Coordination Committee on Hydrometeorology of the Caspian Sea (CASPCOM)

ANNUAL BULLETIN

ON THE CLIMATE STATE AND CHANGE

IN THE CASPIAN SEA REGION

for 2024 year

2025

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 2023–2024 (starting from the first month of the cold period – December of 2023), 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 [3]. 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:

- for Iranian sector: **IRIMO** specialists;

- for Kazakh sector, **Kazhydromet** specialists: Aizat Yeltay, Laura Bazarbay, Nauraily Kuzhageldina, Nazerke Abdolla, Yeren Amanulla, Bota Aitymova;

- for the Russian sector, specialists **of the Caspian Marine Scientific Research center "KaspMNIZ"**: E. V. Gavrilova, I. V. Gontovaya, D. R. Svetasheva, V. O. Tatarnikov;

- 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
Iran				
Amirabad	+	+		+
Babolsar	+	+		
Bandar Torkaman	+	+		
Bandar Gaz	+	+		
Dashtenaz	+	+		
Noshahr	+	+		+
Kiashahr				+
Ramsar	+	+		
Anzali	+	+	+	+
Kazakhstan				
Aktau	+		+	+
Atyrau	+	+		
Ganyushkino	+	+		
Kulaly island	+		+	+
Kyzan	+	+		
Peshnoy	+	+	+	+
Tushchibek	+	+		
Fort Shevchenko	+	+	+	+
Russian Federation				
Derbent	+	+		+
Izberg	+	+		+
Kaspiisky (Lagan)			+	+
Makhachkala	+	+	+	+
Tyuleniy Island	+	+	+	+
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 are 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	Accuracy
Air temperature	°C	0.1
Precipitation	mm	0.1
Water temperature	°C	0.1
Linear trend coefficient for annual and seasonal averages of air temperature	°C	0.01
Linear trend coefficient for annual and seasonal averages of water temperature	°C	0.01
Linear trend coefficient for annual and seasonal precipitation	mm	0.1
Determination coefficient	%	1

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 2024

Iranian sector

Table 2.1.1 – Average annual and seasonal air temperature (°C) according to the data of observation points in the Iranian sector in 2024

Observation post	Year			Winter			Spring			Summer			Autumn		
	T	vT	s	T	vT	s	T	vT	s	T	vT	s	T	vT	s
Anzali	17.8	1.8	0.6	9.9	2.2	1.6	15.6	2.0	0.8	26.5	1.5	0.6	19.1	1.2	0.9
Babolsar	18.9	2.4	0.6	10.7	2.8	1.2	17.2	2.8	0.7	27.6	2.3	0.7	20.1	1.9	0.8
Ramsar	17.9	2.1	0.8	9.9	2.1	1.5	15.1	1.7	0.9	27.0	2.8	0.7	18.2	0.4	0.8

Notes:

T_{av} – the current average value of air temperature (°C); vT – anomalies relating to the standard normals for 1961–1990 (°C); s – the average square deviation for the period 1961–1990 (°C)

Kazakhstan sector

According to the data from meteorological stations located in the Kazakh part of the Caspian Sea, 2024 was an extremely warm year, with the exception of Kulaly island, where the average annual temperature anomaly was within the normal range and amounted to +0.5 °C. The average annual air temperatures were +10.8...+14.1 °C, which were by 0.5−1.4 °C higher than the climatic normal for the period 1991−2020, and 1.3−1.6 times higher than the standard deviation.

Air temperatures in the spring, summer and autumn seasons were slightly above their normals: by 0.7–1.6 °C in the spring season; by 1.0–1.5 °C in the summer period; by -0.1– +1.4 °C in the autumn season. Winter anomalies ranged from +1.0 to +2.3 °C. In almost all cases, seasonal anomalies did not exceed the standard deviation (Table 2.1.2).

Table 2.1.2 – Average annual and seasonal air temperature according to the data of observation posts in the Kazakhstan sector in 2024

Observation post	Year			Winter			Spring			Summer			Autumn		
	Tav	vT	s	Tav	vT	s	Tav	vT	s	Tav	vT	s	Tav	vT	s
Aktau	13.8	1.1	±0.8	1.9	1.4	±1.8	13.1	1.2	±1.1	26.1	1.0	±1.3	14.5	1.3	±1.4
Atyrau	11.8	1.4	±1.0	-3.4	2.0	±2.6	12.5	1.5	±1.6	27.2	1.2	±1.4	11.2	1.2	±1.5
Ganyushkino	11.7	1.4	±0.9	-1.9	2.2	±2.2	11.9	1.3	±1.2	26.3	1.5	±1.1	11.3	1.4	±1.3
Kulaly island	12.3	0.5	±0.8	-0.7	1.0	±1.7	11.7	0.7	±1.2	26.5	1.0	±0.9	12.1	-0.1	±1.3
Kyzan	13.4	1.3	±0.9	-0.7	2.3	±2.3	13.6	1.2	±1.5	28.4	1.2	±1.3	12.4	0.8	±1.4
Peshnoy	10.8	1.2	±0.8	-3.5	1.9	±2.4	11.4	1.1	±1.4	25.5	1.2	±0.9	10.2	0.9	±1.4
Tushchibek	12.9	1.0	±0.8	-0.4	1.6	±1.8	12.8	1.1	±1.3	27.3	1.1	±1.3	12.4	0.7	±1.4
Fort Shevchenko	14.1	1.3	±0.8	1.8	1.6	±1.7	13.2	1.6	±1.2	27.0	1.4	±1.2	14.6	1.0	±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 2.1.3 presents monthly and annual mean temperature values, anomalies relative to their climatic normals, as well as maximum (minimum) daily air temperature (°C) for a month and the year with indication of their dates.

Table 2.1.3 – 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 2024 in the Kazakhstan sector

Observation post	Characteristics	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Aktau	T_{av}, 2024	0.6	2.0	5.9	16.1	17.4	25.2	26.7	26.4	22.2	13.4	8.0	2.2	13.8
	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	0.9	1.4	0.1	4.4	-0.8	1.7	0.6	0.7	1.9	-0.1	2.1	0.9	1.1
	Maximum, 2024	11.5	19.1	16.4	31.5	32.4	37.6	42.2	39.0	35.5	27.4	19.4	10.4	42.2
	Date of maximum	08.01	13.02	31.03	21.04	31.05	11.06. 20.06	07.07	07.08	01.09	07.10	2.11	18.12	07.07
	Minimum, 2024	-12.0	-10.0	-5.5	4.8	9.2	18.3	15.5	15.9	9.0	-0.3	-0.7	-5.9	-12.0
	Date of minimum	25.01	19.02	13.03	01.04	20.05	28.06	01.07	18.08	28.09	15.10	13.11	10.12	25.01
Atyrau	T_{av}, 2024	-5.7	-2.9	2.5	17.8	17.3	27.4	28.3	25.8	19.9	10.6	3.1	-2.6	11.8
	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	0.7	2.7	0.6	6.2	-2.1	2.3	0.9	0.2	1.5	0.4	1.6	1.6	1.4
	Maximum, 2024	5.5	10.0	14.7	31.6	34.0	41.5	38.9	37.8	30.3	25.5	18.4	4.1	41.5
	Date of maximum	01.01	08.02. 13.02	31.03	21.04	31.05	18.06	06.07	06.08	04.09	02.10	01.11	30.12	18.06
	Minimum, 2024	-18.6	-14.3	-6.8	4.6	5.3	15.5	16.6	14.7	7.8	0.1	-4.6	-10.3	-18.6
	Date of minimum	11.01	16.02	08.03	01.04	05.05	30.06	01.07	25.08	19.09	23.10	24.11	10.12	11.01
Ganyushkino	T_{av}, 2024	-4.0	-1.9	2.3	16.5	16.8	26.0	27.6	25.2	19.0	10.7	4.2	-1.4	11.7
	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	1.0	2.5	0.0	5.6	-1.9	2.0	1.6	0.9	1.4	0.7	2.1	1.6	1.4
	Maximum, 2024	10.9	14.7	17.4	30.4	31.4	39.4	40.6	38.0	30.0	24.8	21.5	5.4	40.6
	Date of maximum	05.01	08.02	31.03	21.04	31.05	18.06	07.07	06.08	11.09	02.10	01.11	16.12	07.07
	Minimum, 2024	-19.8	-16.5	-8.0	2.3	4.1	13.1	15.2	14.4	5.1	-1.3	-5.4	-8.8	-19.8
	Date of minimum	11.01	21.02	09.03	01.04	04.05	30.06	01.07	26.08	19.09	23.10	24.11	20.12	11.01
Kulaly island	T_{av}, 2024	-1.9	-0.7	2.9	15.8	16.3	25.5	27.7	26.3	19.8	11.5	5.1	-0.9	12.3
	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	0.7	1.6	-0.4	4.6	-2.3	1.3	1.1	0.5	0.2	-0.7	0.2	-0.7	0.5
	Maximum, 2024	7.6	12.6	10.9	29.7	32.9	34.3	35.9	33.8	31.7	26.6	13.8	5.6	35.9
	Date of maximum	04.01	13.02	15.03	19.04	31.05	17.06	04.07	06.08	01.09	07.10	02.11	16.12	04.07
	Minimum, 2024	-12.1	-8.3	-3.9	4.6	8.1	16.9	21.4	18.7	10.6	3.0	-0.5	-5.6	-12.1
	Date of minimum	25.01	18.02	01.03	01.04	06.05	02.06	25.07	31.08	28.09	15.10	30.11	10.12. 15.12	25.01
Kyzan	T_{av}, 2024	-2.4	0.3	4.5	18.3	18.1	28.3	29.2	27.7	20.5	11.9	4.9	-0.8	13.4
	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	1.5	3.4	0.4	5.6	-2.3	2.2	0.7	0.6	0.5	0.2	1.7	1.3	1.3
	Maximum, 2024	10.1	16.6	18.6	32.7	36.0	42.6	42.2	41.0	33.6	29.8	19.2	7.0	42.6
	Date of maximum	05.01	08.02	31.03	22.04	31.05	18.06	06.07	05.08	01.09	08.10	02.11	18.12	18.06
	Minimum, 2024	-14.3	-11.4	-7.0	4.8	7.0	17.9	17.1	16.3	5.1	-1.9	-4.0	-7.8	-14.3
	Date of minimum	25.01	26.02	04.03	09.04	10.05	28.06	01.07	29.08	28.09	14.10	13.11	08.12	25.01
Peshnoy	T_{av}, 2024	-5.7	-3.2	1.9	16.0	16.2	25.9	26.6	24.1	18.1	9.6	2.9	-2.6	10.8
	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

Table 2.1.3 continued

	Anomalies	0.6	2.5	0.7	5.1	-2.5	2.3	1.0	0.3	0.9	0.1	1.6	1.5	1.2
	Maximum, 2024	4.9	8.5	13.8	32.4	33.7	39.2	39.3	37.0	31.0	23.9	19.5	3.2	39.3
	Date of maximum	01.01. 06.01	08.02	31.03	21.04	31.05	18.06	07.07	06.08	01.09	02.10	03.11	27.12	07.07
	Minimum, 2024	-20.0	-14.7	-8.6	1.6	2.4	14.2	14.3	11.8	1.0	-2.6	-5.0	-12.4	-20.0
	Date of minimum	15.01	26.02	09.03	01.04	05.05	30.06	28.07	29.08	28.09	23.10	24.11	10.12	15.01
Tushchibek	T_{av}, 2024	-2.0	0.3	4.3	17.5	16.6	27.0	28.1	26.7	20.9	11.2	5.2	-0.6	12.9
	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	0.9	2.2	0.1	5.7	-2.5	2.3	0.7	0.3	1.2	-0.7	1.6	0.6	1.0
	Maximum, 2024	10.4	18.4	18.2	32.6	35.4	39.2	40.2	40.6	35.2	27.4	16.6	5.8	40.6
	Date of maximum	05.01	13.02	31.03	21.04	31.05	18.06	06.07	05.08	01.09	07.10. 08.10	02.11	18.12	05.08
	Minimum, 2024	-13.7	-11.2	-6.4	5.5	6.5	16.2	16.8	13.8	10.0	-1.5	-2.6	-8.4	-13.7
	Date of minimum	15.01	19.02	13.03	05.04	18.05	30.06	01.07	17.08 18.08	19.09	15.10	14.11	15.12	15.01
Fort Shevchenko	T_{av}, 2024	0.2	2.3	5.3	16.9	17.4	25.7	28.0	27.2	22.6	13.4	7.7	2.0	14.1
	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	0.8	2.4	0.4	5.5	-1.1	1.4	1.3	1.3	1.9	-0.4	1.4	0.6	1.3
	Maximum, 2024	9.2	19.0	13.3	30.9	32.8	35.7	38.4	35.0	35.6	26.2	16.8	9.1	38.4
	Date of maximum	07.01	13.02	30.03	21.04	31.05	17.06	05.07	05.08	01.09	07.10	02.11	16.12	05.07
	Minimum, 2024	-9.7	-7.4	-4.7	4.5	9.9	17.7	19.0	19.3	13.5	3.5	0.6	-3.8	-9.7
	Date of minimum	25.01	18.02	13.03	01.04	05.05	03.06	01.07	18.08	28.09	15.10	13.11	10.12	25.01

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

All observation stations in the region recorded average annual temperatures exceeding their climatic normals (for 1991–2020) by +0.5…+1.4 °C. The highest exceedances were recorded at the Atyrau MS (+1.4 °C) and the Ganyushkino MS (+1.4 °C). The largest seasonal anomalies were observed in spring and winter, especially in April (+4.4...+6.2 °C) and February (+1.4...+3.4 °C). The winter season was characterised by a stable positive temperature background with an excess of the climatic normal at all meteorological stations in the region. In December 2023, positive air temperature anomalies were observed along the entire Caspian coast, from +0.8 °C at the Kulaly island, to +3.1 °C at Ganyushkino MS. In January 2024, temperature anomalies ranged from +0.6 °C at Peshnoy MS to +1.5 °C at Kyzan MS. The temperature in January was slightly above its climatic normal at all stations. February turned out to be the warmest month of the season. Anomalies in the average monthly temperature reached +3.4 °C at Kyzan and +2.7 °C at Atyrau, which allowed to refer February 2024 to as one of the warmest ones in the entire period of instrumental observations at these meteorological stations. The minimum temperatures of -20.0 °C and -19.8 °C were recorded at Peshnoy and Ganyushkino in January. The spring season was characterised by significant temperature variations. At all meteorological stations in the region, March was about the normal or slightly warmer, while April showed excessively high air temperatures: from +4.4 °C at Aktau to +6.2 °C at Atyrau. At the same time, April values at most stations were among the warmest for the entire period of instrumental observations. Meanwhile,

May was characterised by negative temperature anomalies ranging from -0.8 °C to -2.5 °C, which brought down the overall spring average temperatures. The summer season was generally characterised by warm weather with positive air temperature anomalies in all months and at all meteorological stations in the region. The greatest deviations from the normal were recorded in June, when the anomalies reached +2.2...+2.3 °C (for Atyrau, Kyzan, Peshnoy, Tushchibek), and brought this month to the top ten warmest ones for the entire observation period at most stations. Anomalies in July and August were less pronounced, with values ranging from +0.2 °C to +1.6 °C. At all observation posts, maximum summer temperatures exceeded +40 °C, with the exception of Peshnoy, Kulaly island and Fort Shevchenko. The highest temperature for the whole year (42.6 °C) was recorded at Kyzan on 18 June. The autumn season was characterised by an uneven temperature course with a predominance of positive anomalies. September was the warmest month, with anomalies reaching +1.9 °C at Aktau and Fort Shevchenko, making it one of the warmest Septembers in the entire observation period. In October, temperatures were close to their normals, with slight negative deviations observed at Kulaly island, Tushchibek and Fort Shevchenko. Average temperatures were significantly exceeded in November, especially at Aktau and Ganyushkino, where the anomaly reached +2.1 °C. The air temperature most greatly varied in continental areas – at Peshnoy, Atyrau and Ganyushkino meteorological stations. The coastal stations of Aktau and Fort Shevchenko had a more stable temperature regime, with less extreme values.

Russian sector

The year 2024 was exceptionally warm across the Russian sector of the Caspian Sea, setting new records at multiple meteorological stations, and it became the warmest year on record at Izberg and Derbent since the beginning of instrumental observations (table 2.1.4).

Table 2.1.4 – Average annual and seasonal air temperature according to the data of observation posts in the Russian sector in 2024

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
Derbent	15.3	1.6	±0.8	5.4	1.7	±1.2	13.1	1.9	±0.9	26.7	2.0	±1.1	16.2	1.0	±1.3
Izberg	14.4	1.5	±0.7	4.6	1.9	±1.3	12.2	1.8	±0.8	25.6	1.7	±1.0	15.4	0.9	±1.2
Makhachkala	14.0	1.5	±0.9	4.0	2.2	±1.5	12.2	1.6	±1.0	25.2	1.3	±1.1	15.1	1.1	±1.4
Tyuleniy Isl.	13.8	1.0	±0.6	2.0	1.4	±1.5	12.7	1.6	±1.0	26.6	1.3	±0.9	14.0	0.0	±1.0

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)

The annual mean air temperature reached +14.4 °C at Izberg, while it rose to +15.3 °C at Derbent, ranking 1st in the historical record at both stations. These values exceeded the 1991–

2020 climatological normal by +1.5 °C and +1.6 °C, respectively. Temperature anomalies at these stations were 2.0–2.1 times higher than the long-term standard deviation, emphasizing the exceptional nature of the warming event. In Makhachkala, the annual mean temperature was +14.0 °C, placing it 2nd in the record. The anomaly of +1.5 °C was substantial, though slightly lower than the record of 2023 (+14.2 °C; anomaly +1.6 °C), which remains the warmest year since 1882.

On Tyuleniy Island, the 2024 annual mean temperature was +13.8 °C, ranking 4th warmest since 1960. The anomaly of +1.0 °C was moderate compared to other stations, with the warmest year on record remaining 2023 (+13.9 °C; anomaly +1.2 °C).

Winter 2023/2024. The winter season (December 2023 – February 2024) was markedly mild across the Middle Caspian coastal zone. Mean seasonal temperatures ranged from +4.0 °C to +5.4 °C, surpassing the 1991–2020 climatological normal by +1.7 °C to +2.2 °C. This placed the season among the top five warmest winters in the entire observational record (5th to 7th rank, depending on location). On Tyuleniy Island, the winter mean temperature was +2.0 °C, that was +1.4 °C above the normal, ranking 9th warmest since 1960. While significant, this was far milder than the record-setting winter of 2021/2022 (+3.6 °C on Tyuleniy and +6.1 °C in Derbent), which remains the warmest winter in the instrumental record for both locations. The record mild winter remains 1965/1966 (+5.1 °C) at Izberg, while the warmest winter in Makhachkala occurred in 1980/1981 (+4.8 °C). Conversely, the coldest winters on record persist in the historical record: the winter of 1953/1954 along the west coast of the Middle Caspian recorded mean temperatures between −1.8 °C and −5.0 °C, while the coldest winter at Tyuleniy Island occurred in 1971/1972, with a mean of −4.6 °C.

Spring 2024. Unusually high temperature anomalies were observed across the southern Russian Caspian coast during spring 2024. The seasonal mean air temperature reached +12.2 °C at Izberg (2nd warmest on record), while it rose to +13.1 °C (1st rank) at Derbent; they exceeded the 1991–2020 climatological normals by +1.8 °C and +1.9 °C, respectively. The magnitude of these anomalies was exceptional, surpassing the long-term standard deviation by 2.1 times at Izberg and 2.3 times at Derbent. In Makhachkala and on Tyuleniy Island, the spring mean temperatures were +12.2 °C and +12.7 °C, respectively, both ranking 3rd warmest, with anomalies of +1.6 °C above the normals. April 2024 was particularly exceptional, recording the warmest April ever observed at all meteorological stations in the Russian sector of the Caspian Sea. Historically, the warmest spring on the west coast of the Middle Caspian occurred in 2023, with mean temperatures of +12.3 °C to +13.0 °C. On Tyuleniy Island, the record warm spring remains 2016 (+12.9 °C).

The summer season (June–August) 2024 was markedly warmer than average across the region. Mean seasonal temperatures ranged from +25.2 °C to +26.7 °C, with anomalies of +1.7 °C at Izberg (rank 2), +2.0 °C at Derbent (rank 2), +1.3 °C at Makhachkala (rank 3), and +1.3 °C at Tyuleniy Island (rank 4). June 2024 stood out as an exceptionally warm month. It became the warmest June on record at both Makhachkala and Derbent, with anomalies of +3.1 °C (1st rank). June also recorded an anomaly of +3.1 °C (rank 2) at Izberg, while the anomaly was +2.2 °C (rank 4) at Tyuleniy Island. The hottest summer in the instrumental record at Derbent remains 2021 (+26.8 °C; anomaly +2.0 °C), since observations began in 1922. For Izberg, Makhachkala, and Tyuleniy Island, the warmest summer continues to be 2010, with anomalies ranging from +1.8 °C to +2.2 °C.

Autumn 2024 was unusually warm along the west coast of the Middle Caspian. In Derbent, the seasonal mean temperature exceeded the climatological norm by +1.0 °C, ranking 9th warmest since 1951. In Makhachkala, the anomaly was +1.1 °C, placing it 12th in the ranked series. In Izberg, the anomaly was +0.9 °C, corresponding to the 14th warmest autumn since 1951. In all three locations, the anomalies remained below the long-term standard deviation. On Tyuleniy Island, autumn 2024 remained near the climatological normal, with no significant deviation observed. The warmest autumn in the entire observational record for the region remains 2012, with mean temperatures of +15.8 °C to +17.7 °C and anomalies from +1.7 °C to +2.7 °C. The coldest autumn on the Middle Caspian coast occurred in 1993 (+9.1 °C to +11.1 °C; negative anomalies of −4.0 °C to −4.9 °C), however the coldest autumn was 1953 on Tyuleniy Island (+9.9 °C; anomaly −4.1 °C).

Table 2.1.5 presents summary data on the average monthly and average annual air temperature, anomalies (indicating the sign: positive or negative), the maximum (minimum) air temperature for months and the year together with their dates are indicated.

Table 2.1.5 – 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 2024 in the Russian sector

Obser-vation post	Characteristics	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Derbent	T_{av}, 2024	4.0	5.2	7.2	15.1	17.0	25.9	27.5	26.8	22.8	15.8	10.1	6.5	15.3
	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	0.8	2.2	1.3	4.4	0.0	3.1	1.7	1.1	1.7	0.5	0.8	1.4	1.6
	Maximum, 2024	15.2	21.0	17.7	26.8	28.7	35.4	35.7	33.1	31.1	26.5	20.3	12.3	35.7
	Date of maximum	6	8	31	30	31	25	8	6	1	8	2	4	08.07
	Minimum, 2024	-5.7	0.1	1.0	7.0	10.6	17.3	19.0	18.8	14.4	6.4	4.2	-3.8	-5.7
	Date of minimum	14	26	6	3	19	27	29	16	29	28	7	15	14.01

Table 2.1.5 continued

Izberg	Tav, 2024	2.9	4.4	6.4	14.1	16.2	25.0	26.3	25.5	21.8	15.2	9.1	5.7	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	0.8	2.4	1.2	4.1	0.0	3.1	1.4	0.6	1.4	0.5	0.7	1.6	1.5
	Maximum, 2024	13.1	17.7	15.7	25.1	26.2	33.5	34.4	31.0	29.9	28.4	21.4	11.1	34.4
	Date of maximum	6	8	31	19	31	20	7	9. 27	1	8	1	22	07.07
	Minimum, 2024	-6.0	-1.5	0.2	6.7	9.3	15.6	18.0	20.2	14.0	4.0	1.7	-5.4	-6.0
	Date of minimum	14	29	1	3	11	27	29. 30	31	30	28	18	15	14.01
Makhach-kala	T_{av}, 2024	1.8	4.3	6.3	14.0	16.4	25.1	25.9	24.6	22.0	14.7	8.6	4.6	14.0
	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	0.8	2.9	1.1	3.7	-0.1	3.1	1.1	-0.2	1.7	0.5	1.2	1.7	1.5
	Maximum, 2024	13.3	16.7	18.0	27.3	26.3	35.2	36.1	32.9	28.8	27.5	20.7	10.6	36.1
	Date of maximum	6	8	28	30	31	18	7	8	4	8	1	12	07.07
	Minimum, 2024	-8.2	-5.3	0.5	5.2	8.0	15.4	16.1	17.3	14.5	2.2	-0.9	-6.7	-8.2
	Date of minimum	31	1	12	13	11	28	2	19	23. 25	28	18	15	31.01
Tyuleniy Isl.	T_{av}, 2024	0.2	2.2	5.1	15.9	17.1	26.0	27.5	26.3	21.4	13.2	7.5	2.8	13.8
	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	0.5	2.4	0.8	4.9	-1.0	2.2	1.2	0.5	0.7	-0.9	0.2	0.8	1.0
	Maximum, 2024	9.4	15.1	15.4	23.9	24.5	34.1	35.0	33.4	29.5	22.4	15.8	9.6	35.0
	Date of maximum	5	10	31	23	31	20	7	4	1	7	2	11	07.07
	Minimum, 2024	-9.0	-2.4	-1.9	6.1	10.3	18.8	17.3	20.1	12.2	5.3	-1.1	-4.3	-9.0
	Date of minimum	25	16	12	2	7	27	2	15	19	27	18	15	25.01

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

Turkmenistan sector

Table 2.1.6 presents the average annual and average seasonal values of the surface air temperature according to the Turkmen stations in 2024. For almost all stations, the average air temperature exceeded their normals, the exception was the summer season at Ogurchinsky station, where the average temperature was below the standard normal.

Table 2.1.6 – Average annual and seasonal air temperature according to the data of observation posts in the Turkmenistan sector in 2024

Observation post*	2024 г.			Winter			Spring			Summer			Autumn		
	Tcp.	vT	*s*	Tcp.	vT	*s*	Tcp.	vT	*s*	Tcp.	vT	*s*	Tcp.	vT	*s*
Turkmenbashi (Krasnovodsk)	18.0	0.9	0.9	6.9	1.3	1.1	17.4	1.7	1.3	29.7	0.6	0.8	18.4	0.5	0.7
Khazar (Cheleken)	16.4	0.6	0.8	5.7	0.9	0.9	15.7	1.4	1.2	27.2	0.1	0.3	17.5	0.5	0.7
Garabogaz (Bekdash)	14.7	0.7	0.8	4.1	1.0	1.0	14.0	1.4	1.2	25.3	0.3	0.5	16.2	1.1	1.0
Guvlymayak (Kuuli Mayak)	15.4	0.7	0.8	6.0	1.1	1.0	14.1	1.3	1.1	25.1	0.0	0	17.1	1.0	1.0
Duzlybogaz (Kara-Bogaz-Gol)	15.4	0.8	0.9	4.9	1.2	1.1	14.6	1.6	1.3	26.4	0.4	0.6	16.3	0.4	0.6
Ogurdzhaly (Ogurchinsky)	16.7	0.7	0.8	7.3	1.3	1.1	15.6	1.7	1.3	26.0	-0.2	0.4	18.5	0.5	0.7

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 (℃)
**data are taken since 1989, as previously the stations belonged to the Azerbaijani Department for Hydrometeorology*

Average monthly temperatures were above their normals for almost the whole year 2024 (Table 2.1.7). The hottest day on the coast of the Turkmen sector was July 9, when the temperature reached +42.0 °C at Turkmenbashi station (Krasnovodsk), and the coldest day was January 25 with -9.6 °C at Garabogaz station (Bekdash).

Table 2.1.7 – 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 2024 in the Turkmenistan sector

Observation post*	Characteristics	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Turkmenbashi (Krasnovodsk)	T_{av}, 2024	5.7	6.8	11.0	20.2	21.1	29.1	29.8	30.2	25.7	17.6	12.0	6.4	18.0
	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	0.7	1.3	1.1	5.0	-0.9	1.8	-0.1	0.0	0.9	-0.4	1.1	0.2	0.9
	Maximum, 2024	15.0	21.6	22.0	32.5	36.5	40.8	42.0	41.2	38.0	32.2	21.6	13.0	42.0
	Date of maximum	01	13	30	20	30	01	09	06	01	02	01	18	09.07
	Minimum, 2024	-4.5	-4.4	2.0	8.8	13.0	18.0	20.4	19.4	16.1	9.0	4.0	-1.4	-4.5
	Date of minimum	15	19	01	01	19	03;27	02	17	28	22	14	15	15.01
Khazar (Cheleken)	T_{av}, 2024	4.6	5.7	9.8	17.7	19.6	26.3	27.2	28.2	24.7	16.9	10.8	5.2	16.4
	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	0.4	0.6	0.5	3.6	-0.1	1.6	-0.7	-0.5	0.7	-0.1	0.9	0.0	0.6
	Maximum, 2024	13.2	23.4	23.0	29.4	36.2	40.4	36.4	37.9	36.8	32.5	20.4	13.4	40.4
	Date of maximum	05	12	30	19	30	01	07	10	02	02	03	24	01.06
	Minimum, 2024	-5.7	-6.7	-1.6	6.8	12.1	18.1	20.4	20.3	14.8	7.2	-0.6	-1.6	-6.7
	Date of minimum	25	18	02	01	19	02	02	18	30	28	15	23	18.02
Garabogaz (Bekdash)	T_{av}, 2024	3.3	3.1	7.3	16.7	18.0	23.8	25.7	26.4	23.4	15.3	9.8	3.6	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	0.8	0.2	0.0	4.4	-0.2	0.8	0.2	-0.2	1.6	0.1	1.5	-0.4	0.7
	Maximum, 2024	12.4	18.8	17.3	31.0	36.2	36.4	36.8	37.2	39.0	27.2	18.8	10.3	39.0
	Date of maximum	07	13	30	19	31	01	26	24	02; 03	08	03	18	02;03.09
	Minimum, 2024	-9.6	-7.4	-2.6	7.9	11.1	15.9	17.9	17.8	15.7	4.6	2.9	-2.8	-9.6
	Date of minimum	25	18	03	01	19	03;28	22	16	19; 30	30	14	14	25.01
Guvlymayak (Kuuli Mayak)	T_{av}, 2024	5.1	5.2	8.5	16.0	17.7	23.8	24.9	26.7	23.7	16.5	11.1	5.8	15.4
	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	0.7	0.6	0.4	3.5	-0.1	1.3	-0.9	-0.5	1.2	0.4	1.3	0.2	0.7
	Maximum, 2024	12.8	16.6	17.5	30.3	35.8	39.4	36.8	39.2	37.8	30.4	20.1	13.1	39.4
	Date of maximum	21	13	30	19	30	01	11	24	02	07	01	18	01.06
	Minimum, 2024	-6.5	-7.1	-1.9	7.3	11.9	15.9	17.5	17.5	13.1	7.7	2.6	-1.0	-7.1
	Date of minimum	15	19	02	02	05	28	04	17	28	23	14	14	19.02
Duzlybogaz (Kara-Bogaz-Gol)	T_{av}, 2024	3.9	4.3	7.9	17.3	18.6	25.0	27.0	27.2	22.9	15.8	10.2	4.5	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	0.8	0.9	0.3	4.6	-0.2	1.1	0.2	-0.1	0.3	-0.1	1.0	0.1	0.8
	Maximum, 2024	12.3	15.8	17.4	29.7	34.4	34.5	38.1	35.7	36.1	27.0	18.9	12.4	38.1
	Date of maximum	01	13	30	19	31	05	06	23	01	08	03	18	06.07
	Minimum, 2024	-7.7	-5.0	0.3	8.2	11.0	16.3	18.0	16.2	15.0	5.9	4.4	-2.7	-7.7
	Date of minimum	15	19	02	05	17	28	02	17	19	28	14; 30	15	15.01

Table 2.1.7 continued

Ogurdzhaly (Ogur-chinsky)	T_{av}, 2024	6.5	6.8	10.1	17.4	19.2	24.5	25.5	27.9	24.8	18.2	12.6	6.8	16.7
	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	1.2	0.9	0.8	3.7	0.7	1.2	-1.5	-0.5	0.6	0.0	1.1	0.0	0.7
	Maximum, 2024	13.4	18.8	20.9	28.1	31.1	33.4	32.2	34.0	33.3	29.3	20.2	13.2	34.0
	Date of maximum	05	14	30	28	30	01;07	07	23	02	07	03	17	23.08
	Minimum, 2024	-1.6	-0.8	2.6	9.3	13.5	18.2	18.6	22.1	18.4	11.4	6.6	1.3	-1.6
	Date of minimum	15	19	01	01	19	31	01;02	17	30	23	14	15	15.01

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 Azerbaijani Department for Hydrometeorology*

2.1.2. Climatological characteristics

Iranian sector

Table 2.1.8 – Absolute maximum/minimum of the monthly average air temperature (°C) recorded in the Iranian sector in 2024

Observation post	Month	Absolute maximum of 2024	Previous maximum and a year of its occurrence	Absolute minimum of 2024	Previous minimum and a year of its occurrence
Amirabad	Jul	27.7	29.7(2018)	6.7(Feb)	3.2(2008)
Anzali	Aug	27.5	28.9(2017)	7.4(Jan)	2.6(1977)
Babolsar	Aug	28.2	29.3(2021)	10.2(Dec)	3.2(1964)
Bandar Gaz	Aug	29.4	32.5(2021)	9.4(Dec)	7.9(2017)
Bandar Torkaman	Aug	28.1	30.3(2014)	9.9(Dec)	3.1(2008)
Dashtenaz	Aug	27.8	29.1(2021)	7.3(Jan)	3.0(2008)
Noshahr	Aug	27.3	28.3(2017)	10.0(Feb)	3.7(2008)
Ramsar	Aug	27.5	28.8(2017)	10.0(Feb)	3.0(1972)

Table 2.1.9 – Records of monthly maximum air temperature (°C) in the Iranian sector in 2024

Observation post	Date	Month	Air temperature, °C	Previous maximum, °C	Date of the previous maximum
Amirabad	2024	Aug	32.3	37.4	2023
Anzali	2024	Aug	31.1	35.2	2023
Babolsar	2024	Aug	31.9	36.2	2023
Bandar Gaz	2024	Aug	34.5	39.2	2023
Bandar Torkaman	2024	Aug	32.7	35.5	2023
Dashtenaz	2024	Aug	32.8	38.0	2023
Noshahr	2024	Aug	30.6	35.2	2023
Ramsar	2024	Aug	30	33.4	2023

Table 2.1.10 – Records of monthly minimum air temperature (°C) in the Iranian sector in 2024

Observation post	Date	Month	Air temperature, °C	Previous minimum, °C	Date of the previous minimum
Amirabad	2024	Dec	4.7	2.1	2023
Anzali	2024	Feb	6.6	0.8	2023
Babolsar	2024	Dec	5.9	4	2023
Bandar Gaz	2024	Dec	3.8	2.0	2023
Bandar Torkaman	2024	Dec	3.6	2.7	2023
Dashtenaz	2024	Dec	2.8	2.4	2023
Noshahr	2024	Feb	6.0	1.4	2023
Ramsar	2024	Feb	6.5	1.5	2023

Table 2.1.11 – Ranks of the warmest years and related anomalies of the annual average air temperature in the Iranian sector in 1961–2024

R	Year	Average annual temperature	Anomaly	Year	Average annual temperature	Anomaly	Year	Average annual temperature	Anomaly
	Anzali			Babolsar			Ramsar		
1	2022	18.0	2.02	2024	18.9	2.42	2024	17.9	2.13
2	2010	17.92	1.92	2010	18.76	2.26	2010	17.92	2.12
3	2024	17.8	1.84	2022	18.5	2.02	2022	17.7	1.88
4	2021	17.79	1.79	2018	18.5	2.00	2018	17.63	1.83
5	2019	17.73	1.73	2023	18.4	1.87	2021	17.56	1.76

Kazakhstan sector

Table 2.1.12 presents the records of the maximum monthly air temperature (°C) observed at the stations in the Caspian region in 2024.

Table 2.1.12 – Maximum of the average monthly air temperature (°C) recorded in the Kazakhstan sector in 2024 and in the previous time since the start of observations

Observation post	Maximum in 2024		Previous maximum		
	average monthly air temperature	month	average monthly air temperature	month	year
Aktau	16.1	April	15.2	April	1986
Ganyushkino	16.5	April	15.8	April	2012
Kulaly island	15.8	April	14.6	April	1975
Fort Shevchenko	16.9	April	16.0	April	1975

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

In April 2024, meteorological stations in Aktau, Ganyushkino, Kulaly island, and Fort Shevchenko recorded new highest average monthly air temperatures, exceeding previously established values: at Aktau – 16.1 °C, the previous value of 15.2 °C was recorded in April 1986; at Ganyushkino – 16.5 °C, previously 15.8 °C in April 2012; at the Kulaly island – 15.8 °C, previously 14.6 °C in April 1975; at the Fort Shevchenko – 16.9 °C, previously 16.0 °C in April 1975. Thus, April 2024 was the warmest at a number of stations on the coast and islands of the Northern and Middle Caspian Sea in the entire observation period, with a record average monthly air temperature.

No records of minimum monthly air temperatures (°C) were observed at observation posts in the Caspian region in 2024.

In 2024, no absolute maximum or minimum daily air temperatures were recorded in the Kazakh sector of the Caspian Sea.

Table 2.1.13 shows the rankings of the warmest years on the Kazakh coast of the Caspian Sea and the corresponding average annual surface air temperatures and their anomalies.

Table 2.1.13 – Ranks of the warmest years and related anomalies of the average annual air temperature in the Kazakhstan sector

R	Year	Average annual tempe-rature	Ano-maly	Year	Average annual tempe-rature	Ano-maly	Year	Average annual tempe-rature	Ano-maly	Year	Average annual tempe-rature	Ano-maly
Station Aktau				Station Atyrau			Station Ganyushkino			Station Kulaly island		
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	2024	11.7	1.4	2010	12.7	0.9
4	2024	13.8	1.1	2010	11.9	1.5	2020	11.6	1.3	2021	12.7	0.9
5	2021	13.8	1.1	2022	11.9	1.5	1995	11.6	1.3	2013	12.7	0.9
Station Kyzan				Station Peshnoy			Station Tushchibek			Station Fort Shevchenko		
1	2023	14.1	2.0	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	2024	14.1	1.3
3	2022	13.6	1.5	1995	11.0	1.4	2010	13.3	1.4	2022	14.0	1.2
4	2024	13.4	1.3	2022	10.9	1.3	2022	13.1	1.2	2004	13.8	1.0
5	2010	13.1	1.0	2024	10.8	1.2	2024	12.9	1.0	2021	13.8	1.0

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

On the Kazakh coast, the five warmest years include various years of the current century, including 2024, and at some stations, 1995 from the last century.

According to observations, 2024 ranked second among the warmest years at the Fort Shevchenko. The average annual temperature was +14.1 °C, and the positive anomaly was +1.3 °C. The greatest excess was observed in 2023, when the temperature reached +14.3 °C (anomaly +1.5 °C).

At the meteorological stations of Aktau, Ganyushkino, Kyzan, Peshnoy and Tushchibek, the year ranked third to fifth among the warmest in the entire observation period, with the anomaly of the average annual temperature ranging from 1.0 to 1.4 °C. At Atyrau and Kulaly island, unlike the other stations, 2024 did not rank among the five warmest years. The warmest years at these meteorological stations remain 2023 and 2004, respectively.

In 2024, the average annual surface air temperature in the Caspian region of the Kazakh sector significantly exceeded the climatic normal (1991–2020) at all observation points, without entering the list of the coldest years for the entire observation period (Table 2.1.14).

A comparative analysis with historical minimums shows a significant excess of temperatures: for example, at the Atyrau MS, the temperature in 2024 was 6.0 °C higher than in the coldest year (1928 – 5.8 °C), and at the Fort Shevchenko MS, the excess was 5.1 °C relative to the minimum value (1911 – 9.0 °C). These data confirm the continuing warming trend and highlight the need for further monitoring of climate change.

Table 2.1.14 – Ranks of the coldest years and related anomalies of the average annual air temperature in the Caspian Sea of the Kazakhstan sector

R	Year	Average annual tempe-rature	Ano-maly	Year	Average annual tempe-rature	Ano-maly	Year	Average annual tempe-rature	Ano-maly	Year	Average annual tempe-rature	Ano-maly
Station Aktau				Station Atyrau			Station Ganyushkino			Station Kulaly island		
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	1942	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	1954	7.7	-2.6	1954	9.4	-2.4
Station Kyzan				Station Peshnoy			Station Tushchibek			Station 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 2.1.15 presents the highest recorded monthly mean air temperatures (°C) across the entire observational period. April 2024 was the warmest April in the history of meteorological observations in the Russian sector of the Caspian Sea. This extreme event was driven by persistent atmospheric circulation patterns dominated by the expansion of ridges and spurs from the Azorean and Asian anticyclones, accompanied by the frequent passage of southern cyclones. These conditions resulted in sustained anomalously high temperatures throughout the month. On the west coast of the Middle Caspian, between 7 and 8 daily maximum temperature records were exceeded, and 15 daily records were surpassed at Tyuleniy Island. The average monthly air temperature ranged from +14.0 °C to +15.9 °C, exceeding the 1991–2020 climatological normal by +3.7 °C to +4.9 °C, the largest April anomaly recorded since observations began.

Table 2.1.15 – Maximum of the average monthly air temperature (°C) recorded in the Russian sector in 2024 and in the previous time since the start of observations

Observation post	Maximum in 2024		Previous maximum		
	average monthly air temperature	month	average monthly air temperature	month	year
Derbent	15.1	April	13.4	April	2012
	25.9	June	25.8	June	2019
Izberg	14.1	April	12.4	April	2012
Makhachkala	14.0	April	12.7	April	2012
	25.1	June	25.08	June	2019
Tyuleniy Isl.	15.9	April	14.0	April	2012

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

In June 2024, two new monthly mean temperature records were set: +25.1 °C at Makhachkala (surpassing the previous record of +25.08 °C in 2019), and +25.9 °C at Derbent (exceeding the prior record of +25.8 °C in 2019). The prevailing synoptic pattern featured strong spurs of the Azores anticyclone, along with the influence of northwestern, western, and southern cyclonic systems, which collectively sustained an elevated temperature regime. Daily maximum temperature records were exceeded on the following dates:

- Makhachkala: 1–2, 7–8, 12–13, 18–19 June;
- Derbent: 3, 7–8, 12–14, 19–20 June.

The overall average monthly temperature in June exceeded the climatological normal by +3.1 °C, reinforcing the exceptional warmth of the season.

The minimum value of the monthly mean air temperature (°C) in 2024 did not exceed the previous minimum.

Table 2.1.16 presents the absolute monthly air temperature maxima (°C) recorded at observation stations in the Russian sector of the Caspian Sea over the entire observational period.

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

Observation post	Absolute maximum in 2024		Previous absolute maximum		
	air temperature	day, month	air temperature	day, month	year
Derbent	21.0	08.02	20.7	19.02	1958
Izberg	17.7	08.02	15.1	29.02	2020

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

Two record-high monthly mean air temperatures were recorded in February:

- at Izberg: +7.7 °C on 08.02, surpassing the previous record of +15.1 °C set in 2020;
- at Derbent: +21.0 °C on 08.02, breaking the prior record of +20.7 °C from 1958.

On 8 October, a new record for the highest monthly mean air temperature was set at Izberg: +28.4 °C, exceeding the previous record of +26.8 °C (established in 2003) by +1.6 °C. On this day, the region was under the influence of a subtropical anticyclone, which contributed to anomalously warm and dry conditions.

No absolute monthly minimum air temperature records were exceeded in the Russian sector of the Caspian Sea in 2024. However, an unusual rise in the monthly minimum air temperature was observed in April. On 3 April, record-high minimum monthly temperatures were recorded at Izberg (+6.7 °C) and Derbent (+7.0 °C). These values constitute absolute records when ranking monthly minimum temperatures from highest to lowest.

Table 2.1.17 presents the rankings of the warmest years in the Russian sector of the Caspian Sea and the corresponding anomalies of annual mean near-surface air temperature.

Table 2.1.17 – Ranks of the warmest years and related anomalies of the average annual air temperature 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	2024	15.3	1.6	2024	14.4	1.5	2023	14.2	1.6	2023	13.9	1.2
2	2023	15.2	1.5	2023	14.4	1.5	2024	14.0	1.5	2020	13.8	1.1
3	2019	15.0	1.3	2010	14.1	1.1	1966	13.9	1.3	2010	13.8	1.1
4	2022	14.9	1.1	2022	13.9	1.0	2010	13.8	1.3	2024	13.8	1.0
5	2020	14.8	1.1	1966	13.9	1.0	2019	13.7	1.2	2019	13.7	0.9

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

The year 2024 did not rank among the five coldest years on record.

Turkmenistan sector

Tables 2.1.18 and 2.1.19 present the highest monthly mean near-surface air temperatures recorded at stations in the Turkmen sector of the Caspian Sea in 2024, compared to the entire observational record.

Compared to the previous period (1989–2022), the maximum monthly mean air temperatures in 2024 were lower, while the minimum monthly mean air temperatures were higher than those observed earlier.

Table 2.1.18 – Maximum of the average monthly air temperature (°C) recorded in the Turkmenistan sector in 2024 and in the previous time since the start of observations

Observation post*	Maximum in 2024		Previous maximum		
	average monthly air temperature	month	average monthly air temperature	month	year
Turkmenbashi (Krasnovodsk)	30.2	08	33.8	07 08	2018 2021
Khazar (Cheleken)	28.2	08	31.6	07	2018
Garabogaz (Bekdash)	26.4	08	30.4	08	2014
Guvlymayak (Kuuli Mayak)	26.7	08	30.0	07 08	2010 2014
Duzlybogaz (Kara-Bogaz-Gol)	27.2	08	30.7	08	2021
Ogurdzhaly (Ogurchinsky)	27.9	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 Azerbaijani Department for Hydrometeorology*

Table 2.1.19 – Minimum of the average monthly air temperature (°C) recorded in the Turkmenistan sector in 2024 and in the previous time since the start of observations

Observation post*	Minimum in 2024		Previous minimum		
	average monthly air temperature	month	average monthly air temperature	month	year
Turkmenbashi (Krasnovodsk)	5.7	01	-1.9	01	2008
Khazar (Cheleken)	4.6	01	-4.1	01	2008
Garabogaz (Bekdash)	3.1	02	-5.4	01	2008
Guvlymayak (Kuuli Mayak)	5.1	01	-3.1	01	2008
Duzlybogaz (Kara-Bogaz-Gol)	3.9	01	-4.2	01	2008
Ogurdzhaly (Ogurchinsky)	6.5	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 Azerbaijani Department for Hydrometeorology*

Tables 2.1.20 and 2.1.21 present the absolute maximum and minimum temperatures for 2024, which did not exceed those recorded during the preceding period (1989–2022).

Table 2.1.20 – Absolute daily maximum air temperature (°C) in the Turkmenistan sector

Observation post*	Absolute maximum in 2024		Previous absolute maximum		
	air temperature	day, month	air temperature	day, month	year
Turkmenbashi (Krasnovodsk)	42.0	09.07	47.0	30.08	2017
Khazar (Cheleken)	40.4	01.06	45.8	21.07	1989
Garabogaz (Bekdash)	39.0	02;03.09	44.2	13.07	2002
Guvlymayak (Kuuli Mayak)	39.4	01.06	44.6	10.08	2006
Duzlybogaz (Kara-Bogaz-Gol)	38.1	06.07	42.6	10.08 01.07	2006 2018
Ogurdzhaly (Ogurchinsky)	34.0	23.08	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 Azerbaijani Department for Hydrometeorology*

Table 2.1.21 – Absolute daily minimum air temperature (°C) in the Turkmenistan sector

Observation post*	Absolute minimum in 2024		Previous absolute minimum		
	air temperature	day, month	air temperature	day, month	year
Turkmenbashi (Krasnovodsk)	-4.5	15.01	-13.6	02.02	2014
Khazar (Cheleken)	-6.7	18.02	-19.9	06.02	2012
Garabogaz (Bekdash)	-9.6	25.01	-16.2	13.01	2008
Guvlymayak (Kuuli Mayak)	-7.1	19.02	-17.2	02.02	2014
Duzlybogaz (Kara-Bogaz-Gol)	-7.7	15.01	-12.8	12.01	2008
Ogurdzhaly (Ogurchinsky)	-1.6	15.01	-8.5	23.11	2016

Note:
- if similar minimum were 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 Azerbaijani Department for Hydrometeorology*

The year 2024 ranked among the five warmest years at the stations of Duzlybagaz (Kara-Bogaz-Gol) and Ogurjaly (Ogurchinsky) (Table 2.1.22).

Table 2.1.22 – Ranks of the warmest years and related anomalies of the average annual air temperature in the Turkmenistan sector*

R	Year	Average annual temperature	Anomaly	Year	Average annual temperature	Anomaly	Year	Average annual temperature	Anomaly
Turkmenbashi				Khazar			Garabogaz		
1	2010	18.5	1.4	2010	17.0	1.2	2010	15.3	1.3
2	2023	18.3	1.2	2015	16.9	1.1	2002	15.3	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	2024	15,4	0.8	2019	16.8	0.8
4	2023	15.5	0.8	2023	15.4	0.8	2024	16.7	0.7
5	2019	15.5	0.8	2021	15.4	0.8	2022	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 Azerbaijani Department for Hydrometeorology*

Table 2.1.23 shows that 2024 did not rank among the five coldest years.

Table 2.1.23 – Ranks of the coldest years and related anomalies of the average annual air temperature in the Turkmenistan sector

R	Year	Average annual temperature	Anomaly	Year	Average annual temperature	Anomaly	Year	Average annual temperature	Anomaly
Turkmenbashi				Khazar			Garabogaz		
1	2011	16.4	-0.7	2003	15.2	-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 Azerbaijani Department for Hydrometeorology*

2.1.3. Trend in the air temperature

Iranian sector

Table 2.1.24 – Estimates of the linear trend of average annual and seasonal air temperatures in the Iranian sector for the period of 1976-2024

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Anzali	2.6	37	2.6	11	2.4	20	3.3	42	2	18
Babolsar	3	64	3	29	3	45	4	59	3	37
Ramsar	2	34	2	18	2	18	3	45	2	23

Notes:
a – the coefficient of the linear trend; D – the coefficient of determination.

Kazakhstan sector

Table 2.1.25 presents estimates of the linear trend in average annual and seasonal air temperatures at observation posts in the Kazakh sector of the Caspian Sea for the period 1976–2024.

According to data from all meteorological stations on the Kazakh coast, there has been an increase in average seasonal temperatures. The rate of increase varies from 0.31 to 0.88 °C/10 years. The temperature increase in all seasons was statistically significant at almost all stations, with the exception of one station (Kulaly island) in the winter period, where the share of the trend component in the total dispersion of the series was about 10 % and above. Mean annual temperatures increased by 0.40–0.64 °C every 10 years, which were statistically significant at the 5 % level. The fastest temperature increase in all seasons (except summer) and year was observed at Atyrau, with the maximum summer warming rate observed at Aktau, reaching to 0.88 °C/10 years.

Table 2.1.25 – Estimates of the linear trend of average annual and seasonal air temperatures in the Kazakhstan sector for the period of 1976-2024

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Aktau	**0,56**	63	**0,44**	12	**0,50**	37	**0,88**	63	**0,39**	17
Atyrau	**0,64**	54	**0,59**	11	**0,67**	30	**0,69**	48	**0,57**	27
Ganyushkino	**0,48**	41	**0,48**	9	**0,49**	25	**0,50**	39	**0,39**	17
Kulaly island	**0,40**	42	0,35	8	**0,42**	23	**0,46**	47	**0,38**	17
Kyzan	**0,58**	59	**0,51**	10	**0,66**	35	**0,56**	41	**0,44**	18
Peshnoy	**0,45**	39	**0,49**	9	**0,57**	27	**0,40**	34	**0,31**	10
Tushchibek	**0,45**	51	**0,43**	13	**0,48**	23	**0,53**	36	**0,36**	13
Fort Shevchenko	**0,53**	59	**0,47**	15	**0,47**	27	**0,65**	55	**0,51**	27

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 2.1.26 presents the linear trend estimates of annual and seasonal mean air temperatures at observation stations in the Russian sector of the Caspian Sea over the period 1976–2024. The linear trend coefficient characterizes the average rate of temperature change over the specified time interval. The year 1976 was selected, somewhat arbitrarily, as the starting point of the modern warming phase, in accordance with the global temperature trend.

Table 2.1.26 – Estimates of the linear trend of average annual and seasonal air temperatures in the Russian sector for the period of 1976-2024

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Derbent	**0.58**	**73**	**0.49**	**31**	**0.55**	**54**	**0.70**	**67**	**0.58**	**41**
Izberg	**0.47**	**60**	**0.45**	**24**	**0.49**	**48**	**0.49**	**44**	**0.43**	**27**
Makhachkala	**0.39**	**38**	**0.40**	**15**	**0.36**	**25**	**0.42**	**33**	**0.37**	**17**
Tyuleniy Isl.	**0.47**	**60**	**0.47**	**19**	**0.42**	**29**	**0.54**	**53**	**0.46**	**30**

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

Between 1976 and 2024, a consistent upward trend in annual mean temperature was observed, with an increase of 0.39–0.58 °C per decade. The rate of rise in seasonal mean temperatures ranged from 0.36 to 0.70 °C per decade. The most pronounced warming continues to occur in the southern part of the Russian coast, particularly at Derbent. The summer season experienced the highest warming rate at 0.70 °C per decade, followed by autumn (0.58 °C/decade), spring (0.55 °C/decade), and winter (0.49 °C/decade). The weakest warming trend was recorded in Makhachkala, where the annual mean temperature increased by 0.39 °C per decade (winter: 0.40 °C/decade; spring: 0.36 °C/decade; summer: 0.42 °C/decade; autumn: 0.37 °C/decade). These trends are statistically significant and confirmed at a high level of confidence ($p < 0.05$).

Turkmenistan sector

As indicators of air temperature change, the linear trend coefficient, which represents the average rate of temperature change from 1989 to 2024, is provided in Table 2.1.27, along with the coefficient of determination, which reflects the proportion of variance in the time series explained by the trend.

Table 2.1.27 – Estimates of the linear trend of average annual and seasonal air temperatures in the Turkmenistan sector for the period of 1976-2024

Observation post*	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Turkmenbashi (Krasnovodsk)	0.55	54.8	0.41	10.4	0.52	31.5	0.95	51.7	0.23	3.8
Khazar (Cheleken)	0.49	45.4	-0.06	0.2	0.58	37.8	0.91	38.7	0.09	0.7
Garabogaz (Bekdash)	0.48	40.7	0.31	3.9	0.51	32.2	0.73	28.9	0.37	8.7
Guvlymayak (Kuuli Mayak)	0.41	38.8	0.24	3.4	0.50	39.5	0.58	22.2	0.22	3.8
Duzlybogaz (Kara-Bogaz-Gol)	0.36	37.0	0.20	1.8	0.42	18.7	0.49	17.7	0.23	4.1
Ogurdzhaly (Ogurchinsky)	0.25	17.5	0.09	0.5	0.49	14.2	0.66	21.5	0.03	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 Azerbaijani Department for Hydrometeorology*

2.2. PRECIPITATION

2.2.1 Precipitation regime in 2024

Iranian sector

Table 2.2.1 – Characteristics of annual and seasonal precipitation in 2024

Observation post	Year		Winter		Spring		Summer		Autumn	
	R	RR	R	RR	R	RR	R	RR	R	RR
Anzali	1928.64	1818.7	756.9	548.1	239.87	212.941	291.09	214.6653	846.2	843.0
Babolsar	847.09	884.9	331.15	294.3	88.21	118.4	73.29	107.3	354.4	364.8
Ramsar	1470.4	1228.7	463.75	285.2	250.8	180.0	128.02	164.9	627.8	598.6

Kazakhstan sector

Table 2.2.2 presents the characteristics of annual and seasonal precipitation in 2024. At Kazakh coastal stations in 2024, the humidity regime was either close to the standard normal or above it. At meteorological stations located in the Middle Caspian, it was humid, with annual precipitation above the normal, amounting to 203.0 mm at Aktau (120.4 % of the normal, rank 18) and 164.9 mm at Fort Shevchenko (131.3 % of the normal, rank 20). Annual precipitation about the standard normal was observed at Ganyushkino, Peshnoy and Atyrau located in the Northern Caspian, as well as at other meteorological stations in the Middle Caspian Sea, where the annual precipitation amounted to 95.0–119.5 % of the normal.

Table 2.2.2 – Annual and seasonal precipitation (mm) in the Caspian Sea of the Kazakhstan sector in 2024

Observation post	Year		Winter		Spring		Summer		Autumn	
	R	RR	R	RR	R	RR	R	RR	R	RR
Aktau	203.0	120.4	47.3	93.3	87.2	189.6	8.7	29.1	54.3	129.3
Atyrau	221.4	119.5	74.3	169.6	70.0	116.7	32.2	84.3	50.7	117.1
Ganyushkino	159.9	106.0	55.8	224.1	43.7	101.2	17.3	38.9	46.4	121.5
Kulaly island	80.6	102.4	7.5	42.6	36.7	132.5	1.1	8.0	32.4	165.3
Kyzan	151.5	95.0	22.7	71.6	72.1	125.2	7.5	19.2	56.8	183.2
Peshnoy	176.7	108.7	61.5	155.3	57.8	109.7	7.9	26.6	52.5	129.3
Tushchibek	201.5	114.0	22.0	57.4	75.8	113.6	19.7	54.4	76.3	214.3
Fort Shevchenko	164.9	131.3	20.7	79.6	74.4	185.1	9.4	35.5	52.4	159.3

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

During the winter season, there was a significant precipitation deficit at meteorological stations in the Middle Caspian region, while the total amount of precipitation for the winter period was above the normal, exceeding the 90th percentile, at meteorological stations in the Northern Caspian. In December 2023, significant excesses of monthly precipitation totals were observed at Aktau (128.9 % of the normal) and Fort Shevchenko (230.5 % of the normal). Precipitation deficits in December were observed at Kyzan and Peshnoy, amounting to 48.3–79.3 % of the normal. In January, precipitation was below the normal along the entire Kazakh coast of the Caspian Sea, ranging from 21.3 % to 77.0 % of the normal, with the exception of Aktau and Atyrau, where it was near normal. The highest amount of precipitation exceeding the normal (127.9 %) was recorded only at the Ganyushkino. In February, the Northern Caspian region was extremely wet, with precipitation exceeding the normal by 3.2– 5.2 times. The greatest amount of precipitation of 517.5 % of the normal (or 32.6 mm, rank 1) was recorded at Ganyushkino. On the contrary, the weather was very dry, with precipitation 2.7–7.8 mm below the long-term average at Fort-Shevchenko, Kyzan, and Kulaly in the Middle Caspian. As a result, in the Kazakh territory of the Caspian Sea, precipitation during the winter period was above the normal (155.3–224.1 %) in the Northern Caspian, while precipitation deficit of 42.6–79.6 % of the normal was observed on the eastern coast of the Middle Caspian, with the exception of Aktau, where precipitation was around the normal.

Precipitation during the spring period was close to or above the normal along practically the entire Kazakh coast of the Caspian Sea, ranging from 101.2 % to 189.6 % of the normal. Excessive precipitation was observed at all meteorological stations in March (174.4–277.3 % of the normal), excluding the mainland stations Kyzan and Tushchibek, where the precipitation was around the normal. April was extremely dry, with a significant precipitation deficit observed across almost the entire Kazakh coast of the Caspian Sea, amounting to 2.6–60.2 % of the normal. It was record dry at the Fort-Shevchenko, with no precipitation throughout the month. In May, most of

the territory of the Kazakh sector of the Caspian Sea received significantly more precipitation than the normal, with 5% and 10% extremes recorded. Seasonal precipitation totaled to 386.5 % of the normal at Aktau in the eastern part of the Middle Caspian Sea, while May was extremely wet (520.2 % of the normal) at Fort-Shevchenko. At Kyzan and Tushchibek, the precipitation exceeded the normal by 2.0–2.5 times. A significant precipitation deficit in May was observed at Ganyushkino, where precipitation amounted to 8.2 mm (47.4 % of the normal).

During the summer months, most of Kazakhstan's Caspian Sea coastline experienced a significant rainfall deficit. The monthly precipitation in June was 34.8–61.4 % of the normal on the Kazakh coast of the Northern Caspian, except for Atyrau, where precipitation was above the normal (122.5 %). On the eastern coast of the Middle Caspian, it was 13.7–79.9% of the normal. A significant deficit of monthly precipitation persisted over the next two months: July and August. Kulaly island experienced record dry conditions, with no precipitation during these months, and no precipitation was observed at Fort-Shevchenko in July. As a result, the Kazakh coast of the Caspian Sea experienced a significant precipitation deficit during the summer, ranging from 8 % to 54.4 % of the normal.

According to the data from stations located on the Kazakh coast of the Caspian Sea, the autumn moisture regime was around and above the normal. Precipitation was above the normal (129.3–214.3 %) along the eastern coast of the Middle Caspian. There was a significant excess of seasonal precipitation totals at 183.2 % of the normal at Kyzan, and the season was extremely wet (214.3 % of the normal, 5 % extremes) at Tushchibek, while the precipitation was around the normal (117.1 % of the normal) at Atyrau on the eastern coast of the Northern Caspian.

In September, there was a significant precipitation deficit at all stations, amounting to 13.1–35.9 % of the normal. At Ganyushkino, Kulaly, Fort-Shevchenko, there was no precipitation throughout the month.

Practically at all stations in October and November, there was a significant excess of precipitation, amounting to 123.0–340.0 % of the normal.

In October, there was an uneven distribution of precipitation, with extremely wet conditions at Tushchibek (5 % extremes) and a significant precipitation deficit at Peshnoy.

In November, station Peshnoy received the greatest amount of precipitation (39.4 mm), which amounted to 251.0 % of the normal.

Table 2.2.3 presents monthly and annual precipitation amounts (mm), the ratio of the current value to the normal (%), and the maximum daily precipitation (mm) for a month and a year according to data from observation posts on the Kazakhstan coast of the Caspian region in 2024.

Table 2.2.3 – 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 2024 in the Kazakhstan sector

Observation post	Characteristics	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Aktau	T_{av}, 2024	14.6	11.0	34.8	1.0	51.4	1.6	6.4	0.7	1.4	26.2	26.7	27.2	203.0
	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	83.0	91.7	230.5	5.7	386.5	13.7	63.4	8.6	19.7	198.5	123.0	128.9	120.4
	Maximum, 2024	5.8	5	15.9	1	19.4	1.6	5.8	0.7	0.9	8.6	6.8	13.5	19.4
	Date of maximum	28.01	17.02	20.03	04.04	08.05	27.06	27.07	15.08	21.09	03.10	29.11	29.12	08.05
Atyrau	T_{av}, 2024	15.3	39.0	27.2	10.0	32.8	20.7	7.8	3.7	2.2	16.2	32.3	14.2	221.4
	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	95.6	325.0	174.4	60.2	118.0	122.5	67.2	38.1	24.4	88.5	201.9	89.9	119.5
	Maximum, 2024	3.5	14	12.7	9.6	31	10.9	6.7	2.3	2.2	20.8	7.2	5.1	31
	Date of maximum	13.01	06.02	26.03	23.04	08.05	26.06	24.07	14.08	24.09	07.10	21.11	17.12	08.05
Ganyushkino	T_{av}, 2024	11.0	32.6	30.5	5.0	8.2	10.8	4.0	2.5	0.0	19.0	27.4	8.9	159.9
	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	127.9	517.5	277.3	33.6	47.4	61.4	25.5	22.3	0.0	149.6	256.1	89.0	106.0
	Maximum, 2024	5.4	13.4	23.6	4.1	8.2	5.7	4	1.7	0	7	17.4	3.8	23.6
	Date of maximum	09.01	10.02	26.03	14.04	08.05	01.06	07.07	12.08	01.09	28.10	21.11	28.12	26.03
Kulaly island	T_{av}, 2024	1.3	1.4	14.0	2.4	20.3	1.1	0.0	0.0	0.0	15.3	17.1	7.7	80.6
	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	21.3	34.1	177.2	21.2	238.8	22.4	0.0	0.0	0.0	340.0	156.9	104.1	102.4
	Maximum, 2024	1.3	1.4	3.4	1.3	7	1.1	0	0	0	5.7	6.9	3.1	7
	Date of maximum	09.01	07.02	20.03	04.04	08.05	26.06	01.07	01.08	01.09	18.10	05.11	29.12	08.05
Kyzan	T_{av}, 2024	8.7	0.6	14.2	1.2	56.7	6.4	0.6	0.5	0.8	24.0	32.0	5.8	151.5
	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	77.0	7.1	86.1	6.5	252.0	34.4	4.7	6.4	13.1	222.2	227.0	48.3	95.0
	Maximum, 2024	5.8	0.6	4.7	0.7	27.7	4.2	0.6	0.5	0.5	8.8	6.9	2	27.7
	Date of maximum	10.01	21.02	26.03	14.04	08.05	27.06	22.07	15.08	23.09	19.10	17.11	18.12	08.05
Peshnoy	T_{av}, 2024	11.0	36.0	29.7	0.4	27.7	4.6	1.3	2.0	0.0	13.1	39.4	11.5	176.7
	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	74.8	346.2	212.1	2.6	119.4	34.8	16.5	23.3	0.0	78.4	251.0	79.3	108.7
	Maximum, 2024	3.2	12	12.2	0.4	26.1	3.4	1.3	1.7	0	17.3	6.1	5.1	26.1
	Date of maximum	09.01	06.02	26.03	15.04	08.05	28.06	24.07	08.08	01.09	07.10	17.11	17.12	08.05
Tushchibek	T_{av}, 2024	5.4	8.4	15.0	1.2	59.6	12.7	1.8	5.2	2.8	34.8	38.7	15.9	201.5
	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	39.1	100.0	92.6	5.7	202.0	79.9	14.8	64.2	35.9	300.0	238.9	98.8	114.0
	Maximum, 2024	1.4	3.7	5.8	1.2	20.6	6.3	1	5.2	1.8	9.2	9	7.6	20.6
	Date of maximum	13.01	17.02	20.03	05.04	18.05	18.06	21.07	16.08	23.09	18.10	07.11	18.12	18.05
Fort Shevchenko	T_{av}, 2024	6.6	0.2	20.3	0.0	54.1	8.9	0.0	0.5	0.0	26.2	26.2	21.9	164.9
	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	70.2	2.8	181.3	0.0	520.2	106.0	0.0	6.2	0.0	270.1	213.0	230.5	131.3
	Maximum, 2024	2.6	0.2	7.2	0	26.9	8.9	0	0.5	0	8.7	9.8	16.8	26.9
	Date of maximum	10.01	20.02	21.03	01.04	08.05	26.06	01.07	08.08	01.09	03.10	05.11	29.12	08.05

Note: *If the same maximum (daily) value was observed multiple times during the month or year, all corresponding dates are indicated.*

In 2024, annual precipitation ranged from 80.6 mm at Kulaly to 221.4 mm at Atyrau. The greatest excess of the climatic normal was recorded at Fort-Shevchenko – 131.3 % of the normal, with months with extremely high values standing out in particular: May (520.2 % of the normal) and October (270 % of the normal). Several observation stations recorded monthly precipitation exceeding the average values by more than 3–5 times: at Ganyushkino MS in February – 517.5 %, at Kulaly MS in October – 340.0 %. The maximum daily precipitation also showed significant fluctuations. The absolute maximum was recorded at Atyrau – 31.0 mm (May 8), while at other meteorological stations the extremes were less pronounced but still exceeded 20 mm, except for Aktau (19.4 mm, May 8) and Kulaly (7 mm, May 8). In most cases, the maximum amount of precipitation fell in winter, spring and autumn. Despite local exceedances of the normal, a number of stations showed a precipitation deficit relative to the climatic normal. In particular, there was no or extremely low precipitation at Kulaly and Fort-Shevchenko in specific months, especially in the spring and summer-autumn months.

Russian sector

Table 2.2.4 presents the characteristics of annual and seasonal precipitation totals for 2024.

Table 2.2.4 – Annual and seasonal precipitation in the Russian sector in 2024

Observation post	Year		Winter		Spring		Summer		Autumn	
	R	RR	R	RR	R	RR	R	RR	R	RR
Derbent	462.9	114	164.3	149	113.6	179	73.0	110	188.6	114
Izberg	323.8	111	130.5	187	70.8	131	54.7	98	116.7	108
Makhachkala	365.7	98	145.0	147	76.2	104	83.0	110	98.8	79
Tyuleniy Isl.	183.4	93	61.6	151	48.0	83	10.7	22	72.9	140

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

According to the data from stations located in the Russian sector of the Caspian Sea, precipitation during the year was distributed unevenly. In the western coastal zone of the Middle Caspian, precipitation totaled between 323.8 and 462.9 mm (98–114% of the normal). On Tyuleniy Island, situated in the northwestern part of the sea, the annual precipitation amounted to only 183.4 mm (93% of the normal).

Seasonal precipitation analysis revealed even more pronounced contrasts. Winter was anomalously wet, with precipitation reaching 147–187% of the normal (rank 4–8; at Makhachkala, rank 25). Spring was also rainy: precipitation totals in Izberbash and Derbent reached 131% and 179% of the normal (ranks 14 and 8, respectively). In contrast, autumn in Makhachkala was anomalously dry, with precipitation amounting to only 79% of the normal (rank 41 since 1882). On Tyuleniy Island, autumn and winter were anomalously wet (140% and 151% of the normal,

ranks 11 and 8, respectively), whereas summer was anomalously dry, with precipitation reaching just 22% of the seasonal normal (rank 6). Precipitation deficit was also observed on the Tyuleniy Island in spring, with only 83% of the normal recorded (rank 25).

Table 2.2.5 provides summary data on monthly and annual precipitation totals, the ratio of the current value to the normal (%), as well as the maximum daily precipitation for each month and for the year, along with corresponding dates.

Table 2.2.5 – 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 2024 in the Russian sector

Observation post	Characteristics	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Derbent	Total, 2023	6.4	34.2	68.6	2.8	42.2	36.1	27.8	9.1	27.1	87.4	74.1	47.1	462.9
	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	20	97	288	15	204	202	114	37	55	146	133	103	114
	Maximum, 2023	3.0	8.1	15.4	2.2	16.0	15.1	17.8	3.4	20.7	25.4	22.2	9.4	25.4
	Date of maximum	13	17	19	15	13	26	27	15	26	3	12	4	03.10
Izberg	Minimum, 2023	1.1	31.3	55.7	1.4	13.7	21.3	25.5	7.9	19.9	50.2	46.6	49.2	323.8
	Date of minimum	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
	Total, 2023	5	160	336	9	63	111	182	36	54	140	134	172	111
	Standard normal, 1991–2020	0.8	10.1	17.2	0.4	9.3	7.8	17.3	5.5	12.7	16.4	16.2	16.7	17.3
	Anomalies	23	18	20	11.15	17	22	28	25	26	3	27	4	28.07
Makhachkala	Maximum, 2023	9.3	40.0	56.5	2.0	17.7	42.5	17.9	22.6	26.0	34.0	38.8	58.4	365.7
	Date of maximum	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
	Minimum, 2023	26	146	262	11	53	161	86	80	57	91	92	157	98
	Date of minimum	3.9	16.6	17.3	1.4	5.3	18.6	10.2	10.2	13.0	13.3	19.6	15.5	19.6
	Total, 2023	23	7	20	11	17	26	27	13	26	3	12	4	12.11
Tyuleniy Isl.	Standard normal, 1991–2020	19.4	8.5	35.6	1.0	11.4	5.1	0.4	5.2	0.5	50.2	22.2	23.9	183.4
	Anomalies	14.0	11.2	14.6	21.5	21.7	15.9	14.5	17.7	14.4	21.2	16.5	p	198.9
	Maximum, 2023	138	76	244	5	52	32	3	29	3	237	135	152	92
	Date of maximum	5.9	2.8	11.9	0.7	8.1	2.6	0.4	4.9	0.5	16.0	13.1	14.8	16.0
	Minimum, 2023	28	7	25	4	5	26	3	6	5	18	27	18	18.10

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

Turkmenistan sector

Table 2.2.6 shows that total precipitation in 2024 did not exceed the 1991–2020 normal. However, precipitation exceeded the normal at the Turkmenbashi (Krasnovodsk) during the autumn season; precipitation also exceeded the normal at the Khazar (Cheleken), Guvlymayak (Kuuli-Mayak), Duzlybogaz (Kara-Bogaz-Gol), and Ogurdzhaly (Ogurchinskiy) in the summer season; and precipitation was higher than the normal at Garabogaz (Bekdash) and Ogurdzhaly (Ogurchinskiy) in the spring season.

Table 2.2.6 – Annual and seasonal precipitation in the Turkmenistan sector in 2024

Observation post*	Year		Winter		Spring		Summer		Autumn	
	R	RR	R	RR	R	RR	R	RR	R	RR
Turkmenbashi (Krasnovodsk)	105.9	75	21.6	45	14.3	30	8.9	89	56.8	**154**
Khazar (Cheleken)	59.4	56	6.9	21	26.3	71	11.0	**220**	14.7	46
Garabogaz (Bekdash)	100.3	95	19.9	49	38.8	**105**	5.9	84	21.6	98
Guvlymayak (Kuuli Mayak)	95.0	73	17.2	39	17.4	39	5.0	**100**	36.1	98
Duzlybogaz (Kara-Bogaz-Gol)	52.1	69	13.8	51	5.3	20	17.6	**440**	8.9	52
Ogurdzhaly (Ogurchinsky)	78.6	80	0.0	0	33.1	**107**	24.7	**412**	16.6	61

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 since 1989, as previously the stations belonged to the Azerbaijani Department for Hydrometeorology*

Table 2.2.7 presents data on monthly and annual precipitation totals. In Turkmenistan, the majority of precipitation typically falls during the spring season. Overall, 2024 precipitation totals did not exceed the annual normal, although precipitation exceeding the monthly normal was recorded in certain months. Precipitation used to be nearly absent during the summer period; therefore, any rainfall recorded during this time represented a daily maximum. In 2024, rainfall was observed in almost every summer month, while precipitation was recorded only at Turkmenbashi (Krasnovodsk) and Khazar (Cheleken) in September.

Table 2.2.7 – 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 2024 in the Turkmenistan sector

Observation post*	Characteristics	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Turkmen-bashi (Krasno-vodsk)	Total, 2023	12.3	3.5	10.0	0.0	4.3	3.5	0.4	5.0	0.0	30.3	26.5	10.1	105.9
	Standard normal, 1991–2020	16	17	19	20	8	3	3	4	6	11	20	15	142
	Anomalies	77	21	53	0	54	**117**	13	**125**	0	**275**	**133**	67	75
	Maximum, 2023	4.8	2.2	10.0	0.0	2.8	2.9	0.4	3.7	0.0	14.6	10.2	9.2	14.6
	Date of maximum	14	24	20	07;11;13	14	15	25	17	21	20	28	14	20.10
Khazar (Cheleken)	Minimum, 2023	4.4	2.5	6.9	10.0	9.4	0.0	10.6	0.4	0.0	5.0	9.7	0.5	59.4
	Date of minimum	11	10	15	16	6	2	1	1	5	10	17	12	106
	Total, 2023	40	25	46	63	**157**	0	**1060**	40	0	50	57	4	56
	Standard normal, 1991–2020	2.3	2.5	5.3	10.0	5.5	0.0	10.2	0.4	0.0	3.2	4.8	0.5	10.2
	Anomalies	10	24	20	11	14	02;15	29	13	21	20	28	15	29.07
Garabogaz (Bekdash)	Maximum, 2023	7.0	10.8	36.7	0.0	2.1	4.5	0.7	0.7		9.9	11.7	16.2	100.3
	Date of maximum	13	12	12	17	8	4	3	1	3	6	13	16	106
	Minimum, 2023	54	90	**306**	0	26	**113**	23	70		**165**	90	**101**	95
	Date of minimum	4.7	5.5	32.6	0.0	0.9	3.8	0.3	0.4		9.5	6.7	8.4	32.6
	Total, 2023	28	17	20	07	04	27	22	12		26	29	14	20.03
Guvly-mayak (Kuuli Mayak)	Total, 2023	11.9	5.0	10.1	0.0	7.3	1.4	1.0	2.6		14.3	21.8	19.6	95.0
	Standard normal, 1991–2020	15	14	16	20	9	2	3	1	6	13	19	15	130
	Anomalies	79	36	63	0	81	70	33	**260**		**110**	**115**	**131**	73
	Maximum, 2023	2.7	3.9	8.6	0.0	5.3	0.7	1.0	1.3		8.1	10.4	15.1	15.1
	Date of maximum	13;24	24	20	07;11	17	15;27	25	13;17		20	28	14	14.12

Table 2.2.7 continued

Duzlybogaz (Kara-Bogaz-Gol)	Minimum, 2023	3.7	8.0	3.1		2.2	2.8		14.8		1.7	7.2	8.6	52.1
	Date of minimum	9	10	11	11	5	2	2	1	1	6	9	8	75
	Total, 2023	41	80	28		44	**140**		**1480**		28	80	**108**	69
	Standard normal, 1991–2020	2.0	3.8	2.2		1.9	2.4		14.8		1.7	2.8	4.5	14.8
	Anomalies	28	24	20		04	27		16		26	29	13	16.08
Ogurdzhaly (Ogurchin-sky)	Maximum, 2023		0.0	6.5	21.5	5.1	1.3	22.7	0.7		0.9	15.7	4.2	78.6
	Date of maximum	10	10	13	14	5	3	2	1	4	8	15	14	98
	Minimum, 2023		0	50	**154**	**102**	43	**1135**	70		11	**105**	30	80
	Date of minimum		0.0	6.5	14.1	4.3	1.3	22.7	0.7		0.9	11.1	4.2	22.7
	Total, 2023		25	20	11	14	15	29	13		14	30	14	29.07

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 Azerbaijani Department for Hydrometeorology*

2.2.2. Climatological characteristics

Iranian sector

Table 2.2.8 – Absolute maximum/minimum of precipitation (mm) recorded in the Caspian Sea region in 2024 (year)

Observation post	Absolute maximum of 2024		Previous maximum		Absolute minimum of 2024		Previous minimum	
	value	date	value	date	value	date	value	date
Amirabad	93.71	Feb	232.31	Oct	14	Aug	3.9	Jan
Anzali	407.62	Oct	231.71	Jan	15.22	Aug	17.13	Jun
Babolsar	175.11	Feb	199.6	Oct	3.72	Mar	14	Mar
Bandar Gaz	80.51	Feb	117.7	May	8	Aug	3.4	Jan
Bandar Torkaman	86.02	Feb	163.41	May	5.81	Jul	0.3	Aug
Dashtenaz	109.9	Feb	144.81	Oct	15.81	Jul	2.42	Jan
Noshahr	340.41	Oct	297.21	Oct	13.4	Aug	35.6	Aug
Ramsar	294.7	Nov	225.11	Dec	21.61	Aug	18.71	Aug

Kazakhstan sector

Table 2.2.9 shows the maximum monthly precipitation (mm) recorded at observation posts on the Kazakh coast of the Caspian region in 2024. According to the data from Ganyushkino, 32.6 mm of precipitation (517.5 % of the normal) fell in February 2024, which is a record since 1961; the previous maximum was observed in 1985 and amounted to 28.8 mm.

Table 2.2.9 – Maximum of the monthly precipitation (mm) recorded in the Kazakhstan sector in 2024 and in the previous time since the start of observations

Observation post	Maximum in 2024		Previous maximum		
	precipitation	month	precipitation	month	precipitation
Ganyushkino	32.6	February	28.8	February	1985

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

On the territory of the Kazakhstan part of the Caspian Sea in 2024 records of the minimum monthly amount and absolute maximum daily amount of precipitation were not observed.

Table 2.2.10 presents the ranks of the wettest years at meteorological stations in the Caspian Sea region, as well as the corresponding annual precipitation amounts (R, mm) and their ratio to the 1991–2020 normal (RR, %).

At the Caspian Sea coast, the top 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 data from the meteorological stations of Aktau, Atyrau, Kyzan, Peshnoy and Tushchibek, 2016 was one of the wettest years since the beginning of regular instrumental observations, with the ratio of annual precipitation to the normal ranging from 247.0 to 337.0 mm. According to data from the Tuschibek meteorological station, 1991 ranks first with an annual precipitation of 382.3 mm (216,2 % of the normal).

Table 2.2.10 – 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 island		
1	1981	305.0	180.9	2016	337.0	181.9	1958	304.3	201.8	1963	311.2	395.4
2	2016	302.2	179.2	1953	302.8	163.4	1954	298.7	198.1	1965	304.9	387.4
3	1991	266.6	158.1	1941	274.6	148.2	2013	284.6	188.7	1981	283.2	359.8
4	2003	243.1	144.2	1958	271.8	146.7	1960	283.4	187.9	1969	218.1	277.1
5	1988	237.7	141.0	2015	268.3	144.8	1957	274.8	182.2	1987	205.8	261.5
Kyzan				Peshnoy			Tushchibek			Fort-Shevchenko		
1	2000	270.2	169.5	2016	305.9	188.1	1991	382.3	216.2	1965	293.2	233.4
2	2016	247.0	155.0	1953	276.0	169.7	1981	333.6	188.7	1941	246.0	195.9
3	2005	241.2	151.3	1958	272.6	167.7	2016	317.6	179.6	1981	237.9	189.4
4	2003	232.3	145.7	2003	272.3	167.5	1963	271.0	153.3	1988	225.7	179.7
5	1965	231.3	145.1	2000	261.3	160.7	2011	265.7	150.3	1992	206.4	164.3

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

Table 2.2.11 presents the ranks of the driest years at meteorological stations in the Caspian region, as well as the corresponding annual precipitation amounts (R, mm) and their ratio to the 1991– 2020 normal (RR, %). On the Caspian Sea coast, the top five driest years included various years of the last and current century. According to the data of meteorological stations Kulaly island and Kyzan, the five driest years included mainly the years of the XXI century. At Peshnoy – 2018 with 62.5 mm (38,4 % of the normal), at Fort-Shevchenko – 2021 with 42.6 mm (29.9 % of the normal) and Kyzan – 2021 with 50.1 mm (31.4 % of the normal) are ranked first among the driest years.

Table 2.2.11 – Ranks of the driest years and related anomalies of the precipitation in the Caspian Sea of the Kazakhstan sector

Rank	Year	R	RR	Year	R	RR	Year	R	RR	Year	R	RR
Aktau				Atyrau			Ganyushkino			Kulaly island		
1	1996	82.4	48.9	1984	72.8	39.3	1972	57.5	38.1	2018	32.9	41.8
2	1987	95.8	56.8	1968	79.5	42.9	1984	58.9	39.1	2010	37.7	47.9
3	1984	101.3	60.1	1972	83.2	44.9	1944	66.1	43.8	2021	39.0	49.6
4	1968	108.0	64.1	2018	97.3	52.5	1943	77.9	51.7	2020	39.9	50.7
5	1974	109.4	64.9	1975	106.4	57.4	2000	83.1	55.1	2007	45.6	57.9
Kyzan				Peshnoy			Tushchibek			Fort-Shevchenko		
1	2021	50.1	31.4	2018	62.5	38.4	1968	85.2	48.2	2021	42.6	33.9
2	1972	63.2	39.6	1943	64.6	39.7	2021	94.0	53.2	1942	54.0	43.0
3	2014	78.7	49.4	1968	68.6	42.2	1996	97.5	55.1	1949	56.0	44.6
4	2018	83.8	52.6	1972	69.0	42.4	1986	98.5	55.7	1994	69.6	55.4
5	1996	86.8	54.5	2021	77.1	47.4	1966	100.0	56.6	1986	70.7	56.3

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

Russian sector

Table 2.2.12 presents the maximum monthly precipitation totals (in mm) recorded at observation stations in the Russian sector of the Caspian Sea over the entire observation period. March 2024 in Izberg became the wettest on record for the entire observational period. Weather conditions were primarily influenced by troughs associated with southern and Mediterranean cyclones, which brought abundant precipitation. A total of 55.7 mm of precipitation fell during the month (336% of the normal), surpassing the previous record in March 2022 (54.2 mm).

Table 2.2.12 – Maximum of the monthly precipitation (mm) recorded in the Russian sector in 2024 and in the previous time since the start of observations

Observation post	Maximum in 2024		Previous maximum		
	precipitation	month	precipitation	month	year
Izberg	55.7	March	54.2	March	2022

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

In 2024, monthly precipitation totals did not reach the lowest values previously recorded. A similar pattern was observed for daily precipitation: the record-high daily values established in earlier years were not surpassed in 2024. The year 2024 did not rank among the five wettest or the five driest years on record.

Turkmenistan sector

Table 2.2.13 shows that, the maximum monthly precipitation totals recorded at stations in the Turkmen sector in 2024 were lower compared to the previous period (1989–2022). The

minimum monthly precipitation totals observed at Turkmenistan stations in 2024 did not fall below the lowest values recorded earlier.

Table 2.2.13 – Maximum of the monthly precipitation (mm) recorded in the Turkmenistan sector in 2024 and in the previous time since the start of observations

Observation post*	Maximum in 2024		Previous maximum		
	precipitation	month	precipitation	month	year
Turkmenbashi (Krasnovodsk)	30.3	10	95.9	4	2003
Khazar (Cheleken)	10.6	7	64.9	4	2003
Garabogaz (Bekdash)	36.7	3	66.8	4	2003
Guvlymayak (Kuuli Mayak)	21.8	11	76.2	4	2003
Duzlybogaz (Kara-Bogaz-Gol)	14.8	8	48.4	11	1993
Ogurdzhaly (Ogurchinsky)	22.7	7	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 since 1989, as previously the stations belonged to the Azerbaijani Department for Hydrometeorology*

Table 2.2.14 demonstrates that the absolute maximum daily precipitation amount in 2024 did not exceed the previous absolute maximum recorded between 1989 and 2022.

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

Observation post	Absolute maximum in 2024		Previous absolute maximum		
	precipitation	day, month	precipitation	day, month	year
Turkmenbashi (Krasnovodsk)	14.6	20.10	50.6	28.04	2003
Khazar (Cheleken)	10.2	29.07	44.0	17.04	2004
Garabogaz (Bekdash)	32.6	20.03	39.5	23.05	1991
Guvlymayak (Kuuli Mayak)	15.1	14.12	40.2	23.03	2015
Duzlybogaz (Kara-Bogaz-Gol)	14.8	16.08	29.5	07.01	2000
Ogurdzhaly (Ogurchinsky)	22.7	29.07	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 since 1989, as previously the stations belonged to the Azerbaijani Department for Hydrometeorology*

Furthermore, 2024 did not appear among the five wettest years on record (Table 2.2.15).

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

Table 2.2.15 continued

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 since 1989, as previously the stations belonged to the Azerbaijani Department for Hydrometeorology*

Over the entire Turkmenistan sector, 2024 was ranked as one of the five driest years only at the Khazar (Cheleken) station (Table 2.2.16).

Table 2.2.16 – Ranks of the driest years and related anomalies of the precipitation in the Turkmenistan 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	2024	59.4	56	2021	44.5	42
5	2013	94.1	66	2014	64.2	61	2018	46.2	44
Guvlymayak				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 since 1989, as previously the stations belonged to the Azerbaijani Department for Hydrometeorology*

2.2.3 Trends in the precipitation

Iranian sector

Table 2.2.17 – Estimates of the linear trend of annual and seasonal precipitation in the Caspian Sea of the Iranian sector for the period 1976–2024

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Anzali	-65	0	-76	0	-57	2	42	0	25	0
Babolsar	45	0	-14	0	-33	1.2	-18	0	111	2
Ramsar	108	0	0	10^{-6}	47	2	-47	1	107	0

Notes:
a – the coefficient of the linear trend; D – the coefficient of determination.

Kazakhstan sector

Table 2.2.18 presents estimates of the linear trend of annual and seasonal precipitation amounts at observation stations located in the Kazakhstan sector of the Caspian Sea for the period 1976–2024.

Table 2.2.18 – Estimates of the linear trend of annual and seasonal precipitation in the Caspian Sea of the Kazakhstan sector for the period 1976–2024

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Aktau	-1.4	0	0.4	0	0.6	0	-1.3	3	-1.8	3
Atyrau	**11.6**	18	**5.6**	6	**1.7**	6	2.4	10	2.5	9
Ganyushkino	-4.1	1	0.9	2	-0.5	2	**1.1**	5	1.9	8
Kyzan	-8.6	1	-0.9	0	-0.1	0	-0.9	3	-0.2	0
Peshnoy	8.6	3	2.2	1	**0.9**	1	0.9	1	2.8	12
Tushchibek	-2.8	3	2.2	4	1.2	4	-0.2	0	-2.5	5
Fort-Shevchenko	-5.8	2	1.2	7	1.4	7	-0.1	0	-0.6	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

In Kazakhstan, there has been a slight decrease in seasonal precipitation, but statistically insignificant. The rate of change in annual precipitation totals across Kazakhstan's Caspian Sea coast varies from -8.6 to 11.6 mm/10 years. Annual precipitation totals with statistical significance at the 5 % level have increased only on the eastern part of Kazakhstan's Northern Caspian coast. In winter, there is mainly a statistically insignificant increase in precipitation in the eastern part of the Northern and Middle Caspian Sea by 0.4–5.6 mm/10 years, with the exception of Atyrau station, where a statistically significant precipitation increase of 5.6 mm/10 years at the 5 % level has been recorded. In spring, the statistically significant increase in precipitation of 0.9–1.7 mm/10 years has been observed at Peshnoy and Atyrau meteorological stations in the Northern Caspian. At the same time, the statistically insignificant decrease in precipitation of 0.6–1.4 mm/10 years has been recorded on the eastern coast of the Middle Caspian. In the summer and autumn periods, the Kazakh coast of the Caspian Sea has faced the statistically insignificant decrease in precipitation, with the exception of the Ganyushkino, where the statistically significant increase in precipitation of 1.1 mm/10 years was recorded in 2024. In addition, the statistically insignificant decrease in precipitation of 1.8–2.5 mm/10 years has been observed at Tushchibek and Aktau in the summer and autumn seasons, respectively.

Russian sector

Table 2.2.19 presents estimates of the linear trends in annual and seasonal precipitation totals at observation stations located in the Russian sector of the Caspian Sea for the period 1976–2024. From 1976 to 2024, a noticeable increase in annual precipitation has been observed along the western coast of the Middle Caspian. The rate of this increase ranges from 6.3 to 16.3 mm per decade, with the strongest trend recorded in Derbent. In both Derbent and Izberg, these changes are statistically significant at the 5% level, accounting for 6% and 11% of the total variance, respectively. Makhachkala also shows a positive trend, although it does not reach statistical

significance. In contrast, a statistically significant (at 5% level) decreasing trend in precipitation has been observed at Tyuleniy Island.

Table 2.2.19 – Estimates of the linear trend of annual and seasonal precipitation in the Russian sector for the period 1976–2024

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Derbent	**16.3**	**6**	**7.6**	**6**	-0.2	0	-1.6	1	**11.2**	**5**
Izberg	**13.6**	**11**	**5.7**	**5**	1.0	0	-1.5	1	**11.7**	**8**
Makhachkala	6.3	1	**6.6**	**5**	1.1	0	-4.2	3	2.9	0
Tyuleniy Isl.	**-6.2**	**4**	1.5	2	-3.2	3	-2.5	2	-2.8	2

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

Seasonal analysis reveals that winter precipitation is increasing, particularly along the coastal zone of the Middle Caspian, where the rise amounts to 5.7–7.6 mm per decade, explaining 5–6% of the variance. This linear trend is also statistically significant at the 5% level. In spring, precipitation trends show varying directions across the region. Summer, however, exhibits a general decline in precipitation throughout the entire area. Conversely, autumn shows an overall increase in precipitation, especially in the stretch between Derbent and Izberg, where the increase ranges from 11.2 to 11.7 mm per decade, contributing 5–8% to the variance. This autumn trend is likewise statistically significant at the 5% level.

Turkmenistan sector

Table 2.2.20 – Estimates of the linear trend of annual and seasonal precipitation in the Turkmenistan sector for the period 1976–2024

Observation post*	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Turkmenbashi (Krasnovodsk)	-19.86	22.9	-5.69	7.7	-5.41	4.1	-3.82	13.2	-5.17	6.0
Khazar (Cheleken)	-24.42	43.0	-8.31	19.1	-6.38	9.8	-1.27	4.1	-7.24	18.5
Garabogaz (Bekdash)	-13.55	8.7	-4.55	3.8	-2.75	1.3	-0.47	0.4	-4.09	6.6
Guvlymayak (Kuuli Mayak)	-12.46	9.3	-8.21	25.9	-4.14	2.2	1.10	3.1	-1.78	0.8
Duzlybogaz (Kara-Bogaz-Gol)	-29.66	50.1	-9.24	29.2	-10.30	29.1	-1.18	2.7	-6.97	24.5
Ogurdzhaly (Ogurchinsky)	-6.06	3.1	-2.53	1.8	-0.50	0.1	0.30	0.2	-1.62	0.8

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 Azerbaijani Department for Hydrometeorology*

3. HYDROLOGICAL CONDITIONS

3.1. RIVER FLOW INTO THE CASPIAN SEA

3.1.1 The Volga River

In 2024, the annual runoff of the Volga River, according to data at the Verkhnelebyazhye station (top of the Volga delta), amounted to 210.589 km³. This is significantly below the 1991–2020 climatic normal of 247.032 km³. The spring flood began on April 12, which is one week earlier than normal. The flood peak occurred unusually early, between April 28 and 30 (the normal is May 14), with reduced maximum discharge of 17,000 m³/s compared to the normal of 21,203 m³/s. Under natural (unregulated) flow conditions (1942–1955), the maximum discharge typically occurred in early June (June 4 on average), and the mean peak of the river discharge was 25,236 m³/s. The spring flood ended significantly earlier than normal, on June 20. During the 1991–2020 period, the average flood end date was July 1, whereas under natural, unregulated flow conditions, the flood used to end on August 5. The longest flood on record lasted till August 27, 1946.

The 2024 flood duration was 70 days, four days shorter than the normal. During the period of natural flow, this duration used to reach 109 days. The longest flood in the entire observation period occurred in 1946, lasting 137 days. The flood discharge volume in 2024 amounted to 74.025 km³, substantially below the climatic normal (94.520 km³) and far lower than the 147.144 km³ observed under natural flow conditions. The most water-abundant flood on record occurred in 1947, when its runoff reached a record high of 225.099 km³.

The 2024 flood contributed 35% of the total annual discharge, whereas the normal for its share is 38%. Under natural flow conditions, the flood used to account for approximately 60% of the annual runoff. The magnitude and pattern of the Volga River discharge from January to December 2024 are presented in Table 3.1.1.

Table 3.1.1 – The Volga River discharge at the top of its delta (m³/c) and modular coefficients in January-December 2024

Parameter	Month												Year
	1	2	3	4	5	6	7	8	9	10	11	12	
Qav, 2024	4270	5400	5610	9190	14400	8480	5540	5260	5680	5270	5560	5220	6657
Qn, 1991-2020	5739	6112	6650	8663	18540	12289	6943	6104	5765	5437	5620	6064	7827
K, 2024	0.74	0.88	0.84	1.06	0.78	0.69	0.80	0.86	0.99	0.97	0.99	0.86	0.85
Qmax, 2024	4490	5810	6390	17000	16800	13400	5940	5400	5810	5560	5750	5510	17000
Qmin, 2024	4000	4460	5030	5370	13400	5280	5260	5180	5460	5190	5300	5150	4000

Note: hereinafter, modular coefficient K is a ratio of the current discharge to its multi-year average

Figure 3.1.1 shows the intra-annual distribution of the Volga water discharge in 2024 compared to the climatic normal (1991–2020). Low discharge values were observed throughout

the entire year, with the exception of April, when the average monthly discharge exceeded the normal by 6% (K = 1.06).

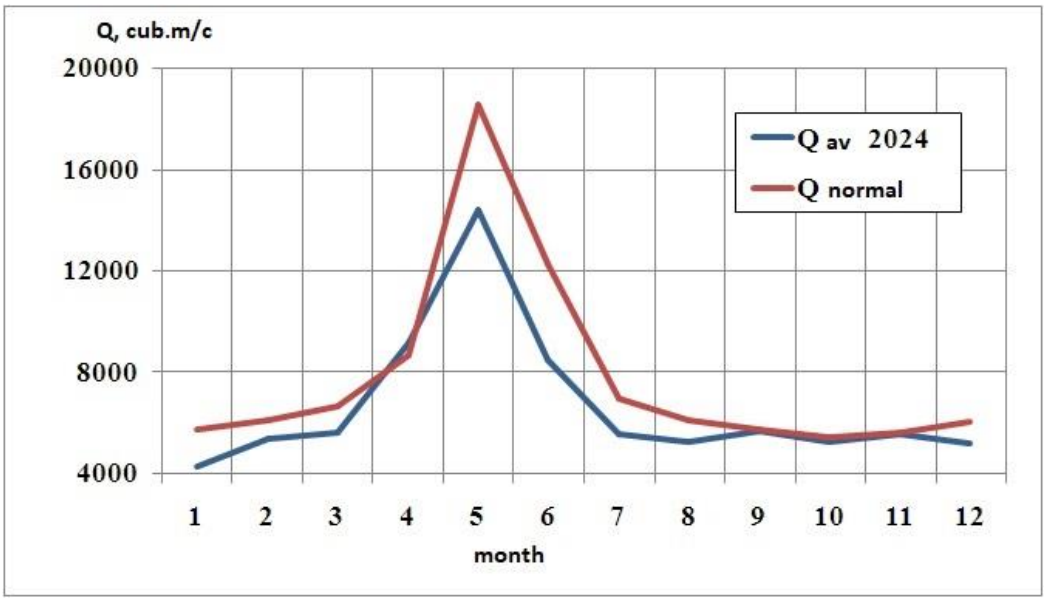


Figure 3.1.1 – Monthly discharge of the Volga River at the Verkhnelebyazhye station in 2024 compared to the 1991–2020 normal

The difference-integral curve based on modular coefficients from 1958 to 2024 is given on the Figure 3.1.2.

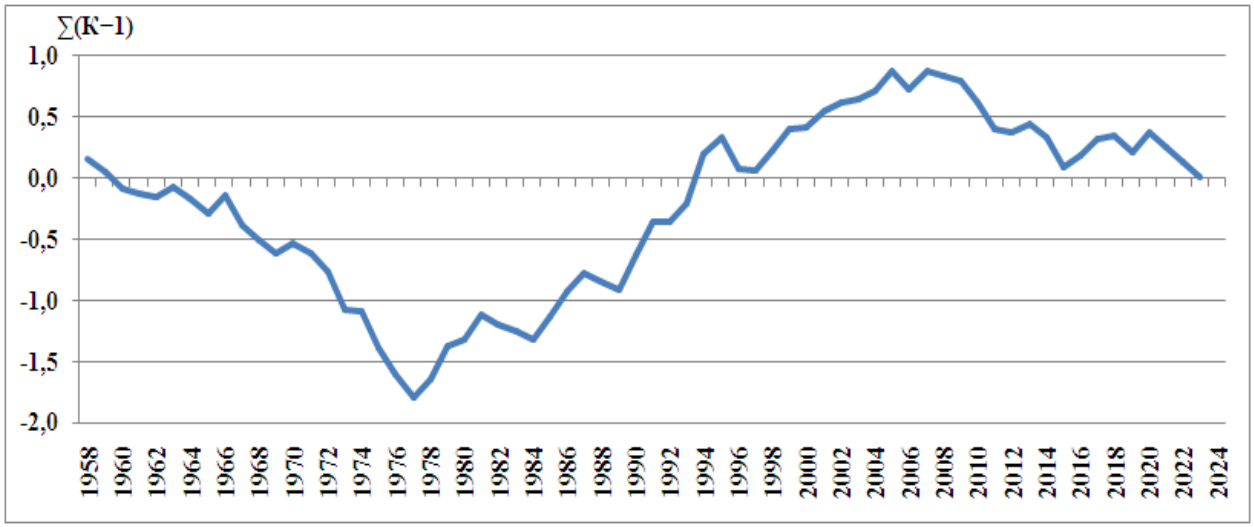


Figure 3.1.2 – Difference-integral curve (data at the Verkhnelebyazhye station)

3.1.2 The Terek River

The Terek River delta is located in the northwestern part of the Caspian Sea. The main watercourse of the delta is the Novy Terek (New Terek). The Novy Terek is dissected by small alluvial islands and embanked along both banks. The former delta outlets, Borozdinskaya Prorva,

Talovka, and Stary Terek (Old Terek), have gradually silted up and lost their direct connection to the sea. Today, they have been converted into main irrigation canals of the delta irrigation system, which are artificially supplied with Terek River water from the Kargalinsky hydrosystem.

The Kargalinsky hydrosystem (dam system) was constructed in 1956. It consists of a dam with a spillway into the Novy Terek. Its construction significantly altered the hydrological regime of the Terek River delta. The primary purpose of this structure was to fill the main irrigation canals (Deltovyy, Sulu-Chubutla, and Novoterechnyy) with water. Intensive irrigation withdrawals within the delta substantially affect the river's discharge regime.

According to the data from the Kargalinsky hydrosystem, the annual runoff of the Terek River in 2024 amounted to 6.912 km³, which was 15% below its climatic normal (1991–2020 average: 8.122 km³; K = 0.85). From January to April, river discharge exceeded the normal by 7–46% (K = 1.07–1.46), likely due to heavy snowfall in the mountains and early snow melting. From May to September, intensive water withdrawals for irrigation via the delta canal system led to a significant reduction in the discharge. The modular coefficients during this period ranged from 0.24 to 0.77.

In June, a rainfall-induced flood occurred on the Terek River. On June 29, according to data from Kargalinsky hydrosystem, the peak annual discharge was recorded at 676 m³/s, with the water level reaching its yearly maximum of 334 cm. For comparison, in 2023, the highest discharge was 1,010 m³/s on June 21.

The magnitude and pattern of the Terek River discharge from January to December 2024 are presented in Table 3.1.2.

Table 3.1.2 – Discharge 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	
Qav, 2024	216	206	215	131	267	664	511	210	169	244	343	318	291
Qn, 1991-2020	191	196	215	191	250	439	472	318	200	193	216	207	257
K, 2024	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
Qmax, 2024	224	219	262	268	612	1010	961	519	311	317	446	396	1010
Qmin, 2024	205	187	143	75.4	79.8	370	207	71.1	77.6	160	301	279	71.1

Figure 3.1.3 shows the intra-annual distribution of water discharge in 2024 compared to the 1991–2020 climatic normal.

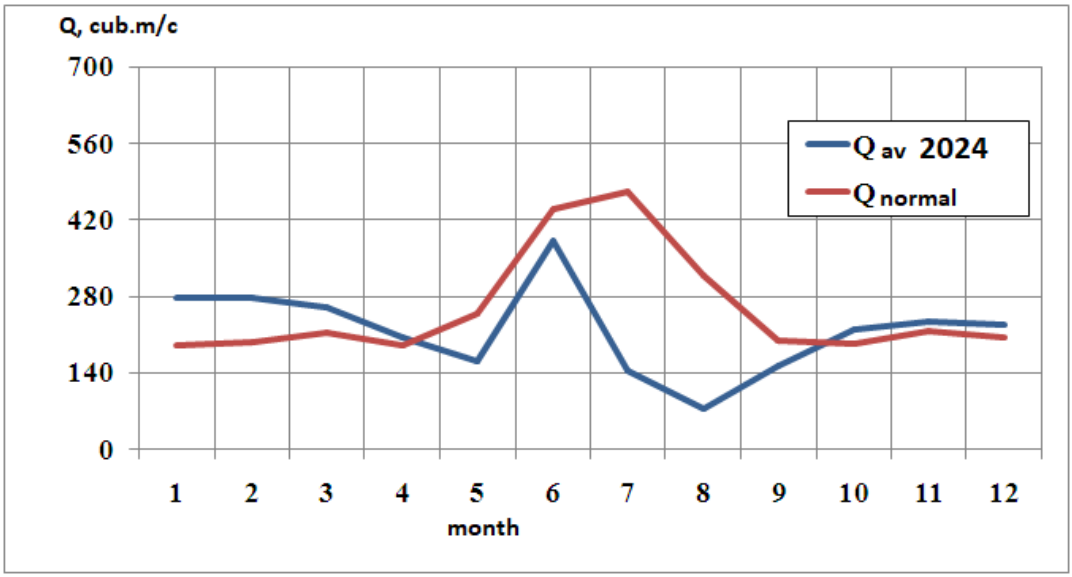


Figure 3.1.3 – Monthly discharge of the Terek River at Kargalinsky hydrosystem in 2024 compared to the 1991–2020 normal

3.1.3 The Sulak River

The mouth of the Sulak River comprises a pre-delta reach approximately 30 km long, a delta covering about 50 km², and a coastal zone (near-mouth marine area) of roughly 60 km². The Sulak estuary is of the deltaic type. The upstream boundary of the estuarine (pre-delta) reach is located 30 km upstream from the delta apex, the farthest point to which storm surges currently propagate. This section of the river has no tributaries.

The construction of the Chirkey Hydroelectric Power Station, completed in August 1974, significantly altered hydrological processes in the delta. Water releases from the power station disrupt the river's natural flow regime and now control the intra-annual distribution of discharge along the estuarine reach. Within the Sulak delta, there is a single hydrological station located in the urban-type settlement, approximately 3 km upstream from the river mouth in the village of Glavnyy Sulak.

In 2024, the annual runoff of the Sulak River totaled 4.193 km³, which was below the climatic normal of 4.901 km³ (K = 0.85). A distinctive feature of the Sulak River's hydrological regime in 2024 as in 2023 was persistently low discharge throughout most of the year, with only a slight increase in flow from September to November, exceeding the normal by 1–8%. The lowest annual discharge, typical for the summer low-water period, was recorded at 107 m³/s during August 9–12. Discharge in June and July was 25% below their normals. Average and minimum monthly water levels during the summer low-water period dropped to record-low levels. The

highest annual discharge occurred on November 7, with November's total discharge reaching 108% of the normal.

The magnitude and pattern of the Sulak River's discharge from January to December 2024 are presented in Table 3.1.3 and showed in Figure 3.1.4.

Table 3.1.3 – Discharge of the Sulak River at the Sulak Station (m³/s) and modular coefficients in January–December 2024

Parameter	Month												Year
	1	2	3	4	5	6	7	8	9	10	11	12	
Qav., 2024	138	134	130	125	123	150	129	114	124	127	154	143	133
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 2024	0.93	0.82	0.81	0.83	0.68	0.75	0.75	0.83	1.04	1.01	1.08	0.95	0.85
Qmax, 202	141	140	134	133	130	166	143	129	142	134	177	155	177
Qmin, 2024	133	128	127	108	116	120	113	107	118	123	130	135	107

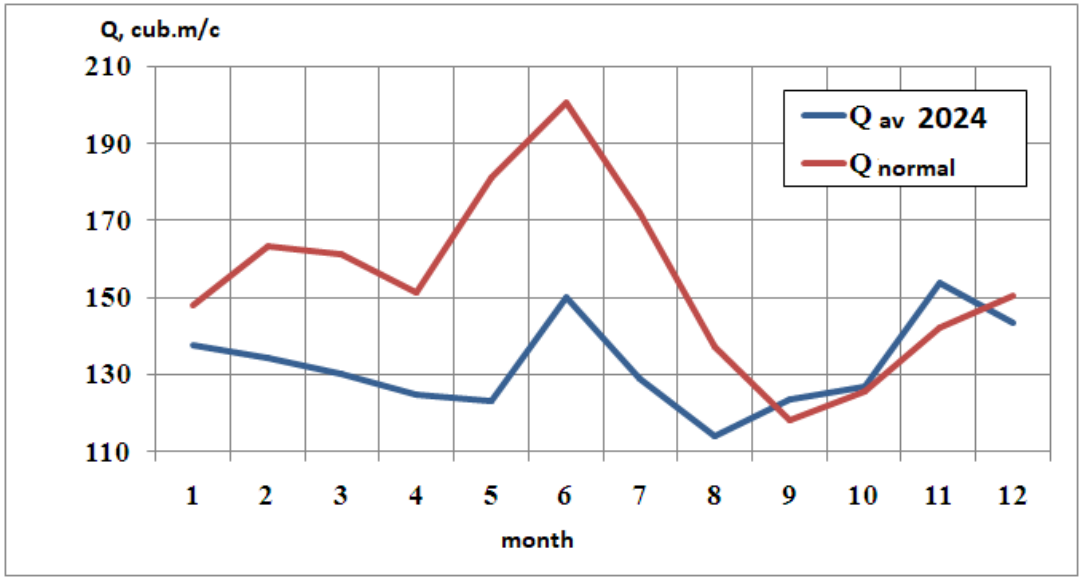


Figure 3.1.4 – Monthly discharge of the Terek River at Kargalinsky hydrosystem in 2024 compared to the 1991–2020 normal

3.1.4 The Ural (Zhaiyk) River

The runoff of the Ural (Zhaiyk) River is characterized by significant interannual and seasonal variability, driven by both natural and anthropogenic factors. At the hydrological gauge near the village of Makhambet, the average long-term annual runoff volume for the period 1936–

2024 amounts to 8.12 km³, ranging from 2.85 km³ in low-water years to 20.5 km³ in high-water years.

The river's hydrological regime is significantly influenced by human activities, particularly by the Iriklinsky Reservoir, which has been in operation since 1958 and belongs to the category of multi-year regulation reservoirs. The period up to 1957 is conventionally considered to represent near-natural flow conditions. Starting with 1958, the regulation period begins, during which a substantial portion of the spring flood runoff is retained in the reservoir (Chibilev, 2008). In addition to Iriklinsky, a cascade of reservoirs has been constructed in the Russian part of the Ural basin (Verkhneuralsky, Magnitogorsky, and others), primarily intended for industrial water supply.

On the Kazakhstani side of the basin, reservoirs have also been built, mainly for irrigation and multipurpose use. The largest of them is the Kargalinsky Reservoir on the Karagaly River (commissioned in 1975, with an active storage capacity of 262 million m³). Other significant reservoirs include the Aktyubinsky (1988) and Chagansky (1965), which are utilized for water supply and irrigation purposes.

Analysis of the annual runoff volume chart (Fig. 3.1.5) at the Makhambet site for the period 1936–2024 indicates a pronounced downward trend in the river runoff. The trend line demonstrates a consistent decline in mean annual water volumes, confirming the presence of a prolonged low-water period in recent decades. Additionally, the difference-integral curve (Fig. 3.1.6) shows a steady accumulation of deviations toward the runoff deficit compared to the normal, which is particularly pronounced over the past 20 years.

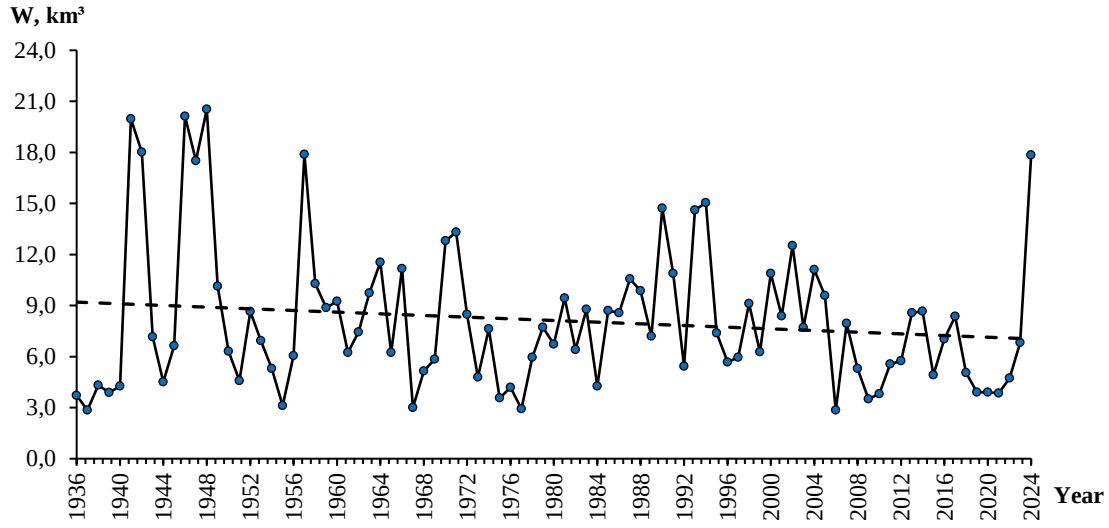


Figure 3.1.5 – Dynamics of mean annual runoff of the Zhaiyk River at Makhambet station for the period 1936–2024

Nevertheless, a substantial increase in water availability was observed in 2024. The annual runoff at the Makhambet gauge amounted to 17.9 km³, which exceeded the long-term average (8.12 km³) by more than 2.2 times. This anomalously high runoff resulted from the intensive spring flood caused by a combination of hydrometeorological factors, including: elevated soil moisture levels in autumn 2023 exceeding long-term normals; early and deep soil freezing (up to 15–150 cm), which promoted surface runoff of meltwater; formation of an ice crust due to winter thaws, hindering water infiltration; rapid onset of a «synchronous spring», characterized by simultaneous snowmelt over large areas; and an abnormally warm and wet winter, which contributed to moisture accumulation and rapid basin inundation during the spring period.

All of these conditions led to the formation of an intense spring flood in the lowland rivers of the Zhaiyk-Caspian region, including the Ural River.

Figure 3.1.6 demonstrates that, while there is evident cyclic variation with the presence of both high-water and low-water phases, the river discharge tends to decrease, that has been particularly pronounced for the last two decades. However, it should be noted that the river runoff increased significantly in 2024 compared to the previous year (2023 – 8.01 km³), by approximately 11.0 km³.

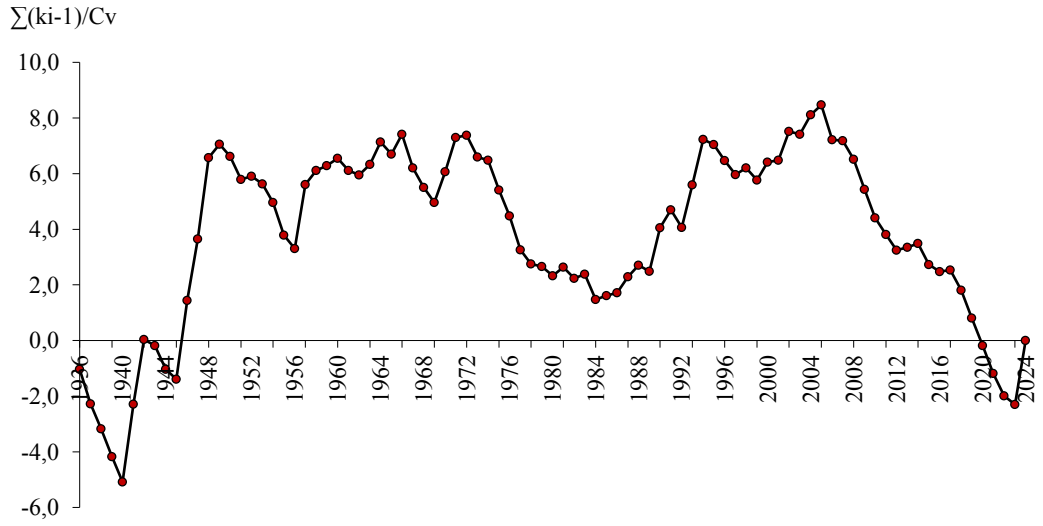


Figure 3.1.6 – Difference-integral curve of mean annual discharge of the Ural (Zhaiyk) River at Makhambet for the period 1936–2024

3.2. THE LEVEL OF THE CASPIAN SEA

Kazakhstan sector

According to the data from coastal and island marine stations and Kazhydromet posts, in 2024 the level of the Caspian Sea in its northeastern shallow part fluctuated around -28.95 m abs within the range of -27.08 m and -29.59 m abs.

In the deep-water Kazakh part of the Caspian Sea, according to the data from Fort Shevchenko, Aktau, and Fetisovo, the average sea level corresponded to -29.29 m, with the maximum value of -28.43 m during the seasonal rise and the minimum value of -29.86 m during the decline.

Surge fluctuations in the level of the Caspian Sea

At the north-eastern coast of the Caspian Sea for the period from January to December 2024 marine stations and posts of «Kazhydromet» RSE recorded 48 cases with downsurge, and 48 cases with upsurge.

The most significant wind-induced surge phenomena are presented below:

- On 9–10 January, a 30 cm rise in water level was recorded at Fort Shevchenko station, caused by northwesterly wind with the maximum speed of up to 12 m/s.
- On 22 January, a 31 cm drop in water level was recorded at Fort Shevchenko, caused by northerly wind with the maximum speed of up to 10 m/s.
- On 9–10 February, a 30 cm rise in water level was recorded at Fort Shevchenko, caused by southeasterly wind with the maximum speed of up to 7 m/s.
- On 22 February, a 31 cm drop in water level was observed at Fort Shevchenko, caused by sustained easterly winds.
- On 8–10 April, a 38 cm rise in water level was recorded at the Peshnoy station, caused by southwesterly wind with the maximum speed of up to 4 m/s.
- On 16 May, a 30 cm drop in water level was observed at Peshnoy, caused by sustained west-northwesterly wind with the speed of up to 8 m/s.
- On 5–6 November, a 31 cm drop in water level was observed at Fort Shevchenko station, caused by northwesterly wind with the maximum speed of up to 20 m/s.
- On 18 December, a 40 cm drop in water level was recorded at Fort Shevchenko, caused by sustained westerly wind with the speed of up to 10 m/s.

Russian sector

In 2024, the ongoing trend of declining sea level sustained. In the Russian sector of the Caspian Sea, the annual mean water level dropped by 12–26 cm compared to the previous year, reaching elevations of −28.63 m abs at Lagan and −28.94 m near Tyuleniy Island. Along the western coast of the Middle Caspian, in the Makhachkala area, the annual mean water level was −28.86 m. Compared to 2022, the cumulative decline over the two-year period was even more pronounced and reached 31–38 cm.

One of the causes of this sea-level drop was the persistently low discharge of the Volga River, observed for the fourth consecutive year. Against the climatic normal of 247.032 km³, the period from 2021 to 2024 has been characterized by markedly low river runoff, with the annual runoff ranging between 207.586 and 211.739 km³. Throughout nearly the entire year, water levels remained below normal at all monitoring stations in the Russian sector (see Table 3.2.1).

Table 3.2.1 – Mean and extreme sea levels (cm) in the Russian sector of the Caspian Sea in 2024

Parameter	Month												Year
	1	2	3	4	5	6	7	8	9	10	11	12	
Makhachkala													
H av	-89	-86	-80	-77	-64	-70	-73	-79	-91	-106	-107	-105	-86
H max	-62	-66	-65	-63	-37	-49	-60	-45	-73	-81	-79	-68	-37
H min	-110	-133	-98	-100	-83	-94	-89	-99	-110	-127	-131	-156	-156
Tyuleniy Island													
H av	-82	-77	-87	-81	-68	-71	-98	-120	-96	-107	-119	-122	-94
H max	-60	-52	-59	-57	-21	-51	-55	-89	-57	-83	-91	-24	-21
H min	-96	-99	-116	-103	-94	-93	-126	-149	-121	-130	-144	-156	-156
Lagan													
H av	-78	-58	-70	-50	-41	-51	-62	-63	-41	-81	-86	-75	-63
H max	-35	13	19	33	45	-9	-33	-21	25	-15	-7	25	45
H min	-107	-87	-125	-107	-87	-93	-89	-85	-85	-125	-131	-127	-131

Note: Values highlighted in yellow indicate water levels that reached record lows over the entire observation period; Light blue marks the lowest maximum monthly water levels in the historical record, ranked in ascending order; red colored – have reached or exceeded the established thresholds for hazardous hydrological events [1].

Figure 3.2.1 shows the annual run of mean monthly sea levels in 2024. According to data from the coastal stations, the lowest water levels occurred during the autumn–winter period. In May, sea level rose as the Volga River discharge increased, and mean monthly levels reached their annual maximum.

In the Lagan area, located along the northwestern Caspian coast, the annual pattern of sea level exhibited distinct features differing from the other stations. By September, the mean monthly water level rose by 22 cm. This increase was attributed to a significant rise in the frequency of easterly wind-driven surges. While easterly winds occurred in 35% of observations in August, their frequency nearly doubled in September, reaching 64%. Concurrently, the occurrence of northwesterly and westerly (offshore) winds declined sharply, from 7% and 12% in August to just 0.4% and 0.8%, respectively, in September. Under these synoptic conditions, two significant wind-

driven upsurge events were recorded in September: the level rise on 37–64 cm on September 2–4 and 31–57 cm on September 29–30. As a result, the mean monthly water level in September reached its second annual peak, equaling that of May at –41 cm (Figure 3.2.1).

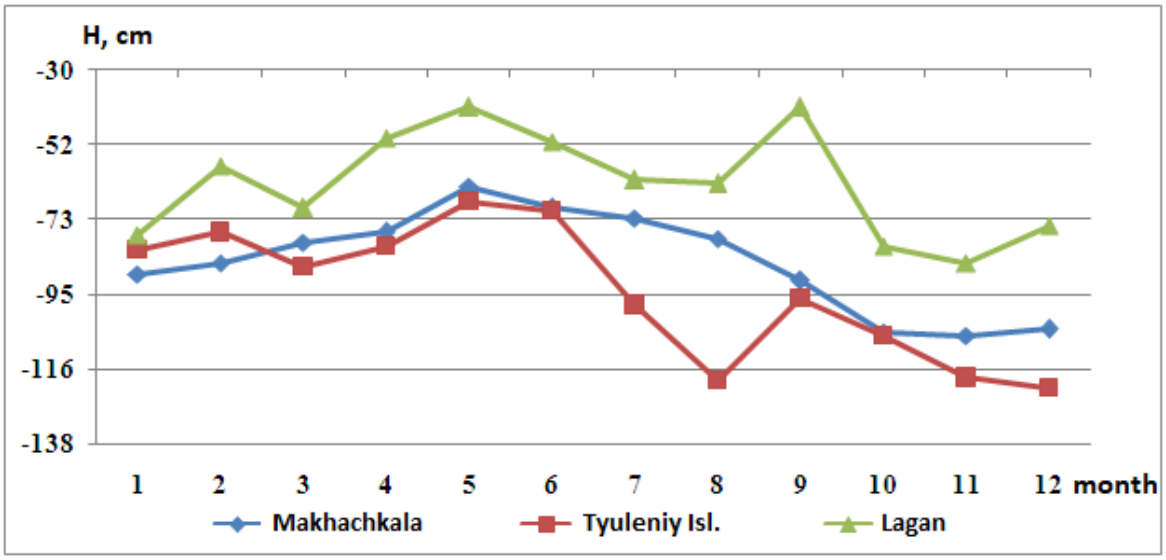


Figure 3.2.1 – Variations in mean monthly sea level in the Russian sector of the Caspian Sea in 2024

The annual amplitude of sea level fluctuations in 2024 was 119 cm at Makhachkala, 135 cm at Tyuleniy Island and 176 cm at Lagan.

Wind-driven sea level fluctuations

In the shallow Northern Caspian, non-periodic wind-driven sea level fluctuations significantly influence hydrological conditions. Recurrent southeasterly and easterly winds over the Northern Caspian cause upsurges along the western and northwestern coasts, while downsurge events are induced by winds of the western directions.

In 2024, the highest number of such wind-driven surge events was recorded at Lagan, due to the station's unique location, at the site of a former Volga delta tributary watercourse approximately 80 meters wide. Over the year, the Lagan Station documented 32 wind-driven surge events: 19 upsurges and 13 downsurges. At Tyuleniy Island, only three upsurges and one downsurge were observed. Along the western coast of the Middle Caspian, near Makhachkala, three wind-driven downsurge events occurred.

Most significant wind-driven surge events in 2024:

- early January (Makhachkala): exceptionally low water levels occurred. On January 10, 11, and 14, northerly winds drove the sea level down to a hazardous threshold (–100 cm). On January 13, the monthly minimum water level exceeded the hazardous event criterion by 10 cm.

- February 7 (Makhachkala): under persistent northwesterly winds, the monthly minimum water level reached -133 cm, exceeding the hazardous threshold by 33 cm.

- February 16–18: strong easterly winds caused a notable upsurge in the western part of the Northern Caspian. In the Lagan area, the wind-driven level rise ranged from 39 to 67 cm.

- March 2–4 (Lagan): induced by strong southeasterly winds (16–18 m/s), an upsurge of 31–43 cm was observed. On March 14–15, southeasterly winds intensified further (up to 20 m/s), triggering another upsurge of 68–71 cm (Fig. 3.2.2).

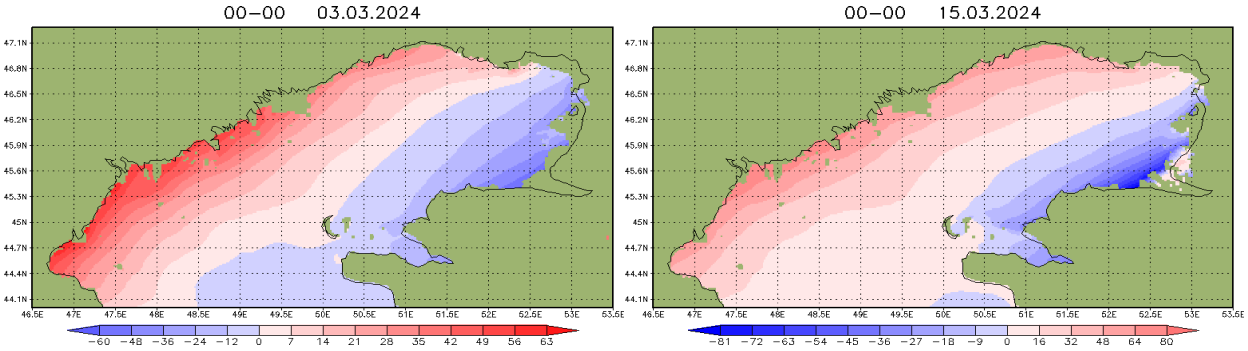


Figure 3.2.2 – Typical sea level fields in the Northern Caspian Sea in March 2024 (data from the Russian Hydrometeorological Center)

- March 9 and March 27–29, westerly winds caused significant downsurges. The magnitude of these water level drops reached 34 cm and 35–53 cm, respectively. On March 28, during the wind-driven downsurge event, the water level in Lagan dropped to a record low of -125 cm, the lowest value ever recorded since observations began in 1935 (with a gap in measurements between 1950 and 1971) (Fig. 3.2.3).

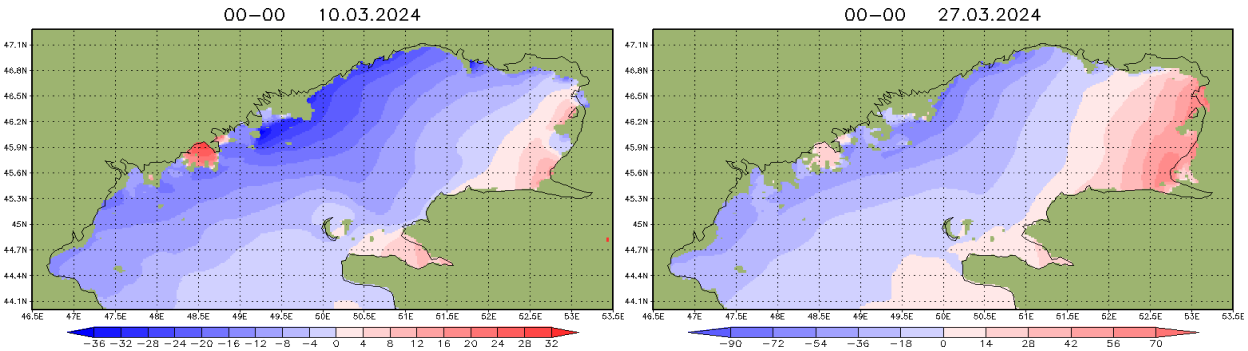


Figure 3.2.3 – Typical sea level fields in the Northern Caspian Sea in March 2024 (data from the Russian Hydrometeorological Center)

- April 5–7, April 15, and April 22–24: during periods of intensive northwesterly winds, water level dropped in Lagan. The magnitudes of these level falls were 32–41 cm, 36 cm, and 34–56 cm, respectively (Fig. 3.2.4).

- April 17–19 and April 27–29: strengthening southeasterly winds caused wind-driven upsurges with amplitudes of 38–74 cm and 33–53 cm, respectively (Fig. 3.2.4).

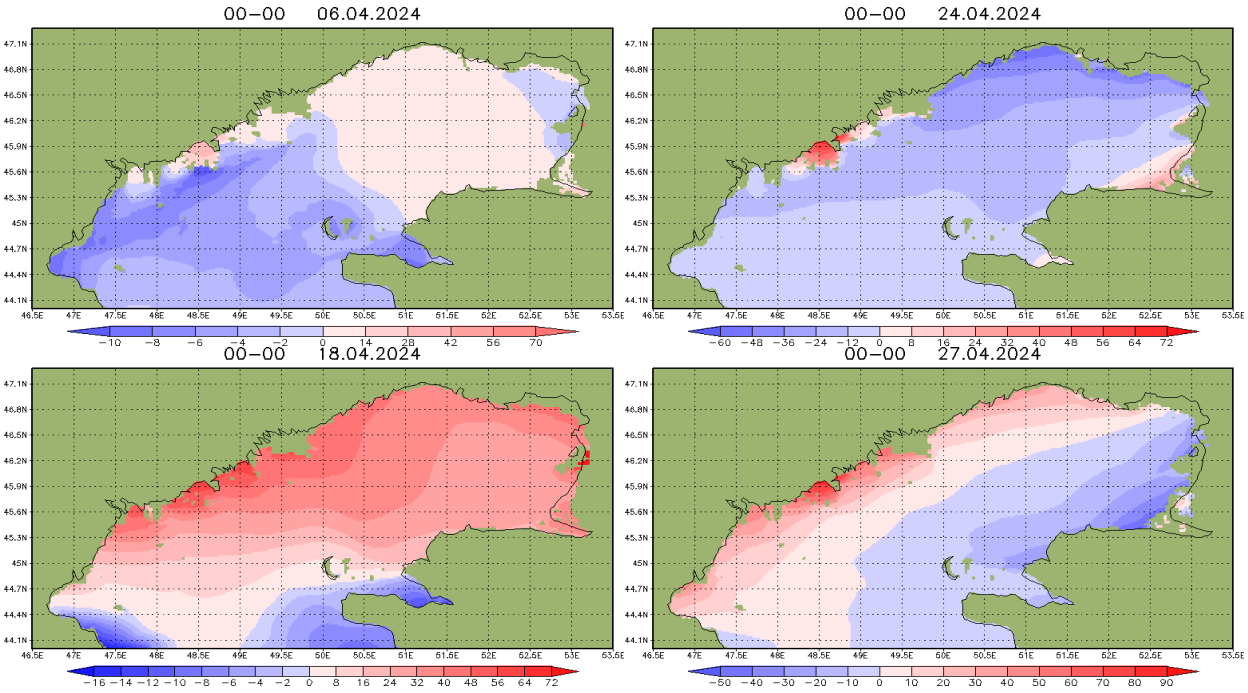


Figure 3.2.4 – Typical sea level fields in the Northern Caspian Sea in April 2024 (data from the Russian Hydrometeorological Center)

- May 25–27: in the northwestern part of the Caspian Sea, easterly winds induced a significant surge with the amplitude of 44–83 cm. During this wind-driven surge, the highest annual water levels of 2024 were recorded at Tyuleniy Island and at Lagan (Fig. 3.2.5).

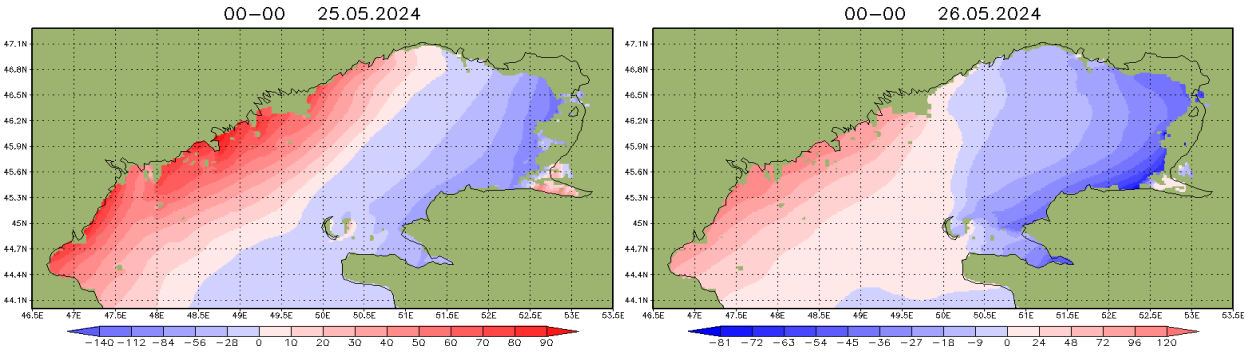


Figure 3.2.5 – Typical sea level fields in the Northern Caspian Sea in May 2024 (data from the Russian Hydrometeorological Center)

- September 2–4 and September 29–30: intensification of southeasterly winds led to two notable wind-driven upsurges in the Lagan area, with water level rises of 37–64 cm and 31–57 cm, respectively (Fig. 3.2.6).

- October 1–2 and October 14–15: under southeasterly winds with speeds of up to 10–17 m/s, wind-driven surges were recorded at Lagan, raising water levels by 32–63 cm and 47–59 cm, respectively.

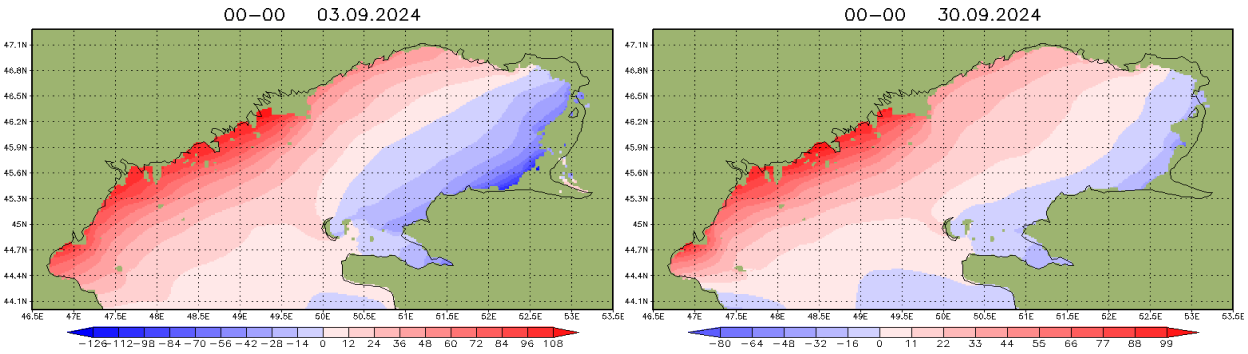


Figure 3.2.6 – Typical sea level fields in the Northern Caspian Sea in September 2024 (data from the Russian Hydrometeorological Center)

- November 5–12: the Northern Caspian was under the influence of persistent northwesterly winds. During this period, the daily mean wind speed ranged between 11.6–12.5 m/s, with peak gusts reaching 21–23 m/s. In the Lagan area, an eight-day wind-induced upsurge occurred, with a magnitude of 30–44 cm. On November 6, the annual minimum water level of –131 cm was recorded during this event (Fig. 3.2.7, left).

- From November 21 to 25, under southeasterly winds, a significant wind-driven upsurge occurred in the Lagan area, raising the water level by 36–77 cm (Fig. 3.2.7, right).

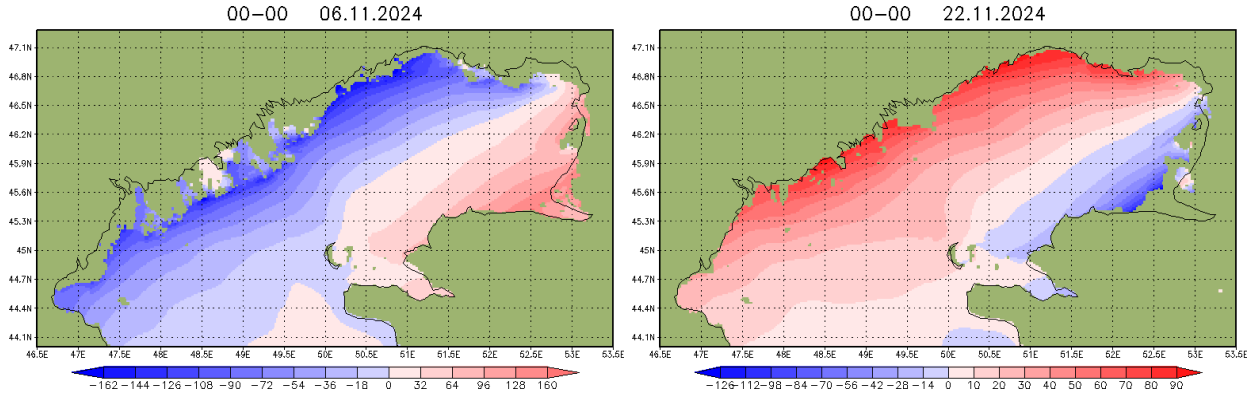


Figure 3.2.7 – Typical sea level fields in the Northern Caspian Sea on November 6 (left) and 22 (right), 2024 (data from the Russian Hydrometeorological Center)

- December 14–15 and 18–19: two wind-driven downsurge events occurred along the western coast of the Middle Caspian, near Makhachkala. The magnitudes of the level drops were 36–48 cm and 33–40 cm, respectively. On December 14, during the first downsurge, the annual minimum water level of –156 cm was recorded, exceeding the hazardous event threshold by 56 cm.

- December 8–11 and 22–23: wind-driven surges were observed along the northwestern Caspian coast. At Lagan, the surge amplitudes reached 34–94 cm and 36–41 cm, respectively. A simultaneous surge was also recorded at Tyuleniy Island, where water levels rose by 34–61 cm during December 8–10.

- Two additional downsurges were registered at Lagan: on December 19–21, water level dropped by 31–49 cm; on December 30–31, water level dropped by 40–46 cm (Fig. 3.2.8).

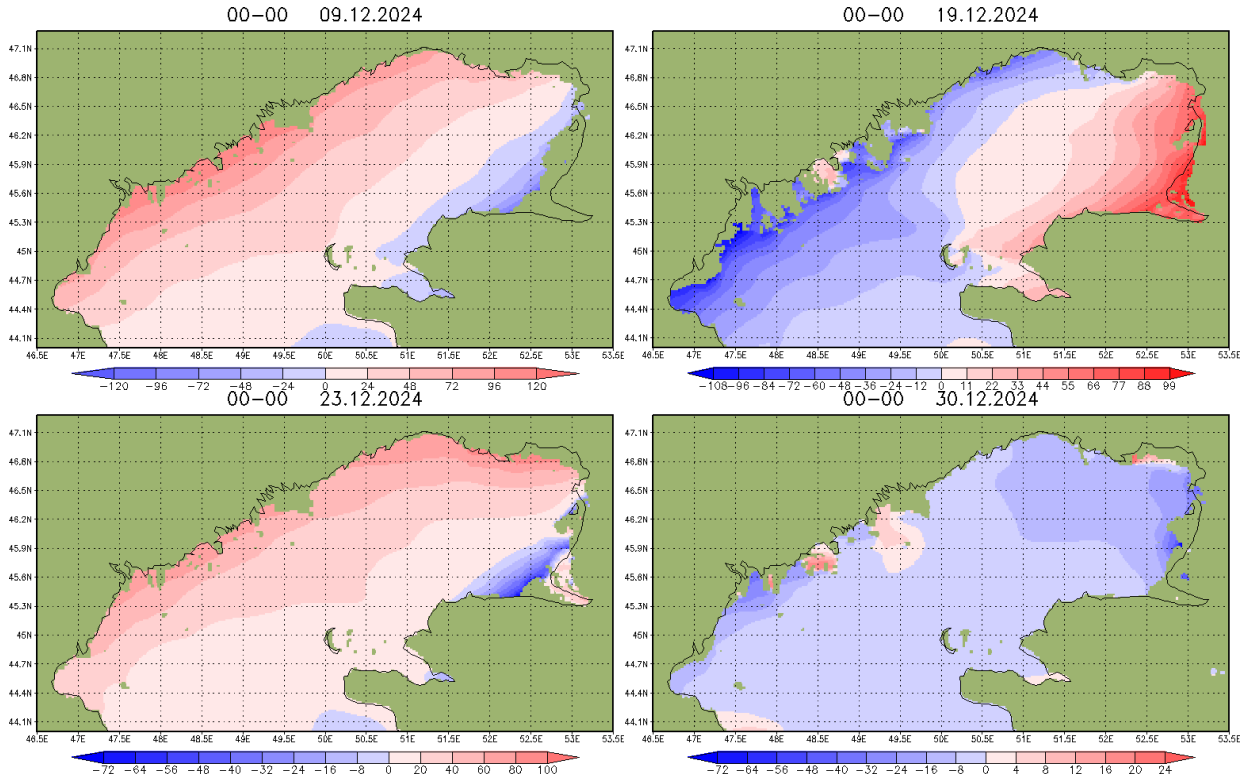


Figure 3.2.8 – Typical sea level fields in the Northern Caspian Sea in December 2024 (data from the Russian Hydrometeorological Center)

The maximum amplitude of the sea level surge fluctuations occurred in December and reached 88 cm at Makhachkala, 132 cm at Tyuleniy Island, and 152 cm at Lagan.

3.3. SEA WATER TEMPERATURE

3.3.1 Sea water temperature in 2024

Iranian sector

Table 3.3.1 – Average values, anomalies from the standard normal*, maximum and minimum in the seawater temperature (°C) recorded in Iranian sector in 2023 and 2024

Obser-vation post	Charac-teristics	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Anzali	Average in 2023	12.3	10.8	12.0	15.3	19.9	25.6	28.1	29.2	26.8	23.4	21.1	17.4	20.2
	Max, 2023	14.0	11.5	14.7	18.5	24.5	27.0	28.6	30.2	28.5	25.0	22.3	19.4	30.2
	Min, 2023	10.7	9.9	10.6	13.5	18.0	24.2	26.8	28.3	24.9	22.0	19.6	15.7	9.9
	Average in 1981-2021	11.8	10.2	10.3	13.3	18.9	24.6	27.3	27.8	24	22.3	18.2	14.3	18.5
	Anomalies	0.5	0.6	1.7	2	1	1	0.8	1.4	2.8	1.1	2.9	3.1	1.7
	Average in 2024	14.3	11.9	11.3	16.1	20.0	25.8	28.2	28.5	27.3	23.1	18.6	14.9	20.0
	Max, 2024	16.1	12.9	13.5	19.1	22.0	27.1	29.0	29.0	29.0	25.0	20.1	16.6	29.0
	Min, 2024	11.9	11.1	10.5	13.8	19.1	22.6	26.0	27.4	25.0	20.3	16.9	13.5	10.5
	Average in 1981-2021	11.8	10.2	10.3	13.3	18.9	24.6	27.3	27.8	24	22.3	18.2	14.3	18.5
	Anomalies	2.5	1.7	1	2.8	1.1	1.2	0.9	0.7	3.3	0.8	0.4	0.6	1.5
Kiashahr	Average in 2023	12.3	10.7	11.7	14.7	19.4	25.2	27.8	29.1	26.6	23.2	21.0	17.4	20.0
	Max, 2023	13.9	11.4	14.1	18.5	24.0	26.8	28.3	30.2	28.5	25.0	22.1	19.3	30.2
	Min, 2023	10.6	10.0	10.4	12.9	17.4	23.8	26.6	28.2	24.6	21.8	19.5	15.7	10.0
	Average in 1981-2021	11.9	10.4	10.6	13.6	19.2	24.8	27.6	28.2	26.2	22.7	18.6	14.6	19.1
	Anomalies	0.4	0.3	1.1	1.1	0.2	0.4	0.2	0.9	0.4	0.5	2.4	2.8	0.9
	Average in 2024	14.3	12.0	11.6	15.7	19.5	25.5	27.8	28.3	27.1	22.9	18.4	14.8	19.9
	Max, 2024	15.9	12.9	13.2	18.7	21.8	27.0	28.8	28.9	28.8	24.7	19.9	16.6	28.9
	Min, 2024	12.0	11.3	10.9	13.4	18.2	22.1	25.6	27.3	24.8	19.8	16.8	13.3	10.9
	Average in 1981-2021	11.9	10.4	10.6	13.6	19.2	24.8	27.6	28.2	26.2	22.7	18.6	14.6	19.1
	Anomalies	2.4	1.6	1	2.1	0.3	0.7	0.2	0.1	0.9	0.2	-0.2	0.2	0.8
Noshahr	Average in 2023	12.3	11.4	12.2	15.1	19.7	25.5	27.8	29.8	26.9	23.4	21.2	17.7	20.3
	Max, 2023	13.8	12.0	14.2	18.9	23.4	26.8	28.6	30.9	28.8	25.5	22.5	19.5	30.9
	Min, 2023	11.3	10.9	11.2	12.7	17.6	23.7	26.8	28.5	25.1	22.0	19.6	15.9	10.9
	Average in 1981-2021	12.3	10.9	11.3	14.0	19.5	24.9	27.4	28.4	26.5	23.0	18.8	14.7	19.3
	Anomalies	0	0.5	0.9	1.1	0.2	0.6	0.4	1.4	0.4	0.4	2.4	3	1
	Average in 2024	14.7	13.3	12.7	16.6	20.3	26.0	28.0	28.4	26.9	23.0	17.9	15.1	20.3
	Max, 2024	16.1	14.4	14.0	20.4	22.6	28.4	29.0	28.8	29.0	24.5	19.6	16.7	29.0
	Min, 2024	13.0	12.2	11.8	13.9	19.3	22.1	26.0	27.8	24.4	19.1	16.7	13.7	11.8
	Average in 1981-2021	12.3	10.9	11.3	14.0	19.5	24.9	27.4	28.4	26.5	23.0	18.8	14.7	19.3
	Anomalies	2.4	2.4	1.4	2.6	0.8	1.1	0.6	0	0.4	0	-0.9	0.4	1
Amirabad	Average in 2023	12.4	11.5	13.1	16.5	21.2	26.0	28.1	29.6	26.9	23.6	21.2	17.3	20.7
	Max, 2023	14.1	12.0	15.8	20.1	24.4	26.8	28.8	30.5	28.7	25.3	22.4	19.2	30.5
	Min, 2023	11.4	10.9	11.5	14.2	19.5	24.5	27.0	28.6	25.7	22.2	19.2	15.2	10.9
	Average in 1981-2021	12.7	11.2	11.6	14.7	19.9	24.6	27.2	28.1	26.6	23.3	19.2	15.3	19.6
	Anomalies	-0.3	0.3	1.5	1.8	1.3	1.4	0.9	1.5	0.3	0.3	2	2	1.1

Table 3.3.1 continued

Amirabad	Average in 2024	14.2	12.9	13.1	17.1	21.3	26.3	28.1	28.6	27.7	23.5	18.7	15.0	20.6
	Max, 2024	15.5	14.2	14.8	20.2	23.4	28.4	29.0	29.2	29.3	25.3	20.5	16.9	29.3
	Min, 2024	12.5	11.7	11.8	14.6	20.0	23.0	26.6	27.5	25.3	20.4	17.1	13.7	11.7
	Average in 1981-2021	12.7	11.2	11.6	14.7	19.9	24.6	27.2	28.1	26.6	23.3	19.2	15.3	19.6
	Anomalies	1.5	1.7	1.6	2.4	1.4	1.7	0.9	0.5	1.1	0.2	-0.5	-0.3	1

** the normal is calculated as the average for the period 1981-2021.*

Kazakhstan sector

In 2024, the average annual water temperature according to the data from the coastal marine stations located in the ***Kazakhstan sector of the sea*** was +10.7...+14.7 °C.

The surface water temperature is subject to noticeable seasonal variations and has a well-defined annual course. In the northeastern part of the sea, the average surface water temperature varied from 1.4...9.1 °C in the cold period of the year to 20.9...28.1 °C in the summer months; on the eastern coast of the Middle Caspian Sea, the average surface water temperature varied from 1.6...9.4 °C in the cold period of the year to 18.7...25.9 °C in the summer months (Table 3.3.2).

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 2024 in the Kazakhstan sector

Observation post	Characteristics	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Peshnoy	Average in 2024	1.4	1.5	3.3	10.8	13.7	20.8	22.2	21.0	16.4	10.3	4.8	1.9	10.7
	Max, 2024	4.8	3.2	7.6	18.8	23.2	26.6	29.4	27.6	25.8	21.4	15.0	3.3	29.4
	Min, 2024	0.4	0.5	1.2	2.7	2.4	12.6	13.6	11.8	4.2	2.4	1.6	0.8	0.4
	Average in 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
Kulaly*	Average in 2024	2.5	3.1	9.1	16.6	19.4	26.5	28.1	27.6	20.7	13.2	7.8	1.6	14.7
	Max, 2024	7.8	8.6	12.9	22.4	22.6	30.8	29.9	29.9	27.9	20.4	14.2	4.1	30.8
	Min, 2024	0.2	0.6	3.0	9.1	15.7	19.5	25.9	26.1	16.2	8.4	4.6	0.4	0.2
	Average in 1991-2020													
	Anomalies													
Fort Shev-chenko**	Average in 2024	1.6	1.6	4.8	14.0	16.5	23.6	25.9	24.4	18.3	13.3	8.6	3.8	13.0
	Max, 2024	5.0	5.9	8.7	19.3	19.4	28.2	28.7	28.0	21.8	18.2	13.3	6.7	28.7
	Min, 2024	-0.9	-1.8	1.1	6.7	12.9	17.1	21.6	18.2	14.7	9.6	6.1	1.6	-1.8
	Average in 1991-2020													
	Anomalies													
Aktau	Average in 2024	2.9	2.1	4.1	12.8	14.5	20.5	18.7	18.9	18.9	14.7	9.4	3.7	11.8
	Max, 2024	6.2	4.4	9.3	17.6	17.2	25.4	24.9	22.2	22.5	18.8	14.9	6.6	25.4
	Min, 2024	-0.3	0.3	0.8	6.8	10.4	14.9	14.4	16.1	16.5	11.1	6.2	1.8	-0.3
	Average in 1991-2020	2.7	2.3	5.5	11.0	15.3	17.7	17.9	19.0	18.0	14.3	8.8	4.6	11.4
	Anomalies	-2.2	-1.0	0.8	-0.8	-0.4	1.1	-0.9	2.0	-0.6	0.2	2.8	0.3	0.3

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 3.3.3 presents summary data on the average monthly and average annual water temperature, anomalies (positive or negative), the maximum (minimum) water temperature for 2024 at observation posts located in the Russian sector of the Caspian Sea.

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 2024 in the Russian sector

Observation post	Characteristics	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Derbent	Average, 2024	5.0	6.5	7.8	13.4	17.0	24.6	26.4	23.7	22.5	17.4	9.9	6.9	15.1
	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	0.8	3.2	2.5	3.7	1.6	3.6	1.8	-1.9	0.6	0.3	-1.6	0.1	1.2
	Maximum, 2024	6.9	8.4	10.0	17.0	20.7	28.7	29.1	26.8	26.8	20.6	13.0	8.3	29.1
	Minimum, 2024	3.2	3.2	6.5	9.3	14.0	18.7	21.4	20.7	18.7	12.9	8.0	5.8	3.2
Izberg	Average, 2024	4.8	6.1	6.8	11.8	16.6	24.3	25.4	23.3	21.9	16.3	10.4	6.4	14.5
	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	1.0	3.1	1.6	2.0	0.9	2.9	1.0	-1.9	0.2	-0.4	-0.5	0.3	0.8
	Maximum, 2024	9.2	9.0	7.8	17.6	23.0	30.6	30.2	27.8	26.6	23.2	16.4	9.4	30.6
	Minimum, 2024	1.0	2.0	5.0	6.6	12.8	18.2	3.0	17.8	17.0	8.5	5.0	2.5	1.0
Makhachkala	Average, 2024	7.1	7.0	9.2	14.7	18.8	25.2	23.6	22.4	23.2	16.2	9.9	6.8	15.3
	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	3.9	4.4	4.3	5.4	3.7	4.8	0.3	-2.3	1.7	-0.3	-0.6	1.3	2.2
	Maximum, 2024	10.6	9.8	12.0	18.8	23.4	29.7	26.2	27.4	26.7	21.0	12.8	8.4	29.7
	Minimum, 2024	4.0	4.5	6.8	10.9	16.8	22.0	21.0	16.6	20.2	11.8	7.7	5.6	4.0
Tyuleniy Isl.	Average, 2024	5.8	6.2	7.8	13.6	20.8	27.6	27.0	25.3	24.7	21.7	12.7	7.1	16.7
	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	4.8	5.0	3.1	1.7	2.0	3.8	0.8	-0.3	3.9	7.0	4.9	4.4	3.4
	Maximum, 2024	8.9	7.6	8.8	19.0	25.5	29.8	28.5	27.8	27.8	24.4	18.2	8.8	29.8
	Minimum, 2024	2.1	2.7	6.5	7.6	17.6	24.6	24.4	21.5	22.3	18.0	9.4	4.4	2.1
Lagan	Average, 2024	1.5	2.3	5.5	18.2	19.8	26.6	28.0	25.5	20.1	13.5	7.7	1.9	14.2
	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	0.2	0.6	-0.1	5.2	-0.5	1.4	0.8	-1.0	-1.2	-1.0	0.8	-0.3	0.4
	Maximum, 2024	3.6	6.2	14.2	22.4	23.8	30.2	31.2	28.8	24.0	18.4	12.2	5.2	31.2
	Minimum, 2024	0.2	0.6	1.6	12.6	17.2	22.4	24.6	22.6	17.0	9.6	5.6	0.2	0.2

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

2024 was abnormally warm, which had a significant impact on the temperature regime of water in the Caspian Sea. According to observations, the average annual water temperature was above the standard normal. The water temperatures exceeded the normal by 0.8–2.2 °C on the west coast of the Middle Caspian and by 0.4 °C at Lagan. At Tyuleniy Island, the anomaly was 3.4 °C. The significant increase in the average monthly water temperature was observed in February, March, April, and June, when temperature anomalies varied from 1.6 to 5.4 °C. At Tyuleniy Island, the water temperature was above the normal almost throughout the year, minor deviations were observed only in July and August (± 0.3–0.8 °C).

The seawater temperature has a pronounced seasonal course. The minimum monthly averages were observed in January, at Makhachkala station in December. Rapid warming occurred from March to June-July: from + 5.5...+ 9.2 °C to peak values + 25.2...+ 28.0 °C. Then, starting with August, the temperature gradually decreased. It dropped to + 1.9 °C at Lagan and to + 6.4...+ 7.1 °C at the other stations by December. The range of seasonal fluctuations was: + 18.4...+ 21.3 °C on the west coast of the Middle Caspian, +21.8 °C at Tyuleniy Island. At Lagan, seasonal fluctuations were more pronounced, reaching + 26.4 °C.

The thermal seawater regime in the northwestern part of the sea is influenced by climatic conditions, depth and fresh water inflow of the Volga River. In the coastal zone of the Middle Caspian, surge fluctuations in the water level can significantly change the local water temperature as well.

In early January 2024, air temperature rose, that led to a significant destruction of the ice cover and an increase in seawater temperature. At the end of the first and third decades of the month, frosty weather caused ice cover restoration and a drop in water temperature. The minimum annual water temperature was recorded on 13-14 and 24 January (+ 0.2 °C) at Lagan and on 30–31 January (+ 2.1 °C) at Tyuleniy Island. On the west coast of the Middle Caspian, the minimum values ranged from + 1.0 to + 4.0 °C. In early February, water temperature sharply dropped due to the invasion of cold air masses. On 01 February, the water temperature at Derbent reached a secondary annual minimum, amounting to + 3.2 °C.

In June with abnormally hot weather, low river flow and overall low water levels, seawater in shallow areas was intensely warmed up. At Tyuleniy Island, the average monthly water temperature in June reached record values: + 27.6 ºC, exceeding the normal by 3.8 ºC. Derbent documented a new record for the average monthly water temperature in June (+24.6 °C), which was 3.6 °C above the normal and 0.9 °C higher than the previous record in 2022, when the water temperature reached +23.7 °C. In June, the maximum annual water temperature was also recorded: + 29.8 °C (20.06) at Tyuleniy Island; + 30.6 °C (20.06) at Izberg; + 29.7 °C (24.06) at Makhachkala. The weather was influenced by the Azores anticyclone in late July, with the rise in the air temperature to + 29...+ 32 °C. This resulted in the further warming of the seawaters. At Derbent, the maximum annual water temperature was recorded on 23 July (+ 29.1 °C). The maximum water temperature reached + 31.2 °C at Lagan (11.07). The water temperature regime off the west coast of the Middle Caspian was affected by upwelling in July. Water temperature anomaly was observed in coastal waters at Izberg on 10 July. The average daily water temperature sharply dropped from + 27.2 °C to + 20.8 °C, cold deep water went up to the sea surface, that resulted in this temperature drop by 6.4 °C. The upwelling led to the minimum water temperature decrease till + 3.0 °C.

Turkmenistan sector

Table 3.3.4 – 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 2024 in the Turkmenistan sector

Observation post*	Characteristics	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Turkmenbashi (Krasnovodsk)	Average, 2024	5.3	6.1	9,6	18,1	20,6	25,4	24,7	25.4	22.2	17.6	12.9	7.0	16.2
	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	0.2	0.5	-0.2	3.0	0.5	1.8	-1.6	-1.2	-0.7	-0.3	0.9	0.7	0.2
	Maximum, 2024	7.6	10.5	15.5	22.7	23.0	27.8	27.5	26.4	25.8	22.6	16.0	12.1	27.8
	Minimum, 2024	2.8	3.3	4.8	14.0	18.2	22.8	22.8	23.4	19.4	13.8	10.8	4.2	2.8
Khazar (Cheleken)	Average, 2024	7.0	7.4	9.2	14.4	19.6	23.7	25.0	26.7	23.7	19.3	12.7	6.7	16.3
	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	1.1	1.5	0.3	1.7	1.6	1.7	-0.8	-0.3	0.8	1.4	0.9	-1.0	0.8
	Maximum, 2024	11.2	10.8	13.0	24.8	25.1	28.0	27.8	30.3	28.6	24.4	17.2	11.6	30.3
	Minimum, 2024	4.5	4.8	5.4	9.8	16.2	19.6	22.2	23.4	20.2	13.8	8.4	3.6	3.6
Duzlybogaz (Kara-Bogaz-Gol)	Average, 2024	6.1	6.2	8.1	12.8	17.0	19.5	20.7	21.0	20.0	17.4	11.5	6.3	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	0.7	1.1	-0.3	0.2	0.0	0.0	-0.4	-2.0	-0.3	1.4	0.4	-0.3	0.0
	Maximum, 2024	10.8	10.8	11.4	19.2	20.1	23.7	25.4	26.4	25.2	22.8	17.3	9.6	26.4
	Minimum, 2024	1.8	2.2	5.5	8.6	13.8	15.6	17.8	17.3	16.7	13.0	9.4	2.9	1.8
Garabogaz (Beckdash)	Average, 2024	5.0	5.0	8.0	13.6	15.3	18.1	18.8	18.9	19.3	16.0	11.5	5.8	12.9
	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	-0.1	0.3	0.6	2.4	-2.3	-4.9	-0.3	-1.9	0.9	0.6	0.4	-0.8	0.2
	Maximum, 2024	8.6	9.1	12.8	16.8	17.2	20.4	23.6	21.8	22.8	19.0	15.4	9.0	23.6
	Minimum, 2024	1.0	1.8	2.8	10.1	12.1	15.8	14.7	14.5	17.1	12.8	8.5	3.8	1.0
Guvlymayak (Kuuli-Mayak)	Average, 2024	7.1	6.4	9.0	15.5	16.7	18.8	20.1	23.0	21.7	17.5	12.7	8.3	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	0.3	0.0	-0.1	2.6	0.8	0.8	-1.5	-1.4	0.2	-0.2	-0.3	-0.5	0.3
	Maximum, 2024	11.8	11.8	14.2	20.5	21.2	24.0	26.4	27.7	27.4	22.4	17.6	12.0	27.7
	Minimum, 2024	3.4	2.6	3.6	10.0	13.0	16.4	15.2	17.0	16.6	13.6	9.0	5.6	2.6
Ogurdzhaly (Ogurchinsky)	Average, 2024	7.9	9.5	11.7	18.8	20.6	25.4	26.6	26.5	22.8	19.3	14.5	6.4	17.5
	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	1.5	2.5	1,3	4,1	1,1	2,2	-0,2	-1,1	-1,0	0,6	1,6	-1,5	0,9
	Maximum, 2024	15.2	19.8	21.6	29.0	33.3	34.3	33.6	34.0	30.2	26.8	20.0	12.4	34.3
	Minimum, 2024	-1.0	4.0	7.0	11.0	14.0	17.5	18.4	21.0	16.4	13.0	10.2	2.0	-1.0

Notes:

**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)

3.3.2. Climatological characteristics

Iranian sector

Table 3.3.5 – Absolute maximum/minimum of the monthly average seawater temperature (°C) recorded in the Caspian Sea region in 2023-2024

Observation post	Month	Absolute maximum of 2023	Previous maximum and a year of its occurrence	Absolute minimum of 2023	Previous minimum and a year of its occurrence
2023					
Anzali	August	29.2	30.6 (August 2018)	10.8 Feb.	9.4 (March 2018)
Kiashahr	August	29.1	30.6 (July 2018)	10.7 Feb.	9.4 (February 2018)
Noshahr	August	29.8	31.3 (August 2018)	11.4 Feb.	10.1 (February 2017)
Amirabad	August	29.6	31.2 (August 2018)	11.5 Feb.	10.2 (February 2017)
2024					
Anzali	August	28.5	30.6 (August 2018)	11.3 March	9.4 (March 2018)
Kiashahr	July	27.4	30.6 (July 2018)	10.4 March	9.4 (February 2018)
Noshahr	August	28.4	31.3 (August 2018)	12.7 March	10.1(February 2017)
Amirabad	August	28.6	31.2 (August 2018)	12.9 Feb.	10.2 (February 2017)

Table 3.3.6 – Records of monthly maximum seawater temperature (°C) in Iranian sector in 2023-2024

Observation post	Date	Month	Maximum seawater temperature, °C	Previous maximum, °C	Date of the previous maximum
2023					
Anzali	16	August	30.2	30.6	08.02.2018
Kiashahr	14	August	30.2	31.05	07.31.2000
Noshahr	14	August	30.9	31.7	08.10.2010 08.09.2000
Amirabad	13	August	30.5	31.5	08.03.2011
2024					
Anzali	-----	July, August, September	29	30.6	08.02.2018
Kiashahr	23	July	28.7	31.05	07.31.2000
Noshahr	23	July	29	31.7	08.10.2010 08.09.2000
Amirabad	5	September	29.3	31.5	08.03.2011

Table 3.3.7 – Records of monthly minimum seawater temperature (°C) in Iranian sector in 2023-2024

Observation post	Date	Month	Minimum seawater temperature, °C	Previous minimum, °C	Date of the previous minimum
2023					
Anzali	14	February	9.9	7.7	03.12.2012
Kiashahr	19	February	10	8.2	03.05.1991
Noshahr	25	February	10.9	8.6	02.26.1988
Amirabad	16	February	10.9	7.9	02.26.1994
2024					
Anzali	5	March	10.5	7.7	03.12.2012
Kiashahr	26	February	9.4	8.2	03.05.1991
Noshahr	3	March	11.8	8.6	02.26.1988
Amirabad	27	February	11.7	7.9	02.26.1994

Kazakhstan sector

In the Kazakh part of the Caspian Sea, the maximum and minimum average monthly water temperatures in 2024 did not exceed the corresponding records for the entire observation period.

The maximum average monthly water temperatures in 2024 were: at Peshnoy – 29.4 °C, at Kulaly – 30.8 °C, at Fort-Shevchenko – 28.7 °C, and at Aktau – 25.4 °C. The minimum values were: at Peshnoy – 0.4 °C, at Kulaly – 0.2 °C, at Fort-Shevchenko – 0.9 °C, at Aktau – 0.3 °C.

The absolute maximum and minimum daily water temperatures also did not exceed the previously recorded values for the entire observation period at stations on the Kazakhstan coast.

Russian sector

Table 3.3.8 presents the maximum values of the average monthly water temperature recorded at observation posts in the Russian sector of the Caspian Sea. The minimum monthly average water temperature in 2024 did not exceed the previous minimum.

Table 3.3.8 – Maximum of the average monthly water temperature (°C) recorded in the Russian sector in 2024 and in the previous time since the start of observations

Observation post	Maximum in 2024		Previous maximum		
	average monthly water temperature	month	average monthly water temperature	month	year
Derbent	6.5	February	6.2	February	2002
	13.4	April	12.7	April	2023
	24.6	June	23.7	June	2022
Makhachkala	7.1	January	6.9	January	2022
	14.7	April	14.5	April	2023
Tyuleniy Isl.	5.8	January	4.0	January	2023
	6.2	February	5.2	February	2022
	27.6	June	26.7	June	2019
	24.7	September	22.8	September	2015
	21.7	October	18.7	October	2023
Lagan	18.2	April	16.8	April	2012

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

Table 3.3.9 presents absolute maximums of water temperature recorded in the Russian sector. The absolute minimum water temperature in 2024 did not exceed the previous minimum.

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

Observation post	Absolute maximum in 2024		Previous absolute maximum		
	water temperature	day, month	water temperature	day, month	year
Derbent	8.4	February	8.0	February	2002
Izberg	9.2	January	8.9	January	1982
Makhachkala	10.6	January	9.8	January	2022
	29.7	June	29.4	June	2021
Tyuleniy Isl.	8.9	January	7.4	January	1982

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

At stations of Derbent (in March), Makhachkala (in March and May), Tyuleniy Island (from January to March, from May to July, in September and October) and Lagan (in April), the minimum water temperature reached abnormally high values. In the ranked series of observations (from the warmest to the coldest), the minimum water temperatures in these months take the first places at these stations.

Turkmenistan sector

Table 3.3.10 – Maximum of the average monthly water temperature (°C) recorded in the Russian sector in 2024 and in the previous time since the start of observations

Observation post*	Maximum in 2024		Previous maximum		
	average monthly water temperature	month	average monthly water temperature	month	year
Turkmenbashi (Krasnovodsk)	25.4	August	29	July	2018
Khazar (Cheleken)	26.7	August	30.1	August	2000
Duzlybogaz (Kara-Bogaz-Gol)	21.0	August	27.3	August	2014
Garabogaz (Beckdash)	19.3	September	26.3	August	2014
Guvlymayak (Kuuli-Mayak)	23.0	August	27.5	August	2014
Ogurdzhaly (Ogurchinsky)	26.6	July	29.5	August	2014

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

Table 3.3.11 – Minimum of the average monthly water temperature (°C) recorded in the Turkmenistan sector in 2024 and in the previous time since the start of observations

Observation post*	Minimum in 2024		Previous minimum		
	average monthly water temperature	month	average monthly water temperature	month	year
Turkmenbashi (Krasnovodsk)	5.3	January	-0.3	January	1977
Khazar (Cheleken)	6.7	December	1.5	February	2012
Duzlybogaz (Kara-Bogaz-Gol)	6.1	January	-0.3	January	1977
Garabogaz (Beckdash)	5.0	January, February	-0.4	January	1977
Guvlymayak (Kuuli-Mayak)	6.4	February	0.3	January	1977
Ogurdzhaly (Ogurchinsky)	6.4	December	0.5	January	1977

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

Table 3.3.12 – Absolute daily maximum water temperature (°C) in the Turkmenistan sector

Observation post*	Absolute maximum in 2024		Previous absolute maximum		
	water temperature	day, month	water temperature	day, month	year
Turkmenbashi (Krasnovodsk)	27.8	10.06	32.8	01.08	2011
Khazar (Cheleken)	30.3	05.08	35	13.08	2011
Duzlybogaz (Kara-Bogaz-Gol)	26.4	31.08	31.7	28.07	2009
Garabogaz (Beckdash)	23.6	08.07	30.2	01.08	2011
Guvlymayak (Kuuli-Mayak)	27.7	24.08	34.2	12.08	2014
Ogurdzhaly (Ogurchinsky)	34.3	01.06	39.1	11.08	2021

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

Table 3.3.13 – Absolute daily minimum water temperature (°C) in the Turkmenistan sector

Observation post*	Absolute minimum in 2024		Previous absolute minimum		
	water temperature	day, month	water temperature	day, month	year
Turkmenbashi (Krasnovodsk)	2.8	27.01	-1.2	3.02	2014
Khazar (Cheleken)	3.6	24.12	-1.5	5.02	2014
Duzlybogaz (Kara-Bogaz-Gol)	1.8	26.01	-2.4	14.02	2010
Garabogaz (Beckdash)	1.0	16.01	-0.9	08.02	2014
Guvlymayak (Kuuli-Mayak)	2.6	26.02	-1.1	05.01	1977
Ogurdzhaly (Ogurchinsky)	-1.0	29.01	-2.2	29.01	2018

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

3.3.3. Trends in the seawater temperature

Kazakhstan sector

For the Kazakhstan sector of the Caspian Sea, Table 3.3.14 presents an assessment of the linear trend in average annual and seasonal water temperatures based on the data from the Peshnoy observation station for the period 1976–2024.

The mean annual water temperature decreased on average by 0.16 °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 0.48 °C every 10 years. During the other seasons of the year, water temperature decreased by 0.1–0.71 °C every 10 years.

Table 3.3.14 – Estimates of the linear trend of average annual and seasonal water temperatures in the Kazakhstan sector for the period of 1976-2024

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Peshnoy	**-0.16**	12	**0.48**	67	-0.1	1.8	**-0.71**	44	**-0.33**	12

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 3.3.15 presents estimates of the linear trend of average annual and seasonal water temperatures at observation points of the Russian sector of the Caspian Sea for the period 1976-2024.

At all stations, both average annual and seasonal temperatures have steadily been increasing. Average annual temperatures have been increasing by an average of 0.28–0.50 °C every 10 years, and this change has been statistically significant at p = 5%. The rate of the rise in seasonal temperatures has ranged from 0.14 to 0.66 °C/10 years, which is statistically significant at the 5% level for all stations and seasons, with the exception of the autumn in Izberg.

Table 3.3.15 – Estimates of the linear trend of average annual and seasonal water temperatures in the Russian sector for the period of 1976-2024

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Derbent*	**0.31**	**38**	**0.21**	**7**	**0.44**	**29**	**0.34**	**21**	**0.23**	**11**
Izberg	**0.28**	**37**	**0.22**	**9**	**0.45**	**36**	**0.29**	**25**	0.14	5
Makhachkala	**0.50**	**43**	**0.47**	**22**	**0.61**	**32**	**0.49**	**27**	**0.42**	**24**
Tyuleniy Isl.	**0.46**	**45**	**0.42**	**22**	**0.37**	**17**	**0.33**	**33**	**0.66**	**34**
Lagan	**0.41**	**59**	**0.25**	**29**	**0.45**	**34**	**0.54**	**50**	**0.55**	**40**

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
** at Derbent station, estimates of the linear trend are presented for the period 1977–2024*

Turkmenistan sector

Table 3.3.16 – Estimates of the linear trend of average annual and seasonal water temperatures in the Russian sector for the period of 1976-2024

Observation post*	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Turkmenbashi (Krasnovodsk)	0.28	5.07	0.30	12.1	0.27	21.1	0.42	44.6	0.27	11.9
Khazar (Cheleken)	1.18	7.15	0.13	0.64	0.35	4.85	0.01	0.00	0.29	4.05
Duzlybogaz (Kara-Bogaz-Gol)	0.24	29.1	0.35	18.2	0.21	8.5	0.21	4.74	0.24	9.72
Garabogaz (Beckdash)	0.07	0.56	0.26	8.43	0.41	24.4	0.92	53.5	0.1	1.46
Guvlymayak (Kuuli-Mayak)	0.24	31.7	0.16	4.56	0.33	28.0	0.38	17.2	0.03	0.12
Ogurdzhaly (Ogurchinsky)	0.34	39.7	0.42	19.7	0.38	29.0	0.38	17.1	0.23	8.26

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 2023-2024 in the Caspian Sea was mild with unstable ice cover in the northern shallow part of the Caspian Sea.

From 8 December 2023, the first ice showed up near the northern coast of the Caspian Sea according to the data of the Peshnoy station; at the time of ice appearance, the mean daily water temperature at Peshnoy was 2.1 °C and the air temperature was -3.9 °C. On 9 December, initial ice types appeared (Fig. 4.1). On 15 December, according to data of Fort-Shevchenko, initial ice types were present in the area of Fort Shevchenko and in Kenderly Bay.

8 December 2023 ***11 December 2023***

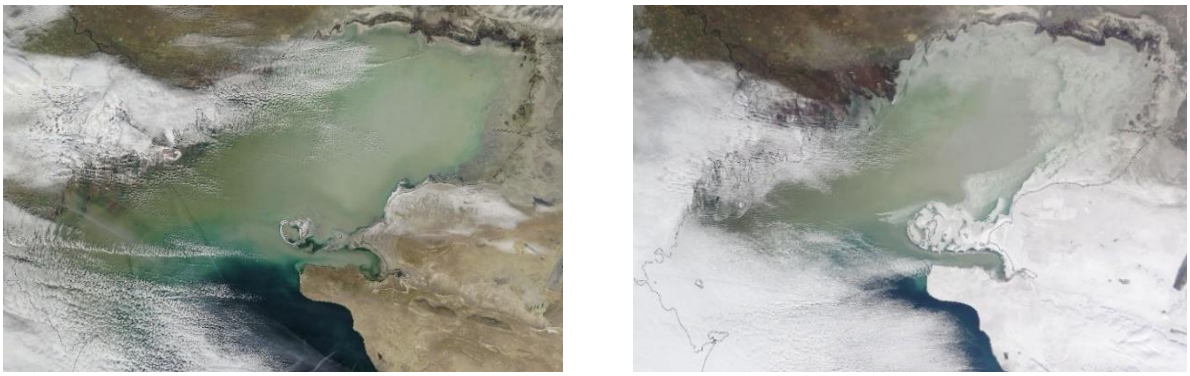


Figure 4.1 – Formation of ice cover in the Northern Caspian in December 2023 (NASA project image)

The maximum ice thickness was recorded near the northeastern coast of the Northern Caspian at the end of January–February 2024. It reached 23 cm in the area of the hydrometeorological station Peshnoy on 3–4 and 25–29 February and 15 cm in the area of Kuryk on 16 December (Fig. 4.2).

26 February 2024 ***29 February 2024***

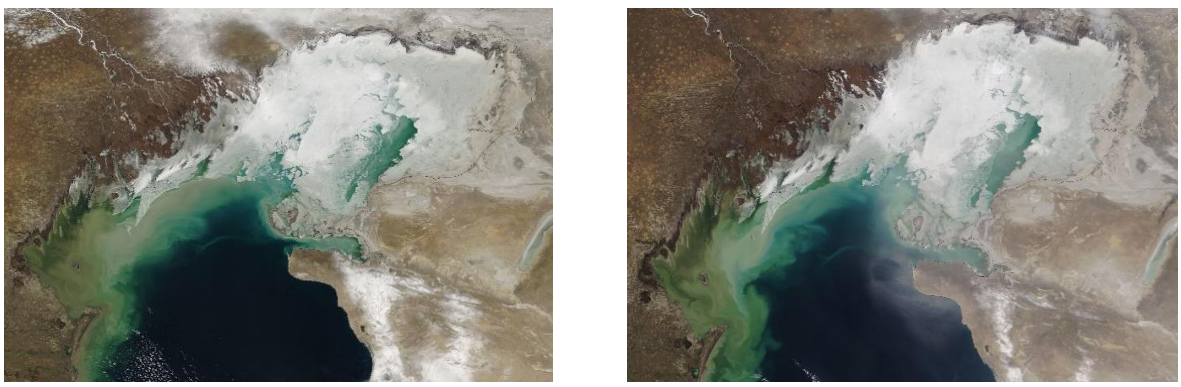


Figure 4.2 – Formation of a stable ice cover in the Northern Caspian Sea (NASA project image, February 26-29, 2024)

From 13 March 2024, a gradual spring ice melting began (Fig. 4.3).

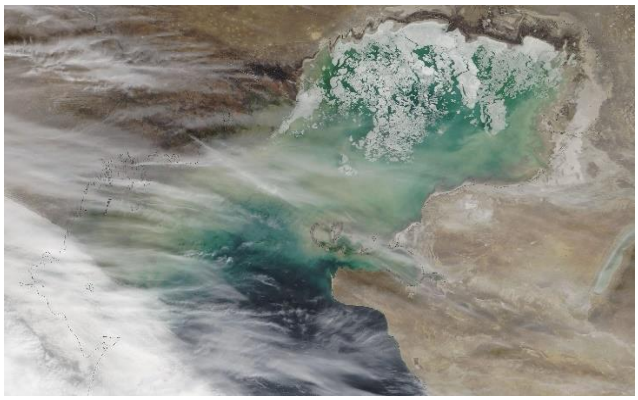


Figure 4.3 – Beginning of spring ice melting in the Northern Caspian (NASA project image, March 14, 2024)

On 23 March 2024, the entire northern coast of the Caspian Sea was completely ice-free (Fig. 4.4).

Figure 4.4 – Spring ice melting in the Northern Caspian (NASA project image, March 29, 2024)

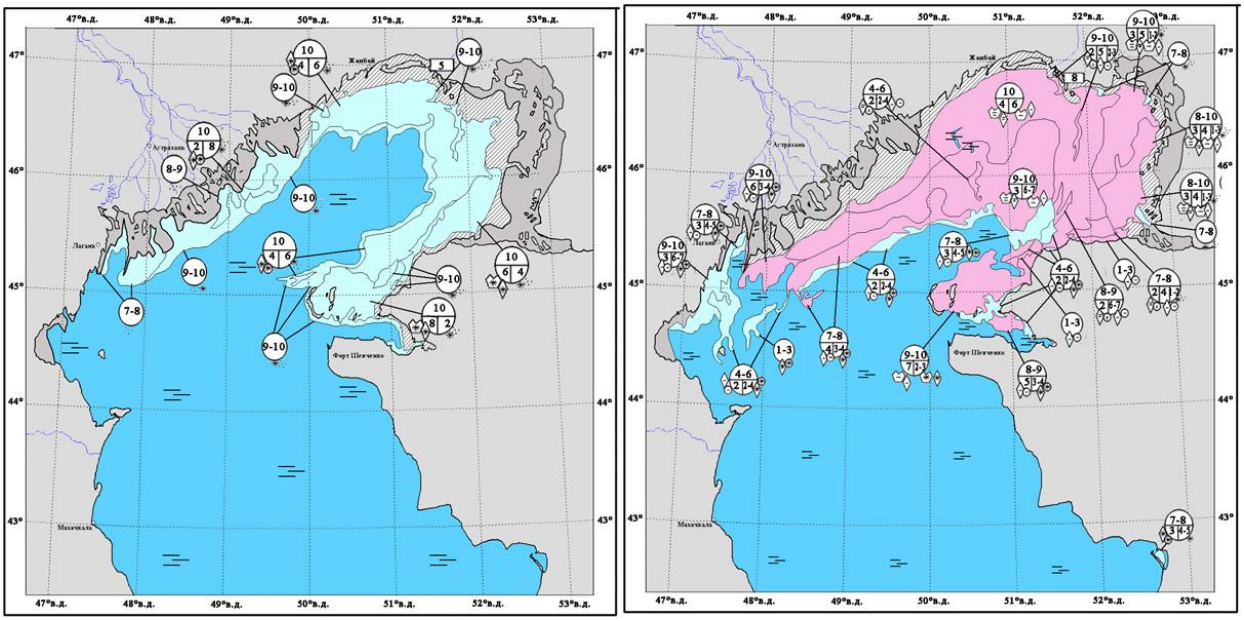
In the winter of 2023–2024, the ice formed a week later than in the previous winter season and melted a week earlier. The total duration of the ice life period was about four months; ice phenomena were observed for 73 days at Peshnoy.

Russian sector

Initial ice formation in the northwestern part of the Caspian Sea began in the second decade of December 2023: near Lagan and Iskusstvenny Island on December 13 and 17, respectively. According to satellite observations on December 11, initial ice types predominated in the northwestern Caspian Sea, specifically in the area of the Volga–Caspian Sea Shipping Channel.

By December 18, an extensive zone of initial ice types and dark nilas extended northward from Chechen Island to the mainland coast in the west. Along the delta, starting from 48° E, a consolidated belt of grey drifting ice formed, stretching toward the northern and eastern shores of the Northern Caspian Sea. In the northern part of the sea, fast ice reached a thickness of 10 cm.

From December 25 to 26, nilas and grey drifting ice were observed in the northwestern Caspian Sea and in the northern part of Kizlyar Bay. In the northern section of the Volga-Caspian Channel, fast ice and consolidated grey drifting ice were present, whereas grey drifting ice predominated in the southern part of the channel. Open water remained to the west of the channel. In the northern and western parts of the Astrakhan raid, sparse and fragmented drifting ice ranged from nilas to grey. In the Volga Delta, fast ice 7–12 cm thick was observed along the shores, with grey and grey-white drifting ice occurring seaward of the fast ice (Fig. 4.5).



11.12.2023 **25.12.2023**

Figure 4.5 – Ice cover maps for December 2023 (data from the Russian Hydrometeorological Center)

In the first half of January, warm air masses came from the Atlantic and led to a significant sea ice melting in the Northern Caspian. Ice cover remained primarily along the western coast, from Morskaya Chapura Island to Lagan. Dark nilas dominated in this area, locally interspersed with grey drifting ice, with concentrations between 4 and 8 on the ice concentration scale.

In the eastern part of the sea, east of 48° E and near the Volga Delta, grey drifting ice zone extended northeastward along the coastline (Fig. 4.6).

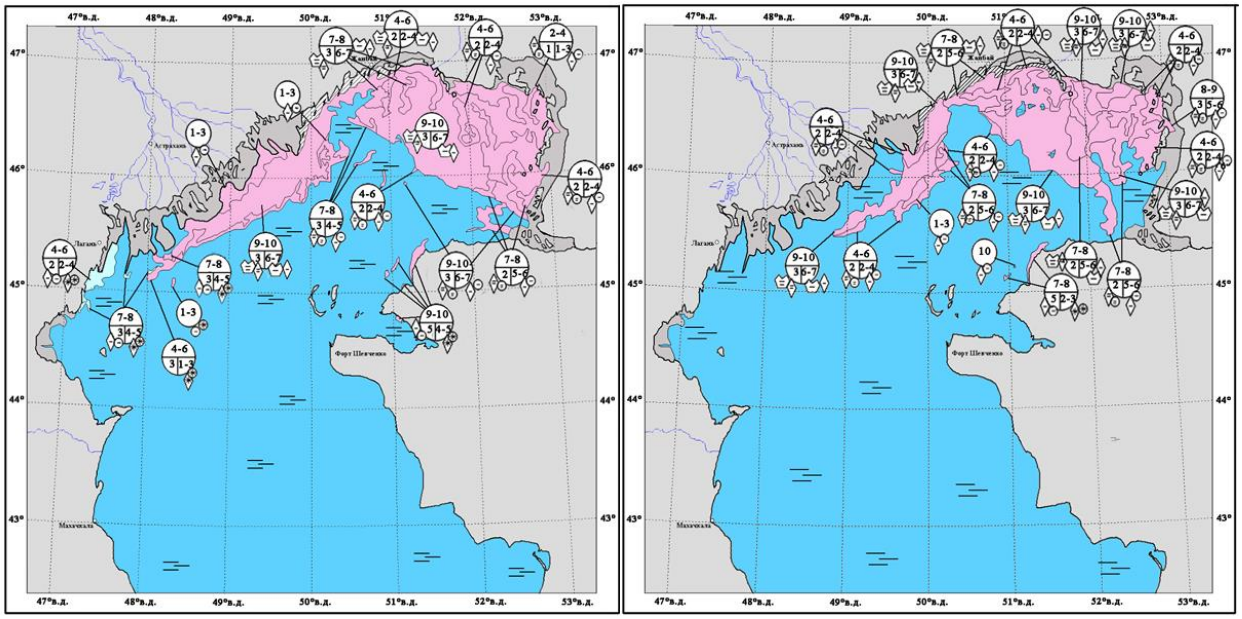


Figure 4.6 – Ice cover maps for 1 and 8 January 2024 (data from the Russian Hydrometeorological Center)

In the second half of January, freezing temperatures were quite stable, ranging from –6.3 °C to –10.7 °C, they triggered active ice formation. By January 23, landfast ice extended from 45° N along the western and northeastern coasts of the sea. In the northern part of Kizlyar Bay, drifting nilas mixed with grey ice. In the Volga Delta, a continuous belt of fast ice was observed, with denser fields of grey and grey-white drifting ice seaward.

At Lagan, the maximum ice thickness reached 7 cm at the end of January (January 30–31). Near Iskusstvenny Island, ice cover was sporadic, as it was regularly broken up to maintain navigation for vessels (Fig. 4.7).

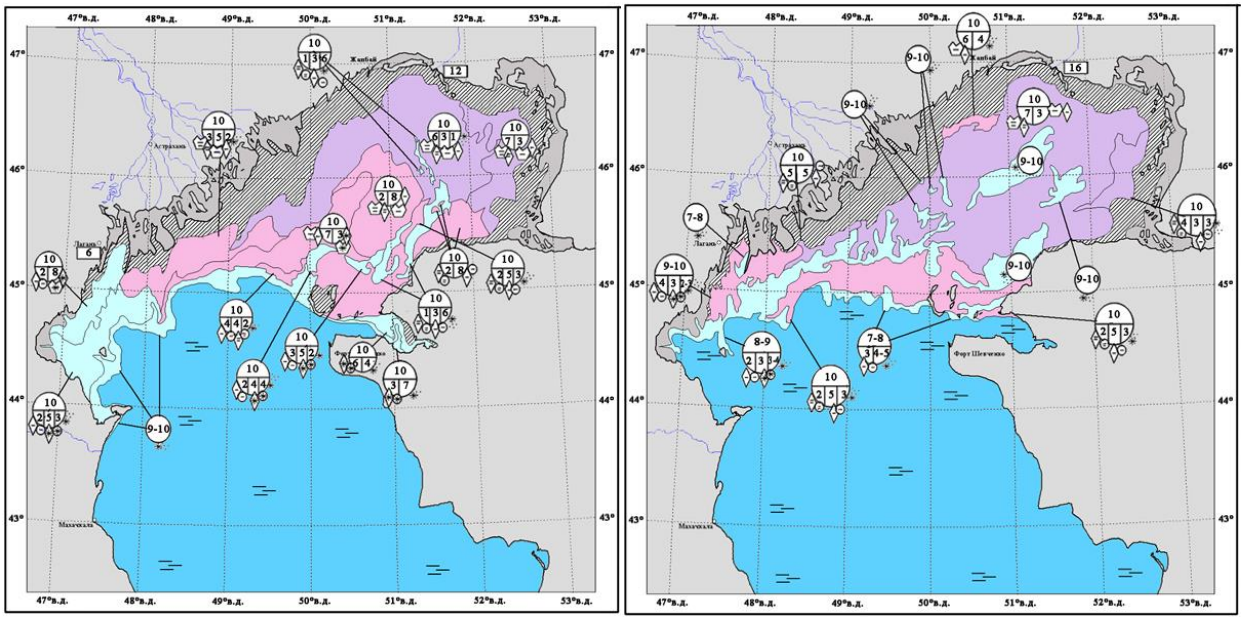


Figure 4.7 – Ice cover maps for 15 and 23 January 2024 (data from the Russian Hydrometeorological Center)

In early February, fast ice was observed in the northern part of the sea adjacent to the Volga Delta, while southward it was bordered by grey drifting ice with a thickness ranging from 10 to 15 cm (Fig. 4.8).

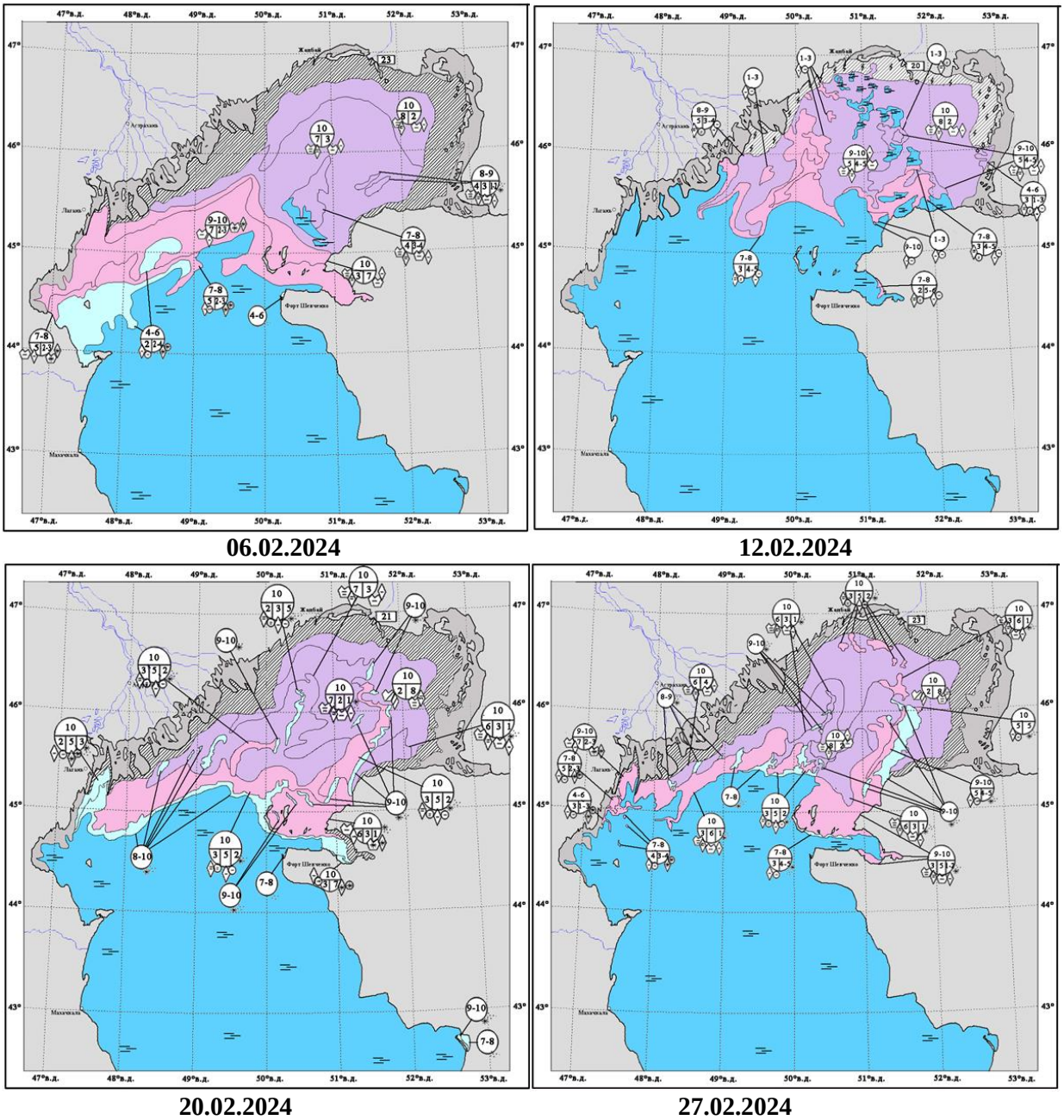
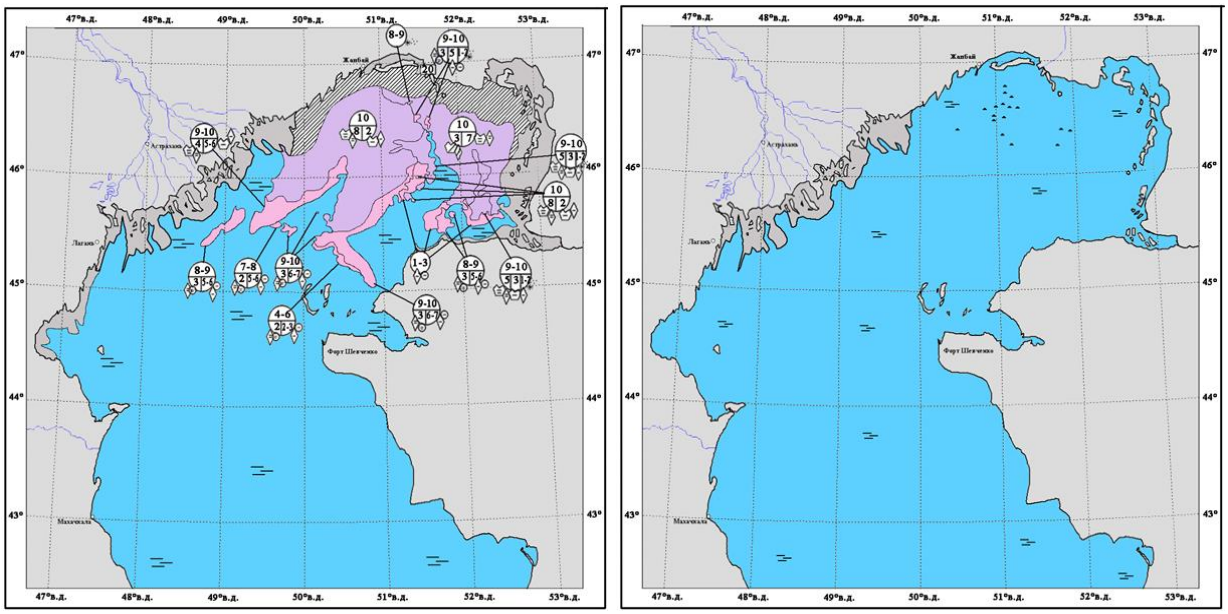


Figure 4.8 – Ice cover maps for February 2024 (data from the Russian Hydrometeorological Center)

From the Agrakhan Peninsula toward Kizlyar Bay, predominantly nilas with a thickness of up to 10 cm and concentration ranging from 4 to 6 points on the ice concentration scale, was present. From February 5 to 13, a significant warming spell occurred due to the influx of warm air masses from the Atlantic and the Mediterranean. This triggered active ice melting in the southwestern part of the sea. By this time, fast ice remained only southeast of the Volga Delta, beyond which a belt of grey and grey-white drifting ice extended. By February 12, the western

part of the Northern Caspian Sea from the coast eastward to 49° E became completely ice-free. In the third decade of February, weather conditions were dominated by the Siberian anticyclone. Air temperatures dropped to –2.0 °C at Tyuleniy Island and as low as –10.2 °C along the coast. By February 20, the ice edge extended to the north of Morskaya Chapura Island. Toward the Volga Delta, initial ice types and light nilas were observed, locally interspersed with grey drifting ice. By the end of February, the sea surface from 45° N to Lagan and further toward the Volga Delta was covered with grey drifting ice with some patches of dark nilas. In the delta area, east of 48° E, grey-white drifting ice predominated seaward of the fast ice, followed farther offshore by a zone of grey ice. At Lagan, the maximum ice thickness recorded between February 1 and 4 was 7 cm.

In early March, drifting ice still remained in the northeastern part of the Caspian Sea. However, the ice had completely melted in the south of the Volga Delta and in the northwestern shallow areas seaward. By the end of March, the entire Northern Caspian was completely free of ice (Fig. 4.9).



06.03.2024 **26.03.2024**

Figure 4.9 – Ice cover maps for 6 and 26 March 2024 (data from the Russian Hydrometeorological Center)

CONCLUSION

Kazakhstan sector

2024 was one of the five warmest years on record on the Kazakh coast of the Caspian Sea. The average annual temperature anomaly ranged from 0.5 to 1.4 °C.

Average seasonal temperatures rose at a rate of 0.31 to 0.88 °C/10 years. The greatest temperature increase in all seasons (except summer) and year was observed at Atyrau (0.59 °C/10 years in winter; 0.67 °C/10 years in spring; 0.57 °C/10 years in autumn), while the maximum rate of summer warming at Aktau was 0.88 °C/10 years.

In 2024, there was an uneven moisture regime. Practically all of Kazakhstan's Caspian Sea coastline received above-average annual precipitation: 120.4 % of the normal at Aktau and 131.3 % of the normal at Fort-Shevchenko. Annual precipitation within the normal range were observed at Ganyushkino, Peshnoy and Atyrau, located on the Northern Caspian coast, as well as at other meteorological stations in the Middle Caspian, where the annual precipitation amounted to 95.0–119.5 % of the normal.

During the winter period, there was a significant difference in moisture conditions: the coast of the Northern Caspian recorded a significant excess in precipitation (155.3–224.1 % of the normal), while its deficit was typical in the eastern part of the Middle Caspian Sea (42.6–79.6 % of the normal), with the exception of Aktau, where precipitation was around the normal. In spring, most meteorological stations recorded above-normal precipitation (101.2–189.6 % of the normal), especially in March and May, while April was extremely dry. The summer months were characterized by a significant precipitation deficit, with most stations recording only 8–54.4 % of the normal, moreover, some stations recorded no precipitation at all in July and August. In autumn, moisture conditions were mostly above normal (up to 214.3 % of the normal), especially in October and November. A significant precipitation deficit was observed at Peshnoy in October, while the greatest precipitation compared to the other stations was recorded there in November (251.0 % of the normal).

In the long term (1936–2024), the annual volume of water on the Ural River (Zhaiyk) has decreased. In 2024, the annual runoff volume near the village of Makhambet amounted to 17,9 km³, which was as high as 2,2 times than the average annual value (8,12 km³).

According to the data of coastal and island stations and posts of the «Kazhydromet» RSE, the average level of the Caspian Sea in 2024 was -28,95 m in its northeastern part and -29,29 m in the middle part.

At the northeastern coast of the Caspian Sea, marine stations and posts located in the Kazakhstan coast recorded 48 upsurge and 47 downsurge events in 2024.

In 2024, the average annual water temperature according to the data from the coastal marine stations located in the Kazakhstan sector of the sea was +10,7...+14,7 ºC.

The winter of 2023-2024 was mild with unstable ice cover in the northern shallow part of the Caspian Sea. The maximum ice thickness was recorded near the northeastern coast of the Caspian Sea at the end of January–February 2024. On March 23, 2024, the entire northern coast of the Caspian Sea was completely ice-free.

Russian sector

The year 2024 was anomalously warm. Absolute records for annual mean air temperature were documented at Izberg and Derbent, they reached +14.4 °C and +15.3 °C, respectively. These values represent positive anomalies of +1.5 °C and +1.6 °C compared to the climatic standard normal. Throughout the year, multiple temperature records were registered, including two annual mean temperature records, six monthly mean temperature records, and three maximum temperature records.

Spring in Derbent became the warmest on record for the entire climatic observation period (1922–2024). At both Izberg and Derbent, anomalously high minimum monthly air temperatures of +6.7 °C and +7.0 °C, respectively were observed in April, they took first places in the historical ranking from warmest to coldest years.

From 1976 to 2024, an ongoing warming trend has been observed across the Russian sector of the Caspian Sea, with annual mean temperatures increasing by 0.39–0.58 °C per decade. The rate of seasonal warming varied from 0.36 to 0.70 °C per decade, with the most pronounced warming in all seasons occurring in the southern coastal zone, particularly at Derbent.

Precipitation in 2024 was unevenly distributed. Annual totals ranged from 323.8–462.9 mm (98–114% of the norm) along the western coast of the Middle Caspian to 183.4 mm (93% of the norm) at Tyuleniy Island. Analysis revealed significant seasonal variations. Winter was exceptionally wet, with precipitation 47–87% above the normal. Spring brought precipitation excesses in Izberbash and Derbent (131% and 179% of the normal, respectively). Autumn in Makhachkala was anomalously dry (79% of the normal). At Tyuleniy Island, autumn and winter were extremely wet (140% and 151% of the norm), while summer was exceptionally dry (only 22% of the norm). Spring also faced a deficit there (83% of the normal).

Monthly precipitation patterns were highly irregular. Severe deficits were registered along the Middle Caspian coast in January and April, with only 5–26% of the normal. March at Izberg was record-breaking, with 336% of the normal. October was the wettest month at Derbent (146% of the norm). At Tyuleniy Island, July and September were extremely dry (just 3% of the normal),

while October was exceptionally wet (237% of the normal). Long-term trajectories (1976–2024) show an increasing trend in annual precipitation along the western coast of the Middle Caspian and a decreasing one at Tyuleniy Island. Winter precipitation is rising significantly, especially near the Middle Caspian coast. Spring shows mixed trends. Summer exhibits consistent drying across the region. Autumn precipitation is rising primarily along the western Middle Caspian coast.

Hydrological conditions in 2024 were marked by persistent low water levels. The year ranked among the eight driest in the past 25 years. At the Verkhnelebyazhye station, the annual discharge of the Volga River was 210.589 km³, significantly below the normal of 247.032 km³ (K = 0.85). Dagestan's mountain rivers runoff was also reduced. The Sulak River runoff was 4.193 km³ vs. the normal of 4.901 km³ (K = 0.85). The Terek River runoff (at Kargalinsky hydrosystem) reached 6.912 km³ vs. the normal of 8.122 km³ (K = 0.85).

The Caspian Sea level continued to decline in 2024. Compared to 2023, water levels in the Russian sector dropped by 12–26 cm. Since 2022, the cumulative decline reached 31–38 cm. Hazardous hydrological events were frequent. At Makhachkala, monthly minimum sea levels exceeded the thresholds by 10–56 cm during January, February, and September–December. At Lagan, mean monthly levels in January, March, and November reached the historical lows: -78 cm, -70 cm, and -86 cm, respectively, which are lower than in he extreme low-level years of 1976–1978. Record-low maximum monthly levels were observed throughout summer across the Russian sector. In March, a wind-driven downsurge in Lagan produced the lowest monthly minimum in nearly 90 years (since regular observations started in 1935). At Tyuleniy Island, mean monthly levels from July to September and in November–December were record lows. Moreover, maximum monthly levels from February–March and July–November were the lowest in over 80 years (since 1938). Wind-driven fluctuations were most frequent at Lagan, due to its location in a former Volga tributary watercourse. Major surges occurred there in March–May and September–December, raising water levels by 68–94 cm above monthly means. The strongest downsurge events were recorded in March, April, and December, with water levels dropping by 46–56 cm.

Water temperature in 2024 was exceptionally high, driven by the extreme air warmth. A series of records was registered: 3 annual mean water temperature records, 11 monthly mean records, 5 records for maximum monthly water temperature. There were 13 cases when the minimum monthly water temperature was the highest ever recorded. Positive anomalies ranged from +2.5 °C to +9.8 °C, confirming a robust warming trend in the Caspian water masses.

The 2023/2024 winter was mild, the cumulative sum of negative daily mean temperatures at Astrakhan meteorological station was only -234.9 °C. Ice cover was weak and unstable. Frequent warm spells, especially in early January and February, caused partial ice melting and

significant reduction in the ice extent. As a result, large areas of the sea have remained ice-free throughout the whole winter.

Turkmenistan sector

To assess changes in air temperature and atmospheric precipitation, observations from 1989 to 2024 were analyzed, including the baseline climatic reference period of 1991–2020.

Along the Turkmen Caspian coast, there are six hydrometeorological stations (Garabogaz, Duzlybogaz, Guvlymayak, Khazar, Turkmenbashi, Ogurchinskiy Island), where meteorological and hydrological conditions have been monitored from 1989 on. Prior to that, observations in this region were carried out by the Department for Hydrometeorology in Azerbaijan.

According to long-term data, a clear upward trend in annual mean air temperature is evident along the Turkmen Caspian coast, which is consistent with the overall warming pattern observed across Turkmenistan as a whole. Conversely, annual precipitation totals have shown a decline, a trend also characteristic of the broader national territory.

It should be noted that not only the average temperatures have increased in recent years, but the frequency of anomalously high temperatures has also risen significantly. Regarding precipitation, while the number of rainy days has remained relatively unchanged, the total amount of rainfall has decreased.

It is projected that ongoing climate change will lead to further increases in average temperatures, resulting in hotter, longer, and more frequent summer heatwaves and droughts. Additionally, a likely reduction in annual precipitation totals is expected, exacerbating arid conditions in the region.

LITERATURE

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