Coordination Committee on Hydrometeorology of the Caspian Sea

(CASPCOM)

ANNUAL BULLETIN OF MONITORING THE CLIMATE STATE AND CHANGE IN THE CASPIAN SEA REGION

for 2022 year

2023

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INTRODUCTION

Since the Caspian region is currently actively developing economically, and reliable and up-to-date hydrometeorological information is required, 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 provides analysis of hydrometeorological regime in 2021–2022 (starting from the first month of the cold period – December), 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.

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.).

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 Azerbaijanian sector, **Azhydromet** specialists;

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

- for Kazakh sector, **Kazhydromet** specialists**:** Tursyn Tillakarim, Elena Smirnova, Nazerke Abdolla, and in the field of monitoring the state and changes in hydrological conditions - Aizat Yeltay, Nurgalym Serikbay;

- for Russian sector, **Roshydromet** specialists**:** Elena V. Ostrovskaya, Elena V. Gavrilova, Vitaliy O. Tatarnikov, Irina V. Gontovaya, Diana R. Svetasheva;

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

1. DATA DECRIPTION

This chapter provides a list of hydrometeorological stations and posts of NHMS on the Caspian Sea coasts.

1.1 For the preparation of the Bulletin, the data observed at the coastal hydrometeorological stations/posts were used on the following characteristics (parameters):

Observation post	Air temperature	Precipitation	Sea level	Seawater temperature
Azerbaijan				
Baku	+		+	+
Zhiloy isl.	+		+	+
Lenkoran	+		+	+
Oil Rocks	+		+	+
Sumqayit	+		+	+
Iran				
Amirabad	+			+
Ashoradeh			+	
Babolsar	+	+		
Bandar Torkaman	+			
BandarGaz	+			
Dashtenaz	+			
Neka			+	
Noushahr	+		+	+
Ramsar	+	+		
Freydoonkenar			+	
Anzali	+	+	+	+
Kazakhstan				
Aktau	+		+	+
Atyrau	+	+		
Ganyushkino	+	+		
Kulaly	+	–	+	+
Kyzan	+	+		
Peshnoy	+	+	+	+
Tushchibek	+	+		
Fort Shevchenko	+	+	+	+
Russian Federation				
Derbent	+	+		+
Izberg	+	+		+
Kaspiisky (Lagan)			+	+
Makhachkala	+	+	+	+
Tyuleniy isl.	+	+	+	+
Turkmenistan				
Bekdash	+	+	+	+
Kara-Bogaz-Gol	+	+	+	+
Kuuli-mayak	+	+	+	+
Krasnovodsk	+	+	+	+
Ogurchinsky	+	+	+	+
Cheleken	+			

1.2. To prepare the Bulletin, the data on the river flow into the Caspian Sea observed at the estuarine hydrological stations and posts were used:

Country	River	Observation post
Azerbaijan	Kura	Saliany
Iran	Sefidrood	Pole Astane
	Haraz	Kore Sang
	Chaloos	Pole Zoghal
	Polrood	Toollat
Kazakhstan	Ural	Makhambet
Russian Federation	Volga	V. Lebyazhye village
	Sulak	Sulak village
	Terek	Kargalinsky hydrosystem

1.3. The Bulletin uses the data from Roshydromet and Kazhydromet to characterize ice conditions in the Northern Caspian.

1.4. The average annual value is calculated for a calendar year (from January to December of the described year). Seasonal descriptors and statistics are calculated for a meteorological year: **Winter** is from December of the previous year to February of the analyzed one, **Spring** – March, April, May, **Summer** – June, July, August, etc.

According to WMO guidance, period from 1 January 1991 to 31 December 2020 is endorsed as the climatic reference period to assess climate change. Anomalies of the average monthly air temperature are calculated against these normals, as recommended by the WMO for climate change monitoring. Basic statistics – ranks (ordinal numbers in an ordered series of values) are also used as additional characteristics of anomalies. The change in air temperature is characterized by the linear trend coefficient, which is the average rate of air temperature variation, and the coefficient of determination, which shows the dispersion of the series taken into account by the trend.

The anomalies of monthly precipitation amounts are determined against the standard normal calculated for the period of 1991-2020, which is recommended by the WMO as the baseline for monitoring the current climate change. Annual and seasonal precipitation amounts are expressed in mm, or as a percentage of the standard normal. The ranks are also used as additional characteristics of anomalies.

The bulletin adopted the average annual value of water temperature for the period 1991-2020 as the climate normal. Water temperature anomalies were defined as deviations of the observed value from the normal.

In case of the other periods being used as a climatic reference period it is specifically pointed out in the text.

2. METEOROLOGICAL CONDITIONS

2.1. AIR TEMPERATURE

2.1.1 Air temperature in 2022

Azerbaijan sector

Table 2.1.1 – Characteristics of the average annual and seasonal air temperature according to the data of observation posts of the Azerbaijan sector in 2022: *T – the current value of air temperature;* ***vT*** *– deviations from the long-term average for 1961-1990, ℃; s – the average square deviation in °C for the period 1961-1990*

Observation post	Year			Winter			Spring			Summer			Autumn		
	T	vT	s	T	vT	s	T	vT	s	T	vT	s	T	vT	s
Oil Rocks	16.1	14.5	1.6	8.7	6.5	2.2	11.6	10.7	0.9	25.0	23.4	1.6	19.5	17.4	2.1
Baku	16.3	14.7	1.6	7.7	5.2	2.5	13.5	12.3	1.2	26.7	25.0	1.7	17.9	16.4	1.5
Sumgait	16.1	14.3	1.8	7.5	4.9	2.6	13.2	11.8	1.4	26.2	24.4	1.8	18.2	16.1	2.1
Zhiloy Isl.	15.8	14.4	1.4	8.0	5.8	2.2	11.6	10.9	1.0	25.4	23.9	1.5	18.8	17.0	1.8

Table 2.1.2 – Ranks of the warmest years on the Azerbaijan coast and related anomalies of the average annual air temperature (1961-2022): *R - the rank of the current values in a series ordered in descending order for positive anomalies and in ascending order for negative ones; the period for calculating the ranks: whole observation period*

R	Year	Average annual temperature	Anomaly	Year	Average annual temperature	Anomaly	Year	Average annual temperature	Anomaly	Year	Average annual temperature	Anomaly
	Baku			Sumgait			Oil Rocks			Zhiloy Isl.		
1	2019	16.7	2	2010	16.1	1.8	2010	16.5	2	2010	16.3	1.9
2	2020	16.5	1.8	2021	16.1	1.8	2019	16.2	1.7	2021	15.9	1.5
3	2010	16.5	1.8	2018	16	1.7	2021	16.1	1.6	2022	15.9	1.5
4	2018	16.1	1.4	2019	16	1.7	2018	16.1	1.6	2018	15.8	1.4
5	2021	16.1	1.4	2020	15.9	1.6	2022	16.1	1.6	2019	15.8	1.4
6	2022	16.1	1.4	2015	15.6	1.3	2020	15.9	1.4	2020	15.7	1.3
7	2012	15.9	1.2	2017	15.6	1.3	2012	15.9	1.4	2012	15.6	1.2
8	2015	15.7	1	2012	15.5	1.2	2013	15.8	1.3	2013	15.4	1
9	2017	15.7	1	2014	15.5	1.2	2017	15.8	1.3	2017	15.4	1
10	2013	15.6	0.9	2007	15.4	1.1	2015	15.6	1.1	2015	15.3	0.9
11	2016	15.2	0.5	2013	15.3	1	2016	15.4	0.9	2007	15.3	0.9
12	2007	15.1	0.4	2016	15.3	1	2007	15.4	0.9	2006	15	0.6
13	2014	15.1	0.4	2006	15.1	0.8	2006	15.2	0.7	2014	15	0.6
14	2008	14.9	0.2	2008	14.9	0.6	2014	15.2	0.7	2016	14.9	0.5
15	2011	14.8	0.1	2009	14.7	0.4	2011	15.1	0.6	2011	14.8	0.4
16	2009	14.8	0.1	2011	14.6	0.3	2008	14.8	0.3	2009	14.7	0.3
17	2006	14.8	0.1	2022	14.3	1.9	2009	14.7	0.2	2008	14.6	0.2

Table 2.1.3 – Absolute maximum/minimum of the average monthly air temperature (°C) recorded in the Azerbaijan sector in 2022

Observation post	Month	Absolute maximum of 2022	Previous maximum and a year of its occurrence	Absolute minimum of 2022	Previous minimum and a year of its occurrence
Oil Rocks	January	11.9	12.2	3.7	2.6
	February	12.4	11.4	4.5	-2.4
	March	12.4	12.9	3.5	1.5
	April	22.5	16.8	5.5	8.4
	May	24.7	22.6	10.4	11.7
	June	26.6	30.3	19.8	18.0
	July	28.2	31.5	22.2	24.1
	August	31.6	33.7	24.6	26.0
	September	30.8	30.2	20.6	16.5
	October	25.0	20.9	14.7	11.1
	November	17.8	16.1	8.5	8.6
	December	12.1	14.9	3.3	4.9
Sumgait	January	18.0	19.8	-0.8	0.6
	February	16.4	16.3	1.3	-5.1
	March	20.7	18.5	1.9	1.1
	April	27.4	23.6	5.6	8.0
	May	32.9	34.1	11.1	11.1
	June	34.4	41.0	16.8	17.9
	July	38.5	35.7	19.8	22.3
	August	40.0	41.6	18.3	23.2
	September	40.1	31.8	15.4	14.7
	October	29.0	22.2	10.8	8.8
	November	19.8	27.8	8.2	3.7
	December	13.2	22.9	1.6	1.0
Baku	January	16.2	17.7	0.3	-1
	February	19.0	22.2	1.7	-6.3
	March	17.4	28	1.3	0.2
	April	30.1	27.1	7.0	7.7
	May	32.5	34.1	10.3	8.8
	June	34.6	41.2	17.1	18.1
	July	38.6	38.5	17.8	20.9
	August	38.1	41.2	19.1	21.7
	September	39.7	36.1	14.1	13.7
	October	28.5	22.6	10.6	7.3
	November	20.5	19.5	7.1	1.8
	December	13.1	26	1.9	0.2
Zhiloy	January	12.2	9.2	2.2	2.7
	February	11.9	11.0	-2.0	-3.8
	March	14.4	13.3	2.8	1.2
	April	23.7	17.3	5.6	7.6
	May	28.0	22.3	11.9	12.3
	June	29.4	32.0	18.4	17.6
	July	31.3	31.9	21.3	23.4
	August	33.5	34.0	23.5	24.6
	September	33.5	30.6	18.4	16.8
	October	25.7	21.0	11.9	10.3
	November	18.2	16.0	8.0	7.0
	December	12.5	16.0	2.5	4.1

Table 2.1.4 – Records of maximum monthly air temperature (°C) in the Azerbaijan sector in 2022

Observation post	Date	Month	Air temperature, °C	Previous maximum, °C	Date of the previous maximum
Oil Rocks	17	August	31.6	34.7	07.08.2010

Table 2.1.5 – Records of minimum monthly air temperature (°C) in the Azerbaijan sector in 2022

Observation post	Date	Month	Air temperature, °C	Previous maximum, °C	Date of the previous maximum
Oil Rocks	21	март	3.3	-4.1	02.02.2014

Iranian sector

Year of 2022 was referred to as warm at the weather stations located on the Iranian coast of the Caspian Sea. The average annual air temperatures were +17.6... +18.3°C, which is 1.8°C higher than the normal (the reference period of 1961-1990), the anomalies were 2.3-3.0 times higher than the standard deviation.

The air temperatures of the winter, spring and summer seasons significantly exceeded the normal: by 1.9-2.4°C in the winter; by 1.7-2.1°C in the spring; by 2.6-2.9°C in the summer. Anomalies exceeded the standard deviation by 1.4-4.3 times in summer. Positive anomalies of autumn temperatures were 0.2-0.4°C and did not exceed the standard deviation (Table 2.1.6).

Table 2.1.6 – Characteristics of the average annual and seasonal air temperature according to the data of observation posts of the Iranian sector in 2022: *T – the current value of air temperature;* ***vT*** *– deviations from the long-term average for 1961-1990, ℃; s – the average square deviation in °C for the period 1961-1990*

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	10.1	2.4	1.6	15.5	1.9	0.8	27.6	2.6	0.6	18.0	0.2	0.9
Babolsar	18.3	1.8	0.6	9.8	1.9	1.2	16.5	2.1	0.7	28.2	2.9	0.7	18.6	0.4	0.8
Ramsar	17.6	1.8	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

Table 2.1.7 presents the ranks of the warmest years on the Iranian coast of the Caspian Sea and the corresponding anomalies of the average annual surface air temperature.

On the Iranian coast, 2010 remains the warmest with an air temperature of +17.9... +18.8° C, which is 1.9-2.3° C above normal.

Table 2.1.8 shows the records of the maximum/minimum of the average monthly air temperature (°C) recorded at the observation points of the Iranian sector in 2022.

Table 2.1.7 – Ranks of the warmest /or coldest / years on the Iranian coast and related anomalies of the average annual air temperature (1961-2022): *R - the rank of the current values in a series ordered in descending order for positive anomalies and in ascending order for negative ones (only the first 5 ranks are shown); the period for calculating the ranks: whole observation period*

R	Year	Average annual temperature	Anomaly	Year	Average annual temperature	Anomaly	Year	Average annual temperature	Anomaly
	Anzali			Babolsar			Ramsar		
1	2010	17.92	1.92	2010	18.76	2.26	2010	17.92	2.12
2	2021	17.79	1.79	2018	18.50	2.00	2018	17.63	1.83
3	2019	17.73	1.73	2021	18.31	1.81	2021	17.56	1.76
4	2018	17.67	1.67	2019	18.19	1.69	2019	17.39	1.59
5	1966	17.48	1.48	2012	18.11	1.61	1962	17.35	1.55

Table 2.1.8 – Absolute maximum/minimum of the average monthly air temperature (°C) recorded in the Iranian sector in 2022

Observation post	Month	Absolute maximum of 2022	Previous maximum and a year of its occurrence	Absolute minimum of 2022	Previous minimum and a year of its occurrence
Amirabad	Aug	27.7	28.7(2017)	8.4(Jan)	3.2(2008)
Anzali	Aug	28.0	28.9(2017)	8.8(Jan)	2.6(1977)
Babolsar	Aug	28.0	29.3(2021)	9.3(Jan)	3.2(1964)
Bandar Gaz	Aug	31.0	32.5(2021)	10.2(Jan)	7.9(2017)
Bandar Torkaman	Aug	28.6	30.3(2014)	8.7(Jan)	3.1(2008)
Dashtenaz	Aug	27.5	29.1(2021)	7.6(Jan)	3.0(2008)
Noshahr	Aug	27.3	28.3(2017)	8.9(Jan)	3.7(2008)
Ramsar	Aug	27.7	28.8(2017)	8.6(Jan)	3.0(1972)

Tables 2.1.9 and 2.2.10 present the records of the maximum and minimum of the monthly air temperature (°C) recorded at observation points on the Iranian coast of the Caspian Sea in 2022.

In 2022, seven records of the maximum monthly air temperature were observed on the Iranian coast of the Caspian Sea, the previous records were noted in 2021.

Table 2.1.9 – Records of maximum monthly air temperature (°C) in the Iranian sector in 2022

Observation post	Date	Month	Air temperature, °C	Previous maximum, °C	Date of the previous maximum
Amirabad	2022	Sep	36	34	2021
Anzali	2022	Aug	35.5	35.2	2021
Babolsar	2022	Sep	35.4	34.6	2021
Bandar Gaz	2022	Sep	40.8	37.9	2021
Bandar Torkaman	2022	Sep	39.5	35.1	2021
Dashtenaz	2022	Jun	38.4	38.6	2021
Noshahr	2022	Sep	33.6	33.2	2021
Ramsar	2022	Apr	37	27.6	2021

Table 2.1.10 – Records of minimum monthly air temperature (°C) in the Iranian sector in 2022 (year)

Observation post	Date	Month	Air temperature, °C	Previous minimum, °C	Date of the previous minimum
Amirabad	2022	Jan	-1.0	-4.0	2021
Anzali	2022	Jan	0.6	0.6	2021
Babolsar	2022	Jan	0.4	0.4	2021
Bandar Gaz	2022	Jan	-1.8	-2.0	2021
Bandar Torkaman	2022	Jan	-0.4	-1.7	2021
Dashtenaz	2022	Jan	-2.8	-3.4	2021
Noshahr	2022	Jan	0	0	2021
Ramsar	2022	Jan	-0.8	-0.4	2021

Kazakh sector

In 2022, according to data from meteorological stations (MS) located in the Kazakhstan territory of the Caspian Sea was extremely warm, and for MS Fort Shevchenko it was record warm. Mean annual air temperatures amounted to +10.9…+14.0°C, which is 0.7-1.5°C above the climatic normal (1991-2020), the values of anomalies were significantly higher than the standard deviation by a factor of 0.9-1.7.

The air temperatures of the winter, summer and autumn seasons significantly exceeded the normal: in the winter season by 2.9-4.6°C; in the summer by 0.7-1.6°C; in the autumn season by 1.0-1.9°C, and anomalies in these seasons exceeded the values of the standard deviation by 1.1-1.9 раза; positive anomalies of spring temperatures were +0.2…+0.4°C, which in all cases did not exceed the standard deviation (Table 2.1.11). The winter of 2021/2022 at meteorological stations Peshnoy, Kulaly, Fort-Shevchenko and Tushchibek were the hottest season since the beginning of meteorological observations, while the month of February became record warm at all weather stations on the Kazakh coast of the Caspian Sea.

Table 2.1.11 - Characteristics of the average annual and seasonal air temperature according to the data of observation posts of the Kazakh sector in 2022: ***T*** *– the current value of air temperature;* ***vT*** *– deviations from the long-term average for 1991-2020, ℃; s – the average square deviation in °C for the period 1991-2020*

Observation post	Year			Winter			Spring			Summer			Autumn		
	T	vT	*s*	T	vT	*s*	T	vT	*s*	T	vT	*s*	T	vT	*s*
Aktau	13.9	1.2	±0.8	3.4	2.9	±1.8	12.2	0.3	±1.1	26.7	1.6	±1.3	14.7	1.5	±1.4
Atyrau	11.9	1.5	±1.0	-0.8	4.6	±2.6	11.2	0.2	±1.6	27.2	1.2	±1.4	11.6	1.6	±1.5
Ganyushkino	11.5	1.2	±0.9	0.1	4.2	±2.2	10.8	0.2	±1.2	25.5	0.7	±1.1	11.4	1.5	±1.3
Kulaly	12.5	0.7	±0.8	1.5	3.2	±1.7	11.0	0.0	±1.2	26.2	0.7	±0.9	13.2	1.0	±1.3
Kyzan	13.6	1.5	±0.9	1.1	4.1	±2.3	12.8	0.4	±1.5	28.7	1.5	±1.3	13.5	1.9	±1.4
Peshnoy	10.9	1.3	±0.8	-1.1	4.3	±2.4	10.5	0.2	±1.4	25.5	1.2	±0.9	10.4	1.1	±1.4
Tushchibek	13.1	1.2	±0.8	1.4	3.4	±1.8	11.6	-0.1	±1.3	27.7	1.5	±1.3	12.9	1.2	±1.4
Fort Shevchenko	14.0	1.2	±0.8	3.5	3.3	±1.7	11.8	0.2	±1.2	27.1	1.5	±1.2	14.9	1.3	±1.4

Table 2.1.12 presents the ranks of the warmest years on the Kazakhstan coast of the Caspian Sea and the corresponding mean annual surface air temperatures and their anomalies.

On the Kazakhstan coast, the top five warmest years included various years of the current century, including 2022, and at some stations 1995 of the last century. According to the data of the Fort Shevchenko meteorological station, 2022 was the warmest year since the beginning of regular instrumental observations (since 1921), the anomaly of the mean annual temperature was +1.2°C.

According to MS Aktau (+13.9°C) and MS Kyzan (+13.6°C), 2022 ranks second, and 2010 remains the warmest on MS Aktau (+14.0°C), which is 1.3°C above the normal and 2021 at MS Kyzan (+13.7°C) with an anomaly of 1.6°C above the normal.

At MS Tushchibek, Peshnoy, Atyrau and Ganyushkino the warmest year is 2021 with an average annual air temperature of +11.0…+13.5°C, 2022 in the ranked series of observations (from the warmest year to the coldest) took the third place at meteorological stations Tushchibek (+13.1°C) and Peshnoy (+10.9°C) and the fourth place - at meteorological stations Atyrau (+11.9°C) and Ganyushkino (+11.5°C).

At meteorological station Kulaly, the warmest year is still 2004 with air temperature +13.1°C, which is +1.3°C above the normal.

Table 2.1.12 – Ranks of the warmest or coldest years on Kazakhstan coast of the Caspian Sea and related anomalies of the average annual air temperature (ºC): R - *the rank of the current values in a series ordered in descending order for positive anomalies and in ascending order for negative ones (only the first 5 ranks are shown); the period for calculating the ranks: whole observation period*

R	Year	Average annual tempe-rature	Ano-maly	Year	Average annual temperat ure	Ano-maly	Year	Average annual tempe-rature	Ano-maly	Year	Average annual tempe-rature	Ano-maly
MS Aktau				MS Atyrau			MS Ganyushkino			MS Kulaly		
1	2010	14.0	1.3	2021	12.4	2.0	2021	11.8	1.5	2004	13.1	1.3
2	2022	13.9	1.2	2020	12.0	1.6	2020	11.6	1.3	2010	12.7	0.9
3	2021	13.8	1.1	2010	11.9	1.5	1995	11.6	1.3	2021	12.7	0.9
4	2004	13.7	1.0	2022	11.9	1.5	2022	11.5	1.2	2013	12.7	0.9
5	2019	13.5	0.8	2013	11.6	1.2	2010	11.3	1.0	2007	12.6	0.8
MS Kyzan				MS Peshnoy			MS Tushchibek			MS Fort Shevchenko		
1	2021	13.7	1.6	2021	11.0	1.4	2021	13.5	1.6	2022	14.0	1.2
2	2022	13.6	1.5	1995	11.0	1.4	2010	13.3	1.4	2004	13.8	1.0
3	2020	13.1	1.0	2022	10.9	1.3	2022	13.1	1.2	2021	13.8	1.0
4	2010	13.1	1.0	2004	10.8	1.2	1995	12.9	1.0	2010	13.8	1.0
5	2019	13.1	1.0	2013	10.7	1.1	2019	12.8	0.9	2020	13.6	0.8

Table 2.1.13 presents the records of the maximum monthly air temperature (°C) recorded at the observation points of the Caspian region in 2022.

At all stations of the Kazakhstan coast, the records of the mean monthly temperature of February, set earlier, were updated: in 2002 in the western water area of the Kazakhstan coast of the North Caspian (Ganyushkino, Peshnoy), in 2020 in the eastern part of the North Caspian

(Atyrau, Kulaly) and on the continental MS Kyzan and in 1999 at meteorological stations located on the eastern the coast of the Middle Caspian Sea (Fort Shevchenko, Aktau, Tushibek).

The record of average temperature in August was also set at MS Fort Shevchenko, the previous one was recorded in 2021. In this month daytime temperatures rose to +34.4…+40.2°C, during 4 weeks night temperatures did not fall below 20°C (so-called tropical nights). Precipitation was practically absent during the whole month (only 1 mm of precipitation fell only on August 7). At meteorological station Kyzan a new record of mean monthly temperature was also established in September, the previous record was recorded in 2005. In this month the daytime temperatures rose to +28.8…+32.1°C, during 3 weeks the night temperatures were within +12.1…+19.8°C. At the same time, precipitation was practically absent during the whole month (2.1 mm fell in two days).

Table 2.1.13 – Absolute maximum/minimum of the average monthly air temperature (°C) recorded in the Caspian Sea region in 2022

Observation post	Month	Absolute maximum of 2022	Previous maximum and a year of its occurrence	Absolute minimum of 2022	Previous minimum and a year of its occurrence
Aktau	February	4.9	4.6 (1999)	–	
Atyrau	February	1.6	1.1 (2020)	–	
Ganyushkino	February	1.7	1.5 (2002)	–	
Kulaly	February	2.6	2.1 (2020, 2002, 2000)	–	
Kyzan	February	3.5	2.5 (2020)	–	
	September	22.9	22.7 (2005)		
Peshnoy	February	0.9	0.3 (2002)	–	
Tushchibek	February	3.6	2.6 (1999)	–	
Fort Shevchenko	February	4.8	3.8 (1999)	–	
	August	29.4	29.3 (2021)		

Table 2.1.14 presents the records of maximum monthly air temperature (°C) recorded at observation points on the Kazakhstan coast of the Caspian Sea in 2022.

In July 2022, the maximum air temperature at the Peshnoi weather station was exceeded, with a maximum air temperature of +42.8°C on 17 July, which is 0.4°C above the 2020 record (+42.4°C).

Table 2.1.14 – Records of maximum monthly air temperature (°C) in the Caspian Sea region in 2022

Observation post	Date	Month	Air temperature, °C	Previous maximum, °C	Date of the previous maximum
Peshnoy	17	Jule	+42.8	+42.4	15.07.2020

On the territory of the Kazakhstan part of the Caspian Sea in 2022 no records of the minimum monthly air temperature were observed.

Russian sector

According to data of the meteorological stations in the Russian sector of the Caspian Sea, 2022 was exceptionally warm. The average annual air temperature varied from +13.6 to +14.9°C, which is 0.8-1.1°C higher than the normal, the values of anomalies were 1.2-1.4 times higher than the standard deviation (Table 2.1.15).

The air temperature in the winter season (December 2021 – February 2022) was 2.3-3.1°C above the normal. It was especially warm in the southernmost part of the Russian coast of the Caspian Sea – in Derbent. The winter of 2021/2022, according to data from Derbent, became the warmest since the beginning of regular instrumental temperature observations (since 1922), the average temperature was +6.1°C, which is 2.3°C higher than the normal and 0.1°C higher than the previous maximum of 2019/2020 (+6.0°C).

Table 2.1.15 - Characteristics of the average annual and seasonal air temperature according to the data of observation posts of the Russian sector in 2022: *T – the current value of air temperature;* ***vT*** *– deviations from the long-term average for 1991-2020, ℃; s – the average square deviation in °C for the period 1991-2020*

Observation post	Year			Winter			Spring			Summer			Autumn		
	T	vT	s	T	vT	s	T	vT	s	T	vT	s	T	vT	s
Derbent	14,9	1,1	±0,8	6,1	2,3	±1,2	11,5	0,3	±0,9	25,6	0,8	±1,1	16,8	1,6	±1,3
Izberg	13,9	1,0	±0,7	5,1	2,3	±1,3	10,6	0,2	±0,8	24,6	0,6	±1,0	15,8	1,4	±1,2
Makhachkala	13,7	1,1	±0,9	4,4	2,7	±1,5	10,2	-0,4	±1,0	24,9	1,0	±1,1	15,6	1,6	±1,4
Tyuleniy Isl.	13,6	0,8	±0,6	3,6	3,1	±1,5	10,8	-0,3	±1,0	25,8	0,5	±0,9	14,7	0,7	±1,0

In Izberg, the winter of 2021/2022 was the warmest since 1978, the average air temperature in the winter season was +5.1°C, which is 2.3°C higher than the normal, the second place is occupied by the abnormally warm winter of 2019/2020 (+4.9°C).

The winter of 2021/2022 was the warmest since 1959 on Tyuleniy Island. The average air temperature was +3.6°C, which is 3.1°C higher than the normal, the second place is occupied by the winter of 2019/2020 (+3.3°C).

According to data from Makhachkala, the winter of 2021/2022 ranks fifth in the ranked series of observations (from the warmest to the coldest). The winter of 1980/1981 with the temperature of +4.8°C remains the warmest for the entire observation period (since 1882), followed by winters in: 1947/1948 (+4.7°C), 1913/1914 (+4.6°C), 1965/1966 (+4.5°C), 2021/2022 (+4.4°C).

The average air temperature in the spring of 2022 varied in the range of +10.2...+11.5°C, slight deviations of ±0.4...0.3°C from the normal were observed. High positive anomalies were

typical in April (1.4-2.0°C). It was cold in March, with negative temperature anomalies of 1.0-1.7°C.

The average air temperature in the summer of 2022 reached up to +24.6...+25.8°C, which is 0.5-1.0°C higher than the normal. High positive anomalies were observed on the western coast of the Middle Caspian Sea in June (1.0-1.4°C), as well as in Makhachkala and Tyuleniy Island in August (1.2-1.8°C). For Izberg, Makhachkala and Tyuleniy Island, the summer of 2010 remains the hottest with a temperature of +25.8...+27.4°C. According to data from Derbent, the hottest summer in the hundred-year history of meteorological observations was the summer of 2021 (+26.8°C), the second place is taken by the summer of 2010 (+26.5°C). In 2022, the average anomaly of summer temperatures was 0.8°C (rank 8).

The autumn was also warm. The average air temperature ranged from + 14.7 to + 16.8°C, which is 0.7-1.6°C higher than the normal (rank 2 in Derbent, rank 3 in Izberg, rank 5 in Makhachkala, rank 7 on Tyuleniy Island). November was especially warm on the western coast of the Middle Caspian Sea, the average air temperature exceeded the normal by 1.8-2.3°C. High positive anomalies were also observed in October (1.3-1.6°C). However, the autumn of 2012 remains the warmest, with a temperature of +15.8...+17.7°C.

Table 2.1.16 shows the ranks of the warmest years in ***the Russian sector*** of the Caspian Sea and the corresponding anomalies of the average annual surface air temperature.

Table 2.1.16 – Ranks of the warmest /or coldest / years on the Russian coast of the Caspian Sea and related anomalies of the average annual air temperature: *R - the rank of the current values in a series ordered in descending order for positive anomalies and in ascending order for negative ones (only the first 5 ranks are shown); the period for calculating the ranks: whole observation period*

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
Derbent				Izberg			Makhachkala			Tyuleniy Isl.		
1	2019	15.0	1.3	2010	14.1	1.1	1966	13.9	1.3	2010 2020	13.8	1.1
2	2022	14.9	1.1	2022	13.9	1.0	2010	13.8	1.3	2019	13.7	0.9
3	2021 2020 2018	14.8	1.0	2019	13.8	0.9	2022 2020 2019	13.7	1.1	2021 2022	13.6	0.8
4	2010	14.7	1.0	2021 2020 2018	13.7	0.8	2018	13.6	1.0	2004 1966	13.4	0.7
5	2015	14.5	0.7	2015 2005	13.5	0.6	2021 1981	13.5	1.0	2007 2005	13.3	0.6

According to Derbent data, 2022 took the 2nd place in a descending series of average annual temperatures since 1922, the anomaly of the average annual air temperature (deviation from the average for 1991-2020) was +1.1°C, and the warmest year in the history of

meteorological observations was 2019 (+15.0°C). At the same time, the period from 2018 to 2022 became the warmest five-year period for the entire observation period, positive anomalies in these years amounted to 1.0-1.3°C.

In Izberg, 2010 remains the warmest year with an average annual temperature of +14.1°C, while 2022 (+13.9°C) became second warmest.

According to data from Makhachkala, 2022, together with 2019 and 2020 (+13.7°C) took the third place, the anomaly of the average annual air temperature was +1.1°C. The warmest year since the beginning of regular instrumental observations of air temperature (since 1882) remains 1966 (+13.9°C), the second place is occupied by 2010. (+13.8°C). It is worth noting that the average temperature in these years was about 2.1-2.4 °C above the pre-industrial (1882-1900) level.

According to data from Tyuleniy Island of 2022, together with 2021 (+13.6°C), took the third place, the anomaly of the average annual air temperature was + 0.8°C. 2010 and 2020 remain the warmest since 1959 (+13.8°C), 2019 takes the second place. (+13.7°C).

Table 2.1.17 shows the records of the maximum of the average monthly air temperature (°C) recorded at observation points in ***the Russian sector*** in 2022.

Table 2.1.17 – Absolute maximum/minimum of the average monthly air temperature (°C) recorded in the Russian sector in 2022

Observation post	Month	Absolute maximum of 2022	Previous maximum and a year of its occurrence	Absolute minimum of 2022	Previous minimum and a year of its occurrence
Derbent	February	6.1	5.8 (2002)	-	
Makhachkala	February	4.9*	4.5 (1999, 2016)	-	
Tyuleniy Isl.	February	4.1	3.9 (2002)	-	

* 4.9°C – maximum of the average monthly air temperature for the current climatic period

In Derbent and on Tyuleniy Island, the average monthly temperature records of 2002 were exceeded in February of 2022. The average temperature was +4.1°C on Tyuleniy Island (+3.9°C in 2002) and +6.1°C in Derbent (+5.8°C in 2002). Such a warm weather was caused by air masses, which came from the Atlantic Ocean and the Mediterranean Sea. In Makhachkala, the average monthly temperature in February was close to the monthly record of 2002 (+4.9°C). The previous record was observed in 1999 and 2016 (+4.5°C). February of 1914 remains the warmest month (+5.1°C) for the entire observation period (since 1882).

Table 2.1.18 shows the records of the maximum monthly air temperature (°C) recorded at observation posts in ***the Russian sector*** of the Caspian Sea in 2022.

In July 2022, the maximum air temperature in Izberg was exceeded. On July 18, the maximum air temperature was +35.9°C, which was 1.0° higher than the record of 2018 and 2019 (+34.9°C). In September, the maximum air temperatures were exceeded at all stations on the western coast of the Middle Caspian Sea. In Derbent, the maximum monthly air temperature was +34.7°C, which was 1.7°C higher than the record of 2007 (+33.0°C). In Izberg, the maximum monthly air temperature in September was close to the maximum in the September 2010 (+32.4°C), which was 0.7°C higher than the record of 2015 (+31.7°C). On September 2, the warmest absolute air temperature of this month ever measured in Makhachkala (since 1889) was observed and reached +37.4°C, which was 3.3°C higher than the record of 1890 (+34.1°C).

Table 2.1.18 – Records of maximum monthly air temperature (°C) in the Russian sector in 2022

Observation post	Date	Month	Air temperature, °C	Previous maximum, °C	Date of the previous maximum
Derbent	2	September	34.7	33.0	04.09.2007
Izberg	18	July	35.9	34.9	02.07.2018; 25.07.2019
	1, 3	September	32.4	31.7	04.09.2015
Makhachkala	2	September	37.4	34.1	*09.1890*

In the Russian sector of the Caspian Sea, records of the minimum monthly air temperature were not updated in 2022.

Turkmen sector

Table 2.1.19 - Characteristics of the average annual and seasonal air temperature according to the data of observation points of the Turkmen sector in 2022: *T – the current value of air temperature;* ***vT*** *– deviations from the long-term average for 1991-2020, ℃; s – the average square deviation in °C for the period 1991-2020*

Observation post	2022			Winter			Spring			Summer			Autumn		
	T	vT	*s*	T	vT	*s*	T	vT	*s*	T	vT	*s*	T	vT	*s*
Turkmenbashi (Krasnovodsk)	18.1	1.0	1.0	7.6	1.0	1.0	15.6	-0.1	0.0	30.3	1.2	1.5	19.8	1.9	3.6
Khazar (Cheleken)	16.5	0.7	0.5	6.1	0.5	0.3	14.3	0.0	0.0	27.9	0.8	0.6	18.5	1.5	2.3
Garabogaz (Bekdash)	14.9	0.9	0.8	5.6	0.9	0.8	12.6	0.0	0.0	26.1	1.1	1.2	16.9	1.8	3.2
Guvlymayak (Kuuli-mayak)	15.6	0.9	0.8	6.5	0.6	0.4	12.8	0.0	0.0	26.2	1.1	1.2	17.8	1.7	2.9
Duzlybogaz (Kara Bogaz Gol)	15.5	0.9	0.8	5.8	0.6	0.4	13.1	0.1	0.0	27.1	1.1	1.2	17.3	1.4	2.0
Ogurdjaly (Ogurchinsky)	16.7	0.7	0.5	7.4	0.5	0.3	14.0	0.1	0.0	27.0	0.8	0.6	19.3	1.3	1.8

Note: data since 1989 as older data were collected by Azerbaijan Department for Hydrometeorology

Tables 2.1.20 and 2.1.21 present the ranks of the warmest and coldest years on the Turkmen coast of the Caspian Sea and the corresponding anomalies of the average annual surface air temperature.

Table 2.1.20 – Ranks of the warmest /or coldest / years on the Turkmen coast of the Caspian Sea and related anomalies of the average annual air temperature: *R - the rank of the current values in a series ordered in descending order for positive anomalies and in ascending order for negative ones (only the first 5 ranks are shown); the period for calculating the ranks: whole observation period*

R	Year	Average annual tempe-rature	Anomaly	Year	Average annual tempe-rature	Anomaly	Year	Average annual tempe-rature	Anomaly
Turkmenbashi (Krasnovodsk)				Khazar (Cheleken)			Garabogaz (Bekdash)		
1	2010	18.5	1.4	2010	17.0	1.2	2010	15.3	1.3
2	2022	18.1	1.0	2018	16.7	0.9	2004	15.0	1.0
3	2021	18.1	1.0	2022	16.5	0.7	2022	14.9	0.9
4	2018	18.1	1.0	2019	16.5	0.7	2021	14.8	0.8
5	2019	17.7	0.6	2004	16.5	0.7	2018	14.8	0.8
Guvlymayak (Kuuli-mayak)				Duzlybogaz (Kara Bogaz Gol)			Ogurdjaly (Ogurchinsky)		
1	2022	15.6	0.9	2022	15.5	0.9	2008	18.1	2.1
2	2018	15.6	0.9	2010	15.5	0.9	2019	16.8	0.8
3	2019	15.5	0.8	2021	15.4	0.8	2022	16.7	0.7
4	2004	15.4	0.7	2004	15.4	0.8	2018	16.7	0.7
5	2021	15.3	0.6	2018	15.3	0.7	2004	16.6	0.6

Table 2.1.21 – Ranks of the warmest /or coldest / years on the Turkmen coast of the Caspian Sea and related anomalies of the average annual air temperature: *R - the rank of the current values in a series ordered in descending order for positive anomalies and in ascending order for negative ones (only the first 5 ranks are shown); the period for calculating the ranks: whole observation period*

R	Year	Average annual tempe-rature	Anomaly	Year	Average annual tempe-rature	Anomaly	Year	Average annual tempe-rature	Anomaly
Turkmenbashi (Krasnovodsk)				Khazar (Cheleken)			Garabogaz (Bekdash)		
1	1993	15.2	-1.9	1993	13.6	-2.2	1993	11.6	-2.4
2	1994	16.1	-1.0	1992	14.3	-1.5	1994	12.6	-1.4
3	1996	16.4	-0.7	1994	14.5	-1.3	1996	12.9	-1.1
4	2011	16.4	-0.7	2011	15.2	-0.6	2011	13.2	-0.8
5	2008	16.7	-0.4	2008	15.2	-0.6	2008	13.2	-0.8
Guvlymayak (Kuuli-mayak)				Duzlybogaz (Kara Bogaz Gol)			Ogurdjaly (Ogurchinsky)		
1	1993	12.8	-1.9	1994	13.5	-1.1	1992	14.8	-1.2
2	1992	13.4	-1.3	1992	13.6	-1.0	1994	15.2	-0.8
3	1994	13.6	-1.1	2003	13.7	-0.9	2011	15.3	-0.7
4	1996	13.9	-0.8	2011	13.9	-0.7	2003	15.3	-0.7
5	2011	14.1	-0.6	2012	14.4	-0.2	2020	15.7	-0.3

Records of the absolute maximum/minimum of the average monthly air temperature on the Turkmen coast of the Caspian Sea were not observed in 2022 compared to the period 1991-2021.

Tables 2.1.22 and 2.1.23 present records of maximum/minimum of the average monthly air temperature (°C) recorded at observation points of the Turkmen sector in 2022.

Table 2.1.22 – Records of maximum monthly air temperature (°C) in the Turkmen sector in 2022

Observation post	Date	Month	Air temperature, °C	Previous maximum, °C	Date of the previous maximum
Turkmenbashi (Krasnovodsk)	26	II	21.1	21.2 20.9	II (1996) II (2004)
	05	X	32.8	32.0	X (1995)
Khazar (Cheleken)	12	VII	43.8	43.2	VII (2018)
Garabogaz (Bekdash)	25	II	17.7	16.4	II (2002)
Ogurdjaly (Ogurchinsky)	25	II	16.8	16.4	II (2003)

Note: data for the period of 1991-2022

Table 2.1.23 – Records of minimum monthly air temperature (°C) in the Turkmen sector in 2022

Observation post	Date	Month	Air temperature, °C	Previous minimum, °C	Date of the previous minimum
Garabogaz (Bekdash)	04	VII	14.1	14.1 14.4	VII (2004) VII (1992)

Note: data for the period of 1991-2022

2.1.2 Trends in the air temperature

Iranian sector

Table 2.1.24 presents estimates of the linear trend of average annual and seasonal air temperatures at observation points of the Iranian sector of the Caspian Sea for the period 1976-2022.

According to all weather stations, the average seasonal temperatures were rising. The rate of their increase varies from 0.19 to 0.41°C/10 years. The fastest growth at all seasons was observed at Babolsar station, the maximum rate of summer warming was 0.41°C/10 years (it contributes 56% to the overall variability). Average annual temperatures rose by an average of 0.24-0.35°C every 10 years. The highest rate of the annual average temperature growth was also observed at Babolsar station; the growth rate was 0.35°C/10 years (with contribution of 59% to the overall variability).

Table 2.1.24 – Estimates of the linear trend of average annual and seasonal air temperatures in the Iranian sector for the period 1976-2022: *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*

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Anzali	0.24	30	0.22	8	0.2	14	0.32	37	0.2	14
Babolsar	0.35	59	0.34	24	0.35	39	0.41	56	0.3	31
Ramsar	0.25	27	0.2	6	0.19	13	0.38	41	0.23	18

Kazakh sector

Table 2.1.25 presents estimates of the linear trend of mean annual and seasonal air temperatures at observation points in the Kazakhstan sector of the Caspian Sea for the period 1976-2022.

According to data from all meteorological stations of the Kazakhstan coast, an increase in average seasonal temperatures is observed. The rate of increase varies from 0.25 to 0.92°C/10 years. The temperature increase in winter, spring and summer is statistically significant practically at all stations, except for one meteorological station (Peshnoy) in autumn period, where the share of the trend component in the total variance of the series is about 10 % and higher. Mean annual temperatures increased on average by 0.40 – 0.61°C every 10 years, the increase is statistically significant. The fastest temperature increase in all seasons (except summer) and year was observed at Atyrau meteorological station, the maximum rate of summer warming was observed at Aktau meteorological station and amounted to 0,92°C/10 years.

Table 2.1.25 – Estimates of the linear trend of average annual and seasonal air temperatures in the Caspian Sea region for the period 1976-2022: ***a*** *– the coefficient of the linear trend (°C/10 years);* ***D*** *– the coefficient of determination (%). The trend values that are significant at the level of 5% are highlighted*

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Aktau	**0.55**	58.9	**0.48**	13.5	**0.47**	31.3	**0.92**	63.6	**0.34**	12.1
Atyrau	**0.61**	49.5	**0.61**	10.9	**0.59**	24.2	**0.70**	46.1	**0.53**	22.2
Ganyushkino	**0.44**	35.2	**0.51**	9.5	**0.44**	19.7	**0.49**	35.0	**0.33**	11.3
Kulaly	**0.40**	39.1	**0.40**	9.2	**0.39**	18.6	**0.47**	44.9	**0.36**	15.3
Kyzan	**0.55**	54.1	**0.52**	9.6	**0.60**	29.9	**0.57**	38.2	**0.40**	14.0
Peshnoy	**0.41**	32.9	**0.52**	8.8	**0.51**	21.9	**0.38**	29.9	0.25	6.1
Tushchibek	**0.43**	46.0	**0.46**	12.8	**0.42**	17.9	**0.54**	33.9	**0.32**	9.9
Fort Shevchenko	**0.51**	54.6	**0.49**	14.8	**0.41**	21.2	**0.66**	53.1	**0.47**	22.2

Russian sector

Table 2.1.26 presents estimates of the linear trend of average annual and seasonal air temperatures at observation points in the ***Russian sector*** for the period 1976-2022. According to all weather stations, average seasonal temperatures were growing. The rate of the increase varies from 0.31 to 0.69°C/10 years. The fastest growth in all seasons was observed in Derbent, the maximum summer warming was 0.69°C/10 years. The average annual temperatures increased by 0.36-0.56°C every 10 years. The temperature increase, both over the year and in certain seasons, was statistically significant at all stations.

Table 2.1.26 – Estimates of the linear trend of average annual and seasonal air temperatures in the Russian sector for the period 1976-2022: *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*

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Derbent	**0.56**	69	**0.47**	28	**0.51**	49	**0.69**	64	**0.57**	37
Izberg	**0.42**	50	**0.37**	14	**0.47**	43	**0.47**	37	**0.37**	18
Makhachkala	**0.36**	32	**0.37**	11	**0.31**	19	**0.41**	30	**0.32**	12
Tyuleniy Isl.	**0.43**	50	**0.38**	11	**0.42**	27	**0.56**	49	**0.37**	20

Turkmen sector

According to the data at all weather stations, the average annual temperatures were growing in 2022. The rate of the increase varied from 0.21 to 0.53°C per 10 years. The fastest growth in the average annual air temperatures was observed in Turkmenbashi.

In all seasons and at almost all stations (excluding Khazar in the winter and Ogurjaly in the autumn), the air temperature increased, the increase ranged from 0.05°C/10 years (Khazar, autumn season) to 1.06°C/10 years (Turkmenbashi, summer season). The temperature increase for the year and spring-summer period was statistically significant at all stations. Temperature changes in the autumn, for all stations, were statistically insignificant.

Table 2.1.27 – Estimates of the linear trend of average annual and seasonal air temperatures in the Caspian Sea region for the period 1976-2022: ***a*** *– the coefficient of the linear trend (°C/10 years);* ***D*** *– the coefficient of determination (%). The trend values, which are significant at the level of 5%, are highlighted*

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Turkmenbashi (Krasnovodsk)	**0.53**	**47.9**	**0.46**	**11.6**	**0.41**	**22.1**	**1.06**	**55.6**	0.14	1.3
Khazar (Cheleken)	**0.31**	**17.9**	-0.05	0.1	**0.42**	**19.7**	**0.74**	**18.4**	0.05	0.2
Garabogaz (Bekdash)	**0.49**	**38.3**	**0.42**	**6.7**	**0.43**	**24.2**	**0.89**	**36.7**	0.28	4.8
Guvlymayak (Kuuli-mayak)	**0.40**	**33.6**	0.31	4.9	**0.42**	**31.1**	**0.73**	**30.1**	0.13	1.3
Duzlybogaz (Kara Bogaz Gol)	**0.21**	**12.4**	0.28	3.1	**0.31**	**10.7**	**0.58**	**21.3**	0.16	1.8
Ogurdjaly (Ogurchinsky)	**0.24**	**14.5**	0.13	0.9	**0.39**	**8.3**	**0.82**	**28.6**	-0.03	0.0

Note: data since 1989 as the older data were collected by Azerbaijan Department for Hydrometeorology

2.2 PRECIPITATION

2.2.1 Precipitation in 2022

Iranian sector

Table 2.2.1 presents the characteristics of annual and seasonal precipitation in 2022.

Table 2.2.1 – Characteristics of annual and seasonal precipitation on the Iranian coast in 2022: *R* – *the amount of precipitation, mm;* ***RR*** *– the ratio of the current value to the normal for 1961-1990, %*

Observa-tion post	Year		Winter		Spring		Summer		Autumn	
	R	RR	R	RR	R	RR	R	RR	R	RR
Anzali	1448.7	1818.7	525.17	548.1	225.79	212.9	53.84	214.66	118.43	843.01
Babolsar	672.7	884.9	314.0	294.3	140.7	118.4	35.4	107.3	182.7	364.8
Ramsar	875.5	1228.7	277.38	285.14	189.9	180.0	53.8	164.9	354.4	598.6

Table 2.2.2 presents absolute maximum/minimum of monthly precipitation (mm) recorded at observation points of the Iranian coast of the Caspian Sea in 2022.

Table 2.2.2 – Absolute maximum/minimum of precipitation (mm) recorded in the Iranian sector in 2022

Observation post	Absolute maximum of 2022		Previous maximum		Absolute minimum of 2022		Previous minimum	
	value	date	value	date	value	date	value	date
Amirabad	110.5	JAN	123.93	OCT	0	JUN	0	JUN-AUG
Anzali	318.2	DEC	547.8	OCT	0.11	JUN	5	AUG
Babolsar	166.22	JAN	224.4	OCT	0	JUN	0.53	AUG
Bandar Gaz	86.2	OCT	108.7	OCT	1	AUG	0	AUG
Bandar Torkaman	82.32	JAN	57.42	OCT	0	JUN	0	AUG
Dashtenaz	126	JAN	69.81	JAN	0	JUN	0.01	AUG
Noshahr	265	DES	266.8	OCT	2.11	JUN	6.95	APR
Ramsar	211.72	SEP	211.72	NOV	3.1	AUG	7.2	AUG

Kazakh sector

Table 2.2.3 presents the characteristics of annual and seasonal precipitation amounts in 2022.

At the Kazakhstan coastal stations in 2022, the moisture regime was heterogeneous. In general, precipitation at Fort Shevchenko and Aktau stations exceeded the normal for the year, the annual precipitation total amounted to 154.5 mm (123.0 % of the multiyear average, rank 23) and 230.9 mm (137.0 % of the multiyear average, 7 rank), respectively. A significant precipitation deficit was observed at the station of Kulaly Island with the annual precipitation total of 60.7 mm (77.1 % of the multiyear average). At the other stations, the annual precipitation total was within a multiyear average of 153.5-193.7 mm (96.3-104.6 of the multiyear average). In the seasonal resolution with a rare exception, a significant deficit of seasonal precipitation totals was recorded.

Precipitation amounted to 91.4-188.4% of the normal in the Northern Caspian during the winter season, while it was very dry on the eastern coast of the Middle Caspian, where the precipitation amounted to 29.4-48.6% of the normal. The exceptions were meteorological stations Fort Shevchenko and Kulaly, where the amount of precipitation for the winter period fell

near the normal – 85.8% of the normal and 108.5% of the normal, respectively. The winter period was extremely dry for the MS Aktau 6.4 mm (29.4%, 3 rank). December 2021 was record dry at the MS Tushchibek, there was no precipitation for the entire month.

The amount of precipitation for the spring period was near and above the normal practically on the whole Kazakhstan coast of the Caspian region and amounted to 102.0-178.5% of the normal, except for the MS Kulaly Island, where it was very dry – only 68.6 % of the normal (the probability of not exceeding 30%). Significant excess of monthly precipitation totals over the normals was observed at all meteorological stations in March (132.1-323.6% of the normal) and May (171.9-397.0% of the normal), except for MS Kulaly, where the precipitation deficit amounted to 51.8% of the normal (probability of not exceeding 33%). Extreme wetness was observed in March at MS Ganyushkino and in May at Kyzan and Tushchibek (5% extremes) and Atyrau MS (10% extremes). In April, a significant precipitation deficit (0-56.4% of the normal) was observed almost everywhere. April was record dry at the Kyzan and Aktau stations, with no precipitation during the whole month.

A significant precipitation deficit was observed in the summer months of June and August, especially on the eastern coast of the Middle Caspian. Monthly precipitation in June on the Kazakhstan coast of the North Caspian amounted to 14.2-52.7% of the normal, and on the eastern coast of the Middle Caspian 0-13.4% of the normal. Record dryness was observed at MS Kulaly, Fort Shevchenko, Tushchibek and Aktau, where precipitation was absent throughout the month. Significant excess of monthly precipitation amounts over the normals was observed in July at the meteorological stations on the eastern coast of the Middle Caspian Sea: Fort Shevchenko (159% of the normal), Kulaly (177.1% of the normal), Tushchibek (232.8% of the normal) and record wetness at MS Aktau (61.5 mm or 608.9% of the normal). As a result, on the territory of the Kazakhstan coast of the Caspian Sea in general for the summer period there was a significant deficit of precipitation: 9.5-78.5 % of the norm. At the Kyzan MS in 2022, the second driest summer in the observation history was recorded: 9.5 % of the norm with a probability of not exceeding 1 %. At the same time at the Aktau MS, the summer period was extremely humid: 208.7 % of the norm (10 % extreme).

The humidity regime of the autumn period according to the data of stations located on the Kazakhstan coast of the Caspian Sea was heterogeneous. On the eastern coast of the Northern Caspian, precipitation was about the multiyear average 82.5-112.3% of the normal, on the eastern coast of the Middle Caspian at MS Aktau there was a significant excess of seasonal precipitation totals of 160.2% of the normal, and at MS Fort-Shevchenko the season was extremely wet (224.6%), at the MS Kulaly Island and continental MS Kyzan and Tushchibek the amount of precipitation was about the multiyear average 82.6-99.7% of the normal. The months

of September and November were dry, and in October, a significant excess of precipitation was observed practically at all stations and amounted to 144.8-243.2% of the normal, the record precipitation in October fell at MS Fort Shevchenko (58.4 mm), which amounted to 602.1% of the normal.

Table 2.2.3 – Characteristics of annual and seasonal precipitation on the Kazakhstan coast in 2022: ***R*** *– the amount of precipitation, mm;* ***RR*** *– the ratio of the current value to the normal for 1991-2020, %*

Observation post	Year		Winter		Spring		Summer		Autumn	
	R	RR	R	RR	R	RR	R	RR	R	RR
Aktau	230.9	137.0	14.9	29.4	80.4	174.8	62.4	208.7	67.3	160.2
Atyrau	193.7	104.5	62.1	141.8	87.8	146.3	28.7	75.1	32.1	74.1
Ganyushkino	157.7	104.6	46.9	188.4	77.1	178.5	9.9	22.2	42.9	112.3
Kulaly	60.7	77.1	19.1	108.5	19.0	68.6	8.5	61.6	17.3	88.3
Kyzan	153.5	96.3	13.0	41.0	101.9	176.9	3.7	9.5	30.9	99.7
Peshnoy	166.2	102.2	36.2	91.4	92.7	175.9	13.3	44.8	33.5	82.5
Tushchibek	173.3	98.0	18.6	48.6	95.1	142.6	28.4	78.5	29.4	82.6
Fort Shevchenko	154.5	123.0	22.3	85.8	41.0	102.0	16.9	63.8	73.9	224.6

Table 2.2.4 presents absolute maximums/minimums of monthly precipitation (mm) recorded at the observation points of the Kazakhstan coast of the Caspian region in 2022.

According to MS Aktau in July 2022, 61.5 mm of precipitation (608.9 % of the norm) fell in July 2022 - a record since 1961, the previous maximum was 52.2 mm in 2021.

At MS Fort-Shevchenko in October 2022, the maximum precipitation amount for the period since 1935 was established. 58.4 mm of precipitation (602.1 % of the norm) fell during the month, the previous record was 31.5 mm in 1979.

Table 2.2.4 – Absolute maximum/minimum of monthly precipitation (mm) recorded in the Kazakh sector in 2022

Observation post	Absolute maximum of 2022		Previous maximum		Absolute minimum of 2022		Previous minimum	
	value	date	value	date	value	date	value	date
Aktau	61.5	July	52.2	July (2021)	0.0	June	0.3	June (2015)
Kulaly					0.0	June	0.5	1979
					0.0	August	0.3	2006
					0.0	September	0.2	1978
Kyzan					0.0	April	0.2	1960
					0.0	August	0.2	2019
Peshnoy					0.0	August	0.2	2005
Tushchibek					0.0	June	0.4	2015
					0.0	August	0.4	2005
Fort Shevchenko	58.4	October	31.5	October (1979)	0.0	June	0.3	1982, 1954

Russian sector

According to the data from the stations located in the Russian sector of the Caspian Sea, the humidity highly varied in 2022 (Table 2.2.5). In Izberg, precipitation fell more than the normal; the annual amount was 113% (rank 12). In Derbent, the annual precipitation was within the normal range (102%). Precipitation deficit was observed on Tyuleniy Island and in Makhachkala: 81 and 82% of the normal (ranks 13 and 21).

Table 2.2.5 – Characteristics of annual and seasonal precipitation on the Russian coast in 2022: *R* – *the amount of precipitation, mm;* ***RR*** *– the ratio of the current value to the normal for 1991-2020, %*

Observation post	Year		Winter		Spring		Summer		Autumn	
	R	RR	R	RR	R	RR	R	RR	R	RR
Derbent	417.5	102	67.8	61	107.2	169	63.3	95	177.8	108
Izberg	329.7	113	39.3	57	84.7	157	49.2	88	143.4	133
Makhachkala	307.6	82	40.8	41	138.5	190	24.3	32	110.7	90
Tyuleniy Isl.	160.2	81	23.0	56	103.9	176	7.6	16	32.8	62

A significant shortage in precipitation was observed in all months of the winter season, with the exception of December (107% of the normal) in Izberg and Derbent, on Tyuleniy Island and in Makhachkala – 58 and 70% of the normal. In January, a severe shortage in precipitation was observed in Makhachkala (9.9% of the normal – rank 2) and in Izberg (15.4% of the normal – rank 3). In Derbent, the monthly precipitation in January was 12.9 mm (41.2% of the normal), on the Tyuleniy Island – 10.3 mm (73.4% of the normal). Little precipitation fell in February 3.4-11.2 mm (17-41% of the normal). As a result, the seasonal rainfall amounted to 41-61% of the normal.

The precipitation reached up to 157-190% of the normal in the spring season. A significant excess of monthly precipitation over the normal was observed in March: 54.2 mm (324% of the normal) was the historical maximum in Izberg (since 1978); 40.6 mm (278% of the normal, rank 2) fell on Tyuleniy Island; 61.6 mm (259% of the normal, rank 5) in Derbent; 42.5 mm (197% of the normal) in Makhachkala.

In April, there was a significant shortage in precipitation at all the stations (11-41% of the normal). In Izberg, the monthly precipitation was only 1.8 mm (rank 4, 2022 among the “driest years” since 1978); in Derbent – 2.0 mm (rank 7 since 1936). In May, precipitation exceeded 132-267% of the normal. A large amount of water was observed in Makhachkala – 88.6 mm (267% of the normal), which showed a historical maximum for the entire observation period (since 1882). 58.1 mm (267% of the normal, rank 2) fell on Tyuleniy Island; 132% of the normal (rank 11) in Izberg and 211% of the normal in Derbent (Rank 10).

According to the data of Tyuleniy Island and Makhachkala, summer was dry (16-32%, rank 4); 88% of the normal fell in Izberg and 95% in Derbent. A significant shortage of moisture was observed in the summer months on Tyuleniy Island: 0.3 mm in June (2% of the normal), 2.7 mm in July (19% of the normal) and 4.6 mm in August (26% of the normal). August was exceptionally dry on the western coast of the Middle Caspian, with monthly precipitation of 1.6-4.5 mm (7-18% of the normal). In Izberg, August 2022 ranks 4th among the "driest"; in Makhachkala – 9th place (since 1882).

The humidity regime of the autumn was heterogeneous. A significant excess of precipitation was observed in Izberg (133% of the normal). Precipitation fell around the normal (108%) in Derbent, while, there was a water shortage (62-90% of the normal) on Tyuleniy Island and in Makhachkala. In September, precipitation over the normal (145-182%) was observed in the western coastal zone of the Middle Caspian in the Derbent-Izberg section, while there was much less moisture in Makhachkala (48% of the normal). The minimal precipitation was observed at the Tyuleniy Island station, where only 7.3 mm (51% of the normal) fell, and most days of the month were completely dry. In October, monthly precipitation significantly exceeded the normal on the western coast of the Middle Caspian (135-166% of the normal), while there was little moisture on Tyuleniy Island (40% of the normal). In November, there was lesser moisture on the western coast of the Middle Caspian (46-68% of the normal) than on Tyuleniy Island, where the monthly precipitation was within the normal range.

Table 2.2.6 shows the absolute maxima/minima of monthly precipitation (mm) recorded at the observation posts of the Russian sector of the Caspian Sea in 2022.

According to data from Izberg, 54.2 mm of precipitation fell in March 2022 (324% of the normal) – a record since 1978, the previous maximum reached up to 53.3 mm (1995).

In Makhachkala, the historical maximum for the entire observation period was recorded in May of 2022 (since 1882). 88.6 mm of precipitation fell during the month (267% of the normal), which exceeded the previous record in May of 1888 (82.0 mm).

Table 2.2.6 – Absolute maximum/minimum of precipitation (mm) recorded in the Russian sector in 2022

Observation post	Absolute maximum of 2022		Previous maximum		Absolute minimum of 2022		Previous minimum	
	value	date	value	date	value	date	value	date
Izberg	54.2	март	53.3	1995	-			
Makhachkala	88.6	май	82.0	1888	-			

Turkmen sector

Table 2.2.7 – Characteristics of annual and seasonal precipitation on the Turkmen coast in 2022: *R* *– the amount of precipitation, mm;* ***RR*** *– the ratio of the current value to the normal for 1991-2020, %*

Observation post	Year		Winter		Spring		Summer		Autumn	
	R	RR	R	RR	R	RR	R	RR	R	RR
Turkmenbashi (Krasnovodsk)	87	61	37	77	41	87	2	20	7	19
Khazar (Cheleken)	45	42	33	100	4	11	1	20	6	19
Garabogaz (Bekdash)	133	125	34	85	55	149	6	86	39	177
Guvlymayak (Kuuli-mayak)	103	79	46	105	28	62	1	20	29	78
Duzlybogaz (Kara Bogaz Gol)	48	60	22	81	13	48	0	0	12	71
Ogurdjaly (Ogurchinsky)	43	44	24	71	6	19	3	50	11	41

Table 2.2.8 shows the absolute minimum of the monthly precipitation (mm) recorded at the observation points of the Turkmen coast of the Caspian Sea in 2022. Records of the maximum monthly precipitation were not observed in 2022.

Table 2.2.8 – Absolute maximum/minimum of precipitation (mm) recorded in the Turkmen sector in 2022

Observation post	Absolute minimum of 2022		Previous minimum	
	value	date	value	date
Turkmenbashi (Krasnovodsk)	no precipitation at all	June	no precipitation 0.0	June 2009; 2017; 2021 June 2020
Khazar (Cheleken)	0.0	May	0.0	May 2020
	no precipitation at all	June	no precipitation 0.0	June 2019; 2020; 2021 June 2016
	0.0	August	no precipitation 0.0	August 2017;2018; 2021 Avgust 2011
	0.0	September	no precipitation 0.0	September 2020; 2021 September 2015
Garabogaz (Bekdash)	0.0	June	no precipitation 0.0	June 2006; 2013; 2019; 2021 June 2015
	no precipitation at all	July	no precipitation 0.0	July 2017; 2018 July 2011
Guvlymayak (Kuuli-mayak)	no precipitation at all	June	no precipitation 0.0	June 2019 June 2021
	no precipitation at all	July	no precipitation 0.0	July 2017; 2021 July 2010

Table 2.2.8 continued

Observation post	Absolute minimum of 2022		Previous minimum	
	value	date	value	date
Duzlybogaz (Kara Bogaz Gol)	no precipitation at all	June	no precipitation 0.0	June 2019; 2021 June 2018
	no precipitation at all	July	no precipitation 0.0	July 2017 – 2021 July 2010
	no precipitation at all	September	no precipitation 0.0	September 2019 – 2021 September 2018
Ogurdjaly (Ogurchinsky)	0.0	February	0.0	February 2001
	0.0	April	no precipitation 0.0	April 2011 April 2021
	0.0	May	no precipitation 0.0	May 2015; 2018 May 2017
	no precipitation at all	June	no precipitation 0.0	June 2021 June 2020
	no precipitation at all	August	no precipitation 0.0	August 2021 August 2019
	no precipitation at all	September	no precipitation 0.0	September 2020; 2021 September 2017

Note: 1. Data for the period 1991-2020
2. There is usually no precipitation in summer

2.2.2 Trends in the precipitation

Iranian sector

Table 2.2.9 presents estimates of the linear trend of annual and seasonal precipitation amounts at observation points located in the Iranian sector of the Caspian Sea for the period 1976-2022.

Table 2.2.9 – Estimates of the linear trend of annual and seasonal precipitation in the Iranian sector for the period 1976-2022: *a – linear trend coefficient; D – determination coefficient*

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Anzali	3.28	0.62	3.14	2.01	-1.26	2.95	-1.28	1.8	1.14	0.0
Babolsar	6.45	16	1.16	2.12	-0.38	0.9	1.45	4.42	4.22	8.77
Ramsar	-2.38	0.67	-0.43	0.14	-1.16	6.27	0.15	0.0	0.6	0.0

Kazakh sector

Table 2.2.10 presents estimates of the linear trend of annual and seasonal precipitation amounts at observation sites in the Caspian region for the period 1976-2022.

On the Kazakhstan territory, there is mainly a decrease in seasonal precipitation amounts, but statistically insignificant. The rate of change of annual precipitation amounts over the Kazakhstan territory of the Caspian region varies from 8.6 to 10.1 mm/10 years. And only on the eastern coast of the Kazakhstan territory of the Northern Caspian there is an increase in annual precipitation amounts, but statistically insignificant. In winter period, there is mainly an increase in precipitation amounts in the eastern part of the Northern and Middle Caspian by 1.0-4.9 mm/10 years, the increase is statistically insignificant, except for Atyrau MS where a statistically significant increase in precipitation by 4.9 mm/10 years was recorded. In the spring period in the North Caspian Sea there is an increase in precipitation by 3.7-8.7 mm/10 years, with a statistically significant increase at Peshnoy and Atyrau meteorological stations. At the same time, a statistically insignificant decrease in precipitation by 2.8-6.2 mm/10 years was recorded in the Middle Caspian, and only at MS Fort Shevchenko the rate of spring precipitation decrease by 6.0 mm/10 years is statistically significant. In the summer and autumn periods on the Kazakhstan coast of the Caspian Sea there is mainly a statistically insignificant decrease in precipitation amounts, except for meteorological stations Tushchibek and Aktau, where in the summer season there is a statistically insignificant increase in precipitation by 2.4 and 4.3 mm/10 years, respectively.

Table 2.2.10 – Estimates of the linear trend of annual and seasonal precipitation in the Kazakhstan sector for the period 1976-2022: ***a*** *– linear trend coefficient (mm/10 years);* ***D*** *- determination coefficient (%). The trend values that are significant at the level of 5% are highlighted*

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	a	D	a	D	a
Aktau	-1.4	0.1	1.0	0.3	-5.2	4.2	4.3	7.3	-0.2	0.0
Atyrau	10.1	7.8	**4.9**	13.7	**8.5**	12.9	-1.6	0.9	-1.3	0.8
Ganyushkino	-6.9	4.0	-0.0	0.0	3.7	5.1	-7.1	8.2	-3.1	4.7
Kyzan	-8.6	6.2	-0.6	0.4	-2.8	1.6	-2.4	1.6	-3.9	7.2
Peshnoy	7.3	3.6	1.9	1.7	**8.7**	14.6	-0.9	0.3	-2.0	2.1
Tushchibek	-2.8	0.4	3.3	6.6	-6.2	3.7	2.4	2.1	-1.8	1.9
Fort Shevchenko	-8.5	6.2	1.6	2.9	**-6.0**	9.8	-1.7	0.9	-2.1	2.1

Russian sector

Table 2.2.11 presents estimates of the linear trend of annual and seasonal precipitation at observation points located in the Russian sector of the Caspian Sea for the period 1976-2022.

In the Russian sector, trends in seasonal precipitation were statistically insignificant. The rate of change in annual precipitation varied from -8.0 to 16.6 mm per10 years. The general trend for all stations was a slight decrease in summer precipitation, and an increase is observed in winter. In autumn, precipitation increases at all stations on the western coast of the Middle

Caspian. Though, the increase in precipitation was more pronounced than the decrease. In the spring, moisture amounts changed in various directions.

Table 2.2.11 – Estimates of the linear trend of annual and seasonal precipitation in the Russian sector for the period 1976-2022: *a – linear trend coefficient; D – determination coefficient. The trend values that are significant at the level of 5% are highlighted*

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Derbent	**16,6**	**6**	**6,8**	**4**	-0,7	0	-1,1	0	**12,3**	**5**
Izberg	**13,8**	**9**	3,3	1	1,2	1	-1,0	0	**11,3**	**6**
Makhachkala	7,1	1	**6,3**	**5**	1,4	1	**-4,9**	**4**	5,3	1
Tyuleniy Isl.	**-7,1**	**4**	1,7	3	-2,3	1	-1,9	1	**-4,2**	**4**

Turkmen sector

Table 2.2.12 – Estimates of the linear trend of annual and seasonal precipitation in the Turkmen sector for the period 1976-2022: *a – linear trend coefficient; D – determination coefficient*

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	a	D	a	D	a
Turkmenbashi (Krasnovodsk)	-17,93	17,6	-3,36	2,6	-4,18	2,2	-4,35	14,9	-6,19	7,6
Khazar (Cheleken)	-22,4	36,1	-6,75	12,1	-6,33	8,3	-1,50	4,9	-6,49	13,6
Garabogaz (Bekdash)	-12,55	6,6	-2,96	1,4	-2,49	0,9	-0,59	0,6	-3,64	4,6
Guvlymayak (Kuuli-mayak)	-10,19	5,5	-6,31	16,3	-3,19	1,2	1,40	4,2	-1,89	0,8
Duzlybogaz (Kara Bogaz Gol)	-31,50	49,5	-9,22	23,8	-10,10	25,0	-2,54	12,5	-7,39	23,6
Ogurdjaly (Ogurchinsky)	-3,53	0,9	0,85	0,2	-0,20	0,01	-0,74	1,3	-1,31	0,4

Note: data since 1989 as the older data were collected by Azerbaijan Department for Hydrometeorology

3. HYDROLOGICAL CONDITIONS

3.1 RIVER FLOW INTO THE CASPIAN SEA

3.1.1 The Volga River

Analysis of the differential integral curve of the annual flow of the Volga River at the station Verkhnelebyazhye, located at the top of the delta (Fig. 3.1.1), makes it possible to distinguish several periods. The period 1942-1955 – the period of conditionally natural runoff of the Volga; 1956-1961 – the period of filling of large reservoirs of the Volga–Kama cascade; from 1962 to the present – the period of regulated runoff. At the top of the delta, the average long-term runoff of the Volga River during the period of conditionally natural runoff was 240 km^3, during the period of filling of large reservoirs – 233 km^3, during the period of regulated runoff (1962-2022) – 241 km^3, during the new climatic reference period (1991-2020) – 247 km^3.

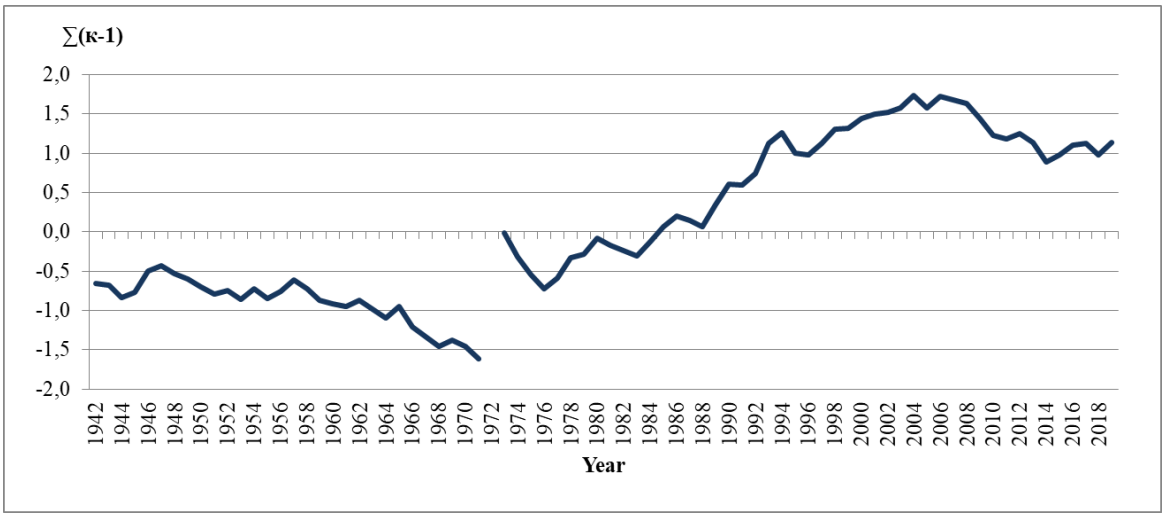

Figure 3.1.1 – Differential integral curve of the annual Volga River flow at Verkhnelebyazhie station in the period of 1942-2022

Over the entire observation period, the maximum annual runoff was 333 km^3 (1994), the minimum was 166 km^3 (1975) (Fig. 3.1.2). The regulation of the Volga led to an intra-annual redistribution of the runoff. Compared with the natural period, the runoff in winter (XII-III) doubled – from 14% to 27% of the annual flow, in summer (VI-IX), on the contrary, decreased – from 46.5% to 33%. The decrease occurred due to a reduction in the duration and volume of runoff in high water. The average duration of high water and the average volume of runoff had been 109 days and 147 km^3 in natural conditions, while they reduced to 73 days and 90 km^3 accordingly after the river regulation. During the new climatic reference period (1991-2020), the volume of runoff during the flood was 94.5 km^3. The average date of the flood peak shifted from

the first decade of June to the second decade of May in conditions of regulated runoff, the average end date of the flood shifted from the first decade of August to the first decade of July, as a result of which the duration of the flood was reduced by 36 days.

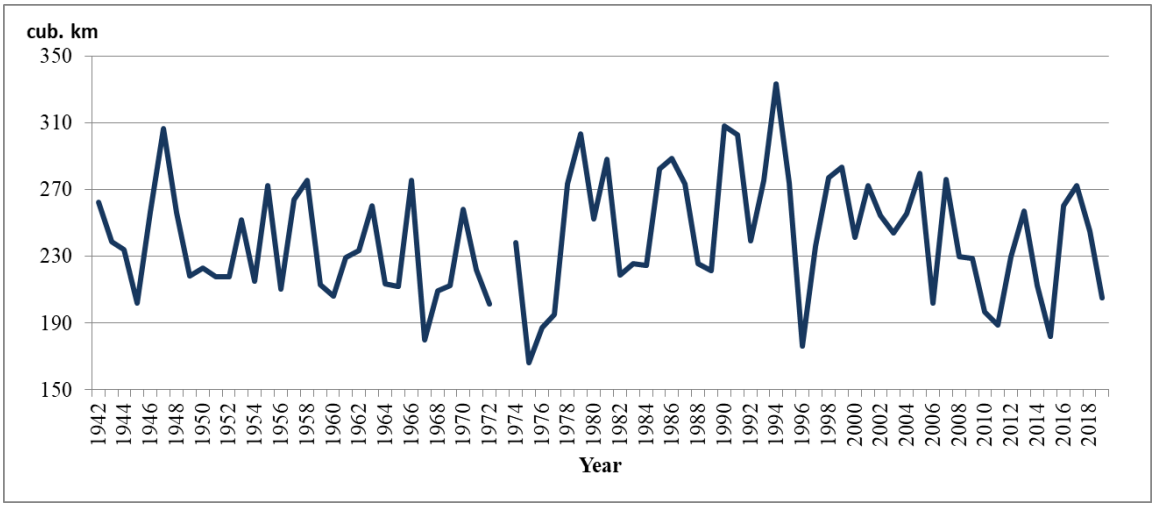

Figure 3.1.2 – Yearly water flow of the Volga River at Verkhnelebyazhie station in the period of 1942-2022

2022 was a low-water year in terms of water runoff. The annual flow of the Volga according to data from the station Verkhnelebyazhie was 212 km^3, which is 35.29 km^3 less than the normal (247 km^3). A characteristic feature of the water regime in 2022 was low water consumption throughout the year, and only in May and July the average monthly water consumption was within the normal range. Large negative deviations occurred in March (K=0.72), April (K=0.74) (Table 3.1.1).

Table 3.1.1 – Water runoff at the top of the Volga Delta (m^3/c) and modular coefficients in January-December 2022

Parameter	Month												Year
	1	2	3	4	5	6	7	8	9	10	11	12	
Q av. in 2022	4700	5150	4790	6420	17700	9820	6750	5370	5040	4860	4880	5080	6710
Q av. for 1991-2020	5739	6112	6650	8663	18540	12289	6943	6104	5765	5437	5620	6064	7827
K for 2022	0,82	0,84	0,72	0,74	0,95	0,80	0,97	0,88	0,87	0,89	0,87	0,84	0,86
Q max in 2022	4890	5700	4970	15600	19900	12300	9730	5540	5320	4980	4940	5680	19900
Q min in 2022	4440	4680	4660	4690	12900	8600	5390	5320	4680	4700	4840	4710	4440

Note: modular coefficient K is the ratio of the runoff in a month or the year to the respective average value in the reference period

3.1.2 The Kura River

Figure 3.1.3 shows the long-term changes in the average annual water flow rate in the Kura River. There is a downward trend in water discharge of the river, whish is observed after a severe flood in 2010 and goes especially noticeable during the last 11 years.

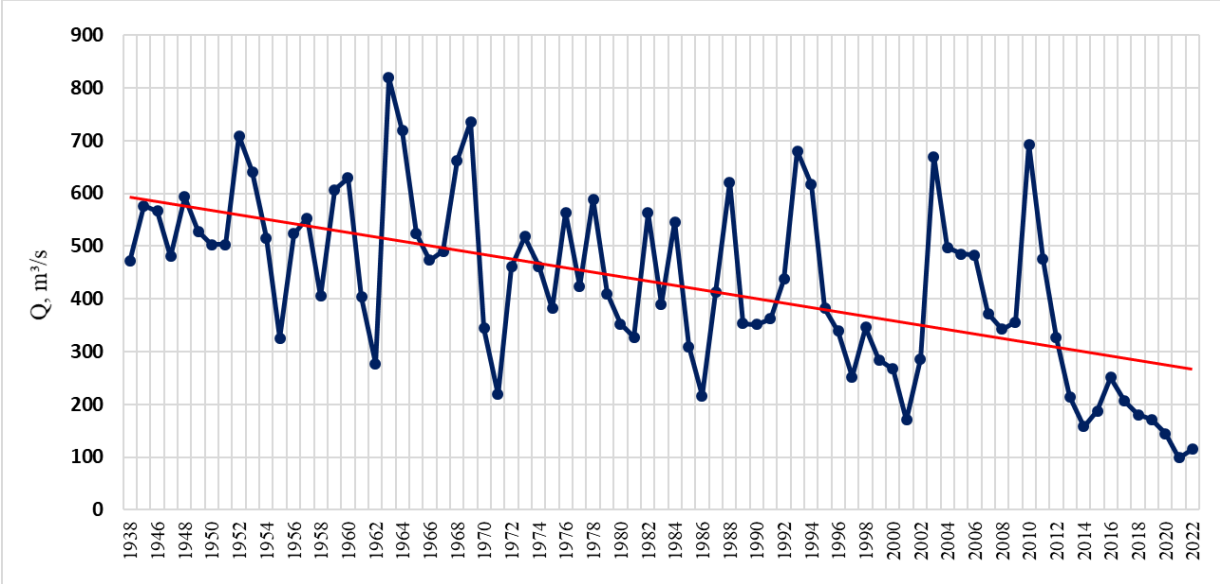

Figure 3.1.3 - Change in the average annual discharge of the Kura River near Salyan station for the period 1938-2022

Figure 3.1.4 shows that the average annual discharge of the Kura River has decreased by 53% over the past 11 years compared to the period of 1961-1990.

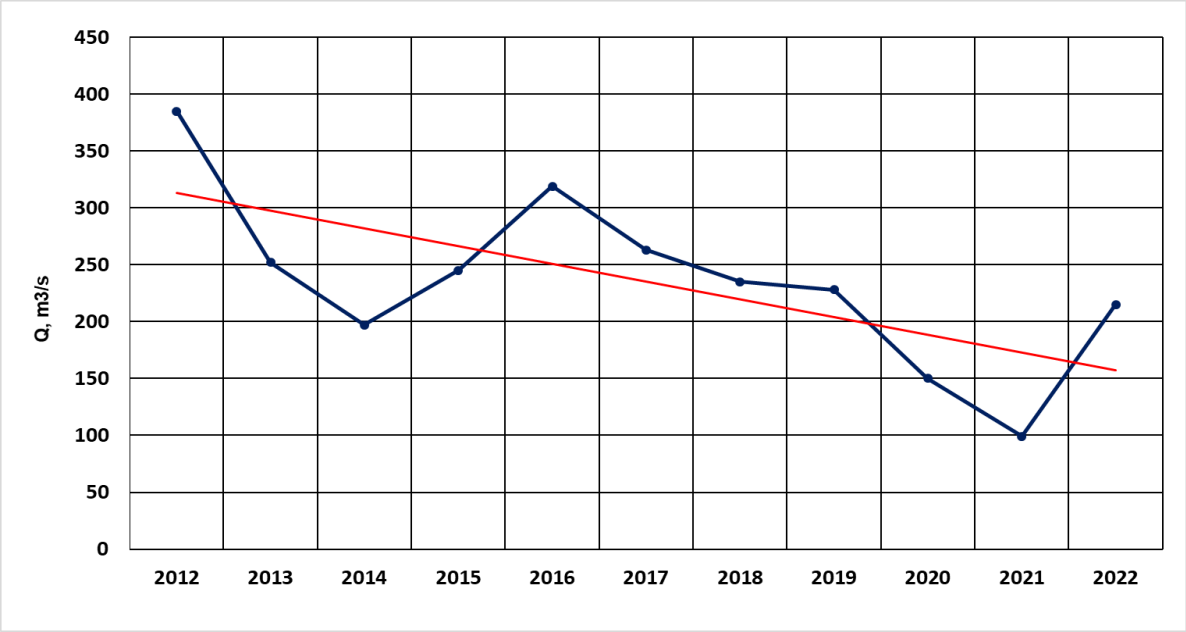

Figure 3.1.4 - Change in the average annual discharge of the Kura River near Salyan station for the last 11 years

Impact of climate change on the flow of the Kura-Salyan River

The flow of the main rivers of Azerbaijan went down in 1991-2020 compared to 1961-1990. At the same time, a significant decrease in the river flow entering the Republic is observed as a result of the use of transboundary waters on the territory of neighboring states. Demand for water is growing at an increasing rate due to population grow and irrigated agriculture expansion. Figure 3.1.5 shows that a decrease in the river water flow is observed in all seasons of the year. The average annual water discharge has decreased by 26% over the past 30 years compared with the period of 1961-1990.

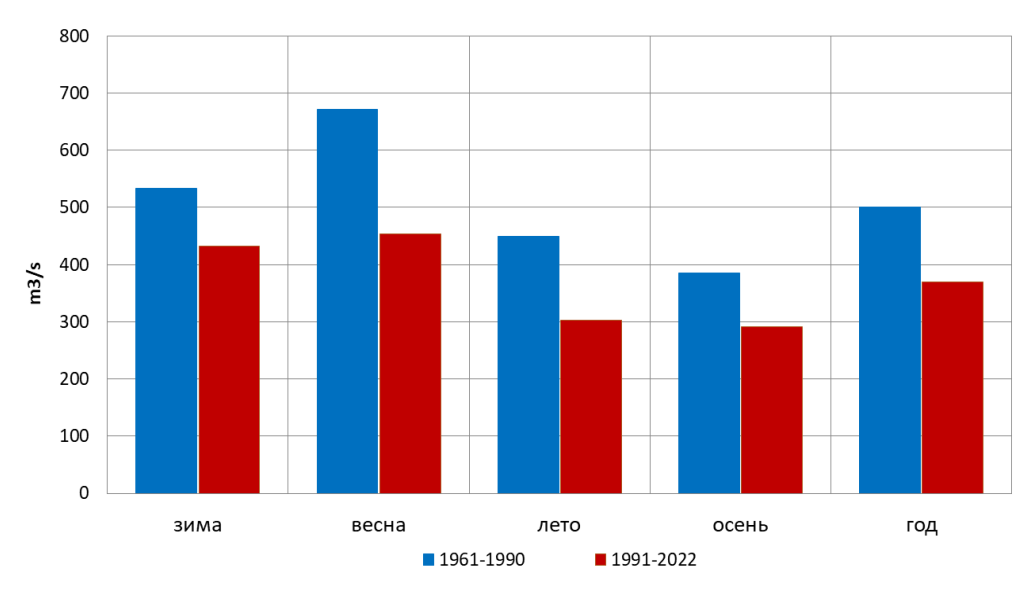

Figure 3.1.5 - Change in the average annual and seasonal discharge of the Kura River near Salyan station

3.1.3 The Terek River

The Terek River is one of the largest rivers in the Northern Caucasus. It originates on the slopes of the Great Caucasian Ridge in the Trusovsky gorge, from the glacier of Zilga-Khokh Mount. The height of the source above the ocean level is 2713 meters, the total length of the river along the dug and straightened channel through the Agrakhan peninsula is 586 km, the catchment area is 37400 km^2. The Terek River is fed by mixed meltwater from glaciers and snow, as well as by groundwater and rainfall.

A characteristic feature of the Terek is its highly varied runoff. For instance, the annual runoff was 4.4 times higher in wet 2005 than in dry 1976. The annual runoff in these years amounted to 11.37 and 2.57 km^3, respectively. The average runoff is 6,813 km^3 for the entire

observation period (since 1965 to 2022), while it reaches 8,122 km^3 in the climatic base period (1991-2020).

In 2022, the average annual water discharge was 226 m^3/sec, and the annual runoff amounted to 7,143 km^3. The highest water discharge was observed in June (435 m^3/sec, on 29 and 30 June), the lowest in April (24.4 m^3/sec, on 22, 23 and 27 April). There was a large shortage of precipitation in June and especially in August. Following to the distribution of precipitation, the water flow of the Terek River in the summer months was low and amounted to 67% of the normal in June, 65% in July, 62% in August. There was a shortage of precipitation in September, and the water flow of the Terek River was 31% below the normal. In October and November, there were rainy floods, and the water flow of the Terek exceeded the normal (131 and 126%) (Table 3.1.2).

Table 3.1.2 – Water runoff of the Terek River at Kargalinsky hydrosystem (m^3/c) and modular coefficients in January-December 2022

Parameter	Month												Year
	1	2	3	4	5	6	7	8	9	10	11	12	
Q av. in 2022	221	209	225	139	209	296	305	197	139	252	273	254	226
Q av. for 1991-1998 and 2001-2020	191	196	215	191	250	439	472	318	200	192	216	207	257
K for 2022	1,15	1,07	1,05	0,73	0,84	0,67	0,65	0,62	0,69	1,31	1,26	1,23	0,88
Q max in 2022	230	214	265	271	387	435	430	377	258	291	298	275	435
Q min in 2022	210	205	204	24,4	86,7	162	146	96,5	63,7	110	265	233	24,4

3.1.4 The Sulak River

The Sulak River drains in Dagestan, it is merged by flows of the rivers of Avar Koysu and Andian Koysu, which originate from the glaciers of the Greater Caucasus. It flows into the Caspian Sea through 169 km long and drains a basin of 16620 km^2. The river's feeding is mixed with a predominance of snow.

The flow of the Sulak River is regulated by the cascade of reservoirs. The largest of them is Chirkeyskoye reservoir located 142 km far from the Caspian Sea. Its construction was completed in August 1974, and the filling with water was completed in 1975. Therefore, the intra-annual distribution of its runoff is disrupted and depends on human regulation.

The average long-term water discharge of the Sulak River for the period 1976-2021 is 150 m^3/sec (runoff W = 4,739 km^3) and for the climatic reference period (1991-2020) is a little greater – 155 m^3/sec (W = 4,901 km^3).

The highest average annual water discharge was observed in 2002 and reached 246 m^3/sec (W = 7,761 km^3), the lowest was in 1996 – 84.75 m^3/sec (W = 2,680 km^3). The maximum

measured water discharge was 1,250 m^3/sec (July 20, 1997), and the minimum was 5,46 m^3/sec (August 30, 2000).

In 2022, the average annual water discharge reached 124 m^3/sec, the annual runoff was 3.904 km^3, which was 20% lower than the normal. The highest discharge was observed in May (166 m^3/sec) and the lowest in September (98.1 m^3/sec) (Table 3.1.3).

Table 3.1.3 – Water runoff of the Sulak River at Sulak station (m^3/c) and modular coefficients in January-December 2022

Parameter	Month												Year
	1	2	3	4	5	6	7	8	9	10	11	12	
Q av. in 2022	120	132	129	123	132	145	128	116	106	117	113	126	124
Q av. 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 for 2022	0,81	0,81	0,80	0,81	0,73	0,72	0,74	0,85	0,89	0,93	0,79	0,83	0,80
Q max in 2022	124	145	135	128	166	159	139	123	113	124	117	135	166
Q min in 2022	116	118	123	114	118	139	118	106	98,1	106	100	114	98,1

3.1.5 The Ural (Zhaiyk) River

The runoff of the Ural (Zhaiyk) River is characterized by significant interannual and seasonal variability. On the river hydrological post Ural - Makhambet, the average long-term volume of annual runoff for the period 1936-2022, amounted to 7.91 km^3, varying from 20.59 km^3 in wet years to 2.85 km^3 in dry years. This watershed closes the catchment area of 230,000 km^2.

On the river drain, The Urals (Zhaiyk) are influenced by many factors of economic activity, the most significant of which is the presence of the Iriklinskoye reservoir, commissioned in 1958 and related to reservoirs of many years of regulation. Therefore, the period from the beginning of observations to 1957 is considered conditionally natural. Since 1958, a period with a disturbed flow regime has begun, since this year the operation of the reservoir began with a constant spillway, and this made it possible to keep the spring flood in the reservoir (Chibilev, 2008). The flow of the Ural River in the territory of Russia are regulated by a cascade of reservoirs built both on the Ural River itself and on its tributaries. The largest of them are Verkhneuralskoe - volume of 601 million m^3, Magnitogorskoe - volume of 189 million m^3, and Iriklinskoe – volume of 3257 million m^3. Reservoirs on tributaries are Kumakskoye, Dombarovskoye, Krasnochabanskoye, Sakmarskoye, Chernovskoye (Russia), Aktobe, Karagalinskoye (Kazakhstan).

After analyzing the graph of runoff volumes (Figure 3.1.6), we can conclude that there is a trend towards a decrease in annual water volumes in the long-term section in the Ural River (Zhaiyk) at Makhambet post for the observation period 1936-2022. This can be proved by the trend line. At present, the Ural River runoff belongs to the low-water phase of water content. In 2022, the river flow near the Makhambet post was 4.71 km^3, which is 60% less than the long-term average (1936-2022).

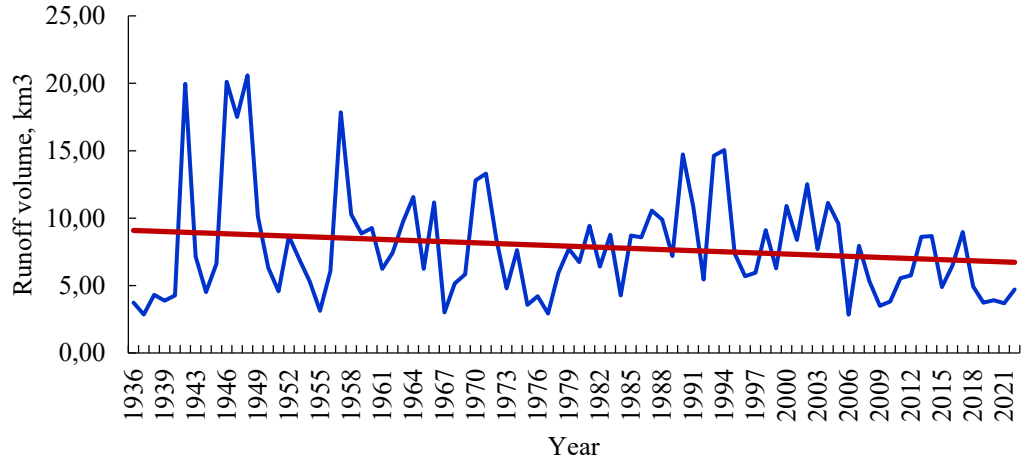

Figure 3.1.6 – Graph of the runoff volumes of the Ural River (Zhaiyk) at Makhambet post for the period of 1936-2022

Figure 3.1.7 shows that in the presence of a clear manifestation of cyclic fluctuations with the release of high-water and low-water phases, a decrease in water flow in the river is found, this is especially clearly seen in the last 20 years. However, it should be noted that in 2022 the volume of water increased by almost 1 km^3 compared to the previous year.

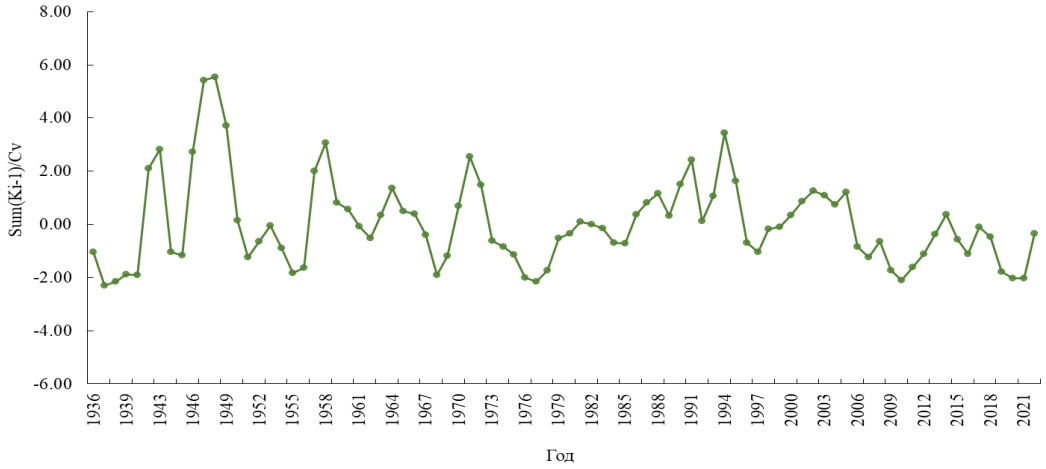

Figure 3.1.7 – Differential integral curve of runoff volumes Ural (Zhaiyk) at Makhambet post for the period of 1936-2022

3.1.6 The Chalus River

The Chalus River is a stable river in the west of Mazandaran, which originates from the northern slopes of Kandavan and Taleghan highlands and flows into the Caspian Sea after traveling for about 72 kilometers next to Chalus near De Faraj Abad. This river with its two main branches, Zanos and Mihsaz and its sub-branches, has a catchment area of 1550 km^3. The path of this river is mountainous, and the riverbed is narrow and its flow is rapid and torrential. Its average water yield at the measuring station located in Pol Zaghal has been measured as 430 million cubic meters per year. Figure 3.1.8 shows long-term data on the flow of the Chalus River for the period 1949-2021.

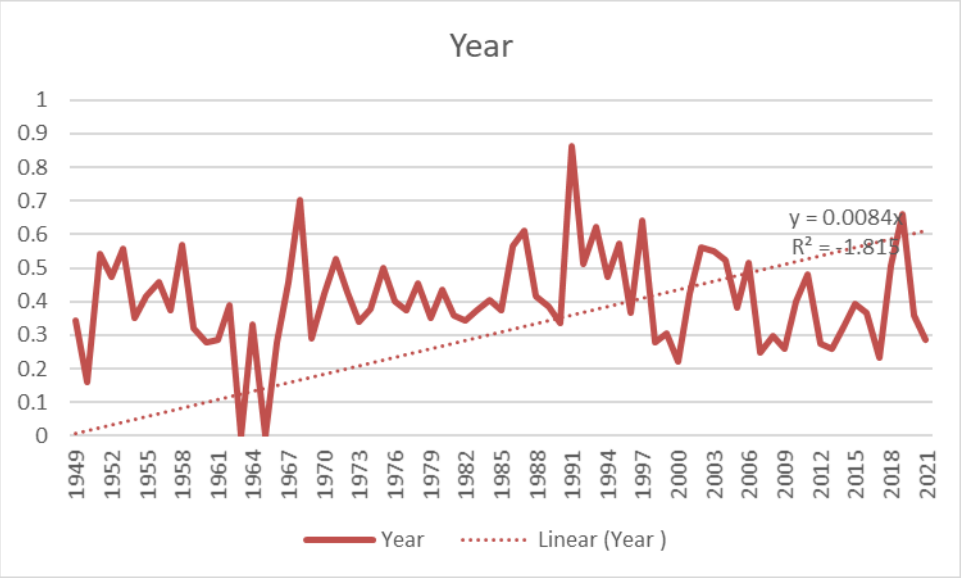

Figure 3.1.8 – Runoff of the Chalus River in 1949-2021

3.1.7 The Haraz River

The Haraz River is a river in Mazandaran province in the north of Iran, which originates from the Lar Valley in the south of Damavand Mountain and flows into the Caspian Sea. The Haraz River flows in a relatively wide valley towards the north, and on its way there are several villages and neighborhoods and at least 8 sand factories. There is sand. The most important cities that have developed on the alluvium of Haraz River are Amel and Faridoonkanar. The slope of Haraz River is very variable in the mountainous area. The slope of Haraz River from the mountain border to the north of Amol city is 13 per thousand and within the limits of Amol city is seven per thousand. The area of Haraz catchment area is more than 4100 square kilometers. Figure 3.1.9 shows long-term data on the flow of the Haraz River for the period 1951-2021.

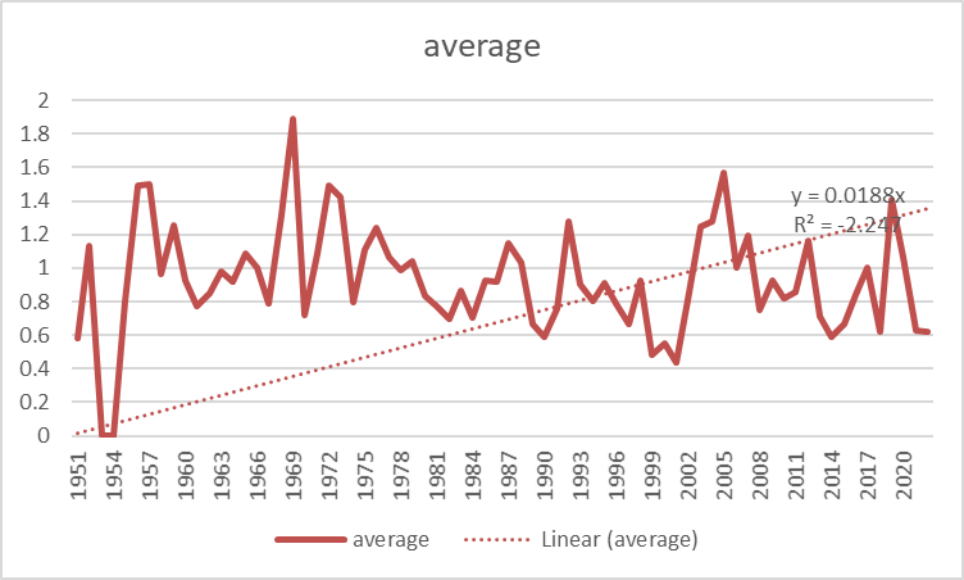

Figure 3.1.9 – Runoff of the Haraz River in 1951-2021

3.1.8 The Polrud and Sefid-rud Rivers

The Polrud River is the largest and most abundant river in the sub-basin of east Gilan, originates from the Lahijan-Noor catchment, it is also the second largest river in Gilan province after Sefidroud and consists of two main branches. The first branch, which originates from the heights of Ashkur, forms the Pelrud branch with Tinkarud and Kakrud rivers. The second branch, which springs from Dilman, Shahijan and Lesbo mountains, is known as Chakrud. These two branches join together in a place called May Bridge and form the Polrud River. The size of the Polrud catchment area at the Darzlat station, which is the water measuring station of this river, is 1564 square kilometers and the average height of the basin is 1883 meters. The length of the main branch of the river is 60 km and the area of the watershed of this river is 8147 hectares. The volume of water discharge and runoff of rivers is a function of the variability of precipitation, rainfall and its flow rate, hence many fluctuations are observed in their runoff and monthly discharge volume of rivers. In the summer season, due to the decrease in rainfall, the flow rate of the rivers greatly reduced. At such times of the year, feeding the rivers by springs and water from melting snows also reduces. The annual rainfall in this basin is 1356.4 mm and the rainfall distribution is 32.6% in autumn, 30.8% in summer, 19.5% in winter and the lowest amount is 17.1% in spring. The irrigation regime of the Polrud River at the Darazlat station is based on the average annual flow equal to 482.4 million cubic meters (15.3 cubic meters per second) and the water regime of this river is snowy-rainy. Figure 3.1.10 shows long-term data on the flow of the Polrud River for the period 1956-2021.

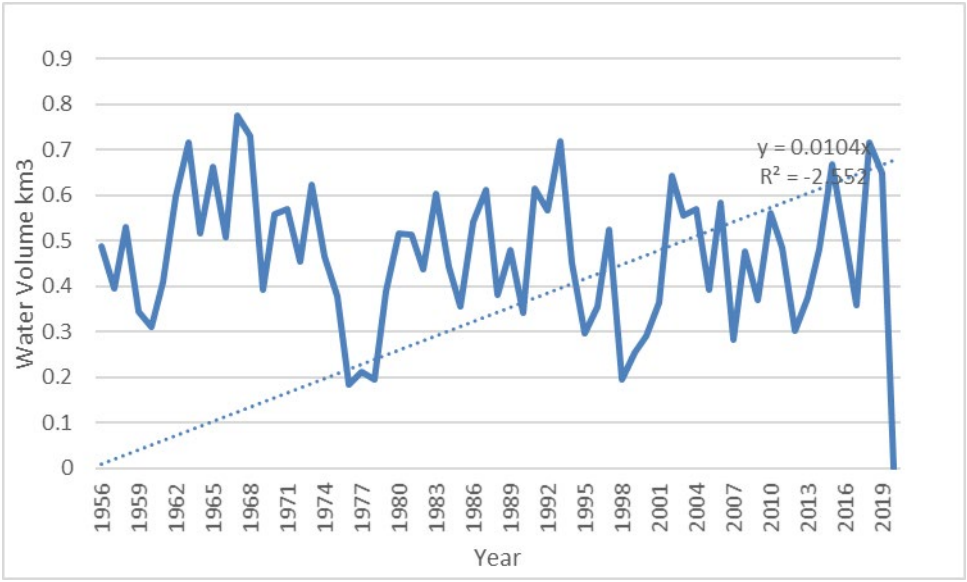

Figure 3.1.10 – Runoff of the Polrud River in 1956-2021

Sefid-rud River is the largest river in the north of Iran, which is formed by the confluence of two rivers, Shahroud and Qezal Ozen, which meet in the city of Manjil, and crosses the width of Gilan province until entering the Caspian Sea. Figure 3.1.11 shows long-term data on the flow of the Sefid-rud River for the period 1958-2021.

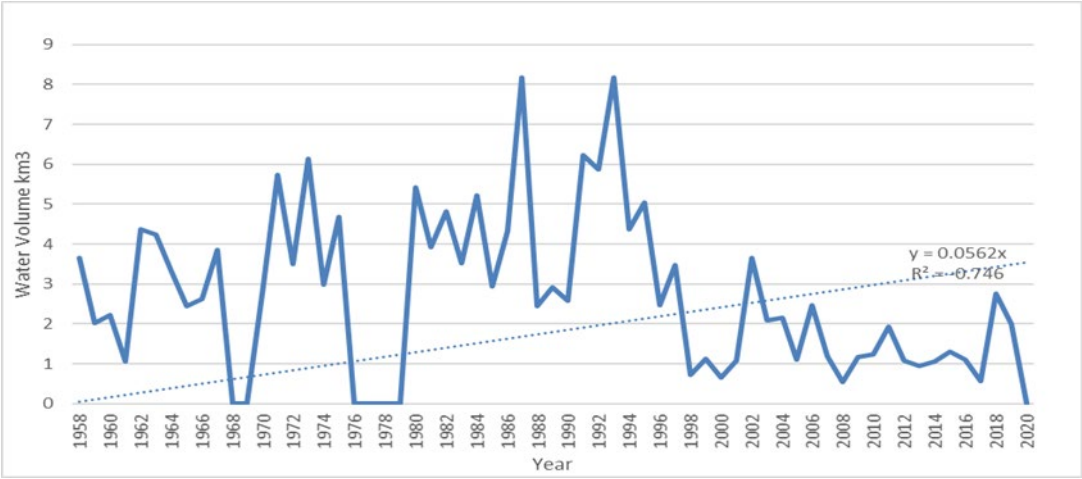

Figure 3.1.11 – Runoff of the Sefid-rud River in 1958-2021

3.2. THE LEVEL OF THE CASPIAN SEA

Azerbaijan sector

According to observations at the offshore hydrometeorological station Neft Dashlary ("Oil Rocks") in 2022, the maximum sea level was recorded in June (-28.23 m abs), and the minimum was in February (-28.42 m BS). The average annual level reached -28.42 m BS in 2022, and compared to 2021(-28.14 m abs), it decreased by 28 cm.

In 2022, according to the observations of the offshore hydrometeorological station "Oil Stones," the average annual wave height was 1.6 m, the maximum reached 5.2 m. The average annual wavelength amounted to 24 m, the maximum was 65 m. The average annual wave period was 3.3 seconds, and the maximum reached 7.2 seconds.

Iranian sector

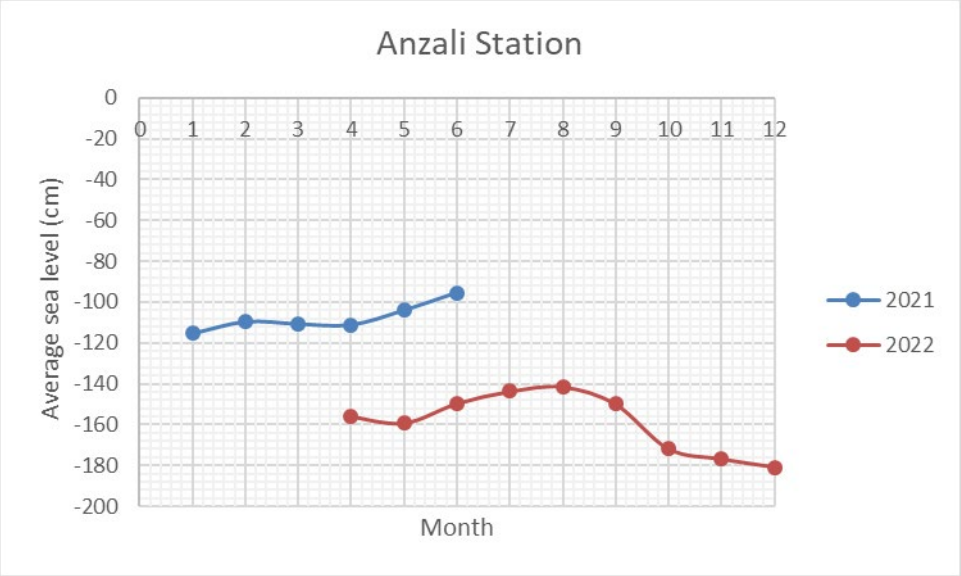

Figure 3.2.1 – Average sea level at Anzali station in 2021 and 2022

Kazakh sector

According to the data of coastal and inland marine stations in 2022, the level of the Caspian Sea in its northeastern shallow part fluctuated around the mark of -28.46 m abs within the range from -27.61 m to -29.44 m.

In the deep-water Kazakhstani part of the Caspian Sea, according to the Fort-Shevchenko, Aktau and Fetisovo stations, the average sea level corresponded to the mark of -

28.71 m with the maximum value when rising to the mark of -28.05 m and the minimum when falling to the mark of -29.27 m.

Surge fluctuations in the level of the Caspian Sea

Near the north-eastern coast of the Northern Caspian Sea, during the period from January to December, the marine stations of Kazhydromet recorded 27 cases with negative surge, and 33 cases with positive surge. The most significant surge phenomena:

- On March 26-30 near Peshnoy station, a critical increase in water level by 82 cm was observed, caused by a steady south-southwest wind with a speed of up to 20 m/s.
- On May 1-5, near Peshnoy, a critical increase in the water level by 71 cm was observed, caused by a steady northerly wind with a speed of up to 10 m/s.
- On May 9-15, near Peshnoy, a critical increase in the water level by 77 cm was observed, caused by a steady southwesterly wind with a speed of up to 12 m/s.
- On January 17-27, near Peshnoy, a critical drop in the water level by 72 cm was observed, caused by a steady east wind with a speed of up to 10 m/s.
- On March 8-13, near the northeastern coast of the Caspian Sea in the area of the Peshnoy station, a dangerous drop in the water level by 62 cm was observed, caused by the steady influence of the northwestern wind with a speed of up to 8 m/s.
- On November 2-7, Peshnoy station recorded a dangerous drop in the water level by 61 cm, caused by a northerly wind with a maximum wind speed of up to 8 m/s.
- On November 22-33, a dangerous drop in the water level by 60 cm was observed near Peshnoy, caused by a steady east wind with a speed of up to 12 m/s.

Russian sector

The sea level at Russian marine stations decreased by 19...25 cm in 2022 compared to 2021. The main reason for the decrease in the level was low runoff of the Volga River observed for the second year in a row. In 2021 and 2022, the volume of its runoff was 208 km^3 and 212 km^3, which are 38.68 km^3 and 35.29 km^3 less than the normal, respectively.

Table 3.2.1 – Average monthly sea level at the stations in the Russian sector in 2021 и 2022

Year	Monthly average												Yearly average
	1	2	3	4	5	6	7	8	9	10	11	12	
Makhachkala													
2021	-25	-31	-28	-27	-23	-18	-20	-24	-36	-37	-42	-42	-29
2022	-44	-50	-48	-46	-45	-38	-44	-40	-49	-53	-67	-57	-48

Table 3.2.1 continued

Year	Monthly average												Yearly average
	1	2	3	4	5	6	7	8	9	10	11	12	
Tyuleniy Isl.													
2021	-23	-38	-34	-30	-26	-21	-28	-28	-43	-42	-51	-46	-34
2022	-55	-55	-61	-58	-57	-50	-55	-42	-60	-57	-64	-56	-56
Lagan													
2021	5	-22	-12	-3	16	14	-6	5	-27	-11	-25	-19	-7
2022	-36	-37	-55	-23	-23	-12	-27	1	-33	-39	-55	-42	-32

Surge fluctuations in the level of the Caspian Sea

Wind surges are the part of the Caspian Sea hydrological regime. The northwestern and western coasts of the Northern Caspian are most affected by the wind-induced fluctuations.

In the period from January to December 2022, the maximum number of water run-up was observed in Lagan, which is explained by the specific conditions of the post location. As a rule, the largest number of surge floods is observed near shallow shores, in long and narrowing bays, as well as in narrow straits. Lagan station is located on the western coast of the Northern Caspian Sea, 300 m from the northern shore of the Lagan Bank, which is a narrow long bay that was someday a channel of the Volga Delta. The width of the bay near the station is about 80 m.

In 2022, number of level drops (33) prevailed over the number of surge floods (30) at the Lagan station. The maximum number of surge fluctuations was observed in February and March. The maximum duration of the surge level run-up was 6 days (7-12.07); the maximum duration of the level drops was 4 days (27-30.12).

According to the data at Tyleniy Island station, five positive surge were recorded with a level rise of 35-53 cm. The only case of surge flood was observed at the Iskusstvennyi station in October. An increase in the water level (by 31-32 cm) was associated with the stabilized ice cover, which was noted on 24, 25 and 28 January.

The maximum amplitude of the wind-induced level fluctuations was observed in October 2022 and amounted to 40 cm at the Iskusstvennyi station, 97 cm on the Tyuleniy Island and 196 cm in Lagan.

The most significant surge-induced fluctuations at the Lagan station:

- On March 2, 3 and 24, 25, there was an increase in the water level by 67 and 74 cm, caused by a stable southeast wind with maximum gusts up to 16-20 m/s.
- On April 18-20, the water level increased by 110 cm. The surge was induced by a southerly and southeasterly wind; maximum wind gusts reached 20-21 m/s.
- On August 20 and 21, there was a surge of 81 cm caused by the southeasterly wind; maximum wind gusts reached 19-20 m/s.

- On September 12-14, a strong southeasterly wind induced a severe surge flood with the level rise of 92 cm.
- On September 24-26, the sea level fell up to 52-58 cm due to the strengthening of the north and northwesterly wind (18-22 m/s).

On October 3 to 5, there was a wind-induced rise in the sea level in the Northwestern part of the sea along the line from Iskusstvennyi and Tyuleniy Island stations to the north-west coast. The increase in the sea level was synchronously seen at all the stations and amounted to 31 cm on the Iskusstvennyi island, 53 cm on the Tyuleniy Island and 131 cm in the Lagan. At that time, the level droped in the Southeastern coast of the Northern Caspian, including Komsomolets Bay and Mangyshlag Bay (Figure 3.2.2).

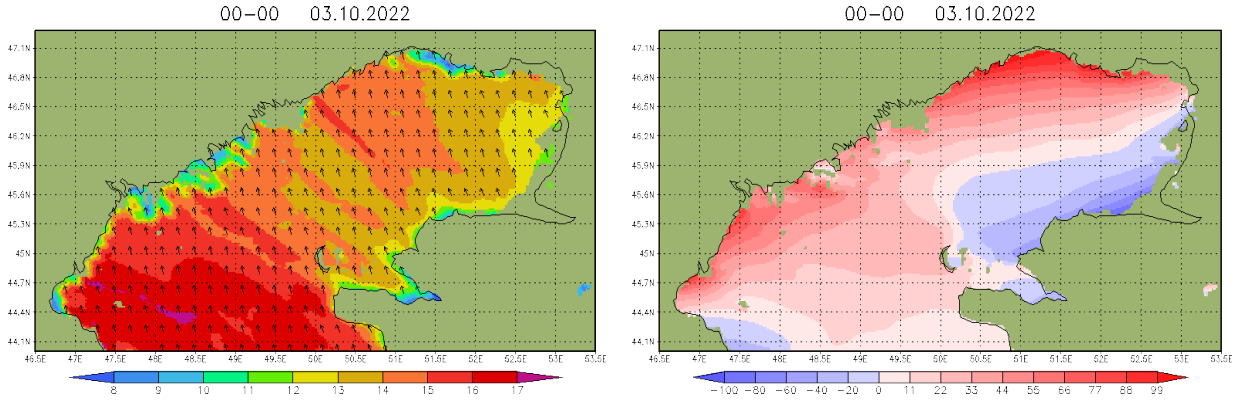

Figure 3.2.2 – Maps of wind (left) and level (right) in the Northern Caspian on 3 October 2022

On November 13-16 2022, the sea level dropped by 40-58 cm due to a steady northwesterly wind with maximum wind gusts of 12-21 m/s. On November 15, the minimum annual water level was marked (-115 cm), the level decreased for 60 cm on that day compared to the previous one.

On November 26 and 27, the water level rose by 75 cm due to a southeasterly wind (12-18 m/s).

In 2022, the minimum monthly levels at Makhachkala station on the western coast of the Middle Caspian reached dangerous limits. The level of -50 cm is referred to as the nationally established criterion of dangerous phenomenon for Makhachkala [1]. From January to May 2022, in July and from September to December, the minimum monthly levels were in the range between -50 and -81 cm. In June and August, the minimum monthly levels approached the dangerous limit criterion and amounted to -48 and -49 cm, respectively.

3.3. SEA WATER TEMPERATURE IN 2022

Azerbaijan sector

Table 3.3.1 – Absolute maximum/minimum of the average monthly water temperature (°C) recorded in the Azerbaijan sector in 2022

Observation post	Month	Absolute maximum of 2022	Previous maximum and a year of its occurrence	Absolute minimum of 2022	Previous minimum and a year of its occurrence
Oil Rocks	January	10.6	10.3	7.3	7.4
	February	9.8	9.4	5.3	2.7
	March	10.1	12.5	5.7	6.1
	April	17.5	14.6	7.2	9.3
	May	22.6	20.7	11.1	11.8
	June	25.1	28.1	19.9	17.8
	July	27.5	30.5	22.4	24.8
	August	28.7	31.1	24.5	26.1
	September	29.1	30.1	21.7	19.9
	October	24.0	22.3	16.1	13.6
	November	17.9	16.6	11.8	10.9
	December	13.0	12.8	8.5	6.1
Baku	January	8.4	8.2	5.6	5.6
	February	11.4	8.8	5.0	3.2
	March	11.6	14.2	6.4	5.0
	April	22.2	19.4	10.0	12.4
	May	27.0	26.0	15.2	15.0
	June	28.2	31.4	23.6	22.0
	July	27.1	30.8	22.2	26.2
	August	31.9	31.8	26.0	27.2
	September	26.8	29.2	22.3	20.0
	October	24.6	19.4	16.6	13.0
	November	17.2	14.2	11.8	9.2
	December	11.2	11.4	6.9	7.4
Sumgait	January	8.0	7.8	4.4	4.6
	February	8.2	7.1	6.0	2.8
	March	9.8	9.6	5.1	5.0
	April	16.0	16.0	8.0	9.0
	May	18.5	19.8	14.8	14.2
	June	25.2	25.6	17.8	19.5
	July	26.0	28.4	23.5	23.2
	August	27.7	29.0	21.6	25.2
	September	22.5	28.7	16.3	19.7
	October	22.6	18.6	16.3	13.8
	November	16.5	15.6	12.0	10.0
	December	12.0	10.8	6.5	7.1
Zhiloy	January	10.4	8.6	4.3	4.6
	February	11.0	8.7	4.0	1.6
	March	12.2	12.5	3.8	1.9
	April	17.7	17.5	7.6	9.5
	May	21.3	22.3	12.5	12.3
	June	26.0	27.6	19.0	19.0
	July	28.0	30.4	23.0	23.8
	August	30.8	31.0	19.5	26.0
	September	28.8	30.1	20.0	19.5
	October	23.5	21.1	14.6	12.7
	November	16.0	16.0	9	7.0
	December	12.1	16.0	2.5	4.1

Table 3.3.2 – Records of maximum monthly seawater temperature (°C) in the Azerbaijan sector in 2022

Observation post	Date	Month	Seawater temperature, °C	Previous maximum, °C	Date of the previous maximum
Oil Rocks	02	September	29.1	31.1	29.08.2021
Baku	16	August	31.9	31.8	12.08.2021
Sumgait	05	August	27.7	29.0	11.08.2021
Zhiloy	16; 17	August	30.8	31.0	22.07.2021

Таблица 3.3.3 – Records of minimum monthly seawater temperature (°C) in the Azerbaijan sector in 2022

Observation post	Date	Month	Seawater temperature, °C	Previous maximum, °C	Date of the previous maximum
Oil Rocks	06	February	5.3	2.7	24.02.2021
Baku	14	February	5.0	3.2	25.02.2021
Sumgait	22	January	4.4	2.8	25.02.2021
Zhiloy	21	March	3.8	1.6	24.02.2021

Iranian sector

In 2022, the average annual water temperature according to the data of coastal stations located in ***the Iranian sector of the sea*** was +19.6...+20.4°C, which is 0.5–0.8°C higher than the normal (reference period of 1981-2021).

The average water temperature on the surface varied from +11.0...+12.3°C in the cold season to +28.5...+29.3°C in the summer months. The minimum annual water temperature was observed in February and in March (+10.4...+10.9°C), the maximum annual temperature was in August (+28.7...+29.8°C) (Table 3.3.4).

Table 3.3.4 – Average values, anomalies from the standard normal, maximum and minimum in the seawater temperature (°C) recorded in data on the Iranian coast of the Caspian Sea in 2022

Obser-vation post	Year, period	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Anzali	Average in 2022	-	11.4	11	13.8	18.1	24	27.2	28.5	26.7	23.4	18.5	14.5	18.1
	Max.	-	12	12.1	17.1	16.9	26.5	28.5	29.4	28.9	25.1	20.3	16.8	21.2
	Min.	-	11	10.5	12.4	16.9	20.7	25.8	27.7	25	20.1	16.8	12.1	18.1
	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	-0,7	1,2	-1,3	0,5	0,8	-0,3	-1,0	2,9	-0,6	-1,4	-0,5	1,2	0,1
Kiashahr	Average in 2022	12.6	11.7	11.4	14.1	18.3	23.9	27.9	28.9	27.2	24	19.2	15	19.6
	Max.	13.6	12.2	12.6	16.7	20.4	26.8	29.3	29.8	29.1	25.8	21.2	17.3	21.2
	Min.	11.5	11.2	10.4	11.8	16.7	20.4	26.4	28.3	25.7	21.2	17.3	12.6	17.8
	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	0.7	1.3	0.8	0.5	-0.9	-0.9	0.3	0.7	1.0	1.3	0.6	0.4	0.5
	Average in 2022	13.6	12.3	12.4	14.8	18.6	24.7	27.2	29.1	27.8	24.0	18.5	15.1	19.9
	Max.	12.6	11.4	11.8	14.4	20.3	25.5	28.2	28.7	27.1	23.5	19.1	14.8	19.7
	Min.	12	10.5	10.8	13.8	18.8	24.2	26.9	27.5	25.7	22.3	18.4	14.6	18.7
	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	1.3	1.4	1.1	0.7	-0.8	-0.2	-0.2	0.8	1.3	1.0	-0.2	0.4	0.6

Table 3.3.4 continued

Observation post	Year, period	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Amirabad	Average in 2022	13.6	12.3	12.7	15.5	19.4	25.1	27.8	29.3	28.0	24.9	20.2	15.7	20.4
	Max.	12.8	11.6	12.3	15.3	21.1	26	28.8	29.4	27.8	23.8	19.6	15.4	20.3
	Min.	12.6	10.9	11.1	14.3	19.3	23.6	26	27.2	25.8	22.7	19	15.1	18.9
	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	0.9	1.1	1.1	0.8	-0.5	0.5	0.6	1.2	1.4	1.6	1	0.4	0.8

Table 3.3.5 – Absolute maximum/minimum of the average monthly seawater temperature (°C) recorded in the Iranian sector in 2022

Observation post	Month	Absolute maximum of 2022	Previous maximum and a year of its occurrence	Absolute minimum of 2022	Previous minimum and a year of its occurrence
Anzali	August	29.4	30.6 (August 2018)	10.5 March	9.4 (March 2018)
Kiashahr	August	29.8	30.6 (July 2018)	10.4 March	9.4 (February 2018)
Noshahr	April	30.2	31.3 (August 2018)	10.7 March	10.1 (February 2017)
Amirabad	August	29.3	31.2 (August 2018)	12.3 February	10.2 (February 2017)

Table 3.3.6 – Records of maximum monthly seawater temperature (°C) in the Iranian sector in 2022

Observation post	Date	Month	Seawater temperature, °C	Previous maximum, °C	Date of the previous maximum
Anzali	18	August	29.4	30.6	08.02.2018
Kiashahr	18	August	29.75	31.05	07.31.2000
Noshahr	7,14,15	August	29.1	31.7	08.10.2010 08.09.2000
Amirabad	18	August	30	31.5	08.03.2011

Таблица 3.3.7 – Records of minimum monthly seawater temperature (°C) in the Iranian sector in 2022

Observation post	Date	Month	Seawater temperature, °C	Previous maximum, °C	Date of the previous maximum
Anzali	24	March	10.5	7.7	03.12.2012
Kiashahr	25	March	10.3	8.2	03.05.1991
Noshahr	22,25	March	11.7	8.6	02.26.1988
Amirabad	19	March	11.8	7.9	02.26.1994

Kazakh sector

In 2022, the average annual water temperature, according to data from coastal marine stations located in the Kazakhstani sector of the sea, was +10.0…+14.6°C.

The temperature of surface waters is subject to noticeable seasonal fluctuations and has a clearly defined annual course. In the northeastern part of the sea, the average surface water temperature varied from 0.8-4.9°C in the cold season to 20.7-27.4°C in the summer months; on the eastern coast of the Middle Caspian, the average surface water temperature varied from 1.0-5.1°C in the cold season to 17.4...22.8°C in the summer months (Table 3.3.8).

Table 3.3.8 – Average values, anomalies from the standard normal (reference period of 1981-2010), maximum and minimum in the seawater temperature (°C) recorded in data on the Kazakhstan coasts of the Caspian Sea in 2022

Observation post	Year, period	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Peshnoy	Average in 2022	2.0	2.6	2.8	8.5	11.6	20.7	21.4	22.2	15.5	8.2	2.8	1.6	10.0
	Max.	3.7	7.4	11.8	18.8	24.8	27.1	30.8	29.8	26.8	16.7	5.9	3.0	30.8
	Min.	1.0	1.2	1.4	3.0	3.1	8.8	9.8	13.2	2.8	1.8	1.0	0.6	0.6
	Average in 1981-2010	0.8	0.8	1.9	9.2	16.9	22.4	24.7	23.0	17.1	9.7	3.6	1.4	11.0
	Anomalies	1.2	1.8	0.9	-0.7	-5.3	-1.7	-3.3	-0.8	-1.6	-1.5	-0.8	0.2	-1.0
Kulaly	Average in 2022	1.7	4.9	7.9	17.5	18.9	27.4	27	27.3	21.6	14	6.7	0.8	14.6
	Max.	3.2	10.3	12.4	22.6	23.7	29.9	29.9	30.8	27.7	21.4	9.8	2.9	30.8
	Min.	0.6	0.8	4.1	10.3	12.8	22.6	21.3	22.4	15.6	6.4	1.1	0.1	0.1
	Average in 1981-2010													
	Anomalies													
Fort-Shevchenko	Average in 2022	2.0	2.6	4.1	11.5	16.4	22.7	22.8	22.3	19.4	14.2	7.7	1.0	12.2
	Max.	6.1	5.4	7	17.2	20.3	25.2	26.6	28.5	24.2	19.2	11.5	4.1	28.5
	Min.	0.4	0.8	2.3	3.8	12.4	18.5	18.9	16.4	16.9	9.6	3.1	-1.7	-1.7
	Average in 1981-2010													
	Anomalies													
Aktau	Average in 2022	3.2	5.1	6.0	12.3	15.6	17.7	17.4	19.8	20	15.1	9.3	2.4	12.0
	Max.	5.2	8.1	8.8	17.7	19.8	21.8	23	24.8	25.7	19	13.4	5.9	25.7
	Min.	1.8	3.0	4.0	6.0	12.3	14.4	13.2	15.0	16.7	11.3	6.5	-0.9	-0.9
	Average in 1981-2010	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	0.5	2.8	0.5	1.3	0.3	0.0	-0.5	0.8	2.0	0.8	0.5	-2.2	0.6

Table 3.3.9 shows records of the maximum average monthly water temperature (°C) recorded at observation posts in the Kazakhstan sector in 2022.

Tables 3.3.10 and 3.3.11 show maximum and minimum monthly water temperature (°C) recorded at observation posts in the Kazakhstan sector in 2022.

In Peshnoy, the value of the maximum monthly water temperature (+ 30.8°C) was exceeded in July, the previous maximum was recorded in June 2021 (+ 29.9°C). In Kulaly, the value of the maximum monthly water temperature (+ 30.8°C) was exceeded in August, the previous maximum was recorded in July 2021 (+ 30.2°C).

Table 3.3.9 – Absolute maximum/minimum of the average monthly seawater temperature (°C) recorded in the Kazakh sector in 2022

Observation post	Month	Absolute maximum of 2022	Previous maximum and a year of its occurrence	Absolute minimum of 2022	Previous minimum and a year of its occurrence
Peshnoy	July December	30.8	35.5 (July 2000)	0.6	-0.9 (December 1988)
Kulaly	August December	30.8	33.7 (August 1977)	0.1	-1.8 (February 2021)
Fort-Shevchenko	August December	28.5	32.6 (July 2015)	-1,7	-2.9 (February 1997)
Aktau	September December	25.7	30.8 (August 1977)	-0.9	-1.7 (February 1998)

Table 3.3.10 – Records of maximum monthly seawater temperature (°C) in the Kazakh sector in 2022

Observation post	Date	Month	Seawater temperature, °C	Previous maximum, °C	Date of the previous maximum
Peshnoy	17	July	30.8	29.9	17.06.2021
Kulaly	17	August	30.8	30.2	22.07.2021
Fort-Shevchenko	05	August	28.5	29.8	03.08.2021
Aktau	04	September	25.7	27.3	21.08.2021

Table 3.3.11 – Records of minimum monthly seawater temperature (°C) in the Kazakh sector in 2022

Observation post	Date	Month	Seawater temperature, °C	Previous maximum, °C	Date of the previous maximum
Peshnoy	08	December	0.6	0.2	24.02.2021
Kulaly	08	December	0.1	-1.8	24.02.2021
Fort-Shevchenko	07	December	-1.7	-0.6	26.02.2021
Aktau	13	December	-0.9	-2.0	23.12.2021

Russian sector

In 2022, the average annual water temperature was + 14.3...+ 14.8°C, which is 0.5-1.5°C higher than the normal (reference period of 1991-2020).

A characteristic feature of the water temperature regime in Makhachkala is the observed large positive deviations from the normal of both average annual and average monthly water temperatures. The average annual water temperature was + 16.7°C, which is 3.6°C higher than the normal. The average monthly water temperatures were also higher than the normal: by 3.1-4.8°C in the winter months (January, February); by 2.8-4.4°C in the spring; by 2.1-4.8° C in the summer and by 2.2-3.9° C in the autumn.

Surface water temperatures are subject to significant seasonal fluctuations. On the western coast of the Middle Caspian, the average surface water temperature varied from

+4.2...+8.6°C in the cold season to +22.5...+27.7°C in the summer. In the northwestern part of the sea, the average surface water temperature varied from +1.5...+5.2°C in the cold season to +24.3...+26.7°C in the summer. The minimum values of the average monthly temperature were observed in January-February, the maximum in July- August (Table 3.3.12).

Table 3.3.12 – Average values, anomalies from the standard normal, maximum and minimum in the seawater temperature (°C) recorded in data on Russian coast of the Caspian Sea in 2022

Observation post	Year, period	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Derbent	Average in 2022	5.6	4.2	4.6	12.2	16.4	23.7	26.1	25.9	22.5	17.3	11.8	6.7	14.8
	Max.	6.8	5.8	6.2	17.4	20.5	26.5	28.8	28.8	28.2	21.8	13.8	9.7	28.8
	Min.	4.7	3.5	3.6	4.1	14.6	17.0	23.8	20.5	19.2	13.5	10.0	4.4	3.5
	Average in 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	1.4	0.9	-0.7	2.5	1.0	2.6	1.6	0.3	0.6	0.1	0.3	0.0	0.9
Izberg	Average in 2022	4.9	5.3	5.4	11.0	16.2	22.5	25.3	25.0	22.0	17.2	11.6	5.8	14.4
	Max.	8.0	9.2	8.6	18.0	22.3	27.6	29.8	28.3	28.4	23.8	14.5	9.7	29.8
	Min.	2.0	3.0	2.3	5.8	11.5	17.5	21.2	20.0	16.2	10.2	7.0	2.2	2.0
	Average in 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	1.1	2.2	0.2	1.2	0.5	1.1	0.9	-0.2	0.4	0.5	0.7	-0.3	0.7
Makhachkala	Average in 2022	6.9	7.4	8.2	13.7	18.0	25.3	27.7	26.9	23.7	19.8	14.4	8.6	16.7
	Max.	9.8	10.4	10.8	20.4	22.2	29.2	29.7	29.7	29.7	23.8	17.2	12.1	29.7
	Min.	5.2	5.6	5.4	9.5	13.8	22.6	24.9	20.8	20.0	15.3	11.7	6.0	5.2
	Average in 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	3.7	4.8	3.3	4.4	2.8	4.8	4.4	2.1	2.2	3.3	3.9	3.1	3.6
Tyuleniy Isl.	Average in 2022	2.7	5.2	4.5	14.1	18.2	24.3	26.0	25.8	22.3	15.8	12.7	5.4	14.8
	Max.	5.9	10.5	10.3	21.8	26.4	28.5	31.0	30.4	29.6	23.6	17.2	9.0	31.0
	Min.	0.1	0.9	1.0	8.1	10.2	19.7	21.2	21.3	14.6	11.2	5.5	3.0	0.1
	Average in 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	1.7	4.0	-0.3	2.2	-0.7	0.6	-0.2	0.2	1.5	1.2	4.9	2.7	1.5
Lagan	Average in 2022	1.5	4.5	5.0	15.5	18.9	25.9	26.5	26.7	22.4	15.7	7.5	1.6	14.3
	Max.	3.0	7.8	10.8	22.4	25.6	28.0	29.8	30.2	28.6	22.6	10.6	3.0	30.2
	Min.	0.2	1.2	2.4	9.6	14.0	24.6	23.0	23.8	19.2	10.6	4.2	0.0	0.0
	Average in 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	2.7	-0.6	2.6	-1.4	0.7	-0.7	0.2	1.0	1.2	0.6	-0.6	0.5

In 2022, three average annual water temperature records were set at the stations: Tyuleniy Island and in Derbent (+14.8°C), and Makhachkala (+16.7°C). In Izberg, 2022 took the second place in the ranked series of observations (from the warmest to the coldest), the average annual water temperature was +14.4°C.

Table 3.3.13 shows the records of the maximum average monthly water temperature (°C) recorded at observation posts in the Russian sector of the Caspian Sea in 2022.

Table 3.3.13 – Absolute maximum/minimum of the average monthly seawater temperature (°C) recorded in the Russian sector in 2022

Observation post	Month	Absolute maximum of 2022	Previous maximum and a year of its occurrence	Absolute minimum of 2022	Previous minimum and a year of its occurrence	Observation post
Derbent	June	23.7	23.6 (1998)		-	
Makhachkala	January	6.9	5.6 (2020)		-	
	February	7.4	5.5 (2002)		-	
	March	8.2	8.0 (2002)		-	
	April	13.7	12.2 (1962, 2021)		-	
	May	18.0	17.8 (2019)		-	
	June	25.3	24.2 (2019)		-	
	July	27.7	27.4 (2018)		-	
	September	23.7	23.4 (1986)		-	
	October	19.8	18.8 (2012)		-	
	November	14.4	13.1 (2010, 2012)		-	
Tyuleniy Isl.	February	5.2	4.9 (1983)		-	
	November	12.7	10.5 (2008)		-	
Lagan	February	4.5	3.5 (1983)		-	

In Derbent, the maximum of the average monthly water temperature was updated in June (+23.7°C), the previous record was observed in June 1998 (+23.6°C).

In Makhachkala, ten records of the average monthly water temperature were seen in 2022, which was resulted from the abnormally warm winter of 2021/2022 (Rank 5) and extremely low water levels throughout the year. The minimum monthly sea levels reached the dangerous limits, which contributed to intensive water warming in the summer and the autumn.

The average monthly temperature records have been updated on Tyuleniy Island in February and November 2022 and in Lagan in February.

Table 3.3.14 shows the records of the maximum monthly water temperature (°C) recorded at observation points in the Russian sector of the Caspian Sea in 2022. In Izberg, the maximum water temperature was recorded in February (+9.2°C), the previous maximum was recorded in February 2020 (+8.6 °C). *Five records of the maximum monthly water temperature were seen in Makhachkala in 2022.*

At Tyuleniy Island station, the maximum water temperature in February 2022 was referred to as the highest in the last 62 years (+10.5 °C), the previous maximum was recorded in February 1966 and 2004 (+9.4 °C).

Records of the minimum monthly water temperature in 2022 were ***not observed***. However, it should be noted an abnormal rise in the minimum monthly water temperature according at Makhachkala station in January, February, April, June and July. In the ranked series of observations (from the warmest to the coldest), the values of the minimum water temperatures in these months occupy the first place.

Table 3.3.14 – Records of maximum monthly seawater temperature (°C) in the Russian sector in 2022

Observation post	Date	Month	Seawater temperature, °C	Previous maximum, °C	Date of the previous maximum
Izberg	26	February	9.2	8.6	7 February 2020
Makhachkala	9	January	9.8	8.4	January 1981*
	28	February	10.4	7.2	21 February 2000
	30	April	20.4	17.1	30 April 2021
	18	September	29.7	28.8	4 September2003
	1	October	23.8	23.1	1 October 2002
Tyuleniy Isl.	24	February	10.5	9.4	February1966 29 February 2004
Lagan		February	7.8	6.0	February 2016
		September	28.6	28.4	September 2010

*State Water Cadastre. Annual data on the regime and quality of the waters of the seas and estuaries, 1981. Volume 2, Part I The Caspian Sea. Baku, 1983 (Table 1.2.1 shows only the average decade and monthly values).

Higher air temperatures in January and February 2022, which exceeded the normal by 2.0-3.5°C resulted in an unusual increase in water temperature. The minimum monthly water temperature in January was +5.2°C, in February +5.6°C (rank 1), which is 4.1 and 4.3°C higher than the normal (the average minimum for the period 1991-2020). The minimum monthly water temperatures in June and July were +22.6 and +24.9°C (Rank 1), they were above the normal by 8.0-8.5°C, which is a result of abnormally low water levels and intense warming in the summer.

Summarizing, the increase in the minimum monthly water temperature in relation to the normal was by 3.4-4.3°C in the winter months; 2.7-3.6°C in the spring; 8.0-8.5°C in the summer months (June, July) and 2.4-4.7°C in the autumn.

Table 3.3.15 presents estimates of the linear trend of average annual and seasonal water temperatures at observation stations in the Russian sector of the Caspian Sea for the period 1976-2022.

According to the observation data, the average annual and seasonal temperatures were rising at all stations in 2022. Average annual temperatures rose by 0.26-0.41° C every 10 years, the increase was statistically significant. The rate of increase in seasonal temperatures ranged from 0.15 to 0.57°C per 10 years. The temperature rise was statistically significant at all stations, with the exception of autumn temperatures at Izberg station.

Table 3.3.15 – Estimates of the linear trend of average annual and seasonal air temperatures in the Russian sector for the period 1961-2022: *a – the coefficient of the linear trend; D – the coefficient of determination. The trend values, which are significant at the level of 5%, are highlighted*

Observation post	Year		Winter		Spring		Summer		Autumn	
	a	D	a	D	a	D	a	D	a	D
Derbent	**0.28**	0.31	**0.17**	0.04	**0.34**	0.20	**0.33**	0.18	**0.25**	0.11
Izberg	**0.26**	0.31	**0.20**	0.07	**0.41**	0.29	**0.29**	0.23	0.15	0.05
Makhachkala	**0.41**	0.36	**0.33**	0.13	**0.42**	0.23	**0.47**	0.24	**0.39**	0.20
Tyuleniy Isl.	**0.34**	0.41	**0.28**	0.14	**0.29**	0.11	**0.30**	0.27	**0.45**	0.26
Lagan	**0.40**	0.55	**0.26**	0.28	**0.39**	0.27	**0.56**	0.49	**0.57**	0.39

Turkmen sector

The average water temperature for the period 1994-2020 is referred to as the standard normal in Table 3.3.16.

Table 3.3.16 – Average values, anomalies from the standard normal, maximum and minimum in the seawater temperature (°C) recorded in data on Turkmen coast of the Caspian Sea in 2022

Observation post	Year, period	Month												Year
		1	2	3	4	5	6	7	8	9	10	11	12	
Turkmenbashi (Krasnovodsk)	Average in 2022	5.0	7.7	9.8	15.1	20.1	24.0	26.1	26.4	23.0	18.4	12.6	5.5	16.1
	Max.	6.8	11.6	12.4	20.6	22.2	25.3	29.5	29.0	25.1	22.0	14.2	10.0	29.5
	Min.	3.4	5.8	7.0	13.8	18.0	21.5	23.0	23.0	21.0	13.8	10.8	3.1	3.1
	Average in 1994-2020	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	-0.1	2.1	0.0	0.0	0.0	0.4	-0.2	-0.2	0.1	0.5	0.6	-0.8	0.2
Garabogaz (Bekdash)	Average in 2022	5.7	6.3	7.2	12.6	15.3	18.0	20.1	22.9	20.7	15.9	12.6	3.2	13.4
	Max.	8.6	9.1	10.2	17.9	19.4	24.4	24.9	27.2	26.8	19.1	15.0	9.7	27.2
	Min.	2.8	3.9	4.4	6.8	12.8	15.4	14.4	19.0	15.8	13.0	9.9	1.3	1.3
	Average in 1994-2020	5.1	4.7	7.4	11.2	15.3	17.6	19.1	20.8	18.4	15.4	11.1	6.7	12.8
	Anomalies	0.6	1.6	-0.2	1.4	0.0	0.4	1.0	2.2	2.3	0.5	1.5	-3.5	0.6
Guvlymayak (Kuuli-Mayak)	Average in 2022	6.9	7.9	9.4	14.0	16.2	18.2	22.0	24.6	21.8	18.0	13.4	7.2	15.0
	Max.	9.3	12.6	12.6	19.5	22.4	22.0	27.8	28.2	29.2	23.2	17.2	11.2	29.2
	Min.	4.1	5.2	5.6	8.4	13.0	15.6	15.9	21.2	17.0	14.8	10.6	2.8	2.8
	Average in 1994-2020	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	0.1	1.5	0.3	1.1	0.3	0.2	0.4	0.2	0.3	0.3	0.4	-1.6	0.3
Duzlybogaz (Kara Bogaz Gol)	Average in 2022	5.6	6.2	7.9	14.0	16.5	19.3	22.9	23.3	22.2	17.0	11.0	5.2	14.3
	Max.	9.0	10.5	13.3	19.6	21.6	26.6	28.4	26.6	28.0	21.0	16.3	8.3	28.4
	Min.	1.9	2.7	4.3	8.4	12.5	15.6	18.4	20.2	18.6	13.3	7.4	3.2	1.9
	Average in 1994-2020	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	0.2	1.1	-0.5	1.4	-0.5	-0.2	1.8	0.3	1.9	1.0	-0.1	-1.4	0.4
Ogurdjaly (Ogurchinsky)	Average in 2022	6.5	8.7	10.2	16.1	19.6	24.8	27.9	28.8	24.6	18.9	13.1	5.4	17.1
	Max.	13.0	16.2	17.6	26.6	29.4	34.0	35.4	35.5	32.6	28.8	19.4	10.6	35.5
	Min.	3.0	4.0	3.9	8.0	14.6	19.2	20.0	23.6	19.0	12.2	6.0	1.0	1.0
	Average in 1994-2020	6.4	6.9	10.4	14.7	19.5	23.2	26.8	27.6	23.8	18.7	12.9	7.9	16.6
	Anomalies	0.1	1.8	-0.2	1.4	0.1	1.6	1.1	1.2	0.8	0.2	0.2	-2.5	0.4

Records of the maximum/minimum of the average monthly water temperature were not observed in 2022. Table 3.3.17 presents the records of the maximum monthly water temperature (°C) recorded at observation points in the Turkmen sector of the Caspian Sea in 2022.

In February, records of the maximum monthly water temperature were updated in Turkmenbashi and Guvlymayak, and they reached +11.6 and +12.6°C. The previous records were observed in February 2004 (+11.4 and +12.5°C, respectively for these two stations).

According to the data at Guvlymayak station, the record of the maximum water temperature in April (+ 19.5°C) was also updated, the previous maximum was noted in April 2005 (+ 19.3°C).

Table 3.3.17 – Records of maximum monthly seawater temperature (°C) in the Turkmen sector in 2022

Observation post	Date	Month	Seawater temperature, °C	Previous maximum, °C	Date of the previous maximum
Turkmenbashi (Krasnovodsk)	-	February	11.6	11.4	February 2004
Guvlymayak (Kuuli-Mayak)	-	February	12.6	12.5	February 2004
	-	April	19.5	19.3	April 2005

Records of minimum monthly water temperature were not updated in 2022.

4. ICE CONDITIONS

Kazakh sector

The winter of 2021-2022 in the Caspian Sea was mild in terms of the sum of negative air temperatures in the cold half-year and the extent of the ice boundary, with a stable ice cover in the northern shallow part of the Caspian Sea.

According to the data of the Peshnoy sea station, the first ice was observed near the northern coast of the Caspian Sea since 17 November 2021. The first ice belt was formed and spread evenly over the entire sea surface. In the Zhanbai, the first shore ice was formed on 28 November 2021.

On November 30, the ice cover in the Caspian Sea completely melted due to the increase in air temperature. Since December 12, fast ice started covering the Peshnoy water area, which was more than 200 meters wide.

According to the data of the Peshnoy station, the ice cover gradually increased along the northern coast of the Caspian Sea on December 21, it was quite evenly spread over the entire sea surface. Ice belt of 10 balls has formed, the area was completely ice-covered, the ice thickness reached 5 cm. The area near Zhanbai station was also covered with ice of 7 cm thick (Figures 4.1 and 4.2).

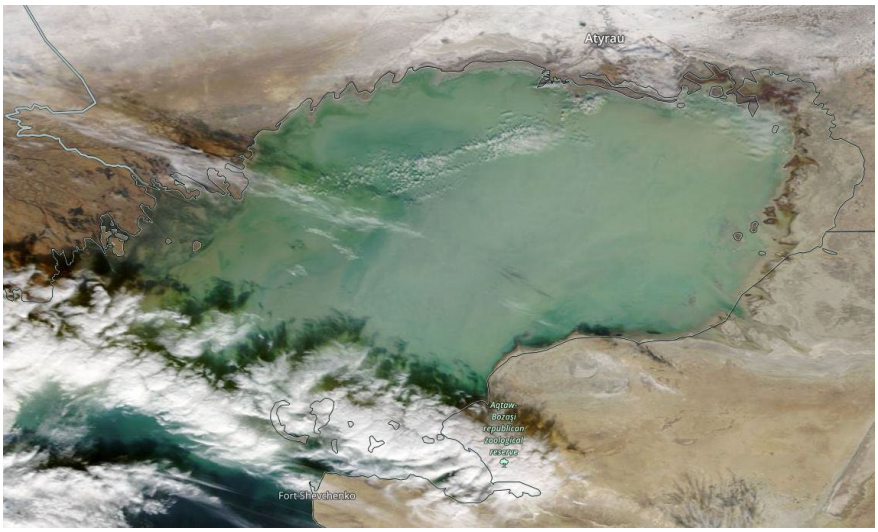

Figure 4.1 – The first ice shows near the northern coast of the Caspian Sea (NASA project image, November 26, 2021)

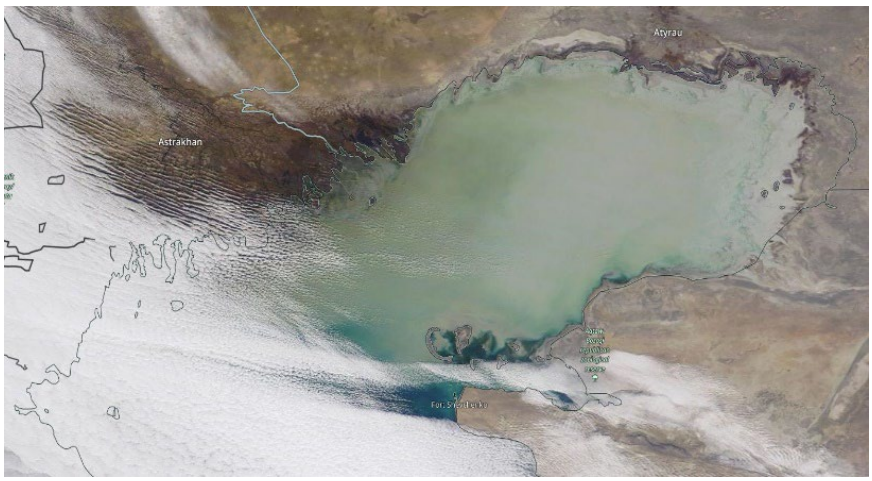

Figure 4.2 – The beginning of the ice belt formation near the coast of the Northern Caspian (NASA project image, December 13, 2021)

The ice belt along the entire northeastern coast of the sea was spread by the beginning of January 2022 (Figure 4.3).

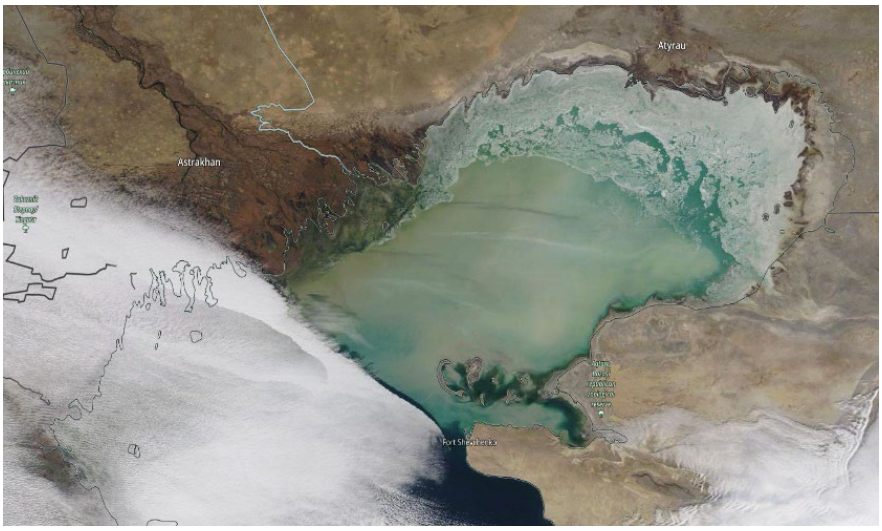

Figure 4.3 – Ice cover in the Northern Caspian (NASA project image, January 9, 2022)

The maximal ice thickness was recorded off the northeastern coast of the Northern Caspian in January 2022. It reached 14 cm in the area of the marine hydrometeorological station Peshnoy and 27 cm near Zhanbay station (Figure 4.4).

Ice meling in the Caspian Sea started from February 6, 2022 on (Figures 4.5 and 4.6).

On February 27, 2022, the ice belt completely melted in the area of the Peshnoy meteorological station.

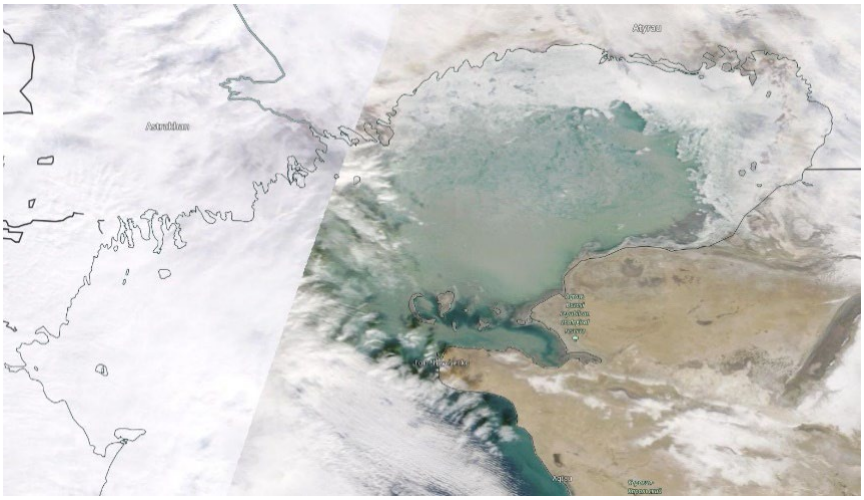

Figure 4.4 – Ice conditions in the Caspian Sea (NASA project image, January 24, 2022)

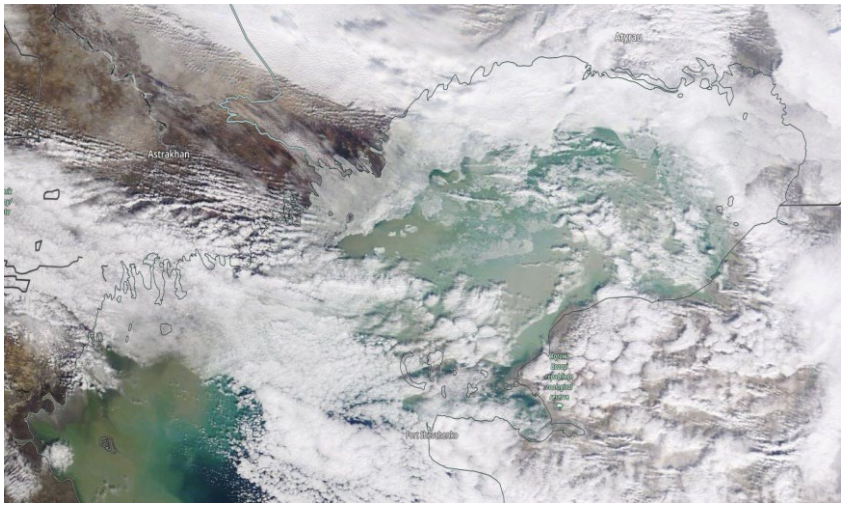

Figure 4.5 – The beginning of the spring melted ice cover of the Northern Caspian (NASA project image, February 6, 2022)

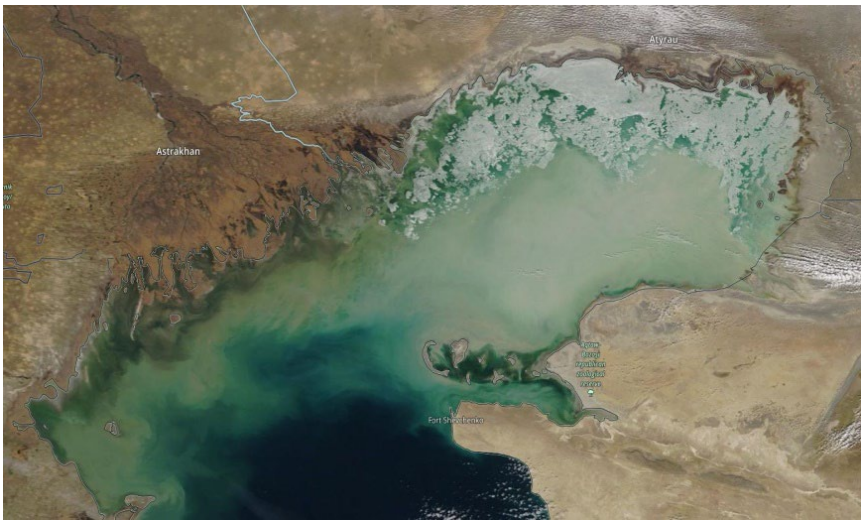

Figure 4.6 – Melting ice cover in the Northern Caspian (NASA project image, February 14, 2022)

The north-eastern coast of the Caspian Sea was completely free of ice on March 3, 2022 (Figure 4.7).

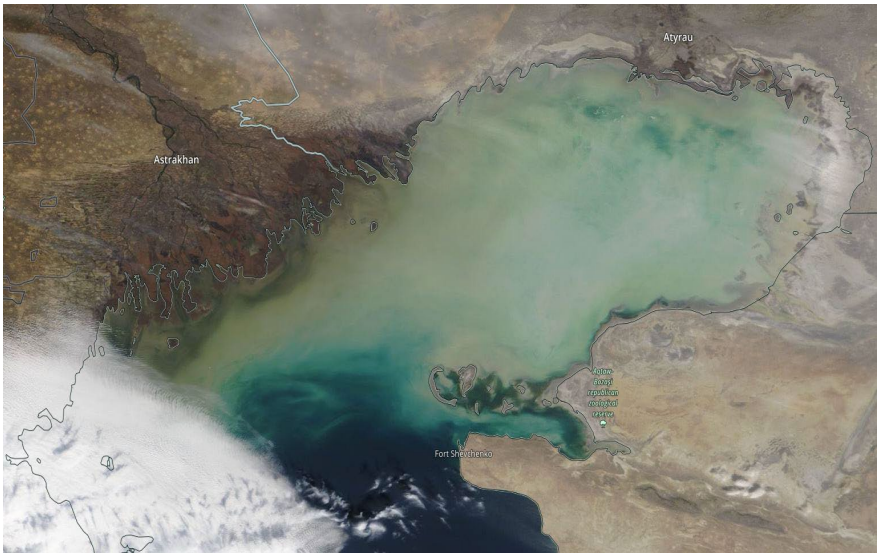

Figure 4.7 – Complete clearing of the Caspian Sea from ice (NASA project image, March 03, 2022)

Russian sector

In the Russian sector, the winter of 2021/2022 was also mild in terms of the sum of negative air temperatures with unstable ice cover in the western part of the Northern Caspian. The sum of the negative daily average values in Astrakhan reached -31.7°C, while it was only -20.6°C at the Tyuleniy Island station.

As the maps of the ice cover by the Hydrometeorological Center of Russia showed, there was no ice in the area of the Volga-Caspian Sea shipping channel and in the Volga Delta in the early third decade of December. Ice of initial types and dark nilas were observed to the east of the delta, near the northeastern coast of the sea. In the middle of the third decade of December, frosty weather was induced by a cold anticyclone from the European part of Russia. The air temperature dropped to -5.7°C. Due to stable frost, ice formation began in the north and northeast of the Caspian Sea. At the end of December, ice of initial types was observed in the shallow zone of the Volga estuary, the ice covered some areas of the northern part of the Kizlyar Bay. According to the Lagan station, the first ice occurred since December 23, 2021.

The warming in the first decade of January caused a noticeable decrease in the area of the ice cover. The ice started again its spread due to decreasing air temperature to -2.4 ...-6.4°C in the second and third decades of January 2022. Ice belt appeared in the Volga delta, followed by nilas and gray drifting ice in some places. Ice of initial types and dark nilas were also observed in the Kizlyar Bay. The area near Lagan was completely frozen on January 21. In the third decade

of January, the ice edge in the northeast of the sea spread along the northern coast of the Tyuleniy Islands (Figure 4.8).

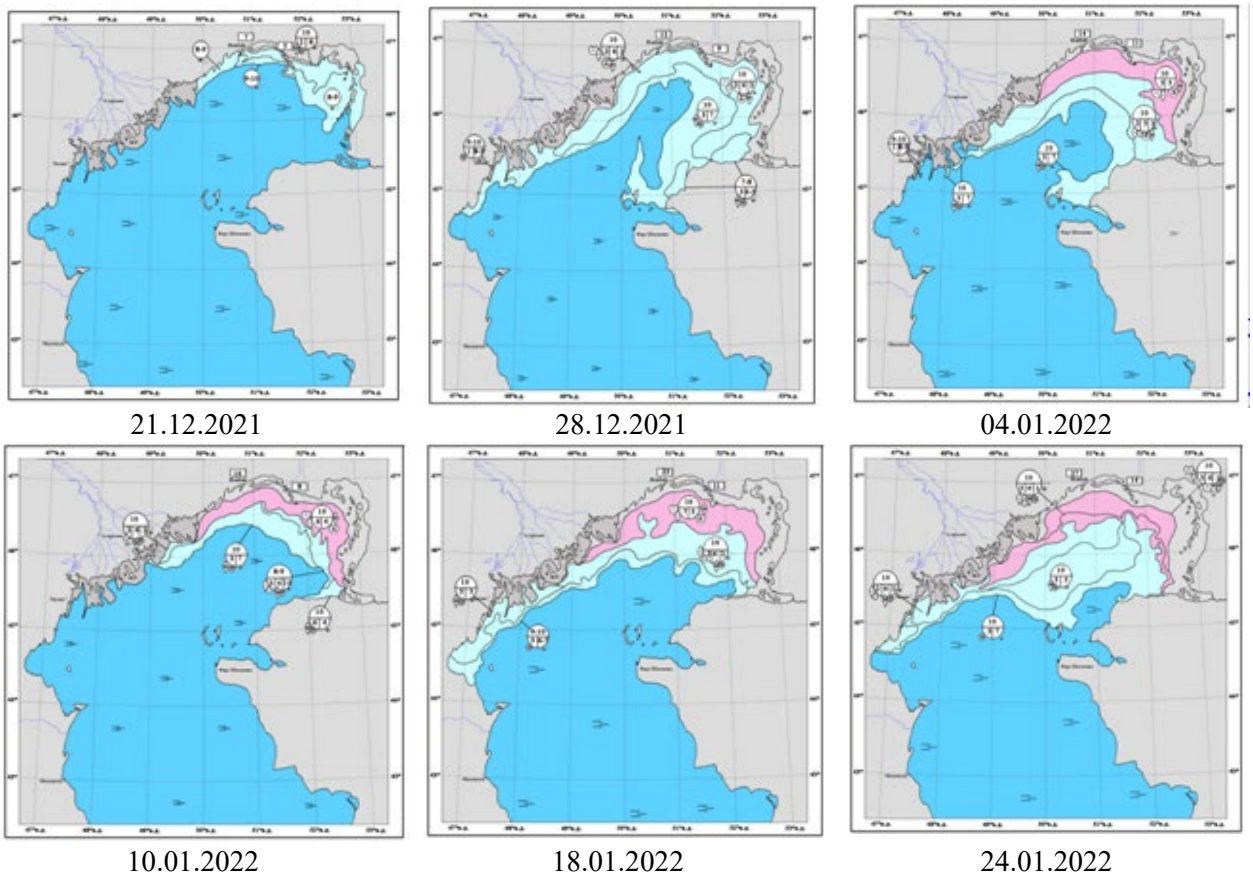

Figure 4.8 – Maps of ice cover for the period from December 2021 to January 2022 (data of the Hydrometcenter of Russia)

The ice cover of the Caspian Sea in early February reached its maximum spread for the winter season of 2021/2022. In the late first decade and the early second one of February, the transfer of warm air masses from the Atlantic and the Mediterranean brought abnormally warm weather to the Caspian that resulted in the ice melting. The schematic maps of the ice cover by Hydrometcenter of Russia showed, that ice belt was preserved in the Lagan area, with separate zones of gray and light drifting ice after the belt farther to the sea. Small narrow zones of gray drifting ice and nilas were observed off the coast to the east of the Iskusstvennyi Island. Ice belt and an extensive zone of gray and gray-white drifting ice were seen in the Volga Delta. In mid-February, there was a noticeable reduction in the ice cover. In the area of the Volga-Caspian shipping channel in the south, ice belt was seen in some places, ice fragments drifted out of the channel to the south. Clean water prevails in the sea area near the Volga Delta. In Lagan, the water area completely was clear from ice on February 16. In the third decade of February, ice was observed only in the northeast of the Caspian Sea (Figure 4.9).

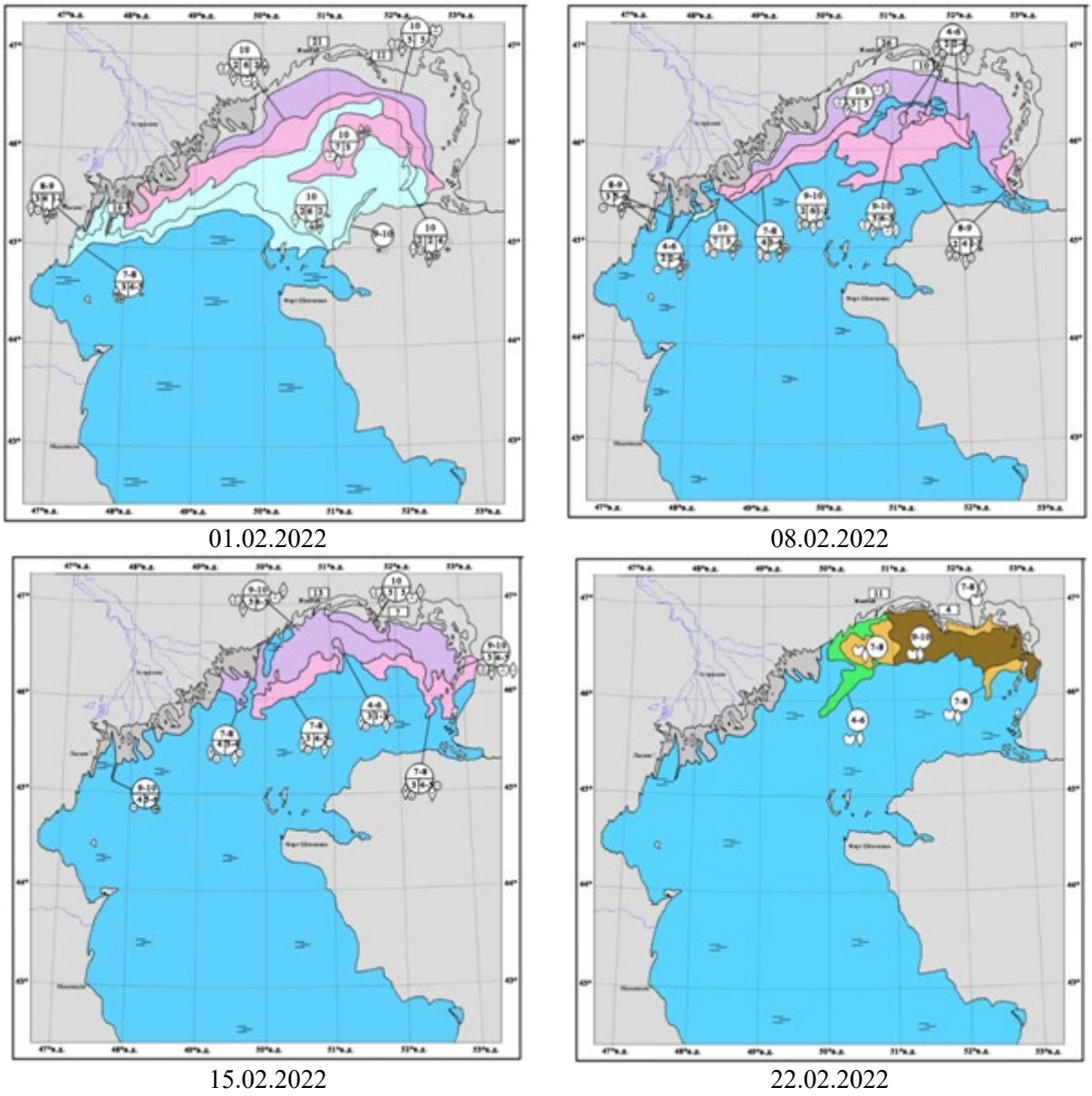

Figure 4.9 – Maps of ice cover for February 2022 (data of the Hydrometcenter of Russia)

In Lagan, the number of days with ice was only 20 days, which is significantly less than the average long-term (the normal is 68 days, the reference period is 1996-2021). In cold winters, the maximum duration of the ice period is 143 days (winter of 1997/1998).

No ice cover was observed on Tyuleniy Island for the whole winter period due to the extremely warm weather.

CONCLUSION

Iranian sector

The year 2022 was warm in the Iranian sector, with seven records of maximum monthly air temperature. The anomalies of the average annual air temperature amounted to +1.8°C.

The rate of increase in average seasonal temperatures varied from 0.19 to 0.41°C per 10 years. The fastest growth in all seasons was observed at Babolsar station, the rate of summer warming was 0.41°C/10 years. The average annual temperatures were rising by 0.24-0.35°C every 10 years.

In the long-term context, there was a tendency to decrease in the annual water runoff of the Iranian rivers as calculated for the following periods: the Chalus River (1949-2021), the Kharaz River (1951-2021), the Polrud River (1956-2021) and the Sefidrud River (1958-2021).

Kazakh sector

The year 2022 was among the four warmest years in the history of meteorological observations of air temperature, the anomalies of mean annual air temperature amounted to 0.8-2.0°C.

The rate of increase in mean seasonal temperatures ranged from 0.25 to 0.92°C/10 years. The most rapid increase in air temperature in winter, spring and autumn was observed in the northernmost part of the Kazakhstan coast – in Atyrau (0.61°C/10 years – in winter; 0.59°C/10 years – in spring; 0.53°C/10 years – in autumn). In the summer season, the highest rate of warming is observed in the southernmost part of the Kazakhstan coast – at the Aktau station (0.92°C/10 years).

The year 2022 was heterogeneous in terms of moisture regime. Annual precipitation amounted to 137% of the normal (rank 7) in Aktau and 123% of the normal in Fort-Shevchenko. A deficit of precipitation (77%) was observed at the Kulaly Island.

Among the seasons, there was an anomalously «dry» winter at the Kazakhstan coast of the Middle Caspian (24-49% of the multiyear average) and anomalously «dry» summer practically at all stations of the Kazakhstan coast of the Caspian Sea (9.5-78.5% of the multiyear average). At the same time, excessive precipitation in the summer season was observed in the southernmost part of the Kazakhstan coast of the Caspian Sea – in Aktau (208.7% of the normal), and only due to excessively wet July. The rest of the year was rather dry in Aktau: June was completely dry, and there was a strong deficit of precipitation (42 % of the normal) in August. Excessive precipitation was observed in winter on the Kazakhstan coast of the Northern

Caspian (141.8-188.4% of the normal) and in spring on the entire Kazakhstan coast of the Caspian Sea (102-178.5% of the normal).

In the period of 1936-2022, the annual water runoff of the Ural (Zhaiyk) River as measured at Makhambet post tends to decrease. In 2022, the flow of the river at the Makhambet post reached 4.71 km^3, which was 60% less than the long-term average (1936-2022). However, the volume of water increased by almost 1 km^3 in 2022 compared to the previous year.

According to the data of coastal and island marine stations and posts in 2022, the level of the Caspian Sea in its northeastern shallow part fluctuated within the range from -27.61 m to -29.44 m with an annual average of -28.46 m.

In the deep-water Kazakhstan part of the Caspian Sea, the average sea level corresponded to the mark of -28.71 m, with a maximum value of -28.05 m and a minimum value of -29.27 m.

Near the north-eastern coast of the Northern Caspian Sea stations and posts of Kazhydromet recorded 27 cases with surge-induced level falls and 33 cases with surge-induced floods.

The winter of 2021-2022 in the Caspian Sea was mild in terms of the sum of negative air temperatures in the cold half-year and the extent of the ice boundary, with a stable ice cover in the north-eastern shallow part of the Caspian Sea.

Russian sector

In the Russian sector, 2022 was among the three warmest years in the history of meteorological observations in terms of air temperature, with average annual air temperature anomalies varied between 0.8 and 1.1°C.

The rate of increase in average seasonal temperatures varied from 0.31 to 0.69°C/10 years. The fastest growth in all seasons was observed in the southernmost part of the Russian coast – in Derbent (0.47°C/10 years – in winter; 0.51°C/10 years – in spring; 0.69°C/10 years – in summer; 0.57°C/10 years – in autumn).

Moisture regime was heterogeneous in 2022. The average annual precipitation reached 113% of the normal in Izberg and 102% in Derbent. Precipitation deficit was observed on Tyuleniy Island and in Makhachkala (81 and 82%, respectively).

An abnormally "dry" winter stands out from the other seasons. Precipitation sum averaged by the weather stations in the Russian sector of the Caspian Sea amounted to 54% of the normal. Excessive precipitation was observed in spring (173% of the normal). The summer was excessively "dry" at Tyuleniy Island and Makhachkala stations (16-32% of the normal).

In 2022, three records of the average annual water temperature were set: it reached +14.8°C at the stations of Tyuleniy Island and Derbent, and +16.7 °C in Makhachkala.

The water temperature in Makhachkala differed from the other stations by the largest positive anomalies of the average annual and monthly values. *In 2022, ten records of the average monthly water temperature and five records of the maximum monthly water temperature were set there due to the abnormally warm winter of 2021/2022 (Rank 5) and excessively low water levels throughout the whole 2022, which contributed to intensive warming of the water in the summer and autumn.*

In 2022, according to Makhachkala, an excessive growth in the minimum monthly water temperature was observed in January, February, April, June and July (rank 1 in the ranked series of observations from the warmest to the coldest). The increase in the minimum monthly water temperature exceeded the normal by 3.4-4.3°C in the winter months; 2.7-3.6°C in the spring; 8.0-8.5°C in the summer months (June, July); 2.9-4.7°C in the autumn.

The water level in the Russian sector of the Caspian Sea fell by 19...25 cm in 2022 compared to the previous year, reaching -28.32 and -28.56 m abs in the western part of the Northern Caspian and -28.48 m abs on the western coast of the Middle Caspian. *This was the lowest level since 1980.*

In 2022, critically low water levels were recorded in Makhachkala, the minimum monthly water levels exceeded the dangerous limits by 20-31 cm during the year, in June and August the minimum monthly levels approached these limits.

The main reason for the level fall was the low Volga inflow, which was observed for the second year in a row. In 2021 and 2022, the Volga runoff amounted to 208 km^3 and 212 km^3, which is 38.68 km^3 and 35.29 km^3 less than the normal, respectively.

Marine stations and posts of Roshydromet recorded 36 cases of surge-induced flood and 33 cases of surge-induced level fall.

The winter of 2021/2022 was mild in terms of the sum of negative air temperatures with an unstable ice cover in the western part of the Caspian Sea.

Turkmen sector

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

To assess the changes in air temperature and precipitation, observation data in the period of 1989-2022 were analysed, including the reference period of 1991-2020.

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

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

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

According to the observation data over the past 10-20 years, the maximum water temperature has increased by 1-2℃, in some years by 3-4℃, along the entire Turkmen coast of the Caspian Sea.

Observations of salinity along the Turkmen coast are made at three stations: Turkmenbashi, Guvlymayak, Duzlybogaz. According to long-term observations, salinity varies in the range from 12 to 14 ‰, but it increased to 15.72 ‰ in Turkmenbashi Bay in July, August and September of 2020. At the stations Guvlymayak and Duzlybogaz, the salinity is always slightly higher in the summer months, than in the winter months.

Salinity at the Duzlybogaz (Kara Bogaz Gol) station significantly differs from that at the other stations as it is located directly in the Kara Bogaz Gol Bay. According to long-term observations, salinity reached 37-39 ‰ at this station.

Regular measurements of water velocities are made in the Duzlybogaz Strait. Seawater flows into the Bay through the strait with the average velocity of about 0.60-0.70 m/s and its maximum reaches 1.00 m/s. The annual seawater flow decreases to 360-400 m^3/s in winter and rises to 480-540 m^3/s in June and July.

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