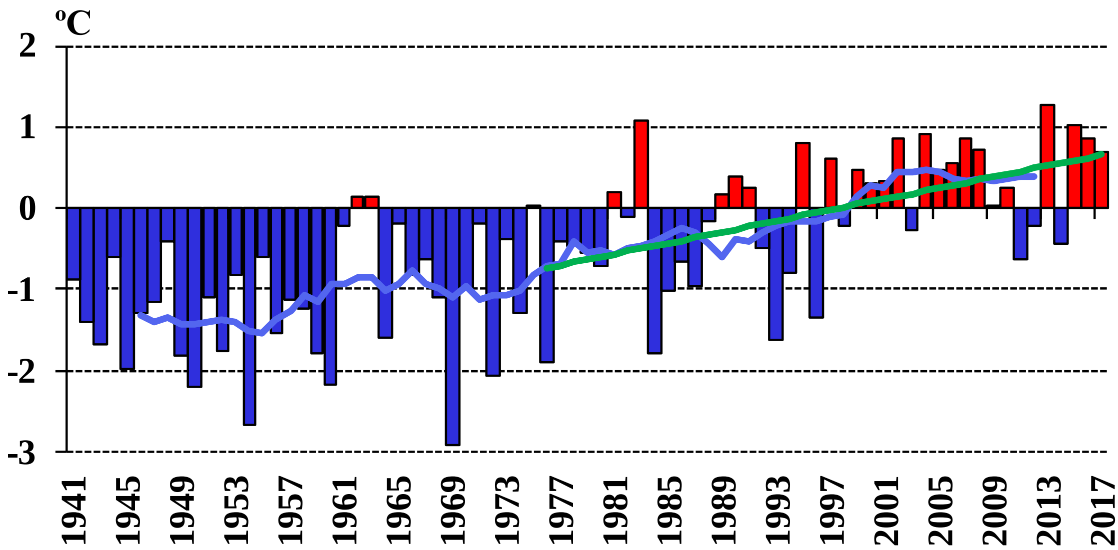
Ministry of Energy of the Republic of Kazakhstan
Republican State Enterprise “Kazhydromet”

Scientific Research Center

ANNUAL BULLETIN OF MONITORING OVER CLIMATE STATE AND CLIMATE CHANGE IN KAZAKHSTAN: 2017



Astana, 2018

CONTENTS

SUMMARY

Features of climate in 2017

Whilst 2017 was a cooler year than the record setting 2016, it was still one of the three warmest years on record, and the warmest not influenced by an El Niño event. Global average temperature in 2017 was 1,1 ± 0,1 °C above the preindustrial level. The average global temperature for 2013–2017 is close the highest five-year average on record. The world's nine warmest years have all occurred since 2005, and the five warmest since 2010. In 2017 sea level rise, which was happening at a somewhat faster pace and also increase in concentration of greenhouse gases were still observed. The cryosphere continued to be reduced along with reduction of extent of the Arctic and Antarctic sea ice. The highest economic losses, which connected with the severe weather and climatic phenomena have been suffered in 2017. The World Economic Forum still assigns extreme weather events a rating of the most significant risks, which is facing humanity, as from the point of view of probability of their emergence, and extent of their influence.

In Kazakhstan 2017 was rather warm and has taken the 10th place in series of observations, ranked by descending since 1941. Average annual air temperature for 1917 was 7,1 °C that is 0,69 °C above the 1981–2010 average. The last 5-year mean temperature for 2013–2017 was +7,06 °C and the highest on record since 1943. The last 10-year mean temperature for 208–2017 was +6.74 °C at 0.35 °C above average. This decade is the second-warmest on record after warmest 1998–2007.

The annual total of precipitation for 2017 averaged for Kazakhstan was 4% below the 1981-2010 average (the 1981–2010 average is 313.7 mm). Extremely dry was observed in the areas of weather stations Beineu (Mangistau region), Shili (Kyzylorda region), Korday (Zhambyl region) and Kokpekty (East Kazakhstan region). The probability of non-exceeding there was below 5 %.

Climate change in Kazakhstan (1976-2017)

An increase in annual mean air temperature averaged over Kazakhstan for 1976-2017 was 0,34 ºC/10 years. The highest growth rates are observed in spring (0.63 ºC/ 10 years), the lowest in winter (0.16 C/10 years). Increase in all seasonal temperature except winter temperature is statistically significant.

At some meteorological stations statistically a reliable positive tendencies of ***daily maximums of air temperature*** within 0,2-0,40 and 0,4-0,90 ºC/10 year has tracing during 1976–2017.

The statistically significant increase in the number of ***very hot days with air temperature higher than 35 ºC*** (by 4-8 days each 10 years) is observed in the west and south of Kazakhstan.

Increase in the duration of heat waves by 2 – 5 days, ***when at least, 6 consecutive days daily maximum air temperature was higher than 90th a percentile***, it was observed on some meteorological stations of the Akmola region and the south of Kazakhstan.

Nearly all of Kazakhstan a decrease in frequency of ***nights with frost*** (by 3-6 days/10 years) ***and days with frost (by*** 4-8 days /10 years) experienced, when the daily minimum and maximum temperature correspondently falls lower than 0 °C.

In the west and south of the country, there were noted tendencies to increase in ***the daily amplitude*** by 0.1-0.4 °C /10 years, while in the east and southeast on the contrary, there were noted tendencies to decrease by 0.1-0.4 °C/10 years.

Statistically reliable increase in ***the maximum daily amount of precipitation*** by 2-4 mm/10 years have been recorded at the weather stations of Arkalyk, Aksay, Atyrau, Ushtobe, Bektauata and Karabalyk.

At some stations of Akmola and Pavlodar regions and in the south and the southeast of the republic, a statistically significant reduction of the ***maximum duration of the period without precipitation*** by 2-6 days/10 years was observed***.***

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 2017, 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 1981-2010.

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

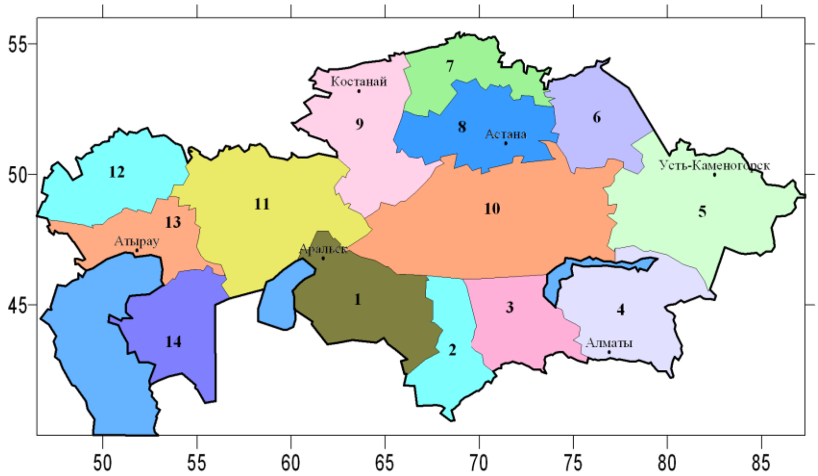
1) time series of monthly mean air temperature and monthly precipitation total from 1941 to 2017: data of more than 200 weather stations were used to assess climate averages for 1981-2010 and more than 190 weather stations data to assess tendencies in temperature and precipitation;

2) time series of daily maximum and minimum air temperatures and daily precipitation totals from 1936 to 2017 (from more than 90 weather stations).

The main approaches and methods. In this bulletin, the "norm" is the climate variable averaged for the period 1981-2010. 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.	8 – Akmola region.
2 – Turkestan region.	9 – Kostanay region.
3 – Jambyl region.	10 – Karaganda region.
4 – Almaty region.	11 – Aktobe region.
5 – East Kazakhstan region.	12 – West Kazakhstan region.
6 – Pavlodar region.	13 – Atyrau region.
7 – North Kazakhstan region.	14 – Mangystau region.

Scheme of administrative-territorial division of the Republic of Kazakhstan

The WMO climate change indices were used to assess extreme temperatures and precipitation in 2017 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. Indexes allow assessing many aspects of climate change, for example, changes in intensity, frequency and duration of extreme temperature and precipitation.

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

- Ilyakova R.M., Lead Engineer (responsible for the issue, general editing, section 2, 3, summary);
- Dolgikh S.A., Head of the Department (introduction, section 1);
- Smirnova E.Yu., Leading Researcher (Section 2);

- Monkayeva G.Y., Leading Researcher (calculation and analysis of extremeness indices)
- Baybazarov D.K., Leading Researcher (mapping);
- Beldeubayev Y.Y., Senior Researcher (mapping).

1 REVIEW OF GLOBAL CLIMATE CHANGES and ITS CONDITIONS in 2017

For the past 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 2017:

- concentration of greenhouse gases are increasing;
- 2017 – the warmest year without El Niño;
- 2013-2017 - the warmest 5 year period in the history of observations;
- global heat content of the ocean has reached record levels in the history of observations;
- sea level is rising;
- ocean oxidation are continues;
- the extent of the Arctic and Antarctic sea ice is significantly below than the average value.

The average global temperature in 2017 was about 1.1 °C higher than that of the pre-industrial era, which means, that we have already reached more than on a half of the maximum limit of the temperature increase is 2 °C and fixed in the Paris Agreement, which still seeks to limit this increase up to 1.5 °C over preindustrial level. 2017 was the warmest in the history of observations year, which wasn't affected by the phenomenon El Niño, and one of the three warmest years, at the same time the record remains for 2016. All the warmest years in the world have occurred since 2005, and five of the warmest since 2010.

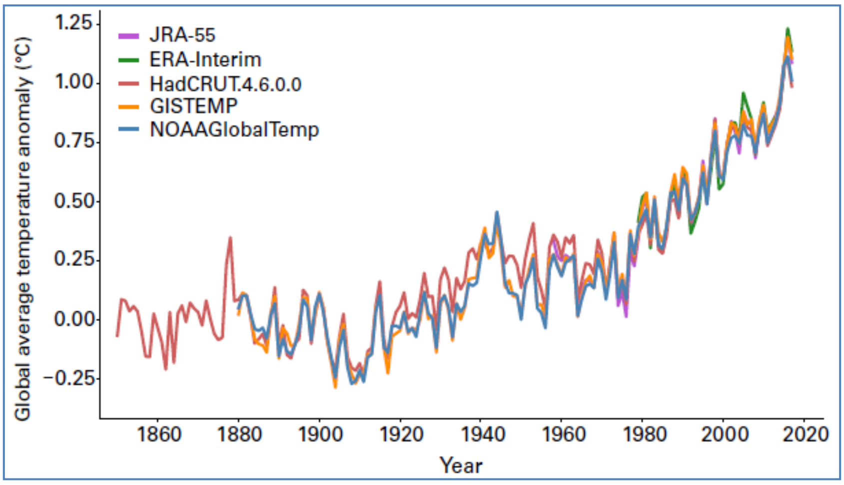


Figure 1.1 - Anomalies of the global average in comparison with the basic period of 1850- 1990 within five global datasets. *Source: UK Met Office Hadley Centre*

Global sea surface temperatures in 2017 were slightly below than the levels of 2015 and 2016, but nevertheless have taken the third place among the highest in the history of observations. The ocean's heat content, which is a measure of heat in the upper layers of the oceans, has reached record maxima in 2017. Mean ocean heat content for 2017 for the 0-700 metre layer was 158.1 ZJ, 6.9 ZJ higher than the previous annual mean record set in 2015.

The pie charts show the contributions of individual components of the sea-level budget (expressed in percentage of the observed global mean sea level) for two periods, 1993-2004 and 2004-2015. It clearly shows that the magnitude of almost all components has increased in recent years, particularly melting of the polar ice sheets, mostly in Greenland and to a lesser extent in Antarctica. Accelerated ice-mass loss from the ice sheets is the main cause of acceleration of the global mean sea-level rise, as revealed by satellite altimetry.

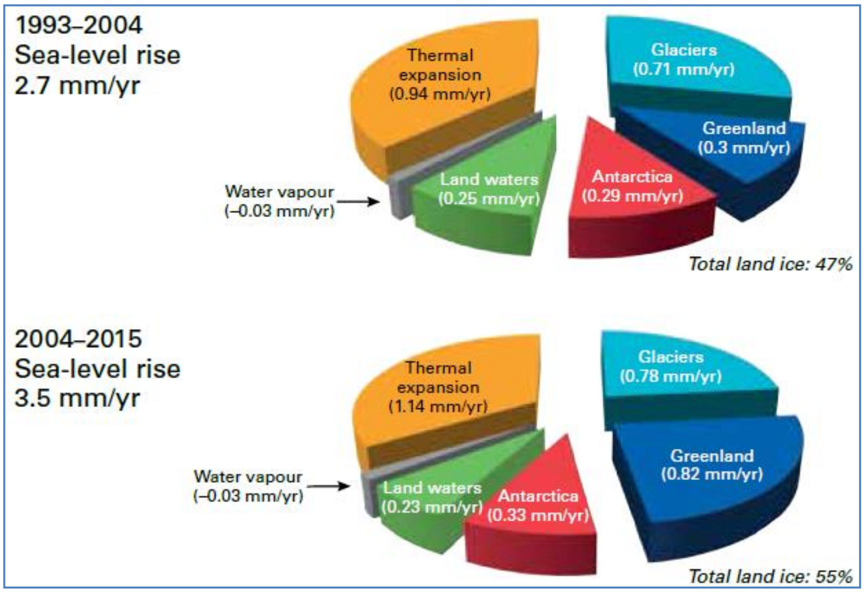


Figure 1.1 - The contributions of individual components of the sea-level budget (expressed in percentage of the observed global mean sea level) for two periods, 1993-2004 and 2004-2015.

Source: Dieng, H. et al., 2017: New estimate of the current rate of sea level rise from a sea level budget approach. Geophysical Research Letters, 44, doi: 10.1002/2017GL073308.

Sea-ice extent was well below the 1981-2010 average throughout 2017 in both the Arctic and Antarctic. The winter maximum of Arctic sea ice of 14.42 million square kilometers, reached on 7 March, was the lowest winter maximum in the satellite record, 0.10 million square kilometers below the previous record low set in 2015. Antarctic sea-ice extent was at or near record low levels throughout the year. The summer minimum of 2.11 million square kilometers, recorded on 3 March, was 0.18 million square kilometers below the previous record set in 1997, whilst the winter maximum of 18.03 million square kilometers, recorded on 12 October (the equal-latest maximum date on record), was second behind 1986.

There were fewer areas with large precipitation anomalies in 2017 than there had been in 2015 or 2016, as the influence of the strong El Nino event of 2015/2016 ended. There were 84 tropical cyclones around the globe in 2017, very close to the long- term average. Three exceptionally destructive hurricanes occurred in rapid succession in the North Atlantic in late August and September. All three of these hurricanes were ranked in the top five for hurricane-related economic losses in the United States (alongside Katrina in 2005 and Sandy in 2012), with estimated costs of US$ 25 billion for Harvey, US$ 90 billion for Maria and US$ 50 billion for Irma.

The drought that affected significant parts of east Africa during 2016 continued into 2017. Many parts of the Mediterranean region experienced significant drought in 2017, as did parts of central Europe. Drought also affected a region of central North America on both sides of the United States-Canada border.

There were numerous significant heat waves around the world during 2017, in both the southern and northern hemisphere summers. Between 2000 and 2016, the number of vulnerable people exposed to heat wave events has increased by approximately 125 million.

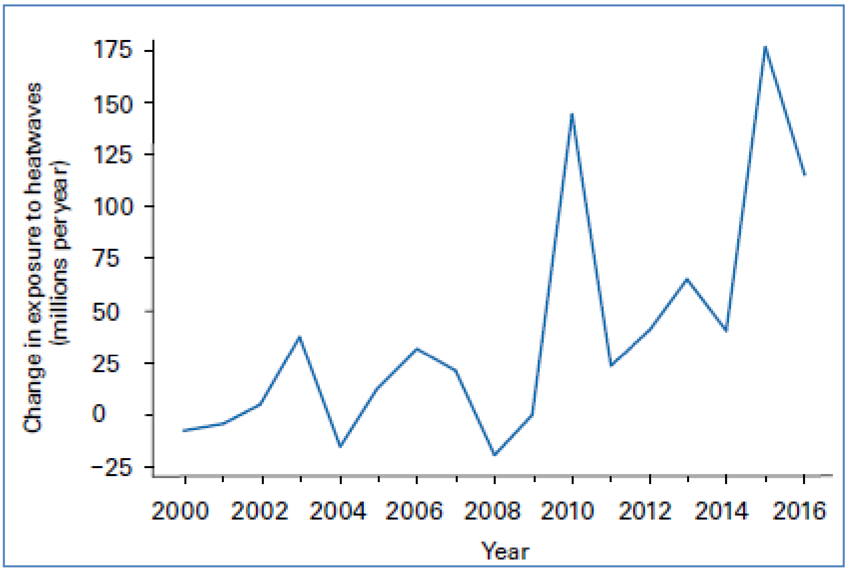


Figure 1.3 – The change in exposure (in people aged over 65 years) to heatwaves from 2000 to 2016 relative to the heatwave exposure average from 1986 to 2008.

Source: World Health Organization (WHO)

The extreme heat and drought promoted emergencing of the numerous destructive natural fires in various tropical regions, numerous regions of middle latitudes also have endured seasons of the fire seasons.

2 AIR TEMPERATURE

The territory of Kazakhstan which is located in the center of the Eurasian continent and far from the ocean on considerable distance (2000-3000 km) warms up at more significant rates, than average by globe, and at the same rates as on average the Northern Hemisphere. The linear trend coefficient of the annual mean air temperature for the globe was + 0.18 °C/10 years (explained by the trend in the share of the series of dispersion – 85 %), + 0.34 °C/10 years for the land of the Northern Hemisphere (the trend contribution in the dispersion is 85 %), and + 0.34 °C/10 years for Kazakhstan (the trend contribution in the dispersion is 26 %) for the period 1976-2017.

Annual mean air temperature anomaly was +0,69 °C rather average long-term values during 1981-2010 average for all Kazakhstan. This is the tenth value in the descending ranked air temperature anomaly. The norm of the average annual air temperature over the territory of Kazakhstan for the period 1981-2010 is 6.4 °C. Annual mean air temperature in 2017 was 7.1 °C, which is 0.1 ° C lower than in 2016. Annual mean value of air temperature over the last five years of 2013-2017 has reached the highest point since 1943: +7,06 °C. The mean air temperature over the last decade of 2008-2017 was +6.74 °C and has exceeded the climatic norm by 0.35 °C, it is the second-large positive decade anomaly, after the warmest record-breaking decade in 1998-2007.

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 2017, 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 anomaly, 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 – The warmest years in the history of observations for the Globe (since 1850) and in Kazakhstan during 1941-2017 and the corresponding annual mean surface air temperatures, which averaged over the territory of Kazakhstan. Anomalies are calculated relatively for the period 1981-2010.

Rank	Globe	Kazakhstan	Anomaly of average annual temperature (Jan.-Dec.), averaged over the territory of Kazakhstan, °C
1	**2016**	2013	1,26
2	**2017**	1983	1,09
3	**2015**	2015	1,02
4	**2014**	2004	1,53
5	**2010**	2002	0,92
6	**2005**	2007	0,87
7	**2013**	2016	0,86
8	**2006**	1995	0,85
9	**2009**	2008	0,71
10	**1998**	2017	0,69

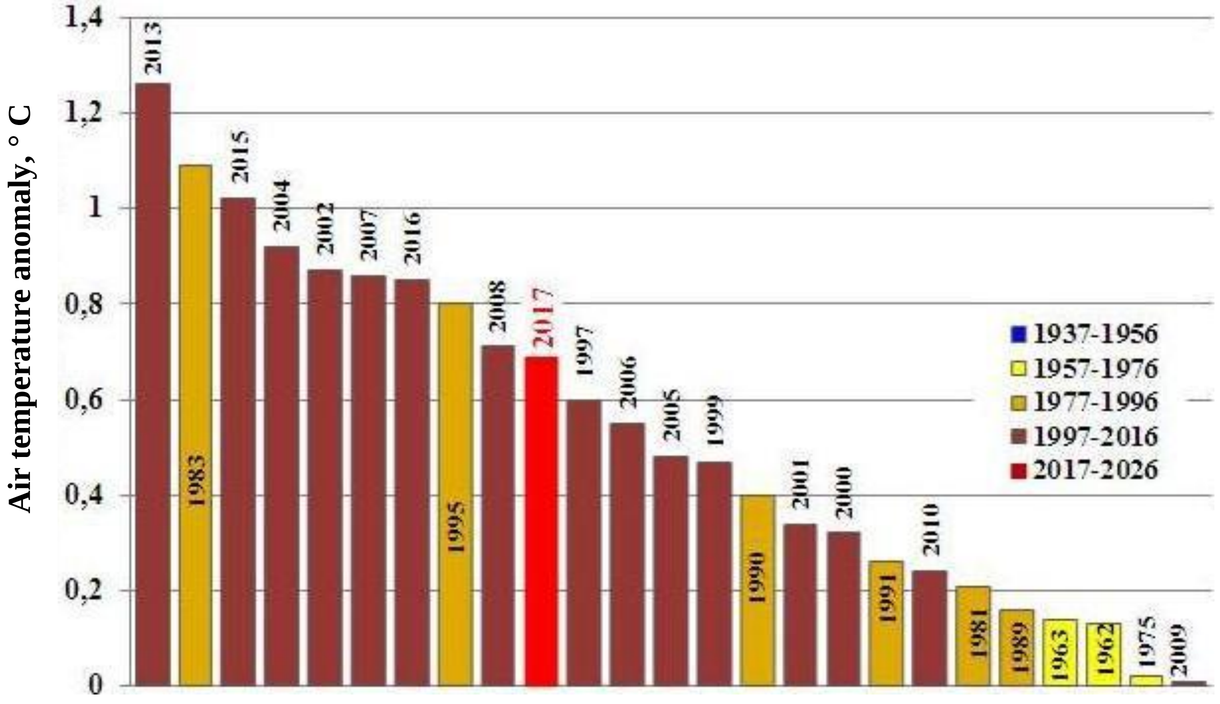


Figure 2.1 – the ranged series of the positive annual mean surface air temperature anomaly (Jan-Dec) averaged over the territory of Kazakhstan (according to 124 weather stations) for the period 1941-2017. Norms were calculated relatively to the basic period of 1981-2010.

2.1 Air temperature anomalies in Kazakhstan in 2017

2017 (January-December) was warm and has taken the 10th place in series of observations, ranked by descending since 1941 (table 2.1).

Table 2.2 shows the annual mean and average seasonal temperature anomalies, table 2.3 shows the mean annual temperature anomalies observed in 2017 and averaged over the regions and all Kazakhstan. For each value of anomalies are given the probabilities of not excess calculating from the data for the period 1941-2017 and also mean square deviation for 1981-2010 (table 2.2). In Tables 2.2 and 2.3, temperature values above the 95th or below the 5th percentile (respectively, warm and cold extremes) are highlighted in bold type and bright color.

Annual mean air temperature averaged over the territory of Kazakhstan was higher than the climatic norm by 0.69 ºC (88th percentile) with standard deviation of 0.78 ºC. Anomaly of given year does not exceed standard deviation value. Anomaly of this year doesn't exceed value of the standard deviation. The highest values of positive air temperature anomaly were observed in Mangystau (1,09 ºC), Atyrau (0,97 ºC), Akmola (0,96 ºC) and East Kazakhstan (0,92 ºC) regions. The probability of not exceeding in these areas was 89–93 %. Air temperature of the winter season (December 2016-February 2017) exceeded climatic norm by 0.86 °C (78th percentile). The negative air temperature anomaly was observed in the territory of Atyrau (minus 0,17 °C), West Kazakhstan (minus 1,33 °C), Kostanay (minus 0,37 °C) and North Kazakhstan (minus 0,35 °C) regions. Air temperature anomaly averaged over Kazakhstan in ***spring season*** was +0.48 °C (the probability of non-exceedance is 69%). In the Aktyubinsk and Zhambyl regions, air temperature was slightly below by norm (on 0.16 °C and 0.15 °C respectively). In May, it was extremely hot in the Turkestan region, where the excess of the norm was 2.83 °C (probability of not exceeding 96%). ***The Summer of 2017*** was rather warmer, anomaly averaged over the territory of Kazakhstan was +0.7 °C (93rd percentile). Extremely hot was in June in the East Kazakhstan region (97th percentile) and in July in Almaty, Zhambyl and Kyzylorda regions (96-97 percentiles). ***The Autumn*** of 2017 was warmer enough in the territory of all Kazakhstan. Average air temperature over the territory of the republic was on 0.94 °C above climatic norm (89 %), positive anomaly was observed in all regions of Kazakhstan. In the Aktyubinsk and Kostanay regions in November excess of climatic norm has made 4,02 °C (probability of non-exceedance of 97 %) and 4.86 °C (probability of non-exceedance of 96 %). Geographical distribution of the centers of cold and heat during various seasons and generally for the year are presented in the figure 2.2.

At the meteorological stations Katon-Karagai, Ust-Kamenogorsk (East-Kazakhstan region), Akkol, Astana, Schuchinsk (Akmola region), the probability of non-exceedance has reached 96-100 %. 2017 in these regions entered the top of the hottest years (Table 2.2; Figure 2.2). At the Astana station, maximum annual air temperature was blocked and amounted to 5.2 ºC (the previous maximum, equal to 5.0 ºC, was observed in 2013).

Table 2.2 – Regionally averaged annual mean (January-December) and seasonal air temperature anomalies in 2017: **vT** - *deviations from multiyear averages for 1981–2010, ℃ P(t≤T₂₀₁₇) – the probability of non-exceedance (in brackets), calculated according to the data for the period 1941-2017 in %;* ***s*** *– standard deviation in ºC for the period 1981-2010.*

Region	Year		Winter		Spring		Summer		Autumn	
	vT (P)	**s**	**vT (P)**	**s**	**vT (P)**	**s**	**vT (P)**	**s**	**vT (P)**	**s**
Kazakhstan	0,69(88)	0,78	0,86(78)	2,03	0,48(69)	1,51	0,72(93)	0,71	0,94(89)	0,78
Almaty	0,53(85)	0,72	1,53(92)	1,68	0,38(71)	1,47	0,54(85)	0,66	0,64(78)	0,72
Akmola	0,96(93)	0,96	1,01(76)	2,52	1,03(71)	1,83	0,64(85)	1,1	0,99(82)	0,96
Aktobe	0,67(85)	0,97	0,23(71)	2,58	-0,16(52)	1,9	0,86(82)	1,32	1,57(89)	0,97
Atyrau	0,97(90)	0,99	-0,17(60)	2,34	1,27(77)	1,38	0,80(82)	1,04	1,30(92)	0,99
East-Kazakhstan	0,92(92)	0,96	2,40(93)	2,27	0,67(72)	1,71	1,01(90)	0,75	0,37(63)	0,96
Zhambyl	0,43(82)	0,72	1,43(82)	2,1	-0,15(53)	1,5	0,53(86)	0,71	0,83(86)	0,72
West-Kazakhstan	0,68(78)	1,08	-1,33(50)	2,8	0,23(61)	1,72	0,65(73)	1,51	1,58(90)	1,08
Karagandy	0,63(86)	0,88	1,49(86)	2,15	0,20(57)	1,87	0,91(94)	0,81	0,70(80)	0,88
Kostanay	0,36(78)	1,02	-0,37(59)	2,52	0,23(57)	1,99	0,06(75)	1,36	1,16(80)	1,02
Kyzylorda	0,67(84)	0,91	0,43(60)	2,61	0,65(71)	1,84	1,03(92)	0,81	1,28(92)	0,91
Mangystau*	1,09(89)	0,87	0,20(57)	1,97	1,34(78)	1,36	1,16(85)	1,13	1,54(91)	0,87
Pavlodar	0,74(86)	1,05	1,60(82)	2,91	0,86(71)	1,73	0,64(86)	0,93	0,30(61)	1,05
North-Kazakhstan	0,55(84)	0,95	-0,35(61)	2,66	0,70(69)	1,7	0,05(69)	1,2	0,71(75)	0,95
Turkestan	0,54(86)	0,7	0,71(64)	2,05	0,23(61)	1,39	0,96(94)	0,76	1,20(93)	0,7

Notes: 1. for Mangystau Region assessment was carried out during 1960-2017;
2. values above of the 95th or below the 5th percentile (respectively warm and cold extremes) are highlighted in bold type and bright color.

The Winter (December 2016-February 2017). In the most part of the territory of Kazakhstan air temperature was within the normal range (minus 8.79 °C). The Winter is characterized as cooler in the western part of the republic with gradual increase in temperature to the East. At meteorological stations Ust-Kamenogorsk and Shemonaiha (East Kazakhstan region), also Almaty-OGMS (Almaty region) was extremely warm. The probability of not exceeding at these stations was 96–100%. The winter in these areas has entered 10 % of the warmest winter seasons. In Atyrau, West Kazakhstan, Kostanay, and North Kazakhstan regions, the negative anomalies ranged from 0.17 to 1.33 °C (the probability of non-exceedance is 50–61 %).

The Spring 2017 was warm in all territory of the republic. Average seasonal temperature was 7.36 °C (69th percentile). The largest anomalies were observed in the south-west and north-east of Kazakhstan. Absolute maximums for the spring season haven't been blocked. Aktobe region was cooler, air temperature in this region was 0.16 °C below than climatic norm.

Table 2.3 - Regionally averaged mean monthly air temperature anomalies in 2017: **vT** – *deviations from averages for 1981-1981,℃; P(t≤T*$_{2016}$*) - the probability of non-exceedance (in brackets) calculated by data during 1941–2017 and expressed in %*

Region	12 (2016)	1	2	3	4	5	6	7	8	9	10	11
Kazakhstan	1,03 (70)	1,65 (88)	-0,02 (59)	-0,02 (60)	0,47 (65)	0,99 (75)	0,47 (78)	0,79 (84)	0,90 (84)	0,52 (71)	-0,49 (53)	2,80 (90)
Almaty	3,36 (90)	0,54 (61)	0,82 (63)	-0,27 (51)	-0,18 (48)	1,64 (89)	0,65 (81)	**2,04 (97)**	-1,09 (21)	0,32 (68)	0,09 (60)	1,44 (76)
Akmola	0,64 (58)	2,51 (86)	-0,01 (61)	0,58 (65)	1,39 (69)	1,05 (65)	1,49 (85)	-1,03 (36)	1,41 (88)	0,28 (55)	-1,30 (40)	4,03 (92)
Aktobe	-1,06 (42)	2,05 (85)	-0,33 (52)	0,05 (59)	-0,29 (52)	-0,23 (35)	-1,13 (42)	0,85 (72)	2,82 (92)	1,39 (90)	-0,72 (53)	**4,02 (97)**
Atyrau	-1,30 (36)	1,17 (73)	-0,23 (57)	2,93 (85)	0,60 (65)	0,33 (47)	-1,07 (30)	1,23 (88)	2,30 (89)	1,93 (92)	-0,37 (57)	2,33 (88)
East-Kazakhstan	3,61 (92)	1,91 (80)	1,82 (76)	-1,14 (46)	1,83 (85)	1,27 (78)	**2,37 (97)**	0,67 (71)	-0,09 (57)	-0,61 (28)	-0,48 (47)	2,14 (75)
Zhambyl	2,93 (85)	2,08 (84)	-0,55 (50)	-1,73 (36)	-0,60 (43)	1,90 (93)	0,58 (78)	**1,57 (96)**	-0,48 (59)	0,48 (71)	0,42 (69)	1,63 (76)
West-Kazakhstan	-3,23 (20)	-0,21 (57)	-0,50 (59)	1,73 (76)	-0,19 (61)	-0,84 (27)	-2,20 (21)	0,89 (80)	3,26 (93)	1,69 (88)	-0,33 (63)	3,36 (94)
Karagandy	2,48 (85)	2,51 (88)	-0,49 (53)	-0,9 4(51)	0,49 (65)	0,99 (67)	1,54 (90)	0,86 (78)	0,35 (73)	0,06 (51)	-0,56 (51)	2,63 (77)
Kostanay	-1,66 (38)	1,43 (78)	-0,83 (52)	0,37 (61)	0,36 (57)	0,00 (40)	-0,69 (50)	-0,77 (44)	1,69 (86)	0,27 (52)	-1,70 (38)	**4,89 (96)**
Kyzylorda	1,07 (68)	2,72 (82)	-2,45 (42)	0,10 (64)	0,42 (65)	1,53 (85)	0,08 (63)	**1,72 (96)**	1,32 (85)	1,23 (86)	0,03 (68)	2,65 (90)
Mangystau	-0,44 (37)	1,80 (84)	-0,74 (49)	2,57 (85)	0,39 (63)	1,10 (64)	-0,81 (40)	1,83 (94)	2,50 (85)	2,49 (92)	-0,19 (56)	2,43 (89)
Pavlodar	1,08 (69)	3,30 (89)	0,64 (64)	0,06 (60)	1,80 (81)	0,82 (71)	1,80 (85)	-0,72 (35)	0,84 (82)	-0,52 (30)	-1,22 (36)	2,66 (77)
East-Kazakhstan	-1,89 (38)	1,14 (77)	-0,24 (56)	0,69 (65)	1,04 (63)	0,43 (59)	0,30 (65)	-1,48 (27)	1,31 (89)	-0,46 (38)	-2,04 (31)	4,66 (93)
Turkestan	1,80 (77)	1,63 (76)	-0,27 (42)	-1,43 (36)	-0,68 (38)	**2,83 (96)**	0,71 (78)	1,87 (94)	0,29 (72)	0,89 (85)	0,74 (72)	1,94 (85)

Notes: 1. for Mangystau Region assessment was carried out during 1960-2017;
2. values above of the 95th or below the 5th percentile (respectively warm and cold extremes) are highlighted in bold type and bright color.

The Summer of 2017 was warm, anomaly averaged over the territory of Kazakhstan was +0.7 °C (93rd percentile). In regions of some meteorological stations of the Karaganda, East Kazakhstan, Almaty, Turkestan and Kyzylorda regions was extremely warmer (96-97 percentile. Summer of 2017 in these areas entered into 10 % of extremely warm spring seasons. **In June**, the absolute maximums on meteorological stations of the East Kazakhstan region are blocked: Zhalgyztobe +22.8 °C (+22.3 °C, 2016), Reserve Markakol +14.4 °C (+14.2 °C, 1998 .) Shar +22.0 °C (+22.3 °C, 2012) and in July at the weather station Kyzylorda +30.3 (+30.0 °C, 1983).

The Autumn of 2017 was rather warm in the territory of all Kazakhstan. Average in the territory of the republic was on 0.94 °C (89th percentile) above climatic norm. In the northeast, east and southeast of Kazakhstan autumn air temperatures were about the norm. In regions of weather stations Shieli (Kyzylorda region), Kazygurt (Turkestan region, Akkuduk (Mangystau region) and Aksai (West Kazakhstan region) probability of non-exceedance was 96–97 %, in such a way 2017 in these regions has entered 10 % of extremely warmer seasons. In October at the Ekidyn station of the Kostanay region has been recorded historical maximum of +1.3 °C, which is on 0.7 °C higher than the previous one (+0.6 °C, 2004).

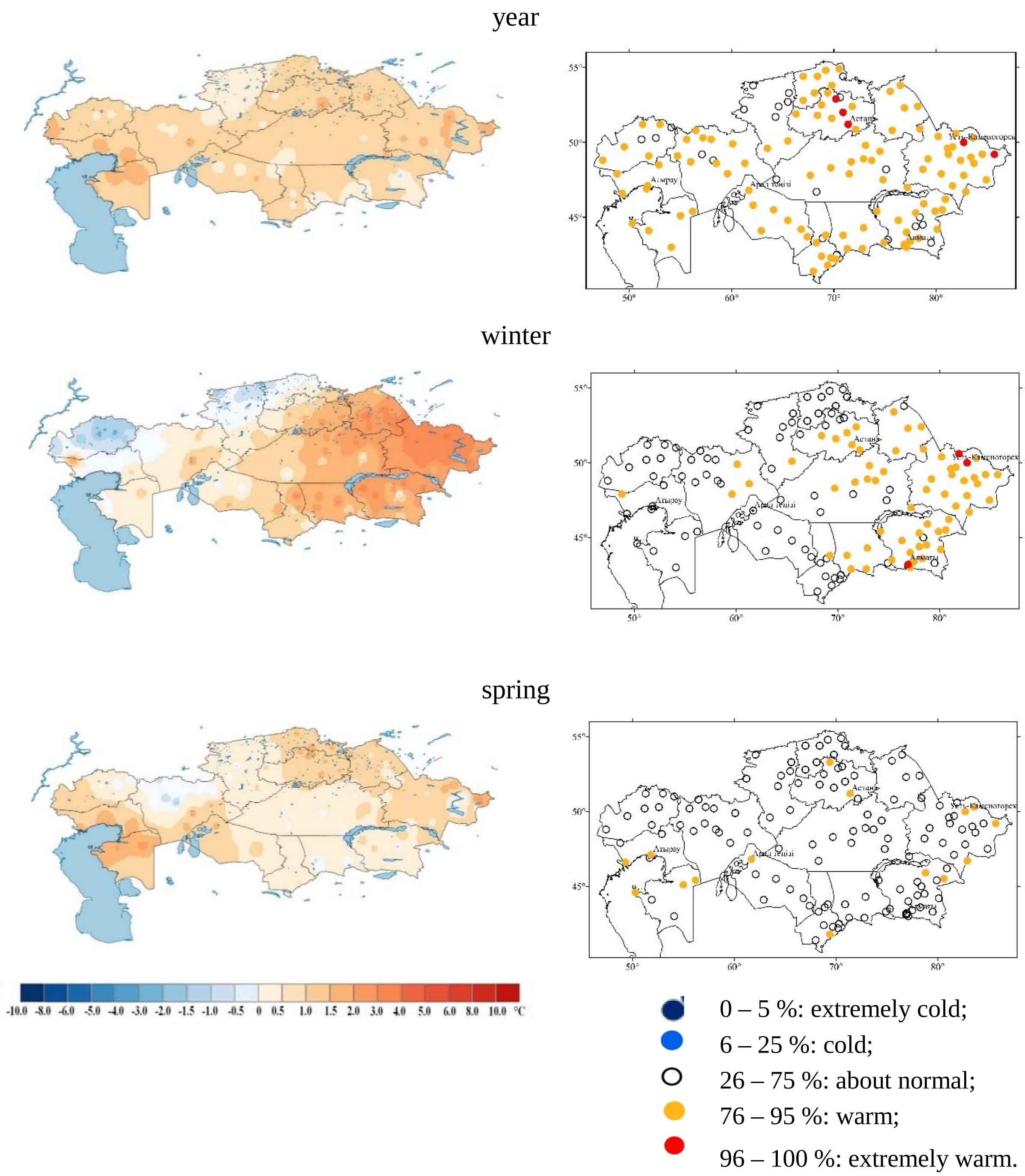
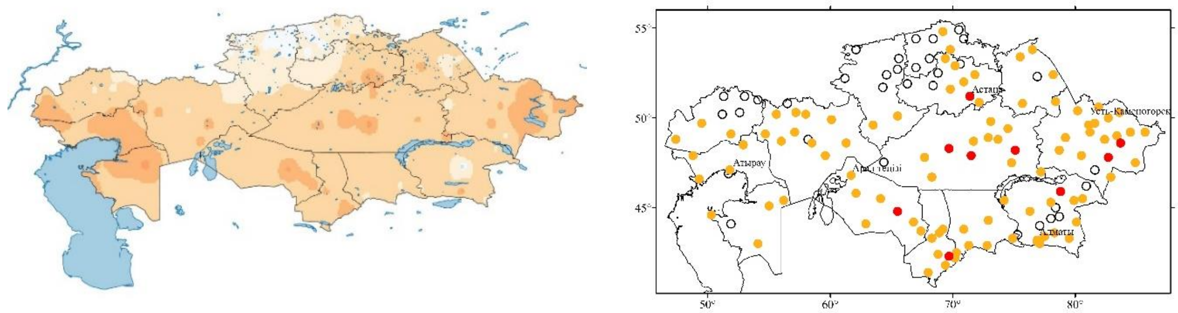
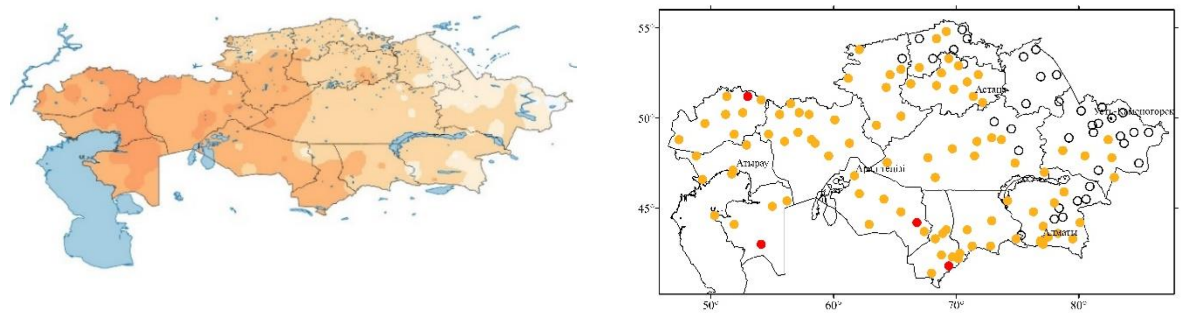


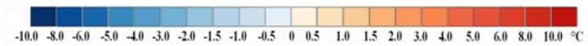
Figure 2.2 - Spatial distribution of air temperature anomalies (°C) in 2017 calculated relatively for basic period of 1981–2010, and the probabilities of not excess of air temperature values in 2017, calculated according by the period of 1941-2017. *Sheet 1*

summer



autumn





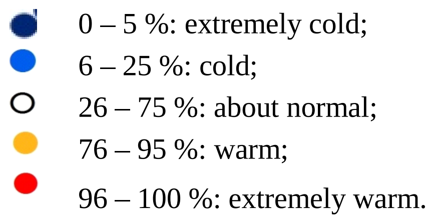


Figure 2.2 - Spatial distribution of air temperature anomalies (°C) in 2017 calculated relatively for basic period of 1981–2010, and the probabilities of not excess of air temperature values in 2017, calculated according by the period of 1941-2017. *Sheet 1*

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 in Kazakhstan for the period 1936-2017 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;

– FD0, 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, days with frosts;

– HWF, total duration of the heat wave of the warm period;

– FDm20, hard frosts;

– TM10a, the number of days with an average daily temperature above $10^{o}C$;

– Hdd heat8, sum of temperatures for the heating period.

Daily maximum air temperature in 2017. Figure 2.3 presents the values of absolute air temperatures maxima, from the beginning weather station opening to 2017. The daily maximums of air temperature observed in 2017 shown in blue color, and values of absolute maximums, which were registered from the moment of the station opening to 2016 shown in red color. In 2017 values of absolute maximums, haven't been exceeded at any stations in Kazakhstan.

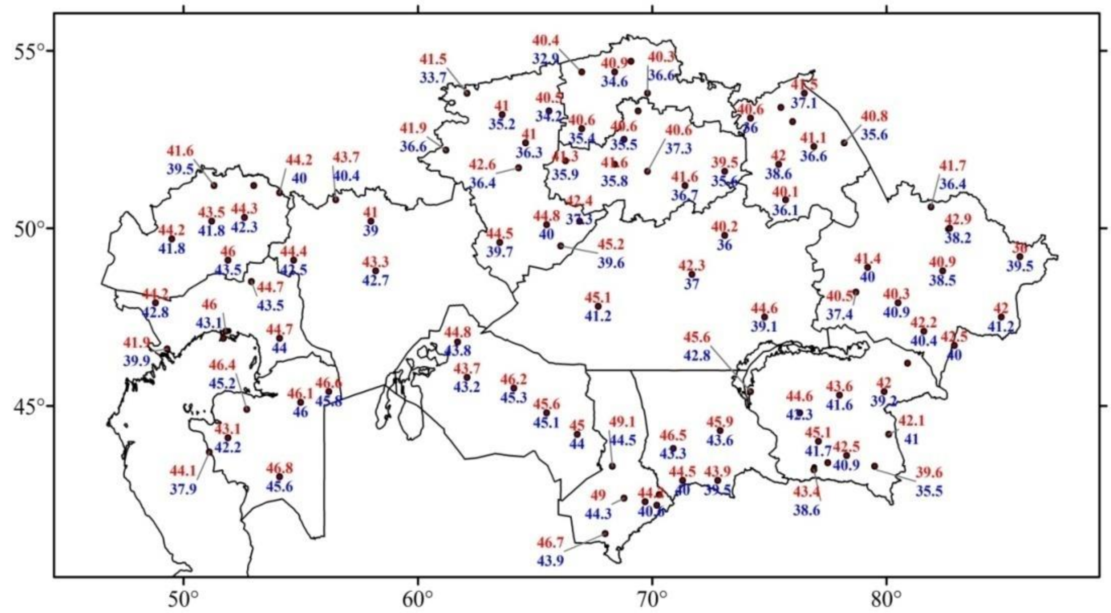


Figure 2.3 – Values of air temperature absolute maxima (°C) was registered from the beginning of the weather station opening to 2016 (are marked in red color) and maximum values of daily air temperatures (°C) observed in 2017 (are marked in blue color)

Most of the highest air temperature values (absolute maximums) in Kazakhstan were recorded in July 1983, when at some meteorological stations in Turkestan region air temperature has reached + 49 ... + 50 °C (MS Turkestan, Chayan, Arys, Tasty), and also in July 1995, when air temperature in MS Kyzylkum has risen up to +51 °C.

Figure 2.4 shows absolute minimum air temperatures (red color) are recorded from the moment of opening weather stations to 2016, and blue color are presented values of the minimum air temperature in 2017. In Kazakhstan absolute minimum temperatures below minus 54 °C were fixed at 2 stations in January, 1931 at Orlovsky settlement (54 °C) and in January 1893 on MS Astana (52 °C). In 2017, as in 2016, daily minimum temperature records haven't been updated. In 2017, air temperatures below minus 30 °C were observed in the northern half of Kazakhstan, at Emba station in the Aktobe region, the lowest air temperature in 2017 was recorded: minus 37.4 °C.

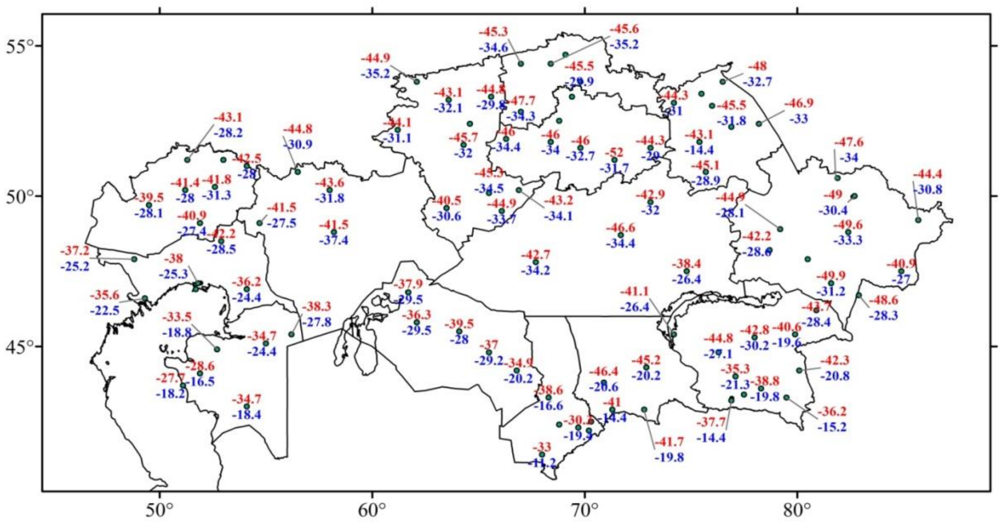


Figure 2.3 – Values of air temperatures absolute maxima (°C) were registered from the beginning of the opening of the weather station to 2016 (are marked in red color) and maximum values of daily air temperature (°C) observed in 2017 (are marked in blue color)

The number of very hot days with air temperatures above 35 ºC 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.

In the northern, central, and northeastern flat regions, as well as in the mountainous regions of the south and southeast temperatures above 35 ºC weren't observed, or were observed extremely rarely, which is symbolizing probabilities of non-exceedances (Fig. 2.5b). In the western and southern regions, the number of hot days often exceeded 30 days, the maximum number was observed in Turkestan and Mangystau regions (53–72 days). The probability of not exceeding these values was rather high here: 76 – 95 %.

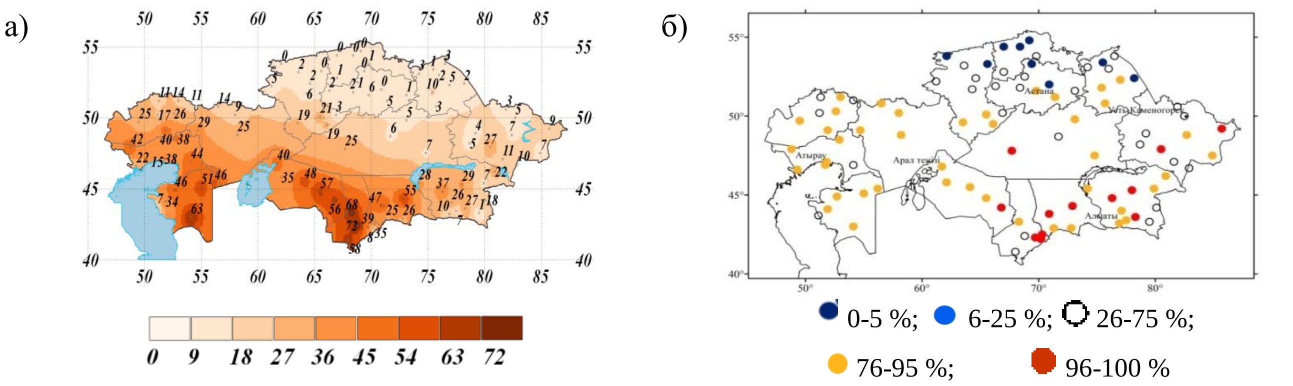


Figure 2.5 - The number of days (a) and probability of not exceeding the number of days (b) in 2017 with air temperatures above 35 ºC. Probabilities are calculated during the period 1941 - 2017

The percentage of warm days with daily maximum air temperatures above the 90th percentile in 2017 in the territory of Kazakhstan ranged from 8 % to 26 % (Figure 2.6a). In the northern and central regions of the country, an extremely high daily maximum air temperatures were observed by 8-16 % of days. In most of the western regions of the country, as well as in Kyzylorda, Turkestan, East Kazakhstan, and Zhambyl regions, warm days were observed in 16-26 % cases. Regularities of distribution of the values of this index over the territory of Kazakhstan are consistent with distribution of the number of hot days.

The percentage of cold nights in a year when daily minimum air temperature was below the 10th percentile characterizes repeatability of cases with extremely low daily temperatures (the figure 2.6). In 2017, the number of cold nights in most parts of Kazakhstan were mainly from 6 to 10 % of cases, maximum number of cold nights were observed in Akkuduk (Mangystau oblast) in 15 % of cases. This index is consistent with distribution of the index of frosty days (FD0 index).

а) б)

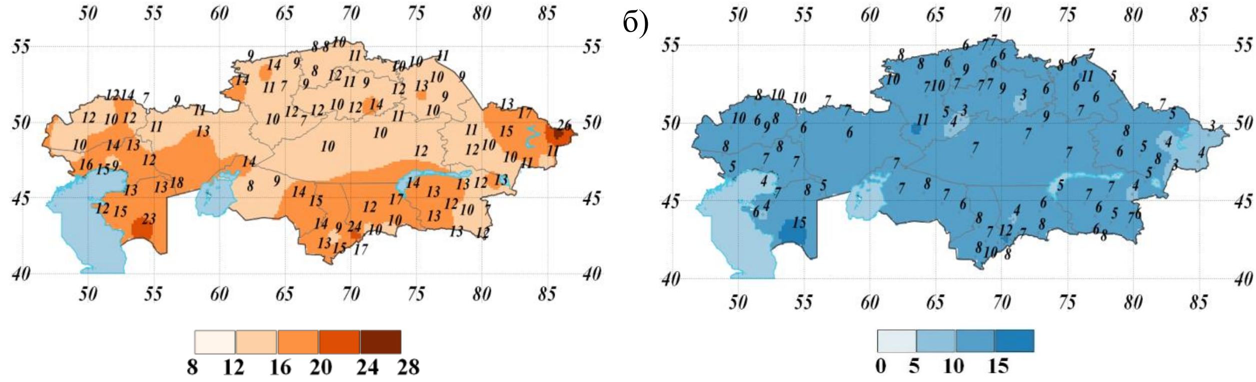


Figure 2.6 – Percent of cases in 2017 when daily maximum temperature was above the 90th percentile (a) and the daily minimum temperature was below the 10th percentile (b)

In the figure 2.7a are shown ***the total duration of heat waves*** in Kazakhstan in 2017 (the sum of days when at least 6 consecutive days the daily maximum air temperature was above the 90th percentile). The maximum total duration of heat waves from 20 to 32 days were observed in some areas of Mangystau, Kyzylorda, Turkestan and East Kazakhstan regions. At some stations in Kostanay, Karaganda, Pavlodar, Almaty and Aktobe regions, the duration of heat waves was 6–14 days.

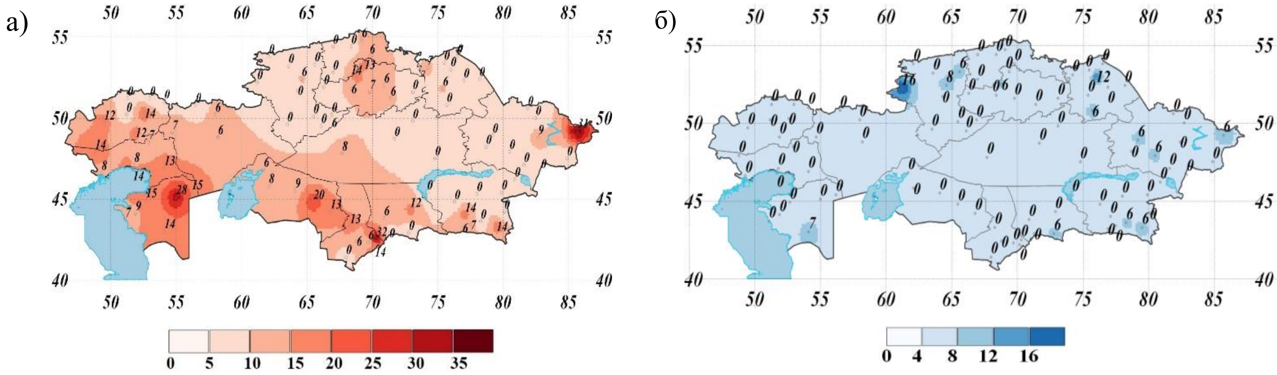


Figure 2.7 – Total amount of days in 2017, when at least 6 consecutive daily maximum air temperature was above the 90th percentile (a) and at least 6 consecutive days the daily minimum air temperature was below the 10th percentile (b)

The sum of days per 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 2017, only at some stations in Mangystau, Pavlodar, Almaty, Turkestan, East Kazakhstan regionscold waves were observed (Figure 2.7 b), at two stations (Kushmurun and Dzhetygara) their duration was 12-16 days, and they were observed during the cold period of the year.

In the figure 2.8 is presented ***distribution of the growing season*** in 2017 (the period between the first date when the mean daily temperature of the five-day week was ≥ 5 °C, and the last date when the mean daily temperature of the five-day week was ≤ 5 °C). The minimum vegetative period (160-180 days) was observed in the northern regions of the country. In the southern half of Kazakhstan (except mountainous areas) the growing season was more than 220 days, in the extreme South more than 260 days, the maximum was observed 277 days in a year in Shymkent.

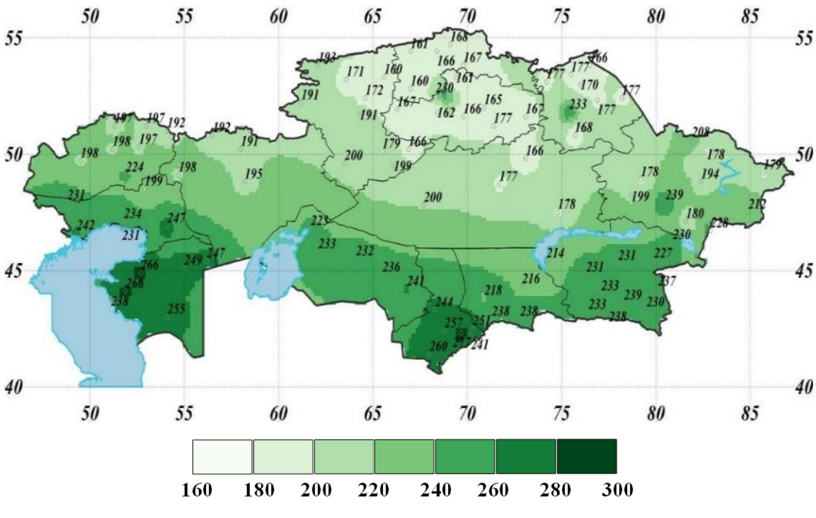


Figure 2.8 – Duration of the vegetative period (days) in 2017.

Figure 2.9 shows ***the number of days with frost, when the daily maximum air temperature fell below 0 °C***. In the northern regions of the country such days in 2017 there were more than 100, in some places more than 120 days, the minimum number of days with day frosts, 14–15 days, were observed in the southern regions.

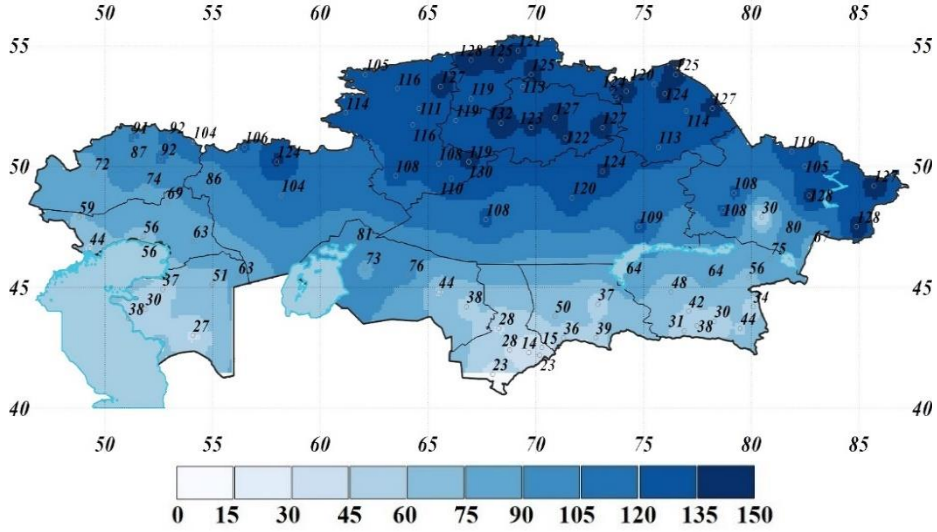


Figure 2.9 – The number of days in 2017 with day frosts

The number of days with severe frosts, when the minimum air temperature was below 20 °C on the territory of Kazakhstan in 2017 has showed that in the southern regions of the country such days or wasn't observed or they were no more than 15 days, in northern regions of Kazakhstan such number of days was from 30 to 40, places of 50-60 days in a year.

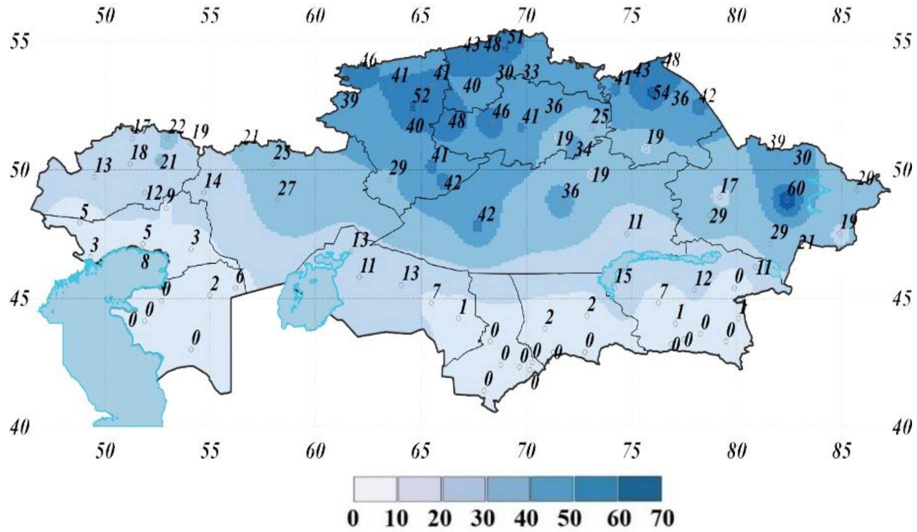


Figure 2.10 – The number of days with severe frosts in 2017

The number of days with temperatures above 10 °C characterizes the period of active growing season. In 2017, in the southern regions of such days were observed 180 to 232 days in a year. In the northern and central regions of the republic from 137 to 180 days in a year.

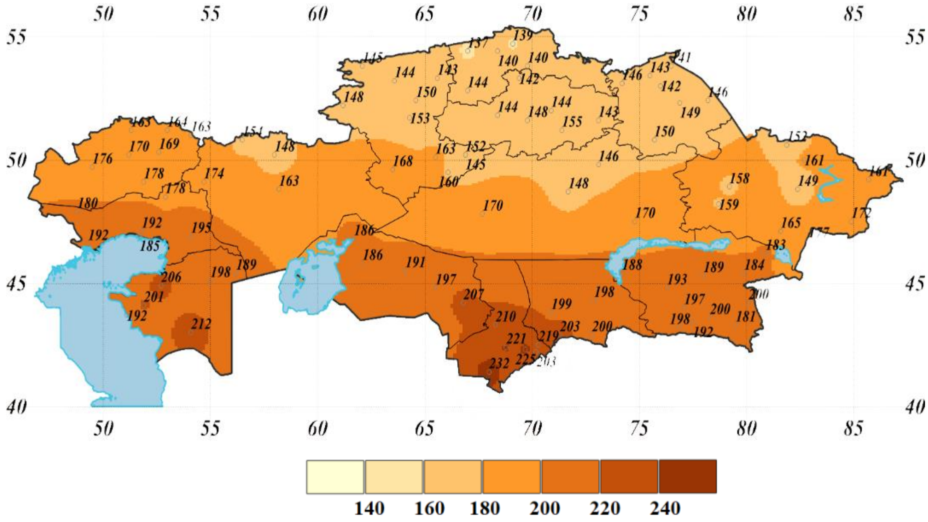


Figure 2.11 – The number of days with an average daily temperature above 10 °C in 2017

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.

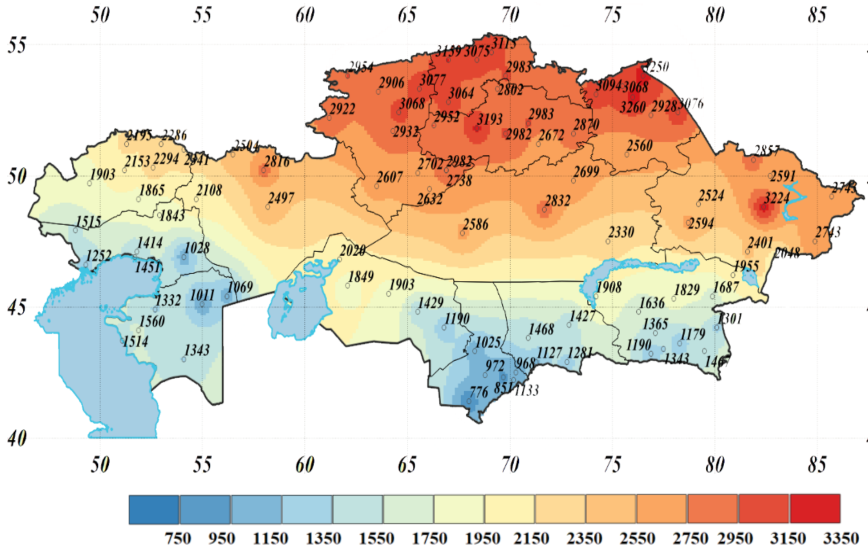


Figure 2.12 – The sum of temperatures for the heating season of 2017

The sum of temperatures for the heating period in the northern half of the territory of Kazakhstan ranged from 2750 °C to 3350 °C, in the southern regions – from 750 °C to 2350 °C. The sums of temperatures for the heating season is the lowest in the Turkestan region.

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 - 2017, also linear trends of air temperature change over the period 1976 - 2017. Anomalies are calculated relatively for the basic period of 1981-2010. 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 - 2017: 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.

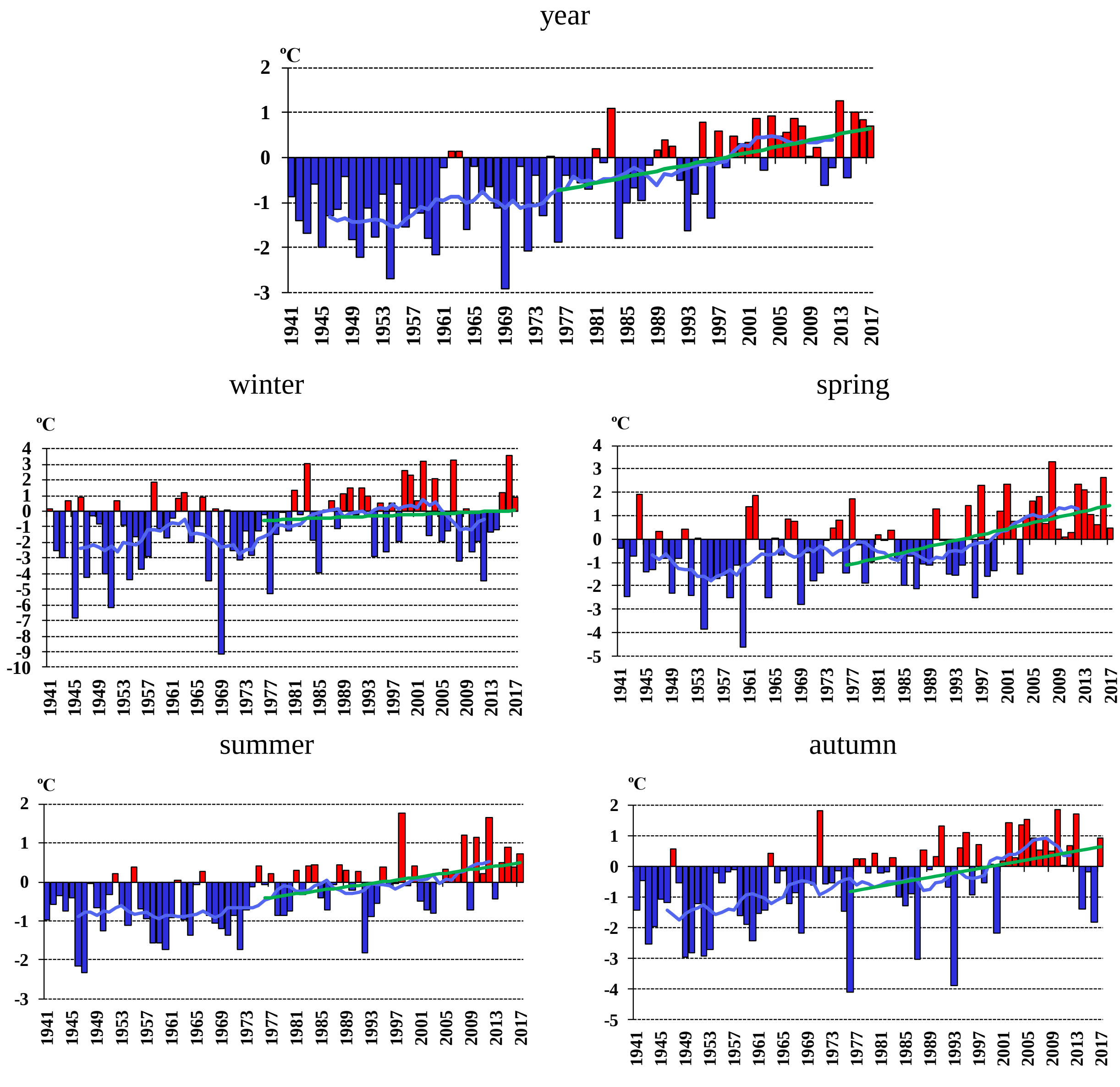
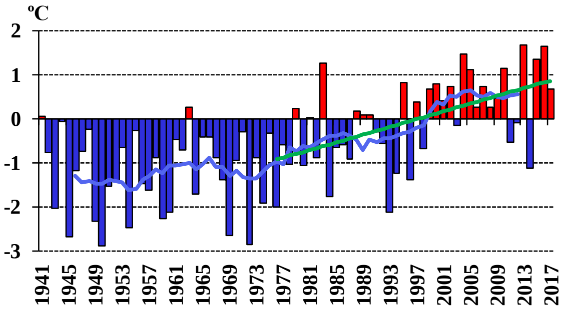
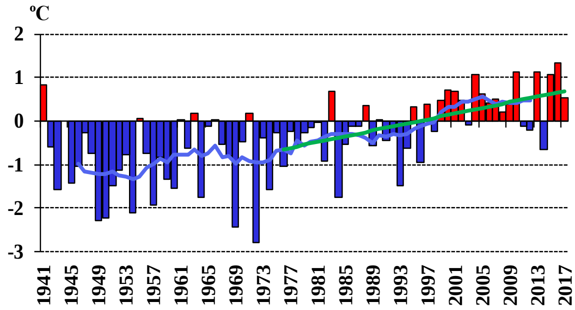


Figure 2.13 – Time series of anomalies of annual and seasonal air temperatures (ºC), averaged over the territory of Kazakhstan for the period 1941 - 2017. Anomalies are calculated relatively to the base period of 1981–2010. Linear trend during 1976-2017 is highlighted in green color. *Smoothed curve is received by the 11th sliding averaging*

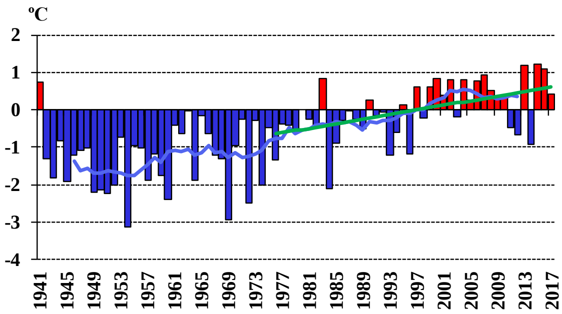
Kyzylorda region



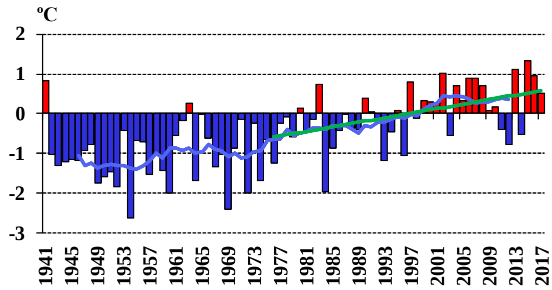
Turkestan region



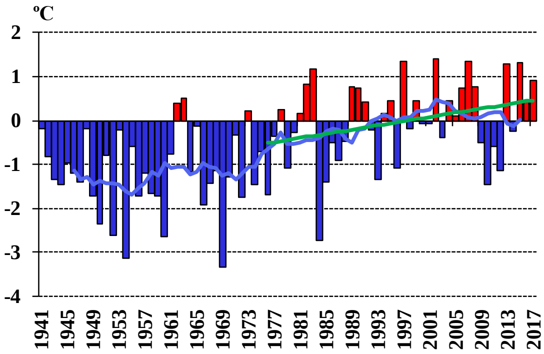
Zhambyl region



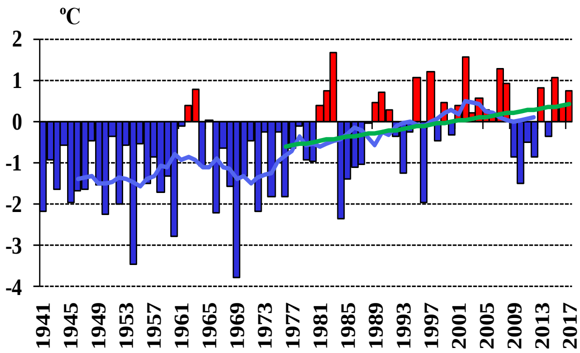
Almaty region



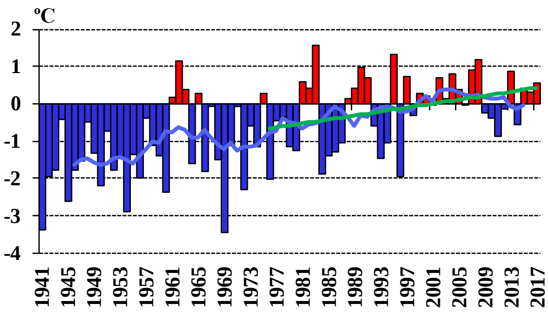
East-Kazakhstan region



Pavlodar region



North-Kazakhstan region



Akmola region

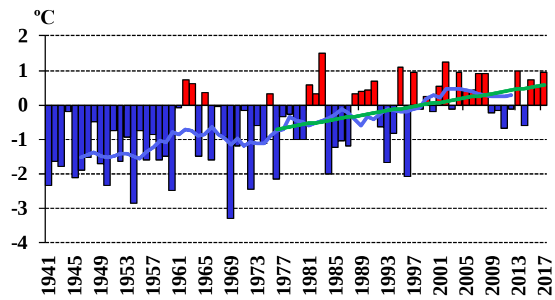


Figure 2.14 – Time series of anomalies of annual air temperatures (°C), averaged over the regions of Kazakhstan for the period 1941 - 2017. Anomalies are calculated relatively to the base period of 1981–2010. Linear trend during 1976-2017 is highlighted in green color. *Smoothed curve is received by the 11th sliding averaging, Sheet 1*

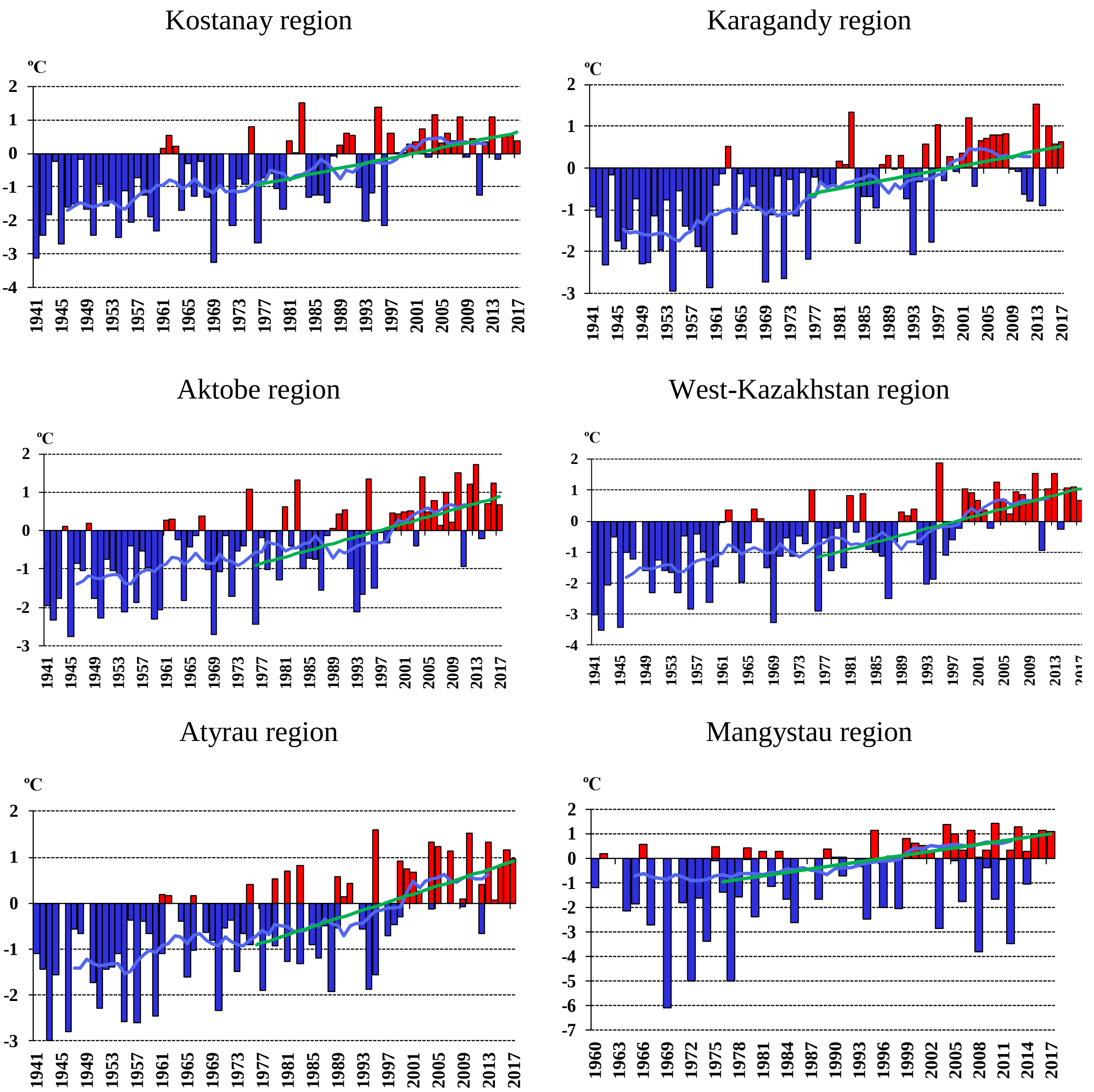


Figure 2.14 – Time series of anomalies of annual air temperatures for the period 1941–2017, averaged over the regions of Kazakhstan. Anomalies are calculated relatively to the base period of 1981–2010. Linear trend during 1976-2017 is highlighted in green color. *Smoothed curve is received by the 11th sliding averaging, Sheet 2*

On average over the territory of Kazakhstan for the period 1976 – 2017 increasing annual mean air temperature is 0.34 ºC every 10 years. The highest growth rates are observed in spring (0.63 ºC/10 years), the lowest in winter (0.16 ºC/10 years). The trend contribution for total dispersion of annual mean temperatures is 27 %, 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).

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 – 2017.

Region	Year		Winter		Spring		Summer		Autumn	
	a*	**R^2	a	R^2	a	R^2	a	R^2	a	R^2
Kazakhstan	0,34	**27**	0,16	1	0,63	**26**	0,22	**14**	0,36	**10**
Almaty	0,29	**23**	0,12	1	0,58	**24**	0,20	**15**	0,27	**9**
Akmola	0,31	**16**	0,08	0	0,72	**23**	0,03	0	0,39	**7**
Aktobe	0,44	**27**	0,26	2	0,61	**15**	0,33	**10**	0,44	**14**
Atyrau	0,44	**30**	0,36	4	0,48	**16**	0,47	**30**	0,42	**14**
East-Kazakhstan	0,24	**10**	-0,04	0	0,64	**21**	0,16	**7**	0,22	3
Zhambyl	0,31	**25**	0,19	1	0,58	**24**	0,19	**11**	0,30	**10**
West-Kazakhstan	0,54	**33**	0,43	4	0,61	**17**	0,59	**24**	0,50	**16**
Karagandy	0,28	**15**	0,07	0	0,77	**26**	0,03	0	0,25	4
Kostanay	0,39	**21**	0,16	1	0,62	**15**	0,17	3	0,55	**14**
Kyzylorda	0,44	**29**	0,31	2	0,82	**30**	0,27	**16**	0,36	**10**
Mangystau	0,32	**34**	0,20	3	0,35	**16**	0,45	**40**	0,29	**14**
Pavlodar	0,25	**9**	-0,03	0	0,74	**27**	0,05	0	0,26	3
North-Kazakhstan	0,27	**12**	0,02	0	0,55	**16**	0,03	0	0,44	**8**
Turkestan	0,33	**32**	0,25	2	0,53	**23**	0,21	**11**	0,34	**13**

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

More detailed information on change in the average annual, seasonal and monthly air temperatures (in ºC/10 years) over the territory of Kazakhstan for the period 1976 – 2016 are submitted in the figure 2.15–2.16.

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 (from 0.26 ºC/10 years to 0.53 ºC/10 years), the lowest warming rate (from 0.18 ºC/10 years to 0.45 ºC/10 years) is observed in the north-eastern part of the republic.

In winter, the highest rate of air temperature rising was observed in the southern and western regions – from 0.25 °C/10 years to 0.56 °C/10 years. Negative trend in air temperature In January, in the North-Eastern part of the Republic, was from 0.09 °C/10 to 0.56 °C/10 years in December, a slight decrease in air temperature from 0.01 °C/10 to 0.015 °C/10 years was observed in the South-East of the Republic. All the obtained trends in winter air temperatures are statistically insignificant, only at the Urzhar station (East Kazakhstan region) a slight decrease in air temperature (0.56 °C/10 years) was statistically significant.

In spring across all territory of Kazakhstan is observed the most intensive warming from 0,42 ºC/10 years to 0,79 ºC/10 years. The largest speed of increase in air temperature is noted in March (from 0,63 ºC/10 years to 1,4 ºC/10 years). All trends of the spring period are statistically reliable (figure 2.15–2.16).

In summer, steady positive trends were observed in the eastern, southern and western regions of the republic (from 0.11 ºC/10 years to 0.45 ºC/10 years, respectively), in the central and northern regions of Kazakhstan, slight positive trends (from 0.003 ºC/10 years to 0,017 ºC/10 years) were statistically insignificant. Slight cooling in July is observed in the northern and central regions (from 0.02 ºC/10 years to 0.29 ºC/10 years). However, statistically significant negative tendencies (0,10 ºC/10 years) were noted only in Karaganda region (Figure 2.15–2.16).

In autumn over the last 4 and decades (Figure 2.15–2.16), steady rising in air temperature was observed in the north-west and south of the republic (from 0.26 ºC/10 years to 0.51 ºC/10 years). The main contribution to this was made by September and October, when statistically significant positive trend in air temperature was 0.15–0.65 ºC/10 years.

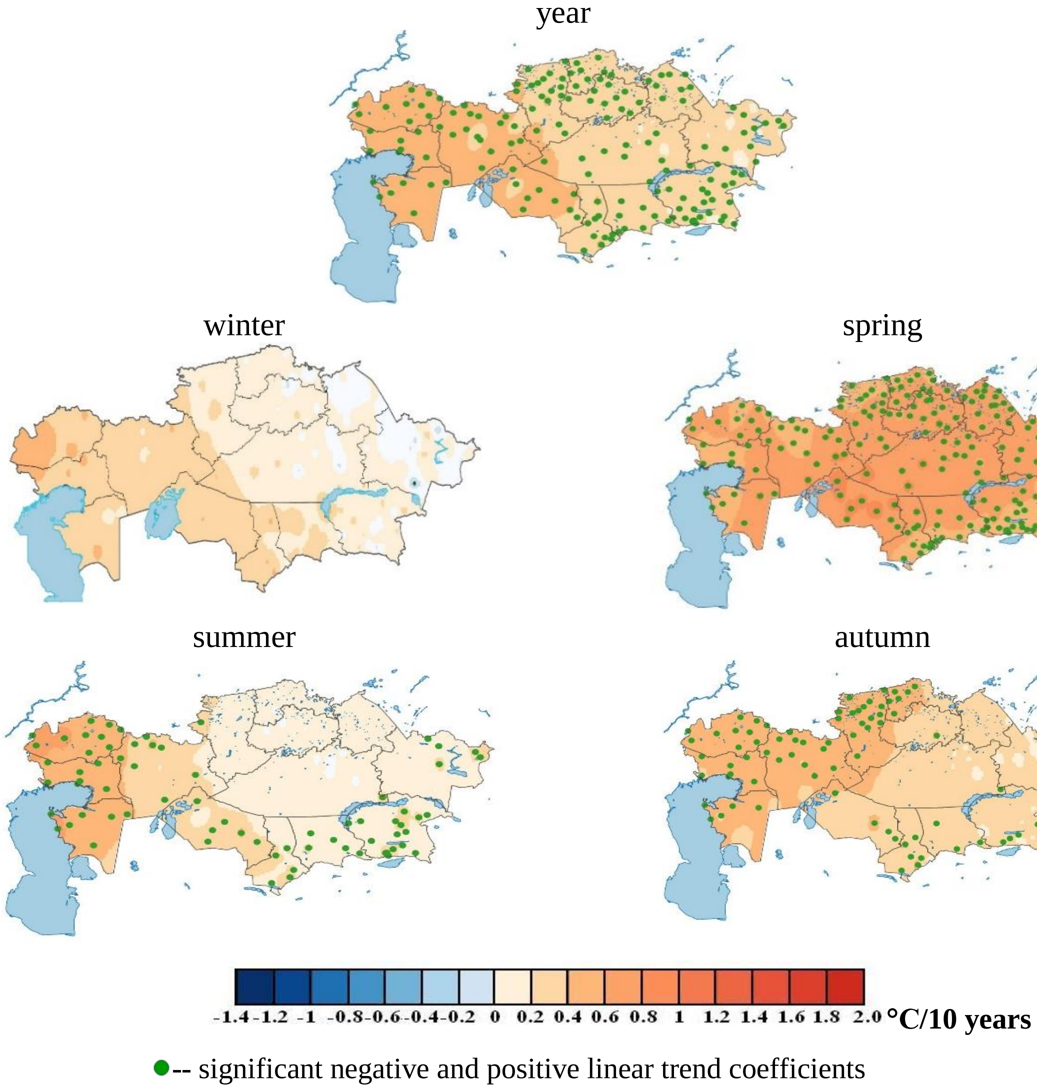
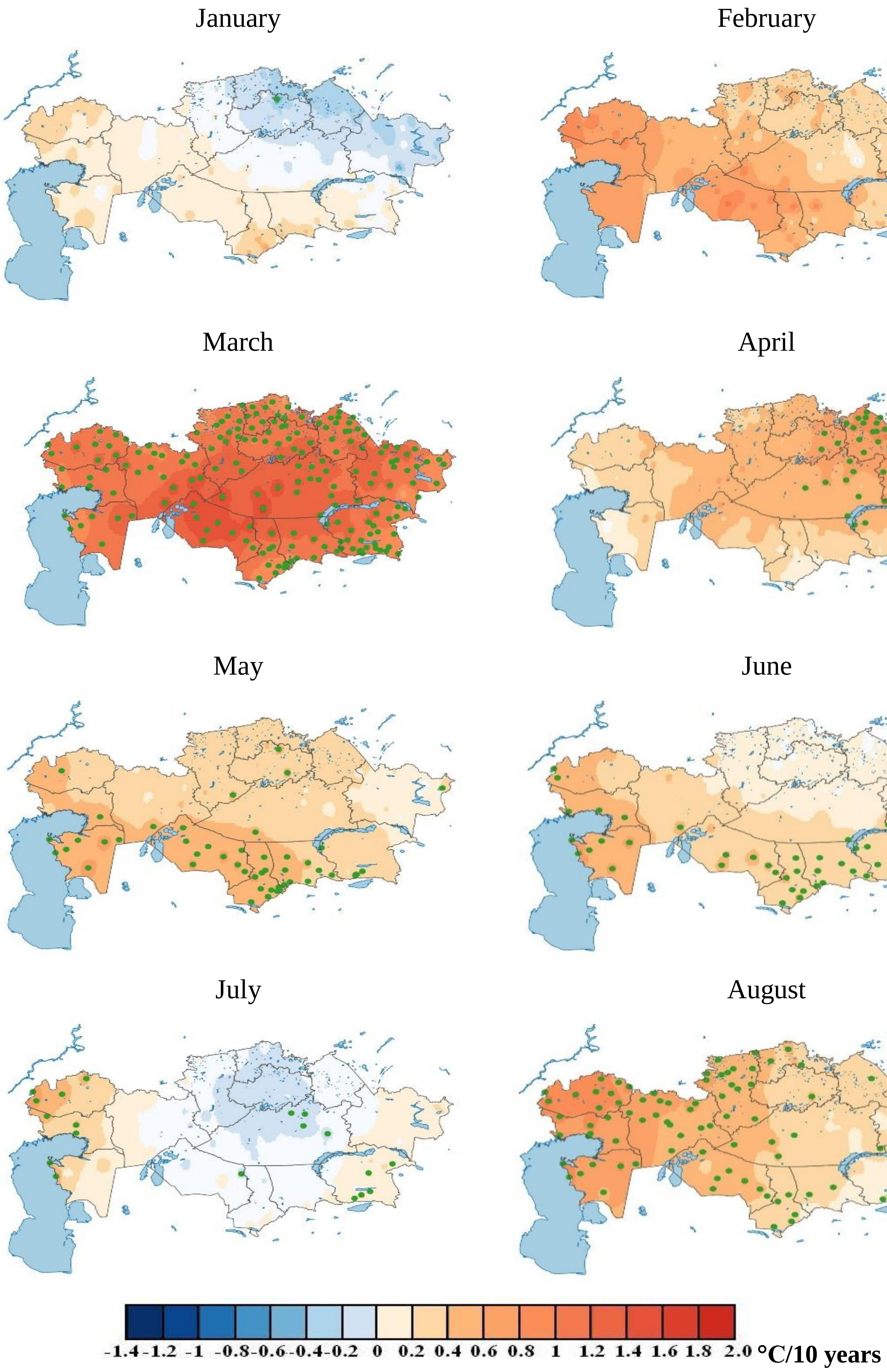


Figure 2.15 – Spatial distribution of the values of the linear trend coefficient of the average annual and seasonal surface air temperature (°C/10 years)



●-- significant negative and positive linear trend coefficients

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 – 2017, *Sheet 1*

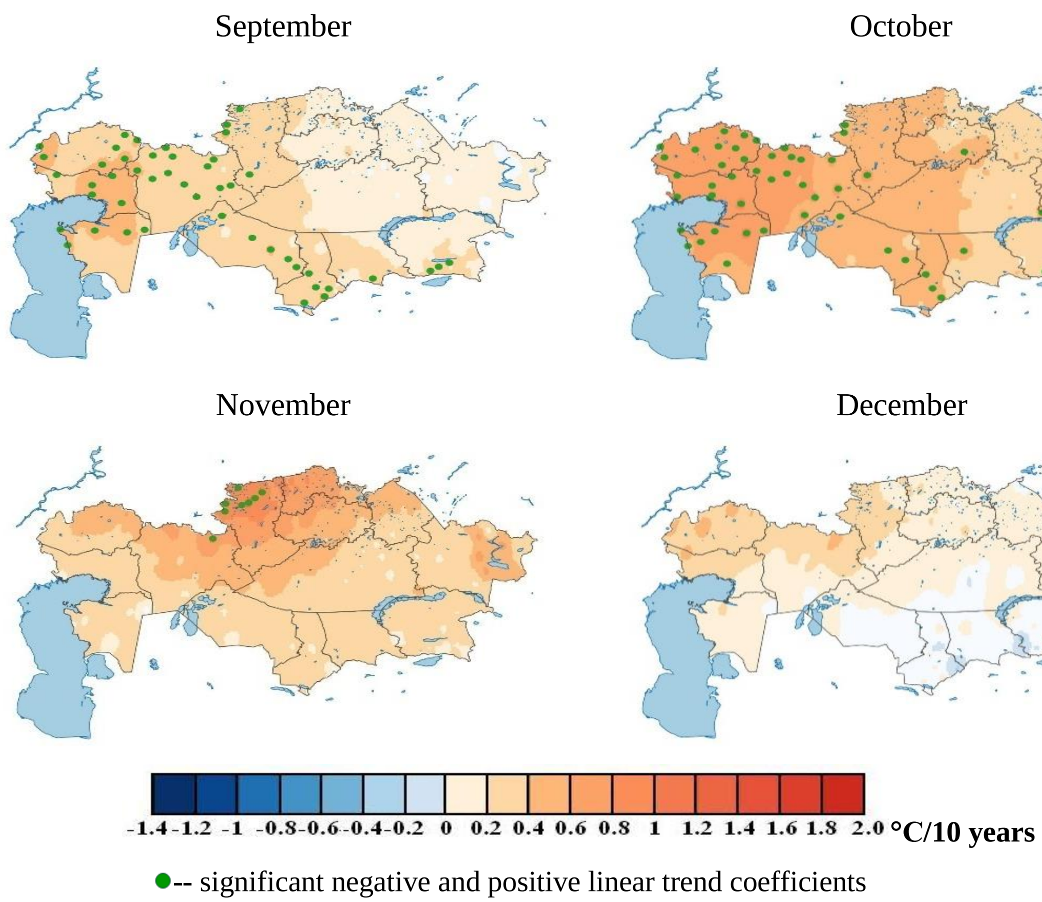


Figure 2.16 – Spatial distribution of linear trend values of coefficient mean monthly surface air temperature (°C/10 years), calculated according to observations during 1976 – 2017 *Sheet 2*

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. Significant decrease of the surface air temperature daily maximum is observed at the Shardara station (at 0.20 ºC/10 years), that it is connected with the fact that, this station is surrounded by Shardara reservoir, which renders local cooling effect.

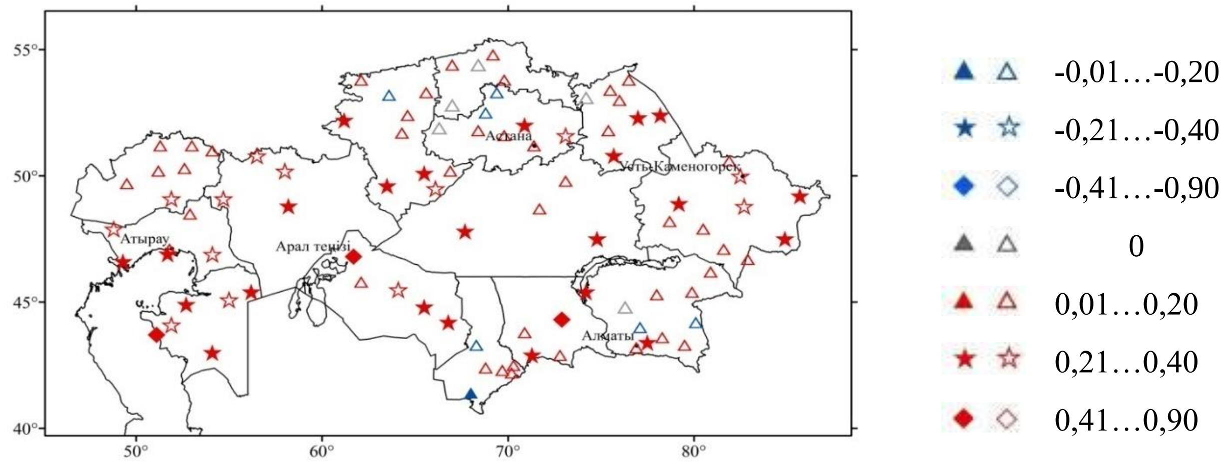


Figure 2.17 – Spatial distribution of the linear trend coefficient for values of daily maximum air temperature (°C /10 years) for the period 1976 - 2017

Designations of gradation are shaded in cases of the statistical trend importance

Statistically significant trend of increasing ***the number of very hot days*** *with air temperature above 35 ºC* is observed in the West Kazakhstan, Aktobe, Atyrau, Mangystau, Kyzylorda, Turkestan regions: 4-8 days every 10 years (Figure 2.18). Every 3 years repeatability of hot days in southeast regions increases by 1-3 days. In other territory of the republic, there was observed statistically insignificant both increase and decrease in the number of days with temperatures above 35 ºC.

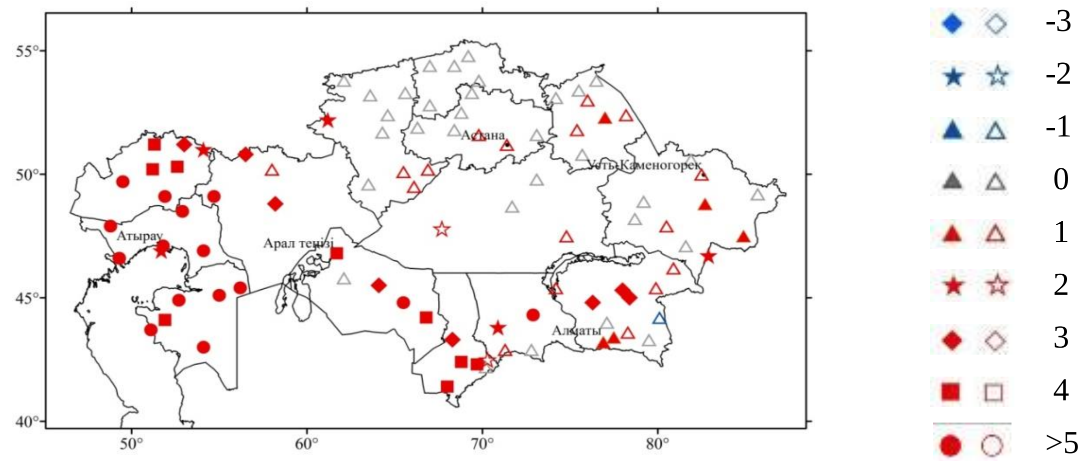


Figure 2.18 – Spatial distribution of the linear trend coefficient of the number of days with air temperature above 35 °C (days/10 years) for the period 1976-2017

Designations of gradations are shaded in cases of the statistical importance of the trend

Almost everywhere is observed reduction tendency of repeatability of cases with ***night frosts*** in the territory of the republic when daily minimum temperature falls below than 0 °C (figure 2.19). Basically the speed of reduction in the number of such cases is from 3 to 6 days every 10 years.

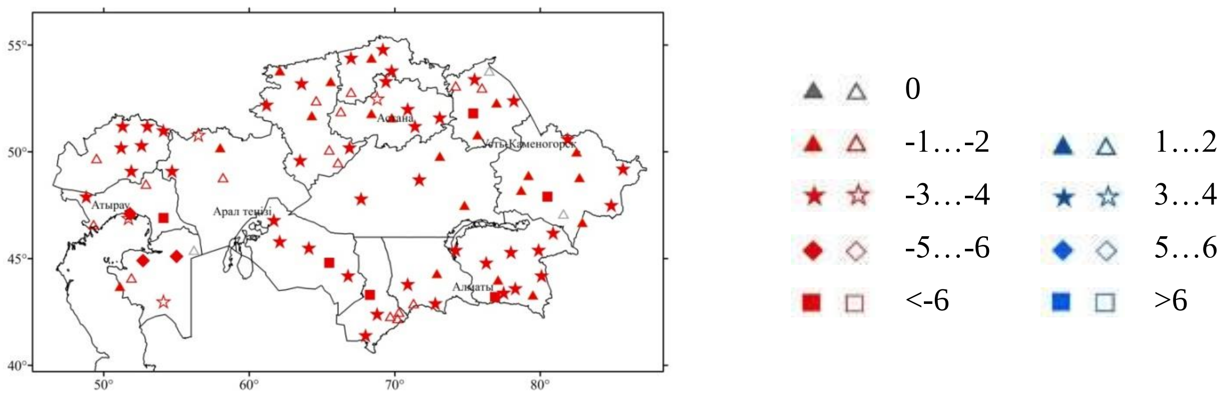


Figure 2.19 – Spatial distribution of the linear trend coefficient of the number of cases with daily minimum air temperature below 0 °C (days/10 years) for the period 1976-2017
Designations of gradations are shaded in cases of the statistical importance of the trend

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

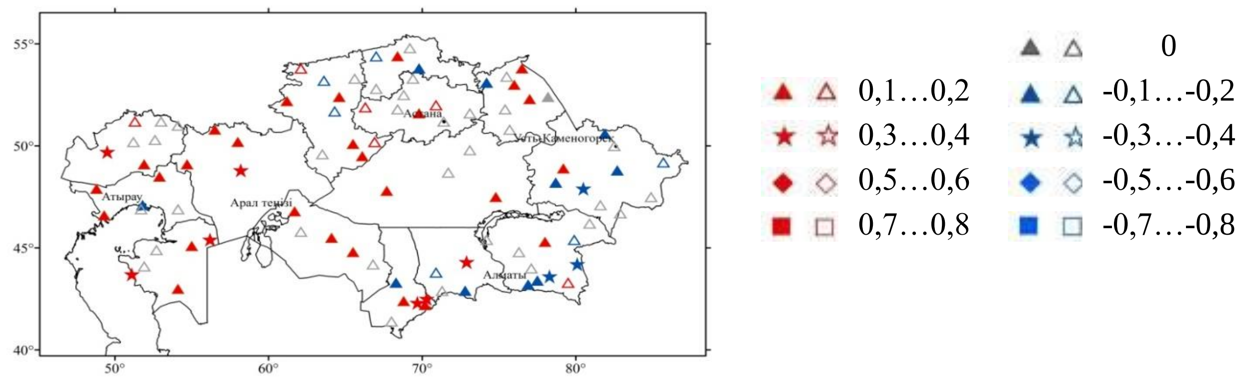


Figure 2.20 – Spatial distribution of the linear trend coefficient of the daily amplitude of air temperature (°C/10 years) for the period 1976 - 2017
Designations of gradations are shaded in cases of statistical importance of the trend.

On the most part of the territory of Kazakhstan were observed significant decreasing with frost, by 4 - 8 days/10 years (figure 2.21). Exceptions are made by the southern, southeast and east regions where the repeatability of such cases has decreased, but not significantly.

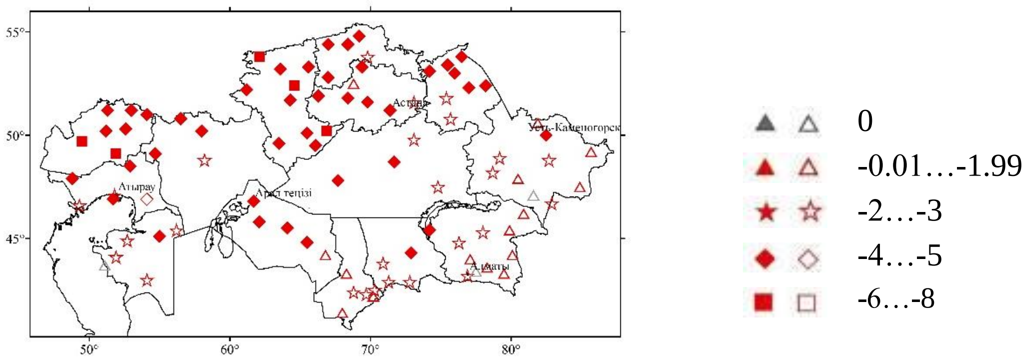
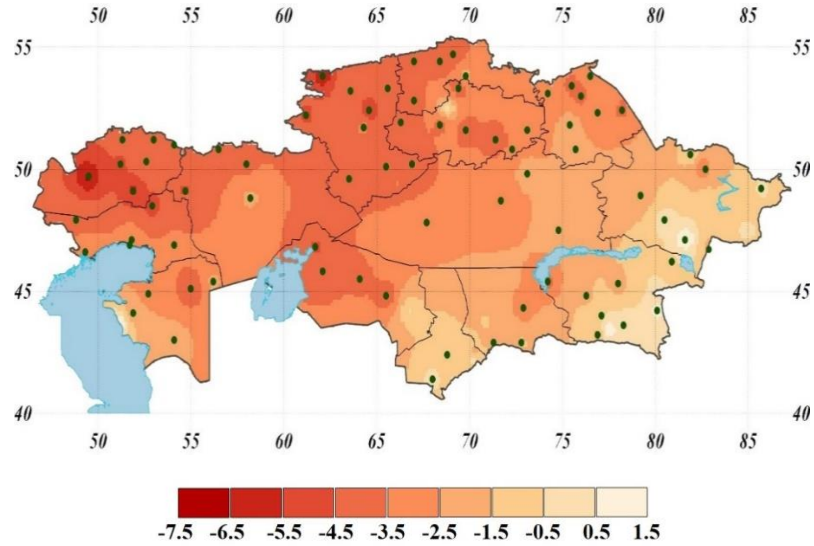


Figure 2.21– Spatial distribution of the linear trend coefficient of the number of days when the daily maximum temperature was below 0 °C (°C/10 years) for the period of 1976 - 2017. *Designations of gradations are shaded in cases of statistical significance of the trend.*

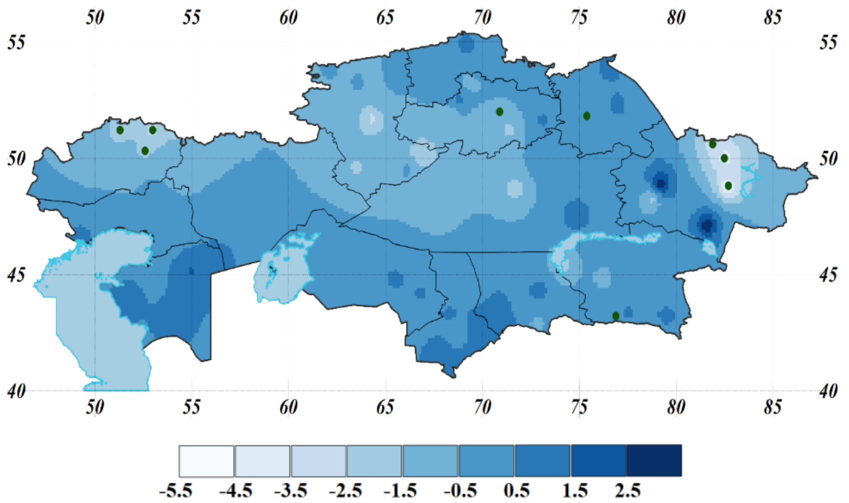
The highest reduction rate (4–8 days/10 years) of ***the number of days with daytime frosts (when the daily maximum temperature is below 0 °C)*** in the territory of Kazakhstan is observed mainly in the north-west of the republic and in the central part (ID index, figure 2.22). In the southern and south-eastern regions the number of days with day frosts is slower rates (1–3 days/10 years).



●– significant negative and positive linear trend coefficients

Figure 2.22 – Spatial distribution of the linear trend coefficient of the number of days with day frosts (days/10 years) for the period 1976 - 2017

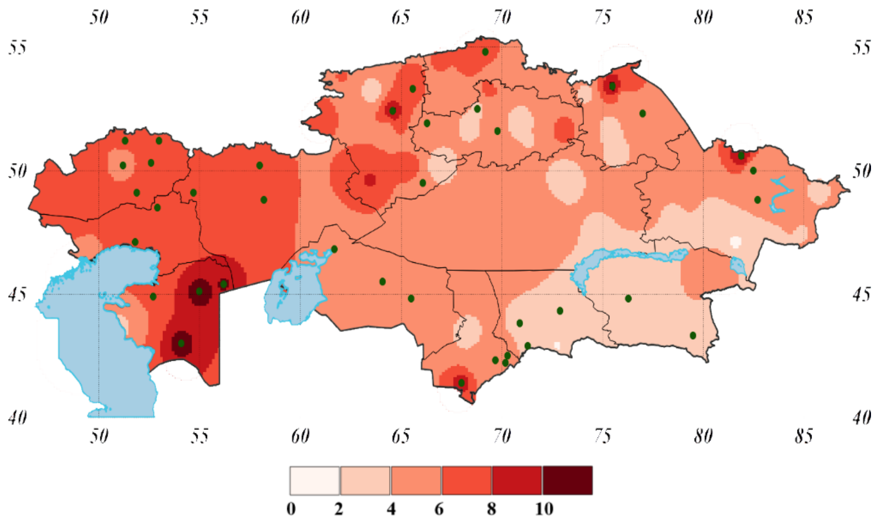
The number of days with ***severe frosts (when the daily minimum of air temperature is below minus 20 °C, FDm20 index***, figure 2.23) decreases in the territory of the republic by 1-3 days/10 years, but significant decrease (2-3 days/10 years) is reduced only at some meteorological stations in the West-Kazakhstan region and in the north-east of the republic.



●– significant negative and positive linear trend coefficients

Figure 2.23 – 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*)

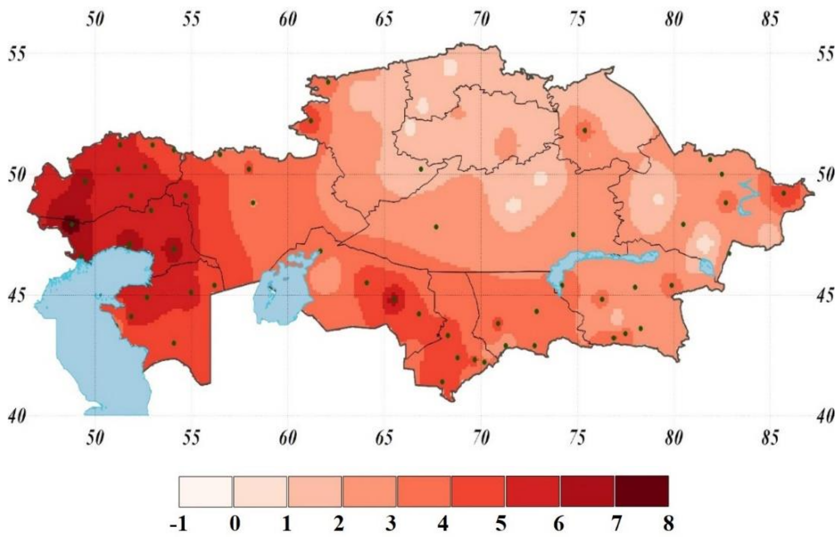
The total duration of heat waves for year (when at least 6 consecutive days the daily maximum air temperature was above the 90th percentile) in the territory of the republic increases everywhere. The highest increase rate was 9–10 days/10 years at the weather stations of Mangystau region, as well as at some meteorological stations of Kostanay and Pavlodar regions (Figure 2.24).



●– significant negative and positive linear trend coefficients

Figure 2.24 – Spatial distribution of the linear trend coefficient of the total annual heat wave duration (days/10 years) for the period 1976 - 2017.

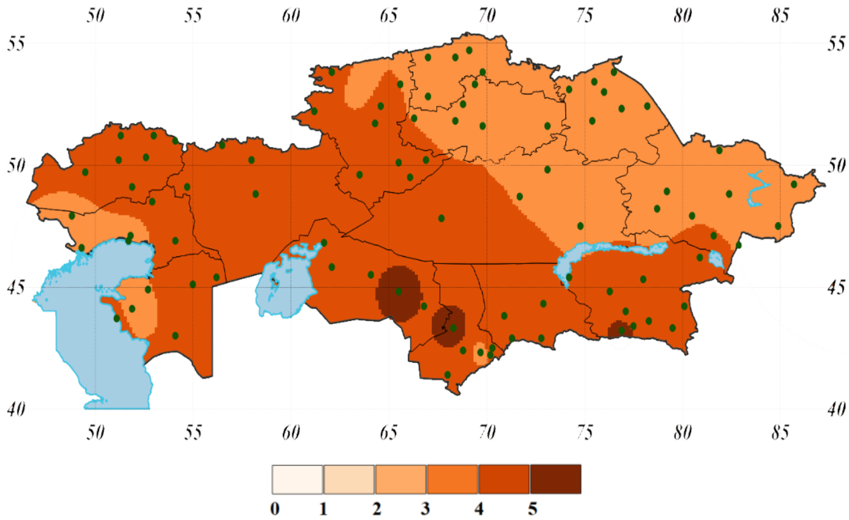
From the north-east to the south-west of the republic is well-observed trend of increasing the duration of heat waves during the warm period (***when the daily maximum of air temperature is above the 90th percentile, HWF index***, in Figure 2.25). The highest speed of increase in the duration of heat waves (4-7days/10 years) are observed in West Kazakhstan, Atyrau and Mangystau regions.



●– significant negative and positive linear trend coefficients

Figure 2.25 – Spatial distribution of the linear trend coefficient of the total duration of heat waves in the warm period (days/10 years) during 1976 - 2017.

The number of days with average daily air temperature above or equal on 10 ℃ (TM10a index) for the period 1976-2017 on the territory of Kazakhstan increases by 3–5 days/10 years. In the northeast and southwest the positive trend is 3 days/10 years (figure 2.26).



●– significant negative and positive linear trend coefficients

Figure 2.26 – 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 - 2017.

Thus, tendency in indexes of the surface air temperature shows that for the period 1976–2017 increases: repeatability of days with high temperatures, duration of heat waves and the vegetative period, also repeatability of days in year has decreasing with negative temperatures, day frosts and hard frosts.

3 PRECIPITATION

3.1 Anomalies of precipitation in Kazakhstan in 2017

The monthly amount of precipitation averaged over Kazakhstan in 2017 was below the climatic norm (figure 3.1). The deficit of rainfall was from 2 % (June) up to 40 % (July). In February and October precipitation has exceeded the climatic norm by 28 %, in April by 22 %.

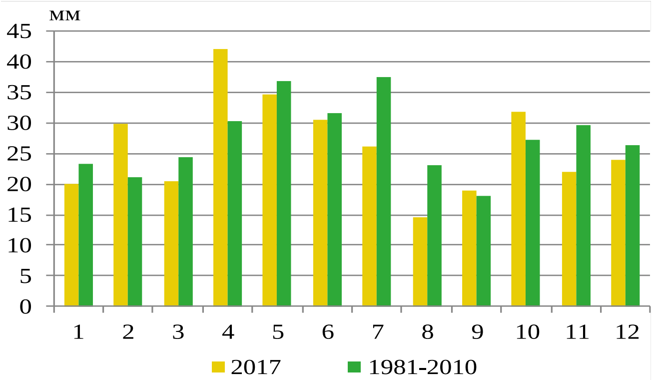


Figure 3.1 - Monthly sums of precipitation in 2017 and norms for the period 1981-2010, averaged over Kazakhstan

Figure 3.2 shows the territorial distribution of annual and seasonal precipitation in 2017, expressed as a percentage of the norm for the period 1981-2010, and also shows the probabilities annual and seasonal precipitation does not exceed at these given year. Probability of not exceeding characterizes the frequency of emergence corresponding value of anomaly in series of observations.

Annual rainfall in all Kazakhstan was within climatic norm and has made 96 % of norm (313,7 mm) in 2017. Extremely dry was in the areas of weather stations Beineu (Mangystau region), Shili (Kyzylorda region), Korday (Zhambyl region) and Kokpekty (East Kazakhstan region). The probability of non-exceeding here was 0-5 % (table 3.1, figure 3.2).

The Winter (December 2016 - February 2017)

The Winter on the territory of Kazakhstan by rainfall takes 2nd place (132 % of the norm) for the period of observations from 1941 to 2017. Extremely wet was in Akmola (174 % of norm), Pavlodar (156 % of norm) and Turkestan (161 % of norm) regions. Probability of not exceeding in these areas were from 90 to 100 %. The winter season in these regions entered into 10 % of extremely wet seasons (Figure 3.2, Table 3.1, 3.2). Historical maximums have been blocked on the following meteorological stations:

- Pavlodar region: MS Krasnoarmeyka of 76.3 mm (prior maximum of 60.5 mm); MS Pavlodar 83.1 mm (81.20 mm); MS Shalday 76.4 mm (71.6 mm).
- Almaty region: MS Almaty-Kamenskaya plato 214.1 mm (211.6 mm);
- Turkestan region: MS Shymkent 370 mm (363.2 mm).

Table 3.1 – Regionally averaged annual and seasonal anomalies of precipitation in 2017: **vR** deviations from multiyear averages for 1981–2010, mm; ***P(r≤R$_{2017}$)*** - not excesses probability (in brackets), calculated according by data for the period 1941 – 2017 and expressed in %; **RR** - ratio to norm **R2017**, expressed in %

Region	Year		Winter		Spring		Summer		Autumn	
	vR (P)	**RR**	**vR (P)**	**RR**	**vR (P)**	**RR**	**vR (P)**	**RR**	**vR (P)**	**RR**
Kazakhstan	-14,4 (32)	96	**23,6(100)**	**132**	5,7(56)	102	-21,1 (14)	76	-2,3 (43)	98
Almaty	-5,7 (44)	98	19,3 (82)	124	26,1 (65)	118	-36,1 (18)	74	-3,9 (51)	96
Akmola	-20,1 (15)	86	**36,7 (98)**	**174**	-4,3 (47)	95	-44,2 (11)	65	3,8 (53)	105
Aktobe	-10,0 (44)	99	22,4 (89)	137	3,7 (71)	105	-21,4 (23)	76	16,7 (75)	132
Atyrau	-23,1 (22)	85	10,9 (69)	131	2,7 (55)	108	-27,0 (13)	42	0,0 (52)	98
East-Kazakhstan	-35,8 (18)	91	9,9 (71)	113	-27,2 (14)	67	-9,6 (30)	95	7,3 (60)	105
Zhambyl	16,3 (63)	104	33,8(90)	142	50,2 (85)	136	-22,6 (22)	62	-23,5 (19)	68
West-Kazakhstan	-38,4 (25)	87	9,1 (75	117	-1,3 (56)	98	8,0 (21)	62	-8,5 (31)	91
Karagandy	-3,4 (44)	99	6,8 (73)	112	-7,1 (39)	89	-15,9 (35)	78	4,4 (59)	112
Kostanay	-23,1 (36)	91	10,7 (76)	122	5,1 (56)	106	-14,1(27)	82	-7,4 (38)	92
Kyzylorda	-5,2 (53)	97	4,7(65)	111	-2,9 (50)	95	-6,3 (43)	75	-1,3 (47)	98
Mangystau*	-15,7(34)	89	16,7 (92)	155	-3,1 (57)	91	-14,1 (18)	61	2,0 (57)	104
Pavlodar	22,5 (64)	107	**23,3 (100)**	**156**	8,7 (76)	115	-3,9 (47)	99	2,7 (52)	104
North-Kazakhstan	-36,6 (27)	89	17,8 (90)	129	18,0 (82)	125	-29,5 (19)	81	-12,9 (39)	85
Turkestan	44,4 (68)	110	**99,1 (100)**	**161**	22,8 (61)	114	-11,5 (34)	65	-24,2 (28)	66

Notes: 1. for Mangystau Region assessment was carried out during 1960-2017
2. values above the 95th and below the 5th percentile are highlighted in bold and bright color

Spring

In the spring rainfall (or precipitation) on all republic was close to norm 102 %, except for the East Kazakhstan region where an atmospheric precipitation fell 67 % of norm (probability of nof non-exceedance is 14 %). Extremely dry was in the near Aksuat station (probability of not exceeding 2 %). Extremely wet recorded in the Mugodzhar station (Aktobe region) and Taraz (Zhambyl region) stations, probability of not exceeding at these weather stations was 97 %. The spring season near these stations is included in 10 % of extremely dry and extremely wet seasons, respectively (Figure 3.2, Table 3.1).

Summer

The summer of 2017 was dry, as well as the previous 2016 (Figure 3.2, Table 3.1). The amount of precipitation for all season has made 76 % of climatic norm (probability of non-exceedance is 14 %). It was the driest in West and South of Kazakhstan, probability of not exceeding in these areas was from 11 % to 23 %. It was extremely dry on meteorological stations Taypak (West Kazakhstan region), Temir, Novoalekseevka, Novorossiysk (Aktobe region), Kokpekty and Leninogorsk (East Kazakhstan region), Astana (Akmola region). The summer season in these areas has entered 10 % of extremely dry seasons (figure 3.2, table 3.1).

Table 3.2 – Regionally averaged monthly anomalies of the amount of precipitation in 2017: **vT** – *deviations from multiyear averages for 1981 - 2010*, mm; ***P(r≤R$_{2017}$)*** *- non-exceedance probability (in brackets), calculated according by data for the period 1941–2017 and expressed in %*

Region	12 (2016)	1	2	3	4	5	6	7	8	9	10	11
Kazakhstan	17.24 (97)	-3,31 (42)	8,78 (94)	-3,81 (31)	11,93 (80)	-2,11 (47)	-1,06 (43)	-11,34 (22)	-8,68 (19)	0,88 (47)	4,52 (68)	-7,76 (23)
Almaty	20,4 (90)	-5,69 (46)	3,99 (73)	-16,5 (11)	38,31 (92)	4,15 (59)	7,16 (59)	-39,48 (2)	-3,84 (44)	4,46 (64)	-10,47 (39)	2,19 (63)
Akmola	33,5 (100)	2,44 (86)	0,21 (61)	0,76 (65)	1,36 (69)	-6,4 (65)	-16,84 (85)	0,7 (36)	-28,2 (88)	-11,53 (55)	7,71 (40)	7,66 (92)
Aktobe	21,96 (93)	-4,93 (38)	4,91 (80)	-0,54 (56)	1,33 (61)	2,91 (65)	-7,43 (39)	-3,34 (44)	-10,68 (28)	-6,51 (23)	23,95 (96)	-0,68 (50)
Atyrau	8,9 (80)	-5,15 (19)	7,4 (82)	13,5 (85)	-10,15 (28)	-0,4 (56)	-8,15 (31)	-7,75 (30)	-11,05 (17)	-9,5 (3)	10,9 (80)	-1,35 (48)
East-Kazakhstan	9,19 (78)	-5,36 (35)	5,02 (75)	-9,55 (9)	1,7 (50)	-19,32 (19)	6,17 (61)	-5,59 (38)	-10,23 (18)	21,71 (93)	4,09 (59)	-18,38 (5)
Zhambyl	18,66 (85)	-9,39 (25)	24,0 (96)	-10,7 (17)	43,23 (94)	17,56 (77)	-1,41 (48)	-17,9 (14)	-2,99 (51)	6,31 (81)	-10,74 (38)	-19,09 (9)
West-Kazakhstan	12,34 (84)	-12,28 (10)	9,44 (85)	0,8 (51)	0,86 (63)	-2,98 (52)	9,91 (73)	-17,66 (13)	-18,39 (6)	-11,06 (23)	6,19 (67)	-3,56 (44)
Karagandy	3,4 (76)	-2,98 (51)	5,86 (80)	4,82 (71)	8,23 (68)	-20,16 (9)	0,16 (53)	-16,89 (19)	0,67 (56)	2,66 (57)	5,99 (71)	-4,39 (52)
Kostanay	10,2 (76)	-2,47 (40)	2,1 (72)	-1,62 (50)	1,62 (52)	5,05 (69)	-9,83 (32)	1,55 (60)	-5,95 (46)	-11,03 (17)	14,07 (76)	-10,25 (23)
Kyzylorda	5,95 (73)	3,52 (72)	-4,7 (32)	-5,7 (23)	7,08 (73)	-4,27 (55)	-5,22 (42)	-4,97 (30)	3,93 (81)	-2,97 (23)	3,67 (67)	-1,98 (60)
Mangystau	16,1 (96)	0,31 (58)	-6,2 (17)	12,94 (86)	-12,64 (12)	2,33 (74)	-2,09 (47)	-6,06 (33)	-4,96 (5)	-6,74 (7)	9,2 (86)	-1,51 (52)
Pavlodar	16,56 (98)	1,92 (64)	6,48 (88)	0,2 (59)	-3,16 (53)	11,64 (89)	-5,54 (44)	14,2 (77)	-12,6 (19)	5,9 (63)	0,02 (55)	-3,2 (43)
North-Kazakhstan	18,34 (98)	-0,38 (65)	-1,2 (56)	5,48 (84)	3,68 (63)	8,96 (68)	-3,44 (34)	-1,0 (53)	-25,04 (13)	-12,66 (17)	14,23 (81)	-14,41 (15)
Turkestan	41,32 (90)	5,41 (60)	52,6 (98)	-2,99 (40)	26,97 (80)	-1,06 (60)	-5,18 (38)	-10,94 (27)	4,67 (80)	2,46 (76)	-0,24 (59)	-26,36 (18)

Notes: 1. for Mangystau Region assessment was carried out during 1960-2017

2. values above the 95th and below the 5th percentile are highlighted in bold and bright color

Autumn

In autumn of 2017, precipitation on the most part of the territory of Kazakhstan fell within the climatic norm of 98 %. It was dry at some meteorological stations in North Kazakhstan, Zhambyl and Turkestan regions. Extremely dry recorded at weather stations Sholakkurgan (Turkestan region) and Ulanbel (Zhambyl region). Probability of not exceeding at these meteorological stations was 5 % and 1 %, respectively. The autumn in these areas has entered into 10 % of extremely dry seasons (figure 3.2, table 3.1).

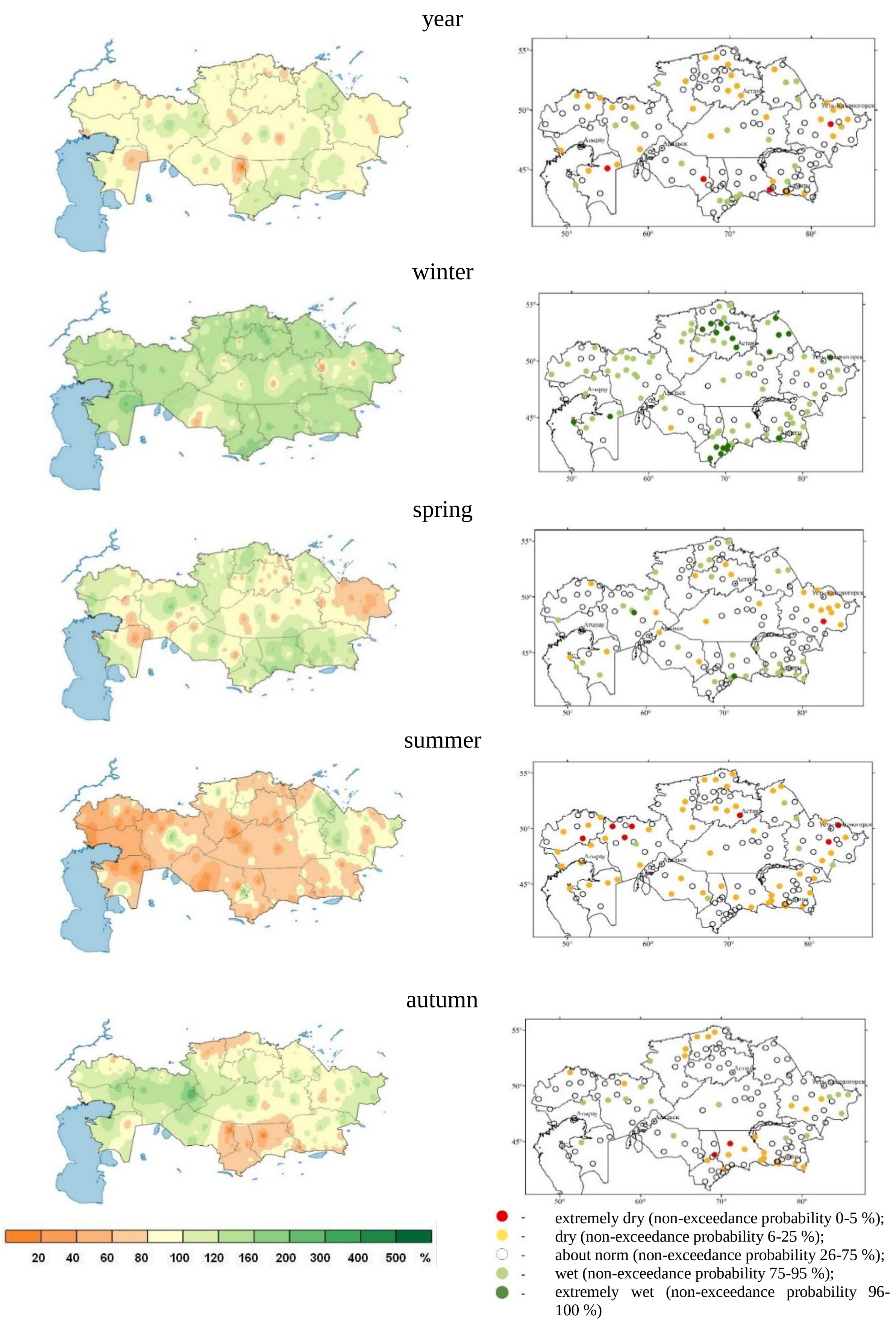


Figure 3.2 – Precipitation in 2017, expressed in % of the norm calculated for the period 1981–2010 (at the left), as well as probabilities of non exceedance of precipitation, observed in 2017, calculated according to the data of the period 1941–2016 (on the right).

For assessment of extremeness of precipitation in 2017 the indexes of climate change offered by the World Meteorological Organization were used. The analysis of some of the most indicative indexes of precipitation and features of distribution of their values over the territory of Kazakhstan in 2017 is given below.

Maximums of daily precipitation in 2017 (index Rx1day). Maximums of daily precipitation in 2017 (index Rx1day). In Figure 3.3, values of the absolute maximums of daily precipitation determined for the period from the beginning of the opening of the weather station for 2016 are shown in red, values of the daily maximums observed in 2017 are shown in blue. Absolute maximum of the daily precipitation in 2017 was not exceeded at any weather station in Kazakhstan.

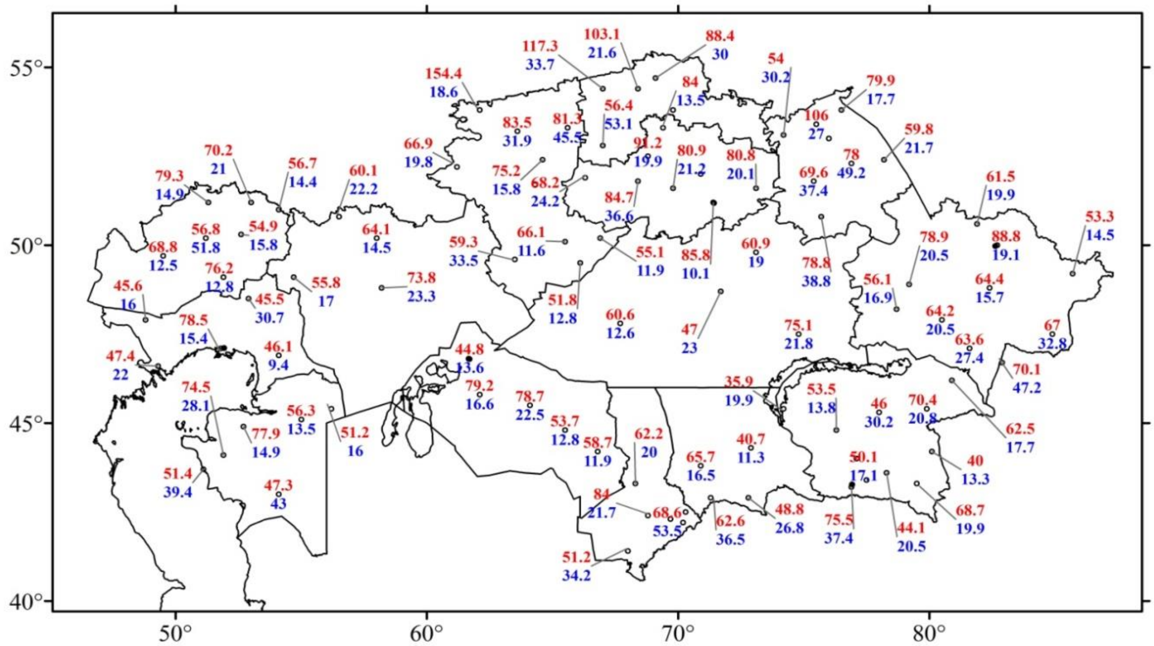


Figure 3.3 – Absolute maximum of the daily precipitation is selecting for the period from the beginning of opening of the meteorological station to 2016 (*marked in red*) and maximum amount of precipitation per day in 2017 (*marked in blue*), mm. *In Square is marked stations with updated record*

Figure 3.4 shows proportion of precipitation in day with an extremely large amount of precipitation (more than the 95th percentile) in the total precipitation for the whole of 2017. The largest proportion of extreme precipitation was observed at the Akkuduk (45 %) and Pavlodar (41 %) meteorological stations. At 10 and weather stations in southern Kazakhstan, the share of extreme precipitation is also quite high (30-38 %).

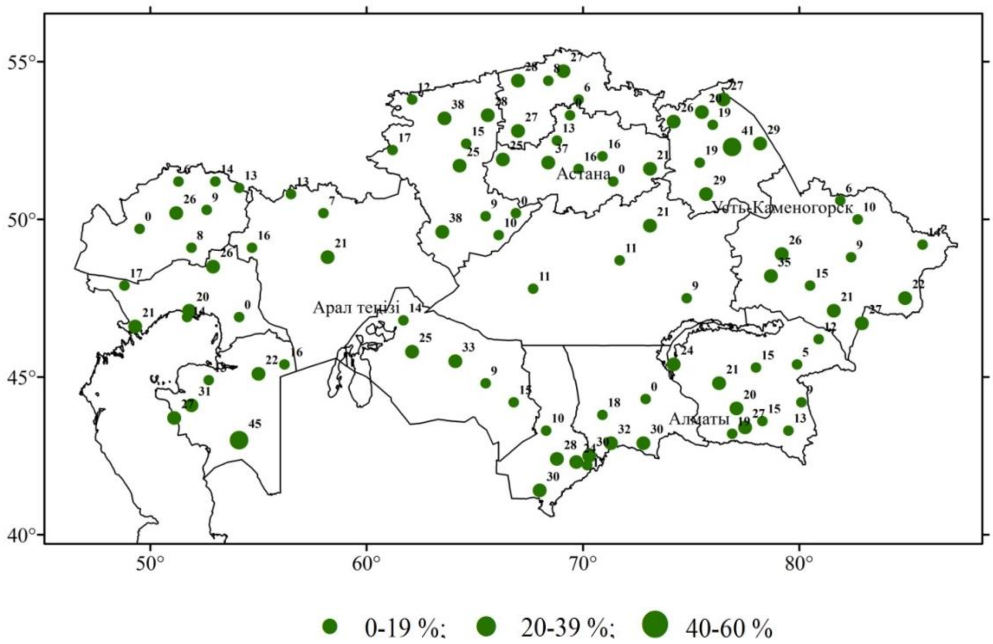


Figure 3.4 – Share (in %) of extreme precipitation in annual precipitation in 2017. Extreme precipitation is calculated as the sum of daily precipitation exceeding the 95th percentile

In the arid climate of Kazakhstan very important index is CDD, which shows ***the maximum duration of the dry period*** *when the daily precipitation is less than 1 mm* (figure 3.5). In 2017, the maximum duration of no-rainless period was recorded at Ganyushkino, Shardara, Shieli stations (102, 116 and 125 days per year, respectively). In the South, South-West and East of the Republic, no-rainless period ranged from 30 to 80 days a year, and in the northern regions of the country from 28 to 116 days a year.

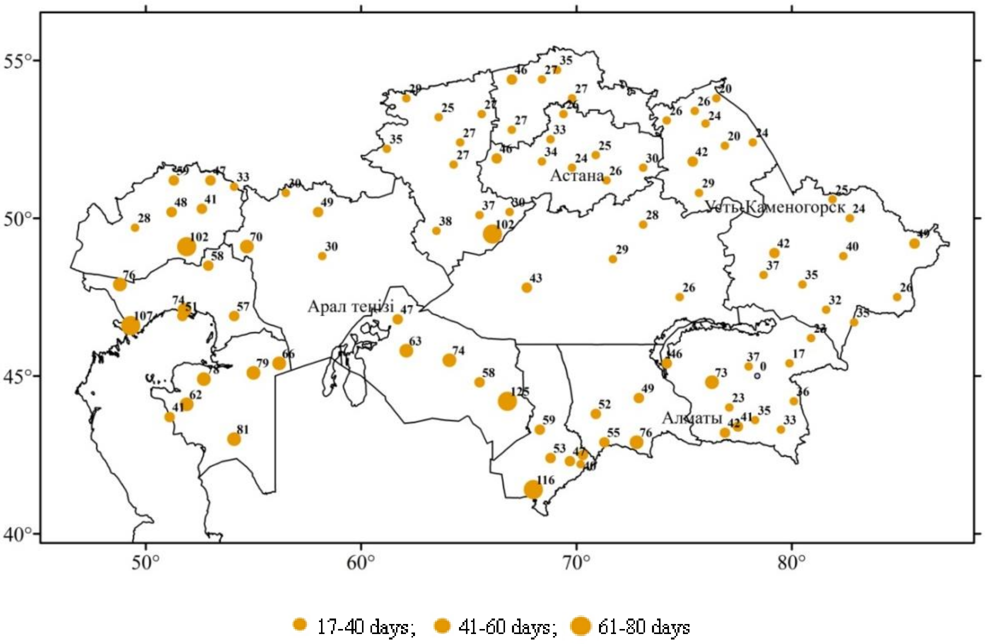


Figure 3.5 – Maximum duration of the no-rainless period (in days) in 2017

In 2017 ***maximum duration of the rainy period***, *when the amount of precipitation was equal or greater than 1 mm* (CWD index), is shown in figure 3.6. According to results of the index calculation, the maximum duration of the period with precipitation was from 6 to 9 days. The longest rainy period was observed at the weather stations Tasaryk and Aul Turar Ryskulov - 9 days.

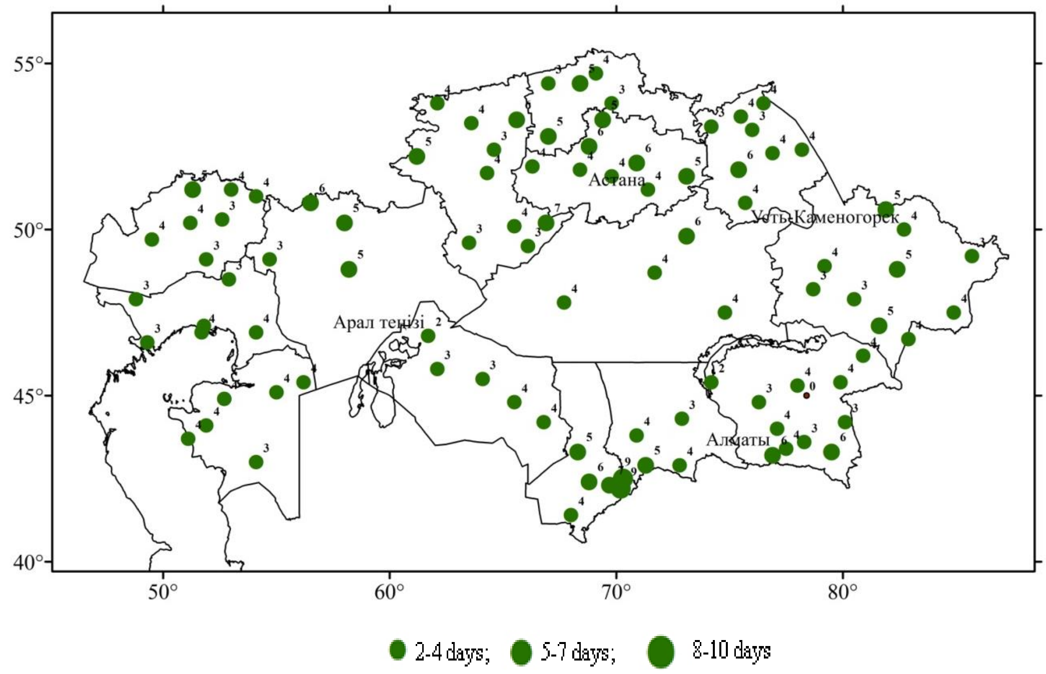


Figure 3.6 – Maximum duration of the period (in days) in 2017, when the amount of precipitation was equal or greater than 1 mm

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 - 2017, calculated relatively to the base period of 1981 and 2010, and spatially averaged over the territory of Kazakhstan and regions are give a general idea about the nature of contemporary changes of mode of atmospheric precipitation. In recent decades, short periods have alternated with positive and negative precipitation anomalies (figures 3.7 and 3.8). Averaged for Kazakhstan for the period 1976 - 2016 there was a tendency for annual precipitation increasing by 5.9 mm/10 years (figure 3.7, table 3.1). In the regional context, almost all regions also showed increasing in precipitation, with exception of Kyzylorda and the West Kazakhstan regions, where precipitation decreases every 10 years by 5.1 mm and 1.0 mm, respectively. Statistically significant increase in annual precipitation was revealed only in the North Kazakhstan region (13 mm/10 % years).

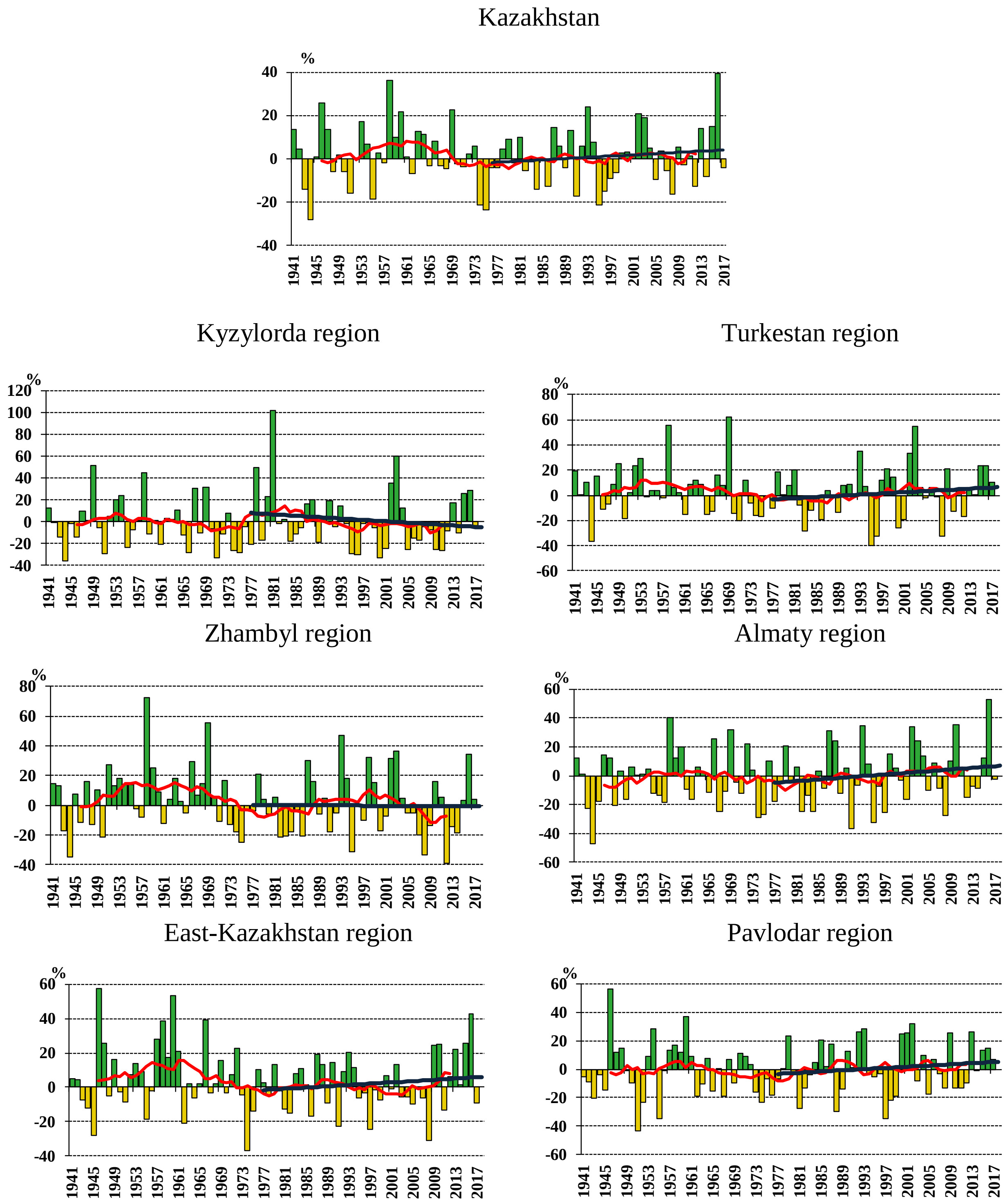


Figure 3.7 - time series of annual precipitation anomalies (in %) for the period 1941-2017, spatially averaged over the territory of Kazakhstan and its regions. Anomalies are calculated relatively for the base period 1981 to 2010. Linear trend for the period 1976 to 2017 highlighted in blue. *Smoothed curve is received by the 11 years sliding averaging. Sheet 1*

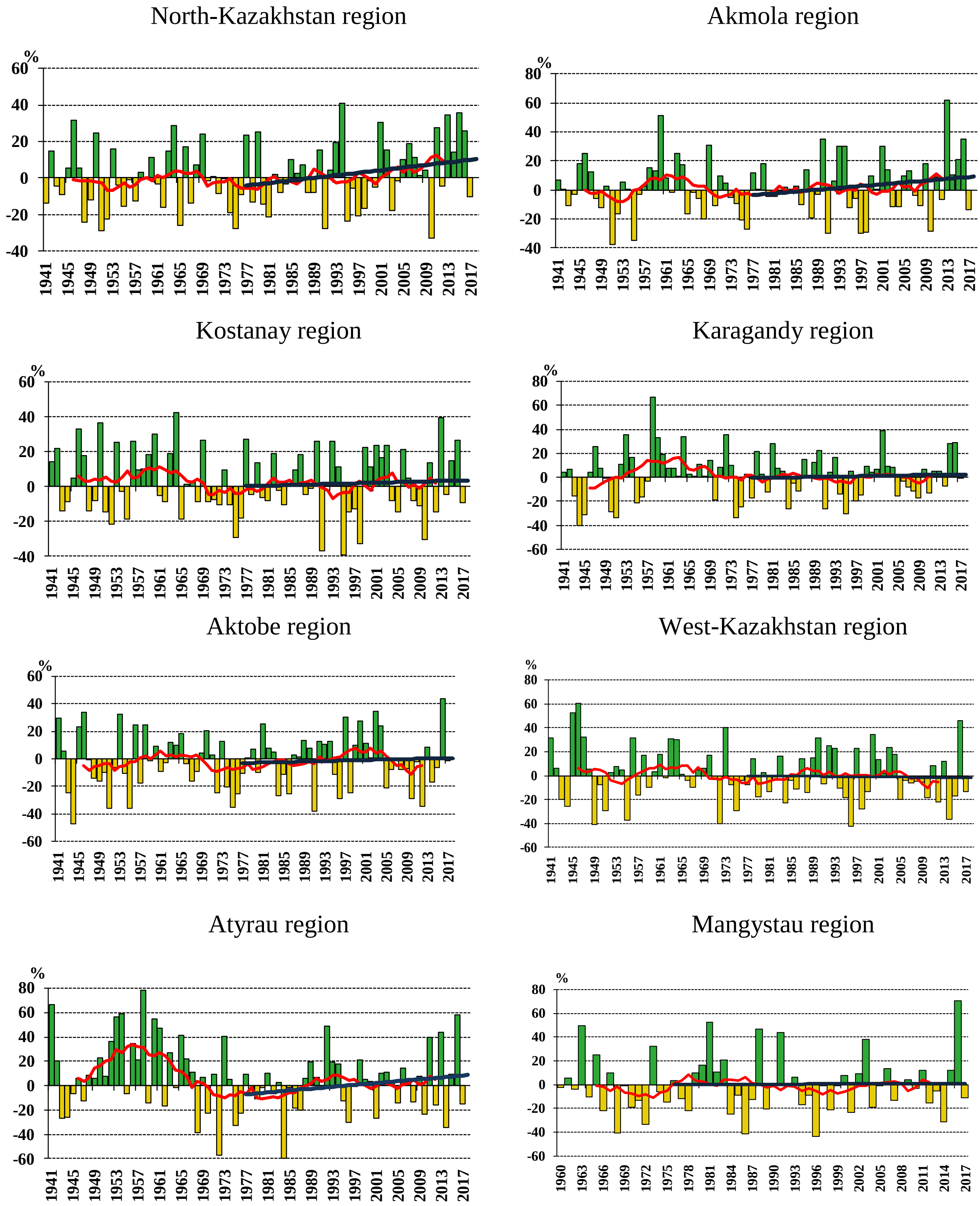


Figure 3.7 - time series of annual precipitation anomalies (in %) for the period 1941-2017, spatially averaged over the territory of Kazakhstan and its regions. Anomalies are calculated relatively for the base period 1981 to 2010. Linear trend for the period 1976 to 2017 highlighted in blue. *Smoothed curve is received by the 11 years sliding averaging. Sheet 2*

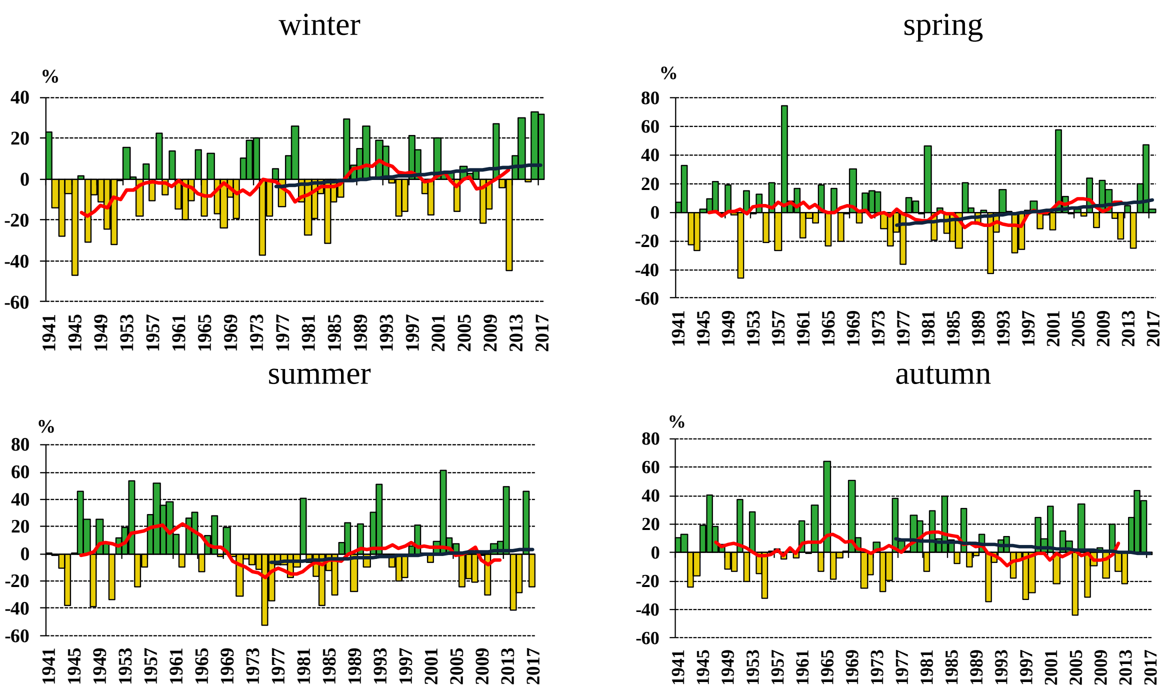


Figure 3.7 - time series and linear trends of seasonal precipitation anomalies (in %) for the period 1941 2017, spatially averaged over the territory of Kazakhstan and its regions. Anomalies are calculated relatively for the base period 1981 to 2010. Linear trend for the period 1976 to 2017 highlighted in blue. *Smoothed curve is received by the 11 years sliding averaging. Sheet 2*

For the period 1976-2017 averaged over regions during all seasons is observed increasing tendency in rainfall, except for autumn season, when reduction of rainfall was 1.3 mm/10 years (figure 3.8, table 3.1). All received seasonal trends are statistically not significant.

Spatial distribution of the linear trend coefficient values for annual, seasonal and monthly rainfall (%/10 years) calculated for the period 1941-2017 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 (or rainfall) over the territory of Kazakhstan were mostly positive, but insignificant. Statistically significant increase in precipitation is observed at some weather stations in the Western, Northern, Central and South-Eastern parts of the Republic (4-10 %/10 years). At the weather station Aktogay, Besoba (Qaraghandy), Kazakhstan (Kostanay region) and Uyuk (Zhambyl region) sustained negative tendencies are amounted to 8-14 %/10 years.

The greatest significant rate of increase in winter precipitation (8-20 %/10 years) is observed in the West, North and South-East of Kazakhstan. The greatest contribution to the positive trend of the winter season for the Western and South-Eastern regions was made in January and February, for the Northern regions – in December.

Table 3.1 – 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 - 2017. Anomalies are calculated relatively for the base period 1981 - 2010.

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	5,9	3	2	4	3,4	6	1,9	1	-1,3	2
	%	1,4		2,6		4,2		2,3		-2,5	
Kyzylorda	mm	-5,1	2	-1,2	1	-0,8	0	0	0	-3,2	**8**
	%	-3,2		-1,6		-1,1		0,8		-10,5	
Turkestan	mm	11,6	3	5,4	3	3,7	1	2,6	2	-0,2	0
	%	2,4		2,3		2,2		6,5		0,4	
Zhambyl	mm	1,8	0	2,2	1	-3	2	3,5	2	-0,6	0
	%	0,3		2,4		-3,7		6,2		-1,9	
Almaty	mm	11,8	3	5,7	**9**	2,9	1	2,5	1	1	0
	%	2,9		7,2		2,3		2,4		1,4	
East-Kazakhstan	mm	6	2	1,6	1	2,2	1	4	5	-1,2	0
	%	1,9		2,5		2,2		4,7		-1,5	
Pavlodar	mm	6,5	2	0,3	0	4,3	**9**	3,2	1	-1,1	0
	%	2,1		0,7		7,5		2,6		-1,6	
North-Kazakhstan	mm	13	**6**	2,1	2	9,4	**22**	2,3	0	0	0
	%	3,5		3,1		13,2		1,6		-0,1	
Akmola	mm	10,8	4	4,3	**10**	2,9	3	5,5	2	-1,8	1
	%	3,1		8,4		3,9		4,3		-2,4	
Kostanay	mm	4,5	1	-0,1	0	8,2	**20**	0,7	0	-4,4	**7**
	%	0,9		-0,4		11,3		0,7		-6,6	
Karagandy	mm	4,5	2	-0,2	2	1,7	1	6,1	**8**	-3,3	7
	%	0,8		-3,2		1,8		7,7		-7,9	
Aktobe	mm	2,2	0	0,7	0	7	**8**	-2,2	1	-3,3	4
	%	0,9		1,2		9,3		-2,5		-5,3	
West-Kazakhstan	mm	-1	0	-2,9	5	6,6	**12**	-4,6	4	-0,2	0
	%	-0,4		-4,8		10,2		-6,5		-0,2	
Atyrau	mm	7	5	3,6	**8**	7,4	**14**	-3,2	2	-0,5	0
	%	3,8		9,0		15,0		-6,7		-1,5	
Mangystau	mm	0,8	0	4	**12**	-3,6	4	1,5	1	-1,1	1
	%	0,3		11,3		-6,9		4,4		-3,6	

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

Steady decreasing in rainfall was observed at the weather stations of the West Kazakhstan, Kostanay, Karaganda and East Kazakhstan regions (9-25 % /10 years).

Increasing in rainfall ***in spring*** can be traced almost throughout the country. Significant positive trends in the North and North-West of Kazakhstan amounted to 9-25 %/10 years. The greatest contribution to increase in rainfall in the spring period was made in March, when significant positive trends were observed in most of the territory of the republic (figure 3.10).

In summer, decreasing in moisture is observed in the Western part of the territory of Kazakhstan (0,3-20 %/10 years), but trends are mostly insignificant, with exception of the weather station Urda, where significant decreasing in rainfall was 16 % /10 years. June and August are becoming the drier months of this season. Statistically significant increase in precipitation was observed at weather stations of Karaganda region – Aksu-Ayuly, Zhanaarka, Zharyk (10-12 %/10 years) and Barshatas station of the East Kazakhstan region (15 %/10 years).

Autumn season for the study period is becoming more dry, especially in September and October (figure 3.10). Negative trends in the autumn period from 2 to 39 %/10 years are statistically significant at the weather stations of Kyzylorda, Aktobe, Kostanay and Karaganda regions.

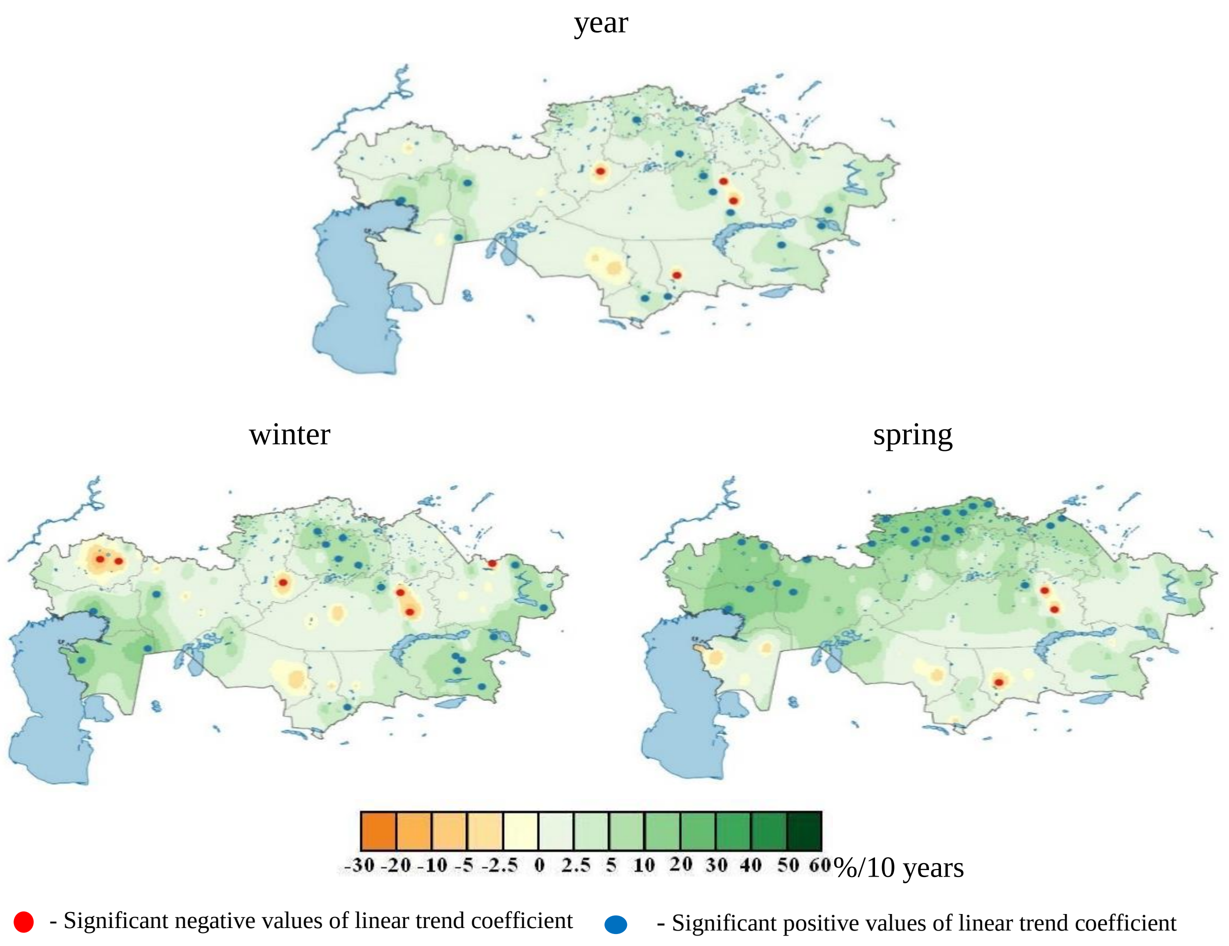
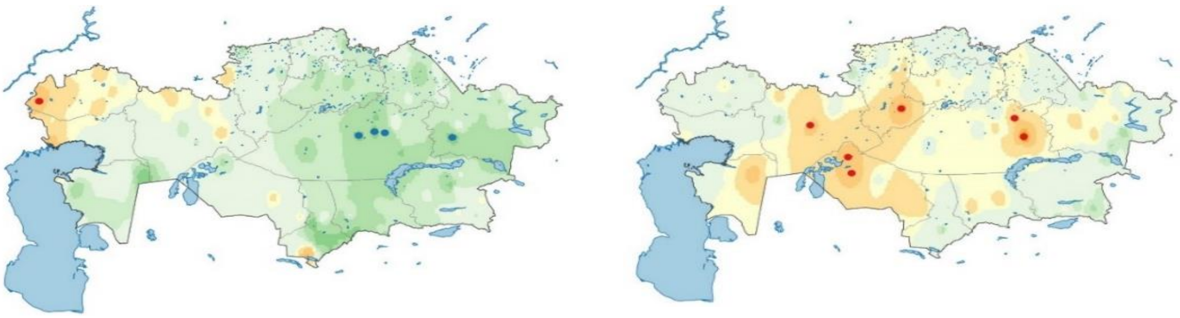
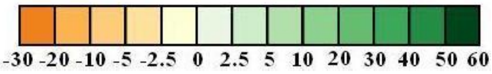


Figure 3.9 – Spatial distribution of the linear trend coefficient values of annual and seasonal precipitation (% /10 years) calculated for the period 1976 - 2017, Sheet 1

summer autumn





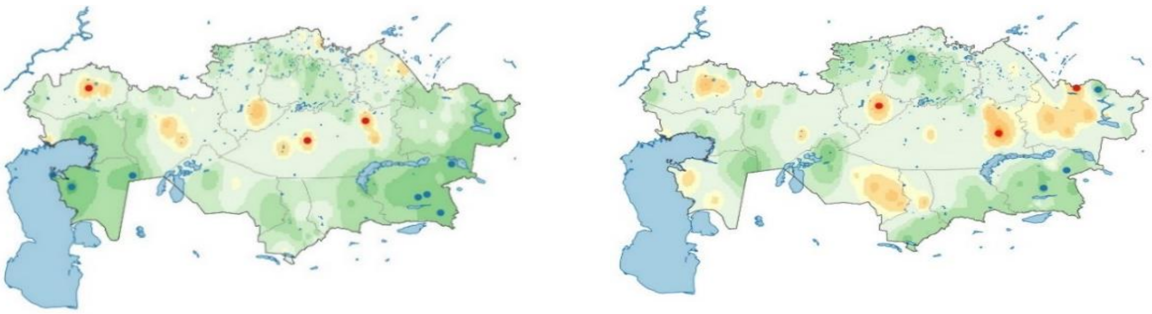
%/10 years

- Significant negative values of linear trend coefficient

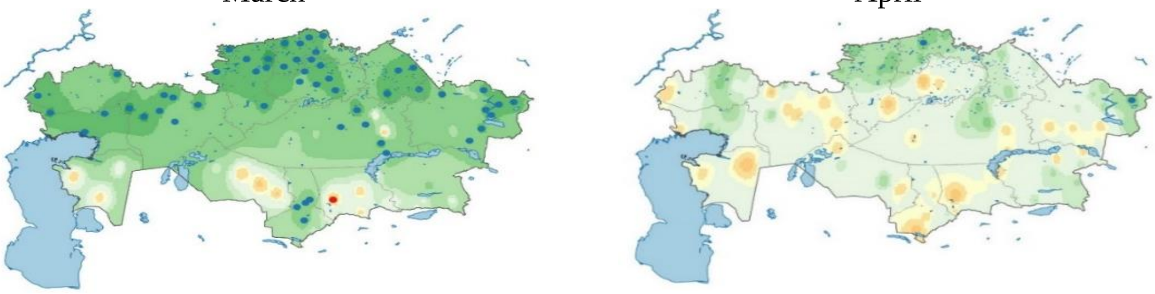
- Significant positive values of linear trend coefficient

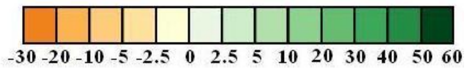
Figure 3.9 – Spatial distribution of the linear trend coefficient values of annual and seasonal precipitation (% /10 years) calculated for the period 1976 - 2017, Sheet 2

January February



March April





%/10 years

- Significant negative values of linear trend coefficient

- Significant positive values of linear trend coefficient

Figure 3.10 – Spatial distribution of values of the linear trend coefficient of monthly precipitation (%norm/10 years), calculated for the period 1976 - 2017. Sheet 1

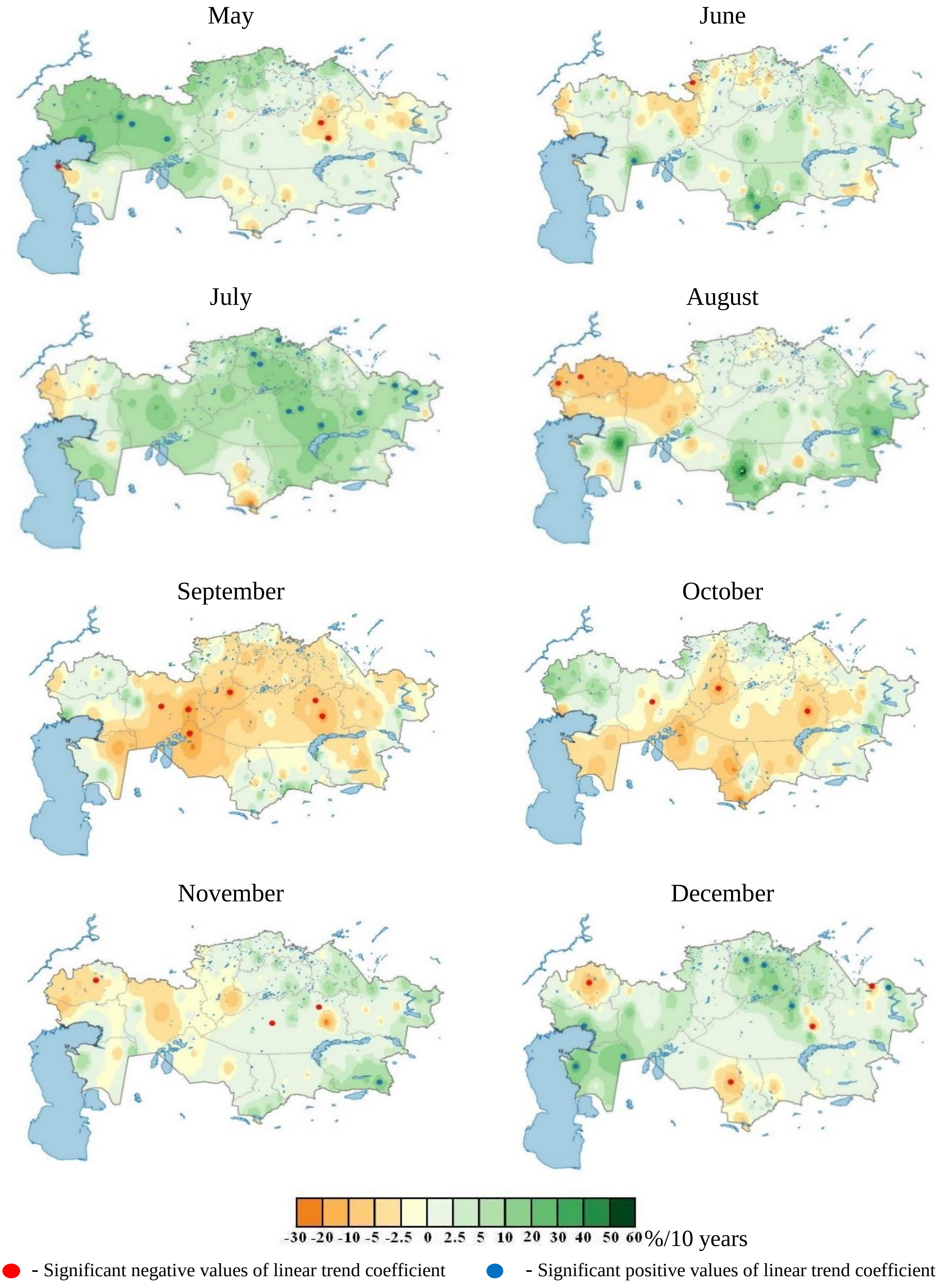


Figure 3.10 – Spatial distribution of values of the linear trend coefficient of monthly precipitation (%norm/10 years), calculated for the period 1976 - 2017. Sheet 2

3.3 Trends in precipitation extremes

Trends in precipitation extremes were analyzed for the period 1976 to 2017 on 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.

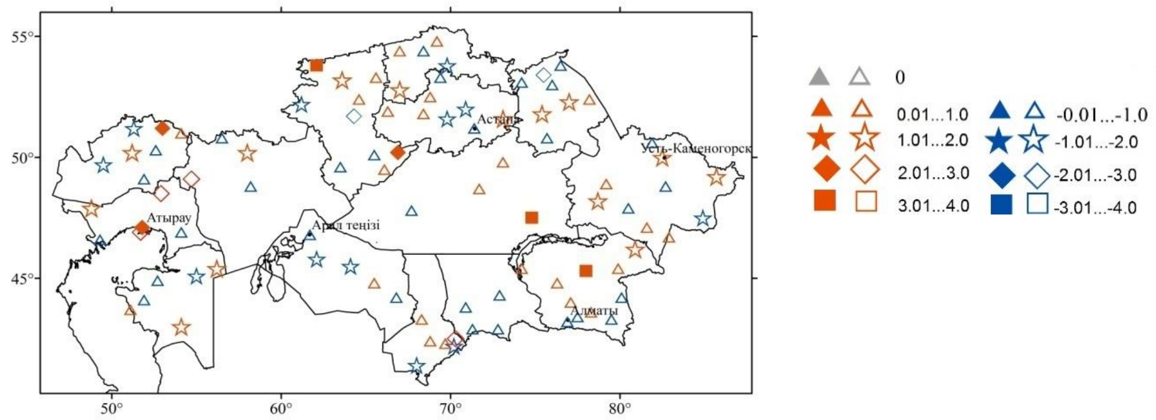


Figure 3.11 – Spatial distribution of the linear trend coefficient of maximum in the year values of daily precipitation (mm/10 years) calculated for the period 1976 - 2017. *Designations of gradations are shaded in cases of statistical significance of trend*.

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).

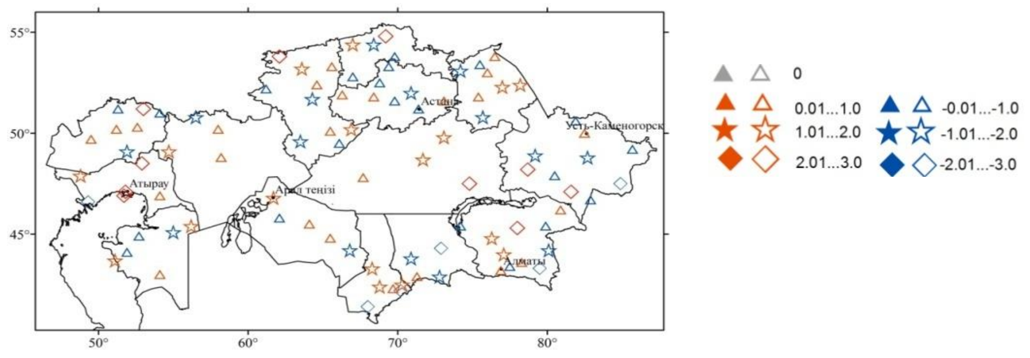


Figure 3.12 – Spatial distribution of the linear trend coefficient of the share (%/10 years) of extreme precipitation in annual precipitation amounts calculated for the period 1976 - 2017. *Extreme precipitation is calculated as the sum of daily precipitation exceeding the 95th percentile. Gradation 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).

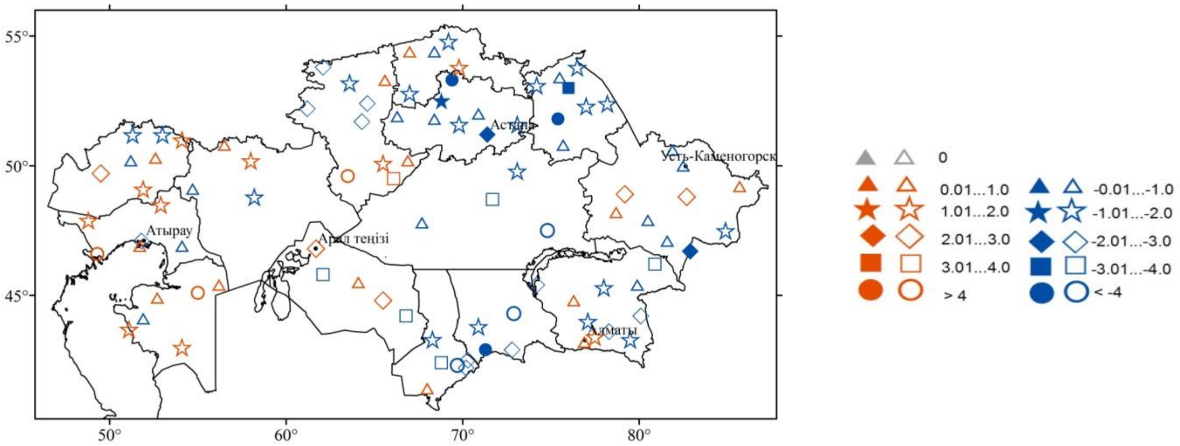
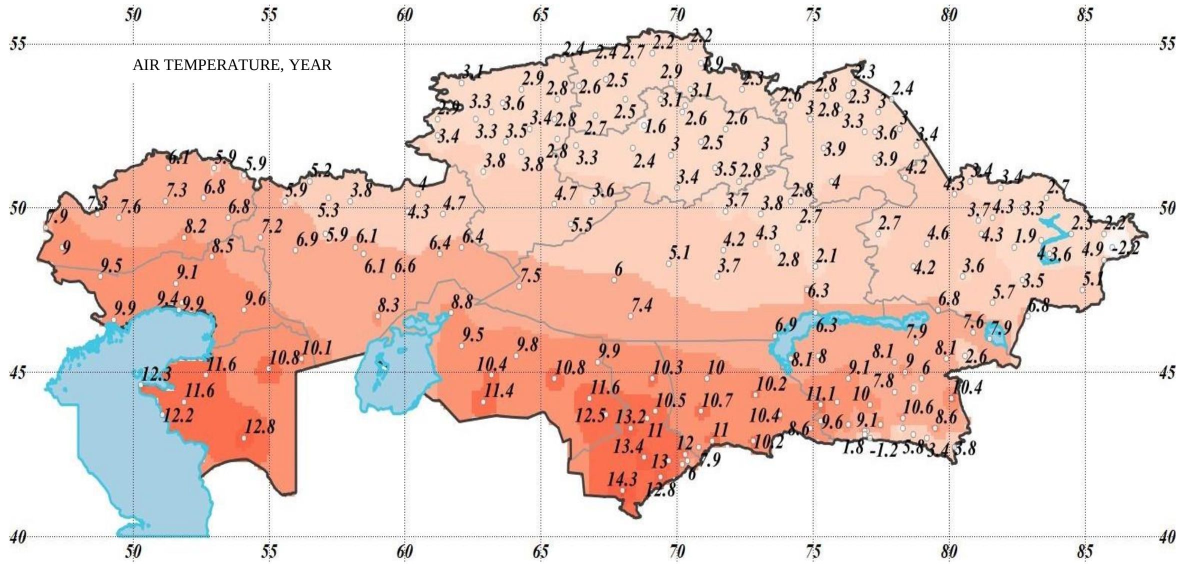


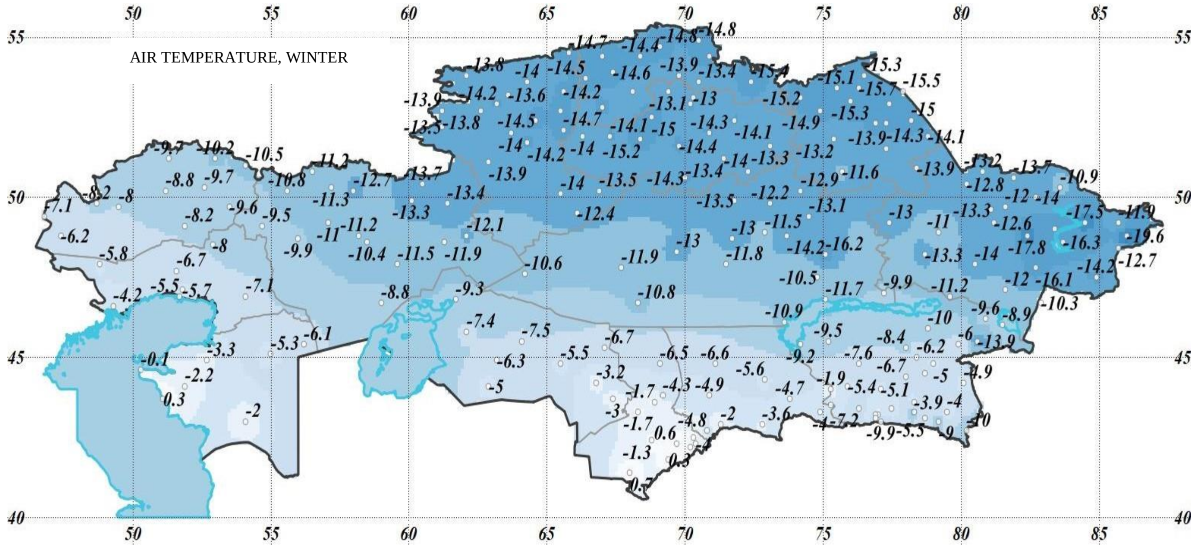
Figure 3.13 – Spatial distribution of the linear trend coefficient of maximum duration of the no rainless period (days/10 years) calculated for the period 1976 - 2017. Gradation. Symbols are shaded in cases of statistical significance of trend

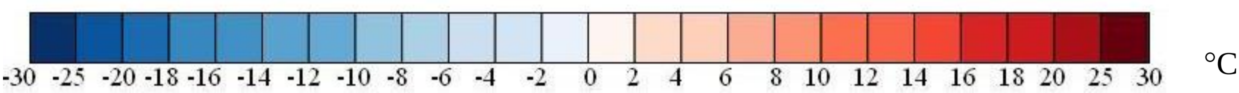
Values of the CDD index are very important characteristic of climate, especially for agriculture.

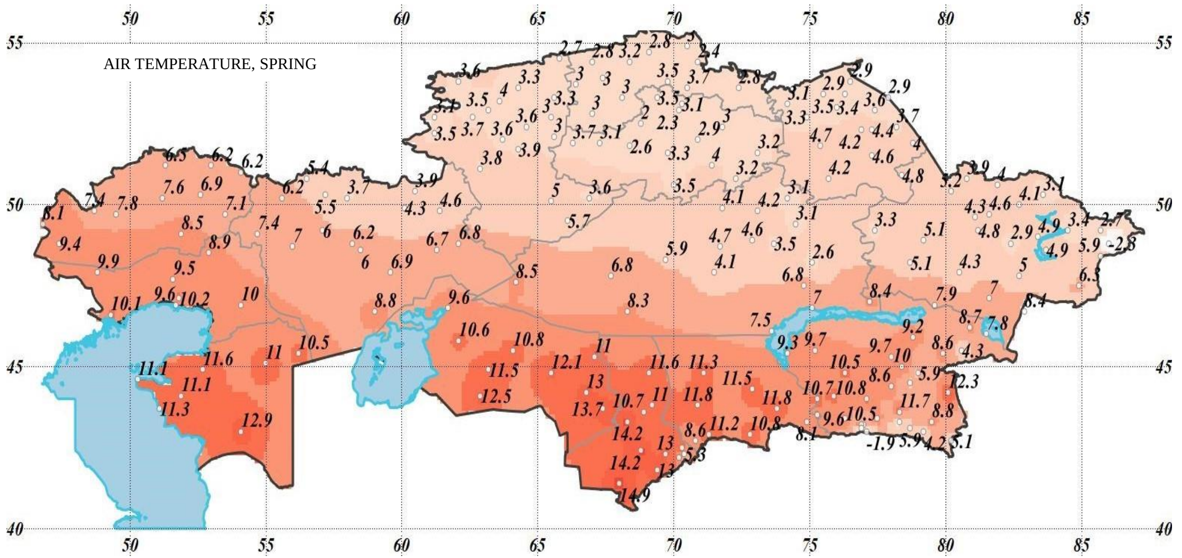
ANNEX 1

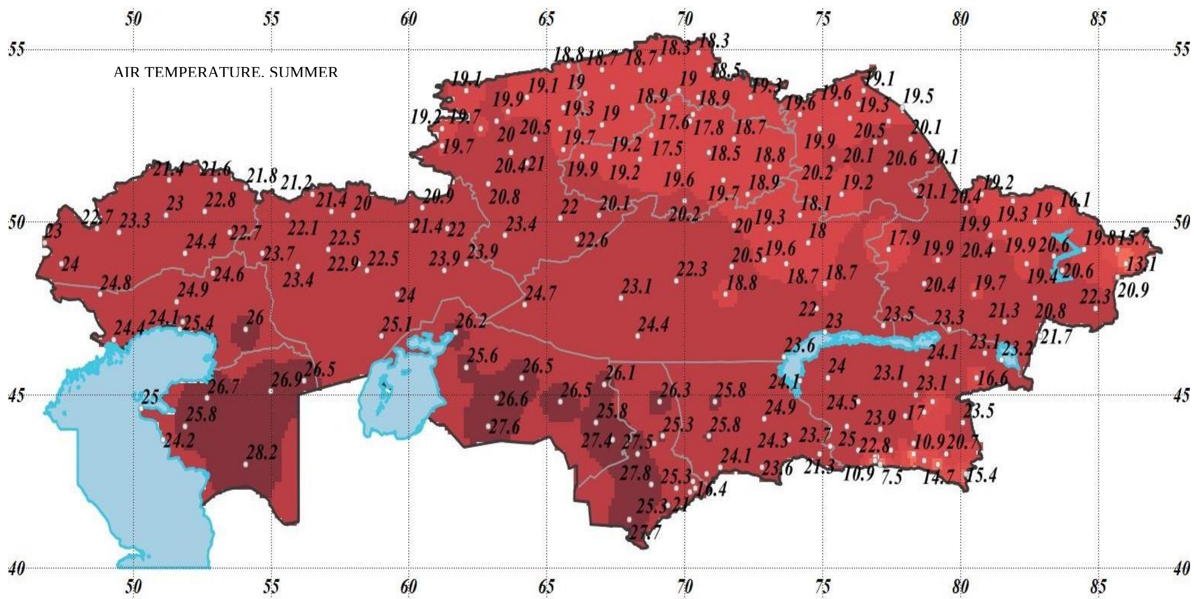
SPATIAL DISTRIBUTION OF ANNUAL MEAN AND MEDIUM-SEASON AIR TEMPERATURES IN KAZAKHSTAN, CALCULATED FOR THE PERIOD 1981-2010

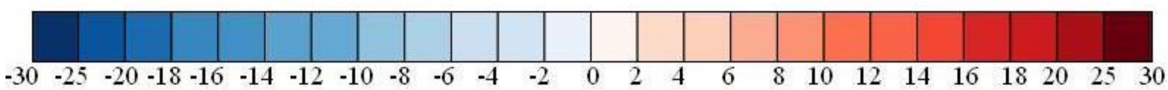







AIR TEMPERATURE, SPRING


AIR TEMPERATURE, SUMMER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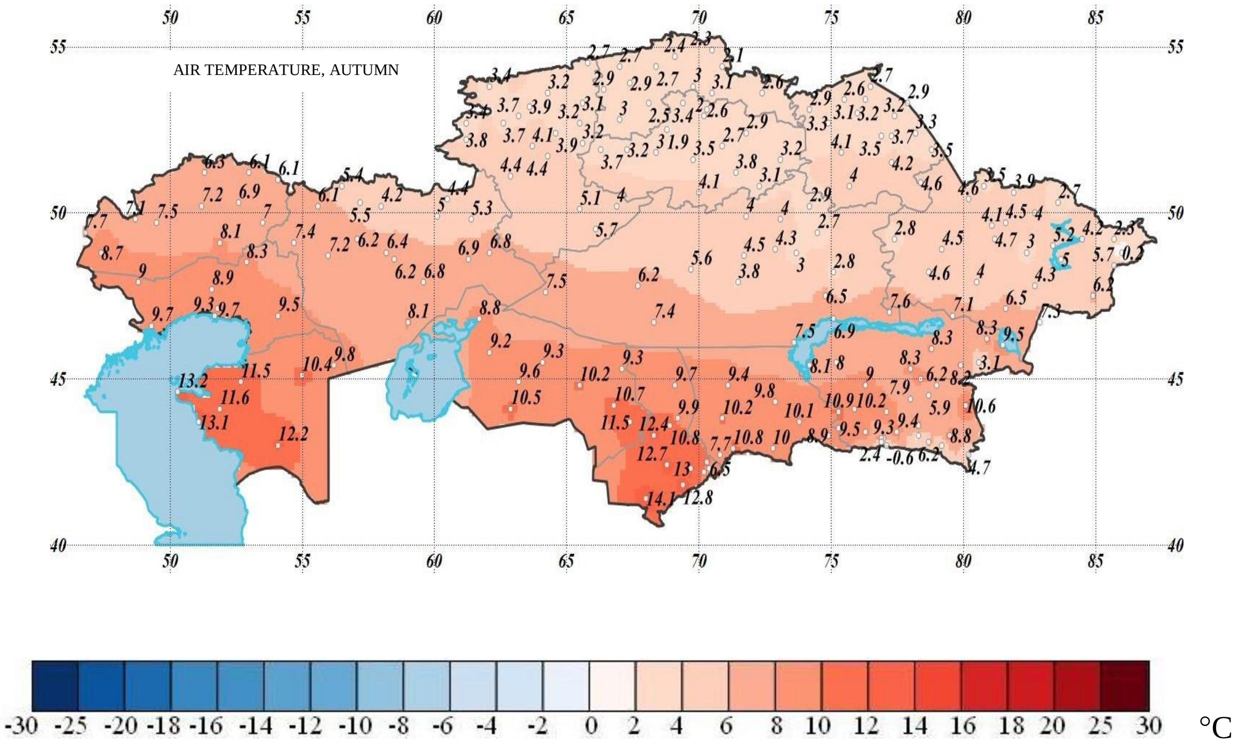
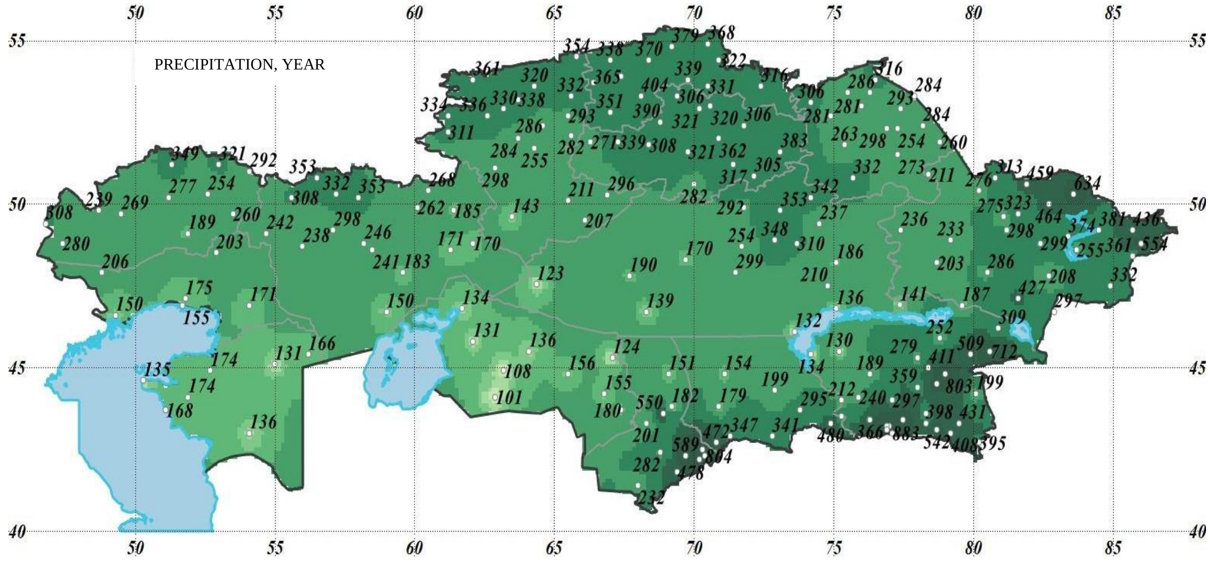
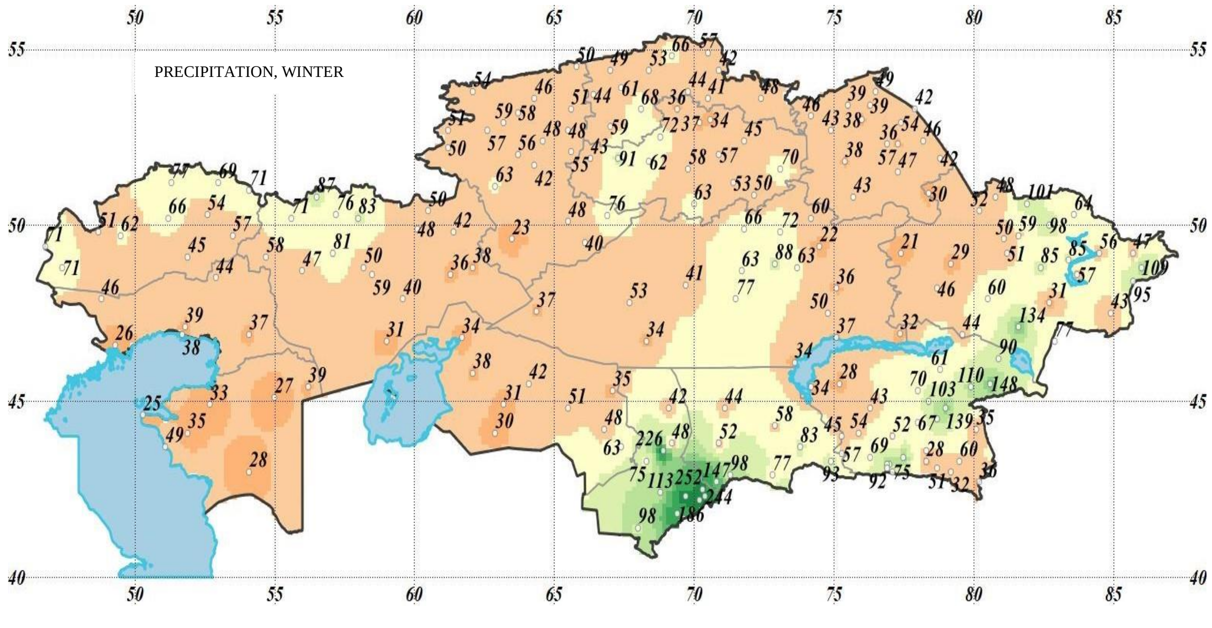
°C

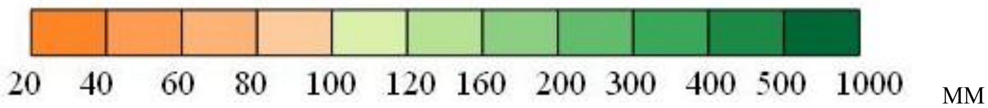

AIR TEMPERATURE, AUTUMN
-30 -25 -20 -18 -16 -14 -12 -10 -8 -6 -4 -2 0 2 4 6 8 10 12 14 16 18 20 25 30
°C

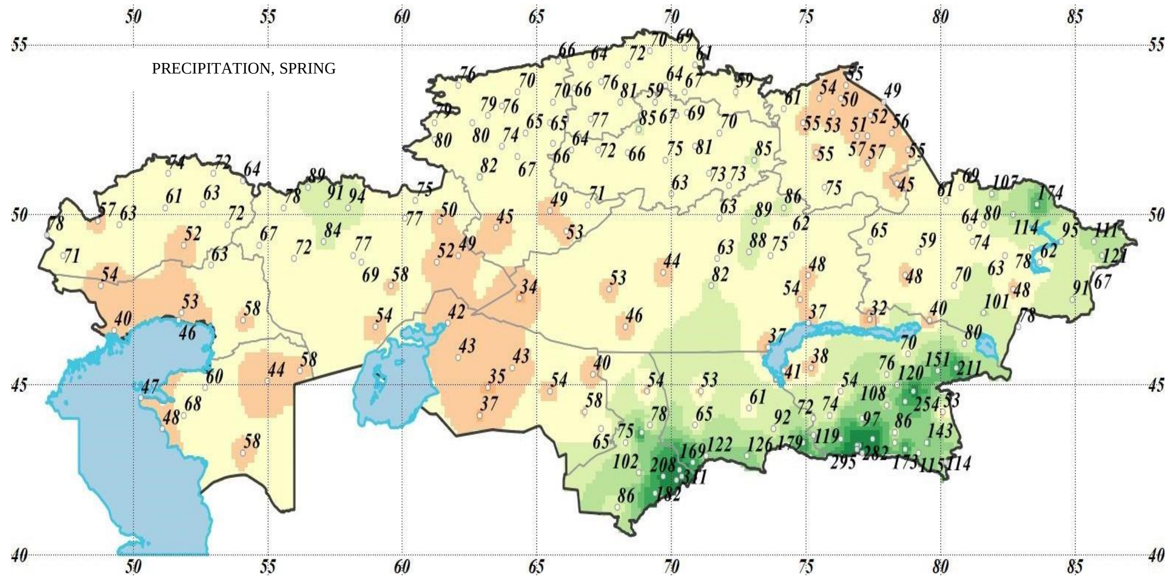
ANNEX 2

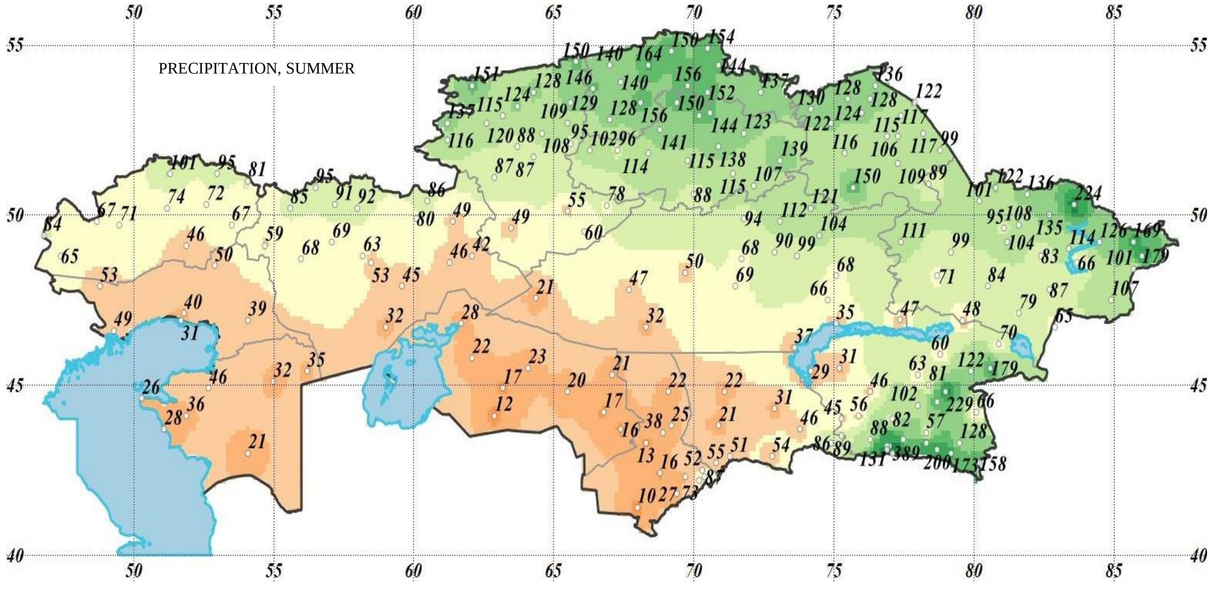
SPATIAL DISTRIBUTION OF ANNUAL AND SEASONAL SUM OF PRECIPITATION IN KAZAKHSTAN, CALCULATED FOR THE PERIOD 1981-2010

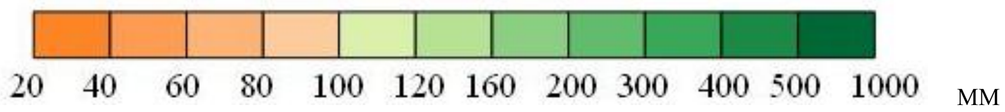







PRECIPITATION, SPRING


PRECIPITATION, SUMMER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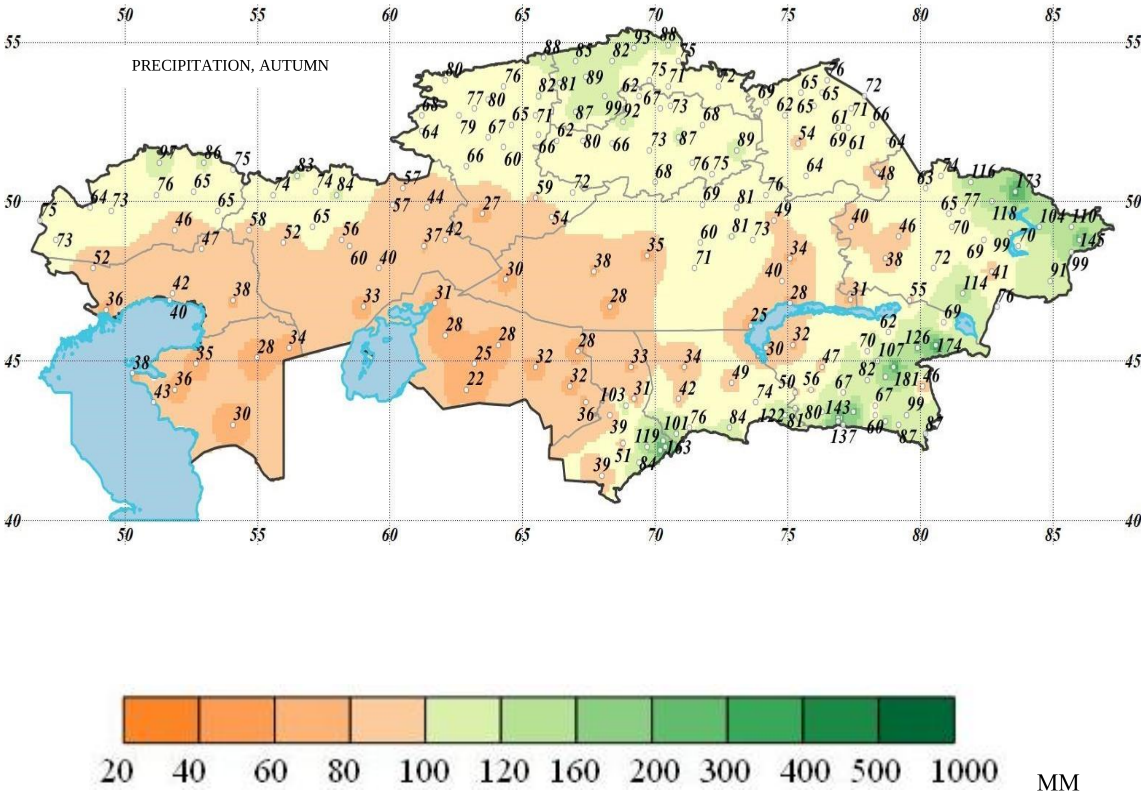
MM


PRECIPITATION, AUTUMN
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MM