ANNUAL BULLETIN ON CLIMATE CHANGE AND CONDITION MONITORING IN THE TERRITORY OF THE REPUBLIC OF KAZAKHSTAN FOR 2024

MINISTRY OF ECOLOGY AND NATURAL RESOURCES OF THE REPUBLIC OF KAZAKHSTAN

REPUBLICAN STATE ENTERPRISE "KAZHYDROMET"

SCIENTIFIC RESEARCH CENTER

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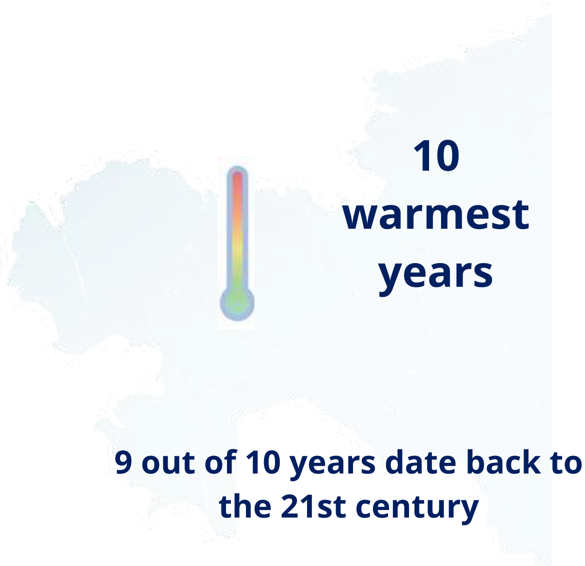
BRIEF SUMMARY

Climate features in 2024

- 2024 took 6th place among the ten warmest years in Kazakhstan for the entire observation period since 1941.
- The average air temperature in Kazakhstan was +1.72 °C higher than the climatic norm. Extremely high values were recorded at 17 meteo stations, where temperatures were above the climatic norm up to +3.3 °C.



Year	Anomalies
2023	2,58
2020	1,92
2013	1,89
2022	1,78
1983	1,76
2024	1,72
2015	1,64
2021	1,58
2002	1,55
2004	1,53

- The average monthly air temperatures in 2024 were above the climatic norm (1961–1990) in almost all months, with the exception of May and September, when there were decreases in temperature relative to the norm.
- The warm period of 2024 was characterized by frequent extremely hot days. The maximum daily temperature in most of the territory exceeded +30 °C and in some places reached +35 °C.
- Annual precipitation was unevenly distributed throughout the country. The average rainfall in Kazakhstan was 391.8 mm (123.3 % of the norm). A decrease in precipitation was observed in the northwestern, central and southern regions.

Climate change in Kazakhstan

A steady increase in the average annual air temperature was observed in all regions of Kazakhstan. On average, for the period 1976–2024 in Kazakhstan, the average annual air temperature increased by 0.36 ˚ C every 10 years, while the global temperature rises at a rate of 0.19 °C every 10 years.

On average, for the territory of individual regions, the rate of increase in air temperature ranges from 0.26 °C (Karaganda region) to 0.56 °C (West Kazakhstan region) every 10 years.

Over the past 48 years, there has been a weak trend towards an increase in annual precipitation by 3.3 mm/10 years, mainly due to precipitation in the spring season. In Kazakhstan, all trends in the average annual and seasonal rainfall are statistically insignificant.

There is a steady increase in the number of summer days with temperatures above 30 ºC, as well as tropical nights with temperatures above 20 ºC, especially noticeable in the south, southwest and west of the republic

Changes in the maximum duration of idle periods with precipitation less than 1 mm per day reached 1–4 days/10 years, both upward and downward.

Everywhere there is a steady increase in the growing season with an average daily temperature above 10 ºC, as well as the sum of active temperatures for this period.

There is a reduction in heat deficiency (need for heating) during the cold season and an increase in cold deficiency during the warm period (need for air conditioning), especially in the south-west and west of the republic

An increase in the recurrence and duration of hot periods in the warm season negatively affects the health of people and animals, the state of transport infrastructure, urban environment, recreation areas and increases the burden on the energy industry, and an increase in ground temperature reduces periods with negative temperatures, which leads to a predominance of liquid precipitation, a decrease in snow accumulation and a reduction in the area and duration of solid precipitation in the mountains, affecting glacial systems.

INTRODUCTION

Climate is a natural resource that is vital for determining the directions of development of many sectors of the economy and the health of the population of any state. Meteorological information collected, managed and analyzed by national hydrometeorological services helps users of this information, including decision makers, to plan any activity taking into account current climatic conditions and observed climate changes. The use of up-to-date meteorological and climate information helps to reduce risks and damage and optimize socio-economic benefits. Monitoring of the climate system is carried out by national, regional and international organizations in coordination with the World Meteorological Organization and in cooperation with other environmental programs.

The study of the regional climate and the constant monitoring of its changes is one of the priorities of the national hydrometeorological Service of Kazakhstan RSE "Kazhydromet". Since 2010, Kazhydromet has been issuing annual bulletins to provide reliable scientific information about the regional climate, its variability and change. Taking into account the geographical location of Kazakhstan and its vast territory, the observed changes in climatic conditions in various regions of the Republic can have both negative and positive effects on biophysical systems, economic activity and the social sphere. Consideration of climatic conditions and assessment of their changes are necessary to identify potential consequences and take timely and adequate adaptation measures, ultimately, to ensure the sustainable development of Kazakhstan.

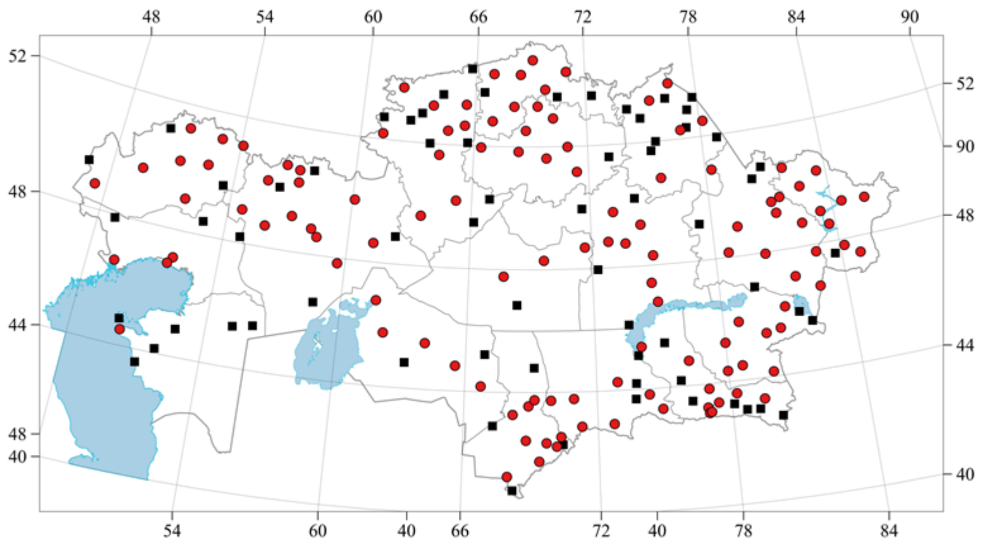
This issue of the bulletin describes the climatic conditions observed in 2024, including an assessment of the extremes of temperature and precipitation regimes, and provides historical information on changes in surface air temperature and precipitation that have occurred since 1941. This issue of the bulletin also contains estimates of climate change over a shorter period – since the mid-1970s of the last century, when, according to many experts, global climate change has become more intense, especially in the Northern Hemisphere. Appendices 3 and 4 show maps of the distribution of average long-term values of air temperature and precipitation for the period 1961–1990, averaged by season and per year.

The initial data. Data from the Republican Hydrometeorological Fund of RSE "Kazhydromet" are used to prepare the bulletin:

1) the series of average monthly air temperatures and monthly precipitation amounts, while about 120 meteostations have homogeneous series since 1941 and their data are involved in the generalization of information on the territory of the regions and in Kazakhstan as a whole, since 1961, there are about 190 such stations, and their data were used to assess climatic norms for the period 1961–1990., to assess anomalies and trends in a particular point;

2) the series of daily maximum and minimum air temperatures and daily precipitation since 1961 (about 190 meteostations).

The network of meteorological stations used for climate monitoring is shown on the schematic map below.

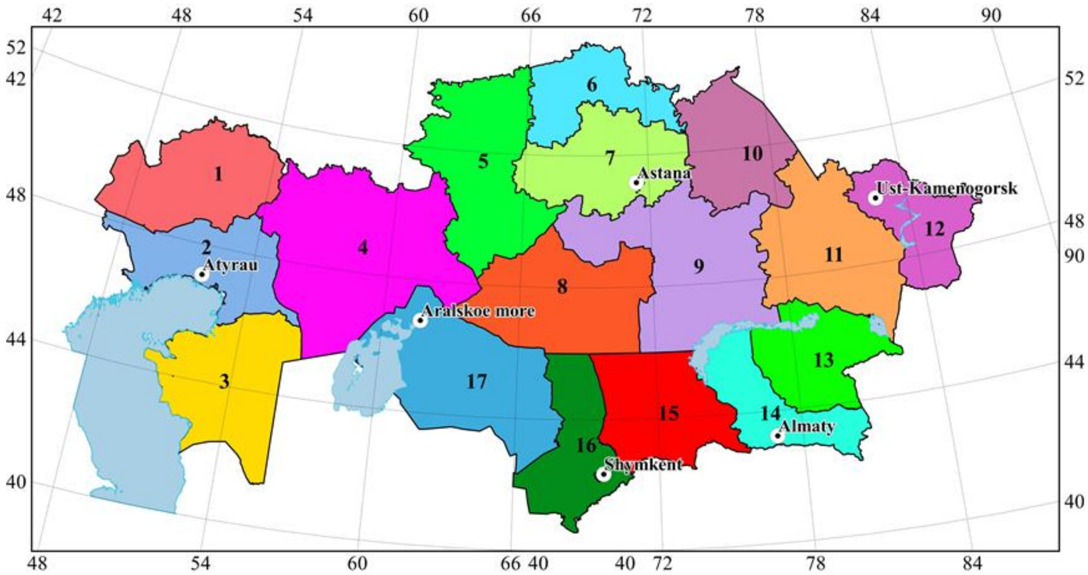


Network of meteorological stations in Kazakhstan used for climate monitoring (stations used for averaging over the area of regions are shown in red circles)

The main approaches and methods. The "norm" in the bulletin refers to the average annual value of the considered climatic variable for the period 1961–1990. Temperature anomalies are calculated as deviations of the observed value from the norm. Precipitation anomalies are usually considered both in deviations from the norm (similar to air temperature) and as a percentage of the norm. As additional characteristics of anomalies, indicators based on the distribution function (probability of non-excess, which characterizes the frequency (in %) of occurrence of the corresponding anomaly value in a series of observations) and ordinal statistics (ranks, i.e., ordinal numbers in an ordered series of values relative to other numbers in the dataset) are used, periods for evaluating these statistics are specifically specified in every case.

Linear trend coefficients determined by the least squares' method are used as an estimate of changes in climate characteristics over a certain time interval. The measure of trend materiality is the coefficient of determination (D), which characterizes the contribution of the trend component to the total variance of the climate variable over the period under consideration (as a percentage).

The assessment of trends in surface air temperature and precipitation, the average values of anomalies of meteorological variables are given both according to data from individual stations and on average for the territory of Kazakhstan as a whole and for 17 of its administrative-territorial regions. The average values of anomalies of meteorological variables for the territory are calculated by averaging station data on anomalies. The borders of the administrative-territorial regions of Kazakhstan are shown on the schematic map below.



1	*West Kazakhstan region*	*10*	*Pavlodar region*
2	*Atyrau region*	*11*	*Abay region*
3	*Mangystau region*	*12*	*East Kazakhstan region*
4	*Aktobe region*	*13*	*Zhetysu region*
5	*Kostanay region*	*14*	*Almaty region*
6	*North Kazakhstan region*	*15*	*Zhambyl region*
7	*Akmola region*	*16*	*Turkestan region*
8	*Ulytau region*	*17*	*Kyzylorda region*
9	*Karaganda region*		

The scheme of administrative-territorial division of the Republic of Kazakhstan

To assess the temperature and precipitation regime in a particular year and its changes since 1961, climate indices recommended by the World Meteorological Organization are used and contribute to the "detection" (mathematically) of significant climate change, including the characteristics of extremes. Some indices are based on fixed uniform thresholds for all stations, while others are based on thresholds that may vary from station to station. In the latter case, the thresholds are defined as the corresponding percentiles of the data series. The indices also allow us to assess the impact of the current climate and its changes on various aspects of socio-economic conditions in the studied region. There are indices reflecting the potential impact on human health, on energy generation needs in different seasons, on agrometeorological conditions, on transport infrastructure, on the extremity of hydrometeorological conditions, etc.

Responsible for the issue: Head of the Department of Climate Research Kuzhageldina N.U. Leading researchers Amanulla E.E., Aktayeva G.S. and leading engineers Abdolla N.S., Kukenova B.T.. also participated in the preparation of the bulletin.

1 OVERVIEW OF GLOBAL CLIMATE CHANGE AND ITS STATUS IN 2024

For more than 30 years, the World Meteorological Organization (WMO), through the Commission on Climatology and in cooperation with its members, has been issuing an annual report on the state of the climate, in response to concerns expressed in 1993 about projected climate change. The annual Global Climate report identifies indicators of the climate system, including greenhouse gas concentrations, rising land and ocean temperatures, rising sea levels, melting ice and retreating glaciers, as well as extreme weather events. It also highlights the impact on socio-economic development, migration and displacement, food security and terrestrial and marine ecosystems. Global climate indicators provide a broad view of climate change on a global scale, covering atmospheric composition, energy changes, and the response of land, ocean, and ice. These indicators are closely interrelated. For example, an increase in the content of CO_2 and other greenhouse gases in the atmosphere leads to an energy imbalance and, thus, to a warming of the atmosphere and the ocean. Ocean warming, in turn, leads to an increase in sea level, to which is added the melting of ice on land in response to an increase in atmospheric temperature.

Together, the indicators create a coherent picture of global warming, which affects all parts of the Earth's system. There are clear links between key climate indicators as a physical system and cascading risks for most of the 17 Sustainable Development Goals. Thus, monitoring global climate indicators, as well as the risks and consequences associated with them, is crucial for achieving the Sustainable Development Goals by 2030.

Key provisions on the state of the global climate in 2024:

The WMO Report on the State of the Global Climate in 2024 confirms that numerous climate records have once again been broken — in many cases, by a considerable margin. Concentrations of greenhouse gases, surface air temperatures, ocean heat content and acidification, as well as sea level rise, sea-ice decline, and glacier retreat, continue to exhibit unprecedented changes, providing clear evidence of ongoing global warming. According to the report, 2024 was one of the warmest years on record, surpassing the previous annual average temperature record set in 2023. The intensification of the El Niño phenomenon, combined with the continued rise in greenhouse gas concentrations, contributed to a further substantial increase in global temperatures, underscoring the acceleration of climate change.

The annually averaged global mean near-surface temperature in 2024 was 1.55 °C ± 0.13 °C above the 1850–1900 average. The year 2024 was the warmest year in the 175-year observational record. The previous warmest year was 2023 with an anomaly of 1.45 °C ± 0.12 °C. Each of the past ten years, 2015–2024, were individually the ten warmest years on record. The analysis is based on a synthesis of six global temperature datasets (Figure 1.1).

A single year with an annual global mean temperature over 1.5 °C above the 1850–1900 average does not indicate that we have exceeded the warming levels from the Paris Agreement.

In 2023, atmospheric concentrations of carbon dioxide (CO_2), as well as methane (CH_4) and nitrous oxide (N_2O), reached their highest levels in at least 800,000 years. Real-time data from specific monitoring sites indicate that the concentrations of these three major greenhouse gases continued to rise in 2024.

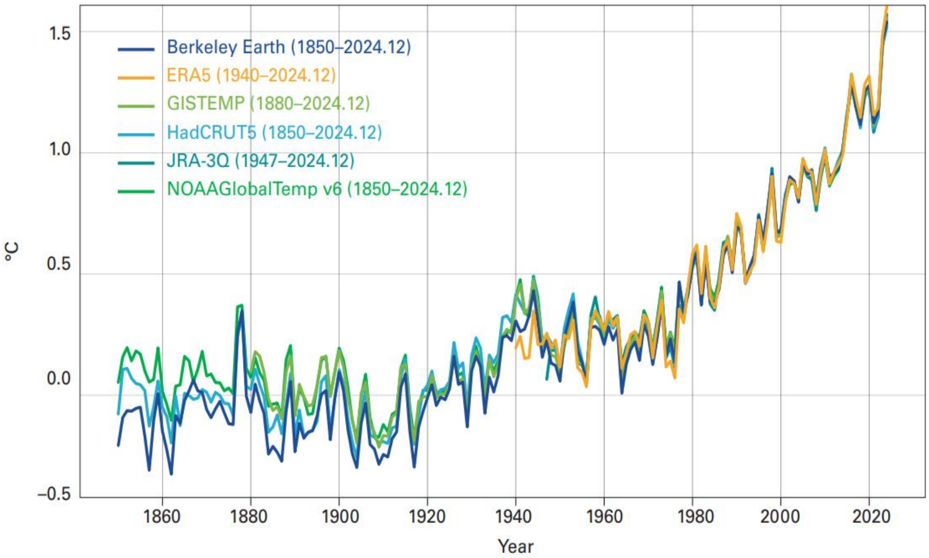


Figure 1.1 *–Annual global mean temperature anomalies relative to a pre-industrial (1850–1900) baseline shown from 1850 to 2024*

Source: Data are from the six datasets indicated in the legend

The global annual average mole fraction of carbon dioxide (CO_2) in the atmosphere – the atmospheric concentration – reached a new observed high in 2023, the latest year for which consolidated global annual figures are available. At 420.0 ± 0.1 parts per million (ppm), the concentration in 2023 was 2.3 ppm more than in 2022 and 151 % of the pre-industrial concentration (in 1750). The concentration of 420 ppm corresponds to 3 276 Gt CO_2 in the atmosphere. Between 1 January 2023 and 31 December 2023, the concentration of CO_2 increased by 2.8 ppm, the fourth largest within-year change since modern CO_2 measurements started in the 1950s. The rate of growth is typically higher during El Niño conditions due to an overall increase from fire emissions and reduced net terrestrial carbon sinks.

Concentrations of methane (CH_4) and nitrous oxide (N2O), two other key greenhouse gases, also reached record high observed levels in 2023. The concentration of CH4 reached 1 934 ± 2 parts per billion (ppb), 265 % of pre-industrial levels, and that of N2O reached 336.9 ± 0.1 ppb, 125 % of pre-industrial levels. Real-time data show that levels of CO2, CH4 and N_2O continued to increase in 2024.

Global mean sea level. In 2024, the global mean sea level reached a record high for the entire period of satellite observations (from 1993 to the present). The rate of sea-level rise over the past decade (2015–2024) was more than double the rate observed during the first decade of satellite records (1993–2002).

Ocean Heat Content. The ocean heat content in 2024 set a new record, exceeding the previous high from 2023 by 16 ± 8 zettajoules (ZJ). The rate of ocean warming over the last two decades (2005–2024) – 0.99–1.07 W/m², or 11.2–12.1 ZJ per year — is more than twice the rate observed during 1960–2005 (0.27–0.34 W/m², or 3.1–3.9 ZJ per year).

The latest Intergovernmental Panel on Climate Change (IPCC) report concludes that it is *virtually certain* that ocean heat content has increased since the 1970s and *extremely likely* that human influence is the dominant cause. Based on the datasets used in this report, global ocean heat content increased at a rate of 0.6 ± 0.1 W/m² (equivalent to 6.8 ZJ per year), averaged across ocean surface area, between 1971 and 2024, consistent with IPCC findings.

Glacier mass balance. Glacier mass loss from 2021/2022 to 2023/2024 represents the most negative three-year glacier mass balance on record, and seven of the ten most negative annual glacier mass balances since 1950 have occurred since 2016. Extremely negative mass balances were recorded in Norway, Sweden, Svalbard, and the tropical Andes, confirming the trend of accelerated glacier mass loss during the 2020s. The past three years mark the largest cumulative three-year glacier mass deficit ever recorded, further emphasizing the rapid and ongoing decline in global glacier mass.

Extreme weather events. In 2024, tropical cyclones were responsible for some of the most destructive weather events of the year. Typhoon Yagi, in early September, swept across the Philippines and southern China before making landfall in northern Viet Nam. Casualties and population displacement were reported in Viet Nam, the Philippines, the Lao People's Democratic Republic, Thailand, and Myanmar. Significant wind damage was recorded in China and the Philippines.

In the United States, Hurricanes Helen (September) and Milton (October) made landfall on Florida's west coast as major hurricanes. Helen brought extreme rainfall and flooding across inland areas of the southeastern United States, particularly North Carolina. The economic losses from both hurricanes are estimated in the tens of billions of US dollars. Helen claimed over 200 lives, becoming the deadliest U.S. hurricane since Katrina (2005).

In the Southern Hemisphere, Cyclone Chido crossed Mayotte in December before making landfall along the Mozambique coast and continuing into Malawi, causing widespread destruction and numerous fatalities. In Mozambique, about 100,000 people were displaced, and extensive damage to roads and infrastructure severely hampered relief operations.

Afghanistan, Pakistan, and Iran suffered a sequence of disasters — severe cold and heavy snowfall in late February and early March, followed by intense flooding in May, which inundated approximately 35,000 hectares of agricultural land and resulted in hundreds of deaths.

Extreme Weather Events (continued). An exceptionally active monsoon from mid-2024 caused widespread flooding across the Sahel and East Africa. Kenya and Tanzania experienced extensive destruction, casualties, and population displacement. Lake Victoria reached record-high water levels, triggering downstream flooding that extended into South Sudan.

In contrast, northwestern and southern Africa faced severe drought, particularly affecting Zimbabwe, Zambia, Botswana, and Namibia, leading to significant impacts on agriculture and hydropower generation.

In Chile, devastating wildfires occurred in February, particularly in the Viña del Mar region, where over 300 people lost their lives and thousands of buildings were destroyed — one of the most severe wildfire disasters of the 21st century. An active fire season was also recorded in Canada, with carbon emissions reaching the second-highest level since 2003 and the burned area ranking among the largest in the historical record.

Drought conditions also affected Mexico, as well as Central and South America. In the Amazon Basin, the number of wildfires was the highest since 2010, while water levels in the Rio Negro and Paraguay Rivers dropped to record lows. The main exception was the severe flooding in May in Rio Grande do Sul, Brazil, where torrential rains caused over 200 deaths and widespread damage.

On 29 October, extreme rainfall triggered catastrophic flooding in the Valencia region of Spain. In Turís, 772 mm of rain fell within 24 hours, setting a national record and causing widespread destruction and over 200 fatalities.

Throughout 2024, numerous heatwaves brought record-breaking temperatures. During the summer, intense heat affected East Asia, Southeastern Europe, the Mediterranean region, the Middle East, and the southwestern United States. In Saudi Arabia, temperatures reached 50 °C, resulting in numerous fatalities among pilgrims.

Source: *WMO Report No. 1368 — "State of the Global Climate in 2024"*, permanent link: *https://library.wmo.int/idurl/4/69455*

2 AIR TEMPERATURE

In 2024, the average annual air temperature anomaly in Kazakhstan was +1,72 °C relative to the long-term average for the period 1961–1990 (5,4 °C), and was 0,86 °C lower than in the record-breaking year of 2020. Since the 1960s, each subsequent decade in Kazakhstan has been warmer than the previous one. The average annual air temperature for the last decade (2015–2024) was +6,98 °C, exceeding the climatic norm by 1.55 °C. which is a record value among positive decadal anomalies. The previous warmest decade was 2014–2023, with an anomaly of +1,42 °C. The last five years, 2020–2024, were also the warmest, with an average annual air temperature of +7,35 °C, which exceeded the climatic norm by 1,92 °C.

Table 2.1 presents lists and rankings of the ten warmest years on average for the Globe and for Kazakhstan (according to the terrestrial network). Each year that is among the 10 warmest years for the Globe and for Kazakhstan is assigned its own fill color, which allows us to judge the coincidences in the rankings that appear in both lists of the warmest years. Six of the warmest years in Kazakhstan are included in the list of the ten warmest years for the Globe. 2024 was a record warm year for the globe, while in Kazakhstan it only ranked sixth.

Table 2.1 – The warmest years in the history of observations on the Globe (since 1850) and in Kazakhstan for the period 1941–2024 and the corresponding anomalies of the average annual surface air temperature averaged over the territory of Kazakhstan. The anomalies are calculated relative to the period 1961–1990

Rank	The globe	Kazakhstan	The anomaly of the average annual temperature (Jan.-Dec.), averaged over the territory of Kazakhstan, °C
1	**2024**	**2023**	2,58
2	2023	2020	1,92
3	2020	2013	1,89
4	2016	2022	1,78
5	2019	1983	1,76
6	2017	2024	1,72
7	2022	2015	1,64
8	2015	2021	1,58
9	2021	2002	1,55
10	2018	2004	1,53

Figure 2.1 shows a ranked series of average annual surface air temperature anomalies averaged by meteostations in Kazakhstan for the period from 1941 to 2024. Globally, all 10 extremely warm years occur in the current century. In Kazakhstan, this feature is also well traced, with the exception of 1983, which ranks fifth in the rank of the warmest years.

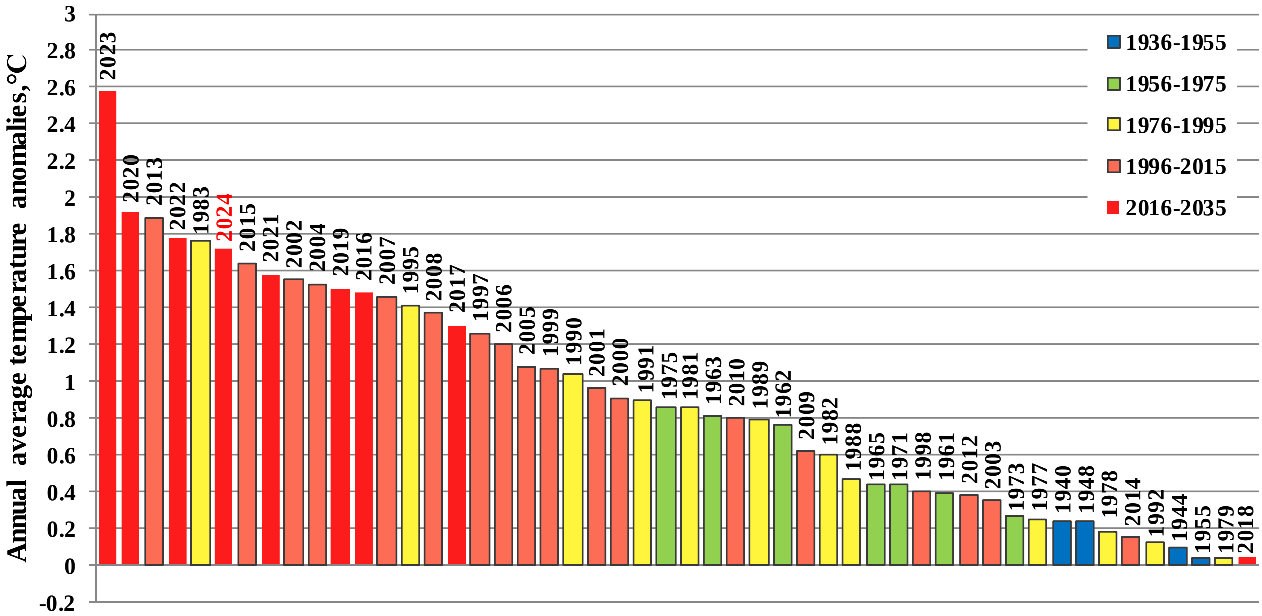


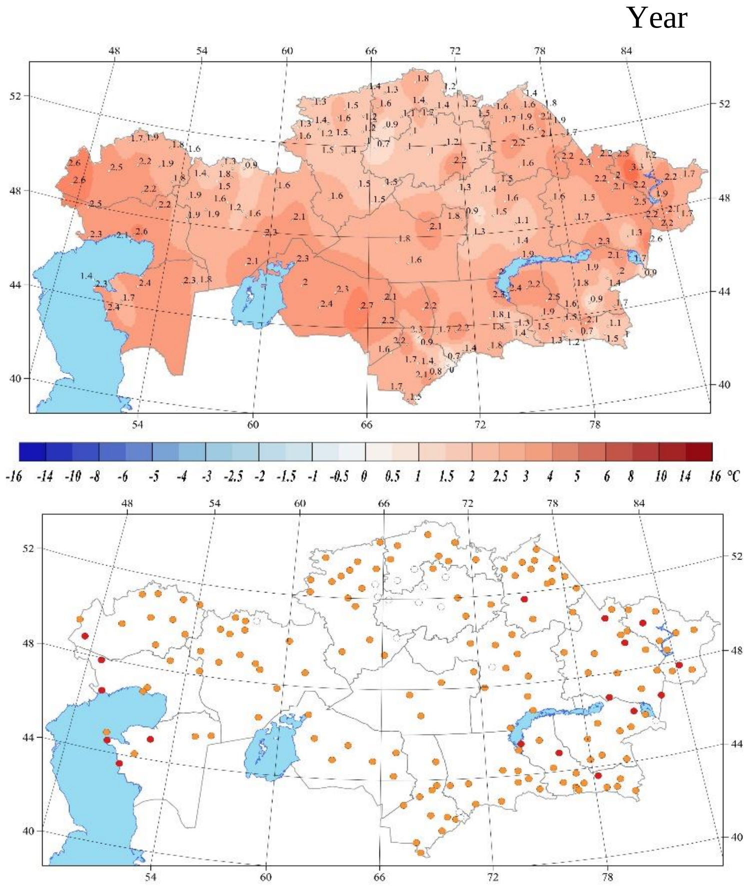
Figure 2.1 *– A ranked series of positive anomalies of average annual (January-December) surface air temperatures averaged over the territory of Kazakhstan (according to 121 meteostations) for the period 1941-2024. Anomalies are calculated relative to the base period 1961–1990*

2.1 Air temperature anomalies in 2024

The year 2024, with an air temperature anomaly of 1,72 °C, ranked sixth in the descending order of average annual temperatures since 1941 and was among the ten warmest years. Of the ten warmest years, nine are in the 21st century (Figure 2.1).

Table 2.2 shows the average annual and seasonal air temperature anomalies averaged by region and for Kazakhstan as a whole, while Table 2.3 shows the anomalies in average monthly air temperature. For each anomaly value, the probabilities of non-exceedance are given, calculated based on data for the period 1941–2024, as well as the standard deviations for 1961–1990 (Table 2.2). In Tables 2.2 and 2.3, temperature values above the 95th percentile or below the 5th percentile (warm and cold extremes, respectively) are highlighted in bold and color.

Anomalies in the average annual air temperature in 2024 were positive across the entire territory of Kazakhstan (Figure 2.2, top). In the eastern, southwestern, and western regions of the country, as well as locally in the northeastern, central regions, and in the Balkhash region, anomalies reached 2,0–2,7 °C, with a maximum value of +3,3 °C in the East Kazakhstan region. The probability of anomalies not exceeding these values in the listed regions was higher than 95 %, which corresponds to the characteristic of temperature conditions as “extremely warm” (Figure 2.1, bottom). In the rest of the territory, air temperature anomalies ranged from 1,0 to 1,9 °C, with the exception of the mountainous regions of the south, southeast, as well as a small area in the Karaganda region and a separate area on the border between the North Kazakhstan and Akmola regions, where air temperatures were close to normal, ranging from 0,1 to 0,9 °C.



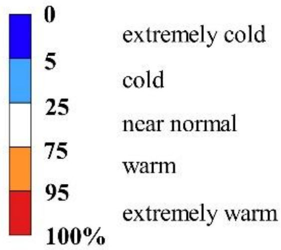


***Figure 2.2** – Geographical distribution of average annual air temperature anomalies (above, °C) on the territory of Kazakhstan in 2024, calculated relative to the base period of 1961–1990, and the probability of not exceeding them (below), calculated based on data from the period 1961–2024*

For the Abay, Almaty, Atyrau, and East Kazakhstan regions, the year was among the top 5 % of extremely warm years (Table 2.1), with anomalies ranging from +1,73 to +2,35 °C on average across the regions. The average anomalies for the Zhetysu, Zhambyl, West Kazakhstan, Karaganda, Kyzylorda, Pavlodar, and Ulytau regions were among the 10 % highest values, ranging from +1,64 to +2,30 °C. In the rest of the regions, the average anomalies ranged from +1,22 to +1,67 °C.

Extremely high annual temperatures (5 % extremes) were recorded at 17 meteostations in Kazakhstan, where temperature anomalies reached 3,3 °C, including at the Aktogay and Bakty meteostations in the Abay region. 2024 was the warmest year since 1941. (Figure 2.2, below).

In 2024, the average monthly air temperatures across Kazakhstan were mostly above the climatic norm (1961–1990) in all months, ranging from +0,51 °C (July) to +3,74 °C (April), with the exception of May and September, when air temperatures were below normal by 0,35 °C and 0,54 °C, respectively (Figure 2.3). Extremely warm (5 % extremes) were June with an anomaly of +2,53 °C (2nd rank) and April with an anomaly of +3,74 °C (5th rank). The average monthly temperature in January 2024 was among the ten warmest months since 1941, with an anomaly of +3,40 °C (Table 2.3).

The spatial distribution of seasonal air temperature anomalies in 2024 across Kazakhstan is shown in Figure 2.4.

Table 2.2 – Regionally averaged mean annual (January-December) and seasonal air temperature anomalies in 2024: ***vT*** *– deviations from multiyear averages for 1961–1990, °C;* ***P(t≤T₂₀₂₄)*** *- probability of non-exceedance (in brackets) calculated from data for the period 1941–2024 in %;* ***s*** *- mean square deviation in °C for the period 1961–1990, in %.*

Region	Year		Winter		Spring		Summer		Autumn	
	vT (P)	**s**	**vT (P)**	**s**	**vT (P)**	**s**	**vT (P)**	**s**	**vT (P)**	**s**
Kazakhstan	1,72 (94)	0,87	2,34 (86)	2,44	1,99 (81)	1,27	1,48 (94)	0,65	1,21 (80)	1,15
Abay	**2,03 (96)**	**1,08**	2,11 (76)	2,76	2,83 (93)	1,53	**2,21 (100)**	**0,79**	1,12 (65)	1,48
Almaty	**1,73 (95)**	**0,75**	2,33 (83)	2,24	1,90 (84)	1,01	**2,17 (99)**	**0,65**	1,13 (75)	1,03
Akmola	1,22 (82)	1,08	1,70 (73)	2,84	1,31 (67)	1,82	0,64 (76)	1,08	0,57 (54)	1,52
Aktobe	1,67 (88)	0,92	2,79 (82)	2,53	1,90 (80)	1,83	0,62 (64)	0,87	1,42 (78)	1,43
Atyrau	**2,35 (98)**	**0,83**	3,38 (83)	2,46	2,16 (88)	1,54	**2,29 (95)**	**0,84**	1,90 (90)	1,22
East Kazakhstan	**2,07 (96)**	**1,12**	2,22 (73)	2,75	2,89 (94)	1,66	**1,92 (96)**	**0,86**	1,29 (73)	1,51
Zhambyl	1,64 (93)	0,88	2,40 (75)	2,85	1,61 (75)	1,03	**1,96 (98)**	**0,8**	1,23 (77)	1,17
Zhetysu	1,68 (94)	0,79	2,62 (87)	2,46	2,21 (90)	1,11	**1,93 (98)**	**0,63**	0,84 (64)	1,12
West Kazakhstan	2,09 (92)	1,05	2,85 (80)	2,78	1,87 (81)	1,96	1,72 (82)	1,26	**2,28 (95)**	**1,3**
Karaganda	1,40 (92)	0,86	1,86 (80)	2,45	2,23 (86)	1,33	**1,25 (96)**	**0,82**	0,98 (71)	1,34
Kostanay	1,45 (89)	1,04	1,89 (77)	2,74	1,30 (70)	1,84	0,65 (70)	1,11	0,94 (67)	1,53
Kyzylorda	2,30 (94)	0,92	3,55 (84)	2,87	3,01 (86)	1,26	1,69 (89)	0,93	1,55 (84)	1,2
Mangystau[1]	**2,26 (99)**	**0,74**	2,67 (84)	1,91	**2,20 (95)**	**1,28**	**2,57 (96)**	**0,83**	1,87 (86)	1,18
Pavlodar	1,63 (90)	1,18	1,88 (73)	3,17	1,91 (72)	1,76	1,33 (90)	0,99	0,88 (58)	1,61
North Kazakhstan	1,27 (83)	1,16	0,92 (63)	2,94	1,08 (65)	1,84	0,69 (76)	1,21	0,78 (60)	1,55
Turkestan	1,54 (89)	0,8	2,93 (87)	2,6	1,39 (76)	0,84	**1,60 (95)**	**0,84**	1,29 (82)	1,08
Ulytau	1,91 (93)	0,97	3,01 (89)	2,7	2,61 (87)	1,41	1,17 (87)	0,92	1,54 (82)	1,45

Notes: *1. For Mangystau region the assessment was carried out only by MS Fort Shevchenko;*

2. values above the 95th or below the 5th percentile (warm and cold extremes, respectively) are highlighted in bold and bright color;

3. values above the 90th or below the 10th percentile are highlighted in pale color;

4. mean temperature anomalies over the territory of Kazakhstan were obtained by averaging data from 121 stations.

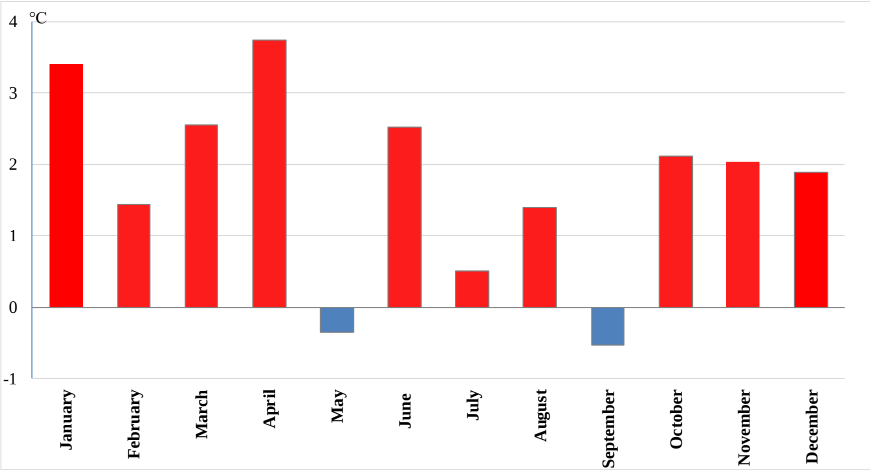


Figure 2.3 *– Mean monthly air temperature anomalies averaged over the territory of Kazakhstan in 2024, calculated relative to the average for the period 1961–1990*

Winter 2023/24 (December 2023–February 2024). On average across the country, the winter season temperature anomaly was 2,34 °C, ranking 13th in the series since 1941 (Table 2.2). In the winter season of 2023/2024, the average air temperature anomalies across the regions were positive and significantly exceeded the climatic norm (from 0,92 °C to 3,55 °C) (Table 2.2). In winter, anomalies were positive throughout the Republic, with the exception of a small area in the mountainous regions of the east and extreme southeast of the country, where they were 0,8–0,9 °C below normal (Figure 2.4). In the northern, eastern, central, and far eastern regions, as well as in the mountainous areas of the southeast and south, temperatures were near normal (anomalies up to 1 °C). In the west, southwest, south, the Balkash lake region, the east, and the northeast, temperature anomalies exceeded 3 °C, reaching maximums of 4,0–4,1 °C in the Aktobe, Turkestan, and Zhetysu regions.

In five regions, air temperature anomalies were among the 10 % of extremely high values, ranging from 3,0 to 4,1 °C in the Turkestan, East Kazakhstan, Zhetysu, and Abay regions (Figure 2.4).

In **December 2023**, the average air temperature anomaly across Kazakhstan was –2,18°C relative to the 1961–1990 climate norm (14th coldest rank, Table 2.3). Positive air temperature anomalies prevailed across almost the entire country, with the exception of the far eastern and northeastern regions, where the anomaly ranged from –0,1 to –1,2 °C (Figure 2.5). The largest positive deviations from the norm, exceeding 3 °C, were observed in the western, central, and eastern regions, reaching a maximum value of 5,2 °C in the East Kazakhstan region. These values corresponded to the 77th–89th percentile. At eight meteostations located in the Atyrau, Aktobe, Kostanay, Karaganda, and Ulytau regions, 10 % extremes were recorded with positive air temperature anomalies ranging from 2,9 to 4,4 °C. Temperature conditions close to the climatic norm (deviations did not exceed ±1 °C) were observed in the northern regions, mountainous areas of the south and southeast, as well as in some parts of the east and northeast of the country (Figure 2.5).

Table 2.3 – Regionally averaged mean monthly air temperature anomalies in 2024: ***vT*** *– deviations from the mean for 1961–1990, ℃;* ***P(t≤T₂₀₂₄)*** *– probability of non-exceedance (in brackets) calculated from data for the period 1941–2024 and expressed in %.*

Region	12 (2023)	1	2	3	4	5	6	7	8	9	10	11
Kazakhstan	2,18 (84)	3,4 (90)	1,44 (49)	2,56 (76)	**3,74 (95)**	-0,35 (37)	**2,53 (99)**	0,51 (66)	1,40 (77)	-0,54 (23)	2,12 (88)	2,03 (77)
Abay	2,33 (77)	4,44 (93)	-0,51 (33)	3,87 (82)	3,08 (88)	1,50 (72)	2,29 (93)	1,24 (80)	**3,13 (99)**	-1,85 (7)	2,26 (89)	2,93 (75)
Almaty	1,86 (78)	**4,5 (98)**	0,62 (42)	2,47 (75)	1,68 (82)	1,61 (83)	**2,83 (98)**	1,11 (80)	**2,60 (99)**	-0,88 (13)	2,06 (87)	2,23 (78)
Akmola	1,68 (73)	2,26 (75)	1,09 (55)	1,82 (69)	3,80 (90)	-1,70 (16)	2,12 (90)	-0,08 (60)	-0,08 (37)	-0,89 (24)	1,62 (65)	0,97 (60)
Aktobe	2,83 (83)	2,68 (75)	2,89 (70)	1,93 (67)	**6,31 (98)**	-2,54 (12)	2,41 (87)	-0,51 (43)	-0,05 (41)	0,38 (54)	2,45 (81)	1,46 (77)
Atyrau	2,63 (89)	2,63 (61)	4,80 (81)	2,30 (71)	**6,03 (99)**	-1,87 (18)	3,27 (90)	1,97 (90)	1,60 (73)	2,00 (89)	2,17 (77)	1,50 (80)
East Kazakhstan	2,80 (77)	4,1 (92)	-0,28 (33)	3,91 (82)	2,99 (87)	1,79 (76)	1,92 (87)	1,29 (83)	**2,58 (99)**	-1,75 (8)	2,31 (89)	3,27 (83)
Zhambyl	1,47 (69)	4,29 (90)	1,43 (48)	2,23 (71)	1,84 (88)	0,74 (63)	**3,07 (100)**	0,57 (66)	**2,29 (99)**	-0,97 (17)	2,09 (86)	2,54 (77)
Zhetysu	2,01 (75)	**5,41 (98)**	0,41 (45)	2,90 (76)	1,85 (82)	1,86 (88)	**2,26 (95)**	1,04 (81)	**2,55 (100)**	-1,56 (10)	2,03 (88)	2,00 (73)
West Kazakhstan	3,34 (84)	1,78 (53)	3,40 (70)	1,70 (65)	**6,71 (98)**	-2,83 (10)	3,19 (87)	1,38 (77)	0,66 (55)	1,56 (83)	3,03 (89)	2,23 (87)
Karaganda	2,83 (86)	3,17 (89)	-0,40 (37)	2,56 (75)	3,50 (92)	0,63 (57)	2,25 (93)	-0,04 (53)	1,52 (75)	-1,70 (12)	2,75 (92)	1,91 (71)
Kostanay	2,03 (72)	2,06 (67)	1,58 (59)	1,65 (67)	**4,81 (96)**	-2,52 (8)	2,38 (88)	-0,21 (52)	-0,24 (40)	-0,25 (41)	1,60 (64)	1,50 (71)
Kyzylorda	2,64 (83)	3,45 (76)	4,60 (70)	4,21 (80)	**4,96 (96)**	-0,13 (37)	**3,63 (99)**	-0,11 (45)	1,60 (76)	0,22 (45)	2,66 (86)	1,70 (73)
Mangystau[1]	1,6 (80)	2,3 (66)	4,10 (82)	2,00 (66)	**5,40 (100)**	-0,80 (34)	2,70 (89)	2,30 (93)	2,80 (83)	3,00 (90)	1,20 (61)	1,40 (80)
Pavlodar	1,08 (60)	2,37 (71)	2,19 (63)	3,78 (81)	3,10 (87)	-1,18 (22)	2,12 (88)	0,78 (80)	1,02 (63)	-1,24 (17)	1,71 (66)	2,15 (69)
North Kazakhstan	0,31 (52)	1,79 (64)	0,64 (53)	1,86 (72)	3,58 (88)	-2,20 (8)	2,23 (93)	-0,26 (53)	0,10 (45)	-0,17 (43)	1,07 (52)	1,46 (72)
Turkestan	1,71 (71)	4,82 (92)	2,26 (55)	1,80 (72)	2,03 (92)	0,36 (53)	**2,72 (98)**	0,42 (63)	1,63 (86)	0,08 (51)	1,64 (72)	2,19 (81)
Ulytau	4,03 (92)	3,70 (86)	1,33 (54)	3,03 (73)	**4,63 (96)**	0,20 (47)	**2,93 (99)**	-0,63 (40)	1,17 (67)	-0,50 (29)	3,30 (94)	1,80 (67)

Notes: *1. For Mangystau region the assessment was carried out only by MS Fort Shevchenko;*

2. values above 95th or below 5th percentile (respectively warm 95 % and cold 5 % extremes) are highlighted in bold and bright color.

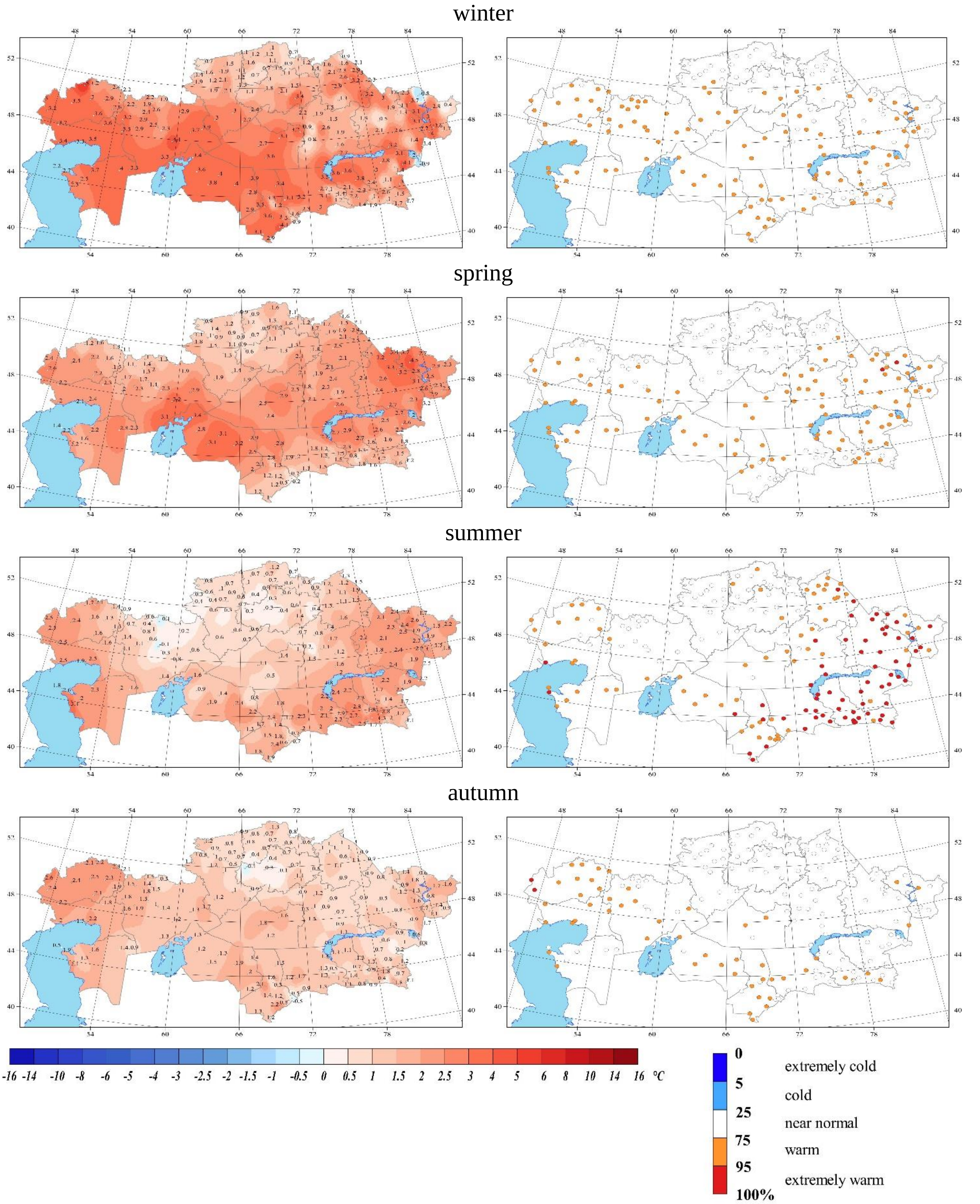


Figure 2.4 *– Spatial distribution of air temperature anomaly (°C) in 2024, calculated relative to the base period 1961–1990, and probabilities of non-exceedance of air temperature values in 2024, calculated from the data of the period 1961–2024*

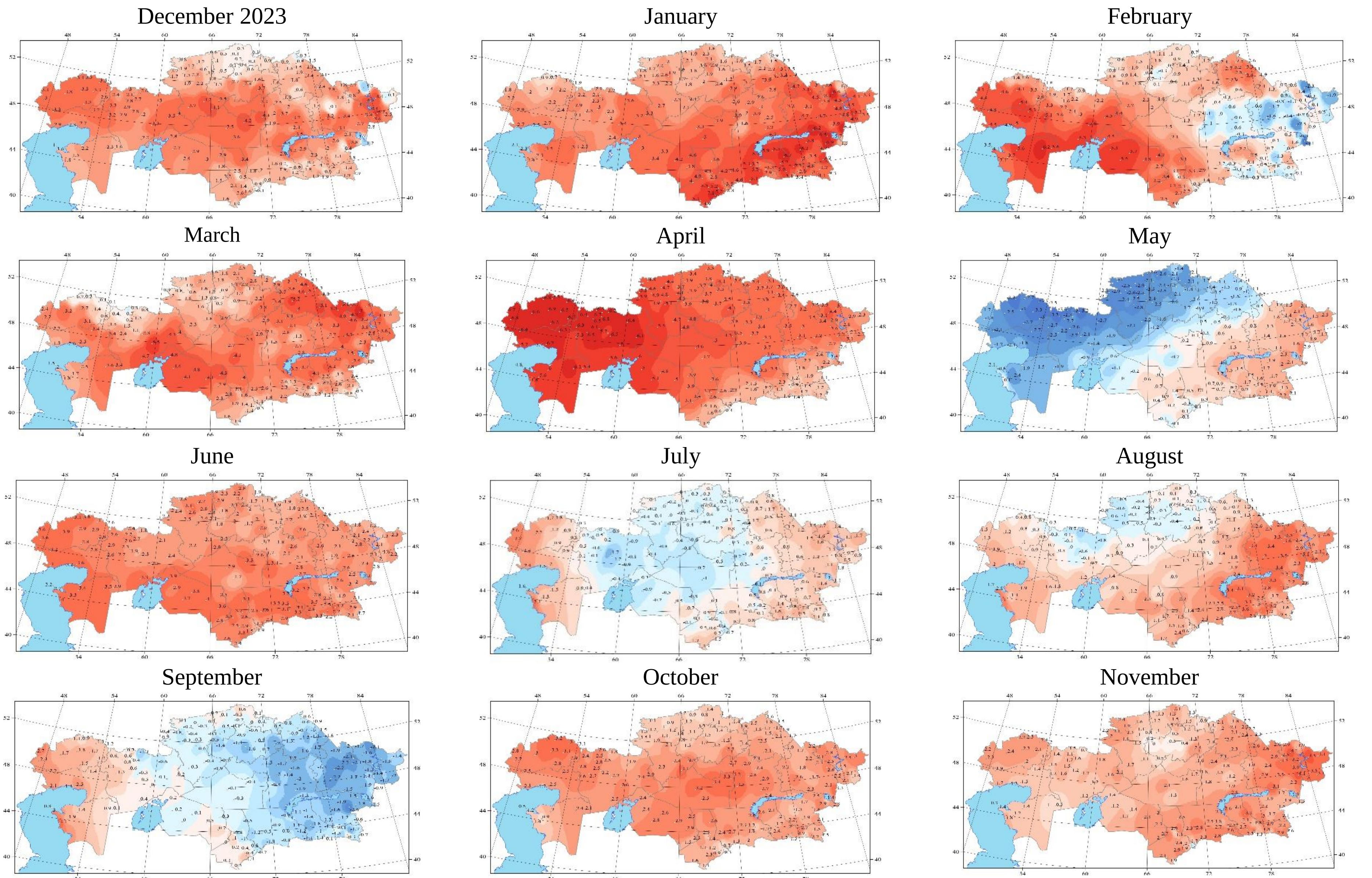


***Figure 2.5** – Spatial distribution of the anomaly of mean monthly air temperature (°C) in 2024 calculated relative to the base period 1961–1990*

In **January 2024**, the average air temperature anomaly across Kazakhstan was above the climatic norm and amounted to +3,40 °C, which corresponds to the 9th rank for the entire observation period since 1941 (probability of not exceeding — 90 %, Table 2.3). The average monthly air temperature anomaly was positive throughout the country. In the Almaty and Zhetysu regions, the average anomalies for the territory were among the 5% highest and amounted to +5,41 °C and +4,50 °C, respectively. In four other regions — East Kazakhstan, Zhambyl, Turkestan, and Abay — 10% extremes were observed, with average anomalies across the territory ranging from +3,40 °C to +4,44 °C. In the south, southeast, in the Balkhash region and in the east of the republic, the average monthly air temperature significantly exceeded the norm — by more than 4 °C, and in some places by more than 6 °C. Temperatures close to normal and slightly above normal (from +1,0 to +2,0 °C) were observed in the north, northwest, and in some areas of the far west of the republic (Figure 2.5).

At 42 meteorological stations in the republic, anomalies in the average monthly air temperature were among the 5 % and 10 % of extremely high values. Five meteostations located in the Turkestan, Zhetysu, and Abay regions recorded record average air temperatures for January (Figure 2.5, Annex 1).

In **February**, the average air temperature anomaly across Kazakhstan was above the climatic norm and amounted to 1,44 °C (rank 43, Table 2.3). Positive air temperature anomalies were observed in the west, southwest, north (except for the southern part of the North Kazakhstan region), northeast, southern part of the Balkhash region, and in some places in the eastern regions (Figure 2.5). Significantly above-normal temperatures were recorded in a number of regions: in most of the Mangystau region, in the southern part of the Aktobe region and in the central part of the Kyzylorda region, as well as locally in the West Kazakhstan and Atyrau regions. Here, the anomalies reached +5,1...5,7 °C, with a maximum value of +6,2 °C. Moderately warm conditions prevailed in the western regions (probability of not exceeding 76 to 89 %), corresponding to the "warm" gradation. Negative air temperature anomalies were recorded in most of East Kazakhstan, Karaganda, and Abay regions, in the mountainous areas of the extreme southeast, as well as in isolated pockets in the north of the country. In the far east, a pocket formed with anomalies significantly below the climatic norm, ranging from −1,9 to −3,1 °C. Lower seasonal temperatures were observed here, corresponding to the "cold" classification (10–25th percentile).

In ***spring***, the average air temperature anomaly across Kazakhstan was +1,99 °C, ranking 17th in the series since 1941 (Table 2.2). The warmest spring season since 1941 remains spring 2020, with an anomaly of +3,84 °C. Throughout the country, anomalies significantly exceeded the climatic norm (Figure 2.2), with average air temperature anomalies ranging from +1,1 to +3,0 °C across the regions of Kazakhstan. Positive air temperature anomalies of more than 2 °C extended from east to west, with significant positive anomalies recorded in the east and southwest of the country, where they ranged from about 3,1 to 4,5 °C. Locally, in the north and in the mountainous areas of the southeast, air temperature anomalies were close to normal, ranging from 0,2 to 0,9 °C. The average temperature anomaly for the Mangystau region was among the top 5% of extremely high anomalies and amounted to +2,20 °C. The average air temperature anomalies for the three regions – East Kazakhstan, Zhetysu, and Abay – were among the 10% highest, at +2,89, +2,21, and +2,89 °C, respectively.

Almost throughout Kazakhstan, with the exception of the northern, northwestern, and mountainous regions of the south and southeast, temperatures corresponded to the "warm" category and exceeded the climatic norm. Two meteostations in the eastern regions recorded anomalies that fell within the 5% range of extremely high values (probability of not exceeding 96–99%).

In **March**, the average air temperature anomaly across Kazakhstan was above the climatic norm and amounted to 2,56 °C (rank 21 with a probability of not exceeding 76 %, Table 2.3). Positive air temperature anomalies were observed throughout the country, with the exception of a small part of the north of the Aktobe region. Temperatures significantly above normal were recorded in the southwestern (+4.1...5.5 °C) and northeastern (4.0...7.0 °C) parts, as well as in separate areas in the east, in the southern part of the Balkhash region, and in the Ulytau region. Warm conditions prevailed here with a probability of not exceeding 76 to 89 %, which corresponds to the “warm” classification. Temperature anomalies close to normal (up to ±1°C) were observed in the far north of the West Kazakhstan and Aktobe regions, in some areas of the northern regions, as well as in the mountainous areas of the extreme south and southeast of the country.

In **April**, the average air temperature anomaly across Kazakhstan was 3.74 °C (rank 5 with a 95 % probability of not being exceeded, Table 2.3). Record warm conditions in June were observed in the Mangystau region: the average monthly air temperature anomaly across the region was +5.40 °C. In six other regions (West Kazakhstan, Atyrau, Aktobe, Kostanay, Kyzylorda, and Ulytau regions) had average air temperature anomalies in the top 5 % of extremely high values, ranging from +4.63 °C (Ulytau region) to +6.71 °C (West Kazakhstan region). Positive anomalies were observed throughout almost the entire territory of the republic. Temperature anomalies of more than +4 °C covered the entire western half of the territory, as well as separate areas in the north and east of the country. Temperature anomalies above +6 °C covered the entire territory of the West Kazakhstan region, most of the Atyrau and Aktobe regions, as well as a separate area in the Mangystau region (Figure 2.5). Anomalies close to normal and slightly below normal (from +0.4 to +1.7 °C) were observed in the mountainous areas of the south and southeast.

In April, 63 meteostations in Kazakhstan recorded extremely high air temperatures, exceeding the 95th percentile. Eight of these stations (Annex 1), located in the far western regions, recorded record high seasonal air temperatures for the entire observation period since 1941 (Figure 2.5). At another 38 meteostations, temperature anomalies were among the 10% highest seasonal anomalies.

In **May**, the average temperature anomaly across Kazakhstan was 0.35 °C below the 1961–1990 norm (rank 53, Table 2.3). Most of the country was in the zone of negative air temperature anomalies in May: this includes the entire western, northern, northeastern, central, and southwestern parts of the republic. The most pronounced negative anomalies were observed in most of West Kazakhstan, in the north of Atyrau and Aktobe, in the northwest of Kostanay, as well as in some parts of North Kazakhstan. The minimum values of anomalies reached −2.4...−3.3 °C (Figure 2.5). In West Kazakhstan, Kostanay, and North Kazakhstan regions, the average air temperature anomalies across the territory were among the 10% of extremely low values, ranging from −2.20 to −2.83 °C. Positive air temperature anomalies were observed in the eastern, southeastern, and most of the central and southern regions of the country (Figure 2.5). The most significant positive deviations from the norm (up to +2.9 °C) were recorded in the mountainous areas of Almaty, East Kazakhstan, and Abay regions, as well as in the east of Zhetysu region.

Among the extreme characteristics of May, it is worth noting the cold temperatures that prevailed in the far north-west and northern parts of the western regions of Kazakhstan. At 13 meteostations located in these areas, air temperature anomalies fell within the 5 % range of extremely low values. Another 31 meteostations recorded anomalies that fell within the 10 % range of extremely low temperatures (Figure 2.5). At the same time, at six meteostations located in the extreme southeast of the country, air temperature anomalies fell within the top 5 % and 10 % of extremely high values.

In ***summer***, the average summer temperature anomaly across the country was extremely high, reaching +1.48 °C, which is the sixth highest value in the series with a probability of not exceeding 94 % (Table 2.2). The warmest summer season remains 1998, with an anomaly of 2.23 °C. Temperature anomalies were above the climatic norm across virtually the entire territory of Kazakhstan, with the exception of the Aktobe region, where anomalies were 0.1 °C below the norm at two meteostations (Figure 2.4). Starting from the northwest and north, where they were about 0.2–0.4 °C, the magnitude of positive air temperature anomalies gradually increased in the western, southern, southeastern, and eastern regions, reaching 2.1–3.4 °C. Record temperature anomalies on average across the territory were recorded in the Abay region (+2.21 °C). In 11 regions located in the central, southern, southeastern, eastern, and western regions of Kazakhstan, air temperature anomalies were among the 5 % of extremely high values (probability of not exceeding 96–99 %) with values ranging from 1.1 °C (Almaty region) to 2.8 °C. In five other regions — West Kazakhstan, Aktobe, North Kazakhstan, Akmola, and Ulytau — temperatures exceeded the climatic norm within the “warm” range, with anomalies ranging from 1.0 °C to 2.5 °C.

According to data from approximately 66 meteostations in Kazakhstan, summer temperatures exceeded the 95th percentile, including 23 meteostations located in the southern, southeastern, and eastern regions, which recorded record high seasonal temperatures since 1941. In addition, 22 meteostations recorded air temperature anomalies that were among the top 10 % of extremely high seasonal anomalies.

In **June**, the average air temperature anomaly across Kazakhstan was 2.53 °C (rank 2, Table 2.3). Record high temperatures in June were recorded in the Zhambyl region, with an average monthly air temperature anomaly of +3.07 °C across the region. In five other regions (Almaty, Kyzylorda, Turkestan, Ulytau, and Zhetysu), the average temperature anomalies across the territory were among the 5% most extreme, with values ranging from +2.26 °C (Zhetysu) to +3.63 °C (Kyzylorda region). Positive air temperature anomalies were observed throughout the country (Figure 2.5). The highest anomaly values – within the range of +3.0...+4.0 °C – were recorded in the western, southwestern, and most of the southern regions, as well as locally in the central, northwestern, and northeastern regions. Temperatures above the climatic norm within the “warm” range (probability of not exceeding 76–89 %) were recorded almost throughout the entire territory of Kazakhstan.

Extremely high air temperatures (above the 95th percentile) were recorded at 51 meteostations located in the southern, southeastern, eastern, and central parts of the country, as well as in the south of Pavlodar and north of Akmola regions. Of these, 11 meteostations recorded absolute records for the average monthly air temperature for the entire observation period (since 1941) (Annex 1).

July was close to the climatic norm: the average monthly air temperature across Kazakhstan was 0.51 °C above the climatic norm (Table 2.3). Air temperatures within the range of ±1 °C (within the norm) were observed in most of the country, except for the extreme western and eastern regions, where positive anomalies were recorded, as well as a separate area in the central part of the Aktobe region with a negative anomaly of up to −1.7 °C. In the coastal zone of the Caspian Depression, the western part of the East Kazakhstan region, the extreme south, as well as in the mountainous areas of the southeast and east of the country, positive air temperature anomalies were observed with values ranging from +1.5 to +2.4 °C. According to data from five meteostations located in these regions, the temperature anomalies were among the 10 % of extremely high values.

In **August**, the average monthly air temperature across Kazakhstan was 1.40 °C above the climatic norm (rank 20 with a 77 % probability of not exceeding, Table 2.3). The Zhetysu region experienced record high temperatures, with an average monthly air temperature anomaly of +2.55 °C across the region. In four other regions, the average temperature anomalies across the territory were among the 5 % of extremely high anomalies, with values ranging from +2.29 °C for the Zhambyl region to +3.12 °C for the Abay region. Positive air temperature anomalies were observed across most of the republic. Values above +3°C were recorded across a significant part of the Almaty and Abay regions, as well as in some parts of the East Kazakhstan and Zhetysu regions. Air temperature anomalies within ±1 °C (close to normal) were recorded across most of the Aktobe and West Kazakhstan regions, in some areas of the central regions, and in the Pavlodar region. Negative anomalies were observed only in a small area in the north-west of the country, where deviations reached −1.2 °C (Figure 2.5).

At 55 meteostations, air temperature anomalies reached 5% of extremely high values. At the same time, 20 stations located in the southeastern regions recorded new record values for the average monthly air temperature for the entire observation period (Annex 1).

In ***autumn***, the average air temperature across the country was +1.21 °C above normal (rank 17, Table 2.2). The warmest autumn season since 1941 remains autumn 2024, with an anomaly of +3.27 °C, and the coldest autumn period is autumn 1976, with an anomaly of –3.56 °C. In addition, most regions experienced above-normal air temperature anomalies, averaging between +1.03 and +1.61 °C. The average anomaly in the West Kazakhstan region was among the top 5% of extremely high values, reaching +2.28 °C. In the Atyrau region, the air temperature anomaly was among the 10% of extremely high values and amounted to +1.90 °C. Air temperatures exceeded the norm in most of the country, with the exception of a small area with a negative anomaly (-0.1 °C) in the Akmola region. In the north, northeast, east, and eastern part of the central regions, temperatures were near normal (up to +1.0 °C). In the central, southwestern, southern, southeastern, and eastern regions, temperatures exceeded the norm by more than 1.1 °C, and in the west and locally in the southern regions — by more than 2.0 °C, reaching a maximum of +2.6 °C in the extreme part of the West Kazakhstan region. At seven meteostations in the West Kazakhstan and Atyrau regions, air temperature anomalies reached 5 % and 10 % of extremely high values.

In **September**, the average temperature anomaly across Kazakhstan was 0.54 °C below the 1961–1990 norm (probability of not exceeding 23%, Table 2.3). Extremely cold conditions (10 % extremes) were observed in the Zhetysu, East Kazakhstan, and Abay regions, where the average anomalies across the territory were –1.56 °C, –1.75 °C, and –1.85 °C, respectively. Almost the entire eastern half of Kazakhstan was in the zone of negative air temperature anomalies, with their intensity increasing in the western direction. Significant negative anomalies were observed in most eastern regions, in most of the Karaganda Region and the Zhetysu Region (up to –2.6 °C), as well as in separate areas and pockets in the Akmola, Pavlodar, and Almaty regions (up to –2.0 °C). Temperature anomalies within ±1 °C, corresponding to values close to the climatic norm, were observed in the northern and southern regions of the country, in most of the central regions, in the Aktobe region, as well as in the eastern part of the Mangystau region and the mountainous regions of the southeast. Positive air temperature anomalies were observed in the East Kazakhstan and Atyrau regions, most of the Mangystau region, and the western part of the Aktobe region. In the far west of the country, there were sustained positive air temperature anomalies significantly exceeding the climatic norm, ranging from +2.1 to +3.1 °C (Figure 2.5).

Twenty-six meteostations located in the eastern, southeastern, and central regions recorded extremely low air temperatures, corresponding to the 10 % and 5% extremes. At the same time, meteostations located in the western regions of West Kazakhstan and Mangystau regions recorded temperature anomalies in the 5 % and 10 % range of extremely high values.

In **October**, the average monthly air temperature anomaly across Kazakhstan was 2.12 °C (rank 11, probability of not exceeding 88 %, Table 2.3). In the Karaganda and Ulytau regions, the average temperature anomalies across the territory were among the 10 % of extremely high anomalies, with values of +2.75 °C and +3.30 °C, respectively. Temperatures close to and slightly above normal, ranging from 0.3 to 2.0 °C, were observed in the north of the country, in most of the southern and southeastern regions, in the west of the Mangystau region, as well as in some areas in the eastern regions. Air temperature anomalies above +3.0 °C were observed mainly in the north of the West Kazakhstan region, the south of the Kostanay region, and in the central regions.

At 21 meteostations located in the western, central, eastern, and southern regions, the average monthly air temperature anomalies were in the 5 % and 10 % range of extremely high values (Figure 2.5).

In **November**, the average monthly air temperature anomaly across Kazakhstan was +2.03 °C (Table 2.3). Positive air temperature anomalies were observed throughout the country. Temperatures close to normal (from −0.1 to +2.0 °C) were recorded in a significant part of the northern, western, southwestern, and central regions, as well as in the mountainous areas of the south and southeast of the country. Positive air temperature anomalies within the range of +2.1...+2.9 °C prevailed in most of the southern, southeastern, and northeastern regions, as well as in West Kazakhstan, the northwestern part of the Kostanay region, and in isolated areas in the east of the Aktobe region, the north of the North Kazakhstan region, the east of the Akmola region, and in the central regions. In these regions, such values corresponded to the 77–89th percentile. Areas of more pronounced heat with anomalies within +3.0...+4.5 °C were observed in the east of the country, as well as in separate areas in the Almaty and Zhetysu regions (Figure 2.5). In the east of the Abay region, temperature anomalies were among the 10 % highest for the entire observation period.

For the purpose of monitoring extreme values of climatic parameters that are most significant for specific sectors of the economy and social sphere, the WMO Commission for Climatology has developed the ClimPACT software product (www.climpact sci.org), which allows for the calculation of a set of specialized climate indices based on daily maximum and minimum air temperature and precipitation data. Below are the indices that are most indicative of the degree of temperature extremes in 2024.

In 2024, the warm period of the year is characterized by maximum daily temperatures exceeding 30 and even 35 °C across most of Kazakhstan (with the exception of the high-altitude areas of the southeast and east). ***The number of days when the maximum daily air temperature exceeded 30 °C (index Txge30***) increases from north to south (Figure 2.6). In the northern regions and in the northern part of the Aktobe region, the number of such days did not exceed 20, and in the mountainous areas of the southeast and east, it ranged from 0 to 13 days. In the northeastern, eastern, central, and northern parts of the western regions, the duration of periods with maximum temperatures above 30 °C varied between 21 and 79 days. In the rest of the country, the number of such days ranged from 80 to 120, with the highest value recorded in the south of the Turkestan region – 122 days.

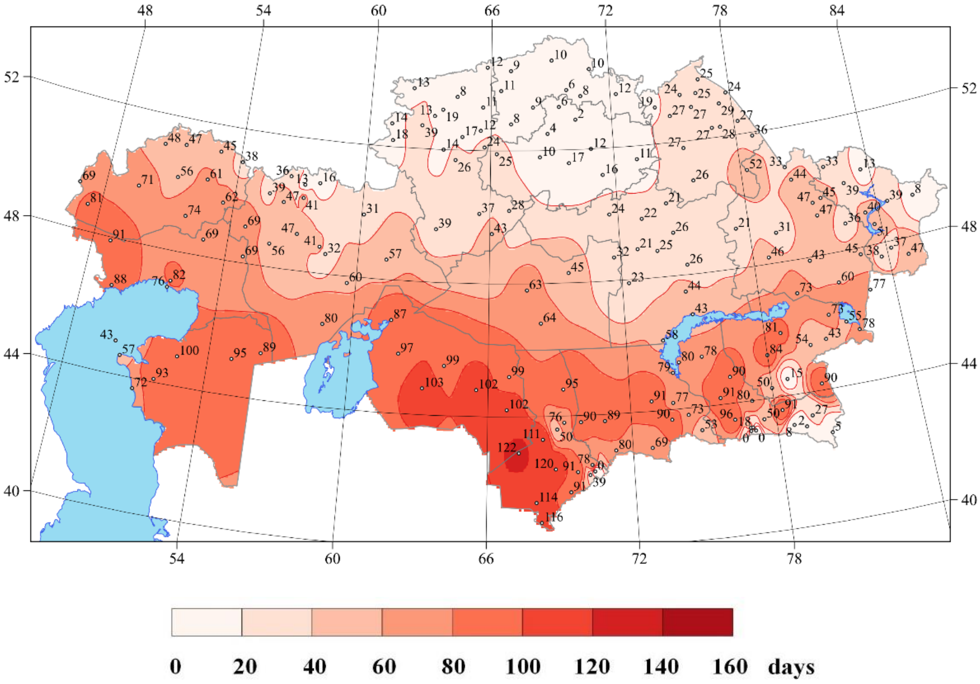


Figure 2.6 *– Number of days in 2024 when the maximum air temperature exceeded 30 °C (Txge30 index)*

One indicator of extreme temperatures during the warm season is the total duration of all heat waves. A heat wave is defined as a period of six or more consecutive days during which the heat excess coefficient has a positive value (HWF/EHF index, Figure 2.7). In Kazakhstan, the HWF/EHF index values ranged from 8 to 20 days in the northern, northwestern, northern parts of the western and central regions. Towards the south, southeast, and east, as well as in the western regions and the northwestern part of the Kostanay region, the index values increase. As a result, the total duration of all heat waves in 2024 was 31–46 days in the western regions, 32–58 days in the southern regions, and 30–52 days in the eastern and southeastern regions.

In 2024, across most of the western and southern regions of the country, with the exception of mountainous areas, as well as in certain areas of the Ulytau region and eastern regions, the **daily maximum air temperature (TXx index**) exceeded 40 °C. No daily maximum temperatures above 45 °C were recorded at any meteostation in 2024 (Figure 2.8). In other regions, the TXx index ranged from 35 to 39 °C, while in the northern regions, as well as in the mountainous areas of the south, southeast, and east, it ranged from 19 to 33 °C.

Despite the elevated temperature background in the summer months of 2024, no new records for daily maximum air temperatures were recorded. The blue color shows the absolute maximum values recorded since the station opened in 2024. In Kazakhstan, most of the highest air temperatures (absolute maximums) were recorded in July 1983, when some meteostations in the Turkestan region (MS Turkestan, Arys, Tasty), air temperatures reached +49...+50 °C, as well as in July 2023. The highest absolute maximum value for the territory of the republic was recorded in July 1995 at MS Kyzylkum, where the air temperature reached +51.0 °C (Figure 2.9).

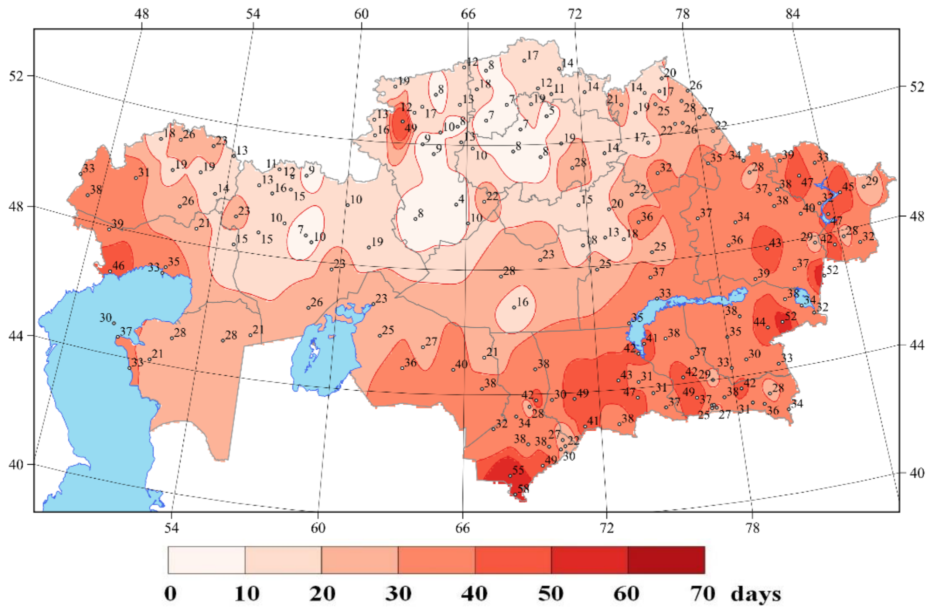


Figure 2.7 *– Total duration of warm period heat waves in 2024 (HWF/EHF index, days)*

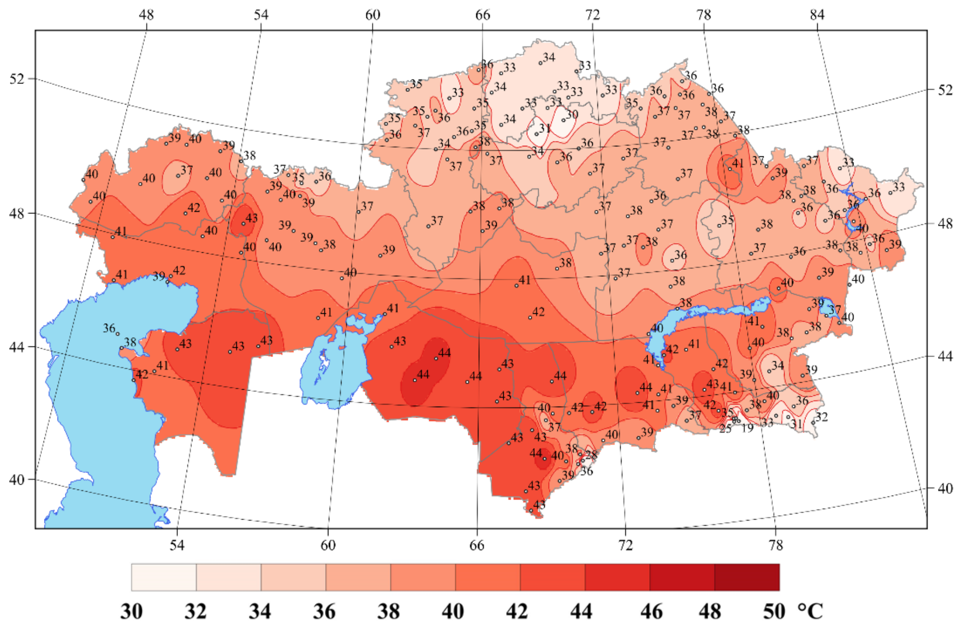


Figure 2.8 *– Values of maximum daily air temperature maxima (°C, index TXx) recorded in 2024*

Following WHO recommendations, an index has been introduced to characterize the number of days when the daily minimum temperature does not fall below 20 °C (TR index, "tropical night"), since at such nighttime temperatures the human body does not have time to recover from the daytime heat. In most of the southern and western regions, the number of days with high nighttime temperatures was the highest. In the Turkestan, Kyzylorda, and Zhambyl regions, the TR index values remained above 42–75 days, in the Mangystau and southeastern Atyrau regions – above 65–69 days, and in some places above 85 days (Figure 2.10). The minimum number of tropical nights, or their absence, was observed in the northern, central, southeastern, eastern, and mountainous regions of Kazakhstan.

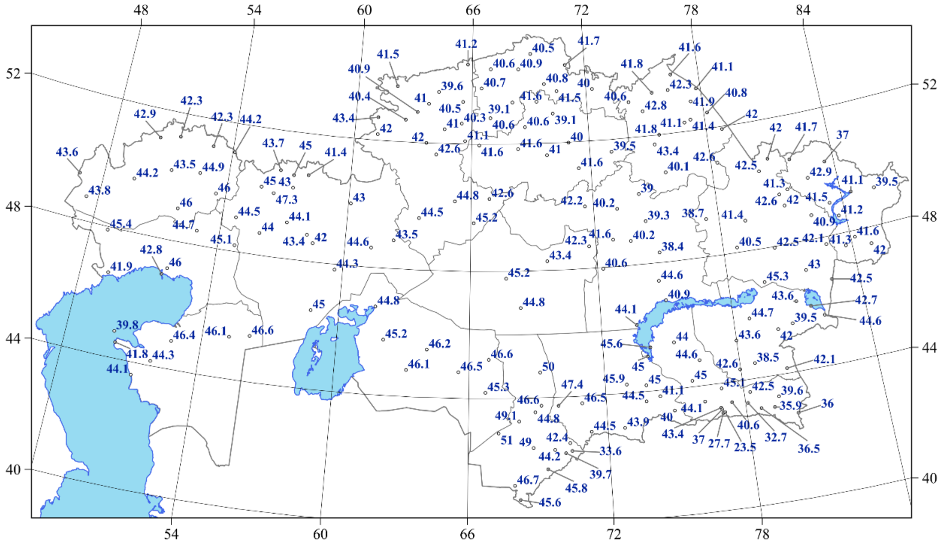


***Figure 2.9** – Absolute maximum air temperature values (°C) recorded from the beginning of the meteostation opening to 2024. If the record value of the maximum daily air temperature is recorded in 2024, this value is plotted in red*

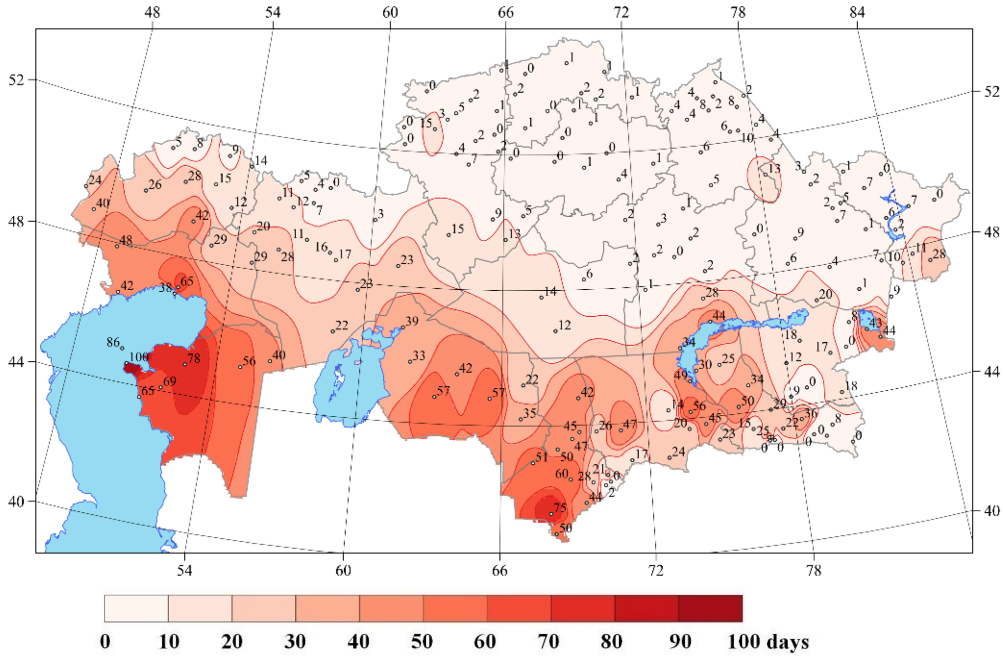


***Figure 2.10** – Number of days when the daily minimum temperature is above 20 °C in 2024 (TR index)*

Due to high air temperatures during a significant part of the warm season, especially in the western and southern regions of Kazakhstan, there was an urgent need to maintain a comfortable temperature indoors, i.e., air conditioning. In this case, a threshold of 23 °C was taken as the comfortable temperature, exceeding which means a cold deficit (CDDcold23 index, Figure 2.11). The highest index values were observed in the Mangystau and Turkestan regions, where the cold deficit reached 543–654 degree-days.

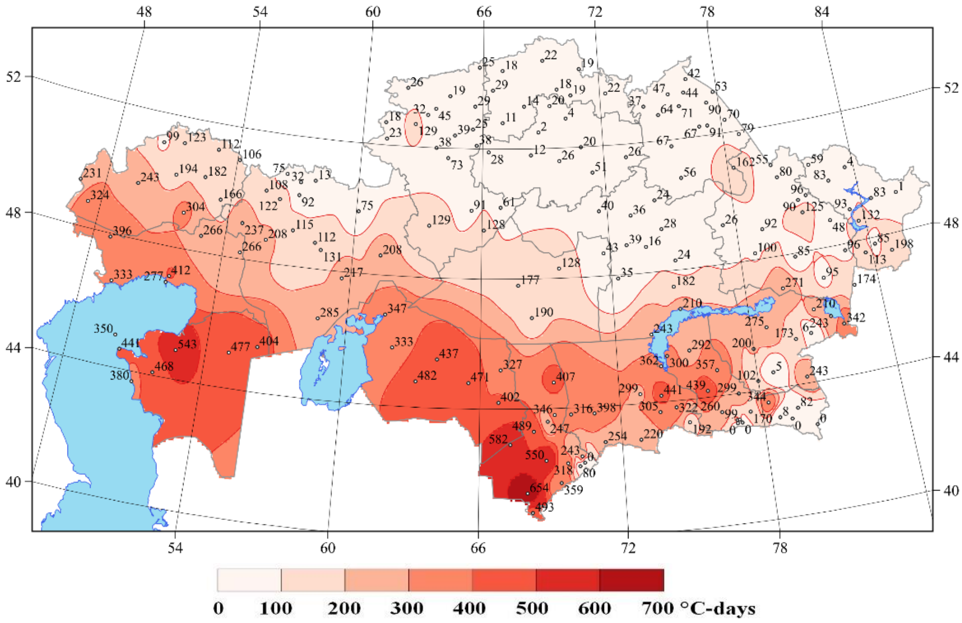


Figure 2.11 *– Cold deficit (ºC-days) observed in 2024 (CDDcold23 index)*

In January 2024, typically the coldest month of the year, significant negative anomalies and daily minimum air temperatures (TNn index, Figure 2.12) fell below minus 35–40 °C, reaching –44 °C in some places. In 2024, air temperatures below minus 30 °C were observed in the north of the Aktobe region, in the northern, north-eastern, eastern and most of the central regions, as well as in some places in the Almaty and Zhetysu regions; The lowest air temperature in 2024 was recorded at the Kokpekty meteorological station in the Abay region: minus 44.5 °C.

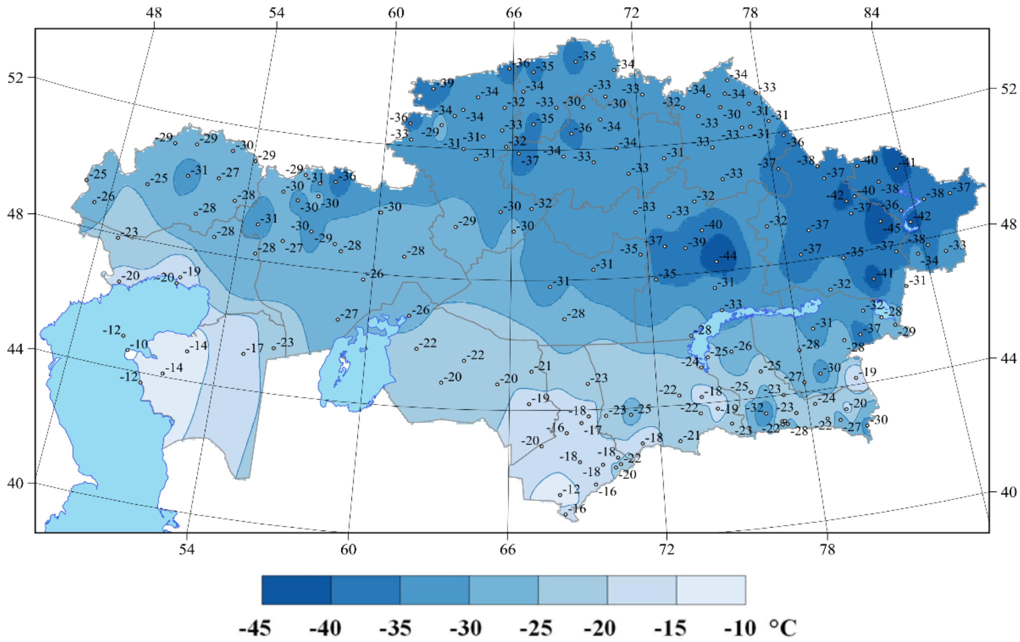


Figure 2.12 *– Daily minimum air temperature values (ºC) recorded in 2024 (TNn index)*

Figure 2.13 shows the absolute minimum air temperatures recorded since the opening of the meteostation. In Kazakhstan, absolute minimum air temperatures below minus 50 °C were recorded at two stations: in January 1931 at the Shaganatty/ Orlovsky settlement (minus 54.2 °C) and in January 1893 at the Astana meteostation (minus 52 °C). Air temperatures below minus 45 °C were observed mainly in the northern and eastern regions of Kazakhstan. In 2024, no new records for daily minimum temperatures were recorded.

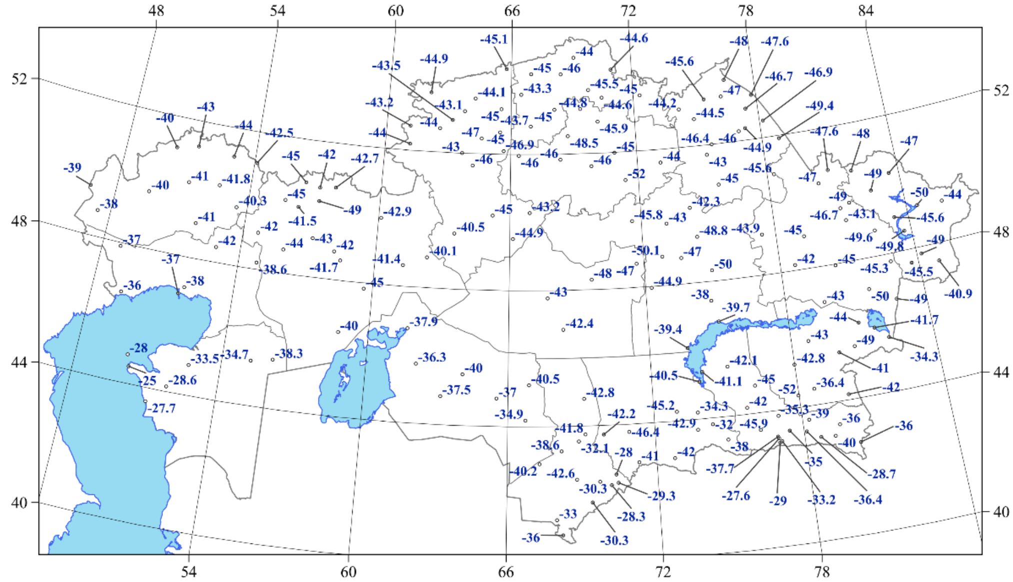


Figure 2.13 *– Absolute minimum air temperature values (°C) recorded from the beginning of the meteostation opening to 2024. If the record value of the minimum daily air temperature is recorded in 2024, this value is plotted in red*

2.2 Observed changes in air temperature

Figures 2.14–2.15 show time series of average annual and seasonal anomalies in surface air temperature averaged across Kazakhstan and its administrative regions, their 11-year moving averages for the period 1941–2024, and linear trends in air temperature change for the period 1976–2024. The anomalies are calculated relative to the base period 1961–1990. The linear trends provide clear information about the gradual increase in average annual and seasonal surface air temperatures over the last decades. Table 2.4 presents estimates of air temperature change for the period 1976–2024: the linear trend coefficient, which characterizes the average rate of change in air temperature anomaly over the time interval under consideration; and the coefficient of determination, which shows the contribution of the trend to the total variance of the time series.

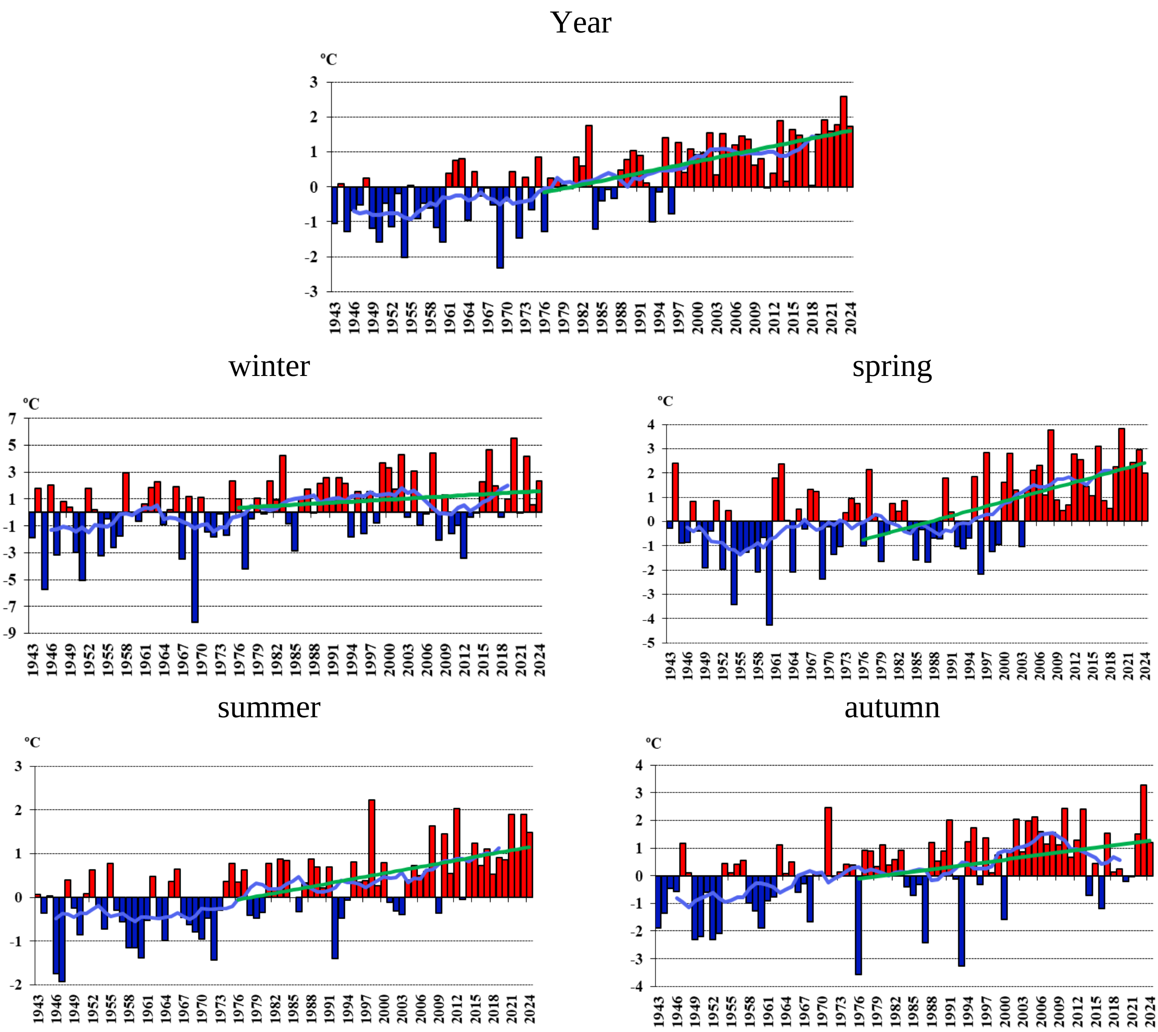


***Figure 2.14** - Time series of annual and seasonal air temperature anomalies (ºC) averaged over the territory of Kazakhstan for the period 1941–2024. Anomalies are calculated relative to the base period 1961–1990. The linear trend for the period 1976–2024 is highlighted in green color.*
The smoothed curve is obtained by 11-year moving average

On average across Kazakhstan for the period 1976–2024, the average annual air temperature has increased by 0.36 °C every 10 years, contributing 36 % to the overall temperature variability (Figure 2.14, Table 2.4). On average across all regions of Kazakhstan for the period 1976–2024, there has also been a steady increase in the average annual air temperature – the coefficients of determination are in the range of 15–59 %, with trends significant at the 5% level (Figure 2.15, Table 2.4). The warming is faster in the western, southwestern, and southern regions of Kazakhstan (from 0.47 °C/10 years to 0.56 °C/10 years), and at a slower rate in the central, northeastern, eastern, and southeastern regions (from 0.26 °C/10 years to 0.39 °C/10 years).

On average across Kazakhstan, the warming trend for the winter season is 0.26 °C/10 years (Table 2.4), but it should be noted that the trend accounts for only about 3% of the total variance and is insignificant at the 5 % level. Winter temperature trends were positive in all regions on average across their territory, but the trends mainly explain up to 5 % of the dispersion of the series and are statistically insignificant. The most noticeable rate of winter temperature increase, 0.36–0.52 °C/10 years, was observed in the western, southwestern, and southern regions of Kazakhstan – in the Atyrau, West Kazakhstan, Mangystau, Kyzylorda, Aktobe, and Turkestan regions, where the coefficient of determination is 5–15 %. In the West Kazakhstan, Atyrau, and Mangystau regions, the trend describes 7, 10, and 15 % of the total variance, respectively, and is statistically significant at the 5 % level. According to data from several stations in the far west and far south, this trend is stable (Figure 2.14). There is still a fairly large area in Kazakhstan where there is a downward trend in temperature – in the centre and north-east (up to −0.1 °C/10 years) and in the mountainous region of the east and south-east (up to −0.4 °C/10 years) of Kazakhstan.

In December 2023, there are no stable trends in changes in average monthly temperatures. Most of Kazakhstan will see negative trends, with several pockets in the southern half of the country experiencing a downward trend in air temperatures, reaching a maximum of 0.53 °C/10 years in the southern, eastern, and southeastern regions of the republic (Figure 2.17). Positive anomalies were observed in the western and northern regions, as well as locally in the east, south, and center of the country. The maximum values (0.43 °C/10 years) were recorded at the Zhalpaktal MS (West Kazakhstan Region) and the Ust-Kamenogorsk MS (East Kazakhstan Region).

In January, the area with a downward trend in air temperature covered a vast territory in the central, northern, northeastern, and eastern parts of the republic, with the maximum rate of decrease reaching 0.30–0.63 °C/10 years in the eastern region and in the south of the Abay region (Figure 2.17). The maximum positive trends were observed in the west and south, reaching 0.33–0.60 °C/10 years. Although the values of the angular coefficient for December and January temperatures are quite high, due to the large interannual variability of temperatures in these months, the contribution of the trend component to the total dispersion is insignificant. No statistically significant temperature trends have been observed.

In February, there is a trend of rising air temperatures across Kazakhstan, with maximum values in the western regions, Kyzylorda, Turkestan, and the western part of South Balkhash (0.81–1.21 °C/10 years). Only in the south of the Abay region did a slight cooling persist, with the rate of cooling reaching −0.1 °C/10 years in the center of this region. Statistically significant rates of air temperature increase in February were recorded at 57 meteostations located in the western, southern, and southeastern regions of the republic, as well as in the city of Astana (Figure 2.17).

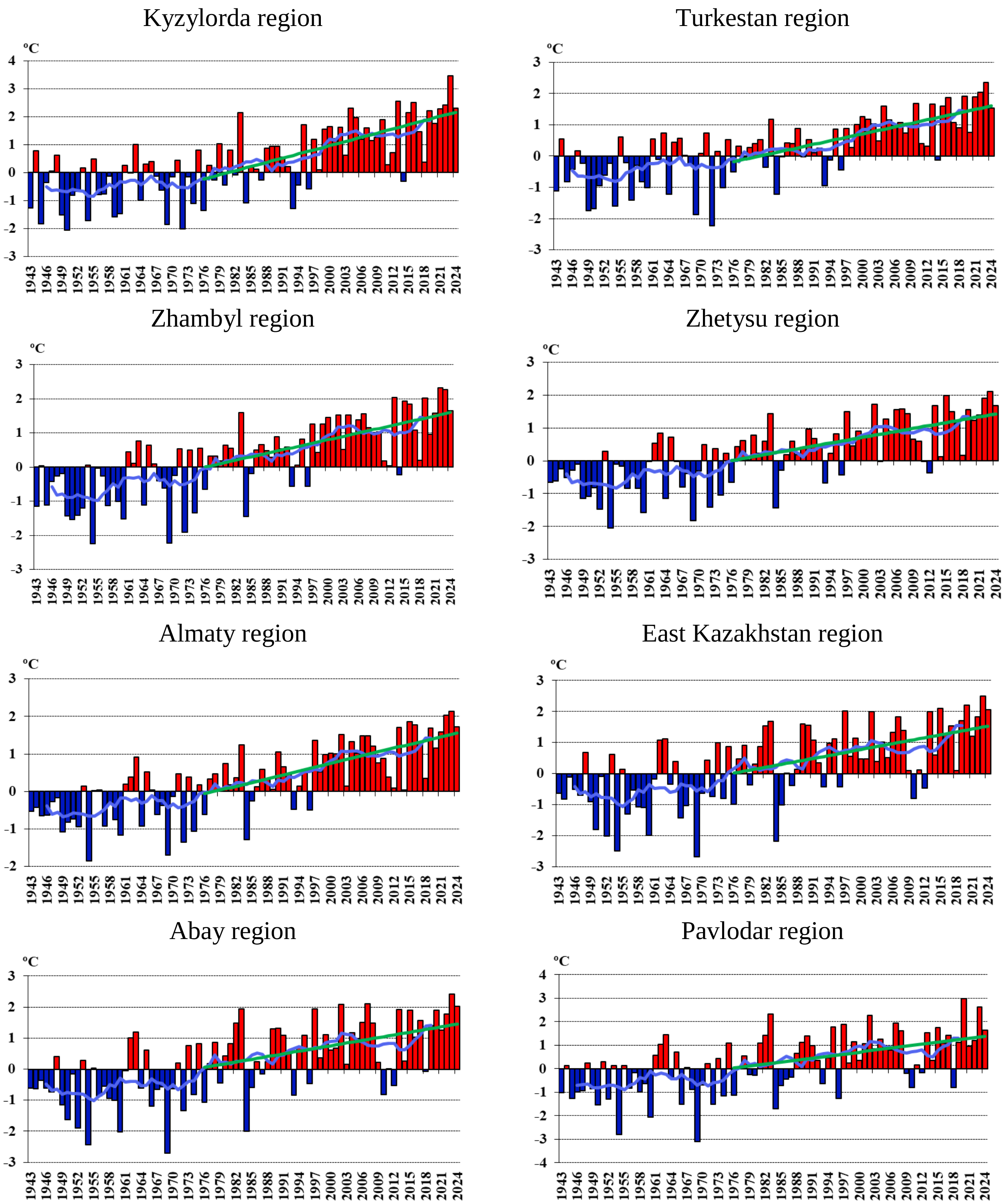


Figure 2.15 *- Time series of annual air temperature anomalies (ºC) averaged over regions of Kazakhstan for the period 1941–2024. Anomalies are calculated relative to the base period 1961–1990. The linear trend for the period 1976–2024 is highlighted in green colour. The smoothed curve is obtained by 11-year moving average. Sheet 1*

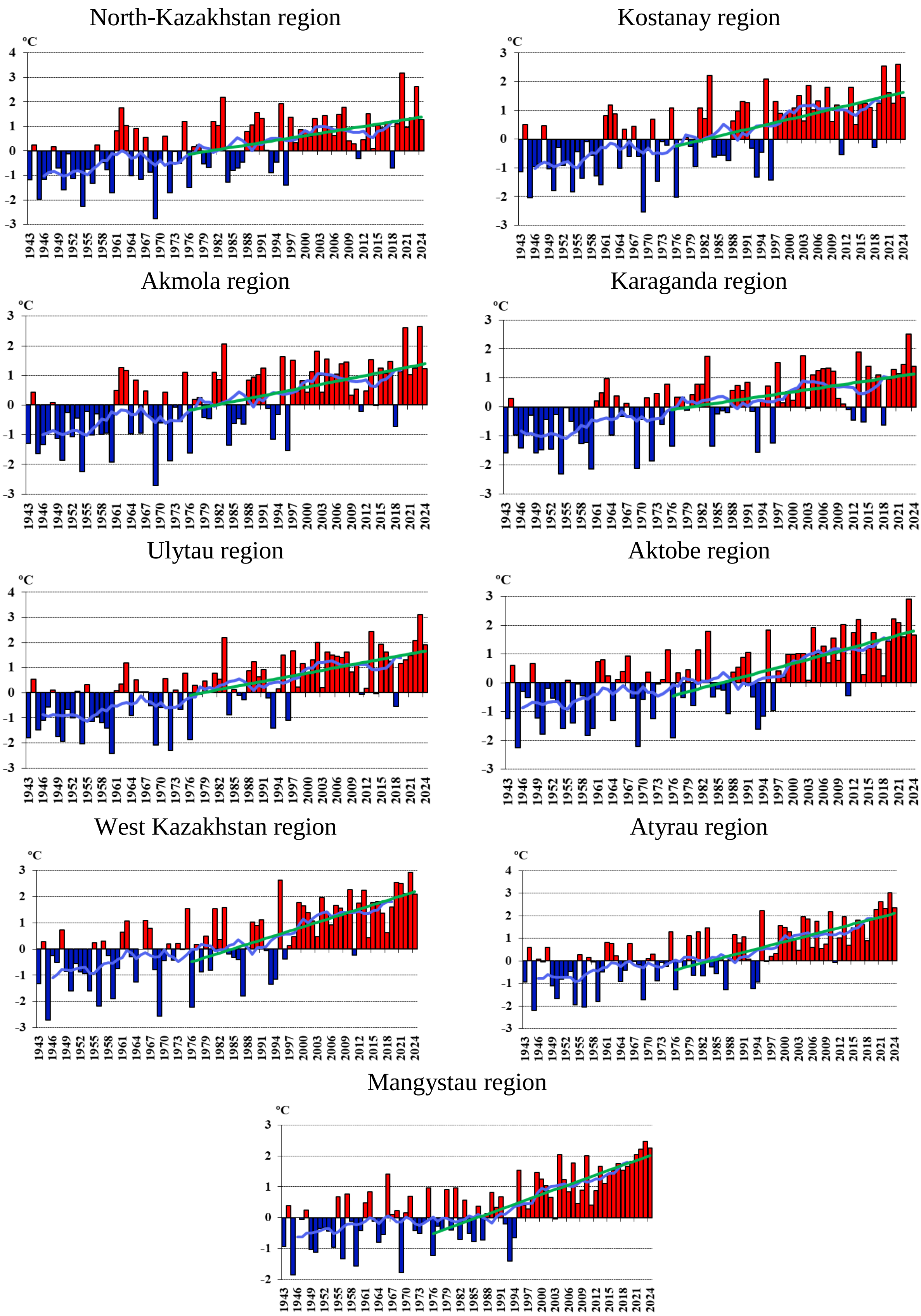


***Figure 2.15** - Time series of annual air temperature anomalies (ºC) averaged over regions of Kazakhstan for the period 1941–2024. Anomalies are calculated relative to the base period 1961–1990. The linear trend for the period 1976–2024 is highlighted in green color. The smoothed curve is obtained by 11-year moving average. Sheet 2*

The spring season shows the most intense warming trend in all regions of Kazakhstan (Table 2.4). The range of average air temperature increase by region is from 0.47 °C/10 years (Mangystau region) to 0.90 °C/10 years (Kyzylorda region) with 20–42 % explained variance. The most intense warming is observed in the eastern part of Mangystau, the south-eastern part of Aktobe, in Kyzylorda, Ulytau, Pavlodar regions and Abay region (0.73–1.00 °C/10 years) (Figure 2.16). The lowest rate of warming in the spring period is observed in the coastal part of the Caspian Sea, in the mountainous and foothill areas of the south, southeast, and the Zaisan Basin, as well as the extreme northern and northwestern regions (0.47–0.62 °C/10 years). The trends are statistically significant at all meteostations in the country. On average, the rate of air temperature increase across Kazakhstan was 0.66 °C/10 years (the contribution of the trend component was 35 %). The trend estimates are significant at the 1 % level.

Table 2.4 - Characteristics of linear trend of surface air temperature anomalies averaged over the territory of Kazakhstan and its regions for the period 1976–2024

Region	Year		Winter		Spring		Summer		Autumn	
	a	**D**	**a**	**D**	**a**	**D**	**a**	**D**	**a**	**D**
Kazakhstan	**0,36**	36	0,26	3	**0,66**	35	**0,25**	24	**0,28**	9
Abay	**0,29**	18	0,07	0	**0,70**	32	**0,20**	16	0,18	3
Almaty	**0,34**	41	0,25	4	**0,64**	38	**0,29**	32	**0,19**	6
Akmola	**0,33**	21	0,20	1	**0,66**	25	0,07	1	**0,32**	7
Aktobe	**0,47**	38	0,40	5	**0,67**	23	**0,35**	15	**0,42**	14
Atyrau	**0,52**	46	**0,52**	10	**0,58**	28	**0,53**	42	**0,43**	18
East Kazakhstan	**0,32**	20	0,15	1	**0,67**	29	**0,23**	17	0,21	4
Zhambyl	**0,33**	34	0,28	3	**0,63**	36	**0,26**	27	0,17	4
Zhetysu	**0,30**	29	0,19	2	**0,62**	33	**0,25**	28	0,15	3
West Kazakhstan	**0,56**	43	**0,50**	7	**0,62**	23	**0,56**	29	**0,50**	22
Karaganda	**0,26**	17	0,14	1	**0,69**	31	0,07	2	0,13	1
Kostanay	**0,39**	28	0,27	2	**0,64**	21	0,19	5	**0,43**	12
Kyzylorda	**0,50**	41	0,45	5	**0,90**	42	**0,35**	30	**0,29**	8
Mangystau	**0,53**	59	**0,47**	15	**0,47**	27	**0,65**	55	**0,51**	27
Pavlodar	**0,28**	15	0,06	0	**0,69**	29	0,10	2	0,27	5
North Kazakhstan	**0,31**	19	0,15	1	**0,57**	20	0,08	1	**0,40**	11
Turkestan	**0,37**	46	**0,36**	6	**0,59**	37	**0,30**	28	**0,23**	7
Ulytau	**0,37**	26	0,25	2	**0,82**	35	**0,16**	8	0,23	4

Notes: *1. a - linear trend coefficient, ºC/10 years*

2. D is the coefficient of determination, %

3. statistically significant trends at the 5 % level are highlighted in bold

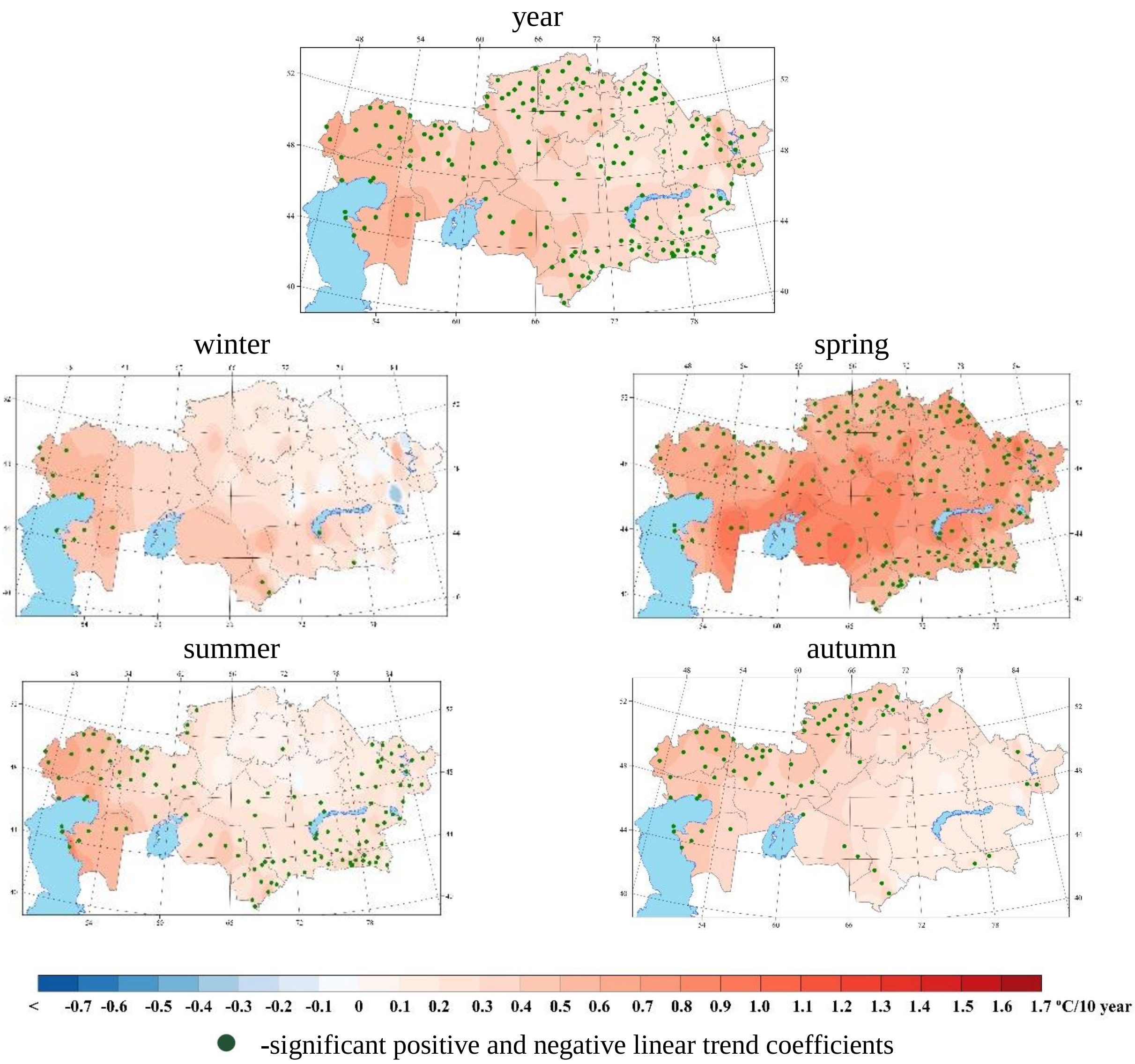


***Figure 2.16** – Spatial distribution of values of the linear trend coefficient of mean annual and seasonal surface air temperature (°C/10 years) calculated from observations for the period 1976–2024*

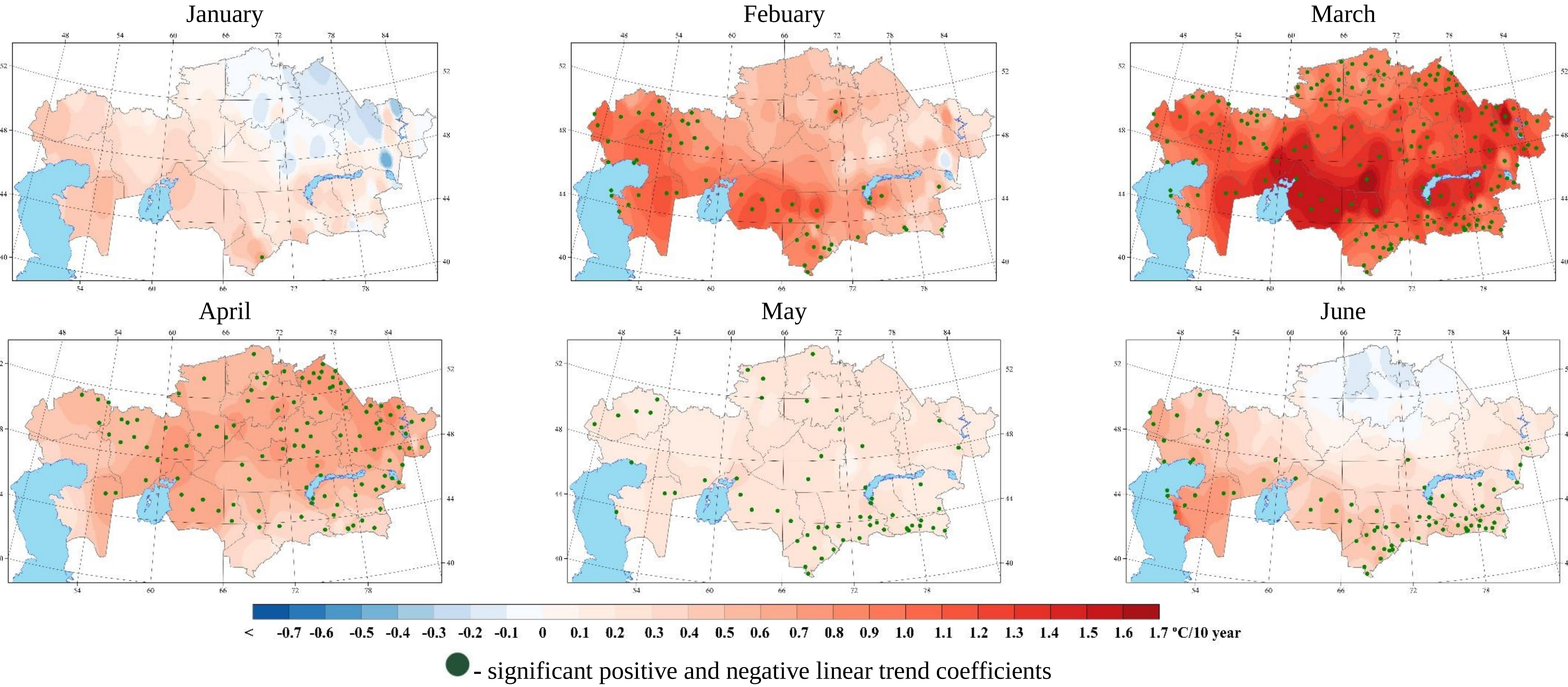
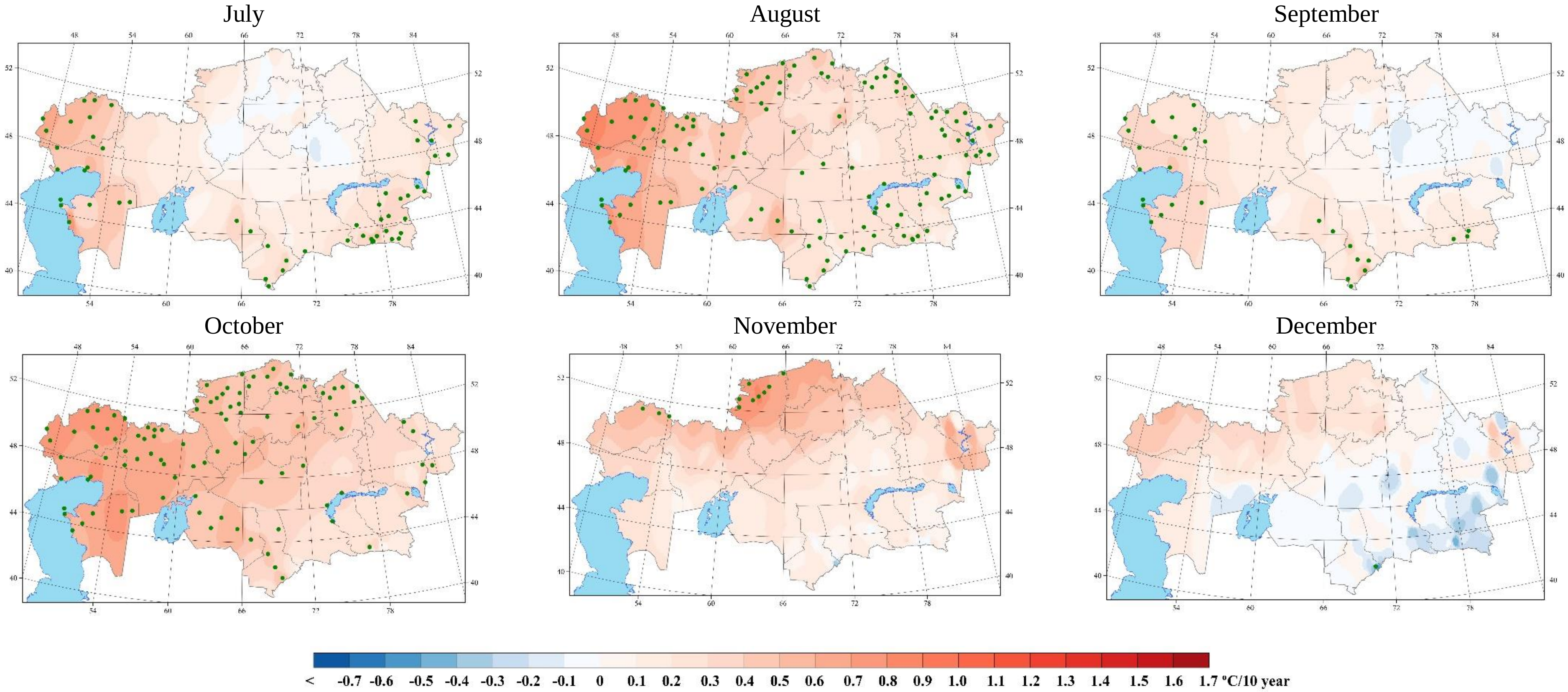


***Figure 2.17** – Spatial distribution of values of the linear trend coefficient of the mean monthly surface air temperature (°C/10 years) calculated from the observation data for the period 1976–2024. Sheet 1*



● - significant positive and negative linear trend coefficients

Figure 2.17 *– Spatial distribution of values of the linear trend coefficient of the mean monthly surface air temperature (°C/10 years) calculated from the observation data for the period 1976–2024. Sheet 2*

The highest and statistically significant rate of air temperature increase in spring, according to data from all stations, was recorded in March (by 0.72–1.76 °C/10 years), Figure 2.17. In April and May, a significant increase in air temperature was also observed throughout the country. In April, statistically significant growth rates were observed mainly in the eastern part of the Karaganda region, in the eastern region of the country, and in the southeast, approximately from 70º east longitude (in the range from 0.35 to 0.91 ºC/10 years), and in May in the opposite part (north, northwest, west, southwest, and south) of the republic (ranging from 0.36 to 0.87 °C/10 years).

In ***summer***, the average seasonal air temperature in Kazakhstan increases by 0.25 °C/10 years (coefficient of determination 24 %, Table 2.4). The most significant rates of air temperature increase are observed in the western and some southern regions – by 0.30–0.65 °C/10 years. Less intense warming is observed in most southern and southeastern regions of Kazakhstan, where summer air temperatures tend to increase by 0.25–0.30 °C/10 years (Figure 2.16). The trends here describe 27 to 32 % of the dispersion of time series. In the northern, northeastern, and central regions, trends are practically absent (0.0–0.1 °C/10 years) – the share of the trend component in the total dispersion of the series in these regions is practically zero, although the trend remains positive. In some areas of the central region, there are areas where, on average, over the period 1976–2024, the temperature has even decreased, and the rate of cooling in these areas reaches −0.1 °C/10 years.

In **June and July**, a slight cooling trend is observed in the northern, northeastern, and central regions (maximum of 0.26 °C/10 years, Figure 2.17). In some western, southwestern, southern, and southeastern regions of the country, statistically significant increases in surface air temperature of 0.13–0.84 °C/10 years were observed. In August, most regions of Kazakhstan saw statistically significant positive trends in air temperature ranging from 0.12 to 0.73 °C/10 years. The highest rate of air temperature increase in August was observed in the western region.

In ***autumn,*** a warming trend is observed in all regions of Kazakhstan. On average, the seasonal temperature in Kazakhstan increases by 0.28 °C/10 years (coefficient of determination 9 %, Table 2.4). The most significant rates of temperature increase are observed in the western and northern regions – by 0.32–0.50 °C/10 years, with the share of variance explained by the trend being 7–27 %. In the central, some southern, and eastern regions, there are practically no warming trends—although the trend sign is positive, the share of the trend component in the total dispersion of the series is no more than 5 %. It should be noted that during the period 1976–2024, the average rate of warming in autumn increased slightly in all regions and on average across the country, and the trends became statistically significant at the 5 % level for the country as a whole and in three other regions: Akmola, Kyzylorda, and Turkestan. It should also be noted that in summer, the maximum and most significant trends were observed in the western, southern, and southeastern regions, and in autumn, in the western and northern regions (Figure 2.16). In other words, significant climate warming was observed in the western regions of the country in all seasons of the year.

In **September**, most of the republic experiences warming, with some southern and western regions of the country seeing statistically significant increases in surface air temperature of 0.15–0.46 °C/10 years (Figure 2.17). In the central and some eastern regions, there are practically no trends, although the trend sign is positive, but the share of the trend component in the total dispersion of the series is no more than 4%. In some areas of the eastern and central regions, there were pockets of slight cooling to −0.18 °C/10 years. In October, warming occurred throughout Kazakhstan, with statistically significant positive air temperature trends ranging from 0.32 to 0.83 °C/10 years observed in the western and northern regions, and in some places in the south – in the Kyzylorda and Turkestan regions. In November, positive trends (in the range of 0.21–0.85 °C/10 years) covered the northern half of Kazakhstan, including the eastern region, but in most cases they were insignificant, and only at 11 meteostations in Aksai, Uralsk, and Chingirlau (West Kazakhstan Region) and Arshalinsky z/svkh, Zhitikara, Karabalyq, Kostanay, Mikhailovka, Presnogorkovka, Rudny, and Tobol (Kostanay Region) was statistically significant at the 5 % level. In November, the region where there was virtually no warming (0.0–0.1 °C/10 years) also had some areas with negative trends (from −0.0 to −0.42 °C/10 years), covering the southern, southeastern, and central regions of the country. Only at the Shuylak meteostation in the Turkestan region was the most significant negative trend observed, but it was statistically insignificant (−0.42 °C/10 years).

2.3 Trends in surface air temperature extremes

Not only are average air temperatures and precipitation levels changing, but other characteristics of these basic climate elements are also changing, including the frequency and intensity of extremes. Thus, climate change can affect virtually all areas of human life, as well as physical and chemical processes in the biosphere.

A correct assessment of such impacts of climate change must be distinctly regional and even local in nature, since both climate change and the vulnerability of systems, as well as the possibilities for adaptation, depend significantly on the physical, geographical, economic, and demographic characteristics of regions, which are specific in this regard.

Rising air temperatures are causing shifts in the timing of phenological events in plants and animals, in the boundaries of plant zones, mainly northward and upward in mountainous areas, as well as changes in ecosystem structure.

Throughout the republic, there has been an increase in the length of the growing season (GSL index, Figure 2.18) of 1–6 days/10 years. A statistically significant increase of 3–6 days/10 years can be seen in the data from most stations in the West Kazakhstan, Aktobe, Kyzylorda, Turkestan, Zhambyl, Almaty, Karaganda, Zhetysu, Abay, and East Kazakhstan regions. Here and further in the figures, red or green circles highlight the points for which the trend coefficients are statistically significant at the 5 % level. In the northern and northeastern regions, the increase in the length of the growing season is largely statistically insignificant. The most significant increase in the length of the growing season was observed at the Shardara meteorological station in the Turkestan region and amounted to 6 days/10 years.

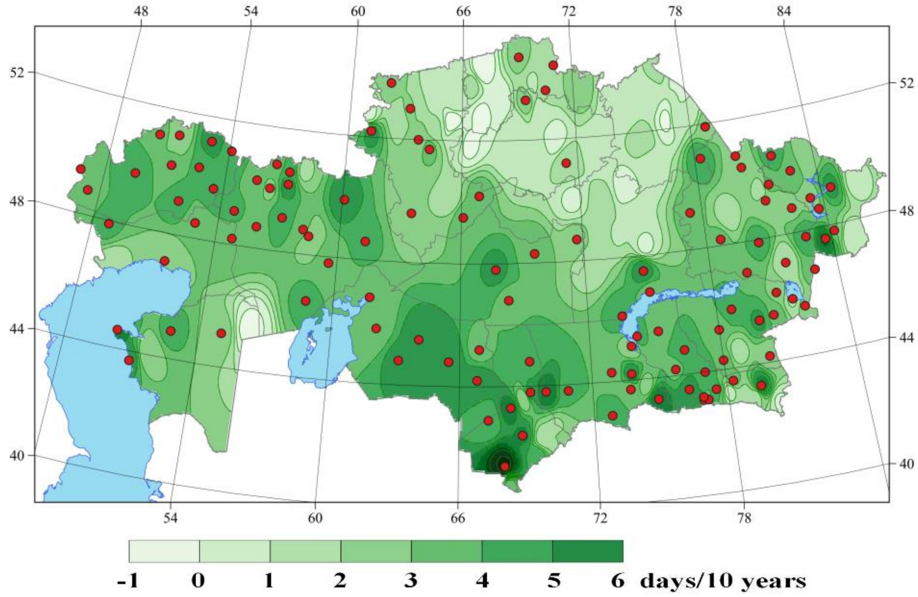


Figure 2.18 *– Rates of change in growing season length (days/10 years) for the period 1961–2024 (GSL index)*

In addition to the increase in the length of the growing season, a statistically significant increase in the sum of temperatures during the growing season (GDDgrow10 index, Figure 2.19) has been observed throughout Kazakhstan. In the southern and western parts of the country, the increase in the sum of temperatures is significantly higher than in the northern and eastern parts. The largest and statistically significant increase, more than 80 degree days/10 years, is observed according to data from most stations in the southwestern part of West Kazakhstan, Atyrau, Mangystau, Aktobe, Kyzylorda, Turkestan, Zhambyl, and Almaty regions.

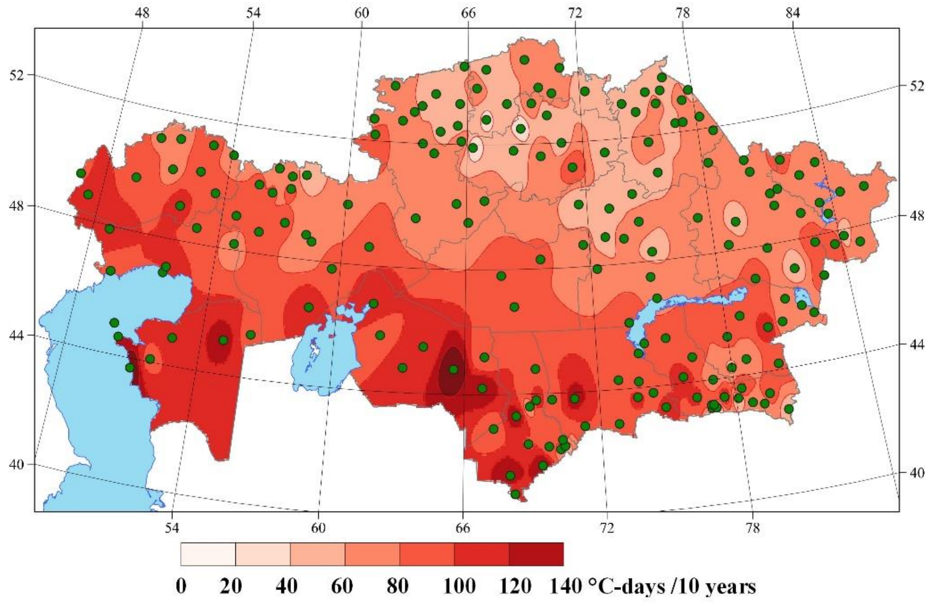


Figure 2.19 *– Rate of change in the sum of temperatures during the growing season (degree-days/10 years) for the period 1961–2024 (GDDgrow10 index)*

Not only is the average air temperature rising, but the frequency of high summer temperatures is also increasing. In the hot and dry summers of southern Kazakhstan, this has a negative impact not only on vegetation, but also on humans and animals. For example, the number of days with temperatures above 30 °C is increasing almost everywhere, especially in the western and southern regions of the republic – by 4–7 days over 10 years (Figure 2.20). The highest rate of increase in the frequency of high summer temperatures was observed at the meteorological stations in Aktau (7.3 days/10 years, Mangystau region) and Aral Teniz (6.7 days/10 years, Kyzylorda region). Stations in the North Kazakhstan, Akmola, and Karaganda regions observed a statistically insignificant negative trend in the recurrence of hot days.

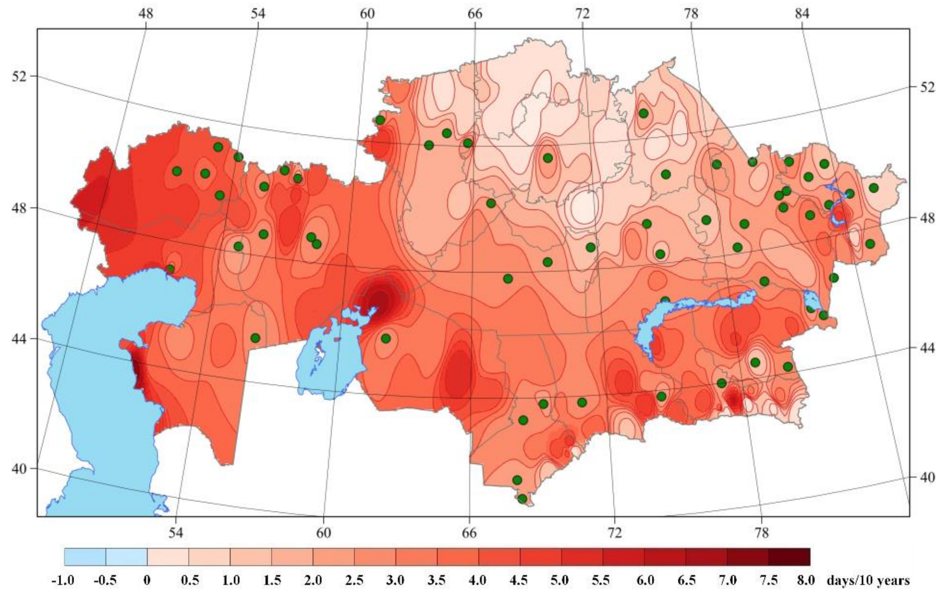


Figure 2.20 *– Rate of change in the number of days when the maximum daily temperature is equal to or above 30 °C (days/10 years) in the period 1961–2024 (TXge30 index)*

Most of the republic has seen a statistically significant positive trend in the total duration of all heat waves during the warm season (a heat wave is defined as three or more consecutive days when the excess heat coefficient has a positive value, HWF/EHF index, Figure 2.21). The most significant positive trend (more than 6–9 days/10 years) was observed at three meteorological stations: Aktau (8 days/10 years) in Mangystau, Kazygurt and Kyzylorda (6 days/10 years) in Turkestan and Kyzylorda regions, respectively.

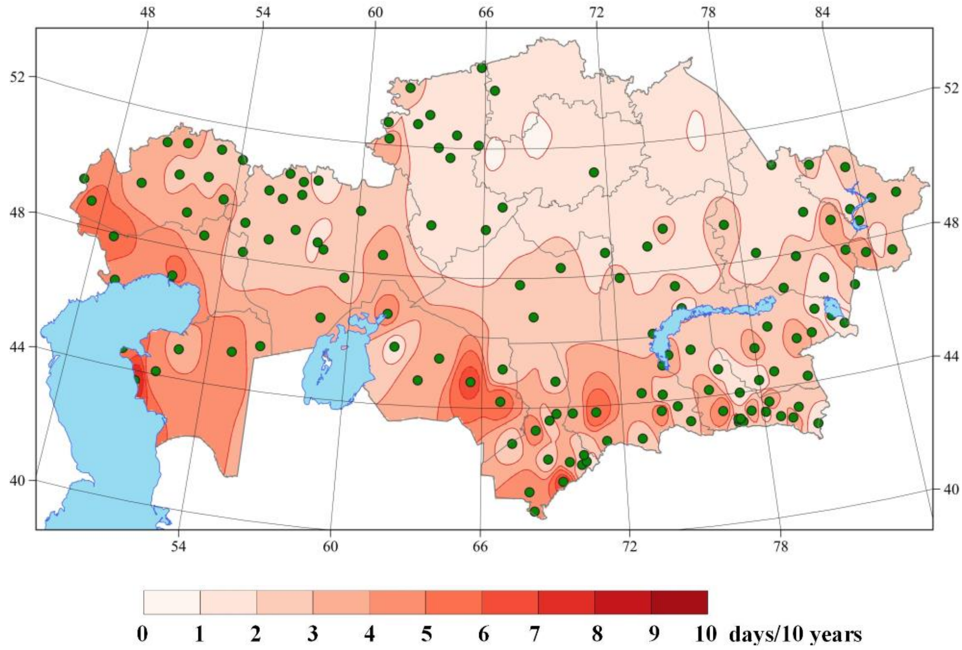


Figure 2.21 *– Rates of change in total warm period heat wave duration (days/10 years) for 1961–2024 (HWF/EHF index)*

Almost throughout the entire territory of the republic, there is a slight trend toward an increase in the number of individual heat waves during the warm season (HWN index, Figure 2.22). At stations in the southern and southwestern regions, such waves are becoming 50 % more frequent on average every 10 years.

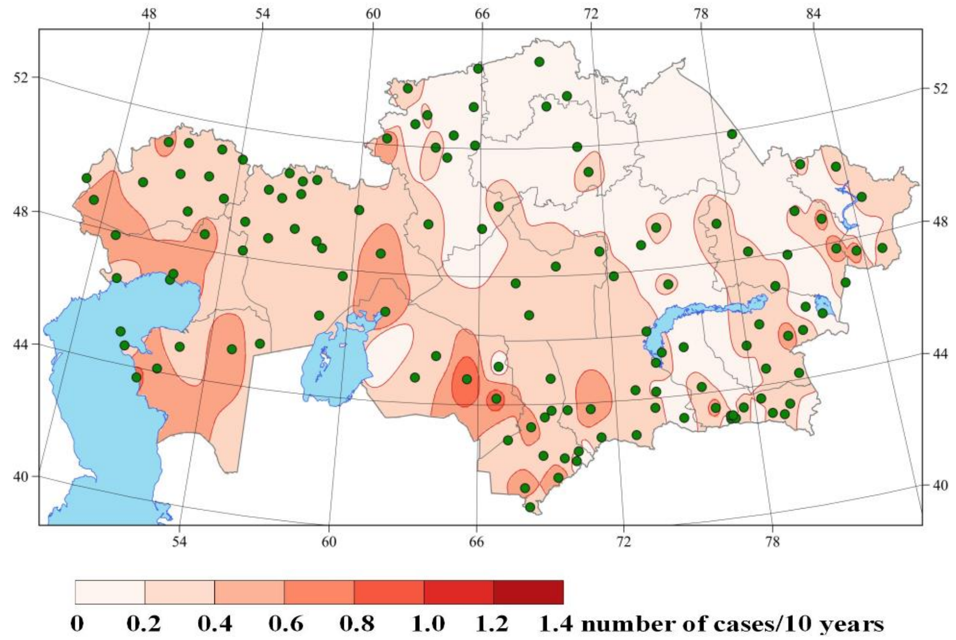


Figure 2.22 *– Rate of change in the number of heat waves during the warm period (number of occurrences/10 years) during 1961–2024 (HWN index)*

The duration of the maximum heat wave during the warm season is increasing everywhere (HWD index, Figure 2.23), with the wave lengthening by more than one day on average every 10 years in the western and southern regions. In the northern regions, on the contrary, it is shortening by 0.2 days or less over 10 years.

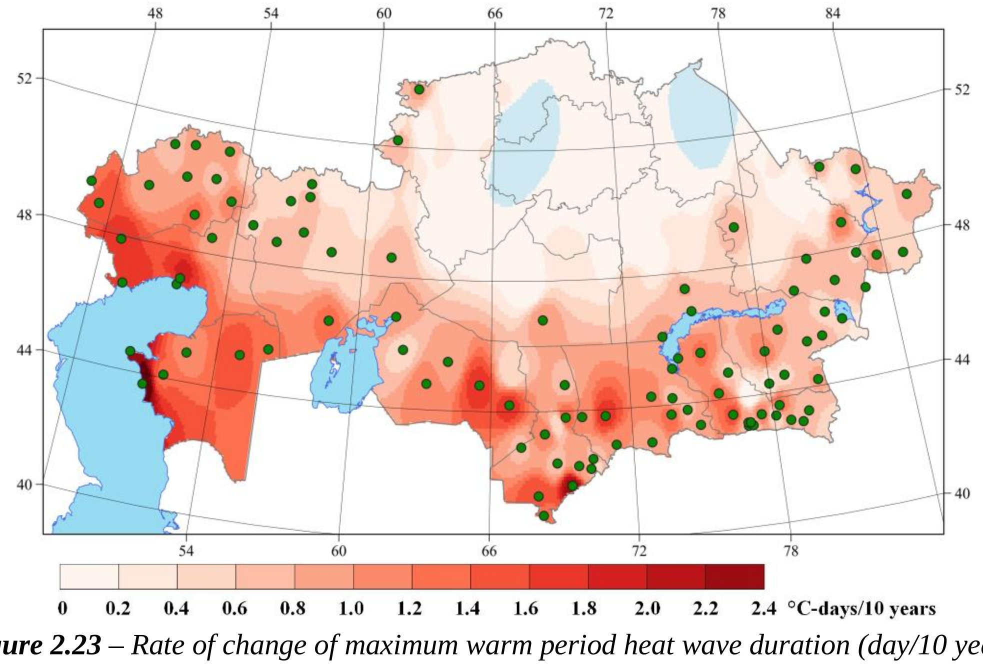


Figure 2.23 *– Rate of change of maximum warm period heat wave duration (day/10 years) in 1961–2024 (HWD index)*

The increase in air temperature throughout all seasons of the year leads to an increase in the total duration of heat waves (when, for at least 6 consecutive days, the daily maximum air temperature was above the 90th percentile, WSDI index) throughout the entire territory of the republic (Figure 2.24). In the northern regions and in some central, southern, and eastern regions, the increase is 1–3 days/10 years.

The most significant increase (3–6 days/10 years) is observed in the western half of the country.

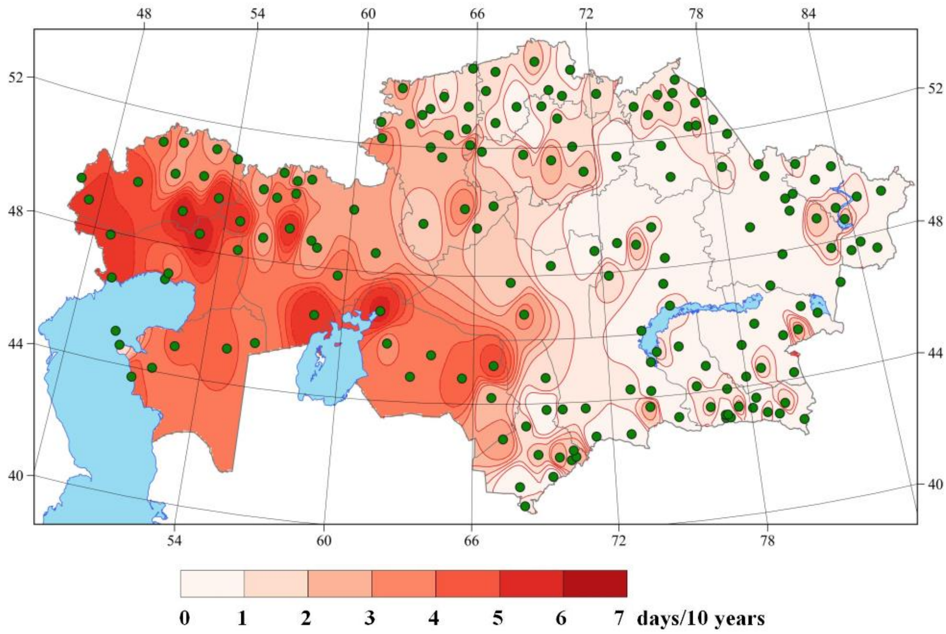


Figure 2.24 *– Rate of change in total annual heat wave duration (days/10 years) for the period 1961–2024 (WSDI index)*

The rise in air temperature during most months of the warm season results in an increase in the cold deficit, or the need to maintain a comfortable temperature indoors, in this case a threshold of 23 °C (index CDDcold23, Figure 2.25). Only in the north and northeast of the republic are there small pockets with some reduction in the cold deficit. In the rest of the country, there is an increase in the cold deficit, with the rate of increase in the cold deficit in the western regions, the southwest, and the south exceeding 10 °C every 10 years. The maximum increase in the cold deficit is observed in the western and southern regions of the country (30–50 °C/10 years).

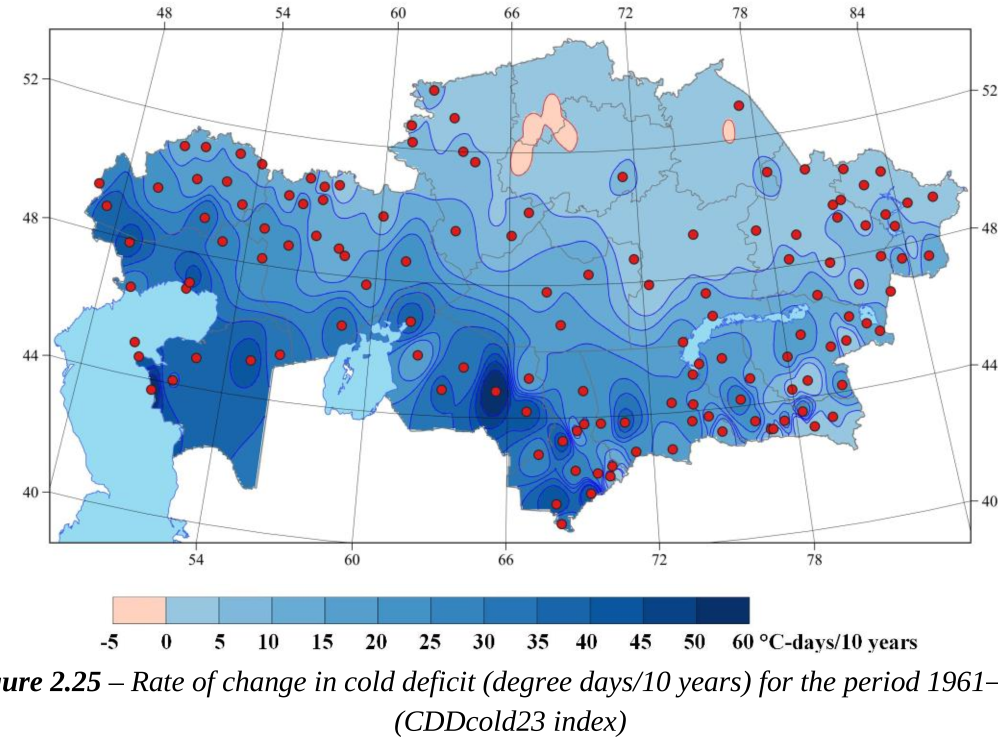


Figure 2.25 *– Rate of change in cold deficit (degree days/10 years) for the period 1961–2024 (CDDcold23 index)*

In many regions of Kazakhstan, the daily minimum temperature is increasing, in about half of the cases at a faster rate than the daily maximum. Figure 2.26 shows the change in the number of days when the minimum temperature is ≥ 20 °C (TR index, number of tropical nights). Over the past 60 years, Kazakhstan has seen an increase in the number of such days, with the greatest increase in the western and southwestern regions of the country (from 4 days/10 years and more). In the Mangystau, Atyrau, Kyzylorda, and Turkestan regions, the number of tropical nights reached 6 days/10 years and more.

Thus, conditions for the human body to rest at night from the daytime heat, which, as shown above, is also intensifying, are significantly deteriorating here.

As a result of rising air temperatures, the number of days per year when the daily minimum temperature is equal to or below 0 °C (days with frost, FD0 index, Figure 2.27) and below minus 2 °C (severe frosts, TNltm2 index, Figure 2.28). The rate of reduction varies across the territory, mainly from 0 to 4 days/10 years, with the rate of reduction exceeding 5–6 days per 10 years in some places.

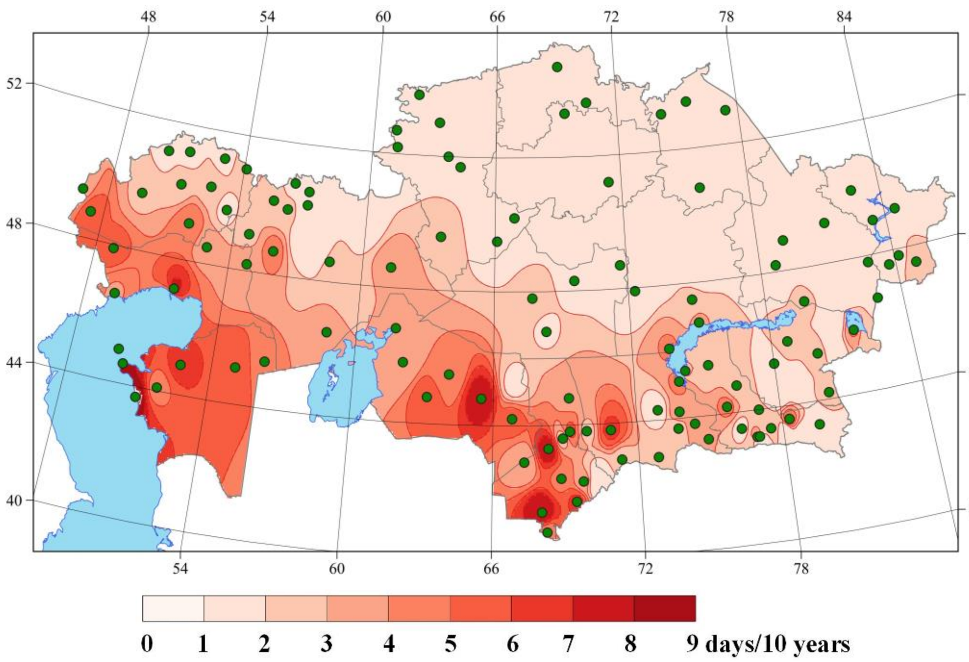


Figure 2.26 *– Rate of change in the number of tropical nights (days/10 years) for the period 1961–2024 (TR index)*

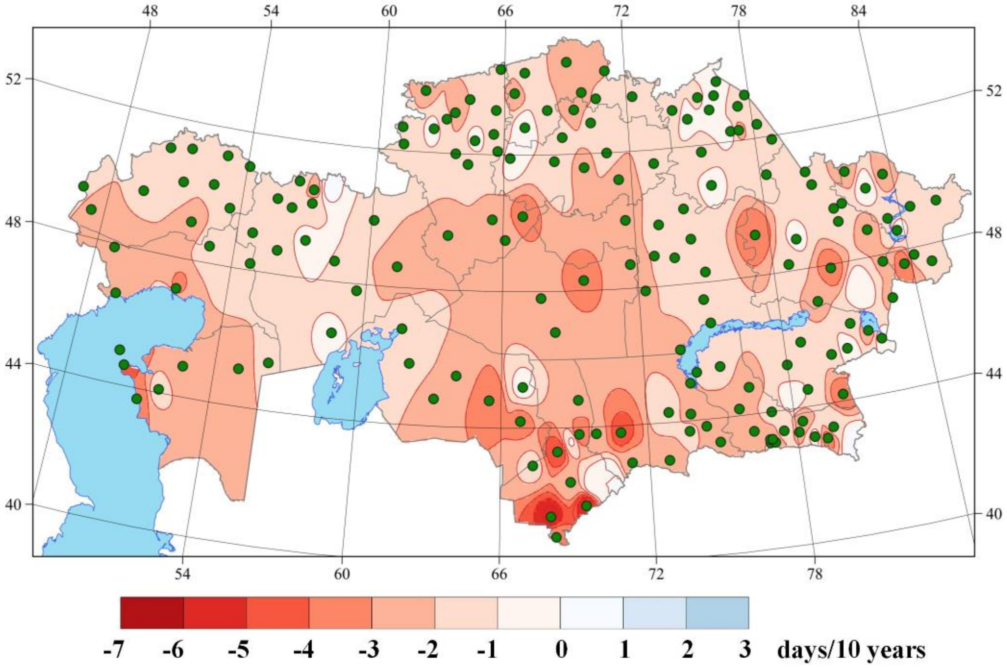


***Figure 2.27** – Rate of change in the number of days with frost (days/10 years) in the period 1961–2024 (FD0 index)*

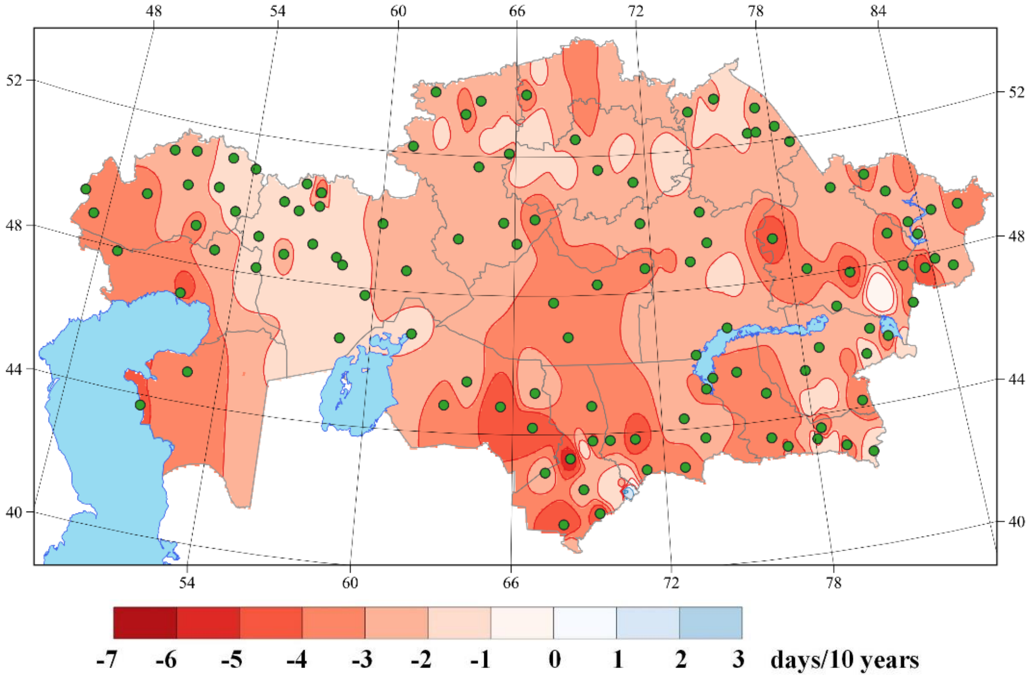


***Figure 2.28** – Rate of change in the number of days with hard frosts (days/10 years) in the period 1961–2024 (TNltm2 index)*

Across the republic, the number of days with very severe frosts (when the daily minimum air temperature is below minus 20 °C, TNltm20 index, Figure 2.29) is decreasing almost everywhere. A significant reduction in the number of such days has been observed in the northwestern and central regions, as well as in the Balkashsky district—by 2–3 days/10 years. In some areas of the East Kazakhstan region, the frequency of days with very severe frosts is decreasing at a more significant rate—by 4–5 days/10 years.

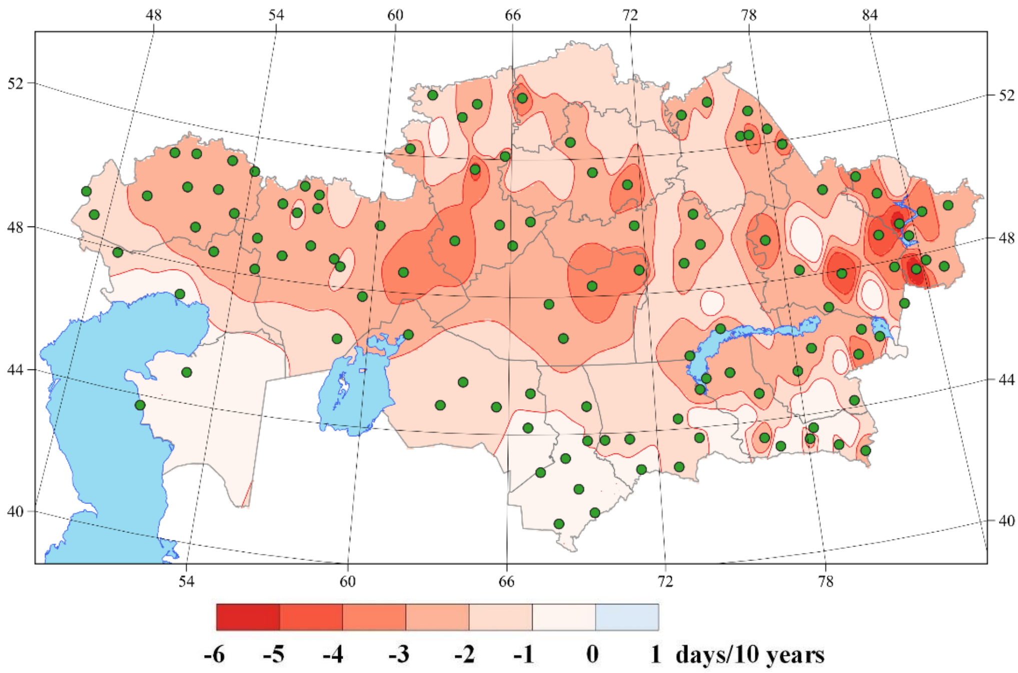


Figure 2.29 *– Rates of change in the number of days with very hard frost (days/10 years) in the period 1961–2024 (TNltm20 index)*

The reduction in the number of days with sub-zero temperatures leads to a widespread reduction in the heat deficit during the cold season (HDDheat23 index, Figure 2.30). Here, the threshold value for the air temperature that is desirable to maintain indoors is taken to be 23 °C. Over most of Kazakhstan, the range of reduction in heat deficit is between 60 and 100 degree days per decade. The reduction in heat deficit in most of the northern and eastern parts of the central regions is up to 40 degree days per 10 years, but in some areas of these regions there is no reduction in heat deficit. The greatest changes have been recorded locally in the west, southwest, and in a number of areas in eastern Kazakhstan, where the reduction in heat deficit reaches 130–160 degree days/10 years.

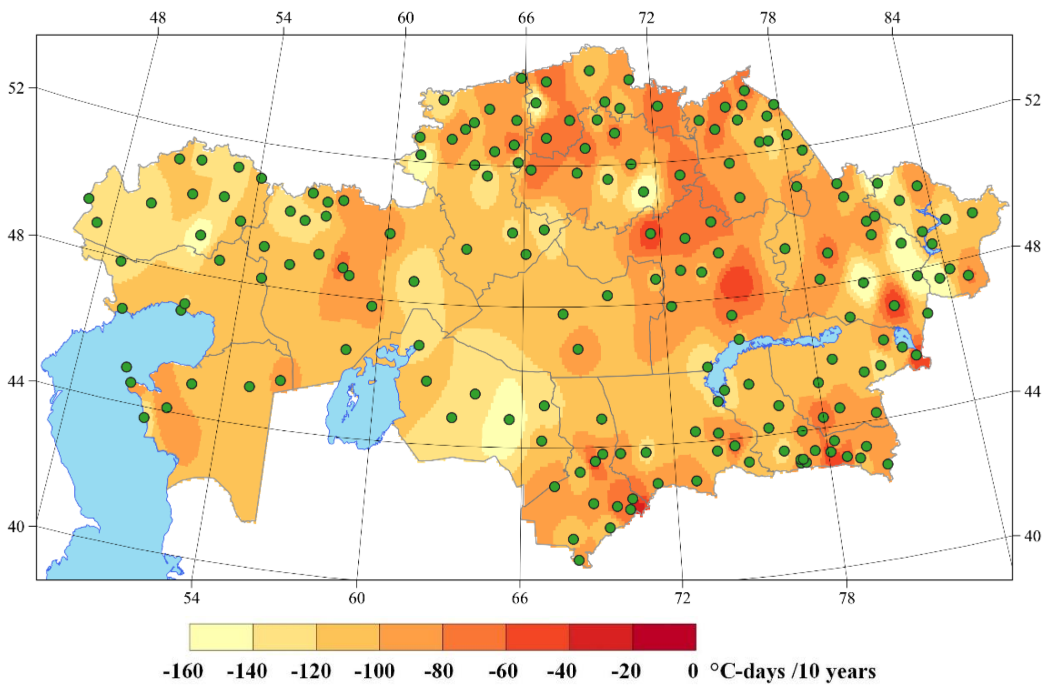


Figure 2.30 *– Rate of change of heat deficit (degree days/10 years) in the period 1961–2024 (HDDheat18 index)*

3 ATMOSPHERIC PRECIPITATION

To describe the climatic conditions observed in 2024, including an assessment of the extremity of atmospheric precipitation and an analysis of climate change, data on monthly and daily precipitation totals were used, obtained from approximately 190 meteorological stations from the Republican Hydrometeorological Fund of the RSE Kazhydromet. Annual, seasonal, and monthly precipitation totals are expressed in millimeters or as a percentage of the 1961–1990 norm. Table 3.1 shows the values of anomalies in annual and seasonal precipitation totals, while Table 3.2 shows the anomalies in monthly precipitation totals observed in 2024 and averaged across Kazakhstan and its regions. For each anomaly value, the probabilities of non-exceedance for the period 1941–2024 are calculated, characterizing the frequency of occurrence of the corresponding values in the series of observations. Precipitation anomalies that occupied the first or last five positions in the descending order are highlighted in bold.

3.1 Precipitation anomalies in 2024

In 2024, the average annual precipitation across Kazakhstan was above normal, reaching 123.3 % of the norm, or 391.8 mm (6th rank, probability of not exceeding 93 %). In eight regions of the country, the amount of precipitation was in line with the climatic norm, while in nine regions, it exceeded the norm by more than 120 %. The maximum excess of annual precipitation was observed in the Pavlodar, Akmola, and North Kazakhstan regions: here, the annual amount was 133–155% of the norm, and the average precipitation reached 448.8–504.8 mm. According to the criteria of extremity, such indicators are classified as among the 5 % wettest years (Table 3.1).

In 2024, most of Kazakhstan received either near-normal or above-normal precipitation (Figure 3.1). The highest precipitation values relative to the climatic norm were recorded in the northern (140–184 % of the norm), eastern (135–161 %), southern (140–176 %), and central (131–154 %) regions, as well as in the area around Lake Balkhash (168–178 %). In addition, a significant excess of annual precipitation was recorded in most areas of the Aktobe region (122–173 %). The greatest precipitation deficit was observed in the southern part of the Kostanay region, where only 35–44 % of the norm fell, as well as locally in the southern part of the Kyzylorda region, in the south-west of the Turkestan region and in the south-east of the Zhambyl region (54–73 % of the norm).

At the Amangeldy meteostation (Kostanay region), the annual precipitation was 83.4 mm, which placed 2024 among the 5 % of extremely dry years. At the Torgay meteostation (also in the Kostanay region), the year was among the 10 % most extremely dry years (Figure 3.1). According to data from 70 meteostations located in the western, northwestern, central, eastern, and southeastern regions, 10 % precipitation extremes were recorded; while 54 stations recorded 5 % extremes, indicating extremely wet conditions. Of these, 20 MS recorded record values for maximum annual precipitation (Annex 1).

Table 3.1 – Regionally averaged average annual (January-December) and seasonal precipitation anomalies in 2024: **vR** – *deviations from long–term averages for 1961–1990, mm/season;* ***P(r≤R2024)*** *- probability of non-excess (in parentheses), calculated from data for the period 1941– 2024 in %;* ***RR*** *-the ratio of R2024 to the norm in %*

Region	Year		Winter		Spring		Summer		Autumn	
	vR (P)	RR	vR (P)	RR	vR (P)	RR	vR (P)	RR	vR (P)	RR
Kazakhstan	74,1 (93)	123,3	35,1 (100)	155,5	18,4 (79)	121,0	32,4 (87)	136,8	5,0 (72)	106,3
Abay	86,8 (93)	130,2	36,1 (97)	162,9	1,2 (54)	101,7	35,3 (80)	140,8	9,3 (72)	112,4
Almaty	86,7 (85)	118,0	35,3 (93)	154,7	24,8 (69)	114,0	8,4 (60)	106,1	37,4 (90)	137,1
Akmola	177,2 (98)	154,5	66,9 (100)	240,8	50,2 (100)	172,5	76,3 (91)	158,7	11,5 (71)	114,6
Aktobe	62,2 (83)	123,6	40,6 (98)	168,2	2,6 (51)	104,0	65,2 (98)	196,2	-16,7 (36)	76,9
Atyrau	35,8 (73)	123,8	32,5 (92)	203,4	19,5 (74)	151,6	-21,6 (20)	47,0	9,5 (73)	123,4
East Kazakhstan	94,2 (91)	123,9	42,7 (97)	168,7	21,4 (71)	123,1	25,9 (73)	120,2	7,3 (69)	106,5
Zhambyl	19,8 (61)	106,5	29,2 (86)	139,8	-4,0 (51)	96,7	-1,2 (43)	96,9	16,9 (72)	122,9
Zhetysu	55,6 (78)	114,5	37,4 (89)	151,2	14,8 (60)	112,5	4,3 (57)	104,7	13,7 (74)	113,6
West Kazakhstan	-0,4 (54)	99,9	36,0 (98)	154,9	4,4 (50)	107,6	1,5 (60)	101,9	-19,9 (31)	74,7
Karaganda	76,7 (95)	130,1	25,0 (91)	149,3	7,2 (62)	111,1	38,8 (81)	150,1	3,4 (67)	105,5
Kostanay	24,2 (61)	108,3	32,2 (100)	165,9	1,8 (49)	103,1	43,9 (89)	140,9	-24,9 (18)	66,3
Kyzylorda	35,4 (90)	125,0	0,2 (44)	100,5	24,3 (85)	149,4	9,2 (79)	148,4	2,2 (66)	106,7
Mangystau[1]	22,3 (77)	115,6	-3,3 (44)	86,2	27,7 (92)	159,3	-25,2(18)	27,2	15,1 (81)	140,5
Pavlodar	156,0 (98)	153,3	39,0 (100)	187,1	55,2 (97)	200,4	48,7 (85)	140,4	33,0 (93)	145,6
North Kazakhstan	152,2 (98)	143,2	48,9 (100)	203,3	18,1 (75)	127,6	125,2 (98)	182,0	-14,6 (36)	83,3
Turkestan	77,0 (79)	118,0	21,2 (65)	114,0	60,0 (83)	136,0	-0,2 (43)	99,0	18,1 (73)	119,0
Ulytau	29,5 (73)	114,0	12,8 (83)	124,0	-0,6 (55)	99,0	13,5 (71)	125,0	14,6 (80)	129,0

Notes: *1. For the Mangystau region, the assessment was carried out only according to MS Fort Shevchenko;*
2. values above the 95th or below the 5th percentile (wet 95 % and dry 5 % extremes, respectively) are highlighted in bold and bright color;
3. values above the 90th or below the 10th percentile are highlighted in pale color;
4. Average precipitation anomalies were obtained by averaging the data of 121 stations of the Republic of Kazakhstan.

On average, Kazakhstan received 98 mm and 120 mm of precipitation in winter and summer, respectively, which is 155.5 % and 136.8 % of the seasonal climate norm. The winter season ranked first in the series of observations from the wettest to the driest season since 1941. The spring season of 2024 was also characterized by excessive moisture: the average precipitation was 105.7 mm, or 121 % of the norm (this is the 18th wettest spring). In autumn, the average precipitation across the country was 84.1 mm, which corresponds to 106.3 % of the climatic norm (Table 3.1).

Figure 3.1 shows the territorial distribution of annual and seasonal precipitation in 2024, expressed as a percentage of the norm for the period 1961–1990, as well as the probabilities of annual and seasonal precipitation totals not being exceeded.

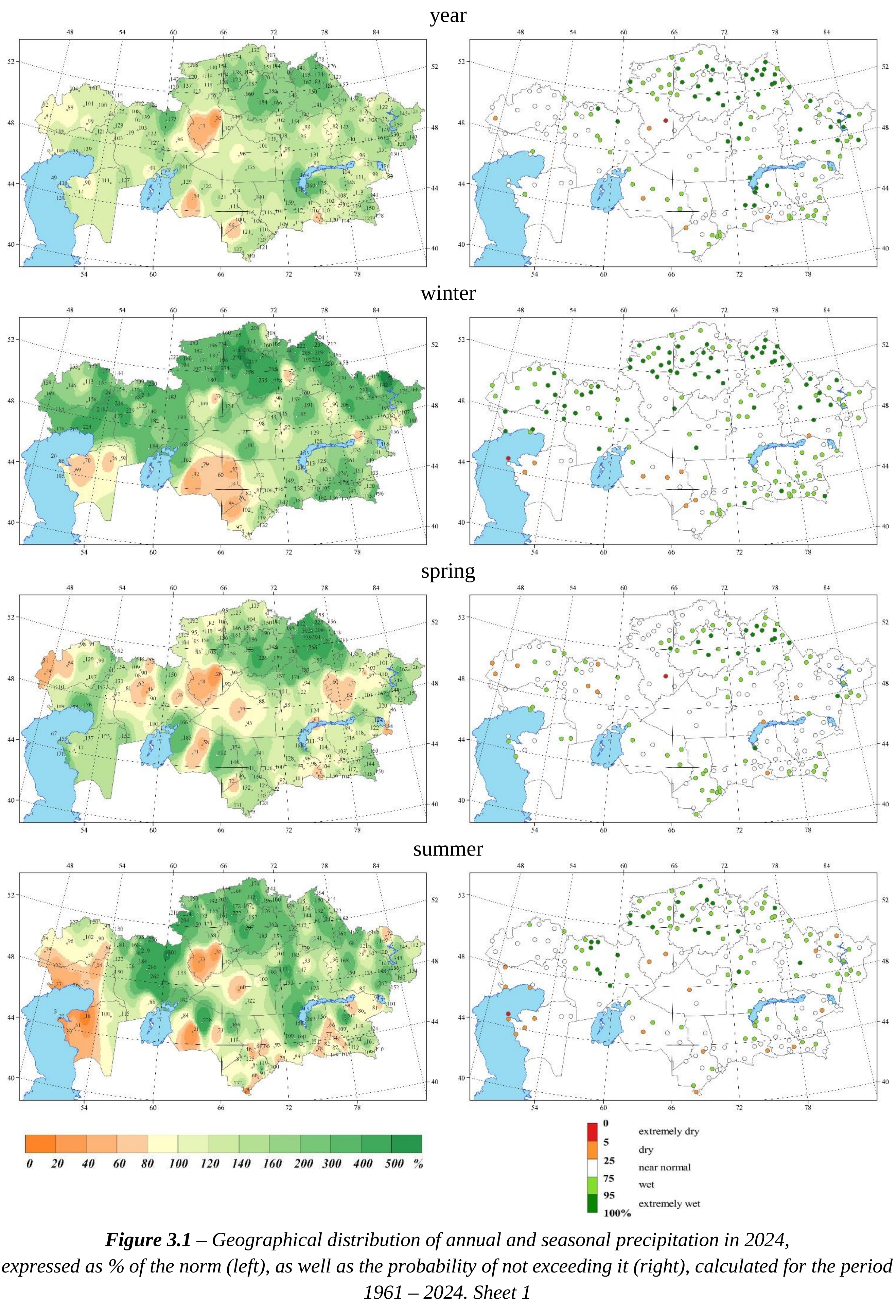


***Figure 3.1** – Geographical distribution of annual and seasonal precipitation in 2024, expressed as % of the norm (left), as well as the probability of not exceeding it (right), calculated for the period 1961 – 2024. Sheet 1*

autumn

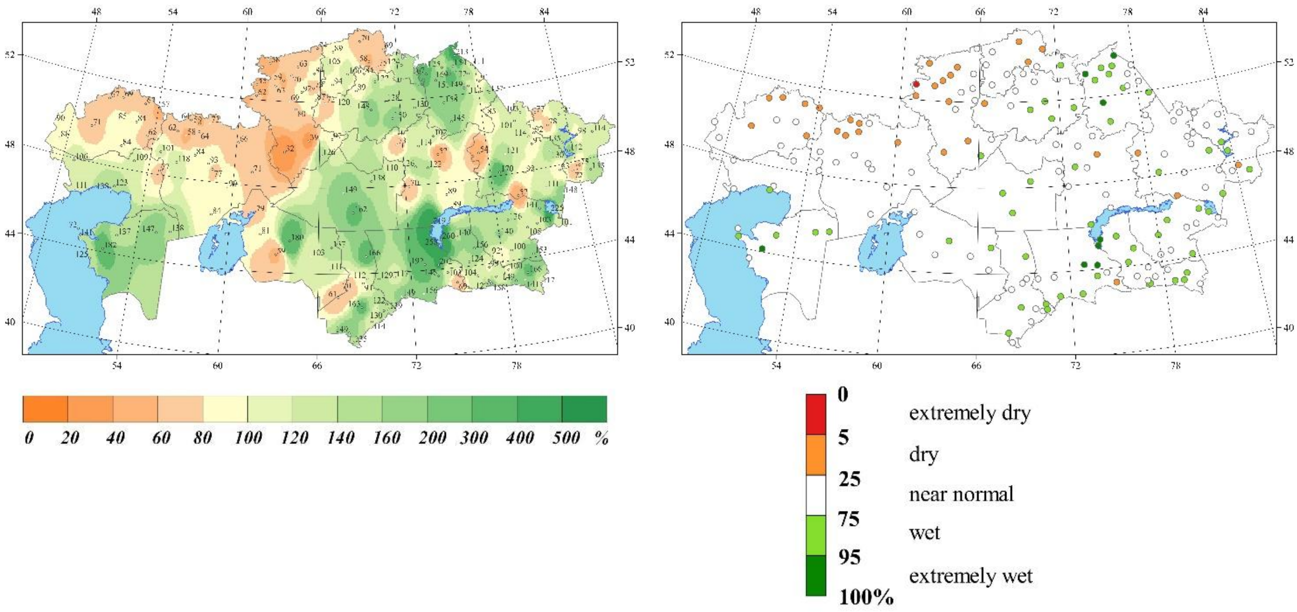


Figure 3.1 *– Geographical distribution of annual and seasonal precipitation in 2024, expressed as % of the norm (left), as well as the probability of not exceeding it (right), calculated for the period 1961 – 2024. Sheet 2*

Figure 3.2 shows the intra-annual distribution of precipitation in 2024, averaged across Kazakhstan, as well as the average long-term monthly precipitation for the period 1961–1990

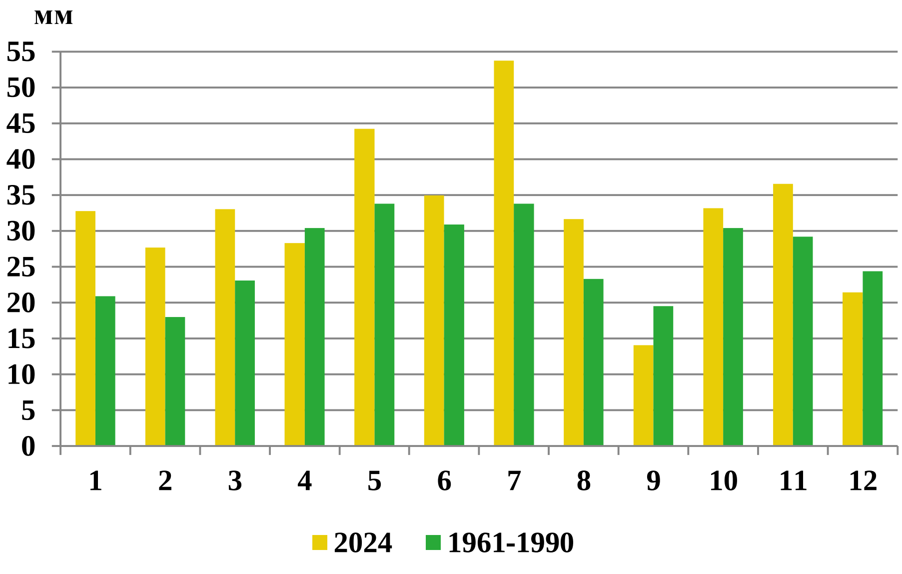


Figure 3.2 *– Monthly precipitation amounts averaged over the territory of Kazakhstan in 2024 and their norms calculated for the period 1961–1990*

Most months of 2024 saw excessive precipitation in Kazakhstan (except for April, September, and December) – in January–March, May–August, and October–November (Figure 3.2). January 2024 was extremely wet: the average precipitation across the country was 32.8 mm, or 156.8 % of the climatic norm, which corresponds to the 96th percentile. This is the fourth highest value in terms of humidity since observations began in 1941; the record maximum was recorded in 2014 – 37.6 mm. In February, the average precipitation was 27.7 mm (153.9 % of normal), and in July, it was 53.8 mm (159.1 % of normal), which allowed July to be included in the top ten wettest months (10 % extremes). Excess precipitation was also observed in March (33.1 mm – 143.1 % of normal), August (31.7 mm – 135.8 % of normal), May (44.3 mm – 130.9 % of normal), and November (36.6 mm – 125.2 % of normal). Precipitation deficits were observed in April, September, and December. In April, the average precipitation was 28.3 mm (93.1 % of the norm), in December – 21.4 mm (87.8 % of the norm), and in September – 14.1 mm (72.3 % of the norm), with probabilities of not exceeding the norm of 42 %, 38 % and 26 %, respectively.

In the ***winter of 2023/2024*** (December 2023 – February 2024), the average precipitation across Kazakhstan was 155.5 % of the climatic norm, making it the wettest winter season since records began in 1941 (1 rank) (Table 3.1). Most of the country saw precipitation exceed the norm by more than 120 % (Figure 3.1). In the western regions, precipitation was 123–230 % of the norm, in the northern regions – 126–278 % of the norm, in the eastern regions – 121–354 % of the norm, in the central regions – 128–191 % of the norm, in the southern regions – 125–195 % of the norm, and in some areas of the northern part of the Kyzylorda region – 162–168 % of the norm. According to data from 104 meteostations located throughout the country, with the exception of the southern and southwestern regions, the winter season was 5 % to 10 % extremely wet in terms of precipitation, with 30 meteostations recording record maximum precipitation levels. The largest areas of precipitation deficit were observed in the Mangystau and Kyzylorda regions (26–79 % of the norm), as well as locally in the north, east, and south of the country. At the Kulaly Island meteostation (Mangystau region), the winter period was among the 5 % driest winters.

In December 2023, there was an excess of precipitation, with average relative precipitation anomalies across Kazakhstan reaching 150 % of the 1961–1990 climate norm, which is 13.5 mm above normal (92 % probability of not exceeding, Table 3.2). Most of the country saw significant precipitation above normal (more than 120 %), covering the western regions (130–329 % of normal), the northern regions (136–386 % of normal), most of the eastern regions (137–227 % of the norm), and the mountainous areas of the southeast (129–239 %) (Figure 3.3). Thirty-nine percent of meteostations covering the country recorded extremely high precipitation with a probability of 90 and 95 % (extremes). According to data from nine meteostations located in all northern regions, as well as in the Aktobe and Turkestan regions, new records were set for maximum monthly precipitation (Annex 2). The largest precipitation deficits were observed in the Kyzylorda (18–58% of normal) and Turkestan (25–66 % of normal) regions, in the Balkash region (46–79 % of normal) and in a significant part of the eastern regions (24–70 % of normal), as well as locally in some areas of the Mangystau region (63 % of normal). According to data from the Aksuat (3.5 mm, 24.5 % of normal) and Aktogay (4.6 mm, 23.6 % of normal) meteostations located in the Abay region, December was among the 5% of extremely dry months.

In January, most of the country experienced extremely wet conditions. On average, precipitation across Kazakhstan amounted to 156.8 % of the norm, or 11.9 mm above the long-term average (4th rank, Table 3.2). Overall, the most extremely wet regions were West Kazakhstan (193.9 % of the norm), Kostanay (180.6 % of normal), North Kazakhstan (206.5 % of normal), and Akmola (211.7 % of normal) regions, which corresponds to the 2nd and 4th wettest Januaries for the entire observation period. In the northern, northern parts of the western and central regions, the Aral Sea region, the southern and southeastern regions, precipitation exceeded the norm by 1.2–2.7 times, in the eastern regions by 1.4–4.1 times, and in the northeastern and central parts of the country by 1.2–1.8 times (Figure 3.3). Extremely wet conditions were observed at 66 meteostations across almost the entire country, with 5 % and 10 % extremes recorded. The highest amount of precipitation (66 mm) fell at the Leninogorsk meteostation (East Kazakhstan region), which was 412.5 % of the norm, breaking the 2023 record (59.7 mm, 373.1 % of the norm). Record monthly precipitation values in January were also recorded at the Arshaly (43.7 mm, 291.3 % of the norm) and Tobyl (43 mm, 226.3 % of the norm) meteostations in the Kostanay region; The previous records were 39.0 mm (2000) and 41.2 mm (1976), respectively (Annex 2). An area of severe precipitation deficit (20–64 % of normal) covered part of the Abay region, as well as local areas of the Mangystau, Kostanay, Akmola, East Kazakhstan, Turkestan regions, and the central region (50–79 % of normal). The minimum amount of precipitation for the month (1.3 mm) fell at the Kulaly Island meteostation (Mangystau region), which was 16.5 % of the norm, and January was among the 5 % of extremely dry months.

Table 3.2 – Regionally averaged monthly precipitation anomalies in 2024, calculated as deviations from the long-term average values for 1961-1990, (in mm), and the *probability of non-excess (in parentheses), calculated from data for the period 1941–2024 and expressed in %*

Region	12 (2023)	1	2	3	4	5	6	7	8	9	10	11
Kazakhstan	13,5 (92)	11,9 (96)	9,7 (90)	10,0 (81)	-2,1 (42)	10,5 (80)	4,0 (59)	20,0 (90)	8,4 (81)	-5,4 (26)	2,8 (75)	7,4 (83)
Abay	1,1 (56)	11,5 (89)	23,6 (100)	0,2 (55)	-1,3 (42)	2,3 (61)	10,0 (71)	29,7 (90)	-4,4 (39)	-0,8 (53)	-3,5 (61)	13,5 (86)
Almaty	19,6 (89)	7,1 (81)	8,5 (77)	31,2 (93)	-6,3 (45)	-0,1 (54)	-29,9 (8)	25,3 (89)	13,0 (78)	21,1 (93)	16,2 (83)	0,1 (55)
Akmola	33,9 (98)	19,2 (96)	13,8 (93)	2,6 (62)	7,0 (74)	40,6 (98)	33,5 (93)	-3,8 (45)	46,7 (97)	-6,9 (34)	3,6 (72)	14,7 (89)
Aktobe	19,1 (92)	13,7 (90)	7,8 (83)	1,6 (53)	0,9 (59)	0,0 (46)	27,1 (95)	20,2 (90)	17,9 (93)	-19,2 (0)	-0,2 (44)	2,7 (65)
Atyrau	3,0 (60)	2,4 (55)	27,1 (98)	17,4 (87)	-8,1 (21)	10,1 (69)	-2,9 (53)	-9,9 (19)	-8,8 (28)	-11,4 (3)	3,3 (62)	17,5 (93)
East Kazakhstan	7,6 (75)	19,5 (93)	15,6 (93)	6,4 (73)	7,3 (59)	7,8 (66)	0,4 (53)	29,6 (91)	-4,2 (48)	-10,9 (31)	-2,5 (59)	20,7 (91)
Zhambyl	11,5 (78)	13,7 (89)	4,1 (61)	2,4 (61)	1,1 (59)	-7,6 (46)	-9,6 (19)	12,4 (86)	-4,0 (32)	-3,3 (44)	17,5 (84)	2,8 (63)
Zhetysu	15,3 (83)	12,0 (86)	10,1 (77)	25,3 (86)	-14,0 (28)	3,5 (66)	-15,7 (19)	16,2 (80)	3,8 (65)	-5,1 (36)	4,2 (71)	14,6 (74)
West Kazakhstan	11,7 (87)	20,6 (97)	3,7 (68)	9,9 (74)	-3,3 (38)	-2,2 (36)	11,4 (81)	-1,4 (50)	-8,5 (38)	-21,3 (0)	6,7 (62)	-5,3 (55)
Karaganda	10,5 (85)	3,3 (75)	11,2 (93)	4,5 (72)	-9,4 (21)	12,0 (79)	0,4 (51)	38,5 (95)	-0,1 (56)	-10,2 (15)	4,0 (80)	6,4 (74)
Kostanay	17,6 (97)	13,9 (96)	0,7 (51)	-2,8 (31)	1,7 (53)	3,0 (53)	7,0 (66)	18,0 (75)	19,0 (86)	-12,1 (18)	-15,2 (14)	2,5 (65)
Kyzylorda	-1,6 (50)	3,5 (63)	-1,7 (37)	15,6 (95)	-6,7 (49)	15,4 (86)	-5,6 (31)	14,7 (93)	0,2 (60)	-4,5 (27)	4,7 (80)	2,0 (66)
Mangystau[1]	2,4 (71)	1,3 (57)	-7,0 (6)	6,3 (81)	-15,5 (0)	36,9 (96)	-6,0 (66)	-10,9 (0)	-8,3 (26)	-13,5 (0)	14,5 (90)	14,1 (93)
Pavlodar	17,2 (97)	4,4 (75)	17,4 (100)	4,5 (71)	-0,4 (55)	51,2 (98)	-5,0 (37)	28,9 (81)	24,9 (90)	33,6 (98)	-3,7 (56)	3,1 (66)
North Kazakhstan	28,0 (100)	18,1 (97)	2,7 (69)	1,1 (50)	1,3 (55)	17,0 (81)	38,0 (92)	54,0 (96)	33,2 (89)	-8,4 (27)	-16,5 (18)	10,3 (85)
Turkestan	4,9 (63)	8,6 (61)	7,8 (50)	36,6 (84)	-4,0 (46)	27,3 (83)	-7,0 (18)	10,3 (85)	-3,5 (40)	-5,1 (36)	17,4 (80)	5,9 (65)
Ulytau	6,6 (80)	-1,0 (62)	7,2 (79)	7,2 (79)	-12,2 (20)	4,4 (73)	-15,4 (4)	30,8 (95)	-2,0 (49)	-11,3 (6)	16,0 (90)	9,9 (85)

Notes: *1. For the Mangystau region, the assessment was carried out only according to MS Fort Shevchenko;*
2. Values above the 95th or below the 5th percentile are highlighted in bold and bright color;
3. values above the 90th or below the 10th percentile are highlighted in pale color;
4. Average precipitation anomalies were obtained by averaging data from 121 stations in Kazakhstan.

February saw uneven precipitation distribution, with average monthly precipitation across Kazakhstan amounting to 153.9 % of the norm, or 9.7 mm above the long-term average (9th rank, 90 % probability of not exceeding, Table 3.2). Significant excesses were observed in the Caspian Depression, in the north of the western region, and in most of the northern and eastern regions. In the western regions, precipitation exceeded the norm by 1.3–4.2 times, in the northern and central regions by 1.2–3.3 times, and in the mountainous areas of the east and south, as well as in the Southern Balkash lake region, by 1.2–2.3 times (Figure 3.3). Extremely wet conditions were observed in the Atyrau region, while record monthly precipitation amounts were recorded in the Pavlodar and Abay regions. The average moisture content across the territory ranged from 124.3 to 163.4 % of the norm (probability of not exceeding 98 and 100 %, respectively), which allows us to characterize February as the wettest and second wettest month for the entire observation period since 1941. A significant excess of the norm was recorded at the Karaul meteostation (Abay region) — 46.7 mm (622.7 % of the norm), exceeding the previous record set in 1977 (27.8 mm). The highest amount of precipitation was recorded at the ShalAbay meteostation (69.8 mm, 425.6 % of the norm, Abay region), and a new absolute maximum was also set (the previous one was 62.2 mm in 1966). In addition to these stations, new maximums for monthly precipitation totals were recorded at six other meteostations located in various regions of the country (Annex 2). Overall, 27 % of meteostations across the country recorded cases of excessive moisture, with 90 % and 95 % extremes.

In the southwestern part of the country, in the Mangystau (0–79 % of normal) and Kyzylorda (20–61 % of normal) regions, there was a significant moisture deficit. Small pockets of precipitation deficit were observed in some regions of the western (51–76 % of normal), northern (48–72 % of normal), East Kazakhstan (60 % of normal), and southern (17–77 % of normal) regions. According to data from two meteostations located in the Mangystau region, the humidity was characterized as extremely dry: the Kyzan meteostation recorded a 5 % extreme, and the Beineu meteostation recorded no precipitation at all during the month.

In spring, the average precipitation across Kazakhstan was 121 % of normal, with a 79 % probability of not exceeding normal (or the 18th driest spring in the observation series, Table 3.1). Precipitation distribution across the territory was uneven (Figure 3.2). Significant excess precipitation (more than 120 % of normal) was observed in most of the western and northern regions, as well as in some areas of the eastern, central, and southern regions. According to data from 36 meteostations, 5% and 10 % extremes were recorded. In the Akmola and Pavlodar regions, pronounced pockets of moisture formed, with average precipitation across the territory ranging from 172.5 to 200.4 % of the norm (probability of not exceeding 97 and 100 %), which corresponds to the wettest and third wettest spring in the entire observation period. New seasonal precipitation records were set at five meteostations in these regions: Zhaltyr – 158.7 mm, Pavlodar – 149.3 mm, Ekibastuz – 135.9 mm, Shchuchinsk – 130.3 mm, Krasnoarmeysk – 123.2 mm, the previous maximums of which were recorded in 1981, 1993, and 2000 (Annex 2). A precipitation deficit was observed in the West Kazakhstan and Aktobe regions (48–75 % of the norm), Kostanay region (26–48 % of normal), Abay region (62–77 % of normal), as well as in certain areas of Zhetysu, Ulytau, and Zhambyl regions, Kyzylorda region, and in the north of the Balkhash region (61–73 % of normal). Only 12.9 mm of precipitation fell at the Amangeldy meteorological station (Kostanay region), which corresponds to an extreme of 5 % and is classified as "extremely dry."

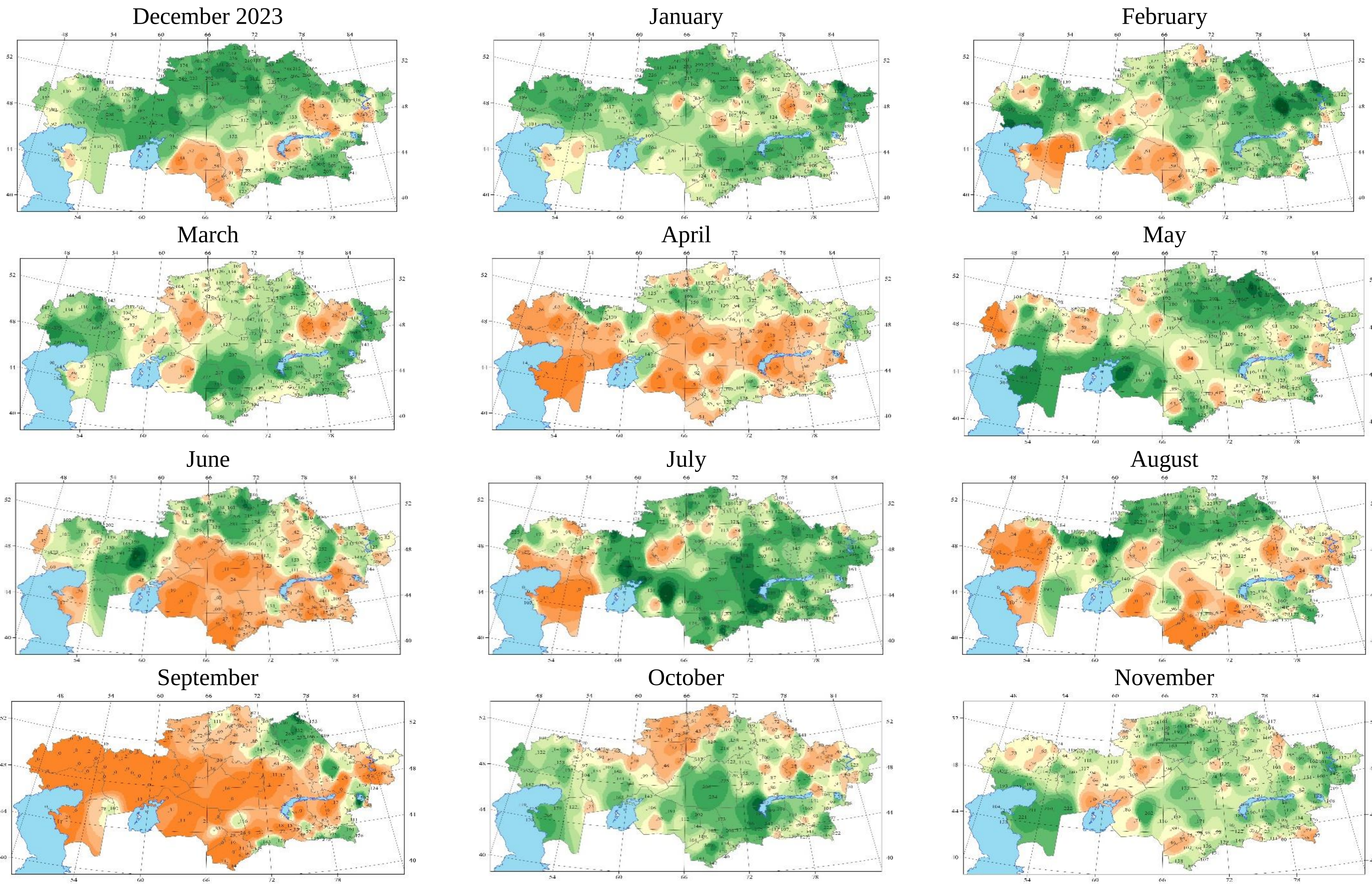


***Figure 3.3** – Spatial distribution of monthly precipitation in 2024 (in % of the norm calculated relative to the base period of 1961–1990)*

In March, the average precipitation across Kazakhstan was 143.1 % of the 1961–1990 norm, which is 10 mm above the long-term average (16th rank, probability of not exceeding 81 %, Table 3.2). Significant excess precipitation was observed in most of the western, northeastern, central, eastern, and southern regions of the country, as well as in the Balkhash region and in the north of the Aral Sea region – from 1.2 to 3.9 times higher than normal (Figure 3.3). Particularly pronounced areas of waterlogging were recorded in the east of the West Kazakhstan region (317 % of the norm), in the north of the Atyrau region (370 % of the norm), in the east of the Abay region (360 % of the norm), in the south of the Balkhash region (392 % of the norm), in the north of the Turkestan region (365% of the norm), and in the east of the Kyzylorda region (336 % of the norm). In these regions, 29 meteostations recorded extremely wet conditions with 5 and 10 percent extremes, with three stations setting new monthly precipitation records: Shieli (Kyzylorda region) – 74.5 mm, Tasty (Turkestan region) – 67.9 mm, Shyganak (Zhambyl region) – 54.9 mm. The previous records at these stations (57.8 mm, 50.1 mm, 42.2 mm) were recorded in 1984, 2016, and 2018, respectively. A significant precipitation deficit was observed in most of the Kostanay region (21–74 % of the norm), in the Abay region (78 % of the norm), in the central part of the Kyzylorda region (36–79.9 % of the norm), as well as in some areas of the Mangystau, North Kazakhstan, Akmola, Pavlodar, East Kazakhstan, and Karaganda regions, where local pockets of precipitation deficiency (below 41–79 % of normal) were observed. According to data from five meteostations located in Kostanay and Abay regions, March was among the most extremely dry months (5 and 10 % extremes), including at the Kainar meteostation (Abay region), where only 0.8 mm was recorded, and at the Karaul station, where 2.2 mm was recorded, which corresponds to the minimum monthly precipitation.

In April, the average precipitation across the country was 93.1 % of normal, which is 2.1 mm below the long-term average (49th rank, probability of not exceeding 42 %, Table 3.2). Although average moisture levels across the country were within the norm, most of the country experienced a precipitation deficit (less than 70 % of the norm). Large areas of precipitation deficit (1–59 % of normal) were observed in most of the western, central, and southern regions, including the Abay region and the south of the Kostanay region (Figure 3.3). Local areas of precipitation deficit were also observed in the north of the Kostanay region (57–74 % of normal), in the North Kazakhstan (66–79 % of normal) and Pavlodar (57–76 % of normal) regions. According to data from 15 meteostations, extremely dry conditions were recorded (5 and 10 % extremes), with no precipitation at all in April at the Fort Shevchenko station (Mangystau region); the previous record (0.3 mm) was observed in 2012 (Annex 2). In the north of the West Kazakhstan and Aktobe regions, in the central part of the Kostanay region, in most of the Akmola and Pavlodar regions, as well as in the East Kazakhstan region and the adjacent areas of the Abay region and in some areas of the Zhambyl region, on the contrary, there were pockets of significant excess precipitation (160–240 % of the norm). In these regions, precipitation across the territory amounted to 120–177 % of the norm, and nine meteostations recorded extremely wet conditions (5 and 10 % extremes were recorded).

May was wetter than April: average precipitation across the country was 130.9 % of normal, which is 10.5 mm above the long-term average (Table 3.2). Nevertheless, pockets of precipitation deficit persisted in some areas of the western regions (37–79 % of normal), as well as in parts of the north, east, center, and south of the country, where local areas with 41–77 % of normal were recorded (Figure 3.3). The most pronounced deficit was observed in the western part of West Kazakhstan and Atyrau regions, where average precipitation values across the territory amounted to 95–99 % of the norm. According to data from three meteostations, extremely dry conditions were recorded (5 and 10 % extremes): the stations of Zhana Ushtogan (1.6 mm) and Urda (1.9 mm) recorded monthly minimum precipitation (previous records date back to 1957 and 2019), and the station of Janibek (West Kazakhstan region) had no precipitation throughout the entire month (Annex 2). The Amangeldy meteostation (Kostanay region) also recorded a precipitation deficit of 37.5 % of the norm, which corresponds to the 19th percentile. Most of the southwestern, western, northern, northeastern, eastern, and southern regions saw significant precipitation above normal – more than 150 % of normal. Four large areas of increased humidity were recorded in Mangystau (384 % of the norm), Kyzylorda (458 % of the norm), Akmola (328 % of normal) and Pavlodar (513 % of normal) regions, where the average values for the territory were 180–290 % of normal. According to data from 27 meteostations, extremely wet conditions (5% of extremes) were recorded in these areas. The Aktogay meteostation (Pavlodar region) recorded 112.4 mm of precipitation, which is 90.5 mm above the long-term average. In May, seven meteostations in the Akmola and Pavlodar regions recorded new absolute records for monthly precipitation: Shchuchinsk meteostation – 80 mm (previous record 76.3 mm in 2007), MS Zhaltyr – 112.2 mm (previous maximum – 100.3 mm in 1988), MS Golubovka – 80 mm (76.8 mm in 1994), MS Ertis – 84.8 mm (76.1 mm in 1954), MS Shaldai – 98.2 mm (72.0 mm in 2018), MS Ekibastuz – 103.8 mm (83.8 mm in 2000) (Annex 2).

In summer, precipitation was unevenly distributed across Kazakhstan, with average precipitation at 136.8 % of normal, corresponding to the 11th wettest summer season in the entire observation period, with a probability of not exceeding 87 % (Table 3.1). Excessive moisture during the summer was observed in most of the Aktobe region (135–301 % of the norm), as well as in the northern (133–232 % of the norm), eastern (125–188 % of the norm), central (122–217 % of normal) regions and in some areas of Zhetysu (124–207 % of normal), Almaty (124–189 % of normal), Zhambyl (131–199 % of the norm) and Kyzylorda (182–238 % of the norm) regions. In these regions, 34 meteostations recorded extremes at the 5th percentile level, corresponding to the category “extremely wet,” with six of them setting new seasonal records for precipitation (Figure 3.2). For example, the Karabutak meteostation in the Aktobe region recorded three times the normal amount – 216.5 mm (compared to the previous record of 211.7 mm in 1946). New absolute maximums were also recorded at the following meteostations: Tayynsha – 351.4 mm (North Kazakhstan region), Arshaly – 292.3 mm, Zhitikara – 241.7 mm (Kostanay region), Kos Istek – 267.2 mm, Mugalzhar – 161 mm (Aktobe Region); the previous records were set in 1960, 1993, 1994, and 2003 (Annex 2). Localized areas of precipitation deficit (60–78 % of normal) were recorded in certain districts of the central, eastern, and southeastern regions. Areas with severe drought were observed in most of the Mangystau (3–51 % of normal) and Atyrau (26–72 % of normal) regions, as well as in certain areas of the Kostanay (33–35 % of normal), Kyzylorda (21–73 % of normal) and Turkestan (9–66 % of normal) regions, and in the southern regions as a whole. Two meteostations in the Mangystau region – MS Kulaly Island and MS Kyzan – experienced extreme drought, with 5 % extremes recorded, while the total amount of precipitation during the summer season was 1.1 mm (3 % of the norm) and 7.5 mm (18 % of the norm), respectively.

In June, the average precipitation across Kazakhstan was 113.1 % of normal, which is 4 mm above the annual average (Table 3.2). A significant precipitation deficit (3–39 % of normal) covered the Mangystau region, a large part of the southern and central regions, as well as the adjacent southern areas of the Kostanay region and the Abay region. In the Ulytau region (probability of not exceeding 4 %), as well as in the Kyzylorda, Turkestan, Zhambyl, Almaty (probability of not exceeding 8 %), and Zhetysu regions, the average precipitation across the territory ranged from 16.9 % to 52 % of the norm, which is 5.6–29.9 mm below the long-term average. Based on data from 15 meteostations, these areas were among the 5–10% driest Junes in the entire observation period (Table 3.2). No precipitation was observed during the month at the Karak, Kyzylkum, Shardara, and Ashysai meteostations, while the Aksengir meteostation recorded a new minimum monthly precipitation of 0.9 mm (the previous minimum was 6.7 mm in 1995 (Annex 2). Small pockets of precipitation deficit (less than 43–78 % of normal) were also observed in the southern part of the Atyrau region, the western part of the West Kazakhstan region, most of the Pavlodar region, as well as in some areas of the Kostanay, Karaganda, East Kazakhstan regions and the Abay region. In June, excessive moisture was observed in most areas of Aktobe (145–535 % of normal), Kostanay (145–259 % of normal), North Kazakhstan (138–407 % of normal), Akmola (178–283 % of normal) regions, and in the Abay region (183–252% of normal), where average precipitation for the region was 161–172 % of normal. In addition, high precipitation values were observed in the east of the Mangystau region, the north of the West Kazakhstan region, and the central part of the East Kazakhstan region (171–202 % of the norm, Figure 3.3). Extreme precipitation values (90 and 95 % extremes) were recorded at 21 meteostations in the western, northern, and eastern regions of the country. Three of them recorded new monthly precipitation records: MS Tayynsha – 156 mm (previous record: 132.5 mm in 1938), Chkalovo – 144.1 mm (2005 record: 108.8 mm), Mugalzhar – 113.7 mm (2003 record: 92 mm).

In July, most of Kazakhstan experienced significantly above-normal precipitation, with average precipitation at 159.1 % of normal, which is 20 mm above the annual average (the ninth highest July precipitation since 1941, with a 90% probability of non-recurrence, Table 3.2). The highest excesses (4–6.1 times) were recorded in the north and south of the Aktobe region, in the east of the Ulytau region, in the southern part of the Karaganda region along Lake Balkhash, in the central and eastern parts of the Zhambyl region, in the central districts of the Kyzylorda region, and in the north of the Aral Sea region. In these areas, the average excess of the norm ranged from 181% to 319% of the norm. In addition, excess precipitation (150–389% of the norm) was observed in the western, most northern and eastern, as well as southern and southeastern regions of the country. According to data from 51 meteostations located in the above-mentioned regions, “extremely wet” conditions were observed in July, with 5 % and 10% extremes recorded. The Dmitrievka meteostation (Abay region) recorded 160.1 mm of precipitation for the month, which is a new record (the previous record was 134.3 mm in 1993). New monthly precipitation maximums were also recorded at the following meteostations: MS Saryshagan (Karaganda region) – 46.6 mm, MS Khantau (Zhambyl region) – 47.8 mm, MS Tugyl (East Kazakhstan region) – 70.8 mm (Annex 2). A severe precipitation deficit (less than 60 % of normal), extreme in some places (less than 40 %, less than 20 %) and even record-breaking (less than 6 % of normal), was recorded across most of the Mangystau and Atyrau regions. Average precipitation values for these regions were 9.9–10.9 mm below normal (extremes of 5% were recorded). No precipitation was recorded during the month at the Kulaly Island, Fort Shevchenko, and Beineu meteostations (Mangystau region), as well as at the Zhetysai meteostation. Small areas with precipitation deficits (28–78% of normal) were observed in the northeast of the West Kazakhstan region, the south of the Kostanay region and adjacent areas in the east of the Aktobe region, as well as in some areas of the Akmola, Pavlodar, East Kazakhstan, and Kyzylorda regions.

In **August**, the average precipitation across Kazakhstan was 135.8 % of normal, or the probability of not exceeding normal was 81 % (Table 3.2). Most of the northern, central, southeastern, and southwestern parts of the country experienced pockets of excessive precipitation, where the amount exceeded the norm by 1.4–4.8 times (Figure 3.3). Five meteostations located in these regions recorded record precipitation values (Annex 2), and according to data from 27 meteostations, August 2024 was characterized as extremely wet (5% and 10% extremes were recorded). As a result, on average across the regions, the highest humidity was observed in the Akmola (3rd rank), Aktobe (6th rank), and Pavlodar (9th rank) regions, where precipitation ranged from 166.6 to 222.5 % of the norm. A significant precipitation deficit (from 3 to 77% of the norm) affected many areas in the western and southern regions of the country. According to data from 16 meteostations located in these regions, the month was among the driest in the observation period (5% and 10% extremes, Figure 3.3), with 12 of them recording no precipitation throughout the month. The average values for the region were as follows: in the Mangystau region – 26 % of the norm, in the Atyrau region – 23.7 %, in the Turkestan region – 20.7 %, and in the Zhambyl region – 43.7 %, which is 3.3–8.8 mm below the long-term values. Small pockets of precipitation deficit (from 17 to 79% of the norm) were observed in the south of the Kostanay region, in the east and center of the adjacent Aktobe region, in some areas of the Ulytau and Karaganda regions, as well as in most of the East Kazakhstan and Abay regions, and in the border areas near Lake Alakol.

In autumn, the average rainfall in Kazakhstan was 84.1 mm, which corresponds to 106.3 % of the norm. The distribution of precipitation across the country was uneven (Figure 3.2). In most of the Kostanay, Aktobe and West Kazakhstan regions, there were large foci of precipitation deficiency (from 32 to 77 % of the norm), while the region's average values were 66.3–76.9 % of the norm. Small foci of precipitation deficiency (from 52 to 78% of the norm) were observed in certain areas of Atyrau, North Kazakhstan, Karaganda and eastern regions, as well as in certain areas of the Zhambyl region, in the western and central parts of the Turkestan region and the adjacent Kyzylorda region, as well as in the Aral Sea region. According to 31 meteostations located in these areas, 5 % and 10 % extremes were observed. At MS Arshaly (Kostanay region), a new minimum rainfall for the autumn season was recorded - 31.1 mm, with a previous minimum of 34.9 mm, in 1975.

Excess precipitation on average in the territory was observed in Pavlodar and Almaty regions, where the amount of precipitation ranged from 137.1 to 145.6 % of the norm (the probability of non-exceedance is 90 and 93 %, respectively). According to a number of observations, this is the sixth and ninth most humid autumn season. In addition, large pockets of excessive moisture were observed in certain areas of Mangystau, Zhambyl, Turkestan, Kyzylorda regions, Ulytau and Abay regions, as well as in the Caspian lowland, near Lake Alakol and on the southwestern coast of Lake Balkhash (Figure 3.2). Very wet conditions were observed at 20 meteostations located in the western, northern, central and eastern regions, while 5 % extremes were recorded at 14 MS of them. MS Mikhailovka (Pavlodar region) and Chiganak (Zhambyl region) recorded record values of seasonal precipitation (Annex 2).

In **September**, there was a pronounced deficit of precipitation in most of the country: the average amount of precipitation in Kazakhstan was 72.3 % of the norm (the probability of non-exceedance is 26 %), which is 5.4 mm lower than the long-term average (Table 3.2). Large pockets of precipitation deficit (less than 30 % of the norm) covered almost the entire territory of the western and central regions, as well as a significant part of the northern, southern and eastern regions (Figure 3.3). According to 41 MCs located in these areas, the month was characterized as "extremely dry" (5 % extremes were recorded), while 31 of them did not have precipitation throughout September. A sharp deficit of precipitation was noted in Mangystau, Aktobe, West Kazakhstan regions and the Ulytau region, where the average values for the territory ranged from 0 to 6.9% of the norm, which is 11.3–21.3 mm lower than long-term values. Excessive precipitation was observed in the north-east of the country (144–435 % of the norm), in some areas of the Abay region (129-292 % of the norm), in the south of Balkhash (155 % of the norm), in the Alakol region (502 % of the norm) and in the mountainous regions of the south-eastern part of Kazakhstan (135–270 % of the norm) (Figure 3.3). In these areas, 16 meteostations had very humid conditions (5 % and 10 % extremes were noted), of which the record value of the maximum monthly rainfall was noted at the Aktogay MS (Pavlodar region) (Annex 2).

In October, humidification in the country as a whole corresponded to the norm: the average rainfall was 109.1% of the norm, which is 2.8 mm higher than the long-term average (Table 3.2). Excessive precipitation (over 150% of the norm) was observed in several regions of the western, central, northern and southern regions, as well as in certain regions of the Abay region (Figure 3.3). Large pockets of moisture were located in the western and southwestern parts of Balkhash and in the adjacent territory of the Zhambyl region: at MS Saryshagan (38 mm, 436.8 % of the norm) and MS Khantau (101.8 mm, 340.5% of the norm), record maximum values of monthly precipitation were updated, noted in 1976 and 2006, respectively (Annex 2). In these areas, at 17 MS, humidification conditions were characterized by 90 % and 95 % extremes. Small areas with a precipitation deficit (29–79 % of the norm) covered a significant part of the northwestern and northern regions of the country, the north of Pavlodar region, certain areas in the north and south of Abay region, East Kazakhstan region, as well as some areas in the west, center and south of Kazakhstan (Figure 3.3).

In November, an uneven distribution of precipitation was observed throughout the country. The average amount of precipitation in the territory was 125.2 % of the norm (rank 15, probability of non-exceedance 83 %, Table 3.2). Excessive precipitation was observed in Mangystau and Atyrau regions (158–251 % of the norm), in most of the Akmola region and in the adjacent border areas of Kostanay, North Kazakhstan and Pavlodar regions (124–214 % of the norm), in most of the central and eastern regions (122–201 % of the norm), as well as in certain areas of the southern part of the country (151–262 % of the norm). Significant excess of precipitation was also observed in the Balkhash region (137–187 % of the norm) and in the Alakol region (166–225 % of the norm) (Figure 3.3). In Atyrau (213.1 % of the norm) and Mangystaussky (216.5 % of the norm) regions, November was among the 50 % of the wettest months. At 5 meteostations located in the southwestern and eastern regions of the country, humidification conditions were characterized as extremely humid (95 percent extremes were noted). At Kurshim MS (East Kazakhstan Region), the November 2018 record for precipitation was updated – 72.1 mm (264.1 % of the norm) (Annex 2). Small foci of precipitation deficiency covered the West Kazakhstan region, the north-west of Kostanay, Pavlodar regions and the Abay region, as well as certain sections of the southern regions, where the amount of precipitation was 60–78% of the norm. More pronounced foci of precipitation deficiency (38–54 % of the norm) were observed in Kostanay and Aktobe regions, as well as in the adjacent Aral Sea region (Figure 3.3).

To assess the extreme rainfall in 2024, climate change indices recommended by the World Meteorological Organization were assessed. Below is an analysis of some of the most indicative precipitation indices and features of the distribution of their values across Kazakhstan in 2024.

Figure 3.4 shows the values of absolute maximums of daily precipitation recorded from the beginning of the opening of the meteostation to 2024 (shown in blue). The values of the daily maximums of precipitation that covered the previous absolute maximum in 2024 are highlighted in red. In 2024, the value of the absolute maximum rainfall was exceeded at 6 meteorological stations in Kazakhstan: 77.6 mm fell per day at Aktobe MS, the previous maximum was in 2021 and amounted to

58.9 mm; at MS Kos-Istek – 100.5 mm (the previous maximum in 1983 was 57.2 mm); at Zhanaark MS – 50.8 mm (the previous maximum in 1967 was 47.0 mm); on MS Taiynsha – 85.5 mm (the previous maximum in 1963 was 84.0 mm); at Timiryazevo MS – 106.2 mm (the previous maximum in 1988 was 84.7 mm); at Chiganak MS, where 35.0 mm fell per day, the previous maximum daily rainfall was observed in 2004 and amounted to 31.9 mm.

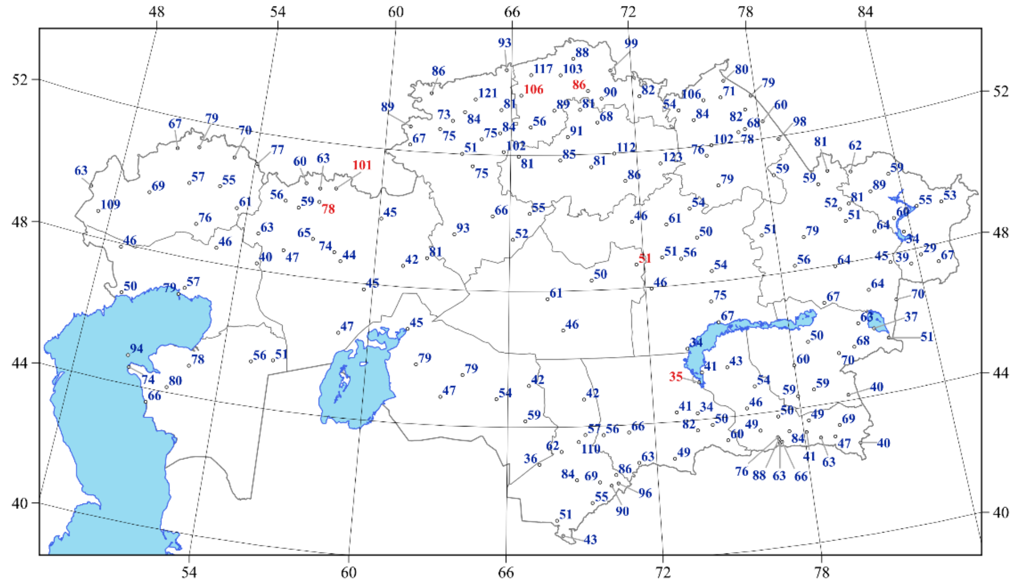


Figure 3.4 – *The absolute maximum of daily precipitation (mm), selected for the period from the beginning of the opening of the meteostation to 2024. If the record daily precipitation is recorded in 2024, the value is marked in red*

The daily maximum rainfall selected according to data for 2024 (Rx1day index) was 10–30 mm in most of Kazakhstan (Figure 3.5). The highest maximum daily rainfall was observed in the North Kazakhstan and northern parts of Aktobe regions, where they reached 77–106 mm, in the northern part of the Abay region – 72 mm, in the north, northeast, east, in the central regions, in the foothill and mountainous regions of the south and southeast, in the northern part of the western and northwestern regions it was in places more than 30–40 mm, in the region Ulytau in places more than 50 mm. The lowest maximum daily rainfall (less than 10 mm) was observed in the southern part of Aktobe and Kyzylorda regions.

In 2024, the share of very heavy precipitation (when the daily rainfall is equal to or more than the 95th percentile, the r95ptot index) in the annual rainfall in most of Kazakhstan was less than 30 % (Figure 3.6).

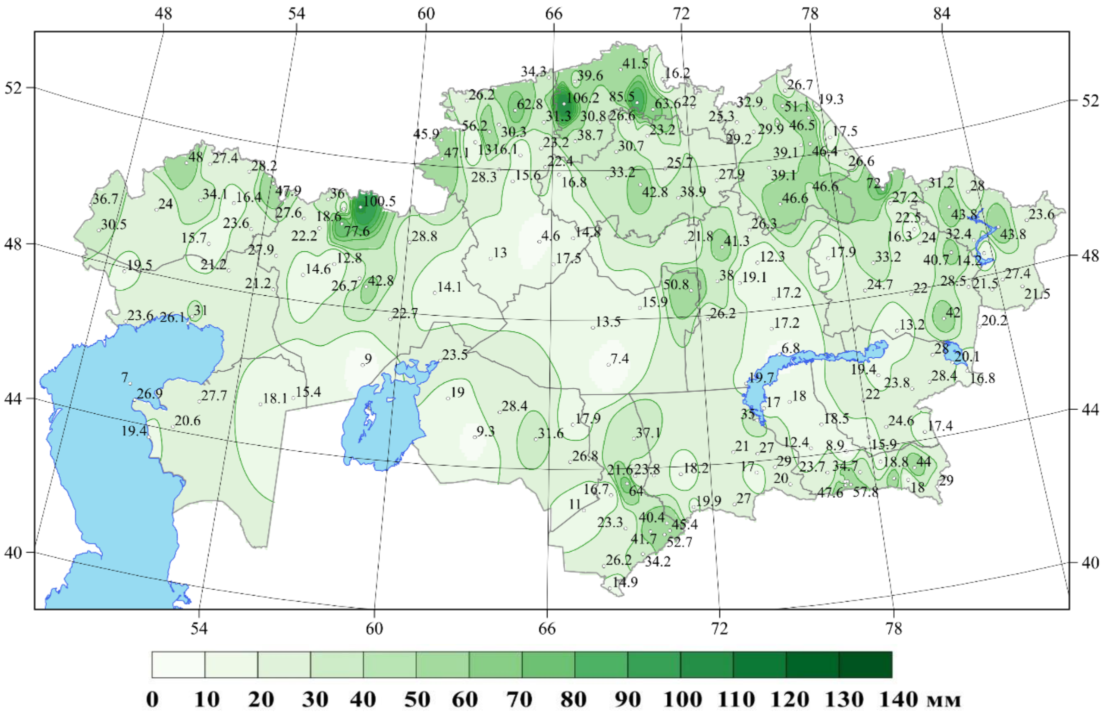


Figure 3.5 *– Daily maximum precipitation in 2024 (Rx1day index)*

The largest contribution of very heavy precipitation (more than 40–50 %) was noted in most of the northern and northeastern regions, in the Kyzylorda region, as well as in some places in the western, southeastern and eastern regions of the country. At the same time, in a number of regions there were situations when the daily rainfall did not reach the 95th percentile, which indicates the absence of extreme precipitation in these meteostations.

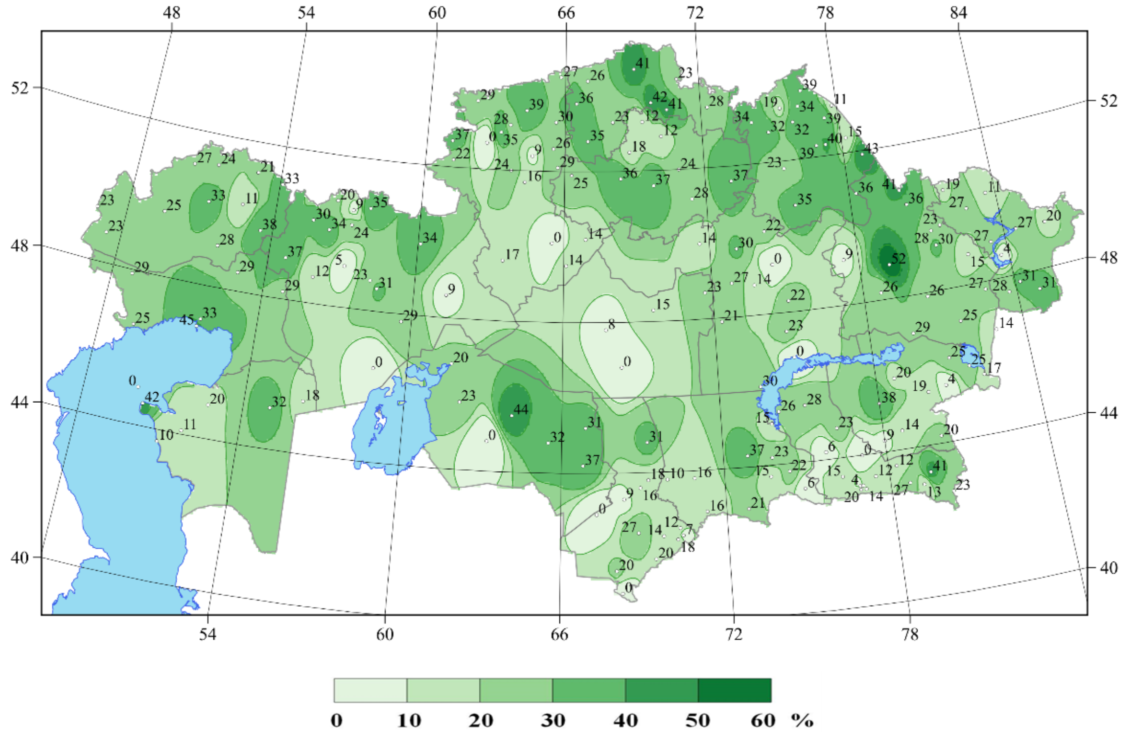


Figure 3.6 *– The share (in %) of extreme daily precipitation in the annual precipitation amount for 2024 (r95ptot index)*

In the arid climate of Kazakhstan, the CDD index is very important, which shows the maximum duration of the idle period, when the daily rainfall was less than 1 mm. In 2024, in most of the territory of the republic, the maximum continuous duration of the idle period was 20–60 days. The longest period of idle time was observed in Turkestan, Kyzylorda, Mangystau and West Kazakhstan regions – more than 75 days (Figure 3.7). The maximum duration of the idle period was recorded in the Turkestan region: on MS Zhetysai – 142 days without precipitation, Kyzylkum – 98 days, Shardara – 90 days. In the Mangystau region, long idle periods were noted at Fort Shevchenko MS and Kulaly Island (98 days each), as well as Kyzan MS (97 days). In the West Kazakhstan region at MS Chapaevo and in the Kyzylorda region at MS Karak, the maximum duration of the idle period was 84 days. The shortest duration of the idle period (12 days) was recorded at the Mynzhylky MS in the Almaty region.

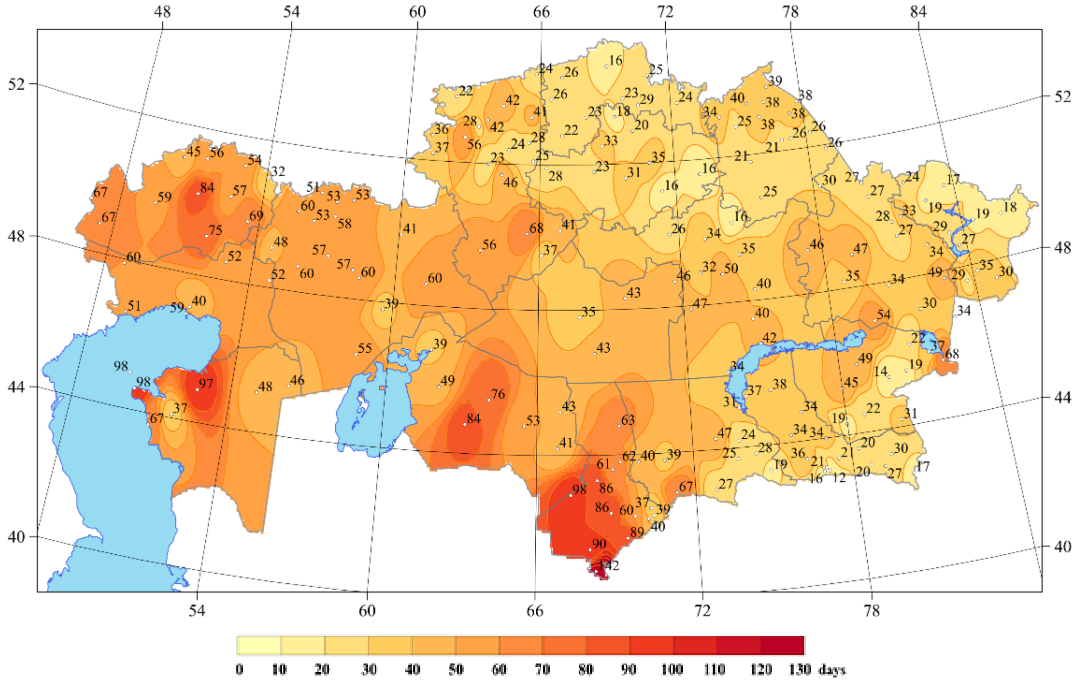


Figure 3.7 *– Maximum duration of the idle period in 2024, day (CDD index)*

3.2 Observed changes in precipitation

Linear trends in the series of monthly, seasonal and annual amounts of atmospheric precipitation were estimated according to the data of the 121st station.

Time series of anomalies of annual and seasonal amounts of precipitation for the period 1941–2024, calculated relative to the base period 1961–1990. and spatially averaged over the territory of Kazakhstan and regions give a general idea of the nature of modern changes in the precipitation regime (Table 3.3, Figures 3.8 and 3.9). The annual rainfall on average in Kazakhstan decreased in the 1960s and 1970s, in the last 40-year period there were no long-term trends, there was an alternation of short periods with positive and negative anomalies in the amount of atmospheric precipitation.

In the period 1976–2024 trends in the average relative anomalies of annual and seasonal precipitation amounts in Kazakhstan are practically absent - the share of the trend component in the total dispersion of the series mainly does not exceed 3 %, a positive trend sign is observed for winter, spring, summer and annual precipitation amounts, for autumn - negative (Table 3.3, Figure 3.8).

Table 3.3 – Characteristics of the linear trend of the anomaly of seasonal and annual precipitation amounts (% norm/10 years) averaged over the territory of Kazakhstan and its regions for the period 1976–2024

Region/region	Year		Winter		Spring		Summer		Autumn	
	a	**D**	**a**	**D**	**a**	**D**	**a**	**D**	**a**	**D**
Kazakhstan	1,1	1	1,9	2	2,5	3	0,5	0	-0,4	0
Abay	2,0	3	2,1	1	0,5	0	3,9	3	1,1	0
Almaty	0,8	0	2,4	1	0,8	0	-0,6	0	1,9	1
Akmola	4,5	**10**	**10,8**	15	3,1	2	3,4	2	3,7	3
Aktobe	-0.5	0	0.1	0	4.6	2	-2.4	1	-3,8	3
Atyrau	3.6	4	9.2	8	**17.1**	14	-8.3	5	-1.2	0
East Kazakhstan	1.4	2	3.4	2	1.7	1	0.3	0	1.3	1
Zhambyl	-1.3	1	-0.3	0	-1.0	0	0.6	0	-2.9	1
Zhetysu	1.4	1	4.7	3	2.8	2	-0.9	0	-0.5	0
West Kazakhstan	0.1	0	-1.5	1	**9.7**	12	-4.4	3	-1.1	0
Karaganda	1.3	1	1.7	1	-0.9	0	4.6	3	-1.7	1
Kostanay	-0.1	0	0.6	0	**5.0**	4	-0.9	0	-2.9	2
Kyzylorda	-3.8	4	-0.6	0	-1.4	0	-4.8	1	**-10.4**	13
Mangystau 1	-4.1	3	**5.0**	2	**-8.6**	5	**-5.8**	1	-3.2	1
Pavlodar	2.4	3	3.0	3	4.8	3	1.6	1	2.3	1
North Kazakhstan	2.8	5	4.9	3	**8.1**	**10**	1.7	1	0.0	0
Turkestan	0.6	0	0.1	0	1.8	1	2.2	0	-0.7	0
Ulytau	0.9	0	-2.4	2	2.7	1	4.0	2	0.0	0

Notes: *1. a – linear trend coefficient, %norm/10 years;*

2. D – coefficient of determination, %;

3.statistically significant trends are highlighted in bold.

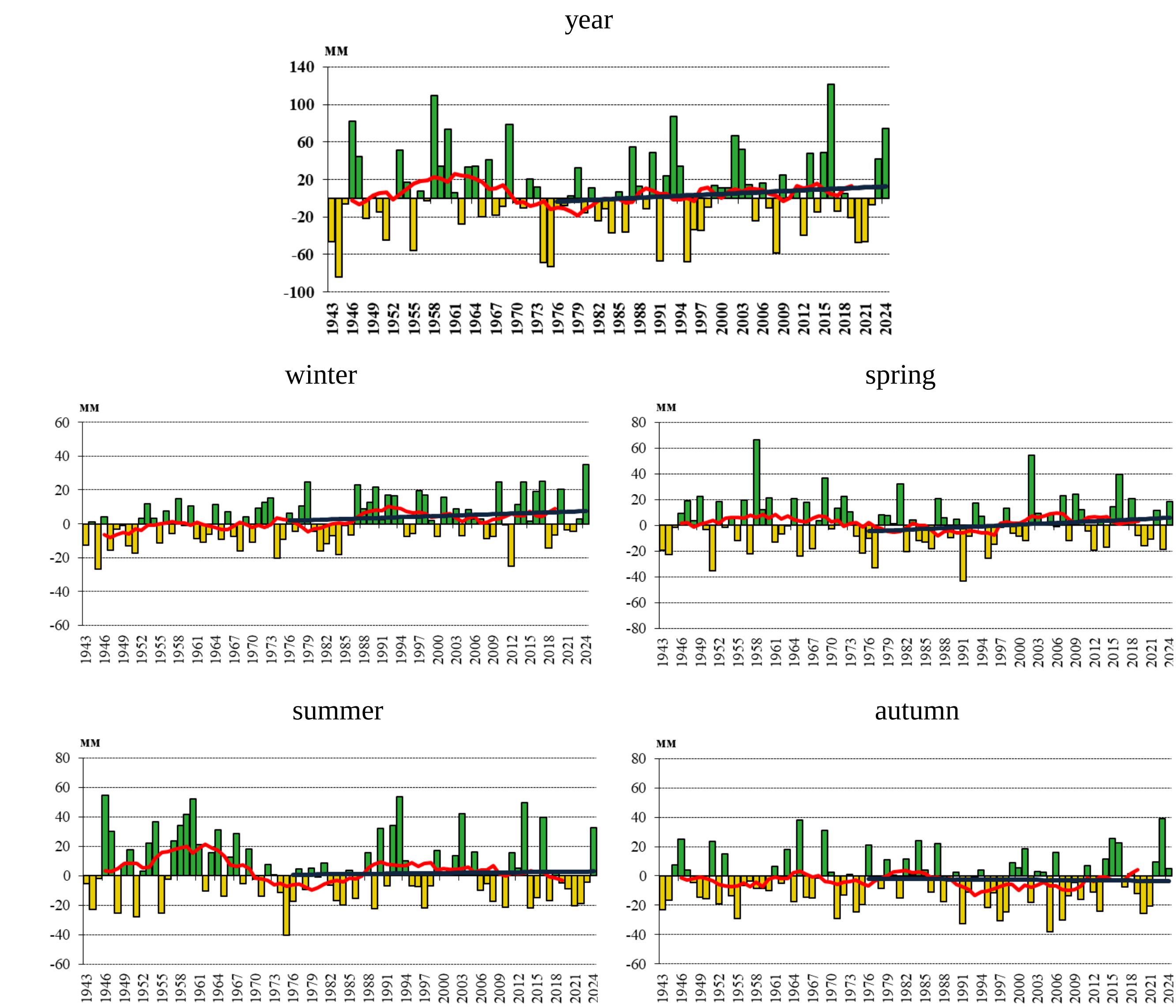


***Figure 3.8** – Time series of anomalies of annual and seasonal precipitation amounts (%) spatially averaged over the territory of Kazakhstan for the period 1941 – 2024. Anomalies are calculated relative to the base period of 1961 – 1990. The linear trend for the period 1976 – 2024 is highlighted in black. The smoothed curve is obtained by an 11-year moving average*

In most areas, both increasing and decreasing trends in annual precipitation are negligible, with a coefficient of determination of 3 % or less. In Akmola and North Kazakhstan regions, the rate of increase in annual precipitation was about 4.5 % and 2.8 % of the norm/10 years with a coefficient of determination of 10 % and 5 %, respectively. In Kyzylorda and Mangystau regions, precipitation decreased at a rate of 3.8 and 4.1 % norm/10 years with a coefficient of determination of 4 % and 3 %, respectively (Table 3.3, Figure 3.9). On average, in the territory of Kazakhstan in the period 1976–2024. there is a slight trend towards an increase in the annual amount of precipitation by 1.1 % of the norm/10 years (Table 3.3).

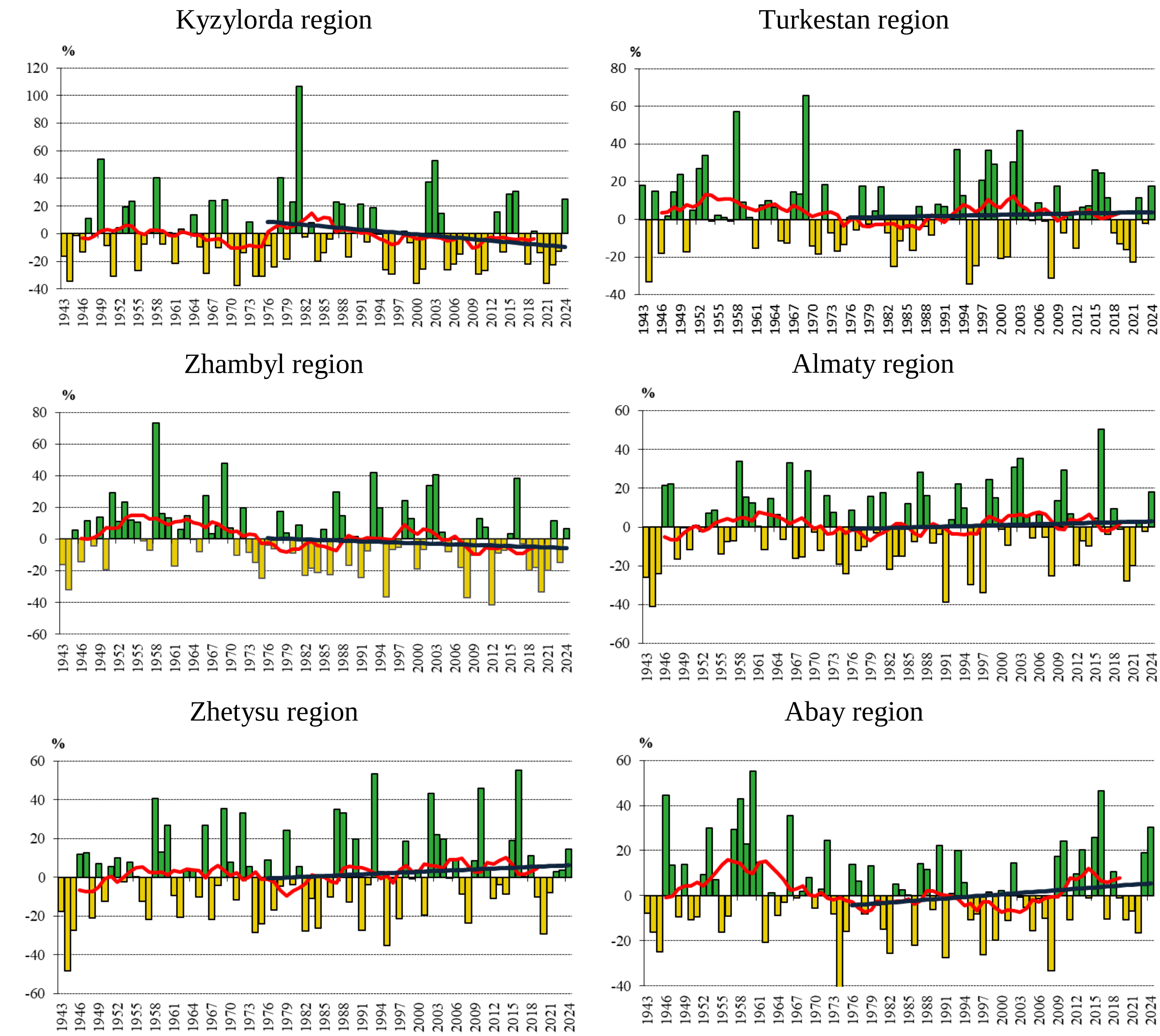


Figure 3.9 *– Time series of anomalies of annual precipitation amounts (%) for the period 1941-2024, spatially averaged across the regions of Kazakhstan. Anomalies are calculated relative to the base period of 1961 – 1990. The linear trend for the period 1976 – 2024 is highlighted in black. The smoothed curve is obtained by an 11-year moving average. Sheet 1*

In winter, on average in Kazakhstan, the trends in relative anomalies of seasonal rainfall slightly increased – by 1.9 % of the norm every 10 years. The most significant trends towards an increase in precipitation are observed in the Akmola region - 10.8 % of the norm/10 years (coefficient of determination is 15%), Atyrau – 9.2 % norm/10 years (coefficient of determination – 8 %), Mangystau – 5 % norm/10 years (coefficient of determination – 2 %), North Kazakhstan regions – 4.9 % norm/10 years (coefficient of determination - 3 %) and in the region of Zhetysu – 4.7 % norm/10 years (coefficient of determination – 3 %) (Table 3.3, Figure 3.9). The trends towards an increase in precipitation in Akmola and Atyrau regions are statistically significant. A noticeable decrease in precipitation on average in the territory is noted in the West Kazakhstan region, as well as in the Ulytau region – by 1.5 and 2.4 % of the norm/10 years, respectively (the coefficients of determination are 1 % and 2 %, respectively).

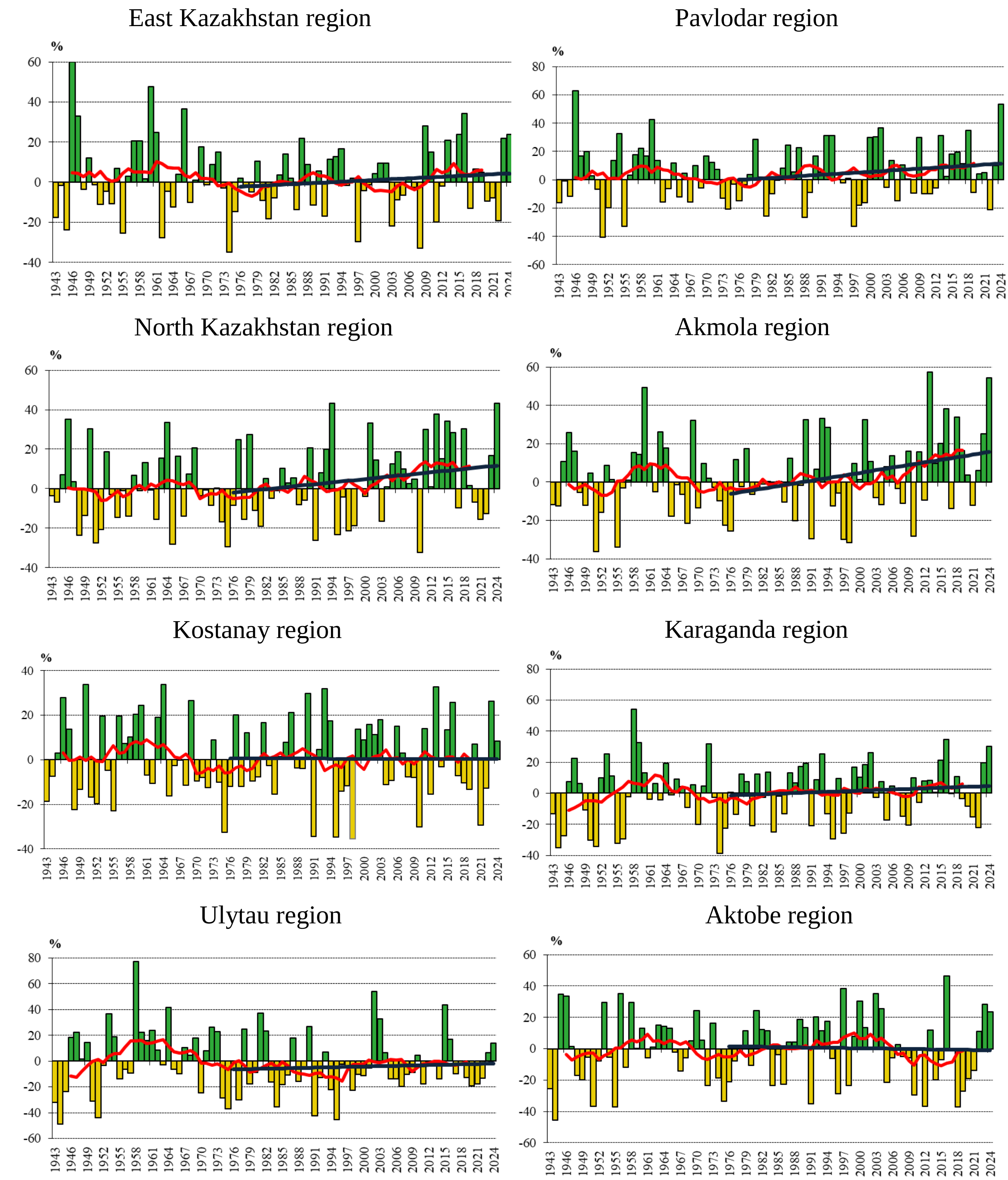


***Figure 3.9** – Time series of anomalies of annual precipitation amounts (%) for the period 1941–2024, spatially averaged across the regions of Kazakhstan. Anomalies are calculated relative to the base period of 1961 – 1990. The linear trend for the period 1976 – 2024 is highlighted in black. The smoothed curve is obtained by an 11-year moving average. Sheet 2*

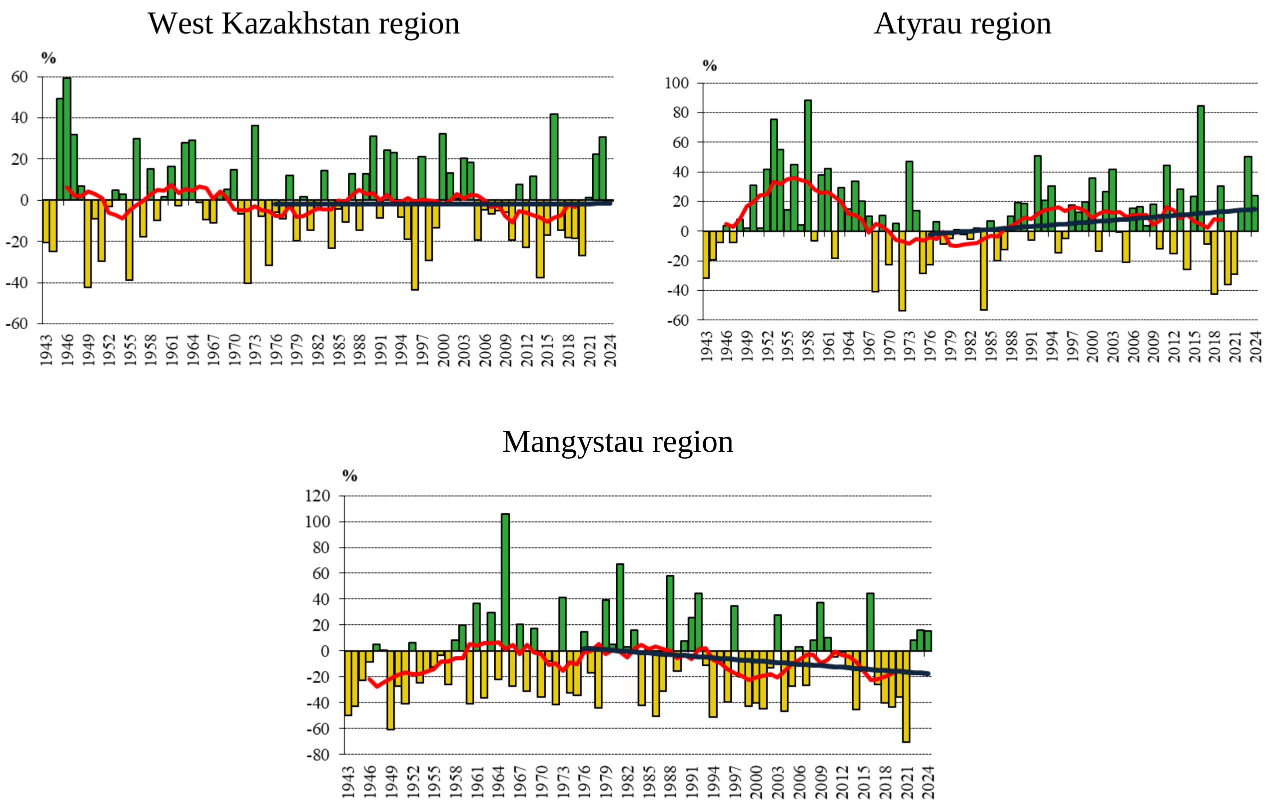


Figure 3.9 *– Time series of anomalies of annual precipitation amounts (%) for the period 1941–2024, spatially averaged across the regions of Kazakhstan. Anomalies are calculated relative to the base period of 1961 – 1990. The linear trend for the period 1976 – 2024 is highlighted in black. The smoothed curve is obtained by an 11-year moving average. Sheet 3*

In ***the spring***, the average precipitation in Kazakhstan increased slightly – by 2.5 % of the norm every 10 years. In the territory of most regions, positive, but also insignificant, are noted. The highest rate of increase in precipitation was recorded in the western and northern regions of the republic. In the western regions - Atyrau (17.1 % norm/10 years), West Kazakhstan (9.7 % norm/10 years) and Aktobe (4.6 % norm/10 years) - the coefficients of determination are 14 %, 12 % and 2 %, respectively. In the north, statistically significant trends were detected in Kostanay (5 % norm/10 years), North Kazakhstan (8.1 % norm/10 years) and Pavlodar (4.8 % norm/10 years) regions with coefficients of determination from 3 % to 10 % (Table 3.3, Figure 3.9). A stable and statistically significant trend towards a decrease in precipitation is observed in the Mangystau region - by 8.6 % of the norm every 10 years, with a coefficient of determination of 5 %. The greatest contribution to the increase in precipitation of the spring season falls on March, when stable statistically significant trends are observed almost throughout Kazakhstan and reach up to 24.4 % of the norm/10 years.

In summer, the trends in the amount of seasonal precipitation in the territory of all regions of Kazakhstan are weakly expressed, the average tendency for Kazakhstan to increase precipitation was 0.5 % of the norm every 10 years. The most significant positive trend in precipitation was observed in the Karaganda region and amounted to 4.6 % of the norm/10 years and the region Ulytau - 4 % of the norm/10 years with coefficients of determination of 3 % and 2 %, respectively. In summer, significant trends towards decreasing rainfall are expressed. This phenomenon was noted in Atyrau - by 8.3 % of the norm/10 years (the coefficient of determination was 5 %), Mangystau – 5.8 % of the norm/10 years and Kyzylorda regions – 4.8 % of the norm/10 years, where the coefficient of determination was 1 %. (Table 3.3, Figure 3.9).

In ***autumn***, in most regions, the trends in the amount of precipitation for the autumn season are negative, the average for Kazakhstan was 0.4 % of the norm/10 years. An increase in precipitation was observed only in the Akmola region – by 3.7 % of the norm/10 years with a coefficient of determination of 3 %. The most significant rates of precipitation decrease are observed in Kyzylorda (10.4 % of the norm/10 years) and Mangystau (3.2 % of the norm/10 years) regions. The trend of decrease in Kyzylorda region is statistically significant with a coefficient of determination of 13 % (Table 3.3, Figure 3.9).

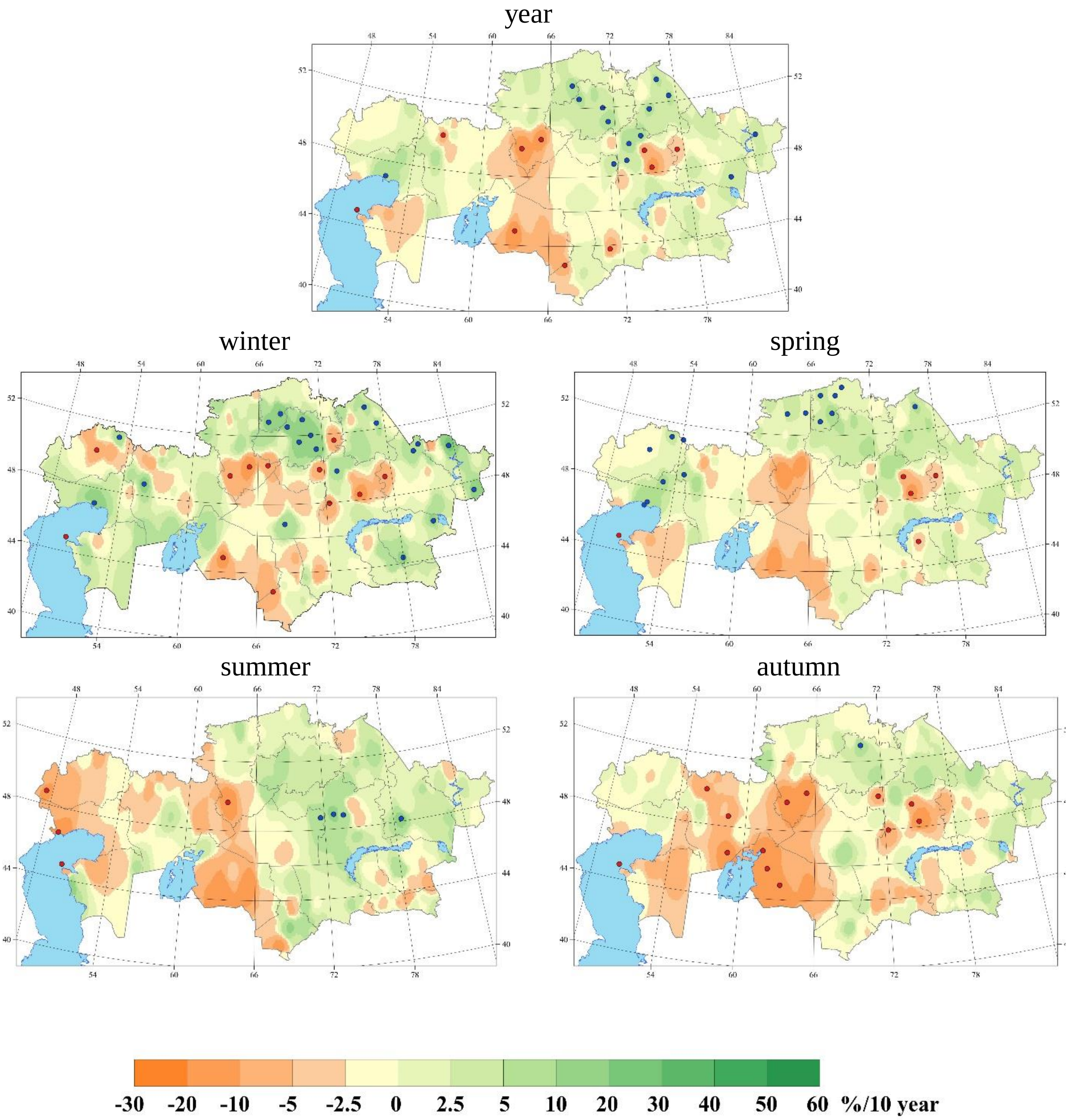
More detailed information on the nature of changes in the precipitation regime in Kazakhstan is provided by the spatial distribution of the values of the linear trend coefficient per annum, relative anomalies of seasonal and separately for each month of precipitation amounts (% norm/10 years) presented in Figures 3.10 and 3.11. Estimates were obtained for station time series of annual, seasonal and monthly anomalies of precipitation for the period 1976–2024. In the republic, there is a spotting in the direction of changes in seasonal and monthly precipitation (Figures 3.10 and 3.11).

In ***winter***, a significant increase in precipitation was recorded in almost all parts of the country - in the west, north (mainly in the Akmola region), southeast, east, as well as in the central regions (by 8–21 % of the norm/10 years). The main contributor to this increase was February (Figure 3.11). Foci of statistically significant trends within 7-14 % of the norm/10 years to a decrease in seasonal precipitation is observed in the center of West Kazakhstan, in the west of Mangystau, in the south of Kostanay, in the east of Akmola, in some areas of Karaganda, in the south of Kyzylorda, Turkestan regions, as well as in the west of the Abay region.

In **December**, trends towards a decrease in precipitation were observed in the western and northwestern parts, in the eastern part of central Kazakhstan, as well as in the southern and southeastern half of Kazakhstan (Figure 3.11). Significant trends towards a decrease in precipitation were observed mainly in the south in the Kyzylorda, Turkestan and Zhambyl regions (by 12-17 % of the norm/10 years) at some meteorological stations in the north of West Kazakhstan and the south of Kostanay regions (by 13 % of the norm/10 years) and in central Kazakhstan (by 13 % of the norm/10 years).

In **January**, trends towards a decrease in precipitation are observed in the west, north and northeast, in the central region and in some small foci in the south-west (Figure 3.11). Statistically significant trends in the decrease in precipitation are noted at some stations in the central and northern parts of the country from 10.3 % to 14.6 % of the norm/10 years. Trends towards an increase in precipitation are observed in some areas of the north (by 12.5–20.2 %/10 years), east (by 14.4–23.5 % of the norm/10 years), in the south of the country (12-19 % of the norm/10 years).

In **February**, an increase in precipitation is observed in most of Kazakhstan, with the exception of foci of decreasing precipitation in the west, south of Kostanay region, southern regions and in the east of Central Kazakhstan. Statistically important trends to reduce precipitation are observed in four meteostations: in the west, north, south and center and ranges from 10.3 % to 17.3 % of the norm per decade. In the northern and southeastern regions of the country, as well as at three meteostations in the west and one in Central Kazakhstan, statistically important trends towards an increase in precipitation are noted and range from 12.2 % to 33 % of the norm per decade.



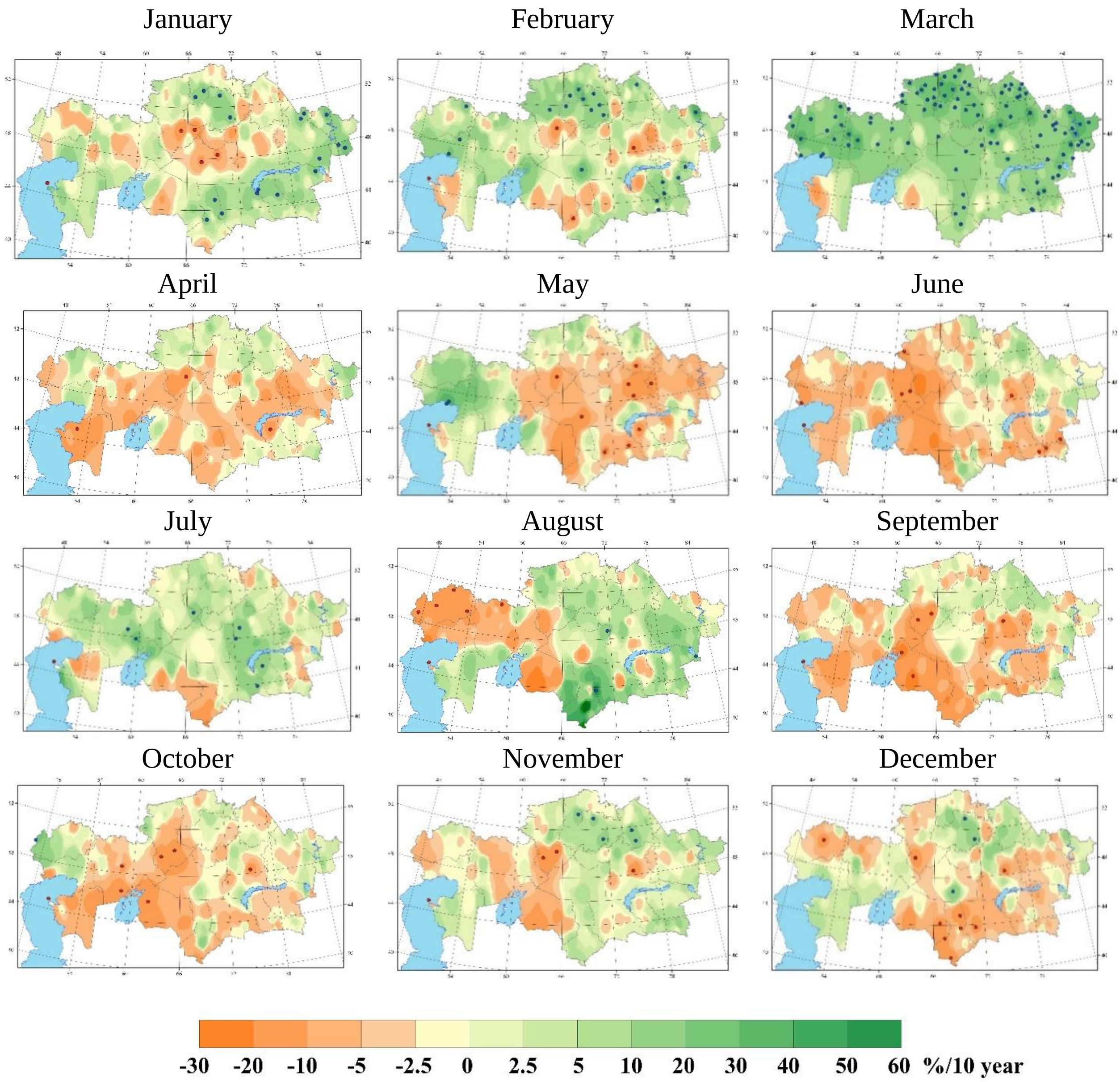
significant positive and negative values of the linear trend coefficient are highlighted in green (increase in precipitation) and red (decrease in precipitation)

***Figure 3.10** – Spatial distribution of values of the linear trend coefficient of annual and seasonal precipitation amounts (%/10 years) calculated for the period 1976 – 2024*

In ***the spring***, the trend towards an increase or decrease in precipitation is not so great, but statistically important indicators are still present. Increase in number seasonal precipitation is observed in the west, northwest and north of the country. Statistically important trends of increasing rainfall range from 8 % to 24.2 % norm/10 years. A decrease in precipitation is observed in the Mangystau region, the Turan lowland, in the east of Central Kazakhstan, as well as in individual small foci in the west and east of the country. Statistically important are 5 meteostations, where a decreasing trend is noted from 9.4 to 27.6 % of the norm per decade.

Among the spring months, **March** stands out, when a statistically significant increase in monthly precipitation is recorded almost throughout Kazakhstan. The downward trend in precipitation is observed in small foci in the west of Mangystau and in the south of Kyzylorda regions. On average in

Kazakhstan, the trend towards an increase in precipitation exceeded 13 % of the norm/10 years with a coefficient of determination of 24 %. The most statistically important indicators of the trend towards an increase in precipitation were recorded in the western, northern and eastern regions (by 9.8–39.6 % of the norm/10 years). (Figure 3.11).



significant positive and negative values of the linear trend coefficient are highlighted in blue and red

***Figure 3.11** – Spatial distribution of values of the linear trend coefficient of monthly precipitation (%/10 years) calculated for the period 1976 –2024*

In **April**, in the territory of Kazakhstan from west to east, also covering the southern regions, a tendency towards a decrease in monthly precipitation prevails. In the area of the Caspian lowland and the Mugojar ranges, precipitation varies from 10.8 to 33.2 % of the norm/10 years (MS Kulaly island in the Mangystau region). In the Aral Sea region, Sary Arka and in the south of the Kostanai region, precipitation decreases to 16 % of the norm per decade. April was distinguished by insufficient moisture and 4 meteostations are statistically important, where the trend ranged from 15.6 % to 33.2 % of the norm/10 years.

In **May**, in the west, northwest, north, as well as small foci in the southeast, there is a tendency to increase rainfall, while in the central and eastern parts of the country there is a significant decrease in rainfall. 2 meteostations in the Atyrau region have a statistically important tendency to increase 30.2–36.9 % of the norm/10 years. According to 9 meteostations located in the central and southern parts of the country, there are trends towards a decrease in precipitation. On MS Kulaly Island in Mangystau Region, the rainfall trend was 32.9 % normal/10 years, the largest decrease nationwide.

In summer, in Kazakhstan, a tendency towards a decrease in precipitation is observed in the western half of the country, with centers of moisture in the southern part of the Mangystau region, in the south-west of the country, while in the eastern half, a steady trend towards an increase in precipitation is recorded. In the west, the decrease is noted to 19.3 % of the norm/10 years. A trend towards increased precipitation of the summer period is observed in the coastal part of the Caspian Sea, in the south of the country, however, statistically important trends towards increased precipitation are observed at the Kazakh shallow source and range from 9 % to 10.9 % of the norm/10 years (Figure 3.10).

In **June**, the western half of Kazakhstan, the central part of the Kazakh small hills and the southeastern region are in the zone of decreasing precipitation (Figure 3.11). The trend towards an increase in rainfall is observed mainly in the south and north of the country, however, for the month of June there were no statistically important indicators of an increase in rainfall. The most significant and statistically significant trends in the decrease in monthly precipitation are observed in the coastal regions of the Caspian Sea (17–20.2 % norm/10 years), in the Turan lowland (18.6–23.9 % norm/10 years) and in the southeast of the country (11.8–14.5 % norm/10 years).

In **July**, most of the country shows trends towards an increase in precipitation (Figure 3.11). The coastal regions of the Caspian Sea, the southern parts of the Kyzylorda and Turkestan regions, as well as in small foci in the east of the country, there is a tendency to reduce precipitation. Of these, only one meteostation is statistically important – MS Kulaly Island in the Mangystau region with a trend of 24.1 % norm/10 years. At 7 meteorological stations located in Aktobe, Kostanay, Karaganda, Zhambyl, as well as Almaty regions, there is a tendency towards an increase in precipitation (16.2–22.5 % of the norm/10 years).

In **August**, in the western half of the country, with the exception of the Mangystau and southern parts of Aktobe regions, there is a decrease in precipitation, while in the other half of the country there is a rapid increase in precipitation. as well as in June, rainfall trends are observed everywhere in the western half of the country (with the exception of the Mangystau region). Statistically significant trends of decreasing precipitation were recorded only at 6 meteostations located in the northern part of West Kazakhstan and Aktobe regions, in the western coastal part of Mangystau region and amounted to 16.5–18.7 % of the norm/10 years (Figure 3.11). Statistically important trends in increasing rainfall are observed at two meteostations located in the center and southeast of the country and amounted to 18–19.4 % of the norm/10 years. In Zhambyl region, on MS Saudakent, the trend towards an increase in precipitation was 56.2 % of the norm/10 years with a coefficient of determination of 12 %.

In ***autumn***, most of the area was in the zone of negative trends in precipitation (Figure 3.10). The amount of precipitation for the autumn season decreased significantly according to many meteorological stations in Aktobe, the southern part of Kostanay, Kyzylorda regions, in some places in the central and southern regions. In these regions, at some stations there is a statistically significant (at the level of 5 %) reduction in precipitation in the range of 8.6–19.7 % of the norm/10 years, while only in the Kyzylorda region the coefficient of determination is 13 %. Trends towards an increase in precipitation are observed in the north, east, mountain and foothill regions of the southeast, and only MS Shchuchinsk in the Akmola region is statistically important in 10.1 % of the norm/10 years (Figure 3.10).

In **September**, rainfall trends are recorded in most of the country. The most significant rates of precipitation reduction are observed at five meteostations located in Mangystau, Kyzylorda and Kostanay regions (17.2–23.3 % of the norm/10 years). In some northern, eastern and southeastern regions, there is a slight trend towards an increase in precipitation and it is statistically insignificant (Figure 3.11).

In **October**, as in September, mostly weak trends towards increased precipitation were noted in Kazakhstan. A decrease in precipitation is observed in most of the republic (Figure 3.11). In the western, northwestern, southwestern and central regions of the country, statistically significant rates of rainfall reduction are observed by 11.6–23.6 % of the norm/10 years. The most significant rates of precipitation decline were noted on MS Kulaly Island (Mangystau region). In some areas in the far west, north and east, there are practically no trends towards an increase in precipitation, the share of the trend component in the total dispersion of the series is not more than 2 %. The most significant rates of increase in precipitation are observed in the far west and north-west of the country (6.1–14.8 % of the norm/10 years), and a statistically significant increase in precipitation only at MS Zhanybek (West Kazakhstan region) by 25.8 % of the norm/10 years.

In **November**, trends towards a decrease in precipitation were mainly observed in the western half of Kazakhstan, the Kazakh small hills and some areas of the southern region. At most stations, the trends are statistically insignificant. Statistically significant trends were noted only at 4 meteostations located in these regions, where the rate of decrease in precipitation was in the range of 15.6–20.7 % of the norm/10 years. A steady trend of the most significant decrease in precipitation is observed at MS Aktogay (Karaganda region) by 17.7 % of the norm/10 years, while the share of the dispersion explained by the trend is 24 %. Trends towards increased precipitation are observed in most of the northern, northeastern, western parts of the central, mountainous and foothill regions of the eastern and southern regions of Kazakhstan. At most stations in these regions, the trends are mostly statistically insignificant, except for the values at 4 meteostations located in the northern and northeastern regions, where there is a significant trend towards an increase in precipitation by 13.8–17.5 % norm/10 years. (Figure 3.11).

Annual precipitation decreases significantly in some northwestern, central and southern regions (by 4.1–12.2 % norm/10 years), as well as in all months statistically significant trends in the decrease in precipitation are noted on MS Kulaly Island in the Mangystau region, where the decreasing trend is 19.9 % norm/10 years, and the coefficient of determination is 68 %. According to the data of 14 meteostations in the northern, north-eastern part of the central regions, they increase significantly (by 3.5–8.3 %of the norm/10 years, Figure 3.10).

3.3 Trends in precipitation extreme

Figure 3.12 shows the change in the maximum duration of the idle period when the daily rainfall was less than 1 mm (CDD index). On the territory of Kazakhstan, weak trends were noted, both in the direction of decreasing and in the direction of increasing the idle period by 1–4 days/10 years. Trends are mostly insignificant, with the exception of some stations in the northern, northeastern and northern parts of the central regions, as well as locally in the eastern, southeastern and southern regions, where a statistically significant decrease in such a period was recorded; and in the southwestern region, the Aral Sea region and some mountainous regions of the southeastern region, an increase in the maximum duration of the idle period by 1–6 days/10 years was recorded.

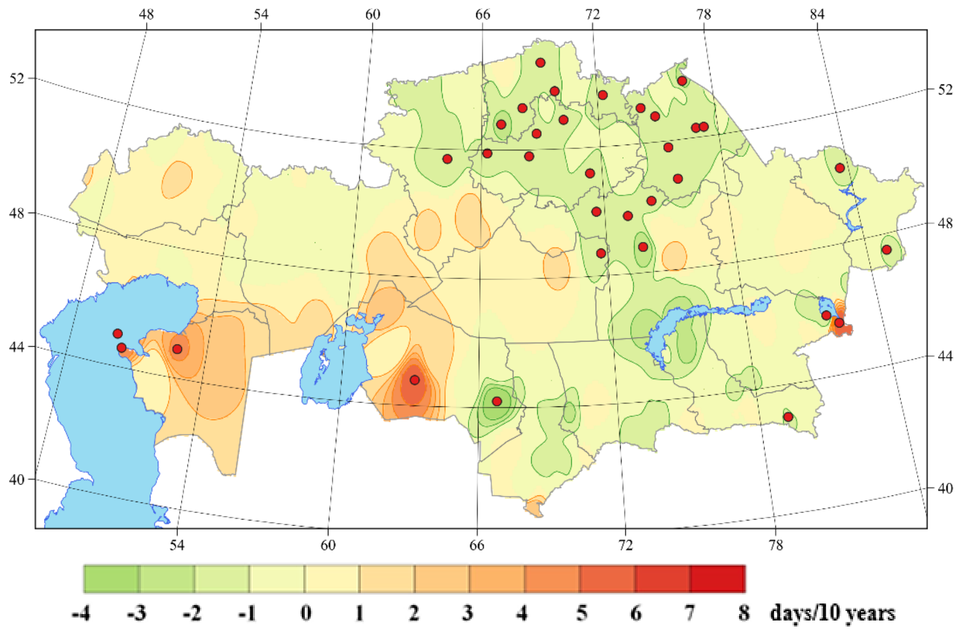


Figure 3.12 – *The rate of change in the maximum duration of the idle period (days /10 years) in the period 1961–2024 (CDD index)*

ANNEX 1

RECORD VALUES OF AVERAGE MONTHLY AIR TEMPERATURES SET IN 2024

№	Name of Meteorological Station	Region	Maximum Air Temperature, °C	Previous Record High Air Temperature, °C
January, 2024				
1	Aktogay	Abay	-7.8	-8.2 (2022 y.)
2	Alakol	Zhetysu	-6.2	-6.8 (2022 y.)
3	Lepsi	Zhetysu	-10.3	-10.7 (2022 y.)
4	Usharal	Zhetysu	-6.1	-6.8 (2022 y.)
5	Tasaryk	Turkestan	1.9	1.7 (2016 y.)
April, 2024				
1	Zhanibek	West Kazakhstan	15.7	15.4 (2012 y.)
2	Urda	West Kazakhstan	17.0	16.7 (2012 y.)
3	Kamenka	West Kazakhstan	13.9	13.5 (2012 y.)
4	Ganyushkino	Atyrau	16.5	15.8 (2012 y.)
5	Novy Ushtagan	Atyrau	17.1	16.9 (2012 y.)
6	Aktau	Mangystau	16.1	15.2 (1986 y.)
7	Fort-Shevchenko	Mangystau	16.9	16.0 (1975 y.)
8	Kulaly Island	Mangystau	15.8	14.6 (1975 y.)
June, 2024				
1	Almaty, Kamenskoe Plato	Almaty	21.9	21.7 (2008 y.)
2	Kuigan	Almaty	26.1	25.9 (2022 y.)
3	Sholakkorgan	Turkestan	27.4	27.2 (2022 y.)
4	Zhetysay	Turkestan	28.5	28.4 (1980 y.)
5	Zhosaly	Kyzylorda	29.1	28.8 (1977 y.)
6	Karak	Kyzylorda	29.1	28.8 (2010 y.)
7	Moyinkum	Zhambyl	26.9	26.7 (2022 y.)
8	Tole Bi	Zhambyl	26.1	25.9 (2022 y.)
9	Uyuk	Zhambyl	27.8	27.4 (2022 y.)
August, 2024				
1	Aktogay	Abay	25.5	25.3 (1998 y.)
2	Bakty	Abay	24.4	23.4 (2019 y.)
3	Karauyl	Abay	21.7	21.6 (2002 y.)
4	Urzhar	Abay	23.1	23.0 (1999 y.)
5	Ust-Kamenogorsk	East Kazakhstan	21.4	21.3 (1998 y.)
6	Aidarli	Almaty	27.2	26.4 (2002 y.)
7	Aksengir	Almaty	25.4	24.9 (2019 y.)
8	Aul №4	Almaty	25.6	25.4 (1998 y.)
9	Bakanas	Almaty	26.6	25.8 (1998 y.)
10	Esik	Almaty	24.1	23.7 (1987 y.)
11	Shelek	Almaty	26.3	25.6 (1984 y.)
12	Alakol	Zhetysu	25.8	25.5 (1998 y.)
13	Matai	Zhetysu	26.1	25.9 (1998 y.)
14	Sarkand	Zhetysu	24.2	23.6 (1998 y.)
15	Saryozek	Zhetysu	23.3	22.9 (2002 y.)
16	Usharal	Zhetysu	25.2	24.9 (1998 y.)
17	Ushtobe	Zhetysu	24.4	24.3 (1998 y.)
18	Zhalanashkol	Zhetysu	26.7	26.5 (2019 y.)
19	Tole Bi	Zhambyl	25.8	25.6 (1999 y.)

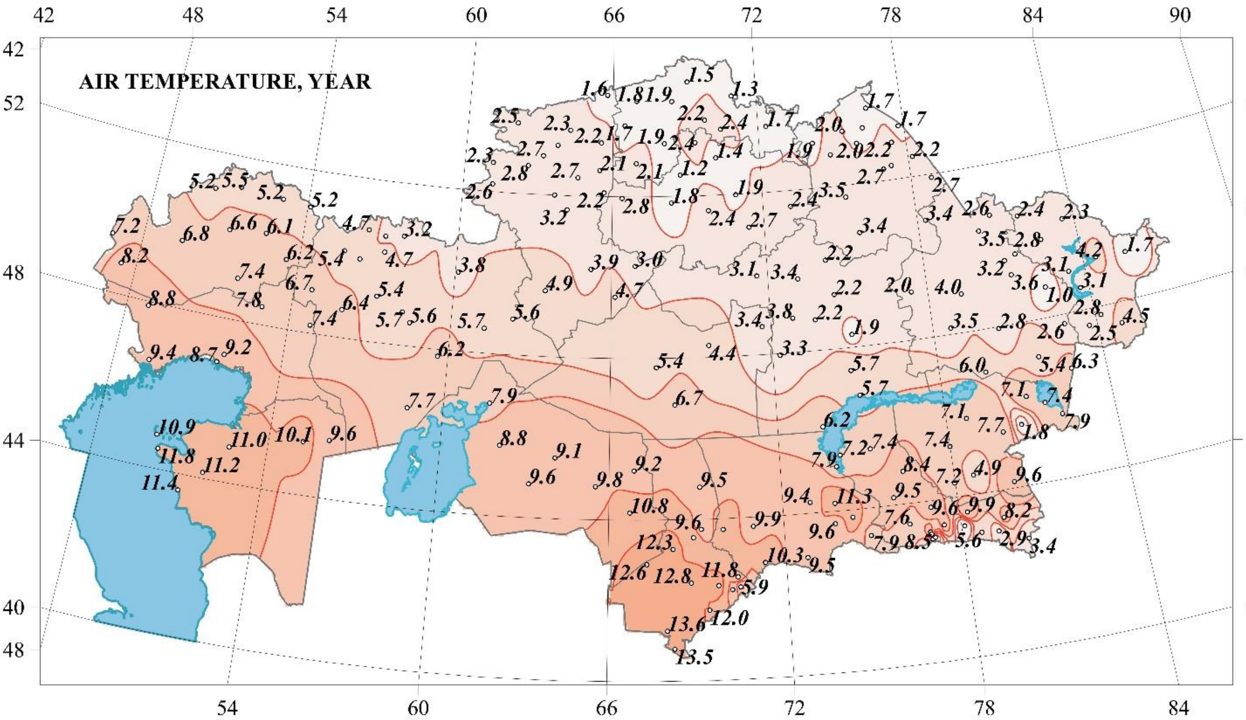
ANNEX 2

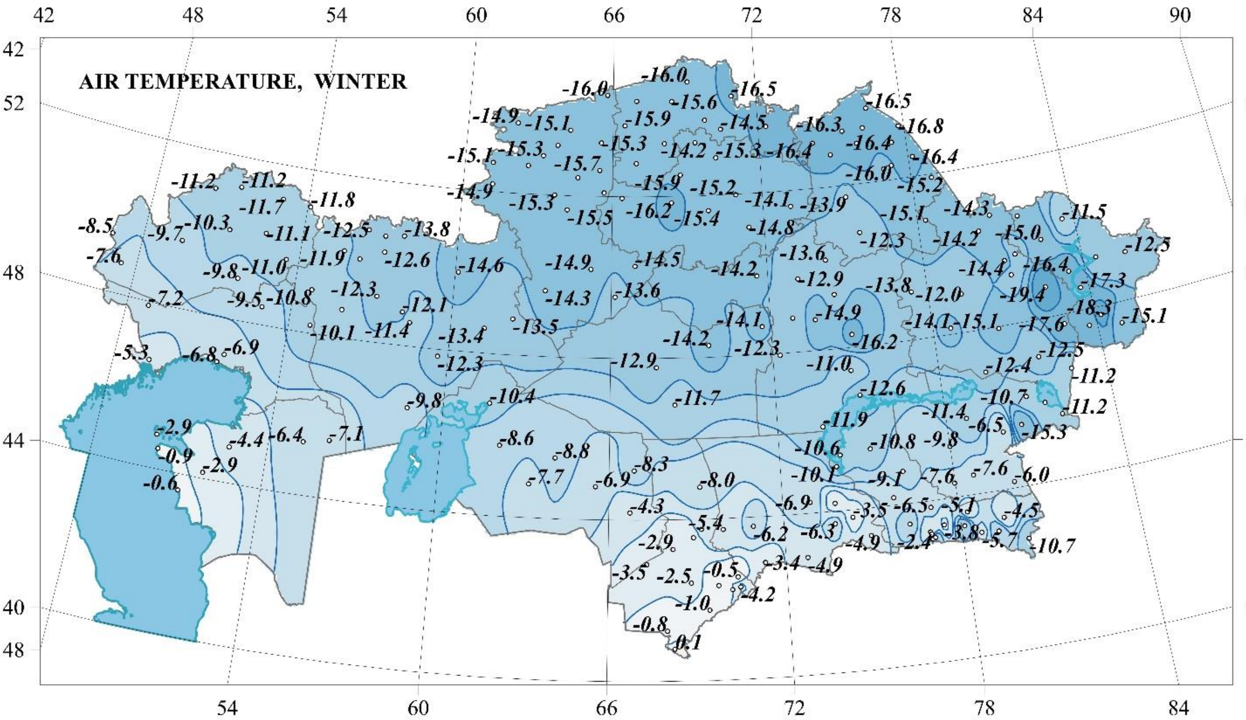
RECORD VALUES OF MONTHLY PRECIPITATION, SET IN 2024

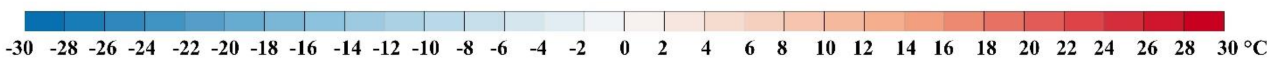
№	Name of the MS	Area	Maximum amount of precipitation, mm	Previous maximum precipitation, mm	Minimum amount of precipitation, mm	Previous minimum rainfall, mm
December, 2023						
1	Nura	Aktobe	48.7	44.7 (2004 y.)		
2	Karasu	Kostanay	47.6	43.0 (1963 y.)		
3	Petropavlovsk	North Kazakhstan	58.4	56.9 (1989 y.)		
4	Ruzaevka	North Kazakhstan	57.6	55.8 (2016 y.)		
5	Balkashino	Akmola	76.9	62.5 (2016 y.)		
6	Astana	Akmola	61.8	56.0 (1991 y.)		
7	Pavlodar	Pavlodar	45.4	45.3 (2004 y.)		
January, 2024						
1	Leninogorsk	East Kazakhstan	66.0	59.7 (2023 y.)		
2	Tobol	Kostanay	43.0	41.2 (1976 y.)		
3	Arshalinsky z/svh.	Kostanay	43.7	39 (2000 y.)		
February, 2024						
1	Narynkol	Almaty	25.7	25.5 (2019 y.)		
2	Ganyushkino	Atyrau	32.6	28.8 (1985 y.)		
3	Dmitrievka	Abay	39.2	38.9 (1966 y.)		
4	Karauyl	Abay	46.7	27.8 (1977 y.)		
5	Shalabay	Abay	69.8	62.2 (1966 y.)		
6	Lozovaya	Pavlodar	31.0	28.2 (2020 y.)		
7	Yertis	Pavlodar	33.3	30.5 (2007 y.)		
8	Krasnoarmeyka	Pavlodar	34.5	32.5 (1966 y.)		
March, 2024						
1	Chiganak	Zhambyl	54.9	42.2 (2018 y.)		
2	Shieli	Kyzylorda	74.5	57.8 (1984 y.)		
3	Tasty	Turkestan	67.9	50.1 (2016 y.)		
May, 2024						
1	Zhaltyr	Akmola	112.2	100.3 (1988 y.)		
2	Shchuchinsk	Akmola	80.0	76.3 (2007 y.)		
3	Shaldai	Pavlodar	98.2	72.0 (2016 y.)		
4	Yertis	Pavlodar	84.8	76.0 (1954y.)		
5	Golubovka	Pavlodar	80.0	76.8 (1994y.)		
6	Ekibastuz	Pavlodar	103.8	83.8 (2000 y.)		
7	Zhanibek	West Kazakhstan			0.0	0.5 (1984y.)
June, 2024						
1	Mugodzharska ya	Aktobe	113.7	92.0 (2003 y.)		
2	Chkalovo	North Kazakhstan	144.1	108.8 (2005 y.)		
3	Taiynsha	North Kazakhstan	156.0	132.5 (1938y.)		
4	Aksengir	Almaty			0.9	6.7 (1995 y.)
July, 2024						
1	Dmitrievka	Abay	160.1	134.3 (1993 y.)		
2	Tugyl	East Kazakhstan	70.8	62.1 (1961 y.)		
3	Khantau	Zhambyl	47.8	36.0 (2001 y.)		
4	Saryshagan	Karaganda	46.6	42.0 (1967 y.)		
August, 2024						
1	Atbasar	Akmola	105.0	92.0 (2001 y.)		
2	Aktobe	Aktobe	104.1	74.9 (1964 y.)		

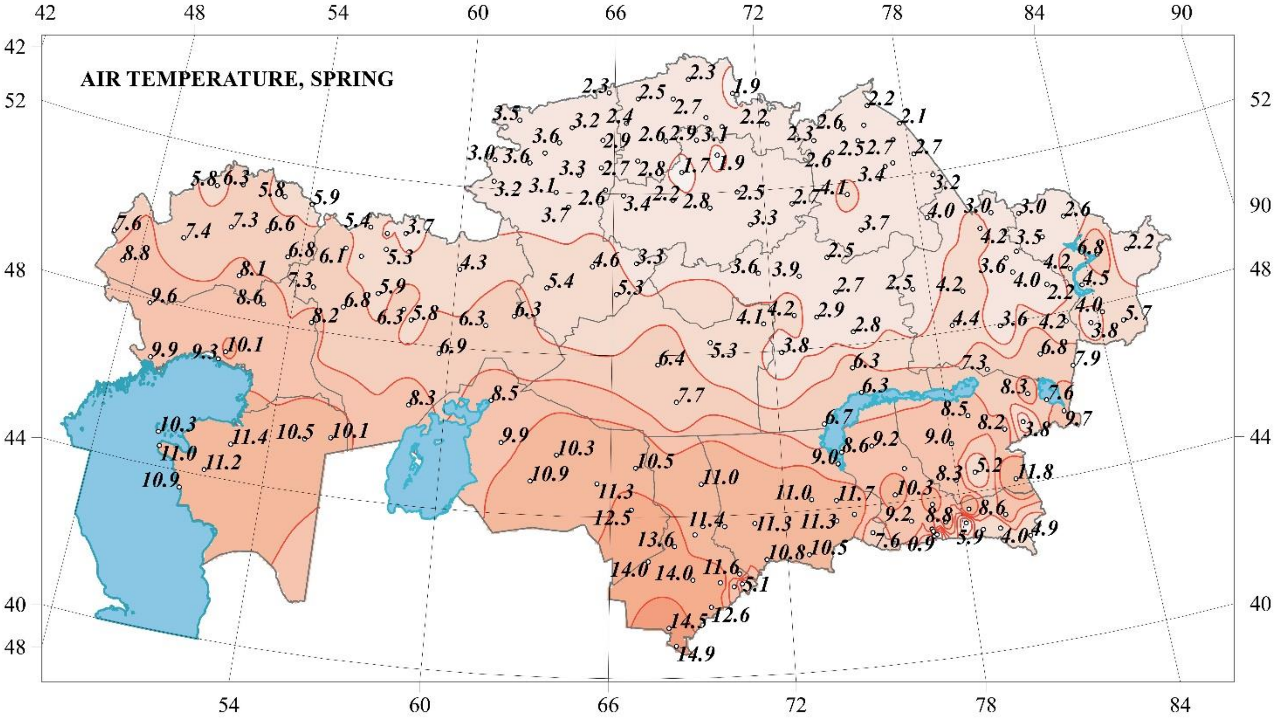
№	Name of the MS	Area	Maximum amount of precipitation, mm	Previous maximum precipitation, mm	Minimum amount of precipitation, mm	Previous minimum rainfall, mm
3	Karabutak	Aktobe	88.7	68.6 (1982 y.)		
4	Uspenka	Pavlodar	138.2	103.9 (2021 y.)		
5	Ruzaevka	North Kazakhstan	123.8	122.1 (1993 y.)		
September, 2024						
1	Aktogay	Pavlodar	64.4	59.2 (1981 y.)		
2	Zhanibek	West Kazakhstan			0.0	0.1 (1994 y.)
3	Kamenka	West Kazakhstan			0.0	1.8 (1994 y.)
4	Uralsk	West Kazakhstan			0.0	1.0 (1944 y.)
October, 2024						
1	Khantau	Zhambyl	101.8	97.1 (1976 y.)		
2	Saryshagan	Karaganda	38.0	35.2 (2006 y.)		
November, 2024						
1	Kurchum	East Kazakhstan	72.1	61.7 (2018 y.)		

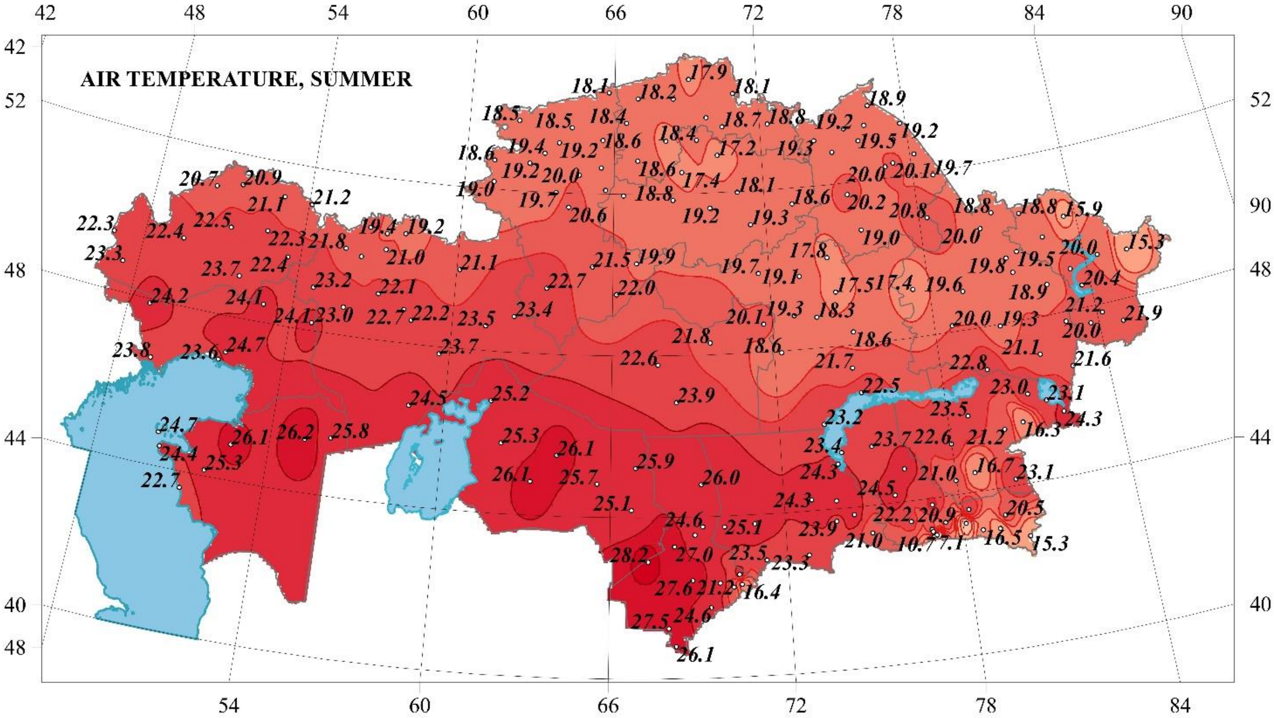
SPATIAL DISTRIBUTION OF AVERAGE ANNUAL AND SEASONAL AIR TEMPERATURES OVER THE TERRITORY OF KAZAKHSTAN, CALCULATED FOR THE PERIOD 1961–1990

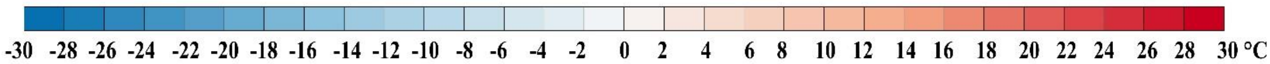


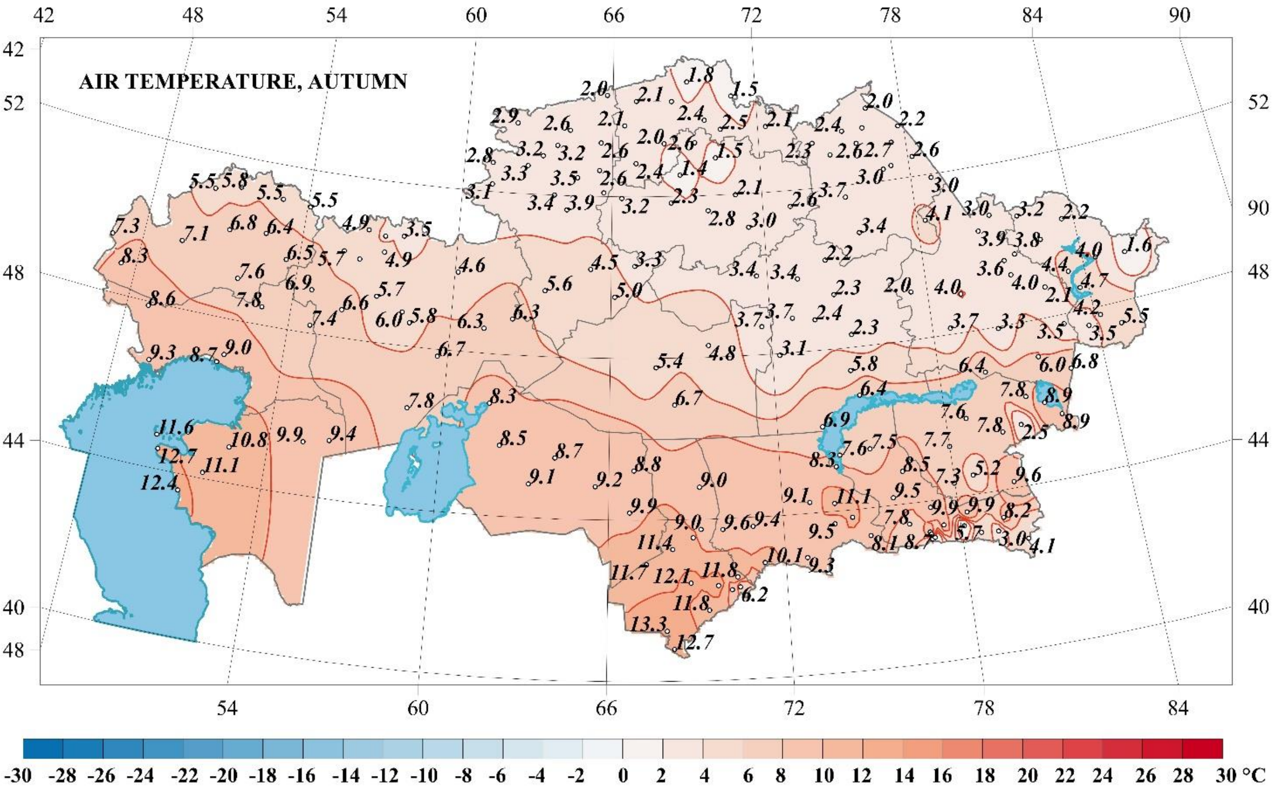





AIR TEMPERATURE, SPRING

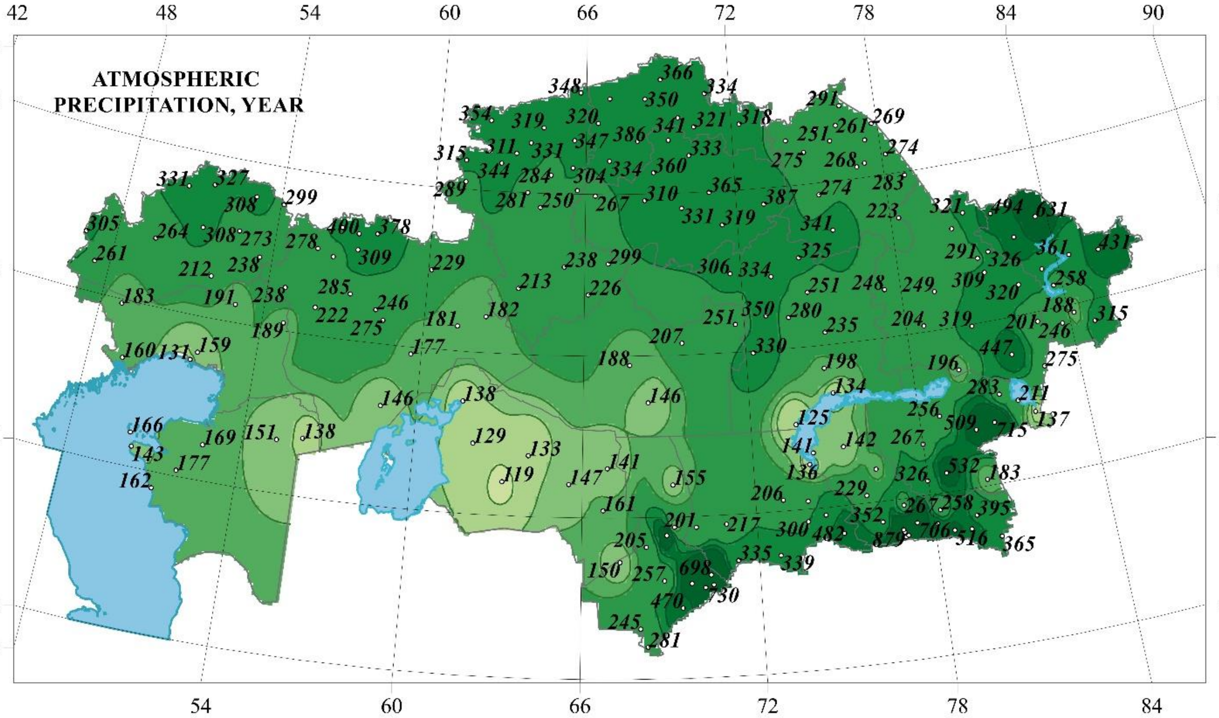

AIR TEMPERATURE, SUMMER

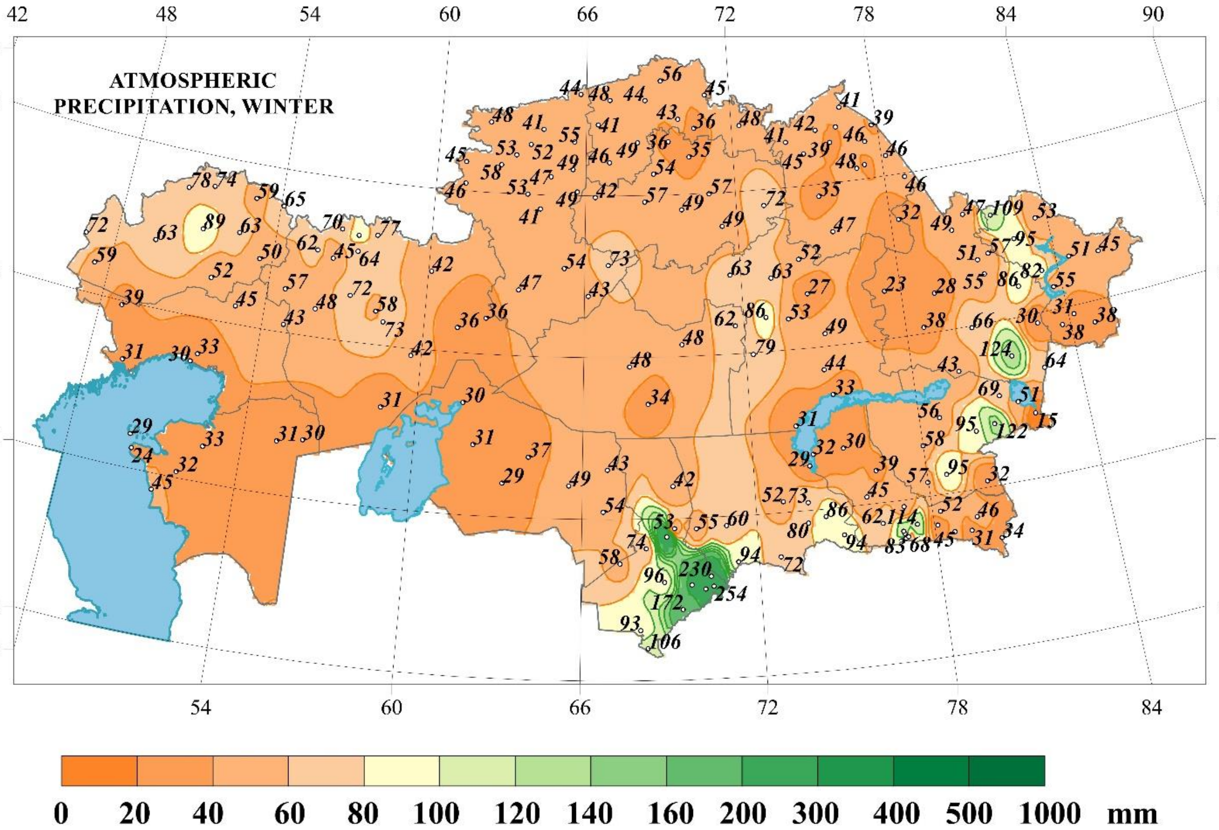

-30 -28 -26 -24 -22 -20 -18 -16 -14 -12 -10 -8 -6 -4 -2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 °C

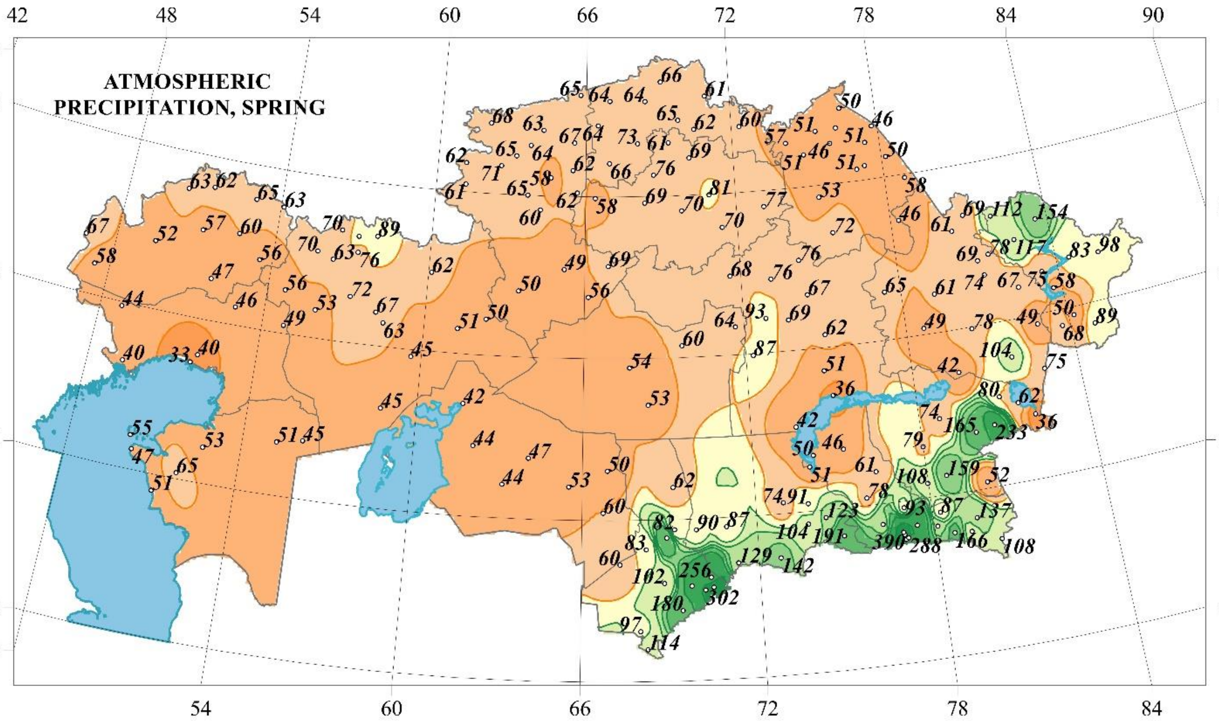

AIR TEMPERATURE, AUTUMN
-30 -28 -26 -24 -22 -20 -18 -16 -14 -12 -10 -8 -6 -4 -2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 °C

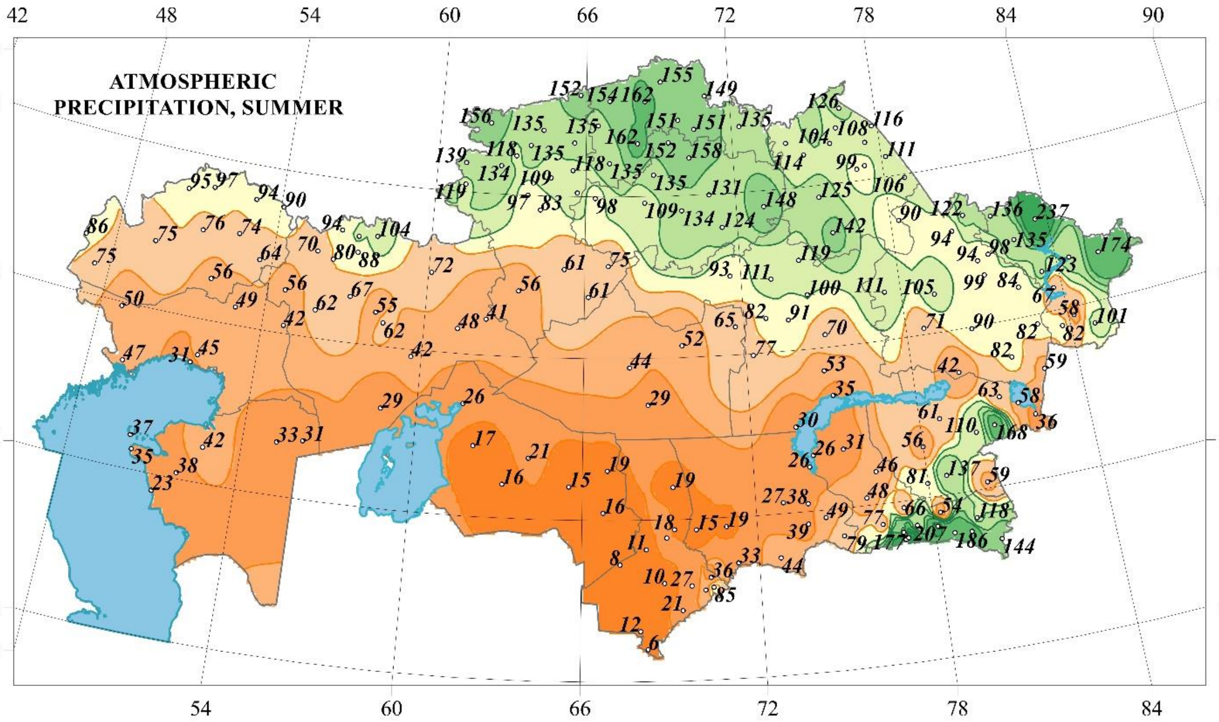
ANNEX 4

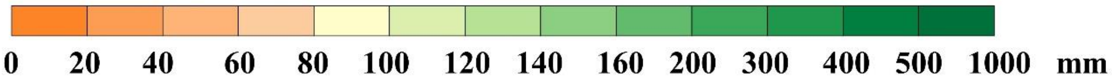
SPATIAL DISTRIBUTION OF ANNUAL AND SEASONAL PRECIPITATION AMOUNTS OVER THE TERRITORY OF KAZAKHSTAN, CALCULATED FOR THE PERIOD 1961– 1990

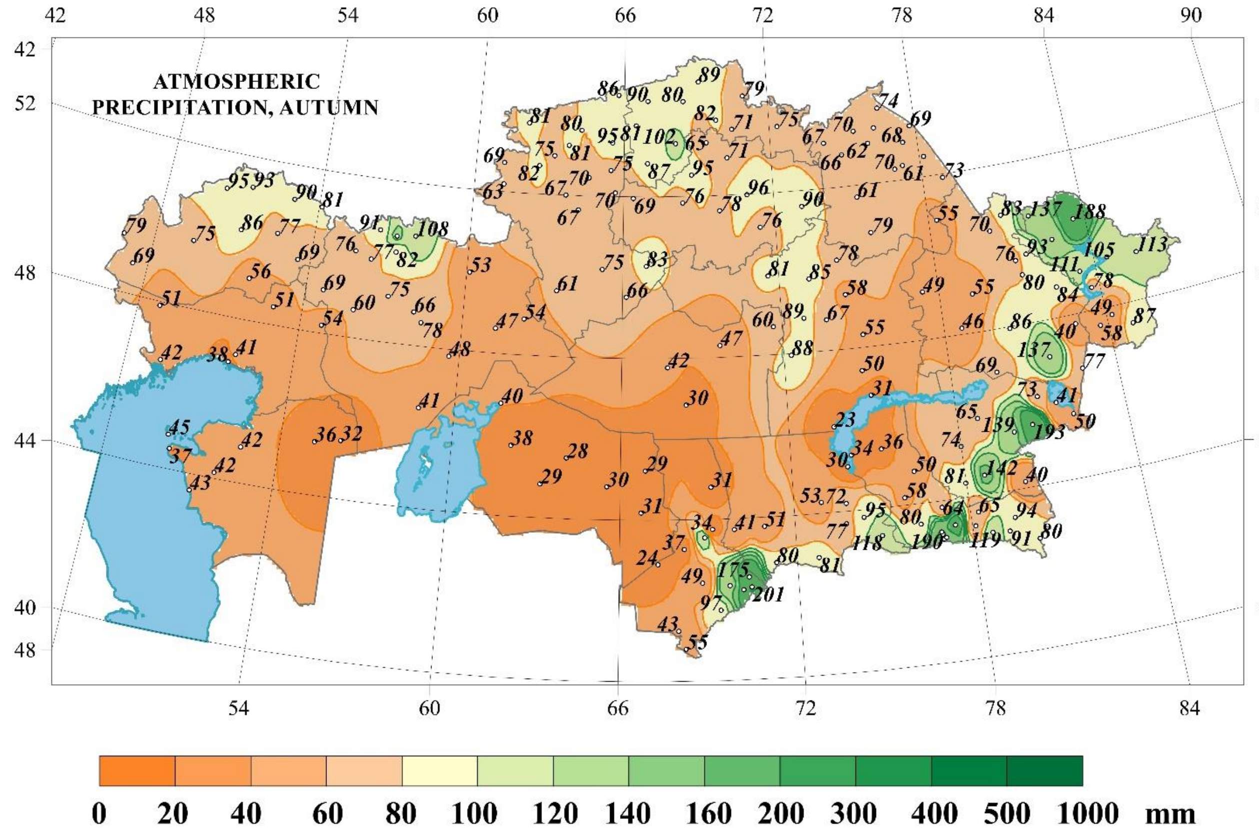





ATMOSPHERIC
PRECIPITATION, SPRING


ATMOSPHERIC
PRECIPITATION, SUMMER


0 20 40 60 80 100 120 140 160 200 300 400 500 1000 mm


ATMOSPHERIC
PRECIPITATION, AUTUMN
0 20 40 60 80 100 120 140 160 200 300 400 500 1000 mm

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