's chain with discrete time is a chain, changes in the states of which occur in the certain fixed points of time. First of all, the relative simplicity of the quantitative evaluation of the analyzed relationships should be attributed to the advantages of this method, as well as the possibility of practical use in water-economic calculations. However, it would be not correct to assert about unidirectional changes without the analysis of reliability of availability of trends. There is a number of methods to check the availability of linear unidirectional changes.

Methods to check the availability of linear unidirectional changes. Methods of averaging values with the further graphic representation of their course are also accepted in the statistics. Sliding averages are generally used with data of temporal series to smooth out short-term fluctuations and to distinguish key trends or cycles. Mathematically, the sliding average is one of types of verification, and can therefore be considered as a low-pass filter, used in signals processing.

Identification of linear trends was carried out for three periods: 1) for a long-term period; 2) for the period from the beginning of observations till 1972–1973; 3) for the current period (from 1973–1974 to 2007).

In the long-term dynamics of water resources everywhere there is some tendency to increasing (figure 2). Summary water resources of the region for the current period are slightly higher than this characteristics for a long-term period. The increase of runoff of winter and the beginning of spring periods is particularly noticeable.

In our case, the methodology, widely applicable in hydrology and meteorology (Research Report 2005; Polyak I.I., 1975), is used. According to this methodology, based on the check of statistical significance of parameters of the trend, the following equation of linear regression is calculated:

$$Y(t) = a_0 + a_1 t$$

where Y(t) – the values of the study water resources (river basin); t – the serial number of the observed value; a_0, a_1 – the regression coefficients.

To accept the hypothesis about the presence of a linear trend on the methodology of I.I. Polyak it is necessary to meet the following conditions:

$$\overline{\sigma} \le \sigma^2, \quad |a_1| \ge 2\sigma_{a_1}$$

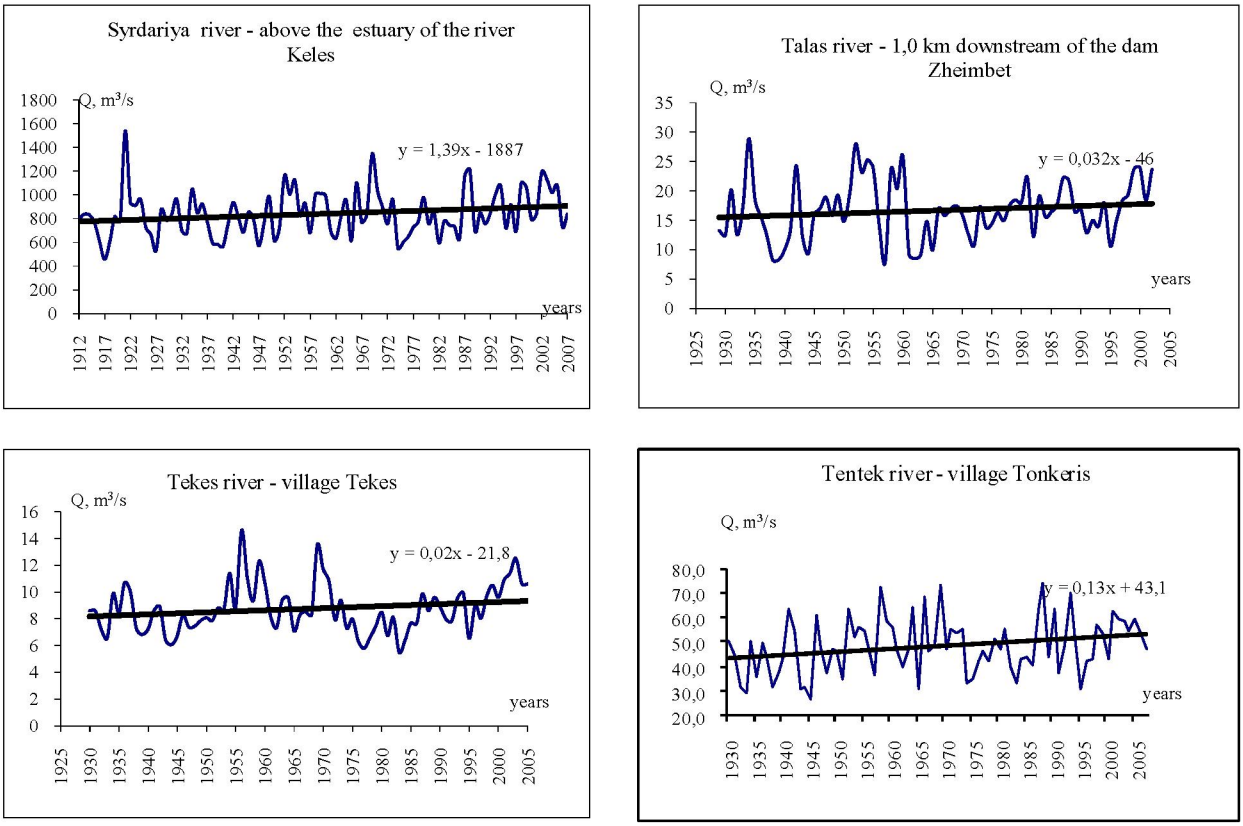

Figure 2 – Long-term fluctuations of runoff of the major rivers of South and South-East Kazakhstan

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

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

σ_{a_1} – the average quadratic deviation of the regression coefficient a_1, which is defined as follows:

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

If the conditions (2) are not met, the linear trend is not significant with the probability of 5 % (Polyak I.I., 1975).

The considered method is effective with normally distributed sampling (of «white noise»). However, the runoff series usually do not meet that condition, so the evaluation of the linear trend, and hence, the output of stationarity of the original series, is justified to the extend when the initial information differs from the normal distribution.

The check of the presence of the linear trend, series of water resources of river basins of South and South-East Kazakhstan. Thus, the identification of linear trends by the given method was carried out for the three periods: 1) for a long-term period; 2) for the period from the beginning of the observations till 1972-1973; 3) for the current period (from 1973-1974 to 2007). The results of calculations of some of the stations are shown in Table.

In order to identify patterns of fluctuations of river runoff let us refer to the analysis of differential integral curves of the annual runoff: the course in the time of the accumulated difference $\Sigma(k_i-1)/C_v$, at which the phase of rise of curve means high-water period (runoff of the sampling average), a recession - low-water (below average), and a point of inflection – the boundaries of those periods (Bronstein I.N., 1967; Davletgaliyev S.K, 2000; Rozhdestvenskiy A.V., 1974).

The course of the integral curves of the major rivers of South and South-East Kazakhstan is shown in figure 4. The long homogenous series were previously chosen for the major rivers of the region. It follows out of the calculations that on the major rivers of the basin of Syrdariya river two phases including small

The check of the presence of the linear trend, series of water resources of river basins of South and South-East Kazakhstan

№	River-settlement	Period	Dispersions		a_1	$2\sigma_{a_1}$	Significance of the trend
			$\overline{\sigma}^2$	σ^2			
1	Syrdariya river – above the mouth of the Keles river	1912-2007	34641	36685	1,39	13,9	–
		1912-1972	36225	38202	2,34	22,4	–
		1973-2007	32311	34539	8,21	37,3	–
2	Arys river – Zhaskeshu village	1912-2007	1,39	1,46	0,004	0,088	–
		1912-1972	1,70	1,80	0,018	0,15	–
		1973-2007	0,86	0,89	0,036	0,19	–
		1973-2002	77,2	100	0,41	2,01	–
3	Talas river – in 1,0 km lower then Zheimbet dam*	1929-2002	21,2	24,2	0,032	0,36	–
		1929-1972	28,1	32,2	-0,014	0,65	–
		1973-2002	10,9	12,1	-0,12	0,70	–
4	Assa river – r-w.st. Maimak*	1929-2002	6,34	7,85	0,025	0,20	–
		1929-1972	8,64	11,0	0,035	0,38	–
		1973-2002	2,85	3,16	0,063	0,36	–
5	Sharyn river – Sarytogai hole	1930-2006	73,1	53,3	0,14	0,77	–
		1930-1973	56,4	51,2	0,2	1,17	–
		1974-2006	93,6	50,7	0,68	2,13	–
6	Turgen river – Tauturgen village	1930-2006	1,17	1,11	0,007	0,10	–
		1930-1973	1,08	1,07	0,008	0,16	–
		1974-2006	1,31	1,14	0,056	0,25	–
7	Tekeli –Tekeli	1930-2006	0,46	0,45	0,003	0,06	–
		1930-1973	0,45	0,45	0,006	0,10	–
		1974-2006	0,49	0,41	0,034	0,15	–
8	Eginsu river – Blagodatnoye village	1930-2006	0,63	0,65	0,006	0,06	–
		1930-1973	0,83	0,84	0,011	0,10	–
		1974-2006	0,32	0,42	0,037	0,13	–
		1930-1973	6,49	6,49	0,049	0,29	–
		1974-2006	2,40	3,65	0,11	0,38	–
9	Tentek river – Tonkeris village	1930-2006	127	128	0,13	0,82	–
		1930-1973	140	140	0,38	1,36	–
		1974-2006	109	115	0,43	2,15	–

cycles are distinguished in the course of runoff: high-water from 1912 to 1972 and low-water 1973, some increase in runoff in the end of 80-ies and in the beginning of 90-ies was observed.

The year of 1969 was the high-water year for the Syrdariya river, after that a sharp decrease of river runoff till 90-ies is observed, in the last decades (1991-2007) an increase in runoff is traced. There is a synchrony in the course of runoff of all river basins of the Syrdariya river with slight differences in fluctuations in 1-2 years.

On the rivers of the basin of rivers Shu and Talas (figure 4) from 1936 to 2009 there are 3 periods of different water content in the region. 1 cycle – from 1936 to 1950 a decrease of runoff was observed. The second low-water cycle was from 1960 to 1975-ies and the third cycle was from 1989 to 1996. Each time the duration of each cycle decreased from 15 to 7 years.

On the rivers of the study region high-water years were from 1951 to 1959 and from 1975 to 1989, as well as after 1996 there is an increase of river runoff. The duration of high-water periods is 9 and 15 years.

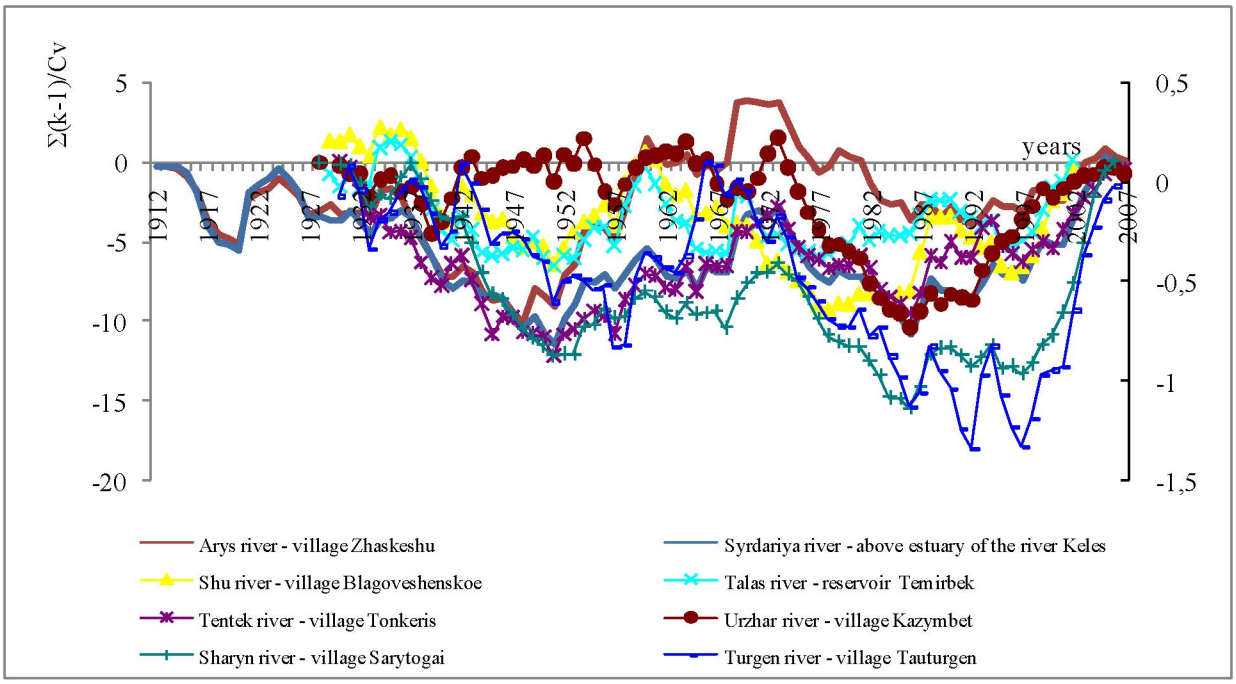

Figure 4 – The superposed integral curves of modular coefficients of major rivers of South and South-East Kazakhstan

The following two main elements are distinguished on the majority of integral curves of the Balkhash river basin: peak (transition from high-water to low-water phase) – from the middle of 50-ies till the end of 70-ies, minimum from 40-ies till the middle of 50-ies. On some curves there is a minor third element – a small peak in the end of 30-ies. Even a tendency to alternation of anomalies sign is typical for the Ile river. The cyclicality of runoff with a duration of 11-12, 5-6 and 3 years is observed. Here, the earlier made findings on the absence of a clear territorial localization of the long-term course of annual runoff neither within the Ile nor Zhetysu Alatau are confirmed. Some asymmetry is observed in the course of runoff of the Ile and Zhetysu Alatau, which is associated with the difference in the conditions of feeding of rivers (Galperin R.I., 1986; Sosedov et al. 1984.). To the analysis conducted before by other authors it can only be added (Galperin R.I., 1986; Galperin R.I., 1990; Research Report 1987; Sosedov I.S., 1976; Coll. of scientific proceedings 1993; Water resources Coll. of scientific proceedings 1993) that a significant change of the course of differential integral curve at all stations of the catchment basin of the Ile river is observed since 1970, that cannot be explained only by the influence of anthropogenic factor on runoff, possibly the ongoing climate changes increase the runoff of glacier-fed rivers in recent decades.

In the basin of the Alakol lake, in general, fluctuations of water content of rivers of the study region are synchronous. The certain features are caused by orographical features and geographical location.

In the basin of the Tentek river in 50-ies and in 1974-1986 low water periods, and in 1951-1973 and in 1987-2007 high-water periods were observed. There are some features in fluctuations of water content of rivers of northern basins of the study area, for example, such as in the Tentek river. Thus, while the Tentek river in 1962-1968 was characterized by high-water, other rivers of the study area were characterized by low-water during the same period.

2 main phases can be distinguished on the most part of integral curves: from 1912 (1928-30) to 1972-73 - the high-water phase and from 1973-74 to the mid 80-ies - the low-water phase. Later, starting from 1984-86, the beginning of rise of the curve is observed, i.e. high-water phase, which is continuing till present. This period (1986-2007) differs with minor fluctuations of runoff during 2-3 years and the change of rise and fall of the curve.

Conclusion. The differential integral curves are widely used to identify the phases of high and low water content of rivers, the point of change of phases. But it is necessary to take into consideration that they illustrate the course of the accumulated anomaly only relatively to the sampling average. The comparison of the course of the study characteristic on different rivers is ideal only in case of the same composition of years of the original series, which is not always possible in practice of hydrological observations.

In the long-term dynamics of water resources of *South and South-East Kazakhstan* everywhere there is some tendency to increasing. As for the summary water resources of the region for the current period, they are slightly higher than this characteristic for the long-term period. The data analysis shows that there are no existing significant trends of water resources of the study river basins. Though some increase in water content, which is justified with quantitative values of runoff, takes place.

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ҚАЗАҚСТАННЫҢ ОҢТҮСТІГІ ЖӘНЕ ОҢТҮСТІК-ШЫҒЫСЫ СУ РЕСУРСТАРЫНЫҢ УАҚЫТША ТЕРБЕЛІСІ

Аннотация. Әлемдік ауқымдағы жарияланымдарды талдау жер шарында климат, су ресурстарының өзгерісі, сонымен қатар географиялық ортада да өзгерістер туындап жатқандығын көрсетеді. Соңғы 25–30 жылда Қазақстан аумағында су ресурстары тербелісін және олардың кеңістік және уақыт бойынша өзгерістерін айқындайтын негізгі факторлары елеулі өзгерістерге ұшырады. Мақала Қазақстанның Оңтүстігі және Оңтүстік-Шығысы беттік су ресурстарының қазіргі жағдайына, қалыптасу және таралу заңдылықтары туралы маңызды мәселелеріне арналған.

Түін сөздер: ағынды, өзен алабы, су ресурстары,көпжылдық тербеліс, су ресурстарының динамикасы.

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ВРЕМЕННЫЕ КОЛЕБАНИЯ ВОДНЫХ РЕСУРСОВ ЮГО И ЮГО-ВОСТОКА КАЗАХСТАНА

Аннотация. Анализ публикаций в мировом масштабе вынуждает нас признать, что во всем мире происходят глобальные изменения климата, водных ресурсов, также в географической среде происходят значительные изменения. За последние 25–30 лет в Казахстане произошли наиболее серьезные изменения основных факторов, определяющих колебания водных ресурсов и их изменение во времени и по территории, к которым относятся кардинальные преобразования в социально-экономической сфере и наблюдающиеся изменения климата. Настоящие исследования посвящены актуальным вопросам современного состояния и изменения в закономерностях формирования и распространения ресурсов поверхностных вод Юга и Юго-Востока Казахстана.

Ключевые слова: сток, речной бассейн, водные ресурсы, многолетние колебания, динамика водных ресурсов.