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REGIONAL CLIMATE CHANGE IN THE ILE RIVER BASIN

This study analyzed the historical climate change in Ile River basin of Kazakhstan. The average annual air temperature and precipitation of 13 meteorological stations covering the period of 1950–2016 was used to detect the climate change employing Mann Kendall statistical test. The results of the study show the increasing trend in the average annual temperature in the areas of Ile River basin. The intensity of the temperature increase is higher (0,30–0,40°C/10 years) in the lower reaches and the lower increase in the upper reaches of the river. Whereas, there is no statistically significant trend observed for precipitation in the basin. The multi-direction changes (both increase and decrease) are observed for precipitation, most of which the decrease in precipitation is observed in August and September. The results of this study are helpful for water resources development, planning and management in the Ile River basin.

Key words: air temperature, precipitation, anomaly, climate change, the test of Mann-Kendal.

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Іле өзені алабының аймақтық климаттық өзгерісі

Бұл мақалада Қазақстан аумағындағы Іле өзені алабындағы тарихи климат өзгерістеріне талдау жүргізілді. Климаттық өзгерістердің үрдісін нақтылау үшін, 13 метеорологиялық станция бойынша 1950–2016 жылдар аралығындағы жауын-шашын мен ауа температурасының өзгерісі қарастырылды. Жауын-шашын мен температура тренд өзгерісінің маңыздылығы Манна-Кендалла статистикалық тестінің көмегімен тексерілді. Зерттеу нәтижелері бойынша Іле өзені алабы ауданында ауа температурасы өзгерісінің жоғарғы мәні өзен ағысының атырауында (0,30–0,40°C/10 жыл) және төменгі мәні таулы аудандарда тіркелген. Қарастырылған аймақта жауын-шашын үрдісінің өзгерісінде статистикалық маңыздылығы жоқ және әртүрлі бағыттағы трендтер (жоғарылауы және төмендеуі) байқалды, бірақ көбінесе тамыз және қыркүйек айларында жауын-шашынның азаюы тіркелген. Бұл зерттеу жұмысының нәтижелері Іле өзені алабының су ресурстарын басқару, жоспарлау және дамуы үшін пайдалы болып табылады.

Түйін сөздер: ауа температурасы, атмосфералық жауын-шашын, аномалия, климат өзгерісі, Манна-Кендалла тесті.

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Региональные изменения климата в бассейне р. Иле

В данном исследовании проанализированы исторические изменения климата в бассейне реки Или в Казахстане. Для уточнения тенденции климатических изменений представлен анализ годовой температуры воздуха и осадков по 13 метеорологическим станциям в 1950–2016 гг., а также значимость изменений тренда температуры воздуха и атмосферных осадков были проверены с использованием статистического теста Манна-Кендалла. Результаты исследования

показывают, что интенсивность повышения средней годовой температуры воздуха в районе бассейна р. Иле постепенно возрастает по направлению течения реки, где наименьшее увеличение температуры воздуха произошло в верхнем течении, а наибольшее увеличение – в нижнем течении реки (0,30-0,40°C/10 лет). Однако в рассматриваемом районе статистически значимой тенденции для осадков в не отмечается. В основном наблюдаются разнонаправленные тенденции (как увеличение, так и уменьшение) в ходе осадков, но больше всего уменьшается в августе и сентябре. Результаты этого исследования полезны для развития, планирования и управления водными ресурсами в бассейне реки Или.

Ключевые слова: температура воздуха, атмосферные осадки, аномалия, изменения климата, тест Манна-Кендала.

Introduction

The relevance of this work is determined by the lack of knowledge of regional features of contemporary climate change and their consequences, as well as practical needs for reliable information on the state of the climate regime of the region, affecting on the livelihood and productivity of natural ecosystems. Among the most significant effects of expected climate warming will be changes in water resources and the water regime of rivers.

There now exist the large number of scientific papers on climate change (Pachauri, 2007, Jones, 1994, Houghton, 2001, Perevedentsev, 2005, Ramstorf, 2009), which confirms, on the one hand, the importance and relevance of this problem for civilization and, on the other hand, the lack of a single, non-controversial assessment of climate trends and the causes of them.

The problem of “climate change” remains one of the most complex and confusing in earth sciences. Since the beginning of the 70s of the last century, the issues of climate change have been increasingly discussed in the world scientific literature. Already at that time, a graph describing the expected change in average air temperature in the Northern hemisphere until 2070 was published. From this forecast, it followed that in the 21st century, the air temperature will rise by more than 2°C, that is, by an amount that markedly exceeds the natural climate fluctuations that have occurred over the past several thousand years (Budyko, 1974:280).

At present, the increase in average, on a global scale, air temperature is considered to be a well-established fact. In accordance with the results of studies (WMO Statement on the status of the Global Climate in 2017, 2018) that the global average temperature was $0,46 \pm 0,1^\circ\text{C}$ above the average for 1981-2010 years and approximately $1,1 \pm 0,1^\circ\text{C}$ above the pre-industrial levels. At the same time, warming was incoherently: it was noted in two periods – from 1910 to 1940 and from 1976 to 2000, and a slight cooling was observed in the interval

1946-1975. Since 1976 the air temperature change rates have approximately been three times higher than those of the last 100 years in general (Solomon, 2007:14). The same periods of warming and cooling were noted in the works of K.Y. Vinnikov (1986), Willett (1950, 1974) and Mitchell (1961). And both of these processes were more clearly expressed in high latitudes. Willett (1950: 195) drew attention to the fact that the cooling trend, first noted according to data for high latitudes, gradually shifted to lower latitudes. In the temperate latitudes of the Northern hemisphere it appeared only in 1950-e years, and in tropical and equatorial much later.

In accordance with observational data on the world meteorological network, in the past ten to twenty years there has been a clear trend in the increase in global air temperature, the reason for which most climatologists consider the increase in “greenhouse gases” CO₂ concentration in the atmosphere as a result of human economic activity. The Synthesis Report (WMO Statement on the Status of Global Climate in 2017, 2018) states with 95% confidence that human activity is the main cause of global warming. According to the Intergovernmental Panel on Climate Change (IPCC), global temperature will inevitably rise over current century.

However, the “greenhouse” concept of climate change is a unilateral one (Kondratyev, 2001:124). In the view of A. S. Monin (2000:122) the main cause of warming is not the technogenic activity, but also the strengthening of external influences. The anthropogenic impact, certainly, is and will be present in the future, but humanity, through its economic activity, is not yet able to influence such gigantic flows that lead to climate change. In the work of Y.V. Kazantsev (2001:126) it is shown that the absence of the “greenhouse” effect on the Earth, and the observed increase in air temperature is the result of increased solar activity. Having carefully considered the thermal and radiation balance of the Earth, Pabat A.A. (2006:42) came to the following conclusion that “the increased

greenhouse effect due to anthropogenic increase in carbon dioxide concentration is not confirmed by the theoretical radiation and thermal balance of the Earth". Moreover, this effect is not confirmed by experimental studies, it allows to raise the issue of insolvency the concept of anthropogenic global climate change. The detailed critical analysis of the greenhouse effect is given in the monograph of E.A. Leonov (2010:352). In his opinion, the global warming has been caused by superposition of technology-related and cosmogenic causes.

Also V. Zharkova reports that (2015), recently, there has been the decrease in solar activity, and by 2030, this activity, expert forecasts that it may decrease by 60%, which is sufficient to start a "mini-ice age" similar to that observed in mid-1645 to 1715. During this period of time, known as the "Minimum of Maunder," a long-term and approximately thousand-fold decline in the number of sunspots was recorded, coinciding with a period of significant cooling and even freezing of some water bodies, both before and after this event that remained untouched by ice. At the same time, Zharkova claims that the new cooling will last much less than the previous one – for three 11-year cycles, after which the temperature will start to rise again. In the expert's opinion, the cooling will be especially noticeable in the Northern Hemisphere and may even lead to a lack of food.

In the author's view S.K. Alamanov, (2006:41) global climate variations observed in the 20th century, characterized by mainly two periods of warming, have a similar response in the regional climate of the countries of Central Asia. At the same time, local climatic conditions, especially in mountainous areas, varied widely in temperature, when its growth in terms of 100 years in some areas reached 2,5°C, which means much more than for the Earth as a whole. Precipitation averaged over the territory could almost not change, but in some areas there was both their growth from 1-2 to 20-30%, and ever greater fall to 40-45%. All this points to the heterogeneity of local responses to global and even regional climate change and the mandatory practical need for local climate change assessments.

Kazhydromet reported that the territory of Kazakhstan located in the center of the Eurasian Continent and remote from the ocean at a considerable distance (2000 – 3000 km), is warming at a significant pace than the globe average, and the same rate as on the average Northern hemisphere. For the period 1976-2016 the coefficient of linear trend of average annual air temperature for the Earth stood at +0,18°/10 years, +0,34°C/10 years for the Northern

hemisphere and +0,34°C/10 years for Kazakhstan (contribution of the trend in the dispersion of 25 %) (Annual Bulletin of monitoring of state and changes in climate of Kazakhstan: 2016, 2017:3).

Research methods

In the works devoted to the study of climate change, the temperature and air precipitation fluctuations are mainly studied, as these elements contain the longest and most reliable series of observations. The accumulation of long-term series of instrumental observations makes it possible to objectively analyze climate fluctuations that have occurred in recent years.

When studying the internal dynamics of temporary meteorological series, it is often required to reveal the presence of the tendency in changes in the time series, either as the linear or the parabolic trend. By the type of trend with a certain degree of reliability, it is possible to predict the future behavior of the time series. (Tudry, 2009: 34).

The most consistent methodological side of evaluation of the linear trends described in the works of I. I. Polyak (1975, 1979), where for estimation of the linear one is proposed to use the least squares adjustment for independent observations.

The required regression equation in case of linear relationship is (1):

$$y_i = ax_i + b \quad (1)$$

where a – coefficient of the linear trend, characterizing the rate of change of the studied quantity; x_i – time, year; b – series level at the initial time.

The essence of the least squares adjustment is to determine the calculated parameters a and b , at which the sum of the squared deviations of the observed values of y_i from that calculated by formula (1) will have a minimum value (Sickan, 2007:138).

More informed conclusions could be obtained by applying statistical criteria for the detection of monotonous trends. When analyzing meteorological data, we can use a Mann-Kendall test (Mann-Kendall test). Mann Kendall test is the statistical test commonly used for the analysis of trend in climatologic time series (Mavromatis, 2011:13). The advantages of this test are the following indicators. First, it is a non-parametric test that does not require the normal distribution of data. Secondly, due to non-uniform time series, it has low sensitivity to abrupt interruptions. (Tabari, 2011:128). According to this test, the null hypothesis H_0 implies the absence of the trend (the data are independent and randomly ordered), and this is tested on the alternative

hypothesis H_1 , which assumes the presence of the one (Onoz, 2003:247).

The computational procedure for the Mann Kendall test considers the time series of n data points and T_i and T_j as two subsets of data where $i = 1, 2, 3, \dots, n-1$ and $j = i+1, i+2, i+3, \dots, n$. The data values are evaluated as an ordered time series. Each data value is compared with all subsequent data values. If a data value from a later time period is higher than a data value from an earlier time period, the statistic S is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, S is decremented by 1. The net result of all such increments and decrements yields the final value of S (Drapel, 1997:133). The Mann-Kendall S Statistic is computed as follows (2,3):

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n \text{sgn}(x_j - x_k) \quad (2)$$

$$\text{sgn}(T_j - T_k) = \begin{cases} +1 & \text{if } (T_j - T_k) > 0 \\ 0 & \text{if } (T_j - T_k) = 0 \\ -1 & \text{if } (T_j - T_k) < 0 \end{cases} \quad (3)$$

where T_j and T_i are the annual values in years j and i , $j > i$, respectively [10].

If $n < 10$, the value of $|S|$ is compared directly to the theoretical distribution of S derived by Mann and Kendall. The two tailed test is used. At certain probability level H_0 is rejected in favor of H_1 if the absolute value of S equals or exceeds a specified value $S_{\alpha/2}$, where $S_{\alpha/2}$ is the smallest S which has the probability less than $\alpha/2$ to appear in case of no trend. A positive (negative) value of S indicates an upward (downward) trend [40] For $n \geq 10$, the statistic S is approximately normally distributed with the mean and variance as follows: $E(S)=0$

The variance (σ^2) for the S -statistic is defined by (4):

$$\sigma^2 = \left[\frac{n(n-1)(2n+5) - \sum_t t(t-1)(2t+5)}{18} \right] \quad (4)$$

in which t_i denotes the number of ties to extent i . The summation term in the numerator is used only if the data series contains tied values. The standard test statistic Z_s is calculated as follows (5):

$$Z_s = \begin{cases} \frac{S-1}{\sigma} & \text{or } S > 0 \\ 0 & \text{or } S = 0 \\ \frac{S+1}{\sigma} & \text{or } S < 0 \end{cases} \quad (5)$$

The test statistic Z_s is used a measure of significance of trend. In fact, this test statistic is

used to test the null hypothesis, H_0 . If $|Z_s|$ is greater than $Z_{\alpha/2}$, where α represents the chosen significance level (eg: 5% with $Z_{0.025} = 1.96$) then the null hypothesis is invalid implying that the trend is significant (Drapel, 1997:133).

Results and Discussion

The Earth's climate in a century has changed both globally and regionally. At the regional level, they differ significantly from global and have its own characteristics in each region. This article focused on characteristics of regional differences in climate change in the Ile River Basin. The Ile River is the main watercourse in the Balkhash-Alakol water basin. One of its tributaries is Tekes river rises in Kazakhstan, in the North-Eastern slopes of the Terskey Alatau and then flows through the territory of China, where it merges with the rivers Kunes and Kash, at 205 km from the confluence, it again enters Kazakhstan within the abounding river and at 1001 km flows into the Lake Balkhash. (Surface Water Resources of the USSR, 1970, 1977; Dostay, 2012).

Research on climate change in the Ile River basin is important both for Kazakhstan and China, as future allocation of water resources between two countries is based on forecasts of precipitation and air temperature (CMIP 5).

In China, changes in the main climatic parameters in the Ile River basin are considered in (Huilan Sun, 2010:652), in which, according to 7 meteorological stations (MS) in the upper Ile River, it was shown that precipitation increased significantly in the summer and winter months, and the air temperature also rose from the mid-1980s to the present. In another study (Ye, 1997:46), the nature of changes in precipitation and air temperature in various low and high mountainous areas in the Ile River basin in the Tien Shan mountains is analyzed in detail. There is the close link between precipitation and air temperature with altitude above sea level has been revealed; thus, in high-altitude areas, precipitation grows, and the value of the air temperature gradient in summer is much greater than in winter.

In our territory, regional climate change in the Ile River basin was not considered separately, but there are many works that assess the impact of climate change on the river flow and on modeling HBV (Galaeva, 2013:108, Choduraev, 2016:43). The papers consider the results of research on the possibility of using the HBV model for the Ile River. The model was calibrated and adapted for a specific catchment area using the observed data on air temperature, precipitation, runoff and evaporation for the base period (1961–1990). The results of calibration and

adaptation of the HBV model showed that the model gives good results when modeling the flow of the Ile River for the base period, and therefore can be used to model the runoff for the future.

The aim of this work is to study the features of spatial-temporal distribution of air temperature and atmospheric precipitation in the studied basin. The initial meteorological information to meet the tasks was the monthly average, most complete, time series of ground-level air temperature and precipitation for the period 1950–2016 through 13 representative

MS covering the entire length of the Ile River in the Kazakhstan part on the basis of which the map was created (figure 1). Also, to study the temporal variability of temperature and precipitation, the Mann-Kendall statistical test was used to determine the approximate time of the beginning of the trend or trend change points in time series and check its statistical significance. For the statistical test, 5 MS out of 13 representative ones were selected with the observation period from the opening of the MS station until 2016 (figure 1).

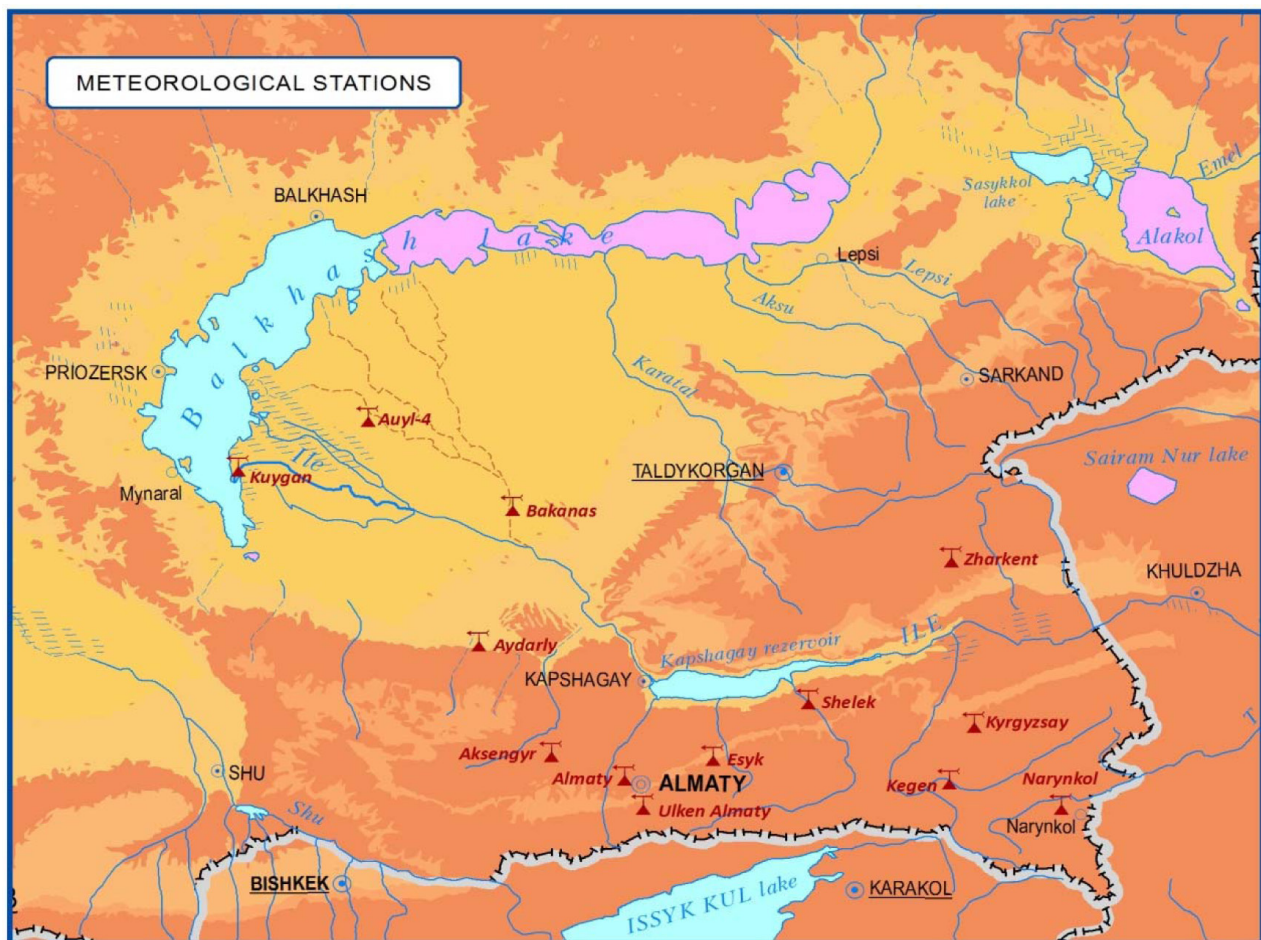


Figure 1 – Map of the location of meteorological stations (▲) of the Ile River basin

In the basin of the Ile River, to identify the long-term dynamic of meteorological parameters, the rolling five-year graphs of changes in average annual air temperature and annual precipitation were constructed. For a visual representation of the trend of

the observed parameters, trend lines were plotted on the charts. Changes of average annual air temperature and precipitation ($^{\circ}\text{C}/10$ years and $\text{mm}/10$ years) over the period 1950 – 2016 are presented in figure 2 (6 MS are shown as an example).

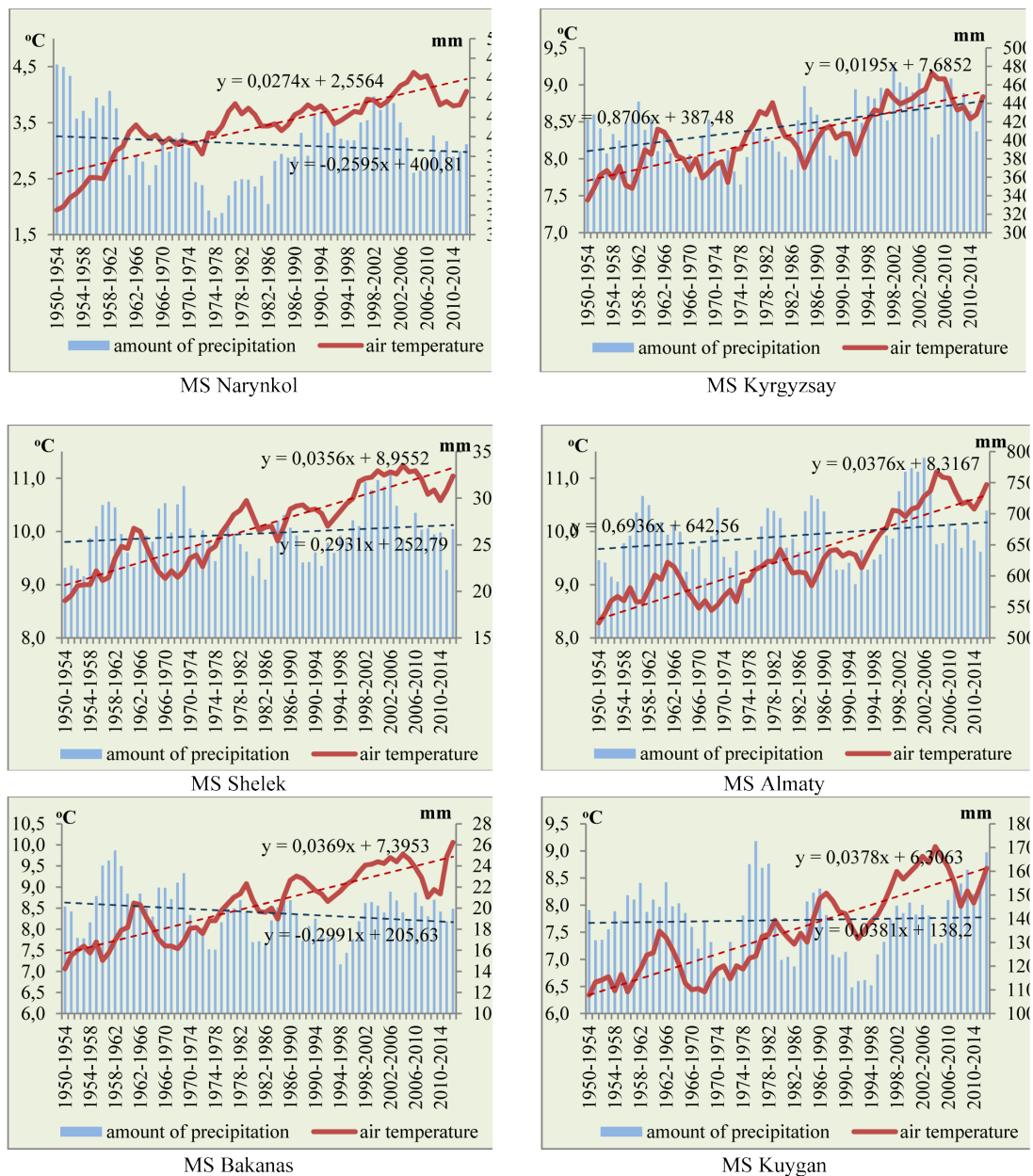


Figure 2 – The multiyear course of air temperature and precipitation in the Ile River basin (five-year rolling average)

The average annual temperature for all meteorological stations in the Ile River basin has the positive trend, but the temperature increase is uneven. The greatest increase in temperature over the past 66 years has been observed at meteorological stations located in the Ile Delta area: the MS Aksengyr – 0,36 °C/10 years, the MS Aydarly – 0,33 °C/10 years, the MS Bakanas – 0,36 °C/10 years, the MS Kuygan – 0,37 °C/10 years, as well as on the MS Almaty – 0,37 °C/10 years, and least in mountainous areas of the basin: the MS Esyk – 0,25 °C/10 years, the MS Ulken Almaty – 0,16 °C/10 years, the MS Narynkol – 0,27 °C/10 years, the MS Kyrgyzsay – 0,19 °C/10 years.

In most of the meteorological stations in the river basin under consideration over the past 66 years, there has been the statistically insignificant, multidirectional trend in annual precipitation. (figure 2). The statistically significant drop in precipitation occurs in the MS Issyk – 15 mm/10 years, as well as on the flat territory of the Ile River basin at most meteorological stations are marked not significant decrease in precipitation. The rise in annual precipitation for the period 1950-2016 is observed on the MS – Kyrgyzsay – 9 mm/10 years, the MS Almaty – 7 mm/10 years, the MS Zharkent and the MS Kegen – 4 mm/10 years.

For the more detailed analysis of regional climate change, the anomalies of air temperature and precipitation are calculated over decades (tables 1 and 2). When calculating the air temperature and precipitation anomalies, the average long-term values of meteorological parameters for the base period 1981–2000 were taken as the climatic norm.

Table 1 – Air temperature anomalies for different periods

MS	Air temperature anomalies for different periods (°C)*						
	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009	2010-2016
Narynkol	-1,57	-0,62	-0,51	-0,25	-0,05	0,29	0,23
Kegen	-1,39	-0,95	-0,54	-0,30	-0,07	0,34	0,45
Kyrgyzsay	-0,90	-0,54	-0,44	-0,29	-0,07	0,36	0,18
Zharkent	-1,80	-1,03	-1,00	-0,41	-0,05	0,47	0,11
Shelek	-1,62	-1,14	-0,86	-0,40	-0,13	0,53	0,36
Esyk	-1,05	-0,75	-0,66	-0,46	-0,04	0,45	0,36
Almaty	-1,36	-1,05	-0,94	-0,65	-0,19	0,75	0,77
Ulken Almaty	-0,54	-0,44	-0,44	-0,38	-0,05	0,38	0,41
Aksengyr	-	-1,45	-0,97	-0,31	-0,14	0,50	0,21
Aydarly	-1,53	-1,05	-0,68	-0,46	-0,18	0,65	0,30
Bakanas	-1,72	-1,20	-0,87	-0,36	-0,11	0,53	0,56
Auy1-4	-1,46	-1,10	-0,84	-0,25	-0,25	0,54	0,31
Kuygan	-1,56	-1,25	-1,17	-0,44	-0,26	0,66	0,35

*Anomalies are calculated relative to the base period of 1981 – 2010.

Table 1 clearly shows the increase in temperature in all regions over the past twenty years. The temperature anomalies presented in the table show the fairly well-defined period of warming, which was located in the time period 2000-2009. Mostly large negative anomalies cover the period between 1950 and 1969. Analysis of changes in air temperature anomalies for individual stations allows to identify differences in features of the physical-geographical

location. Thus, at high-altitude meteorological stations (the MS Narynkol, the MS Kegen) the positive temperature anomaly is lower compared with meteorological stations located in the lower part of the basin.

Changes in the signs of precipitation anomaly over decades are not constant, but a phase with the positive anomaly after the 2000s is clearly distinguished (table 2).

Table 2 – Precipitation anomalies for different periods

MS	Precipitation anomalies for different periods (mm)*						
	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009	2010-2016
Narynkol	51,5	-10,7	-39,4	-30,8	16,3	8,6	12,9
Kegen	-31,5	4,5	-2,4	4,4	-18,8	13,8	22,0
Kyrgyzsay	-19,4	-33,8	-49,5	-18,8	2,9	1,5	42,9

Zharkent	3,7	-26,9	-5,3	-4,9	-8,4	1,5	37,9
Shelek	-19,6	-2,1	-2,4	-18,2	-19,6	15,9	16,2
Esyk	29,9	87,0	31,9	25,7	-55,5	10,0	16,4
Almaty	-32,8	-12,9	-41,7	6,6	-50,0	35,3	32,2
Ulken Almaty	29,2	36,6	-70,0	-11,9	-38,8	26,9	64,2
Aksengyr	-	0,8	-9,7	-23,6	-13,4	16,7	26,4
Aydarly	10,7	7,9	-10,1	-18,3	15,9	11,0	18,4
Bakanas	17,8	27,9	1,4	1,3	-14,9	7,3	21,9
Auyl-4	13,9	13,4	4,6	14,2	-11,2	-6,6	0,9
Kuygan	6,9	10,6	5,6	2,2	-9,1	3,7	36,8

*Anomalies are calculated relative to the base period of 1981 – 2010

Until the 2000s, often changing multidirectional anomalies of precipitation do not allow to distinguish “wet” and “dry” periods. However, in the area of the Ile River delta (MS Bakanas, MS Aul-4 and MS Kuygan) there is mainly a positive anomaly, which is only 1990-2000 is below normal. The visual analysis of the data suggests that long-term averages for meteorological parameters tend to decrease or increase. More robust

findings can be obtained by applying statistical criteria for the detection of monotonous trends. Mann-Kendall nonparametric test is most commonly used for climate data. Meteorological parameters are characterized by an uneven intra-annual distribution, therefore the test was applied on the monthly basis. Summary test results for analyzing data trends are presented in table 3.

Table 3 – Mann – Kendall test (Z-statistics) for monthly and annual air temperature (T) and precipitation (R) trends

Time series	Test Z									
	MS Almaty (1921-2016 yy.)		MS Esyk (1938-2016 yy.)		MS Zharkent (1923-2016 yy.)		MS Kyrgyzsay (1935-2016 yy.)		MS Bakanas (1936-2016 yy.)	
	T	R	T	R	T	R	T	R	T	R
January	4,12	2,45	-0,39	1,63	4,23	-0,05	1,39	1,39	1,99	0,27
February	2,88	2,33	0,19	0,99	2,99	0,52	0,50	2,36	2,67	1,16
March	3,02	1,81	1,89	-0,75	3,05	0,48	1,87	0,86	2,54	0,20
April	2,79	1,43	2,27	0,51	2,98	1,52	2,14	1,57	2,88	-0,98
May	2,37	0,60	2,01	-0,88	2,59	0,24	0,87	-0,20	1,78	-0,42
June	4,18	0,79	4,09	-0,45	3,85	0,42	3,15	1,06	3,18	0,60
July	2,82	-0,44	2,55	0,24	1,99	1,45	0,40	1,07	0,13	1,42
August	2,73	0,45	3,31	-0,29	1,92	0,15	0,61	0,83	2,18	-0,47
September	3,35	-0,30	3,44	-1,27	3,91	-0,21	2,20	-1,07	3,02	-0,04
October	1,06	-0,12	2,82	-0,06	2,29	1,36	0,71	2,80	3,31	0,68
November	3,28	1,11	2,44	0,14	4,30	0,57	2,94	1,85	3,43	0,82
December	3,50	2,26	0,35	0,88	3,18	-0,07	1,95	1,99	2,24	0,19
Annual	6,64	2,80	4,75	0,00	6,79	1,29	4,27	2,44	5,84	0,60

The results of the monthly tests of the trends showed that in the course of the year, the change in the average monthly values of air temperature is uneven for different seasons of the year and non-uniform for the studied region. It is common that the most intensive warming is observed in the winter months and in June at almost all meteorological stations were being considered. Intensive warming in the winter months also affects the hydrological regime of rivers in the region, which is confirmed by previous research (Alimkulov, 2016:227), where there is a shift in the timing of the beginning of the flood to an earlier date. In the spring (April-May) and autumn (September-October) months, warming occurs evenly throughout the region under study. Test results for monthly precipitation data show a combination of positive and negative trends for all MCs. Significant negative trends are observed at the MS Esik, the decrease in the amount of monthly precipitation can be traced in six (March, May, June, August, September and October) months out of twelve. The slight growth in precipitation occurs on the MS Almaty and Kyrgyzsay. At the remaining stations, the slight rise in precipitation is observed in the cold period and the decline in the warm period of the year.

Conclusions

The study showed that at the regional level there is a significant spatial and temporal heterogeneity

in the trends of changes in meteorological parameters. It is shown that the intensity of the increase in the average annual air temperature in the area of the Ile River basin gradually rises in the direction of the flow of the river, which means on high mountain MCs, the temperature growth is not significant, and in the region of the river delta the temperature increase stands at 0.30-0.40 ° C / 10 years. In the majority of meteorological stations under consideration, there is the statistically insignificant, multidirectional trend in the annual total precipitation.

The decay temperature anomaly over the decade demonstrates a well-marked period of warming, which is located in the 2000-2009 time interval. Deviations from the norm of the annual amounts of precipitation until the 2000s were mostly well below the norm, and in recent years, positive anomalies have prevailed.

The results of the Mann-Kendal test show that the most significant warming is typical for the winter months of the year, and it does not occur evenly throughout the entire region under study. In the spring and autumn months, warming occurs evenly throughout the MS.

Changes in precipitation within the year over the multi-year period include negative and positive trends, most of which the decrease in precipitation is observed on the main MSs in August and September.

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