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Dynamics of changes in air temperature and precipitation in the Karaganda region

Abstract. *The article examines the long-term variability of a number of meteorological parameters in the Karaganda region. It analyzes reliable data from the site "Climate and Weather" of the international databases SYNOP and METAR. The average annual air temperature and precipitation for 1940-2020 were studied using the linear trend method. The results showed that the climate of the Karaganda region changed significantly between 1940-2020, both in temperature and precipitation. Over 80 years, the average annual temperature has increased by 1.1 ° C, which is high for the short term. Due to the warming of winter, the climate of the region has warmed up, and the average annual precipitation has increased by 145 mm.*
Keywords: *Climate, climate change, temperature, precipitation, linear trend, Karaganda region.*

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Introduction

The issue of climate change is relevant not only now, but also in the future from a global and regional perspective [1]. The results of instrumental meteorological observations and analysis of various indirect data showed that the global climate is changing. It depends on temperature, precipitation, evaporation, etc. determined by the average characteristics of the factors. In general, in the XX century, the average surface air temperature increased by about 0.6 °C [2]. This is due to the increase in greenhouse gas emissions, including carbon dioxide, due to the growth of the world economy [3].

World science has become more interested in research on climate change, and the study of the dynamics of climate change in individual regions has come to the fore [4]. In particular, the authors' views on changes in the average annual temperature in Kazakhstan were unanimous. For example, many authors predict that the average annual temperature in Kazakhstan will increase by 1.4° C by 2030, by 2.7° C in 2050 and by 4.6°C in 2085 [5,6,7]. As a result, an increase in the average annual temperature may have a negative impact on livestock and crops in the region, water resources [8].

By the middle of the XXI century, Kazakhstan is expected to increase precipitation in winter (9%) and spring (5%), as well as increase the intensity and variability of precipitation. Some models predict an increase in annual precipitation by 2% by 2030, 4% by 2050, and 5% by 2085, while other models predict an average decrease in precipitation by 11% by 2085. In the case of increased greenhouse gas emissions, the humidity zone is expected to shift 250-300 km to the north by 2085. In the latter case, all the northern regions of Kazakhstan may become semi-desert [8].

Climate indicators have changed in the Karaganda region. Changes in air temperature also affect the amount of precipitation in the region. The impact of precipitation and changes in air temperature on the water resources of small lakes in the region is particularly significant. This is because most of the small lakes in the region are fed by melted snow and rainwater [9].

The territory of the Karaganda region is of great strategic importance for the development of agriculture and heavy industry in the cities located in the central region of the country [10]. However, in recent years, a number of problems related to climatic phenomena in the region have arisen, in particular, floods, abnormal droughts, and depletion of water resources [11]. Due to this, the area under crops has decreased and grain yields have decreased. That is, forecasting the impact of climatic factors is important for the sustainable development of industries and agriculture in the region.

The article aims to study the dynamics of climate change in the Karaganda region on the basis of meteorological indicators.

Materials and methods

In this study, the main meteorological indicators for the Karaganda region were taken from the site "Climate and weather" [12]. The site uses actual data from international SYNOP and METAR reports. This site provides information on temperature, precipitation, and humidity in the Karaganda region from 1933 to the present. In this paper, the average annual air temperature and precipitation for 1940-2020 were studied using the linear trend method. The linear trend method accurately determines whether the total air temperature changes in a positive or negative direction [13]. Methods for calculating the arithmetic mean and the arithmetic mean error was used in compiling the average annual trend of temperature and precipitation.

Karaganda region is located in the continental steppe zone of Western Siberia and in the middle of the republic (Figure 1), bordered by Akmola and Pavlodar in the north, Kostanay in the northwest, East Kazakhstan in the east, Zhambyl and South Kazakhstan in the south, and Kyzylorda in the southwest. The area of the region is 428 thousand km2. The territory stretches 1300 km from north to south and 700 km from east to west [14,15].

The climate of the Karaganda region is sharply continental. The territory of the region is under high air pressure throughout the year. In winter it is under the influence of the Siberian anticyclone, and in summer this anticyclone completely disappears and merges with the eastern Azores anticyclone. Therefore, open weather prevails throughout the year, with cold winters and hot summers [16]. There are three main types of air masses in the region: arctic, polar, and tropical. Arctic air masses entering the territory of Central Kazakhstan led to a decrease in temperature to 30-40°C. In the warm season, the region is affected by the tropical air of Turan and Iran. This period is characterized by high temperatures, low precipitation, and relatively dry air [5].

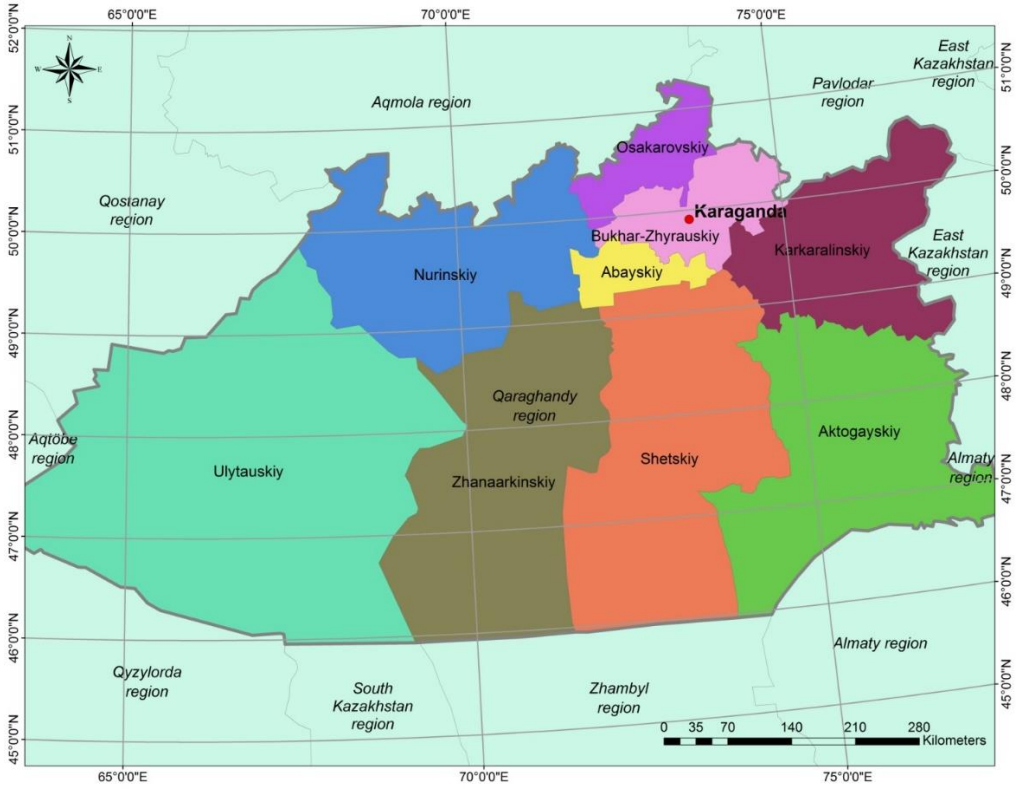

Figure 1. The territory of the Karaganda region

Research results

In this work, the changes in the average air temperature of the Karaganda region for the period 1940-2020 and every ten years were studied. The average seasonal temperature regime (winter, spring, summer, and autumn) was also studied. Changes in air temperature, as well as seasonal and annual precipitation regimes and amounts, were identified in the region. Particular attention was paid to determining the air temperature and precipitation cycles over the past 80 years.

In general, in order to determine the changes in the average annual air temperature in the territory of the Karaganda region, the average air temperature for 1940-2020 was analyzed. The study was conducted using the linear trend method. As a result of this method of analysis, it is possible to determine the increase or decrease in the average annual air temperature (Figure 2). An analysis of the average annual air temperature from the 1940s to the 2020s revealed an increase in the average annual air temperature. Based on the linear trend, the average annual increase in air temperature over 80 years (1940–2020) was 1.2°C (Figure 2). The average annual air temperature in the study period (1940-2020) was 2.2°C.

No constant cycles in temperature dynamics were found for the time period studied. The maximum average annual temperature peaks range from 3.8 °C to 5.2°C. In general, the highest average annual temperature was in 1940. (3.8°C), 1963 (4.7°C), 1983 (5.2°C), 1997 (5.1°C), 2002 (4.9°C), 2004-2005. (4.5°C), 2008 (4.6°C), 2013 (5°C), 2017 (4.6°C) and 2020 (4.8°C). The intervals between these peaks are gradually decreasing, namely: 23 years, 20 years, 14 years, 5 years, 4 years, 3 years, and 2 years. Over the last 20 years, the peak values of the average air temperature have been uniform.

The annual average temperature increased at the lowest peak values, but the intervals between the lowest temperature peaks decreased (from 3-4 years to 8-22 years). There is no information until 1940, but it is known that for 14 years from 1943 (1.7°C), to 1946. (1.5°C), 1949 (1.4°C), 1952 (1.6°C) until 1954 (0.8°C). The temperature often drops. Since 1960 (1.1°C) lower annual average temperature peaks have been rare; 1969 (1.1°C), 1976 (1.9°C), 1984. (2°C), 1993 (2°C), 1996 (2°C), 2018 (2.3°C). After 1980, the average air temperature did not fall below 2°C. Thus, the peak of the minimum annual average temperature in 1954. (0.8°C) and the maximum value of the lower peak in 2018 (2.3°C).

The average annual air temperature in the Karaganda region showed a steady upward trend from 2.2°C in 1940 to 3.3°C in 2020. In other words, the average temperature has risen by 1.1° C for 80 years, which is a huge increase in a short period of time.

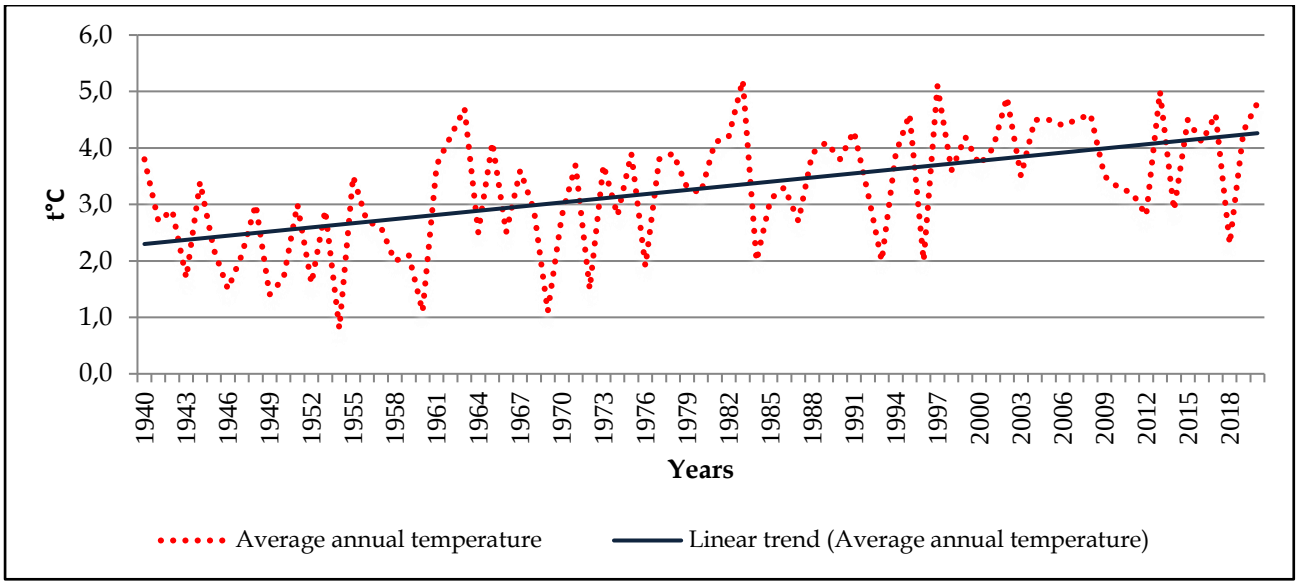

Figure 2. Dynamics of average air temperature for 1940-2020

Figure 3 shows the average air temperature fluctuations between 2000 and 2020. From this we can see that after the 2000s, the trend of rising temperatures not only persisted, but also increased significantly compared to all periods under study. In addition, it can be seen that it has a certain stability and no large deviations.

The study analyzed the average annual air temperature every 10 years for 80 years in order to accurately determine the trend of rising average air temperature (Figure 4). As a result of the analysis, it is clear that the average air temperature rises by about 0.5 °C every 20 years. In the first two decades of the study period (1940-2020) (2.5 °C in 1940-1949, 2.3 °C in 1950-1959) the average annual temperature was below 3 ° C, and in subsequent years it was 3 °C. C was high. In the 50s of the twentieth century and the last 10 years, the average air temperature has slightly decreased. But the general trend is that the temperature is rising.

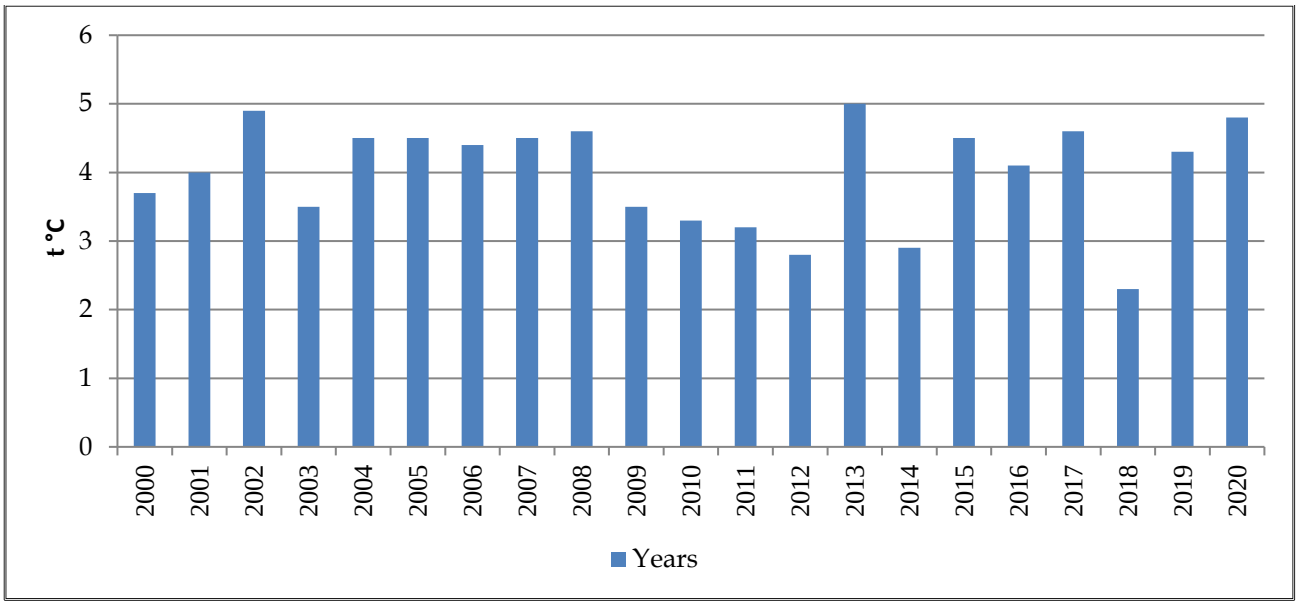

Figure 3. Fluctuations in the average air temperature between 2000 and 2020

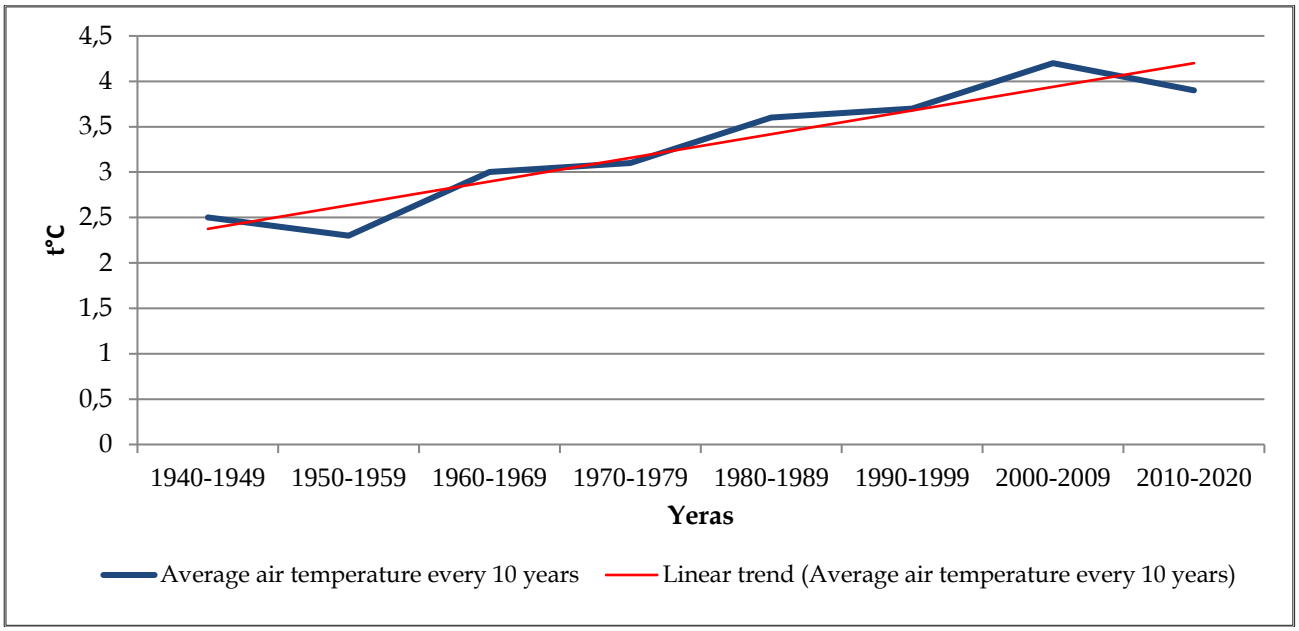

Figure 4. Average air temperature every 10 years

Fluctuations in the average annual air temperature do not fully reflect the overall heat regime of the seasons. The average seasonal temperature fluctuates due to various anticyclones. For example, if the winter is less cloudy and has clear frosts, the spring and autumn months may be characterized by alternating warm or cold weather and precipitation [16].

The fact that part of the territory of the Karaganda region extends to the south, and the other part to the north, contributes to the uneven temperature regime [14]. In this regard, the most objective manifestation of deviations in air temperature is determined by seasonal analysis.

Analysis of the dynamics of average seasonal changes in air temperature showed their variability throughout the year (Figure 5). Thus, the average winter temperature is characterized by its variability, as shown in Figure 5. For example, the average temperature in winter increased by 3.1°C. However, despite the fact that the average winter temperature has risen over the past 80 years, its changes have not been uniforming. For example, in the 50s of the twentieth century, the average temperature was -14.2°C, and in the 90s - -9.8°C. However, in recent years (2012–2020), the average winter temperature has dropped significantly to -11.5°C. Based on these indicators, we can say that the average air temperature fluctuated significantly, for example, the average winter temperature in 2012 was -19.6°C, in 2016 -9.6°C, in 2018 -14.9°C, in 2020 -10, Showed 2°C.

Thus, over the past 80 years, we can see a gradual increase in winter temperatures, and the frequency of the coldest winters decreased from 2 to 28 years: in 1943. (-16.3°C), 1945 (-16.2°C), 1947 (-16°C), 1954 (-17.3°C), 1969. (-19.4°C), 1974 (17.9°C) 1984 (-18.1°C) 2012 (-19.6°C). Therefore, it corresponds to the following intervals between the cold winter seasons: 2 years, 2 years, 7 years, 15 years, 5 years, 10 years, 28 years.

As can be seen in the graph (Figure 5), there were large fluctuations in the average air temperature in the spring. In general, fluctuations in air temperature at this time are normal. The relatively warm spring months were replaced by very cold weather. Temperatures below 0°C were recorded twice (0.9°C in 1954 and -1.2°C in 1960) during the study period. Since the 2000s, the average air temperature has not dropped below 3°C. In total, the average spring temperature for eighty years has increased by 1.1°C.

Based on the graph, the dynamics of changes in the average air temperature in autumn can be formulated as the spring season. The average air temperature during the study period was 3.2°C, while in the last twenty years (2001-2020) it was 3.9°C. In comparison, between 1940 and 1960, the average air temperature was 2.2°C. This suggests that the overall autumn season is also an indicator of rising temperatures. Compared to the winter season, the average seasonal air temperature has not changed significantly. The average air temperature increased by 0.9°C during the study period.

Spring and autumn temperature trends coincide. At the same time, it can be observed that the trajectories of temperature rise and fall are similar in both seasons, ie in autumn and spring, the peak and low peak values of the year are repeated. The intervals between high and low-temperature peaks correspond to the overall annual average temperature.

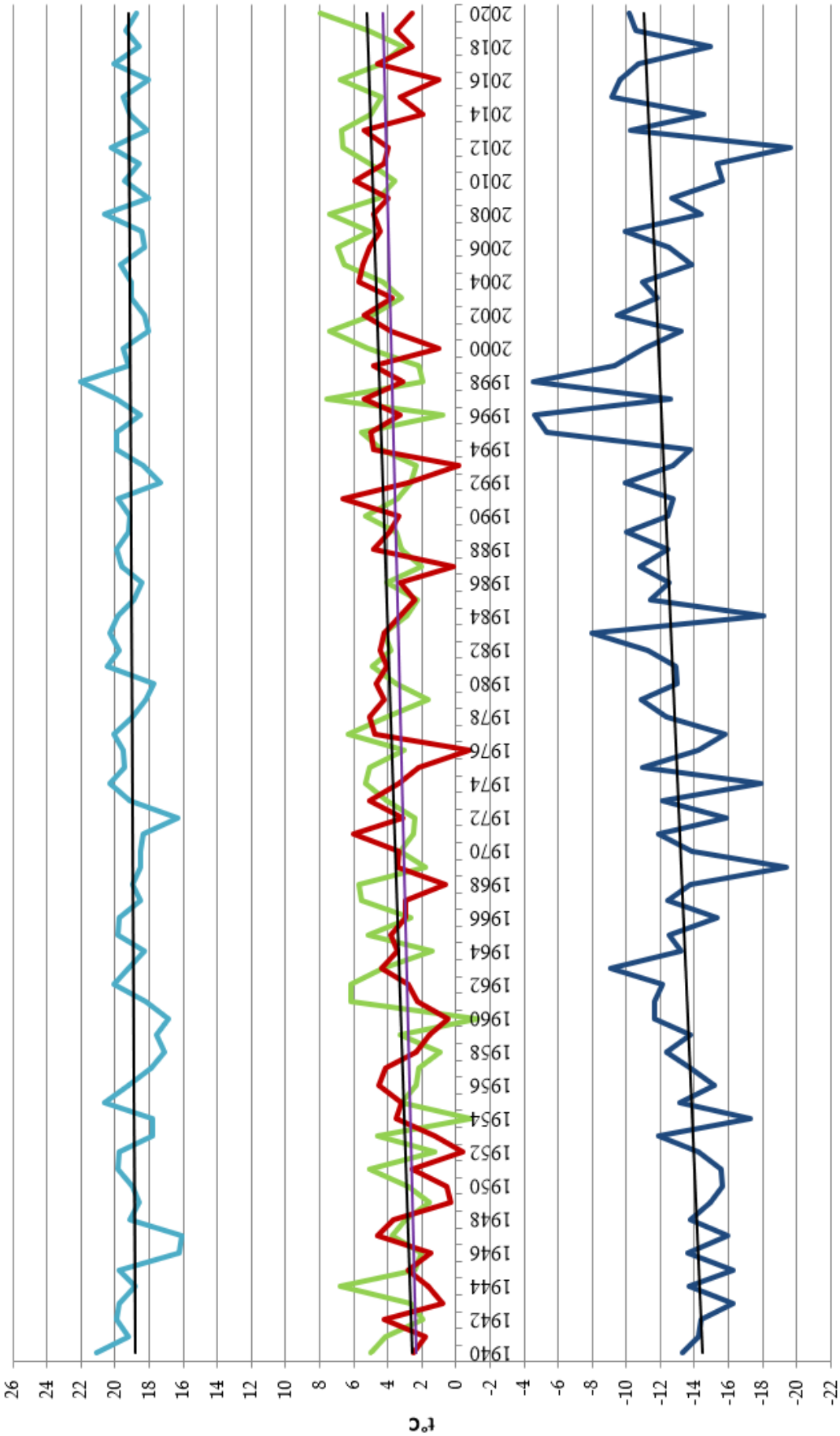

Figure 5. Dynamics of average seasonal changes in air temperature

The annual distribution of the average seasonal temperature in the summer months was more uniform than in other seasons, which indicates the relative stability of the summer weather. This process is clearly shown in Figure 5 through a vertical straight line. In general, the average summer temperature during the study period was 19 °C. The largest fluctuations in air temperature occurred in 1940-1970 of the twentieth century. registered between. Specifically, 1946-1972. 16.3 °C and 1947. 16.1 °C, the average air temperature decreased by 3 ° C. In general, the average summer temperature in the studied period exceeded the norm by about 0.3 ° C.

In general, the dynamics of summer temperatures do not show an increase in temperature during the study period, ie it can be said that the summer was not hot. However, the frequency of years of rising summer temperatures has changed according to the above-mentioned average annual temperature trend, namely: the intervals between hot summers from 1940 to 2020 decreased from 5-15 years from 1940 to 1990, and from 2-3 years after 2000.

It was found that the average precipitation between 1940 and 2020 has increased in recent years (Figure 6). The linear trend showed that the average precipitation increased from 275 mm to 420 mm, ie by 145 mm. No regular precipitation cycle was observed. The average annual rainfall during the years under study was 346 mm. Over the past twenty years, the average annual rainfall was 414 mm, which is 64 mm higher than the average. The lowest average annual precipitation was 123 mm (1951) and the highest was 548 mm (1958) in the 1950s.

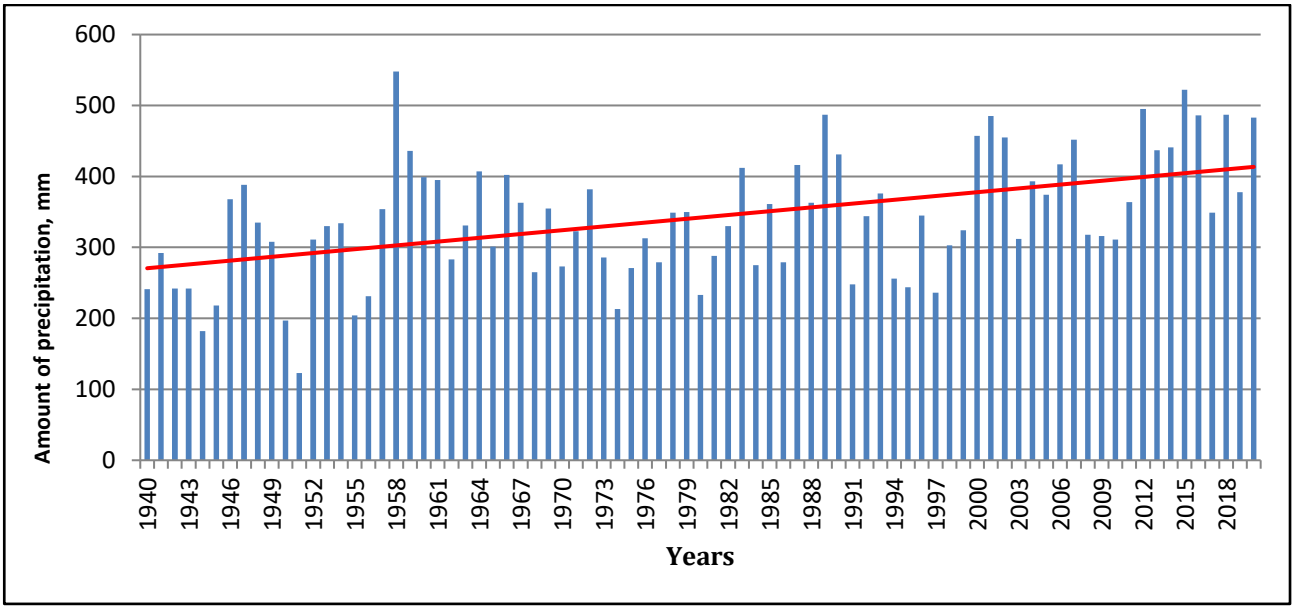

Figure 6. Dynamics of annual precipitation for the period 1940-2020

Based on the linear trend, some differences were identified when considering the amount of seasonal precipitation in warm (April, May, June, July, August, and September) and cold (October, November, December, January, February, and March) (Figure 7). The linear trend showed that in the warm season, the amount of precipitation increased from 175 mm to 220 mm, ie 45 mm. In general, the average precipitation in the warm season during the study period was 202 mm.

The increase in precipitation in the cold season can be clearly seen in Figure 7.

The linear trend showed that in the warm season, the amount of precipitation increased from 90 mm to 195 mm, ie 105 mm. For eighty years, the average rainfall was 145 mm. Over the last twenty years, the average precipitation has increased to 186 mm, exceeding the average by 41 mm. A significant increase in precipitation in the cold season compared to the warm season can be attributed to the increase in average air temperature in the winter months. Thus, the trend of precipitation in the cold months showed a sharp increase compared to the precipitation in the warm months.

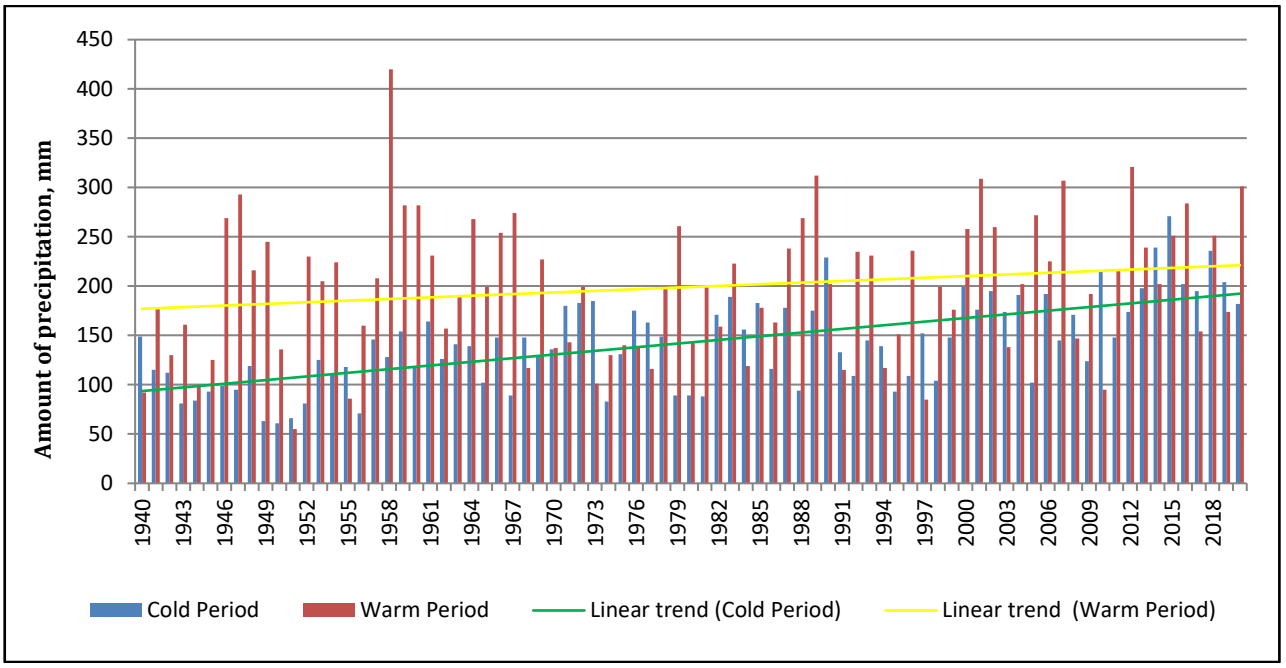

Figure 7. Dynamics of atmospheric precipitation in warm and cold periods

Conclusion

In conclusion, we can clearly see that the climate of the Karaganda region from 1940 to 2020 has changed significantly, both in terms of temperature and precipitation. Due to the warming of the winter, the climate of the region was significantly warmer and there was an increase in annual precipitation. In this context, the following conclusions can be drawn:

1. From 1940 to 2020 there is a steady increase in average annual temperature by 1.1 C;

2. The increase in the average annual temperature is associated with an increase in winter temperatures;

3. The frequency of positive trends increases, while the frequency of negative trends decreases. In particular, the last eighty years have seen frequent warm winters;

4. The positive trend of average annual air temperature has reached its maximum level and has not changed in the last 20 years;

5. In general, the average annual precipitation has increased by 145 mm over 80 years;

6. Precipitation in the cold months (105 mm) increased sharply compared to the warm months (45 mm).

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Қарағанды облысының ауа температурасы мен жауын-шашын көрсеткіштерінің өзгеру динамикасы

Аңдатпа. Мақалада Қарағанды облысындағы бірқатар метеорологиялық параметрлердің ұзақ мерзімді құбылмалылығы зерттелді. SYNOP және METAR халықаралық дерек қорының «Климат и погода» сайтынан алынған сенімді деректері талданды. 1940-2020 жылдар аралығындағы орташа жылдық ауа температурасы және жауын-шашын мөлшері сызықтық тренд әдісін қолдану арқылы зерттелді. Алынған нәтижелер Қарағанды облысының климаты 1940-2020 жылдар аралығында температурада да, жауын-шашында да айтарлықтай өзгергенін көрсетті. 80 жыл ішінде орташа жылдық температура 1,1°С-қа өсті, бұл қысқа мерзім үшін жоғары көрсеткіш. Қыстың жылынуына байланысты облыстың климаты біршама жылынып, орташа жылдық жауын-шашын мөлшері 145 мм-ге артқан.

Түйін сөздер: Климат, климаттың өзгеруі, температура, жауын-шашын, сызықтық тренд, Қарағанды облысы.

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Динамика изменения показателей температуры воздуха и осадков Карагандинской области

Аннотация. В статье исследована долгосрочная волатильность ряда метеорологических параметров в Карагандинской области. Проанализированы достоверные данные международной базы данных SYNOP и METAR с сайта «Климат и погоды». Среднегодовая температура воздуха и количество осадков в период с 1940 по 2020 год изучались с использованием метода линейного тренда. Полученные результаты показали, что климат Карагандинской области в указанный период существенно изменился как по температуре, так и по осадкам. За 80 лет среднегодовая температура выросла на 1,1°С, что является высоким показателем за короткий срок. В связи с зимним потеплением климат области несколько потеплел, а среднегодовое количество осадков увеличилось на 145 мм.

Ключевые слова: климат, изменение климата, температура, осадки, линейный тренд, Карагандинская область.

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