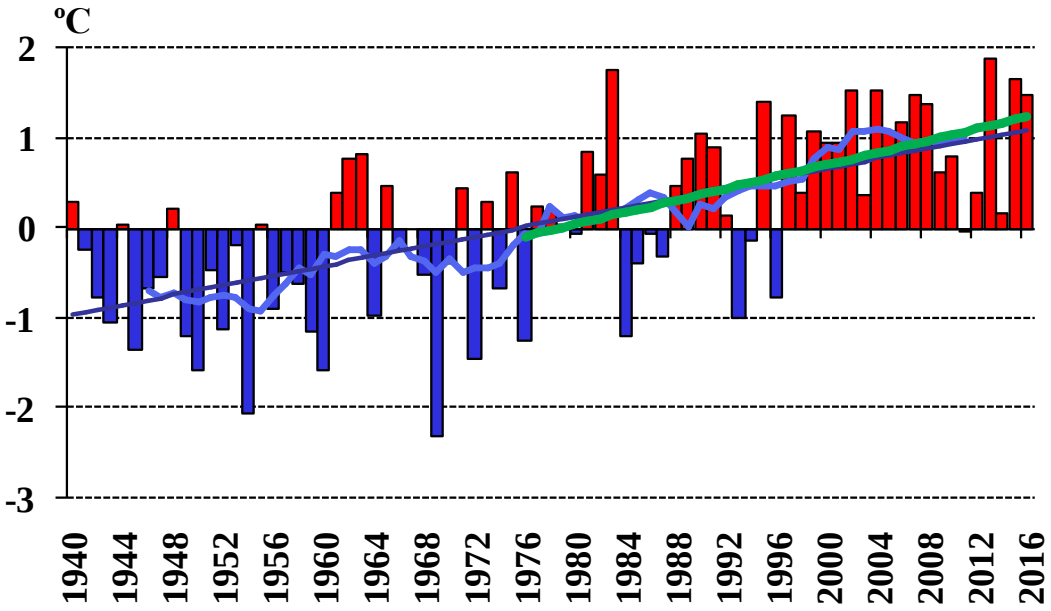
Ministry of Energy of the Republic of Kazakhstan
Republican State Enterprise "Kazhydromet"

Scientific Research Center

ANNUAL BULLETIN OF CLIMATE CHANGE MONITORING IN KAZAKHSTAN:

2016



Astana, 2017

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INTRODUCTION

Climate is a natural resource and is very important for our well-being, health and prosperity. National Hydrometeorological services collect and analyze information that helps decision-makers and users to plan and adapt their activities and projects within the expected conditions. Thus, decisions can be made in the planning process, reduce risks and optimize socio-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.

The study of regional climate and continuous monitoring of its change is one of the priority tasks of the National Hydrometeorological service "Kazhydromet." Since 2010 the National Hydrometeorological Service annually prepares and publishes the bulletin on the climate state in Kazakhstan to provide reliable scientific information on climate, its variability and change. Taking into account the geographic location of Kazakhstan and its vast territory, the observed changes in climatic conditions in different regions can have both negative and positive impacts on the biophysical system, economic activities and social services. A better understanding of climate formation and climate change are critical to assess the potential impact and to take timely and appropriate adaptation measures for sustainable development of Kazakhstan.

The given bulletin describes the climatic conditions of 2016 including the meteorological extremes assessment. It also includes historical information about climate variability and trends since the 1940's. Also in this bulletin added distribution maps of air temperature and precipitation averaged over the seasons for the period 1961...1990 (see. Annex 1 and 2).

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

1) The series of average monthly air temperature and monthly precipitation from 1941 to 2016. Data of more than 190 weather stations were used to assess climate normal for 1961...1990. Also experts used more than 110 weather stations data to assess trends;

2) The series of daily maximum and minimum air temperatures and daily precipitation from 1941 to 2016 (more than 90 meteorological stations).

Basic approaches and methods.

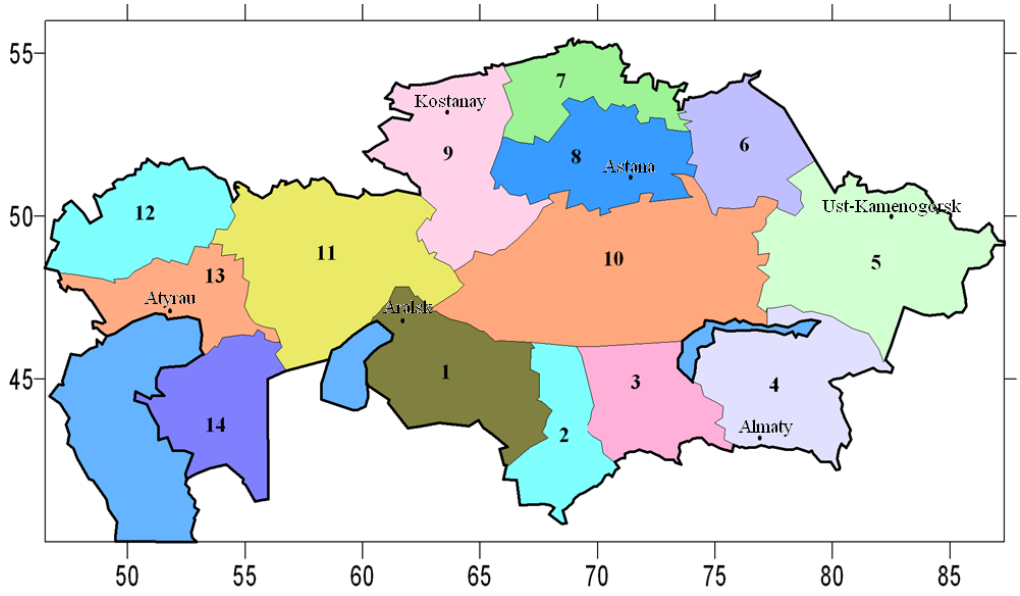
Climate "normal" in the bulletin means average value of the considered climatic variable for the 1961…1990. Temperature anomalies are calculated as the deviation of the observed values from the norm. Precipitation anomalies are usually considered both as deviation from the norm (like temperature) and as percentage of the norm, i.e. ratio of observed precipitation and the norm. Probability of non-exceedance shows the percentage frequency of particular anomaly in the observation record.

Linear trend factors defined by the least-squares method were used as climate change indicators for a certain period. Trend significance was assessed with the determination factor (R^2), representing a percentage share of variance.

The surface air temperature and precipitation trends were assessed both for individual stations and on average for the 14 administrative areas in Kazakhstan. Experts fitted observation time series to the linear function using the least-squares method. The mean anomalies for the

area were calculated by averaging the station data anomalies. The map below shows the administrative areas in Kazakhstan.

Experts used the WMO climate change indices to assess extreme temperatures and precipitation in 2016. Some indexes are based on a fixed threshold values for all stations, the other - on the threshold values, which can vary from station to station. In the latter case, the threshold values are defined as the corresponding percentile of the data series. 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.



Administrative areas in Kazakhstan

1 – Kyzylorda oblast
2 – Southern Kazakhstan oblast
3 – Zhambyl oblast
4 – Almaty oblast
5 – Eastern Kazakhstan oblast
6 – Pavlodar oblast
7 – Northern Kazakhstan oblast
8 – Akmola oblast
9 – Kostanay oblast
10 – Karaganda oblast
11 – Aktobe oblast
12 – Western Kazakhstan oblast
13 – Atyrau oblast
14 – Mangystau oblast

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1 REVIEW OF THE GLOBAL CLIMATE CHANGE AND ITS STATE IN 2016

Every year, the World Meteorological Organization (WMO) issues a Statement on the State of the Global Climate based on data provided by National Meteorological and Hydrological Services (NMHSs) and other national and international organizations. For more than 20 years, these reports have been published in the six official languages of the United Nations to inform governments, international agencies, other WMO partners and the general public about the global climate and significant weather and climate trends and events at the global and regional levels.

At the request of the Conference of the Parties (COP) to the UNFCCC at its annual session, which took place in Marrakesh in 2016, both the annual WMO Statement on the State of the Global Climate and the annual WMO Greenhouse Gas Bulletin will from now on be submitted to COP to inform its decisions on the implementation of the Paris Agreement. In this way, the Statements will complement the assessment reports that the Intergovernmental Panel on Climate Change (IPCC) produces every six to seven years. In addition to providing information about scientific progress, WMO is committed to supporting its Members in building operational climate services that enable climate resilience and adaptation.

The year 2016 was the warmest on record in all major global surface temperature datasets, although, in some, the difference between 2016 and the second warmest year, 2015, was within the margin of uncertainty. In the three dataset mean used by WMO, 2016 was 0.83 °C ± 0.1 °C warmer than the average for the 1961–1990 reference period (0.52 °C above the 1981–2010 average), 0.06 °C above the previous highest value set in 2015. This is also about 1.1 °C above the pre-industrial period.

Each of the 16 years since 2001 has been at least 0.4 °C above the 1961–1990 average, a mark which, prior to 2001, had only been reached once, in 1998. Global temperatures continue to be consistent with a warming trend of 0.1 °C to 0.2 °C per decade.

Global temperatures in 2016 were substantially influenced by the strong El Nico event of 2015/2016, especially early in the year. Temperatures in years in which strong El Nico events finish, such as 1973, 1983 and 1998, are typically 0.1 °C to 0.2 °C warmer than background levels (as indicated by 10-year mean temperatures centered on each of those years) and temperatures in 2016 were consistent with that pattern.

Warmth extended almost worldwide in 2016. Temperatures were above the 1961–1990 average over the vast majority of the world's land areas, the only significant exceptions being northern and central Argentina, and parts of south-western Australia.

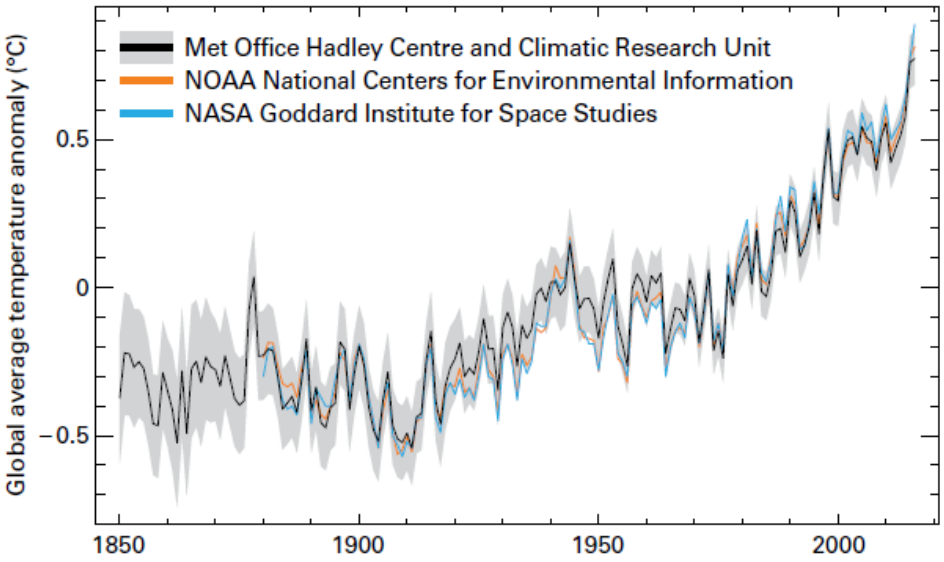


Figure 1.1 – Global average temperature anomalies (1961–1990 reference period) for the three major datasets used in this Statement. The grey shading indicates the uncertainty in the HadCRU dataset. *Source: UK Met Office Hadley Centre*

The rate of energy increase in the climate system – the Earth's energy imbalance – is the most fundamental metric that defines the rate of global climate change. On timescales longer than about a year, the vast majority (more than 90%) of the Earth's energy imbalance goes into heating the oceans. As the oceans warm, they expand, resulting in both global and regional sea-level rise. Increased ocean heat content accounts for about 40% of the observed global sea-level increase over the past 60 years. Global sea levels rose strongly during the 2015/2016 El Nico, and values reached new record highs in the early 2016.

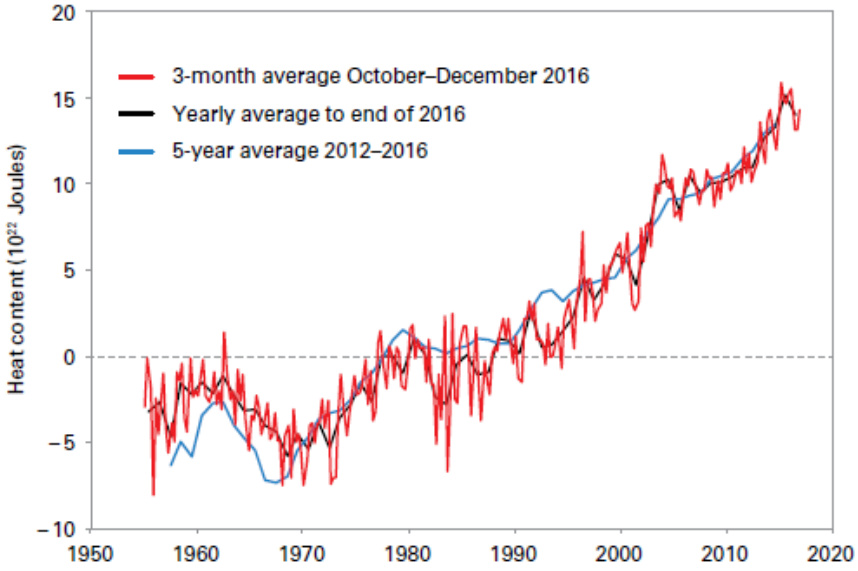


Figure 1.2 - Total global ocean heat content (in units of 1022 J) for the 0–700 m layer, compared with 1955–2006 reference period. Data averaged over periods of three months (red line), one year (black) and five years (blue). *Source: prepared by WMO using data from the US NOAA National Centers for Environmental Information*

Globally averaged sea-surface temperatures in 2016 were the warmest on record. The very warm ocean temperatures contributed to significant coral bleaching in some tropical waters. Among the areas significantly affected was the Great Barrier Reef off the east coast of Australia, where record high sea-surface temperatures occurred in March. Coral mortality of up to 50% was reported in northern parts of the reef north of Lizard Island.5 Later in the year, severe coral bleaching was also reported in the Okinawa region of Japan, with government surveys in November and December revealing coral mortality up to 70% in the Sekisei lagoon.

Arctic sea-ice extent was well below average throughout 2016 and was at record low levels for large parts of the year. The seasonal maximum of 14.52 million km^2 on 24 March was

the lowest seasonal maximum in the 1979–2016 satellite record, just below that of 2015. In 2016, the annual minimum was equal to the second lowest on record in 2007.

Antarctic sea-ice extent was close to the 1979–2015 average for the first eight months of 2016, reaching a seasonal maximum of 18.44 million km^2 on 31 August. This was the earliest seasonal maximum on record. The spring melt was then exceptionally rapid, resulting in a November mean extent of 14.54 million km^2 – by far the lowest on record (1.0 million km^2 below the previous lowest) – and 5.7 standard deviations below average: easily the largest monthly anomaly in the satellite record. The reasons for the rapid collapse of Antarctic sea ice in late 2016 are not yet completely understood, although local winds are likely to have been a substantial contributor.

Preliminary data from the World Glacier Monitoring Service indicate that mountain glaciers continued to melt in 2016. Those reference glaciers for which 2015/2016 data are available show a mean mass balance of −858 mm, with only one of 26 glaciers showing a positive mass balance. This mean mass balance deficit is less extreme than that of 2014/2015, but is slightly above the 2003–2015 average.

Global precipitation in 2016 was strongly influenced by the transition from El Nico conditions in the early part of the year to neutral or weak La Nica conditions in the second half. This resulted in strong seasonal contrasts but annual totals relatively close to average in many parts of the world. It was a wet year in many high-latitude parts of the northern hemisphere. A large area with precipitation above the 90th percentile extended from Kazakhstan westwards across the western Russian Federation into Finland, northern Sweden and Norway. Large parts of the north-central Russian Federation were dry, however, with much of the region north of 55°N between the Urals and Lake Baikal having precipitation below the 10th percentile. It was an exceptionally dry year in much of Chile from the Santiago region southwards and in the far south of Argentina. In contrast, on the eastern side of the Andes in Argentina, precipitation was well above average over many areas from northern Patagonia northwards.

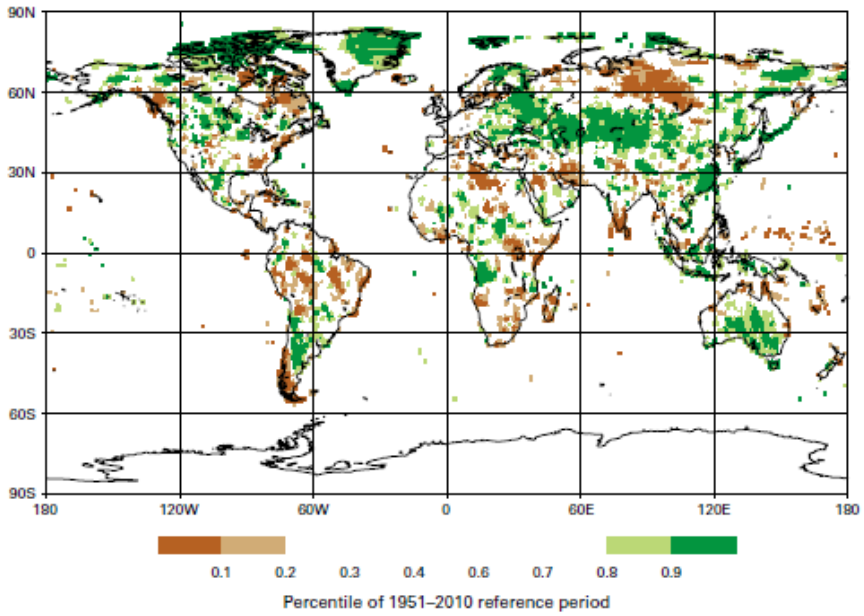


Figure 1.3 – Annual total precipitation expressed as a percentile of the 1951-2010 reference period for areas that would have been in the driest 20% (brown) and wettest 20% (green) of years during the reference period, with darker shades of brown and green indicating the driest and wettest 10%, respectively. *Source: Global Precipitation Climatology Centre, Deutscher Wetterdienst, Germany*

Severe droughts and floods displaced hundreds of thousands of people. Much of southern Africa began 2016 in severe drought. For the second year in succession, rainfall was widely

20%–60% below average for the summer rainy season (October–April) in 2015/2016. Provisional figures show 2016 as the driest calendar year on record averaged over the Amazon basin. Drought continued in north-east Brazil, where heavy rain in January was not followed up with further rainfall and more than 60% of the region was classified as being in exceptional drought by the end of the year. In Australia Droughts were well established early in the year in two separate regions – inland Queensland and a region of the south-east encompassing Tasmania, western Victoria and south-east South Australia – with below-average rainfall extending back to 2012 in parts of both regions. Since May many parts of eastern Australia had record high monthly rainfall. After the driest eight months on record from September 2015 to April 2016, Tasmania had its wettest May to December on record. Other regions where the year started with significant droughts in place included much of India, parts of Viet Nam (especially the Mekong Delta), northern Ethiopia and large parts of Indonesia. In the South Pacific, abnormally dry conditions in late 2015 and the early months of 2016 affected a region extending from southern Papua New Guinea across the Solomon Islands and Vanuatu to Fiji, Tonga, Samoa and the southern Cook Islands. Dry conditions affected parts of East Africa. In October–December rainfall was still widely 50% or more below average, particularly in eastern United Republic of Tanzania, eastern Kenya, and Somalia, reaching 70% to 90% below average in the coastal strip of Kenya and the United Republic of Tanzania. Rainfall was generally 30%–60% below average in most of southern and central Chile, as well as the far south of Argentina. In central Chile, with Santiago's mean rainfall for the six years 2011–2016 being 40% below the long-term average. The dry conditions contributed to major forest fires which broke out late in the year before worsening in January 2017. The interior south-east of the United States was especially dry in October and November, where some locations had little or no rainfall for two months, contributing to major wildfires. It was the driest October–December on record over most of India with seasonal rainfall 65% below average (in marked contrast to the severe flooding which affected the region in late 2015). The dry conditions also affected Sri Lanka.

Averaged over China as a whole, it was the wettest year on record, with national mean rainfall of 730 mm being 16% above the long-term average. The Yangtze basin in China experienced its most significant flood season since 1999, with some tributaries experiencing record flood levels.

Extreme flooding affected parts of the southern United States, various parts of Sri Lanka, India, Nepal and Bangladesh. In Paris, the Seine River reached its fifth highest level on record (and the highest outside the winter months), leading to major property damage. In the upper Niger, the river reached its highest level since 1964 at Mopti (Mali) on 6 September and flooding in the inner Niger Delta in Mali in November and December attained some of its highest levels of the last 50 years.

Global tropical cyclone activity was close to normal, although their geographic distribution had some unusual features, or tropical cyclones had unusual timing. For example, three landfalls on the Japanese island of Hokkaido: the first time this has occurred since records began in 1951. The most destructive tropical cyclone of the year (and also the most damaging meteorological disaster of any type) was Hurricane Matthew, which affected various parts of the North Atlantic in late September and early October. The heaviest casualties associated with Matthew occurred in Haiti, with at least 546 deaths23 reported.

During of 2015/2016 it was observed the most damaging wildfire in the history of Canada, in the south-eastern United States, central and western Tasmania.

In 2016 there were a number of major heat waves, when all-time records were set at many individual locations: in southern Africa, South and South-East Asia, in parts of the Middle East and northern Africa, in many parts of western, central and northern Europe.

The most significant cold wave occurred in late January in eastern Asia, with extreme low temperatures extending southwards from eastern China as far south as Thailand.

Severe thunderstorms and tornadoes triggered significant losses in many parts of the world. The worst single incident occurred in Yancheng, Jiangsu province, China, on 23 June, when a tornado was associated with 99 deaths. It was one of the most destructive tornadoes in recorded Chinese history, at a time when the region was also experiencing severe flooding.

In a total of 17 tornado-related fatalities were occur in the United States for the year. There were, however, many other severe, destructive thunderstorms. Hailstones with a diameter of 11 cm were reported in San Antonio. A notable hailstorm occurred in North Brabant province of the Netherlands on 23 June, with hailstones of 5 cm-10 cm in diameter and losses estimated at 500 million euros.

2 AIR TEMPERATURE

The territory of Kazakhstan is located in the center of the Eurasian continent and removed from the ocean on a considerable distance (2000 - 3000 km) and gets warm more considerable rates, than the globe on average, and the same rates as on average the Northern hemisphere. During 1976-2016 the coefficient of a linear trend of average annual air temperature made for the Globe of +0,18 °C/10 years (the share of dispersion of a row explained with a trend - 84%), +0,34 °C/10 years for the Northern hemisphere (a trend contribution to dispersion – 83%), and +0,34 °C/10 years for Kazakhstan (a trend contribution to dispersion of 25%). In 2016, the anomaly of the average annual air temperature relative to the base period of 1961 1990 for the Globe was +0.83 °C. It is a historical maximum since 1850 which blocked a record of the past 2015 by + 0,07 °C. On average in Kazakhstan the anomaly of average annual air temperature was +1,48 °C relative to 1961 – 1990 baseline and +0,85 °C concerning the period of 1981 - 2010. The norm of average annual air temperature during 1961 - 1990 is 5,5 °C. In 2016 air temperature reached 7,2 °C. For the last five years (2012 – 2016) the average annual air temperature reached the highest point +6,66 °C. For the past decade (2007 - 2016) air temperature was +6,50 °C and exceeded norm on 1,01 °C, it is the second-large positive anomaly, after record-warm decade 1997 - 2006.

Each of the 10 warmest years for the Earth has its own fill color, which makes it easy to judge whether this year is among the warmest years for Kazakhstan. Only five of the warmest years in Kazakhstan entered the list of the ten warmest years of the Globe (table 2.1).

Table 2.1 – The ranked 10 warmest years for the globe (1850 – 2016) and for Kazakhstan (1941 – 2016) and corresponding annual average temperature anomalies for Kazakhstan. Anomalies estimated relative to 1961 – 1990 baseline

Rank	Globe	Kazakhstan	Annual average temperature anomaly for Kazakhstan, °C
1	2016	2013	1,89
2	2015	1983	1,76
3	2014	2015	1.66
4	2010	2002	1,53
5	2005	2004	1,54
6	1998	2016	1,48
7	2003	2007	1,48
8	2002	1995	1,41
9	2013	2008	1,38
10	2007	1997	1,26

Figure 2.1 presents the ranked positive annual average temperature anomalies estimated relative to the1961 – 1990 and averaged over 124 weather stations in Kazakhstan for the 1940 – 2016. All of extremely warm years on average for the globe come from the last 20 years. In Kazakhstan, this feature is also clearly seen, with the exception of 1983.

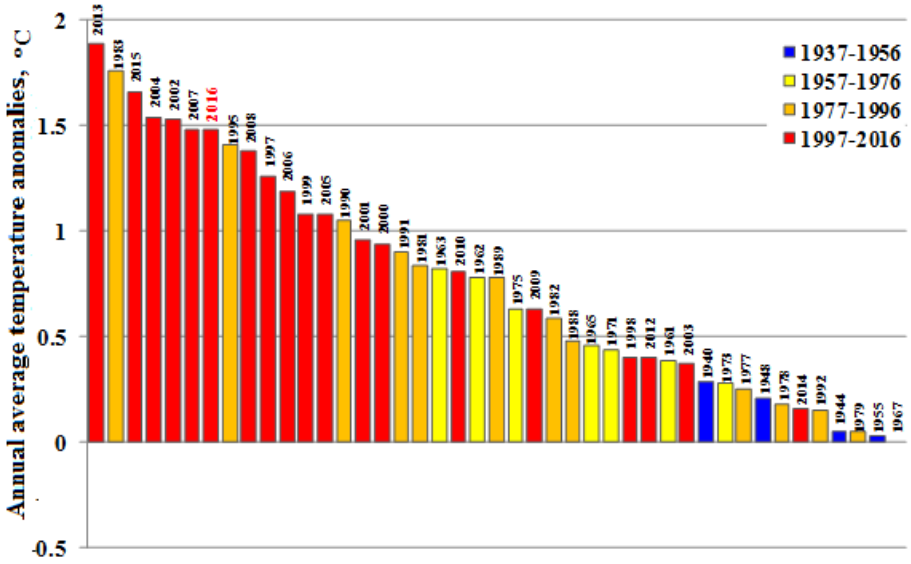


Figure 2.1 – Ranked positive annual average air temperature anomalies for Kazakhstan (date of 124 weather stations) for 1941 – 2016. Anomalies estimated relative to 1961 – 1990 baseline

2.1 Temperature anomalies in Kazakhstan in 2016

In table 2.2; 2.3 shows the annual, seasonal and monthly air temperature anomalies observed in 2016 and averaged over the regions and in general across Kazakhstan. For each anomaly value, the probability of non-exceedance is calculated the data for the period 1941-2015. and the mean square value for 1961 - 1990. Temperatures above 95 or below the 5th percentile (warm 95% e and cold 5% e extremes) are highlighted in bold and bright color.

Year

2016 was warm and extremely warm on the most part of the territory of the republic. *The anomaly of* average annual air temperature *exceeded climatic norm at 1:48 ºC (97% extreme) with the standard deviation of 0.86 ºC.* In 8 of the 14 regions of Kazakhstan, 2016 entered the top ten, and in six regions - the top five warmest years. Extremely warm year was in Zhambyl, South Kazakhstan and Kyzylorda region. The maximum of average annual temperature was fixed at 38 stations for the period from 1941 to 2016. In some northern and northeastern regions, the air temperature was about normal (Figure 2.2).

Winter (December 2015 – February 2016)

Winter was extremely warm and record-warm: positive seasonal temperature anomalies were observed throughout Kazakhstan (table 2.2). The average annual temperature anomaly in the Republic was +4.6 °C, which is the absolute maximum for the period since 1941 and by 0.26 °C higher than the previous record value recorded in 2007. Record high anomalies were observed in the western and southern regions of Kazakhstan: Mangystau (+4.9 °C), Kyzylorda (+7.2 °C), Zhambyl (+4.9 °C), South Kazakhstan (+4.7 °C) regions where 2016 became the warmest winter season in the history of observations, beginning in 1941. Record high anomalies were observed in the western and southern regions of Kazakhstan: Mangystau (+4.9 °C), Kyzylorda (+7.2 °C), Zhambyl (+4.9 °C), South Kazakhstan (+4.7 °C) regions where 2016 became the warmest winter season in the history of observations, beginning in 1941. In another

regions of Kazakhstan, the anomalies were included in the five highest positive anomalies, except Kostanay, North Kazakhstan and Pavlodar. Extremally high winter air temperatures were observed at 70% of Kazakhstan stations (the temperature was higher than the 95th percentile, figure 2.2).

In *December* the anomaly of air temperature throughout the country was +5,28 ºC, that is a historical maximum since 1941 and by 0,53 ºC above the previous record observed in 1989 (table 2.3). It was extreme warmly in all territory of Kazakhstan, except the Almaty, Southern Kazakhstan and Zhambyl regions. Record high values of anomaly were fixed in Akmola (+6,6 ºC), Aktyubinsk (+6,0 ºC), Kostanay (+6,2 ºC) and Pavlodar (+7,3 ºC) regions.

Table 2.2 – Regional averaged annual and seasonal air temperature anomalies in 2016 (**vT**) relative to 1961-1990, ºC; **P** (t≤T2016) - probability of non-exceedance , calculated from the data for the period 1941-2016, %; **s** - is the standard deviation for the period 1961-1990, ºC.

Region	Year		Winter		Spring		Summer		Autumn	
	vT (P)	**s**	**vT (P)**	**s**	**vT (P)**	**s**	**vT (P)**	**s**	**vT (P)**	**s**
Kazakhstan	**1,48 (97)**	**0.86**	**4,65 (100)**	**2.45**	**3,05 (98)**	**1.27**	0,79 (93)	0.65	-1,20 (18)	1.16
Almaty	1.56 (94)	0.77	**3.84 (98)**	**2.36**	**2.71 (96)**	**0.99**	0.44 (61)	0.63	-0.68 (26)	1.07
Akmola	1.08 (81)	1.08	**4.29 (96)**	**2.84**	**3.66 (97)**	**1.84**	-0.09 (53)	1.04	-1.59 (16)	1.51
Aktobe	1.73 (93)	0.95	**5.87 (98)**	**2.51**	3.19 (94)	1.91	1.03 (82)	0.92	-0.84 (25)	1.40
Atyrau	1.80 (93)	0.82	**5.17 (98)**	**2.40**	**2.77 (97)**	**1.55**	**2.00 (96)**	**0.85**	-0.87 (20)	1.20
East Kazakhstan	1.11 (80)	1.07	**3.92 (97)**	**2.71**	2.87 **(96)**	1.51	0.51 (66)	0.79	-1.96 (14)	1.50
Zhambyl	**1.83 (97)**	**0.85**	**4.87 (100)**	**2.84**	**2.77 (98)**	**0.99**	0.58 (73)	0.83	-0.80 (28)	1.17
West Kazakhstan	1.84 (94)	1.06	**5.70 (96)**	**2.74**	2.98 (90)	2.01	2.20 (93)	1.22	-0.68 (32)	1.27
Karaganda	1.16 (85)	0.9	**4.83 (97)**	**2.57**	3.29 (93)	1.35	-0.54 (22)	0.85	-1.86 (14)	1.40
Kostanay	1.23 (86)	1.06	4.56 (93)	2.76	3.24 (92)	1.92	1.00 (81)	1.09	-1.33 (17)	1.49
Kyzylorda	**2,42 (98)**	**0.9**	**7,17 (100)**	**2.87**	**3,65 (97)**	**1.21**	1,32 (88)	0.93	-1,07 (21)	1.19
Mangystau	1.73 (91)	0.76	**4.91 (100)**	**2.26**	2.63 **(92)**	1.25	2.11 (89)	0.90	-1.23 (10)	1.15
Pavlodar	1.10 (78)	1.16	3.68 (94)	3.15	**3.98 (98)**	**1.73**	0.42 (66)	0.93	-1.78 (14)	1.62
North Kazakhstan	0.93 (77)	1.15	3.56 (92)	2.94	**3.25 (96)**	**1.86**	0.70 (80)	1.17	-1.33 (20)	1.53
South Kazakhstan	**1.88 (100)**	**0.8**	**4.74 (100)**	**2.60**	**2.52 (96)**	**0.86**	0.87 (84)	0.84	-1.48 (28)	1.10

1. Mangystau oblast – parameters calculations were performed for 1960 – 2016
2. Values above 95th or below 5th percentiles are shaded in fat and bright color

In *January* the anomaly of air temperature throughout the country was +2,22 ºC (table 2.3). Extremely warmly was in the southern regions of Kazakhstan, the historical maximum of anomaly of average monthly air temperature is recorded in Jambyl (+5,92 ºC) and Southern Kazakhstan (+6,13 ºC) areas. In the north and the northeast negative anomalies of air temperature were observed from minus 0,70 ºC (Kostanay region) to minus 3,84 ºC (Pavlodar region). In *February* the anomaly of air temperature throughout the country was +6,45 ºC (table 2.3). In all areas, the temperature anomalies were positive. Extremely warm was in the territory

of ten regions. The historical maximum was recorded in the Mangystau region, where the temperature anomaly was 6.90 ° C (Table 2.3).

Table 2.3 – Regional averaged mounts air temperature anomalies in 2016 (**vT**) relative to 1961-1990, ºC; **P** (t≤T2016) - probability of non-exceedance , calculated from the data for the period 1941-2016, %

Region	12 (2015)	1	2	3	4	5	6	7	8	9	10	11
Kazakhstan	**5,28 (100)**	2,22 (84)	**6,45 (97)**	**5,89 (97)**	3,02 (94)	0,24 (57)	0,40 (70)	-0,20 (57)	**2,17 (96)**	**2,01 (98)**	**-2,07 (5)**	-3,52 (14)
Almaty	3,58 (91)	**4,46 (97)**	3,35 (77)	**6,21 (98)**	2,47 (92)	-0,54 (32)	1,40 (90)	-0,13 (49)	0,06 (45)	**3,12 (98)**	**-2,54 (4)**	-2,59 (22)
Akmola	**6,61 (100)**	-1,24 (32)	**7,43 (97)**	**6,23 (97)**	4,4 (94)	0,33 (50)	-1,33 (22)	-1,25 (37)	2,38 (88)	2,03 (90)	**-2,39 (2)**	-4,40 (14)
Aktobe	**5,95 (100)**	1,88 (62)	**9,77 (98)**	6,56 (94)	2,81 (86)	0,28 (60)	-0,9 (40)	-0,71 (44)	**4,7 (100)**	0,20 (49)	-0,86 (21)	-1,80 (32)
Atyrau	**4,57 (98)**	2,83 (65)	**8,03 (98)**	**4,77 (97)**	2,43 (89)	1,2 (77)	0,93 (65)	0,73 (70)	**4,27 (100)**	0,13 (45)	-0,63 (25)	-2,07 (33)
East Kazakhstan	**6,87 (98)**	0,78 (61)	3,99 (78)	5,60 (92)	3,88 (94)	-0,83 (34)	1,08 (73)	0,39 (68)	0,07 (46)	**3,20 (97)**	**-3,33 (2)**	-5,74 (8)
Zhambyl	3,40 (86)	**5,92 (100)**	5,18 (81)	**6,18 (98)**	1,72 (88)	0,33 (54)	1,40 (82)	-0,12 (52)	0,52 (65)	**3,22 (100)**	**-2,45 (2)**	-3,17 (20)
West Kazakhstan	**5,56 (98)**	1,99 (57)	**9,55 (98)**	5,66 (94)	2,63 (84)	0,66 (69)	0,33 (57)	0,64 (62)	**5,68 (100)**	-0,64 (32)	0,00 (45)	-1,40 (41)
Karaganda	**5,64 (98)**	3,49 (89)	5,31 (88)	6,90 (94)	3,38 (90)	-0,38 (41)	-0,40 (33)	-1,43 (29)	0,20 (52)	2,33 (94)	**-3,34 (1)**	-4,56 (12)
Kostanay	**6,21 (100)**	-0,70 (33)	**8,06 (97)**	5,39 (92)	3,76 (90)	0,7 (58)	-0,73 (37)	-0,79 (45)	**4,49 (97)**	1,00 (66)	-1,36 (17)	-3,64 (17)
Kyzylorda	**5,12 (98)**	**7,23 (98)**	**9,13 (97)**	**7,83 (98)**	2,1 (82)	1,03 (69)	0,73 (62)	0,37 (66)	2,83 (93)	2,03 (93)	-1,53 (10)	-3,75 (9)
Mangystau	**3,89 (98)**	4,1 (89)	**6,9 (100)**	**4,6 (96)**	1,6 (80)	1,7 (85)	1,50 (75)	0,6 (58)	**4,30 (96)**	0,20 (50)	-1,00 (16)	**-2,9 (5)**
Pavlodar	**7,28 (100)**	-3,84 (20)	**7,64 (98)**	**6,24 (96)**	**5,3 (96)**	0,36 (49)	0,30 (58)	-0,64 (40)	1,56 (78)	**3,18 (98)**	**-3,26 (2)**	-5,26 (10)
North Kazakhstan	**5,98 (98)**	-2,99 (24)	**7,71 (98)**	4,31 (89)	**4,56 (96)**	0,75 (58)	-0,74 (37)	-0,74 (50)	3,63 (94)	1,83 (29)	**-1,80 (4)**	-4,05 (16)
South Kazakhstan	2,16 (78)	**6,13 (100)**	**5,92 (96)**	**5,54 (98)**	0,96 (69)	1,08 (73)	0,97 (74)	0,20 (58)	1,43 (82)	**3,23 (100)**	-1,98 (8)	-2,68 (21)

1. Mangystau region – parameters calculations were performed for 1960 – 2016
2. Values above 95th or below 5th percentiles are shaded in fat and bright color

During the winter period (2015 – 2016) the maximum of the average monthly air temperature from 1941 was updated at some stations: in December at stations of Aktobe, West Kazakhstan, Mangystau, Karaganda, East Kazakhstan, North Kazakhstan, Akmola, Kostanay, Pavlodar, Kyzylorda (59 stations); in January at stations of Almaty, South Kazakhstan, Zhambyl, Kyzylorda (18 stations); in February at stations of Atyrau, Mangystau, Aktobe and Kostanay (8 stations).

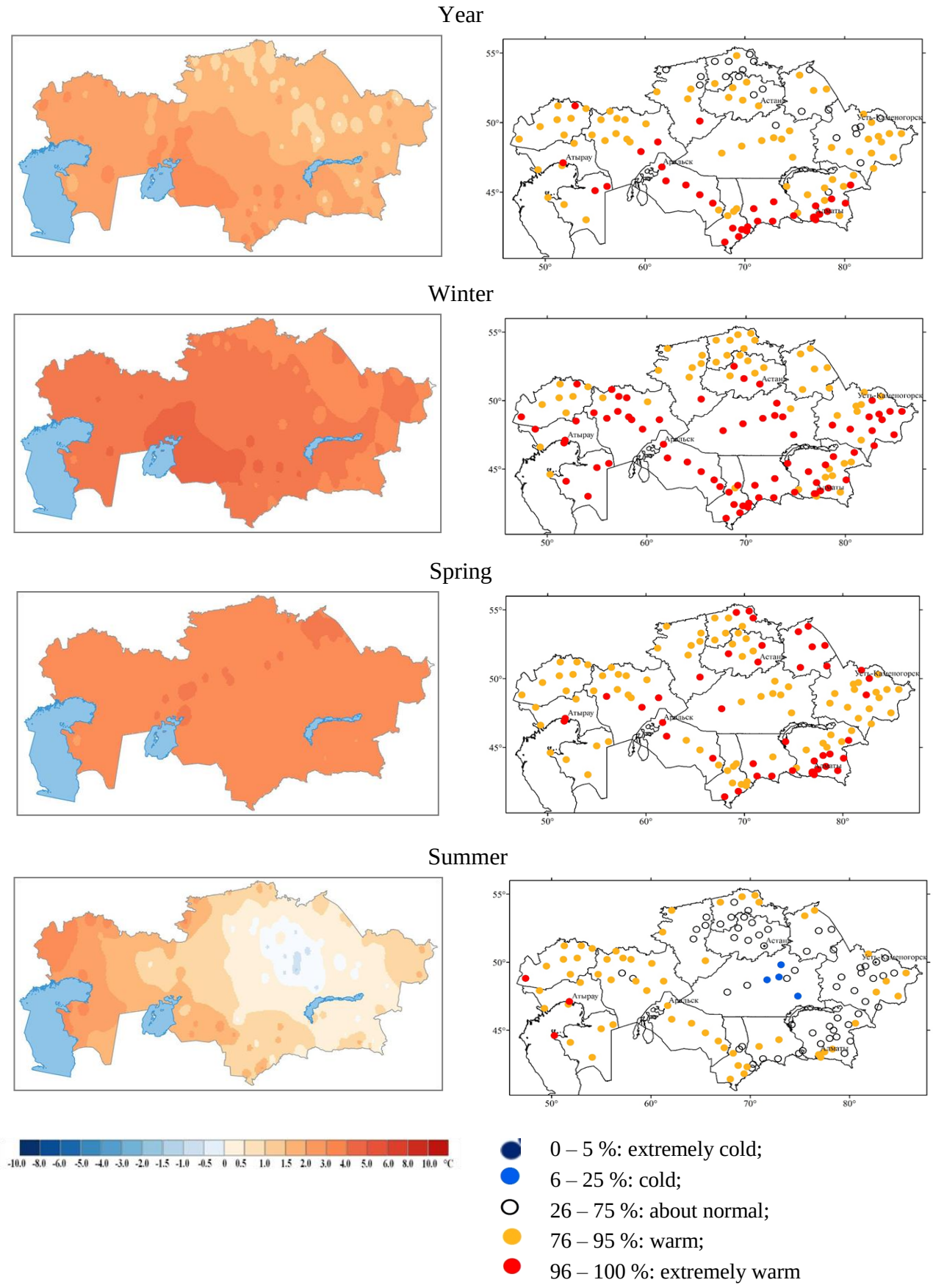


Figure 2.2 - Spatial distribution of air temperature anomalies (^{0}C) in 2016 relative to the 1961 – 1990 baseline and nonexceedance probabilities for 2016 air temperatures calculated over 1941 – 2016. List 1

Autumn

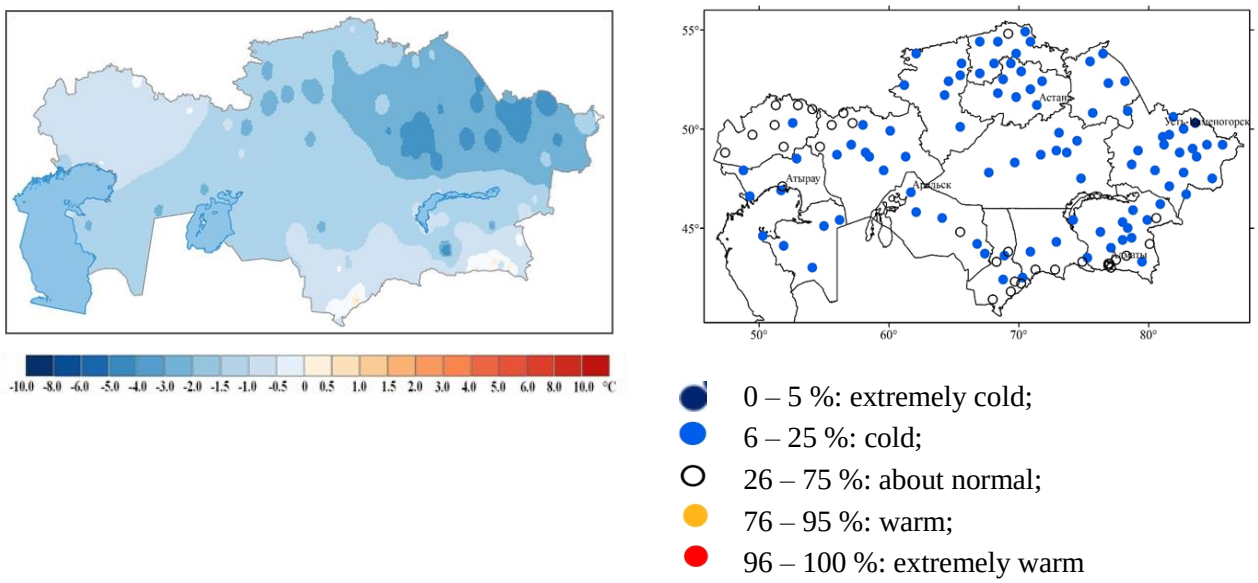


Figure 2.2 - Spatial distribution of air temperature anomalies (^{0}C) in 2016 relative to the 1961 – 1990 baseline and nonexceedance probabilities for 2016 air temperatures calculated over 1941 – 2016. List 2

Spring was also extremely warm. The average seasonal air temperature in Kazakhstan was +3.1 °C, which is the second magnitude since 1941 (Table 2.2) and more than 2 times the mean square value (± 1.27 °C). In all regions of Kazakhstan, the anomalies of spring temperature were part of 10 % of the highest positive anomalies. Extremely warm was on the territory of 9 out of 14 regions (Figure 2.2). Such an extreme spring was, mainly, due to the extremely warm March and warm April. In March the average monthly air temperature anomaly was +5,89 ºC (98th a percentile and 3rd the size of anomaly (table 2.3). It was extremely warm for 55% of stations. In April the average monthly air temperature anomaly, average across Kazakhstan, was +3,02 ºC, falling in 10% of years with high positive anomalies (rank of 5). It was extremely warm in North Kazakhstan (+4,56 ºC) and Pavlodar (+5,30 ºC) regions (rank of 4). Anomalies of air temperature are higher 90 percentiles were observed in Kostanay, Akmola, Karaganda, East Kazakhstan and Almaty regions. In May average monthly air temperatures were within norm, on the average in the territory of Kazakhstan the anomaly was +0,24 ºC (table 2.3). In the Karaganda, Almaty and East Kazakhstan regions were observed negative anomalies of air temperature – from minus 0,38 ºC to minus 0,83 ºC. In spring of 2016, the maximum of the average monthly air temperature for the period since 1941 were updated at some stations: in March, at the stations of Zhambyl and Almaty regions (16 stations); in May at the station Assy of Almaty region.

The summer of 2016 the anomaly averaged over the territory of Kazakhstan was +0.8 °C, this is the 93th percentile and the 11th magnitude in the series of positive anomalies since 1940. The temperature was higher than the norm in most of Kazakhstan except Akmola and Karaganda regions, where negative anomalies were observed. In Atyrau region, it was extremely warm: +2.0 °C (96th percentile, 4th rank). In June average monthly temperatures were about norm. In Almaty region the anomaly of air temperature was +1,4 °C, became one of the 10% of very warm years. In northern and central regions of Kazakhstan the area of negative anomalies of air temperature was observed: from minus 0,7 °C to minus 1,3 °C. July was rather cool, the anomaly

of air temperature was 0,2 °C lower than average long-term value. August was extremely warm: the anomaly of air temperature reached +2,2 °C (96th a percentile and rank of 5 among positive values of anomaly of temperature). It was extreme warmly in the western and northwest part of Kazakhstan. Record-breaking warmly in Aktobe (+4,70 °C), West Kazakhstan (+5,68 °C), the Atyrau (+4,27 °C) regions. Extremely warmly (higher than 95 percentile) was in Kostanay (+4,49 °C) and the Mangystau (+4,30 °C) regions. In North Kazakhstan (+3,63 °C) and Kyzylorda (+2,83 °C) areas of anomaly of air temperature entered 10% of the highest anomalies.

In the summer of 2016, a maximum of the average monthly air temperature for the period since 1941 was updated at individual stations: in June at the station of Assy, Almaty region; in August at the stations of West Kazakhstan, Atyrau, Mangystau, Aktobe, Kostanay regions (21st station).

The autumn of 2016 was cold due to relatively low air temperatures in October and November. The average air temperature in Kazakhstan in the autumn season was below the norm by 1.2 °C. The temperature anomalies averaged over the regions of Kazakhstan were from minus 0.8 °C to minus 2.0 °C. The coldest was in Pavlodar, Karaganda and East Kazakhstan regions (Figure 2.2). September was extremely warm month in the autumn season: in most part of Kazakhstan the anomalies of the average monthly air temperature were above the norm by 2.3 °C; the air temperature anomaly averaged over the territory of the country was +2.0 °C - second-large among positive anomalies after record September, 1971. Record high anomalies were observed in Zhambyl (+3.22 °C), South Kazakhstan (+3.23 °C) areas. In other regions of Kazakhstan, except areas of the western region, anomalies have entered into 10% of the highest positive anomalies. October was extremely cold month practically in all territory of Kazakhstan: the anomaly of air temperature across the territory of Kazakhstan was minus 2,07 °C (4th rank among negative values). It was extremely cold in the east of Kazakhstan where average monthly air temperature was below norm by 1,80 - 3,33 °C. Only in the West Kazakhstan region air temperature was about the norm. In November air temperature was 3,52 °C below the norm. Anomalies were negative in all areas of Kazakhstan: in East Kazakhstan, Kyzylorda and Pavlodar regions this month have entered into of 10% of the coldest months. It was extremely cold in Mangystau region (5% of an extremum with anomaly minus 2,90 °C).

In September at separate stations of Karaganda, East Kazakhstan, Pavlodar, Almaty, South Kazakhstan Kazakhstan, Zhambyl regions the maximum of average monthly air temperature from 1941 were updated (30 stations). In October the minimum at the station Aktogai in the Karaganda region was updated.

In order to assess the extreme temperature conditions in particular year experts used the climate change indices recommended by the World Meteorological Organization. The analysis of the most representative indices and their distribution in Kazakhstan in 2016 is considered below.

Daily maximum of air temperatures in 2016. Figure 2.3 presents in red the absolute maximum of air temperature recorded since the opening of weather station until 2015. The maximum of daily air temperature observed in 2016 is in blue. Absolute maximum temperature since the beginning of records has not been exceeded in 2016 at any considered weather stations.

The highest values of air temperature (absolute maximum) in Kazakhstan were recorded in July 1983 – 49°ºC and 50°ºC (Turkestan, Shayan, Arys, Tasty) and in July 1995, when air temperature rose to 51 ºC (Kyzylkum).

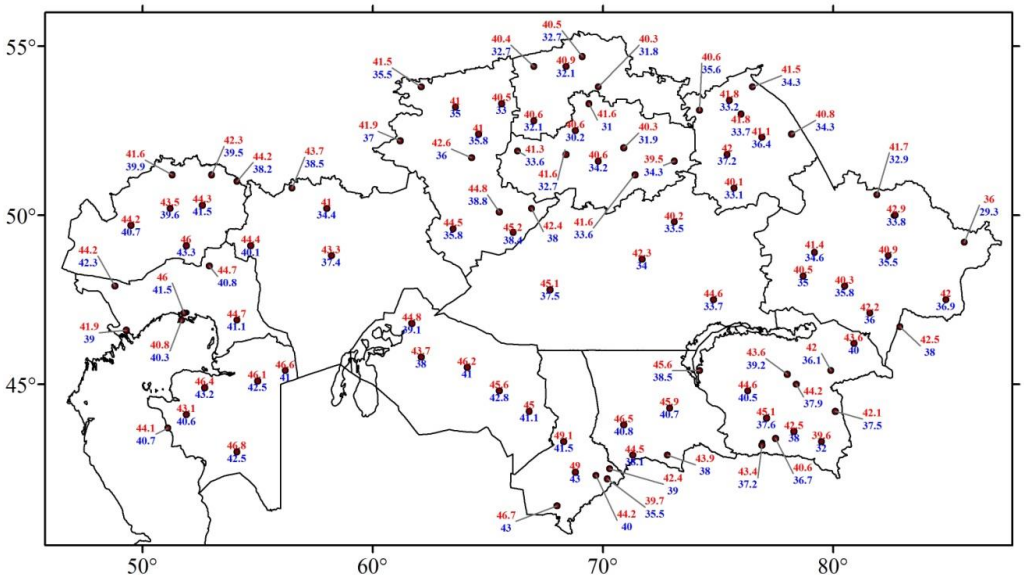


Figure 2.3 – Absolute maximum temperature (°C, red) since the beginning of records until 2015 and the 2016 daily maximum temperature (°C, blue).

Daily minimum of air temperature in 2016. Absolute minimum temperature since the beginning of records has not been exceeded in 2016 at any considered weather stations (figure 2.4). In 2016, the lowest temperature (from minus 35 to minus 39°ºC) were observed at some weather stations in the Akmola, North Kazakhstan, Kostanay, Pavlodar and East Kazakhstan regions.

The lowest values of air temperature (absolute minimum) in Kazakhstan were recorded in January 1893 (minus 52°ºC, Astana) and in January 1931 (minus 54°ºC, Orlovsky Poselok).

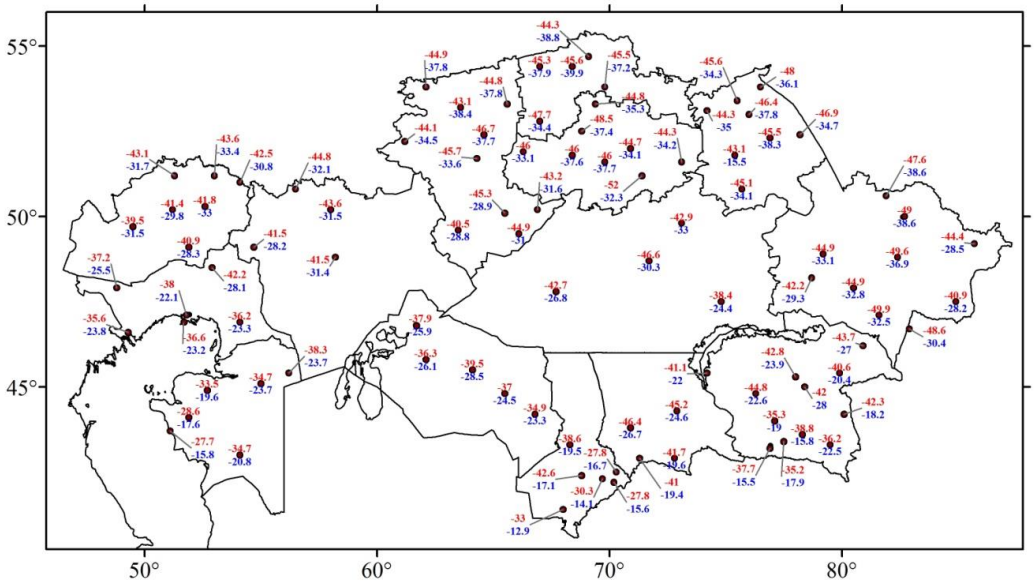


Figure 2.4 - Absolute minimum temperature (ºC, red) since the beginning of records until 2015 and the 2016 daily minimum temperature (ºC), blue

Number of days with temperatures above 35 ℃ in 2016. Figure 2.5a,b presents spatial distribution of the number of days with temperatures above 35 ºC in 2016. The number of days with high temperatures increased from the north to the south and to the southwest of Kazakhstan. In the northern, central and north-eastern plains regions, as well as in the mountain regions of the south and southeast, such temperatures were extremely rare. In the western and southern regions, the number of days with a temperature above 35 ° C exceeded 25-35 days, the maximum number of 55- 65 days was observed in the South Kazakhstan and Mangystau regions. The probability of non-exceedance in these regions was quite high: 76-95%.

a) b)

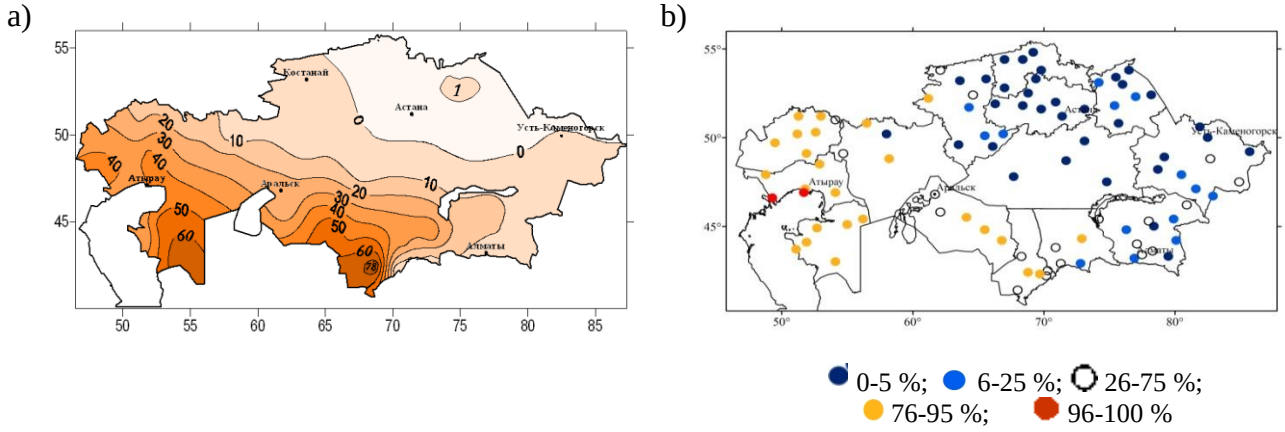


Figure 2.5 – Number of days (a) and the probability of nonexceedance of the number of days with temperatures above 35 ºC in 2016 (b) for 1941 – 2016

Percentage of days with the daily maximum temperatures above the 90th percentile in 2016 across the territory of Kazakhstan amounted from 6% to 22% (the figure 2.6). In the northern and central regions of the country extremely high daily maximum of air temperature was observed in 12 16% of days. In the western and also in the Kyzylorda, East Kazakhstan, Zhambyl regions where percentage of days with the daily maximum temperatures above the 90th percentile amounted about 18 – 22 % cases. The patterns of distribution of the values of this index across Kazakhstan are in many agree with the distribution of the number of hot days.

а) б)

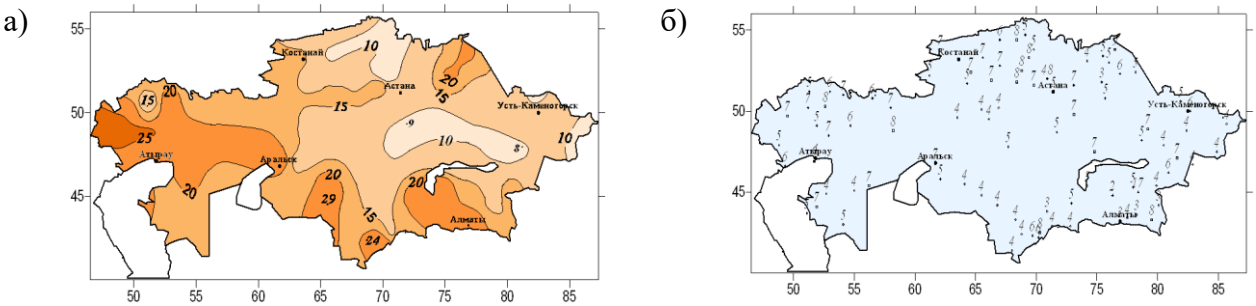


Figure 2.6 – Percentage of days with the daily maximum temperatures above the 90th percentile (a) and with the daily minimum temperatures below the 10th percentile (b) in 2016

Percentage of days with the daily minimum temperatures below the 10th percentile characterizes the frequency of extremely low temperatures (figure 2.6 b). In 2016, the maximum number of daily minimum air temperatures below the 10th percentile was observed, mostly, no more than in 6 % of cases.

Figure 2.7a shows the total duration of heat waves in Kazakhstan in 2016 (***sum of days when at least six consecutive days the daily maximum temperature was above 90th percentile***). The maximum duration of waves of heat was observed in the western and southern areas of the republic where it was more than 30 days. In far western areas duration was more than 70 days in a year. In some northern and east regions of waves of heat it was not observed.

а) б)

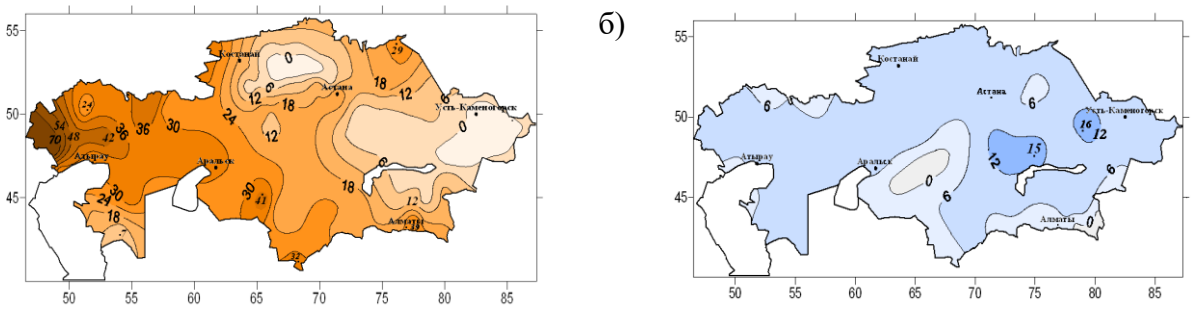


Figure 2.7 – Total sum of days with at least of 6 consecutive days the daily maximum temperature above the 90th percentile (a); and at least of 6 consecutive days the daily minimum temperature below the 10th percentile (b) in 2016

Sum of days during the year when ***at least 6 consecutive days the daily minimum temperature was below the 10th percentile*** characterizes the total duration of cold waves. In 2016 on the most part of the territory of Kazakhstan duration of waves of cold did not exceed 12 days (figure 2.7b). The maximum duration of cold waves (15 - 16 days) were observed in East Kazakhstan and Karaganda regions. The cold waves were not observed in Zhambyl, Kyzylorda regions and also in foothill and mountainous areas of Almaty regions.

Figure 2.8 presents ***duration of vegetation period*** in 2016 (the period between the first 5 days when the average daily temperature was ≥5 °C, and the last 5days when the average daily temperature was ≤5 ºC). The vegetation period about 170 - 180 days was observed in the northern regions of the country. In the south of Kazakhstan, with the exception of mountain regions, the vegetation period was more than 200 days, in far south of the country more than 260 days. As a whole, in 2016, the vegetation period on the vast part of the republic was as in 2015, but in the southern regions of Almaty, Zhambyl and South Kazakhstan regions, the vegetative period was shorter by 20-30 days.

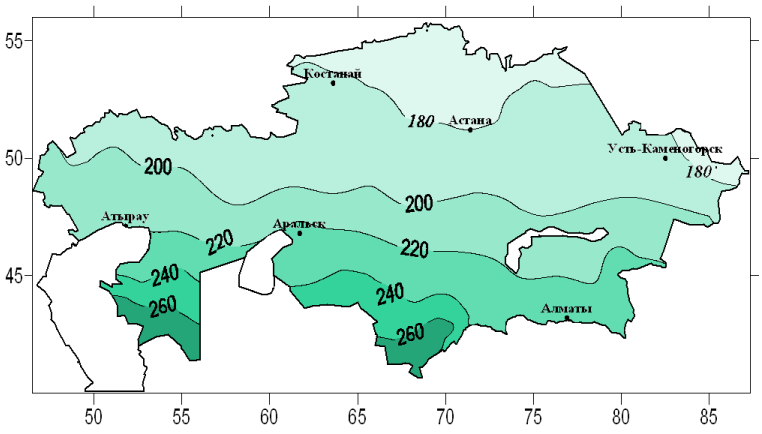


Figure 2.8 - The duration of vegetation period (days) in 2016

2.2 Observed changes in air temperature in Kazakhstan

Figures 2.10 - 2.11 show the time series and linear trends of the annual and seasonal air temperatures anomalies averaged over the territory of Kazakhstan and administrative regions for two periods: 1941-2016 and 1976-1966. Table 2.4 presents estimates of the change in air temperature for the period 1976-2016: the linear trend coefficient, which characterizes the average rate of change in the air temperature anomaly; and the coefficient of determination, which shows the contribution of the trend to the total variance.

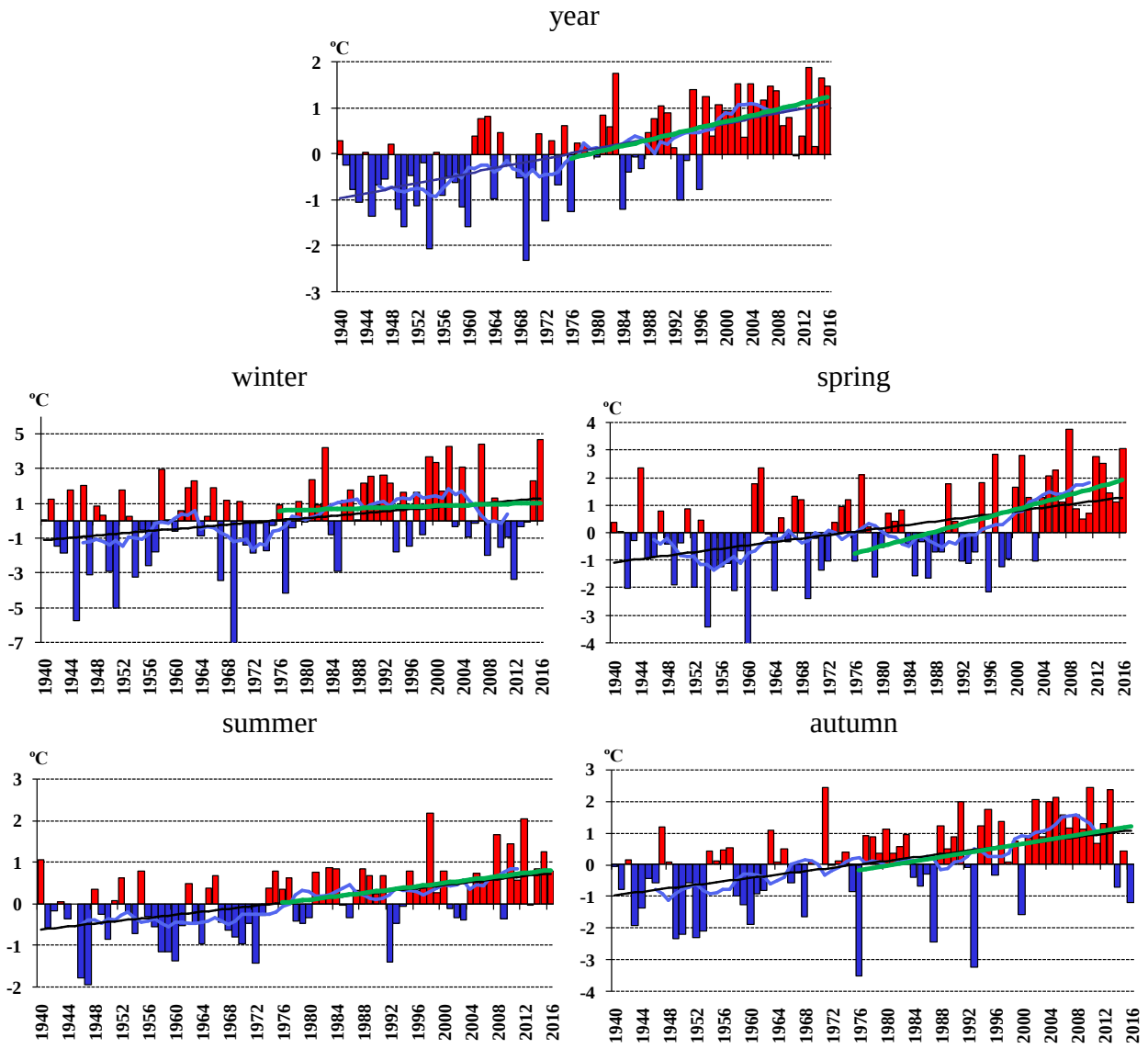


Figure 2.10 – Time series and linear trends in the annual and seasonal air temperatures anomalies for the period 1941-2016. (black line) and for the period 1976-2016 (green line), averaged over the territory of Kazakhstan. Anomalies are calculated relative to the base period of 1961 - 1990. The smoothed curve represents the 11-year moving average

In bulletins published over the past years, estimates are given of the changes in the average annual and seasonal temperatures of surface air over the past 76 years (since 1941). If to consider change of air temperature for shorter period from the middle 1970 x years of the last century when according to many experts, change of global climate became more intensive, then estimates of rates and sometimes even the sign of tendencies is different from estimates during

1941 2016 (table 2.4, figures 2.10 and 2.11). For example, in the winter in the past 41 years, the warming rate is much weaker than the average for 76 years, and in Pavlodar and East Kazakhstan oblasts there is a weak tendency to lower air temperature by 0.11 ºC/10 years and 0.14 ºC/10 years, respectively. The exceptions are Kyzylorda, South Kazakhstan, and Mangystau oblasts, where the rate of warming has increased on the contrary. It should also be noted that in most regions and the average for Kazakhstan, trends since 1976 in winter temperatures are statistically insignificant.

Country average annual temperature for the period 1976 – 2016 has been rising by 0,34 ºC every 10 years (table 2.4), in spring 0,67 ºC/10 years, in summer - 0,20 ºC/10 years, in autumn - 0,35 ºC/10 years. The trend contribution to total dispersion of average annual temperatures makes 25%, for other seasons – from 9% (autumn) to 27% (spring). In the winter the smallest and statistically insignificant speed of temperature increase is observed: (0,13 ºC/10 years).

Table 2.2 – Parameters of the air temperature anomaly linear trend for Kazakhstan and its administrative oblasts for 1976 – 2016

Region	Year		Winter		Spring		Summer		Autumn	
	a*	**R^2	a	R^2	a	R^2	a	R^2	a	R^2
Kazakhstan	0,34	**25*** **	0,13	0	0,67	**27**	0,2	**12**	0,35	9
Almaty	0,29	**22**	0,07	0	0,61	**25**	0,2	**14**	0,26	8
Akmola	0,3	**14**	0,04	0	0,75	**23**	0,01	0	0,37	6
Aktobe	0,45	**27**	0,26	1	0,67	**17**	0,33	**10**	0,48	**12**
Atyrau	0,44	**28**	0,39	4	0,48	**15**	0,48	**29**	0,42	**12**
East Kazakhstan	0,22	8	-0,14	0	0,66	**21**	0,13	5	0,22	3
Zhambyl	0,31	**25**	0,15	1	0,63	**26**	0,18	**10**	0,29	8
West Kazakhstan	0,55	**33**	0,49	5	0,65	**19**	0,61	**24**	0,48	**14**
Karaganda	0,28	**14**	0,01	0	0,82	**28**	0	0	0,24	3
Kostanay	0,4	**21**	0,17	1	0,67	**16**	0,18	3	0,55	**13**
Kyzylorda	0,45	**29**	0,31	2	0,87	**31**	0,25	**14**	0,34	8
Mangystau	0,48	**41**	0,33	4	0,58	**23**	0,58	**36**	0,39	**11**
Pavlodar	0,24	8	-0,11	0	0,77	**27**	0,03	0	0,26	3
North Kazakhstan	0,26	**11**	0,02	0	0,57	**17**	0,03	0	0,44	8
South Kazakhstan	0,33	**31**	0,24	2	0,57	**25**	0,19	**9**	0,32	**11**

* a – linear trend factor,°ºC/10 years
** R^2 – determination factor, %
***«bold» type indicates statistically significant trend

In spring, over the past 41 years, more intensive warming has been observed in the territory of Kazakhstan than the average for the period of 76 years, and ranges from 0.48 ºC/ 10 years in Atyrau oblast to 0.87 ºC/10 years in the Karaganda region. It should be noted that trends in spring temperatures in all regions and on average in Kazakhstan are statistically significant.

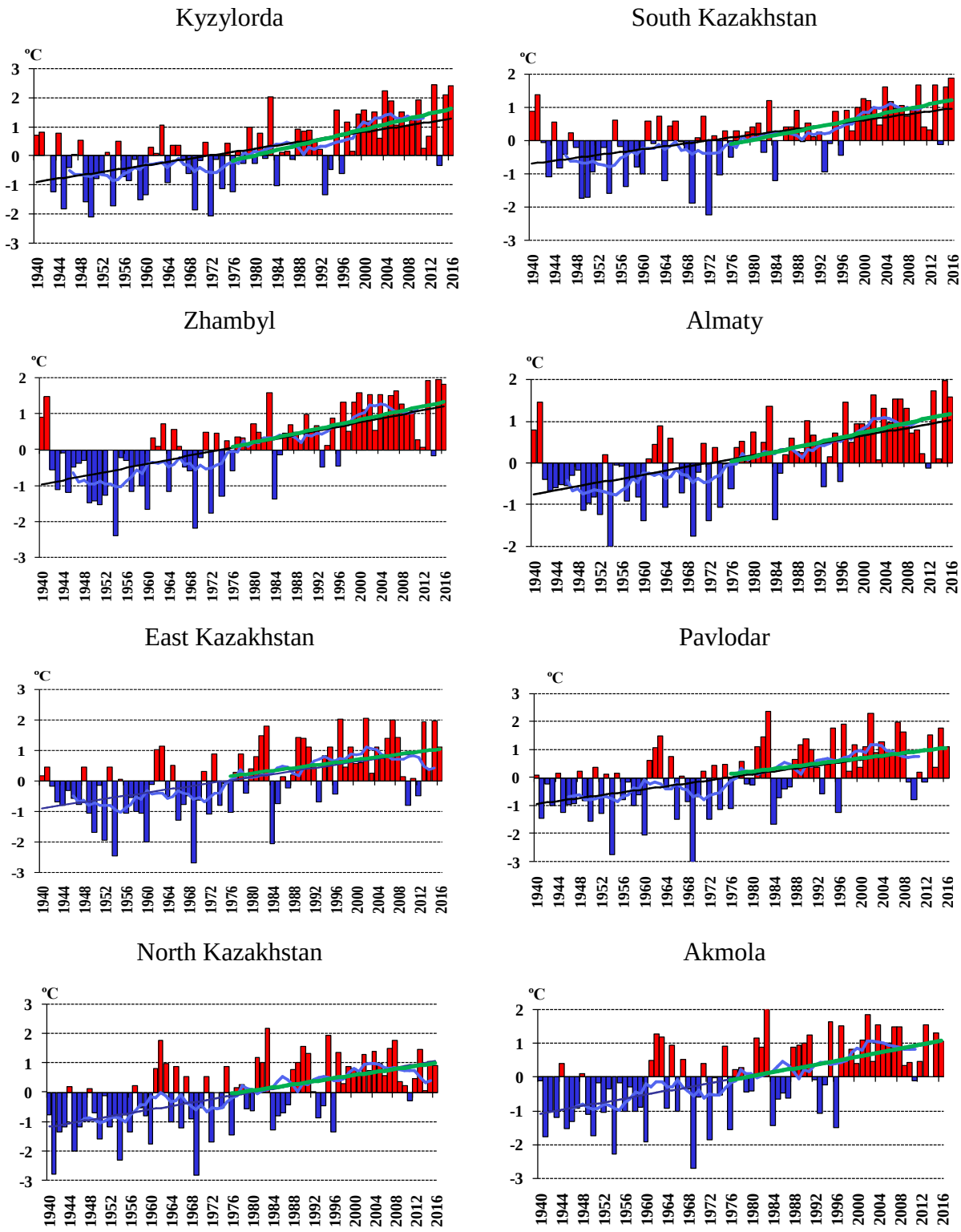


Figure 2.11 – Time series and linear trends of the annual and seasonal air temperatures anomalies relative to 1961 – 1990 for 1941 – 2015 (black line) and 1976 – 2016 (green line) averaged over the territory of the regions of Kazakhstan. The smooth curve represents the 11-year moving average List 1

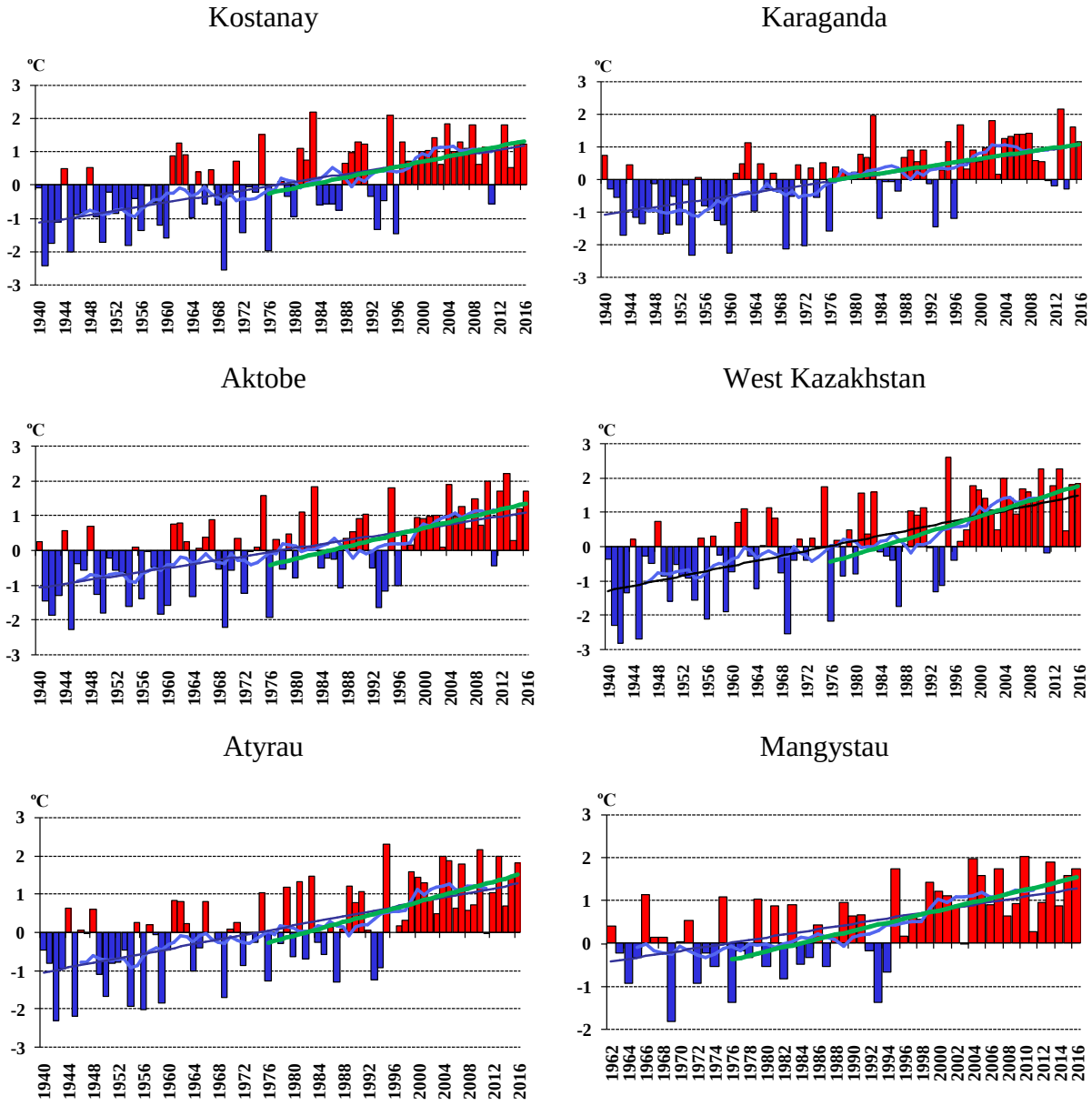


Figure 2.11 – Time series and linear trends of the annual and seasonal air temperatures anomalies relative to 1961 – 1990 for 1941 – 2015 (black line) and 1976 – 2016 (green line) averaged over the territory of the regions of Kazakhstan. The smooth curve represents the 11-year moving average List 2

Summer temperatures in the period 1976 - 2016. increase at a higher rate than for a longer period in the western and southern regions. In the rest of the territory, trends have remained positive in recent decades, but they are mostly statistically insignificant.

In the autumn of the last four decades, the average rate of increase in air temperature in the northern, western and some southern regions increased and slightly decreased in the central, eastern and south-eastern regions.

Figure 2.12 provides more detailed information about changes in average annual, seasonal and monthly air temperatures (°C/10 years) for 1941 – 2015 in Kazakhstan.

Positive and statistically significant trend of average annual air temperatures is observed almost everywhere in Kazakhstan. In the western half of Kazakhstan it is warming up to +0.64 ºC/10 years, in the eastern regions (Pavlodar and East Kazakhstan regions), the warming rate is up to 0.38 ºC/10 years.

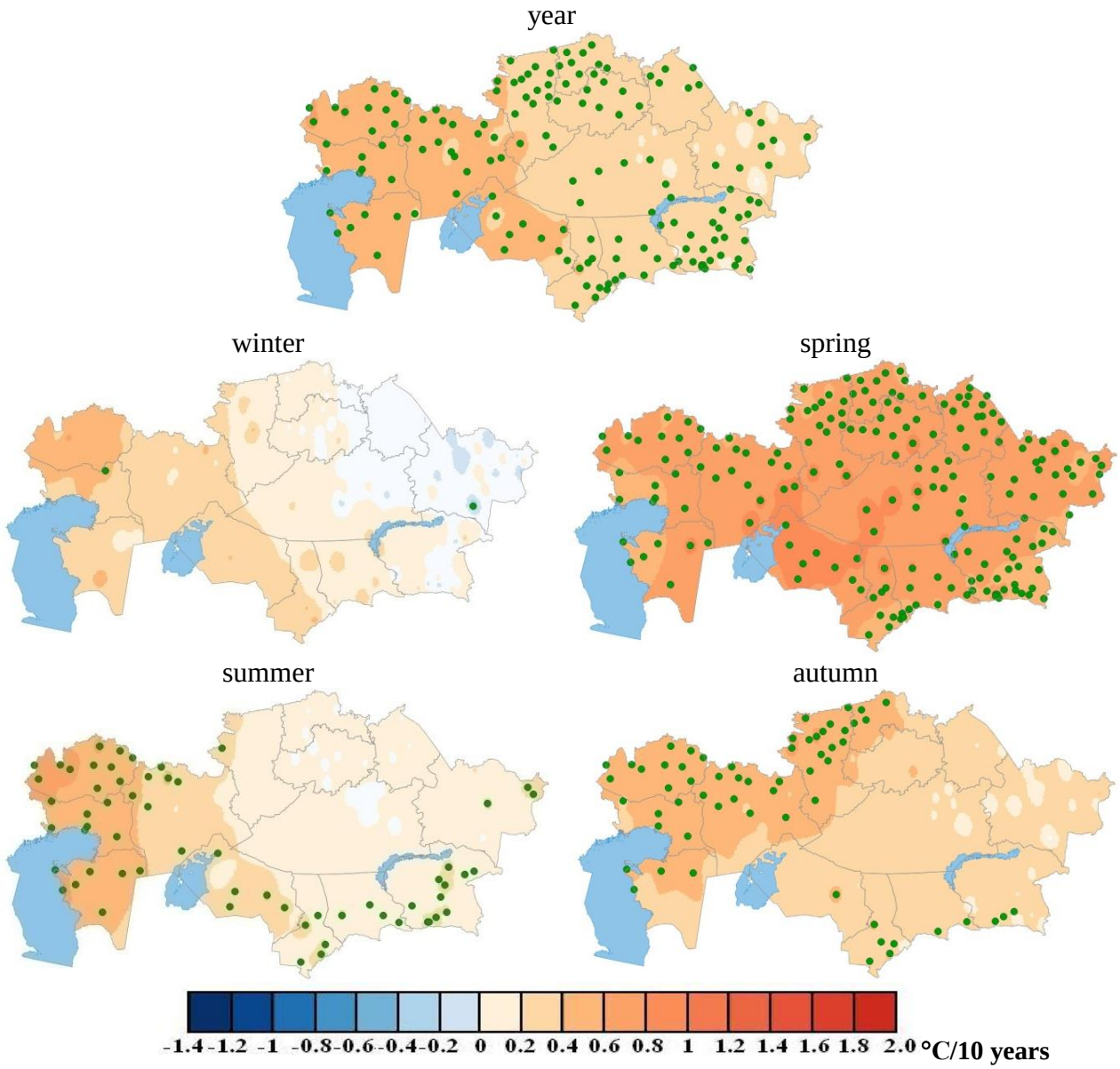


Figure 2.12 – The spatial distribution of the surface linear trend factors (ºC/10 years) of average annual and seasonal air temperature (°C/10 years) in Kazakhstan for 1976 – 2016.

In winter season, the highest rate of warming is observed in the west of Kazakhstan, where the maximum value reaches +0.63 ºC/10 years (Figure 2.12). When moving to the east, positive trends weaken and change sign to negative. In the north-eastern part of Kazakhstan, negative trends reached 0.66 ºC/10 years. The rate of change in winter temperature was affected by the negative trend of air temperature change in the north-eastern part of Kazakhstan in January (Figure 2.13). The temperature trends of the winter months and season as a whole throughout Kazakhstan were insignificant.

In spring, the most intensive warming is observed throughout the territory of Kazakhstan: from +0.48 ºC/10 years to +1.02 ºC/10 years. The highest rate of warming is observed in the

central and southern regions. Especially it is necessary to note the month of March with a high and stable rate of warming throughout Kazakhstan from +0.61 ºC/10 years to 2.0 ºC/10 years. Trends in spring temperatures are statistically significant throughout Kazakhstan (Figure 2.12).

In summer, as well as in winter, the greatest and statistically significant rate of warming is observed in the western regions of Kazakhstan: from +0.40 ºC/10 years to +0.97 ºC/10 years (Figure 2.12). In the southern, southeastern and eastern regions, trends are also significant, but the maximum values reach + 0.2 ºC/10 years. The regions of a weak cooling season in the summer season in some central and northern regions are due to the presence of a stable negative trend in July (minus 0.5 ºC/10 years), Figure 2.13.

In autumn, as in spring, the air temperature rises throughout the territory of Kazakhstan. The highest rate of warming in the autumn season was observed in the northwest part of Kazakhstan and is up to +0.72 ºC/10 years (Figure 2.12), which is mainly due to a significant increase in air temperature (to +0.94 ºC/10 years) in November, figure 2.13.

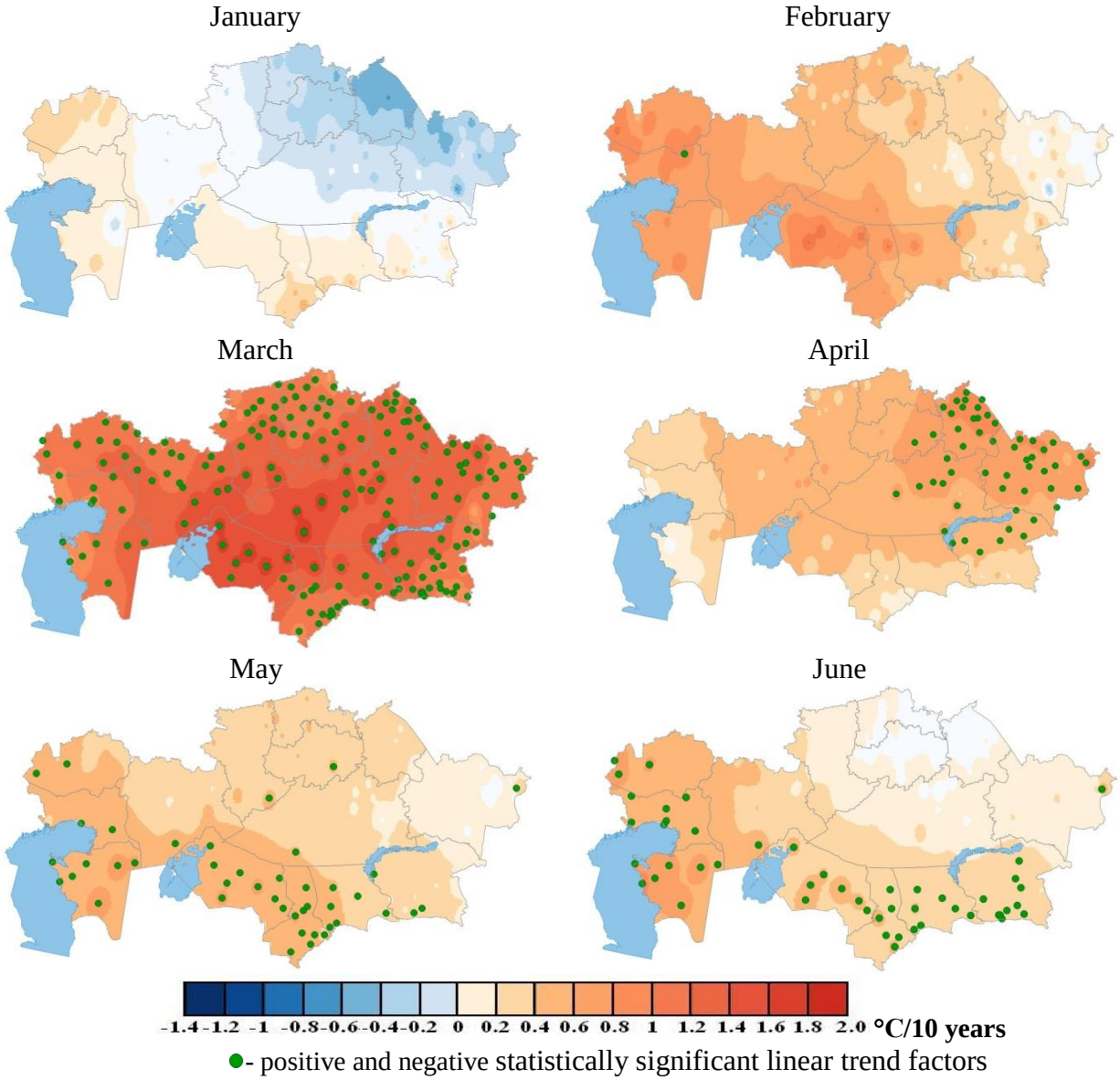


Figure 2.13 – The spatial distribution of the surface linear trend factors (ºC/10 years) of average monthly air temperature (°C/10 years) in Kazakhstan for 1976 – 2016. List 1

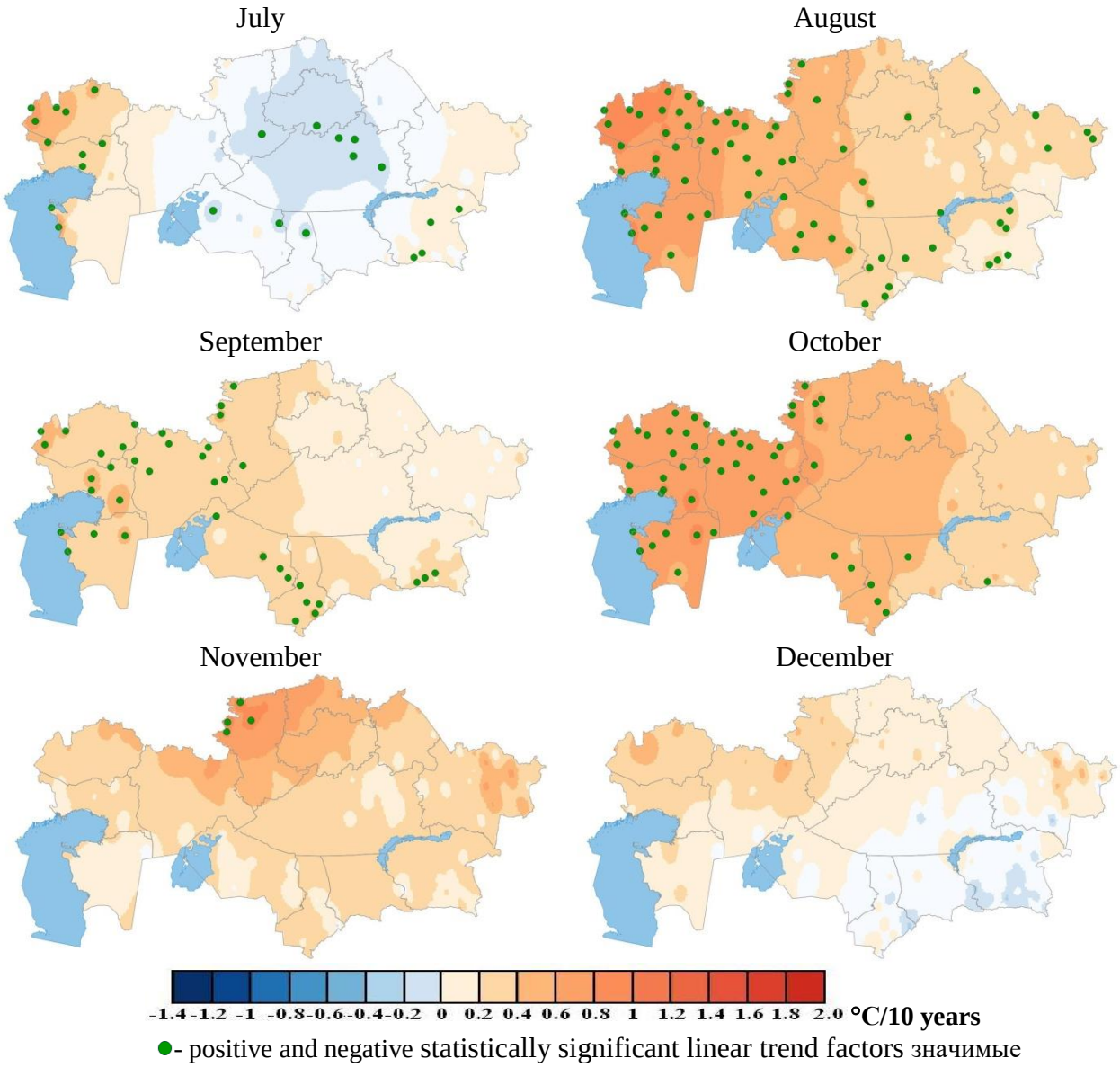


Figure 2.13 – The spatial distribution of the surface linear trend factors (ºC/10 years) of average monthly air temperature (°C/10 years) in Kazakhstan for 1976 – 2016. List 2

2.3 Trends in surface air temperature extremes

For the last 40 years in Kazakhstan generally are traced insignificant tendencies both positive, and negative in daily maximums of surface air temperature. A significant decrease in the daily maximums of the surface air temperature is observed in Balkashino (0.73 ºC/10 years) and Zharkent stations (0.37 ºC/10 years). A significant increase in the daily air temperature maximum was recorded in the western part of the republic (Zhana-Ushtogan, Zhalpaktal, Aktau: 0.41 - 0.90 ºC/10 years); in Kyzylorda region (Kyzylorda - 0.52 ºC/10 years); in East Kazakhstan region (Kokpekty - 0.48 ºC/10 years).

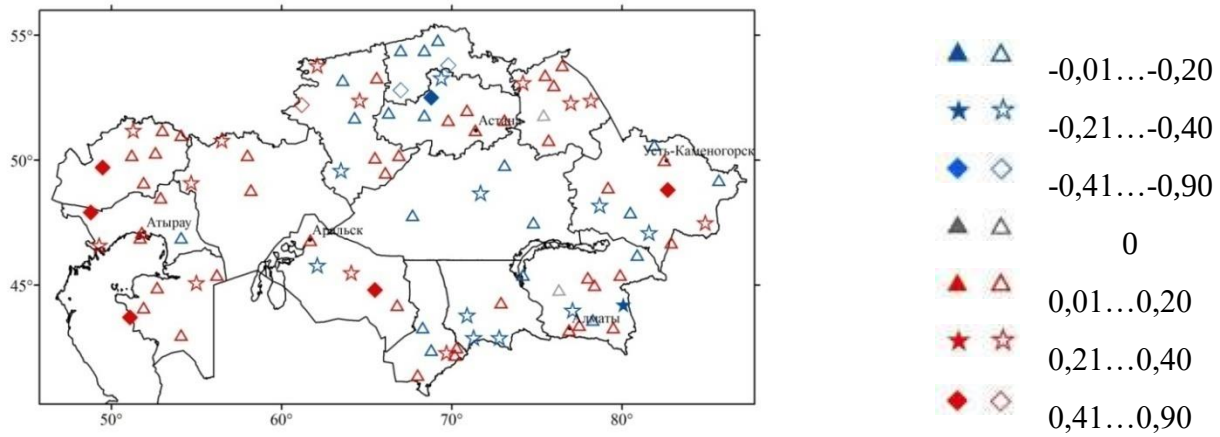


Figure 2.13 – Spatial distribution of the linear trend factors of daily maximum air temperatures (ºC/10 years) for 1976 – 2016. Shaded keys are for statistically significant trend

Statistically significant trend of increasing the number of days with an air temperature above 35 °C is observed in West Kazakhstan, Aktobe, Atyrau, Mangystau, Kyzylorda, South Kazakhstan oblasts: for 4 – 8 days every 10 years (Figure 2.14). In the rest of the republic, a statistically insignificant increase and decrease in the number of days with a temperature of more than 35 °C was observed.

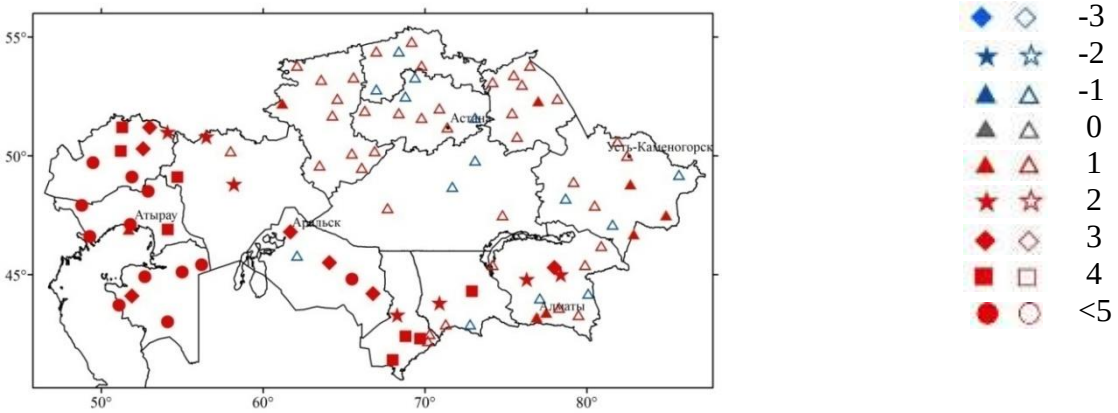


Figure 2.14 - Spatial distribution of the linear trend factors of the total duration of heat waves (day/10 years) during 1976 – 2016. Shaded keys stand for statistically significant trend

The total duration of heat waves increased throughout the country by 6 to 10 days/10 years (Figure 2.15). Heat wave is recorded when ***the daily maximum temperature was above 90th percentile at least six consecutive days***. Statistically significant trends were observed at over 95 % of meteorological stations.

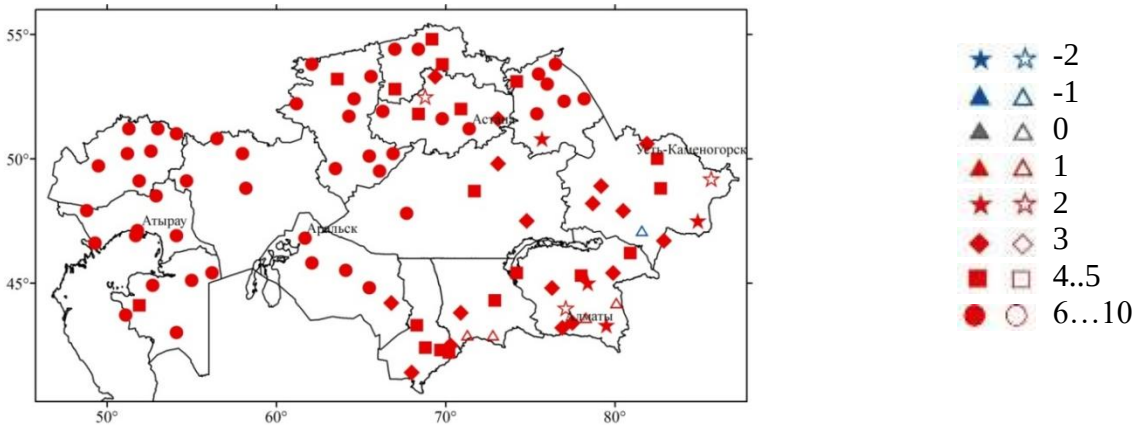


Figure 2.15 – Spatial distribution of the linear trend factors of the total duration of heat waves (day/10 years) during 1976 – 2016. Shaded keys stand for statistically significant trend

Almost everywhere in Kazakhstan the frequency of frost days when **the daily minimum temperature is below 0 °C** tends to decrease (Figure 2.16). The fastest rates of these day frequency decrease are in certain regions of the South Kazakhstan, Kyzylorda and Atyrau regions (5 – 6 days every 10 years). In other regions the number of frost days reduces by 1 – 4 days every 10 years. Generally, the speed of reduction of number of such days is 3 – 4 days each 10 years, on Kyzana, Atyrau, Kokshetay, Beineu, Taiynsha, Bakanas and Shemonaikha – 5 days, in Almaty, Kulsary – 6 days, in Kyzylorda, Ekibastuz, Turkestan: 7-8 days each 10 years.

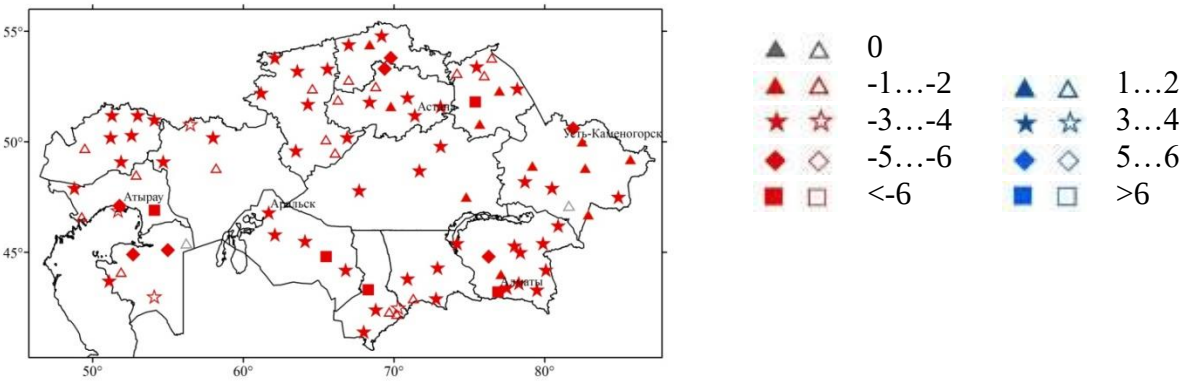


Figure 2.16 – Spatial distribution of the linear trend factors of the number of days with daily minimum temperature below 0 ºC (day/10 years) for 1976 – 2016. Shaded keys stand for statistically significant trend

In most parts of Kazakhstan, there is a significant tendency to increase the daily amplitude of air temperature: by 0.1 - 0.4 ºC (Figure 2.17), which indicates an increase in the continentally of the climate. A significant decrease in the daily amplitude (by 0.1 - 0.2 ºC) is observed at some weather stations in the East Kazakhstan, Almaty region, as well as at the stations: Atyrau, Barshatas, Kulan, Tayinsha and Golubovka.

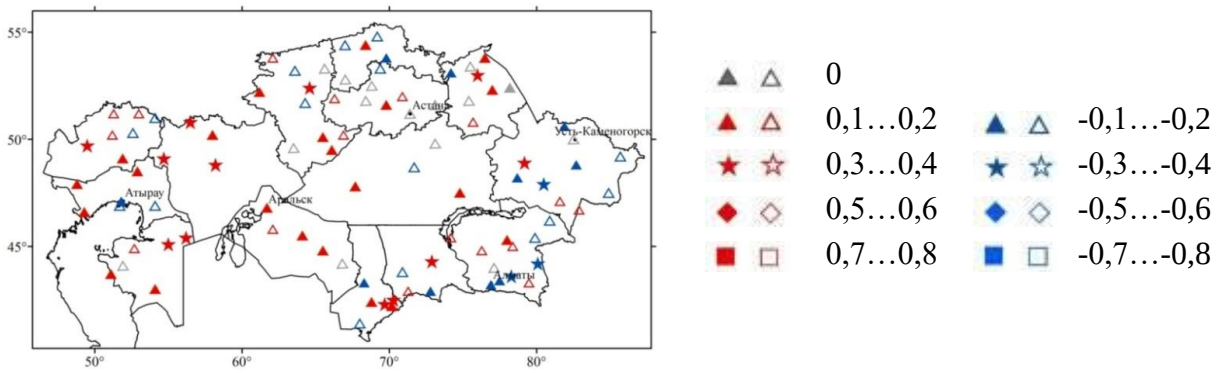


Figure 2.17 – Spatial distribution of the linear trend factors of the daily air temperature amplitude (ºC/10 years) for 1976 – 2016. Shaded keys stand for statistically significant trend

Thus, trends in surface air temperature indices show that since 1976, the frequency of hot days and the duration of heat waves increases, while the frequency of frosty days' decreases.

3 PRECIPITATION

3.1 Precipitation anomalies in Kazakhstan in 2016

The monthly amount of precipitation in 2016, averaged for Kazakhstan was mainly above normal, except February and August (Figure 3.1). The deficit of precipitation in these months was 14% and 59%, respectively. The atmospheric precipitation was significantly higher than the norm in March (71%), May (65%), June (97%) and December (76%). March and May occupied the 4th rank among the wet months for the entire period of observations, and June and December – 2nd rank.

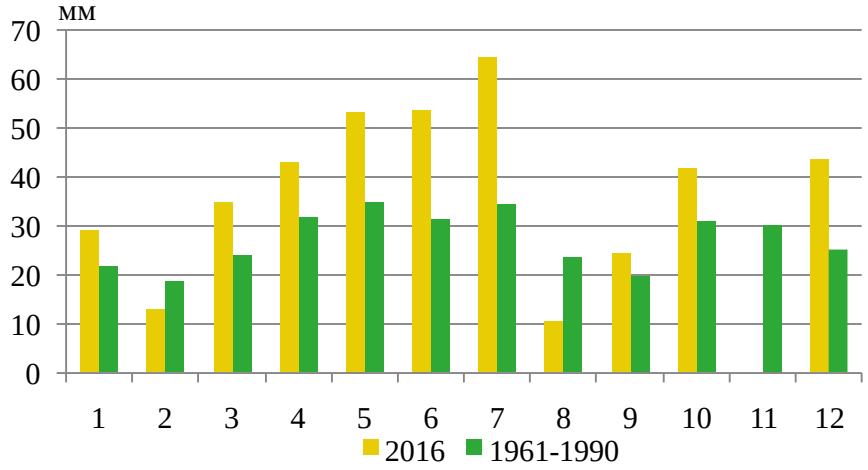


Figure 3.1 – Monthly precipitation in 2016 and climate normal 1961 – 1990 over the territory of Kazakhstan

Figure 3.2 shows the spatial distribution of annual and seasonal precipitation in 2016, expressed as percentage of normal over 1961 – 1990 and nonexceedance probability of annual and seasonal precipitation in 2016. The nonexceedance probability means the frequency of the corresponding anomaly in the observational records.

The annual amount of precipitation in 2016 on average in the territory of Kazakhstan made 140% of norm or 441,3 mm. This is the maximum amount of precipitation observed during the period from 1941 to 2016. (the first rank among wet years). The previous maximum of precipitation was in 1958 (437.8 mm). The historical maximum of precipitation was observed in Aktobe (149%), Mangystau (174%) and Almaty (157%) regions. A considerable excess of the amount of precipitation was observed in the West Kazakhstan. Amount of precipitation reached extreme values (the probability of non-exceedance is 90 - 100%) at many meteorological stations of the republic (47% of stations). Extremely dry (the probability of non-exceedance is 5%) was at weather stations - Amangeldy in Kostanay oblast (Table 3.1 and Figure 3.2).

Table 3.1 – Regional averaged annual and seasonal precipitation anomalies in 2016 (**vR**) relative to 1961-1990, ºC; **P** (r≤R2016) - probability of non-exceedance , calculated from the data for the period 1941-2016, %; **RR** - relationship R to the norm, expressed in %

Region	Year		Winter		Spring		Summer		Autumn	
	vR (P)	**RR**	**vR (P)**	**RR**	**vR (P)**	**RR**	**vR (P)**	**RR**	**vR (P)**	**RR**
Kazakhstan	**123,0 (100)**	**140**	19,7 (92)	140	**41,8 (97)**	**153**	37,1 (89)	157	22,8 (92)	128
Almaty	**231,1 (100)**	**157**	8,2 (56)	117	**87,4 (96)**	**160**	63,8 (93)	174	51,9 (94)	156
Akmola	**115,4 (97)**	**134**	25,6 (90)	152	8,1 (69)	110	43,5 (78)	130	24,8 (88)	133
Aktobe	**131,1 (100)**	**149**	**49,9 (100)**	**184**	**87,1 (98)**	**240**	-7,5 (40)	88	7,8 (74)	109
Atyrau	**102,9 (97)**	**165**	32,5 (92)	198	**80,1 (100)**	**301**	11,3 (72)	126	-9,7 (30)	77
East-Kazakhstan	**134,4 (97)**	**140**	13,6 (72)	120	18,3 (68)	121	**72,2 (96)**	**175**	**35,6 (96)**	**142**
Zhambyl	114,2 (92)	133	-15,8 (22)	84	26,1 (77)	120	54,2 (94)	237	28,3 (84)	135
West-Kazakhstan	**118,0 (97)**	**143**	**34,2 (98)**	**156**	**61,2 (98)**	**206**	6,1 (52)	138	26,8 (82)	134
Karaganda	73,1 (94)	128	**30,1 (97)**	**152**	11,7 (69)	121	52,0 (90)	169	9,8 (77)	114
Kastanay	84,6 (90)	126	**31,3 (98)**	**163**	23,8 (74)	137	17,3 (68)	109	13,8 (74)	119
Kyzylorda	40,7 (89)	128	17,5 (89)	144	24,4 (86)	148	5,7 (70)	134	6,4 (77)	128
Mangystau	**111,6 (100)**	**174**	**39,4 (100)**	**223**	**61,2 (98)**	**218**	11,9 (78)	141	3,9 (60)	111
Pavlodar	56,4 (80)	119	1,5 (61)	103	-6,4 (33)	91	44,7 (78)	139	10,3 (76)	114
North-Kazakhstan	98,5 (90)	127	20,1 (89)	142	13,6 (70)	120	39,7 (76)	126	22,7 (81)	126
South-Kazakhstan	108,2 (86)	125	-1,9 (36)	95	42,8 (76)	128	39,3 (93)	287	13,6 (69)	112

1. Mangystau oblast – parameters calculations were performed for 1960 – 2016
2. Values above 95th or below 5th percentiles are shaded in fat and bright color

Winter (December 2015 – February 2016)

The winter season in terms of the amount of precipitation averaged over the territory of Kazakhstan was wet (Table 3.1 and Figure 3.2). The amount of precipitation in most of the territory of Kazakhstan was above the norm by 40 - 80%. Historical maximum was observed in Aktobe (184%) and Mangystau (223%) regions. Extreme wet (above the 95th percentile) was in West Kazakhstan (156%) and Kostanay (163%) regions - the second largest anomaly in the series of observations and Karaganda (152%) region - the third rank among wet years. In Akmola and Atyrau regions, winter has entered into 10% of the wettest seasons. Precipitation deficit was observed in South Kazakhstan and Zhambyl regions, and at some stations in these regions it was very dry (the probability of non-exceedance was 7 - 25%).

Spring 2016

The spring was wet (153% of the norm) in the territory of most regions of Kazakhstan. Extremely wet was in the west of the republic, as well as in the mountain and foothill areas of the Ili Alatau. In Atyrau region, the amount of precipitation in the spring period was 301% of the norm, which is the historic maximum since 1941. The spring season in these areas has entered into 10% of the wettest seasons. The precipitation deficit was observed in the north-eastern

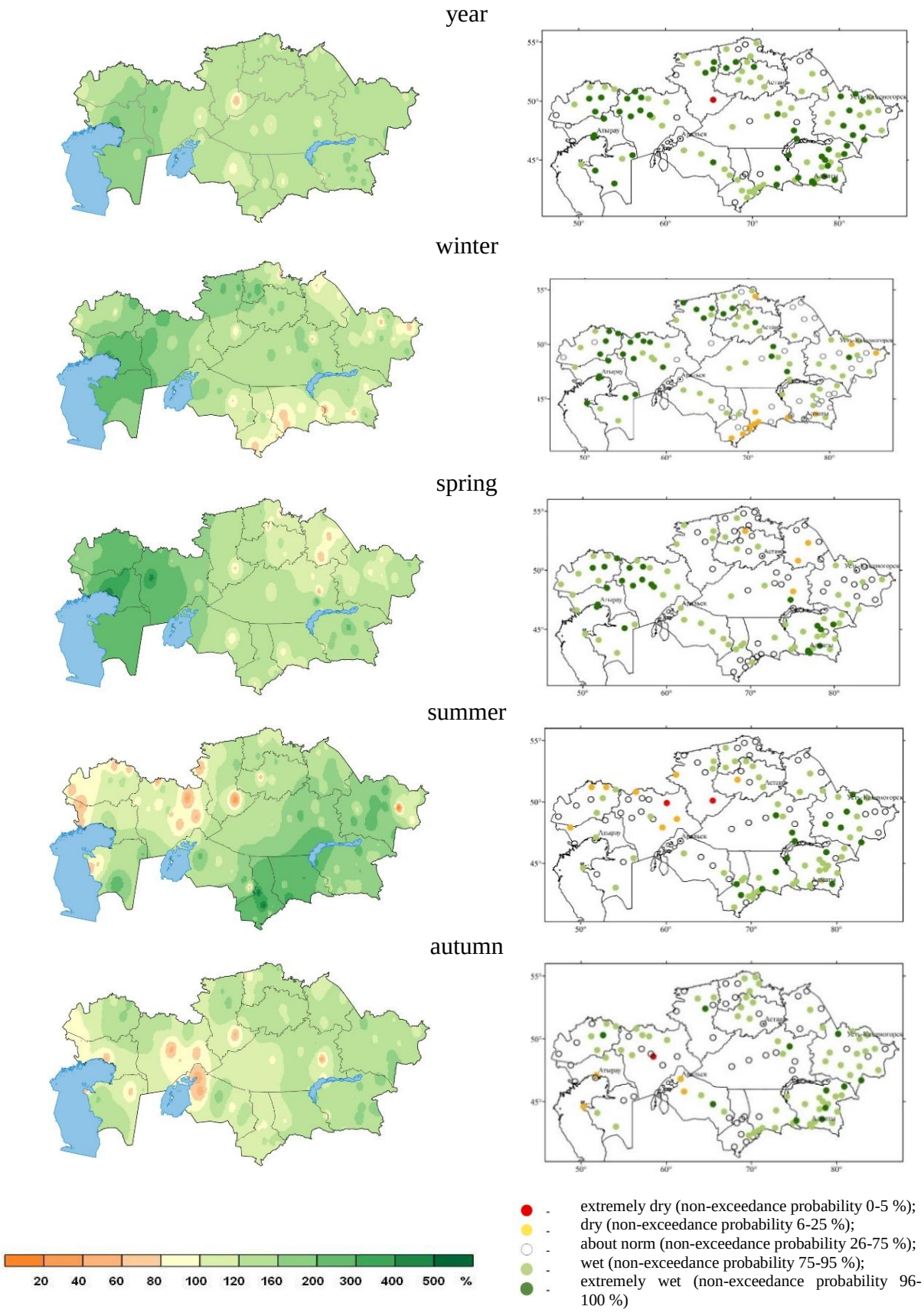


Figure 3.2 - Precipitation in 2016 as % of the norm 1961 – 1990 (left) and non–exceedance probabilities in 2016 calculated according to the period 1941 – 2016 (right)

part of the republic, the probability of non-exceedance in these areas compiled 9-25% (Table 3.1, Figure 3.2).

Summer 2016

In summer, the amount of precipitation was 153% of the norm (Table 3.1, Figure 3.2). Extremely wet was in the East Kazakhstan region. The amount of atmospheric precipitation here was 175% of the norm (96th percentile, the fourth rank), and also at some stations in the south and southeast of the republic. The deficit of moisture was observed in certain areas of the West Kazakhstan, Aktyubinsk and Kostanay regions. At meteorological stations Amangeldy and Karabutak was extremely dry (the probability of non-exceedance 4 and 5% respectively).

Autumn 2016

As a whole for an autumn season the amount of precipitation across the territory of Kazakhstan has made 128% of norm (92nd percentile). The greatest number of precipitation fell out in Almaty and East Kazakhstan regions - 156% and 142% of norm respectively. The deficit of precipitation was observed in Atyrau region – 77% of norm. It was dry also in certain areas of Aktobe and Kyzylorda regions (table 3.1, Figure 3.2).

To assess precipitation extremes in 2016 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 2016 are presented below.

Maximum of daily precipitation in 2015 (index Rx1day). Figure 3.3 shows absolute maximum daily precipitation, since the beginning of records to 2015 in red. Daily maximum observed in 2016 are in blue. In 2016the absolute maximum of daily precipitation has been exceeded at stations Shelek (49 mm), Ereymentau (123 mm), Ecil (81 mm), Chingirlau (77 mm).

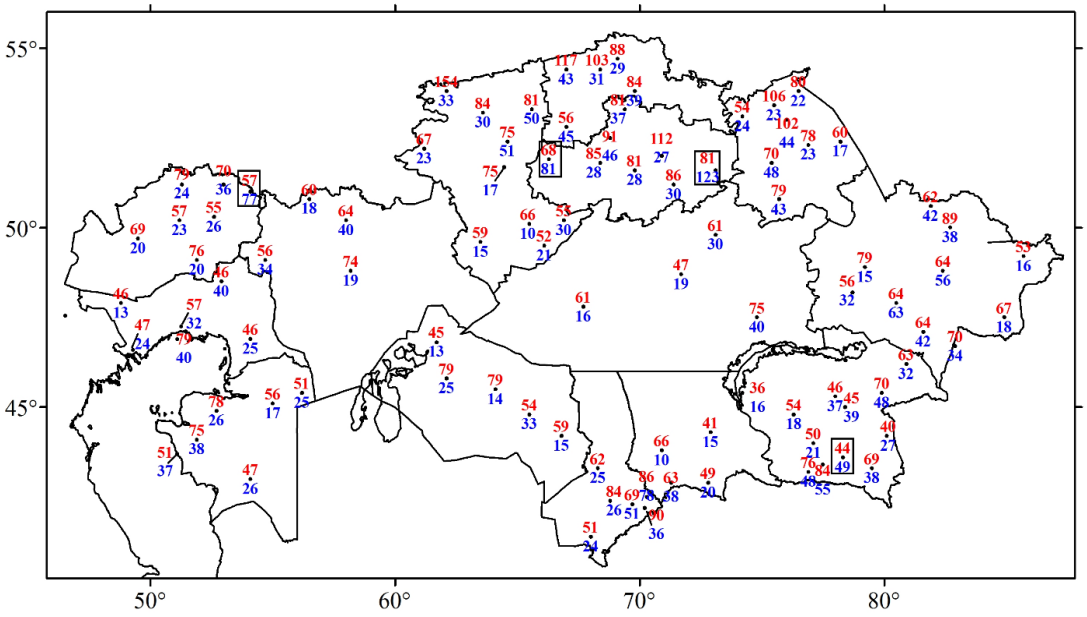


Figure 3.3 – Absolute maximum of daily precipitation, since the beginning of records until 2015 (in red) and the daily maximum in 2016 (in blue), mm

Figure 3.4 shows the share of extreme precipitation (above 95th percentile) in the total precipitation of 2016. Two indexes R95 and PRPTOT were used for calculation. R95 index represents precipitation exceeding the 95th percentile, whereas PRPTOT index shows annual precipitation. The largest share of extreme precipitation was observed at Ereymentau (57 %),

Ayagiz (50 %), Kyzylorda (48 %), Atyrau (47 %), Bektauata (46 %), Kulsary and Bakty (42 %), Ryzayevka and Zhambeity (40 %) stations. 24 stations also recorded rather high share of extreme precipitation – 20...39 % which means the irregularity fall of precipitation in time.

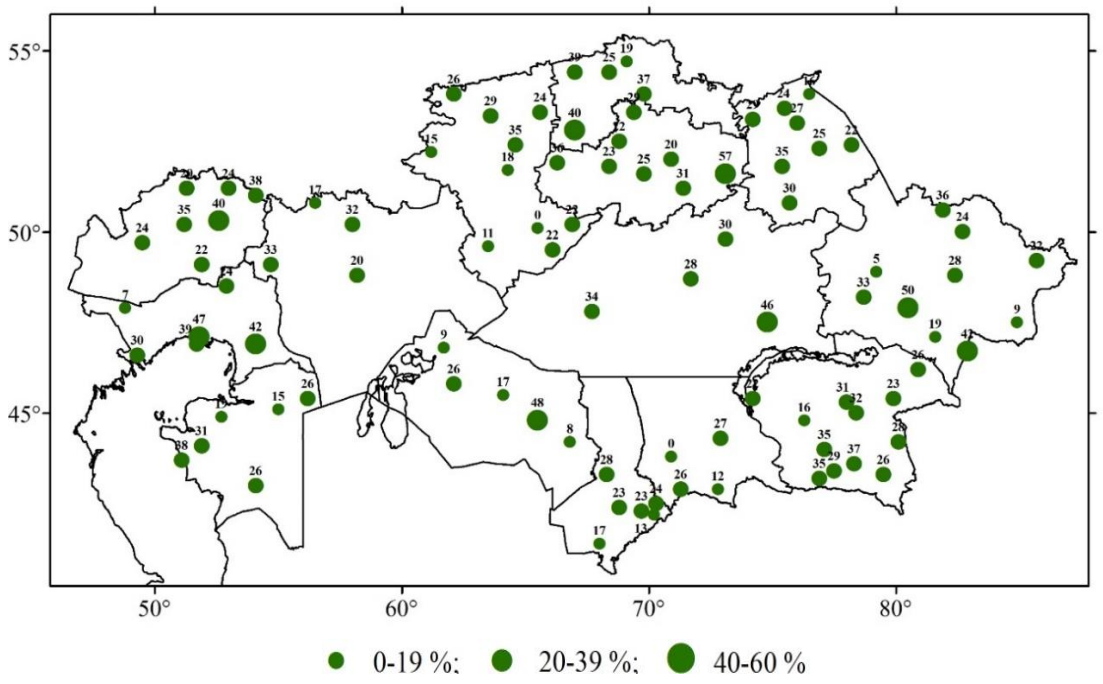


Figure 3.4 - Percentage share of extreme precipitation in the annual total in 2016. Extreme precipitation is the sum of daily precipitation exceeding 95th percentile

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 2016 the dry period lasted for more than a month at 67 weather stations. The largest dry period (60 – 77 days) was recorded at station Arys, Sam, Kuigan, Aralskoe more, Chiili, Kyzylorda and Turkestan.

Figure 3.6 shows ***the maximum duration of the period*** in 2016 ***when precipitation was equal or greater than 1 mm (CWD)***. The CWD index shows that the maximum duration of wet period varied from 8 to 10 days. The longest wet periods were observed at station Ayagos (10 days), Ryzaevka (8 days), Balkashino (8 days), Akkol (8 days) and Mikhailovka (Pavlodar region, 8 days).

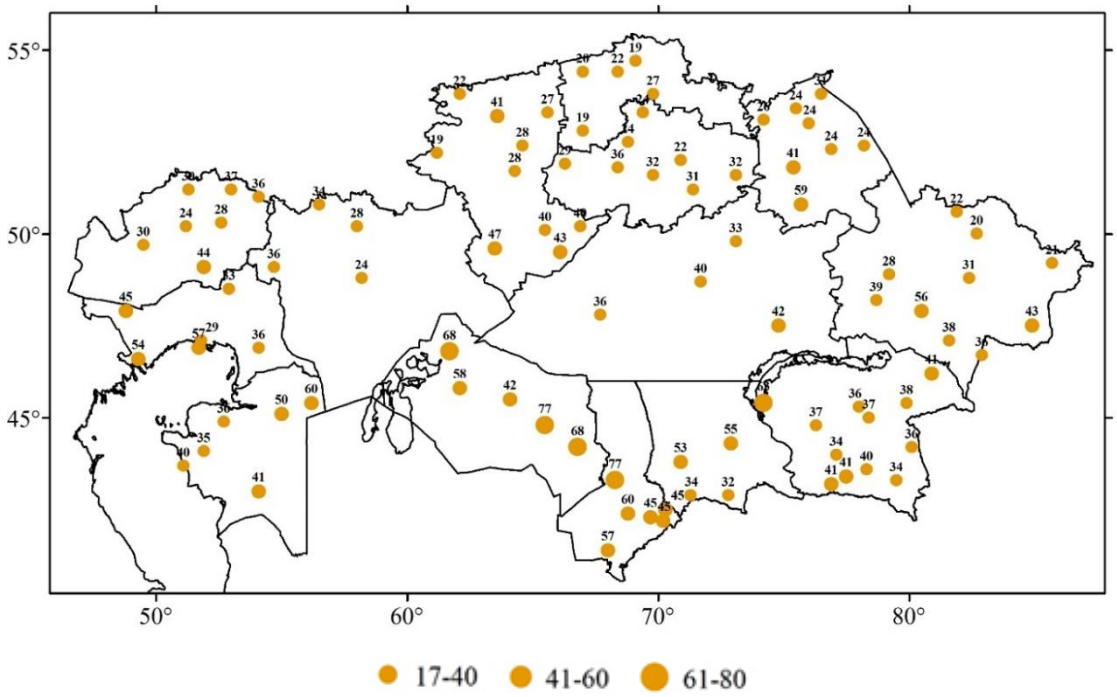


Figure 3.5 – Maximum duration (in days) of dry period in 2016

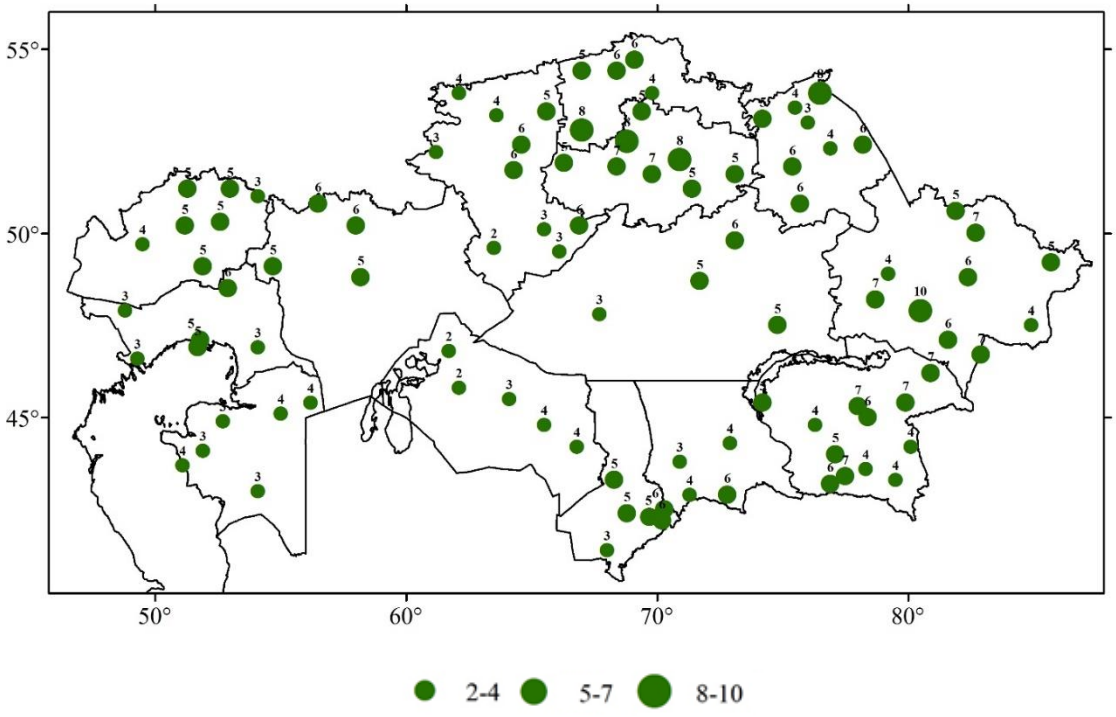


Figure 3.6 – Maximum duration (in days) of wet period in 2016

3.2 Observed changes in precipitation in Kazakhstan

Figure 3.7; 3.8 shows the time series of annual precipitation anomalies for 1940 – 2015 and 1976 - 2016, calculated relative to the 1961 – 1990 baseline and spatially averaged for Kazakhstan and its oblasts.

Linear trends of the monthly, seasonal and annual precipitation time series were estimated for 121 weather stations. For the last ten years there has been an alternation of short periods with positive and negative anomalies in the amount of precipitation. Long-term trends in the amount of precipitation during the study period are absent (Figure 3.7 and 3.8).

On average in Kazakhstan for the period 1976-2016. there was a weak tendency to increase the annual amount of precipitation by 7 mm/10 years (Figure 3.7, Table 3.2). The annual increase in the amount of precipitation is observed in all oblasts, except for the Kyzylorda oblast, where the decrease in the amount of precipitation was 5.2 mm/10 years. In winter, spring and summer seasons, the territory of the republic also has a tendency to increase the amount of precipitation by an average of 2.5 mm/10 years. The decrease in the amount of atmospheric precipitation in the autumn period was 1.2 mm/10 years (Figure 3.8, Table 3.2). All the trends of annual and seasonal precipitation amounts across the territory of the republic are statistically insignificant.

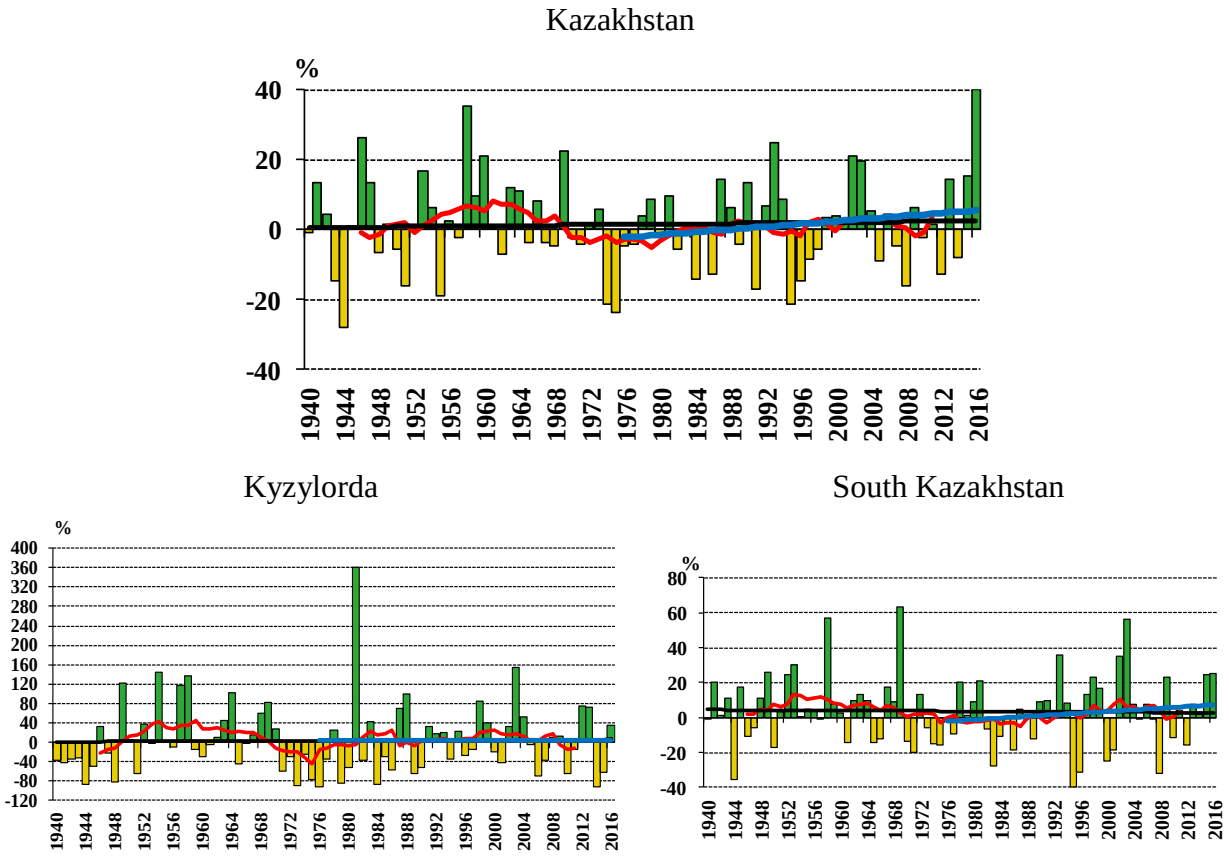


Figure 3.7 – Time series and linear trends of annual precipitation anomalies (%) for 1940 – 2016 (black line) and for 1976 - 2016 (blue line) calculated relative to the 1961 – 1990 baseline for the territory of Kazakhstan and its regions. *The smooth curve shows the 11–year moving average.*

List 1

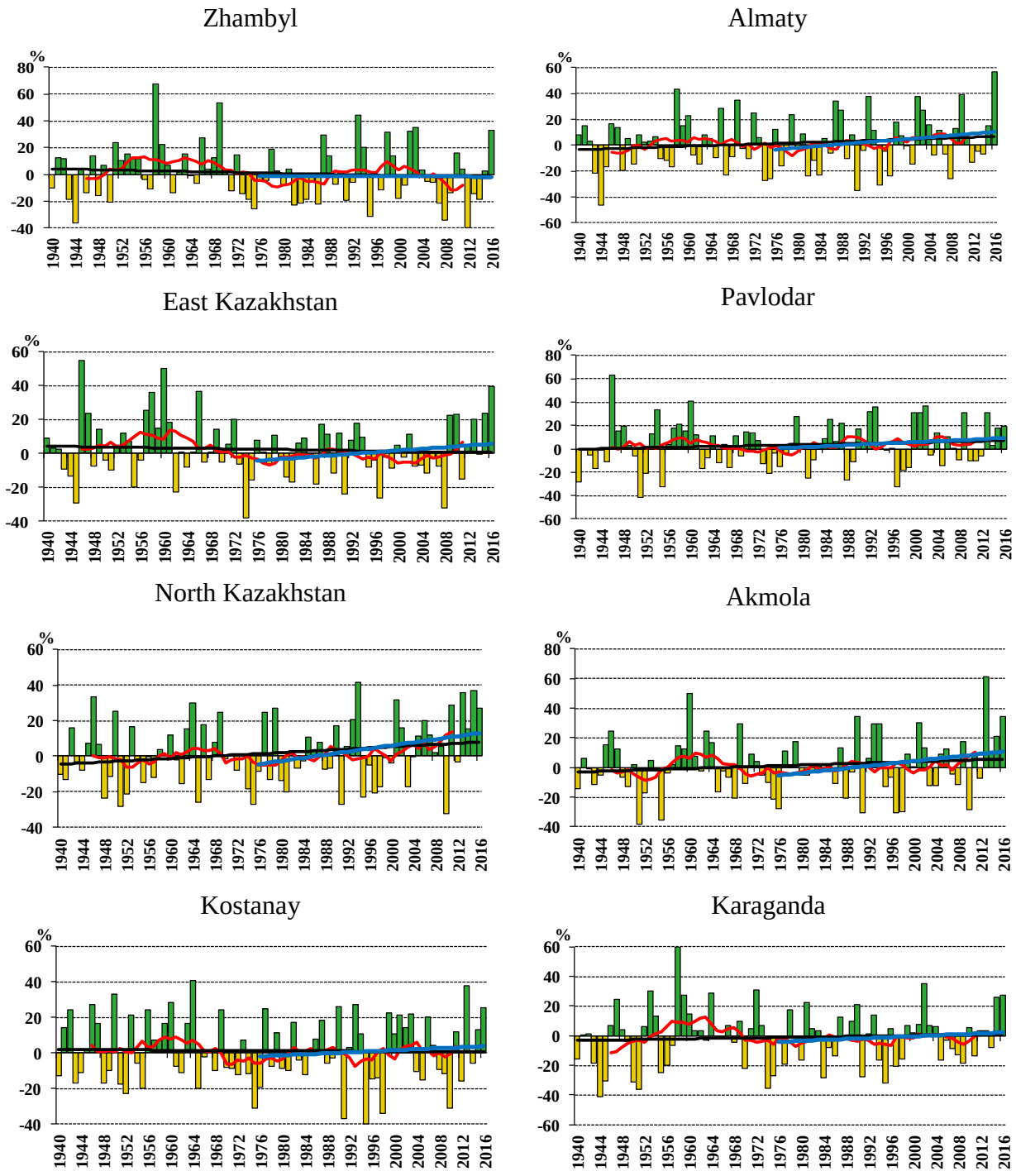


Figure 3.7 – Time series and linear trends of annual precipitation anomalies (%) for 1940 – 2016 (black line) and for 1976 - 2016 (blue line) calculated relative to the 1961 – 1990 baseline for the territory of Kazakhstan and its regions. *The smooth curve shows the 11–year moving average.*
List 2

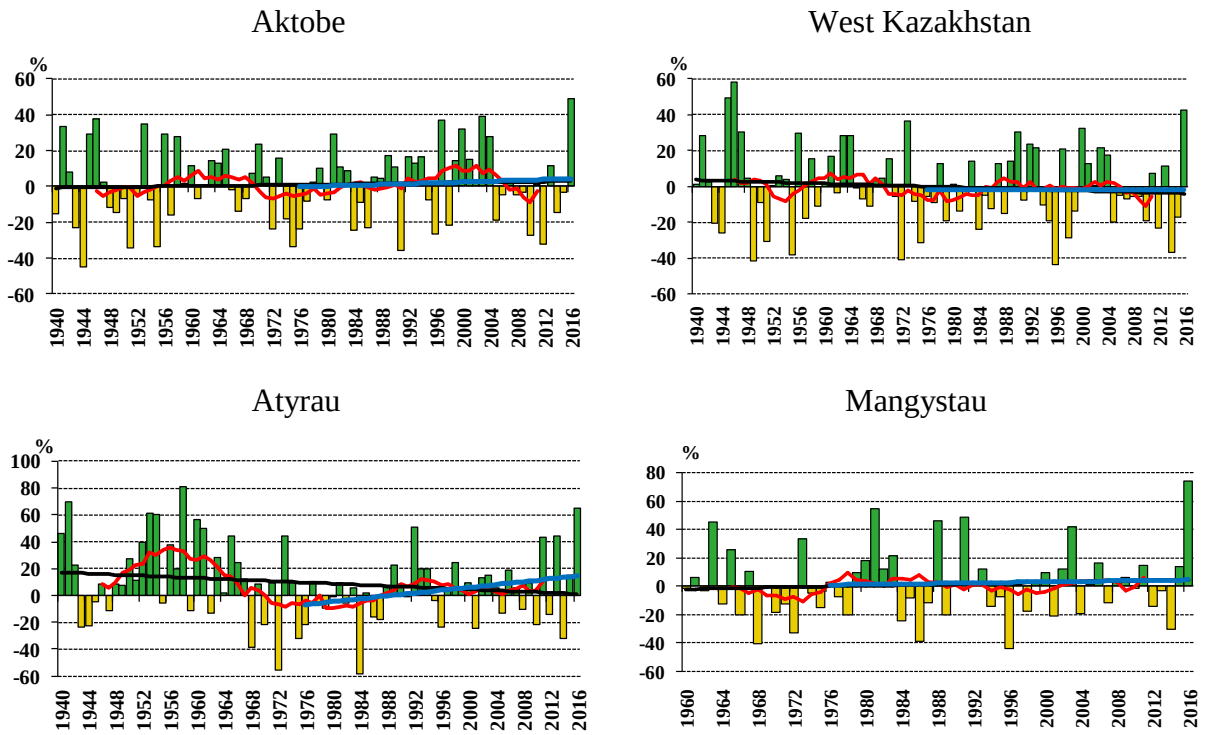


Figure 3.7 – Time series and linear trends of annual precipitation anomalies (%) for 1940 – 2016 (black line) and for 1976 - 2016 (blue line) calculated relative to the 1961 – 1990 baseline for the territory of Kazakhstan and its regions. *The smooth curve shows the 11–year moving average.*

List 3

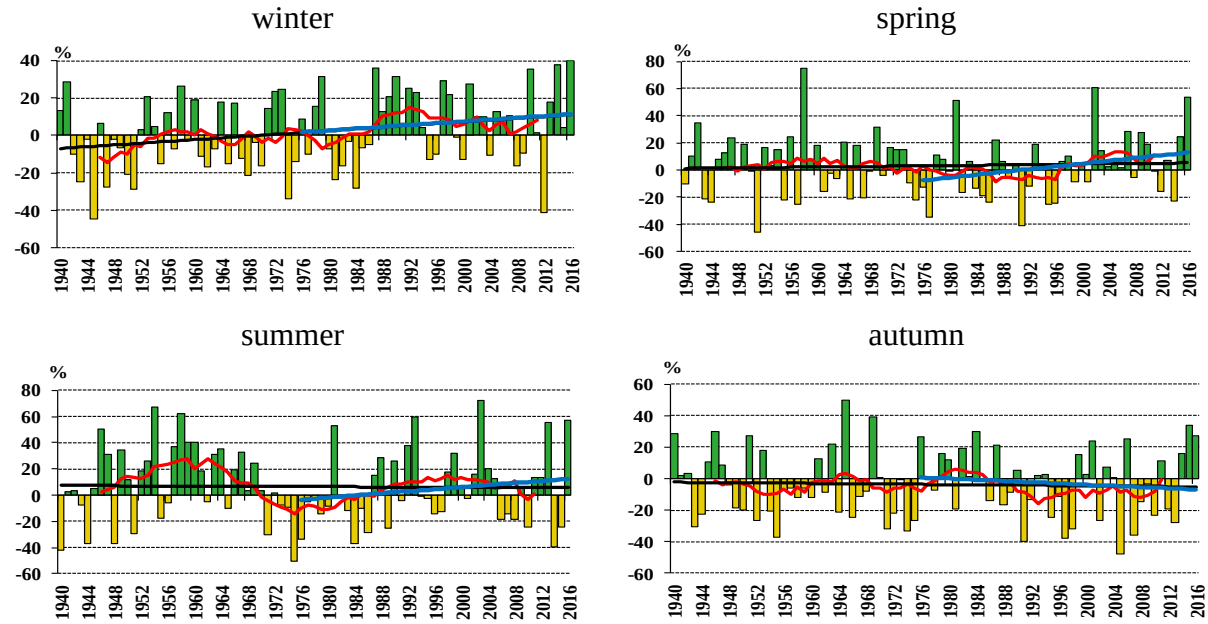


Figure 3.8 – Time series and linear trends of seasonal precipitation anomalies (%) for 1940 – 2016 (black line) and for 1976 - 2016 (blue line) calculated relative to the 1961 – 1990 baseline for the territory of Kazakhstan. *The smooth curve shows the 11–year moving average.*

Table 3.1 – Linear trend parameters of the seasonal and annual precipitation anomalies (mm/10 years, %/10 years) for Kazakhstan and its regions for 1979 – 2016 relative to the 1961 – 1990 baseline.

Region/oblast	Unit	Year		Winter		Spring		Summer		Autumn	
		*a	**R^2	a	R^2	a			*a	**R^2	a
Kazakhstan	mm	7,0	4	1,4	2	3,4	5	2,8	3	-1,2	1
	%	1,9		2,4		5,1		4,0		-1,9	
Almaty	mm	13,5	4	5,5	8	2,2	0	3,9	2	1,4	0
	%	3,4		8,0		1,9		3,7		1,9	
Akmola	mm	13,6	6	3,3	6	3,3	3	7,8	4	-2,0	1
	%	4,0		7,2		4,6		6,1		-2,4	
Aktobe	mm	2,7	0	0,0	0	7,3	8	-1,7	0	-4,0	6
	%	1,1		0,1		11,9		-2,1		-5,6	
Atyrau	mm	8,4	7	3,4	9	7,9	**16**	-2,5	2	-0,5	0
	%	5,3		10,3		19,7		-5,4		-1,1	
East Kazakhstan	mm	8,0	3	1,4	1	3,3	3	4,8	4	-1,4	0
	%	2,5		2,8		3,7		5,4		-1,2	
Zhambyl	mm	1,3	0	1,1	0	-5,0	3	4,5	4	0,2	0
	%	0,2		1,4		-4,3		10,3		-0,5	
West Kazakhstan	mm	0,2	0	-3,5	6	7,1	**13**	-4,1	2	0,1	0
	%	0,1		-4,6		12,2		-5,3		0,2	
Karaganda	mm	5,1	2	-0,4	0	2,1	1	7,0	**10**	-3,6	5
	%	1,5		-2,3		3,1		9,6		-6,1	
Kostanay	mm	5,7	1	-0,4	0	8,6	**23**	1,4	0	-4,4	6
	%	1,4		-0,7		13,6		1,3		-5,7	
Kyzylorda	mm	-5,2	2	-1,4	2	-0,7	0	0,1	0	-3,4	8
	%	-3,2		-1,8		-0,8		-0,2		-9,6	
Mangystau	mm	0,8	0	3,5	**10**	-3,7	3	2,0	2	-1,2	1
	%	0,9		11,1		-6,6		0,6		-3,4	
Pavlodar	mm	6,2	2	-0,7	1	4,3	8	3,7	1	-1,2	0
	%	2,1		-1,4		8,1		3,3		-1,7	
North Kazakhstan	mm	15,7	8	1,6	1	9,5	22	3,8	1	0,6	0
	%	4,4		3,2		14,3		2,4		0,6	
South Kazakhstan	mm	11,2	3	2,3	0	3,2	1	3,1	3	0,9	0
	%	2,4		0,6		1,9		12,3		1,9	

* a – linear trend factor, %/10years, mm/10 years;
** R^2 – determination factor,%
***«bold» type indicates statistically significant trend

Figure 3.9 and 3.10 provide more detailed information about changes in seasonal and monthly air temperatures (ºC/10 years) for 1976 – 2016 in Kazakhstan. Changes in the annual and seasonal precipitation are diverse.

In the most part of Kazakhstan annual precipitation trends were mostly positive, but insignificant. A statistically significant increase in precipitation is observed at some meteorological stations in Atyrau and Aktobe regions (8 – 13 %/10 years), and in the central and eastern parts of Kazakhstan (6 – 10 %/10 years). At meteorological stations Besoba, Amangeldy, Uyuk and Aktogai (Karaganda region), stable negative trends were 7 – 13 %/10 years.

In **winter**, the largest significant rate of increase in the amount of precipitation (9 – 24 %/10 years) is recorded in the southwest, north and southeast of the republic. The amount of precipitation in January and December made the greatest contribution to the positive trend of this

season (Figure 3.10). A statistically significant decrease in the amount of precipitation was recorded at the weather stations of West Kazakhstan (13 – 19 %/10 years), Karaganda (10 – 21 %/10 years) and East Kazakhstan (11 %/10 years) regions.

In **spring**, the amount of precipitation increased throughout the territory of Kazakhstan. Significant positive trends in the north and north-west of the republic were 10 - 38%/10 years. The largest contribution to the increase in the amount of precipitation in the spring was made by March, when significant positive trends from 13 to 45 %/10 years were observed practically across all Kazakhstan (Figure 3.10). A significant decrease in the amount of precipitation by 10 – 12 %/10 years was recorded at the meteorological stations of Aktogay (Karagandy region), Besoba and Uyuk.

In **summer**, the amount of precipitation decreased by 1 – 16 %/10 years in the West Kazakhstan, Aktobe and Atyrau regions. Trends are mostly insignificant, with the exception of Urda, where a significant decrease in precipitation was 14 %/10 years. In June and August, the most significant areas are covered by negative trends (Figure 3.10). Significant positive trends were observed in Mangystau, Karaganda and East Kazakhstan regions at the meteorological stations Sam, Aksu-Ayuly, Zhanaarka, Zharyk and Barshatas (13 - 23%/10 years).

The **autumn** season is characterized by a decrease in the amount of precipitation in most of Kazakhstan, especially in Aral Sea and Balkash lake. At some meteorological stations of Aktobe, Kostanay, Karaganda and Kyzylorda regions, a significant decrease in precipitation was 8 26% / 10 years. In September and October, a decrease in the amount of precipitation is observed in most of the republic's territory (Figure 3.10). Positive trends in the autumn period are statistically insignificant.

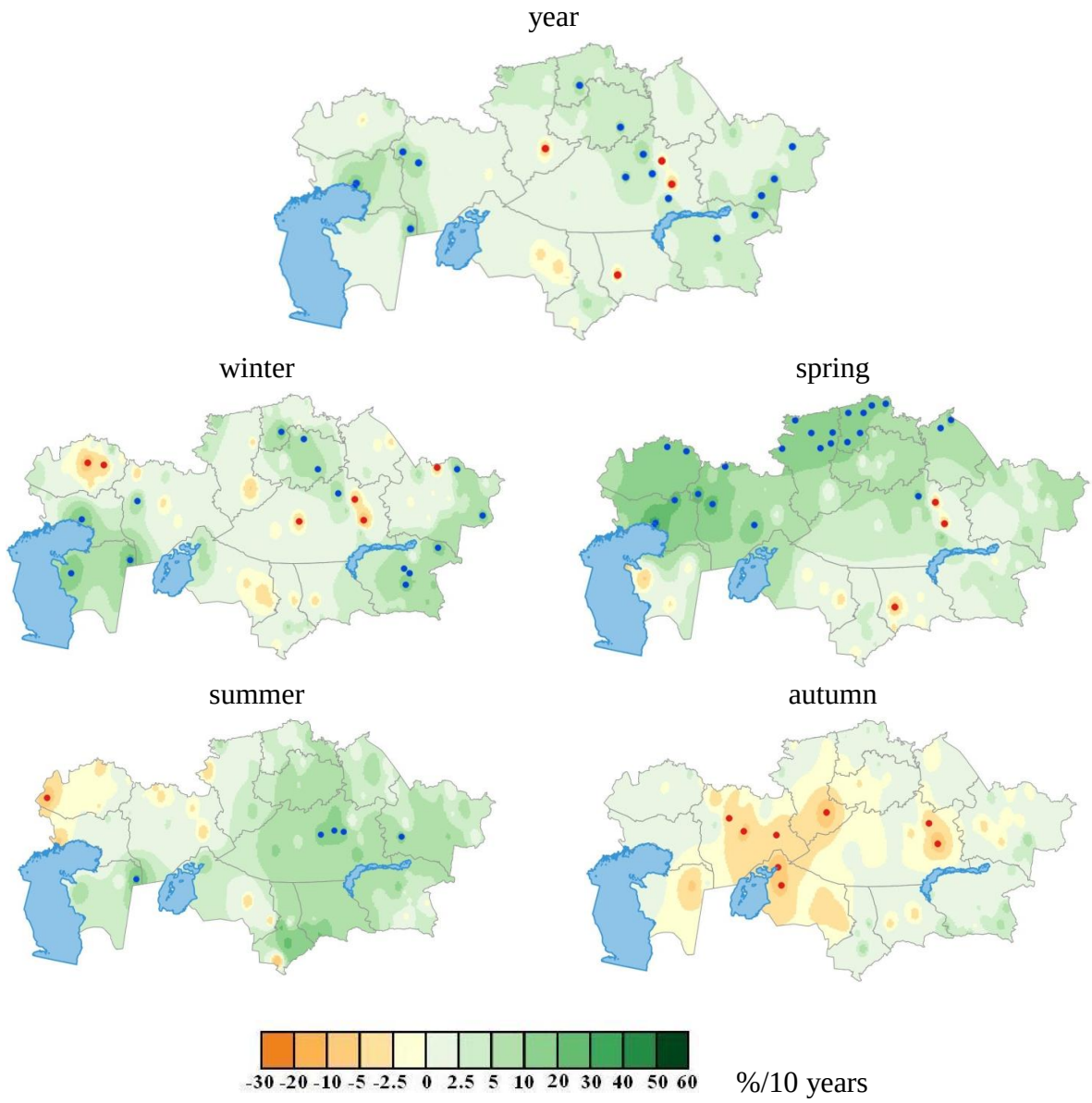


Figure 3.9 – Spatial distribution of the linear trend factor of annual and seasonal precipitation anomalies (%/10 years), over 1976 – 2016. List 2

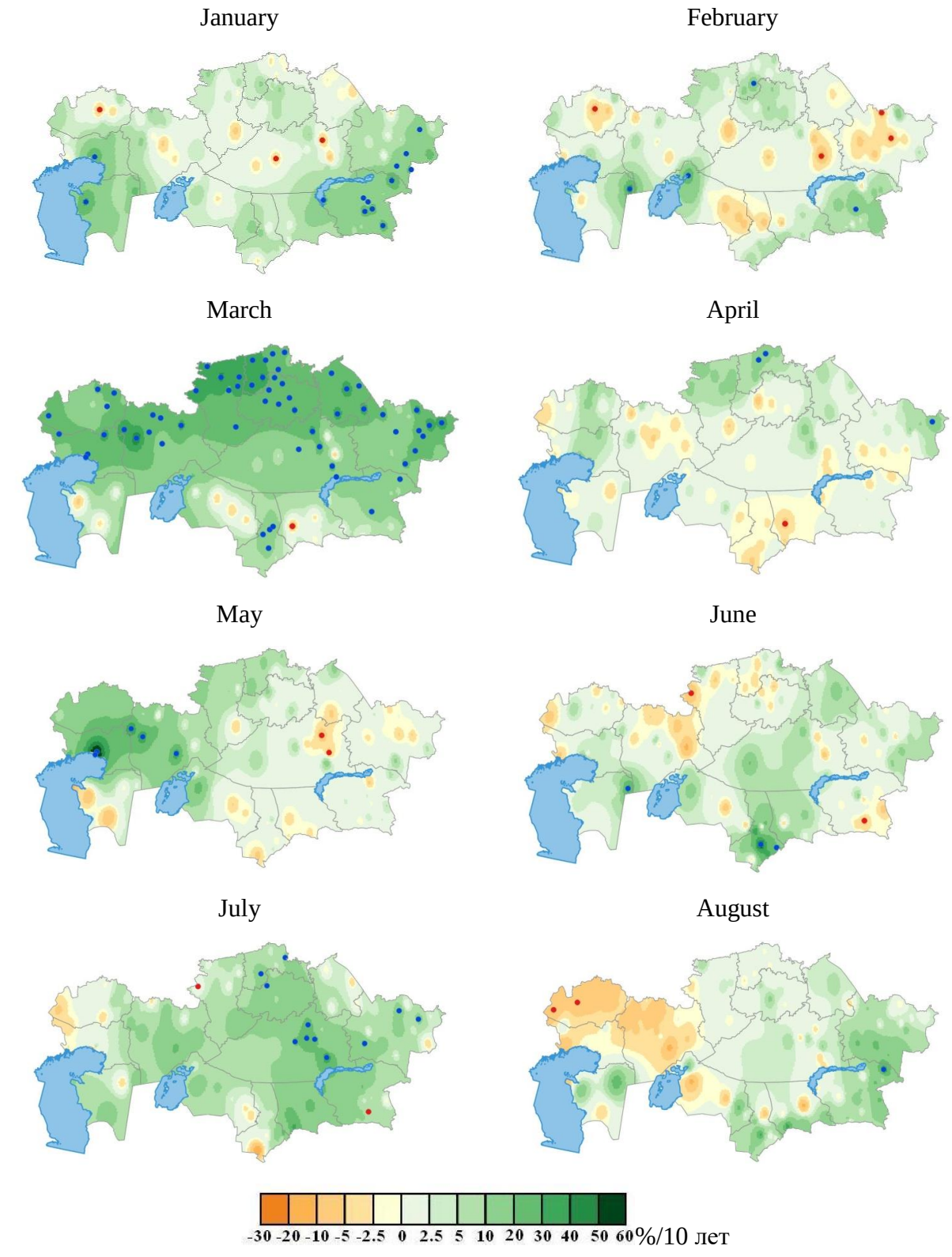


Figure 3.10 – Spatial distribution of the linear trend factor of monthly precipitation anomalies (%/10 years), over 1976 – 2016. List 1

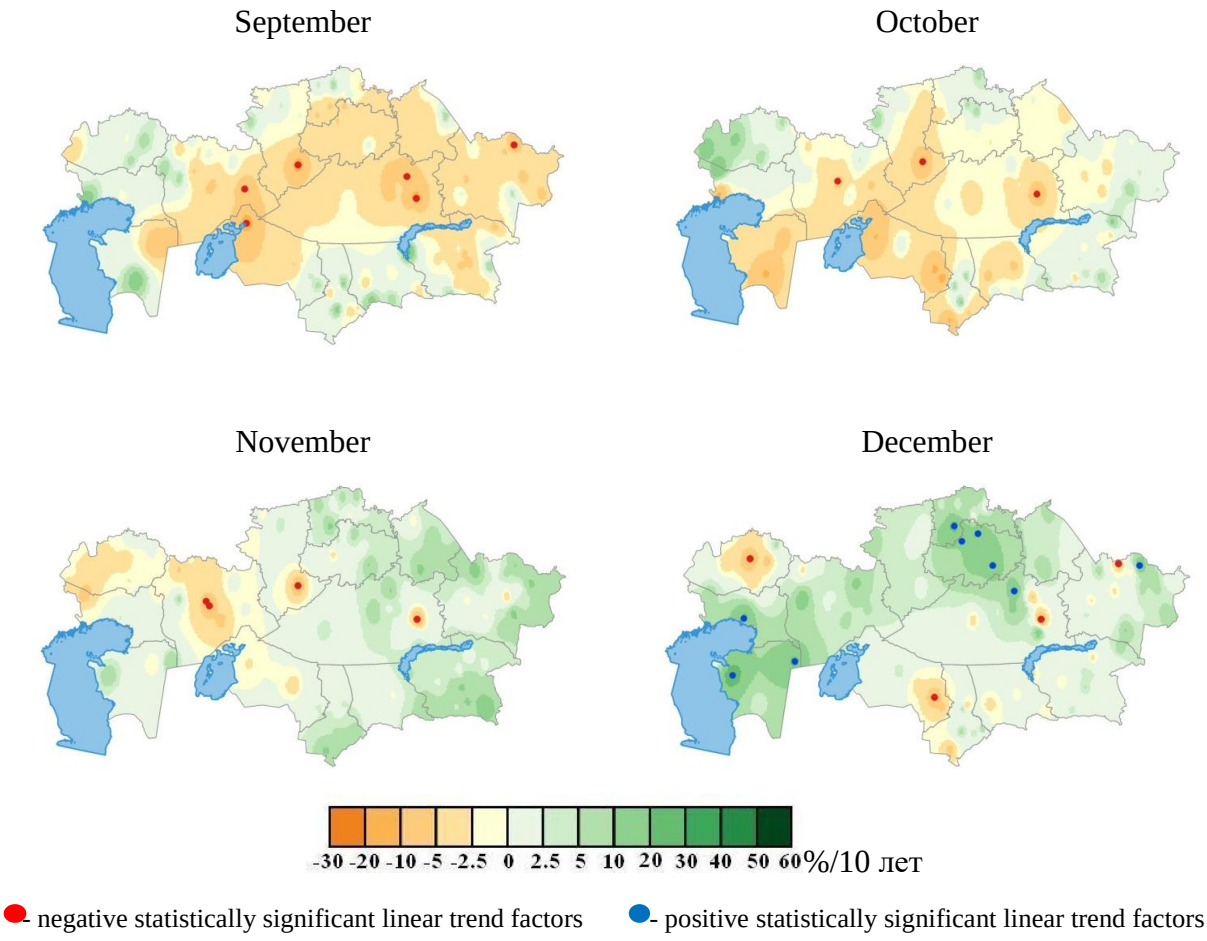


Figure 3.10 – Spatial distribution of the linear trend factor of monthly precipitation anomalies (%/10 years), over 1976 – 2016. List 2

3.3 Trends in precipitation extremes

Trend analysis of precipitation extremes was prepared over 1941 – 2016, based on the most representative indexes proposed by WMO. ***Values of the maximum daily amount of precipitation*** (Rx1day index) in the territory of Kazakhstan have practically not changed (Figure 3.11). Almost throughout the territory of the republic (65 % of the total number of meteorological stations) there was a slight increase in the maximum daily precipitation amount by 0.01 - 2.0 mm/10 years. Statistically significant changes were recorded at weather stations Kuygan, Atyrau, Bektauata, Bayanaul, Aul Turar Ryskulov.

Analysis of ***the percentage share of extreme precipitation in annual total*** (***R95pTOT***) showed that weak trends both decreasing and increasing by 0.01 – 2.0 %/10 years was observed everywhere in Kazakhstan except few stations. The share of extreme precipitation increased by 1.38 – 1.46 % every 10 years at Bakty and Karaganda whereas the share of extreme precipitation decreased by 1.02 - 2.41 %/10 years at aul Turar Ryskulov, Tayinshy and Ayagoz. All changes at these weather stations are statistically reliable (Figure 3.12).

An increase in the extreme amount of precipitation during the warm period leads to an increased risk of erosive processes, in mountainous areas - mudflows of rain genesis, and in the cold period - to an increase in the danger of avalanches.

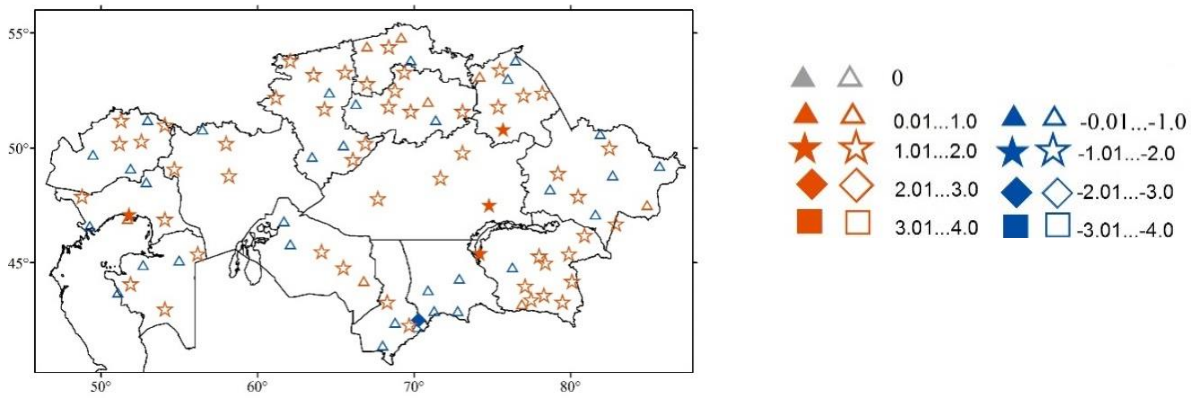


Figure 3.11 – Spatial distribution of the linear trend factor of maximum daily precipitation (mm/10 years), for 1941 – 2016. Shaded keys stand for statistically significant trend

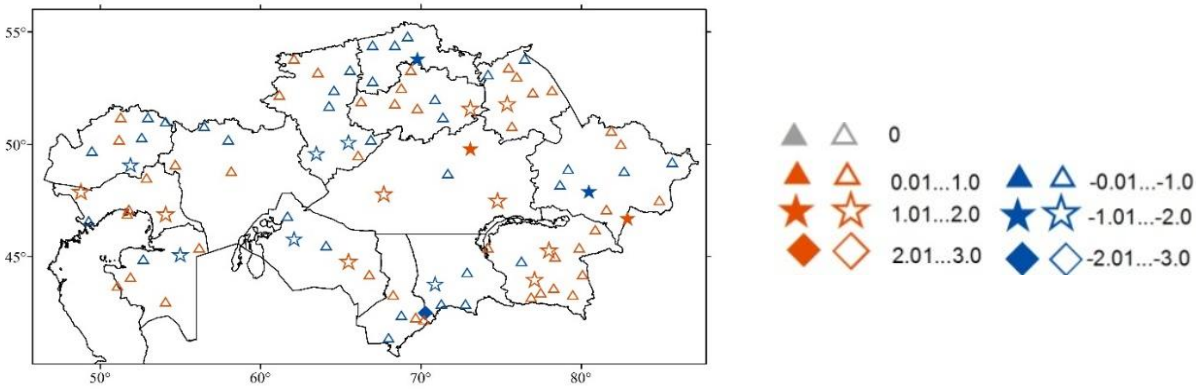


Figure 3.12 – Spatial distribution of the linear trend factor of extreme precipitation share in annual total (%/10 years) over 1941 – 2016. Extreme precipitation is the sum of daily precipitation above the 95th percentile. Shaded keys stand for statistically significant trend.

Most of the territory of Kazakhstan has a tendency to reduce ***the maximum duration of dry period (CDD)*** almost everywhere in Kazakhstan. Statistically significant decrease occurred in the northern and northeastern regions of Kazakhstan by 1 – 5 days every 10 years (Figure 3.13). The values of the CDD index are an important characteristic of the climate, especially for agriculture.

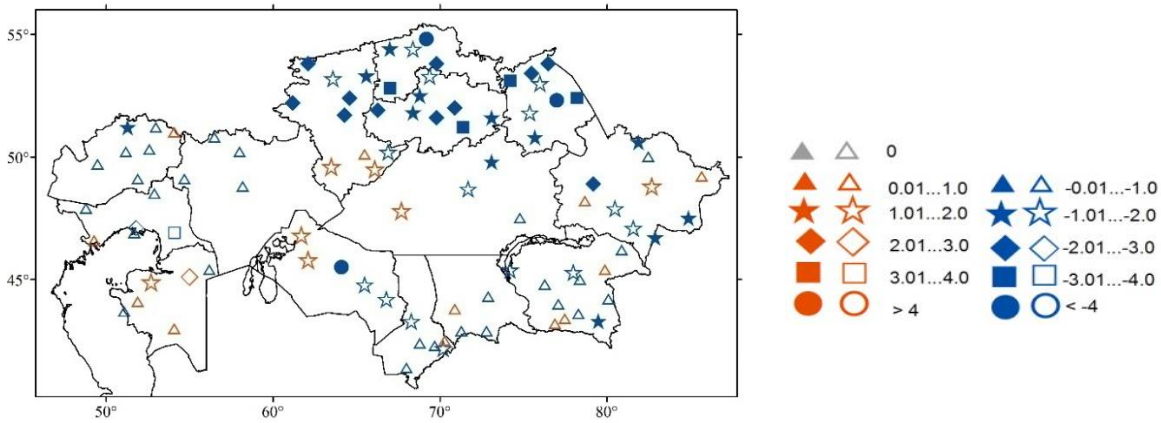


Figure 3.13 – Spatial distribution of the linear trend factor of the maximum dry period duration (day/10 years) over 1941 – 2016. Shaded keys stand for statistically significant trend

CONCLUSION

Features of 2016 year

. In the three dataset mean used by WMO, 2016 was 0.83 °C ± 0.1 °C warmer than the average for the 1961–1990 reference period (0.52 °C above the 1981–2010 average), 0.06 °C above the previous highest value set in 2015. This is also about 1.1 °C above the pre-industrial period.

Global temperatures in 2016 were substantially influenced by the strong El Nico event of 2015/2016, especially early in the year. Temperatures in years in which strong El Nico events finish, such as 1973, 1983 and 1998, are typically 0.1 °C to 0.2 °C warmer than background levels and temperatures in 2016 were consistent with that pattern. Global sea levels rose strongly during the 2015/2016 El Nico, and values reached new record highs in the early 2016.

Global precipitation in 2016 was strongly influenced by the transition from El Nico conditions in the early part of the year to neutral or weak La Nica conditions in the second half. This resulted in strong seasonal contrasts but annual totals relatively close to average in many parts of the world.

In 2016, numerous extreme events were recorded around the world, such as:

– severe droughts and floods;

– tropical cyclones;

– destructive natural fires;

– considerable heat waves;

– considerable cold waves;

– heave thunderstorms and tornadoes.

In several cases it was reported about high material damage, to movement hundreds of thousands of people and also about numerous victims and even deaths of people.

2016 was extremely warm on the most part of the territory of the republic. *The anomaly of* average annual air temperature *exceeded climatic norm at 1:48 ºC (97% extreme).* Extremely warm year was in Zhambyl, South Kazakhstan and Kyzylorda oblasts. The maximum of average annual temperature was fixed at 38 stations for the period from 1941. In far western regions, the maximum duration of heat waves was more than 70 days in year. The vegetation period in Almaty, Zhambyl and South Kazakhstan regions was shorter by 20-30 days than in 2015. In general, in Kazakhstan, 2016 was a record year for the amount of precipitation. The annual amount of precipitation in 2016 on average in the territory of Kazakhstan made 140% of norm or 441,3 mm. This is the maximum amount of precipitation observed during the period from 1941 to 2016. (the first rank among wet years). The previous maximum of precipitation was in 1958 (437.8 mm). The historical maximum of precipitation was observed in Aktobe (148%), Mangystau (173%) and Almaty (157%) regions. A considerable excess of the amount of precipitation was observed in the West Kazakhstan. Amount of precipitation reached extreme values (the probability of non-exceedance is 90 - 100%) at many meteorological stations of the republic (47% of stations).

In 2016 the absolute maximum of daily precipitation has been exceeded at stations Shelek (49 mm), Ereimentau (123 mm), Esil (81 mm), Chingirlau (77 mm). The largest share of extreme precipitation was observed at Ereimentau (57 %), Ayagoz (50 %), Kyzylorda (48 %),

Atyrau (47 %), Bektayata (46 %), Kulsary and Bakty (42 %), Ryzaevka and Zhambeity (40 %) stations. The longest wet periods were observed at station Ayagoz (10 days), Ryzaevka (8 days), Balkashino (8 days), Akkol (8 days) and Mikhailovka (Pavlodar region, 8 days). The largest dry period (60 – 77 days) was recorded at station Arys, Sam, Kyigan, Aral tenizi, Shieli, Kyzylorda and Tyrkestan.

Winter 2015/16 was extremely warm and record-warm. The average annual temperature anomaly in the Republic was +4.6 °C, which is the absolute maximum for the period since 1941. Record high anomalies were observed in the western and southern regions of Kazakhstan, where 2016 became the warmest winter season in the history of observations, beginning in 1941. The maximum duration of cold waves (15 - 16 days) were observed in East Kazakhstan and Karaganda regions. The winter season in terms of the amount of precipitation averaged over the territory of Kazakhstan was record-breaking wet. The amount of precipitation in most of the territory of Kazakhstan was above the norm by 40 - 80%. Historical maximum was observed in Aktobe (184%) and Mangystau (223%) regions. Precipitation deficit was observed in South Kazakhstan and Zhambyl regions, and at some stations in these regions it was very dry (the probability of non-exceedance was 7 - 25%).

Spring 2016 was also extremely warm. The average seasonal air temperature in Kazakhstan was +3.1 °C, which is the second magnitude since 1941. In all regions of Kazakhstan, the anomalies of spring temperature were part of 10 % of the highest positive anomalies. Extremely wet was in the west of the republic, as well as in the mountain and foothill areas of the Ili Alatau. In Atyrau region, the amount of precipitation in the spring period was 301% of the norm, which is the historic maximum since 1941. The spring season in these areas has entered into 10% of the wettest seasons.

Summer 2016. The anomaly averaged over the territory of Kazakhstan was +0.8 °C, this is the 93th percentile and the 11th magnitude in the series of positive anomalies since 1940. Negative anomalies were observed in the Akmola and Karaganda regions. The maximum number of 55-65 days was observed in the South Kazakhstan and Mangystau regions. At meteorological stations Amangeldy and Karabutak was extremely dry (the probability of non-exceedance 4 and 5% respectively). Extremely wet was in the East Kazakhstan region and also at some stations in the south and southeast of the republic.

Autumn 2016 was cold due to relatively low air temperatures in October and November. The average air temperature in Kazakhstan in the autumn season was below the norm by 1.2 °C. The coldest was in Pavlodar, Karaganda and East Kazakhstan regions. In September at separate stations of Karaganda, East Kazakhstan, Pavlodar, Almaty, South Kazakhstan Kazakhstan, Zhambyl regions the maximum of average monthly air temperature from 1941 were updated. In October the minimum at the station Aktogai in the Karaganda region was updated. As a whole for an autumn season the amount of precipitation across the territory of Kazakhstan has made 128%. The greatest number of precipitation fell out in Almaty and East Kazakhstan regions - 156% and 142% of norm respectively. The deficit of precipitation was observed in Atyrau region - 77% of norm.

Climate Change in Kazakhstan

Country average annual temperature for the period 1976 – 2016 has been rising by 0,34 ºC every 10 years. The trend contribution to total dispersion of average annual temperatures makes 25%. The greatest increase in air temperature over the past 40 years is observed in the spring (0.67 ºC/10 years), the smallest and statistically insignificant in the winter (0.13 ºC/10 years).

On average in Kazakhstan for the period 1976-2016. there was a weak tendency to increase the annual amount of precipitation by 7 mm/10 years. All the trends of annual and seasonal precipitation amounts across the territory of the republic are statistically insignificant.

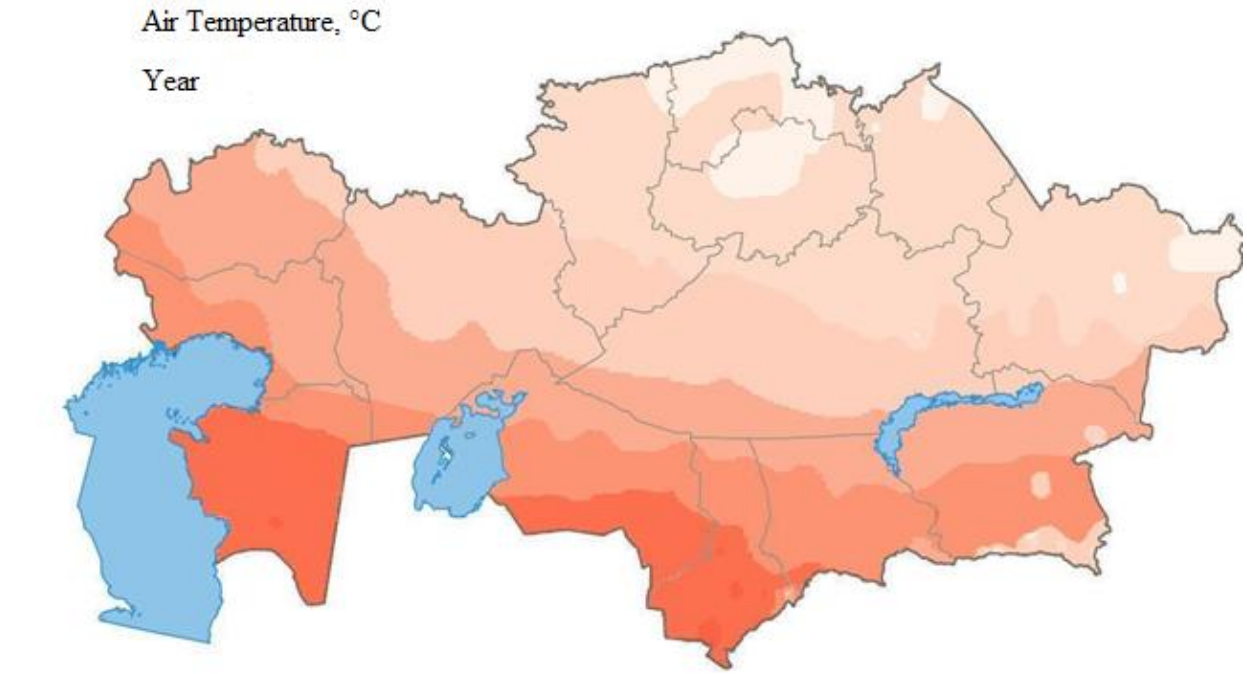
For the period 1976 – 2016 a significant decrease in the daily maximums of the surface air temperature is observed in Balkashino (0.73 ºC/10 years) and Zharkent stations (0.37 ºC/10 years).

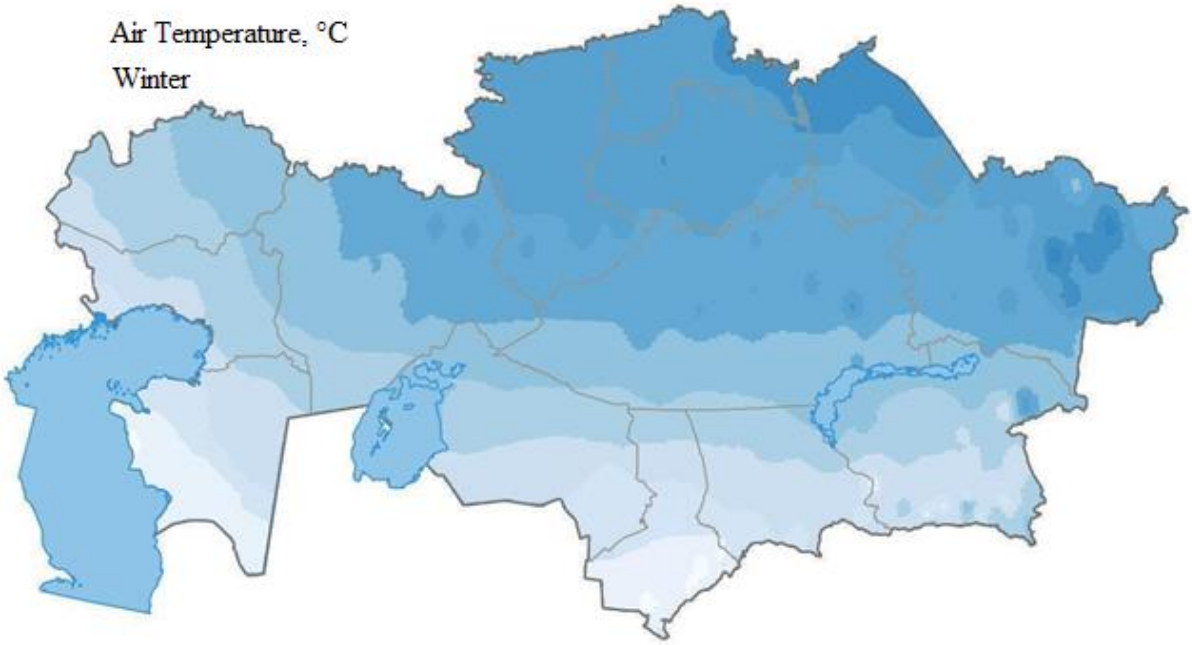
Statistically significant trend of increasing the number of days with an air temperature above 35 °C is observed in West Kazakhstan, Aktobe, Atyrau, Mangystau, Kyzylorda, South Kazakhstan oblasts: for 4 – 8 days every 10 years. The total duration of heat waves increased throughout the country by 6 to 10 days/10 years. Also, there is a general decrease in the frequency of frosty days: by 3 8 days every 10 years.

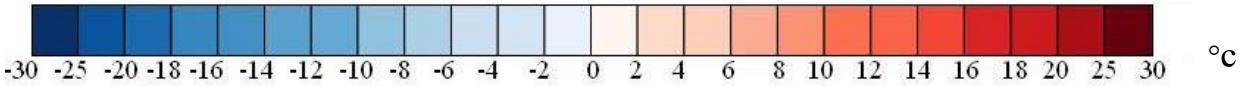
At some stations in Kazakhstan, there have been significant changes in the regime of precipitation. In the northern and north-eastern regions, as well as some meteorological stations in the south and south-east of the republic, there has been a tendency to reduce the dry period by 1 – 5 days/10 years. Statistically significant changes in the maximum daily precipitation amount by 0,7 - 1,5 mm/10 years were recorded at weather stations Kuygan, Atyrau, Bektayata, Bayan. The share of extreme precipitation increased by 1.38 – 1.46 % every 10 years at Bakty and Karaganda whereas the share of extreme precipitation decreased by 1.02 - 2.41 %/10 years at aul Turara Ryskulova, Taiynsha and Ayagoz. All changes at these weather stations are statistically reliable.

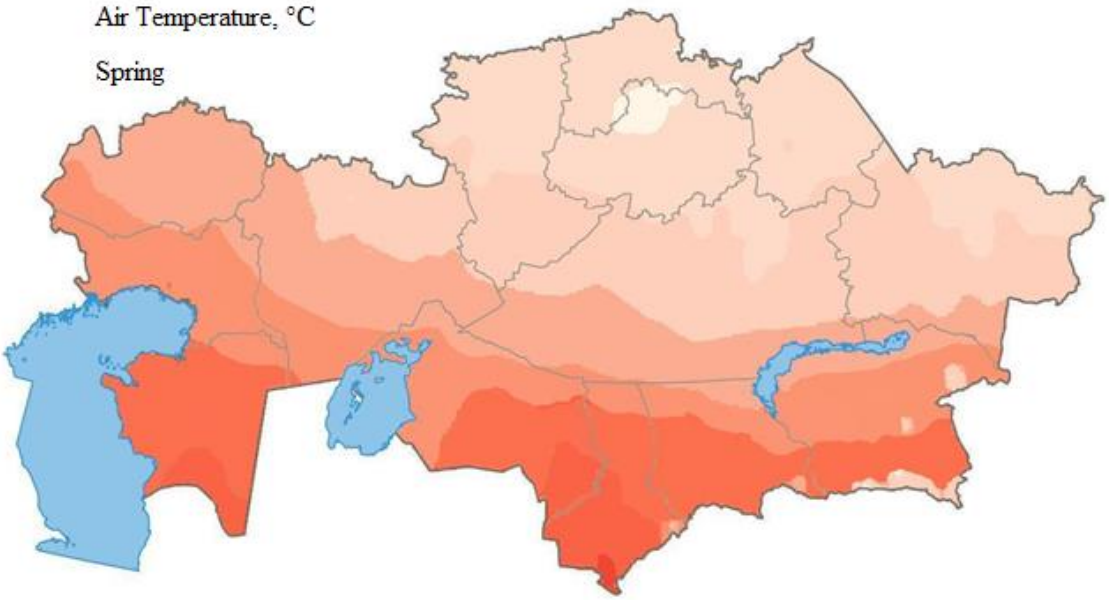
ANNEX 1

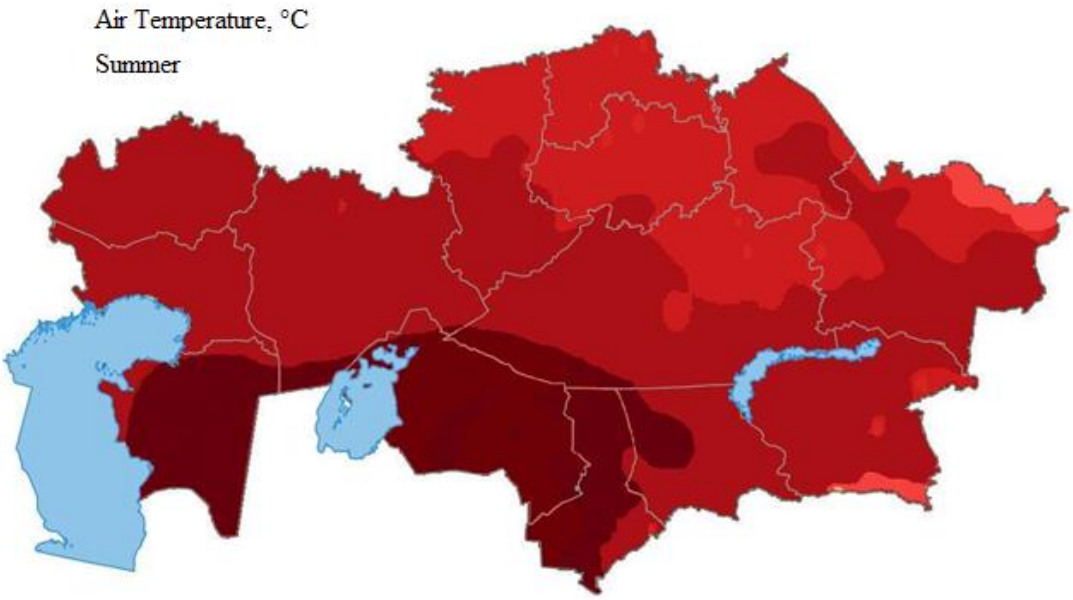
SPATIAL DISTRIBUTION OF AVERAGE ANNUAL AND AVERAGE SEASONAL AIR TEMPERATURE ON THE TERRITORY OF KAZAKHSTAN, CALCULATED OVER THE PERIOD 1961 – 1990

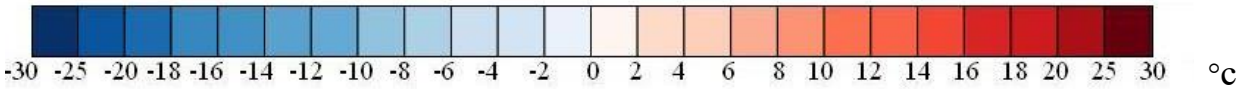


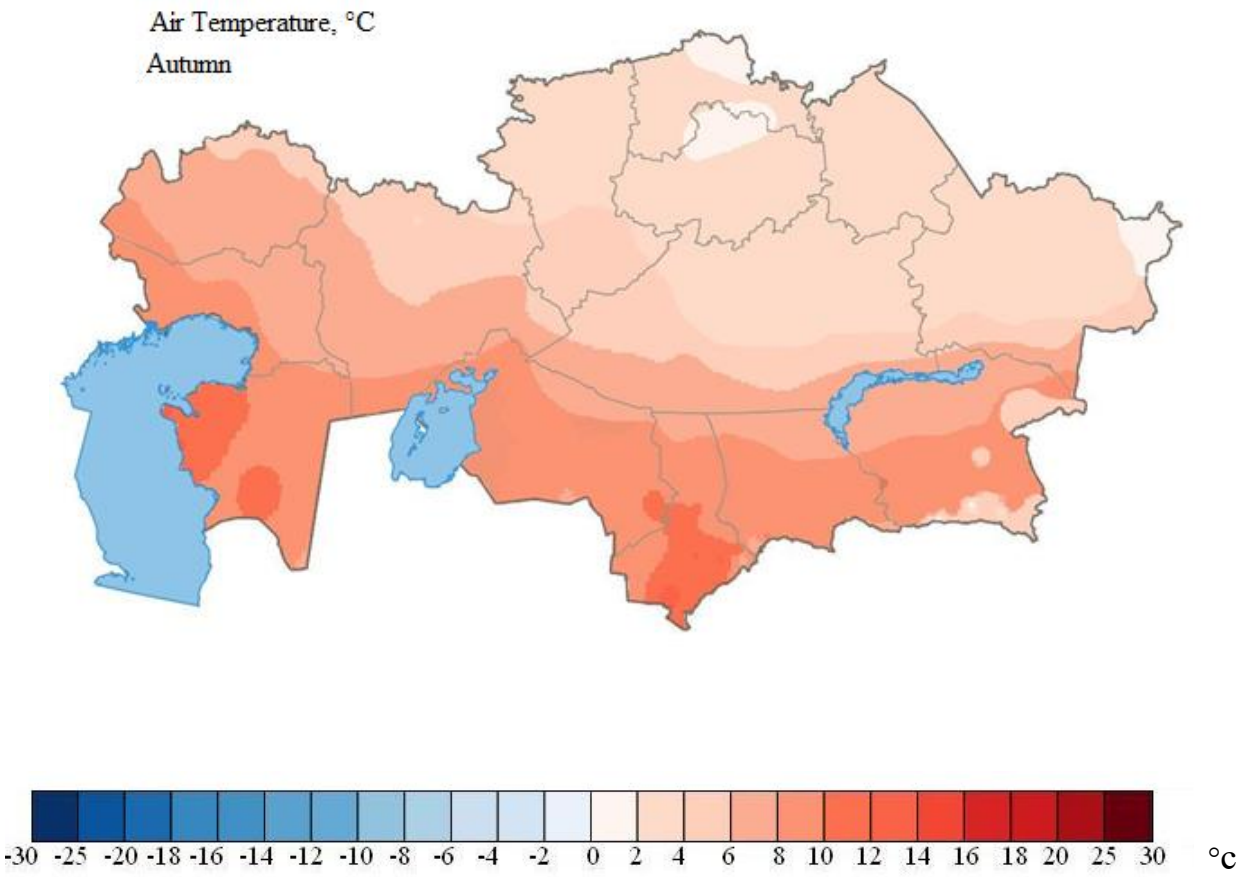





Air Temperature, °C
Spring

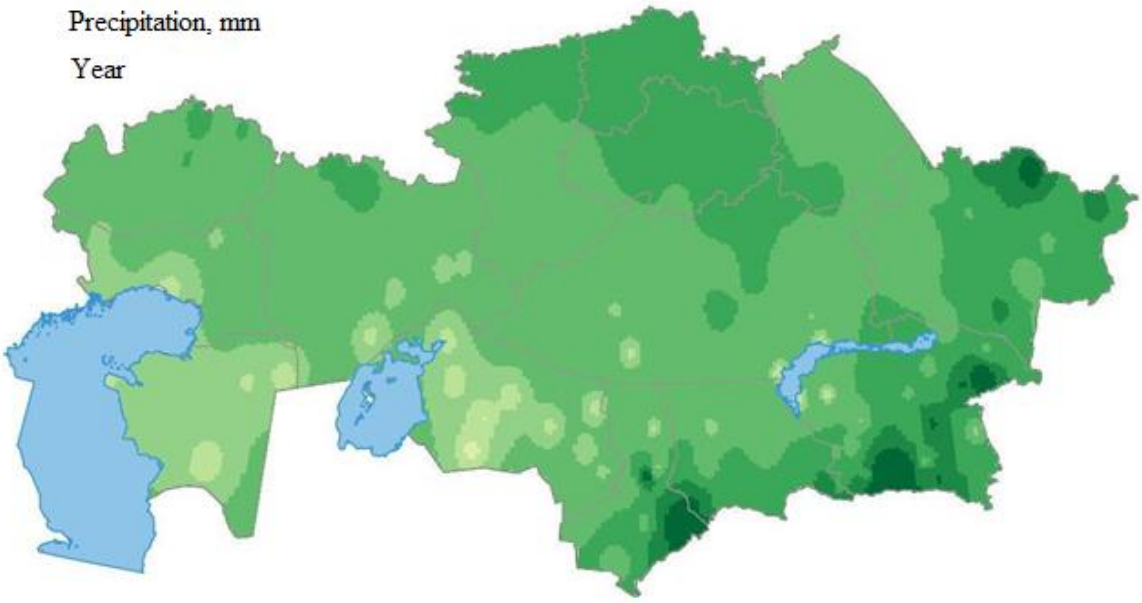

Air Temperature, °C
Summer

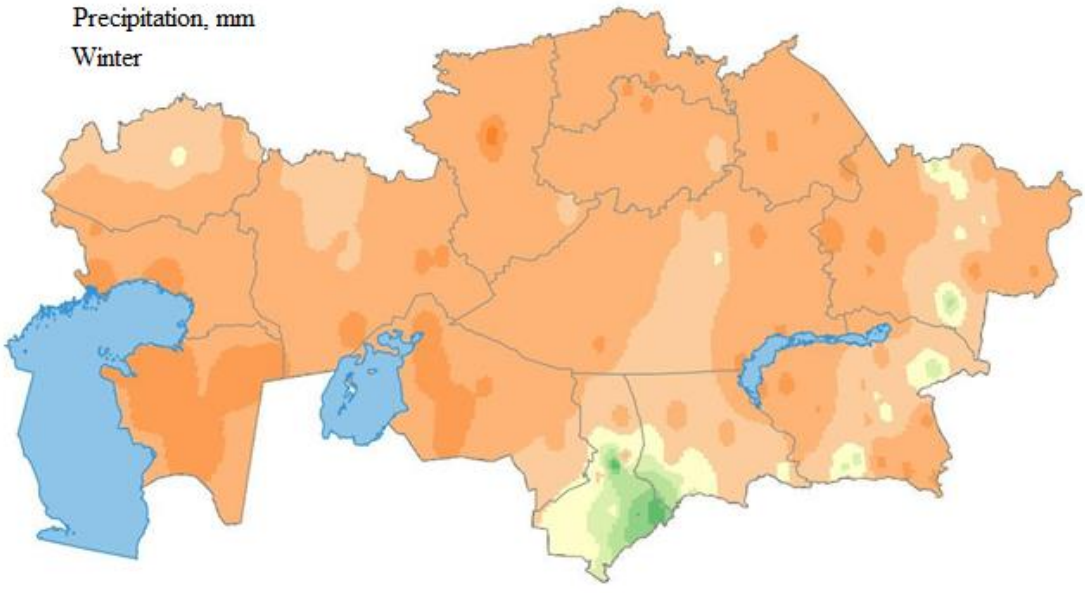

-30 -25 -20 -18 -16 -14 -12 -10 -8 -6 -4 -2 0 2 4 6 8 10 12 14 16 18 20 25 30
°C

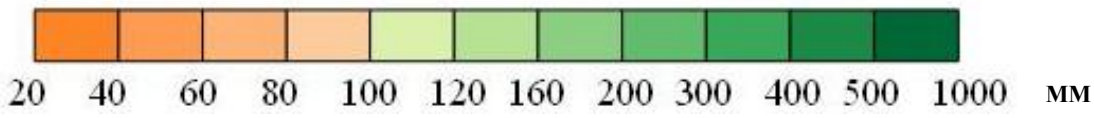

Air Temperature, °C
Autumn
-30 -25 -20 -18 -16 -14 -12 -10 -8 -6 -4 -2 0 2 4 6 8 10 12 14 16 18 20 25 30
°C

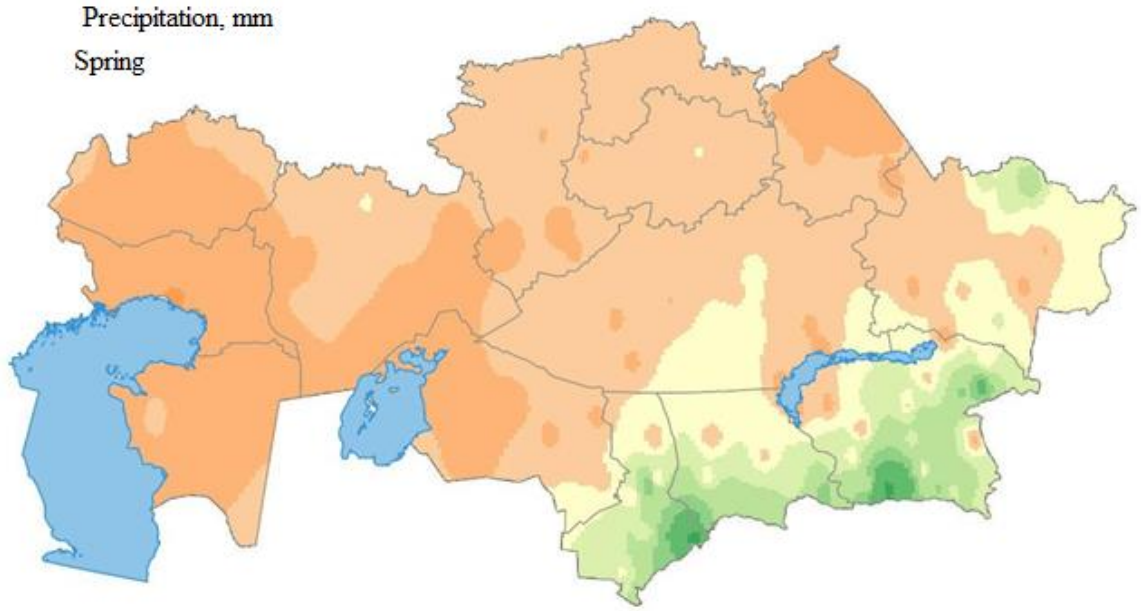
ANNEX 2

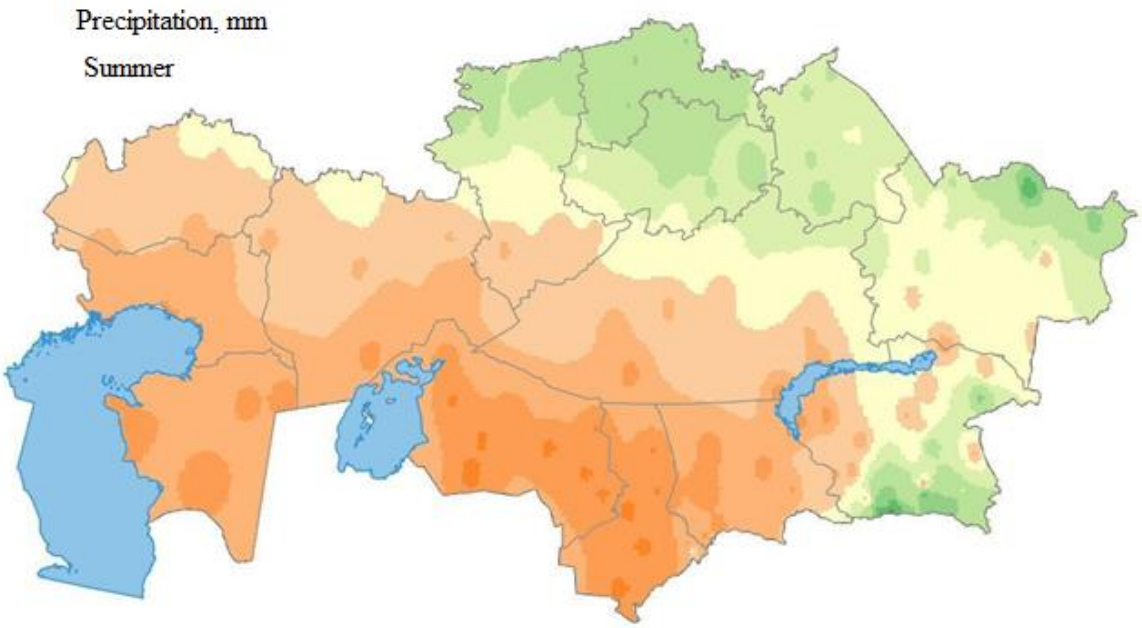
SPATIAL DISTRIBUTION OF ANNUAL AND SEASONAL PRECIPITATION ON THE TERRITORY OF KAZAKHSTAN, CALCULATED OVER THE PERIOD 1961 - 1990

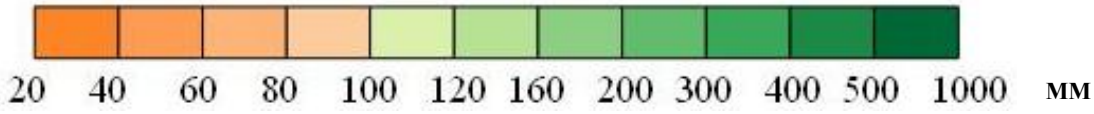


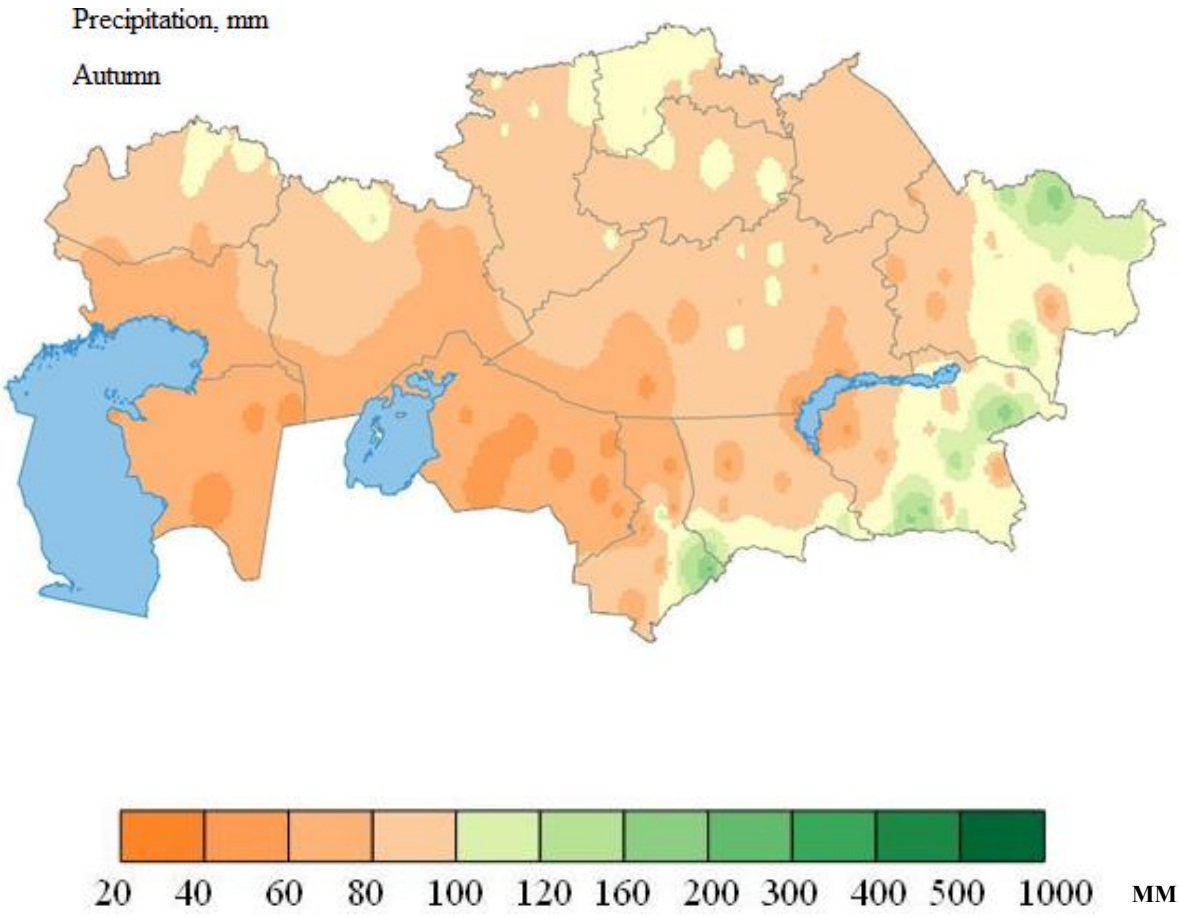





Precipitation, mm
Spring


Precipitation, mm
Summer


20 40 60 80 100 120 160 200 300 400 500 1000 мм


Precipitation, mm
Autumn
20 40 60 80 100 120 160 200 300 400 500 1000
мм