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## Analysis of long-term dynamics of air temperature fluctuations in the Nura River basin

In recent decades, a different frequency of dry years has been observed in the Nura River basin in Central Kazakhstan. This article examines the trend of changes in temperature fluctuations over a long period using materials from a separate climate element from the Besoba and Karaganda meteorological stations located in the Nura River basin and the Arkalyk meteorological station located outside the basin, to the west of it, but characterized by similar natural conditions. In the course of research over an 81-year time interval from 1939 to 2019, the absolute and relative frequency of average monthly air temperatures in July in the Nura River basin were established. The meteorological stations under consideration are part of the global international network of meteorological data of Kazhydromet and have constant, accurate series of values of meteorological indicators. Based on the use of the method of statistical analysis, an assessment of the spatio-temporal fluctuations of the temperature regime over a long-term period in the Nura River basin was identified. The study expressed the formation of an arid climate associated with an increase in the average monthly air temperature in the basin of the study area.

*Keywords:* atmospheric air temperature, dynamics of temperature fluctuations, absolute and relative frequency, cumulative frequency, long-term constant, temperature regime, river basin, statistical analysis, frequency.

### Introduction

The leading role in a number of natural factors that determine the conditions of human life is performed by the characteristics of the climate, and first of all, the conditions of heat and moisture supply. As a rule, the environmental assessment of the climate is based on the average annual and monthly average values of meteorological indicators (precipitation, air temperature, etc.), as well as extreme values in the long-term aspect. However, in the conditions of global climate change (Pachauri & Meyer, 2014; Sada et al., 2019) [1, 2] this approach should be complemented by an assessment of the main long-term trends of the most important meteorological characteristics — atmospheric air temperature and precipitation for ecosystems and humans (Kuzmina, Treshkin, 2007, 2016) [3, 4].

The purpose of the study is to analyze the trend of temperature fluctuations in the air in the Nura River basin, which is the basis for a geocological assessment of the territory.

### Materials and methods

We used constant data for the hot month — July, which were divided into 4 periods (I-IV), for an 81-year time interval since 1939 to 2019, obtained at two meteorological stations — Karaganda, Besoba (Karaganda region) and one meteorological station in Kostanay region (m/s Arkalyk) to analyze the long-term dynamics of temperature fluctuations, as well as temperature conditions in the territory of the Nura River basin. The data obtained at meteorological stations and agricultural posts reflect the features of the landscape structure of the Nura River basin.

The oldest Besoba meteorological station (49.3° north latitude, 74.4° east longitude) is located in the upper reaches, Karaganda meteorological station (49.8° north latitude, 73.1° east longitude) is located in the middle reaches, Kobetey agricultural post (50.2° north latitude, 72.1° east longitude) is located in the lower reaches, but, Kobetey has large gaps in a number of observations, therefore, the Arkalyk meteorological station (50.2° north latitude, 63.3° east longitude), which is located outside the basin, to the west of it, but is characterized by similar natural conditions, was used as representative for the territory of dry-steppe lake-alluvial plains [5, 6].

To analyze the spatial and temporal fluctuations of temperature and precipitation across the region of Northern Kazakhstan with greater precision, the authors use the method of statistical analysis to identify dry

periods at the Blagoveshchenka and Atbasar meteorological stations [7, 8]. Based on this, we also used the statistical analysis method in our article, where the relative and absolute repeatability of  $m_i$  and  $p_i$ , were determined, demonstrating the number of repetitions when we sampled data on atmospheric air temperature  $n$ .

### Results and discussion

Examining the meteorological data presented in Table 1 and Figure 1, we ascertain the absolute and relative reproducibility of the average monthly air temperature in July at the Besoba meteorological station. This investigation reveals that over the duration of the I period (1939–1958), the number of years with an average monthly air temperature of 14–15.9 °C is 1, with an air temperature of 16–17.9 °C is 6, with an air temperature of 18–19.9 °C is 10, with an air temperature of 20–21.9 °C is 3.

Based on this, a high relative repeatability of values (50 %) was determined within the average monthly air temperature of 18–19.9 °C. The accumulated repeatability (80 %) is the average monthly air temperature in July in the range of 16–19.9 °C. The duration of the constant of the average monthly air temperature in July at the Besoba meteorological station is +18.9 °C. As the Table 1 and Fig. 1 show, the relative repeatability of the values of the average monthly air temperature in July during the first period (1939–1958) within the normal range in the upper reaches of the Nura River basin is 50 %. The correspondence of air temperature values with the highest frequency in the long-term norm was revealed.

In the II period (1959–1978), there were 3 years with an average monthly air temperature ranging from 14 to 15.9 °C, 5 years with a temperature between 16 and 17.9 °C, 9 years with temperatures ranging from 18 to 19.9 °C, and 3 years with temperatures between 20 and 21.9 °C. Accordingly, the highest relative consistency of values, at 45 %, was identified within the average monthly air temperature range of 18–19.9 °C. In the investigated upper reaches of the Nura River basin, a cumulative repeatability of 100 % is observed across the spectrum of average monthly air temperatures in July, spanning from 14 °C to 21.9 °C. During the II period, the relative repeatability of the values of the average monthly air temperature in July within the normal range shows 45 %, and the correspondence of the July air temperature value +18.9 °C with the highest frequency in the Besoba meteorological station was revealed.

Table 1

**The number of absolute and relative repeatability values of the average monthly air temperature in July since 1939 to 2019 at the Besoba meteorological station**

Period I (1939–1958)			Period II (1959–1978)			Period III (1979–1998)			Period IV (1999–2019)		
Air t, °C			Air t, °C			Air t, °C			Air t, °C		
t	$m_i$	$p_i$ , %	t	$m_i$	$p_i$ , %	t	$m_i$	$p_i$ , %	t	$m_i$	$p_i$ , %
14–15,9	1	5	14–15,9	3	15	14–15,9	0	0	14–15,9	0	0
16–17,9	6	30	16–17,9	5	25	16–17,9	3	15	16–17,9	8	39
18–19,9	10	50	18–19,9	9	45	18–19,9	13	65	18–19,9	10	48
20–21,9	3	15	20–21,9	3	15	20–21,9	4	20	20–21,9	3	14,3
22–23,9	0	0	22–23,9	0	0	22–23,9	0	0	22–23,9	0	0
24–25,9	0	0	24–25,9	0	0	24–25,9	0	0	24–25,9	0	0

In the III period under consideration (1979–1998), the occurrences are as follows: 3 years with an average monthly air temperature falling between 16 °C and 17.9 °C, 13 years with temperatures ranging from 18 °C to 19.9 °C, and 4 years with temperatures between 20 °C and 21.9 °C. Consequently, a notably high relative repeatability of values, amounting to 65 %, is identified within the range of average monthly air temperatures of 18 °C to 19.9 °C. Furthermore, an accumulated repeatability of 85 % is noted for average monthly air temperatures in July ranging from 18 °C to 21.9 °C. The enduring average monthly air temperature in July recorded at the Besoba meteorological station stands at +18.9 °C.

Table 1 and Figure 1 show the relative repeatability of the values of the average monthly air temperature in July during the III period (1979–1998) within the normal range in this area and it is equal to 65 %, which also corresponds to the long-term norm.

During the IV period (1999–2019), the number of years with an air temperature of 16–17.9 °C is 8, with a temperature of 18–19.9 °C is 10, with the average air temperature for each month of 20–21.9 °C is 3, which allows us to determine a high relative repeatability of values — 10 % within the average monthly air temperature of 18–19,9 °C. According to the analysis of the data, it can be observed that the share of accumulated repeatability is 87 % in the range of 16–19.9 °C, and the relative repeatability of the values of the average

monthly air temperature in July within the normal range shows 48 %, i.e. the highest repeatability in the Besoba meteorological station has a value that corresponds to the long-term norm of July air temperature +18.9 °C.

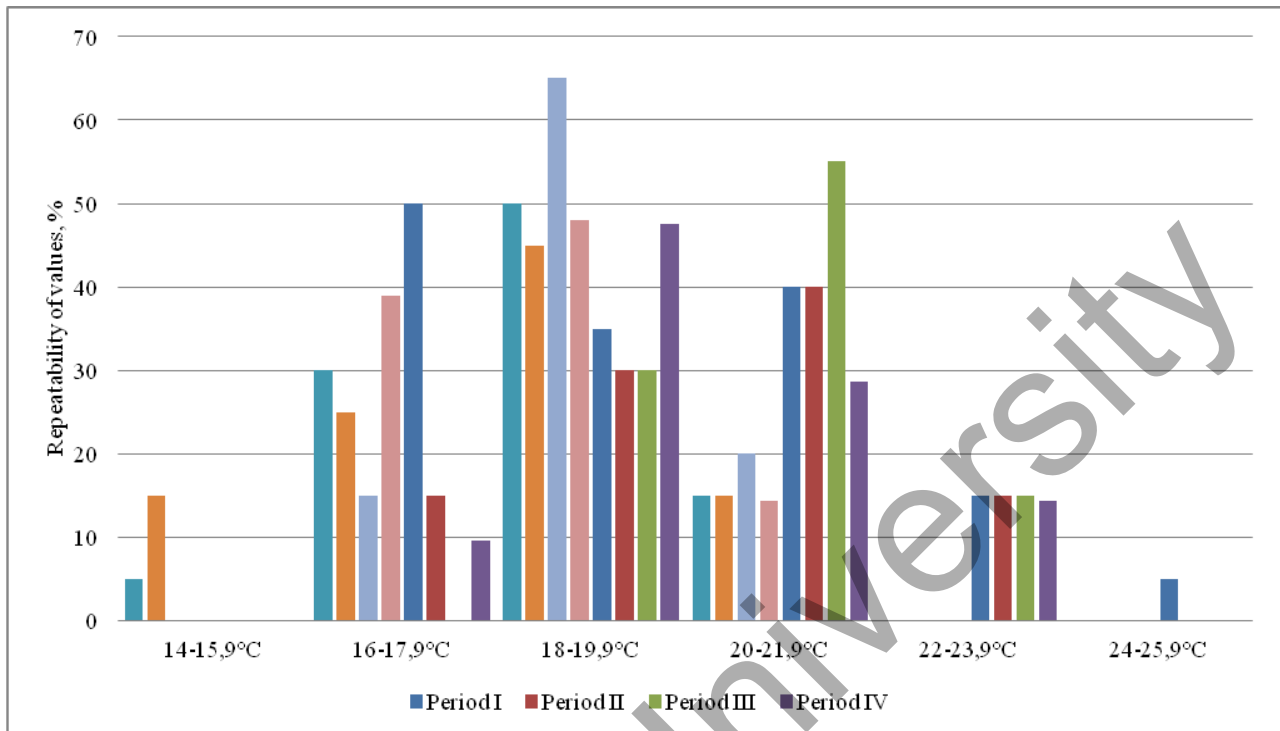


Figure 1. Dynamics of the values of the relative repeatability of the average monthly air temperature in July at the Besoba meteorological station for the I-IV periods

If we compare the data of the first and second periods, we can observe a decrease of 5 % in the repeatability of the average monthly air temperature of 18–19.9 °C, and an increase of 15 % compared to the third period. In comparison with the III period, in the IV period (1999–2019), the repeatability of the average monthly air temperature of 18–19.9 °C decreased by 17 %, and the repeatability of the average monthly air temperature of 20–21.9 °C in the III period (1979–1998) compared with the II period (1959–1978) increased by 1 % (Fig. 1).

The data presented in Table 2 characterizes the absolute and relative repeatability of the average monthly air temperature in July at the Karaganda meteorological station. During the I period (1939–1958), the number of years with an average monthly air temperature of July 16–17.9 °C is 1, with an air temperature of 18–19.9 °C is 7, with an air temperature of 20–21.9 °C is 8, with an air temperature of 22–23.9 °C is 3 and with an air temperature of 24–25.9 °C is 1.

As follows from this Figure 1, the highest relative repeatability of values within the average monthly air temperature of 20–21.9 °C is equal to 40 %. At the same time, the cumulative repeatability — 95 % is the average monthly air temperature in July in the range of 18–21.9 °C. The long-term constant of the average monthly air temperature in July at the Karaganda meteorological station is +20.3 °C. The relative repeatability of the values of the average monthly air temperature in July during the I period (1939–1958) within the normal range in this area of the middle course of the Nura River basin is 35 %.

Analysis of data from the II period (1959–1978) of the Karaganda meteorological station shows that the number of years with an average monthly air temperature of 16–17.9 °C is 3, with an air temperature of 18–19.9 °C is 6, with an air temperature of 20–21.9 °C is 8 and with an air temperature of 22–23.9 °C is 3. According to the analysis of the dynamics of the relative repeatability of the average monthly air temperature in July is 20–21.9 °C, the highest repeatability of values was determined as 40 %, while the accumulated repeatability as 85 % is the average monthly air temperature in July in the range of 16–21.9 °C. The relative repeatability of the values of the average monthly air temperature in July during the II period (1959–1978) within the normal range (+20.3 °C) in this area is 30 %, the highest repeatability at the Karaganda meteorological station is 48 %.

logical station is 20–21.9 °C, the highest repeatability is the air temperature value corresponding to the long-term norm.

During the III period (1979–1998), the number of years with an average monthly air temperature of 18–19.9 °C is 6, with an air temperature of 20–21.9 °C is 11, with an air temperature of 22–23.9 °C is 3. From this data analysis, the highest repeatability of values was determined as 55 % within the average monthly temperature the air temperature is 20–21.9 °C. Cumulative repeatability — 85 % is the average monthly air temperature in July in the range of 18–21.9 °C. The relative repeatability of the values of the average monthly air temperature in July during the III period (1979–1998) within the normal range (+20.3 °C) in this area is 55 %. As in the second period (1959–1978), the highest repeatability at the Karaganda meteorological station has a value of 20–21.9 °C, i.e. the highest repeatability has an air temperature value corresponding to a long-term norm.

During the IV period (1999–2019), the number of years with an average monthly air temperature of 16–17.9 °C is 2, with an air temperature of 18–19.9 °C is 10, with an air temperature of 20–21.9 °C is 6, with a temperature of 22–23.9 °C is 3. Based on this, the highest repeatability of values was determined as 47.6 % within the average monthly air temperature of 18–19.9 °C. The accumulated repeatability of 90.5 % is the average monthly air temperature in July in the range of 18–23.9 °C. The relative repeatability of the values of the average monthly air temperature in July during the IV period (1999–2019) within the normal range (+20.3 °C) in this area is 55 %, the highest repeatability at the Karaganda meteorological station is 18–19.9 °C, which is 1–2 °C lower than the long-term norm of July air temperature.

Table 2

**The number of absolute and relative repeatability values of the average monthly air temperature in July since 1939 to 2019 at the Karaganda meteorological station**

Period I (1939–1958)			Period II (1959–1978)			Period III (1979–1998)			Period IV (1999–2019)		
Air t, °C			Air t, °C			Air t, °C			Air t, °C		
t	m <sub>i</sub>	p <sub>i</sub> , %	t	m <sub>i</sub>	p <sub>i</sub> , %	t	m <sub>i</sub>	p <sub>i</sub> , %	t	m <sub>i</sub>	p <sub>i</sub> , %
14–15,9	0	0	14–15,9	0	0	14–15,9	0	0	14–15,9	0	0
16–17,9	1	5	16–17,9	3	15	16–17,9	0	0	16–17,9	2	9,5
18–19,9	7	35	18–19,9	6	30	18–19,9	6	30	18–19,9	10	47,6
20–21,9	8	40	20–21,9	8	40	20–21,9	11	55	20–21,9	6	28,6
22–23,9	3	15	22–23,9	3	15	22–23,9	3	15	22–23,9	3	14,3
24–25,9	1	5	24–25,9	0	0	24–25,9	0	0	24–25,9	0	0

Compared to period I, in period II the relative frequency of average monthly air temperatures of 16–17.9 °C increased by 10 %, air temperatures of 18–19.9 °C decreased by 5 %. Compared to period II, in period III, the relative frequency of average monthly air temperature of 20–21.9 °C increased by 15 %, compared to period III, in period IV, the relative frequency of average monthly air temperature of 18–19.9 °C increased by 17.6 %, air temperature 22–23.9 °C decreased by 0.7 % (Fig. 2)

According to the data presented in the Table 3 and in Figure 3, the absolute and relative frequency of average monthly air temperature in July for the Arkalyk meteorological station differs as follows. During period I (1939–1958), the number of years with an average monthly air temperature of 16–17.9 °C is 1, with an air temperature of 18–19.9 °C is 2, the number of days with an air temperature of 20–21.9 °C is 10, with an air temperature of 22–23.9 °C it is 5 and with an air temperature of 24–25.9 °C it is 2, respectively.

The analysis of this data indicates that the most frequent occurrence, constituting 50 % of the total, falls within the average monthly air temperature range of 20–21.9 °C. Additionally, a cumulative occurrence of 85 % encompasses average monthly air temperatures in July ranging from 18 °C to 25.9 °C. The sustained average monthly air temperature recorded over the long term in July at the Arkalyk meteorological station stands at +21.3 °C. The relative frequency of average monthly air temperature in July during the first period (1939–1958) within the normal range in this area is 50 %, which corresponds to the long-term norm.

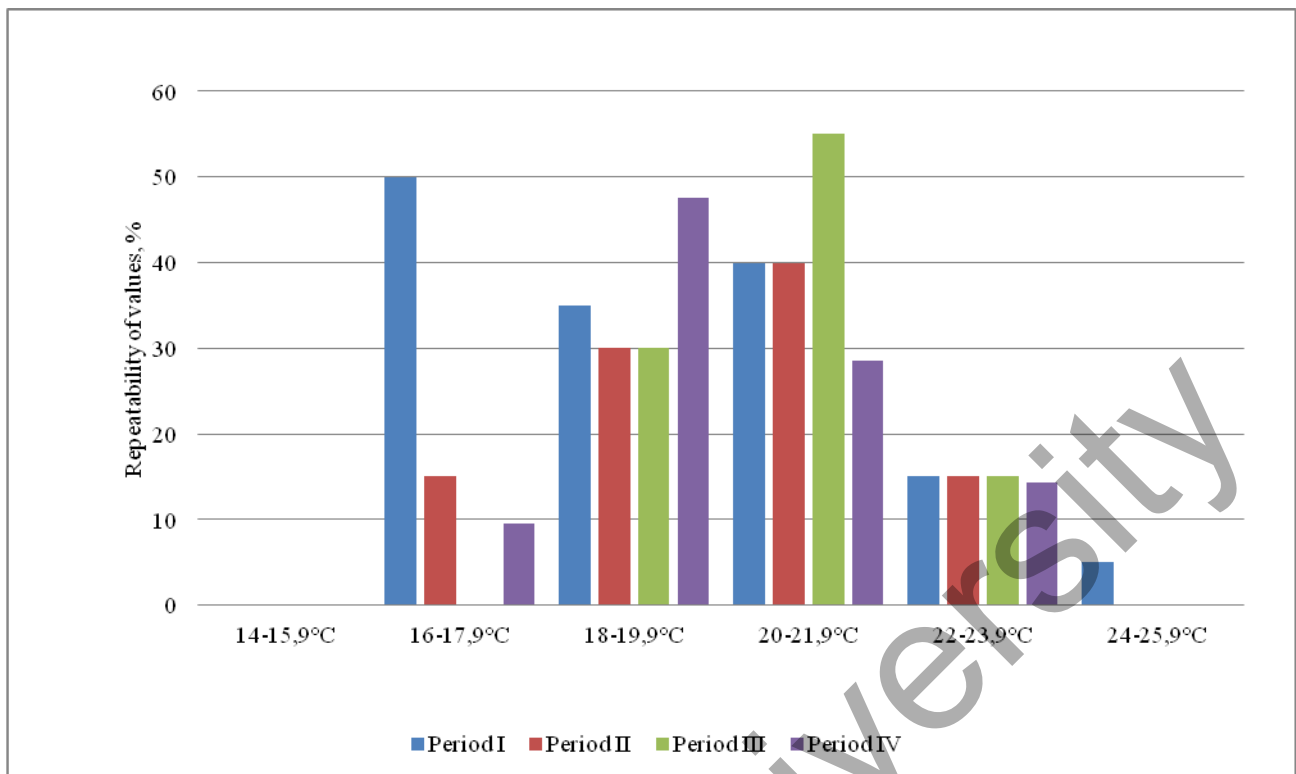


Figure 2. Dynamics of the relative frequency values of the average monthly air temperature in July at the Karaganda meteorological station for periods I-IV

Table 3

The number of absolute and relative repeatability values of the average monthly air temperature in July since 1939 to 2019 at the Arkalyk meteorological station

Period I (1939–1958)			Period II (1959–1978)			Period III (1979–1998)			Period IV (1999–2019)		
Air t, °C			Air t, °C			Air t, °C			Air t, °C		
t	m <sub>i</sub>	p <sub>i</sub> , %	t	m <sub>i</sub>	p <sub>i</sub> , %	t	m <sub>i</sub>	p <sub>i</sub> , %	t	m <sub>i</sub>	p <sub>i</sub> , %
14–15,9	0	0	14–15,9	0	0	14–15,9	0	0	14–15,9	0	0
16–17,9	1	5	16–17,9	0	0	16–17,9	0	0	16–17,9	0	0
18–19,9	2	10	18–19,9	3	15	18–19,9	5	25	18–19,9	1	4,8
20–21,9	10	50	20–21,9	12	60	20–21,9	11	55	20–21,9	11	52,4
22–23,9	5	25	22–23,9	5	25	22–23,9	2	10	22–23,9	8	38
24–25,9	2	10	24–25,9	0	0	24–25,9	2	10	24–25,9	1	4,8

During period II (1959–1978), the number of years with an average monthly air temperature of 18–19.9 °C is 3, with an air temperature of 20–21.9 °C is 12, with an air temperature of 22–23.9 °C is 5, respectively. It follows herefrom that it should be noted that the highest relative frequency of values is 60 % within the average monthly air temperature of 20–21.9 C, while the cumulative frequency is 85 % and falls on the average monthly air temperature in July of 20–23.9 C. The relative frequency of average monthly air temperature in July during the second period (1959–1978) within the normal range (+21.3 C) in this area is 60 %, that is, the highest frequency in the Arkalyk meteorological station is the value corresponding to the long-term temperature norm July air, which is +21.3 C.

Analysis of data from period III (1979–1998) shows that the number of years with an average monthly air temperature of 18–19.9 C is 5, with an air temperature of 20–21.9 C is 11, with air temperatures of 22–23, 9 C and 24–25.9 C is 2.

On the basis of the foregoing, the highest relative repeatability of values was determined, which is equal to 55 %, within the average monthly air temperature of 20–21.9 C. The cumulative frequency, which is 80 %, is the average monthly air temperature in July within the range of 18–21.9 C. The relative frequency

of average monthly air temperature in July during period III (1979–1998) within the normal range in this area is 55 %, which characterizes compliance with a long-term constant.

During the IV period (1999–2019), the number of years with an average monthly air temperature of 18–19.9°C is 1, with an air temperature of 20–21.9°C is 11, with an air temperature of 22–23.9°C is 8, with an air temperature of 24–25.9°C is 1. When analyzing data from the IV period (1999–2019) from the Arkalyk meteorological station, the highest relative frequency of values was determined, which is equal to 52.4 %, within the average monthly air temperature July 20–21.9°C. The cumulative frequency, the value of which is 90.4 %, is the average monthly air temperature in July within the range of 20–23.9°C. The relative repeatability of the average monthly July air temperature during period IV is 52.4 %, which corresponds to the long-term July air temperature norm of +21.3°C.

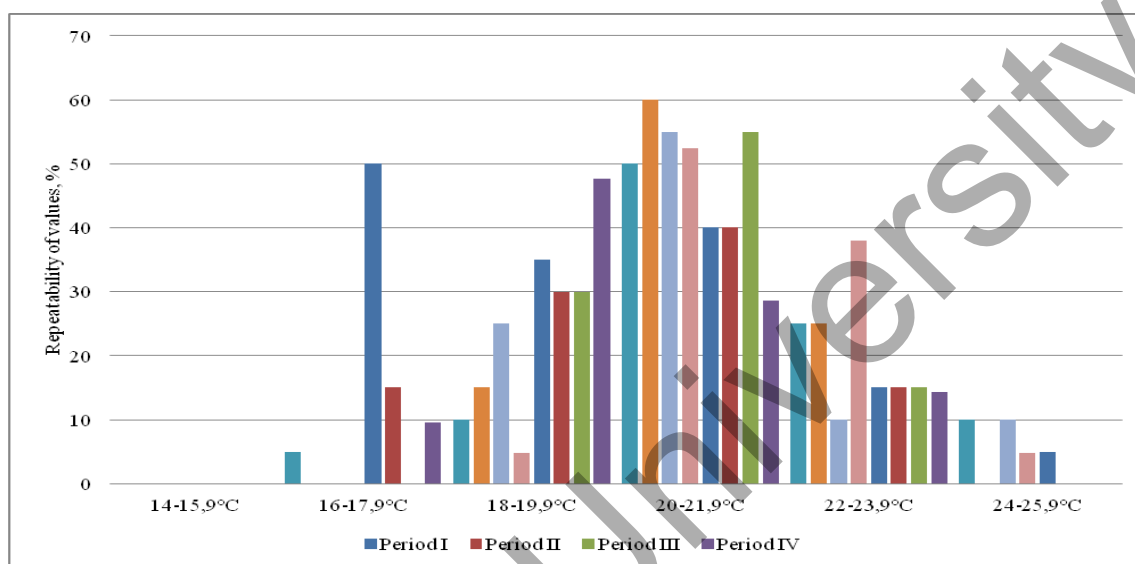


Figure 3. Dynamics of the relative frequency values of the average monthly air temperature in July at the Arkalyk meteorological station for periods I-IV

When comparing data between period I and period II, there was a 5 % increase in the relative frequency of average monthly air temperatures ranging from 18–19.9 °C, and a 10 % increase in temperatures from 20–21.9 °C. In contrast, comparing period II to period III, there was a 10 % decrease in the relative frequency of average monthly air temperatures between 18–19.9 °C, and a 15 % decrease in temperatures falling within the ranges of 20–21.9 °C and 22–23.9 °C, respectively. In period IV, compared to period III, the relative frequency of average monthly air temperature 18–19.9 °C decreased by 20.2 %, air temperature 20–21.9 °C decreased by 2.6 %, air temperature 22–23.9 increased by 28 %, air temperatures of 24–25.9 °C decreased by 5.2 % (Fig. 3).

Thus, at the meteorological stations under consideration, the correspondence of average monthly air temperatures in July +18 — +21.9°C to the long-term constant is generally observed.

### Conclusion

Thus, based on the study conducted, it is revealed that:

1. The highest frequency of occurrence at the Besoba meteorological station during all four periods (1939–2019) is the average monthly air temperature in July of 18–19.9 °C, corresponding to the long-term norm. Compared to period I, in period II at the Besoba meteorological station, the frequency of average monthly air temperature of 18–19.9 °C decreased by 5 %, and the frequency of average monthly air temperature of 18–19.9 °C increased by 15 % compared to period III. Compared with the III period, in the IV period (1999–2019), the frequency of average monthly air temperature of 18–19.9 °C decreased by 17 %, and the frequency of average monthly air temperature of 20–21.9 °C in the III period (1979–1998) compared to period II (1959–1978) increased by 1 %.

2. From periods I to III at the Karaganda meteorological station, the air temperature has the highest frequency within the range of 20–21.9 °C, which corresponds to the long-term norm (+20.3 °C). The relative frequency of average monthly air temperature in July during the IV period (1999–2019) within the normal

range in this area is 55 %, the highest frequency at the Karaganda meteorological station is 18–19.9 °C, which is 1–2 °C below the long-term norm for air temperature in July.

3. At the Arkalyk meteorological station during period II, the average monthly air temperature in July has the highest frequency of 20–21.9 °C with a value of 60 % of the relative frequency. Compared to period I, in period II the relative frequency of average monthly air temperatures of 18–19.9 °C increased by 5 %, air temperatures of 20–21.9 °C increased by 10 %. In all periods, the air temperature value corresponding to a long-term constant has the highest repeatability.

4. For all meteorological stations there is an increase in the values of average monthly air temperatures in July, which has the highest recurrence. In the studied basin of the Nura River, moisture depletion in the summer period is currently expected, which leads to an increase in the number of dry years, i.e. the formation of arid climate associated with an increase in atmospheric air temperature.

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## Нұра өзені алабындағы ауа температурасының ауытқуының ұзақ мерзімді динамикасын талдау

Соңғы онжылдықта Орталық Қазақстандағы Нұра өзені алабының аумағында құрғақ жылдардың әр түрлі қайталануы байқалады. Мақалада Нұра өзенінің алабында тұрған Бесоба және Қарағанды метеорологиялық станциялары мен бассейнің сыртында, оның батысында орналасқан, бірақ ұқсас табиғи жағдайлармен сипатталатын Аркалық метеостанциясы климатының жекелеген элементінің материалдарын пайдалана отырып, көпжылдық кезеңдегі температура ауытқуының өзгеру үрдісі зерттелді. Зерттеу барысында 1939 жылдан 2019 жылға дейінгі 81 жыл уақыт аралығында, яғни шілде айында Нұра өзені алабының аумағында орташа айлық ауа температурасы мәндерінің абсолютті және салыстырмалы қайталануы анықталды. Қарастырылып отырған метеорологиялық станциялар Қазгидрометтің Жаһандық халықаралық метеорологиялық деректер (ХМЖ) желісінің құрамына кіреді және метеорологиялық көрсеткіштер мәндері ұзақ мерзімді, тексерілген және сәйкес келеді. Статистикалық талдау әдісін қолдану негізінде Нұра өзені алабының аумағында көп жылдық кезеңдегі температуралық ауытқудың көпжылдық динамикасын бағалау анықталды. Зерттеу барысында зерттелетін аумақтың алабындағы атмосфералық ауаның орташа айлық температурасының жоғарылауымен байланысты құрғақ климаттың қалыптасуы көрсетілген.

*Кілт сөздер:* атмосфералық ауа температурасы, температуралық тербелістің өзгерісі, абсолюттік және салыстырмалы жиілік, куммулятивтік қайталану, қайталанатын константа, температуралық режим, өзен алабы, статистикалық талдау, жиілік.

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**Анализ многолетней динамики температурного колебания воздуха  
в бассейне реки Нуры**

В последнее десятилетие на территории бассейна реки Нуры в Центральном Казахстане наблюдается различная повторяемость засушливых лет. В настоящей статье исследована тенденция изменения колебания температуры за многолетний период с применением материалов отдельного элемента климата метеорологических станций Бесоба и Караганда, расположенных в бассейне реки Нуры, и метеостанция Аркалык, находящаяся за пределами бассейна, к западу от него, но характеризующаяся сходными природными условиями. В ходе исследований за 81-годовой временной интервал с 1939 по 2019 гг. была установлена абсолютная и относительная повторяемость значений среднемесячной температуры воздуха в июле на территории бассейна реки Нуры. Рассматриваемые метеорологические станции входят в состав Глобальной международной сети метеорологических данных Казгидромета и имеют постоянные, точные ряды значений метеорологических показателей. На основе использования метода статистического анализа выявлена оценка многолетней динамики температурного колебания за многолетний период на территории бассейна реки Нуры. В ходе исследования выражено формирование аридного климата, связанного с увеличением среднемесячной температуры атмосферного воздуха в бассейне исследуемой территории.

*Ключевые слова:* температура атмосферного воздуха, динамика температурного колебания, абсолютная и относительная повторяемость, куммулятивная повторяемость, продолжительная константа, температурный режим, бассейн реки, статистический анализ, частота.

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