ORIGINAL ARTICLE

The climatic factors, determining the biological diversity of the middle Caspian Sea and coastal ecosystems, the atmospheric-synoptic processes, commotions and currents

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Abstract

Background and Objective: The main climatic factors and atmospheric-synoptic processes, determining the biological diversity of the middle Caspian Sea and coastal ecosystems, are outlined. The characteristic features of the wind pattern and the currents are described. The characteristics of commotions, allowing to determine the extreme values of wave elements, are provided. That is necessary for the development of oil and gas deposits on the shelf. **Method:** The features of climate formation, atmospheric-synoptic processes, commotions and currents of the Caspian Sea, are given according to the information, described in numerous scientific publications and reference books, and also according to the Dagestan Center for Hydrometeorology and Environmental Monitoring. **Results:** The peculiarities of climate formation, atmospheric-synoptic processes, commotions and currents of the Caspian Sea, affecting the biological diversity of the middle Caspian and coastal ecosystems, are determined by the geographic position of the sea, the conditions of atmospheric circulation, the nature of the underlying surface, and the orography of the coasts. **Conclusion:** Assessment of the main climatic factors of atmospheric-synoptic processes, peculiarities of the wind regime, characteristics of currents, commotions, extreme values of wave elements, determining the biological diversity of the middle Caspian and coastal ecosystems, is necessary for the development of oil and gas deposits on the shelf.

Key words: Atmospheric-synoptic processes, commotions, currents

INTRODUCTION

The features of climate formation, atmospheric-synoptic processes, commotions and currents of the Caspian Sea, are given according to the information, described in numerous scientific publications and reference books,[1-11] and also according to the Dagestan Center for Hydrometeorology and Environmental Monitoring.

The formation of climate over the Caspian Sea and its coast is determined by the geographical position of the sea, the conditions of atmospheric circulation, the nature of the underlying surface, and the orography of the coasts. [1-11] The Caspian Sea is located in relatively low latitudes that resulted in a large influx of solar energy to it. The annual amount of radiation balance over the Caspian Sea is about 3700 MJ/m^2 per year. The formation of the Caspian Sea climate on the west coast is influenced by mountains. The climatic conditions of the Caspian Sea region are determined by the influence of cold Arctic air masses, wet marine masses, emerging over the Atlantic, dry continental - from Kazakhstan, warm tropical - coming from the Mediterranean Sea and Iran.

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METHODS

During the cold season of the year (December-February), when the intensity of atmospheric circulation over the middle Caspian increases, the average wind speed reaches 4-6 m/s, in open areas of the sea it is 8 m/s. During the warm season, the average wind speed is 2-5 m/s. On the Northwestern Coast of the middle Caspian, two maxima (the main one in the middle of spring and the second one in the late autumn), and two minima (in June-July and February-March) are clearly distinguished in the annual course of the average wind speed. Such a character of the annual course of average wind speed is determined by the change in the activity of atmospheric processes from winter to summer. Since the climate polar front is located in summer in the northern latitudes of the European continent, over the southwestern regions of the European part of Russia, the Caucasus and the Caspian Sea, the cases of allocation of low-gradient baric fields are more frequent during this period of the year. Therefore, in this region and the open sea, the summer minimum of average wind speeds is clearly discernible.

In the transitional seasons of the year, the climate polar front is located in the close proximity to the Caspian Sea that promotes the activation of synoptic processes. There is often observed the passage of cyclones or deep troughs in the southern latitudes of the European part of Russia; accordingly, the average wind speeds in these seasons, in the northwestern region, are the greatest. In winter, it is the secondary maximum of the average wind speed in the region of the Dagestan coast, when the wind regime is mainly formed under the influence of a spur of the Siberian maximum, oriented through Kazakhstan to the Caspian Sea.

The intensity of winds in different parts of the Caspian Sea is not the same. The regions of Absheron, Makhachkala, and Mangyshlak are the stormiest. "Baku Nord" is the storm wind at Absheron, whose speed exceeds 30 m/s annually, and when storming it reaches 40 m/s, it blows continuously up to 10 h. Its hurricane nature is largely due to the orographic effect - the influence of the mountainous terrain of the coast, with a complex shoreline. Monsoons, the most conspicuous in the southern part and breezes are developed in the Caspian Sea, due to the uneven heating and cooling of the sea and the surrounding land. In the warm-season, the sea is cooler than the land during 4-5 months, and the summer monsoon blows from the sea. The rest of the time, the sea is warmer than land, and the winter monsoon blows from the land to the sea. Breezes appear in summer due to the uneven heating and cooling of the sea and land during the day.

Near the western shores of the Middle Caspian, where the mountains are near the shores, there are foehns - dry and warm (often strong) winds, blowing from the mountains. There can be observed winds with a speed of more than 25 m/s (the frequency is 0.3%) during the cold period. The frequency of winds more than 15 m/s is 6-7% on average, and winds more than 20 m/s - is 0.8%. Although the frequency of storm winds is noticeably weaker in summer, very strong winds can also be observed.

The number of days per year with a stormy wind (V >15 m/s) is extremely uneven across the Middle Caspian Sea. The number of days with wind speed more than 15 m/s on the coast, increases from the south to the north, while, at the same time, in the central part of the water area of the Middle Caspian, it increases from the north to the south. The frequency of winds <6 m/s in autumn and winter is 41% and 40%, in spring and summer – is 54% and 56%, correspondingly. The maximum wind speed in the gusts, once for 50 years in Derbent, can reach 58 m/s.

Active cyclogenesis in winter over the Atlantic, and the egress of cyclones to the Caspian Sea contribute to the increase of the winds frequency of the northwestern direction on the territory of Middle Caspian, at this time of the year: 35-50% at the coast, 25-35% at sea. In winter the spur of the Asian anticyclone extends far into the sea, and due to this fact, east and southeast winds form a significant part of the central water area of the Middle Caspian (13-16% - east, 27-32% - southeast).

In spring, the predominant winds over the middle Caspian are the southeast and east (20-50% over the land and 20-35% over the central sea regions).

The regime of wind in the warm season is due to the influence of the Azores maximum: From the extreme northern latitudes of the continent, the air masses are transferred to the central regions. In these conditions, northwest winds dominate almost over the whole water area of the sea (30-40% over the central water area of the middle Caspian and 15-25% near the coasts).

The autumn distribution of winds is similar to the winter one. The annual distribution of the directions frequency has an extreme predominance of the northwest and southeast winds [Figure 1].

RESULTS

Schematically, the currents in the Caspian Sea have cyclonic circulation and consist of several large and small circulations [Figure 2].[1,12,13]

Wind plays the main role in the formation of the Caspian Sea currents. In addition, such factors as the spatial heterogeneity of the sea water density, Coriolis force, the depth of the sea, underwater terrain, and the configuration of the coasts are also of great importance. In some areas, there is a noticeable impact of the surging and river discharge.

Some of these factors are the sources of certain currents types' formation, namely, the resultant of atmospheric circulation, during a long period of time, forms wind drift currents, and the impact of a particular wind type forms wind currents.

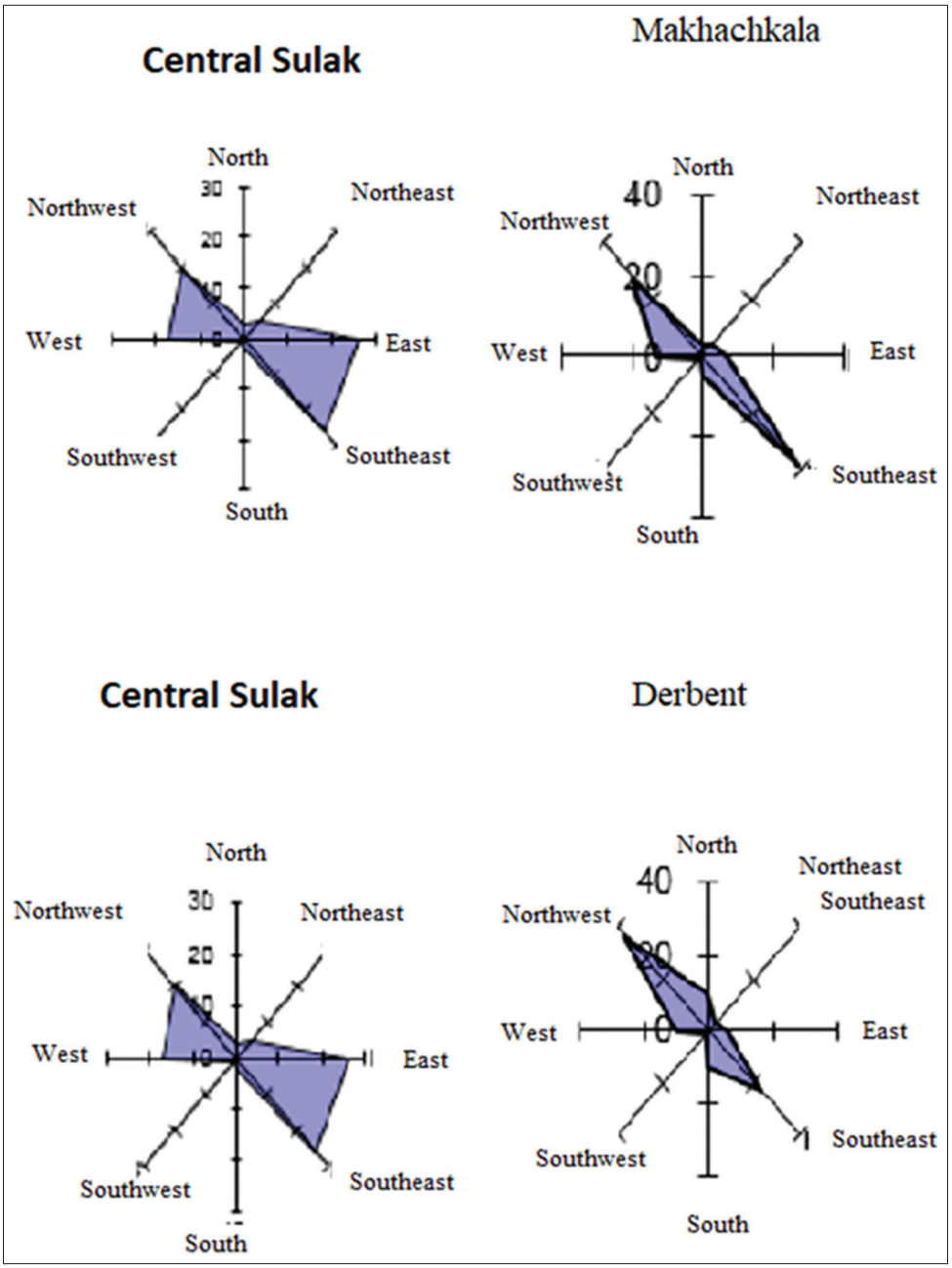

Figure 1: Annual wind roses on the coastal marine hydrometeostations. Главный Сулак - Central Sulak, Махачкала – Makhachkala, Дербент – Derbent, С – North, СВ - Northeast, В – East, ЮВ - Southeast, Ю – South, ЮЗ - Southwest, З – West, СЗ - Northwest

The nonuniformity of the field density resulted in density currents. Banked up water level and its falling are connected with surgins, which form gradient currents. The river flow leads to the formation of discharge currents.

The collective effect of all factors, including those, that do not generate any currents themselves, but which affect the speed and the direction of water movement, resulted in a complex real picture of the currents.

The general water circulation – the result of average annual hydrometeorological conditions over the sea – can be schematically shown in the following form: The winds of the northern directions, which prevail over the greater part of the sea during the year, from wind drift current from the north Caspian to the south along the western seaside. The current is divided into two parts, under the influence of configuration of the Absheron Peninsula coastal part. The more powerful of them, rounding the peninsula, moves to the south. Then, following along the coast of the south Caspian, this flow turns to the north, near the eastern shoal, and goes to the middle and northern Caspian. Near Absheron, the second flow goes to the east, and on the east coast, its waters join with the waters of the first current. The Mangyshlak peninsula baffles

the part of the joined current to the west, and in such a way, the cyclonic cycle in the middle Caspian is completed. In the southern part of the sea, between the mouth of the Kura and Absheron, there is a local anticyclonic circulation. General circulation of the Caspian waters plays an important role in the process of water exchange between the main parts of the sea, transferring water masses, differing in their physical and other properties, from the one part to another.

Found in the process of calculation, the features of average monthly currents, which appear under the influence of atmospheric disturbances and the spatial distribution of density, as well as some details of certain density currents, are of great interest.

Combined drift density currents in the middle Caspian are cyclonic for 8 months of the year, and from April to July they are anticyclonic. In the southern Caspian, the counter-clockwise movement is observed during the first 2 months of the year and from August to November, the rest of the time, the movement is mostly clockwise. In both parts of the sea, the prevailing speed of currents is 10-15 cm/s; the maximum speed is 20-25 cm/s.

In winter, due to the quasi-homogeneity of the sea, density currents are weakened, and the speed of currents do not exceed 5 cm/s almost everywhere. In February, circulation is characterized by a cyclonic cycle in the middle part of the sea.

Meanwhile, density currents are more intense in summer, since in August they form two vertiginous currents in the middle Caspian: Cyclonic with a current speed of 10-15 cm/s in the west, and small anticyclonic current with the speed up to 10 cm/s in the central region. At this time, in the western half of the Southern Caspian, there is an anticyclonic circulation with the currents speed <10 cm/s.

North wind forms the surface down surge from the eastern part of the Northern Caspian to the western, and then to the middle Caspian, that is accompanied by the intake of the Middle Caspian waters to the bottom layer in the continental slope area. South wind induced the currents with the opposite direction.

With southeastern winds, the surface waters from the middle Caspian Sea flow in two streams to the western part of the Northern Caspian (main stream) and its eastern part join with the North Caspian waters, and near the northern coast join with waters of the Ural river and the Volga. In the northwestern region of the North Caspian, there is a surge wave. Very strong and longstanding wind causes significant, even catastrophic rise of the level.

Southeast currents predominate along the western shore of the middle Caspian (from Chechen Island to Absheron). Meanwhile, in the area from Chechen Island to Izberg, there are southeast winds, and only to the south from Izberg, there are north winds. It is due to the fact, that surge waves, appeared with the strong and longstanding southeast winds in the northwestern region of the Northern Caspian and in the neighboring area of the Middle Caspian (to the north from Makhachkala), form gradient currents, directed against the wind, which exceed the speed of currents with other directions.

Vertical circulation plays an important role in the life of the Caspian Sea. It is associated with a significant homogeneity of the waters and their aeration, reaching the bottom, as well as the distribution of biogenic substances. Vertical movements are different in their nature and speed.

North winds induce the rise of waters in the eastern part of the Caspian and the fall in the western part. Southeast wind makes the opposite effect. This is the so-called, vertical

Figure 2: The diagram of currents in the Caspian Sea, according to Lednev, 1943[2]

Table 1: Seasonal frequency of commotions (according to the data of the Dagestan Center for Hydrometeorology and Environmental Monitoring)

Wave height	Frequency, %			
	Winter	Spring	Summer	Autumn
Up to 2 m	70	79	81	70
More than 3 m	10	7	5	10
More than 8 m	0,10	0,10	0,07	0,01

Table 2: The average values of heights (h_{av}) and periods (τ_{av}), as well as the heights of certain waves (h_n), possible once in *n* years, by the characteristic months of the seasons in the western part of the middle Caspian (85)

Frequency period, years	Month												Year		
	Wave parameters														
	January			April			July			October					
	h_{av}	τ_{av}	h_n	h_{av}	τ_{av}	h_n	h_{av}	τ_{av}	h_n	h_{av}	τ_{av}	h_n	h_{av}	τ_{av}	h_n
1	2.8	7.5	11.6	2.4	6.8	9.7	2.4	7.0	10.6	2.7	7.4	10.7	3.3	8.2	12.1
5	3.6	8.3	12.9	2.9	7.4	11.1	3.2	7.7	12.0	3.4	8.1	12.1	3.9	8.6	13.4
10	3.8	8.6	13.6	3.2	7.6	11.6	3.4	8.0	12.6	3.7	8.3	12.7	4.2	8.8	14.0
20	4.2	8.8	14.2	3.4	7.9	12.1	3.7	8.3	13.0	4.0	8.6	13.3	4.4	9.0	14.5
50	4.5	9.2	15.0	3.7	8.2	12.8	3.9	8.6	13.6	4.3	8.8	14.0	4.7	9.4	15.2

drift circulation, which is the reason for negative anomalies of water temperature in summer in the middle Caspian. Its speed increases near the coasts, and with the wind, increase reaches 10-20 cm/h.

Wind-induced waves are accompanied by the movement of water particles up and down, due to the orbital motion with the wave period. The speed of movement, reaching 1 m/s in case of a storm, is exponentially fallen with depth. The intensity of wave action, which forms a thin upper homogeneous layer of the sea, is explained by such high speed. In the middle Caspian, away from the shore, wave action penetrates to a depth of 20-30 m, in the Northern Caspian, in case of the ice absence, it reaches the bottom.

Winter vertical circulation occurs in autumn and winter, when the density of the cooled surface waters increases and they fall down. In the northern part of the sea, it extends to the bottom, in the middle - to a depth of 200-300 m, in the southern part - to a depth of 50-100 m (due to the little cooling of the water surface in this part of the sea). Deeper layers are renewed, due to the North Caspian waters of high density, flowing along the slopes of the sea bottom in its deep water part. In winter, in the north, these waters are cooled down to the freezing point, and due to the inflow of the middle Caspian waters from the south, and salinity in the process of ice formation, they have a salinity of 13 at the ice edge.

In available publications, the regime characteristics of waves for the western part of the middle Caspian are based on the data from coastal observations at the Izberg hydrometeostation,[3,14] following ship observations[15] or indirect calculations for typical wind fields.[2,16,17]

In the absence of special regular measurements in the area under consideration, the above data are used for expert assessment of wind speed regime characteristics.

In the Caspian Sea, north and south storm winds, which have great speed, generate large-sized waves in the deep sea, especially in autumn and in winter, when these winds are the most frequent and prolonged.

According to the calculations, commotions of typical wind fields, built on the basis of the synoptic archive, in the deep water area of the sea, the average wave height, with the frequency once a year, reaches 3 m (it's meant the average height of run waves, fixed instrumentally for about ½ h, during four-time observations), and the average height with the frequency 1 time for 50 years is 4.5 m. The isoline $\overline{h} = 4.5$ m rounds about 1/3 of the offshore water.

In the middle part of the sea, the most intense commotion is observed with northwest winds. To the northeast from Makhachkala, the commotion is more severe with southeast winds. The choppiest areas of the Caspian Sea are the following regions: - The coastal regions: From Derbent to Absheron; - the offshore water: The water area adjacent to the Absheron sill. Calculations show, that in this water area, once for 50 years the average height of waves can reach 5.3 m, the maximum - 17 m. There is the predominance of the northern directions, and in the cold season - the southern ones. Often there is large swell from the north and northwest in the broad areas of the middle Caspian.

As follows from the observations, the commotion has a certain frequency in the middle part of the sea, in winter, spring, summer, and autumn [Table 1].

These values are for the standard regime. Sometimes there may be deviations from these values on any side. For example, the average multi-year frequency of waves ≥6 m is 0.5%, the possible frequency in certain years varies from 0% to 3.5%.

Important characteristics of commotions, necessary for the development of oil and gas deposits on the shelf, are the extreme values of wave elements.[18]

Such information is given according to the calculated data in Table 2.[2]

According to Lopatukhin, the heights of waves of 3% probability, which are possible once for 50 years, are 10 m, once for 100 years - 11 m.[16,19] It should be noted, that

differences in wave heights values connected with different methods, used for calculations, as well, as with the size of the water areas. Since, the maximum wave heights to which, in accordance with BCH 51.2.-84, waves of 0.1% probability are referred, there may be about 30% more waves of 3% probability. Hence, the data of Table 2 does not contradict the results of assessments.[16,19,20]

The peculiarities of climate formation, atmospheric-synoptic processes, commotions and currents of the Caspian Sea, affecting the biological diversity of the middle Caspian and coastal ecosystems, are determined by the geographic position of the sea, the conditions of atmospheric circulation, the nature of the underlying surface, and the orography of the coasts.

CONCLUSION

Assessment of the main climatic factors of atmospheric-synoptic processes, peculiarities of the wind regime, characteristics of currents, commotions, extreme values of wave elements, determining the biological diversity of the middle Caspian and coastal ecosystems, is necessary for the development of oil and gas deposits on the shelf.

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