ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ
Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Казахский национальный исследовательский
технический университет им. К. И. Сатпаева

N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
Kazakh national research technical university
named after K. I. Satpayev

SERIES
OF GEOLOGY AND TECHNICAL SCIENCES

6 (438)

NOVEMBER – DECEMBER 2019

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

«ҚР ҰҒА Хабарлары. Геология мен техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Меншіктенуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).
Қазақстан республикасының Мәдениет пен ақпарат министрлігінің Ақпарат және мұрағат комитетінде 30.04.2010 ж. берілген **№10892-Ж** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Мерзімділігі: жылына 6 рет.
Тиражы: 300 дана.

Редакцияның мекенжайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., 220, тел.: 272-13-19, 272-13-18,
http://www.geolog-technical.kz/index.php/en/

Редакцияның мекенжайы: Қазақстан, 050010, Алматы қ., Қабанбай батыра көш., 69а.
Қ. И. Сәтбаев атындағы геология ғылымдар институты, 334 бөлме. Тел.: 291-59-38.

Типографияның мекенжайы: «Аруна» ЖК, Алматы қ., Муратбаева көш., 75.

«Известия НАН РК. Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан (г. Алматы)
Свидетельство о постановке на учет периодического печатного издания в Комитете информации и архивов Министерства культуры и информации Республики Казахстан **№10892-Ж,** выданное 30.04.2010 г.

Периодичность: 6 раз в год
Тираж: 300 экземпляров

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, ком. 219, 220, тел.: 272-13-19, 272-13-18,
http://nauka-nanrk.kz /geology-technical.kz

Адрес редакции: Казахстан, 050010, г. Алматы, ул. Кабанбай батыра, 69а.
Институт геологических наук им. К. И. Сатпаева, комната 334. Тел.: 291-59-38.

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Owner: RPA "National Academy of Sciences of the Republic of Kazakhstan" (Almaty)
The certificate of registration of a periodic printed publication in the Committee of information and archives of the Ministry of culture and information of the Republic of Kazakhstan N 10892-Ж, issued 30.04.2010

Periodicity: 6 times a year
Circulation: 300 copies

Editorial address: 28, Shevchenko str., of. 219, 220, Almaty, 050010, tel. 272-13-19, 272-13-18,
http://nauka-nanrk.kz/geology-technical.kz

Editorial address: Institute of Geological Sciences named after K.I. Satpayev
69a, Kabanbai batyr str., of. 334, Almaty, 050010, Kazakhstan, tel.: 291-59-38.

Address of printing house: ST "Aruna", 75, Muratbayev str, Almaty

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 6, Number 438 (2019), 223 – 234 **https://doi.org/10.32014/2019.2518-170X.174**

UDC 551.577.53

A. K. Zheksenbayeva, A. S. Nyssanbayeva, M. O. Tursumbayeva

Al-Farabi Kazakh National University, Almaty, Kazakhstan
E-mail: zheksenbaeva@mail.ru, nyssaiman17@gmail.com, Tursumbaeva.madina@gmail.com

DYNAMICS OF MULTI-YEAR CLIMATIC CHANGES OF PRECIPITATION DURING THE VEGETATION PERIOD IN THE NORTH OF KAZAKHSTAN

Abstract. In the context of modern climate change, that is determined by both natural factors and human economic activity, can have a significant impact on various processes. Some of the most significant climatic changes for the agricultural sector are the change in average monthly temperatures and precipitation, especially during the growing season. Since North Kazakhstan is the main agricultural region of Kazakhstan, that ensures country's food independence and security, the problem of climate change and their effect on agricultural production in the region is relevant and important.

This article considers the dynamics of long-term climatic changes in precipitation during the vegetation period in the north of Kazakhstan. The changes in the mean multi-year precipitation values for the period from 1936-2017 were analyzed. After, a comparative analysis of the changes in the mean multi-year values for the observation period relative to the baseline was made. Due to the intensification of global warming in the second half of the 20th century, especially in 1991-2017, precipitation variability was analyzed. The paper also examines the relationship between atmospheric precipitation and the yield of grain crops in Northern Kazakhstan during the vegetation period.

As a result of this study, it was found that (1) the average multi-year precipitation standards tend to grow at all stations considered in Northern Kazakhstan since 1991 with a significant change observed in the cold season; (2) according to average precipitation values the during the growing season, June and July are the most rainy months, and the least is April; (3) atmospheric precipitation regime and their supply during the growing season affects the yield of grain crops in the region.

Key words: precipitation, the territory of Northern Kazakhstan, vegetation period, precipitation dynamics, precipitation anomaly, asymmetry, kurtosis, correlation, productivity, crops, provision of precipitation.

Introduction. In recent years, the attention of scientists around the world has been attracted by the growing frequency of abnormal natural phenomena, such as floods, drought, excessively humid periods, severe frosts, etc., which are causing ever-greater economic and social damage to society.

In the current climate change regime, which is determined by both natural factors and human economic activity, can have a significant effect on various processes that affect the vegetation and soil cover. Observed climate changes affect both the yield and its characteristics, for example, the interannual yield amplitudes.

Areas of risky farming are particularly sensitive to climate change, since environmental systems are in an unstable equilibrium and even small, but prolonged changes in precipitation or temperature rise can lead to irreversible consequences. It is clear therefore, that the analysis of possible climate changes in the North Kazakhstan region has not only scientific but also practical interest.

The relevance of research. North Kazakhstan is the main agricultural region of the Republic that provides food independence and security to the whole country. Therefore, the problem of climate change and their effect on agricultural production in the region is relevant and important. As a part of the task of implementing the food security program, one of the most important tasks is to assess the dynamics of climate change in the region and their effect on agricultural production for the coming decades, especially in the growing season. Knowledge of the expected changes will allow to develop an optimal strategy for adapting the industry to new climatic conditions and minimize possible losses.

From climatic changes, the average monthly temperatures and precipitation, especially during the growing season, are the most significant for the agricultural sector. Because of the lack of precipitation, the region of the Northern Kazakhstan is generally classified as the zone of risky agriculture, where only three years out of every five are yielding.

Study area. The study area was a large part of the territory of Northern Kazakhstan, which included North Kazakhstan, Pavlodar, Akmola and Kostanay regions (picture 1).

Picture 1 – Research area

The length of the region from west to east is 1300 km, and from north to south – about 900 km [1, 2].

The territory is located in the center of Eurasia, and the great distance from the oceans, primarily from the Atlantic Ocean, causes large amplitudes in annual course of air temperature and relatively low precipitation.

Materials and methods. To analyze the dynamics of atmospheric precipitation, two widely used in meteorology methods: statistical analysis and deviation from the climatic norm were applied.

Data of long-term observations (from 1936 to 2017) of monthly and annual precipitation amounts at five meteorological stations located in the forest-steppe and steppe zones in Northern Kazakhstan were used in this study. The stations were Petropavlovsk, Kostanay, Astana, Kokshetau and Pavlodar.

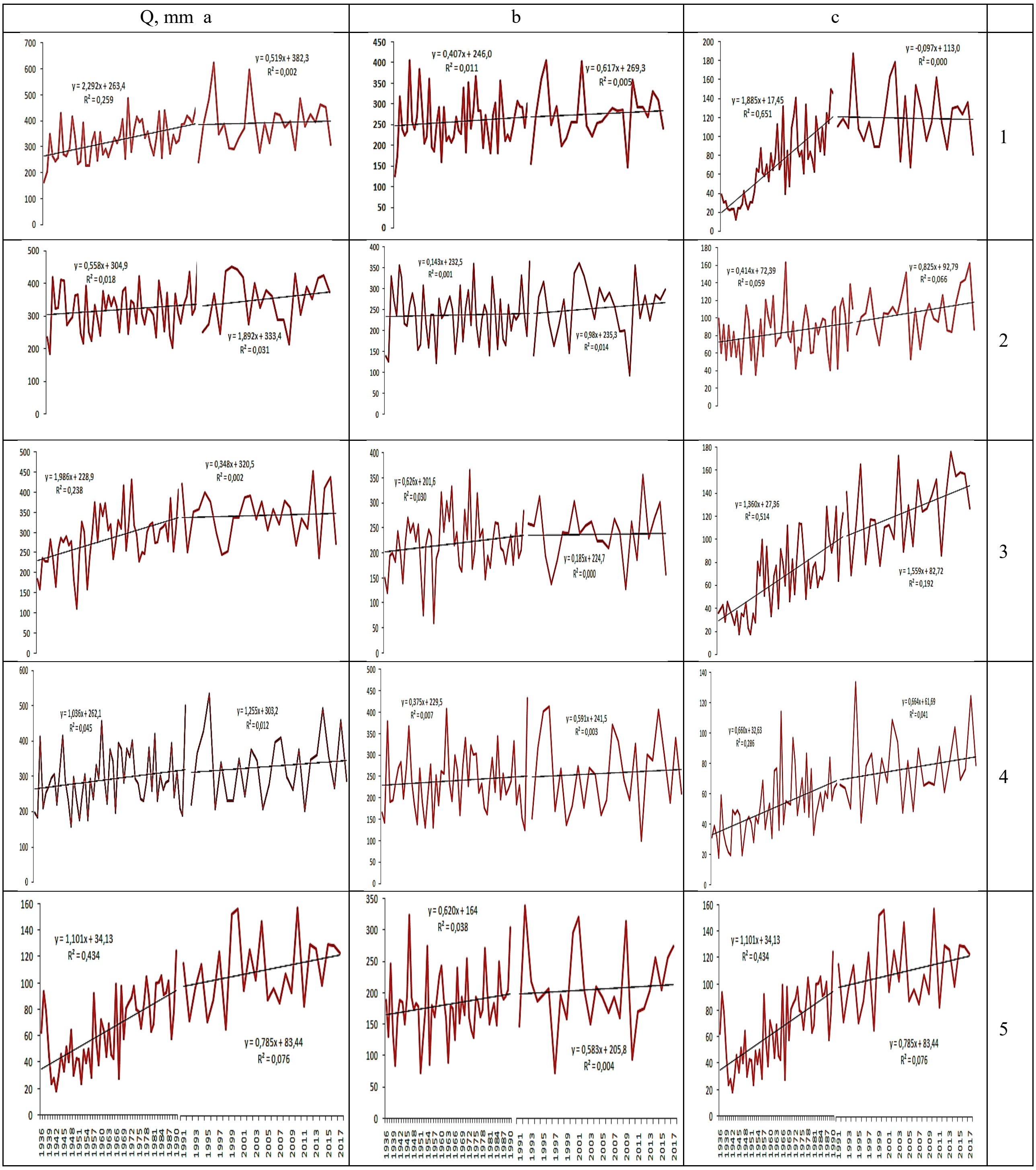
Changes in mean multi-year values were analyzed for the main period of observations (1936-2017). The World Meteorological Organization (WMO) recommends the use of the period 1951-1980 as a reference period, but due to climate variability, the period 1961-1990 was taken as the reference period [3, 4]. A comparative analysis of the change in the mean multiyear values of the main period relative to the reference period was made. Due to intensification of global warming in the second half of the 20th century, especially in 1991-2017, the variability of atmospheric precipitation was analyzed.

Long-term change trends of atmospheric precipitation are obtained by calculating linear trends, and analysis of the linear trend equation.

To assess the climatic characteristics of precipitation in [5-8], 82-year period (from 1936 to 2017) was taken. As a result of statistical processing, a number of characteristics such as annual precipitation sums, standard deviation, asymmetry coefficients, kurtosis and variations were obtained.

In recent decades, the problem has worsened due to global warming, which, according to most scientists, is caused by intensive emissions of greenhouse gases into the atmosphere. Areas of risky farming are the most sensitive to such changes, since there is no margin of stability. Therefore, in addition to the statistical analysis of the series of precipitation for July-September 1936-2017 [9], which made it possible to better understand their internal structure, the dynamics of precipitation [10-12] in the region, including the harvesting period, was studied for the period from 1936 to 2017.

Results and discussion. The study of the regime of long-term changes in atmospheric precipitation is one of the most important problems. Atmospheric precipitation, like other elements of climate, varies significantly both in time and in space. The variability of the mean and anomalous values of precipitation is related to the physical and geographical conditions, the time of the year and the atmospheric circulation. A large number of studies have been devoted to the study of the regime of perennial fluctuations of global air temperature and precipitation fields [13-18].



Picture 2 – Dynamics and linear trends of annual sums of precipitation (a), precipitation of the warm period (b), precipitation of the cold period (c) for the period 1936-1990 and 1991-2017 at considered stations in Northern Kazakhstan: 1 – Petropavlovsk, 2 – Kostanay, 3 – Astana, 4 – Kokshetau, 5 – Pavlodar

Precipitation refers to the category of phenomena that can affect both positively and negatively. The rains with 30 mm of precipitation or more fall per day are considered as abundant, and are dangerous for economic activity [19-21]. On the one hand, precipitation of high intensity leads to flushing of the soil and damage to man-made structures. In some areas, rain floods are accompanied by flooding of settlements. Long and intensive rainfall makes it difficult to carry out agricultural and construction works, motor transport, aviation, etc. On the other hand, abundant precipitation contributes to a significant moistening of the soil, which favorably affects the life of plants.

Northern Kazakhstan is the main agricultural region, grain production is also concentrated here, ensuring the food security of the Republic. Among the early cereals cultivated in Northern Kazakhstan, the leading place belongs to spring wheat. High food value of spring wheat and relatively low requirements to climate conditions made this culture widespread in most territories of Kazakhstan.

Long-term fluctuations in the annual amount of precipitation of cold and warm periods for 1936-2017 were used for statistical assessments, and the changes in the long-term precipitation mean values for the main period of observations (1936-2017) were analyzed (picture 2).

Data averaging for obtaining norms is considered in many in climate studies [22-24]. For the period 1936-2017, the annual precipitation amounts at all considered stations vary from 267 mm (station Pavlodar) to 348 mm (station Petropavlovsk). In their distribution, zonality, one of the general geographic regularities, can be observed. Along with zonality, the annual precipitation in the region decreases from west to east from 332 (Kostanay) to 267 mm (Pavlodar), with the continentality of the climate increasing in this direction. The northern regions of the country are more susceptible to the influence of the northwestern and western air masses. The annual course of precipitation depends both on the general circulation of the atmosphere and on local physical and geographical conditions. For this specific region, the continental type of annual precipitation with a maximum in summer and a minimum in winter is typical. So, within the greater part of the northern half of the country (forest-steppe and steppe), 60-80 % of the annual precipitation amount falls on average in the warm season (April-October), and only 20-40 % are in the cold season [25, 26].

Trends of long-term changes in atmospheric precipitation were determined by calculating linear trends (picture 2) and analysis of the linear trend equation (table 1).

With a significance level $\alpha=0.05$, the correlation coefficient (r) for the periods are: r=0.22 for 1936-2017; r=0.27 for 1936-1990; r=0.35 for 1961-1990; r=0.37 for 1991-2017.

Table 1 show that the amount of precipitation during different averaging periods has certain differences. For the periods from 1936 to 2017 significant changes were noticed for Pavlodar station in the warm period, as well as for all stations in the cold period. Comparison of the annual amount of precipitation for the main period (1936-2017) with the base period (1961-1990) shows that there is a significant reduction in precipitation up to 12 and 13 mm for stations Petropavlovsk and Astana, respectively. In the period 1991-2017, compared with the period 1936-1990, an increase in annual precipitation values is observed in the range from 30 to 62 mm at all the stations under consideration.

Thus, the average long-term precipitation rates at all the considered stations of Northern Kazakhstan have been increasing since 1991, with a significant change observed in the cold season. Thus, at the stations Petropavlovsk and Astana, the long-term norm of precipitation in the cold period increased up to 40-42 mm, and at other stations, it varied within 20-29 mm. In the warm half-year, a positive deviation from the norm at the stations under consideration varied from 6 to 33 mm.

The analysis of the structure of precipitation series was carried out at five stations of Northern Kazakhstan for the period from 1936 to 2017 (82 years). To analyze the time course of precipitation, an anomaly of precipitation was used and a comparison of the signs of the anomaly for the study period was carried out. In addition to that, the mean values of the positive and negative precipitation anomaly were presented during the vegetation period. The results are in tables 2 and 3.

Table 2 shows that the number of cases with negative precipitation anomalies slightly prevails over the number of cases with a positive anomaly at all considered stations, which may serve as a first approximation to the estimation of the trend of precipitation change.

The analysis of the trend of changes in precipitation over the vegetation period in the north of Kazakhstan presents great practical interest. For illustration, the time course of the precipitation anomaly for the growing season is shown for three stations: Petropavlovsk, Kostanay, Astana (pictures 3-5).

Table 1 – Long-term dynamics of precipitation over different averaging periods in Northern Kazakhstan

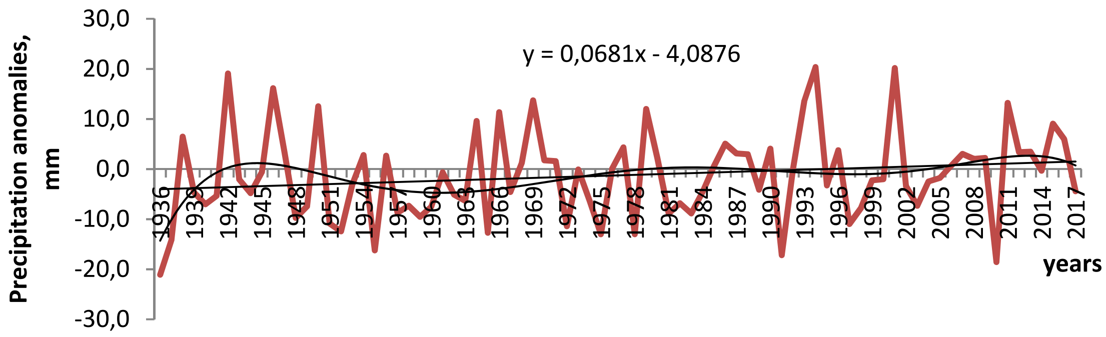
Stations	Periods, years											
	1936-2017			1936-1990			1961-1990			1991-2017		
	norm, mm	standard deviation	coefficientof a linear trend	norm, mm	standard deviation	coefficientof a linear trend	norm, mm	standard deviation	coefficientof a linear trend	norm, mm	standard deviation	coefficientof a linear trend
year												
Petropavlovsk	348	79.7	1.71	328	72.1	2.29	360	60.7	1.43	390	79.5	0.52
Kostanay	332	69.0	0.76	321	65.1	0.56	326	64.2	1.18	353	72.5	1.81
Astana	299	65.6	1.25	285	65.1	1.99	312	51.9	-0.15	323	59.8	1.08
Kokshetau	301	82.2	0.84	291	77.5	1.04	307	75.9	-0.54	321	89.2	1.23
Pavlodar	267	68.1	1.57	246	60.5	1.72	264	51.8	3.43	308	64.6	1.37
warm period												
Petropavlovsk	264	62.2	0.48	257	60.0	0.41	265	52.2	0.04	278	655	0.52
Kostanay	241	63.1	0.28	237	62.3	0.14	237	61.6	0.81	249	65.2	0.98
Astana	221	56.9	0.31	219	57.8	0.63	229	52.3	-1.25	225	55.8	0.64
Kokshetau	243	73.0	0.29	240	70.9	0.38	246	68.2	-0.53	250	78.0	0.59
Pavlodar	192	58.0	0.74	181	51.0	0.62	185	45.1	2.05	214	65.9	0.58
cold period												
Petropavlovsk	84	40.2	1.24	70	37.4	1.89	95	29.8	1.39	112	30.3	-0.10
Kostanay	91	28.2	0.48	84	27.3	0.41	89	28.8	0.37	104	25.4	0.83
Astana	78	34.8	1.10	65	30.4	1.36	83	25.0	1.10	105	28.2	1.56
Kokshetau	58	23.8	0.54	51	19.8	0.66	61	19.1	-0.01	71	25.9	0.66
Pavlodar	75	289	0.84	65	26.8	1.10	80	22.3	1.38	94	22.6	0.79

Table 2 – Number of cases with positive (N_+) and negative (N_-) precipitation anomalies from 1936 to 2017

Station	April		May		June		July		August		September	
	N_+	N_-	N_+	N_-	N_+	N_-	N_+	N_-	N_+	N_-	N_+	N_-
Petropavlovsk	35	47	37	45	28	54	35	47	31	51	31	51
Kostanai	35	47	37	45	37	45	34	48	33	49	29	53
Kokshetau	31	51	36	46	31	51	36	46	34	48	28	54
Astana	30	52	41	41	28	54	37	45	30	52	28	54
Pavlodar	32	50	29	53	36	46	38	44	37	45	34	48

Table 3 – Average values of positive and negative precipitation anomalies during the growing season

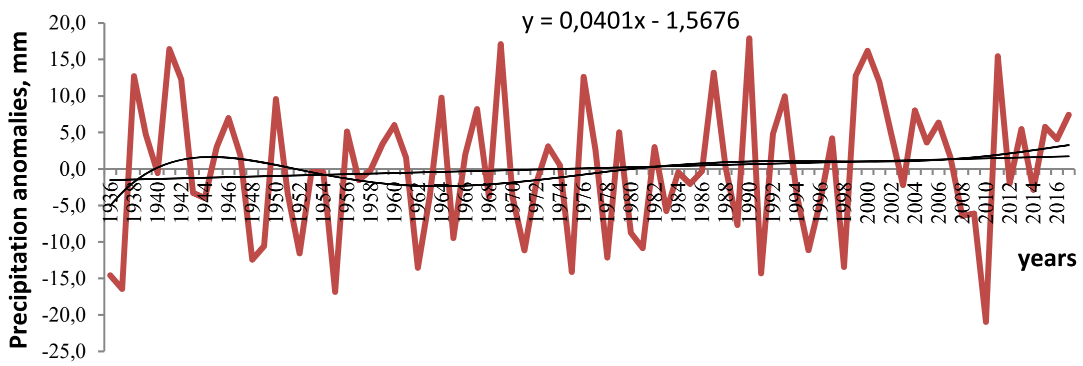
Station	Positive anomalies	Negative anomalies
Petropavlovsk	6.8	-7.3
Kostanai	7.3	-7.2
Kokshetau	8.6	-8.6
Astana	5.5	-6.8
Pavlodar	6.6	-5.4



Picture 3 – The time course of precipitation anomaly
and the trend line during the vegetation period from 1936 to 2017 on MS Petropavlovsk

Thus, an analysis of the time course of precipitation anomalies in the MS Petropavlovsk during the vegetation period shows that positive anomalies were observed during the period between 1938 and 1950; mainly negative anomalies were observed from 1951 to 1965; only positive anomalies were observed from 1966 to 1971; only negative anomalies were observed from 1972 to 1975; and in 1976, before the end of the period under consideration, both negative and positive anomalies were observed.

Two maximums of positive anomalies were observed in 1994 (20.4 mm) and in 2001 (20.2 mm), and two minimums of negative anomalies were observed in 1936 (-21.1 mm) and in 2010 (-18.6 mm). Analyzing the graph of the time course of precipitation anomalies and the trend line at Petropavlovsk MS, we can see the evidence that precipitation over the period under study has a growth tendency.



Picture 4 – The temporal variation of precipitation anomalies
and the trend line for the growing season from 1936 to 2017 on MS Kostanay

An analysis of the time course of the precipitation anomaly in MS Kostanai during the growing season shows that in this period both negative and positive anomalies were observed.

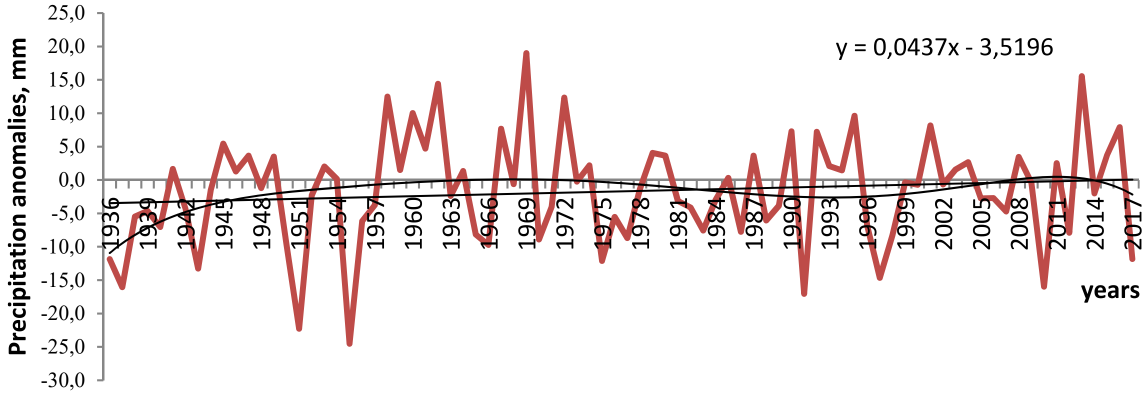
Two maximums were recorded in 1969 (17.1 mm) and 1990 (17.9 mm), and the minimum was observed in 2010 (-21.0 mm).

Two maximums of precipitation anomalies were in 1969 (19.0 mm) and 2013 (15.6 mm) on MS Astana during the vegetation period.

Two minimums were observed in 1951 (-22.3 mm) and in 1955 (-24.5 mm). The trend line at the MS Astana shows that from 1936 to 2017 there was an increase in the amount of precipitation.

Thus, the territorial distribution of precipitation trends in the summer period coincides with the distribution of annual rainfall trends. At all considered stations of Northern Kazakhstan, the precipitation during the period of study has a growth trend.

The most important, or so-called basic climatic characteristics expressing the main properties of climatological series are mean values, standard deviation, asymmetry coefficients, kurtosis and variations.



Picture 5 – The temporal variation of precipitation anomalies
and the trend line for the growing season from 1936 to 2017 on MS Astana

The results of calculations of statistical characteristics of precipitation in the vegetation period for the considered stations of Northern Kazakhstan are given in table 4 below.

Table 4 – Statistical characteristics of the regime of atmospheric precipitation
in the vegetation period in the north of Kazakhstan

Station	Characteristics	Months					
		april	may	june	july	august	september
Petropavlovsk	R_{cp}	19.7	30.9	45.4	62.3	47.3	29.8
	σ	12.8	19.7	26.0	34.6	25.1	18.8
	As	0,.	0.9	0.6	1.2	0.9	1.3
	Ex	-0.04	0.9	-0.1	2.4	1.4	2.4
	Cv	65	64	57	56	53	63
Kostanay	R_{cp}	22.2	29.9	40.5	54.9	37.0	26.1
	σ	15.6	20.4	26.8	35.9	23.1	19.9
	As	1.3	0.9	0.9	0.7	0.7	1.0
	Ex	2.5	0.4	0.4	-0.3	-0.3	0.2
	Cv	70	68	66	65	62	76
Astana	R_{cp}	19.2	32.6	34.5	52.1	34.5	23.1
	σ	12.3	19.7	22.5	36.1	28.3	16.0
	As	1.0	1.2	0.04	1.0	1.5	1.2
	Ex	1.2	2.4	0.8	0.4	3.7	2.3
	Cv	64	60	65	69	82	69
Kokshetau	R_{cp}	17.0	28.7	41.4	70.6	41.4	23.4
	σ	13.2	16.1	26.3	46.3	27.3	14.4
	As	1.3	0.3	0.9	1.3	0.8	0.9
	Ex	1.9	-0.8	-0.02	1.2	0.03	0.5
	Cv	78	56	64	66	66	62
Pavlodar	R_{cp}	14.5	23.5	32.8	48.5	29.7	19.9
	σ	10.4	17.9	21.7	30.6	20.1	13.4
	As	0.9	2.7	0.6	1.3	1.0	0.9
	Ex	-0.2	12.5	-0.6	2.4	0.9	0.5
	Cv	71	76	66	63	68	67

According to the table, it can be seen that the mean values of precipitation during the vegetation period at considered stations of Northern Kazakhstan vary from 14.5 (Pavlodar station) to 70.6 mm (Kokshetau station). And so, in April, they vary within 14.5-22.2 mm, in May -23.5-36.6 mm, in June - 32.8-45.4 mm, in July - 48.5-70.6 mm, in August -29.7-47.3 mm, and in September -19.9-29.8 mm.

Thus, it can be concluded that June and July are persistently rainy months, and the less rainy is April.

The mean square deviations show the scatter of the actual data about the mean. The more the characteristic varies, the greater the magnitude of the standard deviation, and vice versa, with a weak variation in the characteristic, the mean square deviation will be smaller. In this case, the standard deviation during the growing season varies from 10.4 to 46.3. At all considered stations of Northern Kazakhstan, the greatest variation (30.6-46.3) is observed in July, and the smallest (10.4-15.6) is in April.

The asymmetry coefficient almost at all stations is far from normal for almost 100%, except for the station Astana (June), which is considered normal, and for Kokshetau (May), which is considered moderate.

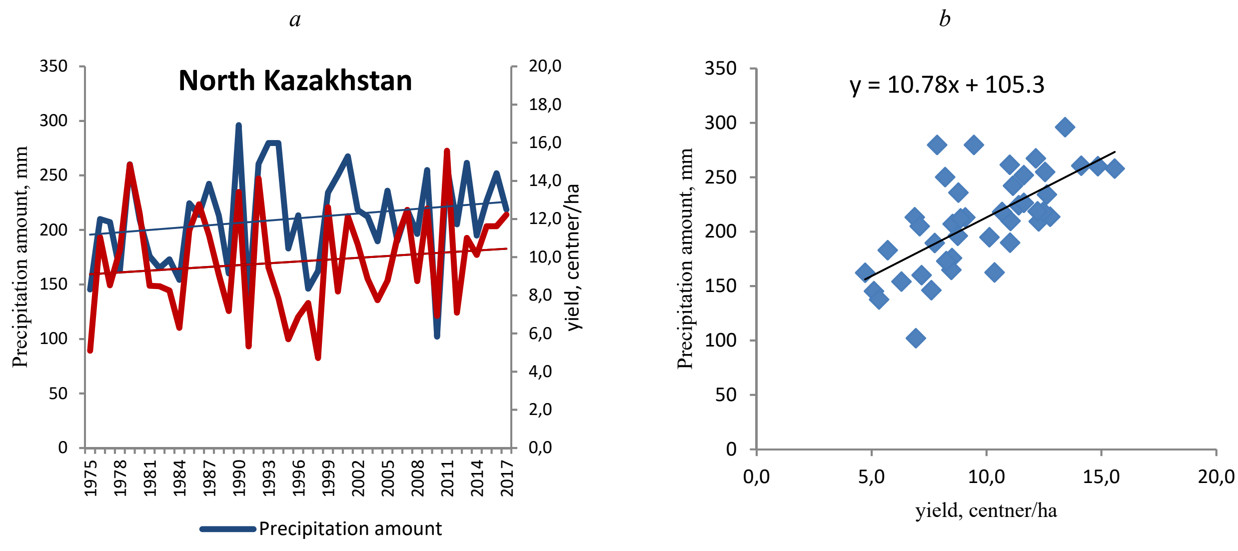
The kurtosis is even more different from the normal, but there is a peculiarity: about 70 % of the distribution is leptokurtic, and only 30 % of the distribution is platykurtic. Platykurtic distribution of precipitation was observed at stations Petropavlovsk, Kokshetau and Pavlodar in April and June.

The coefficient of variation is a measure of the relative spread of a random variable; shows how much the average of this value is its average spread. The greater the value of the coefficient of variation, the greater the scatter. In the statistics, the following estimate of the sign of the test is adopted for different values of the coefficient of variation: up to 10 % - weak variability; 10-25 % - moderate variability; over 25 % - strong variability [27]. In the period under consideration, there is a strong variability in precipitation at all the stations of northern Kazakhstan.

When assessing the influence of atmospheric precipitation and climatic factors that have an impact on agricultural production, it is necessary to take into account the requirements of agricultural crops at various phases of its development. This may allow to determine the degree of risk of hazards dangerous for agriculture, that will allow to determine how the climate of the region meets the requirements of production. Yield fluctuations, both in time and in space, are determined by the nature of the variability of the crop structure.

In this article, the relationship between atmospheric precipitation and productivity of grain crops of Northern Kazakhstan for the growing season 1975-2017 was considered (picture 6).

Picture 6 (a) shows that during the period 1975-2017, the yield varies from 4.7 c/ha to 15.6 c/ha. It should be noted that low yields were mainly observed in years with low atmospheric precipitation (1975, 1991, 1995, 1998, 2010, 2012) and the highest in years with heavy precipitation (1979, 1992, 1999, 2001, 2009, 2011).



Picture 6 – The amount of precipitation (mm) during the vegetation period and the annual yield (c / ha) of cereal crops (a) and relationship between them (b)

Due to aridity in the growing season in 2010, the minimum yield of cereal in the region (6.9 c/ha) was observed. On the contrary, in 2011, the highest yield of cereal (15.6 c/ha) was observed. This can be explained by abundant precipitation during the growing season in that year.

In Northern Kazakhstan, the amount of precipitation and the dynamics of their distribution during the vegetation period is the main factor in crop yields.

For the period from 1975 to 2017, the amount of precipitation during the vegetation period was the highest, in 1979, 1992, 1999, 2001, 2009, 2011 (255-296 mm), and in 1975, 1991 and 2010, the smallest amount of precipitation (102 -145 mm), which affected the yield.

Between the atmospheric precipitation and the yield of grain crops, calculated correlation coefficient revealed a good connection between them 0.67 (picture 6, b). This is because the yield depends not only on precipitation, but also on many factors, for example, on air temperature. Therefore, we examined the correlation dependence on the main factors (air temperature and precipitation), affecting the yield.

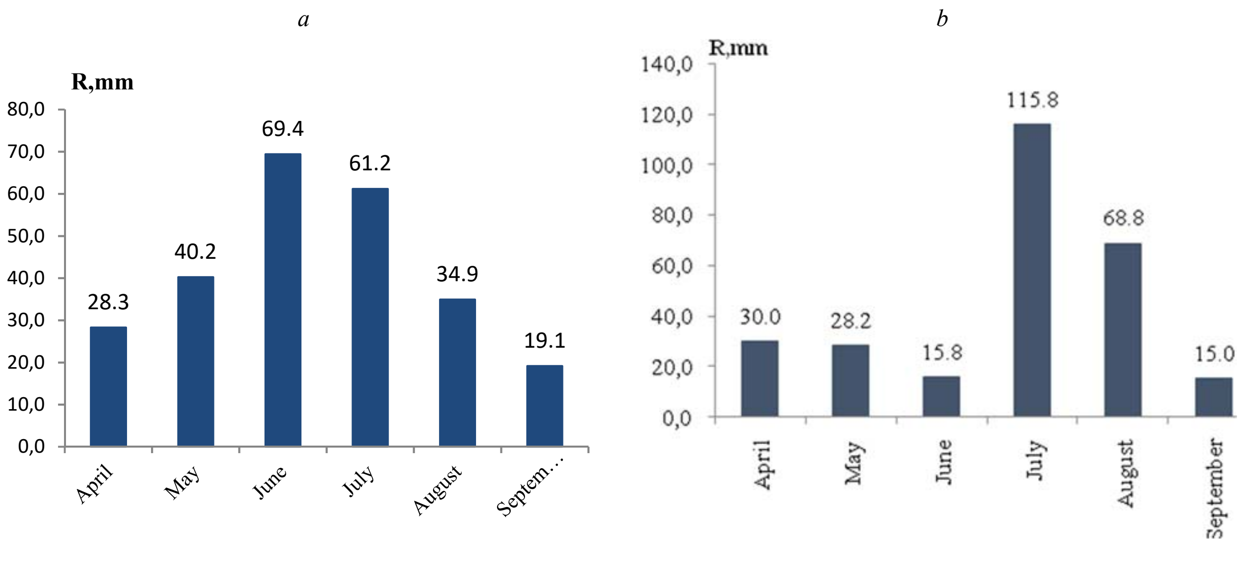
For a three-dimensional normally distributed random variable (z, x, y), the multiple correlation coefficient is a measure of the relationship between one quantity to the other two. It is between zero and one. For $R_z=1$, the relationship between the quantities z and (x, y) is functional, linear: the points (x, y, z) are located in the regression plane z on (x, y). For $R_z=0$, the one-dimensional random variable z and the two-dimensional random variable (x, y) are independent (by the normality of the distribution) [28].

During the period under consideration (1975-2017), the multiple correlation coefficient of yields (x), precipitation (y) and air temperature (z) are $R_x=0.69$, $R_y=0.68$, $R_z=0.42$. From this it can be noted, during the growing season, the role of precipitation is higher than air temperature.

Thus, in North Kazakhstan over the past 43 years due to aridity (102-145 mm of precipitation) in 1975, 1991 and 2010 there was a minimum yield (5.1-6.9 c/ha) of grain crops, and, on the contrary, in 1979, 1992, 1999, 2001, 2009 and 2011 have the highest yield of 12.2-15.6 c/ha of grain, which can be explained by heavy precipitation during the growing season.

The dependence of the yield of most crops on the quantity and timing of precipitation is most noticeable in areas of insufficient moisture, it is especially pronounced in drought-resistant varieties. The spring crops are the most sensitive to arid phenomena during the growing period "going into the tube - flowering", which in most cases is observed in June.

The greatest need for water supply and available nutrients for spring wheat is manifested in the period from tillering to earing, when (in the exit phase) the fruiting organs are laid, and in the period from flowering to milky ripeness when the grain itself is formed. The lack of productive moisture in the soil during these crucial periods of water supply often leads not only to a decrease in yield, but also to its death [29] (picture 7).



Picture 7 – Average monthly precipitation in 2011 (a) and 2013 (b) years
in the north of Kazakhstan during the growing season

Considering the dynamics of precipitation in 2011 (picture 7, a), which was considered the harvest year (15.6 c/ha), it can be seen that the maximum amount of precipitation during the growing season fell in June (69.4 mm), which had a favorable effect during the development of "going into the tube - flowering" stage, on spring grain crops.

For comparison, the year 2013 was taken as an example (picture 7, b), where it can be seen that although there was a sufficient amount of precipitation (273.6 mm) during the growing season, in June there was a minimum precipitation of 15.8 mm, which is not favorable for the period in the development of grain crops (11.0 c/ha). Based on the foregoing, it can be concluded that for North Kazakhstan during the growing season, a sufficient amount of precipitation is crucially important in June, i.e. in the period of development, "going into the tube - flowering".

The productivity of crops with a sufficient amount of heat and the favorableness of other factors is mainly determined by the provision of moisture.

For the calculation of annual amounts of precipitation with varying degrees of supply, the materials of long-term observations in this area were used. The dependence of the amount of precipitation and yield of grain crops in the north of Kazakhstan was studied on the example of the station Petropavlovsk (table 5).

Table 5 – The dependence of the precipitation security and yield of grain crops

Station / Years	Supply (%) / yield (c/ha)											
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Petropavlovsk	49 11.0	38 14.4	30 15.0	33 12.2	32 14.4	98 9.6	7 20.9	28 11.5	28 12.4	43 13.8	13 15.5	20 14.8
Precipitation amount, mm	261	278	294	287	289	143	366	297	297	271	337	315

An analysis of the precipitation supply at Petropavlovsk station shows that 2011, 2015 and 2016 are excessively wet, with a supply less than 25 %, and vary between 7-20 %. The year 2011 is particularly notable, with 7 % supply at 366 mm of precipitation (at a rate of 273 mm), when the average yield of grain crops was 20.9 c/ha.

In 2010, when there was a shortage of precipitation, the availability of precipitation was 98 % with a precipitation amount of 143 mm, which affected the yield of grain crops this year (9.6 c/ha).

Thus, the mode of precipitation and their security during the growing season, affects the yield of grain crops in the region.

Conclusions. As a result of the work done, the following was obtained:

– since 1991, at all considered stations of Northern Kazakhstan, the average long-term rainfall standards tend to grow with a significant change observed in cold season. Thus, at the stations of Petropavlovsk and Astana, the long-term norm of precipitation in the cold period increased up to 40-42 mm, and at other stations, it varied from 20 to 29 mm. In the warm half-year, the positive deviation from the norm at the stations varied from 6 to 33 mm;

– the territorial (spatial) distribution of precipitation trends in summer period coincides with the distribution of annual precipitation trends;

– from the average values of precipitation in the vegetation period at the stations of Northern Kazakhstan, it can be concluded that the June and July are the most rainy months, and the less rainy is April;

– the largest variation in the standard deviation (30.6-46.3) is observed in July, and the smallest (10.4-15.6) in April. The asymmetry coefficient at almost all the stations is far from normal at almost 100%. The kurtosis coefficient differs most strongly from the normal distribution: about 70 % the distribution is extreme, and only in 30 % the distribution is platykurtic. The coefficient of variation shows that at all the stations of Northern Kazakhstan under consideration there is a strong variability in precipitation;

– in Northern Kazakhstan for the last 43 years due to aridity (102-145 mm) in 1975, 1991 and 2010, the minimum yield (5.1-6.9 c/ha) of grain crops was observed, and in 1979, 1992, 1999, 2001 , 2009 and 2011, the highest yield is 12.2-15.6 c/ha of cereals, which is explained by the abundant precipitation during the vegetation period;

– the productivity of crops with sufficient heat and other factors is mainly determined by their moisture supply. For North Kazakhstan, a sufficient amount of precipitation is especially important in June in the period of "exit into the tube - flowering";

– the regime of atmospheric precipitation and their supply during the growing season, affects the yield of grain crops in the region.

А. К. Жексенбаева, А. С. Нысанбаева, М. О. Турсумбаева

Әл-Фараби атындағы ҚазҰУ, Алматы, Қазақстан

СОЛТҮСТІК ҚАЗАҚСТАНДА ВЕГЕТАЦИЯ КЕЗЕҢІНДЕГІ ЖАУЫН-ШАШЫНДАРДЫҢ КӨПЖЫЛДЫҚ КЛИМАТТЫҚ ӨЗГЕРУ ДИНАМИКАСЫ

Аннотация. Климаттың табиғи факторлармен де, және адамның шаруашылық әрекетімен де қазіргі өзгеруі жағдайында әртүрлі процестерге айтарлықтай әсер етуі мүмкін. Ауылшаруашылығы өнеркәсібі үшін ең маңызды климаттық өзгерістердің бірі, әсіресе вегетация кезеңіндегі орташа айлық температураның және жауын-шашындардың орташа мөлшерінің өзгеруі. Солтүстік Қазақстан республиканың негізгі ауылшаруашылық аймағы болғандықтан, азық-түлік тәуелсіздігі мен қауіпсіздігін қамтамасыз ететіндіктен, климаттың өзгеру мәселесі және бұл өзгерістердің аймақтағы ауылшаруашылық өндірісіне қалай әсер етуі қазіргі таңда маңызды және өзекті болып табылады.

Мақалада Қазақстанның солтүстігінде вегетациялық кезеңдегі жауын-шашындардың көпжылдық климаттық өзгеру динамикасы қарастырылады. 1936-2017 жж. негізгі бақылау кезеңіндегі орташа көпжылдық мәндерінің өзгеруі, сонымен қатар базалық кезеңге қатысты негізгі кезеңдегі орташа көпжылдық мәндердің өзгеруінің салыстырмалы талдауы жүргізілді. XX ғасырдың екінші жартысындағы, әсіресе 1991-2017 жылдардағы жаһандық жылынудың күшеюіне байланысты атмосфералық жауын-шашындардың өзгергіштігі зерттелді. Мақалада сонымен қатар Солтүстік Қазақстандағы вегетациялық кезеңдегі жауын-шашындар мен дәнді дақылдардың өнімділігі арасындағы байланыс қарастырылды.

Зерттеу нәтижесінде Солтүстік Қазақстандағы барлық қарастырылған станцияларда, 1991 ж. бастап жауын-шашындардың көпжылдық орташа нормасының өсу тенденциясы, әсіресе маңызды өзгеруі суық мезгілде байқалған; вегетациялық кезеңдегі жауын-шашындардың орташа мәндері бойынша тұрақты жаңбырлы айлар болып - маусым мен шілде, ал сәуір айы аздау жаңбырлы болып табылады; атмосфералық жауын-шашындардың режимі және олардың вегетациялық кезеңдегі қамтамасыздығы аймақтағы дәнді дақылдардың өнімділігіне әсер етеді.

Түйін сөздер: жауын-шашындар, Солтүстік Қазақстан аймағы, вегетациялық кезең, жауын-шашындардың динамикасы, жауын-шашындардыңаномалиясы, асимметрия, эксцесс, корреляция, өнімділік, дәнді дақылдар, жауын-шашындардыңқамтамасыздығы.

А. К. Жексенбаева, А. С. Нысанбаева, М. О. Турсумбаева

КазНУ им. аль-Фараби, Алматы, Казахстан

ДИНАМИКА МНОГОЛЕТНИХ КЛИМАТИЧЕСКИХ КОЛЕБАНИЙ ОСАДКОВ ВЕГЕТАЦИОННОГО ПЕРИОДА НА СЕВЕРЕ КАЗАХСТАНА

Аннотация. В условиях современного изменения климата, которые определяются как природными факторами, так и хозяйственной деятельностью человека, могут оказывать существенное воздействие на различные процессы. Из наиболее значимых климатических изменений для сельскохозяйственной отрасли является изменение средних месячных температур и среднего количества осадков, особенно в вегетационный период. Так как Северный Казахстан является основным земледельческим регионом республики, обеспечивая продовольственную независимость и безопасность, проблема изменения климата, и то, как эти изменения могут повлиять на сельскохозяйственное производство в регионе, является на сегодняшний день актуальной и важной.

В статье рассматривается динамика многолетних климатических колебаний осадков вегетационного периода на севере Казахстана. Анализируются изменения средних многолетних значений по основному периоду наблюдений за 1936-2017 гг., проведен сравнительный анализ изменения средних многолетних значений основного периода по отношению к базовому. В связи с усилением глобального потепления климата во второй половине 20 века, и особенно 1991-2017 гг. анализировалась изменчивость атмосферных осадков. В работе также рассматривается связь между атмосферными осадками и урожайностью зерновых культур Северного Казахстана за вегетационный период.

В результате проведенного исследования получено, что средние многолетние нормы осадков, на всех рассматриваемых станциях Северного Казахстана, начиная с 1991 года, имеют тенденцию роста, причем значительное изменение отмечается в холодное время года; по средним значениям осадков вегетационного периода устойчиво дождливыми месяцами являются июнь и июль, а менее дождливый – апрель; режим атмосферных осадков и их обеспеченность в вегетационный период влияет на урожайность зерновых культур в регионе.

Ключевые слова: осадки, территория Северного Казахстана, вегетационный период, динамика осадков, аномалия осадков, асимметрия, эксцесс, корреляция, урожайность, зерновые культуры, обеспеченность осадков.

Information about authors:

Zheksenbayeva A. K., Candidate of Geographic Sciences, Al-Farabi Kazakh National University, Almaty, Kazakhstan; zheksenbaeva@mail.ru; https://orcid.org/0000-0002-9939-5991

Nyssanbayeva A. S., Candidate of Geographic Sciences, Associate professor, Al-Farabi Kazakh National University, Almaty, Kazakhstan; nyssaiman17@gmail.com;

Tursumbayeva M. O.,, lecturer, Al-Farabi Kazakh National University, Almaty, Kazakhstan; Tursumbaeva.madina@gmail.com; https://orcid.org/0000-0002-7526-8197

REFERENCES

[1] Nacionalnyj Atlas Respubliki Kazahstan. Prirodnye uslovija i resursy. // Institut geografii. Almaty, 2010. Vol. 1. 150 p.

[2] Atlas Kazahskoj SSR. M.: GUGK, 1982. Vol. 1. 300 p.

[3] For Climatology Sixteenth session. Heidelberg, 3-8 July 2014. Abridged final report with resolutions and recommendations // WMO. N 1137. P. 68.

[4] Belokrylova T., Bulygina O., Razuvaev. Temperature Pattern variability on the USSR Territory in 1931–1990 // Proceedings of the Sixteenth Annual Climate Diagnostics Workshop, Los Angeles, October 28 – November 1 1991. – Los Angeles: Dept. of Atmospheric Sciences University of California, 1992. P. 173-178.

[5] Pilifosova O.V. (1990) // Trudy KazNIGMI 105:77-88 (in Russ.).

[6] Pilifosova O.V. (1988) // Trudy KazNIGMI 100:35-45 (in Russ.).

[7] Pilifosova O.V. (1988) // Trudy KazNIGMI 102:64-71 (in Russ.).

[8] Pilifosova O.V. (1991) // Trudy KazNIGMI 111:66-75 (in Russ.).

[9] Zheksenbayeva A.K. (2016) Statisticheskie harakteristiki osadkov v Severnom Kazahstane // Nauka, novye tehnologii i innovacii Kyrgyzstana. 5: 110-117. ISSN: 1694-7649.

[10] Zheksenbayeva A.K. (2016) // Vestnik Kazahskogo nacional'nogo universiteta im. al'-Farabi. Serija geograficheskaja. 1 (42):100-106 (in Russ.).

[11] Zheksenbayeva A.K. (2013) Raspredelenie kolichestva osadkov za teplyj i holodnyj periody po territorii Kazahstana za poslednee desjatiletie // Slushanija mezhdunarodnoj nauchno-prakticheskoj konferenciii po voprosam Problemy sovershenstvovanija upravlenija prirodnymi i social'no-jekonomicheskimi processami. Bishkek, Kyrgyzstan. P. 80-84. ISSN: 1654-5611.

[12] Cherednichenko A.V., Cherednichenko V.S., Zheksenbayeva A.K. (2016) Dinamika klimata Severnogo Kazahstana i adaptacionnye meroprijatija v sel'skom hozjajstve // Slushanija mezhdunarodnoj nauchno-prakticheskoj konferenciii po voprosam Sovremennye problemy biotehnologii: ot laboratornyh issledovanij k proizvodstvu. Almaty, Kazahstan. P. 153.

[13] Battalov F.Z. Mnogoletnie kolebanija atmosfernyh osadkov i vychislenie norm osadkov. L.: Gidrometeoizdat, 1968. 183 p.

[14] Drozdov O.A. Mnogoletnie ciklicheskie kolebanija atmosfernyh osadkov na territorii SSSR. L.: Gidrometeoizdat. 158 p.

[15] Girs A.A. Makrocirkuljacionnyj metod dolgosrochnyh meteorologicheskih prognozov. L.: Gidrometeoizdat, 1974. 280 p.

[16] Litvinova O.S., Guljaeva N.V. (2009) // Vestnik Tomskogo gosudarstvennogo universiteta. 329: 262-266 (in Russ.).

[17] Litvinova O.S., Guljaeva N.V.(2010) Sbornik nauchnyh trudov kafedry JuNESKO Jugorskogo gosudarstvennogo universiteta. Dinamika okruzhajushhej sredy 1: 38-45 (in Russ.).

[18] Madibekov A.S., Nyssanbaeva A.S., Kurmanova M.S. (2018) Role of the chemical composition of an atmospheric precipitation in pollution of a surface water // News Of the academy of sciences of the Republic of Kazakhstan. Series of geology and technical sciences. Vol. 5, N 431. P. 120-127 https://doi.org/10.32014/2018.2518-170X.17 ISSN 2518-170X (Online), ISSN 2224-5278 (Print) (in Eng.).

[19] Nastavlenie po sluzhbe prognozov. M.: Gidrometeoizdat, 1971. Razdel II. Chast' 5. P. 5-17.

[20] Polozhenie o sbore svedenij i porjadke preduprezhdenij ob osobo opasnyh meteorologicheskih javlenijah. M.: Gidrometeoizdat, 1972. P. 4-7.

[21] Dejcheva V.G. (1978) // Trudy KazNIGMI 72: 86-99 (in Russ.).

[22] Zavalishin N.N. (2000) // Trudy SibNIIGMI 103:11-17 (in Russ.).

[23] Guljaeva N.V., Kostjukov V.V. (2006) // Izvestija RAN 6:106-113 (in Russ.).

[24] Guljaeva N.V., Kostjukov V.V. (2003) // Meteorologija i gidrologija 2:97-102 (in Russ.).

[25] Klimat Kazahstana / Pod red. A. S. Utesheva. L.: Gidrometeoizdat, 1959. – 367 s.

[26] Nauchno-prikladnoj spravochnik po klimatu SSSR // Mnogoletnie dannye. Kazahskaja SSR. Serija 3. Kniga 1. L.: Gidrometeoizdat, 1989. Vyp.18. Ch. 1-6. 51 p.

[27] Lakin G.F. Biometrija. Uchebnoe posobie dlja universitetov i pedagogicheskih institutov. M.: Vysshaja shkola, 1973. 343 p.

[28] Dubrov A.M., Mhitrajan V.S., Troshin L.I. (2003) Mnogomernye statisticheskie metody. ISBN: 5-279-01945-3

[29] Agroklimaticheskij spravochnik po Severo-Kazahstanskoj oblasti. L.: Gidrometeoizdat, 1958. 128 p.

Publication Ethics and Publication Malpractice in the journals of the National Academy of Sciences of the Republic of Kazakhstan

For information on Ethics in publishing and Ethical guidelines for journal publication see http://www.elsevier.com/publishingethics and http://www.elsevier.com/journal-authors/ethics.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the described work has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see http://www.elsevier.com/postingpolicy), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics.org/files/u2/New_Code.pdf). To verify originality, your article may be checked by the Cross Check originality detection service http://www.elsevier.com/editors/plagdetect.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of Sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of Sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайте:

www:nauka-nanrk.kz

ISSN 2518-170X (Online), ISSN 2224-5278 (Print)

http://www.geolog-technical.kz/index.php/en/

Верстка *Д. Н. Калкабековой*

Подписано в печать 15.11.2019.
Формат 70x881/8. Бумага офсетная. Печать – ризограф.
19,7 п.л. Тираж 300. Заказ 6.

Национальная академия наук РК
050010, Алматы, ул. Шевченко 28, т. 272-13-19, 272-13-18