

BOOK REVIEW

V. A. IVANOV, V.N. BELOKOPATOV – “BLACK SEA OCEANOGRAPHY”

Institute of Marine Hydrophysics, National Academy of Sciences of Ukraine, Sevastopol, 2011, 209 p.

The “**Black Sea Oceanography**” monograph is an overview of the Black Sea physical oceanography based on direct field data and on information from an extensive bibliography gathered by the authors. The monograph is dedicated to the bright memory of Valentina Sergeevna Tujilchina.

In the “Foreword”, the authors note that the Black Sea is one of the most studied seas of the World Ocean. Many marine research campaigns, hundreds of scientific papers and dozens of monographs have been dedicated to the Black Sea. However, in over 100 years of research, many problems remained unsolved.

The most recent Russian and Ukrainian large papers that present the characteristics of the Black Sea oceanography were published some 20 years ago. Since then, new data have been obtained using equipment of state-of-the-art technology, new computational techniques allow developing modern mathematical models, etc. Researchers from other countries have also published a number of papers giving a more complete view on the Black Sea physical oceanography.

The present review expresses the concepts of the Institute of Marine Hydrophysics, Sevastopol, National Academy of Sciences of Ukraine* on the Black Sea physical oceanography according to the present data.

The monograph follows the traditional style of oceanographic description that analyses the field data and presents the main results of the new mathematical models. Extensive sets of data are gathered in tables and many figures and graphs illustrate the described phenomena. The monograph, with its very rich bibliography, is extremely useful for a wide range of researchers and students in the Black Sea oceanography.

* the monograph was published in 2011

The monograph has the following Table of Contents:

- **Foreword**
- **1. Physical-geographical characteristics:** 1.1. Geographical position; 1.2. Seabed topography; 1.3. Morphometry;
- **2. Climate, water and heat budget:** 2.1. Climate; 2.2. Water budget; 2.3. Heat budget;
- **3. Thermohaline structure of water:** 3.1. Water temperature; 3.2. Water salinity; 3.3. Water density and stability; 3.4. Water masses: 3.4.1. Surface water bodies; 3.4.2. Cold intermediate layer; 3.4.3. Intermediate and deep water masses;
- **4. Water circulation:** 4.1. General circulation scheme; 4.2. Regional circulation: 4.2.1. The main current in the Black Sea; 4.2.2. Circulation on the north-western shelf of the Black Sea; 4.2.3. Quasi-stationary anticyclonic eddies;
- **5. Synoptic and meso-scale changes:** 5.1. General characteristics; 5.2. Synoptic eddies; 5.3. Meso-scale changes: 5.3.1. Seishes; 5.3.2. Long-wave movements; 5.3.3. Inertial movements; 5.3.4. Internal waves with short period.
- **References**

Chapter 1, “Physico-geographical characteristics”, describes the physiographic characteristics of the Black Sea that is one of the largest inland seas, which communicates with the Mediterranean Sea through the Bosphorus-Dardanelles straits and with the Sea of Azov, through the Kerch Strait.

The basin morphometry and the seabed topography, represent major oceanographic features, which determine the main characteristics of the thermohaline structure of the sea and its water masses dynamics.

The water volume of the basin influences the heat budget in the region and, thus, the interactions with the atmospheric processes. The exchange of water through the straits with adjacent seas is limited by the depths and widths of the straits. The coastline configuration, the continental shelf width and the steepness of the continental slope, are features that influence the distribution of water masses, the direction and the speed of sea currents, as well as the stratification of coastal water masses. In areas with steeper slopes of the seabed, internal waves can occur.

The Black Sea coastline is about 4,125 km in length, of which about 1 450 km belong to Turkey and about 1,330 km, to Ukraine.

Different sources indicate the maximum depth of the Black Sea in the interval 2,210 – 2,258 m. Modern measurements, estimate that the maximum depths of the Black Sea could exceed 2,500 m.

In the monograph, there are data about the width of the shelf, of the continental slope, of the deep-sea part of the basin and also the characteristics of the straits. The Black Sea Basin has an area of 416,790 km² and a water volume of 535,430 km³.

The **Chapter 2, “Climate, water and heat balance”**, shows that, in the literature, although there is a similarity in understanding the general features, some data differ in terms of seasonal variations and spatial distribution of some characteristics, such as the distribution of types of climate along the Black Sea coast.

The monograph presents the average monthly air temperature and precipitation values in different ports of the Black Sea, during the 1961-1990 interval. For the same period, maps with the atmospheric pressure distribution and its monthly average values are presented.

The annual and monthly average wind speeds and their areal distribution for the coastal and offshore zones of the Black Sea show a pronounced seasonality. The strongest winds occur in the north-western Black Sea. The values of the friction coefficient of the air on the Black Sea water mirror are given.

The authors pay a special attention to the Black Sea water budget as the almost closed seas depend on this feature. An overview of data from different authors about the water budget components (freshwater river supply, precipitations, evaporation, water outflow and inflow through the strait system, mainly, Bosphorus and Kerch) is presented.

The evaporation exceeds the precipitation values in certain zones of the Black Sea. The annual freshwater supply is lower than the evaporation from July to October, with a minimum in August, and higher than the evaporation from November to June, with a maximum in April-May.

In the annual budget of freshwater, the annual river supply exceeds the rainfall in spring-summer intervals and, vice

versa, is lower in autumn-winter months. Uneven areal distribution of the river supplies causes non-homogeneous distribution of sea water surface salinity.

The Black Sea catchment area is of 1,760,000 km² and the freshwater river inflow from this area is of about 350 km³ / yr. The authors analyse the literature and new data about the water exchange through the strait system of the Black Sea. They give more accurate values of the outflow and inflow through Bosphorus and Kerch straits. Thus, for the Bosphorus, the surface outflow from the Black Sea is of 653 km³/yr., while the deep, bottom inflow from the Marmara to the Black Sea is of some 145 km³/yr. For the Kerch Strait, the values of annual exchange of water are: the inflow from the Azov Sea to the Black Sea - 50 km³/yr. and the reverse current near the bottom - about 20 km³/yr.

The average value of radiative budget is about 100 Bt/m², the contact heat exchange is about 13 Bt/ m² and the heat consumption for evaporation is of some 64 Bt/m².

Chapter 3, the “Thermohaline structure of the sea water”, presents the results of oceanographic research carried out, in over 150,000 hydrological stations, on the thermohaline structure of the Black Sea.

The variation of the water temperature during one year interval ranges between -0.97^o – (-0.54^o) C freezing temperature, in the coastal zone, for water salinities of 18-10 ‰, and 28 to 29 °C, in summer time. The multiannual average temperature of the water at sea surface is 14.87 °C, for the upper layer of water (0-300 m) the value is 8.81 °C and for the deep layer (400-2000 m), 8.99 °C.

The main features of the vertical variation of the water temperature within the active layer of the Black Sea that ranges from 5 to 130 m are as follows: in the summer, the thermocline layer is situated at 15-20 m depths and the cold intermediate layer is placed between the depths of 30 and 100 m.

At water depths of 500-700 m, there is a stationary quasi-isothermal layer. The bottom layer, between 1700-1750 m, is characterized by a constant potential temperature of about 8.897-8.9803 °C.

The general system of vertical circulation of the Black Sea water is characterized by the rise of water masses in the central zone of the sea and by their descent at the basin periphery, leading to a flattened dome-shaped distribution of isothermal surfaces. This explains the differences of thermohaline structure in the central zone of the Black Sea compared to its coastal areas.

During the entire year, the surface water layer temperature increases from the northwestern part of the Black Sea towards its south-eastern part, due to the different climate regimes within these areas: temperate climate in the NW and subtropical one in the SE.

The annual amplitude of temperature variation in the upper water layer (0 – 100 m) is of up to 24 °C and follows seasonal cycles.

In the Black Sea, the exceeding freshwater inflow makes the sea water salinity to be lower than in the World Ocean. The average surface Black Sea water salinity is about 17.85 ‰, the average salinity of the layer 0-300 m depth is of 20.26 ‰, in the layer 400-2,000 m, 22.26 ‰, in the bottom layer, 22.33 ‰, and the overall average for the entire Black Sea water volume is 21.96 ‰. The source of salinisation of the Black Sea water is the Mediterranean water (34-37 ‰) coming by the bottom inflow through the Bosphorus Strait. There are two halocline layers in the Black Sea: a seasonal one, between 0 and 30 m water depth, and the second – permanent – one, from 50 to 100 m deep.

The Black Sea water salinity is higher in the central part than within the coastal zone where the river freshwater supply influences seasonally the upper layer down to 20 m depth.

The average density of the Black Sea water is about 1012.6 kg/m³ at the surface, and 1017.2 kg/m³ at the bottom. The water density increases with the depth down to 800 m, then remains constant to the bottom. Such water density distribution in the Black Sea is similar to its salinity distribution. In the north-western part of Black Sea, zones of high horizontal gradients of salinity occur. Under the influence of seasonal variation in water temperature and salinity, seasonal variation of water density can be measured down to the depth of 25 m.

As already mentioned, the Black Sea water characteristics are influenced by the Mediterranean water inflow by the undercurrent from Marmara - Aegean seas (the incoming Mediterranean water temperature is 12-15° C with 34-37 ‰ salinity) and the river freshwater supply [salinity close to 0 ‰ and temperature from the freezing point (-0.54° C) to over 24° C]. There are five distinct water masses (layers) in the Black Sea: coastal sea water masses with a salinity of about 17 ‰; the open sea masses with salinities of 18 ‰, the cold intermediate layer, characterised by temperatures of 6-8° C and salinities of 18-19 ‰, the deep intermediate masses with salinities of 19-22 ‰ and temperatures of 8-9° C and the deep-sea masses of 9-9.11° C and 22-23 ‰ salinity.

The annual volume of Mediterranean water coming from the Marmara Sea, with a maximum of 312 km³ / year, exceeds the Danube river annual discharge (some 200 km³), but represents only 0.05 % of the total water volume of the Black Sea. For this reason, the formation of the intermediate and bottom layers may take thousands of years. In the past (1940-1950), there was an opinion that the Mediterranean water inflow into the Black Sea could occur only in the periods of the year when the sea level was low. The newest measurements show that the water exchange through the Bosphorus occurs all year long. The Turkish researches pointed out the access route of the Mediterranean water into the Black Sea along the canyon in front of the Bosphorus Strait. The thickness of the bottom Mediterranean inflow current decreases from 20-25

m, at the strait end, to 10-15 m, at 10 km distance offshore, and to only 2-3 m, at the shelf break.

The **Chapter 4, “The water circulation”**, presents the schemes of Black Sea surface waters cyclonic circulation as two large circuits, triggered, mainly, by the cyclonic systems of winds. Some measurements suggest that this surface cyclonic circulation could propagate as far as the bottom of the sea. The dynamic calculation method shows the opposite: in the Black Sea bottom layers, the water masses move anticyclonically.

The current velocities measured in the Black Sea do not exceed 1.5 m/s, while the velocities obtained by drifting floats along the cyclonic circuits of currents are much smaller. There is a seasonal variation of current speed, mainly, due to the variability of winds and freshwater river discharges.

The monograph presents details concerning the stability of the currents measured by a number of methods, the physics of current formation and the mathematical modelling of currents in homogeneous water.

In the **Chapter 5, “Synoptic and meso-scale variation”**, the general features, the synoptic vortices and the meso-scale changes are discussed.

A classification of spatial-temporal changes, as well as an evaluation of the synoptic and meso-scale change intensity is presented. The synoptic vortices are considered as one of the causal agents for the synoptic changes.

The seiches, also known as *standing waves* in an enclosed or partially enclosed body of water, have been analysed by various methods. The occurrence of the seiche is mainly caused by the sudden variations in atmospheric pressure. The seiche periods noticed in the Black Sea were of 4.5, 5.5, 6.5, 7.4, 10.16, 12 and 24 hours, with amplitudes up to 20 cm, in the north-western part of the sea.

The long waves motion characteristics measured *in situ* have also been analysed. In the Black Sea, sometimes inertial movements of water occur (inertial currents) with periods equal to the semi-period of Foucault pendulum on geographic latitude of the Black Sea. Internal waves with periods ranging between 2 and 60 minutes, amplitudes of 0.2-0.3 m, up to 1 m, and lengths of 50-600 m are also described for the Black Sea.

In conclusion, the **“Black Sea Oceanography”** monograph, published by the Institute of Marine Hydrophysics, National Academy of Sciences of Ukraine,, represents an extensive and valuable synthesis of a large volume of new data regarding the physical oceanography of the Black Sea and an interesting and useful contribution to a better knowledge of this sea.

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