Coordination Committee on Hydrometeorology of the Caspian Sea (CASPCOM)

ANNUAL BULLETIN

ON THE CLIMATE STATE AND CHANGE

IN THE CASPIAN SEA REGION

for 2023 year

2024

CONTENT

INTRODUCTION

The 23rd Session of the Coordination Committee on Hydrometeorology of the Caspian Sea (CASPCOM) recommended to start issuing an annual bulletin for monitoring climate and its changes in the Caspian region. The structure and content of the bulletin was approved at 6(26)th CASPCOM session.

The Bulletin contains integrated and calculated characteristics of the main elements of the hydrometeorological regime of the Caspian Sea. They are obtained based on data from observation networks of the Caspian littoral states – members of CASPCOM (Azerbaijan, Iran, Kazakhstan, Russian Federation, and Turkmenistan). The Bulletin is intended to provide hydrometeorological information to economic sectors operating in the coastal and open parts of the Caspian Sea (exploration and mining, marine transport, fishing, etc.).

The Bulletin provides analysis of hydrometeorological regime in 2022–2023 (starting from the first month of the cold period – December of 2022), the climate state and anomalies (air temperature and precipitation), and climate changes. The Bulletin also describes the hydrological conditions (water temperature and sea level), as well as ice cover in the Northern Caspian.

General characteristics of hydrometeorological parameters are presented in the Bulletin: total, average (monthly average, seasonal average, annual average) and extreme (maximum/minimum) values for cpecific time periods (month, year). Anomalies are calculated relating to the climatological standard normal for the period 1991-2020 [6]. Basic statistics (ranks) are used for analysis of anomalies.

Changes in the hydrometeorological value are estimated by a linear trend characterizing the tendency (average speed) of the change over a given time period. The trend is calculated using the least squares method. Trend coefficients are estimated by a level of statistical significance and/or contribution to the total variance of the series.

NMHSs of the Caspian littoral states independently prepare tables and texts of the Bulletin chapters covering hydrometeorological conditions on their national coasts.

The following experts took part in the preparation and compilation of this Bulletin:

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- for the Turkmen sector, **Turkmenhydromet** specialists.

1. DATA AND METHODS OF DATA PROCESSING

1.1. DATA DESCRIPTION

National hydrometeorological services (NHMS) of the Caspian littoral states have provided the list of hydrometeorological stations and posts on the Caspian Sea coasts, where the following hydrometeorological elements used in the Bulletin are monitored:

Observation post	Air temperature	Precipitation	Sea level	Seawater temperature
Kazakhstan				
Aktau	+		+	+
Atyrau	+	+		
Ganyushkino	+	+		
Kulaly	+	–	+	+
Kyzan	+	+		
Peshnoy	+	+	+	+
Tushchibek	+	+		
Fort Shevchenko	+	+	+	+
Russian Federation				
Derbent	+	+		+
Izberg	+	+		+
Kaspiisky (Lagan)			+	+
Makhachkala	+	+	+	+
Tyuleniy isl.	+	+	+	+
Turkmenistan				
Bekdash	+	+	+	+
Kara-Bogaz-Gol	+	+	+	+
Kuuli-mayak	+	+	+	+
Krasnovodsk	+	+	+	+
Ogurchinsky	+	+	+	+
Cheleken	+			

The data on the river flow into the Caspian Sea observed at the following estuarine hydrological stations and posts were used in the Bulletin:

Country	River	Observation post
Kazakhstan	Ural	Makhambet
Russian Federation	Volga	V. Lebyazhye village
	Sulak	Sulak village
	Terek	Kargalinsky hydrosystem

The data from Roshydromet and Kazhydromet is used to characterize ice conditions in the Northern Caspian.

The accuracy of the general parameters is presented in Table 1. The general parameters and average values of each hydrometeorological element are determined with the same accuracy and are presented in the same physical units in which the measurements are made.

Table 1 - Accuracy of presentation of the general parameters of hydrometeorological elements

Hydrometeorological element	Measurement units	A
Air temperature	°C	
Precipitation	mm	
Water temperature	°C	
Linear trend coefficient for annual and seasonal averages of air temperature	°C	
Linear trend coefficient for annual and seasonal averages of water temperature	°C	
Linear trend coefficient for annual and seasonal precipitation	mm	
Determination coefficient		

1.2. TERMS AND DEFINITIONS. METHODS OF DATA PROCESSING

The following terms and definitions are applied to the preparation of the Bulletin:

Absolute maximum: the highest value of a meteorological parameter ***ever recorded*** at a certain station. For example, **absolute maximum** of temperature in January is the highest daily temperature in January ever observed.

Absolute minimum: the lowest value of a meteorological element ***ever recorded*** at a certain station.

Anomaly: deviation of the current value of the meteorological element from its average value over the standard period of **1991**–**2020**.

Annual average: the average value of a meteorological element over a year, usually calculated based on ***daily averages.***

Climatological standard normal: 30-year averages of climatological data for the period from 1 January 1991 to 31 December 2020.

Correlation coefficient: a statistical measure that quantifies the strength and direction of the relationship between two variables.

Extreme values: maximum or minimum values of a hydrometeorological element for a specific period (day, decade, month, season, year).

Homogeneity of observation series (statistical): absence of systematic differences between observations for different time intervals during the studied observation period [6].

Homogeneous series: a series of consecutive values of a hydrometeorological element observed for a sufficiently long time, measured at a station by instruments of the same design and with the same accuracy, the same correct installation and by observers of the similar qualification provided that the environment around the station did not significantly changed over time and did not significantly affect the observations.

Linear coefficient of determination: a percentage that represents the proportion of the dependent variable's variance that can be predicted by the independent variable(s) in a regression model.

Monthly average: the average value of a meteorological element over a month, usually calculated based on ***daily averages***.

Summary values: the sum of the values of the hydrometeorological elements for a certain period of time.

Trend: a gradual change in a random variable over the entire time of observation, the general movement over time of a statistically detectable change and a statistical curve reflecting such a change. For the purposes of this Bulletin, the linear trend is used.

While an incomplete series of observations with some missing observations is used, it should be pointed out in the text of the Bulletin and indicated in the relevant table by asterisk (*) along with the explaining note under the table.

Annual characteristics include total, average, extreme values of hydrometeorological elements, as well as dates when the extreme values were observed.

Absolute extreme values of hydrometeorological elements are selected from their highest or lowest values ***ever recorded***. The date of each extreme value, when it was observed, should be provided. If the same extreme value was observed several times a year, then all dates are selected.

The average annual value of a meteorological element is calculated ***for the calendar year*** as the arithmetic average of the sum for 12 months (by dividing the sum of the average monthly values by 12).

Seasonal characteristics are presented according to calendar seasons: Winter - *from December of the year before analyzed year to February of the analyzed year*, Spring - March, April, May of *the analyzed year*, Summer - June, July, August, Autumn – September, October, November.

The total values are calculated as the sum of the values of a meteorological element for each day of the month or a year.

Anomalies are calculated relating to the climatological standard normal [2], i.e. for the period 1991–2020.

Rank is an additional characteristic of anomalies. They are counted from the beginning of the entire period of observation at a certain station. Ranks are counted in a series ranked in descending order for positive anomalies and in ascending order for negative ones. *The 5 ranks starting with the first one are indicated in the relevant tables of the Bulletin.*

The ratio of the current precipitation to its standard normal (for the period of 1991–2020) is calculated in percent (%).

2. METEOROLOGICAL CONDITIONS

2.1 AIR TEMPERATURE

2.1.1 Air temperature in 2023

Kazakhstan sector

According to the data of the weather stations located in the Kazakhstan territory of the Caspian Sea, the year 2023 was extremely warm, and for MS Atyrau, Ganyushkino, Kyzan, Peshnoy, Tushchibek and Fort-Shevchenko it was extremely warm. Mean annual air temperatures amounted to +11.5…14.3°C, which is 1.2…2.3°C above the climatic norm for the period 1991-2020, the values of anomalies were higher than the standard deviation by 0.4–1.3 times.

The air temperatures significantly exceeded the standard normal in the spring, summer and autumn: in the spring season by 1.9–4.2°C; in the summer season by 0.5–1.2°C; in the autumn season by 1.9–2.6°C, with anomalies in the spring and autumn seasons exceeding the standard deviation values by 0.1–2.6 times. Winter temperature anomalies were -1.3…+0.1°C, which did not exceed the standard deviation at all stations (Table. 2.1.1).

Table 2.1.1 – Average annual and seasonal air temperature (°C) according to the data of the observation posts in the Kazakhstan sector in 2023

Observation post	Year			Winter			Spring			Summer			Autumn		
	T_{av}	vT	s	T_{av}	vT	s	T_{av}	vT	s	T_{av}	vT	s	T_{av}	vT	s
Aktau	13.9	1.2	±0,8	-0.5	-1.1	±1,8	13.8	1.9	±1,1	25.6	0.5	±1,3	15.3	2.0	±1,4
Atyrau	12.7	2.3	±1,0	-5.3	0.1	±2,6	15.2	4.2	±1,6	27.2	1.2	±1,4	12.4	2.4	±1,5
Ganyushkino	12.2	1.9	±0,9	-4.6	-0.5	±2,2	13.4	2.7	±1,2	25.6	0.8	±1,1	12.5	2.6	±1,3
Kulaly	13.0	1.2	±0,8	-3.0	-1.3	±1,7	13.3	2.3	±1,2	26.1	0.6	±0,9	14.2	1.9	±1,3
Kyzan	14.1	2.1	±0,9	-3.7	-0.7	±2,3	16.1	3.7	±1,5	28.3	1.1	±1,3	14.0	2.4	±1,4
Peshnoy	11.5	1.9	±0,8	-6.3	-1.0	±2,4	13.6	3.3	±1,4	25.4	1.0	±0,9	11.6	2.3	±1,4
Tushchibek	13.6	1.7	±0,8	-2.3	-0.3	±1,8	14.9	3.2	±1,3	27.0	0.8	±1,3	13.7	2.0	±1,4
Fort Shevchenko	14.3	1.5	±0,8	-0.1	-0.3	±1,7	14.2	2.6	±1,2	26.4	0.8	±1,2	15.7	2.1	±1,4

Notes:
T_{av} – the current average value of air temperature (°C); vT – anomalies relating to the standard normals for 1991-2020 (°C); s – the average square deviation for the period 1991-2020 (°C)

Table 2.1.2 shows the average monthly and annual temperature values, their anomalies relative to the standard normal, as well as the maximum (minimum) daily air temperature (°C) for the month and the year with the date indicated.

All observation points in the region recorded an excess of the average annual temperatures relative to the climatic normal (1991-2020) by +1.2°C…+2.3°C. The highest excess was recorded at MS Atyrau (+2.3°C) and MS Kyzan (+2.1°C). The greatest anomalies were observed in the spring and autumn, especially in March and November. The winter months were characterized by sharp temperature fluctuations. recorded a minimum of -26.3°C (January), MS Peshnoy and -

25.7°C MS Atyrau. The spring period is marked by early warming, which is confirmed by significant positive anomalies in March (+4.1 ... +6.7°C). The summer was characterized by extremely high temperatures with highs over +40°C in all locations, with the exception of MS Kulaly and MS Fort Shevchenko. The autumn season showed a tendency to extend the warm weather with an excess of 0.5–1.5°C in September and October. Extreme heat was recorded in July-August, where the temperature in Kyzan reached 44.5°C (July 10). The coldest days occurred in January, especially in Peshny (-26.3°C, January 10). The greatest temperature fluctuations were observed in the continental regions (MS Atyrau, MS Peshnoy), while coastal points (MS Aktau, MS Fort Shevchenko) were more resistant to extremes.

Table 2.1.2 – Average monthly and average annual air temperature (°C), deviations from the standard normal (anomalies), maximum and minimum air temperature (°C) for months and the year in the Kazakhstan sector in 2023

Observation post	Characteristics	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Aktau	T_{av}, 2023	-1.7	1.7	9.9	13.7	17.9	23.5	26.2	27.0	20.1	14.4	11.5	3.0	13.9
	Standard normal, 1991–2020	-0.3	0.6	5.8	11.7	18.2	23.5	26.1	25.7	20.3	13.5	5.9	1.3	12.7
	Anomalies	-1.4	1.1	4.1	2.0	-0.3	0.0	0.1	1.3	-0.2	0.9	5.6	1.7	1.2
	Maximum, 2023	11.8	12.1	25.3	31.3	34.1	36.0	39.6	41.5	31.8	27.0	22.5	17.7	41.5
	Date of maximum	04	27	27	24	30	14	24	05	04	03	01	03	05.08
	Minimum, 2023	-17.4	-8.0	-1.1	1.2	8.9	14.2	16.6	13.7	8.8	0.6	2.1	-13.4	-17.4
	Date of minimum	11	10	08	05, 17	07	22	03	31	30	23	24	12	11.01
Atyrau	T_{av}, 2023	-5.9	-4.2	8.6	15.0	21.9	25.7	28.2	27.6	19.1	11.2	6.9	-1.6	12.7
	Standard normal, 1991–2020	-6.4	-5.6	1.9	11.6	19.4	25.1	27.4	25.6	18.4	10.2	1.5	-4.2	10.4
	Anomalies	0.5	1.4	6.7	3.4	2.5	0.6	0.8	2.0	0.7	1.0	5.4	2.6	2.3
	Maximum, 2023	9.4	7.4	25.3	34.5	37.0	39.0	42.0	39.6	29.7	25.5	18.4	11.9	42.0
	Date of maximum	02	27	27	30	30	14	08	08	04	02	01	04	08.17
	Minimum, 2023	-25.7	-18.4	-4.1	-2.0	9.3	11.4	16.7	10.3	8.2	0.1	-4.6	-18.8	-25.7
	Date of minimum	10	09	03	16	06, 13	23	14	29	29	23	24	12	10.01
Ganyushkino	T_{av}, 2023	-5.6	-3.3	7.7	13.4	19.2	23.9	26.4	26.6	18.6	11.5	7.4	0.1	12.2
	Standard normal, 1991–2020	-5.0	-4.4	2.3	10.9	18.7	24.0	26.0	24.3	17.6	10.0	2.1	-3.0	10.3
	Anomalies	-0.6	1.1	5.4	2.5	0.5	-0.1	0.4	2.3	1.0	1.5	5.3	3.1	1.9
	Maximum, 2023	10.4	13.8	22.7	28.9	33.1	35.0	39.0	41.9	32.0	24.8	21.5	12.8	41.9
	Date of maximum	02	28	26	30	28, 31	13	08	09	02	02	01	02	09.08
	Minimum, 2023	-23.8	-19.2	-5.6	-2.4	8.8	10.0	12.6	9.1	8.5	-1.3	-5.4	-13.0	-23.8
	Date of minimum	10	09	03	16	12	20	14	27	11	23	24	12	10.01

Table 2.1.2 continued

Kulaly	T_{av}, 2023	-4.2	-1.7	7.8	12.7	19.3	24.4	26.8	27.1	19.9	13.3	9.4	0.6	13.0
	Standard normal, 1991–2020	-2.6	-2.3	3.3	11.2	18.6	24.2	26.6	25.8	19.6	12.2	4.9	-0.2	11.8
	Anomalies	-1.6	0.6	4.5	1.5	0.7	0.2	0.2	1.3	0.3	1.1	4.5	0.8	1.2
	Maximum, 2023	8.3	5.8	20.0	24.5	30.4	32.0	39.8	36.0	28.6	24.7	20.4	14.4	39.8
	Date of maximum	06	27	26	30	30	14	08	07	05	02	01	03	08.07
	Minimum, 2023	-17.1	-9.9	-1.6	2.4	11.9	16.9	18.8	17.1	12.2	1.6	-1.1	-14.3	-17.1
	Date of minimum	11	09	08	16	04	20	01	28, 31	30	23	24	13	11.01
Kyzan	T_{av}, 2023	-5.0	-1.4	10.3	15.9	22.0	27.0	29.4	28.4	20.1	12.8	9.0	0.1	14.1
	Standard normal, 1991–2020	-3.9	-3.1	4.1	12.7	20.4	26.1	28.5	27.1	20.0	11.7	3.2	-2.1	12.0
	Anomalies	-1.1	1.7	6.2	3.2	1.6	0.9	0.9	1.3	0.1	1.1	5.8	2.2	2.1
	Maximum, 2023	12.6	13.0	29.3	36.3	39.4	40.6	44.5	41.4	32.7	26.2	20.6	14.6	44.5
	Date of maximum	04	27	26	30	30	14	10	03	06	02	02	03	10.07
	Minimum, 2023	-22.8	-14.1	-3.8	1.2	10.3	13.0	17.3	13.9	9.9	0.3	-1.6	-17.2	-22.8
	Date of minimum	11	09	03	17	05, 06	20	02	28	30	23	23	13	11.01
Pesh-noy	T_{av}, 2023	-7.2	-4.8	6.8	13.5	20.4	24.0	26.5	25.7	17.8	10.3	6.6	-1.7	11.5
	Standard normal, 1991–2020	-6.3	-5.7	1.2	10.9	18.7	23.6	25.6	23.8	17.2	9.5	1.3	-4.1	9.6
	Anomalies	-0.9	0.9	5.6	2.6	1.7	0.4	0.9	1.9	0.6	0.8	5.3	2.4	1.9
	Maximum, 2023	7.4	5.8	26.1	34.3	35.0	38.1	41.8	38.0	29.8	23.9	19.5	12.0	41.8
	Date of maximum	03	27	27	30	28, 30	13	09	02	02	02	03	04	09.07
	Minimum, 2023	-26.3	-22.8	-5.9	-3.5	8.4	7.1	15.4	8.2	6.9	-2.6	-5.0	-17.6	-26.3
	Date of minimum	10	09	04	16	07	20	14	29	21	23	24	12	10.01
Tu-shchi-bek	T_{av}, 2023	-3.2	-0.9	10.2	14.4	20.0	25.7	27.9	27.3	19.5	12.4	9.2	0.4	13.6
	Standard normal, 1991–2020	-2.9	-1.9	4.2	11.8	19.1	24.7	27.4	26.4	19.7	11.9	3.6	-1.2	11.9
	Anomalies	-0.3	1.0	6.0	2.6	0.9	1.0	0.5	0.9	-0.2	0.5	5.6	1.6	1.7
	Maximum, 2023	8.8	13.4	26.7	33.2	37.6	38.6	41.0	41.0	33.0	25.8	22.4	16.0	41
	Date of maximum	04	27	27	30	31	13	09	02	06	02	03	03	09.07, 02.08
	Minimum, 2023	-22.4	-12.2	-4.6	0.2	8.2	14.8	16.2	9.8	7.8	-1.4	-1.9	-17.0	-22.4
	Date of minimum	11	09	03	16	05	20	03	30	11	23	24	13	11.01
Fort Shev-chen-ko	T_{av}, 2023	-0.8	0.6	9.6	13.8	19.1	24.3	27.3	27.6	21.0	14.6	11.4	2.8	14.3
	Standard normal, 1991–2020	-0.6	-0.1	4.9	11.4	18.5	24.3	26.7	25.9	20.7	13.8	6.3	1.4	12.8
	Anomalies	-0.2	0.7	4.7	2.4	0.6	0.0	0.6	1.7	0.3	0.8	5.1	1.4	1.5
	Maximum, 2023	10.2	8.3	21.1	27.7	34.2	33.7	40.0	37.2	32.0	26.2	20.2	16.0	40.0
	Date of maximum	05	27	26	30	31	11	09	10	05	02	01	03	09.07
	Minimum, 2023	-15.1	-8.8	-1.0	3.3	11.8	15.7	19.3	17.5	12.4	3.8	0.9	-11.8	-15.1
	Date of minimum	11	09	03	16	06	21	01	31	30	23	24	12	11.01

Note: if similar maximum or minimum were observed several times in a month or the year, their all dates are provided

Russian sector

According to weather stations located in ***the Russian sector*** of the Caspian Sea, 2023 was the warmest year on record. The average annual air temperature was +13.9...+15.2°C (Rank 1), which is 1.2–1.6°C higher than normal, and the values of anomalies were 1.8–2.1 times higher than the standard deviation (Table 2.1.3).

Table 2.1.3 – Average annual and seasonal air temperature (°C) according to the data of observation posts in the Russian sector in 2023

Observation post	2023			Winter			Spring			Summer			Autumn		
	T_{av}	vT	s	T_{av}	vT	s	T_{av}	vT	s	T_{av}	vT	s	T_{av}	vT	s
Derbent	15.2	1.5	±0.8	4.3	0.5	±1.2	13.0	1.8	±0.9	26.0	1.3	±1.1	17.1	1.8	±1.3
Izberg	14.4	1.5	±0.7	3.3	0.6	±1.3	12.3	1.8	±0.8	25.0	1.0	±1.0	16.4	1.9	±1.2
Makhachkala	14.2	1.6	±0.9	2.7	1.0	±1.5	12.4	1.8	±1.0	24.8	0.9	±1.1	16.2	2.2	±1.4
Tyuleniy	13.9	1.2	±0.6	0.8	0.3	±1.5	12.8	1.7	±1.0	26.2	0.9	±0.9	15.6	1.6	±1.0

Notes:
T_{av} – the current average value of air temperature (℃); vT – anomalies relating to the standard normals for 1991-2020 (℃); s – the average square deviation for the period 1991-2020 (°C)

The average air temperature for the **winter of 2022/2023** on the western coast of the Middle Caspian Sea reached to +2.7...+4.3°C, which was 0.5–1.0°C higher than the standard normal (23-31 Rank in the ranked series of observations from the warmest to the coldest season for the entire observation period). The average temperature in the northwestern part of the sea at Tyuleniy Island was +0.8°C (Rank 23), which was 0.3°C higher than normal.

At stations of Tyuleniy Island, Izberg and Derbent, the winter of 2021/2022 was the warmest with an average temperature of +3.6°C, +5.1°C and +6.1°C, respectively. According to Makhachkala, the winter of 1980/1981 (+4.8°C) remains the warmest, and the winter of 1953/1954 is the coldest (-1.8...-5.0°C).

The spring on the western coast of the Middle Caspian Sea was the warmest on record. The average air temperature was +12.3...+13.0°C (Rank 1), which was 1.8°C higher than normal. The spring of 2016 with the temperature of +11.9...+12.8°C has taken the second place. At Tyuleniy Island station, the average air temperature for the season was +12.8°C (Rank 2), the warmest for the entire observation period (since 1960) was the spring of 2016 (+12.9°C).

The summer. The average air temperature for the season was +24.8...+26.2°C, relative anomalies: 0.9°C (Rank 4) at Tyuleniy Island; 1.3°C (Rank 4) in Derbent; 1.0°C (Rank 7) in Izberg; 0.9°C (Rank 10) in Makhachkala. For Izberg, Makhachkala, and Tyuleniy Island, the summer of 2010 remains the hottest with anomalies of 1.8–2.2°C. According to the Derbent weather station, the hottest year since the beginning of regular instrumental observations (since 1922) was April 2021 (+26.8°C), which was 2.0°C higher than normal, and the summer of 2010 (+26.5°C) has taken the second place.

The autumn was abnormally warm in 2023. The average air temperature for the season was 1.6–2.2°C higher than normal and amounted to +15.6...+17.1°C (Rank 2). Autumn 2012 remains the warmest for the entire observation period (+15.8...+17.7°C with anomalies of 1.7–2.7°C).

Table 2.1.4 summarizes the average monthly and average annual air temperature, anomalies (with the sign: positive or negative), and the maximum (minimum) air temperature for the month and year along with their dates.

Table 2.1.4 – Average monthly and average annual air temperature (°C), deviations from the standard normal (anomalies), maximum and minimum air temperature (°C) for months and the year in the Russian sector in 2023

Obser-vation post	Characteristics	Months												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Derbent	T_{av}, 2023	4,5	2,8	8,8	11,9	18,3	23,6	26,2	28,3	21,4	16,9	12,9	7,1	15,2
	Standard normal, 1991–2020	3.2	3.0	5.9	10.8	17.0	22.8	25.7	25.7	21.1	15.4	9.3	5.1	13.7
	Anomalies	1.3	-0.3	2.9	1.1	1.3	0.8	0.5	2.6	0.4	1.5	3.6	1.9	1.5
	Maximum, 2023	18.6	13.0	18.5	22.4	31.4	30.8	33.8	35.9	31.4	24.9	20.4	17.3	35.9
	Date of maximum	2	19	27	26	31	26	8	20	6	2	2	2	20.08
	Minimum, 2023	-5.4	-4.9	2.9	2.8	11.3	15.4	18.7	21.4	12.7	6.9	5.7	-1.1	-5.4
	Date of minimum	9	10, 12	11	1	14	8	1	27, 28	11	12	24	18	09.01
Izberg	T_{av}, 2023	3.6	1.7	7.9	11.1	17.8	22.8	25.1	27.0	20.8	16.2	12.0	6.3	14.4
	Standard normal, 1991–2020	2.1	2.0	5.1	10.0	16.2	21.9	25.0	25.0	20.4	14.7	8.4	4.0	12.9
	Anomalies	1.4	-0.3	2.8	1.0	1.5	0.8	0.2	2.1	0.4	1.5	3.7	2.3	1.5
	Maximum, 2023	15.9	11.9	17.9	20.0	29.0	30.2	32.4	33.9	29.9	23.9	21.1	15.4	33.9
	Date of maximum	2	19	28	25	31	26	8	3	2	6	7	2	03.08
	Minimum, 2023	-7.0	-5.6	1.9	4.7	11.0	14.5	17.6	18.5	11.2	6.6	4.0	-1.3	-7.0
	Date of minimum	9	10	8	1	4	8	12	27	11	12	24	17, 18	09.01
Makhachkala	T_{av}, 2023	3.3	0.8	8.0	11.4	17.9	22.8	24.7	26.8	21.1	15.7	11.8	5.8	14.2
	Standard normal, 1991–2020	1.0	1.4	5.2	10.3	16.5	22.0	24.8	24.9	20.3	14.2	7.4	2.9	12.6
	Anomalies	2.2	-0.6	2.8	1.1	1.4	0.8	-0.1	2.0	0.8	1.4	4.4	2.8	1.6
	Maximum, 2023	19.2	12.6	18.9	20.8	31.2	31.6	34.5	36.3	31.9	25.0	23.8	14.6	36.3
	Date of maximum	2	22	25	21	30	15	22	20	6	24	2	27	20.08
	Minimum, 2023	-9.4	-12.6	2.4	4.4	9.6	10.9	16.8	15.2	11.8	3.9	1.8	-2.6	-12.6
	Date of minimum	10	10	3	1	6	8	1	30	10	12	24	30	10.02

Table 2.1.4 continued

Tyuleniy Isl.	T_{av}, 2023	1.1	-1.2	7.8	12.1	18.6	24.4	26.4	27.8	20.9	14.9	11.1	3.4	13.9
	Standard normal, 1991–2020	-0.3	-0.2	4.3	11.0	18.2	23.8	26.4	25.8	20.7	14.1	7.3	2.0	12.7
	Anomalies	1.4	-1.0	3.5	1.1	0.4	0.7	0.1	2.1	0.2	0.7	3.8	1.4	1.2
	Maximum, 2023	9.4	6.8	15.6	19.0	29.5	33.6	33.7	35.0	28.8	22.7	18.2	12.8	35.0
	Date of maximum	2	25, 26	19	26	30	12, 13	27	13	3	1	7	3	13.08
	Minimum, 2023	-12.0	-9.5	0.0	1.6	10.3	18.5	18.0	15.9	12.4	4.0	-1.7	-4.6	-12.0
	Date of minimum	8	11	3	17	9	20	1	31	10	12	24	14, 15	08.01

Note:
- if similar maximum or minimum were observed several times in a month or the year, their all dates are provided

Turkmen sector

Table 2.1.5 shows the average annual and seasonal average values of the surface air temperature according to the data at Turkmen observation stations in 2023. For almost all stations, the average air temperature were higher than the standard normal, with the exception of the winter and summer seasons, when the average temperatures did not exceed the normal.

Table 2.1.5 – Average annual and seasonal air temperature (°C) according to the data of observation posts in the Turkmen sector in 2023

Observation post*	2023			Winter			Spring			Summer			Autumn		
	T_{av}	vT	s	T_{av}	vT	s	T_{av}	vT	s	T_{av}	vT	s	T_{av}	vT	s
Turkmenbashi (Krasnovodsk)	18.3	1.2	1.1	4.8	-0.8	0.9	17.9	2.2	1.5	29.6	0.5	0.7	19.9	2.0	1.4
Khazar (Cheleken)	16.5	0.7	0.8	3.3	-1.5	1.2	16.3	2.0	1.4	27.0	-0.1	0.3	18.6	1.6	1.3
Garabogaz (Bekdash)	14.7	0.7	0.8	1.2	-1.9	1.4	14.5	1.9	1.4	24.5	-0.5	0.7	17.0	1.9	1.4
Guvlymayak (Kuuli Mayak)	15.5	0.8	0.9	3.4	-1.5	1.2	14.7	1.9	1.4	24.6	-0.5	0.7	17.8	1.7	1.3
Duzlybogaz (Kara-Bogaz-Gol)	15.4	0.8	0.9	1.7	-2.0	1.4	14.9	1.9	1.4	25.8	-0.2	0.4	17.6	1.7	1.3
Ogurdzhaly (Ogurchinsky)	16.5	0.5	0.7	4.3	-1.7	1.3	15.4	1.5	1.2	25.9	-0.3	0.5	19.4	1.4	1.2

Notes:
T_{av} – the current average value of air temperature (°C); vT – anomalies relating to the standard normals for 1991-2020 (°C); s – the average square deviation for the period 1991-2020 (°C)
**data are taken since 1989, as previously the stations belonged to the Azerbaijani Department for Hydrometeorology*

The average monthly temperatures were above normal for almost entire year of 2023, with the exception of January and the summer months (Table 2.1.6). The hottest day on the coast of the Turkmen sector was July 08, when the temperature reached +43.4°C at Garabogaz (Bekdash) station, and the coldest – January 13 (-11.7°° C) at Guvlymayak station (Kuuli-Mayak).

Table 2.1.6 – Average monthly and average annual air temperature (°C), deviations from the standard normal (anomalies), maximum and minimum daily air temperature (°C) for months and the year in the Turkmen sector in 2023

Observation post *	Characteristics	Months												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Turkmenbashi (Krasnovodsk)	T_{av}, 2023	2.5	7.1	13.6	17.8	22.4	27.9	30.3	30.5	25.1	18.8	15.8	8.3	18.3
	Standard normal, 1991–2020	5.0	5.5	9.9	15.2	22.0	27.3	29.9	30.2	24.8	18.0	10.9	6.2	17.1
	Anomalies	-2.5	1.6	3.7	2.6	0.4	0.6	0.4	0.3	0.3	0.8	4.9	2.1	1.2
	Maximum, 2023	15.0	20.0	26.0	36.6	40.7	40.3	41.5	40.9	36.7	31.2	25.1	18.4	41.5
	Date of maximum	04	27	27	30	25	14	08	13	05	02	20	03	08.07
	Minimum, 2023	-10.0	-3.8	4.0	5.4	11.2	18.0	19.7	19.0	16.5	7.4	6.0	-3.9	-10.0
	Date of minimum	12	10	01	02	15	09	18	31	20	13	29	13	12.01
Khazar (Cheleken)	T_{av}, 2023	0.8	5.3	12.0	16.2	20.6	25.0	27.3	28.6	23.4	17.9	14.5	6.7	16.5
	Standard normal, 1991–2020	4.2	5.1	9.3	14.1	19.7	24.7	27.9	28.7	24.0	17.0	9.9	5.2	15.8
	Anomalies	-3.4	0.2	2.7	2.1	0.9	0.3	-0.6	-0.1	-0.6	0.9	4.6	1.5	0.7
	Maximum, 2023	18.4	19.8	27.4	32.4	39.4	37.8	40.3	40.4	33.4	30.8	27.0	18.3	40.4
	Date of maximum	04	27	13	30	25	05	09	12	06	02	20	0.4	12.08
	Minimum, 2023	-10.0	-6.6	1.8	5.0	11.3	18.2	19.6	19.0	14.8	5.6	4.8	-3.8	-10.0
	Date of minimum	14	11	02	17	05	23	02	31	21	13	25	14	14.01
Garabogaz (Bekdash)	T_{av}, 2023	-0.4	3.4	10.4	14.6	18.4	22.1	24.9	26.5	21.6	15.8	13.7	5.8	14.7
	Standard normal, 1991–2020	2.5	2.9	7.3	12.3	18.2	23.0	25.5	26.6	21.8	15.2	8.3	4.0	14.0
	Anomalies	-2.9	0.5	3.1	2.3	0.2	-0.9	-0.6	-0.1	-0.2	0.6	5.4	1.8	0.7
	Maximum, 2023	11.8	13.5	21.9	31.4	36.6	37.0	43.4	37.4	32.2	26.9	21.1	16.8	43.4
	Date of maximum	03	22	16	29	25	12	08	09	04	02	09	04	08.07
	Minimum, 2023	-11.2	-8.0	2.5	5.8	9.6	15.8	16.6	15.0	14.0	5.8	1.2	-7.2	-11.2
	Date of minimum	11	10	03	02	07	26	18	31	11	13	07	15	11.01
Guvlymayak (Kuuli Mayak)	T_{av}, 2023	1.3	5.3	11.0	14.5	18.5	22.3	24.7	26.8	21.7	17.0	14.8	7.6	15.5
	Standard normal, 1991–2020	4.4	4.6	8.1	12.5	17.8	22.5	25.8	27.2	22.5	16.1	9.8	5.6	14.7
	Anomalies	-3.1	0.7	2.9	2.0	0.7	-0.2	-1.1	-0.4	-0.8	0.9	5.0	2.0	0.8
	Maximum, 2023	12.8	13.6	23.8	29.9	37.3	35.4	41.4	41.4	33.2	26.4	28.4	17.9	41.4
	Date of maximum	03	05	12	30	30	14	09	12	03	01	20	03	09.07 12.08
	Minimum, 2023	-11.7	-7.0	4.1	5.4	11.0	15.7	17.3	17.7	13.9	6.2	3.3	-4.7	-11.7
	Date of minimum	13	11	03	17	07	26	18	31	20	13	29	13	13.01
Duzlybogaz (Kara-Bogaz-Gol)	T_{av}, 2023	-0.2	3.7	10.7	15.1	18.8	23.5	26.7	27.2	22.2	16.5	14.1	6.4	15.4
	Standard normal, 1991–2020	3.1	3.4	7.6	12.7	18.8	23.9	26.8	27.3	22.6	15.9	9.2	4.4	14.6
	Anomalies	-3.3	0.3	3.1	2.4	0.0	-0.4	-0.1	-0.1	-0.4	0.6	4.9	2.0	0.8
	Maximum, 2023	13.6	13.4	22.8	33.7	36.0	38.7	39.6	38.6	33.1	25.8	21.9	17.0	39.6
	Date of maximum	04	28	26	30	30	14	10	10	06	02	01	04	10.07
	Minimum, 2023	-9.8	-7.3	2.6	6.1	10.2	15.6	15.8	17.7	14.0	7.8	6.0	-6.6	-9.8
	Date of minimum	12	11	03	02	07	26	02	31	11	21	29	13	12.01
Ogurdzhaly (Ogurchinsky)	T_{av}, 2023	1.9	6.1	11.5	15.6	19.2	23.4	25.8	28.4	22.8	19.2	16.1	8.5	16.5
	Standard normal, 1991–2020	5.3	5.9	9.3	13.7	18.5	23.3	27.0	28.4	24.2	18.2	11.5	6.8	16.0
	Anomalies	-3.4	0.2	2.2	1.9	0.7	0.1	-1.2	0.0	-1.4	1.0	4.6	1.7	0.5
	Maximum, 2023	15.2	16.0	25.4	25.3	33.8	30.2	35.8	35.4	33.3	28.4	22.1	16.4	35.8
	Date of maximum	07	20	30	28	25	05	10	12	04	02	03	01	10.07
	Minimum, 2023	-6.8	-1.0	0.8	7.6	13.1	18.5	20.0	21.0	17.3	11.8	9.5	-2.2	-6.8
	Date of minimum	14	10	08	02	16	09	02	31	11	25	29	13	14.01

Note:
- if similar maximum or minimum were observed several times in a month or the year, their all dates are provided
**data are taken since 1989, as previously the stations belonged to the Azerbaijan Department for Hydrometeorology*

2.1.2. Climatological characteristics of 2023

Kazakhstan sector

Table 2.1.7 shows the records of the maximum monthly air temperature (°C) recorded at the observation points in the Caspian region in 2023.

At all stations of the Kazakhstan coast in 2023, the records of the average monthly temperature in March, which were set earlier, were exceeded. The previous maximums were observed in the water area of the Kazakhstan coast of the Northern Caspian (Ganyushkino, Peshnoy), in the eastern part of the Northern Caspian (Atyrau, Kulaly), on the eastern coast of the Middle Caspian (Fort Shevchenko, Aktau) in 2020, and at the continental MS Kyzan and at the stationsand Tushchibek in 2008. The maximal average November temperature also set a record at stations of Aktau, Kulaly, Kyzan, Peshnoy, Tushchibek and Fort Shevchenko, the previous maximal values were recorded in 2010.

Records of the minimum monthly air temperature (°C) were not observed at the observation posts of the Kazakhstan coast in 2023.

Table 2.1.7 – Maximum of the average monthly air temperature (°C) recorded in the Kazakhstan sector in 2023 and in the previous time since the start of observations

Observation post	Maximum in 2023		Previous maximum		
	average monthly air temperature	month	average monthly air temperature	month	year
Aktau	9.9	March	8.9	March	2020
	11.5	November	10.2	November	2010
Atyrau	8.6	March	7.3	March	2020
Ganyushkino	7.7	March	6.7	March	2020
Kulaly	7.8	March	7.3	march	2020
	9.4	November	9.3	November	2010
Kyzan	10.3	march	9.3	March	2008
	9.0	November	8.0	November	2010
Peshnoy	6.8	March	6.2	March	2020
	6.6	November	6.4	November	2010
Tushchibek	10.2	March	9.4	March	2008
	9.2	November	8.7	November	2010
Fort Shevchenko	9.6	March	8.9	March	2020
	11.4	November	10.6	November	2010

Note:
- if similar maximum was observed several times in a month or a year, their all dates are provided

Table 2.1.8 presents the records of absolute maximum daily air temperature (°C) recorded at observation posts on the Kazakhstan coast of the Caspian Sea in 2023.

In July 2023, a record of maximum daily air temperature was set at the Kulaly meteorological station. The maximum temperature in July was +44.5°C, the previous maximum was recorded on July 26, 1966 (+39.3°C).

In August 2023, the record of maximum daily air temperature was repeated at the Ganyushkino meteorological station. The maximum temperature in August was +41.9°C, the previous maximum was recorded on July 31, 1999 (+41.9°C).

Absolute minimum daily air temperature was not observed in the territory of the Kazakhstan part of the Caspian Sea in 2023.

Table 2.1.8 – Absolute daily maximum air temperature (°C) in the Kazakhstan sector

Observation point	Absolute maximum in 2023		Previous absolute maximum		
	air temperature	day, month	air temperature	day, month	year
Ganyushkino	41.9	09, August	41.9	31, August	1999
Kulaly	39.8	08, July	39.3	26, July	1966

Note:
- if similar maximum was observed several times in a month or a year, their all dates are provided

Table 2.1.9 shows the ranks of the warmest years on the Kazakhstan coast of the Caspian Sea and the corresponding average annual surface air temperatures and their anomalies.

On the Kazakhstan coast, the five warmest years included a few years of the current century, 2023 as well, along with 1995 at some stations. According to the weather stations Atyrau, Kyzan, Ganyushkino, Peshnoy, Tushchibek and Fort-Shevchenko 2023 was the warmest year since the beginning of the regular instrumental observations, the anomalies of the average annual temperature were 2.3; 2.1; 1.9; 1.9; 1.7 and 1.55°C, respectively.

According to MS Aktau (+13.9°C) and MS Kulaly (13.0°C) 2023, the year ranks second, and 2010 remains the warmest. MS Aktau (+14.0°C) and 2004 MS Kulaly (+13.1°C), with an anomaly of air temperature 1.3°C above normal, respectively.

Table 2.1.9 – Ranks of the warmest years and related anomalies of the average annual air temperature (°C) in the Kazakhstan sector

R	Year	Ave-rage annual tempe-rature	Ano-maly	Year	Ave-rage annual tempera ture	Ano-maly	Year	Ave-rage annual tempe-rature	Ano-maly	Year	Ave-rage annual tempe-rature	Ano-maly
Aktau				Atyrau			Ganyushkino			Kulaly		
1	2010	14.0	1.3	2023	12.7	2.3	2023	12.2	1.9	2004	13.1	1.3
2	2023	13.9	1.2	2021	12.4	2.0	2021	11.8	1.5	2023	13.0	1.2
3	2022	13.9	1.2	2020	12.0	1.6	2020	11.6	1.3	2010	12.7	0.9
4	2021	13.8	1.1	2010	11.9	1.5	1995	11.6	1.3	2021	12.7	0.9
5	2004	13.7	1.0	2022	11.9	1.5	2022	11.5	1.2	2013	12.7	0.9
Kyzan				Peshnoy			Tushchibek			Fort Shevchenko		
1	2023	14.1	2.1	2023	11.5	1.9	2023	13.6	1.7	2023	14.3	1.5
2	2021	13.7	1.6	2021	11.0	1.4	2021	13.5	1.6	2022	14.0	1.2
3	2022	13.6	1.5	1995	11.0	1.4	2010	13.3	1.4	2004	13.8	1.0
4	2020	13.1	1.0	2022	10.9	1.3	2022	13.1	1.2	2021	13.8	1.0
5	2010	13.1	1.0	2004	10.8	1.2	1995	12.9	1.0	2010	13.8	1.0

Note:
- top five ranks are provided. Anomalies are related to the standard normal in the period of 1991-2020

In 2023, the average annual surface air temperature in the Kazakhstan sector of the Caspian Sea significantly exceeded the climatic standard normal (1991-2020) at all observation posts, and consequently the year was not being included in the list of the coldest years for the entire observation period. A comparative analysis with historical minimums shows the significant increase in temperature difference between warmest and coldest years: for example, in Atyrau, the temperature in 2023 was 6.9°C higher than in the coldest year of 1928 (5.8°C), and in Kyzan, the difference was 5°C compared to the minimum value (9.1°C in 1959). These data confirm the ongoing warming trend and emphasize the need for further monitoring of climate change (Table 2.1.10).

Table 2.1.10 – Ranks of the coldest years and related anomalies of the average annual surface air temperature (°C) in the Kazakhstan sector

R	Year	Ave-rage annual temper ature	Ano-maly	Year	Ave-rage annual tempera ture	Ano-maly	Year	Ave-rage annual tempera ture	Ano-maly	Year	Ave-rage annual tempe rature	Ano-maly
Aktau				Atyrau			Ganyushkino			Kulaly		
1	1969	9.2	-3.5	1928	5.8	-4.6	1945	7.2	-3.1	1945	8.8	-3.0
2	1964	10.1	-2.6	1929	5.9	-4.5	1942	7.2	-3.1	1942	9.0	-2.8
3	1976	10.2	-2.5	1942	6.9	-3.5	1956	7.7	-2.6	1969	9.1	-2.8
4	1993	10.5	-2.3	1945	6.9	-3.5	1954	7.7	-2.6	1959	9.4	-2.4
5	1972	10.7	-2.0	1956	6.9	-3.5	1969	7.7	-2.6	1954	9.4	-2.4
Kyzan				Peshnoy			Tushchibek			Fort Shevchenko		
1	1959	9.1	-3.0	1956	6.5	-3.1	1969	9.2	-2.7	1911	9.0	-3.8
2	1969	9.3	-2.8	1954	6.6	-3.1	1959	9.3	-2.6	1908	9.4	-3.4
3	1956	9.4	-2.7	1942	6.6	-3.0	1993	9.5	-2.4	1900	9.7	-3.1
4	1976	9.6	-2.5	1945	6.7	-2.9	1956	9.9	-2.0	1928	9.8	-3.0
5	1993	9.8	-2.3	1950	6.9	-2.7	1976	9.9	-2.0	1898	9.8	-3.0

Note:
- top five ranks are provided. Anomalies are related to the standard normal in the period of 1991-2020

Russian sector

Table 2.1.11 presents the maximum values of the average monthly air temperature (°C) for the entire observation period.

According to the data at the stations of Tyuleniy Island, Izberg and Derbent, March of 2023 was the warmest March for the entire observation period, the average monthly air temperatures were +7.8°C, +7.9°C and +8.8°C, accordingly, and exceeded the respective standard normals by 2.8–3.5°C. November of 2023 was also exceptional, it was the warmest November on record, with the temperature anomalies of 3.6-4.4°C. Average November air temperature was +11.1...+12.9°C (Rank 1).

Table 2.1.11 – Maximum of the average monthly air temperature (°C) recorded in the Russian sector in 2023 and in the previous time since the start of observations

Observation post	Maximum in 2023		Previous maximum		
	average monthly air temperature	month	average monthly air temperature	month	year
Derbent	8.8	March	8.4	March	2020
	12.9	November	11.8	November	1966
Izberg	7.9	March	7.8	March	2002
	12.0	November	11.7	November	1966
Makhachkala	11.8	November	10.6	November	1966
Tyuleniy Island	7.8	March	7.7	March	2020
	11.1	November	10.3	November	2010

Note:
- if similar maximum was observed several times in a month or a year, their all dates are provided

The minimum value of the average monthly air temperature in 2023 did not exceed the previous minimum.

Table 2.1.12 shows the absolute maxima of daily air temperature recorded at observation points in the Russian sector of the Caspian Sea for the entire observation period.

The region was under the influence of Atlantic cyclone on 01-04, 6 and 7 January, and the weather was abnormally warm. absolute maxima of the air temperature have been recorded on the western coast of the Middle Caspian Sea on 2 January.

Table 2.1.12 – Absolute daily maximum air temperature (°C) in the Russian sector

Observation point	Absolute maximum in 2023		Previous absolute maximum		
	air temperature	day, month	air temperature	day, month	year
Derbent	18.6	02.01	15.9	01.01	1948
Izberg	15.9	02.01	14.3	03.01	2010
Makhachkala	19.2	02.01	19.0	January	1976

Note:
- if similar maximum was observed several times in a month or a year, their all dates are provided

In the Russian sector of the Caspian Sea, absolute minimum daily air temperature (°C) was not recorded in 2023. Table 2.1.13 shows the ranks of the warmest years in ***the Russian sector*** of the Caspian Sea and the corresponding anomalies in the average annual surface air temperature.

Table 2.1.13 – Ranks of the warmest years and anomalies of the average annual surface air temperature (°C) in the Russian sector

R	Year	Ave-rage annual tempe-rature	Ano-maly	Year	Ave-rage annual tempe-rature	Ano-maly	Year	Ave-rage annual tempe-rature	Ano-maly	Year	Ave-rage annual tempe-rature	Ano-maly
Derbent				Izberg			Makhachkala			Tyuleniy Isl.		
1	2023	15,2	1,5	2023	14,4	1,5	2023	14,2	1,6	2023	13,9	1,2
2	2019	15,0	1,3	2010	14,1	1,1	1966	13,9	1,3	2020	13,8	1,1
3	2022	14,9	1,1	2022	13,9	1,0	2010	13,8	1,3	2010	13,8	1,1
4	2020	14,8	1,1	1966	13,9	1,0	2019	13,7	1,2	2019	13,7	0,9
5	2018	14,8	1,0	2019	13,8	0,9	2020	13.7	1.1	2022	13.6	0.8

Note:
- top five ranks are provided. Anomalies are related to the standard normal in the period of 1991-2020

2023 was not among the five coldest years.

Turkmen sector

Tables 2.1.14 and 2.1.15 show the maximum values of the average monthly surface air temperature at the stations in the Turkmen sector in 2023 compared to the entire pool of observations. The maximum values of the average monthly air temperature in 2023 were lower, and the minimum values of the average monthly air temperature were higher than those observed in the previous period (1989-2022).

Table 2.1.14 – Maximum of the average monthly air temperature (°C) recorded in the Turkmen sector in 2023 and in the previous time since the start of observations

Observation post*	Maximum in 2023.		Previous maximum		
	average monthly air temperature	month	average monthly air temperature	month	year
Turkmenbashi (Krasnovodsk)	30.5	08	33.8	07 08	2018 2021
Khazar (Cheleken)	28.6	08	31.6	07	2018
Garabogaz (Bekdash)	26.5	08	30.4	08	2014
Guvlymayak (Kuuli Mayak)	26.8	08	30.0	07 08	2010 2014
Duzlybogaz (Kara Bogaz Gol)	27.2	08	30.7	08	2021
Ogurjaly (Ogurchinsky)	28.4	08	32.9	08	2008

Note:
- if similar maximum was observed several times in a month or a year, their all dates are provided
**data are taken since 1989, as previously the stations belonged to the Azerbaijan Department for Hydrometeorology*

Table 2.1.15 – Minimum of the average monthly air temperature (□C) recorded in the Turkmen sector in 2023 and in the previous time since the start of observations

Observation post	Minimum value in 2023		Previous minimum value		
	average monthly air temperature	month	average monthly air temperature	month	year
Turkmenbashi (Krasnovodsk)	2.5	01-1	. 9	01	2008
Khazar (Cheleken)	0.8	01-4	. 1	01	2008
Garabogaz (Bekdash)	-0.4	01-5	. 4	01	2008
Guvlymayak (Kuuli Mayak)	1.3	01-3	. 1	01	2008
Duzlybogaz (Kara-Bogaz-Gol)	-0.2	01-4	. 2	01	2008
Ogurdzhaly (Ogurchinsky)	1.9	01	-3.0	01	2008

Note:
- if similar minimum was observed several times in a month or a year, their all dates are provided
**data are taken since 1989, as previously the stations belonged to the Azerbaijan Department for Hydrometeorology*

The absolute maximum and minimum observed in 2023 are presented in Tables 2.1.16 and 2.1.17. They did not exceed the values for the previous period (1989-2022).

Table 2.1.16 – Absolute daily maximum air temperature (°C) in the Turkmen sector

Observation point	Absolute maximum in 2023		Previous absolute maximum		
	air temperature	day, month	air temperature	day, month	year
Turkmenbashi (Krasnovodsk)	41.5	08.07	47.0	30.08	2017
Khazar (Cheleken)	40.4	12.08	45.8	21.07	1989
Garabogaz (Bekdash)	43.4	08.07	44.2	13.07	2002
Guvlymayak (Kuuli mayak)	41.4	09.07 12.08	44.6	10.08	2006
Duzlybogaz (Kara-Bogaz-Gol)	39.6	10.07	42.6	10.08 01.07	2006 2018
Ogurdzhaly (Ogurchinsky)	35.8	10.07	39.9	11.08	2021

Note:
- if similar maximum was observed several times in a month or a year, their all dates are provided
**data are taken since 1989, as previously the stations belonged to the Azerbaijan Department for Hydrometeorology*

Table 2.1.17 – Absolute minimum of daily air temperature (°C) recorded at observation points of the Turkmen (Turkmenistan) sector

Observation post	Absolute minimum in 2023		Previous absolute minimum		
	air temperature	day, month	air temperature	day, month	year
Turkmenbashi (Krasnovodsk)	-10.0	12.01	-13.6	02.02	2014
Khazar (Cheleken)	-10.0	14.01	-19.9	06.02	2012
Garabogaz (Bekdash)	-11.2	11.01	-16.2	13.01	2008
Guvlymayak (Kuuli mayak)	-11.7	13.01	-17.2	02.02	2014
Duzlybogaz (Kara-Bogaz-Gol)	-9.8	12.01	-12.8	12.01	2008
Ogurdzhaly (Ogurchinsky)	-6.8	14.01	-8.5	23.11	2016

Note:
- if similar minimum was observed several times in a month or a year, their all dates are provided
**data are taken since 1989, as previously the stations belonged to the Azerbaijan Department for Hydrometeorology*

The year of 2023 was ranked among the top five warmest stations for Turkmenbashi (Krasnovodsk), Khazar (Cheleken), Guvlymayak (Kuuli Mayak) and Duzlybogaz (Kara-Bogaz-Gol) (Table 2.1.18).

Year of 2023 was not ranked among the five coldest years (Table 2.1.19).

Table 2.1.18 – Ranks of the warmest years and related anomalies of the average annual air temperature in the Turkmen sector

R	Year	Average annual temperature	Anomaly	Year	Average annual temperature	Anomaly	Year	Average annual temperature	Anomaly
Turkmenbashi				Khazar			Garabogaz		
1	2010	18.5.5	1.4	2010	17.0	1.2	2010	15.3	1.3
2	2023	18.3.3	1.2	2015	16.9	1.1	2002	15.3.3	1.3
3	2022	18.1	1.0	2018	16.7	0.9	2004	15.0	1.0
4	2021	18.1	1.0	2023	16.5	0.7	2022	14.9	0.9
5	2018	18.1	1.0	2022	16.5	0.7	2021	14.8	0.8
Guvlymayak				Duzlybogaz			Ogurdzhaly		
1	2015	15.8	1.1	2022	15,5	0.9	2008	18.1	2.1
2	2022	15.6	0.9	2010	15,5	0.9	2015	17.2	1.2
3	2018	15.6	0.9	2023	15,4	0.8	2019	16.8	0.8
4	2023	15.5	0.8	2021	15.4.4	0.8	2022	16.7	0.7
5	2019	15.55	0.8	2004	15.4	0.8	2018	16.7	0.7

Note:
- top five ranks are provided. Anomalies are related to the standard normal in the period of 1991-2020
**data are taken since 1989, as previously the stations belonged to the Azerbaijan Department for Hydrometeorology*

Table 2.1.19 – Ranks of the coldest years and related anomalies of the average annual air temperature in the Turkmen sector*

R	Year	Average annual temperature	Anomaly	Year	Average annual temperature	Anomaly	Year	Average annual temperature	Anomaly
Turkmenbashi				Khazar			Garabogaz		
1	2011	16.4.4	-0.7	2003	15.2.2	-0.6	2008	13.2	-0.8
2	2008	16.7	-0.4	2008	15.2	-0.6	2011	13.2	-0.8
3	2016	17.2	0.1	2011	15.2	-0.6	2012	13.8	-0.2
4	2009	17.3	0.2	2012	15.7	-0.1	2005	13.9	-0.1
5	2012	17.3	0.2	2001	15.8	0.0	2013	14.5	0.5
Guvlymayak				Duzlybogaz			Ogurdzhaly		
1	2003	14.1	-0.6	2008	12.9	-1.7	2003	15.3	-0.7
2	2008	14.1	-0.6	2003	13.7	-0.9	2011	15.3	-0.7
3	2011	14.1	-0.6	2011	13.9	-0.7	2007	15.6	-0.4
4	2020	14.6	-0.1	2012	14.4	-0.2	2020	15.7	-0.3
5	2001	14.7	0.0	2005	14.5	-0.1	2005	15.8	-0.2

Note:
- top five ranks are provided. Anomalies are related to the standard normal in the period of 1991-2020
**data are taken since 1989, as previously the stations belonged to the Azerbaijan Department for Hydrometeorology*

2.1.3 Trends in the air temperature

Kazakhstan sector

Table 2.1.20 shows estimates of the linear trend of average annual and seasonal air temperatures at the observation posts of the Kazakhstan sector of the Caspian Sea for the period 1976-2023.

According to all weather stations on the coast of Kazakhstan, the average seasonal temperatures were increasing in the past decades. The rate of the increase varied from 0.30 to 0.89°C/10 years. Temperature rise in winter, spring, summer, and autumn was statistically significant at almost all stations, with the exception of one station (Peshnoy) in the autumn period, where the share of the trend component into the total series variance was about 10% and higher. Average annual temperatures have been increasing by an average of 0.41–0.56°C every 10 years, that is statistically significant at p = 5%. The fastest temperature rise for all seasons (except autumn) and year was observed at Atyrau Station, the maximum rate of summer warming was observed at the Aktau Station and amounted to 0.89 °C/10 years.

Table 2.1.20 – Estimates of the linear trend of average annual and seasonal air temperatures in the Kazakhstan sector for the period of 1976-2023

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Aktau	**0.55**	60.1.1	**0.42**	11.0	**0.50**	34.7	**0.89**	62.88	**0.38**	15.0
Atyrau	**0.56**	49.9	**0.64**	14.9	**0.63**	31.0	**0.60**	41.7	**0.35**	11.9
Ganyushkino	**0.45**	36.5	**0.45**	8.0	**0.49**	23.5	**0.49**	36.1	**0.38**	14.8
Kulaly	**0.41**	40.2	**0.34**	7.1	**0.43**	22.1	**0.46**	45.3	**0.40**	18.3
Kyzan	**0.55**	51.9	**0.47**	8.4	**0.66**	34.0	**0.56**	39.4	**0.45**	17.2
Peshnoy	**0.43**	34.5	**0.46**	7.5	**0.57**	25.9	**0.39**	32.0	**0.30**	8.7
Tushchibek	**0.44**	48.3	**0.42**	11.2	**0.48**	22.1	**0.53**	34.4	**0.36**	12.4
Fort Shevchenko	**0.51**	55.3	**0.45**	13.1	**0.45**	25.1	**0.64**	53.6	**0.51**	25.4

Notes:
a – the coefficient of the linear trend; D – the coefficient of determination. The trend values that are significant at the level of 5% are highlighted

Russian sector

Table 2.1.21 shows estimates of the linear trend of the average annual and seasonal air temperatures at the observation posts ***of the Russian sector*** for the period 1976-2023.

According to data from all weather stations in the Russian sector, the average annual temperature was increasing from 1976 to 2023, and the positive trend was statistically significant at p = 5%. According to Derbent data, the average annual temperature trend accounted for more than half of the total variability (contribution to variance) – 71%, the smallest contribution to variance (35%) was observed in Makhachkala. The rate of increase in seasonal average temperatures ranged from 0.34 to 0.69°C/10 years. The most rapid growth in all seasons was observed at the southernmost post of the Russian coast – in Derbent. Particularly rapid growth was observed for summer temperatures – 0.69°C/10 (contribution to the overall variance of 65 %). Temperature growth, both over the year and in individual seasons, was statistically significant at all stations at the significance level p = 5 %.

Table 2.1.21 – Estimates of the linear trend of average annual and seasonal air temperatures in the Russian sector for the period of 1976-2023

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Derbent	**0,57**	**71**	**0,48**	**29**	**0,53**	**52**	**0,69**	**65**	**0,59**	**39**
Izberg	**0,45**	**57**	**0,42**	**21**	**0,47**	**45**	**0,47**	**41**	**0,43**	**25**
Makhachkala	**0,38**	**35**	**0,37**	**12**	**0,34**	**22**	**0,41**	**31**	**0,37**	**16**
about. Tyuleniy	**0,47**	**58**	**0,46**	**17**	**0,40**	**26**	**0,53**	**51**	**0,48**	**31**

Notes:
a – the coefficient of the linear trend; D – the coefficient of determination. The trend values that are significant at the level of 5% are highlighted

Turkmen sector

Table 2.1.22 – Estimates of the linear trend of average annual and seasonal air temperatures in the Russian sector for the period of 1989-2023*

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Turkmenbashi (Krasnovodsk)	0.56	53.3	0.38	8.5	0.49	27.4	0.99	53.3	0.23	3.4
Khazar (Cheleken)	0.51	44.8	-0.12	0.8	0.57	34.8	0.98	41.6	0.08	0.5
Garabogaz (Bekdash)	0.49	39.6	0.28	3.1	0.49	28.9	0.78	30.6	0.35	7.4
Guvlymayak (Kuuli Mayak)	0.41	36.9	0.21	2.3	0.48	35.9	0.64	24.7	0.19	2.8
Duzlybogaz (Kara-Bogaz-Goal)	0.35	34.8	0.16	1.0	0.38	15.2	0.52	18.3	0.23	3.8
Ogurdzhaly (Ogurchinsky)	0.24	15.2	0.02	0.0	0.45	11.1	0.73	24.5	0.01	0.0

Notes:
a – the coefficient of the linear trend; D – the coefficient of determination. The trend values that are significant at the level of 5% are highlighted
**data are taken since 1989, as previously the stations belonged to the Azerbaijan Department for Hydrometeorology*

2.2. PRECIPITATION

2.2.1 Precipitation in 2023

Kazakhstan sector

Table 2.2.1 presents the characteristics of annual and seasonal precipitation in 2023. The humidity highly varied along the Kazakhstan's coast in 2023. The weather stations located in the Northern Caspian Sea reported extremely high humidity, with 5% and 10% extremes recorded: the annual precipitation accounted to 214.6 mm per day (132.0% of the normal, rank 6) at Peshnoy, 236.6 mm (127.7% of the norm, rank 10) in Atyrau, 225.2 mm (149.3% of the normal, rank 12) at Ganyushkino. The deficit of precipitation was observed at stations of Kyzan, Tushchibek and Aktau, located on the Middle Caspian coast, annual precipitation totaled 73.5-79.8% of normal. The annual precipitation was around the normal (99.2% of the norm) at Kulaly. The seasonal resolution showed a significant deficit in seasonal precipitation totals on the eastern coast of the Middle Caspian Sea, while in the Northern Caspian, with rare exceptions, precipitation was either near normal or above normal.

Table 2.2.1 – Annual and seasonal precipitation in the Kazakhstan sector in 2023

Observation point	Year		Winter		Spring		Summer		Autumn	
	R	RR	R	RR	R	RR	R	RR	R	RR
Aktau	131.4	77.9	27.7	54.6	43.50	94.6	8.90	29.8	37.70	89.8
Atyrau	236.6	127.7	58.1	132.6	39.5	65.8	30.2	79.1	91.9	212.2
Ganyushkino	225.2	149.3	32.6	130.9	59.3	137.3	24.9	56.0	97.0	253.9
Kulaly	78.1	99.2	12.8	72.7	28.3	102.2	8.4	60.9	26.3	134.2
Kyzan	127.2	79.8	24.0	75.7	26.6	46.2	9.1	23.3	58.4	188.4
Peshnoy	214.6	132.0	32.9	83.1	49.0	93.0	43.4	146.1	76.8	189.2
Tushchibek	129.9	73.5	18.3	47.8	58.4	87.6	11.2	30.9	35.6	100.0
Fort Shevchenko	165.1	131.4	18.1	69.6	68.3	169.9	23.3	87.9	44.8	136.2

Notes:
R – the amount of precipitation, mm; RR – the ratio of the current value to the standard normal for 1991-2020, %. The ratio RR must be given as an integer value

In the winter, there was a significant shortage of precipitation in December 2022 and January 2023, with precipitation values below the 30th percentile. In December 2022, the minimum rainfall of 0.8 mm or 8% of the normal was recorded at Ganyushkino Station, repeating the previous minimum recorded in 1984. December was extremely dry, 5% and 10% extremes were recorded, at stations of Atyrau (19.6% of normal) and Tushchibek (11.2% of normal), while January was dry at stations of Kyzan (19.5% of the normal) and Aktau (4.5% of the normal). In February, the Northern Caspian region was extremely wet; the precipitation exceeded the normal by 2.5–4.4 times, and the maximal precipitation of 408.3 % of the normal (or 49.0 mm) was recorded at Atyrau Station. February was also moderately humid, and the amount of precipitation exceeded the normal by 1.5–2.0 times on the territory of the eastern coast of the Middle Caspian

Sea. As a result, in winter, the amount of precipitation in the Northern Caspian coast was about normal (83.1...132.6% of the normal), and the precipitation accounted to 47.8...75.7% of the normal on the eastern coast of the Middle Caspian.

The amount of precipitation during the spring was about and above the normal on almost the entire Kazakh coast of the Caspian Sea and amounted to 87.6...169.9% of the standard normal, except for the mainland stations of Kyzan and Atyrau, where the spring was very dry and reached to only 43.0 and 65.8% of the normal, respectively. A significant deficit of precipitation was observed at all weather stations in March (3.8-50.9% of the normal), in April and May at the mainland station of Kyzan (37.6 and 79.1% of the normal, respectively), and in May in the eastern part of the Northern Caspian Sea (37.8...61.2% of the normal). It was extremely dry in March at the weather stations of Kulaly and Kyzan (5% extremes), as well as at MS Tushchibek (10% extremes). In April and May, most of the Kazakhstan sector of the Caspian Sea received significantly more precipitation than normal. In April, , precipitation was mostly about normal on the eastern coast of the Middle Caspian, while it exceeded the normal by 1.5-2.1 times on the Kazakh coast of the Northern Caspian. In May, precipitation was about normal (±20%) in almost the entire Kazakhstan sector of the Caspian Sea, however there were some small parts, where it significantly exceeded the normal (140.5...278.8% of the normal).

A substantial deficiency of precipitation was observed in the summer months of June and July, especially on the eastern coast of the Middle Caspian Sea. Monthly precipitation in June was 49.1…84.1% of the normal on the Kazakhstan coast of the Northern Caspian Sea and 0-20.5% of the normal on the eastern coast of the Middle Caspian. It was record-breaking dry on Kulaly island, where precipitation was absent throughout the month. A significant excess of monthly precipitation over the normal was observed in August at stations of Fort Shevchenko (242% of the normal) and Peshnoy (247.7% of the normal). As a result, an uneven distribution of precipitation was observed during the summer on the Kazakh coast of the Caspian Sea, which ranged from 23.3 % to 146.1% of the normal.

According to the data of the stations located on the Kazakhstan coast of the Caspian Sea, the humidity of the autumn was about and above normal. Precipitation fell above the normal (189.2...253.9% of the normal) on the eastern coast of the Northern Caspian. Seasonal precipitation significantly exceeded the normal on the eastern coast of the Middle Caspian Sea, at Fort-Shevchenko (136.2% of the normal). The season was also extremely wet at Kyzan (188.4% of the norm, 10% extremes), while the precipitation was about normal (89.8...100.0%) at Aktau and at the continental station of Tushchibek. In September and October, almost all stations experienced a significant excess of precipitation, which amounted to 100...324.6% of the normal. Maximum of precipitation in October was at Atyrau (56. 9 mm, 310.9% of the normal). In November, there was

an uneven distribution of precipitation, it was highly wet at Ganyushkino Station (5% extremes) and dry at stations of Tushchibek and Fort Shevchenko.

Table 2.2.2 shows monthly and annual precipitation (mm), the ratio of the current value to the normal (%), the maximum daily precipitation (mm) for each month and the year according to observation posts on the Kazakhstan coast of the Caspian Sea in 2023.

Table 2.2.2 – Monthly and annual total precipitation (mm), ratio of the current value to the standard normal (anomalies, %), maximum and minimum precipitation (mm) for months and the year in the Kazakhstan sector in 2023

Observation post	Characteristics	Months												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Aktau	Total, 2023	0.8	18.8	4.0	15.0	24.5	2.4	4.0	2.5	11.7	13.2	12.8	21.7	131.4
	Standard normal, 1991–2020	17.6	12	15.1	17.6	13.3	11.7	10.1	8.1	7.1	13.2	21.7	21.1	168.6
	Anomalies	4.5	156.7	26.5	85.2	184.2	20.5	39.6	30.9	164.8	100	59	102.8	77.9
	Maximum, 2023	0.4	8.1	2.1	3.8	6.6	2.4	3.7	2.5	8.5	7.4	7.4	6.4	8.5
	Date of maximum	09.01, 02.01	18.02	10.03	01.04	15.05	07.06	01.07	26.08	10.09	23.11	23.11	11.12	10.09
Atyrau	Total, 2023	6.0	49.0	3.1	25.9	10.5	8.3	18.1	3.8	14.8	56.9	20.2	20.0	236.6
	Standard normal, 1991–2020	16	12	15.6	16.6	27.8	16.9	11.6	9.7	9	18.3	16	15.8	185.3
	Anomalies	37.5	408.3	19.9	156	37.8	49.1	156	39.2	164.4	310.9	126.3	126.6	127.7
	Maximum, 2023	4.4	14.7	2.2	14.3	4.4	4.9	5.8	2.2	6.3	7.2	7.2	7.2	14.7
	Date of maximum	02.01	04.02	07.03	15.04	23.05	18.06	25.07	29.08	07.09	21.11	21.11	17.12	04.07
Ganyushkino	Total, 2023	4.2	27.6	2.8	32.2	24.3	11.3	2.5	11.1	41.7	21.5	33.8	12.2	225.2
	Standard normal, 1991–2020	8.6	6.3	11	14.9	17.3	17.6	15.7	11.2	14.8	12.7	10.7	10	150.8
	Anomalies	48.8	438.1	25.5	216.1	140.5	64.2	15.9	99.1	281.8	169.3	315.9	122	48.8
	Maximum, 2023	4.2	7.1	2.0	9.2	7.6	10.2	1.8	9.2	24.1	17.4	17.4	6.0	24.1
	Date of maximum	02.01	03.02	07.03	01.04	22.05	18.06	01.07	29.08	13.09	21.11	21.11	17.12	13.9
Kulaly	Total, 2023	4.5	5.8	0.3	14.7	13.3	0	6.1	2.3	13.4	7.1	5.8	4.8	4.5
	Standard normal, 1991–2020	6.1	4.1	7.9	11.3	8.5	4.9	4.8	4.1	4.2	4.5	10.9	7.4	78.7
	Anomalies	73.8	141.5	3.8	130.1	156.5	0.0	127.1	56.1	319.0	157.8	53.2	64.9	99.2
	Maximum, 2023	3.9	3.3	0.3	8.4	2.8	-	4.3	1.4	8.4	3.1	3.1	1.5	8.4
	Date of maximum	02.01	03.02	12.03	01.04	03.05	-	01.07	19.08	10.09	23.11	23.11	26.12	01.04, 10.09
Kyzan	Total, 2023	2.2	17.5	1.8	7.0	17.8	0.8	3.1	5.2	19.8	25.2	13.4	13.4	127.2
	Standard normal, 1991–2020	11.3	8.4	16.5	18.6	22.5	18.6	12.7	7.8	6.1	10.8	14.1	12.0	159.4
	Anomalies	19.5	208.3	10.9	37.6	79.1	4.3	24.4	66.7	324.6	233.3	95.0	111.7	79.8
	Maximum, 2023	2.2	7.5	1.8	4.1	6.9	0.4	2.2	3.6	13.2	7.9	7.9	8.0	13.2
	Date of maximum	02.01	04.02	10.03	15.04	18.05	17.06, 22.06	01.07	26.08	10.09	23.11	23.11	26.12	10.09

Table 2.2.2 continued

Peshnoy	Total, 2023	3.9	27.0	2.6	32.2	14.2	11.1	11.0	21.3	13.3	47.2	16.3	14.5	214.6
	Standard normal, 1991–2020	14.7	10.4	14.0	15.5	23.2	13.2	7.9	8.6	8.2	16.7	15.7	14.5	162.6
	Anomalies	26.5	259.6	18.6	207.7	61.2	84.1	139.2	247.7	162.2	282.6	103.8	100.0	132.0
	Maximum, 2023	3.4	11.2	2.1	16.7	5.0	11.1	4.6	14.7	4.8	6.1	6.1	4.5	16.7
	Date of maximum	02.01	04.02	07.03	26.04	17.05	18.06	25.07	24.08	10.09	17.11	17.11	17.12	26.4
Tushchi-bek	Total, 2023	3.8	12.7	2.2	24.4	31.8	2.2	5.0	4.0	8.2	22.4	5.0	8.2	129.9
	Standard normal, 1991–2020	27.5	151.2	13.6	116.2	107.8	13.8	41.0	49.4	105.1	193.1	30.9	50.9	73.5
	Anomalies	27.5	151.2	13.6	116.2	107.8	13.8	41.0	49.4	105.1	193.1	30.9	50.9	73.5
	Maximum, 2023	3.8	4.0	2.2	9.4	12.0	2.2	2.0	2.8	7.0	2.2	2.2	2.2	12.0
	Date of maximum	02.01	04.02	10.03	26.04	03.05	17.06	17.07	23.08	10.09	21.11	21.11	10.12	03.05
Fort Shev-chenko	Total, 2023	0.8	14.0	5.7	33.6	29.0	0.3	3.4	19.6	28.4	12.2	4.2	13.9	165.1
	Standard normal, 1991–2020	9.4	7.1	11.2	18.6	10.4	8.4	10	8.1	10.9	9.7	12.3	9.5	125.6
	Anomalies	8.5	197.2	50.9	180.6	278.8	3.6	34	242	260.6	125.8	34.1	146.3	131.4
	Maximum, 2023	0.6	6.2	5.2	28.5	10.1	0.3	2.3	13.1	21.5	3.1	3.1	5.1	28.5
	Date of maximum	02.01	04.02	10.03	01.04	14.05	16.06	01.07	19.08	10.09	17.11	17.11	10.12	01.04

Note:
- if similar maximum or minimum were observed several times in a month or the year, their all dates are provided

In 2023, annual precipitation ranged from 127.2 mm at Kyzan to 236.6 mm at Atyrau. The highest excess of the climatic standard normal was recorded in Atyrau – 127.7% of the normal. There were months with extremely high values, for example, February (408.3%) and October (310.9%). Monthly precipitation exceeding the average values by more than two times were recorded at some stations (for example, at Ganyushkino in September – 281.8% and at Peshnoy in October – 282.6%). Maximum daily precipitation also showed significant variations. The absolute daily maximum was recorded at Ganyushkino – 24.1 mm (September 13), while the extremes were less pronounced at other stations, but still exceeded 20 mm (for example, at Fort Shevchenko – 21.5 mm on September 10). The maximum precipitation occurred in the spring and autumn in most cases. Despite local excess of the normal, a number of posts recorded a lack of precipitation relative to the climatic normal. In particular, the annual precipitation was 77.9% of the normal in Aktau, which was due to its extremely low values in the winter and summer months. There was no or very limited precipitation at all in some months at a number of stations (for example, in June at the stations of Kulaly and Peshnoy).

Russian sector

Table 2.2.3 presents the characteristics of annual and seasonal precipitation totals in 2023. According to the data of the stations located *in **the Russian sector*** of the Caspian Sea, the humidity regime highly varied along the Russian coast in 2023. In Makhachkala, Derbent, and Tyuleniy Island, annual precipitation was within the normal range (96, 99, and 105% of the normal). Excessive precipitation was observed in Izberg (117 % of the normal, rank 12). Among the seasons, there was the "wet" winter at Izberg (152% of the normal, rank 7) and the "wet" autumn at Tyuleniy Island (162% of the norm, rank 7), while spring and winter at Tyuleniy Island were "dry" (40 and 45% of the norm, rank 4). On the western coast of the Middle Caspian Sea, the summer and spring were excessively "dry" in Derbent (50 and 68% of the norm, rank 16 and 21) as well as the autumn in Makhachkala (54 % of the norm, rank 18).

Table 2.2.3 – Annual and seasonal precipitation (mm) in the Russian sector in 2023

Observation post	Year		Winter		Spring		Summer		Autumn	
	R	RR	R	RR	R	RR	R	RR	R	RR
Derbent	402.7	99	116.9	106	43.2	68	33.0	50	136.4	83
Izberg	342.4	117	106.5	152	47.5	88	55.5	100	78.6	73
Makhachkala	359.8	96	78.7	80	68.2	93	69.0	91	67.6	54
Tyuleniy Island	208.0	105	18.4	45	23.4	40	50.4	105	84.3	162

Notes:
R – the amount of precipitation, mm; RR – the ratio of the current value to the standard normal for 1991-2020, %. The ratio RR must be given as an integer value

Table 2.2.4 summarizes monthly and annual precipitation amounts, the ratio of the current value to the norm (%), and data on the maximum daily precipitation for the month and for the year with the date.

Table 2.2.4 – Monthly and annual total precipitation (mm), ratio of the current value to the standard normal (anomalies, %), maximum and minimum precipitation (mm) for months and the year in the Russian sector in 2023

Obser-vation post	Characteristics	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Derbent	Total, 2023	27.8	38.6	0.6	16.5	26.1	22.5	8.3	2.2	93.5	23.0	19.9	123.7	402.7
	Standard normal, 1991–2020	31.3	35.3	23.8	19.1	20.7	17.9	24.3	24.5	49.3	59.9	55.7	45.9	407.7
	Anomalies	89	109	3	86	126	126	34	9	190	38	36	269	99
	Maximum, 2023	9.1	13.2	0.3	8.0	13.4	5.0	2.0	1.6	66.4	8.1	6.2	31.1	66.4
	Date of maximum	12	23	4, 30	1	14	1	30	26	9	3	17	7	09.09
Izberg	Total, 2023	46.9	15.8	0.9	18.3	28.3	33.6	19.6	2.3	43.5	15.9	19.2	98.1	342.4
	Standard normal, 1991–2020	23.0	19.5	16.6	15.7	21.7	19.2	14.0	22.0	37.1	35.8	34.9	28.6	291.6
	Anomalies	204	81	5	117	130	175	140	10	117	44	55	343	117
	Maximum, 2023	21.0	6.5	0.3	3.2	10.9	7.8	5.8	2.0	35.6	5.2	6.9	32.2	35.6
	Date of maximum	14	23	4, 11, 12	13	14	7	25	26	9	19	21	7	09.09

Table 2.2.4 continued

Makha-chkala	Total, 2023	41.8	17.5	0.8	35.2	32.2	26.8	39.9	2.3	17.9	28.7	21.0	95.7	359.8
	Standard normal, 1991–2020	35.3	27.3	21.6	18.2	33.2	26.4	20.7	28.3	45.8	37.4	42.1	37.3	373.7
	Anomalies	118	64	4	193	97	101	192	8	39	77	50	257	96
	Maximum, 2023	14.4	4.6	0.4	13.1	12.8	7.3	15.7	1.7	9.7	17.8	14.6	25.6	25.6
	Date of maximum	11	7	2, 31	9	14	7	25	16	17	11	21	13	13.12
Tyuleniy Island	Total, 2023	0.0	16.2	3.0	7.9	12.5	3.0	47.4	0.0	51.8	3.7	28.8	33.7	208.0
	Standard normal, 1991–2020	14.0	11.2	14.6	21.5	21.7	15.9	14.5	17.7	14.4	21.2	16.5	16.1	198.0
	Anomalies	0	145	21	37	57	19	327	0	359	17	175	209	105
	Maximum, 2023	0.0	6.3	1.8	4.6	4.0	2.6	32.7	0.0	41.4	2.9	13.8	15.1	41.4
	Date of maximum	–	3	4	2	2	7	25	–	10	11	21	7	10.09

Note:
- if similar maximum or minimum were observed several times in a month or the year, their all dates are provided

Turkmen sector

Table 2.2.5 provides information on precipitation for 2023 as a whole and by season, according to data from coastal stations in Turkmenistan. Precipitation in 2023 did not exceed the norm of precipitation, with the exception of Garabogaz (Bekdash), where in the summer season precipitation exceeded the norm of precipitation.

Table 2.2.5 – Annual and seasonal precipitation (mm) in the Turkmen sector in 2023 г.

Observation post*	Year		Winter		Spring		Summer		Autumn	
	R	RR	R	RR	R	RR	R	RR	R	RR
Turkmenbashi (Krasnovodsk)	64.9	46	13.9	29	35.3	75	2.1	21	17.0	46
Khazar (Cheleken)	28.9	27	6.2	19	20.1	54	0.0	0.0	7.0	22
Garabogaz (Bekdash)	39.5	37	13.2	32	16.1	44	7.8	**111**	2.7	12
Guvlymayak (Kuuli Mayak)	71.6	55	6.1	14	35.8	80	3.0	60	28.2	76
Duzlybogaz (Kara-Bogaz-Goal)	27.0	36	9.0	33	8.2	30	2.0	50	8.7	51
Ogurdzhaly (Ogurchinsky)	37.7	38	2.6	8	16.1	52	0.0	0.0	20.2	75

Notes:
R – the amount of precipitation, mm; RR – the ratio of the current value to the standard normal for 1991-2020, %. The ratio RR must be given as an integer value;
**data are taken from 1989, as previously the stations belonged to the Azerbaijan Department for Hydrometeorology*

Table 2.2.6 provides data on monthly and annual precipitation totals. In Turkmenistan, most of the precipitation falls in the spring season. In general, precipitation for 2023 did not exceed the monthly and annual precipitation rates. In summer, there is almost no precipitation, and if there was precipitation, it was mostly recorded as a maximum per day.

Table 2.2.6 – Monthly and annual total precipitation (mm), ratio of the current value to the standard normal (anomalies, %), maximum and minimum precipitation (mm) for months and the year in the Turkmen sector in 2023

Observation post*	Characteristics	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Turkmen-bashi (Krasno-vodsk)	Total, 2023	0.0	4.7	9.5	14.2	11.6	0.8	1.0	0.3	1.3	2.7	13.0	5.8	64.9
	Standard normal, 1991–2020	16	17	19	20	8	3	3	4	6	11	20	15	142
	Anomalies	0	28	50	71	**145**	27	33	8	22	25	65	39	46
	Maximum, 2023	0. 0	2.5	4.5	5.5	6.5	0.5	1.0	0.3	1.0	1.3	13.0	5.2	13.0
	Date of maximum	5; 8	17	10	03	16	02	18	26	19	20	22	25	22.11
Khazar (Cheleken)	Total, 2023	0.0	1.8	10.7	9.4	0.0			0.0	2.4	4.6	0.0	0.0	28.9
	Standard normal, 1991–2020	11	10	15	16	6	2	1	1	5	10	17	12	106
	Anomalies	0	18	71	59	0			0	48	46	0	0	27
	Maximum, 2023	0.0	0.0 0.7	4.1	3.5	0.0			0.0	2.4	2.8	0.0	0.0	4.1
	Date of maximum	08	01	07	03	2;18			26	18	12	18; 21;22	14; 15;25; 29	07.03
Garabogaz (Bekdash)	Total, 2023		10.8	0.0	4.3	11.8	0.5	1.0	6.3	0.7	1.6	0.4	2.1	39.5
	Standard normal, 1991–2020	13	12	12	17	8	4	3	1	3	6	13	16	106
	Anomalies		90	0	25	**148**	13	33	**630**	23	27	3	13	37
	Maximum, 2023		6.0	0.0	1.5	6.8	0.3	1.0	4.5	0.3	0.8	0.4	0.8	6.8
	Date of maximum		17	07	02	02	21	17	20	13	05	18	17	02.05
Guvly-mayak (Kuuli Mayak)	Total, 2023	0.0	0.0 4.3	10.6	9.0	16.2	0.1	2.9	0.0	3.1	13.8	11.3	0.3	71.6
	Standard normal, 1991–2020	15	14	16	20	9	2	3	1	6	13	19	15	130
	Anomalies	0	31	66	45	**180**	5	97	0	52	**106**	59	2	55
	Maximum, 2023	0. 0	2.2	4.2	3.7	6.7	0.1	1.9	0.0	1.2	6.8	10.3	0.3	10.3
	Date of maximum	5; 8	09	17	03	16	16	18	26; 29	10	07	22	11	22.11
Duzlybogaz (Kara-Bogaz-Gol)	Total, 2023	0.0	6.0		6.7	1.5		2.0		2.6	6.1		2.1	27.0
	Standard normal, 1991–2020	9	10	11	11	5	2	2	1	1	6	9	8	75
	Anomalies	0	60		61	30		**100**		**260**	**102**		26	36
	Maximum, 2023	0.0	0.0 3.9		2.1	0.9		2.0		2.0	5.4		1.6	5.4
	Date of maximum	07	09		01	02		17		09	11		14	11.10
Ogurjaly (Ogurchin-sky)	Total, 2023	0.0	1.4	11.2	4.9	0.0	0.0			0.0	0.0	20.2		37.7
	Standard normal, 1991–2020	10	10	13	14	5	3	2	1	4	8	15	14	98
	Anomalies	0	14	86	35	0	0			0	0	135		38
	Maximum, 2023	0.0	0.0 0.8	7.0	2.9	0.0	0.0			0.0	0.0	20.2		20.2
	Date of maximum	5; 8	09	07	26	14; 16	1; 2			11; 18;19	11; 20	22		22.11

Note:

- if similar maximum or minimum were observed several times in a month or the year, their all dates are provided. Empty cells mean no precipitation occurred;

**data are taken from 1989, as previously the stations belonged to the Azerbaijan Department for Hydrometeorology*

2.2.2. Climatological characteristics of 2023

Kazakhstan sector

Monthly precipitation maxima (mm) recorded at observation posts on the Kazakhstan coast of the Caspian region in 2023 are presented in the table 2.2.7. At Atyrau weather station, 49.0 mm of precipitation (408.3% of the normal) fell in February 2023, which is maximal since 1961, the previous maximum was observed in 1952 and amounted to 41.66 mm.

Table 2.2.7 – Maximum of the monthly precipitation (mm) recorded in the Kazakhstan sector in 2023 and in the previous time since the start of observations

Observation post	Maximum in 2023		Previous maximum		
	precipitation	month	precipitation	month	year
Atyrau	49.0.0	February	41.7.7	February	1952

Note:
- if similar maximum was observed several times in a month or a year, their all dates are provided

The minimum monthly precipitation and absolute maximum daily precipitation were not recorded at the stations of the Kazakhstan coast of the Caspian Sea in 2023.

Table 2.2.8 shows the ranks of the wettest years at weather stations on the Kazakhstan coast, as well as the corresponding annual precipitation amounts (R, mm) and their ratio to the norm of 1991–2020 (RR,%).

On the coast of the Caspian Sea, the five wettest years included various years of the second half of the XX century and the beginning of the XXI century, including 2016, and at some stations – 1981 and 1991. According to the weather stations of Aktau, Atyrau, Kyzan, Peshnoy and Tushchibek, 2016 was one of the wettest years since the beginning of the regular instrumental observations, while the ratio of annual precipitation to normal was in the range of 247.0...337.0 mm. At Tushchibek weather station, 1991 ranks first with an annual precipitation of 382.3 mm (215.9% of the normal).

Table 2.2.8 – Ranks of the wettest years and related anomalies of the precipitation in the Kazakhstan sector

Rank	Year	R	RR	Year	R	RR	Year	R	RR	Year	R	RR
Aktau				Atyrau			Ganyushkino			Kulaly		
1	1981	305.0	188.6	2016	337.0	211.9	1958	304.3	190.1	1963	311.2	187.7
2	2016	302.2	186.9	1953	302.8	190.4	1954	298.7	186.6	1965	304.9	183.9
3	1991	266.6	164.9	1941	274.6	172.7	2013	284.6	177.8	1981	283.2	170.8
4	2003	243.1	150.3	1958	271.8	170.9	1960	283.4	177.0	1969	218.1	131.5
5	1988	237.7	147.0	2015	268.3	168.7	1957	274.8	171.6	1987	205.8	124.1
Kyzan				Peshnoy			Tushchibek			Fort Shevchenko		
1	2000	270.2	160.3	2016	305.9	232.8	1991	382.3	215.9	1965	293.2	205.6
2	2016	247.0	146.5	1953	276.0	210.0	1981	333.6	188.4	1941	246.0	172.5
3	2005	241.2	143.1	1958	272.6	207.5	2016	317.6	179.3	1981	237.9	166.8
4	2003	232.3	137.8	2003	272.3	207.2	1963	271.0	153.0	1988	225.7	158.3
5	1965	231.3	137.2	2000	261.3	198.9	2011	265.7	150.0	1992	206.4	144.7

Note:
- top five ranks are provided. Anomalies are related to the standard normal in the period of 1991-2020

Table 2.2.9 shows the ranks of the driest years at weather stations in the Caspian region, as well as the corresponding annual precipitation amounts (R, mm) and their ratio to the normal of 1991–2020 (RR,%).

On the coast of the Caspian Sea, the top five driest years are various years in the past and current century. At Kulaly and Kyzan weather stations, the five driest years were mainly the years of the XXI century. 2018 with 62.5 (47.6% of the normal), 2021 with 42.6 (29.9% of the normal) and 50.1 (29.7% of the normal) took the first places among the driest years at the weather stations of Peshnoy, Fort Shevchenko and Kyzan, respectively.

Table 2.2.9 – Ranks of the driest years and related anomalies of the precipitation in the Kazakhstan sector

Rank	Year	R	RR	Year	R	RR	Year	R	RR	Year	R	RR
Aktau				Atyrau			Ganyushkino			Kulaly		
1	1996	82.4	51.0	1984	72.8	45.8	1972	57.5	35.9	2018	32.9	19.8
2	1987	95.8	59.2	1968	79.5	50.0	1984	58.9	36.8	2010	37.7	22.7
3	1984	101.3	62.6	1972	83.2	52.3	1944	66.1	41.3	2021	39.0	23.5
4	1968	108.0	66.8	2018	97.3	61.2	1943	77.9	48.7	2020	39.9	24.1
5	1974	109.4	67.7	1975	106.4	66.9	2000	83.1	51.9	2007	45.6	27.5
Kyzan				Peshnoy			Tushibek			Fort Shevchenko		
1	2021	50.1	29.7	2018	62.5	47.6	1968	85.2	48.1	2021	42.6	29.9
2	1972	63.2	37.5	1943	64.6	49.2	2021	94.0	53.1	1942	54.0	37.9
3	2014	78.7	46.7	1968	68.6	52.2	1996	97.5	55.1	1949	56.0	39.3
4	2018	83.8	49.7	1972	69.0	52.5	1986	98.5	55.6	1994	69.6	48.8
5	1996	86.8	51.5	2021	77.1	58.7	1966	100.0	56.5	1986	70.7	49.6

Note:
- top five ranks are provided. Anomalies are related to the standard normal in the period of 1991-2020

Russian sector

The maximum monthly precipitation in 2023 did not exceed its previous maximum in the Russian sector of the Caspian Sea. Table 2.2.10 shows the minimum value of monthly precipitation (mm), according to the observation points of the Russian sector of the Caspian Sea for the entire observation period.

Table 2.2.10 – Minimum of monthly precipitation (mm) recorded in the Russian sector in 2023 and in the previous time since the start of observations

Observation post	Minimum in 2023		Previous minimum		
	precipitation	month	precipitation	month	year
Derbent	0.6	March	2.6	March	1944
Izberg	0.9	March	1.0	March	1975, 1977
Makhachkala	0.8	March	2.0	March	1890, 1896, 1899, 1975
Tyuleniy Island	0,0	January	1,8	January	1999
	0,0	August	0,1	August	2002, 2005, 2006

Note:
- if similar minimum was observed several times in a month or a year, their all dates are provided

March with its monthly total of only 0.6-0.9 mm (3-5% of the norm, rank 1) was the driest for the entire observation period on the western coast of the Middle Caspian. January was record-breaking dry in the north-western part of the Caspian Sea (Tyuleniy Island), there was no precipitation for the entire month. August turned out to be not only extremely warm (rank 2), but also very dry. The weather was determined by a blocking anticyclone for most of August on the European territory of Russia. At Tyuleniy Island, there was no precipitation at all in August.

Table 2.2.11 shows the absolute maximum of daily precipitation (mm) recorded in the Russian sector of the Caspian Sea for the entire observation period. Heavy rains were observed in the north-western part of the sea in the end of the first decade of September that was resulted from the contrasting frontal sectors passing by the area. The absolute maximum of daily precipitation for the entire observation period was recorded on September 10 at Tyuleniy Island. The daily total was 41.4 mm (80% of the monthly total), the previous maximum was recorded on September 18, 1989 (30.7 mm).

Table 2.2.11 – Absolute maximum of daily precipitation (mm) in the Russian sector

Observation point	Absolute maximum in 2023		Previous absolute maximum		
	precipitation	day, month	precipitation	day, month	year
Tyuleniy Island	41.4	10.09	30.7	18.09	1989

Note:
- if similar maximum was observed several times in a month or a year, their all dates are provided

2023 was not among the five wettest and driest years.

Turkmen sector

Table 2.2.12 shows the maximum values of monthly precipitation at stations in the Turkmen sector in 2023. Compared to the previous period (1989–2022), the maximum monthly precipitation values for 2023 were lower.

Table 2.2.12 – Maximum of the monthly precipitation (mm) recorded in the Turkmen sector in 2023 and in the previous time since the start of observations

Observation post*	Maximum in 2023		Previous maximum		
	precipitation	month	precipitation	month	year
Turkmenbashi (Krasnovodsk)	13.0	11	95.9	4	2003
Khazar (Cheleken)	10.7	3	64.9	4	2003
Garabogaz (Bekdash)	11.8	5	66.8	4	2003
Guvlymayak (Kuuli Mayak)	16.2	5	76.2	4	2003
Duzlybogaz (Kara- Bogaz-Gol)	6.7	4	48.4	11	1993
Ogurdzhaly (Ogurchinsky)	20.2	11	65.8	11	2017

Note:
- if similar maximum was observed several times in a month or a year, their all dates are provided
**data are taken from 1989, as previously the stations belonged to the Azerbaijan Department for Hydrometeorology*

Table 2.2.13 shows the minimum values of monthly precipitation at stations in the Turkmen sector in 2023 compared to the previous period (1989–2022). It should be noted that almost no precipitation was observed in summers and sometimes in autumns, mainly in September, during this whole period.

Table 2.2.13 – Minimum of the monthly precipitation (mm) recorded in the Turkmen sector in 2023 and in the previous time since the start of observations

Observation post*	Minimum in 2023		Previous minimum		
	precipitation	month	amount	month	year
Turkmenbashi (Krasnovodsk)	0.0	1	No precipitation	7; 9 7 8 8 8 6 7 7 7 8 8 6; 7; 8 6; 8 6	1990 1991 1995 1997 2008 2009 2010 2011 2013 2014 2016 2017 2021 2022
Khazar (Cheleken)	No precipitation	6; 7	No precipitation	9 8 6; 8 6; 7 7; 8 6; 7; 8; 9 6; 7; 9 8; 9 6; 8 7; 8 6 ;8 6; 9 8 6; 10 7 7 7; 9 2; 6 8 6; 8 7; 8; 9 6 6; 7 ;9; 12 6; 8 6	1990 1995 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2013 2014 2016 2017 2018 2019 2020 2021 2022

Garabogaz (Bekdash)	No precipitation	1	No precipitation	7; 8; 11 5 6; 7 8 9 7; 9 8 8 6; 8 8; 10 8 7; 8; 9 9 6 5; 8 7; 8 5; 7; 9 6 4; 6; 8 7	1996 1997 1998 2000 2001 2002 2003 2004 2006 2007 2008 2010 2012 2013 2014 2017 2018 2019 2021 2022
Guvlymayak (Kuuli Mayak)	0.0	1; 8	No precipitation	6; 7 9 8 7; 8 8 6 8 8 9 6; 7 8 6; 8 7; 8 7; 8 9 8 6 7 7 8 6 7; 8 8 6 9 7; 8 6; 7	1989 1990 1991 1995 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2011 2013 2014 2015 2017 2018 2019 2020 2021 2022
Duzlybogas (Kara-Bogaz-Gol)	No precipitation	3; 6; 8; 11	No precipitation	6 6 8 7; 8 9 5; 8 7; 9; 10 6; 7 7; 9 7; 9 1 6; 8; 9 6; 8; 9; 12 1; 2; 3; 6; 7; 8	1989 1990 1991 1992 1993 1995 1997 1998 2001 2002 2003 2004 2005 2006

				5; 6; 7; 9; 10; 12	2007
				3; 6; 8	2008
				3; 6	2009
				11	2010
				4; 6; 7; 8; 9	2011
				4; 6; 7; 8	2012
				2; 6; 7; 8; 9	2013
				5; 8 ;9	2014
				5; 6; 7; 9	2015
				8	2016
				5; 7; 8; 9	2017
				7	2018
				6; 7; 8; 9; 10	2019
				7; 8; 9; 10; 12	2020
				5; 6; 7; 8; 10	2021
				6; 7; 8	2022
Ogurdzhaly (Ogurchinsky)	No precipitation	7;8;12	No precipitation	6; 12	1996
				8; 10	1997
				3; 6	1998
				8	1999
				8	2000
				6; 8; 9	2001
				6; 7	2002
				7; 8	2003
				1; 8	2004
				6	2006
				9	2007
				8	2008
				6	2009
				7	2010
				4; 5; 7	2011
				9	2012
				7; 9	2013
				7; 8	2014
				5; 6	2015
				8	2016
				6; 7; 8	2017
				5; 7; 8	2018
				6	2019
				9	2020
				6; 8	2021
				6; 8; 9	2022

Note:
- if similar minimum was observed several times in a month or a year, their all dates are provided.
**data are taken from 1989, as previously the stations belonged to the Azerbaijan Department for Hydrometeorology*

Table 2.2.14 shows the absolute maximum values of daily precipitation in 2023, and it did not exceed the previous absolute maximum values for the period 1989-2022.

2023 was not among the five wettest years (Table 2.2.15).

2023 is one of the five driest years in the entire Turkmen sector (Table 2.2.16).

Table 2.2.14 – Absolute maximum of daily precipitation (mm) in the Turkmen sector

Observation post*	Absolute maximum in 2023		Previous absolute maximum		
	precipitation	day, month	precipitation	day, month	year
Turkmenbashi (Krasnovodsk)	13.0	22.11	50.6	28.04	2003
Khazar (Cheleken)	4.1	07.03	44.0	17.04	2004
Garabogaz (Bekdash)	6.8	02.05	39.5	23.05	1991
Guvlymayak (Kuuli Mayak)	10.3	22.11	40.2	23.03	2015
Duzlybogaz (Kara-Bogaz-Gol)	5.4	11.10	29.5	07.01	2000
Ogurdzhaly (Ogurchinsky)	20.2	22.11	33.2	10.03	2005

Note:
- if similar maximum was observed several times in a month or a year, their all dates are provided.
**data are taken from 1989, as previously the stations belonged to the Azerbaijan Department for Hydrometeorology*

Table 2.2.15 – Ranks of the wettest years and related anomalies of the precipitation in the Turkmen sector

Rank	Year	R	RR	Year	R	RR	Year	R	RR
Turkmenbashi*				Khazar*			Garabogaz*		
1	2003	251.1	177	2002	183.4	173	1991	201.1	190
2	1990	222.3	157	1991	174.5	165	1990	189.7	179
3	2019	196.4	138	2003	169.5	160	2006	188.8	178
4	1991	193.3	136	2004	144.4	136	2015	164.9	156
5	2016	187.3	132	1994	138.2	130	2007	157.9	149
Guvlymayak*				Duzlybogaz*			Ogurdzhaly*		
1	2003	224.7	173	1991	174.3	232	1994	148.1	151
2	2015	190.2	146	1994	155.7	208	2019	145.8	149
3	1996	177.0	136	1992	151.7	202	2006	145.1	148
4	2002	176.2	136	2000	146.5	195	1991	137.0	140
5	2019	172.9	133	2002	124.0	165	2015	134.1	137

Note:
- top five ranks are provided. Anomalies are related to the standard normal in the period of 1991-2020.
**data are taken from 1989, as previously the stations belonged to the Azerbaijan Department for Hydrometeorology*

Table 2.2.16 – Ranks of the driest years and related anomalies of the precipitation in the Turkmen sector

Rank	Year	R	RR	Year	R	RR	Year	R	RR
Turkmenbashi*				Khazar*			Garabogaz*		
1	2014	60.4	43	2022	25.4	24	1998	35.2	33
2	2023	64.9	46	2023	28.9	27	1997	39.1	37
3	2022	76.3	54	2018	46.9	44	2023	39.5	37
4	2021	84.4	59	2014	64.2	61	2021	44.5	42
5	2013	94.1	66	2001	65.4	62	2018	46.2	44
Guvlamayak*				Duzlybogaz*			Ogurdzhaly*		
1	2001	54.9	42	2007	16.6	22	1998	11.0	11
2	2014	57.3	44	2006	21.2	28	2001	19.6	20
3	2018	68.0	52	2014	26.5	35	2022	25.1	26
4	2023	71.6	55	2023	27.0	36	2023	37.7	38
5	2021	74.5	57	2021	27.4	37	2012	60.9	62

Note:
- top five ranks are provided. Anomalies are related to the standard normal in the period of 1991-2020.
**data are taken from 1989, as previously the stations belonged to the Azerbaijan Department for Hydrometeorology*

2.2.3 Trends in the precipitation

Kazakhstan sector

Table 2.2.17 presents estimates of the linear trend of annual and seasonal precipitation at observation points located in the Kazakhstan sector of the Caspian Sea for the period 1976-2023.

In Kazakhstan, seasonal precipitation amounts are mainly decreasing, but statistically insignificant. The rate of change in annual precipitation over the Kazakh coast of the Caspian Sea varies from -9.0 to 11.1 mm/10 years. However, annual precipitation on the northeastern coast of the Caspian Sea there shows an increasing trend, which is statistically significant at the 5 % level. In winter, precipitation in the eastern part of the Northern and Middle Caspian generally goes up by 0.2-5.1 mm/10 years, but the increase is statistically significant only at the Atyrau Station, where it reaches 5.1 mm/10 years. In the spring period in the Northern Caspian Sea, the statistically significant trends are recorded at the Peshnoy and Atyrau weather stations, where precipitation increases by 3.9-8.2 mm/10 years. At the same time, precipitation has a statistically insignificant decrease by 3.4-6.0 mm/10 years on the eastern coast of the Middle Caspian. In summer and autumn seasons, statistically significant decrease in precipitation amounts is found at Ganyushkino Station on the Kazakh coast of the Caspian Sea, where it accounted for 7.2 mm/10 years by 2023. In addition, there is a statistically insignificant increase in precipitation by 1.6 and 3.5 mm/10 years, respectively at the Tushchibek and Aktau weather stations in the summer season. The trends were statistically insignificant at other stations and in time periods.

Table 2.2.17 – Estimates of the linear trend of annual and seasonal precipitation in the Kazakhstan sector for the period 1976-2023

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Aktau	-2.4	0.4	0.4	0.1	-5.0	4.2	3.5	5.2	-0.3	0.0
Atyrau	**11.1**	9.7	**5.1**	15.2	**7.6**	11.0	-1.7	1.1	0.1	0.0
Ganyushkino	-4.6	1.8	0.2	0.0	3.9	6.1	**-7.2**	8.9	-1.4	0.9
Kyzan	-9.0	7.1	-0.8	0.7	-3.4	2.5	-3.0	2.6	-3.0	4.5
Peshnoy	8.5	5.0	1.7	1.5	**8.2**	14.0	-0.5	0.1	-1.0	0.5
Tushchibek	-3.7	0.7	2.7	4.6	-6.0	3.8	1.6	1.0	-1.7	1.8
Fort Shevchenko	-7.1	4.6	1.4	2.2	-5.1	7.2	-1.7	1.0	-1.7	2.1

Notes:
a – the coefficient of the linear trend; D – the coefficient of determination. The trend values that are significant at the level of 5% are highlighted

Russian sector

Table 2.2.18 shows estimates of the linear trend of annual and seasonal precipitation at observation points located in the Russian sector of the Caspian Sea for the period 1976-2023.

Annual precipitation amounts are increasing on the western coast of the Middle Caspian Sea. The rate of the rise varies from 6.6 to 15.7 mm/10 years. The most significant trend is

observed in Izberg with a contribution of 11% to the total variance. Precipitation decreases at Tyuleniy Island.

Precipitation growth in winter and autumn is observed in the western coastal zone of the Middle Caspian Sea, with a significant 5% trend observed in autumn in Derbent and Izberg, and in Makhachkala and Derbent in winter. Precipitation decreases in autumn in the north-western part of the Caspian Sea (Tyuleniy Island). The general trend for all stations is a slight decrease in summer precipitation, and changes in precipitation patterns are more visible in the spring season.

Table 2.2.18 – Estimates of the linear trend of annual and seasonal precipitation in the Russian sector for the period 1976-2023

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Derbent	**15.7**	**5**	**6.6**	**4**	-1.3	0	-1.9	1	**11.0**	**4**
Izberg	**13.5**	**11**	4.5	3	0.6	0	-1.5	1	**12.1**	**8**
Makhachkala	6.6	1	**5.6**	**4**	1.2	0	-4.7	3	3.6	1
Tyuleniy Island	*-6.4*	*4*	1.0	1	-3.1	3	-1.7	1	-3.5	3

Notes:
a – the coefficient of the linear trend; D – the coefficient of determination. The trend values that are significant at the level of 5% are highlighted

Turkmen sector

Table 2.2.19 – Estimates of the linear trend of annual and seasonal precipitation in the Turkmen sector for the period 1976-2023

Observation post*	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Turkmenbashi (Krasnovodsk)	-20.03	21.8	-4.84	5.4	-4.34	2.6	-4.18	14.6	-6.63	9.3
Khazar (Cheleken)	-24.32	40.9	-7.64	15.7	-6.53	9.5	-1.71	6.8	-7.11	16.8
Garabogaz (Bekdash)	-14.66	9.4	-4.02	2.8	-3.21	1.6	-0.48	0.4	-4.36	6.9
Guvlymayak (Kuuli Mayak)	-12.07	8.1	-7.65	22.1	-3.26	1.3	1.19	3.3	-2.03	1.0
Duzlybogaz (Kara-Bogaz-Goal)	-31.29	51.4	-9.39	28.1	-10.16	26.9	-2.18	9.0	-7.19	24.1
Ogurdzhaly (Ogurchinsky)	-6.03	2.8	-0.93	0.3	-0.82	0.2	-0.77	1.5	-1.39	0.5

Notes:
a – the coefficient of the linear trend; D – the coefficient of determination. The trend values that are significant at the level of 5% are highlighted.
**data are taken from 1989, as previously the stations belonged to the Azerbaijan Department for Hydrometeorology*

3. HYDROLOGICAL CONDITIONS

3.1. RIVER FLOW INTO THE CASPIAN SEA

3.1.1 The Volga River

Volga is the largest river in Europe, with a length of 3690 km, originates on the Valdai upland and flows into the Caspian Sea, the catchment area is about a third of the European part of Russia. It belongs to the rivers with the Eastern European type of water regime, with well-defined spring floods, autumn floods, summer and winter low water. The river is mainly snow-fed [1].

There are several periods in the long-term fluctuations of the Volga river runoff:

- 1941–1955 – period of conditionally natural runoff;
- 1956–1961 – period of dam construction and large reservoirs filling;
- 1962–2023 – period of regulated runoff.

During the period of conditional natural runoff (1941-1955), the average annual runoff at the top of the Volga Delta (at Verkhnelebyazhye Station) was 240 km^3, during the period of large reservoirs filling (1956-1960) – 233 km^3, during the period of regulated runoff (1962-2023) – 241 km^3.

Within the regulated flow regime, there are phases with the flow below the average (1962–1970, W=228 km^3), low-water (1971–1977, W=202 km^3), high-water (1978–1995, W=267 km^3), and a phase with the flow close to the average (1996–2023, W=236 km^3).

The low runoff in 1971-1977 was due to previous low water years. Annual runoff was 20–75 km^3 lower than normal. An extremely low annual runoff value was observed in 1975 (W=166 km^3). Since 1978, there has been a significant increase in annual runoff. For the period from 1978 to 1995, 11 out of 18 years had runoff values exceeding the normal by 32-92 km^3, and the runoff was 15–22 km^3 less than the long-term average for only 5 years. Extremely high water runoff was observed in 1979, 1990, 1991, and 1994 (304, 308, 303, and 333 km^3, respectively). During the period of conditionally natural runoff, annual runoff of this magnitude was observed only in 1947 (306 km^3). From 1996 to 2023, there were 9 high-water and medium-water years, and 10 low-water years. Years with modular coefficients $K>1.05$ are classified as high water years, years with $K<0.95$ are classified as low water years, and years with average water flow are with $1.05 \geq K \geq 0.95$ (Table 3.1.1).

2023 was a low-water year in terms of water flow. The annual runoff of the Volga River at Verkhnelebyazhye Station was 208 km^3, which was 39 km^3 less than the normal (the normal in the period 1991–2020 was 247 km^3). 2023 is one of the six most low-water years in terms of annual runoff since 2000: 2015 (181.7 km^3), 2011 (189 km^3), 2010 (196.7 km^3), 2006 (201.9 km^3), 2019 (205 km^3), 2023 (208 km^3).

Table 3.1.1 – **High-water, medium-water and low-water years in the period 1996-2023**

High-water years (K>1.05)		Average flow years (1.05≥K≥0.95)		Low-water years (K<0,95)	
years	K	years	K	years	K
1998	1.15	1997	0.98	1996	0.73
1999	1.18	2000	1.00	2006	0.84
2001	1.13	2002	1.06	2010	0.82
2005	1.16	2003	1.01	2011	0.78
2007	1.15	2004	1.06	2014	0.88
2013	1.07	2008	0.95	2015	0.75
2016	1.08	2009	0.95	2019	0.85
2017	1.13	2012	0.95	2021	0.87
2020	1.16	2018	1.02	2022	0.88
				2023	0.86

Note: hereinafter, the modular coefficient was calculated as the ratio of the current runoff to its multi-year average

A typical feature of the water regime in 2023 was low water discharge throughout the year, and the average monthly water discharge was higher than the normal only in February and April (K=1.09 and K=1.39). The water flow of the Volga River in June and July was only 50 and 70% of the normal (Table 3.1.2).

Table 3.1.2 – Water runoff at the top of the Volga Delta (m^3/ s) and modular coefficients in January–December 2023

Parameter	Month												Year
	1	2	3	4	5	6	7	8	9	10	11	12	
Qav, 2023	4200	6650	5460	12000	15800	6090	4890	4850	4830	4770	4510	4930	6580
Qn, 1991-2020	5739	6112	6650	8663	18540	12289	6943	6104	5765	5437	5620	6064	7827
K, 2023	0.73	1.09	0.82	1.39	0.85	0.50	0.70	0.79	0.84	0.88	0.80	0.81	0.84
Qmax 2023	5420	7300	6480	19200	17200	12500	4960	4900	4890	4800	4670	5940	19200
Qmin 2023	3410	5620	4780	4600	13000	4940	4810	4780	4800	4720	4470	4470	3410

The date of the beginning of the spring flood in 2023 and the date of its highest discharge were observed 10–12 days earlier than in 2022, which was explained by an unusually warm spring and, as a result, early melting of snow and ice in the Volga River basin. The highest discharge at the peak of the flooding in 2023 was 19,200 m^3/s, in 2022 – 19,900 m^3/s (the normal is 21,203 m^3/s), the runoff during the flooding was 75.6 and 89.7 km^3, respectively (the normal is 94.5 km^3). The average runoff in the flooding was 147.1 km^3 during the period of conditional natural runoff (1942-1955), and the averaged date of the highest water discharge was June 4. The duration of the flood was 61 days in 2023 and 83 days in 2022 (the normal is 74 days), while it had been 109 days in 1942–1955.

The share of flooding runoff in the total annual runoff decreased from 60 % under natural runoff conditions to 38 % under the climatic normal (1991-2020); and it amounted to 36 % in 2023.

3.1.2 The Terek River

The Terek River is one of the largest rivers in the North Caucasus. It originates on the slope of the Great Caucasian Ridge in the Trusovsky Gorge, from the glacier of Zilga-Khokh Mount [4]. The Terek River flows into the Caspian Sea and has an estuary with multi-arm delta that occupies the arid plains of the Caspian lowland. The river is 623 km long. The catchment area of the Terek River is 37,400 km^2. The Terek River belongs to the Tien Shan type of water regime with a long summer flood complicated by powerful floods [1].

The Kargalinsky station is located in the lower reach of the hydroelectric system, which allocates the flow of the Terek River between the northern and middle parts of the delta. Therefore, its water flow there reflects both natural and anthropogenic fluctuations in the river flow entering its delta, which is located above the main structure of the Dzerzhinsk Canal [5]**.**

The average long-term flow volume of the Terek River (at Kargalinsky hydrosystem) for the period 1965-2023 is 6.864 km^3, while the climatic norm (1991-2020) is 8.122 km^3. The annual flow of the Terek River is of great long-term variability. Its runoff was high in high-water years: 10,421 km^3 (2002), 10,504 km^3 (2018), 11,291 km^3 (2016), 11,365 km^3 (2005). And it was few times lower in low-water years: 2,863 km^3 (1975), 2,700 km^3 (1986), 2,569 km^3 (1976). Figure 3.1.1 shows long-term variations of the Terek River runoff in 1965-2023.

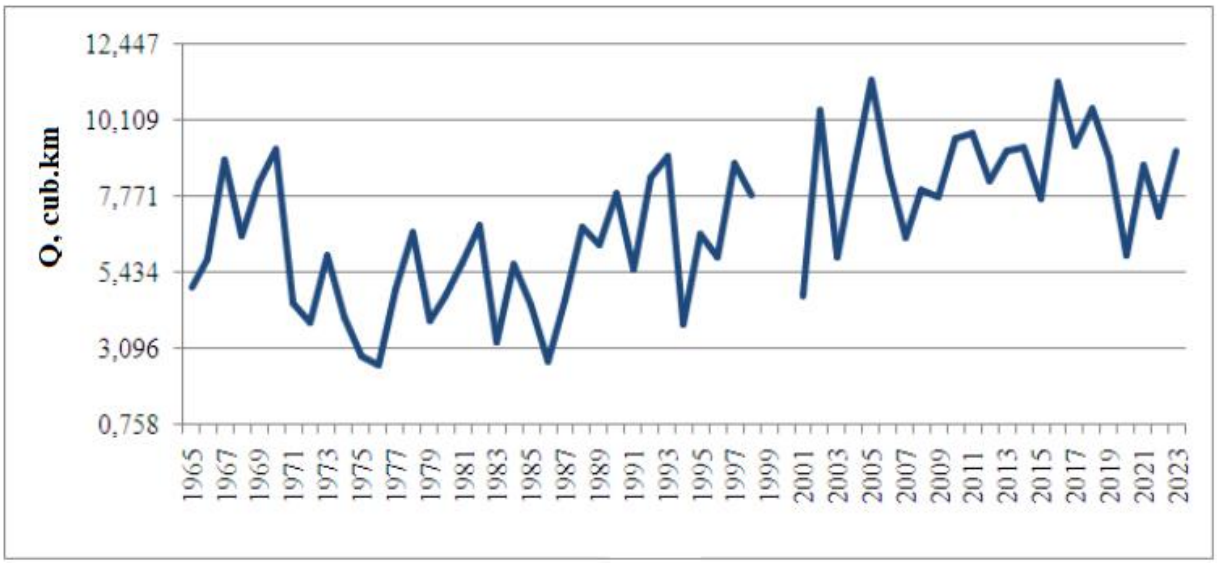

Figure 3.1.1 – The Terek River runoff at the Kargalinsky Hydrosystem in 1965-2023

Analysis of the differential integral curve of the Terek River runoff at the Kargalinsky Station (Figure 3.1.2) shows that from 1965 to the end of the 1980s, there was a long period of decreasing water flow. It was following by the period of the average runoff, which lasted until 2001. Then one can see a sharp increase in the curve, which marked the growing water flow from 2002 on.

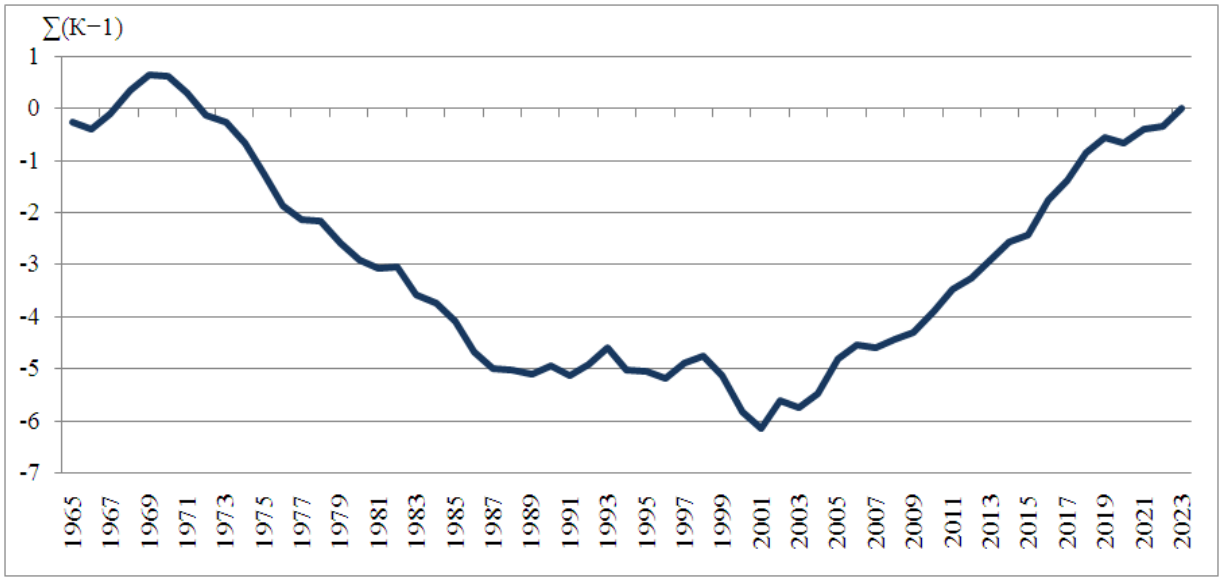

Figure 3.1.2 – Difference-integral curve of the Terek River runoff volumes according to the data of the Kargalinsky Hydrosystem for the period 1965-2023

The annual runoff was 9.182 km^3 (113 % of the normal) in 2023 Water runoff in January and February was 5–13% higher than their normals (K = 1.13 and 1.05). In April, when water was withdrawn for irrigation by channels of the delta system, the flow decreased. The water content in April was 68% of the normal. 21.06 the largest annual water discharge was recorded (1010 m^3/sec) at the Kargalinsky Station.

The flooding of 2023 was characterized by increased water flow. Runoff during the flooding was higher than its normal: by 51% in June, by 7–8% in May and July. In August, there was a large shortage of precipitation, and the river runoff in August reached only 34% of the normal. In August, the lowest water discharge was recorded (71.1 m^3/sec, 26.08). In October, water consumption for irrigation stopped, and the Terek River runoff was higher than the normal since then: by 27 % in October, by 59 % in November, and by 54% in December (Table 3.1.3).

Table 3.1.3 – Runoff of the Terek River at Kargalinsky hydrosystem (m^3/c) and modular coefficients in January–December 2023

Parameter	Month												Year
	1	2	3	4	5	6	7	8	9	10	11	12	
Q av. in 2023	216	206	215	131	267	664	511	210	169	244	343	318	291
Q av. for 1991–2020	191	196	215	191	250	439	472	318	200	193	216	207	257
K for 2023	1.13	1.05	1.00	0,68	1,07	1,51	1,08	0,66	0,84	1,27	1,59	1,54	1,13
Q max in 2023	224	219	262	268	612	1010	961	519	311	317	446	396	1010
Q min in 2023	205	187	143	75,4	79,8	370	207	71,1	77,6	160	301	279	71,1

3.1.3. The Sulak River

The Sulak River is a river in Dagestan, it is merged by flows of the rivers of Avar Koysu and Andian Koysu, which originate from the glaciers in the Greater Caucasus. It flows into the Caspian Sea, length – 169 km, catchment area – 16620 km^2.

The Sulak River belongs to the Tien-Shan type of rivers with a summer flooding complicated by rainy flash floods. The river's feeding is mixed: snow accounts for 34% of the annual runoff, ground water sources – 32%, rain – 24 %, glacial – 10 % [1]. The flow of the Sulak River is regulated with the cascade of water reservoirs. The largest of them, the Chirkeyskoye reservoir, determines the flow regime of the river. Therefore, the intra-annual distribution of the river runoff depends on human economic activity.

The average long-term runoff of the Sulak River (at the Sulak Station), calculated for the period 1976-2023, is 4,704 km^3. This value varies from 2,680 km^3 (1996) to 7,761 km^3 (2002). In the climatic standard period (1991-2020), the average runoff of the Sulak River is 4,901 km^3.

The annual runoff was 4,239 km^3 in 2023, which is slightly higher than in the previous year, but 13 % lower than the normal. The range of the Sulak River runoff fluctuations from January to December 2023 are shown in Table 3.1.4 and Figure 3.1.3.

Table 3.1.4 – Runoff of the Sulak River at Sulak Station (m^3/c) and modular coefficients in January–December 2023

Parameter	Month												Year
	1	2	3	4	5	6	7	8	9	10	11	12	
Qav., 2023	132	131	137	128	130	190	160	119	119	116	118	133	134
Qav. for 1991-1993, 1995-1997, 2000-2005, 2009, 2010, 2012–2020	148	163	161	151	181	201	172	137	118	126	142	151	155
K in 2023	0,89	0,81	0,85	0,85	0,72	0,95	0,93	0,86	1,01	0,93	0,83	0,88	0,87
Qmax, 2023	139	145	147	139	146	227	207	139	122	120	123	142	227
Qmin, 2023	120	122	128	120	119	147	122	112	115	112	112	117	112

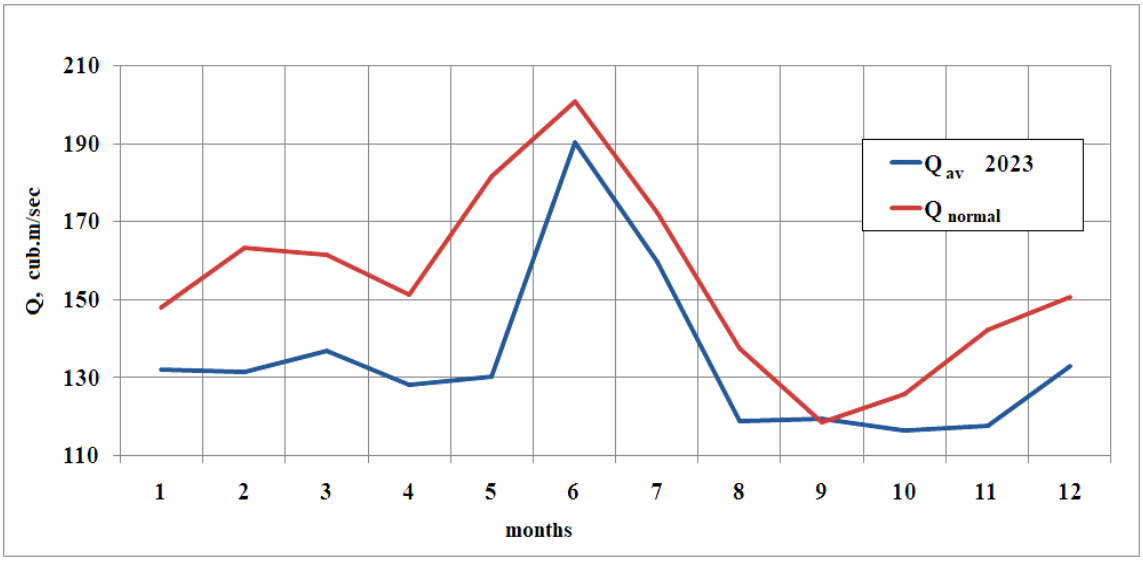

Figure 3.1.3 – Hydrograph of the Sulak River runoff at the Sulak Station in 2023 in comparison with the normal (1991-2020)

3.1.5 The Ural (Zhaiyk) River

The runoff of the Ural (Zhaiyk) River is characterized by significant interannual and seasonal variability. At the river hydrological station Ural – Makhambet, the annual runoff for the period 1936-2023 varied from 20.59 km^3 in wet years to 2.85 km^3 in dry years and averaged to 7.90 km^3.

The Ural (Zhaiyk) River is influenced by many factors of economic activity on its watershed, the most significant of which is the Iriklinskoye reservoir, constructed in 1958 and related to reservoirs of many years of regulation. Therefore, the period from the beginning of observations to 1957 is considered conditionally natural. The regulation of the river flow was started in 1958, as the operation of the reservoir with the constant water discharge began that year, that allowed for keeping the spring flooding water within the reservoir (Chibilev, 2008). The flow of the Ural River in the territory of Russia is also regulated by the cascade of water reservoirs built both on the Ural River itself and on its tributaries. The largest of the reservoirs are Verkhneuralskoe (volume of 601 million m^3), Magnitogorskoe (volume of 189 million m^3) and Iriklinskoe (volume of 3257 million m^3). Reservoirs on the river's tributaries are Kumakskoye, Dombarovskoye, Krasnochabanskoye, Sakmarskoye, Chernovskoye (Russia), Aktobe, Karagalinskoye (Kazakhstan).

Analyzing the graph of the river runoff (Figure 3.1.4), we can conclude that there is an decreasing long-term trend in the Ural River (Zhaiyk) annual flow at Makhambet Station for the observation period of 1936-2023. This is proved by the trend line given in the Figure 3.1.4. The

Ural River is currently experiencing a low-water period. In 2023, the river flow at the Makhambet post was 6.92 km^3, which is 12% less than the long-term average (1936-2023).

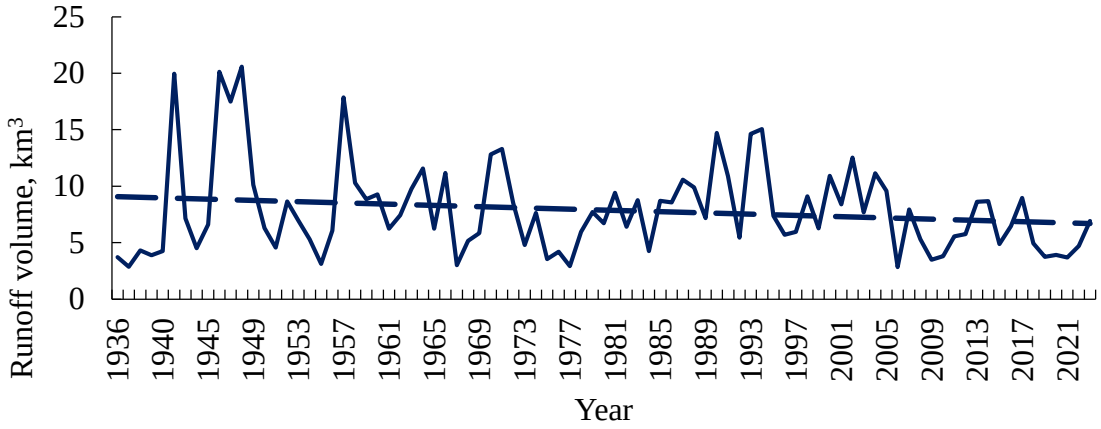

Figure 3.1.4 – Runoff of the Ural River (Zhaiyk) at Makhambet post for the period of 1936-2023

Figure 3.1.5 shows that in spite of the cyclic inter-annual runoff fluctuations with the clear identification of high-water and low-water phases, a decrease in the river water flow is obvious, and is especially evident in the last 20 years. However, it should be noted that the river runoff increased by almost 2.2 km^3 in 2023 compared to the previous year.

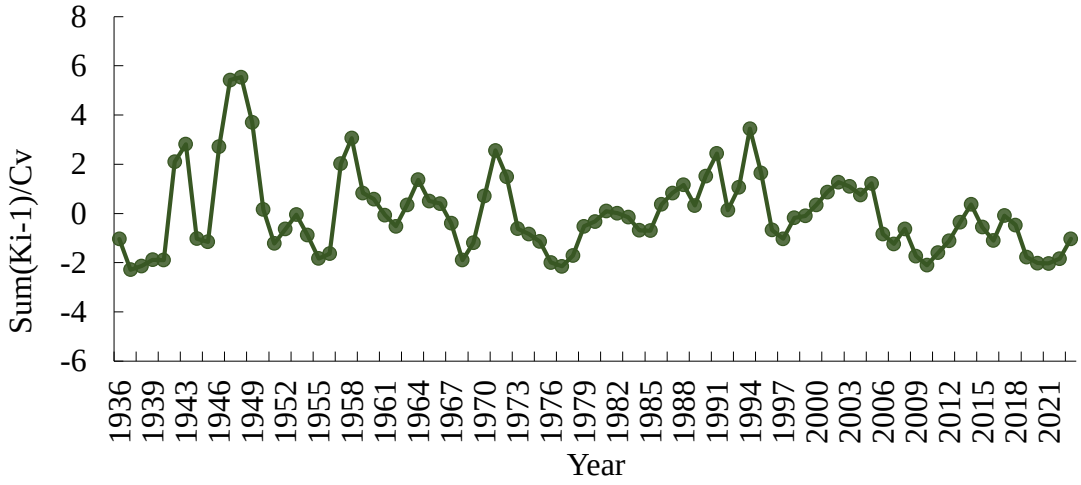

Figure 3.1.5 – Differential integral curve of the Ural (Zhaiyk) River runoff at Makhambet Station for the period of 1936-2023

3.2. THE LEVEL OF THE CASPIAN SEA

Kazakhstan sector

According to the data of coastal and inland marine stations in 2023, the level of the Caspian Sea in its northeastern shallow part fluctuated around -28.73 m abs within the range from -27.67 m to -29.59 m.

In the deep-water Kazakhstani part of the Caspian Sea, according to the Fort-Shevchenko, Aktau and Fetisovo stations, the sea level has averaged to -29.0 m with the maximum value of -28.45 m and the minimum mark of -29.74 m.

Surge fluctuations in the level of the Caspian Sea

Near the north-eastern coast of the Northern Caspian Sea, during the period from January to December 2023, the coastal stations of Kazhydromet recorded 57 cases with down surge and 43 cases with up surge.

The most significant surge phenomena are presented below:

- On 4-11 January, a critical water level drop of 50 cm was observed at Peshnoy Station caused by steady north-western winds of up to 16 m/s.
- On 13-17 March, a critical water level drop of 54 cm was observed in the Peshnoy Station, caused by a steady east-southeastern wind of 16 m/s.
- On 23-27 May, a 45 cm rise in water level was observed near the north-eastern coast of the Caspian Sea in the area of the Peshnoy Station, caused by the sustained impact of southeastern wind with a speed of up to 6 m/s.
- On 2-14 June, the Peshnoy Station recorded a critical drop in water level by 68 cm, caused by a southeastern wind with a maximum wind speed of up to 10 m/s.
- On 20-21 July, the Fort Shevchenko Station recorded a 41 cm drop in water level caused by the southwestern wind with a maximum wind speed of 4 m/s.
- On 24-29 July Peshnoy Station recorded a critical drop in water level by 46 cm caused by south-eastern wind with maximum wind speed up to 6 m/s.
- On 5-9 October Peshnoy Station recorded a 73 cm rise in water level caused by south-south-western wind with maximum wind speed up to 16 m/s.
- On 8-9 October at Fort Shevchenko Station area observed a drop in water level to 56 cm caused by sustained south south-eastern wind up to 10 m/s.

Russian sector

The water level at Russian coastal stations decreased by 12–26 cm in 2023compared to the previous year of 2022, while comparing with 2021, the decrease reached 34-45 cm. The main reason for the level drop was the low runoff of the Volga River, observed for the third year in a row. In the low-water year 2021, the annual runoff was lower than the normal by 38.68 km^3, in 2022 by 35.29 km^3, and in 2023 by 39.45 km^3. During the whole year, low water levels were observed at all Russian stations (Table 3.2.1).

Table 3.2.1 – Average sea level (cm) in the Russian sector in 2021, 2022 and 2023

Year	Months												Yearly average
	1	2	3	4	5	6	7	8	9	10	11	12	
Makhachkala													
2021	-25	-31	-28	-27	-23	-18	-20	-24	-36	-37	-42	-42	-29
2022	-44	-50	-48	-46	-45	-38	-44	-40	-49	-53	-67	-57	-48
2023	-71	-75	-76	-74	-68	-66	-74	-74	-78	-76	-76	-75	-74
Tyuleniy Island													
2021	-23	-38	-34	-30	-26	-21	-28	-28	-43	-42	-51	-46	-34
2022	-55	-55	-61	-58	-57	-50	-55	-42	-60	-57	-64	-56	-56
2023	-46	-64	-63	-60	-69	-74	-72	-70	-70	-78	-78	-75	-68
Lagan													
2021	5	-22	-12	-3	16	14	-6	5	-27	-11	-25	-19	-7
2022	-36	-37	-55	-23	-23	-12	-27	1	-33	-39	-55	-42	-32
2023	-40	-51	-48	-42	-42	-46	-61	-52	-59	-67	-64	-35	-51

On the western coast of the Middle Caspian Sea at Makhachkala Station, the seasonal level range was typical in 2023: an increased level in the spring-summer (May, June) and a reduced level in the autumn. The maximum level was recorded on December 9 (-29 cm), the minimum was on December 28 (-125 cm).

The seasonal run of the minimum monthly levels at Lagan Station had its own peculiarities: the minimum level (-129 cm) was recorded in the spring (April 15), the minimum monthly average levels were observed in October (-67 cm) and in November (-64 cm). The most significant decrease at Tyuleniy Island was observed in October and November (-78 cm), and the minimum level (-99 cm) was recorded on November 22. Significant sea level rise was observed in the western part of the Northern Caspian in the winter months: in December at Lagan Station (by 29 cm), in January at the Tyuleniy Island (by 11 cm). The maximum levels were recorded on January 13 (19 cm) at the Tyuleniy Island and on 13, 14 January (87 cm) in Lagan. The water level has risen at this time mainly due to the ice cover occurred (Figure 3.2.1).

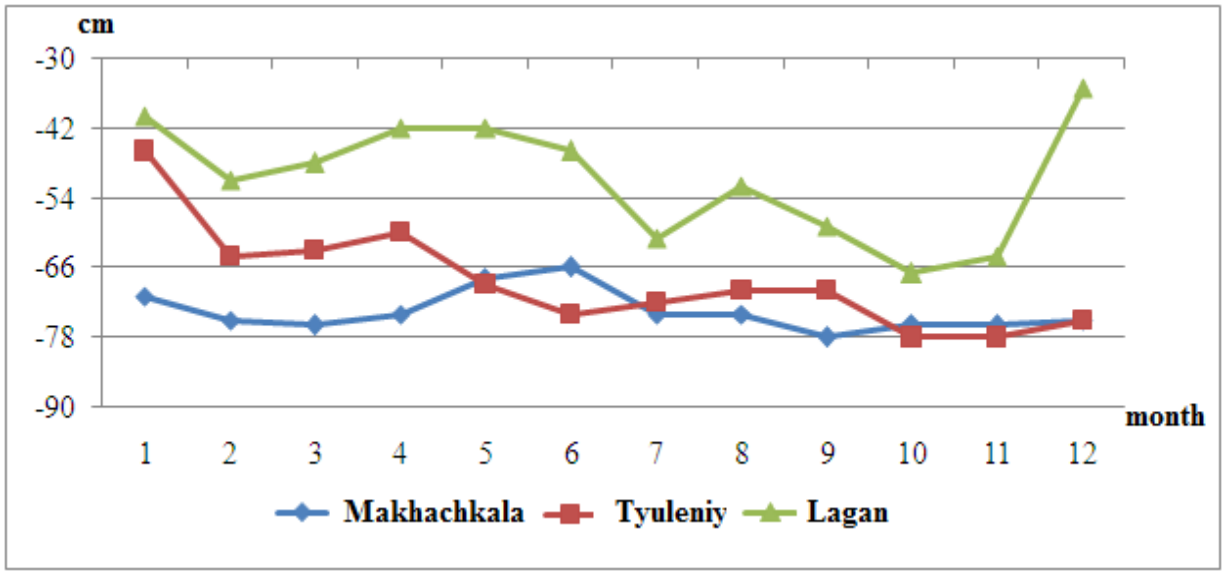

Figure 3.2.1 – The seasonal fluctuations of the Caspian Sea level at the Russian stations in 2023

The range of intra-annual level fluctuations was 96 cm in Makhachkala and 118 cm at Tyuleniy Island. The maximal intra-annual range of fluctuations was observed at Lagan Station, which was characterized by significant wind-induced level fluctuations with the amplitude of 216 cm.

Surge fluctuations in the level of the Caspian Sea

37 cases of wind-induced level fluctuations were registered at the Lagan Station from January to December 2023: 19 upsurges and 18 downsurges. According to the Tyuleniy Island Station, the increase in the water level by 35–61 cm (12–15.01) and 36 cm (13.12) was associated with the ice cover occurred. There was only one upsurge and one downsurge in December on the western coast of the Middle Caspian Sea, according to Makhachkala Station.

The most significant surge phenomena were observed in Lagan:

On April 14–16, the water level decreased by 53–83 cm, caused by a steady north-westerly wind with maximum gusts of up to 12–22 m/s. On April 18–20, the southeastern wind occurred with maximum gusts of up to 22 m/sec that resulted in the sea level rise by 65–96 cm (Figure 3.2.2).

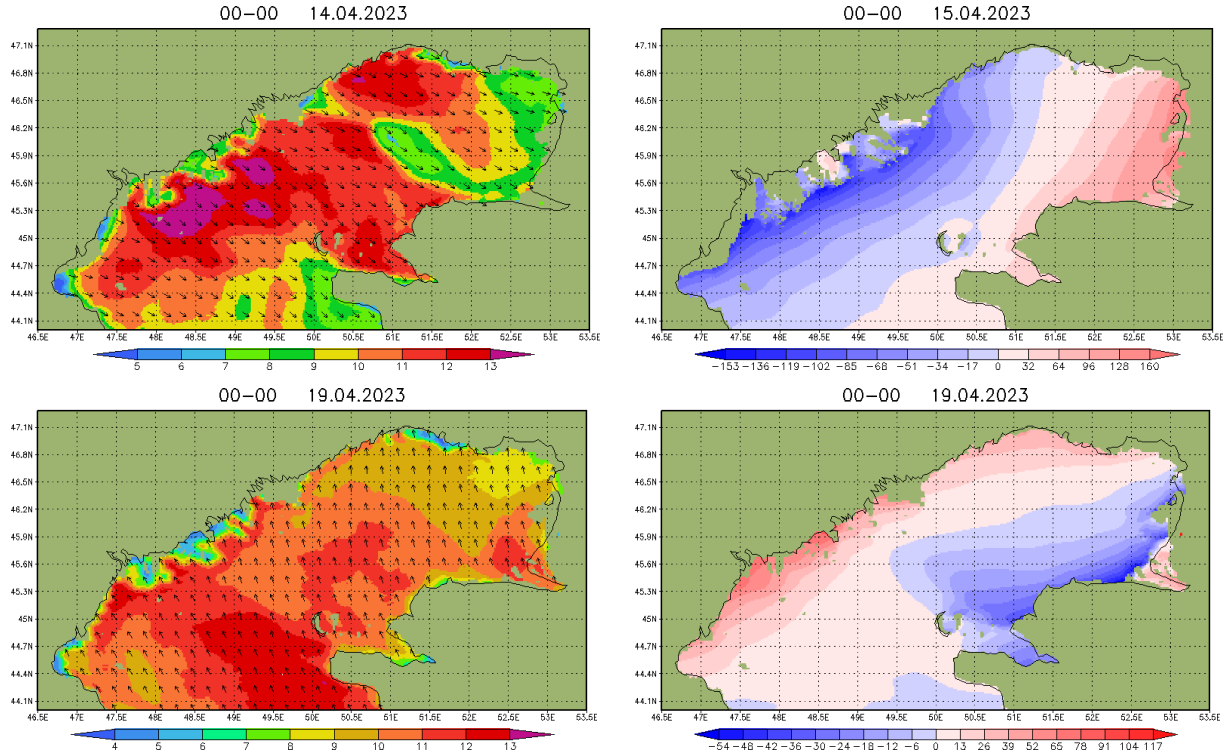

Figure 3.2.2 – Typical winds (left) and water levels (right) in the Northern Caspian on April 14, 15, and 19, 2023 (data by the Hydrometeorological Center of Russia)

On August 11–15, a steady south-eastern wind with maximum gusts of up to 10–20 m/sec raised the water level by 32–44 cm (Figure 3.2.3).

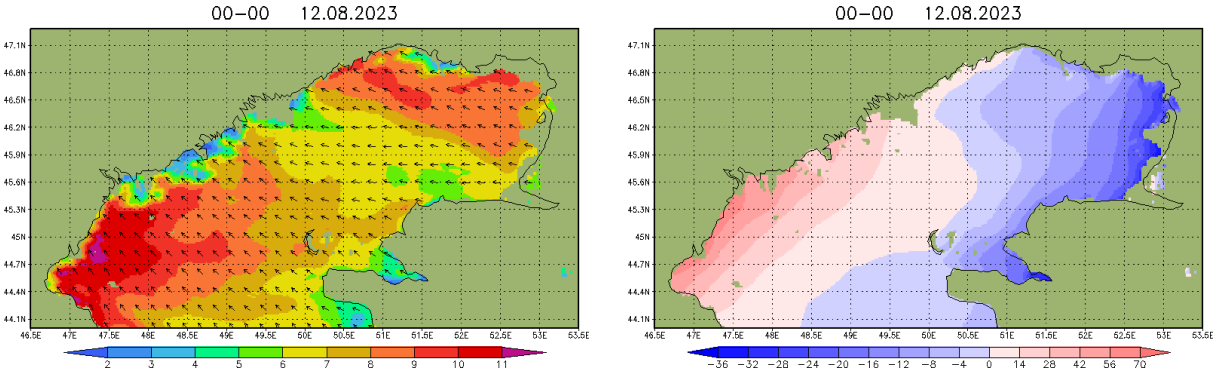

Figure 3.2.3 – Typical winds (left) and water levels (right) in the Northern Caspian on August 12, 2023 (data by the Hydrometeorological Center of Russia)

According to the data of Lagan Station, the minimum monthly water level during the downsurge in April (-129 cm) reached the lowest mark for the entire observation period (1935–1949, 1972–2023).

It should be noted that the level of -50 cm was referred to as the criterion for a "dangerous phenomenon" for Makhachkala until 2022 [2]. Due to the current fall in the sea level, these criteria have been changed. In 2023, this criterion for Makhachkala is the drop in the sea level (including wind-induced) to -100 cm [3]. The minimum monthly levels approached this criterion, amounting to -93 and -90 cm in July and October 2023, respectively. The minimum monthly levels exceeded this criterion with the marks of -108, -100, and -125 cm in September, November and December 2023, respectively.

3.3. SEA WATER TEMPERATURE

3.3.1. Sea water temperature in 2023

Kazakhstan sector

In 2023, the average annual water temperature according to the data from coastal stations located in the ***Kazakhstan sector of the sea*** was +10.4...+15.6ºC.

The surface water temperature shows noticeable seasonal fluctuations and has a well-defined annual course. The average surface water temperature in the northeastern part of the sea varied from +0.7...3.0°C in the cold period of the year to +19.3...28.3°C in summer months. The average surface water temperature on the eastern coast of the Middle Caspian varied from +0.5...4.9°C in the cold period of the year to +18.8...25.4°C in summer months (Table 3.3.1).

Table 3.3.1 – Average monthly and average annual water temperature (°C), deviations from the standard normal (anomalies), maximum and minimum water temperature (°C) for months and the year in the Kazakhstan sector in 2023

Obser-vation post	Characteristics	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Peshnoy	Average, 2023	1.3	1.3	4.6	9.2	14.8	19.3	22.5	21.4	14.1	8.3	5.5	2.1	10.4
	Standard normal, 1991–2020	1.4	1.4	2.4	8.7	16.6	21.6	23.5	21.9	15.8	9.1	3.8	1.9	10.7
	Anomalies	-0.1	-0.1	-2.2	0.5	-1.8	-2.3	-1.0	-0.5	-1.7	-0.8	1.7	0.2	-0.3
	Maximum, 2023	2.9	3.5	12.2	18.8	24.5	27.1	29.4	28.6	22.0	19.1	14.8	5.5	29.4
	Minimum, 2023	0.3	0.6	1.0	2.0	7.1	6.9	13.3	8.5	5.3	2.0	1.5	0.8	0.3
Kulaly*	Average, 2023	0.8	0.7	11.4	16.8	21.6	27.5	28.3	28.0	23.8	14.9	9.8	3.0	15.6
	Standard normal, 1991–2020													
	Anomalies													
	Maximum, 2023	3.2	2.3	19.8	21.9	28.5	29.9	30.9	30.9	27.8	23.2	15.9	10.2	30.9
	Minimum, 2023	-1.4	-0.7	0.3	11.6	15.7	25.6	26.1	25.2	20.5	9.4	1.7	-1.5	-1.5
Fort Shev-chenko**	Average, 2023	0.9	0.9	6.8	11.7	17.5	22.4	25.4	23.1	19.7	14.9	10.7	3.5	13.1
	Standard normal, 1991–2020													
	Anomalies													
	Maximum, 2023	3.5	3.5	12.4	17.2	22.0	25.0	29.6	27.3	24.0	19.6	13.8	8.9	29.6
	Minimum, 2023	0.0	0.0	1.2	6.7	11.8	18.6	22.3	18.0	16.8	11.5	5.2	-0.2	-0.2
Aktau	Average, 2023	0.5	1.3	6.3	10.2	14.9	18.8	18.8	21.0	17.4	14.5	11.6	4.9	11.7
	Standard normal, 1991–2020	3.0	2.6	6.0	11.0	15.4	17.3	17.7	19.6	18.4	14.8	9.2	4.6	11.6
	Anomalies	-2.5	-1.3	0.3	-0.8	-0.5	1.5	1.1	1.4	-1.0	-0.3	2.4	0.3	0.1
	Maximum, 2023	5.6	3.5	12.6	14.9	21.2	23.5	23.2	27.2	20.1	18.6	14.2	10.0	27.2
	Minimum, 2023	-2.4	-0.7	2.3	5.8	11.4	14.2	14.7	16.7	14.8	10.8	7.2	0.3	-2.4

Notes:
* data on water temperature are not available in 1992 (VIII-XII), 1993, 1994, 1995 (I-IV, VIII, IX, XI, XII), 1996, 1997
** no water temperature data available in the period 1966-1975, 1988-1992.

Russian sector

Table 3.3.2 summarizes the average monthly and average annual water temperature, anomalies (positive or negative), and the maximum (minimum) water temperature at observation posts located in ***the Russian sector*** of the Caspian Sea in 2023.

The average annual water temperature was +14.4...+16.6°C, which is 0.7–3.4°C higher than the normal.

The minimum monthly average water temperature was observed in February, at the Tyuleniy Island Station – in January and February, and corresponded to the minimum monthly average air temperatures. The general run of the monthly average water temperature was characterized by the rapid increase from +6.8...+10.3°C in March to +25.7...+27.8°C in August, and a gradual decrease by December, up to +1.9...+2.7°C on the Iskusstvenniy Island and in Lagan, and up to +7.1...+10.0°C at the other stations.

Table 3.3.2 – Average monthly and average annual water temperature (°C), deviations from the standard normal (anomalies), maximum and minimum water temperature (°C) for months and the year in the Russian sector in 2023

Obser-vation post	Characteristics	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Derbent	Average, 2023	4.3	3.3	7.9	12.7	17.6	22.3	24.9	26.7	20.3	16.6	14.2	8.0	14.9
	Standard normal, 1991–2020	4.2	3.3	5.3	9.7	15.4	21.1	24.5	25.6	21.9	17.2	11.5	6.7	13.9
	Anomalies	0.1	0.1	2.6	3.0	2.2	1.2	0.3	1.1	-1.5	-0.6	2.7	1.2	1.0
	Maximum, 2023	5.6	5.2	12.4	14.2	24.4	24.8	27.5	28.4	26.8	21.1	17.0	12.5	28.4
	Minimum, 2023	2.3	1.5	4.4	11.2	13.2	18.8	21.8	25.0	18.0	14.4	11.8	5.5	1.5
Izberg	Average, 2023	4.2	2.6	7.5	11.0	17.4	22.7	23.9	25.7	20.7	16.7	12.9	7.1	14.4
	Standard normal, 1991–2020	3.8	3.1	5.2	9.8	15.7	21.4	24.4	25.2	21.6	16.7	10.9	6.1	13.7
	Anomalies	0.4	-0.5	2.3	1.2	1.7	1.3	-0.5	0.5	-1.0	-0.1	2.0	1.0	0.7
	Maximum, 2023	7.8	5.7	13.5	16.5	24.6	27.6	28.2	28.8	26.6	22.4	17.4	12.8	28.8
	Minimum, 2023	1.0	0.2	2.8	6.0	12.5	17.2	16.2	17.2	15.2	12.6	6.0	2.8	0.2
Makhachkala	Average, 2023	6.8	5.1	10.3	14.5	20.0	24.5	24.2	26.7	22.0	18.6	16.0	10.0	16.6
	Standard normal, 1991–2020	3.2	2.6	4.9	9.3	15.2	20.5	23.3	24.7	21.5	16.5	10.5	5.5	13.1
	Anomalies	3.6	2.5	5.4	5.2	4.8	4.0	0.9	2.0	0.5	2.1	5.5	4.5	3.4
	Maximum, 2023	9.3	8.6	15.6	16.8	26.2	28.2	28.6	29.7	26.7	22.4	19.9	13.5	29.7
	Minimum, 2023	4.0	2.8	6.0	12.7	15.4	21.4	18.9	23.8	20.0	16.0	12.7	6.8	2.8
Tyuleniy Island	Average, 2023	4.0	4.0	9.3	14.5	19.6	25.8	25.9	27.7	22.5	18.7	17.2	7.2	16.4
	Standard normal, 1991–2020	1.0	1.2	4.8	11.9	18.8	23.8	26.2	25.6	20.8	14.7	7.7	2.7	13.3
	Anomalies	3.0	2.8	4.5	2.5	0.7	2.1	-0.3	2.1	1.7	4.1	9.5	4.5	3.1
	Maximum, 2023	5.6	6.3	15.5	18.7	25.7	28.3	29.4	29.7	27.0	24.2	21.1	13.0	29.7
	Minimum, 2023	0.2	1.7	4.8	9.7	15.4	23.2	21.8	23.7	18.0	15.2	13.0	3.7	0.2
Lagan	Average, 2023	1.7	1.6	9.4	15.2	21.1	25.6	27.3	27.8	21.2	15.7	10.3	2.7	15.0
	Standard normal, 1991–2020	1.3	1.7	5.6	13.0	20.3	25.2	27.2	26.5	21.3	14.5	6.9	2.2	13.8
	Anomalies	0.4	-0.1	3.8	2.2	0.8	0.4	0.1	1.3	-0.1	1.2	3.4	0.6	1.2
	Maximum, 2023	4.8	3.0	17.2	19.6	27.6	29.0	31.4	30.6	27.0	20.8	15.4	8.2	31.4
	Minimum, 2023	0.2	0.2	3.2	11.2	15.8	24.0	23.6	22.6	18.8	12.8	4.0	0.2	0.2
Iskusstvenniy Island	Average, 2023	0.7	0.2	6.8	10.9	18.4	24.0	25.5	27.0	21.2	15.1	9.5	1.9	13.4
	Standard normal, 1991–2020	0.5	0.5	3.5	9.7	16.5	22.8	25.5	25.0	20.2	13.8	6.3	1.4	12.2
	Anomalies	0.2	-0.3	3.2	1.2	1.9	1.2	0.1	2.0	1.0	1.4	3.1	0.5	1.3
	Maximum, 2023	6.0	0.2	14.2	16.8	25.0	26.8	28.0	29.4	25.8	21.4	15.0	10.4	29.4
	Minimum, 2023	0.2	0.2	0.2	4.8	11.8	20.8	22.2	22.2	17.8	11.8	1.8	0.2	0.2

Great positive anomalies of the water temperature were observed at the stations of Makhachkala and Tyuleniy Island in the winter. The monthly average temperatures were 2.5–3.6°C higher than the normal, while the deviations were ±0.6-0.4°C at the other stations.

At the end of July, a minor coastal upwelling was observed in the area between Izberg and Makhachkala. The average daily water temperature dropped by 8.6°C in Izberg on 28.07–30.07 and by 4.0°C in Makhachkala on 26.07–29.07. The minimum monthly temperature recorded in upwelling was +16.2…+18.9°C. The greatest warming of seawater and the highest average water temperature was typical in August. The maximum annual temperature was also recorded in August (+28.4...+29.7°C). In Lagan, the maximum water temperature was +31.4°C in July (05.07).

The range of its seasonal fluctuations was +21.6...+23.3°C on the western coast of the Middle Caspian, while the temperature accounted for +23.7°C in the open sea. The temperature was higher on the western coast of the Northern Caspian, up to +26.2°C in Lagan, and it reached +26.8°C in the shallow zone of the Volga mouth area on the Iskusstvenniy Island.

Turkmen sector

Table 3.3.3 — Average monthly and average annual water temperature (°C), deviations from the standard normal (anomalies), maximum and minimum water temperature (°C) for months and the year in the Turkmen sector in 2023

Observation post	Characteristics	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Turkmen-bashi (Krasno-vodsk)	Average, 2023	2.1	3.9	11.8	15.8	19.9	24.5	24.7	26.8	21.4	17.7	15.2	7.5	16.0
	Standard normal, 1991–2020	5.1	5.6	9.8	15.1	20.1	23.6	26.3	26.6	22.9	17.9	12.0	6.3	16.0
	Anomalies	-3.0	-1.7	2.0	0.7	-0.2	0.9	-1.6	0.2	-1.5	-0.2	3.2	1.2	0.0
	Maximum, 2023	6.7	7.2	16.5	20.2	25.7	26.4	27.5	29.2	25.7	19.7	17.6	13.0	28.6
	Minimum, 2023	-2.9	1.0	5.5	11.8	17.0	22.0	22.1	24.3	18.7	16.0	11.8	3.8	-2.9
Khazar (Cheleken)	Average, 2023	4.1	5.9	12.0	16.1	19.7	24.3	26.0	27.4	21.7	18.2	16.0	9.0	16.7
	Standard normal, 1991–2020	5.9	5.9	8.9	12.7	18.0	22.0	25.8	27.0	22.9	17.9	11.8	7.7	15.5
	Anomalies	-1.8	0.0	3.1	3.4	1.7	2.3	0.2	0.4	-1.2	0.3	4.2	1.3	1.2
	Maximum, 2023	10.5	10.5	16.3	25.2	26.1	28.4	29.8	31.0	28.6	23.2	20.0	15.5	31.0
	Minimum, 2023	0.8	3.2	8.0	13.4	15.9	20.0	23.5	24.0	18.6	15.0	12.3	5.5	0.8
Duzlybogaz (Kara-Bogaz-Gol)	Average, 2023	3.5	5.3	9.8	12.0	16.5	19.6	18.8	24.0	18.9	16.7	13.7	8.5	13.9
	Standard normal, 1991–2020	5.4	5.1	8.4	12.6	17.0	19.5	21.1	23.0	20.3	16.0	11.1	6.6	13.9
	Anomalies	1.9	0.2	1.4	-0.6	-0.5	0.1	-2.3	1.0	-1.4	0.7	2.6	1.9	0.0
	Maximum, 2023	10.0	9.6	13.2	15.5	21.5	24.1	21.4	28.9	22.7	20.1	17.6	13.9	28.9
	Minimum, 2023	0.4	2.1	6.2	9.0	12.0	16.8	17.0	17.2	16.2	14.0	10.2	2.7	0.4
Garabogaz (Bekdash)	Average, 2023	3.2	5.5	12.3	13.8	16.8	16.8	18.4	23.9	17.2	15.6	13.6	7.6	13.7
	Standard normal, 1991–2020	5.1	4.7	7.4	11.2	17.6	23.0	19.1	20.8	18.4	15.4	11.1	6.7	12.7
	Anomalies	-1.9	0.8	4.9	2.6	-0.8	-6.2	-0.7	3.1	-1.2	0.2	2.5	0.9	1.0
	Maximum, 2023	7.9	8.6	18.0	19.6	22.0	22.1	21.9	27.0	21.0	22.4	16.1	12.0	27.0
	Minimum, 2023	0.2	1.6	7.5	10.6	12.9	13.4	14.9	19.2	13.8	12.7	11.0	2.0	0.2
Guvly-mayak (Kuuli Mayak)	Average, 2023	5.0	6.1	11.2	14.5	16.4	17.9	18.6	24.8	18.4	17.4	15.5	9.6	15.0
	Standard normal, 1991–2020	6.8	6.4	9.1	12.9	15.9	18.0	21.6	24.4	21.5	17.7	13.0	8.8	14.7
	Anomalies	-1.8	-0.3	2.1	1.6	0.5	-0.1	-3.0	0.4	-3.1	-0.3	2.5	0.8	0.3
	Maximum, 2023	10.4	9.8	16.8	19.7	23.4	22.4	23.8	30.4	24.2	21.2	18.8	14.6	30.4
	Minimum, 2023	1.0	3.6	6.2	9.4	12.9	14.6	15.2	17.5	15.0	13.6	11.2	4.0	1.0
Ogurzhaly (Ogurchin-sky)	Average, 2023	3.0	6.8	13.0	16.6	20.8	24.5	26.5	28.4	23.0	19.6	15.1	9.2	17.2
	Standard normal, 1991–2020	6.4	7.0	10.4	14.7	19.5	23.2	26.8	27.6	23.8	18.7	12.9	7.9	16.6
	Anomalies	-3.4	-0.2	2.6	1.9	1.3	1.3	-0.3	0.8	-0.8	0.9	2.2	1.3	0.6
	Maximum, 2023	13.6	16.1	23.5	26.8	33.5	31.0	35.8	36.4	33.2	28.0	22.6	16.5	35.8
	Minimum, 2023	-1.9	1.0	6.0	9.6	14.0	18.6	20.0	19.6	16.4	13.6	8.0	-2.0	-2.0

3.3.2. Climatological characteristics of 2023

Kazakhstan sector

In the Kazakhstan part of the Caspian Sea, the maximum and minimum values of mean monthly water temperature in 2023 did not exceed the corresponding records for the entire observation period.

The maximum values of mean monthly water temperature in 2023 were: in Peshnoy – 22.5°C, in Kulaly – 28.3°C, in Fort-Shevchenko – 25.4°C, in Aktau – 21.0°C. The minimum values were: in Peshnoy – 1.3°C, in Kulaly – 0.7°C, in Fort-Shevchenko – 0.9°C, in Aktau – 0.5°C.

The absolute maximum of daily water temperature also did not exceed the previously recorded values for the entire observation period at the stations of the Kazakhstan coast.

Table 3.3.2 presents absolute minimums of daily water temperature observed on the Kazakhstan coast of the Caspian Sea in 2023. According to the data at Fort-Shevchenko Station, the water temperature was -2.6°C on January 11, which was lower than the previous minimum (-1.9°C) recorded on January 25, 2015. According to the data at Aktau Station, the water temperature dropped to -2.6°C on January 18, which is below the previous minimum (-1.2°C) recorded on February 21–22, 2012.

Table 3.3.2 – Absolute daily minimum water temperature (°C) in the Kazakhstan sector

Observation post	Absolute minimum in 2023		Previous absolute minimum		
	water temperature	day, month	water temperature	day, month	year
Fort Shevchenko	-2.6	11 January	-1.9	25 January	**2015**
Aktau	-2.6	18 January	-1.2	21-22 February	**2012**

Note:
- if similar minimum were observed several times in a month or a year, their all dates are provided

Russian sector

Table 3.3.5 shows the maximum values of the average monthly water temperature (°C) recorded at observation posts in the Russian sector of the Caspian Sea for the entire observation period.

The minimum value of the average monthly water temperature (°C) in the Russian sector of the Caspian Sea in 2023 did not exceed the previous minimum.

Table 3.3.6 shows the absolute maximum monthly water temperature (°C) recorded in the Russian sector of the Caspian Sea since the beginning of the observation period.

Table 3.3.5 – Maximum of the average monthly water temperature (°C) recorded in the Russian sector in 2023 and in the previous time since the start of observations

Observation post	Maximum in 2023		Previous maximum		
	average monthly water temperature	month	average monthly water temperature	month	year
Derbent	12.7	April	12.5	April	2021
Makhachkala	10.3	March	8.2	March	2022
	14.5	April	13.7	April	2022
	20.0	May	18.0	May	2022
	16.0	November	14.4	November	2022
Tyuleniy Island	4.0	January	3.1	January	2007
	9.3	March	8.9	March	2020
	18.7	October	17.4	October	2012
	17.2	November	12.7	November	2022
	7.2	December	7.0	December	2010
Lagan	9.4	March	8.6	March	2020
	10.3	November	10.0	November	2010
Iskusstvenniy Island	27.0	August	26.9	August	2010

Note:
- if similar maximum were observed several times in a month or a year, their all dates are provided

Table 3.3.6 – Absolute daily maximum water temperature (°C) in the Russian sector

Observation point	Absolute maximum in 2023		Previous absolute maximum		
	water temperature	day, month	water temperature	day, month	year
Derbent	24.4	May	23.6	May	2018
Izberg	13.5	March	12.7	March	2002
Makhachkala	15.6	March	11.4	March	2002
	26.2	May	23.7	may	2005
	19.9	November	18.5	November	2018
	13.5	December	13.3	December	1974
Tyuleniy Island	21.1	November	17.7	November	1974
	13.0	December	11.1	December	1980
Lagan	17.2	March	14.1	March	1978
Iskusstvenniy Island	6.0	January	5.1	January	1981
	10.4	December	10.0	December	2004, 2012

Note:
- if similar maximum was observed several times in a month or a year, their all dates are provided

In the Russian sector of the Caspian Sea, the absolute minimum monthly water temperature (°C) in 2023 did not exceed the previous minimum.

However, it should be noted that an unusual increase in the minimum monthly water temperature was observed at the stations of Derbent (in April), Makhachkala (in March, April, May, November), Tyuleniy Island (in March, June, August, October, November). The minimum water temperature in these months have taken the first place in the ranked series of observations (from the warmest to the coldest).

Turkmen sector

Table 3.3.7 – Maximum of the average monthly water temperature (°C) recorded in the Turkmen sector in 2023 and in the previous time since the start of observations

Observation post	Maximum in 2023		Previous maximum		
	average monthly water temperature	month	average monthly water temperature	month	year
Turkmenbashi (Krasnovodsk)	26.8	August	29	July	2018
Khazar (Cheleken)	27.4	August	30.1	August	2000
Duzlybogaz (Kara-Bogaz-Gol)	24.0	August	27.3	August	2014
Garabogaz (Bekdash)	23.9	August	26.3	August	2014
Guvlymayak (Kuuli Mayak)	24.8	August	27.5	August	2014
Ogurdzhaly (Ogurchinsky)	28.4	August	29.5	August	2014

Note:
- if similar maximum was observed several times in a month or a year, their all dates are provided

Table 3.3.8 – Minimum of the average monthly water temperature (°C) recorded in the Turkmen sector in 2023 and in the previous time since the start of observations

Observation post	Minimum 2023		Previous minimum		
	average monthly water temperature	month	average monthly water temperature	month	year
Turkmenbashi (Krasnovodsk)	2.1	January	-0.3	January	1977
Khazar (Cheleken)	4.1	January	1.5	February	2012
Duzlybogaz (Kara-Bogaz-Gol)	3.5	January	-0.3	January	1977
Garabogaz (Bekdash)	3.2	January	-0.4	January	1977
Guvlymayak (Kuuli Mayak)	5,0	January	0,3	January	1977
Ogurzhaly (Ogurchinsky)	3.0	January	0.5	January	1977

Note:
- if similar minimum was observed several times in a month or a year, their all dates are provided

Table 3.3.9 – Absolute daily maximum water temperature (°C) in the Turkmen sector

Observation post	Absolute maximum in 2023		Previous absolute maximum		
	water temperature	day, month	water temperature	day, month	year
Turkmenbashi (Krasnovodsk)	29.2.2	14.08	32.8	01.08	2011
Khazar (Cheleken)	31.0	12.08	35	13.08	2011
Duzlybogaz (Kara-Bogaz-Gol)	28.9	24.08	31.7	28.07	2009
Garabogaz (Bekdash)	27	22.08	30.2	01.08	2011
Guvlymayak (Kuuli Mayak)	30.4	24.08	34.2	12.08	2014
Ogurdzhaly (Ogurchinsky)	36.8	24.07	39.1	11.08	2021

Note:
- if similar maximum was observed several times in a month or a year, their all dates are provided

Table 3.3.10 – Absolute daily minimum water temperature (°C) in the Turkmen sector

Observation post	Absolute minimum in 2023 г.		Previous absolute minimum		
	water temperature	day, month	water temperature	day, month	year
Turkmenbashi (Krasnovodsk)	-2.9	15.01	-1.2	3.02	2014
Khazar (Cheleken)	0.8	25.01	-1.5	5.02	2014
Duzlybogaz (Kara-Bogaz-Gol)	0.4	20.01	-2.4	14.02	2010
Garabogaz (Bekdash)	0.2	23.01	-0,9	08.02	2014
Guvlymayak (Kuuli Mayak)	1.0	12.01	-1,1	05.01	1977
Ogurdzhaly (Ogurchinsky)	-2.0	29.01	-2,2	29.01	2018

Note:
- if similar minimum were observed several times in a month or a year, their all dates are provided

3.3.3. Trends in the seawater temperature

Kazakhstan sector

For the Kazakhstan sector of the Caspian Sea, Table 3.3.3 presents an assessment of the linear trend of mean annual and seasonal water temperatures based on data from the Peshnoy observation point for the period 1976–2023.

The mean annual water temperature decreased on average by 0.18°C every 10 years, the trend is statistically significant at the 5% level. There is a statistically significant increase in water temperature only in winter by 0.50°C every 10 years. During the other seasons of the year, water temperature decreased by 0.11–0.72°C every 10 years.

Table 3.3.11 – Estimates of the linear trend of average annual and seasonal water temperatures in the Kazakhstan sector for the period of 1976-2023

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D a D
Peshnoy	**-0.18**	13	**0.50**	68	-0.11	2	**-0.72**	44	**-0.37**	15

Notes:
a – the coefficient of the linear trend; D – the coefficient of determination. The trend values that are significant at the level of 5% are highlighted

Russian sector

Table 3.3.12 shows estimates of the linear trend of average annual and seasonal water temperatures at the observation posts ***of the Russian sector*** of the Caspian Sea for the period 1976-2023.

According to all stations, the average annual and seasonal temperatures are increasing. Average annual temperatures increased by an average of 0.27–0.47°C every 10 years, an increase of statistically significant, at a significance level of 5%. The rate of increase in seasonal temperatures ranged from 0.15 to 0.58°C/10 years. The temperature increase is statistically significant at the 5 % level for all stations and seasons.

Table 3.3.12 – Estimates of the linear trend of average annual and seasonal water temperatures in the Russian sector for the period of 1976–2023

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Derbent*	**0.29**	**35**	**0.17**	**5**	**0.40**	**25**	**0.33**	**19**	**0.25**	**12**
Izberg	**0.27**	**34**	**0.19**	**7**	**0.44**	**33**	**0.29**	**24**	**0.15**	**5**
Makhachkala	**0.47**	**39**	**0.39**	**17**	**0.53**	**28**	**0.50**	**27**	**0.44**	**24**
Tyuleniy Island	**0.40**	**43**	**0.34**	**18**	**0.34**	**14**	**0.32**	**30**	**0.56**	**30**
Lagan	**0.42**	**58**	**0.24**	**27**	**0.43**	**31**	**0.55**	**50**	**0.58**	**42**

Notes:
a – the coefficient of the linear trend; D – the coefficient of determination. The trend values that are significant at the level of 5% are highlighted
** the estimates are presented for the period 1977-2023.*

Turkmen sector

Table 3.3.13 – Estimates of the linear trend of average annual and seasonal water temperatures in the Turkmen sector for the period of 1976–2023

Observation post*	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Turkmenbashi (Krasnovodsk)	0.31	5.8	0.29	11.0	0.23	15.0	0.44	46.6	0.28	11.7
Khazar (Cheleken)	1.18	6.57	0.23	1.82	0.32	3.64	0.02	0.02	0.38	6.63
Duzlybogaz (Kara-Bogaz-Gol)	0.24	29.6	0.32	15.7	0.22	9.06	0.24	6.22	0.23	8.76
Garabogaz (Bekdash)	0.53	64.4	0.26	7.81	0.40	22.4	0.97	56.5	0.08	1.07
Guvlymayak (Kuuli Mayak)	0.24	30.7	0.15	4.0	0.31	25.4	0.41	19.3	0.03	0.13
Ogurdzhaly (Ogurchinsky)	0.32	36.9	0.38	16.6	0.34	24.9	0.36	17.0	0.23	7.59

Notes:
a – the coefficient of the linear trend; D – the coefficient of determination. The trend values that are significant at the level of 5% are highlighted.
** the observations were not carried out: from 1988 to 1993 and in 1999 at Turkmenbashi Station (Krasnovodsk); from 1976 to 1993 and in 2001 at Khazar Station (Cheleken); from 1988 to 1993 and in 1999 at Duzlybogaz Station (Kara-Bogaz-Gol); from 1988 to 1993 and in 1999 at Guvlymayak Station (Kuuli Mayak); from 1988 to 1993 and in 1999 at Ogurdzhaly Station* (Ogurchinsky)

4. ICE CONDITIONS

Kazakhstan sector

The winter of 2022–2023 in the Caspian Sea was mild with unstable ice cover in the northern shallow part of the Caspian Sea.

From 28 November 2022, the first ice forms were observed near the northern coast of the Caspian Sea according to the data of the Peshnoy Station and from 30 November at Zhanbay Station, the first fast ice was formed, which was distributed evenly over the entire coast.

Fast ice belt along the entire north-east coast of the sea had settled by early December 2022 (Fig. 4.1). A 3 cm thick shore ice was formed in the Igolkinskaya Banka area. A 3 cm landfast ice was also observed in the Kuryk area on 5–6 December 2022. On 5 December 2022 initial ice formation started in the area of Fort-Shevchenko Station located in the Middle Caspian. On 9 December, 1 ball of shore ice was recorded in Aktau with ice belt of 580 m wide and 2 cm thick with 7 cm snow on it.

4 December 2022 ***13 December 2022***

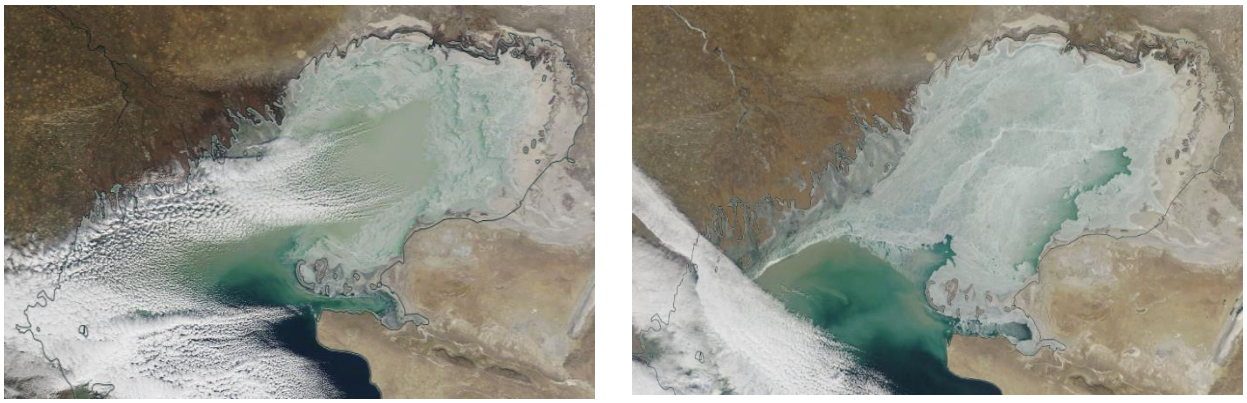

Figure 4.1 – Formation of ice cover in the Northern Caspian in December 2022 (NASA project images)

The maximum ice thickness was recorded off the northeastern coast of the Northern Caspian in late January–February 2023. Ice cover was 42 cm thick (from February 7 to February 19) in the area of Peshnoy Station and 38 cm thick (from January 30 to February 19) in the area of Zhanbai Station (Figure. 4.2).

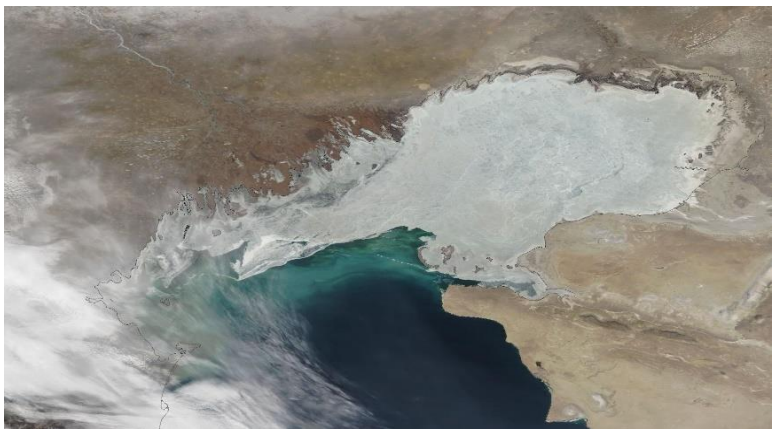

Figure 4.2 – Formation of a stable ice cover in the Northern Caspian Sea (NASA project image, January 30, 2023)

Ice melting in the Caspian Sea started on February 23, 2023 (Figure 4.3).

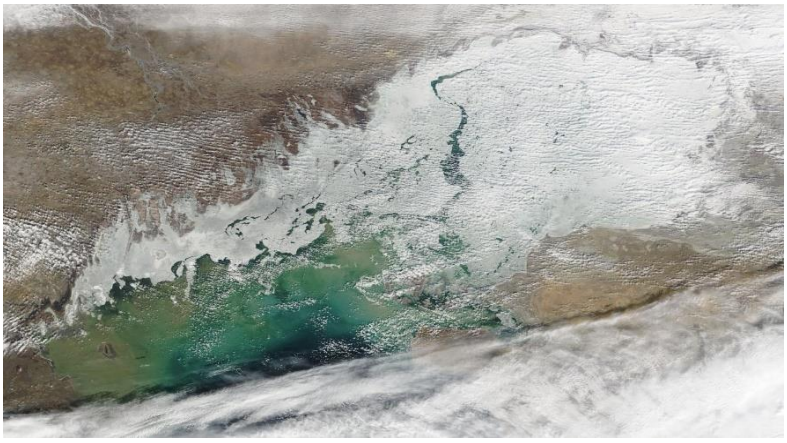

Figure 4.3 – Beginning of spring ice melting in the Northern Caspian (NASA project image, February 23, 2023)

On March 13, 2023, the ice cover completely melted in the area of the Zhanbay station (Figure 4.4).

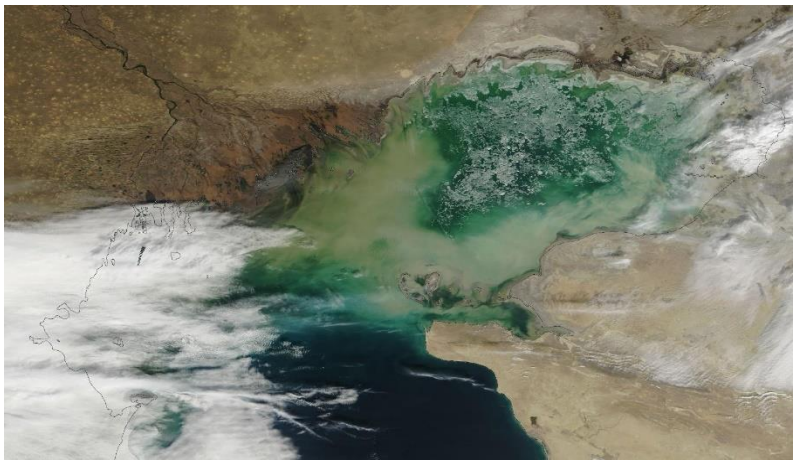

Figure 4.4 – Spring ice melting in the Northern Caspian (NASA project image, March 14, 2023)

On 19 March 2023, the entire northern part of the Caspian Sea was completely ice-free (Fig. 4.5).

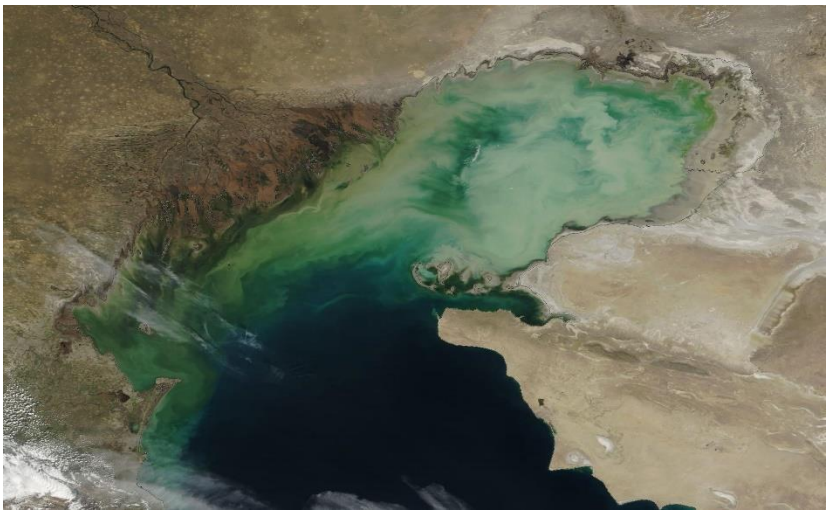

Figure 4.5 – Complete clearance of ice in the Caspian Sea (NASA project image, March 193, 2023)

Russian sector

Winters in the Northern Caspian Region are usually divided into three types: mild – the sum of negative average daily temperatures is > -265ºC, moderate – the sum varies from -265 to -640ºC, and severe – the sum is < -640ºC. The sum of the negative average daily temperatures for the winter season at Astrakhan Station was (-369.5°C), which makes it possible to refer to it as a moderate winter.

In the first decade of December, weather conditions were formed under the influence of the western periphery of the Siberian anticyclone and the inflow of cold air, which caused the significant drop in temperature. The temperature was below the normal by 3–7°C. The air night temperature on the seacoast was -2...-9°C and dropped to -9...-14°C on 4–7 December, to -3.1... -4.6°C at the Tyuleniy Island. According to the ice maps of the Hydrometeorological Center of Russia, the first forms of ice in the western part of the Northern Caspian appeared in early December 2022, in Lagan – 02.12, in the area of Iskusstvenniy Island – 09.01. The sea's ice cover has increased fivefold in the first week of ice formation. In the north-western part of the sea around Lagan Station area, a shore ice up to 5 cm thick was formed by 5 December.

The Siberian anticyclone gave way to the Caspian cyclones in the second decade of December 2022, and the weather conditions were under the alternating influence of the Caspian and Atlantic cyclones in its third decade. The weather was unusually warm. At the Tyuleniy Island, the maximum air temperature rose to +7.6...+8.8°C. The average air temperature was higher than

the normal by 2.6–5.3°C on some days. As a result, the processes of ice formation stopped. In the Kizlyar Bay, a small zone of dark nilas and ice of initial types were observed near the coast. In the third decade of December, clear water prevailed in the north-western part of the sea and in the area of the Volga-Caspian Shipping Channel. Shore ice belt around Lagan area collapsed. In the Volga Delta, the ice shore belt was partially melted (Fig. 4.5).

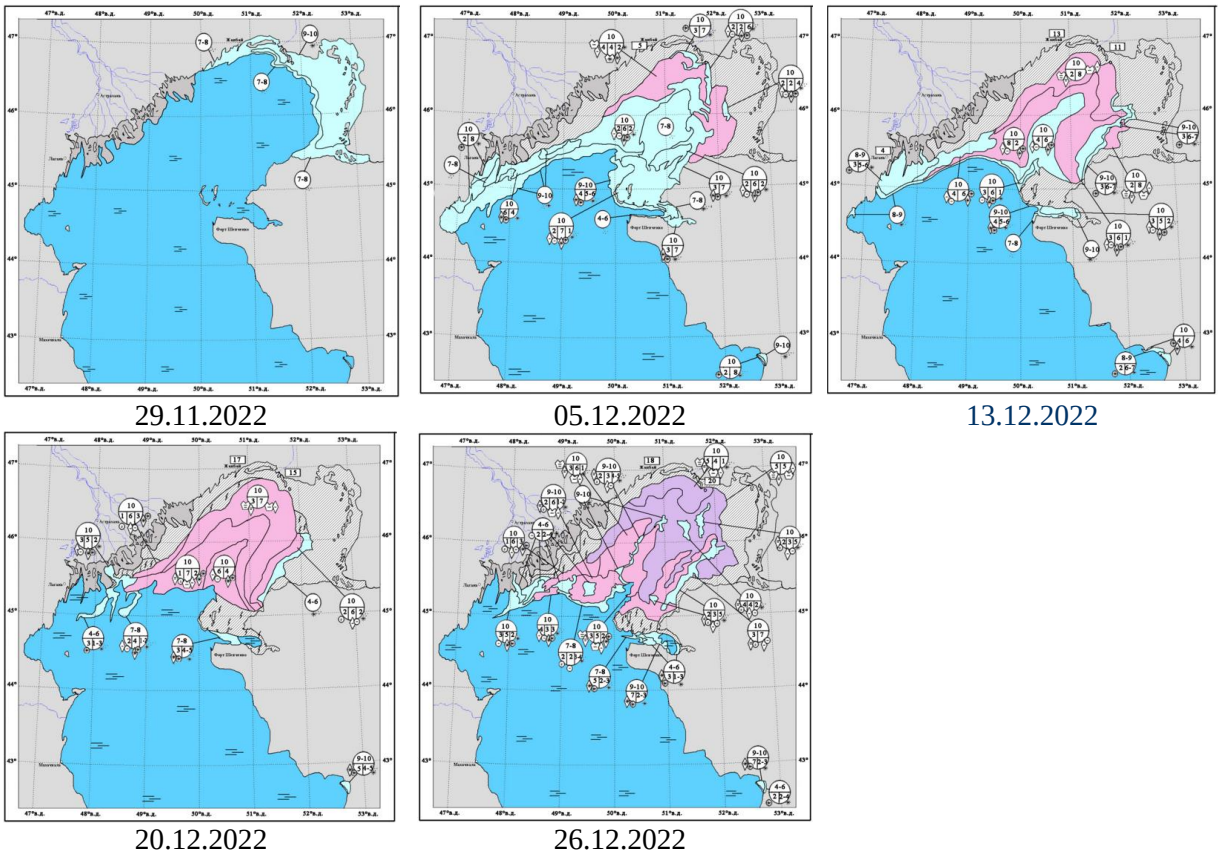

Figure 4.6 – Maps of ice cover for the period from November to December 2022 (data by the Hydrometeorological Center of Russia)

The air temperature in daytime increased to +7.8...+9.4°C at Tyuleniy Island and to +10.3...+16.5°C on the Dagestan coast in the first decade of January 2023. Abnormally warm weather led to partial melting of the ice cover. In the Volga Delta western part, the shore ice belt partially collapsed, and drifting gray and gray-white ice prevailed. At the end of the decade, the northern part of the Caspian Sea was affected by the Arctic anticyclone, which resulted in frosty weather. 8–10 January the minimum air temperature dropped to -11.7...-12.0°C on the Tyuleniy Island and to -14.0...-20.5°C on the north-western coast. In Astrakhan, the temperature dropped to -21.0°C on 10 January, and this was the lowest air temperature of the whole winter season. Active ice formation began in the western part of the Northern Caspian in the end of the first decade of January. An extensive shore ice belt of 4–7 cm thick was shaped in Lagan and the northern part of the Volga-Caspian Channel. The northern part of the Kizlyar Bay

and the Tyuleniy Island coast were also covered with shore ice. The initial types of ice were found along the north-western coast of the sea up to the Agrakhan Peninsula. In the Volga Delta, an extensive 10–20 cm thick shore ice belt was observed, and drifting ice was spread to the south of the delta. At the end of January, there was no clear water from 47 to 45°N. Extensive zones of clear water and some ice floes were observed up to 44°N (Fig. 4.7).

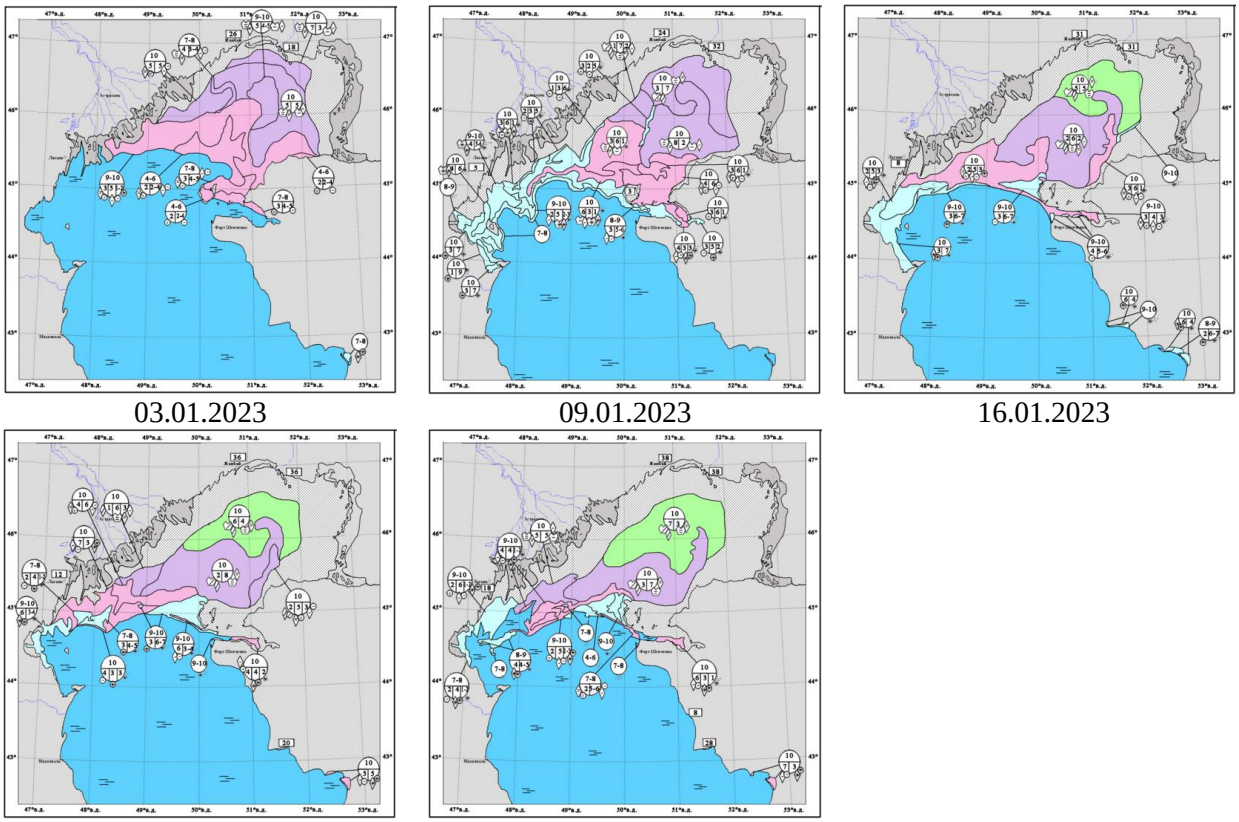

Figure 4.7 – Maps of ice cover for January 2023 (data by the Hydrometeorological Center of Russia)

In the first decade of February, abnormally warm weather was again observed. As a result, the ice formation slowed down, and the ice cover started to melt in the south-west of the sea. In the north-western part of the Caspian Sea, the drifting ice edge was seen near Tyuleniy Island on 6 February. The air temperature was sharply dropped on 10 February. The minimum night temperature dropped to -8.7...-9.4°C on Tyuleniy Island, and to -12.9... -22.0°C on the coast. Frosty weather retained in the second decade of February due to the influence of the Siberian anticyclone. The minimum temperature in the sea dropped to -7.1...-9.5°C, on the coast to -17.8...-23.2°C. In mid-February, the drifting ice edge in the north-western part of the sea spread out to the southern coast of the Agrakhan Peninsula and Chechen Island. Shore ice belt was typical near the Tyuleniy Island coast and in the Volga Delta. The weakening of ice formation and gradual melting of the ice cover started in the third decade of February. has begun. At the end of February, an extensive water area in the north-eastern part of the sea was covered with one-year

thin drifting ice and shore ice. To the south of the thin annual ice – gray-white drifting ice, which stretches to the southwest, along the coast behind the soldered ice, filling the Kizlyar Bay. According to the data at Lagan Station, the maximum ice thickness (27 cm) was observed in the second decade of February.

In the first decade of March, the ice cover in the Caspian Sea gradually melted. In mid-March, ice spread between 50° E and 53° E. There was no ice in the rest of the sea (Figure 4.8).

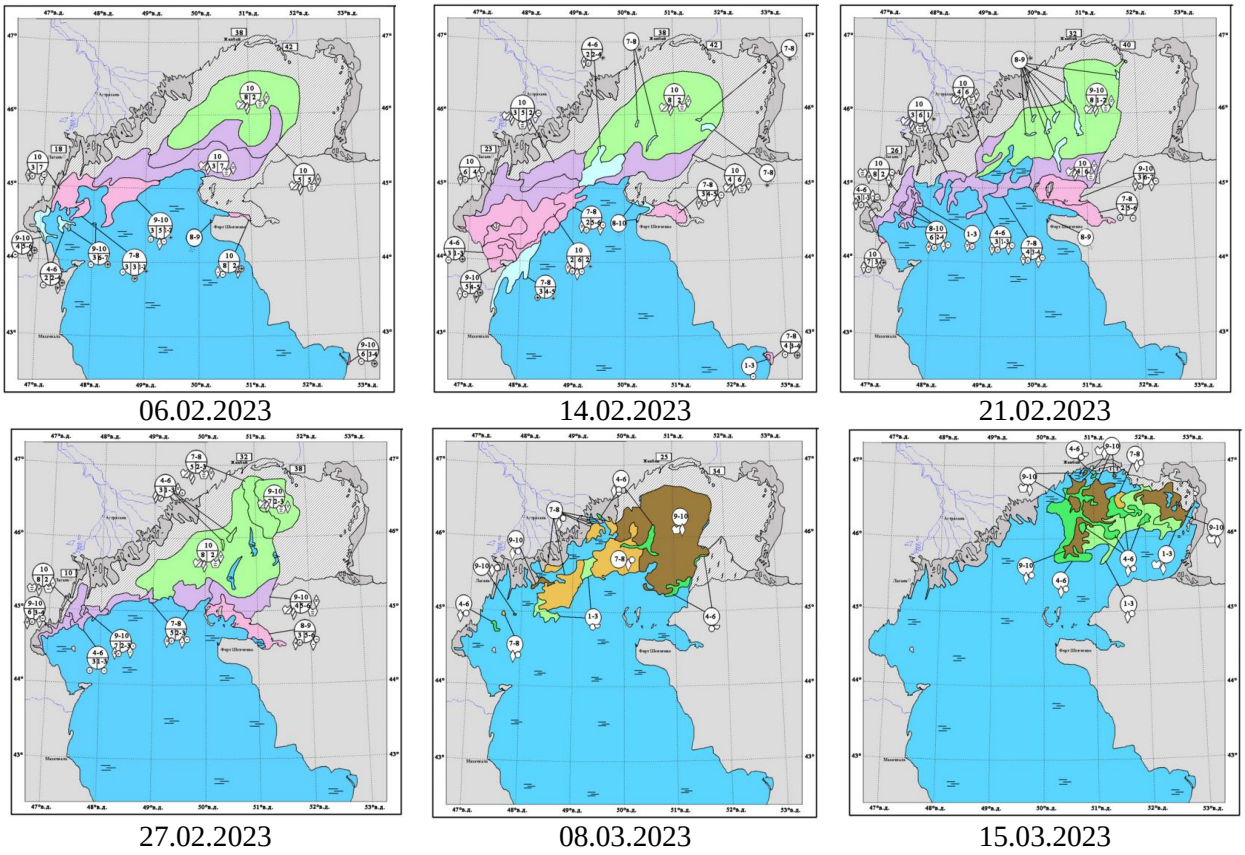

Figure 4.8 – Ice cover maps in February and March 2023 (data by the Hydrometeorological Center of Russia)

According to the coastal stations data, the final clearing from ice was observed: near the Iskusstvenniy Island on 5 March, around Lagan on 7 March. Duration of the ice period with ice at the station of the Iskusstvenniy Island was 67 days (the normal is 81 days[1]) and at Lagan Station was 82 days (the normal is 66 days[2]).

[1] The normal is calculated for the winters in 1975/1976–2021/2022.
[2] The normal is calculated for the winters in 1997/1998–2021/2022.

CONCLUSION

Kazakhstan sector

The year 2023 was extremely warm on Kazakhstan's Caspian Sea coast and was among the five warmest years on record at the weather stations of Atyrau, Ganyushkino, Kyzan, Peshnoi, Tushchibek and Fort Shevchenko. The average annual temperature anomaly ranged from 1.5 to 2.3°C.

In July and August 2023, the highest maximum monthly air temperature was recorded at the meteorological stations of Kulaly (+44.5°C) and Ganyushkino (+41.9°C).

Mean seasonal temperatures increased at a rate from 0.30 to 0.89°C/10 years. The highest temperature rise rate in all seasons (except autumn) and year was observed at Atyrau Station (0.64°C/10 years – in winter; 0.63°C/10 years – in spring; 0.60°C/10 years – in autumn), and the maximum rate of summer warming at Aktau MS was remarkable 0.89°C/10 years.

In 2023, humidity was unevenly distributed. The annual precipitation amounted to 132.0% of the normal at Peshnoy Station, to 127.7% in Atyrau and to 149.3% of the normal in Ganyushkino. At the same time, precipitation was scarce at Kyzan, Tushchibek and Aktau stations (73.5-79.8% of the normal), and it was around the normal (99.2%) at Kulaly station.

Among the seasons, a significant deficit of precipitation in winter at the eastern coast of the Middle Caspian Sea (47.8–75.7% of the normal) and anomalously dry March practically at all stations of the Kazakhstan coast of the Caspian Sea (3.8–50.9% of the normal) were observed. At the same time, excessive precipitation was over most of the coast in spring (87.6–169.9% of the normal), with the exception of Kyzan and Atyrau (43.0 and 65.8% of the normal, respectively). The summer months were characterized by the significant deficit of precipitation, especially on the eastern coast of the Middle Caspian in June (0–20.5% of the normal), although the precipitation was excessively high at Fort-Shevchenko and Peshnoy stations in August (242 and 247.7% of the normal). In the autumn period, precipitation was near and above the normal, especially on the Northern Caspian coast, but it highly varied in November from record high values in Ganyushkino (315.9% of the normal) to the extremely low ones at the stations of Tushchibek and Fort Shevchenko (30.9 and 34.1% of the normal).

The annual water runoff of the Ural (Zhaiyk) River as measured at Makhambet Station tends to decrease in the period of 1936–2023. In 2023, the flow of the river at Makhambet Station reached 6.92 km^3, which was 12% less than the long-term average (1936–2023). However, the water volume increased by almost 2.2 km^3 in 2023 compared to the previous year.

According to the data of coastal and inland stations in 2023, the level of the Caspian Sea in its northeastern shallow part fluctuated within the range from -27.67 m to -29.59 m with an annual average of -28.73 m.

In the deep-water Kazakhstan part of the Caspian Sea, the average sea level was -29.0 m, with the maximum of -28.45 m and the minimum of -29.74 m.

Near the north-eastern coast of the Northern Caspian Sea, the stations of Kazhydromet recorded 43 cases with upsurge events and 57 cases with downsurge events.

In 2023, the average annual water temperature at the coastal marine stations located in the Kazakhstan sector of the sea was +10.4…+15.6ºC.

The winter of 2022–2023 in the Caspian Sea was mild with unstable ice cover in the northern shallow part of the Caspian Sea. Fast ice belt along the entire north-eastern coast of the sea settled by early December 2022. The maximal ice thickness was recorded off the northeastern coast of the Northern Caspian in January–February 2023. On 19 March 2023, the entire northern coast of the Caspian Sea was completely ice-free.

Russian sector

For the Russian sector, 2023 was the warmest year in the entire history of observations of air temperature, with the average annual temperature anomalies of 1.2–1.6°C.

The rate of increase in seasonal average temperatures ranged from 0.34 to 0.69°C/10 years. The most rapid rise in all seasons was observed in the southernmost point of the Russian coast at Derbent Station (0.48°C/10 years in winter; 0.53°C/10 years in spring; 0.69°C/10 years in summer; 0.59°C/10 years in autumn).

Humidity highly varied in 2023: the annual precipitation was within the normal range in Makhachkala, Derbent and on the Tyuleniy Island, while it was excessively high in Izberg.

The seasons include "wet" winter in Izberg (152% of the normal), "wet" autumn on the Tyuleniy Island (162 % of the normal), unusually "dry" spring and winter on Tyuleniy Island (40 and 45% of the normal), "dry" summer and spring in Derbent (50 and 68% of the normal) and abnormally "dry" autumn in Makhachkala (54% of the normal).

The Volga River runoff at Verkhnelebyazhye Station reached 208 km^3 in 2023, which was 39.45 km^3 less than the normal (247 km^3). The runoff of the Sulak River was 4.239 km^3 with the normal of 4.901 km^3, and only the runoff of the Terek River (at Kargalinsky hydrosystem) was 13% higher than its normal.

In 2023, the sea level continued to fall. In the Russian sector of the Caspian Sea, its water level decreased by 12–26 cm compared to the previous year and reached -28.51 and -28.68 m abs in the northwestern part of the sea and -28.74 m abs on the western coast of the Middle Caspian.

In 2023, 19 cases of upsurge events and 18 cases of downsurge were recorded at Lagan Station. During the downsurge in April, the minimum monthly water level reached the lowest mark for the entire observation period.

In the coastal zone of the Middle Caspian Sea, the minimum monthly water level in September and December exceeded the criteria of the "dangerous event" in Makhachkala.

2023 was anomalously warm, that had a significant impact on the surface water temperature. Maximum of the average annual water temperature was recorded in Derbent, Lagan, on Iskusstvenniy and Tyuleniy Islands with positive deviations of 1.0–3.1°C.

In 2023, an abnormal increase in the minimum monthly water temperature was observed at the stations of Derbent, Makhachkala and Tyuleniy Island (rank 1 in the ranked series of observations). The magnitude of positive anomalies in the minimum monthly water temperature was from 3.3°C to 10.7°C. The largest positive anomalies were observed in Makhachkala: 6.8°C in April, 5.1°C in May, and 5.7°C in November. On the Tyuleniy Island, the deviations were 7.0°C in October and 10.7°C in November.

The winter of 2022/2023 was moderate with relatively unstable ice cover in the western part of the Northern Caspian. There were freezing periods along with warming, which led to partial ice melting and reduction in the ice cover. According to the Lagan Station data, ice formation started a week earlier than normal. The duration of the icing period was two weeks longer than the long-term average.

Turkmen sector

To assess the changes in air temperature and precipitation, observation data at the coastal stations in the Turkmen sector of the Caspian Sea were analyzed for the period of 1989-2023, including the reference period of 1991–2020.

There are six hydrometeorological stations on the Caspian coast of Turkmenistan (Garabogaz, Duzlybogaz, Guvlymayak, Khazar, Turkmenbashi and Ogurdzhaly), where monitoring of the sea is carried out since 1989. In the Soviet times, observation data were collected by the Department for Hydrometeorology in Azerbaijan.

According to the long-term data of the coastal stations, the average annual air temperature tends to increase, and this tendency is observed on the entire Turkmenistan territory. The amount of precipitation, on the contrary, goes down, that is also actual for the most of Turkmenistan.

It should be noted that, along with the average temperatures, the number of abnormally high temperatures has also increased in recent years. As for precipitation, the number of days with rain has not changed, while the amount of precipitation has decreased.

It is assumed that climate change will lead to further rise in average temperatures, which will result in higher and long-lasted abnormal summer temperatures and droughts, as well as in lesser annual precipitation.

LITERATURE

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