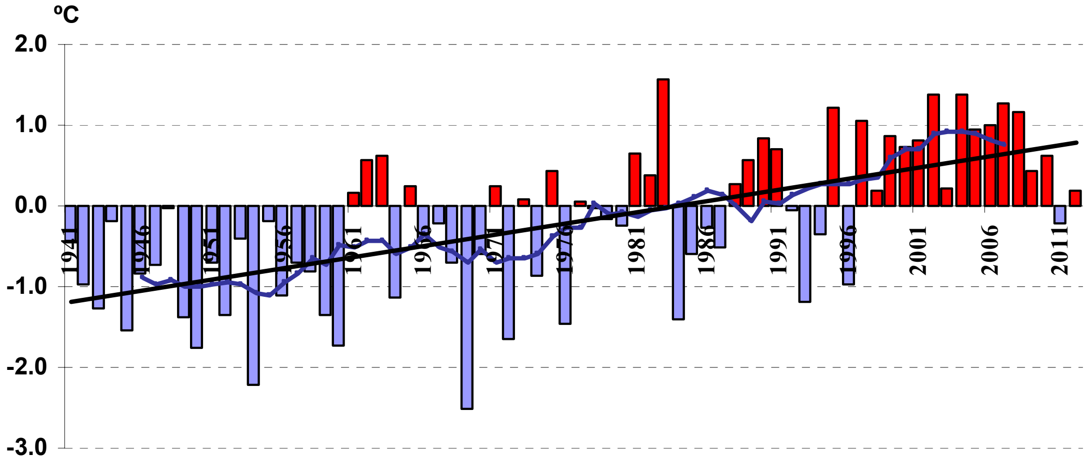
Ministry of Environmental Protection
of the Republic of Kazakhstan

Republican State Enterprise
"Kazhydromet"

ANNUAL BULLETIN OF CLIMATE CHANGE MONITORING IN KAZAKHSTAN:

2012



Astana, 2013

СОДЕРЖАНИЕ

INTRODUCTION

Climate is one of the most important factors for human living support system on the Earth. Thus, climate change is one of the major international challenges of the 21st century that goes far beyond the scientific issue and represents a complex interdisciplinary problem affecting environmental, economic and social aspects of the sustainable development in every country. Therefore study of climate and continuous monitoring of climate change in Kazakhstan 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.

The given bulletin describes the climatic conditions of 2012 including the meteorological extremes assessment. It also includes historical information about climate variability and trends since the 1940's. 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.

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 2012. Data of more than 190 weather stations were used to assess climate normal for 1971...2000. Also experts used more than 110 weather stations data to assess trends;

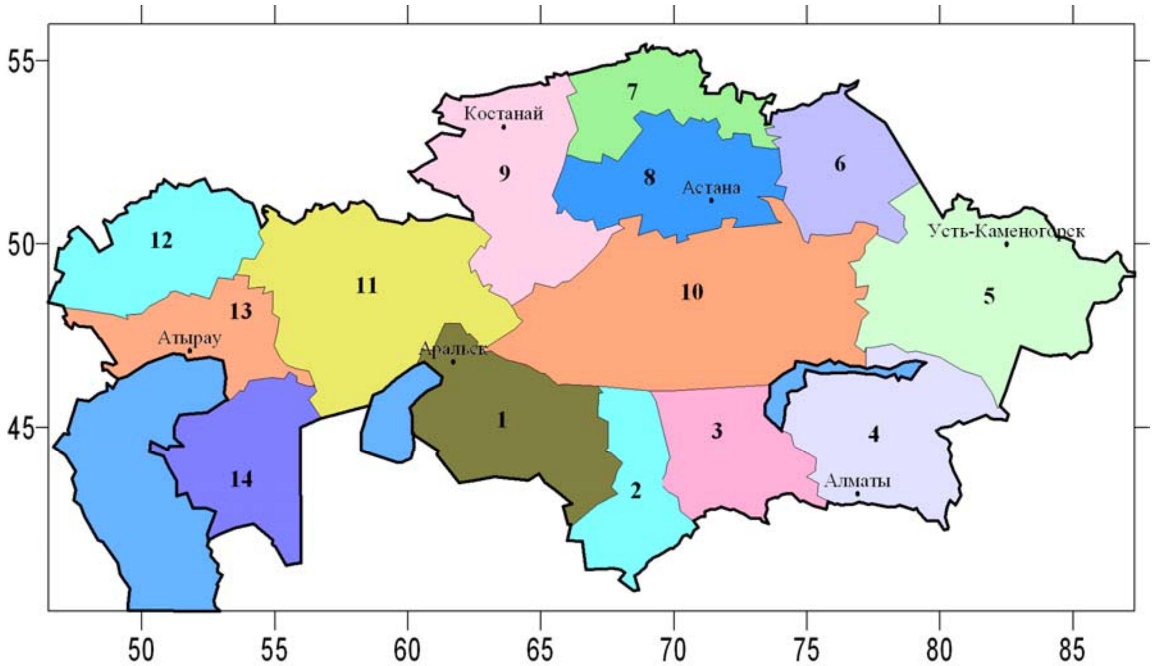
2) The series of daily maximum and minimum air temperatures and daily precipitation from 1941 to 2012 (more than 80 meteorological stations).

Basic approaches and methods. Climate "normal" in the bulletin means average value of the considered climatic variable for 1971...2000. 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 in 2012.



Administrative areas in Kazakhstan

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

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1 AIR TEMPERATURE

1.1 Observed changes in global surface air temperature and precipitation

According to the Intergovernmental Panel on Climate Change (IPCC) surface air temperature has been increasing in the most regions of the globe in the 20th century, although it was not permanent. From the early 20th century and up to 40's warming continued, then there was a slight cooling, and after that from the mid 70's to present the intensive warming is observed (figure 1.1).

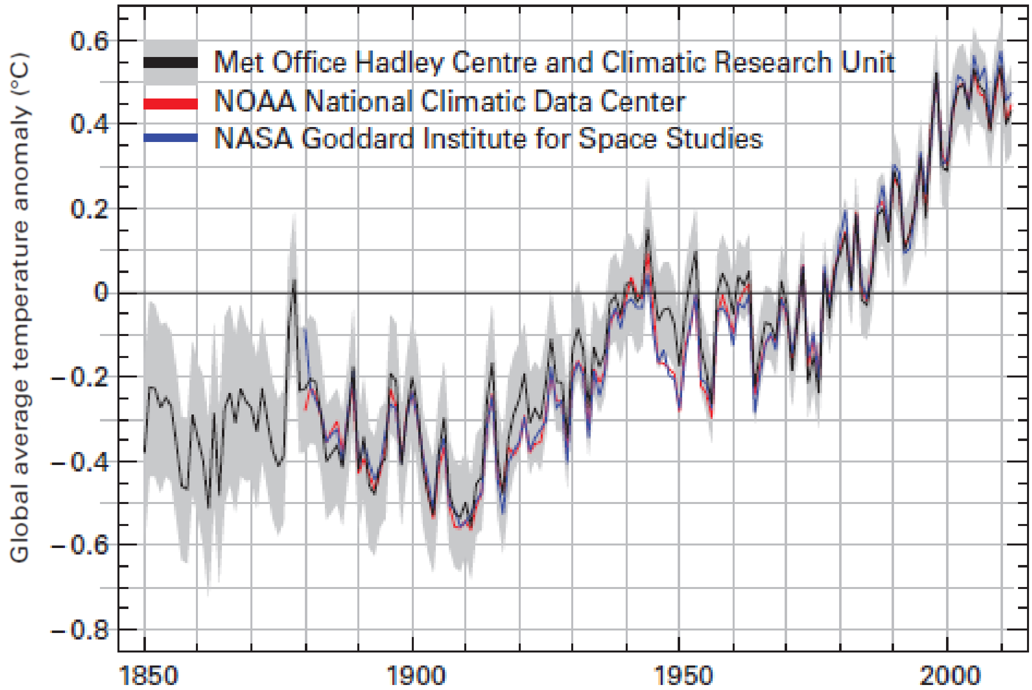
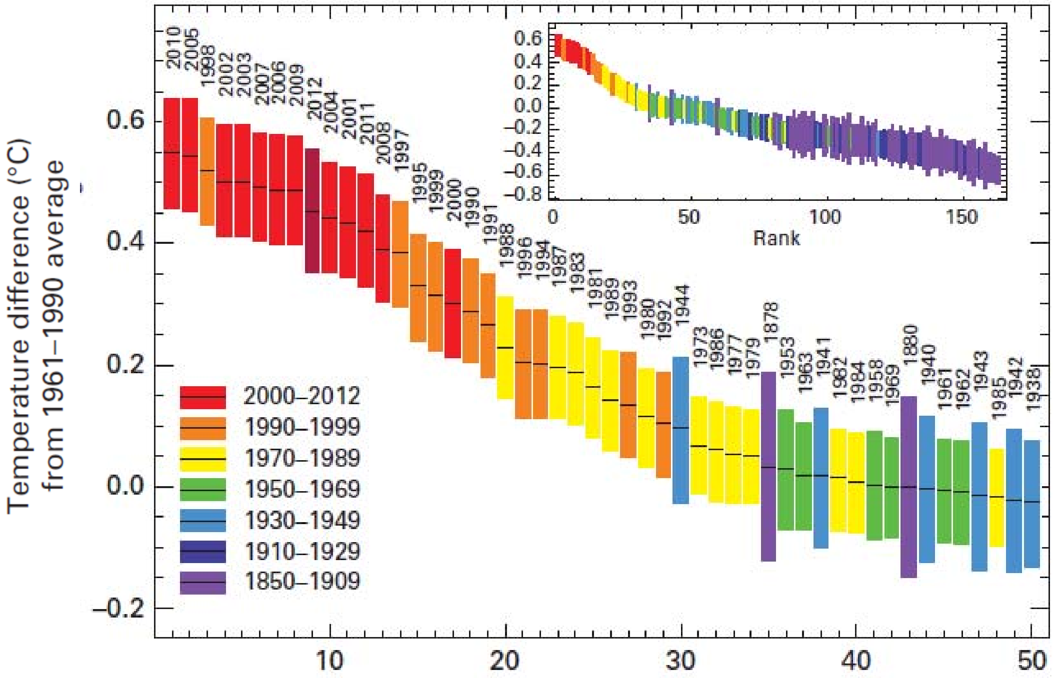


Figure 1.1 – Annual global average temperature anomalies (relative to 1961–1990) from 1850 to 2012 from the Hadley Centre/ CRU (HadCRUT3) (black line and grey area, representing mean and 95 percent uncertainty range), the NOAA National Climatic Data Center (red); and the NASA Goddard Institute for Space Studies (blue) (Source: Met Office Hadley Centre/ CRU, University of East Anglia, United Kingdom)

According to the «Statement of the World Meteorological Organization (WMO) on the status of the global climate» (WMO-№ 1108) 2012 became one of the warmest ten years since 1850. Land-ocean global average air temperature in 2012 was 0.45ºC ± 0.11 °C higher the 1961-1990 annual average of 14 °C. This makes 2012 nominally the ninth warmest year on record since 1850 (Figure 1.2). Also 2012 added to the number of years with air temperature above the baseline period (1961-1990., 14 °C), bringing the total number to 27 years. The warmest year in the observational records was 2010, however in 2012 the average annual land-ocean air temperature anomalies was only 0.1 ºC less.



Rank of hottest years to coldest

Figure 1.2 – Global ranked surface temperatures for the warmest 50 years. Inset shows global ranked surface temperatures from 1850. The size of the bars indicates the 95 per cent confidence limits associated with each year. Values are simple area-weighted averages for the whole year. (Source: WMO statement on the status of the global climate in 2012)

2012 began with the weak-moderate La Niña, which appeared in October 2011. The La Niña in the beginning of the year had a cooling effect on the global air temperatures. Global surface air and ocean average temperature for January, February and March 2012 was the lowest over the last 16 years, although the air temperature anomaly was 0.28 ºC above the 1961-1990 average. La Nina weakened in April due to ocean warming along the Pacific tropical latitudes creating neutral conditions until the end of the year (Figure 1.3).

In 2012, the positive average annual air temperature anomalies were observed in most parts of the globe, with the largest values over the land in North America, southern Europe, western Russia, in North Africa and in the southern part of South America (Figure 1.4). Colder conditions were observed in Alaska, in northern and eastern Australia and in the central parts of Asia.

Air temperature over the ocean was above normal almost everywhere, except central tropical and north-eastern parts of the Pacific Ocean, the South Atlantic Ocean and below 50º S.

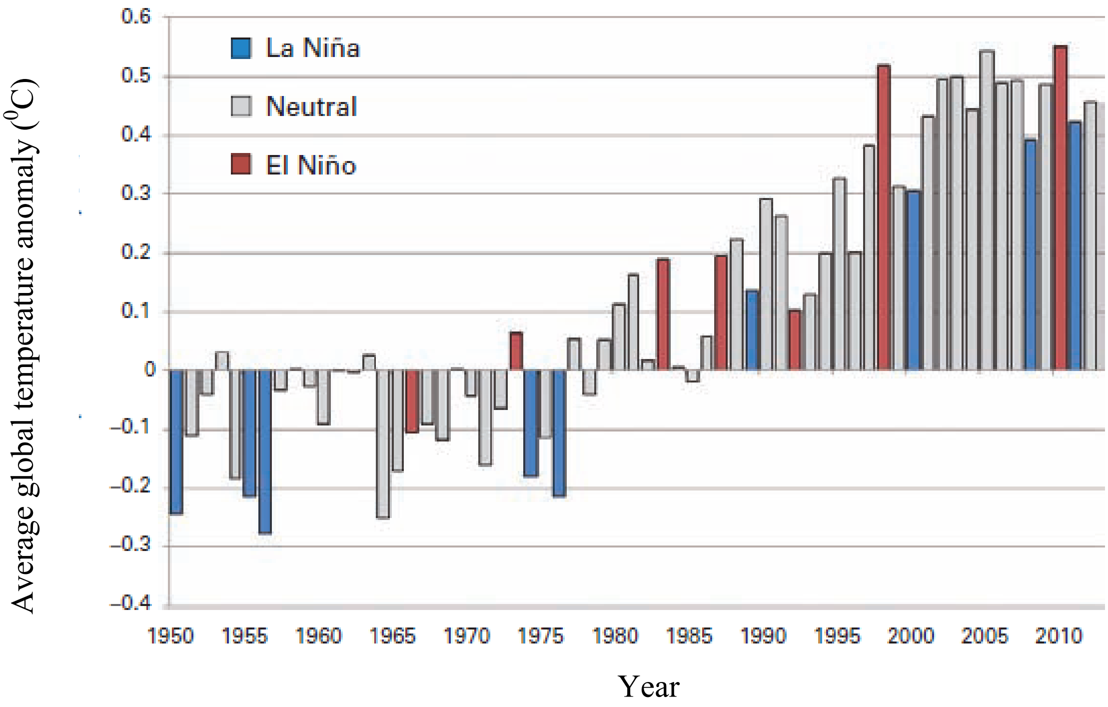


Figure 1.3 – Annual global average combined land-ocean surface temperature anomalies (°C) for 1950-2012 relative to 1961-1990. Blue bars show years with moderate and strong La Niña in the beginning, red bars show years with strong or moderate El Niña. Gray bars show other years.

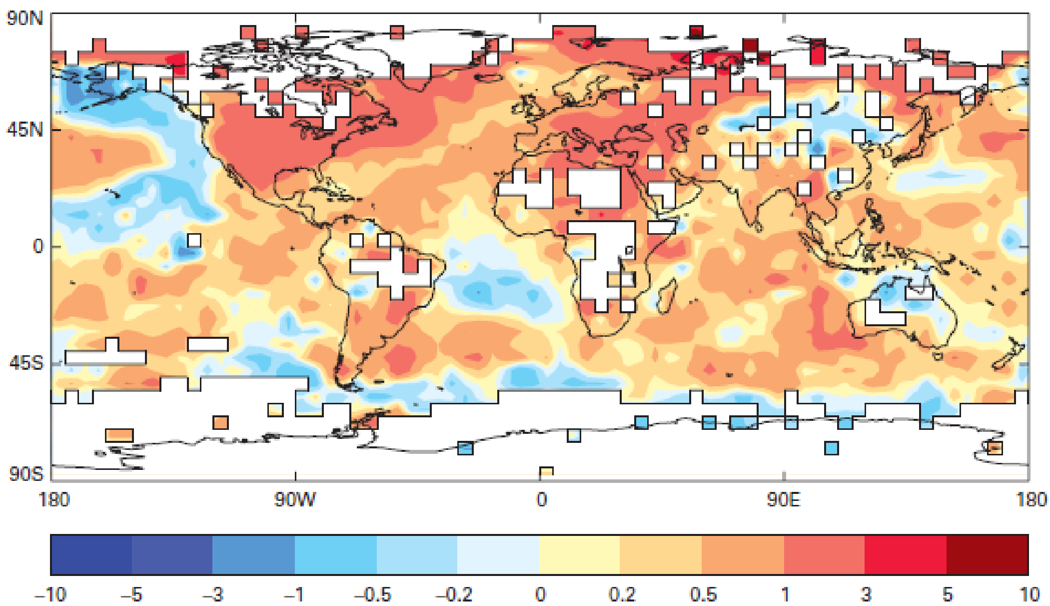


Figure 1.4 – Spatial distribution of the average annual air temperature anomalies over the globe in 2012 (relative to 1961–1990).

According to the US National Climatic Data Center annual land precipitation in 2012 on was 6.3 mm higher that the average long-term value. In 2012, precipitation was unevenly distributed across the globe. Figure 1.5 shows the annual precipitation anomalies in 2012. Significant precipitation deficit was in the centre of the United States, northern Mexico, northeastern Brazil, the central part of Russia, and partly in Australia. Wet conditions were in northern Europe, Western Africa, in northern and central Argentina, western Alaska and most of northern China (figure 1.5).

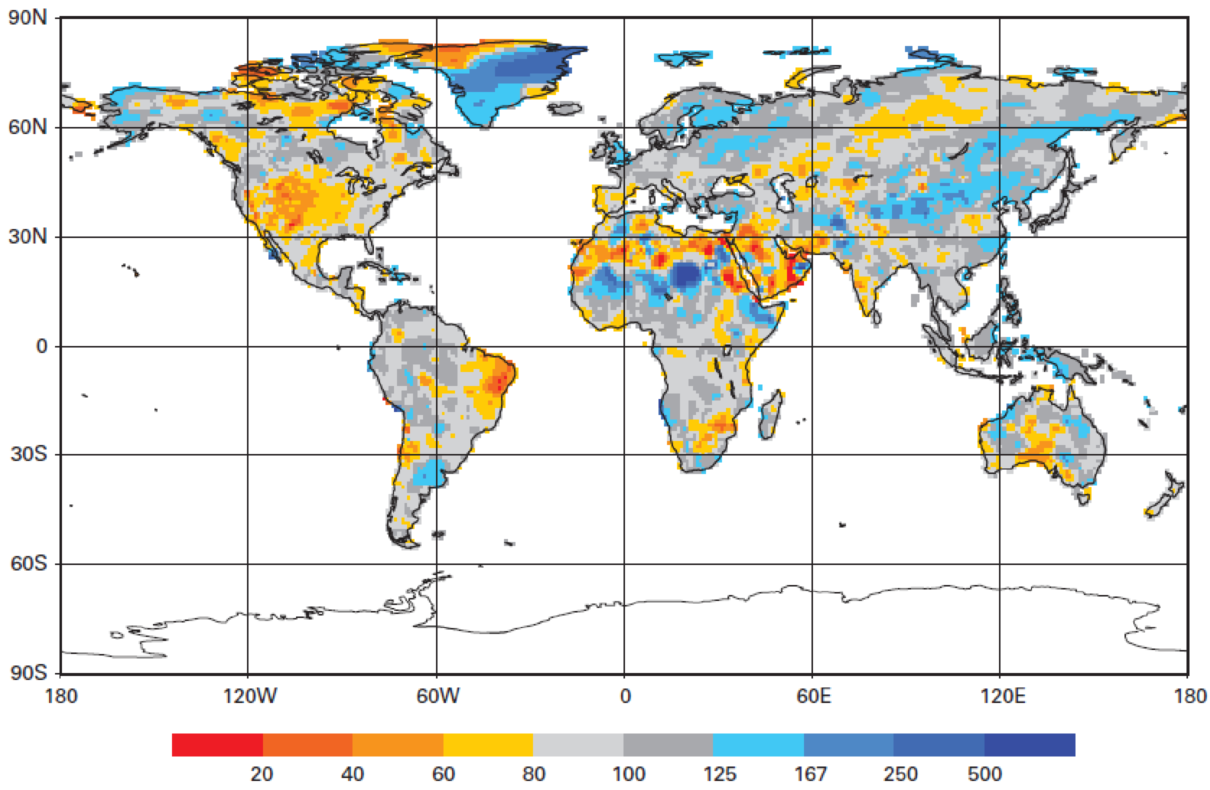


Figure 1.5 – Global spatial distribution of the annual precipitation anomalies in 2012 (anomalies estimated in % relative to 1951–2000). (Source: Global Climate Precipitation Center, German Meteorological Service)

According to the Global Snow Laboratory at Rutgers University (USA), snow extent area in North America in winter 2011-2012 was 4th least in records. This is an outlier as the two previous winters (2009-2010 and 2010-2011) in North America the snow cover areas were the first and third most extensive since 1966. In Eurasia in winter 2012 the snow cover area was more than the average. In general, in the northern hemisphere the snow cover was 590,000 km^2 broader than the average value of 45.2 million km^2.

European Space Agency studies showed that the water reserves in snow in the northern hemisphere have been decreasing gradually since 1979. At high latitudes, snow melting tends to start early spring.

1.2 Observed changes in air temperature in Kazakhstan for 1941-2012

Table 1.1 represents the warmest years for the globe (ground network) and for Kazakhstan. The ranking of extremely warm years for Kazakhstan differs slightly from globally ranked average surface air temperatures. Each of the globe ten warmest years is differently colored that allows easily determine if this year was among the warmest years in Kazakhstan.

Figure 1.6 presents the ranked annual average temperature anomalies estimated relative to 1971…2000 and averaged over 118 weather stations in Kazakhstan for 1940…2012. The ranked data is obtained by averaging data for more than 118 Kazakhstan's meteorological stations. The ten warmest years in descending anomalies in Kazakhstan include were: 1983, 2004, 2002, 2007, 1995, 2008, 1997, 2006, 2005 and 1999. The five warmest years in Kazakhstan correspond to the ten globally warmest years.

In 2012 the average annual air temperature anomaly for Kazakhstan of 0.19 ^{0}C was the 27th for the period. 1969 was the coldest year in Kazakhstan over the last 70 years with the annual average temperature anomaly equal to minus 2.52 ºC. 1983 was the hottest year in Kazakhstan with the temperature anomaly of 1.56 ºC.

Table 1.1 – The ranked 10 warmest years for the globe (1850...2012) and for Kazakhstan (1940…2012) and corresponding annual average temperature anomalies for Kazakhstan

rank	globe	Kazakhstan	Annual average temperature anomaly for Kazakhstan, °C
1	2010	1983	1.56
2	2005	2004	1.38
3	1998	2002	1.38
4	2002	2007	1.27
5	2003	1995	1.21
6	2007	2008	1.17
7	2006	1997	1.05
8	2009	2006	0.99
9	2012	2005	0.94
10	2004	1999	0.87

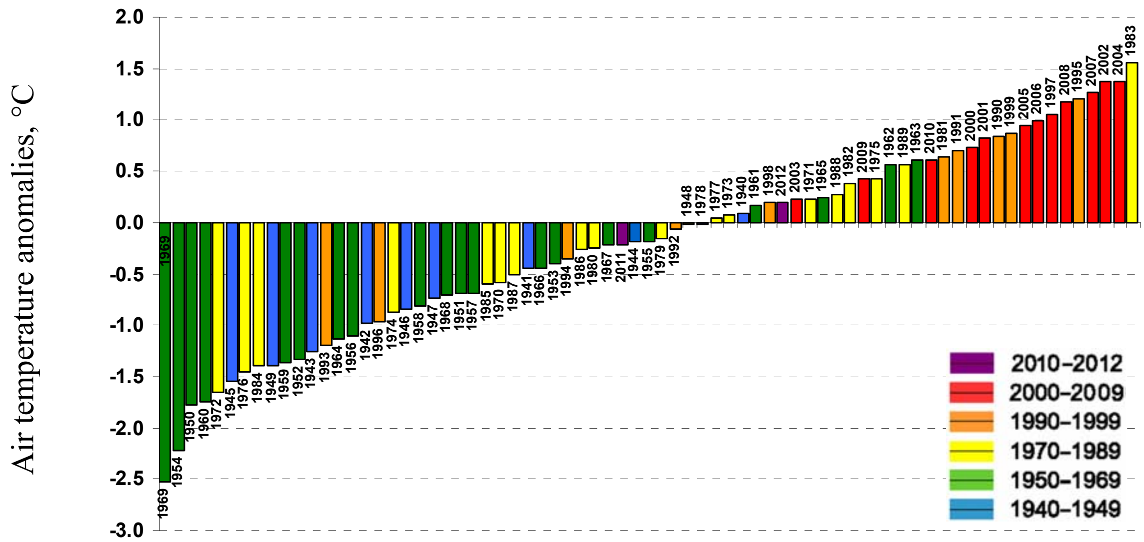
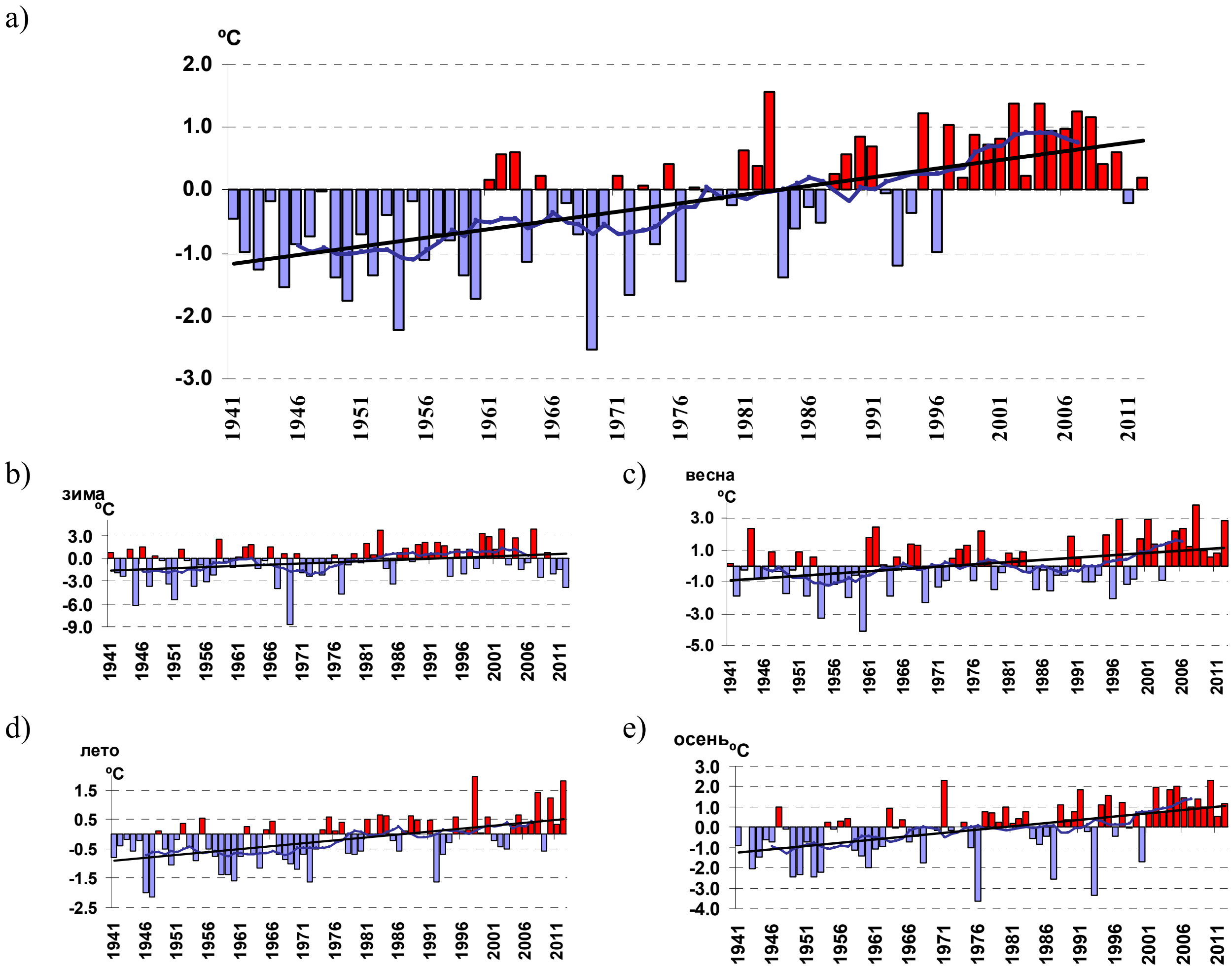


Figure 1.6 – Ranked average annual air temperature anomalies for Kazakhstan for 1940…2012 (data of 118 weather stations). Anomalies estimated relative to 1971…2000 baseline.

Figures 1.7…1.9 and table 1.2 present the air temperature change for 1941-2012 for Kazakhstan and by administrative areas. During the last 70 years the annual and seasonal surface air temperatures have been increasing everywhere in Kazakhstan. Country average annual temperature has been rising by 0.27 ºC every 10 years. The highest warming was in autumn by 0.32 ºC every 10 years. Winter and spring temperatures have been increasing a little slower by 0.29 ºC every 10 years. The slowest warming was in summer – 0.20 ºC every 10 years. In most cases the trends are statistically significant for the 95 % confidence interval. The contribution of trend to the total average annual temperature dispersion is 37 %, for seasons contribution varies from 6 to 27 % (Table 1.2 and Figure 1.7).

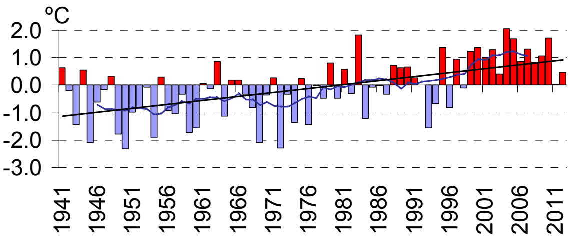


a) year, b) winter, c) spring, d) summer, e) autumn

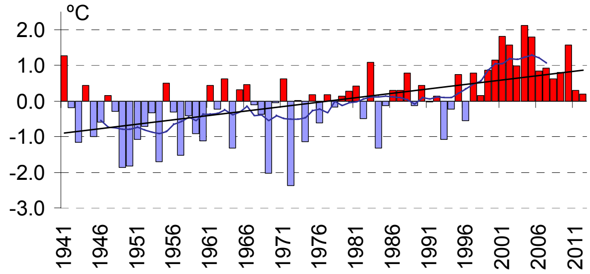
Figure 1.7 – Time series and linear trends of the annual and seasonal air temperatures anomalies (relative to 1971…2000) for 1941...2012 for Kazakhstan. The smooth curve represents the 11-year moving average

The fastest increase in the average annual temperature was in West Kazakhstan oblast equal to 0.38 ^{0}C every 10 years. The lowest warming rates were in South-Kazakhstan Oblast, East Kazakhstan Oblast, Almaty Oblast and Mangistau Oblast amounting to 0.23...0.25 ºC every 10 years. In other oblasts the temperature increase rates were within 0.27...0.31 ºC over 10 years.

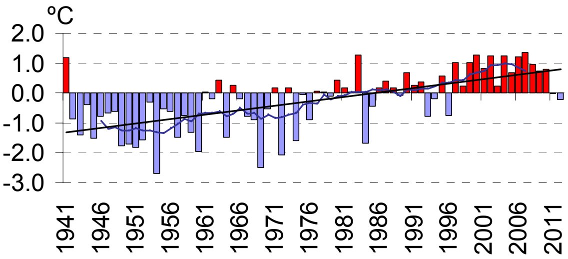
a) Kyzylorda oblast



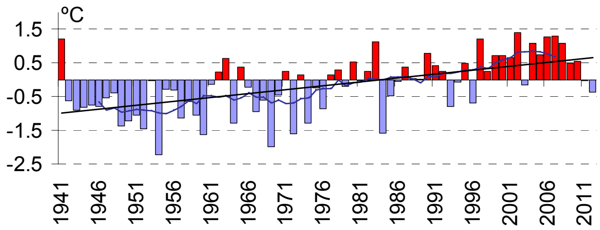
b) South Kazakhstan oblast



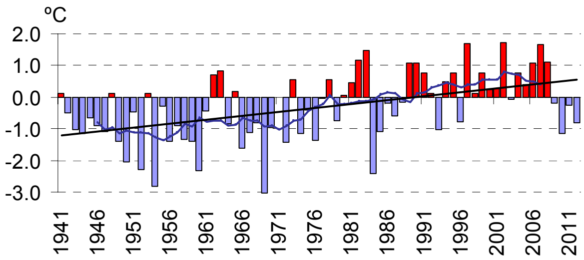
c) Zhambyl oblast



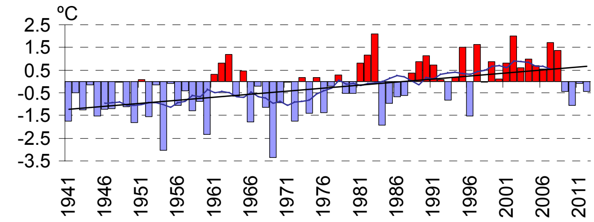
d) Almaty oblast



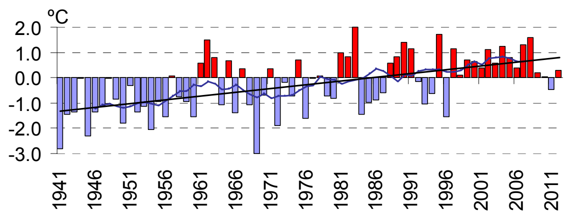
e) East Kazakhstan oblast



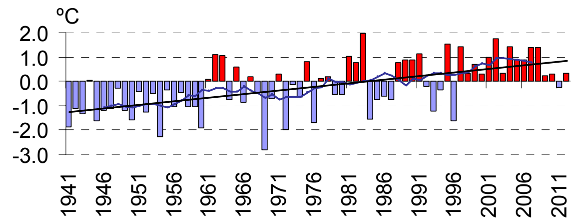
f) Pavlodar oblast



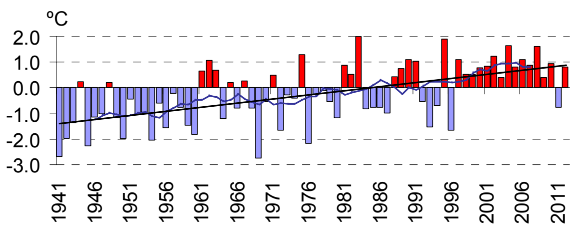
g) North Kazakhstan oblast



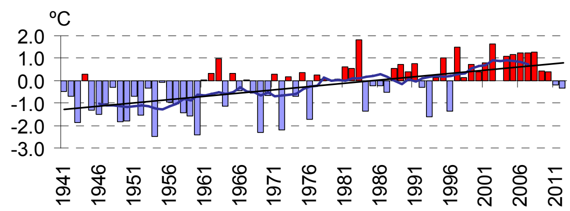
h) Akmola oblast



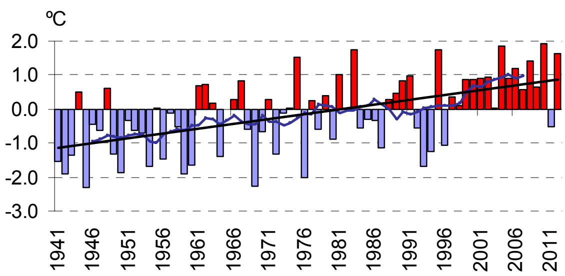
i) Kostanay oblast



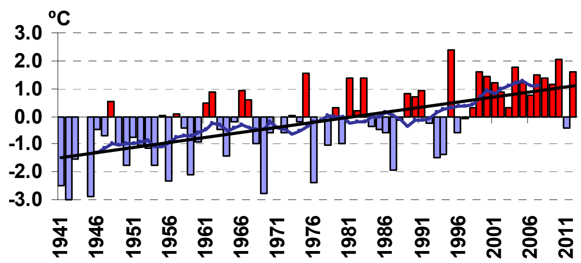
j) Karaganda oblast



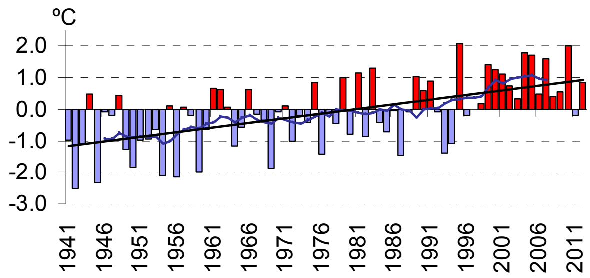
k) Aktobe oblast



l) West Kazakhstan oblast



m) Atyrau oblast



n) Mangistau oblast

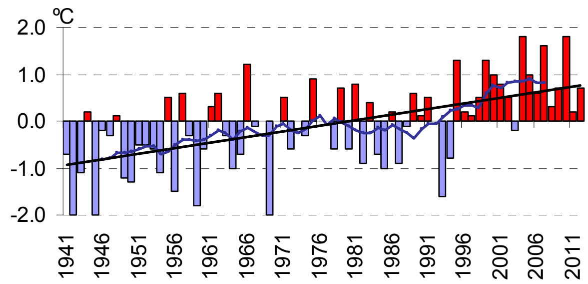


Figure 1.8 – Time series and linear trends of the annual average air temperatures anomalies (relative to 1971…2000) for 1941...2012 for Kazakhstan (^{0}C). The smooth curve represents the 11-year moving average

Previous issues of Bulletin for 2008-2011 showed that the highest warming was observed in winter everywhere in Kazakhstan since 1941. Considering 2012 data the biggest temperature increase was observed in spring in northern and central oblasts (0.33…0.37 ºC every 10 years) and in autumn in southern and eastern oblasts (0.30…0.40 ºC every 10 years, see Table 1.2). In western oblasts the biggest temperature rise still occurred in winter (0.27…0.38 ºC every 10 years) In summer almost everywhere in Kazakhstan the temperature increase linear trend factor was within 0.13 and 0.30 ^{0}C per 10 years. However determination factor is rather high, especially in southern oblasts equal to 25-36%. This means that air temperature increasing trend is stable. The warming rate in autumn amounts to 0.28…0.30 ^{0}C every 10 years and it is also stable with determination factor of 16-35%.

Table 1.2 – Parameters of the air temperature anomaly linear trend for Kazakhstan and 14 administrative oblasts for 1941...2012.

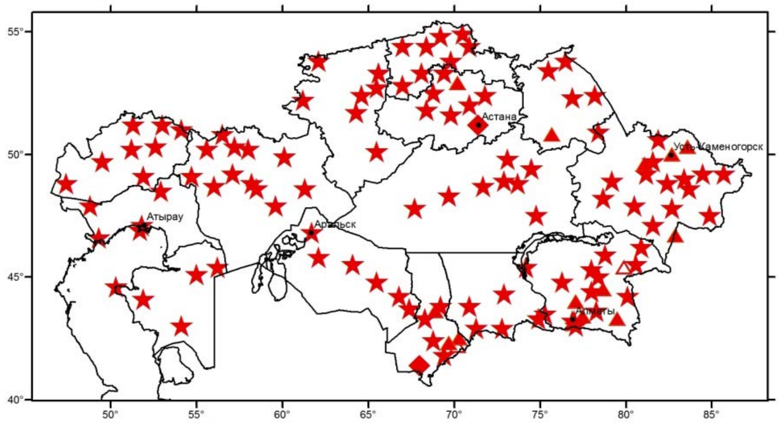
Oblast	Year		Winter		Spring		Summer		Autumn	
	*a	**R^2	a	R^2	a	R^2	a	R^2	a	R^2
Kazakhstan	0.27	37	0.29	6	0.29	15	0.20	27	0.32	25
Kyzylorda	0.29	32	0.25	3	0.31	14	0.27	33	0.30	24
South Kazakhstan	0.24	29	0.18	2	0.22	11	0.23	25	0.40	30
Zhambyl	0.30	39	0.31	6	0.22	11	0.27	36	0.40	35
Almaty	0.23	31	0.30	8	0.20	10	0.13	12	0.30	24
East Kazakhstan	0.25	23	0.29	5	0.25	9	0.15	13	0.31	17
Pavlodar	0.27	23	0.30	4	0.36	15	0.30	13	0.30	24
North Kazakhstan	0.30	30	0.31	5	0.37	15	0.22	14	0.30	16
Akmola	0.29	32	0.28	5	0.37	16	0.20	14	0.30	18
Kostanay	0.31	31	0.34	6	0.35	12	0.25	15	0.30	17
Karaganda	0.28	30	0.27	5	0.33	14	0.21	18	0.30	20
Aktobe	0.29	29	0.32	6	0.30	9	0.21	13	0.31	17
West Kazakhstan	0.38	38	0.47	10	0.41	17	0.27	15	0.36	22

Oblast	Year		Winter		Spring		Summer		Autumn	
	*a	**R^2	a	R^2	a	R^2	a	R^2	a	R^2
Atyrau	0.28	32	0.38	8	0.29	13	0.20	18	0.29	19
Mangistau	0.24	32	0.27	8	0.21	9	0.21	18	0.28	17

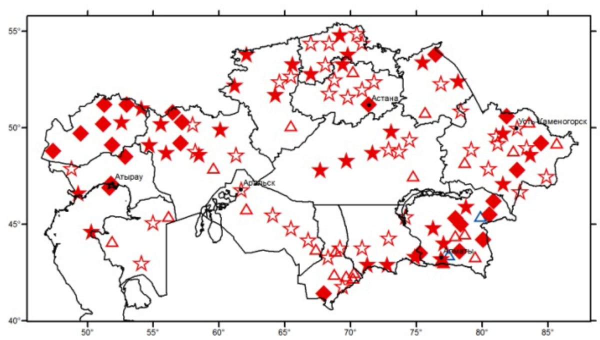
* a – linear trend factor, ºC per 10 years
** R^2 – determination factor, %

Figure 1.9 provides more detailed information about changes in seasonal and monthly air temperatures (ºC/10 years) for 1941...2012 in Kazakhstan. Positive trend of average monthly air temperatures is observed almost everywhere in Kazakhstan. Several weather stations recorded negative trends which are statistically insignificant. In February-March, and November-December the air temperature increase was most significant from 0.41 to 0.80º C/10 years. In April, June and October the warming rate was slower 0.21...0.40 ºC/10 years. In all other months temperature increased from 0.01 to 0.20 ºC every 10 years. Thus, temperature increase was higher in cold season (November-March) than in warm (April-October). Basing on the spatial distribution of the linear trend factor it is evident that characteristics of circulation processes have changed.

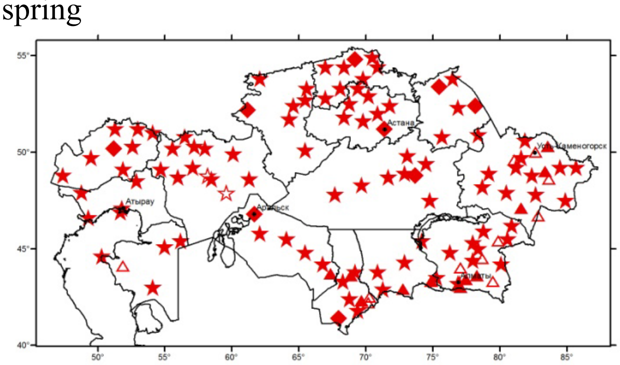
year



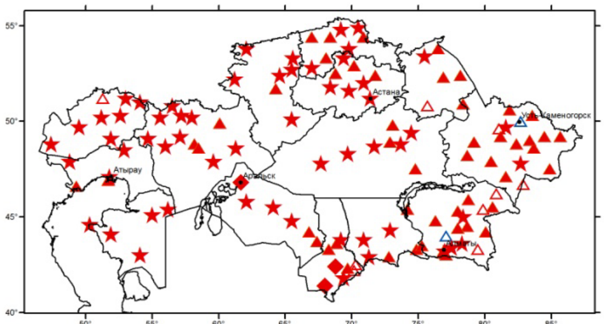
winter



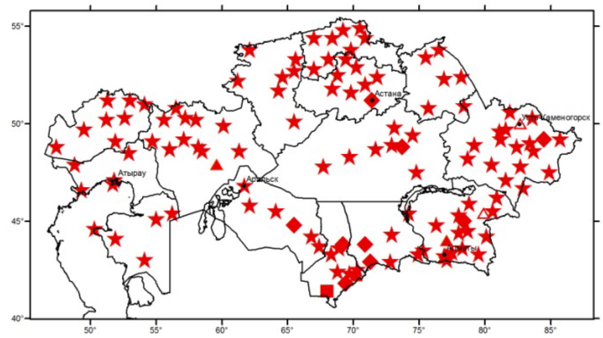
spring



summer



autumn



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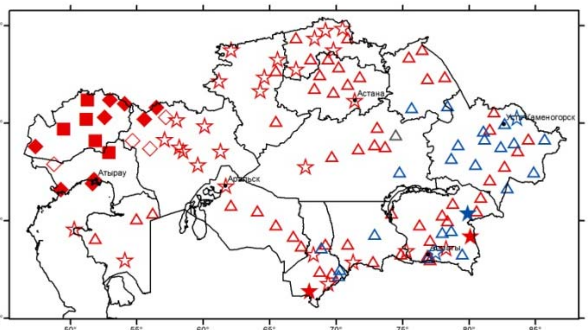

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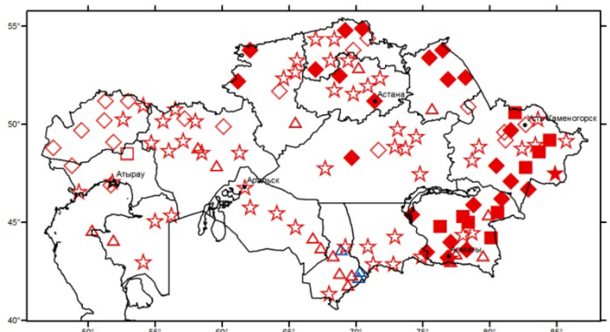

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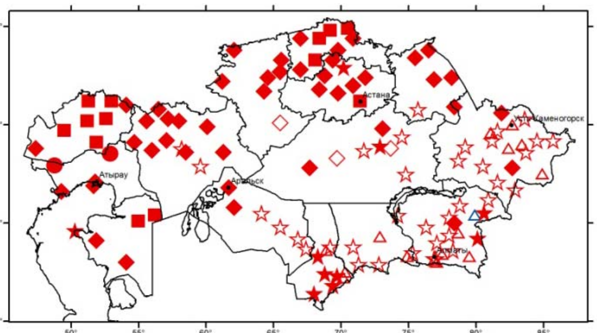

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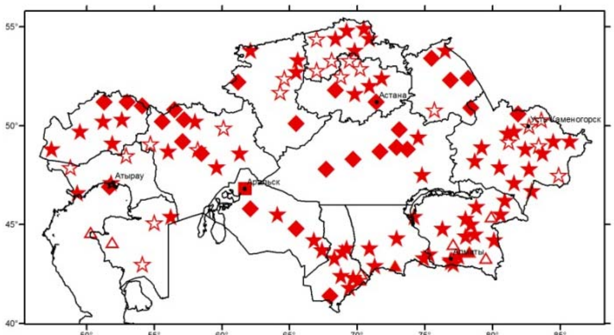
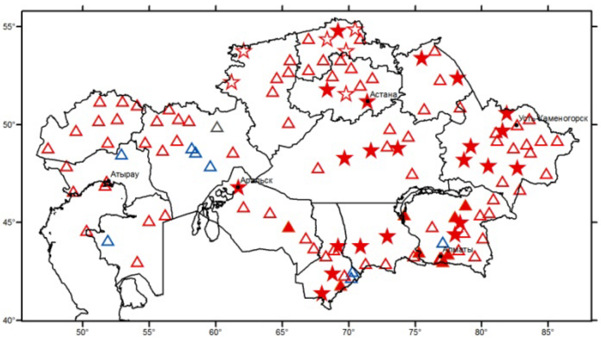
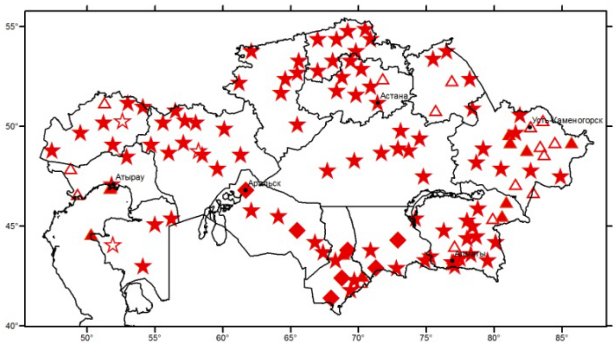


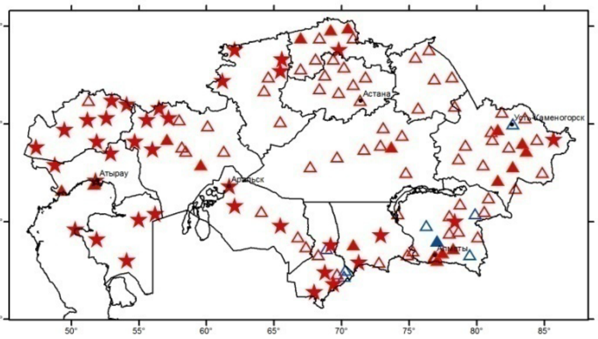
May



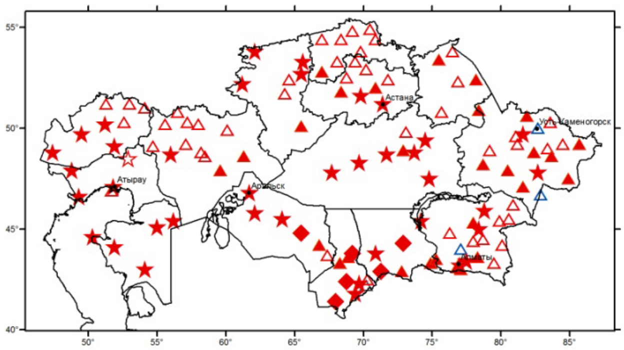
June



July



August



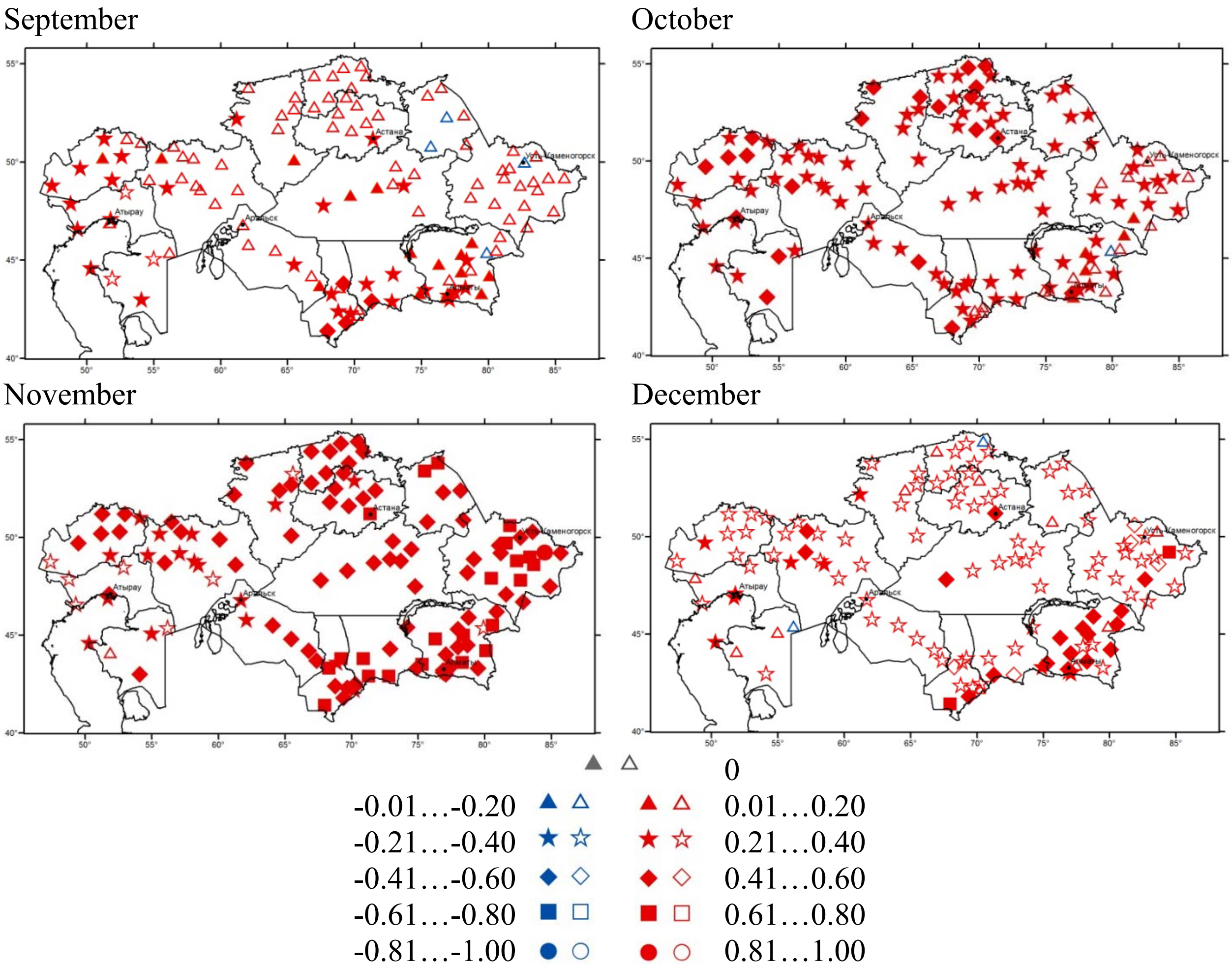


Figure 1.9 – The spatial distribution of the surface air temperature linear trend factors (ºC/10 years) in Kazakhstan for 1941...2012. Legend keys shaded for statistically significant trend

1.3 Temperature anomalies in Kazakhstan in 2012

Annual average temperature anomalies (December 2011-November 2012) were 1-2 ^{0}C higher than the norm in the west and northwest of Kazakhstan. In Aktobe oblast 2012 appeared within 10% of the extremely warm years. In all other regions temperature anomalies were within ±1 °C (figure 1.10a)

Figure 1.10 shows geographical distribution of heat and cold areas in Kazakhstan by seasons.

Winter

The winter of 2012 (December 2011 - February 2012) was cold or extremely cold everywhere in Kazakhstan. Temperature anomalies varied from -2.0 to -7.0 ºC from the west to the east. Extremely low temperatures (5.0 to 7.0 ºC below norm) were recorded in East Kazakhstan, Karaganda and Pavlodar oblasts. At 30% of weather stations the winter appeared to be within 10% of extremely cold since 1941. Such a frost was caused by the Asian anticyclone, which spread over Kazakhstan, Russia and Mongolia. It blocked the usual west-east air transport and thus cold air came from the east (see isotherms on Figure 1.10b).

Spring

Spring was warm or extremely warm everywhere in Kazakhstan. Air temperatures were 1.0-4.5 ^{0}C above the norm. The highest anomalies of 3.0 to 4.5 ^{0}C were recorded on the vast area of the northern, western, central and partly southern regions of Kazakhstan. In these regions the 2012 spring added to the 10% of the extremely warm springs. In the east and south-east temperature anomalies were 1.0-3.0 ^{0}C above the norm (figure 1.10c).

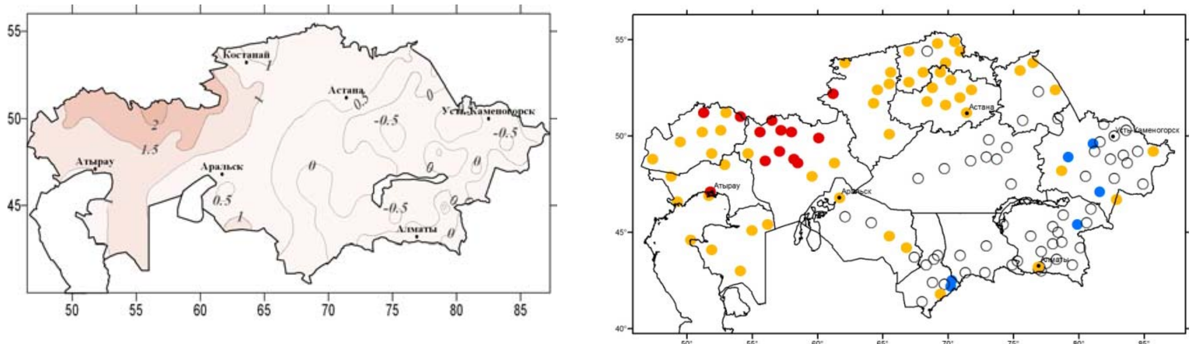
Summer

The summer of 2012 was extremely warm or warm everywhere in Kazakhstan. The air temperatures exceeded the norm by 1,0...4,0 ºC. The greatest temperature anomalies occurred in the west – from 2.5 to 4.0 ^{0}C with the maximum in Aktobe oblast with anomalies more that 4.0 ^{0}C. Rather modest anomalies around 0.1-1.0 ^{0}C were observed near Balkhash Lake and Kazakh Hills. According to the records of 90% of weather stations the 2012 summer was within 10 % of the hottest summers in Kazakhstan since 1941 (Figure 1.10d).

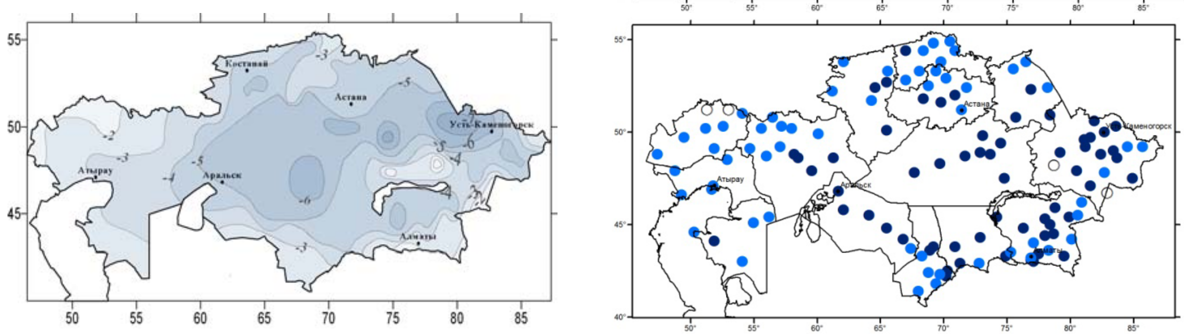
Autumn

Autumn was warm or extremely warm in the northwestern regions of Kazakhstan where temperatures were 1.0-3.0 ^{0}C above the norm. On the southeastern part of Kazakhstan temperature anomalies were within ±1 °C. Most weather stations in West Kazakhstan, Kustanay and Aktobe oblasts reported that the 2012 autumn was within 10% of the warmest autumns (Figure 1.10e).

a)



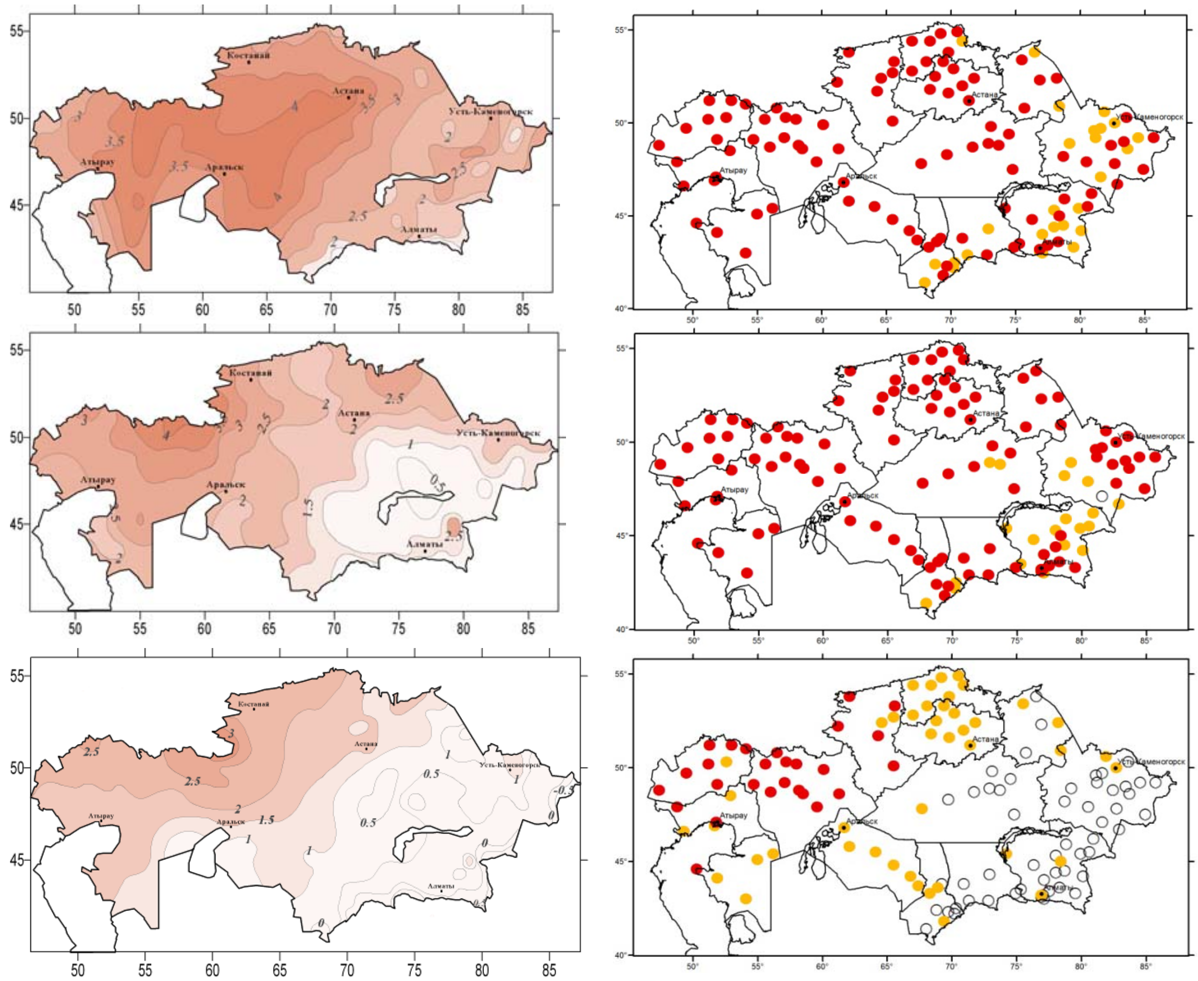
b)



c)

d)

e)



a) year (Dec 2011 – Nov 2012)
b) winter
c) spring
d) summer
e) autumn

(0…9 %) – extremely cold;
(10…29 %) – cold;
(30…69 %) – about normal;
(70…89 %) – warm;
(90…100 %) – extremely warm.

Figure 1.10 – Spatial distribution of air temperature anomalies in 2012 relative to the 1971…2000 baseline (^{0}C) and nonexceedance probabilities for 2012 air temperatures calculated over 1941…2012.

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 2012 is considered below.

Daily maximum of air temperatures in 2012. Figure 1.11 presents in red the absolute maximum of air temperature recorded since the opening of weather station until 2011. The maximum of daily air temperature observed in 2012 is in blue. In 2012 air temperature exceeded absolute maximum by 0.2 ^{0}C at two stations in the northern Kazakhstan – Esil and Blagoveschenka.

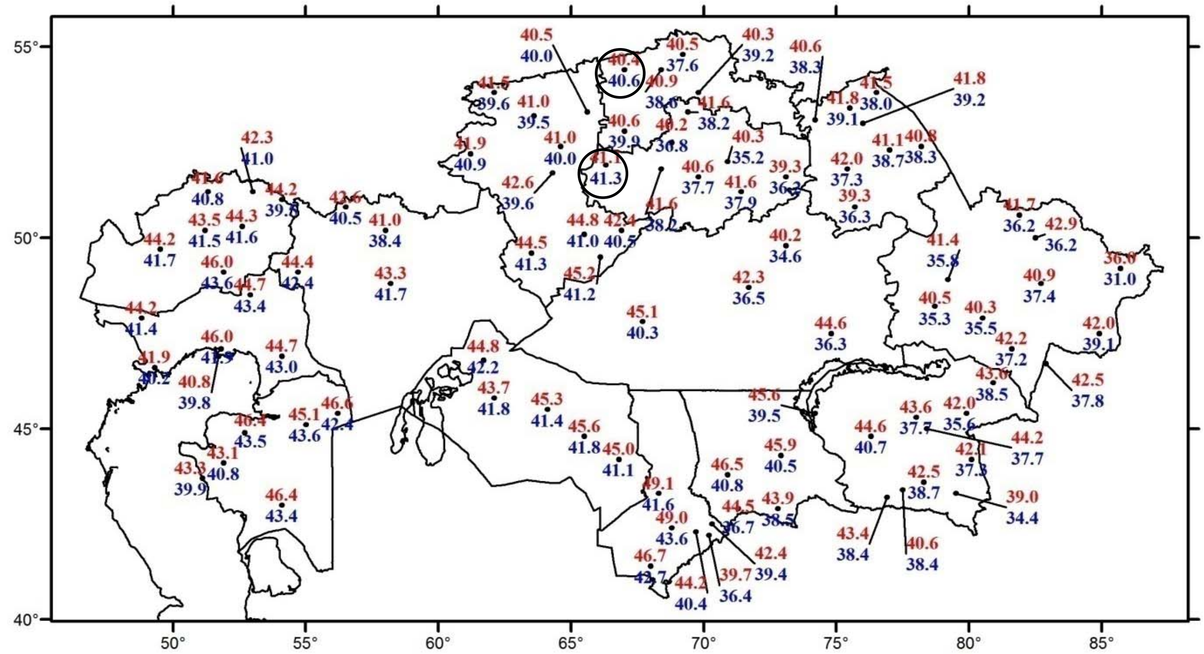


Figure 1.11 – Absolute maximum temperature (°C) since the beginning of records until 2011 (red) and the 2012 daily maximum temperature (°C) (blue)

Daily minimum of air temperature in 2012. Absolute minimum temperature since the beginning of records has not been exceeded in 2012 at any considered weather stations (Figure 1.12).

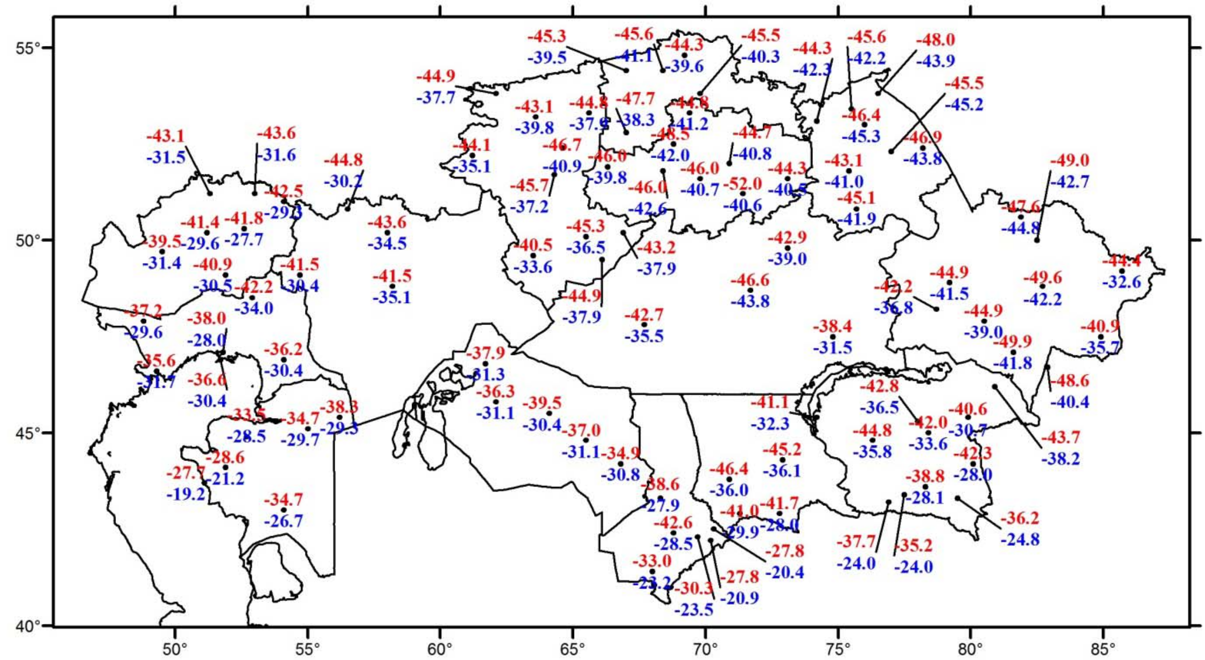


Figure 1.12 – Absolute minimum temperature (°C) since the beginning of records until 2011 (red) and the 2012 daily minimum temperature (°C) (blue).

Number of days with temperatures above 35 °C in 2012. Figure 1.13a presents spatial distribution of the number of days with temperatures above 35 °C in 2012. Maximum number of days with high temperatures (40...70 days) occurred in South Kazakhstan, Kyzylorda, Atyrau and Mangistau oblasts. In East Kazakhstan, Aktobe and Zhambyl oblasts number of hot days was equal to 20-30. In all of these oblasts and in the northern Kazakhstan the number of days with temperatures above 35 °C was extremely high with 90-100 % probability of non-exceedance (Figure 1.13, b).

a) b)

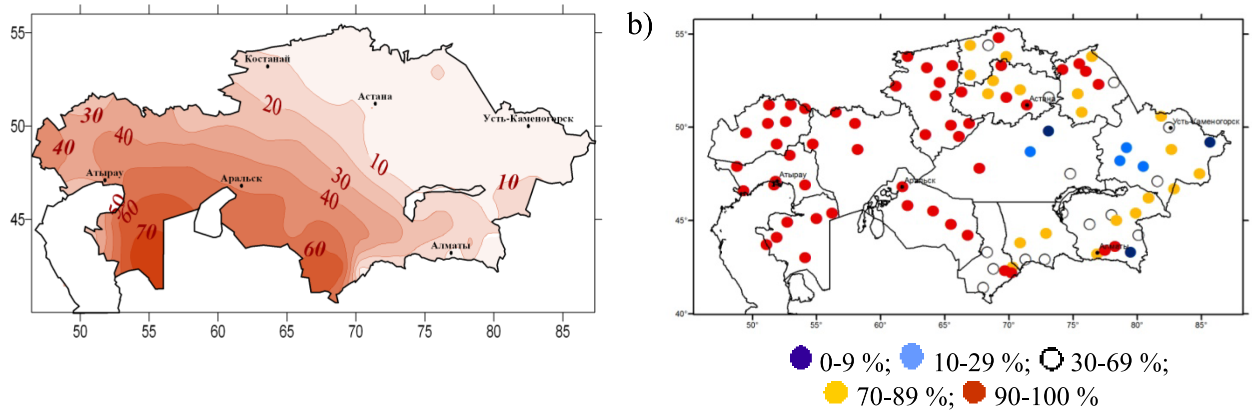


Figure 1.13 – Number of days (a) and the probability of nonexceedance of the number of days with temperatures above 35 ºC in 2012 (b) for 1941...2012

Percentage of days with the daily maximum temperatures above the 90th percentile amounted to 6…26 % in Kazakhstan in 2012 (Figure 1.14a). The most frequently the maximum temperatures exceeded 90th percentile in the western Kazakhstan

Percentage of days with the daily minimum temperatures below the 10th percentile characterizes the frequency of extremely low temperatures. In 2012 the maximum number of such days (> 10 % of days) was observed in the eastern Kazakhstan (Figure 1.14b).

a) b)

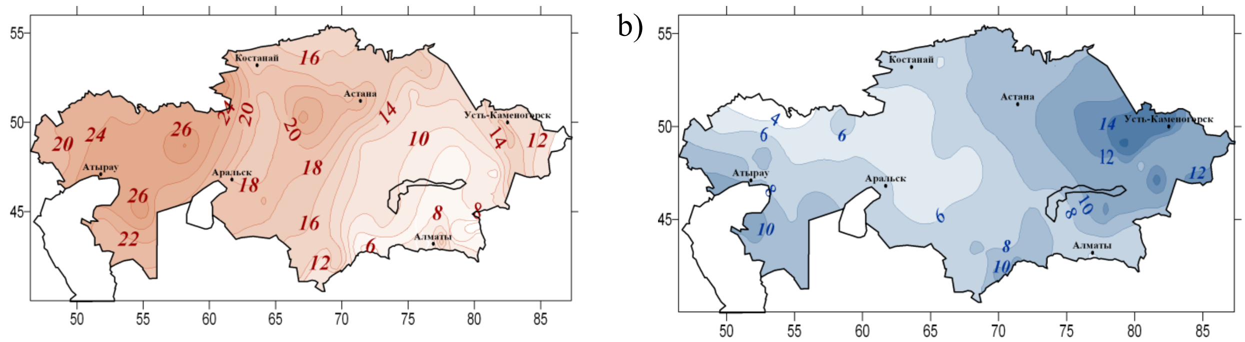


Figure 1.14 – Percentage of days with the daily maximum temperatures above the 90th percentile (a) and with the daily minimum temperatures below the 10th percentile (b) in 2012

Figure 1.15a shows the total duration of heat waves in Kazakhstan in 2012 (***sum of days when at least six consecutive days the daily maximum temperature was above 90th percentile***). The total duration of heat waves was high in western Kazakhstan with maximum in Aktobe oblast (54-66 days). Heat waves only lasted for 6-12 days in other regions.

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 2012 cold waves with duration of 18-30 days occurred only in East Kazakhstan and Pavlodar oblasts (Figure 1.15b).

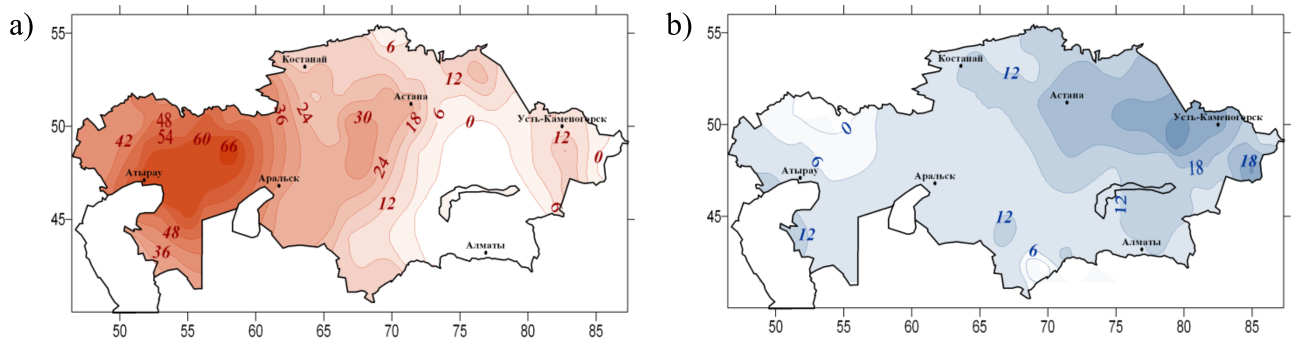


Figure 1.15 – Total sum of days with at least of 6 consecutive days the daily maximum temperature above the 90th percentile (a); and at least of 6 consecutive days the daily minimum temperature below the 10th percentile (b) in 2012

Figure 1.16 presents duration of vegetation period in 2012 (the period between the first 5-day average daily temperature ≥5 °C, and the last 5- day average daily temperature ≤5 °C). The vegetation period was about 200 days in the north and more than 250 days in the south of Kazakhstan.

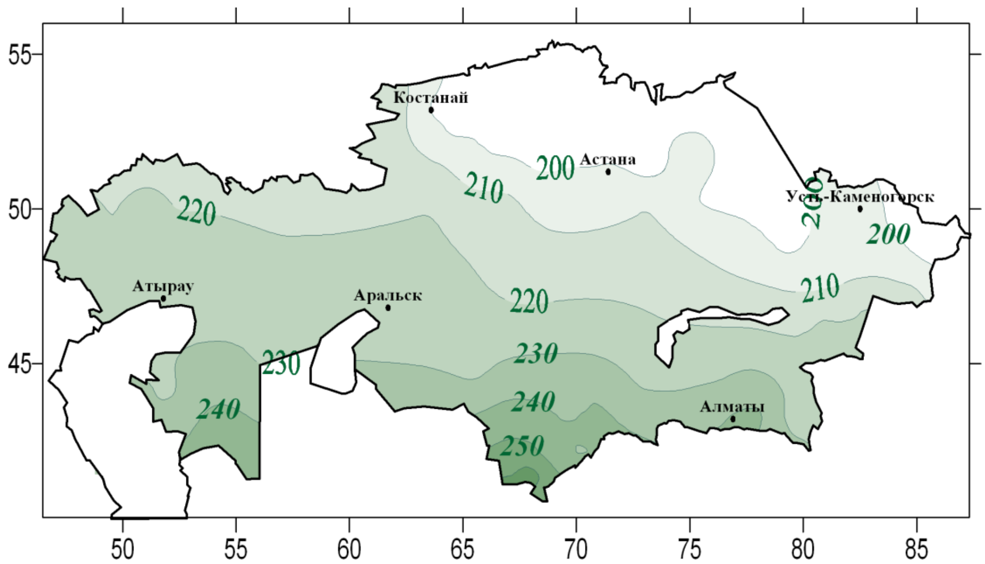


Figure 1.16 – Duration of vegetation period (days) in 2012

1.4 Trends in surface air temperature extremes

Trend analysis of the surface air temperature extremes was performed for 1941...2012.

The ***daily maximum surface air temperatures*** tend to increase at most meteorological stations of Kazakhstan. However statistically significant trends can be observed mainly in East Kazakhstan, Pavlodar, Kyzylorda Mangistau and Atyrau oblasts (Figure 1.17). Daily maximum temperatures increase by 0.01...0.40 ºC every 10 years. In some regions the increase amounts to 0.41...0.60 °C every 10 years.

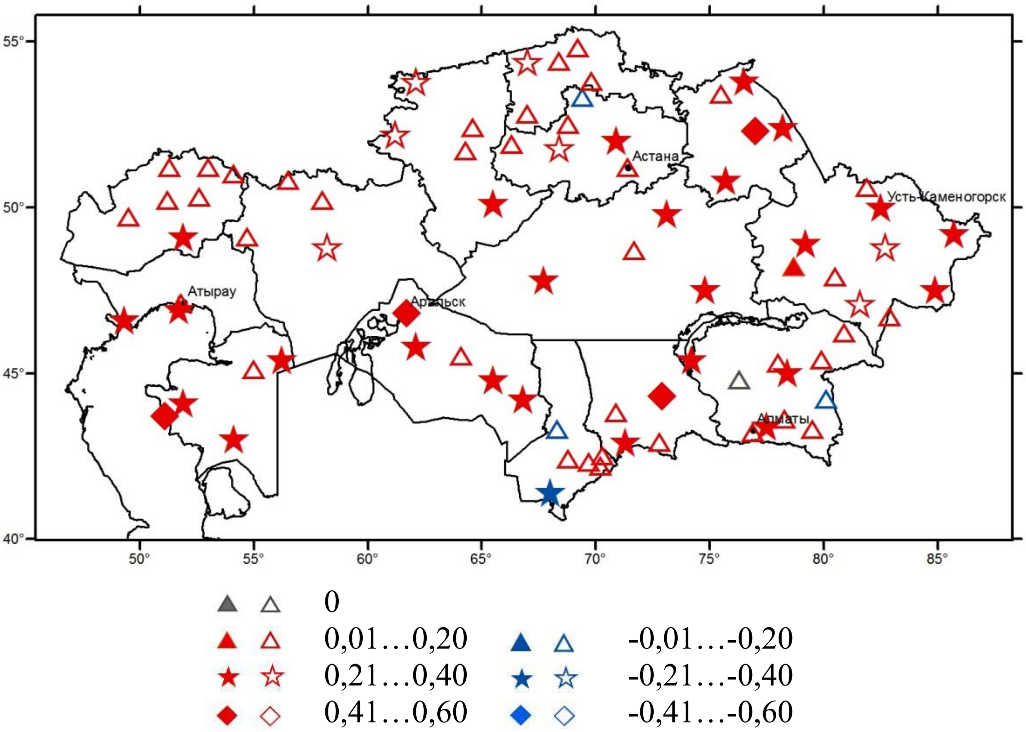


Figure 1.17 – Spatial distribution of the linear trend factors of daily maximum air temperatures (ºC/10 years) for 1941...2012. Shaded keys are for statistically significant trend

Statistically significant increase (1 to 5 days every 10 years) in the ***number of days with temperatures above 35 ºC*** appeared in western and southern regions of Kazakhstan (Figure 1.18). In the northern and eastern regions the frequency of hot days has not changed during 1941...2012.

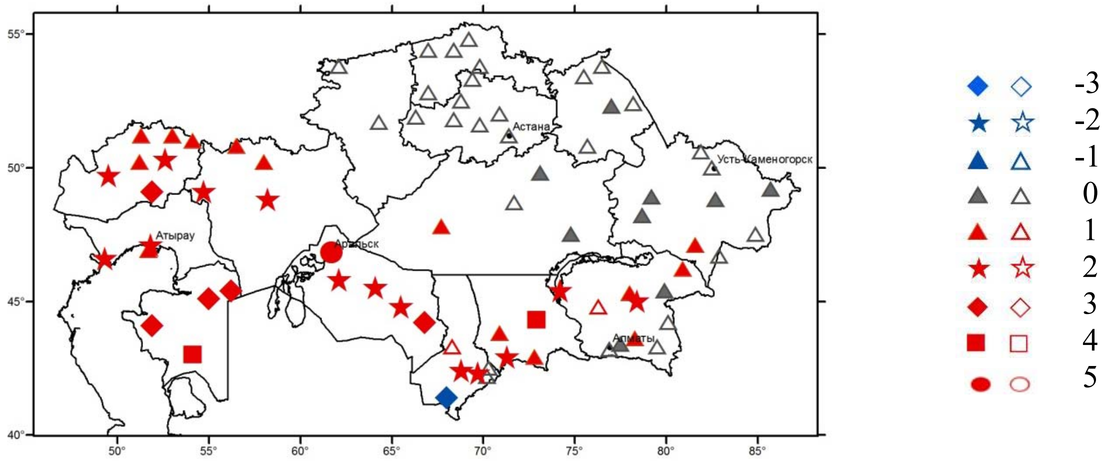


Figure 1.18 – Spatial distribution of the linear trend factors for the number of days with temperatures above 35 ºC (day/10 years) for 1941...2012. Shaded keys are for statistically significant trend

The total duration of heat waves increased throughout the country by 1 to 3 day/10 years (Figure 1.19). 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 70 % of meteorological stations.

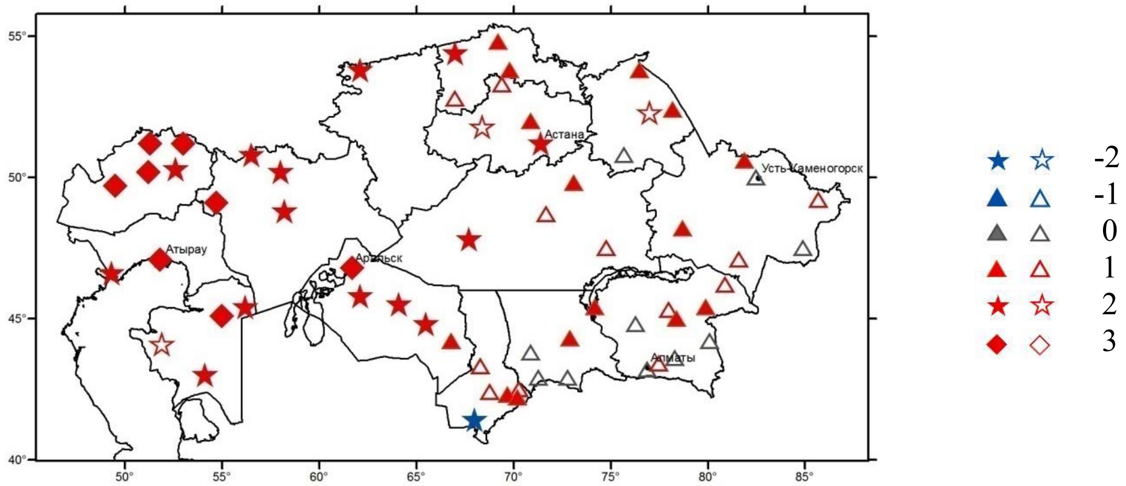


Figure 1.19 – Spatial distribution of the linear trend factors of the total duration of heat waves (day/10 years) during 1941...2012. Shaded keys stand for statistically significant trend.

It should be noted that all temperature extremes listed above (figures 1.17-1.19) have adverse (negative) trend at one weather station Chardara in far south of Kazakhstan. Chardara station is surrounded by Chardara reservoir by three sides causing a cooling effect and forming local climatic conditions.

Almost everywhere in Kazakhstan the frequency of frost days when the daily minimum temperature is below 0 °C tends to decrease (Figure 1.20). The fastest rates of the frost day frequency decrease are in the mountain regions of the southern Kazakhstan (5...6 days every 10 years). In other regions the number of frost days reduces by 1...4 days every 10 years.

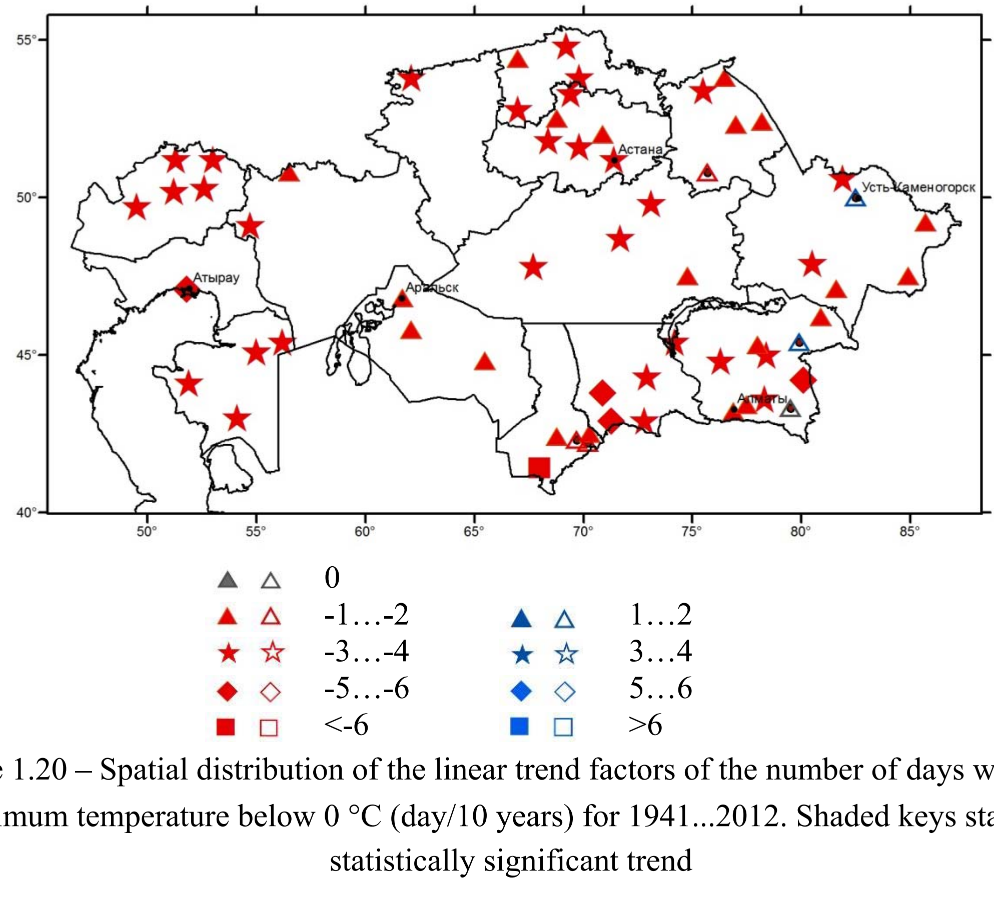


Figure 1.20 – Spatial distribution of the linear trend factors of the number of days with daily minimum temperature below 0 °C (day/10 years) for 1941...2012. Shaded keys stand for statistically significant trend

A significant decreasing trend in the daily temperature amplitude was observed in Kazakhstan amounting to 0.1...0.2 ºC (Figure 1.21). This trend means mitigation of the climate continentality.

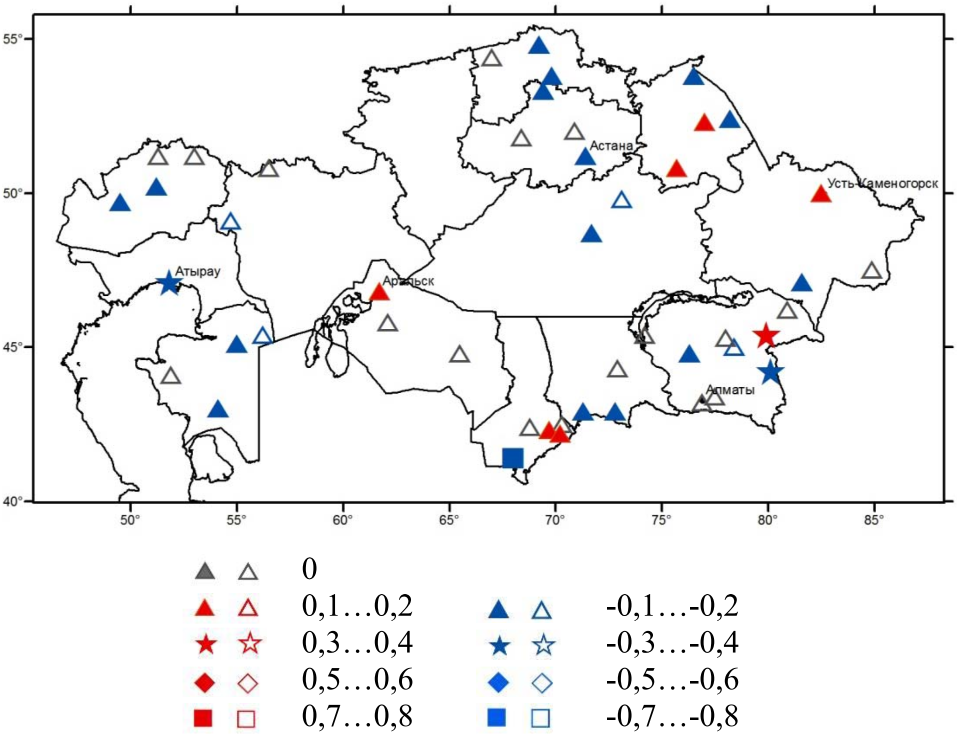


Figure 1.21 – Spatial distribution of the linear trend factors of the daily air temperature amplitude (°C/10 years) for 1941 ... 2012. Shaded keys stand for statistically significant trend

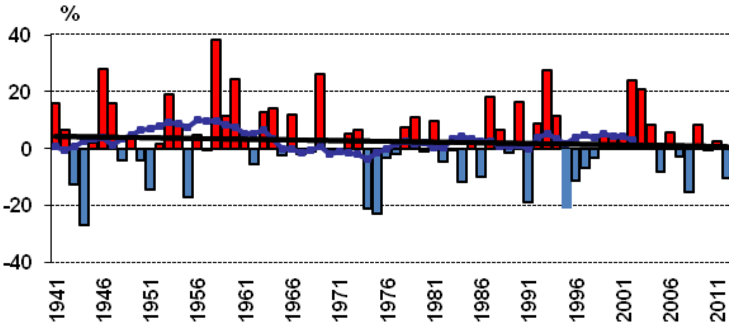
2 PRECIPITATION

2.1 Observed changes in precipitation in Kazakhstan for 1941-2012.

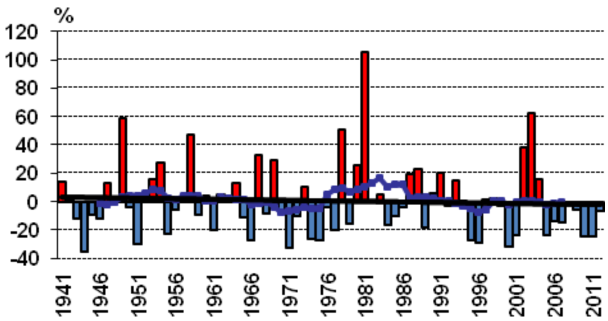
In contrast to the air temperature, changes in precipitation in Kazakhstan are more diverse. Experts estimated linear trends of the monthly, seasonal and annual precipitation time series for 121 weather stations. In some regions of Kazakhstan precipitation increased slightly, whereas in other regions they decreased.

Figure 2.1 shows the time series of annual precipitation anomalies for 1941...2012, calculated relative to the 1971...2000 baseline and spatially averaged for Kazakhstan and oblasts. On average annual precipitation has been decreasing slightly by 1 mm every 10 years, or about by 0.5 % of normal per 10 years (table 2.1). A slight increase in annual precipitation (by 0.4...4.0 mm/10 years) was observed in Karaganda, Aktobe, Mangistau, North Kazakhstan and Almaty oblasts. In other oblasts – Pavlodar, Akmola, Zhambyl, Kyzylorda, Kostanay, South-Kazakhstan, West-Kazakhstan, Atyray and East-Kazakhstan – precipitation has been decreasing by 0.1…5.2 mm per 10 years. All annual trends are statistically insignificant.

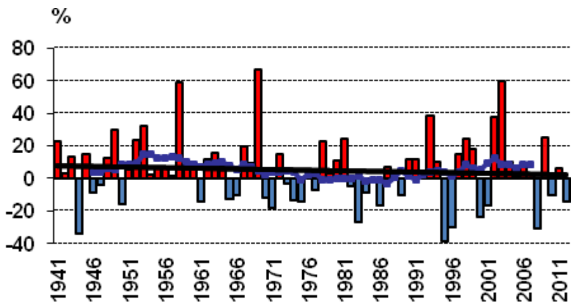
a) Kazakhstan



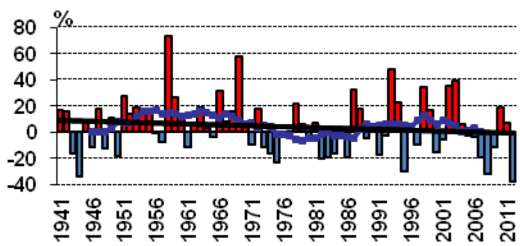
b) Kyzylorda oblast



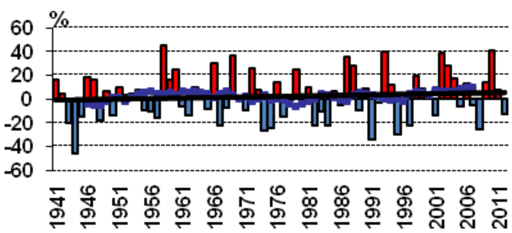
c) South Kazakhstan oblast



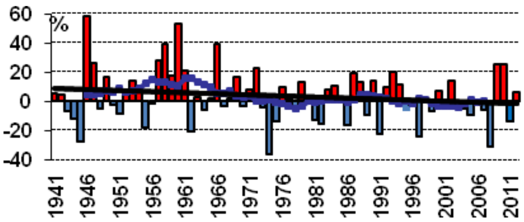
d) Zhambyl oblast



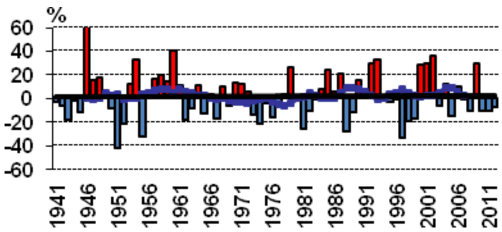
e) Almaty oblast



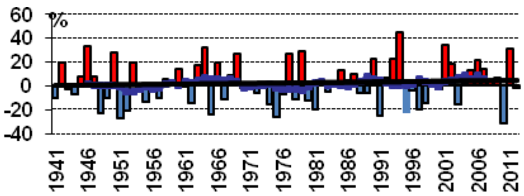
f) East Kazakhstan oblast



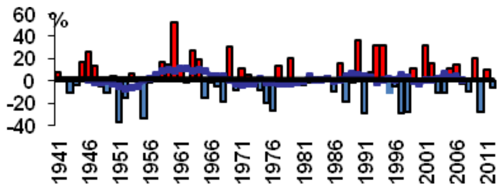
g) Pavlodar oblast



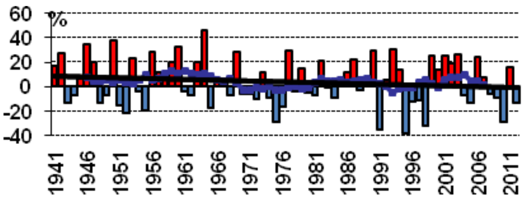
h) North Kazakhstan oblast



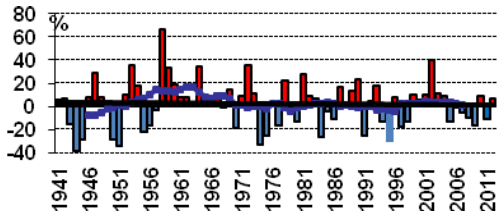
i) Akmola oblast



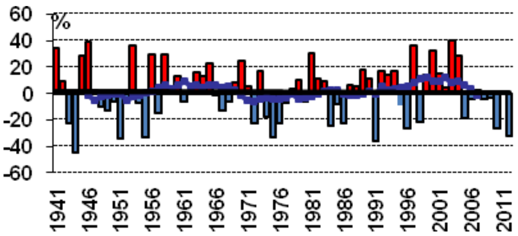
j) Kostanay oblast



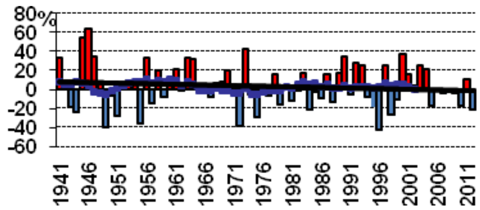
k) Karaganda oblast



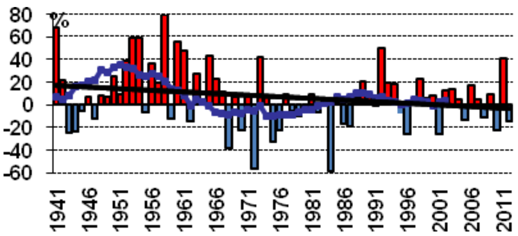
l) Aktobe oblast



m) West Kazakhstan oblast



n) Atyrau oblast



o) Mangistau oblast

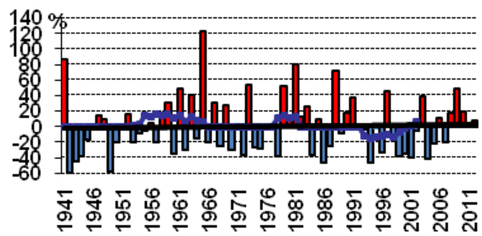


Figure 2.1 – Time series and linear trends of annual and seasonal precipitation anomalies (%) for 1941...2012. calculated relative to the 1971...2000 baseline. The smooth curve shows the 11-year moving average

Table 2.1 – Linear trend parameters of the seasonal and annual precipitation anomalies (mm/10 years, %/ 10 years) for Kazakhstan and oblasts for 1941...2012.

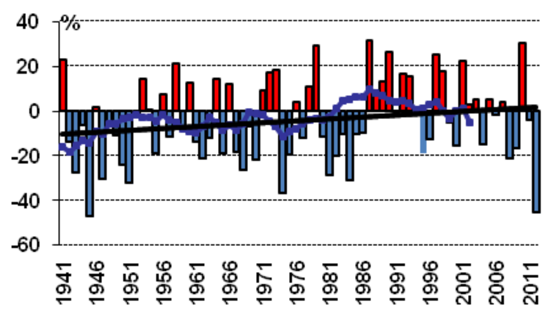
Oblast	Unit	Year		Winter		Spring		Summer		Autumn	
		*a	**R^2	a	R^2	a	R^2	a	R^2	a	R^2
Kazakhstan	mm	-1,0	1	1,3	4	-0,6	0	-1,1	1	-0,7	1
	%	-0,5		1,7		-0,2		-1,2		-1,1	
Kyzylorda	mm	-0.9	0	-0.9	2	-0.2	0	0.2	0	-0.1	0
	%	-0.8		-1.9		-0.5		1.3		-0.2	

Oblast	Unit	Year		Winter		Spring		Summer		Autumn	
		*a	**R^2	a	R^2	a	R^2	a	R^2	a	R^2
South Kazakhstan	mm	-3.2	1	0.8	0	-4.5	2	0.6	0	0.3	0
	%	-0.8		0.2		-2.9		0.4		1	
Zhambyl	mm	-2.1	2	0.9	0	-3.3	4	0	0	0.3	0
	%	-1.3		0.4		-2.4		-0.5		-0.2	
Almaty	mm	4.0	1	3	8	-2.2	1	1.7	1	1	1
	%	1.0		3.8		-1.6		1.4		1.2	
East Kazakhstan	mm	-5.2	3	0.5	0	-1.4	2	-3.4	4	-1.0	1
	%	-1.5		0.8		-2.2		-3.1		-1.1	
Pavlodar	mm	-0.1	0	1.3	6	0.8	1	-0.2	0	-2.2	5
	%	0		2.5		1.4		-0.1		-3.3	
North Kazakhstan	mm	2.0	1	3.3	17	1.8	3	-3.2	2	0.4	0
	%	0.6		6.0		2.9		-2.1		0.5	
Akmola	mm	-0.5	0	1.6	5	0.8	1	-1.3	0	-1.9	3
	%	-0.2		2.9		1		-1.0		-2.6	
Kostanay	mm	-2.7	2	0.4	0	1.1	1	-2.5	2	-2.2	4
	%	-1.2		0.8		1.5		-2.7		-3.1	
Karaganda	mm	0.4	0	1.8	6	0	0	-1.1	1	-0.4	1
	%	0.3		1.7		-0.3		-1.8		-1.4	
Aktobe	mm	0.5	0	1.8	4	2.5	4	-1.6	1	-2.3	4
	%	0.2		2.0		3.7		-2.4		-3.7	
West Kazakhstan	mm	-3.4	2	1.2	2	-0.2	0	-2.3	3	-2.0	3
	%	-1.3		2.0		-0.4		-3.2		-3.2	
Atyrau	mm	-4.6	5	-2.5	12	0.1	0	-1.7	2	-0.5	0
	%	-2.9		-8.5		0.1		-3.7		-1.5	
Mangistau	mm	0.9	0	0.7	1	2.4	3	-2.0	3	0.1	0
	%	0.7		2.8		5.0		-7.2		0.4	

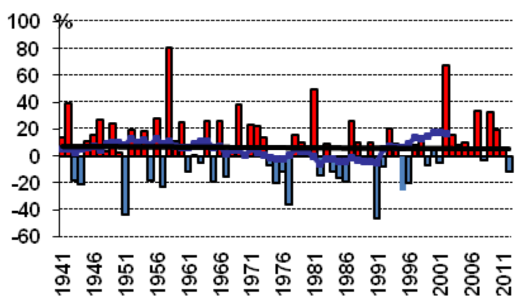
* a – linear trend factor, %/10years, mm/10 years;
** R^2 – determination factor,%

Figure 2.2 shows the inter-annual course of seasonal precipitation anomalies (%) averaged for Kazakhstan. On average in Kazakhstan precipitation tends to slightly decrease by 0.8 mm every 10 years in all seasons except winter when precipitation tends to increase by 1.3 mm every 10 years (statistically significant trend) (table 2.1)

a)



b)



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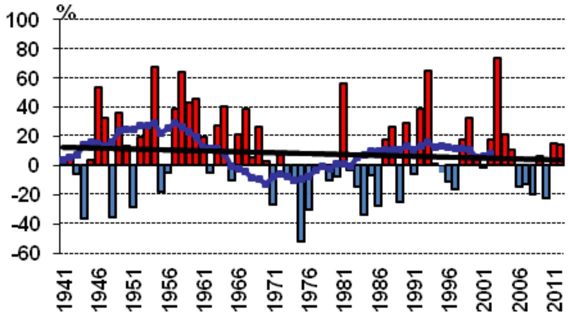
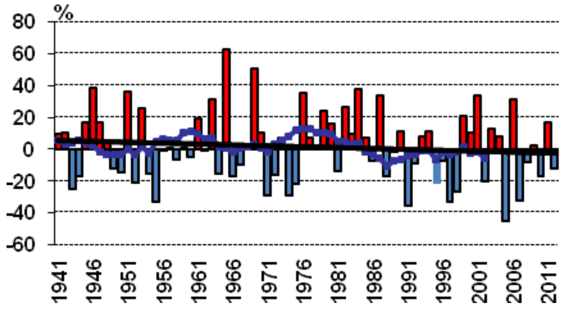


d)



a) winter; b) spring; c) summer; d) autumn.

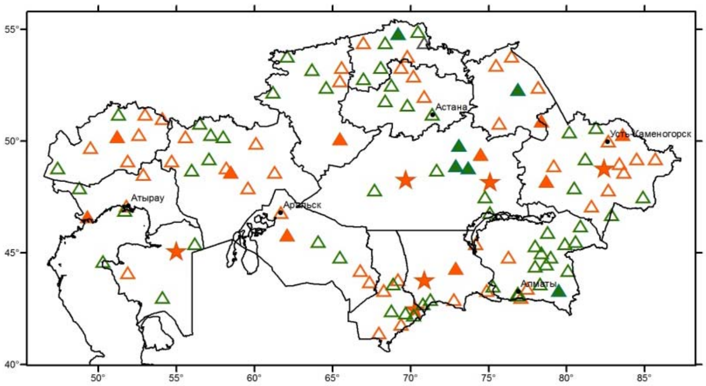
Figure 2.2 – Time series and linear trends of seasonal precipitation anomalies (%) for 1941...2012 relative to the 1971...2000 baseline. The smooth curve represents the 11-year moving average

Figure 2.3 shows the change in annual and seasonal precipitation in Kazakhstan for 1941-2012 (% of norm/10 years). Changes in the seasonal precipitation are diverse. In summer and autumn in most parts of Kazakhstan except mountain south-eastern regions precipitation decreased by 1...7% of norm every 10 years. In winter precipitation mostly increased. Continuous positive trends were observed in the northern and central regions, mountains and foothills north-western, eastern, south-eastern regions by 1...9 % of normal every 10 years. In spring, a positive trend was observed in the north-western part of Kazakhstan, whereas in other regions precipitation decreased. It should be noted that almost all seasonal trends are statistically insignificant, except winter precipitation.

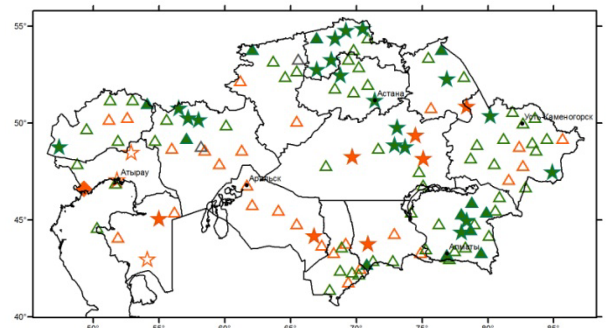
In January and February precipitation increased everywhere in Kazakhstan by 0.1...9 % per 10years. In Almaty, Pavlodar, North Kazakhstan, and Akmola oblasts the increase was statistically significant whereas in Atyrau oblast precipitation decreased by about 13 % every 10 years. In spring and summer change in precipitation both negative and positive was negligible all over Kazakhstan, except North Kazakhstan oblast where precipitation increased by 9.2 % every 10 years in March. In September and October precipitation decreased in most of Kazakhstan. In September precipitation reduction was statistically significant in northern half of Kazakhstan and in Karaganda and Kyzylorda oblasts (by 7...14 % of norm/10 years). In November and December, change in precipitation was mostly positive. In North-Kazakhstan and Karaganda oblasts precipitation increase was statistically significant and amounted to 8...9 % every 10 years.

Figures 2.3 and 2.4 provide details on the changes in precipitation in Kazakhstan during 1941...2012 (%of norm per 10 years).

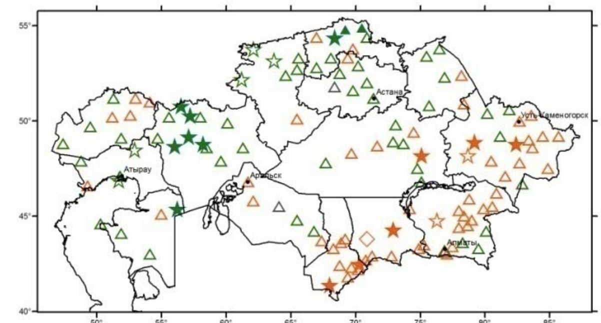
year



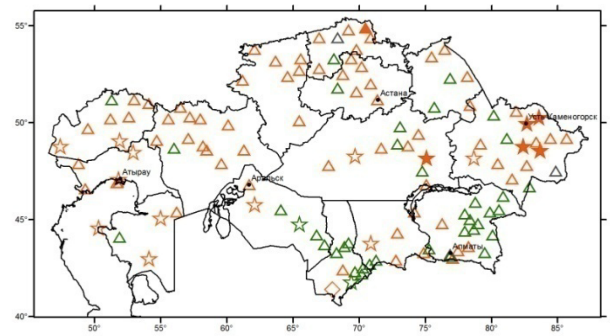
winter



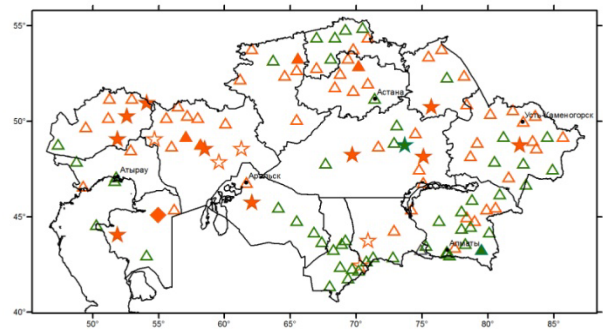
spring



summer



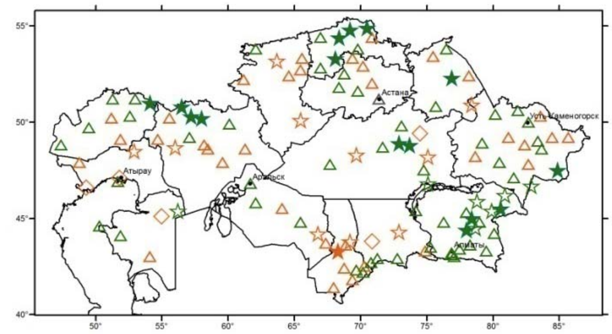
autumn



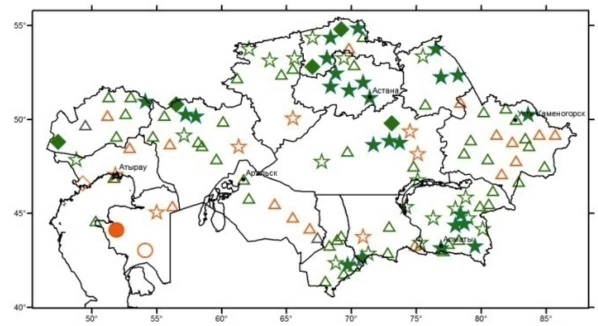
	0
-0,1…-5,0	0,1…5,0
-5,1…-10,0	5,1…10,0
-10,1…-15,0	10,1…15,0
-15,1…-20,0	15,1…20,0
<-20,1	>20,1

Figure 2.3 – Spatial distribution of the linear trend factor of seasonal and annual precipitation anomalies (% of norm/10 years), over 1941...2012, relative to the 1971-2000 baseline. Shaded keys stand for statistically significant trend

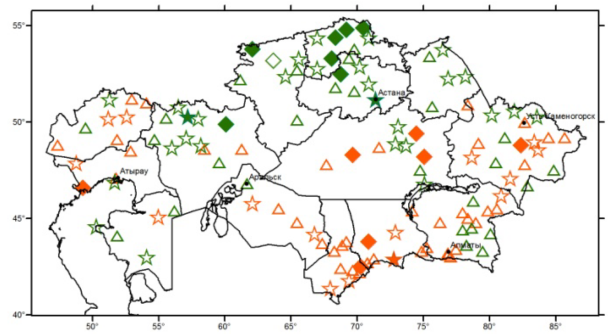
January



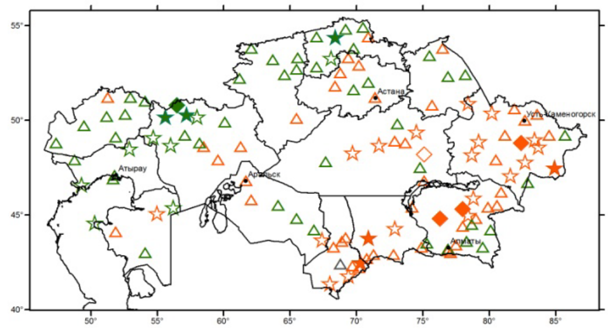
February



March



April



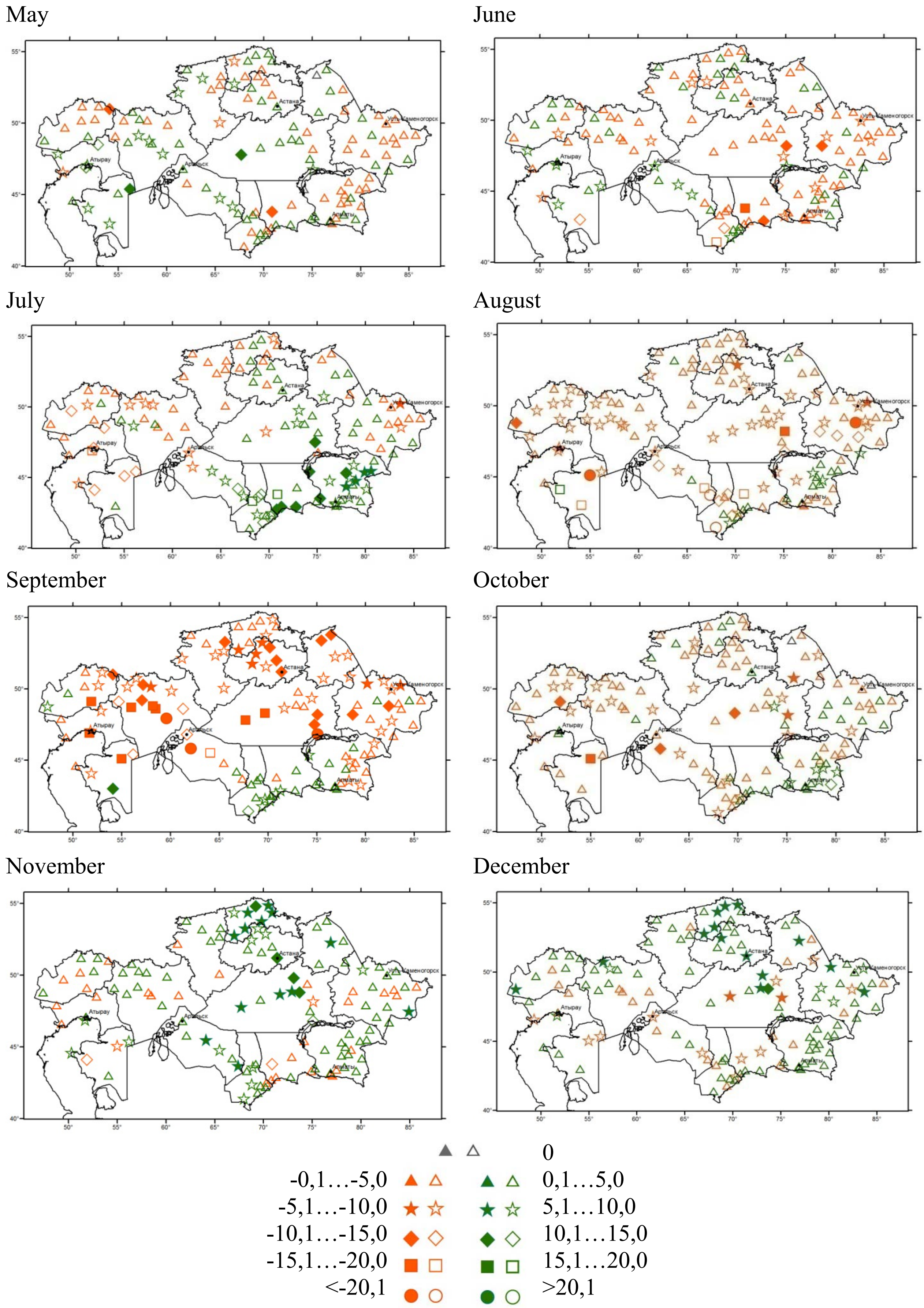


Figure 2.4 – Spatial distribution of the precipitation linear trend factor (% of normal/10 years), over 1941...2012, relative to the 1971-2000 baseline. Shaded keys stand for statistically significant trend

2.2 Precipitation anomalies in Kazakhstan in 2012

Figure 2.5 shows the spatial distribution of annual and seasonal precipitation in 2012, expressed as percentage of normal over 1971...2000 and nonexceedance probability of annual and seasonal precipitation in 2012. The nonexceedance probability means the frequency of the corresponding anomaly in the observational records.

In 2012 (December 2011 through November 2012) the annual precipitation deficit (40…60 % of normal) was observed in Aktobe, Zhambyl and Almaty oblasts (figures 2.5a). In Kyzylorda, North Kazakhstan, Karaganda and East Kazakhsatn oblasts annual precipitation was 20% higher than normal. In the other regions precipitation was 80…100 % normal.

Winter (December 20011 - February 2012).

In western and south-eastern Kazakhstan winter precipitation were 80...120 % normal (figure 2.5b). In western, central, northern and eastern Kazakhstan precipitation amounted only 20…40 % of the norm. In these regions, winter appeared to be within 10 % of extremely dry winters since 1941. Precipitation anomalies in other regions were 40 to 80% of normal.

Spring

In spring precipitation deficit of >80% normal occurred in south-western oblasts of Kazakhstan. In south-eastern and eastern oblasts 2012 spring was within 10% of the driest seasons. In central parts of Kazakhstan precipitation exceeded norm by 20…100 % (figure 2.5c). Precipitation in other regions was within norm.

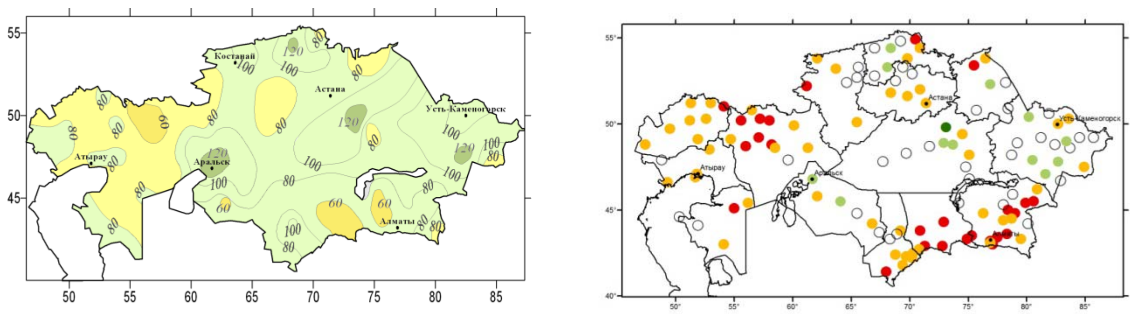
Summer

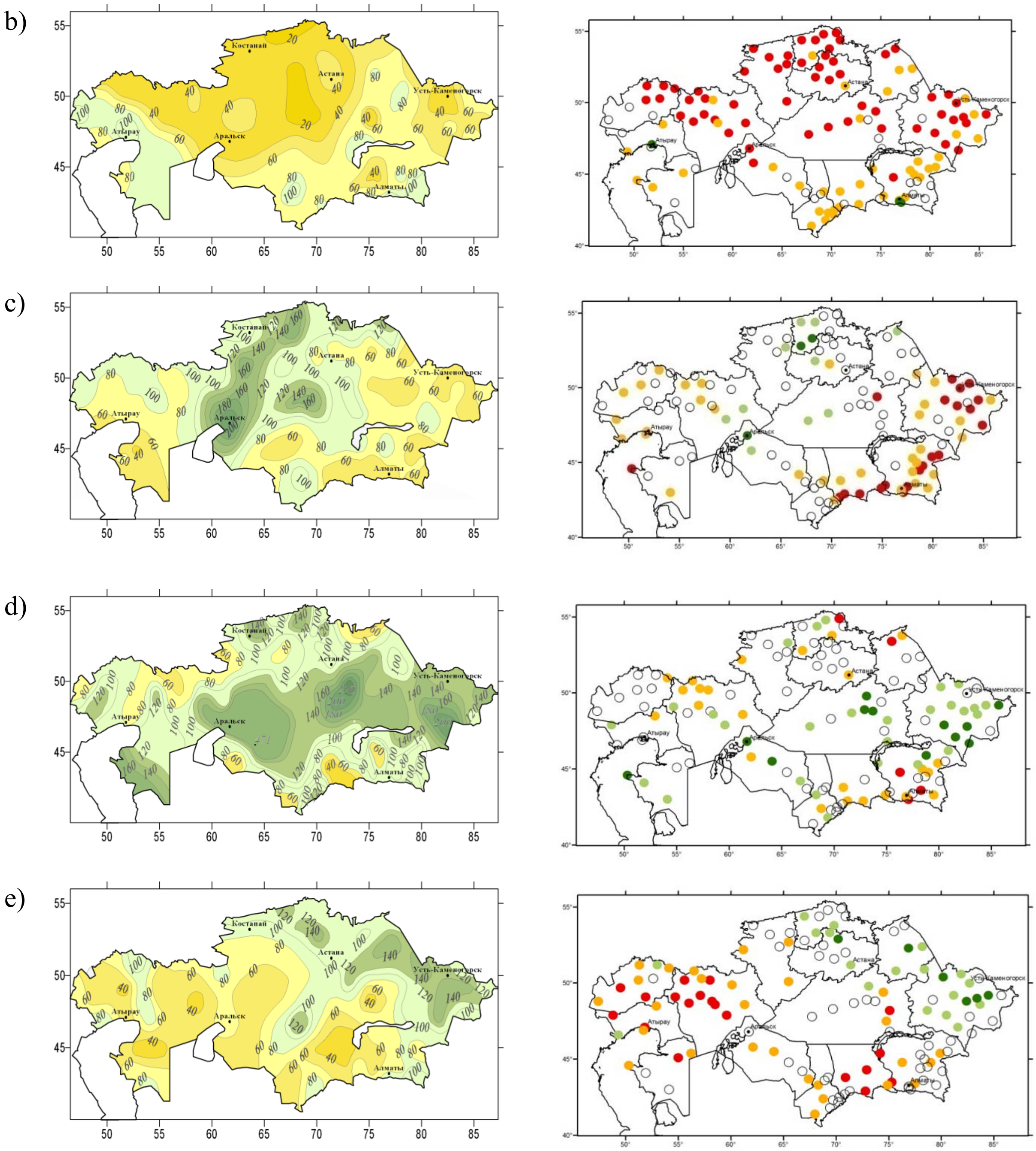
In most of Kazakhstan summer precipitation in 2012 was nearly normal, or 20...100 % higher. Extremely dry summer was in some regions of Aktobe, Kostanay, Pavlodar oblasts and in the southern regions (figures 2.5d), where precipitation was <60 % normal.

Autumn

In autumn precipitation deficit of 40 to 60 % appeared in the southern half of Kazakhstan (Figures 2.5e). n some areas of western and southern Kazakhstan autumn was extremely dry. In Karaganda, North Kazakhstan, Pavlodar and East Kazakhstan oblasts precipitation was 20…40% above normal. In other regions precipitation was within norm.

a)





a) year (Dec 2011 – Nov 2012)
b) winter
c) spring
d) summer
e) autumn

– extremely dry (non-exceedance probability 0-9 %);
– dry (non-exceedance probability 10-29 %);
–about norm (non-exceedance probability 30-69 %);
– wet (non-exceedance probability 70-89 %);
– extremely wet (non-exceedance probability 90-100 %).

Figure 2.5 – Precipitation in 2012 as % of the norm (over 1971…2000) and non - exceedance probabilities for 1941…2012

To assess precipitation extremes in 2012 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 2012 are presented below.

Maximum of daily precipitation in 2012. Figure 2.6 shows absolute maximum daily precipitation, since the beginning of records to 2011 in red. Daily maximum observed in 2012 are in blue. In 2012 the absolute maximum of daily precipitation was exceeded at Shelek weather station where precipitation amounted to 44 mm.

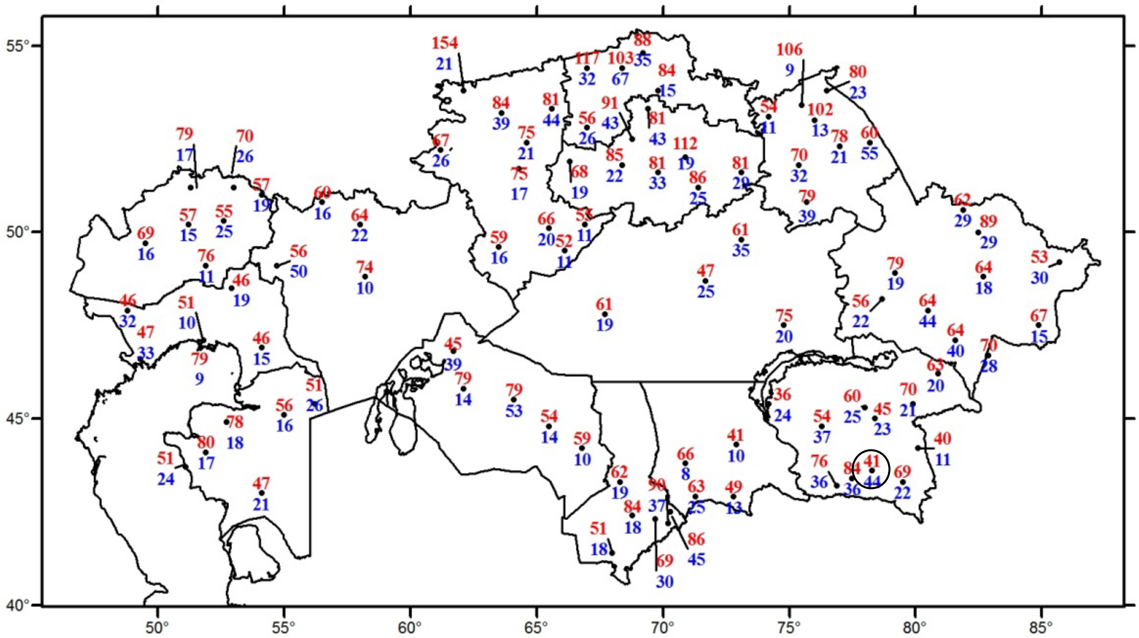


Figure 2.6 – Absolute maximum of daily precipitation, since the beginning of records until 2011 (in red) and the daily maximum in 2012 (in blue), mm

Figure 2.7 shows the share of extreme precipitation (above 95th percentile) in the total precipitation of 2012. 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 Zhusaly station (65 %), Urzhar, Petropavlovsk, Scherbakty, Uil, Aktau, Aral sea, Kuygan and Yavlenka with 40...53 %. 44 of stations also recorded rather high share of extreme precipitation – 20...39 % which means irregularity of precipitation in time.

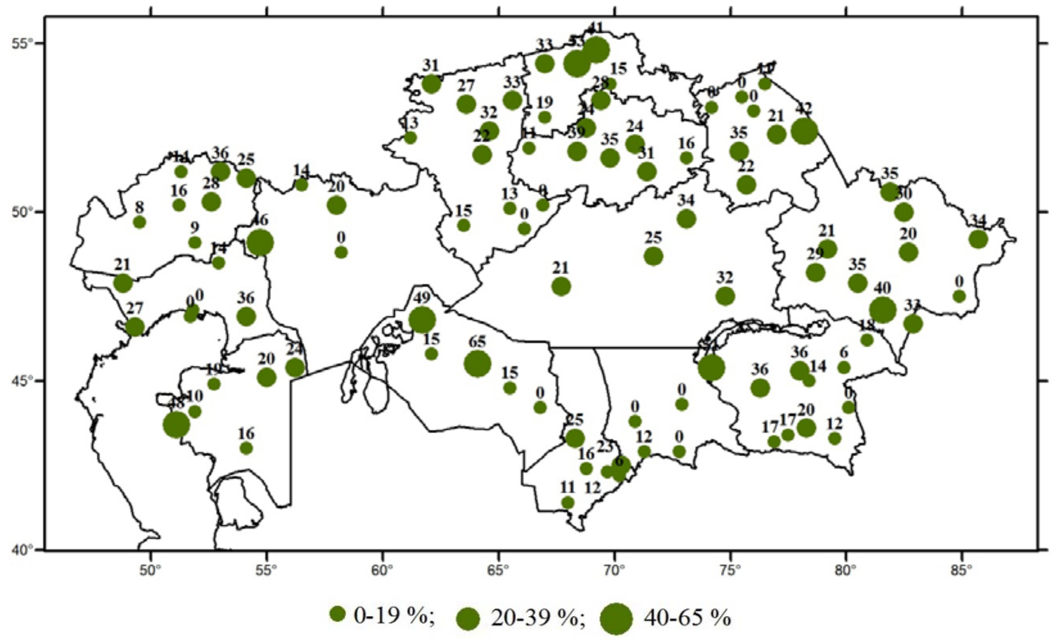
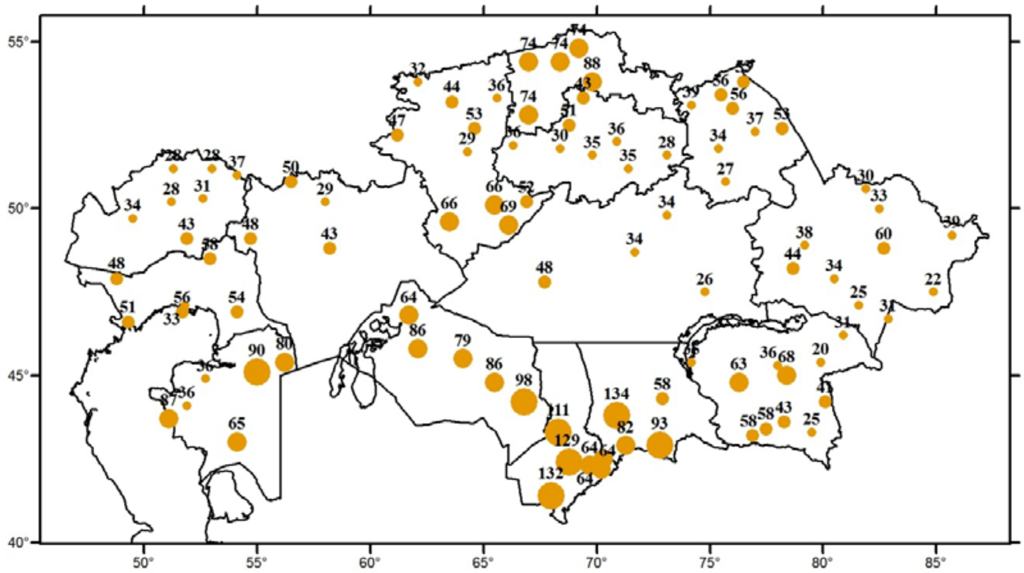


Figure 2.7 – Percentage share of extreme precipitation in the annual total in 2012. Extreme precipitation is the sum of daily precipitation exceeding 95th percentile

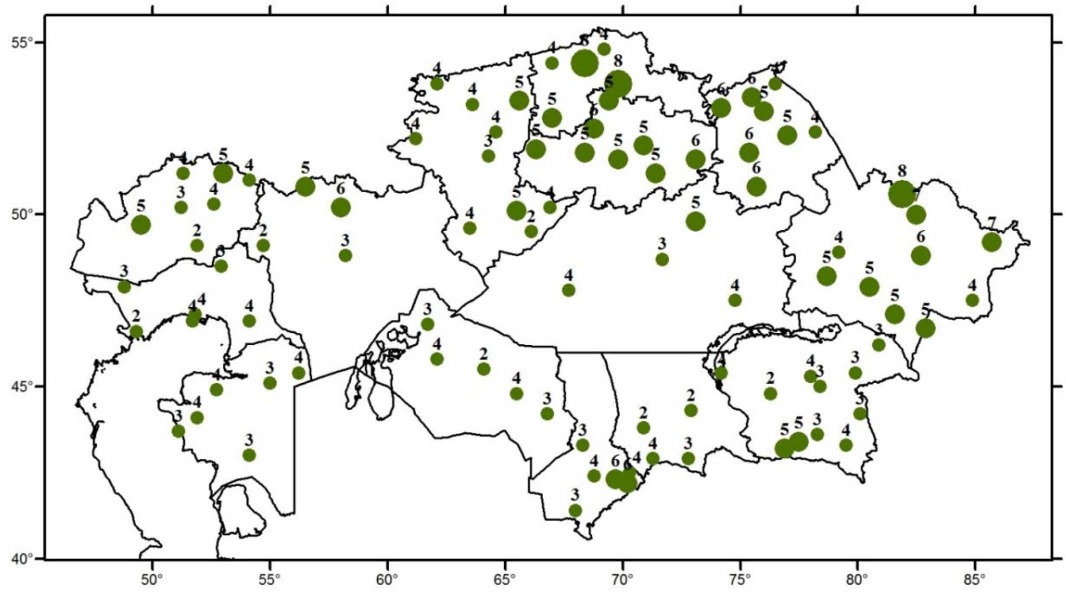
The CDD index which represents the ***maximum length of time when precipitation was less than 1 mm*** (duration of dry period, figure 2.8), is very important in the arid climate of Kazakhstan. In 2012 the dry period lasted for about a month at almost all weather stations. The longest dry periods from 90 to 134 days were in Mangistau oblast (Beyneu), Kyzylorda oblast (Shiili), South Kazakhstan oblast (Turkestan, Shardara, Arys) and Zhambyl oblast (Kulan, Uyuk). The dry period of 60 to 90 days was recorded in North Kazakhstan and Mangistau oblasts and in the southern Kazakhstan.



16-40 days; 41-60 days; 61-89 days; 90-130 days

Figure 2.8 – Maximum duration of dry period in days in 2012

Figure 2.9 shows the maximum duration of the period in 2012 when precipitation was equal or greater than 1 mm (CWD). The CWD index shows that the maximum duration of wet period varied from 2 to 9 days. The longest wet periods of 5…9 days were observed in foothill and mountain areas of the southeast, and in the north and northeast of Kazakhstan.



2-4 days; 5-7 days; 8-9 days;

Figure 2.9 – Maximum duration of wet period in 2012 in days

2.3 Trends in precipitation extremes

Trend analysis of precipitation extremes was prepared over 1941-2012.

The maximum daily precipitation (Rx1day) in Kazakhstan remained almost unchanged (figure 2.10). Both increasing and decreasing trends were weak – around 0.1…1.0 mm per 10 years in all oblasts Kazakhstan. Almost all trends are statistically insignificant except few stations. For instance, maximum daily precipitation decreased by 3.2 mm per 10 years at Bayanaul station, whereas at Bektauata and Turar Ryskulov stations maximum daily precipitation increased by 1.5-1.6 mm per 10 years, respectively.

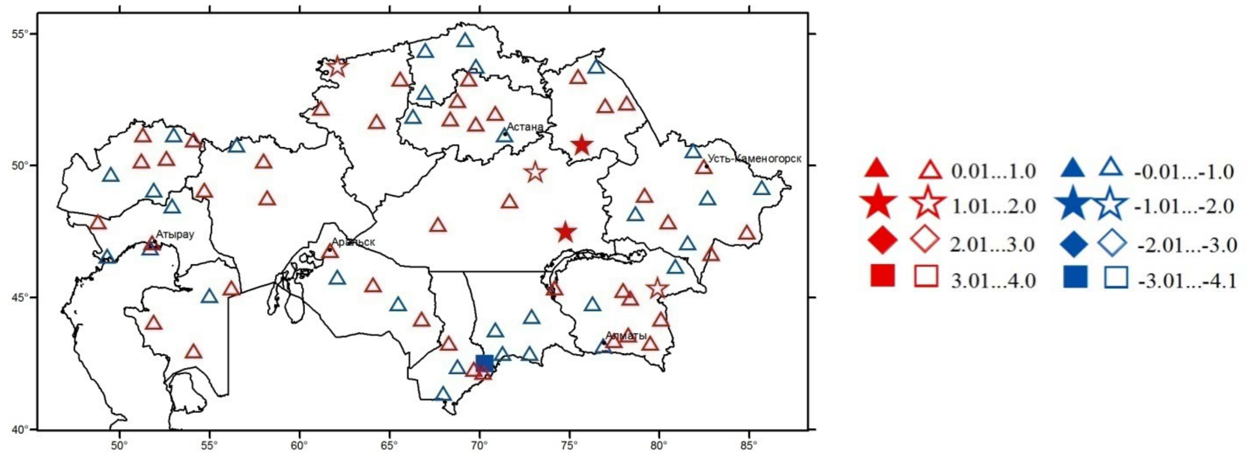


Figure 2.10 – Spatial distribution of the linear trend factor of maximum daily precipitation (mm/10 years), for 1941...2012. Shaded keys stand for statistically significant trend

Analysis of the percentage share of extreme precipitation in annual total (***R95pTOT***) showed that weak trends both decreasing and increasing by 1.01...1.0 %/10 years was observed everywhere in Kazakhstan except few stations. For example, at Karaganda and Zheskazgan stations the share of extreme precipitation increased by 1.6 and 1.7 % every 10 years, respectively. At Ayagoz, Amangeldy and Turar Ryskulov stations extreme precipitation share decreased by 1.3…2.7% every 10 years (figure 2.11). The increase in extreme precipitation during summer cause the higher risk of erosion, and rain-fed mudflow in mountain regions.

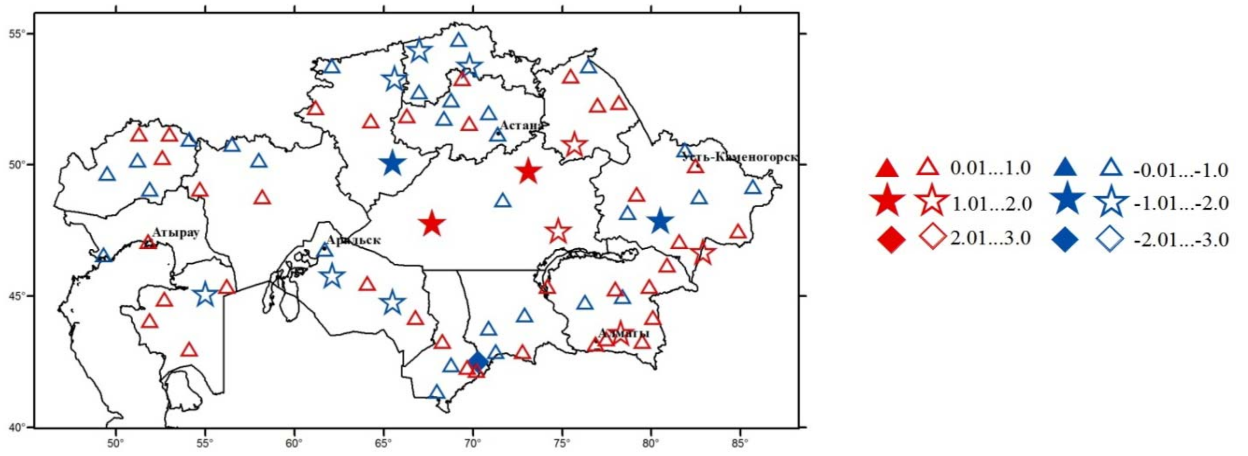


Figure 2.11 – Spatial distribution of the linear trend factor of extreme precipitation share in annual total (%/10 years) over 1941...2012. Extreme precipitation is the sum of daily precipitation above the 95th percentile. Shaded keys stand for statistically significant trend.

The maximum duration of dry period tend to decrease almost everywhere in Kazakhstan. Statistically significant decrease occurred in the northern and northeastern regions of Kazakhstan by 1...4 days every 10 years. At Zhusaly station dry period reduced by 6 days per 10 years. However, at Kokpekty, Ekidyn, Kyzan and Beyneu stations duration of dry period increased by 1…4 days (figure 2.12).

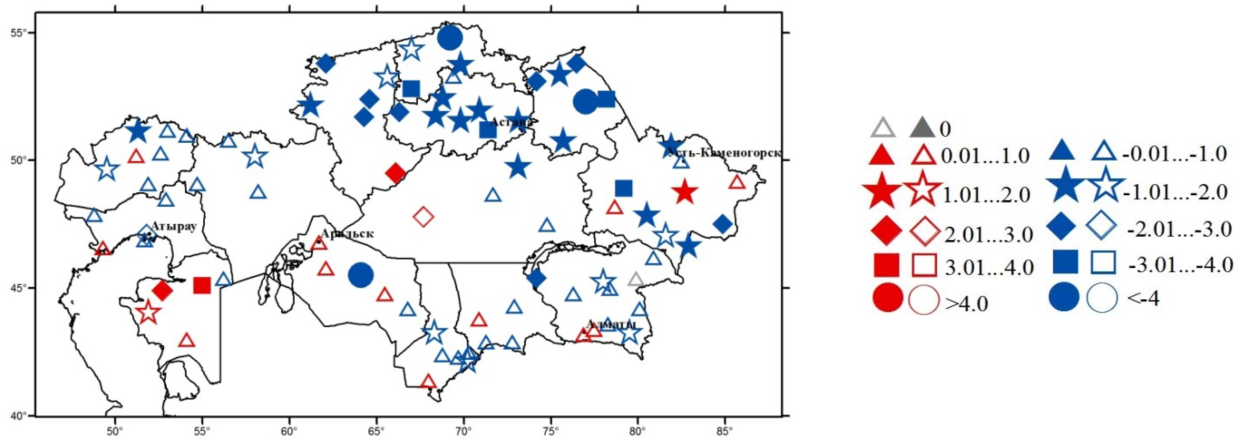


Figure 2.12 – Spatial distribution of the linear trend factor of the maximum dry period duration (day/10 years) over 1941...2012. Shaded keys stand for statistically significant trend.

CONCLUSION

Globally 2012 became the ninth warmest year on record since 1850. Also 2012 added to the number of years with air temperature above the baseline period (1961-1990., 14 °C), bringing the total number to 27 years

The ranked 2012 annual average temperature in Kazakhstan (over 118 weather stations) was the 27th since 1941.

Annual average temperature anomalies (December 2011-November 2012) were 1.0-2.0 ^{0}C higher than the norm in the west and northwest of Kazakhstan. In Aktobe oblast 2012 appeared within 10% of the extremely warm years. In all other regions temperature anomalies were within ±1 °C. The annual precipitation deficit (40…60 % of normal) was observed in Aktobe, Zhambyl and Almaty oblasts. In the other regions precipitation was 80…120 % normal

The winter of 2012 (December 2011 - February 2012) was cold or extremely cold everywhere in Kazakhstan. Temperature anomalies varied from -2.0 to -7.0 ºC. Extremely low temperatures (5.0 to 7.0 ºC below norm) were recorded in East Kazakhstan, Karaganda and Pavlodar oblasts. At 30% of weather stations the winter appeared to be within 10% of extremely cold since 1941. In western, central, northern and eastern Kazakhstan precipitation amounted only 20…40 % of the norm. In these regions, winter appeared to be within 10 % of extremely dry winters since 1941.

Spring was warm or extremely warm everywhere in Kazakhstan. Air temperatures were 1.0-4.5 ^{0}C above the norm. The highest anomalies of 3.0 to 4.5 ^{0}C were recorded on the vast area of the northern, western, central and partly southern regions of Kazakhstan. In these regions the 2012 spring added to the 10% of the extremely warm springs. In spring precipitation deficit occurred in south-western, south-eastern and eastern oblasts of Kazakhstan. In several regions of Kazakhstan precipitation exceeded norm by 20…100%.

The summer of 2012 was extremely warm or warm everywhere in Kazakhstan. The air temperatures exceeded the norm by 1,0...4,0 ºC. The greatest temperature anomalies occurred in the west – from 2.5 to 4.0 ºC, with the maximum in Aktobe oblast with anomalies more that 4.0 ^{0}C. According to the records of 90% of weather stations the 2012 summer was within 10 % of the hottest summers in Kazakhstan since 1941. In most of Kazakhstan summer precipitation in 2012 was nearly normal, or 20...100 % higher. Extremely dry summer was in some regions of Aktobe, Kostanay, Pavlodar oblasts and in the southern regions, where precipitation was <60 % normal.

2012 Autumn was warm or extremely warm in the northwestern regions of Kazakhstan where temperatures were 1.0-3.0 ºC above the norm. Most weather stations in West Kazakhstan, Kustanay and Aktobe oblasts reported that the 2012 autumn was within 10% of the warmest autumns. In autumn precipitation deficit of 40 to 60 % appeared in the southern half of Kazakhstan. In some areas of western and southern Kazakhstan autumn was extremely dry. In Karaganda, North Kazakhstan, Pavlodar and East Kazakhstan oblasts precipitation was 20…40% above normal. In other regions precipitation was within norm.

In 2012 air temperature exceeded absolute maximum by 0.2 ºC at two stations in the northern Kazakhstan – Esil and Blagoveschenka and amounted to 41.3 and 40.6 ºC, correspondingly. Maximum number of days with high temperatures above 35 ºC exceeded

40...70 days in the western Kazakhstan with 90-100 % probability of non-exceedance. The total duration of heat waves was high in western Kazakhstan with maximum in Aktobe oblast (54-66 days). The cold waves with duration of 18-30 days occurred only in East Kazakhstan and Pavlodar oblasts.

During the last 70 years the annual and seasonal surface air temperatures have been increasing everywhere in Kazakhstan. Country average annual temperature has been rising by 0.27 ºC every 10 years. The highest warming was in autumn by 0.32 ºC every 10 years. Winter and spring temperatures have been increasing a little slower by 0.29 ºC every 10 years. The slowest warming was in summer – 0.20 ºC every 10 years. In most cases the trends are statistically significant for the 95 % confidence interval. The contribution of trend to the total average annual temperature dispersion is 37 %, for seasons contribution varies from 6 to 27 %

The fastest increase in the average annual temperature was in West Kazakhstan oblast equal to 0.38 ^{0}C every 10 years. The lowest warming rates were in South-Kazakhstan Oblast, East Kazakhstan Oblast, Almaty Oblast and Mangistau Oblast amounting to 0.23...0.25 ºC every 10 years. In other oblasts the temperature increase rates were within 0.27...0.31 ºC over 10 years

The biggest temperature increase was observed in spring in northern and central oblasts (0.33…0.37 ºC every 10 years) and in autumn in southern and eastern oblasts (0.30…0.40 ºC every 10 years). In western oblasts the biggest temperature rise still occurred in winter (0.27…0.38 ºC every 10 years).

In February-March, and November-December the air temperature increase was most significant from 0.41 to 0.80º C/10 years. In April, June and October the warming rate was slower 0.21...0.40 ºC/10 years. In all other months temperature increased from 0.01 to 0.20 ºC every 10 years. Thus, temperature increase was higher in cold season (November-March) than in warm (April-October).

Daily maximum temperatures increase by 0.01...0.40 ºC every 10 years. In some regions the increase amounts to 0.41...0.60 °C every 10 years. The number of days with temperatures above 35 ºC increased in western and southern regions of Kazakhstan by 1 to 5 days every 10 years. The total duration of heat waves increased throughout the country by 1 to 3 day/10 years

On average annual precipitation has been decreasing slightly by 1 mm every 10 years, or about by 0.5 % of normal per 10 years during 1941-2012. On average in Kazakhstan precipitation tends to slightly decrease by 0.8 mm every 10 years in all seasons except winter when precipitation tends to increase by 1.3 mm every 10 years (1.7 % of norm per 10 years).

Changes in the seasonal precipitation are diverse. In summer and autumn in most parts of Kazakhstan except mountain south-eastern regions precipitation decreased by 1...7% of norm every 10 years. In winter precipitation mostly increased. Continuous positive trends were observed in the northern and central regions, mountains and foothills north-western, eastern, south-eastern regions by 1...9 % of normal every 10 years. In spring, a positive trend was observed in the north-western part of Kazakhstan, whereas in other regions precipitation decreased. It should be noted that almost all seasonal trends are statistically insignificant, except winter precipitation.