BLACK SEA RESOURCES AND PROSPECTS FOR THEIR FURTHER USE

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Abstract. The climate of the Black Sea, which creates favorable conditions for the development of various sectors of the national economy (resort and recreation, fishing, transport, etc.), has significant resource potential. However, global warming affects the marine climate and its hydrological regime.

Over the past 14 years (2000-2014), the processing and analysis of materials on the thermal regime of surface waters in the Adjarian coastal zone of the Black Sea have shown that the annual course and distribution of the temperature of surface waters in the sea by year are subject to patterns. As a result, the lowest temperatures were recorded in February-March (within +7ºC), and the highest – in July-August (+28, +29ºC). The deviation of the sea water surface temperature from the long-term regime was first observed in August 2010 and reached a peak of +33ºC (database of the Georgian Hydrometeorological Institute), which was mainly due to the influence of global warming and was reflected in the thermal regime of the sea surface waters. Similar temperature trends were observed in 2011-2014.

Keywords: sea; climate; resources.

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Introduction. The Black Sea belongs to the Atlantic Ocean basin. Although the Black Sea is one of the most studied seas in the world, its individual ecosystems, resources and landscapes have not yet been fully examined and are still being explored by Georgian and foreign scientists.

The Black Sea is especially rich in natural conditions and resources, such as climatic, biological, transport and navigation, mineral and raw materials (oil, gas, magnetite and titanium-magnetic, magnesite, coal, etc.), recreational (beaches, bioclimate, mineral waters, historical monuments and attractions, etc.) resources.

The aim of the research is to study the climatic resources of the Black Sea and the impact of modern global warming on them in the coastal area of Adjara.

Methods. The study is based on the used and processed existing literary sources, cartographic materials and Internet resources.

The research has been done using general geographical, climatological, cartographic and regression-statistical research methods.

Discussion. The present work focuses on the climatic resources of the Black Sea, which, due to the climatic features of the sea, create favorable conditions for the development of various sectors of the national economy (resort and recreation, fisheries, transport, etc.).

One of the main factors that shape the climate of the Black Sea is solar radiation and the duration of sunshine (Table 1).

Table 1. Main hydrometeorological indicators of the Black Sea basin
(Bondirev I.V., Dzhandzhgava T.S. – Tbilisi-1992).

Observation point	Annual total radiation kcal.cm^2	Duration of sunshine	Radiation balance in kcal (cm)year	Precipitation mm	Average temperature (°C)			
					Air		Water	
					January	July	January	July
Batumi	119	1958	52,5	2665	6,2	2,0	10,4	19,4
Poti	130	2237	69,0	1623	5,7	20,3	9,7	19,4
Sukhumi	131	2089	58,1	1460	6,1	24,2	8,4	21,2
Odesa	138	2013	52,7	450	-3,0	2,27	8,8	21,8
Yalta	120	2223	49,5	586	-0,7	24,1	1,0	19,8
Varna	130	2237	51,4	478	-1,0	22,3	2,2	24,0
Istanbul	140	2240	65,2	650	6,6	23,5	11,2	22,9

The temperature of the Black Sea water is highest along the coast of Georgia throughout the year, and in particular off the coast of Adjara.

In terms of the annual course of air temperature, the territory of Adjara belongs to the coastal type. The average annual temperature on the coast of Adjara is 14º-15º. The thermal influence of the Black Sea is especially noticeable in the temperatures of the winter months. The coastal region of Adjara in Georgia is distinguished by its warmest winters. The coldest month of winter is January, with an average temperature ranging from 6.6º to -1.0º. Summer in the coastal region of Adjara is moderately hot, which is due to the prevailing local winds – „sea breezes", which significantly reduce the air temperature. The warmest month of summer is August, with an average air temperature of 21.1º – 23.2º[1,2,4,7].

The thermal regime of the Black Sea is mainly determined by the physical and geographical features of the region, including: latitude, natural zone, surface characteristics and atmospheric circulation. The thermal regime of the surface waters of the Black Sea is greatly influenced by the cyclonic series of the Atlantic Ocean, which in their predominant format constantly move from west to east. Also, the Black Sea is located in relatively low latitudes, due to which it receives thermal energy from the sun in the form of direct radiation, which is approximately equal to 2000 • 10^{12} kcal.

The thermal regime of the surface waters of the Black Sea, as mentioned above, is mainly determined by solar radiation, prevailing currents, general circulation and is characterized by simple processes. On the Black Sea coast of Adjara, the daily maximum of the surface water temperature occurs 15-16 hours after sunrise, and the minimum – 2 hours after sunrise. The daily amplitude is very insignificant and fluctuates within 0.2-0.5°C. The annual runoff is also simple and reaches a maximum in August, and a minimum – in late February – early March. Extremes vary for different areas of the Black Sea and for the coast of Georgia reach -28 °C in August, and by the beginning of March they drop to 6-7 °C, respectively, the annual amplitude is within 20-22 °C. According to the materials of long-term regime observations,

the average annual temperature of the surface waters of the Black Sea is as follows (Table 2, Fig.1) [2]: in the annual course of the temperature of the surface layer of sea water up to 1996, seasonal periodic fluctuations are observed; however, in general, certain deviations and trends of increase or decrease in temperature are not observed. The absolute maximum of the average annual temperature is 15.4° (in 1987-91), and the minimum is 13.6°, respectively; the amplitude is 1.8°, which is similar to the average annual indicator of surface waters.

Table 2. Average annual temperature of surface water in the Black Sea

year	T°c	year	T°c	year	T°c
1982	15,2	1989	14,3	1996	14,7
1983	14,8	1990	14,5	1997	13,9
1984	14,6	1991	15,4	1998	15,5
1985	13,9	1992	14,4	1999	15,5
1986	14,4	1993	13,6	2000	15,9
1987	15,4	1994	14,8	2001	14,8
1988	13,7	1995	15,1	2002	14,3

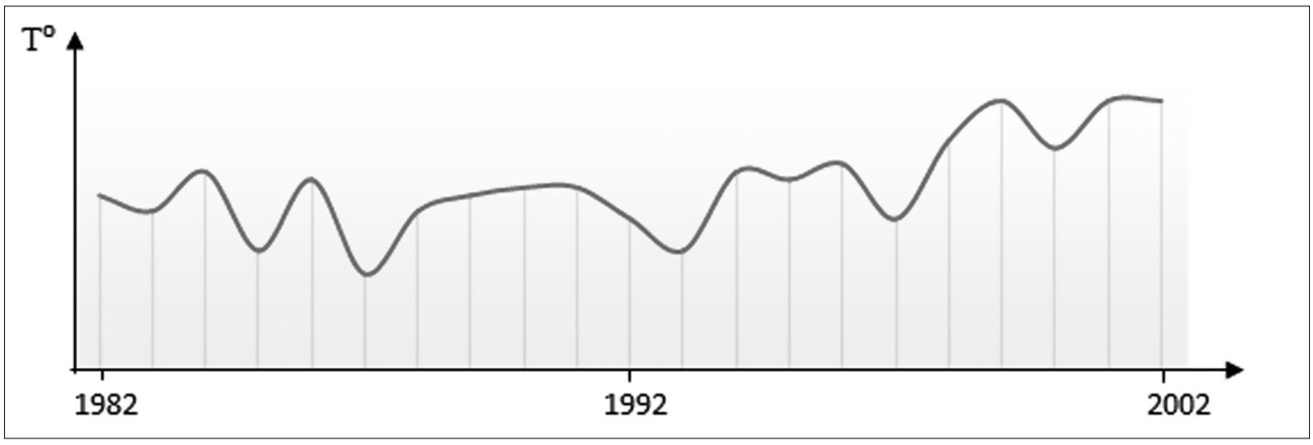

Fig. 1. The course of the average annual temperature of the Black Sea surface water.

Similar average annual trends for surface waters have been observed according to the data of regime observations of the Batumi and Poti hydrometeorological stations (Fig. 2) [2]. The average annual regime of surface water runoff in Batumi and Poti is similar to the general regime of the Black Sea runoff, and the nature of seasonal fluctuations is repeated on the eastern coast.

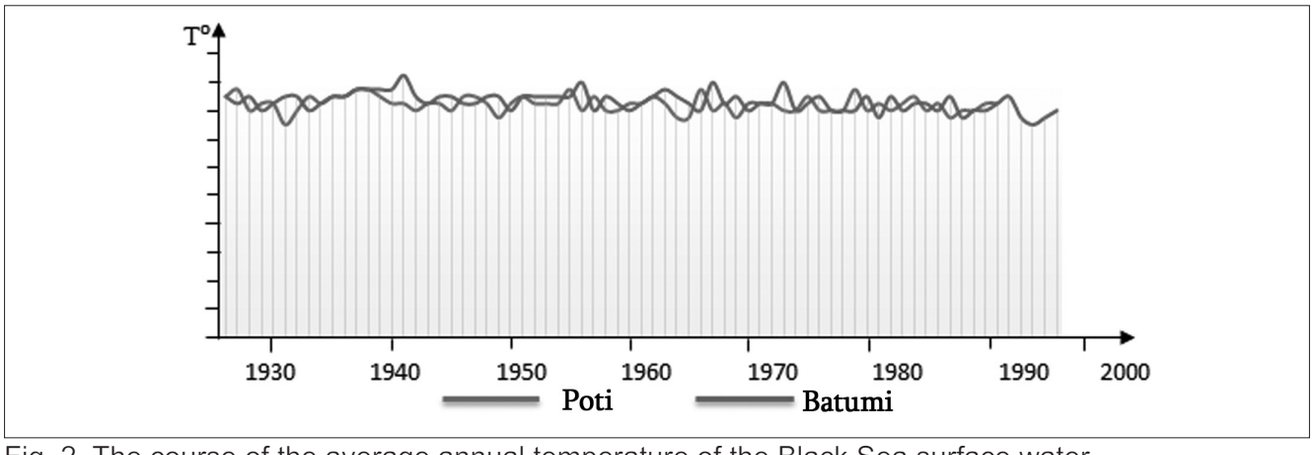

Fig. 2. The course of the average annual temperature of the Black Sea surface water.

According to the Batumi and Poti hydrometeorological stations, the maximum average annual temperature in Batumi was 18°C, the minimum was 15.4°C. The amplitude between them was 2.6°C. Accordingly, the maximum average annual temperature in Poti was 17.5°C, and the minimum was 15.5°C, with an amplitude between them of 2°C.

The average annual temperature variation of the surface water layer in the northwestern part of the Black Sea is characterized by special fluctuations, which are caused by the influence of alternating arctic air masses and western cyclones. Accordingly, the average annual temperature extremes are as follows: the maximum – 14.8°C was recorded in 2002, and the minimum – 9.7°C was recorded in 1985.

Global warming has also affected the thermal regime of the surface waters of the sea. The fluctuations in the thermal regime of the surface waters on the coast of the sea in the Adjara region, against the active background of the dynamics of the hydrological regime of the sea, would seem not to have manifested itself, if one strange fact had not been noted. The thermal regime of the summer of 2010 changed many extreme phenomena that had previously existed in the Adjara region: for the first time in the observation period of the meteorological element in the coastal region of Adjara, there have been recorded the maximum duration of continuous dry weather (more than 3 months) and the maximum temperature of the surface waters of the sea on the coast of Adjara (33ºC), which led to the mass death of mussels and oysters.

Processing and analysis of materials on the thermal regime of surface waters in the Adjarian coastal zone of the Black Sea over the past 14 years (2000-2014) have shown that over a number of years (from the beginning of observations to 2009), the annual course and distribution of the temperature of the sea surface waters were subject to patterns. Thus, the lowest temperatures were recorded in February-March (within +7ºC), and the highest – in July-August (+28, +29ºC). The graphic images clearly show that the deviation of the sea surface layer temperature from the long-term regime was first observed in August 2010, and the peak reached +33ºC (database of the Georgian Hydrometeorological Institute). Similar temperature trends were observed in 2011-2014. In 2011, the maximum temperature of the surface layer of sea water reached 30ºC at the end of July and remained until the end of August, maintaining an extreme state significantly longer than in 2010. A similar trend of increasing temperature of the surface layer of sea water was observed in the northwestern region of the Black Sea (Fig. 3, 4).

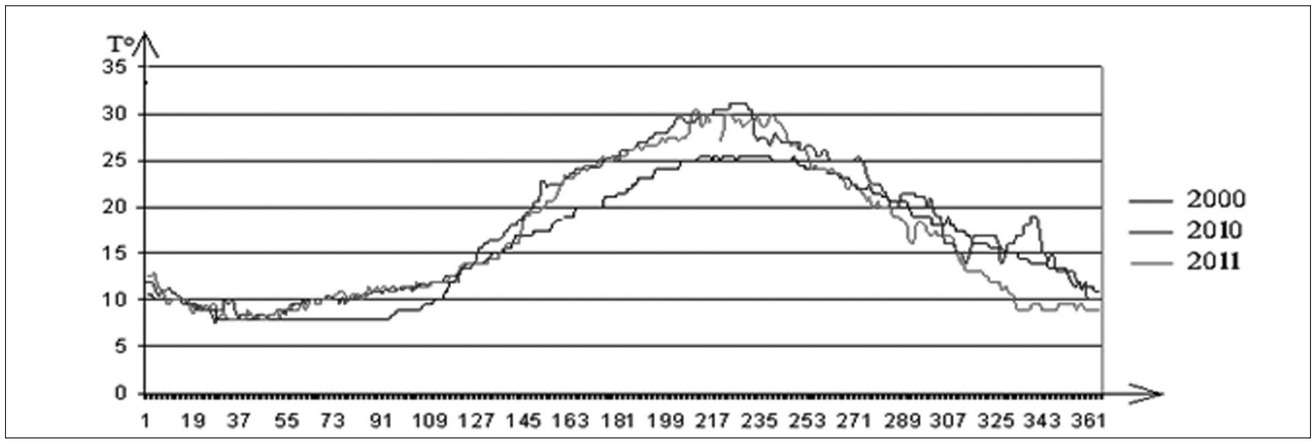

Fig. 3. Annual temperature fluctuations of the Black Sea surface layer of water (Batumi)

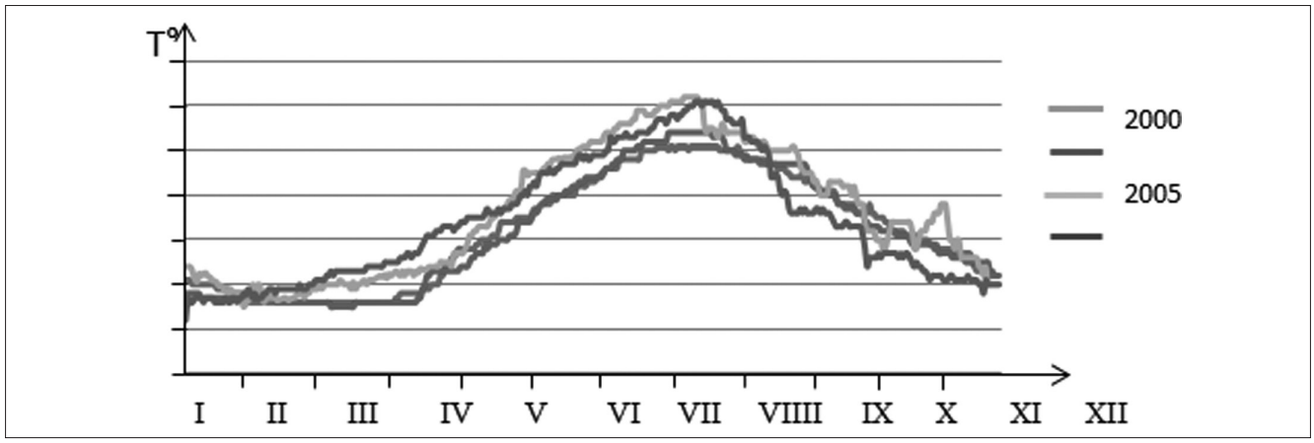

Fig. 4. Distribution of the surface water temperature of the Black Sea by year (Batumi)

It is interesting to see how adequate the annual regime of air and surface water temperatures is. For this purpose, there have been considered data from the weather stations of Batumi and Poti, the processing and analysis of which gave the below picture (Fig. 5). As can be seen from the figure, the thermal regime of air and surface waters are quite closely related to each other, but the increase in water temperature depends to a much greater extent on cloudless, sunny summer weather.

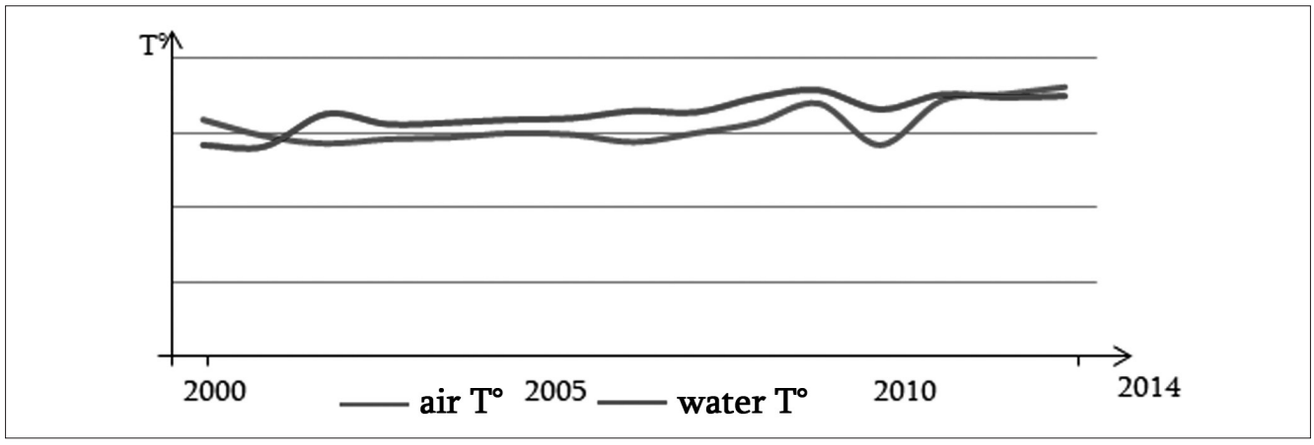

Fig. 5. Average annual trends in air temperature and sea water surface layer (Batumi)

Since 2010, the number of dry sunny days in summer has increased sharply, and, as a result, the temperature of surface waters has increased due to the active impact of solar radiation.

Despite the proximity of Poti's territorial waters to the waters of the Batumi water area, we have obtained a completely different thermal regime of surface waters, what is clearly seen on the graphical representations [4,5].

Table 3. The course of the average annual temperature of the sea surface water.

year / T°c	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Poti	17	17,5	17	16,5	16,5	17	17,5	17,5	17	16	17	15,5	16,5	16	17
Batumi	14,2	14,1	16,3	15,6	15,7	15,9	16	16,5	16,4	17,4	17,9	16,6	17,6	17,4	17,5

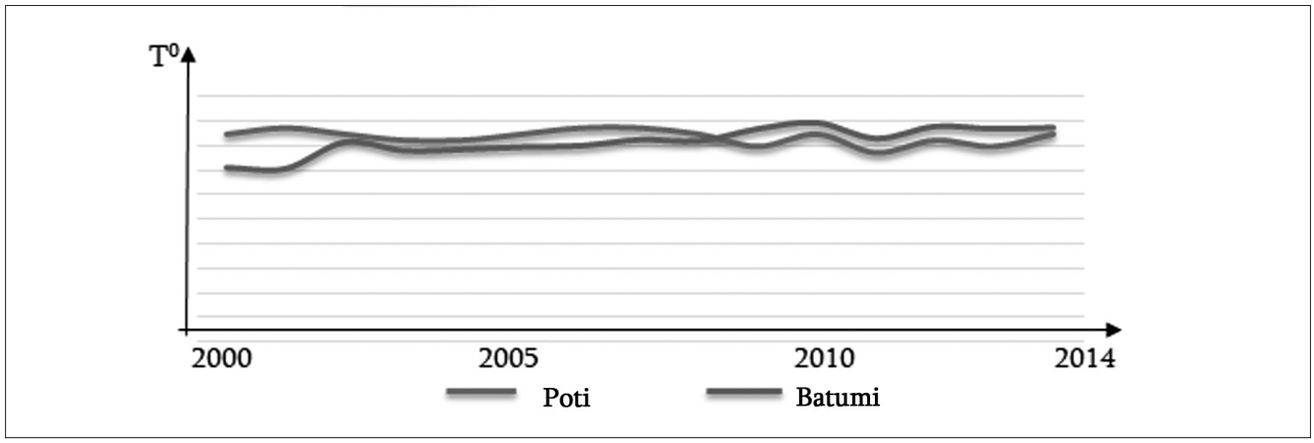

Fig. 6. The course of the average annual temperature of the Black Sea surface water.

It is evident that over the last fifteen years the average annual temperature course in Batumi and Poti is different: while in Batumi it increases, in Poti, on the contrary, there is observed a decrease in temperature or isothermy (this process is caused by the proximity of the Rioni River mouth to the hydrometeorological station and mixing with the relatively cold water of the river).

The average monthly temperature regime of the coldest and warmest months (February and August) of the Black Sea surface waters in Batumi and Poti has shown very interesting dynamics (Tables 4,5, Figs. 7,8).

Table 4. Seasonal changes in the average monthly temperature of the surface layer of sea water in February

year / T°C	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
February (Poti)	8,5	10	8	8,5	8	9	7,5	9	8	8	7	7,5	6,5	9	8,5
February (Batumi)	8	8,5	8,5	9	7,5	8	7	8	8	10	9	8,5	7,5	10	9,5

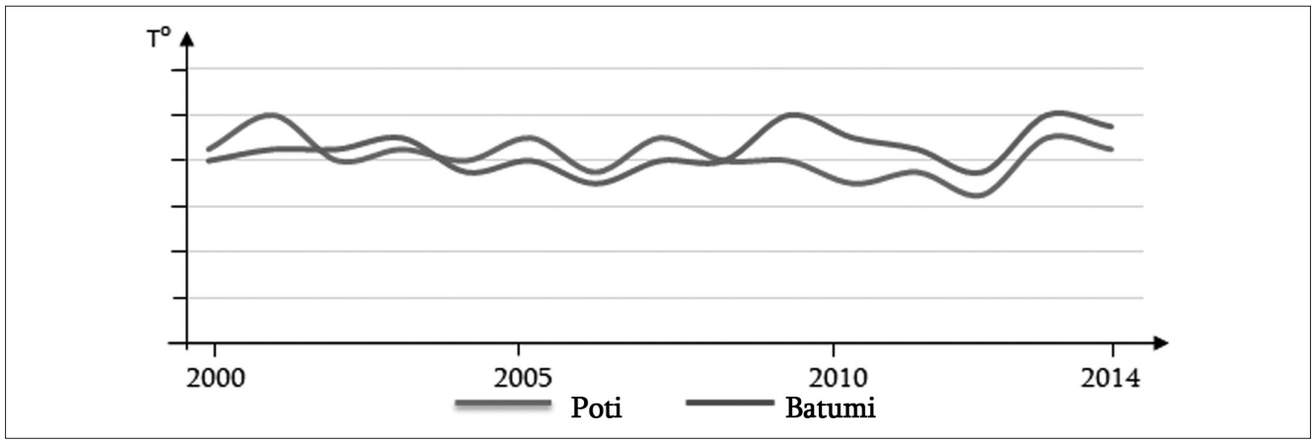

Fig. 7. Seasonal changes in the average monthly temperature of the Black Sea surface water in February.

The graph of seasonal changes in the average monthly temperature for February clearly shows that in Batumi the temperature rises even in winter, while in Poti, on the contrary, the temperature drops, but there is no definite trend, as in the warmest month, but it is characterized by seasonal fluctuations.

An almost identical picture is presented by the graph of the seasonal course of the average monthly temperature of the warmest month – August (Table 5, Fig. 8). If in Batumi the average monthly temperature in August has been constantly high – 29ºC since 2010, then in Poti it fluctuates and is even lower than the long-term norm (2013 – 25.5ºC).

Table 5. Seasonal changes in the average monthly temperature of the surface layer of sea water in August.

Year / T°c	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
August (Poti)	26,5	29	27,5	26	27	28	28	28	26	25	28	26,5	27	25,5	27,5
August (Batumi)	25,5	27,5	25	25	25	27	27	27,5	27	26	29	28	29	27	29,5

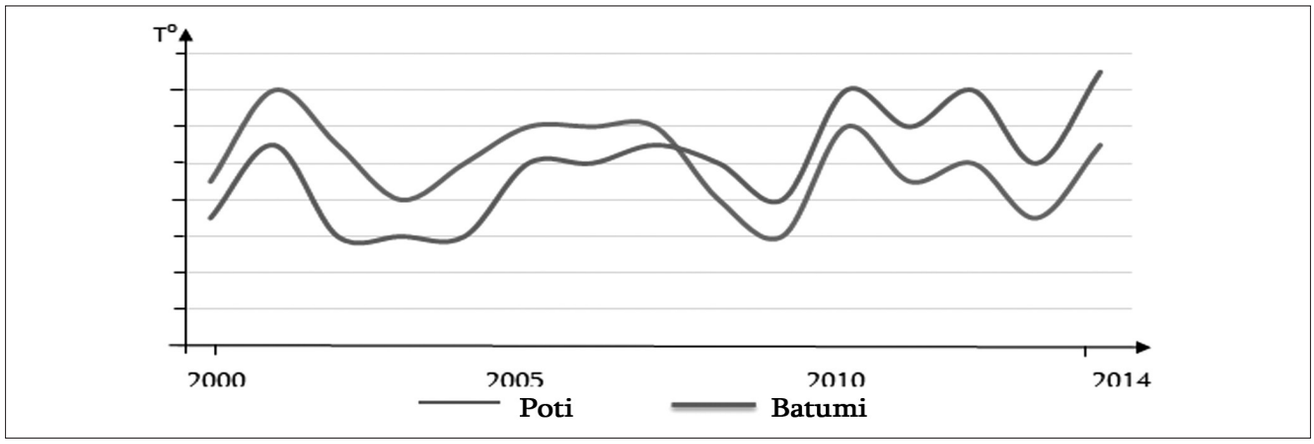

Fig. 8. Seasonal fluctuations of the average monthly temperature of the Black Sea surface water in August.

The dynamics and trend of the thermal regime of the sea surface waters are best shown in the graphical representations of creeping temperature fluctuations (Tables 41, 42, Figs. 32, 33). These trends can be clearly visible both in Batumi and Poti.

Table 6. Average annual fluctuations in the temperature of the surface layer of sea water. (Batumi)

Year	temperature
2000-2009	15,8
2001-2010	16,1
2002-2011	16,4
2003-2012	16,5
2004-2013	16,7
2005-2014	16,9

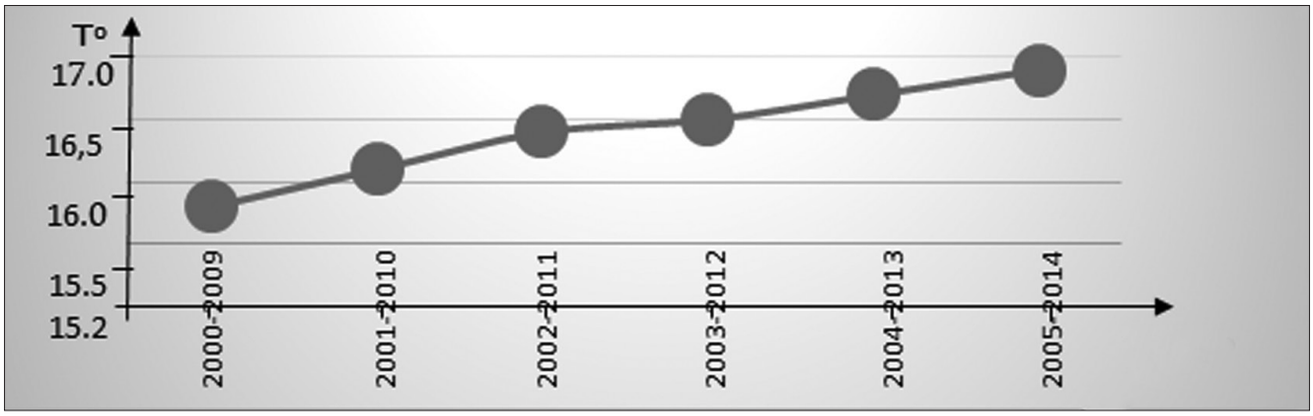

Fig. 9. Fluctuations of the average annual temperature of the surface layer of sea water. (Batumi)

Table 7. Fluctuations in the average annual temperature of the surface layer of sea water. (Poti)

Year	temperature
2000-2009	17
2001-2010	17
2002-2011	17
2003-2012	17
2004-2013	16,5
2005-2014	16,5

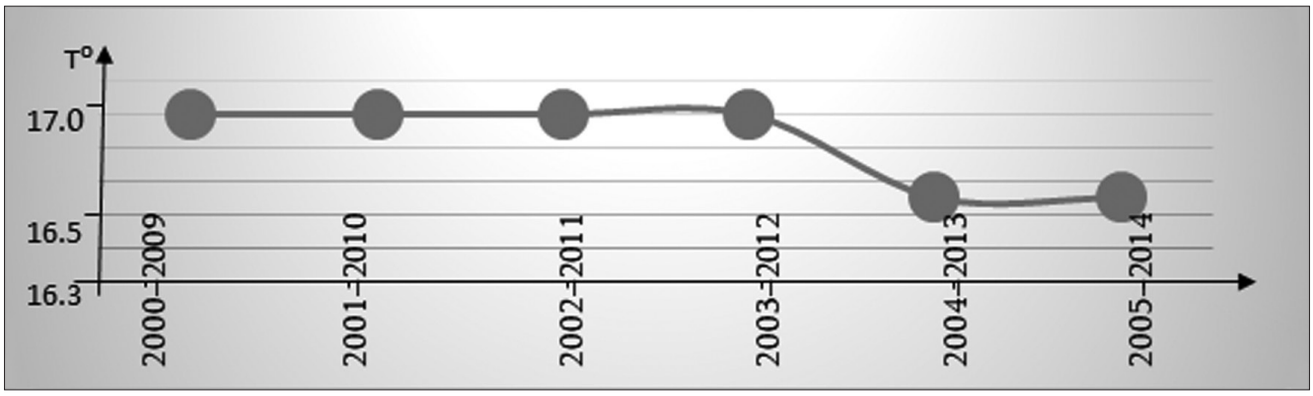

Fig. 10. Average annual temperature of the surface layer of sea water (Poti).

The graph of fluctuations in the average annual temperature of the surface layer of sea water in Batumi conditions has clearly shown the ascending dynamics of water temperature over the years, while the graphical display of hydrometeorological data for Poti shows an isothermal (i.e. constant temperature) state over the years and a slight (0.5ºC) decrease since 2012, which continues to this day.

Conclusions.

1. Processing and analysis of data from the Batumi and Poti meteorological stations has shown that the thermal regime of the air and surface waters are closely related. It is also worth noting that an increase in water temperature depends to a much greater extent on the number of cloudless, sunny days in the summer than on air temperature. For example, in 2010, a sharp increase in the number of dry sunny summer days was observed for the first time (almost the entire summer passed without precipitation), and as a result, the temperature of the surface layer of water increased due to the active influence of solar radiation.

2. Despite the proximity of Poti's territorial waters to Batumi's waters, they are characterized by a completely different thermal regime of surface waters. Over the past fifteen years, average annual temperature trends in Batumi and Poti have been different: while in Batumi they have been rising, in Poti, on the contrary, there has been observed a decrease in temperature, or isothermy (this process can be explained by the proximity of the Rioni River mouth to the hydrometeorological station and mixing with the relatively cold waters of the river).

3. The average monthly temperature regimes of the coldest and warmest months (February and August) of the surface waters of the Black Sea in Batumi and Poti also differ significantly. If in Batumi in winter there is also an increase in temperature, then in Poti, on the contrary, there is a decrease in temperature, and if in August the average monthly temperature in Batumi since 2010 has been consistently high – 29ºC, then in Poti it fluctuates and is even lower than the long-term norm (2013 – 25.5ºC). Based on the above, it can be said that the dynamics of the thermal regime of the surface water of the Black Sea is generally heterogeneous and the regime varies by region.

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