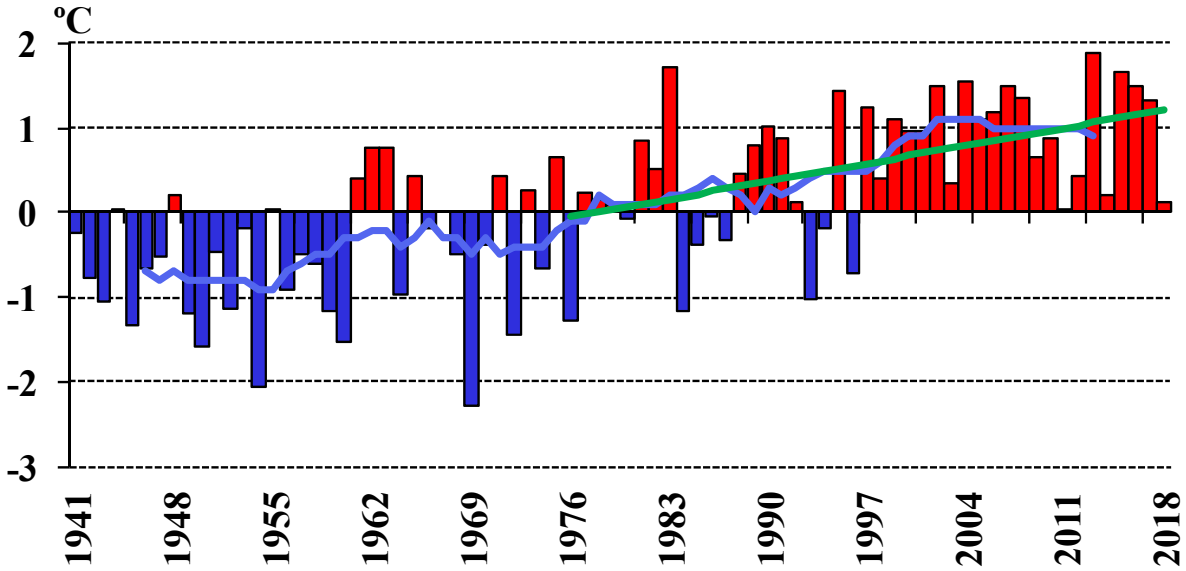
Ministry of Ecology, Geology and Natural Resources of the RK

Republican State Enterprise "Kazhydromet"

Scientific Research Center

ANNUAL BULLETIN OF MONITORING OF THE CLIMATE STATE AND CLIMATE CHANGE IN KAZAKHSTAN: 2018



Astana, 2019

CONTENTS

SUMMARY

Features of climate in 2018

In general, for the globe, 2018 entered the top ten warmest years for the period of instrumental observations (1850-2018), taking 4th place.

Global average temperature in 2018 was by 0,99 °C above the preindustrial level (1850-1900). New record values of the heat content in the upper layers of the ocean, as well as the continued increase in global mean sea level, have been established.

A decrease in the extent of the Arctic and Antarctic sea ice was noted. In 2018, 74 tropical cyclones were registered, which significantly exceeds their long-term average number (63). Floods, extreme rainfall and extratropical storms have caused hundreds of human lives and the destruction of tens of thousands of homes. In the late spring and summer of 2018, unprecedented heat and drought settled in a large part of Europe.

The average annual air temperature in 2018 on average in Kazakhstan was 0.11 °C higher than the climatic norm. This is the fortieth value in the ranked series of anomalies in the average annual air temperature for the observation period since 1941. The annual amount of precipitation in 2018 on average across Kazakhstan was 98 % of the norm (323.2 mm).

The air temperature of the ***winter season*** (December 2017 February 2018) in most of the territory of the republic was near normal, the average anomaly in Kazakhstan was minus 0.29 °C). Extremely cold (probability of not exceeding 5 %) was observed in January in the south-west of Kazakhstan. In general, throughout the republic, the amount of precipitation amounted to 80% of the climatic norm or 50 mm. A moisture deficit of 30–40 % of the norm with a probability of not exceeding 24% was observed in the northwest, east, and south of the republic.

In ***the spring*** of 2018, in the northern half of the republic, the average seasonal temperatures were lower than normal, in places more than 1.5-2.0 °C. In the southern regions, the average seasonal air temperature exceeded the norm, in some places by more than 1.5-2.0 °C. It was extremely warm in March in the south of the republic, and extremely cold in May in the north-east and central part of Kazakhstan. Atmospheric precipitation averaged 123 % of the norm (108 mm) throughout Kazakhstan. Extremely humid conditions were observed in Pavlodar, North Kazakhstan and East Kazakhstan regions (probability of not exceeding 97-98 %).

The ***summer season*** of 2018 was relatively warm in most of the territory of Kazakhstan, the air temperature in the republic was on average 0.6 °C higher than normal. In the western and southern regions, the average seasonal temperatures were significantly higher than normal, mainly due to the steady hot weather in July, when new absolute maximums of average monthly air temperature were reached at many stations. Extremely hot was observed in July in the Aktobe, Atyrau, West Kazakhstan, Kyzylorda and Mangistau regions (96-100 percentiles). The amount of precipitation was 92 % of the norm (90.5 mm). In the north-east of the republic, the amount of precipitation exceeded the norm by 32-55 %. Dryly observed in the east and west of the republic (the probability of not exceeding 14-22 %).

The ***autumn season*** of 2018 was warm in the territory of western and northern Kazakhstan, in some places anomalies of seasonal temperatures of more than 1.5-2.0 °C were recorded. At many stations in the central, southern and southeastern regions, seasonal temperatures were significantly lower than normal by 1.0-1.5 °C. The average temperature of the autumn season in Kazakhstan was only 0.17 °C higher than the climatic norm. The average rainfall in the republic in the autumn was 100 % of the norm (79.8 mm). A significant deficit of precipitation (probability of not exceeding 0-2%) was observed at the weather stations Mugodzharskaya, Novoalekseevka (Aktobe region), Karabau, Peshnoy (Atyrau region) and Akkuduk (Mangystau region).

Climate change in Kazakhstan (1976-2018)

On average across the territory of Kazakhstan for the period 1976-2018 the increase in average annual air temperature is 0.31 ºC every 10 years. Trends in average annual temperature averaged over the regions of Kazakhstan are positive and statistically significant. It warms at a faster pace in the southwestern regions of Kazakhstan (from 0.32 °C/10 years to 0.50 °C/10 years), slower in the north-, north-eastern and central regions (from 0.19 °C/10 years to 0.23 ºC/10 years). The highest growth rates are observed in the spring (0.59 °C/10 years), the lowest - in the winter (0.11 °C/10 years). In all seasons except the winter, an increase in air temperature is statistically significant. For the period 1976-2018 In winter, spring and summer, on average in Kazakhstan, there is a tendency to an increase in precipitation by 1.3-3.8 mm/10 years, a decrease in the amount of atmospheric precipitation in the autumn season was 1.0 mm/10 years. All obtained trends of seasonal precipitation are statistically insignificant.

Trends in extremes of surface air temperature showed that for the period 1976–2018:

– According to most weather stations, there is a positive trend in daily maximums of air temperature, at some stations the trend is steady;

– the frequency of days with extremely high temperatures increases, especially in the western and southern regions of the republic;

– the frequency of occurrence of night and day frosts throughout Kazakhstan is reduced;

– the number of days with severe frosts is reduced (temperature is below minus 20 ºC), especially in the west and north-east of the republic;

– there is a positive trend in the daily amplitude of air temperature in the west and negative in the southeast and east of the republic;

– everywhere there is an increase in the total duration of heat waves;

– the length of the growing season increases (with temperatures above 5 and 10 ºC);

– at some weather stations recorded positive trends in the values of the maximum daily rainfall;

– in the north and southeast, there has been a tendency to reduce the maximum length of the rainless period.

INTRODUCTION

Climate is a natural resource, which is vitally important for the well-being, health and prosperity of the population of any state. Meteorological information collected, managed and analyzed by the National Hydrometeorological Services helps users of this information, including persons, which makers decisions to plan any activity taking into account modern climatic conditions and observed climate changes. Using of current meteorological and climate information helps reduce risks and damage and optimizes social and economic benefits. Climate system monitoring is carried out by national, regional and international organizations, coordinated by the World Meteorological Organization and in cooperation with other environment programs.

Studying of the regional climate and regular monitoring of its changes are the priority tasks of the National hydrometeorological service of Kazakhstan "Kazgydromet". Since 2010 the "Kazgydromet" makes release of annual bulletins for providing reliable scientific information about regional climate, its variability and change. Due to a geographical location of Kazakhstan and its vast territory, observed changes in climate conditions in various regions of the Republic can have both a negative and positive impact on biophysical systems, on economic activity and the social sphere. Taking into account of the climate conditions and the assessment of their changes are necessary for identification of the potential consequences and introducing timely and adequate adaptation measures, and, as the result, for ensuring sustainable development of Kazakhstan.

This edition of the bulletin describes the climatic conditions observed in 2018, including an assessment of the extremes in temperature and precipitation, and provides historical information on changes in surface air temperature and an amount of precipitation since 1941. Also, this release of the bulletin contains climate change estimates for the shorter period from the middle of 1970s years, when according to many experts, global climate change has become more intense, especially in the Northern Hemisphere. Annex 1 and 2 show the maps of the distribution of seasonal and annual air temperatures and rainfall, averaged over the period 1961-1990.

Initial data. Bulletin is based on data of the National Hydrometeorological Fund of "Kazhydromet":

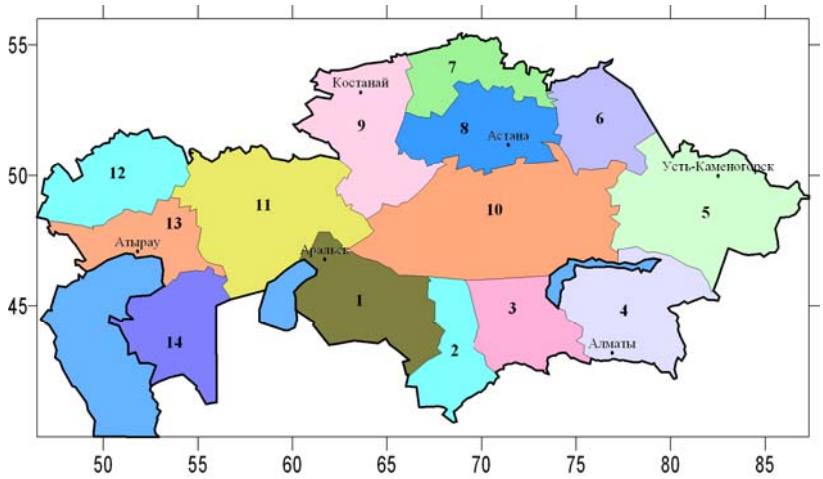
1) time series of monthly mean air temperature and monthly precipitation total from 1941 to 2018: data of more than 200 weather stations were used to assess climate averages for 1961-1990 and more than 190 weather stations data to assess tendencies in temperature and precipitation;

2) time series of daily maximum and minimum air temperatures and daily precipitation totals from 1936 to 2018 (from more than 90 weather stations).

The main approaches and methods. In this bulletin, the "norm" is the climate variable averaged for the period 1961-1990. Temperature anomalies are calculated as deviations of the observed value from the norm. Anomalies of an amount of precipitation can be considered as in deviations from the norm (similar to air temperature), and as a percentage of the norm. The probability of not exceeding characterizes a frequency (in %) emergence of the corresponding value of anomaly in the time series of observations.

As assessment of changes in climate characteristics for a certain time interval the coefficients of linear trends are used, which are determined by the least squares method. The coefficient of determination (R2) represents the strength of a linear trend and characterizes the contribution of the trend to the total variance of the climate variable for the considered time period (in percent).

Assessment of tendencies surface air temperature and amount of precipitation is carried out according to individual stations and on average for 14 regions of Kazakhstan. Averages for the territory anomalies of meteorological variables are calculated by averaging of station data on anomalies. The borders of the regions are given on the schematic map below.



1 – Kyzylorda region.
2 – Turkestan region.
3 – Jambyl region.
4 – Almaty region.
5 – East Kazakhstan region.
6 – Pavlodar region.
7 – North Kazakhstan region.
8 – Akmola region.
9 – Kostanay region.
10 – Karaganda region.
11 – Aktobe region.
12 – West Kazakhstan region.
13 – Atyrau region.
14 – Mangystau region.

Scheme of administrative-territorial division of the Republic of Kazakhstan

To assess the extreme temperature and precipitation in 2018 and its changes since 1936, climate change indices recommended by the World Meteorological Organization were used. Some indices are based on fixed unified threshold values for all stations, others based on threshold values that can vary from station to station. In the latter case, the threshold values are defined as the corresponding percentiles of the data series. The indices allow us to evaluate many aspects of climate change, such as, for example, changes in the intensity, frequency and duration of the manifestation of extremeness in air temperature and rainfall.

The WMO climate change indices were used to assess extreme temperatures and precipitation in 2018 and its changes in the period 1941-2017. Some indexes are based on the fixed uniform threshold values for all stations, others – on threshold values, which can vary from the station to the station. In the latter case threshold values are defined as the corresponding percentiles of the data rows. . Indices allow estimating many aspects of climate change, such, for

example, the change in intensity, frequency and duration of extreme temperature in air and precipitation.

The Bulletin was prepared by the experts of Climate Research Department:

Ilyakova R.M., Lead Engineer (responsible for the issue, section 3, summary);
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1 REVIEW OF GLOBAL CLIMATE CHANGES and ITS CONDITIONS in 2018

More than 25 years, the World Meteorological Organization (WMO) publishes the annual Statement about condition of global climate in order to provide authoritative scientific information on global climate and significant weather and climate events occurring around the world. These publications complement the assessment reports are issued by the Intergovernmental Panel on Climate Change (IPCC) every six to seven years.

Since the issue of the first Statement about the condition of the Global Climate in 1993, the scientific understanding of the complex climate system of our planet had been developing prompt rates. It is especially right of understanding the impact of humankind on climate change and also character and extent of such change. It includes the ability documenting emergence of the extreme weather and climatic phenomena and degree in which they can be connected with influence of the person on climate.

Briefly about the condition of global climate in 2018:

- 2018 was the fourth warmest year on record;
- 2015–2018 were the four warmest years on record as the long-term warming trend continues;
- ocean heat content is at a record high and global mean sea level continues to rise;
- Artic and Antarctic sea-ice extent is well below average;
- average global temperature reached approximately 1 °C above pre-industrial levels.

The global mean temperature for 2018 is estimated to be 0.99±0.13 °C above the preindustrial baseline (1850-1900). In contrast to the two warmest years (2016 and 2017), 2018 began with weak La Niña conditions, typically associated with a lower global temperature.

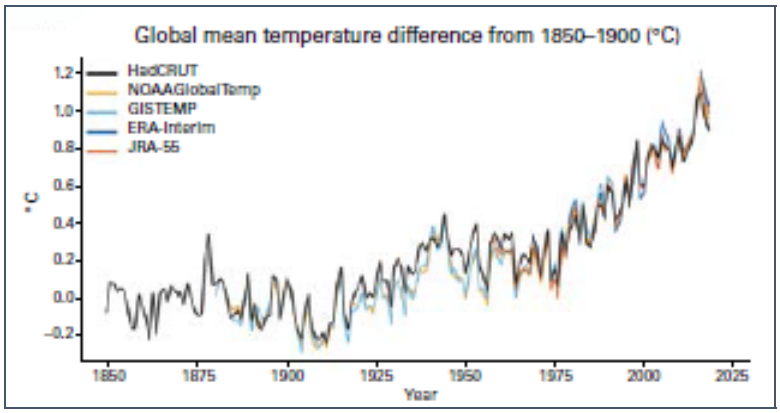


Figure 1.1 - Anomalies of the global average in comparison with the basic period of 1850- 1990 within five global datasets. *Source: UK Met Office Hadley Centre*

According to continental numbers from NOAA, 2018 was ranked in the top 10 warmest years for Africa, Asia, Europe, Oceania and South America. An area extending across Europe, parts of North Africa, the Middle East and southern Asia was also exceptionally warm, with a number of countries experiencing their warmest year on record (Czechia, France, Germany, Hungary, Belgium, Estonia, Israel, Latvia, Pakistan, the Republic of Moldova, Slovenia, Ukraine). For Europe as a whole, 2018 was one of the three warmest years on record.

2018 set new records for ocean heat content in the upper 700 m (data since 1955) and upper 2 000 m (data since 2005), exceeding previous records set in 2017.

Global mean sea level for 2018 was around 3.7.mm higher than in 2017 and the highest on record. Over the period January 1993 to December 2018, the average rate of rise was 3.15±0.3 mm yr^{-1}, while the estimated acceleration was 0.1 mm yr^{-2}. Accelerated ice mass loss from the ice sheets is the main cause of the global mean sea-level acceleration as revealed by satellite altimetry (World Climate Research Programme Global Sea Level Budget Group, 2018).

Arctic sea-ice extent was well below average throughout 2018 and was at record low levels for the first two months of the year. The annual maximum occurred in mid-March and the March monthly extent was 14.48 million km^2, approximately 7 % below the 1981-2010 average. This ranked as the third lowest March extent in the 1979-2018 satellite record. Only March 2016 and 2017 were lower.

Antarctic sea-ice extent was also well below average throughout 2018. The monthly extent in January was the second lowest, and in February the lowest. The annual minimum extent occurred in late February and the monthly average was 2.28 million km^2, 33 % below average and ranked record low in the C3S dataset and second lowest in the NSIDC data.

Preliminary results for 2018, based on a subset of reference glaciers, indicate that the hydrological year 2017/18 was the thirty-first consecutive year of negative mass balance

The tropical cyclone season in the northern hemisphere was active in 2018. The number of tropical cyclones was above average in all four northern hemisphere basins. There were 74 northern hemisphere cyclones in 2018, well above the long-term average of 63. The north-east Pacific basin was especially active, with an accumulated cyclone energy value of 316 kt^2, the highest since reliable satellite records began.

Floods, extreme rainfall and extratropical storms have caused hundreds of casualties. Tens of thousands of houses were destroyed. Several million people were accommodated in relief camps.

Large parts of Europe experienced exceptional heat and drought through the late spring and summer of 2018. Temperatures were well above average and rainfall well below average from April onwards in much of northern and western Europe.

2 AIR TEMPERATURE

The average annual air temperature anomaly was +0,12 °C rather average long-term values during 1961-1990 (+5.74 °C) average for all Kazakhstan and was by 1.21 °C lower than in 2017. For the last five years of 2014-2018 the average annual temperature amounted to +6.70 °C. The warmest five-year period in Kazakhstan with an anomaly of +1.34 °C is the period of 2004-2008.

Average air temperature over the last decade of 2009 to 2018 exceeded the climatic norm by 0.86 °C, this is the second largest decade-long anomaly after a record warm decade of 1999 and 2008.

The ranks of the ten warmest years on average for the Globe (according by the land network) and across Kazakhstan are presented in table 2.1. Each of the ten warmest years for the globe has been assigned own color fill, which makes it easy to judge, that whether this year is among the warmest years for Kazakhstan. Four warmest years in Kazakhstan, including 2018, were included into the list of the ten warmest years for the Globe.

In the figure 2.1 is presented the ranged series of the annual mean surface air temperature anomalies, which averaged according to 124 meteorological stations of Kazakhstan for the period from 1941. On a global scale, all extremely warm years are accounts for on the last 20 years. This feature in Kazakhstan is also well traced with the exception of 1983, which takes the second place in the rank of the warmest years, and 1995 which has also entered ten the warmest years.

Table 2.1 - Ten of the warmest years in the history of observations for the Globe (since 1850) and in Kazakhstan (since 1941) and corresponding annual mean surface air temperature anomalies averaged over the territory of Kazakhstan. Anomalies are calculated relative for the period 1961-1990

Rank	Globe	Kazakhstan	Anomaly of average annual temperature (Jan.-Dec.), averaged over the territory of Kazakhstan, °C
1	**2016**	2013	1,90
2	**2017**	1983	1,73
3	**2015**	2015	1,66
4	**2018**	2004	1,56
5	**2014**	2002	1,51
6	**2010**	2007	1,50
7	**2005**	2016	1,49
8	**2013**	1995	1,44
9	**2006**	2008	1,35
10	**2009**	2017	1,32

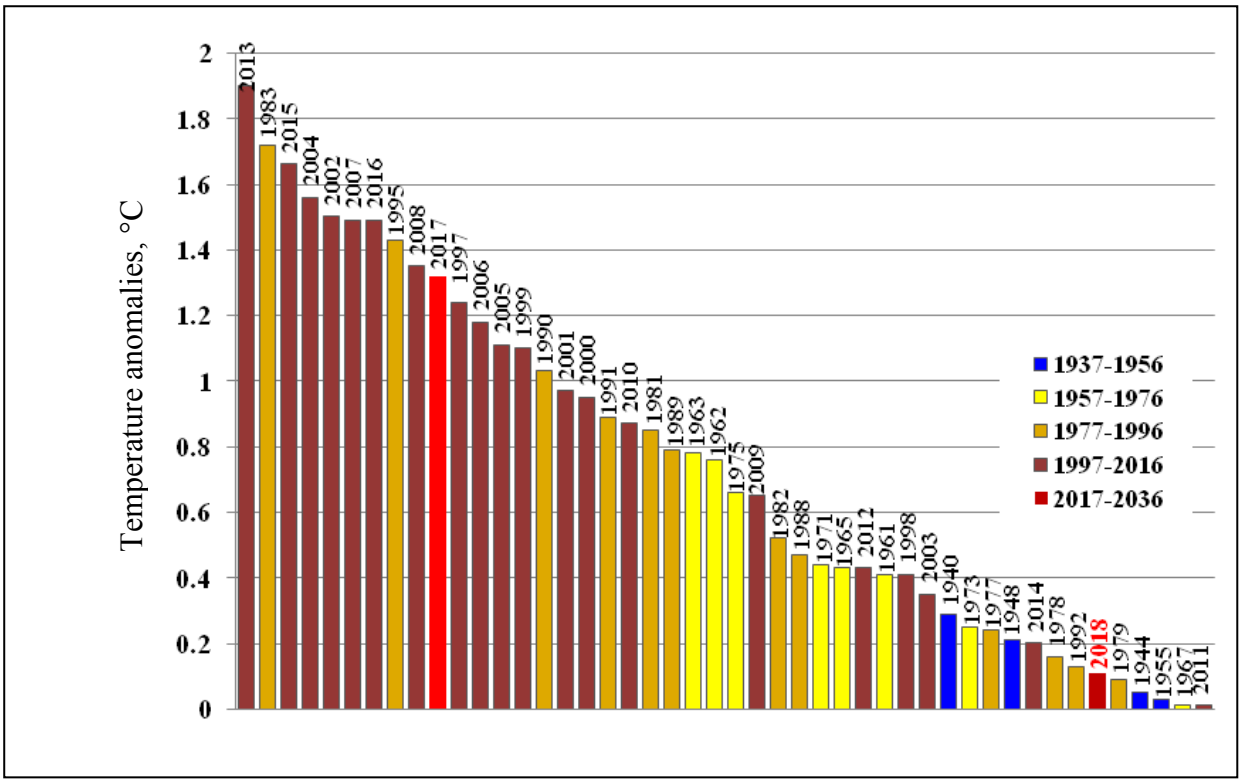


Figure 2.1 - Ranged series of positive annual mean surface air temperature anomalies (Jan-Dec) averaged over the territory of Kazakhstan (according to 124 weather stations) for the period 1941-2018. Norms are calculated relative to the base period of 1961-1990

2.1 Air temperature anomalies in Kazakhstan in 2018

2018 (January-December) has taken only 41st place in the ranked series of observations by descending order since 1941 (table 2.1).

Table 2.2 shows the mean average and seasonal air temperature anomalies averaged over regions and Kazakhstan as a whole, and table 2.3 shows the mean monthly air temperature anomalies observed in 2018. For each anomaly, the probabilities of their non-exceeding are calculated based on data for the period 1941-2018, as well as the standard deviation for 1961-1990. (table 2.2). In tables 2.2 and 2.3, temperatures above the 95th or below the 5th percentile (warm and cold extremes, respectively) are shown in bold and bright colors.

In most of Kazakhstan, the annual average temperature was close to normal (table 2.2; figure 2.2). Significant positive air temperature anomalies, probability of not exceeding which was more than 75%, were observed in Mangistau, Turkestan, Atyrau (0.90 ºC) regions.

The average anomalies over the territory of these regions were 1.30 °C, 0.92 °C and 0.90 °C, respectively, with a probability of not exceeding 74-81 %. Broad regions with significant negative air temperature anomalies, the probability of not exceeding which was less than 25 %, were traced in North Kazakhstan, Akmola (0.72 °C), Karaganda (0.64 °C), Pavlodar (0.76 °C) regions. The average anomalies over the territory of these regions ranged from minus 0.64 °C to minus 0.76 ºC with a probability of not exceeding 25-31 %. The average annual air temperature

averaged over the territory of Kazakhstan was slightly higher than the climatic norm, only by 0.12 ºC, which is much less than the standard deviation (0.85 ºC). In Kostanai region (Torgai weather station), a minimum of average annual air temperature was blocked and amounted to 1.9 °C (previous minimum was 2.5 °C and observed in 1969).

Table 2.2 – Regionally averaged annual mean (January-December) and seasonal air temperature anomalies in 2018: vT - deviations from the long-term average for 1961–1990 (°C), P(t≤T2018) - probability of non-exceedance (in brackets), calculated according to the data for the period 1941-2018 (%;) s – standard deviation (ºC) for the period 1961-1990

Region/Oblast	Year		Winter		Spring		Summer		Autumn	
	vT (P)	**s**	**vT (P)**	**s**	**vT (P)**	**s**	**vT (P)**	**s**	**vT (P)**	**s**
Kazakhstan	0,11(51)	0,85	-0,29(40)	2,44	0,60(61)	1,26	0,64(70)	0,64	0,17(50)	1,14
Almaty	0,19 (48)	0,77	-0,67(36)	2,36	1,97(89)	0,99	0,75(77)	0,63	-0,72(23)	1,07
Akmola	-0,72(28)	1,08	-0,79(35)	2,84	-1,22(25)	1,84	-0,55(35)	1,04	0,81(58)	1,51
Aktobe	0,22(53)	0,95	-0,20(40)	2,51	-0,20(49)	1,91	0,65(68)	0,92	0,68(71)	1,40
Atyrau	0,87(74)	0,82	0,39(48)	2,40	0,65(61)	1,55	1,43(84)	0,85	0,95(75)	1,20
East-Kazakhstan	-0,01(44)	1,07	-0,25(44)	2,71	1,50(74)	1,51	1,00(88)	0,79	-0,48(32)	1,50
Zhambyl	0,25(49)	0,85	-0,96(32)	2,84	2,04(88)	0,99	0,83(79)	0,83	-0,95(23)	1,17
West-Kazakhstan	0,64(66)	1,06	1,27(63)	2,74	-0,69(40)	2,01	1,38(76)	1,22	1,13(75)	1,27
Karagandy	-0,64(25)	0,90	-0,63(40)	2,57	0,17(51)	1,35	-0,10(46)	0,85	-0,95(23)	1,40
Kostanay	-0,12(46)	1,06	-0,59(33)	2,76	-0,85(37)	1,92	0,24(58)	1,09	1,64(77)	1,49
Kyzylorda	0,47(59)	0,90	-0,46(37)	2,87	1,05(64)	1,21	1,00(77)	0,93	0,09(44)	1,19
Mangystau*	1,28(81)	0,76	0,39(46)	2,26	1,56(77)	1,26	2,12(87)	0,91	0,80(60)	1,16
Pavlodar	-0,76(28)	1,16	-1,47(28)	3,15	-0,66(29)	1,73	-0,32(37)	0,93	0,76(57)	1,62
North-Kazakhstan	-0,72(31)	1,15	-0,51(40)	2,94	-1,63(22)	1,86	-0,69(27)	1,17	1,44(77)	1,53
Turkestan	0,93(80)	0,80	0,53(42)	2,60	1,89(88)	0,86	0,92(85)	0,84	-0,37(31)	1,10

Notes: 1. for the Mangistau region, an assessment has been carried out since 1960;
2. values above the 95th or below the 5th percentile (respectively, warm and cold extrema) are shown in bold and bright colors.

At the meteorological station of Torgay, the minimum air temperature during the warm period (April-October) was also updated to +12.8 °C, which is almost 2 °C lower than the previous minimum (+14.6 °C) observed in 1964.

The air temperature of ***winter season*** (December 2017-February 2018) in most of the country was close to normal (Figure 2.2) and the average air temperature anomaly in the country was minus 0.29 °C (40th percentile, table 2.2). Significant negative air temperature anomalies with a probability of not exceeding 25% were observed in the southeastern and northeastern regions. Negative anomalies averaged over the territories of the regions range from minus 0.20 °C (40th percentile) for Aktobe region and to minus 1.48 °C (28th percentile) for Pavlodar region. Inside winter season, it was extremely cold in January (probability of not exceeding 5 %) in

Almaty (minus 4.89 °C) and East Kazakhstan (minus 6.17 °C) regions (table 2.3). A positive anomaly in the average seasonal air temperature was observed in Atyrau (0.39 °C), West Kazakhstan (1.27 °C), Mangistau (0.39 °C), Turkestan (0.53 °C) regions (table 2.2).

Centers of cold (with a probability of not exceeding less then 7-25%, Figure 2.2) were observed in the areas of weather stations Shalkar (-1.8 °C, Aktobe region), Besoba (-2.1 °C, Karaganda region), Leninogorsk, Semiyarka, Shar (-2.6 °C ,-3.0 °C,-1.6 °C, respectively, East Kazakhstan region), Zhetygara (-1.8 °C, Kostanay region), Bayanauyl, Pavlodar (-1.4 °C, -1.7 °C, Pavlodar region), Almaty Kamenskoe plato, Esik, Kyrgyzsay, Sarkand, Saryozek, Taldykorgan (-1 °C,-2.7 °C,-1.1 °C,-3.4 °C, respectively, Almaty region), Taraz, Korday, Otar , Uyuk (-1.4 °C, -1.3 °C,-1.3 °C,-1.4 °C, respectively, Zhambyl region). The absolute maximums and minimums of the temperature of the winter season have not been updated.

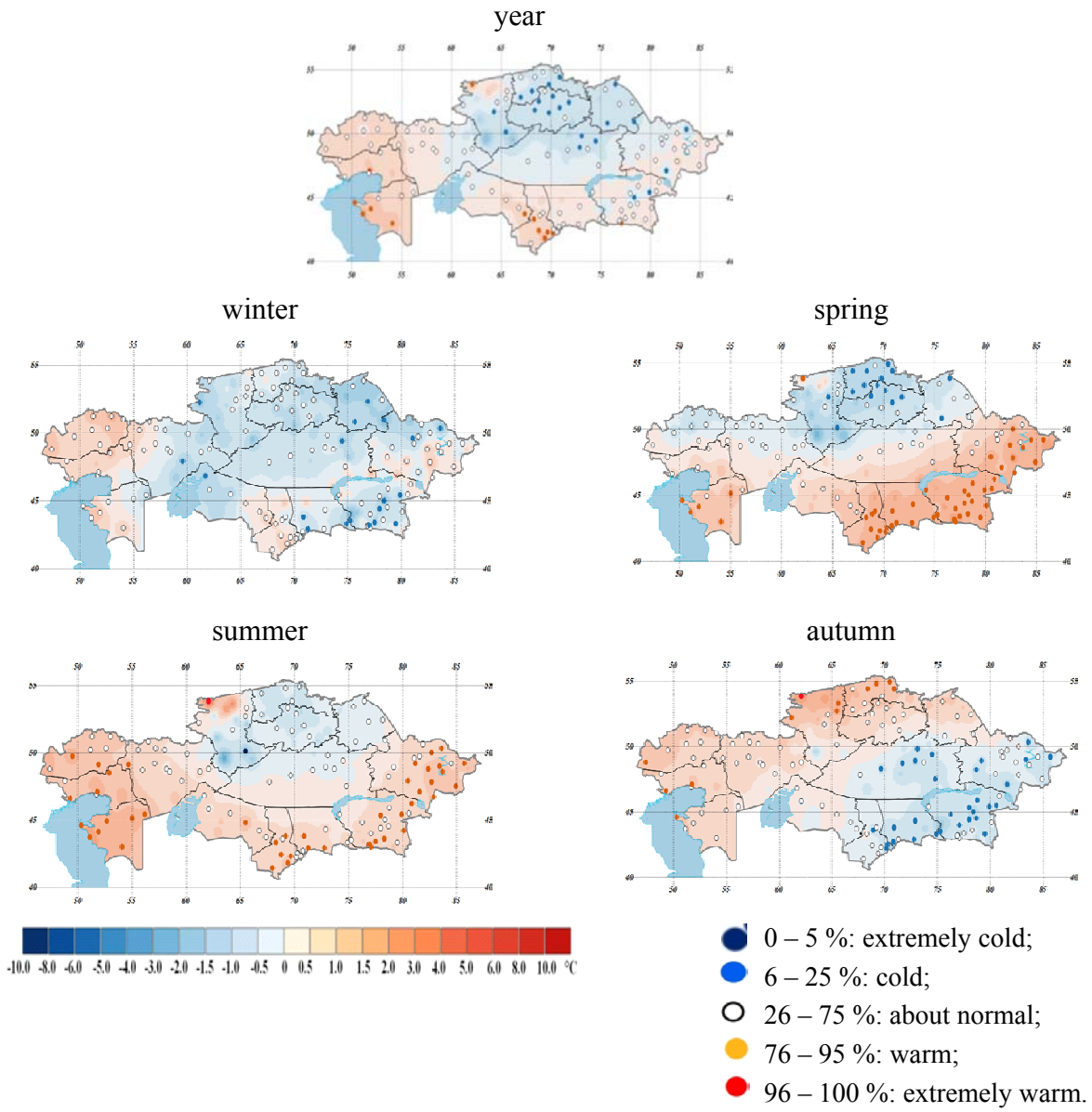


Figure 2.2 - Spatial distribution of air temperature anomalies (°C) in 2018 calculated relatively for basic period of 1961–1990, and the probabilities of not excess of air temperature values in 2018, calculated according by the period of 1941-2018

Spring 2018. In the northern half of the territory of the republic, the average seasonal temperature anomalies were negative (Figure 2.2). In some northern regions, temperatures were significantly below normal. As a result, in the North Kazakhstan and Akmola regions, the average air temperatures over their territory were much lower than normal: by 1.22 and 1.6 °C, respectively (table 2.2). In the southern half of the republic, the air temperature was above normal, in the vast territories of Mangistau, Turkestan, Almaty and East Kazakhstan regions - much higher than normal. As a result, the average air temperature over their territory was above the norm by 1.50-2.0 °C (table 2.2). Among the spring months, it was extremely warm in March in the Almaty and Zhambyl regions, the average anomalies in the region were about 6 °C with a probability of not exceeding 97% (table 2.3). Historical maximums of the average monthly temperature in March were recorded at the meteorological stations of Bakty (+5.8 °C) and Markakol Reserve (-5.3 °C) of the East Kazakhstan Region and at Alakol (+4.7 ° C) and Ucharal (+5,3 °C) Almaty region. In May, it was extremely cold in Akmola (3.0 °C), East Kazakhstan (2.4 °C), Karaganda (2.6 °C), Pavlodar (3.9 °C), North Kazakhstan (3.0 °C) areas. In these areas, May entered 5 % of the extremely cold months of the spring season (table 2.3). Historical air temperature minimums were set at a number of stations in May; these are Aktogay (+8.9 °C), Golubovka (+8.8 °C), Ertis (+8.8 °C), Zholboldy (+9.2 °C) stations, Koktobe (+10.4 °C), Krasnoarmeka (+9.7 °C), Lozovaya (+8.6 °C), Uspenka (+9.2 °C), Fedorovka (+8.5 °C). The average spring air temperature anomaly over Kazakhstan was + 0.6 °C (table 2.2).

Summer of 2018 was warm in most of Kazakhstan, in the western and southern regions the average seasonal temperatures were significantly higher than normal (Figure 2.2), mainly due to the steady hot weather in July, when new absolute maximums of the average monthly air temperature were reached at many stations: Atyrau (+31.2 °C), Kulsary (+32.0 °C), Pedestrian (+28.7 °C) Atyrau region; Akkuduk (+34.1 °C), Beineu (+33.2 °C), Kyzan (32.5 °C), Sam (+32.1 °C), Tuschibek (31.2 °C), Fort-Shevchenko (+29.7 °C) in Mangistau region; Ayakkum (+30.0 °C) in Aktobe region; Karabalyk (+26.7 °C), Kostanay (25.7 °C), Mikhailovka (24.8 °C) in Kostanay region; Kazygurt (+29.2 °C) in Turkestan region; Karak (+30.8 °C), Kyzylorda (+30.8 °C), Shirik-Rabat (+32.0 °C) in Kyzylorda region. As a result, July in Aktobe and West Kazakhstan regions entered 5% of the hottest summer months, the average temperatures in Atyrau, Kyzylorda and Mangistau regions were the highest in the entire history of observations (table 2.3). In June, some extremes were also updated: absolute minimums at weather stations Aralkol (16.3 °C), Zheleznodorozhnyi (15.3 °C), Torgay (16.0 °C), Ekidyn (17.7 °C). Extremely warm in June was in the area of MS Karabalyk (Kostanay region), where an air temperature anomaly of +4.5 °C was recorded with a probability of not exceeding 100 %. At this station, a new maximum of air temperature (16.4 °C) was also reached for the average temperature during the warm period, the previous maximum (16.0 °C) was recorded in 2012. In August, the minimum average monthly temperature was updated at MS Torgay (18,0 °C) Kostanay region. The air temperature anomaly averaged over the territory of Kazakhstan for the summer season 2018 was +0.6 ° C (70th percentile, table 2.2).

Table 2.3 - Regionally averaged mean monthly air temperature anomalies in 2018: vT-deviations from the average for 1961-1990,°C; P (t≤T2018) is the probability of not exceeding (in brackets) calculated according to the data for the period 1941-2018 and expressed in %

Region	12 (2017)	1	2	3	4	5	6	7	8	9	10	11
Kazakhstan	0,50 (58)	-3,01 (16)	1,60 (57)	2,38 (79)	0,36 (54)	-0,96 (22)	0,04 (54)	1,27 (89)	0,60 (67)	0,23 (50)	1,89 (84)	-1,61 (35)
Almaty	0,62 (62)	**-4,89 (5)**	2,13 (61)	**6,00 (97)**	1,04 (68)	-1,08 (22)	0,82 (72)	0,22 (55)	1,22 (85)	-0,29 (29)	0,84 (62)	-2,67 (22)
Akmola	1,18 (64)	-4,13 (18)	0,60 (51)	-0,24 (45)	-0,44 (38)	**-3,00 (5)**	-1,44 (20)	-0,02 (66)	-0,11 (40)	-0,12 (44)	2,24 (80)	0,33 (51)
Aktobe	-0,53 (45)	-1,22 (28)	1,13 (51)	-1,13 (38)	-0,09 (53)	0,60 (64)	-1,14 (27)	**2,99 (98)**	0,06 (45)	1,05 (76)	2,64 (88)	-1,64 (33)
Atyrau	0,45 (61)	-1,11 (25)	1,87 (62)	-0,20 (45)	-0,23 (53)	2,39 (93)	0,05 (49)	**3,93 (100)**	0,25 (50)	1,70 (88)	2,73 (87)	-1,57 (38)
East-Kazakhstan	2,01 (76)	**-6,17 (5)**	3,25 (75)	5,79 (92)	1,42 (68)	**-2,74 (2)**	1,99 (89)	-0,32 (42)	1,29 (77)	-1,08 (16)	1,65 (74)	-2,00 (29)
Zhambyl	0,38 (58)	-4,56 (6)	1,23 (49)	**5,73 (97)**	0,85 (66)	-0,47 (31)	0,47 (61)	0,97 (75)	1,04 (75)	-0,25 (37)	0,76 (63)	-3,34 (18)
West-Kazakhstan	1,33 (66)	0,49 (41)	2,02 (61)	-3,28 (22)	-0,71 (46)	1,87 (81)	-0,21 (44)	**3,53 (96)**	0,83 (64)	2,34 (92)	2,71 (87)	-1,66 (37)
Karagandy	0,25 (55)	-3,42 (14)	1,25 (61)	2,75 (77)	0,32 (57)	**-2,57 (5)**	-0,48 (29)	-0,15 (50)	0,30 (53)	-1,18 (20)	1,37 (62)	-3,01 (23)
Kostanay	0,27 (55)	-2,53 (24)	0,40 (46)	-1,02 (37)	-0,11 (50)	-1,37 (24)	-1,78 (19)	1,78 (87)	0,75 (61)	1,24 (72)	3,22 (92)	0,51 (61)
Kyzylorda	-1,46 (35)	-0,17 (40)	0,23 (46)	2,90 (75)	0,36 (57)	-0,12 (38)	-0,17 (41)	**2,90 (100)**	0,27 (51)	0,13 (41)	2,20 (80)	-2,06 (31)
Mangystau*	-0,62 (39)	0,04 (31)	2,01 (58)	1,76 (63)	-0,18 (36)	3,07 (94)	1,38 (68)	**4,70 (100)**	0,29 (48)	2,05 (84)	2,58 (81)	-2,32 (13)
Pavlodar	0,27 (50)	-5,22 (11)	0,61 (49)	1,34 (63)	0,60 (48)	**-3,87 (1)**	-0,44 (46)	-0,90 (35)	0,39 (48)	-0,46 (32)	2,23 (80)	0,48 (59)
North-Kazakhstan	1,62 (70)	-3,46 (20)	0,36 (51)	-1,12 (35)	-0,82 (36)	**-2,98 (5)**	-2,05 (12)	0,31 (70)	-0,32 (36)	0,62 (61)	2,54 (84)	1,14 (66)
Turkestan	-1,05 (36)	0,80 (50)	1,81 (57)	4,77 (94)	0,70 (63)	0,26 (54)	0,24 (58)	2,00 (94)	0,47 (63)	0,33 (55)	0,88 (63)	-2,31 (27)

Notes: 1. for the Mangistau region, an assessment has been carried out since 1960;
2. values above the 95th or below the 5th percentile (respectively, warm and cold extreme points) are shown in bold and bright colors.

Autumn of 2018 was warm in the territory of western and northern Kazakhstan, where at a number of stations the seasonal temperature anomalies of more than 1.5-2.0 °C were recorded with a probability of not exceeding 75 % (Figure 2.2). In the central, southern and southeastern regions, at many stations, seasonal temperatures were significantly lower than normal (1.0-1.5 °C with a probability of not exceeding 25 %), as well as on average in the territories of Almaty, Zhambyl and Karaganda regions. In the presence of multidirectional deviations of air temperature from the norm in various regions of Kazakhstan, the average temperature in Kazakhstan in autumn season 2018 was only 0.17 °C higher than the climatic norm.

From the point of view of climate change nowadays the greatest interest are representing extreme climate events which makes the big impact on various sectors of economy (health care, water resources, agriculture, etc.). The World Meteorological Organization has recommended a

software package of ClimPact2 which makes it possible to calculate and analyse of the frequency and intensity of changes of these phenomena. According to the daily values of maximum, minimum air temperature and precipitation at meteorological stations of Kazakhstan since 1936 climate indices have been calculated:

- TXx, maximum of daily maximums of air temperature;
- TNn, minimum of daily minimum air temperature;
- SU35, the number of very hot days with temperatures above 35 °C;
- TX90p, percentage of warm days with a daily maximum air temperature over the 90th percentile;
- TN10p, percentage of days when the minimum temperature was below the 10th percentile (cold nights);
- WSDI, duration of the heat waves, or the number of days when at least 6 consecutive days daily maximum air temperature was above the 90th percentile;
- CSDI, duration of the cold waves, or the sum of days when at least 6 consecutive days the daily minimum air temperature was below the 10th percentile;
- FDm20, the number of nights with frost
- ID, the number of days with frost;
- GSL, duration of the vegetative period;
- RX1days, maximum quantity of rainfall in 1 days;
- CDD, duration of the rainless periods, there was not rainfall;
- CWD, duration of periods with precipitation, or the number of days when at least 6 consecutive days when the amount of precipitation was equal or more than 1 mm;
- R95pTOT, the proportion of extreme daily amount of precipitation in the annual precipitation sum;
- ID, cold days
- HWF, total duration of the heat wave of the warm period;
- TM10a, the number of days with an average daily temperature above 10^0C;
- Hdd heat8, sum of temperatures for the heating period.

Daily maximum of air temperature in 2018. Figure 2.3 shows the values of the absolute maximums of air temperature: blue color values indicates the daily maximums of air temperature observed in 2018, and red color values - the absolute maximums recorded from the moment the station was opened until 2017 in red. The values of the absolute maximums were not exceeded at any station in Kazakhstan. The highest values of air temperature (absolute maximum) in Kazakhstan were recorded in July 1983 - +49...+50 °C (Turkestan, Chayan, Aris, Tasty) and air temperature in MS Kyzylkum has risen up to +51 °C.

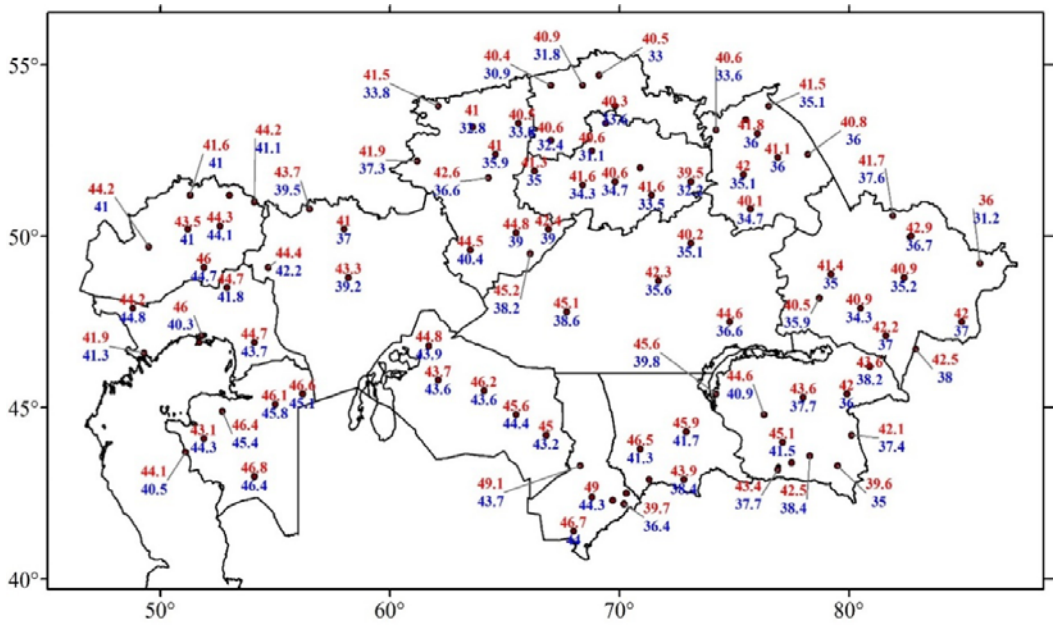


Figure 2.3 – Absolute maximum temperature (°C, red) since the beginning of records until 2017 and the daily maximum temperature 2018 (°C, blue)

Figure 2.4 shows the absolute minimum air temperature (red color) recorded from the moment the weather station was opened in 2017 and the blue color indicates the minimum air temperature in 2018. Lowest values of air temperature (absolute minimum) in Kazakhstan were recorded in January 1893 (-52 °C, Astana) and in January 1931 (-54°C, Shaganatta). In 2018, air temperatures below minus 30 °C were observed in the northern half of Kazakhstan. At MS Mikhailovka (Pavlodar oblast) and MS Dmitrievka (East-Kazakhstan region), the lowest air temperatures (-40 °C) were recorded. Absolute minimum temperature since the beginning of records has not been exceeded in 2018 at any considered weather stations.

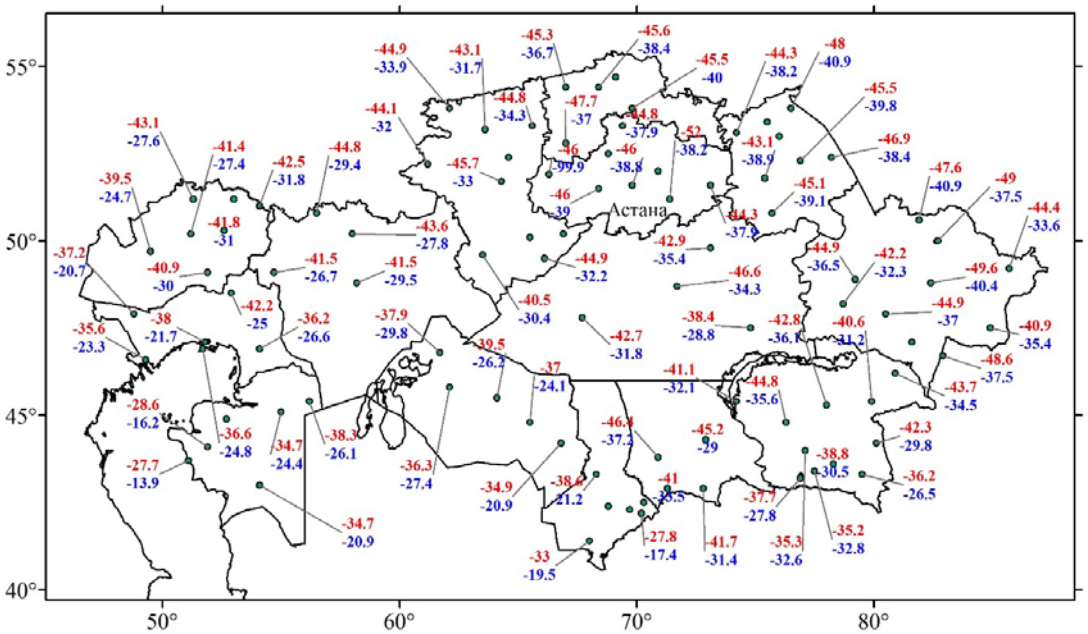


Figure 2.4 - Absolute minimum temperature (ºC, red) since the beginning of records until 2017 and the daily minimum temperature 2018 (ºC, blue)

Number of days with temperatures above 25 ℃ is of interest for different sectors of the economy, for example, for agriculture, as high temperatures are good conditions for the growth of garden and melon crops, but in absence of moisture, high temperatures leads to drought and losses harvest. At high temperatures human body feels some discomfort, which is important to take account in health care and energy, as during periods with such temperature, energy is spent for cooling of rooms.

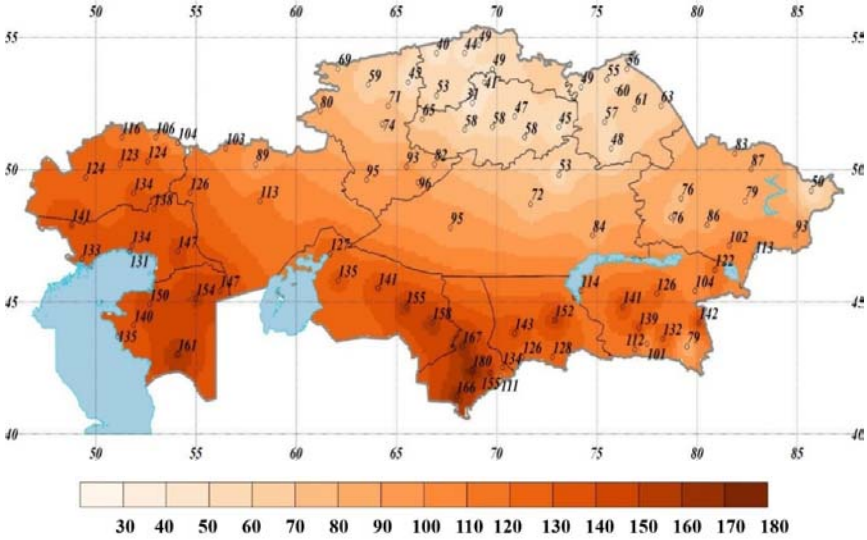


Figure 2.5 - The number of days (a) and probability of not exceeding the number of days (b) in 2018 with air temperatures above 35 ºC. Probabilities are calculated during the period 1941 - 2018

In 2018, in the northern, central and northeastern regions of Kazakhstan, temperatures above 25 ºC were observed for no more than 100 days (Figure 2.5). In the western and southern regions, hot weather repeated more than 130 days, the maximum number of hot days was observed in the Mangistau and Turkestan regions (160,180 days).

The percentage of warm days with a daily maximum air temperature above the 90th percentile in 2018 over the territory of Kazakhstan ranged from 2 % to 24 % (Figure 2.6 a). In the northern and central regions of the country, an extremely high daily maximum of air temperature was observed, as a rule, in no more than 9 % of cases, in the extreme southern regions - in more than 15% of cases. The patterns of distribution of the values of this index across Kazakhstan are consistent with the distribution of the number of hot days.

The percentage of cold nights in a year when the daily minimum air temperature was below the 10th percentile characterizes repeatability of cases with extremely low daily temperatures (Figure 2.6 b). In 2018, the percentage of cold nights ranged from 7 % to 15 % of cases, the maximum number of cold nights (23 % of cases) was observed at MS Peshnoi (Atyrau region). This index is largely consistent with the distribution of the index of frosty days (index FD20).

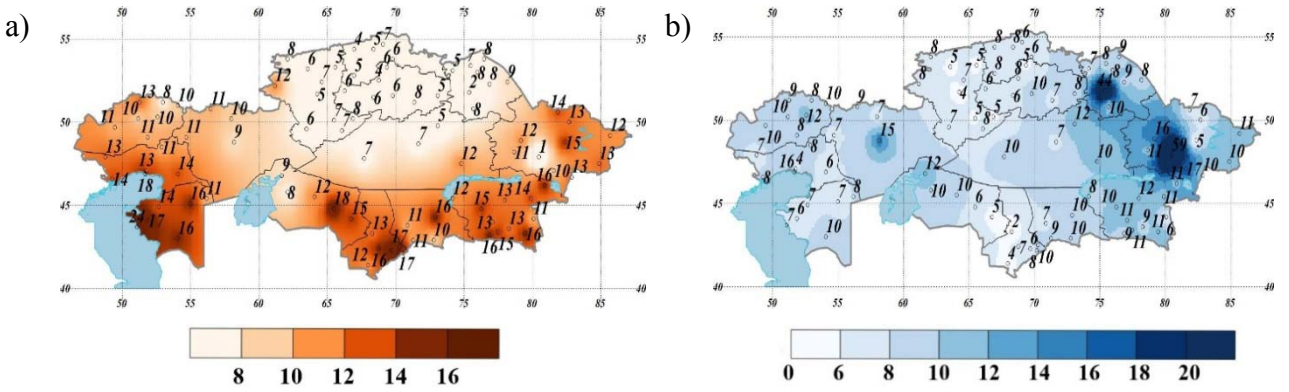


Figure 2.6 – Percent of cases in 2017 when daily maximum temperature was above the 90th percentile (a) and the daily minimum temperature was below the 10th percentile (b)

Figure 2.7 a shows ***the total duration of heat waves*** in Kazakhstan in 2018 (the sum of the days when 6 consecutive days with the daily maximum air temperature was above the 90th percentile). In most of Kazakhstan, heat waves lasting 6 days or more were not observed. At some stations in the East Kazakhstan, Almaty and Aktobe regions, the duration of heat waves was 6-8 days. In the Kyzylorda region, the maximum total duration of heat waves was 9-15 days, in Atyrau and Mangistau regions - from 11–34 days.

The sum of days for a year when at least 6 consecutive days the daily minimum air temperature was below the 10th percentile characterizes ***the total duration of the cold waves***. In 2018, in most of the territory of the Aktobe, West Kazakhstan, Atyrau, Mangistau and Kostanai regions, no cold waves lasting 6 or more days were observed. The maximum duration of cold waves from 15 days to 25 days was observed at stations of Almaty, Zhambyl, and East Kazakhstan regions (Figure 2.7 b).

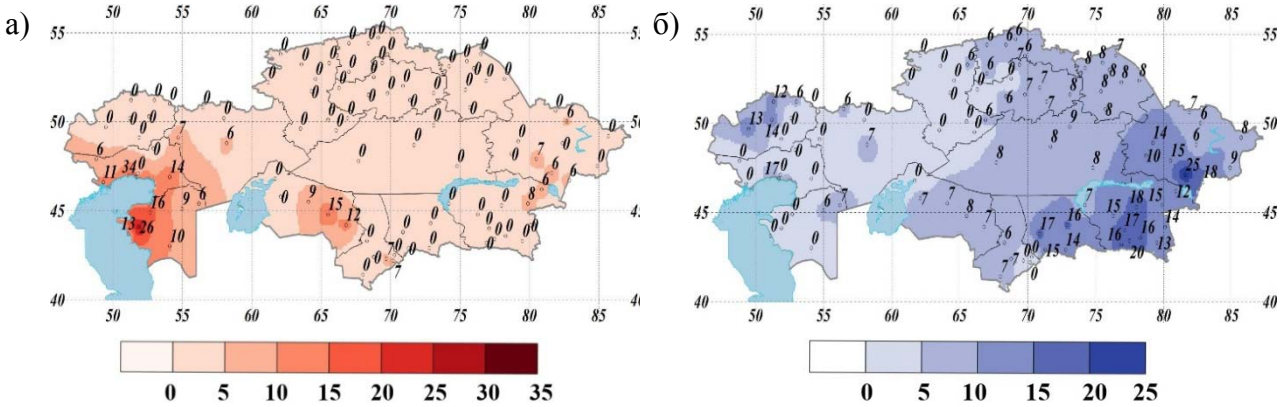


Figure 2.7 – Total amount of days in 2018, when at least 6 consecutive daily maximum air temperature was above the 90th percentile (a) and at least 6 consecutive days the daily minimum air temperature was below the 10th percentile (b)

Figure 2.8 shows the spatial distribution of ***the length of the growing season*** in 2018 (the period between the first date when the average daily temperature of the five-days was ≥ 5 °C and the last date when the average daily temperature of the five days was ≤ 5 °C). In 2018 the minimum growing season was 146-177 days in the northern regions of the country. In the southern

half of Kazakhstan, the growing season lasted more than 220 days, in the far south - more than 260 days, the maximum was observed in Aktau (274 days a year).

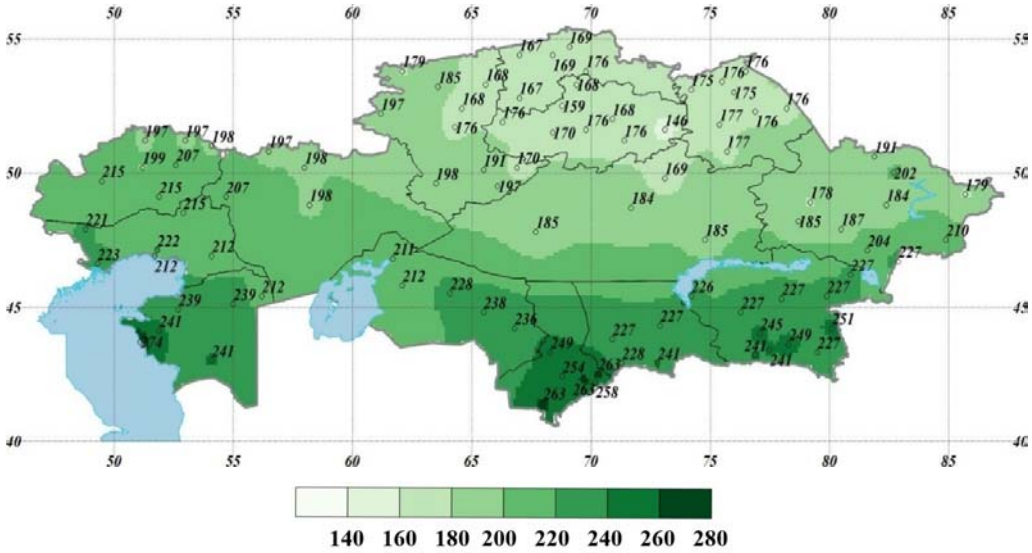


Figure 2.8 – Duration of the vegetative period (days) in 2018 (index GSL)

Figure 2.9 shows ***the number of days with frost when the daily maximum air temperature falls to below 0 °C.*** In 2018, in the northern regions of the country there were more than 120 such days, in places more than 130 days, the minimum number of days with daytime frosts was 9-10 days in the far south of Kazakhstan.

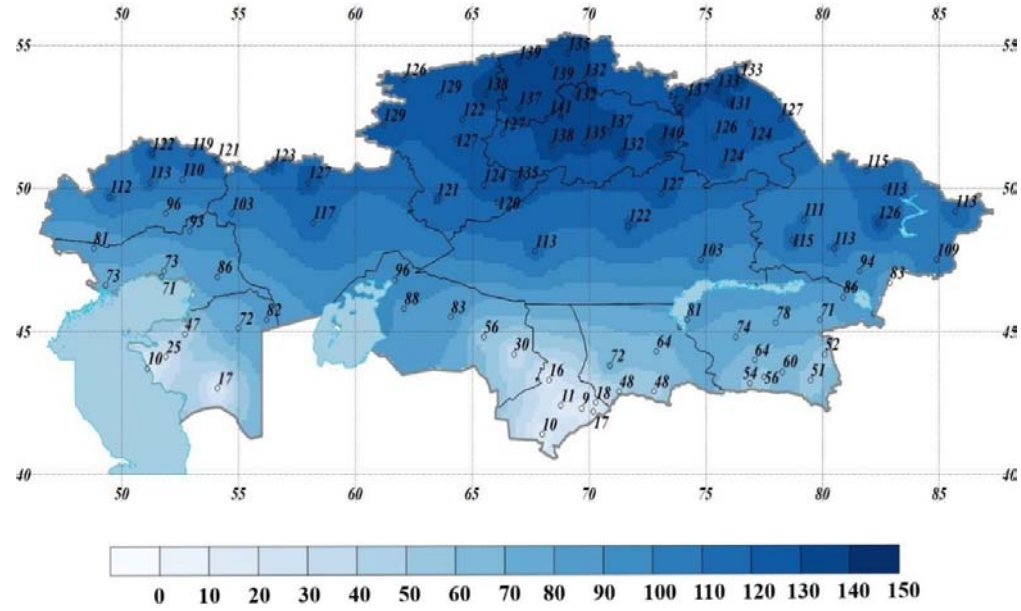


Figure 2.9 – The number of days in 2018 with day frosts (index ID)

In 2018, in the south of the Mangistau and Turkestan regions there were no ***days with severe frosts when the minimum daily air temperature falls to below minus 20 °C***. In the northern and eastern regions of Kazakhstan, the number of days with severe frosts ranged from 40 to 81 days (Figure 2.10).

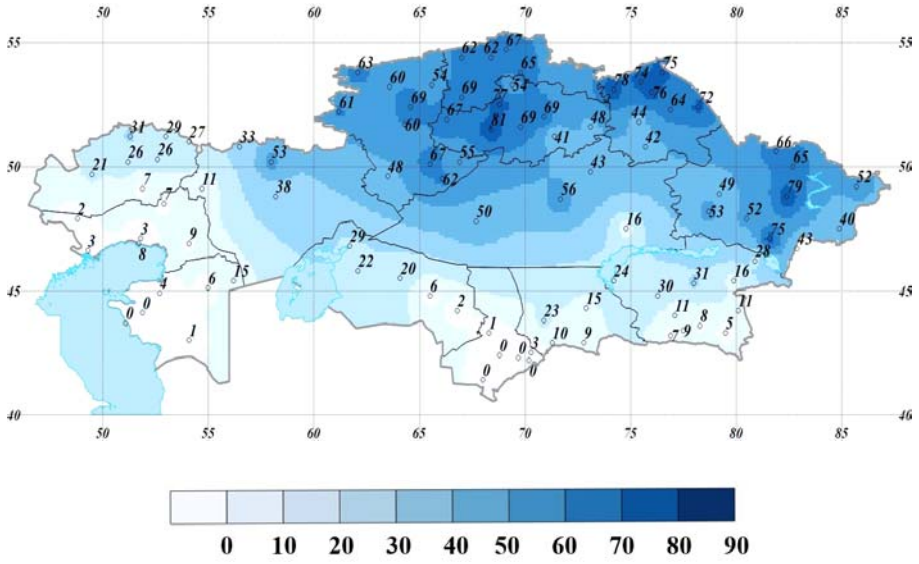


Figure 2.10 – The number of days with severe frosts in 2018 (index FDm20)

The number of days with temperatures above 10 °C characterizes the period of active vegetation). In 2018, in the southern regions of the republic, such days were observed from 180 to 231 days. In the northern and central regions of the country - from 122 to 173 days (Figure 2.11).

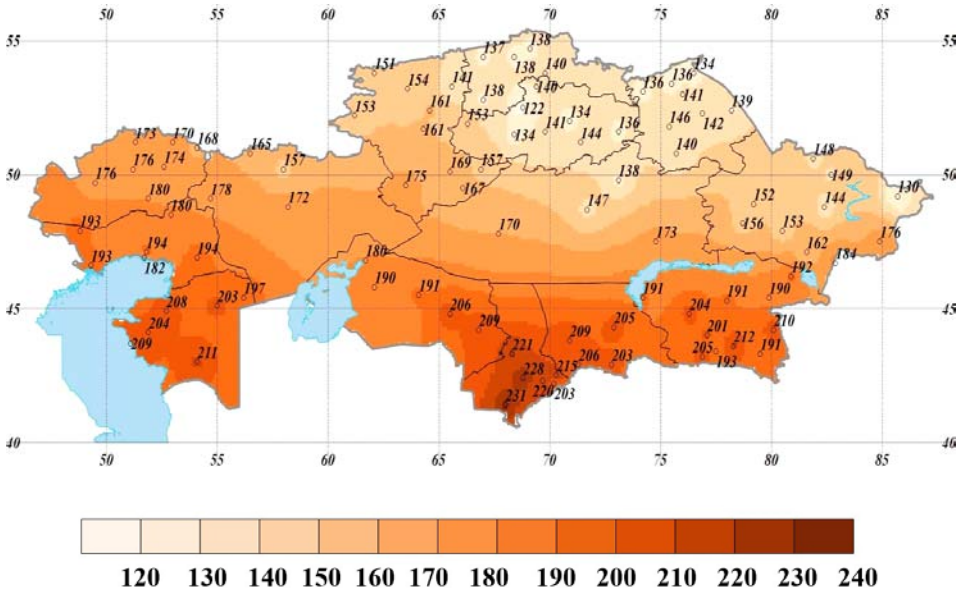


Figure 2.11 – The number of days with an average daily temperature above 10 °C in 2018 (index TM10a)

Great interest represents ***the Hddheat index***, which showing ***the sum of temperatures for the heating period***, which is compensated by heating of residential and production rooms (figure 2.12). This index helps to define the amount of energy needed for heating. The beginning of the heating period is established at the mean daily temperature of external air below +8 °C for 5 consecutive days. In 2018, the sums of the temperature difference during the heating period

decreased from north to south from more than 3500 °C to less than 800 °C (Figure 2.12). The lowest temperature sums for the heating season (720 °C) were recorded in Turkestan region.

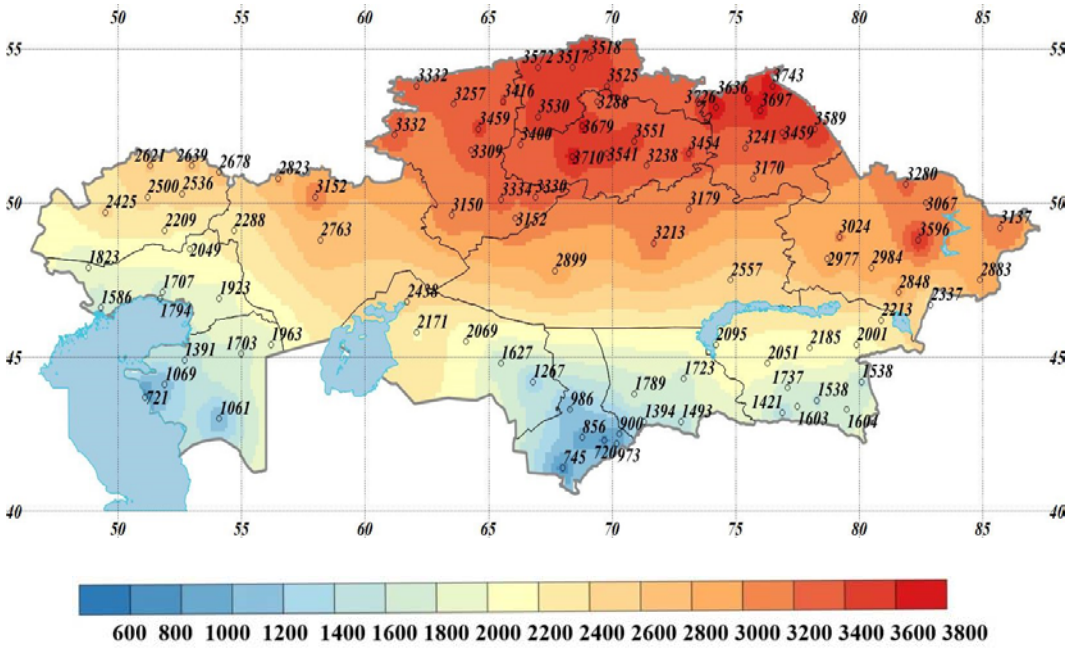


Figure 2.12 – The sum of temperatures for the heating season of 2018 (index HddHeat8)

2.2 The changes of the air temperatures observed in Kazakhstan

Figures 2.13 - 2.14 are shown the time series of averaged over the territory of Kazakhstan and administrative regions of the annual mean and seasonal anomalies of surface air temperatures over the period 1941 - 2018, also linear trends of air temperature change over the period 1976 - 2018. Anomalies are calculated relatively for the basic period of 1961 - 1990. Linear trends gives evident information about the gradual increase in annual mean and seasonal surface air temperatures over the last decades. Table 2.4 presents changes in air temperature over the period 1976 - 2018: the linear trend coefficient characterizing the average rate of change air temperature anomaly; and the coefficient of determination, and the determination coefficient showing trend contribution for the total variance.

On average over the territory of Kazakhstan for the period 1976 – 2018 increasing annual mean air temperature is 0.31 ºC every 10 years. The highest growth rates are observed in spring (0.59 ºC/10 years), the lowest in winter (0.11 ºC/10 years). The trend contribution for total dispersion of annual mean temperatures is 23 %, for other seasons – from 1 % in the winter up to 26 % in the spring. In all seasons except the winter, temperature increasing is statistically significant (table 2.4).

More detailed information on change in the average annual, seasonal and monthly air temperatures (ºC/10 years) over the territory of Kazakhstan for the period 1976 – 2018 are submitted in the figure 2.15–2.16.

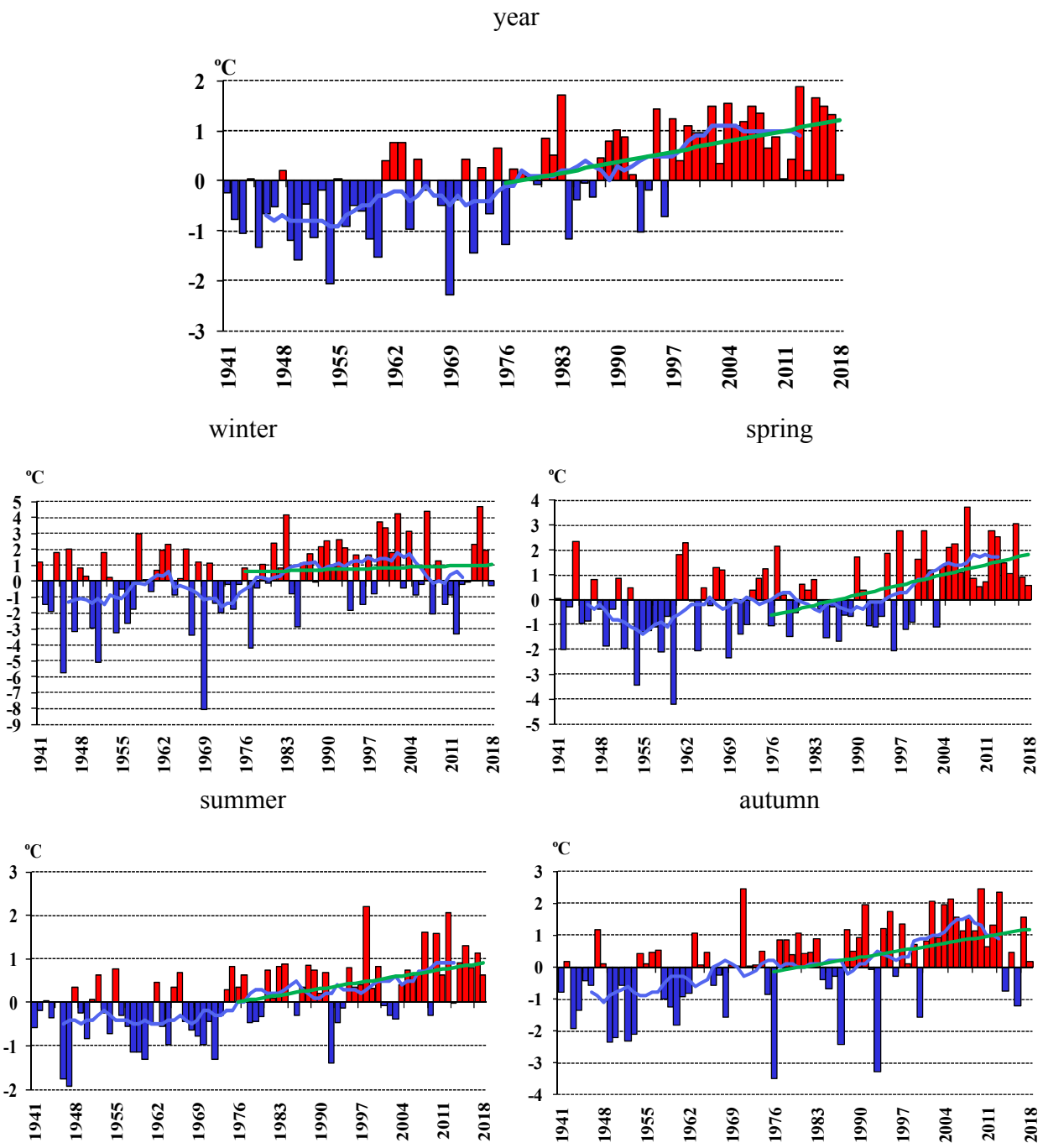


Figure 2.13 – Time series of anomalies of annual and seasonal air temperatures (ºC), averaged over the territory of Kazakhstan for the period 1941 - 2018. Anomalies are calculated relatively to the base period of 1961–1990. Linear trend during 1976-2018 is highlighted in green color.
Smoothed curve is received by the 11th sliding averaging

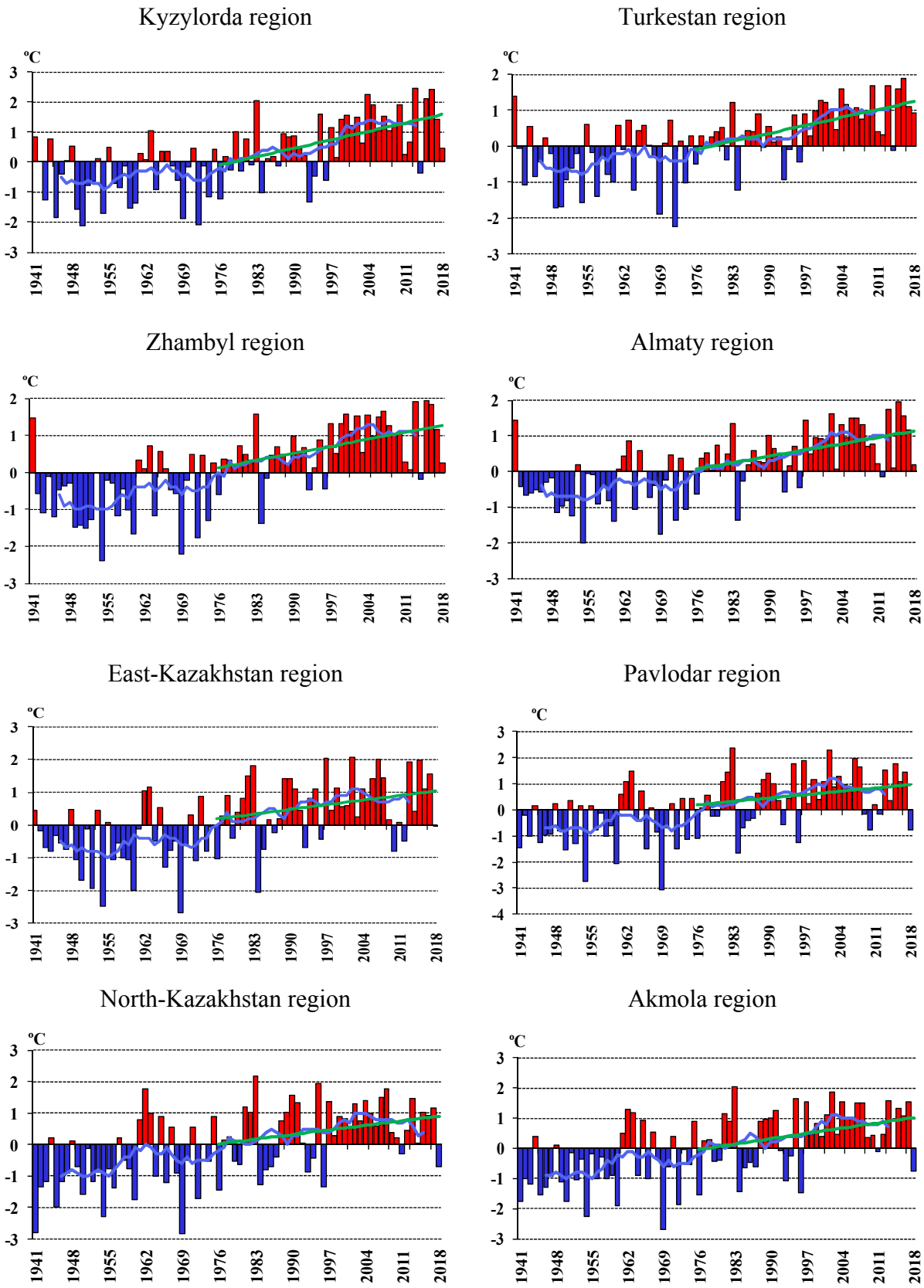


Figure 2.14 – Time series of anomalies of annual air temperatures (ºC), averaged over the regions of Kazakhstan for the period 1941 - 2018. Anomalies are calculated relatively to the base period of 1961–1990. Linear trend during 1976-2018 is highlighted in green color.

Smoothed curve is received by the 11th sliding averaging, Sheet 1

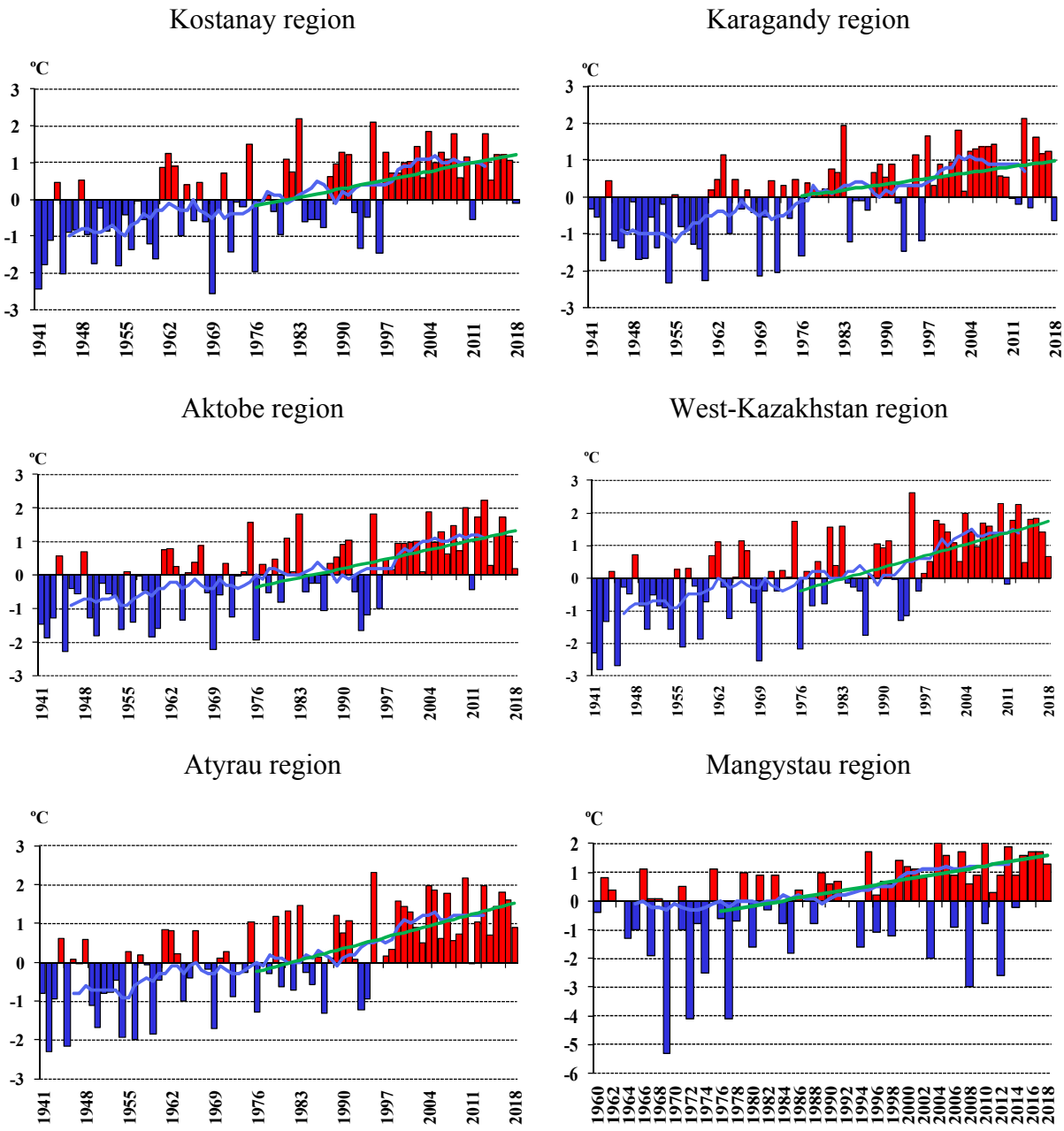


Figure 2.14 – Time series of anomalies of annual air temperatures (ºC), averaged over the regions of Kazakhstan for the period 1941 - 2018. Anomalies are calculated relatively to the base period of 1961–1990. Linear trend during 1976-2018 is highlighted in green color. *Smoothed curve is received by the 11th sliding averaging, Sheet 2*

Table 2.4 – Characteristics of the linear trend of surface air temperature anomalies, averaged over the territory of Kazakhstan and its regions for the period 1976–2018

Region	Year		Winter		Spring		Summer		Autumn	
	a*	**R^2	a	R^2	a	R^2	a	R^2	a	R^2
Kazakhstan	0,31	**23**	0,11	0	0,59	**24**	0,21	**14**	0,32	**9**
Almaty	0,25	**19**	0,07	0	0,58	**26**	0,20	**15**	0,21	**5**
Akmola	0,25	**11**	0,03	0	0,61	**18**	0,01	0	0,37	**6**
Aktobe	0,40	**24**	0,21	1	0,55	**13**	0,32	**10**	0,48	**14**
Atyrau	0,42	**29**	0,32	3	0,46	**15**	0,46	**31**	0,42	**14**
East-Kazakhstan	**0,20**	**7**	-0,07	0	0,62	**21**	0,16	**8**	0,17	2
Zhambyl	0,27	**21**	0,12	0	0,59	**25**	0,18	**12**	0,23	**6**
West-Kazakhstan	**0,50**	**31**	0,40	4	0,53	**14**	0,57	**24**	0,49	**16**
Karagandy	0,23	**10**	0,03	0	0,70	**23**	0,01	0	0,19	2
Kostanay	0,34	**17**	0,11	0	0,54	**12**	0,15	2	0,55	**15**
Kyzylorda	0,40	**26**	0,25	1	0,77	**28**	0,26	**16**	0,32	**8**
Mangystau	0,32	**35**	0,25	4	0,37	**18**	0,46	**42**	0,23	**9**
Pavlodar	**0,19**	**5**	-0,10	0	0,64	**21**	0,03	0	0,25	3
North-Kazakhstan	0,21	**8**	-0,02	0	0,44	**11**	0	0	0,44	**9**
Turkestan	0,32	**32**	0,23	2	0,54	**25**	0,21	**13**	0,28	**10**

Notes: * a – coefficient of the linear trend, ºC/10 year
** R^2 – determination coefficient, %
***«in bold font» has highlighted statistically significant tendencies

Trends of average annual temperature all territory of Kazakhstan were positive and statistically significant (figure 2.15–2.16). Faster warming in the western regions of Kazakhstan (0.24 - 0.60 ºC/10 years), the lowest warming rate (0.10 - 0.43 ºC/10 years) is observed in the north-eastern part of the republic, as well as in the south mountainous regions (0.11 - 0.21 °C/10 years).

In winter, the highest increase air temperature was observed in the southern and western regions - from 0.21 °C/10 years to 0.51 °C/10 years. In January, in the north, north-eastern part of the republic, the negative tendency of air temperature changes ranged from -0.24 °C/10 to -1.20 ºC/10 years. In February, the whole of Kazakhstan showed a tendency to increase air temperature: from 0.37 °C/10 to 0.98 °C/10 years (Figure 2.16). In December, a decrease in air temperature from -0.02 °C/10 to -0.77 °C/10 years was observed in the north-eastern, central and southern regions of the republic. It should be noted that in the foothill and mountainous regions in far east, as well as in the western regions, positive trends of air temperature change up to 0.49 °C/10 years were recorded. All the obtained trends in winter air temperature changes are statistically insignificant, only at the stations Urzhar (East Kazakhstan region) and Borovoye (Akmola region) the decrease in air temperature in January (-1.01 °C/10 years; -1.20 °C/10 years) was statistically reliable.

In spring across all territory of Kazakhstan is observed the most intensive warming from 0.30 °C/10 years to 0.93 °C/10 years is observed throughout Kazakhstan. All average temperature trends for the spring season are statistically significant. The highest rate of increase in air temperature was noted in March (from 0.58 °C/10 years to 1.79 °C/10 years).

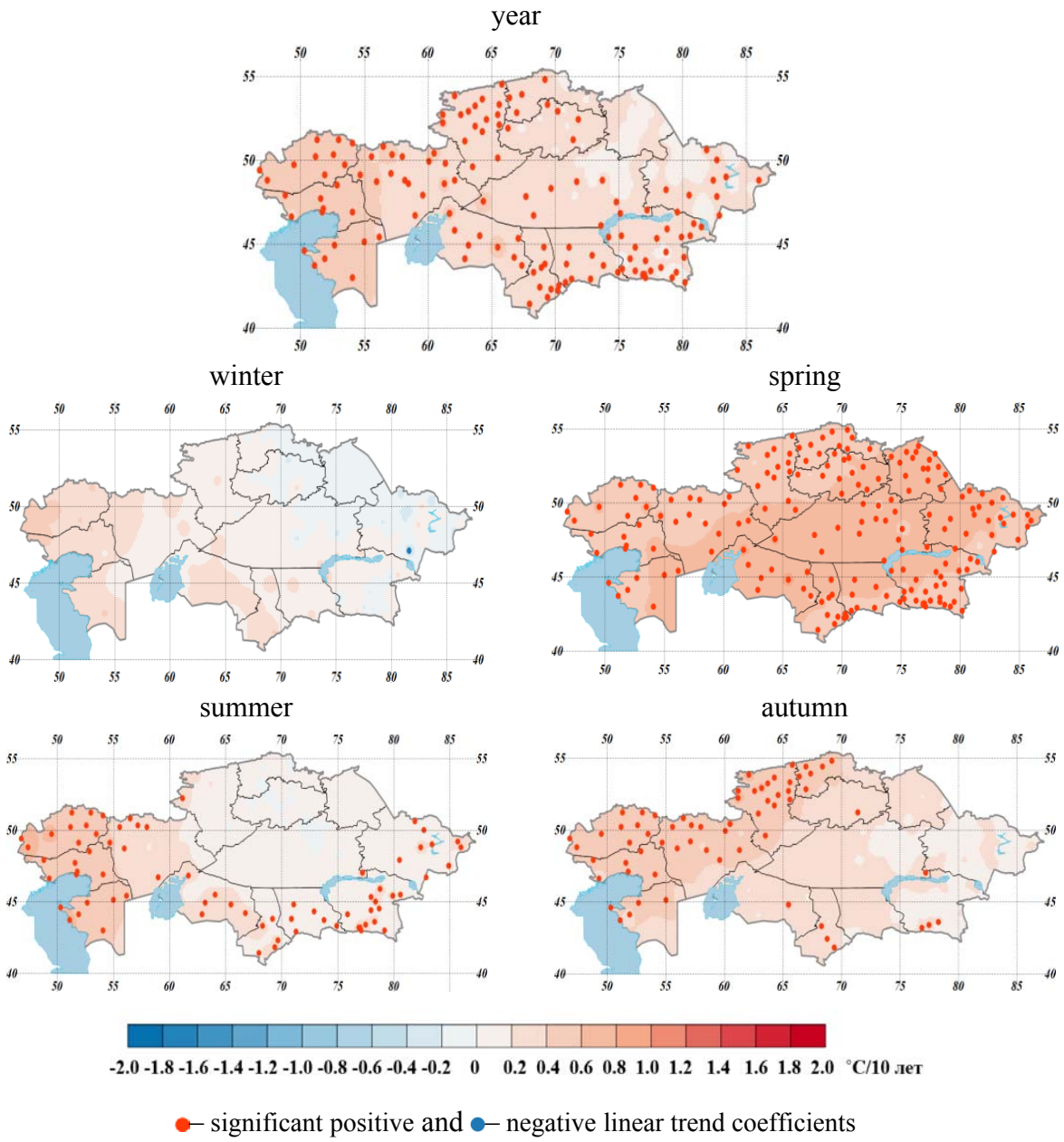


Figure 2.15 – Spatial distribution of the values of the linear trend coefficient of the average annual and seasonal surface air temperature (°C/10 years)

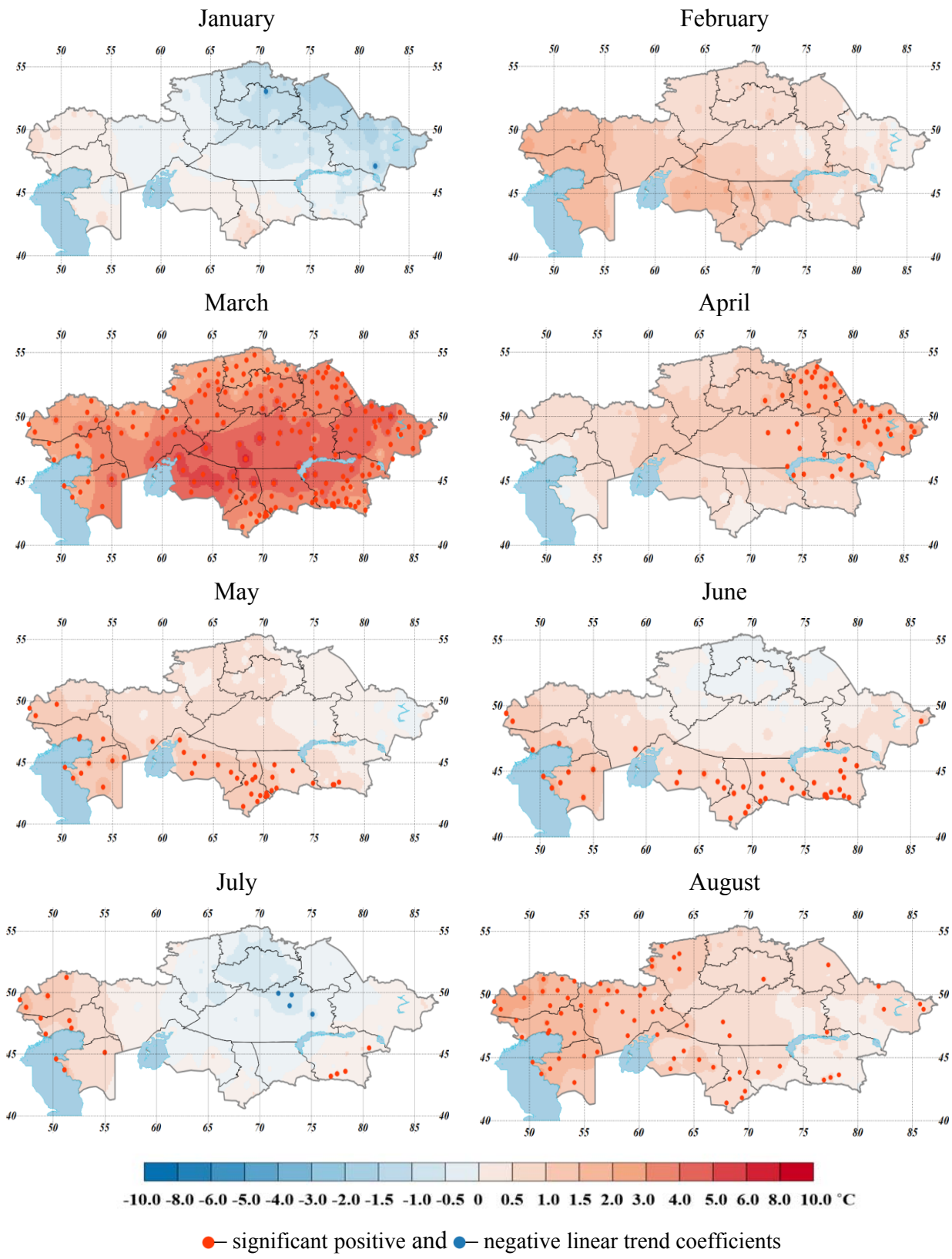


Figure 2.16 – Spatial distribution of the values of the linear trend coefficient of the average monthly surface air temperature (°C/10 years), calculated according to observations during 1976 – 2018, *Sheet 1*

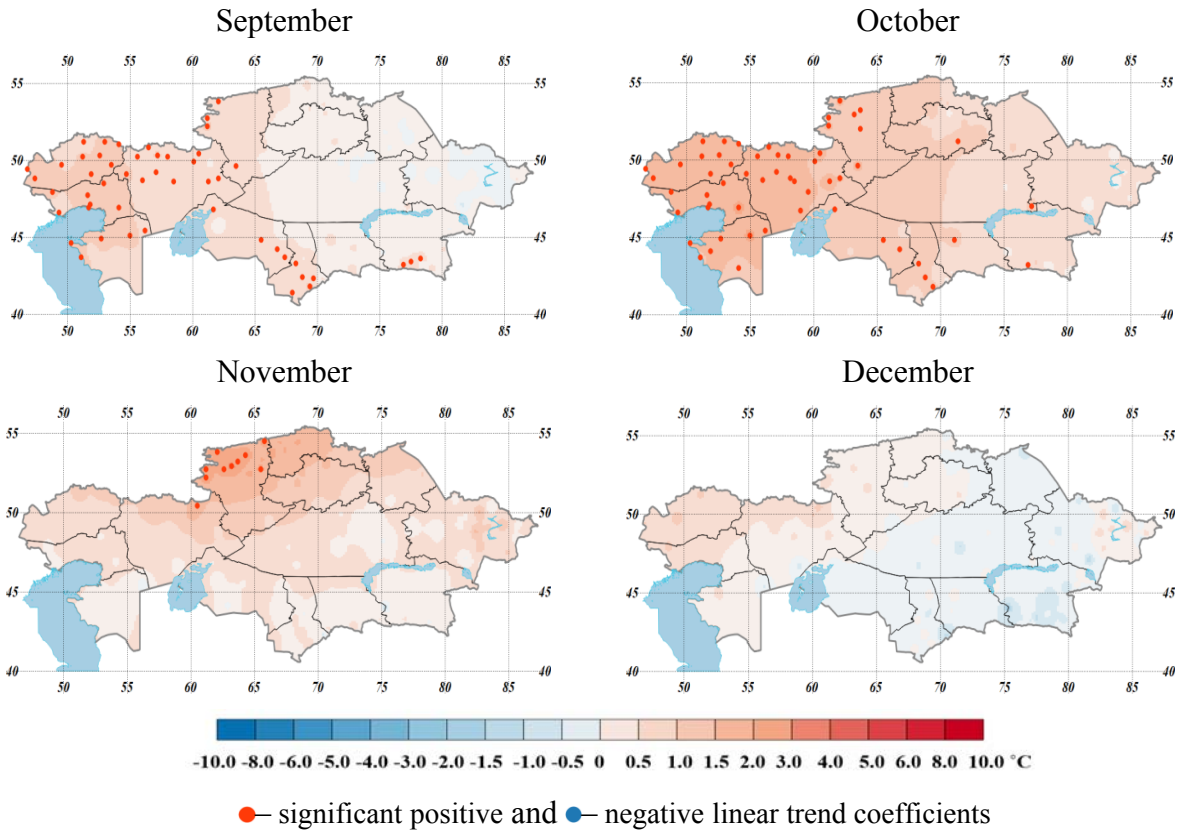


Figure 2.16 – Spatial distribution of linear trend values of coefficient mean monthly surface air temperature (°C/10 years), calculated according to observations during 1976 – 2018 *Sheet 2*

In summer, steady positive trends were observed in the east, as well as in the southern and western regions of the republic (0.15 ºC/10 years - 0.93 ºC/10 years). In the central and northern regions of Kazakhstan, trends in air temperature (0.13 ºC/10 years - 0.35 ºC/10 years) were statistically insignificant, with the exception of the Zhetykara (Kostanay region), where the increase in air temperature was statistically significant and amounted to 0,36 ºC/10 years. In June and July, a slight cooling is observed in the northern and central regions (minus 0.01 - minus 0.13 ºC/10 years). Statistically significant negative trends (minus 0.34 ºC/10 years – minus 0.42 ºC/10 years) were observed only in July at weather stations of the Karaganda region.

In autumn, over the past 4 decades, a steady increase in air temperature was noted in the northwest, west and south of the republic (0.37 ºC/10 years - 0.69 ºC/10 years). The main contribution was made in the months of September and October, when a statistically significant positive trend in air temperature was 0.27 ºC/10 years - 0.59 ºC/10 years and 0.33 ºC/10 years - 0.89 ºC/10 years, respectively.

2.3 Tendencies in extremes of surface air temperature

Over the past more than 40 years, there are mainly positive trends in ***daily maximums of surface air temperature*** in Kazakhstan, but trends are mostly insignificant (Figure 2.17). At some stations of Atyrau, Mangystau, Zhambyl, Pavlodar, Kyzylorda and East Kazakhstan regions were recorded significant positive trends of daily maximums of air temperature within 0.21 - 0.90 ºC/10 years.

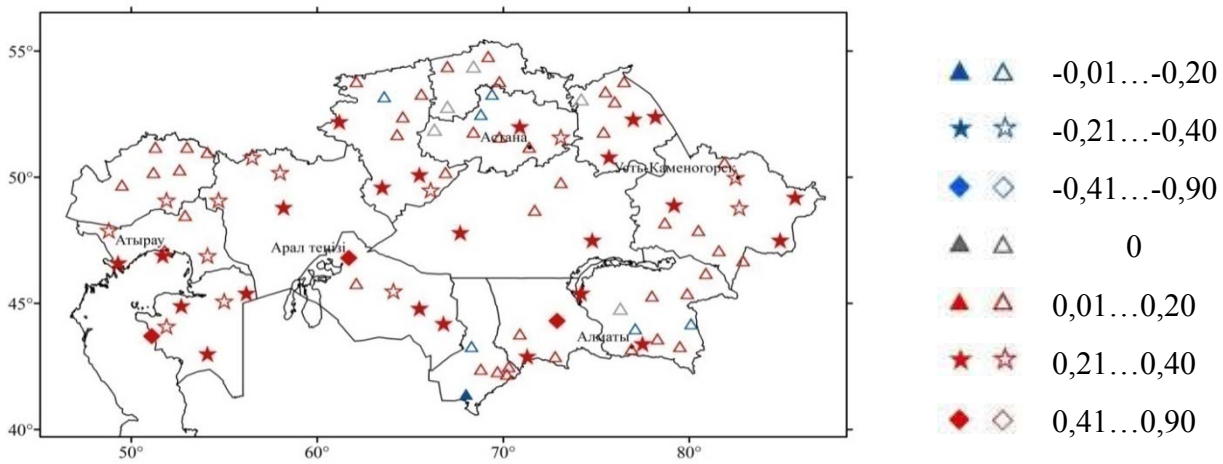


Figure 2.17 – Spatial distribution of the linear trend coefficient for values of daily maximum air temperature (°C/10 years) for the period 1976-2018. *Designations of gradation are shaded in cases of the statistical trend importance*

A statistically significant trend of an increase in ***the number of hot days*** with air temperatures above 25 ºC is observed in the West Kazakhstan, Aktobe, Atyrau, Mangistau, Kyzylorda, Turkestan regions: by 4-8 days every 10 years (Figure 2.18). Repeatability of hot days in southeast regions increases by 1-3 days every 10years.

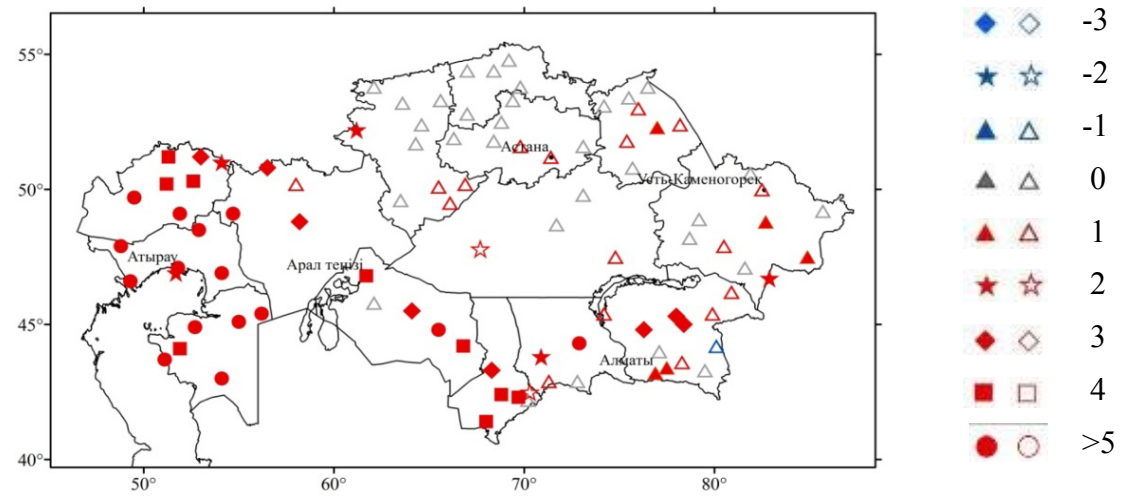


Figure 2.18 – Spatial distribution of the linear trend coefficient of the number of days with air temperature above 25 °C (days/10 years) for the period 1976-2018. *Designations of gradations are shaded in cases of the statistical importance of the trend*

Almost everywhere there is a tendency to reduce the ***frequency of occurrence of night frost*** in the republic, when the daily minimum temperature drops below 0 °C (Figure 2.19). Basically, the rate of reduction in the number of such cases is from 3 to 6 days every 10 years.

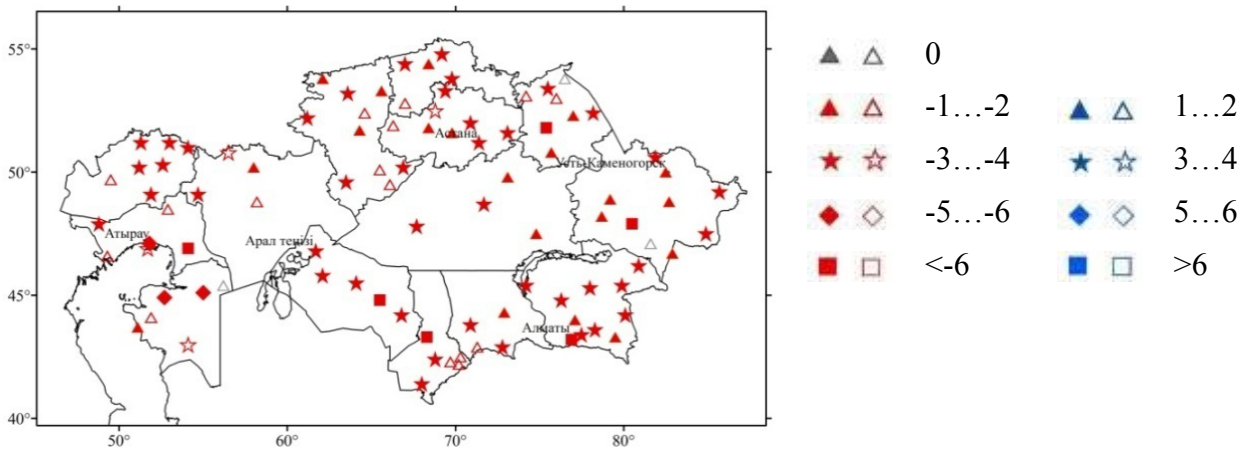


Figure 2.19 – Spatial distribution of the linear trend coefficient of the number of cases with daily minimum air temperature below 0 °C (days/10 years) for the period 1976-2018. *Designations of gradations are shaded in cases of the statistical importance of the trend*

The index of daily amplitude of air temperature shows (Figure 2.20) that over the past 40 years in the western half of Kazakhstan, there have been mainly trends to increase the daily amplitude by 0.1-0.4 °C/10 years, often the trends are statistically significant. In the southeast and east, on the contrary, significant trends were often observed to decrease the daily amplitude by 0.1-0.4 °C/10 years. In the northern and central regions, trends were mostly insignificant.

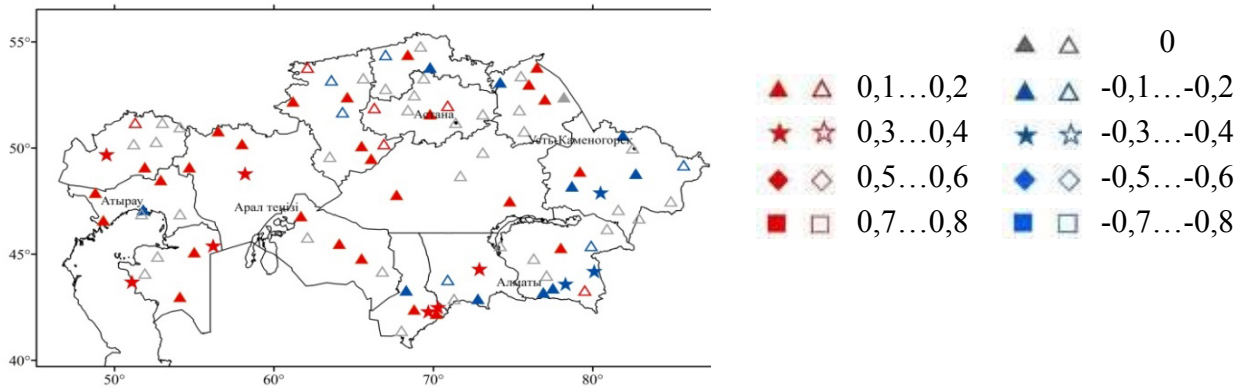
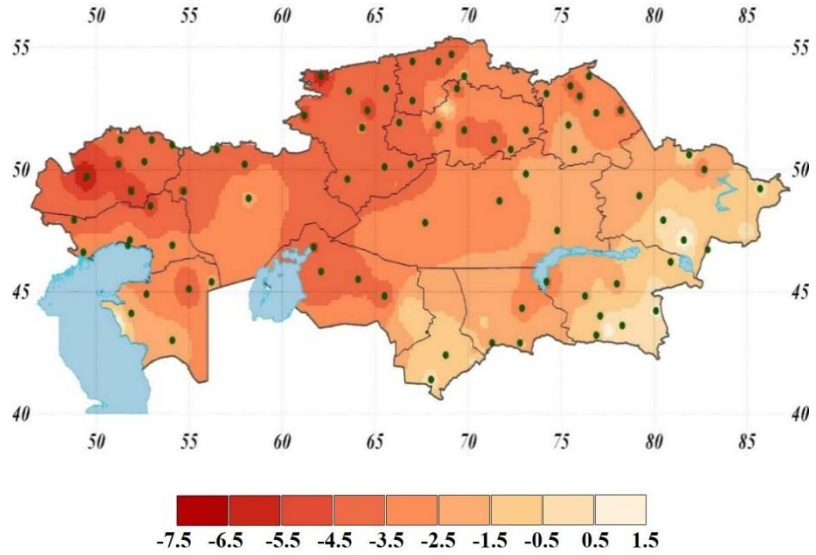


Figure 2.20 – Spatial distribution of the linear trend coefficient of the daily amplitude of air temperature (°C/10 years) for the period 1976–2018. *Designations of gradations are shaded in cases of statistical importance of the trend*

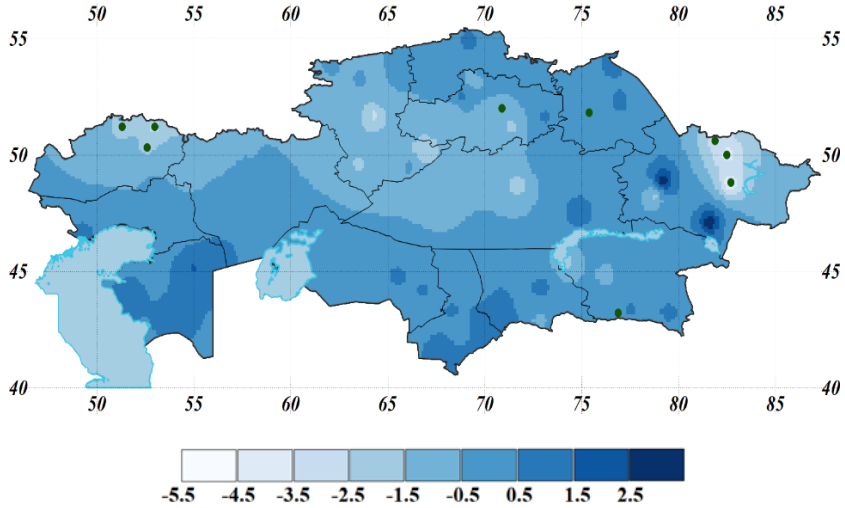
The highest rate of reduction (4-8 days/10 years) of ***the number of days with daytime frosts, when the daily maximum temperature is below 0 °C*** is observed mainly in the north-west and some places of central part of the republic (index ID, Figure 2.21). In the southern and southeastern regions, the number of days with daytime frosts increases slower (1-3 days/10 years).



●– significant negative and positive linear trend coefficients

Figure 2.21 – Spatial distribution of the linear trend coefficient of the number of days with day frosts (days/10 years) for the period 1976-2018

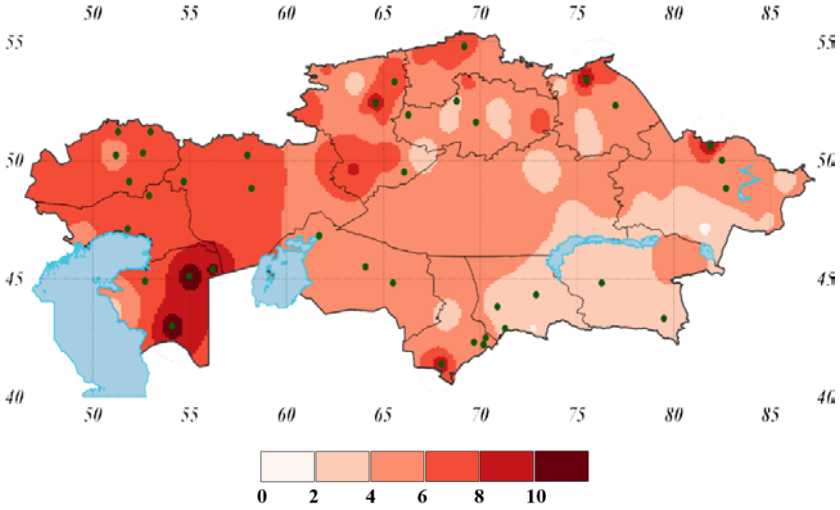
In the territory of the republic, ***the number of days with severe frosts, when the daily minimum of air temperature is below minus 20 °C*** (index FDm20, Figure 2.22) is almost universally reduced by 1-3 days/10 years, but a significant reduction (2-3 days/10 years) is noted only at some weather stations of the West Kazakhstan region and in the north-east of the republic



●– significant negative and positive linear trend coefficients

Figure 2.22 – Spatial distribution of the linear trend coefficient of the number of days in a year with severe frosts (*when the daily minimum of air temperature is below minus 20 °C*) for the period 1976-2018

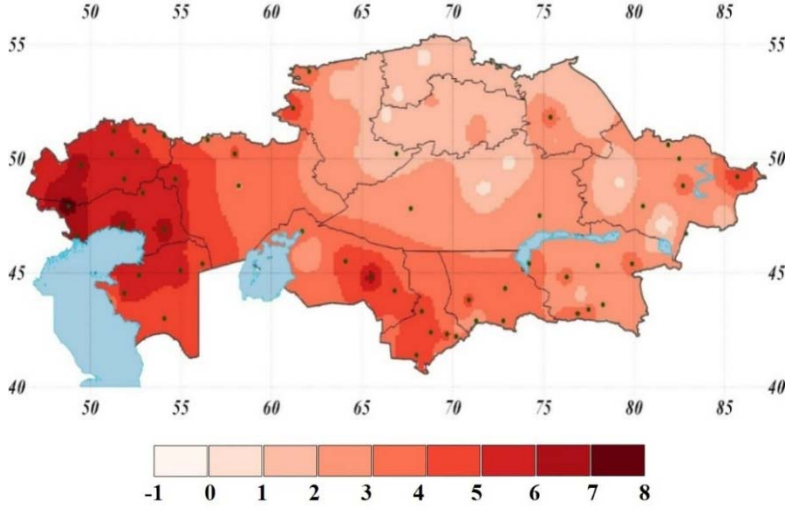
The total duration of heat waves over a year, when at least 6 consecutive days the daily maximum air temperature was above the 90th percentile throughout the republic is increasing everywhere. The highest rate of increase was 9–10 days/ 10 years at weather stations in the Mangistau region, as well as at some weather stations in the Kostanai and Pavlodar regions (Figure 2.23).



●– significant negative and positive linear trend coefficients

Figure 2.23 – Spatial distribution of the linear trend coefficient of the total annual heat wave duration (days/10 years) for the period 1976-2018

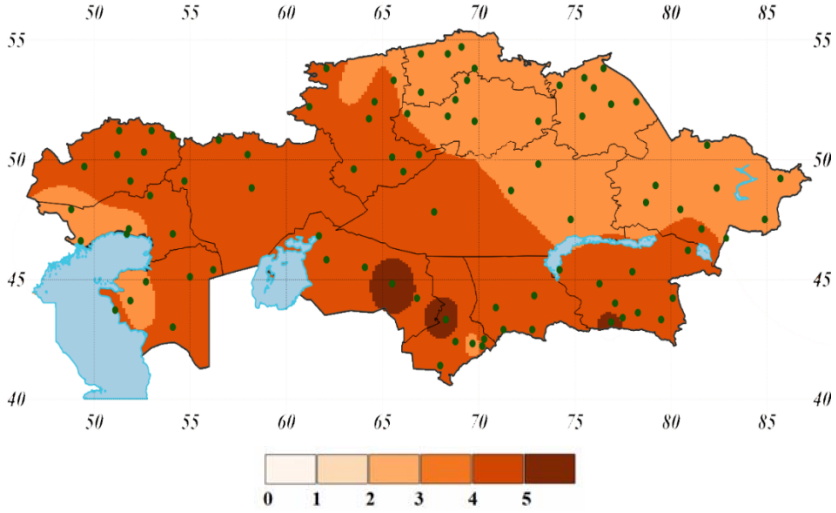
In most regions, there is tendency to increase the duration of ***heat waves in the warm period, when the daily maximum of air temperature is above the 90th percentile*** (index HWF, Figure 2.24). The highest rate of increase in the duration of heat waves (4-7 days/10 years) is observed in the West Kazakhstan, Atyrau and Mangistau regions. In Kyzylorda and Turkestan regions, the positive trend is 3-5 days/10 years.



●– significant negative and positive linear trend coefficients

Figure 2.24 – Spatial distribution of the linear trend coefficient of the total duration of heat waves in the warm period (days/10 years) during 1976-2018

The number of days with an average daily air temperature above or equal to 10 °C (TM10a index, the period of active vegetation) throughout Kazakhstan increases by 3-5 days/10 years (Figure 2.25), in some southern regions even more than 5 days/10 years.



●– significant negative and positive linear trend coefficients

Figure 2.25 – Spatial distribution of the linear trend coefficient of the number of days with an average daily temperature ≥10 °C (days/10 years) for the period 1976-2018

3 PRECIPITATION

3.1 Anomalies of precipitation in Kazakhstan in 2018

Figure 3.1 presents the inter annual course of the distribution of rainfall in 2018, space averaged over the Kazakhstan, as well as long-term average monthly precipitation for the period 1961 - 1990. The greatest amount of the precipitation in 2018 was in March (44,8 mm or 208 % of normal). Positive anomalies of precipitation were also observed in August (33 %) and November (12 %). In December, July and January, the rainfall was below the climatic norm by 25-38 %. In other months there was a slight deficit of moisture (10-16 %).

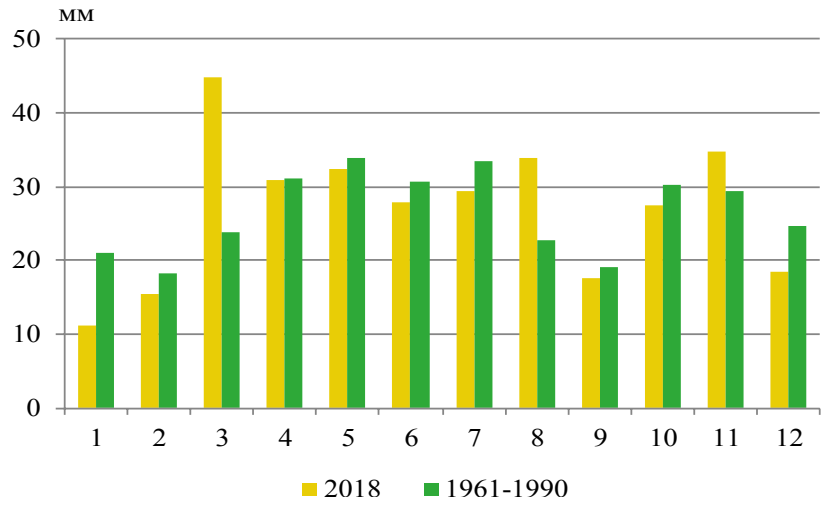


Figure 3.1 - Monthly precipitation in 2018 and norms for the period 1961-1990, averaged over the territory of Kazakhstan

Further presented values of the annual and seasonal precipitation anomalies (table 3.1), as well as the monthly precipitation anomalies (table 3.2), observed in 2018 and averaged over the whole territory of Kazakhstan and its regions. For each value of the anomaly, the probabilities of non-exceedance calculated for the period 1941 2018 are given. Probability of non-exceedance shows the percentage frequency of particular anomaly in the observation record. Precipitation above 95th or below the 5th percentile is shown in bold. Figure 3.2 shows the territorial distribution of annual and seasonal rainfall in 2018, expressed as a percentage of the norm for the period 1961-1990, as well as the probabilities of not exceeding annual and seasonal precipitation totals in a given year.

Table 3.1 - Regionally averaged annual and seasonal anomalies in precipitation in 2018: vR deviations from the long-term average for 1961-1990, mm; P (r≤R2018) is the probability of not exceeding (in brackets) calculated according to the data for the period 1941-2018. and expressed in %; RR - relationship of R_{2018} to normal, expressed in%

Region	Year		Winter		Spring		Summer		Autumn	
	vR (P)	**RR**	**vR (P)**	**RR**	**vR (P)**	**RR**	**vR (P)**	**RR**	**vR (P)**	**RR**
Kazakhstan	5,6 (49)	98	-13,8 (9)	80	19,4 (79)	123	4,0 (54)	92	1,2 (59)	100
Almaty	53,4 (74)	113	-5,7 (32)	97	35,54 (77)	124	22,4 (70)	117	4,0 (61)	111
Akmola	**113,5 (96)**	**134**	-10,3 (24)	80	31,3 (93)	144	76,7 (90)	155	24,8 (87)	131
Aktobe	**-98,1 (1)**	**62**	-25,6 (7)	58	-2,2 (41)	95	**-36,7 (5)**	**42**	-32,5 (10)	54
Atyrau	**-61,3 (2)**	**62**	-6,1 (23)	80	-15,8 (15)	61	-15,9 (27)	65	**-26,2 (2)**	**37**
East-Kazakhstan	27,5 (68)	109	**-21,4 (3)**	**67**	**52,3 (97)**	**162**	-25,3 (14)	79	29,2 (89)	135
Zhambyl	-46,1 (27)	85	-8,1 (31)	93	-13,0 (41)	89	-4,9 (32)	87	-13,3 (44)	84
West-Kazakhstan	-50,7 (20)	82	-18,2 (24)	73	22,4 (72)	137	18,2 (15)	56	-30,4 (14)	60
Karagandy	15,4 (67)	102	-0,8 (59)	96	7,5 (66)	110	12,7 (58)	113	17,9 (89)	121
Kostanay	-33,36 (28)	88	-21,81 (6)	57	27,67 (84)	145	-12,4 (35)	85	-21,7 (23)	71
Kyzylorda	-28,9 (20)	80	1,33 (49)	113	-11,1 (35)	77	-10,9 (18)	42	-4,3 (46)	87
Mangystau*	**-55,8 (5)**	**64**	0,1 (50)	96	**-29,1 (5)**	**44**	-11,1 (22)	69	-18,6 (8)	50
Pavlodar	**102,1 (96)**	**134**	-2,1 (51)	95	**56,1 (98)**	**203**	38,8 (76)	132	24,5 (92)	134
North-Kazakhstan	**115,6 (94)**	**133**	-20,0 (11)	59	**52,8 (98)**	**179**	83,1 (93)	154	-2,5 (57)	96
Turkestan	-31,37 (25)	92	-33,79 (12	78	-9,45 (42)	88	0,8 (41)	89	22,6 (77)	143

Notes: 1. for the Mangistau region, an assessment has been carried out since 1960;
2. values above the 95th or below the 5th percentile are shown in bold and bright colors.

Table 3.2 - Regionally averaged mean monthly precipitation anomalies in 2018: vT-deviations from the average for 1961-1990, mm; $P(r \leq R_{2018})$ is the probability of not exceeding (in brackets) calculated according to the data for the period 1941-2018. and expressed in %

Region	12 (2017)	1	2	3	4	5	6	7	8	9	10	11
Kazakhstan	-1,2 (40)	**-9,8 (5)**	-2,8 (27)	**20,9 (100)**	-0,1 (49)	-1,5 (38)	-2,7 (37)	-4,4 (36)	11,1 (85)	-1,5 (41)	-2,8 (54)	5,4 (76)
Almaty	-0,4 (50)	-4,8 (33)	-0,5 (44)	33,8 (93)	-0,4 (49)	2,1 (58)	-1,8 (48)	12,3 (72)	11,9 (77)	0,9 (59)	-11,1 (46)	14,3 (77)
Akmola	-0,2 (43)	-2,2 (44)	-8,0 (12)	17,3 (93)	7,3 (75)	6,7 (68)	24,0 (83)	-2,1 (59)	**54,6 (98)**	-0,1 (54)	18,8 (93)	5,9 (74)
Aktobe	-8,5 (25)	-12,3 (11)	-5,3 (28)	13,8 (88)	-2,3 (51)	-13,7 (11)	-14,6 (15)	-14,6 (12)	-7,6 (41)	-4,7 (49)	-15,1 (12)	-12,8 (16)
Atyrau	-1,3 (48)	-1,2 (36)	-3,8 (24)	1,3 (54)	-3,8 (46)	**-13,3 (1)**	**-15,2 (5)**	11,8 (80)	-12,4 (6)	-12,3 (6)	-2,4 (42)	-11,5 (11)
East-Kazakhstan	**-4,2 (0)**	-15,7 (39)	-1,2 (54)	**39,9 (100)**	8,68 (68)	3,61 (63)	-19,1 (6)	-13,9 (20)	7,7 (70)	9,9 (79)	0,2 (68)	19,1 (93)
Zhambyl	-4,2 (63)	2,2 (63)	-6,3 (87)	19,8 (35)	-14,2 (19)	-18,6 (59)	5,3 (32)	-7,0 (41)	-3,0 (22)	-7,3 (37)	-11,9 (68)	5,9 (28)
West-Kazakhstan	-1,5 (61)	**-16,6 (0)**	-0,2 (53)	18,2 (90)	-0,3 (49)	4,5 (58)	-22,7 (6)	1,3 (55)	-12,1 (27)	-8,1 (36)	-13,1 (14)	-9,2 (44)
Karagandy	13,9 (92)	-11,2 (10)	-3,6 (44)	**-19,3 (97)**	4,3 (64)	-16,1 (15)	1,9 (54)	-11,7 (24)	22,4 (93)	1,1 (62)	14,1 (90)	2,8 (66)
Kostanay	-5,6 (31)	-13,4 (7)	-3,0 (37)	**24,1 (97)**	4,14 (58)	-0,7 (42)	2,56 (59)	-21,6 (18)	6,1 (59)	-5,8 (41)	-8,9 (31)	-6,7 (38)
Kyzylorda	3,5 (69)	-6,6 (10)	4,4 (70)	5,1 (75)	-7,5 (44)	-8,7 (15)	-6,2 (14)	-5,7 (24)	0,9 (62)	-1,8 (50)	-1,2 (58)	-1,3 (57)
Mangystau*	-1,7 (43)	8,8 (86)	-4,1 (32)	-0,9 (56)	-11,4 (20)	**-15,8 (0)**	**-14,1 (0)**	-1,1 (48)	4,3 (82)	**-9,6 (1)**	-6,0 (27)	-6,5 (27)
Pavlodar	9,3 (85)	-7,5 (27)	-3,9 (35)	16,1 (93)	18,5 (93)	21,5 (94)	24,4 (81)	1,2 (54)	13,2 (77)	12,6 (79)	4,6 (72)	7,4 (83)
North-Kazakhstan	-6,9 (27)	-7,9 (25)	-5,2 (23)	**20,9 (97)**	10,4 (76)	21,6 (89)	14,1 (74)	6,1 (58)	**62,9 (100)**	-9,1 (27)	1,69 (63)	5,1 (70)
Turkestan	-1,1 (53)	**-31,2 (2)**	-2,3 (36)	10,65 (57)	-19,8 (24)	-0,3 (49)	8,6 (63)	**-8,5 (0)**	0,64 (71)	-6,4 (19)	2,9 (68)	26,1 (81)

Notes: 1. for the Mangistau region, an assessment has been carried out since 1960;
2. values above the 95th or below the 5th percentile are shown in bold and bright colors.

On the average, in Kazakhstan, the annual amount of precipitation in 2018 amounted to 98 % of the norm (323.2 mm). In most of the territory of the republic, the amount of precipitation ranged from 80 to 113 % of the norm (Figure 3.2, Table 3.1). It was extremely humid in the northern region of the republic, where the amount of precipitation was 133-134 % of the norm (probability of not exceeding 94-96 %). 2018 in this region has intered into 10 % of the extremely wettest years. A significant deficit of precipitation was observed at weather stations in the western

region (the probability of not exceeding 1-5%), where 2018 has entered into 10 % of the extremely driest years. Absolute maxima have been updated at three stations listed in table 3.3.

Table 3.3 - List of stations with updated maximum annual precipitation in 2018

Region	Station	Maximum in 2018	The previous absolute maximum
East-Kazakhstan	Markakol	724,7 mm	723,5 mm (2016)
Karagandy	Korneevka	525,4 mm	496,8 mm (2015)
North-Kazakhstan	Chkalova	482,6 mm	471,0 mm (1994)

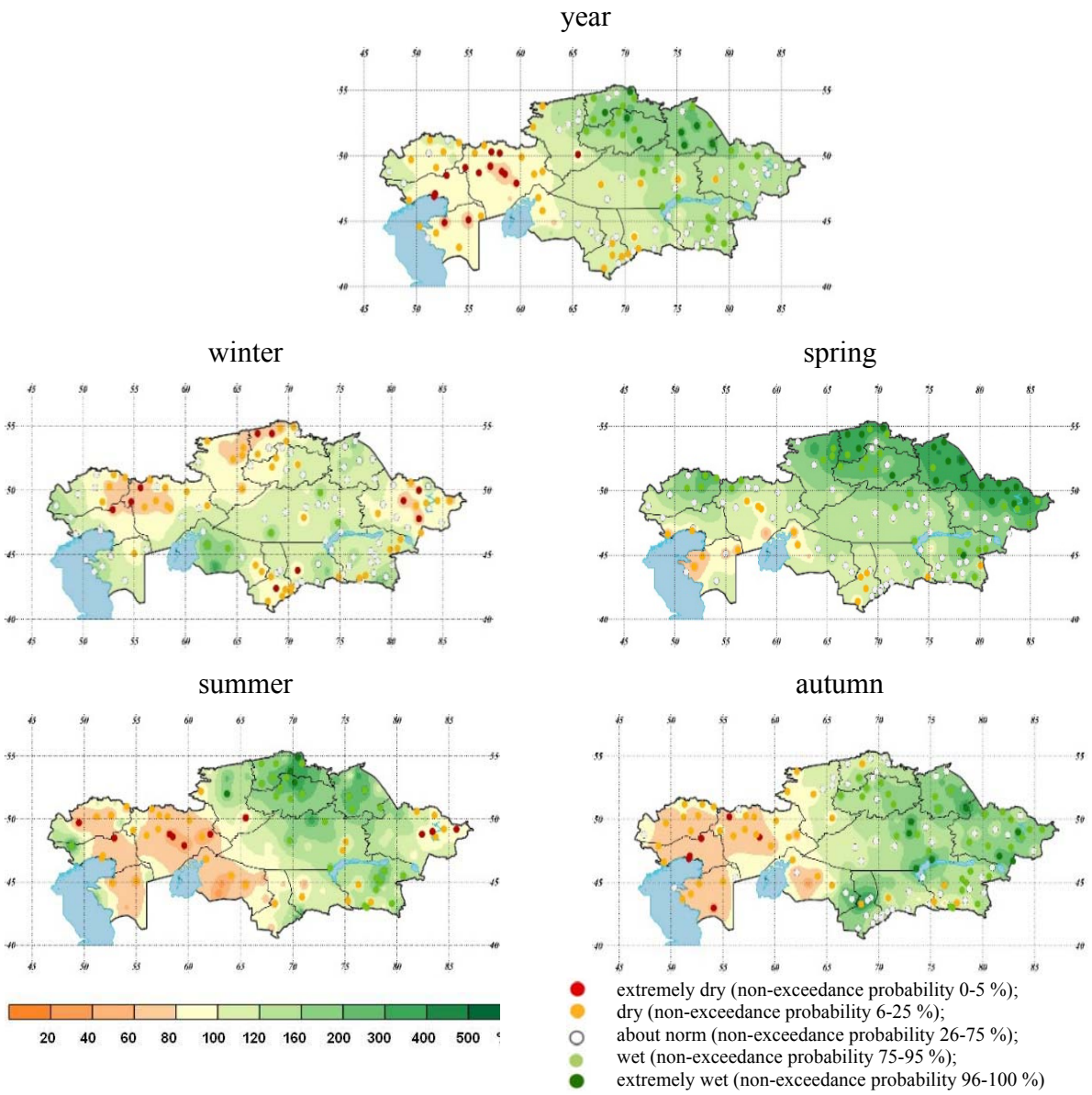


Figure 3.2 - Precipitation in 2018 as % of the norm 1961 – 1990 and non–exceedance probabilities in 2018 calculated according to the period 1941 – 2018

Winter 2017/2018. In general, throughout the republic, the amount of precipitation amounted to 80 % of the climatic norm or 50 mm. A moisture deficit of 30–40 % of the norm with a probability of not exceeding (3–24 %) was observed in the northwest, east, and south of the republic. Extremely dry (the probability of not exceeding 1-5 %) was in Blagoveshchenka, Yavlenka (North Kazakhstan region), Ayaros (Turkestan region), Uyuk (Zhambyl region), Zhalgiztobe, Aksuat (East Kazakhstan region), Uil, Novoalekseevka (Aktobe region), Karabau (Atyrau region). Winter in these areas has entered into 10 % of the driest seasons.

Spring. In Kazakhstan, precipitation was 123 % of the norm (108 mm). Extremely humidity was observed in Pavlodar (203 % of the norm), North Kazakhstan (179 % of the norm) and East Kazakhstan (162 % of the norm) regions (probability of not exceeding 97-98 %). Spring in these areas has entered into 10 % of extremely wet seasons. Absolute maximum has been updated in ten stations given in the table 3.4.

Table 3.4–List of stations with updated maximum precipitation for the spring 2018

Region	Station	Maximum in 2018	The previous absolute maximum
East-Kazakhstan	Dmitrievka	161,4 mm	142,1 mm (1971)
East-Kazakhstan	Markakol	268,2 mm	221,3 mm (2016)
East-Kazakhstan	Semipalatinsk	130,3 mm	120,7 mm (1959)
East-Kazakhstan	Terekty	166,9 mm	136,7 mm (1988)
East-Kazakhstan	Ulken Naryn	190,0 mm	163,9 mm (1988)
East-Kazakhstan	Shemonaikha	197,6 mm	183,0 mm (1979)
North-Kazakhstan	Bulaevo	145,8 mm	130,8 mm (2013)
Pavlodar	Bayanauyl	137,5 mm	134,8 mm (1958)
Pavlodar	Uspenka	112,3 mm	112,0 mm (1987)
Pavlodar	Shaldai	125,1 mm	116,2 mm (1971)

It was extremely dry in Mangistau region (probability of not exceeding 5 %). A lack of moisture was also observed in Atyrau region (probability of not exceeding (15%)

Summer. Atmospheric precipitation in the territory of Kazakhstan was 92 % of the norm (90.5 mm). In the north-east of the republic, the amount of precipitation exceeded the norm by 32-55 %. In East Kazakhstan, West Kazakhstan, Kyzylorda and Mangystau regions the summer season was dry (the probability of not exceeding 14-22 %). It was extremely dry in the Aktobe region (the probability of not exceeding 5 %), the summer of 2018 in this region has entered into 10 % of extremely dry seasons.

Autumn. The amount of precipitation in the autumn period was 100 % of the norm (79.8 mm). In the northern, central, eastern and southern regions, precipitation fell out 11-43 % above the climatic norm. Extremely wet conditions were recorded in Bakty, Samarka, Semiyarka, Urzhar (East Kazakhstan region), Balkash, Zharyk, Karaganda, Saryshagan (Karaganda region), where the amount of precipitation during the autumn period was 170-254 % of the norm (probability of not exceeding 96-100 %). Autumn 2018 in these areas has entered into 10 % of the

wettest seasons. A significant deficit of precipitation (probability of not exceeding 0-2 %) is observed at stations of Mugodzharskaya, Novoalekseevka (Aktobe oblast), Karabau, Peshnoy (Atyrau oblast) and Akkuduk (Mangistau oblast). Autumn in these areas has entered into 10 % of the extremely dry seasons. Absolute maxima have been updated at three stations listed in table 3.5.

Table 3.5–List of stations with updated maximum precipitation in autumn 2018

Region	Station	Maximum in 2018	The previous absolute maximum
East-Kazakhstan	Semijarka	121,0 mm	100,2 mm (1946)
Pavlodar	Koktobe	116,5 mm	101,3 mm (1985)
Turkestan	Turkestan	91,1 mm	85,1 mm (2015)

To assess precipitation extremes in 2018 experts used Indexes of climate change proposed by the World Meteorological Organization. The analysis of the most representative indexes and their distribution throughout Kazakhstan in 2018 are presented below.

Maximum of daily precipitation in 2018(index Rx1day). Figure 3.3 shows absolute maximum daily precipitation, since the beginning of records to 2017 (in red color) and daily maximum observed in 2018 (in blue color). In 2018 the absolute maximum of daily precipitation has not been updated at any weather station in Kazakhstan.

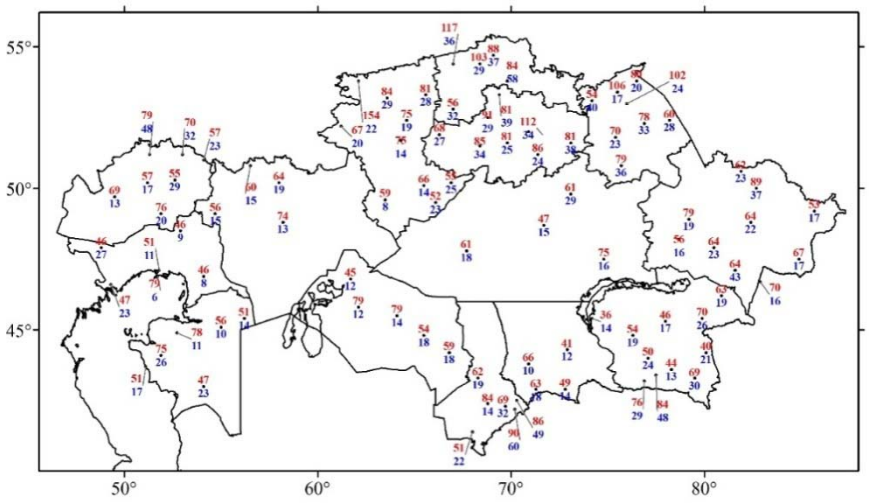


Figure 3.3 – Absolute maximum of daily precipitation, since the beginning of records until 2017 (in red) and the daily maximum in 2018(in blue), mm

Figure 3.4 shows the proportion of rainfall per day with an extremely high rainfall (more than 95th percentile) in the total rainfall for the whole of 2018. For the calculation, the indices R95 and PRPTOT were used. Precipitation index R95 shows the rainfall in excess of the 95th percentile, PRPTOT rainfall for the year. The largest share of the extreme amount of precipitation was observed at Taiynsha (42 %), Ruzayevka (42 %), Atbasar (50 %) and Ayagoz (41 %) weather stations. At nine weather stations the share of extreme precipitation is also quite high (31-39 %).

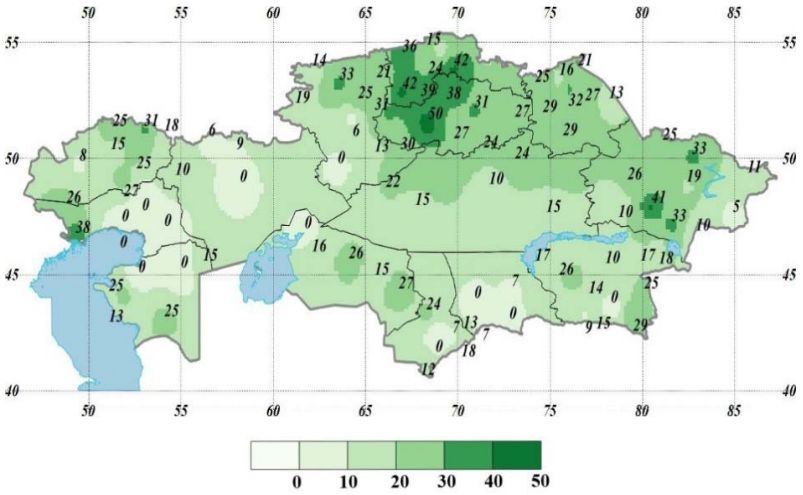


Figure 3.4 - Percentage share of extreme precipitation in the annual total in 2016. Extreme precipitation is the sum of daily precipitation exceeding 95th percentile

The CDD index which represents the ***maximum length of time when precipitation was less than 1 mm*** (Figure 3.5), and it is very important for the arid regions of Kazakhstan. In 2018, the longest maximum dry period was recorded at Arys, Sam, Turkestan, Shardara, Zhosaly, Kazaly and Uyuk stations (102, 103, 105, 105, 107, 120 and 123 days a year). In the southeast and east of the republic, the duration of the dry period was from 19 days/year to 48 days/year, and in the northern regions of the country from 18 days/year to 48 days/year.

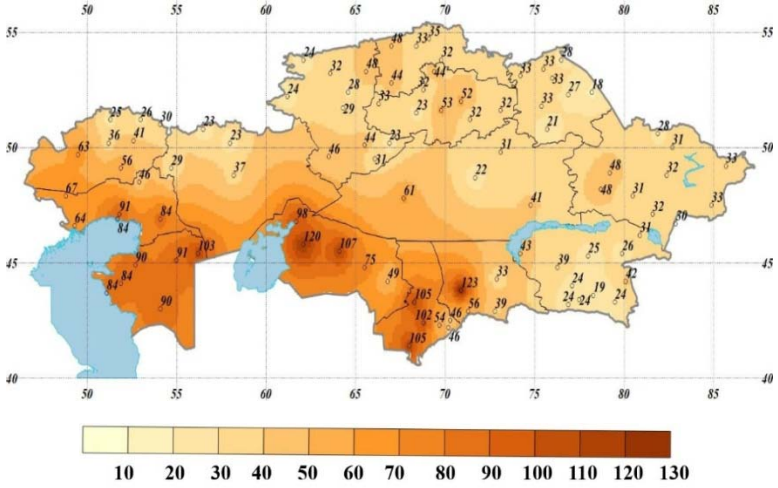


Figure 3.5 – Maximum duration (in days) of dry period in 2018

In 2018, ***maximum duration of the rainy period***, *when the amount of precipitation was equal or greater than 1 mm* (index CWD), is presented in Figure 3.6. According to the calculation of the index, the maximum duration of the period with precipitation was from 2 to 10 days. The longest rainy period (8-10 days) was observed at weather stations Yereymentau, Karaganda, Kertindi and Bayanaul.

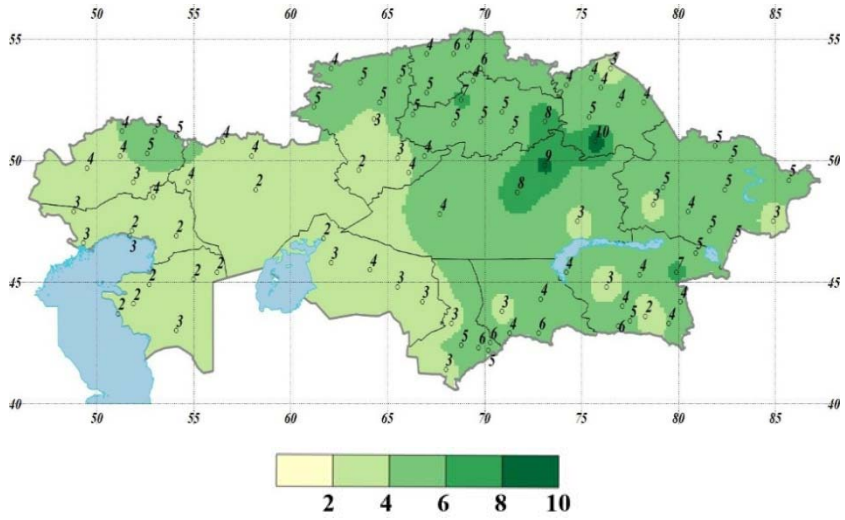


Figure 3.6 – Maximum duration of the period (in days) in 2018, when the amount of precipitation was equal or greater than 1 mm

3.2 Observed changes in precipitation in Kazakhstan

In contrast to the air temperature, the change in precipitation in the territory of Kazakhstan during the study period is more colorful picture. Linear trends in monthly, seasonal and annual precipitation were estimated from 121 stations.

Time series of annual and seasonal precipitation anomalies for the period 1941 - 2018, calculated relatively to the base period of 1961 to 1990, and spatially averaged over the territory of Kazakhstan and regions give a general idea about the nature of contemporary changes of mode of atmospheric precipitation. Over the past decades, alternation of short periods with positive and negative precipitation anomalies has been observed (Figure 3.7 and 3.8). Averaged for Kazakhstan for the period 1976-2018 there was a tendency to increase annual precipitation by 5.5 mm/10 years (Figure 3.7, table 3.6). In the regional context, an increase in precipitation was also observed in most regions, with the exception of Kyzylorda, Aktyubinsk, West Kazakhstan and Mangistau oblasts, where precipitation decreases by 1.2-5.7 mm/10 years. A statistically significant increase in annual precipitation was detected only in the North Kazakhstan region (15.4 mm/10 years).

For the period 1976-2018 on average, in Kazakhstan for all seasons there is a tendency to increase precipitation by 1.3-3.8 mm/10 years, with the exception of autumn season, when the decrease in precipitation was 1.0 mm/10 years (Figure 3.7 and 3.8; table 3.6). All obtained seasonal trends are statistically insignificant.

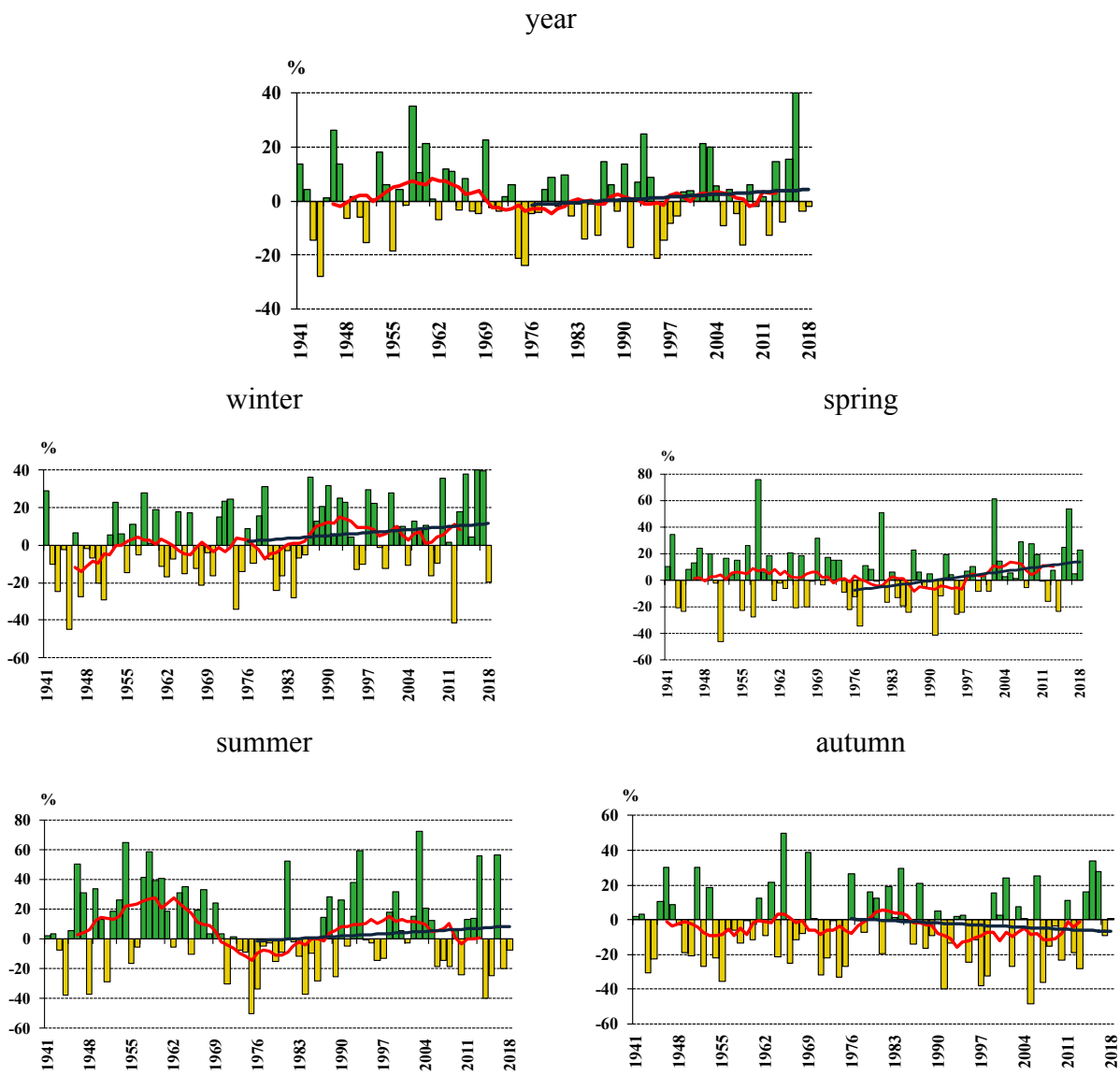


Figure 3.7 - Time series and linear trends of anual and seasonal precipitation anomalies (in %) for the period 1941-2018, spatially averaged over the territory of Kazakhstan and its regions. Anomalies are calculated relatively for the base period 1961 to 1990. Linear trend for the period 1976 to 2018 highlighted in black. *Smoothed curve is received by the 11 years sliding averaging*

Spatial distribution of the linear trend coefficient values for annual, seasonal and monthly rainfall (%/10 years) calculated for the period 1941-2018 and presented in figures 3.9 and 3.10 provides more detailed information on the nature of changes in precipitation regime in Kazakhstan.

According to individual weather stations, there is observed a spotting in distribution of the sign of changing in annual and seasonal precipitation (Figure 3.9).

Trends in ***annual*** precipitation over most part of Kazakhstan were mostly positive, but not significant. A statistically significant increase in precipitation is observed at some weather stations in the north-east and south-east of Kazakhstan (4–9%/10 years), as well as at Atyrau

(9%/10 years). A steady decrease in precipitation (7-8 %/10 years) is observed at Amangeldy (Kostanay region), Uyuk (Zhambyl region), Bes Oba (Karaganda region).

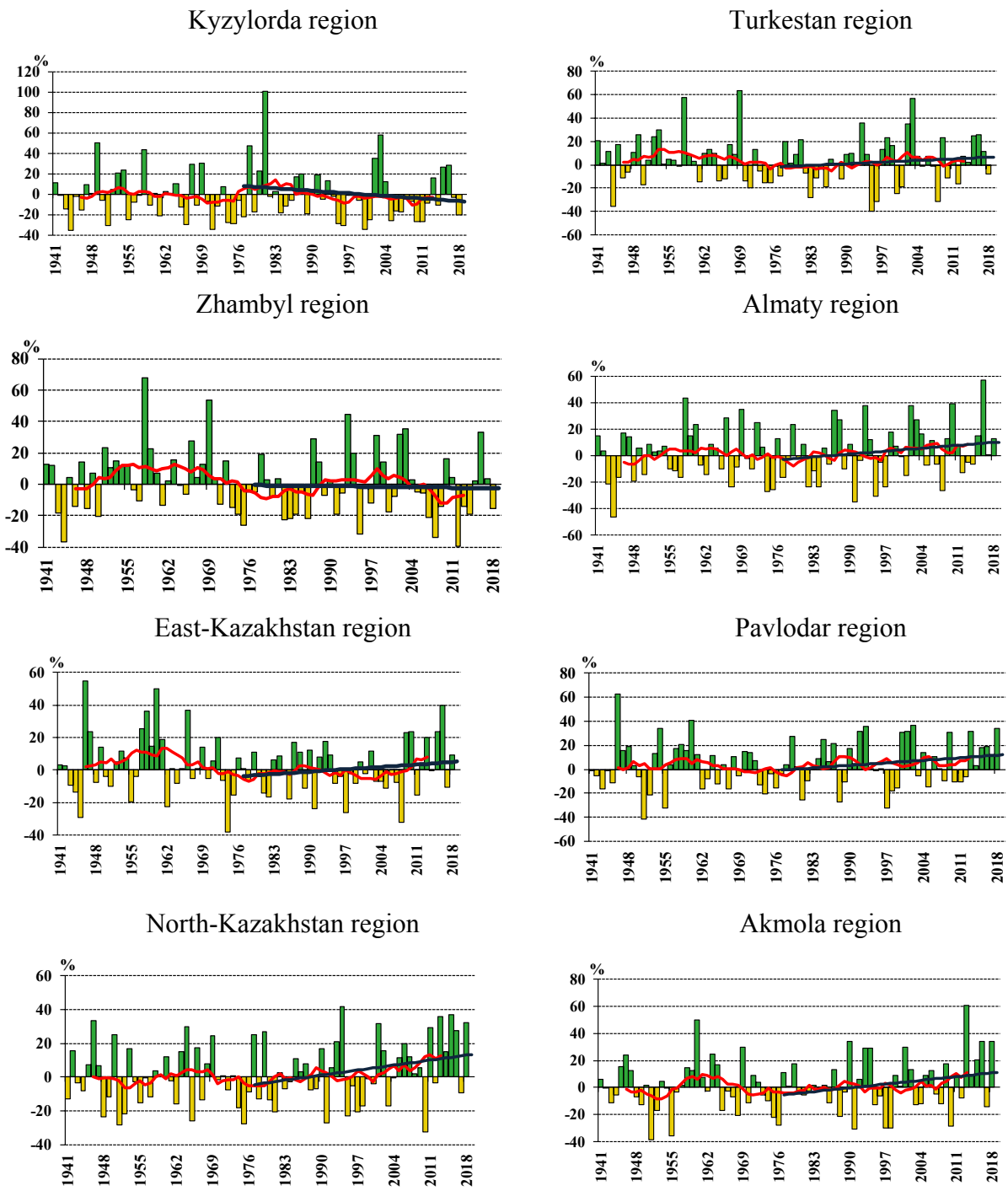


Figure 3.8 - Time series of annual precipitation anomalies (in %) for the period 1941-2018, spatially averaged over Kazakhstan regions. Anomalies are calculated relatively for the base period 1961 to 1990. Linear trend for the period 1976 to 2018 highlighted in blue.
Smoothed curve is received by the 11 years sliding averaging. Sheet 1

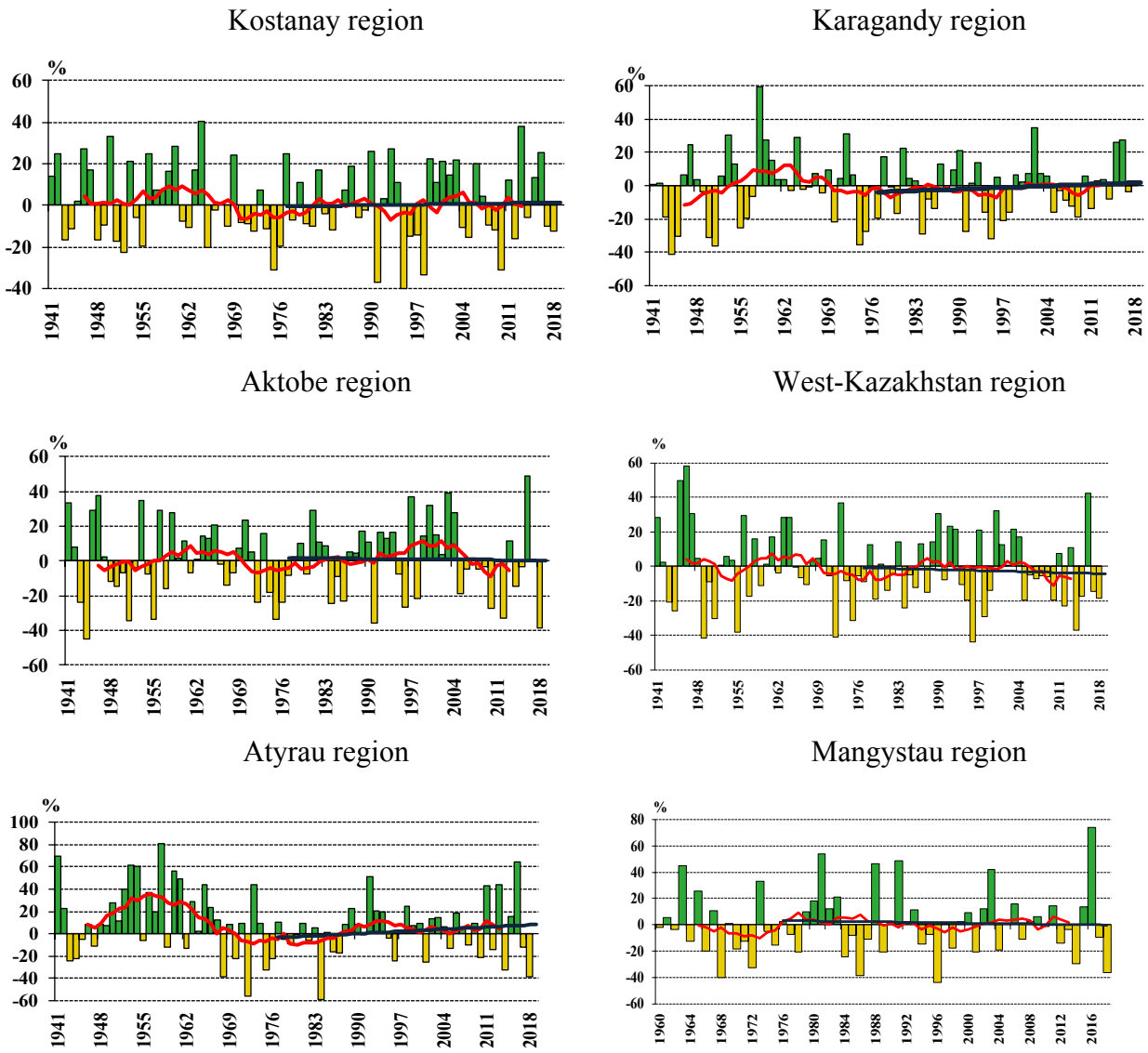


Figure 3.8 - Time series of annual precipitation anomalies (in %) for the period 1941-2018, spatially averaged over Kazakhstan regions. Anomalies are calculated relatively for the base period 1961 to 1990. Linear trend for the period 1976 to 2018 highlighted in blue.
Smoothed curve is received by the 11 years sliding averaging. Sheet 2

Stable positive trends in ***winter*** period are observed at some weather stations in the north-east (3-14 %/10 years), southeast (9-15 %/10 years) and the west (16-22 %/10 years) in Kazakhstan. In February and December, at almost all weather stations, the positive growth trends in precipitation (4-26%/10 years) were statistically significant.

A positive trend in the amount of precipitation in the spring is observed throughout Kazakhstan and amounts to 1-25 %/10 years. A steady increase in precipitation was noted in the northwest of the republic. At faster rate precipitation increases in March (3-45 %/10 years).

Table 3.6 – Characteristics of linear trend (mm/10 years, %/10 years) of seasonal and annual precipitation anomalies averaged over the territory of Kazakhstan and its regions for the period 1976-2018. Anomalies are calculated relatively for the base period 1961-1990

Region	Unit of measure	Year		Winter		Spring		Summer		Autumn	
		a*	**R^2	a	R^2	a	R^2	a	R^2	a	R^2
Kazakhstan	mm	5,5	3	1,3	2	3,8	6	1,8	1	-1,0	1
	%	1,4		2,3		5,2		2,3		-1,8	
Almaty	mm	12,4	3	4,8	**7**	3,9	1	2,9	1	1,2	0
	%	3,1		7,1		3,0		2,8		1,7	
Akmola	mm	13,4	6	3,5	**7**	3,6	4	7,5	4	-0,8	0
	%	4		7,6		5,1		5,7		-0,9	
Aktobe	mm	-1,2	0	-0,3	0	6,2	**7**	-3,1	2	-3,9	6
	%	-0,3		-0,4		10,0		-4,1		-5,3	
Atyrau	mm	4,4	2	3,1	**8**	6,2	**11**	-3,4	3	-1,3	1
	%	2,8		9,2		15,5		-7,3		-3,2	
East-Kazakhstan	mm	6,4	3	0,7	0	3,7	4	2,8	2	-0,10	0
	%	2,1		1,6		4,2		3,6		0,2	
Zhambyl	mm	0,2	0	1,6	1	-2,9	1	2,9	2	-0,9	0
	%	-0,4		2,2		-2,7		6,7		-1,8	
West-Kazakhstan	mm	-2,3	0	-3,3	6	6,7	**14**	-5,1	5	-1,1	0
	%	-0,8		-4,3		11,5		-6,6		-1,3	
Karagandy	mm	4,7	2	-0,2	0	1,8	1	6,0	**8**	-2,4	2
	%	1,4		-1,8		2,7		8,0		-4,4	
Kostanay	mm	2,8	0	-0,8	0	8,3	**24**	0,2	0	-4,7	**8**
	%	0,5		-1,5		13,0		0,1		-6,0	
Kyzylorda	mm	-5,7	3	-1,1	1	-1,1	0	-0,4	0	-3,1	**8**
	%	-3,6		-0,9		-1,6		-2,8		-9,0	
Mangystau	mm	-1,4	0	3,6	12	-4,3	5	1,1	1	-1,5	1/2
	%	-0,8		11,2		-8,1		3,8		-4,5	
Pavlodar	mm	8,8	4	0,1	0	5,7	**14**	3,8	2	-0,1	0
	%	3,0		0,3		10,7		3,5		-0,2	
North-Kazakhstan	mm	15,4	**8**	1,1	1	10,2	**27**	4,7	2	-0,1	0
	%	4,3		2,2		15,4		3,1		-0,2	
Turkestan	mm	9,4	2	3,5	1	3,3	1	2,2	2	0,6	0
	%	2,0		1,6		1,7		8,5		1,9	

Notes: * a – linear trend coefficient, %/10 years, mm10 years;
** R^2 – coefficient of determination, %
*** statistically significant trends are highlighted in bold

In the western region of the republic, negative trends in the amount of precipitation in the ***summer*** period amounted to 0.3-13 %/10 years, but the trends are mostly insignificant, with the exception of the weather station Urda (West Kazakhstan region), where a significant decrease in the amount of precipitation was 13 %/10 years. The highest rate of reduction in precipitation is observed in June and August (4–20 %/10 years). At several weather stations in the North Kazakhstan, East Kazakhstan, Karaganda and Pavlodar regions, the steady positive trend of the summer season was 9–13 %/10 years.

In autumn, a negative trend can be seen in most part of Kazakhstan (2-20 %/10 years). A slight positive trend in precipitation (1-6%/10 years) is observed in the southeast of the republic. All received trends are insignificant, with the exception of several stations (Figure 3.9 and 3.10).

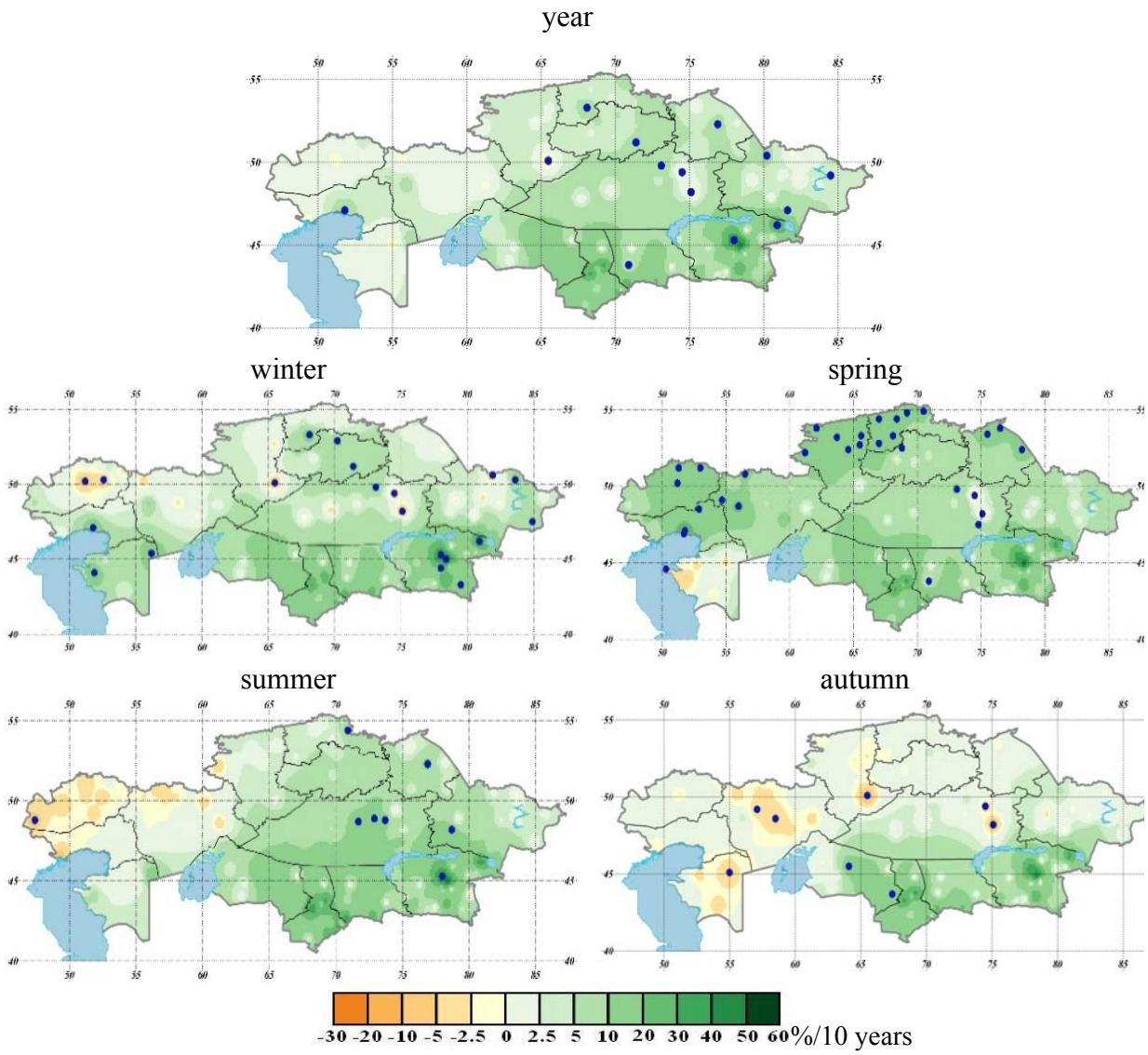


Figure 3.9 – Spatial distribution of the linear trend coefficient values of annual and seasonal precipitation (% /10 years) calculated for the period 1976-2018

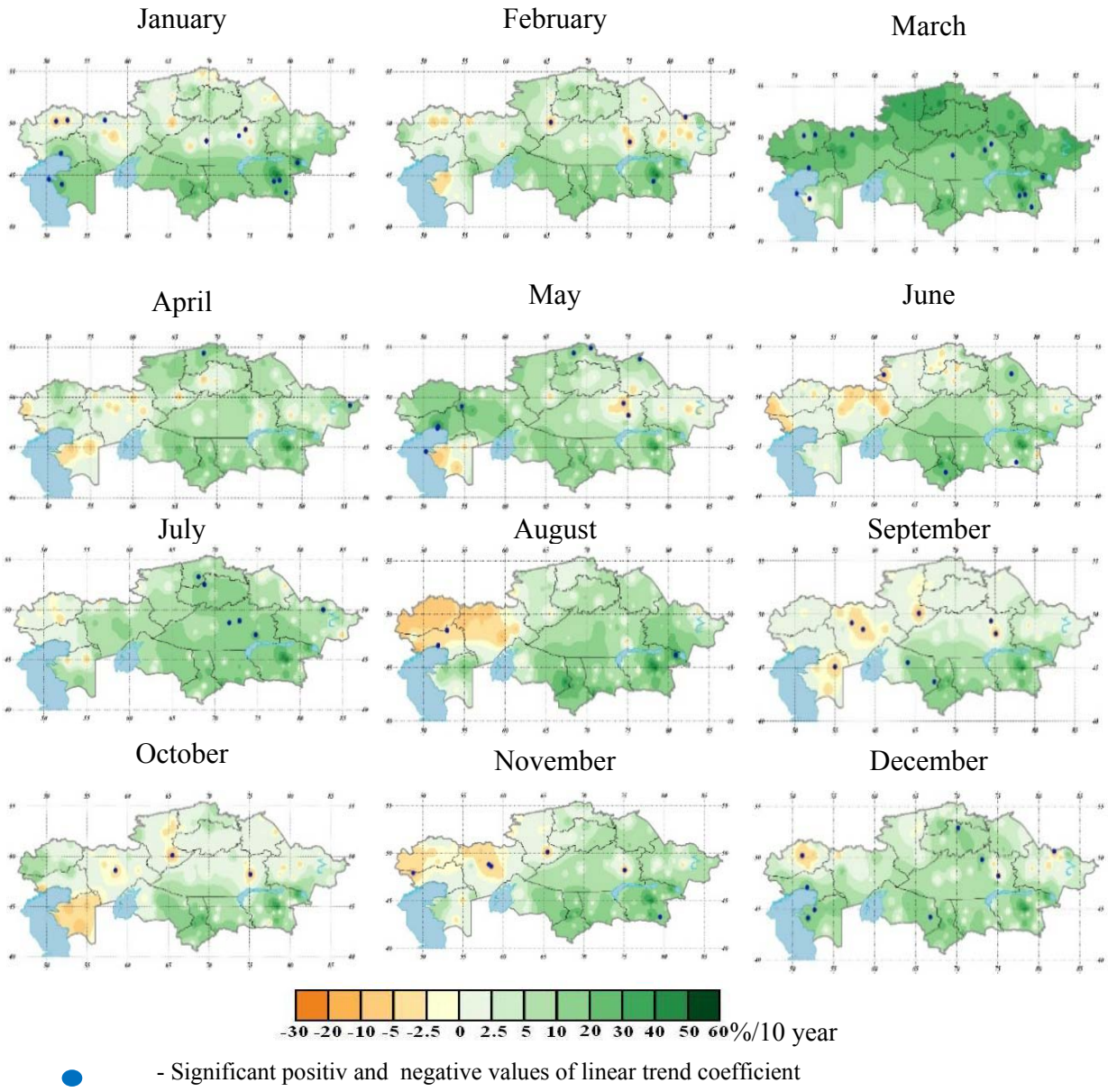


Figure 3.10 – Spatial distribution of values of the linear trend coefficient of monthly precipitation (%norm/10 years), calculated for the period 1976-2018

3.3 Trends in precipitation extremes

Trends in precipitation extremes were analyzed for the period 1976 to 2018on basis of the most indicative indices proposed by WMO.

Values of maximum daily precipitation (rx1day index) on the territory of Kazakhstan have not changed (Figure 3.11). On 65 % of weather stations showed slight decrease in maximum daily precipitation by 0.01 - 2.0 mm/10 years. Statistically significant positive changes from 2 to 4 mm/10 years were recorded at the weather stations Arkalyk, Aksai, Atyrau, Ushtobe, Bektauata and Karabalyk.

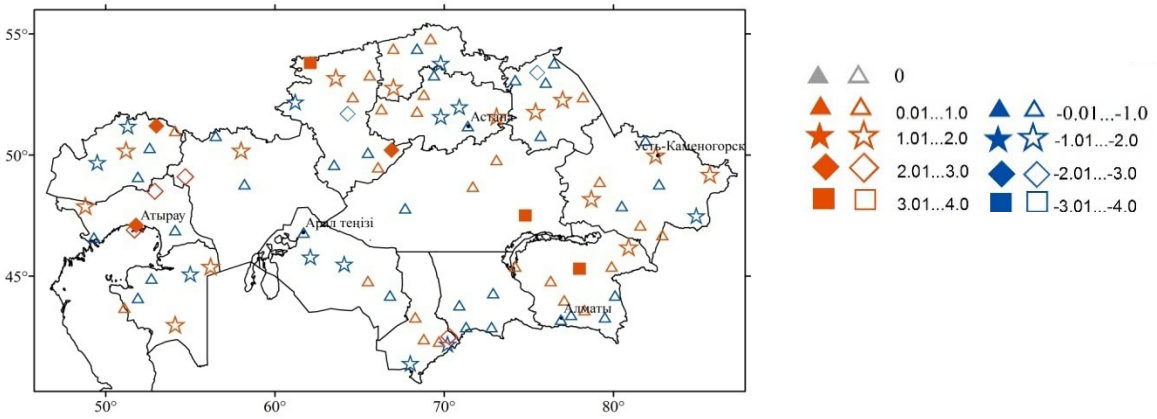


Figure 3.11 – Spatial distribution of the linear trend coefficient of maximum in the year values of daily precipitation (mm/10 years) calculated for the period 1976 - 2018. *Designations of gradations are shaded in cases of statistical significance of trend*

Analysis of trend in ***share (%/10 years) of extreme precipitation in annual precipitation (R95pTOT index)*** showed that in Kazakhstan as a whole there were insignificant statistically insignificant trends, both its decrease and increase by 0.01 - 2.0 % for 10 years (Figure 3.12).

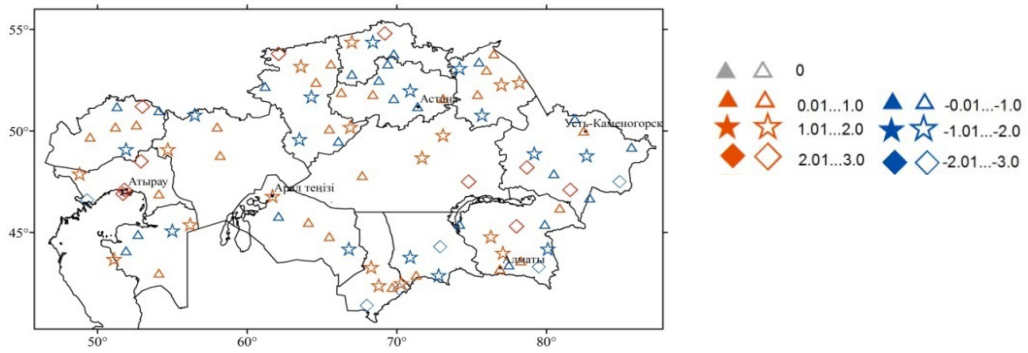


Figure 3.12 – Spatial distribution of the linear trend coefficient of the share (%/10 years) of extreme precipitation in annual precipitation amounts calculated for the period 1976 - 2018. *Extreme precipitation is calculated as the sum of daily precipitation exceeding the 95th percentile. Gradation symbols are shaded in cases of statistical significance of trend*

It is known that the increasing in extreme precipitation in warm period leads to increase in the risk of erosion processes in mountainous areas - mudflows of rain genesis, and in cold period increasing to the danger of avalanches.

In most parts of Kazakhstan, there has been reducing tendency maximum duration of the period without precipitation (***CDD index***, Figure 3.13). At some stations of Akmola, Pavlodar regions, as well as weather stations in the South and South-East of the Republic, there was statistically significant reduction in the no-rain period (from 2 to 6 days/10 years).

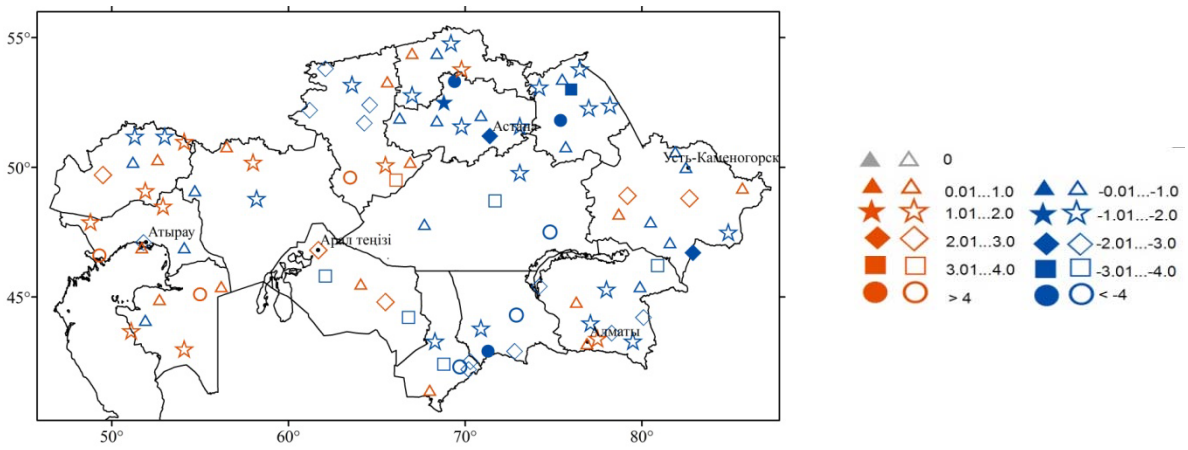
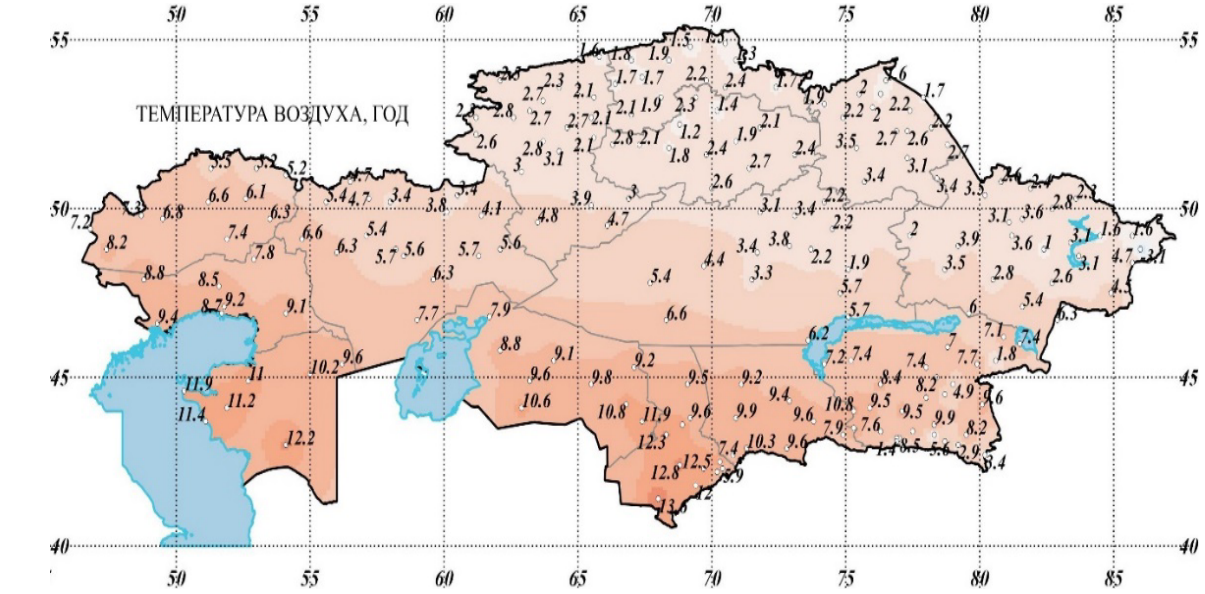


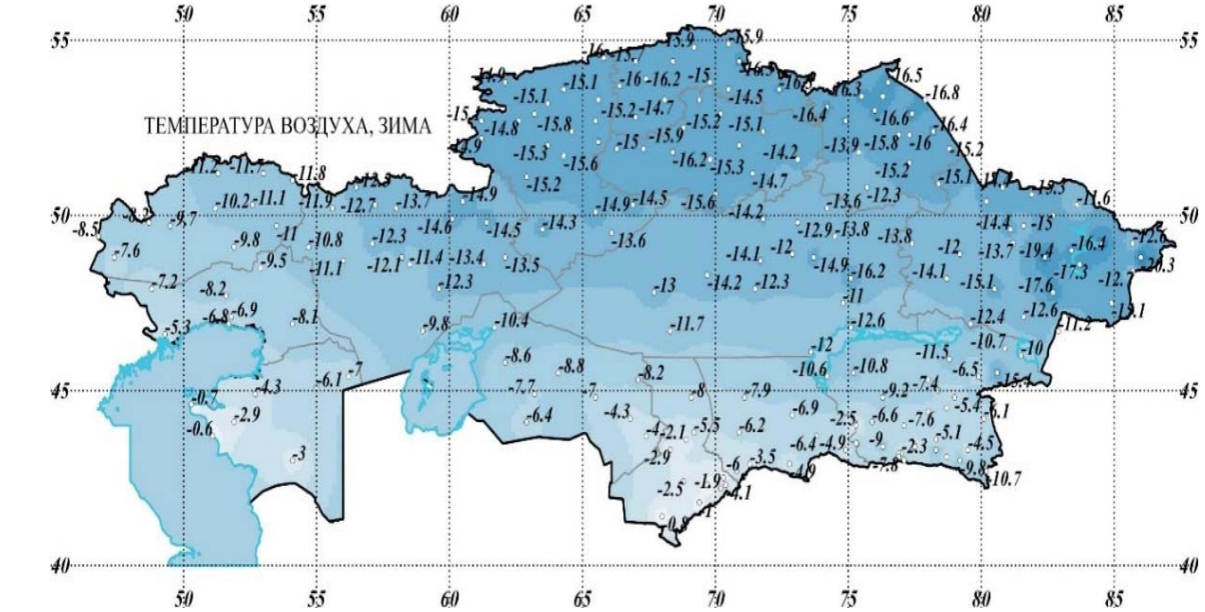
Figure 3.13 – Spatial distribution of the linear trend coefficient of maximum duration of the no rainless period (days/10 years) calculated for the period 1976 - 2018. Gradation. Symbols are shaded in cases of statistical significance of trend

Values of the CDD index are very important characteristic of climate, especially for agriculture.

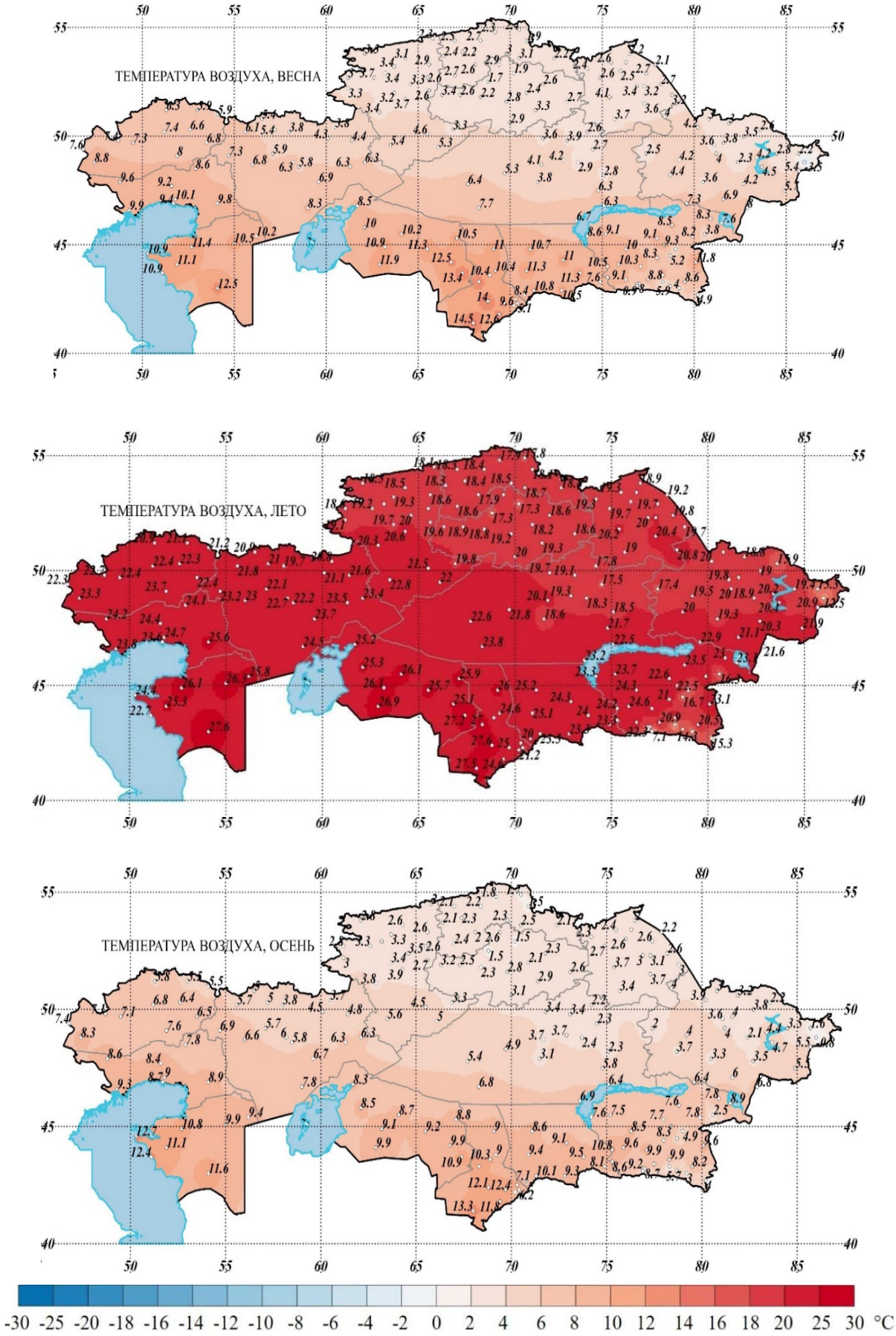
ANNEX 1

SPATIAL DISTRIBUTION OF ANNUAL MEAN AND MEDIUM-SEASON AIR TEMPERATURES IN KAZAKHSTAN, CALCULATED FOR THE PERIOD 1961-1990



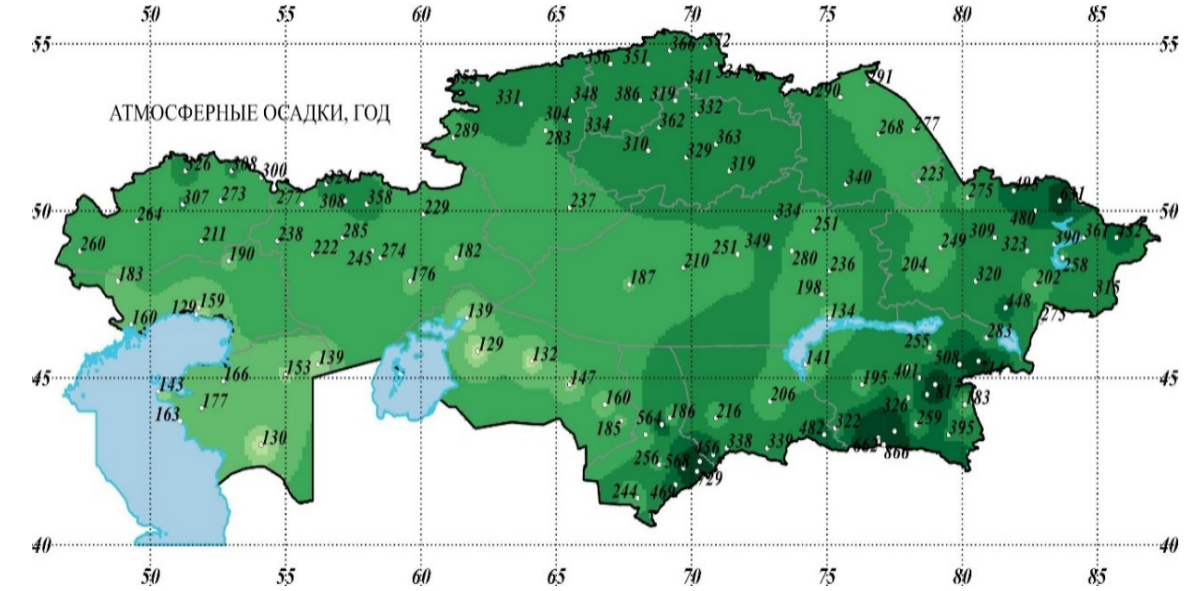


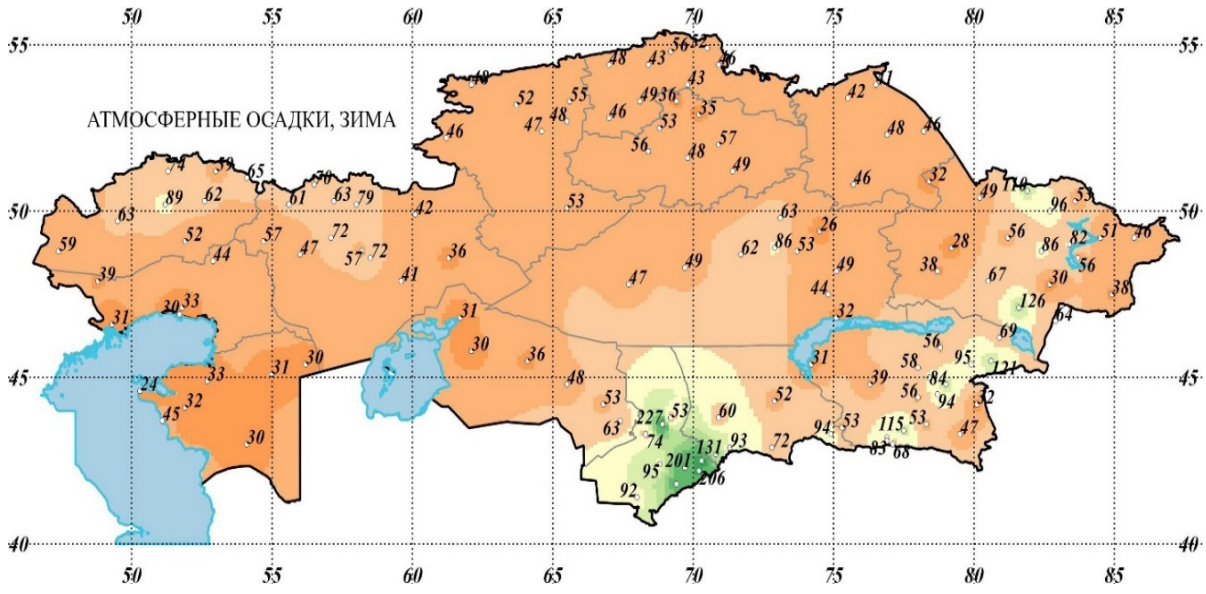
-30 -25 -20 -18 -16 -14 -12 -10 -8 -6 -4 -2 0 2 4 6 8 10 12 14 16 18 20 25 30 °C

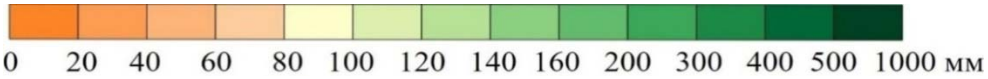

ТЕМПЕРАТУРА ВОЗДУХА, ВЕСНА
ТЕМПЕРАТУРА ВОЗДУХА, ЛЕТО
ТЕМПЕРАТУРА ВОЗДУХА, ОСЕНЬ
-30 -25 -20 -18 -16 -14 -12 -10 -8 -6 -4 -2 0 2 4 6 8 10 12 14 16 18 20 25 30 °C

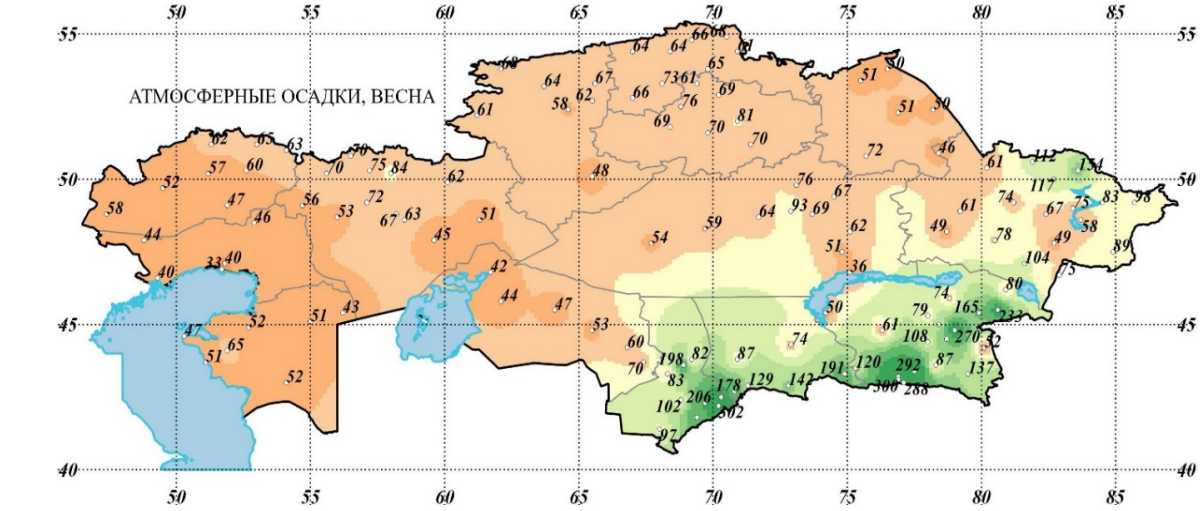
ANNEX 2

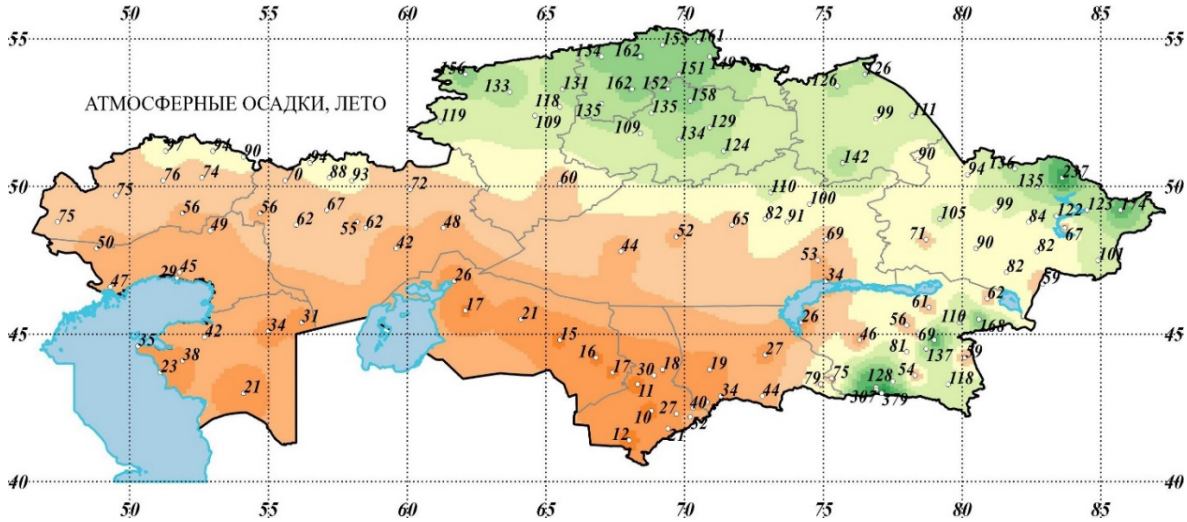
SPATIAL DISTRIBUTION OF ANNUAL AND SEASONAL SUM OF PRECIPITATION IN KAZAKHSTAN, CALCULATED FOR THE PERIOD 1961-1990








АТМОСФЕРНЫЕ ОСАДКИ, ВЕСНА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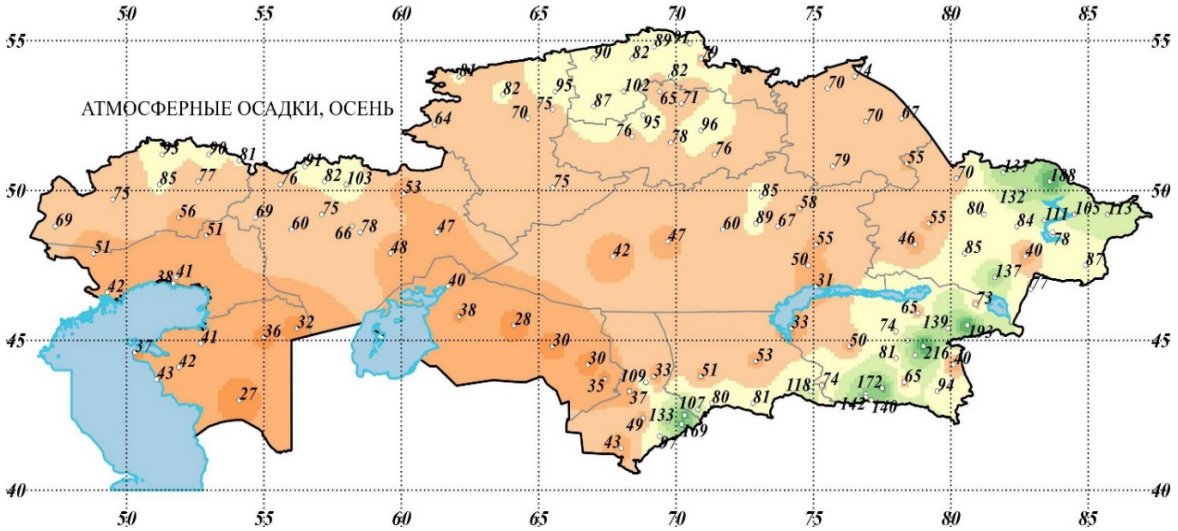
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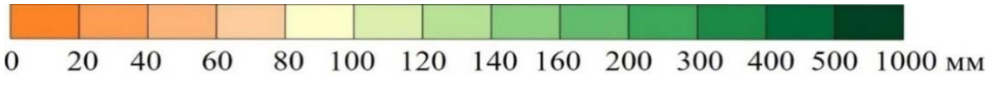
0 20 40 60 80 100 120 140 160 200 300 400 500 1000 мм