GEOGRAPHICAL SCIENCES

RESEARCH OF THE THERMOHALINE STRUCTURE IN THE ACTIVE LAYER OF THE MARINE ENVIRONMENT BASED ON REMOTE MEASUREMENT METHODS (ON THE EXAMPLE OF THE BLACK SEA)

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At the modern level of development of technologies for research and control of the state of the Earth, remote observation methods come to the fore. On their basis monitoring of the processes occurring on the earth's surface is carried out. The simultaneous use of various remote sensing methods – satellite remote sensing of the Earth (ERS) and acoustic sounding provides continuous operational data on the state on the surface and in the water column. By using satellite information, it is possible to quickly obtain satellite observations of individual characteristics of processes over large areas of the sea surface. In the case of acoustic sounding, we obtain integral information about the water layer located in the sounding range. Thus, continuous operational data on the state on the surface and in the water column can be obtained, which makes it possible to monitor the state of the sea regions [1, p. 3].

The studies of the thermohaline structure in the marine environment are based on the original methods of calculating the vertical distribution of water temperature, sound speed and salinity of water by satellite and hydroacoustic data [2; 3; 4]. These methods were developed in the State Institute «Hydroacoustic Branch of Institute of Geophysics by S.I. Subbotin name of the National Academy of Sciences of Ukraine».

Calculations of the vertical distribution of hydrophysical characteristics in the Black Sea was carried out in the deep-water part of the sea at standard levels (0, 10, 20, 25, 30, 50 meters) in the spring – autumn 2018 period. For the efficiency of calculations, the Automated Program Complex (hereinafter referred to as the APC) was used, developed in the Hydroacoustic Branch. The APC includes 864 exponential and linear regression equations for calculation of the vertical distribution of water temperature in the Black Sea deep-water area by the months for the period May – October; linear regression

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equations for calculation of corrections for the temperature at levels of 10, 20, 25, 50 meters; linear regression equations for calculation of the speed of sound and equation for calculation of salinity in the active layer of the sea. Intervals for establishing the type of equations (exponential or linear regression) for calculating water temperature are also added to the APC. Thus, the APC automatically determines where and by what equations the vertical distribution of water temperature and, accordingly, the corrections for water temperature and salinity in a layer up to 50 meters in the Black Sea deep-water area can be calculated. The initial data for the calculations using the APC are only daily satellite data of the sea surface temperature.

To study the thermohaline structure in the active layer of the Black Sea, on the basis of APC calculations, maps of the vertical distribution of water temperature and salinity were built on zonal sections (see Figure 1). The initial satellite data were the daily data on satellite measurements of the Black Sea water surface temperature with 4 km step on latitude and longitude, measured companion NASA (Terra MODIS) for 15.05.2018; 21.06.2018; 08.07.2018; 23.08.2018; 21.09.2018; 15.10.2018 [5].

Figure 1 are built using computer program Ocean Data View (ODV) that is intended for the interactive exploration and graphical display of oceanographic and other geo-referenced profile, trajectory or time – series data [6].

On the basis of the built maps (see Figure 1), confirmation of the state of the thermohaline regime inherent in the Black Sea in the warm season was obtained. Analysis of the results of calculations of the vertical distribution of thermohaline characteristics made it possible to identify the main features in these distributions:

1) the vertical distribution of water temperature and salinity has features more characteristic of a domed distribution. This is mainly due to the influence of the circulation of the Black Sea waters;

2) according to the 8°C criterion, the upper limit of the cold intermediate layer (CIL) is observed in a layer of 30 – 50 meters during the entire period May – October 2018;

3) the distribution of salinity has characteristic features that are inherent in the Black Sea. The maximum salinity values are in the regions of the western and eastern quasi-stationary cyclonic gyres.

4) the maximum vertical gradient of the calculated values of water temperature at standard levels in the Black Sea was observed in a layer of 10 – 20 meters and did not exceed $1.17°C \times m^{-1}$ (see Table 1).

Based on studies of the current state of the thermohaline regime of the Black Sea, the possibilities of its use for testing remote control methods of the marine environment have been established.

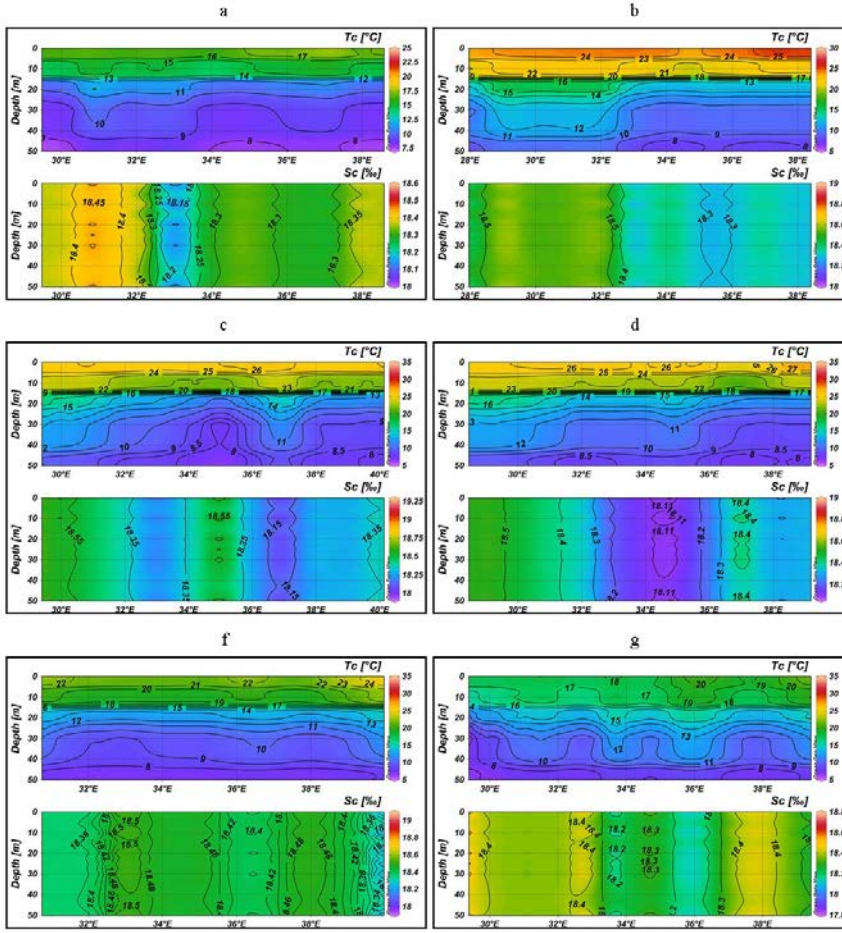

Figure 1. Distribution of the calculated water temperature (*Tc*) and salinity (*Sc*) on zonal sections in the Black Sea at latitudes: 44.00° N for 15.05.2018 (*a*); 43.00° N for 06.21.2018 (*b*); 43.23° N for 07.08.2018 (c); 42.60° N for 08.23.2018 (*d*); 43.31° N for 09.21.2018 (*f*); 43.70° N for 15.10.2018 (*g*)

Table 1

Maximum of the vertical gradient of the calculated values of water temperature at standard levels in the Black Sea

Date	Levels, m	Gradient, °C×m^{-1}
15.05.2018	10 – 20	0.62
21.06.2018	10 – 20	1.03
08.07.2018	10 – 20	1.15
23.08.2018	10 – 20	1.17
21.09.2018	10 – 20	1.00
15.10.2018	10 – 20	0.80

The principles of building of the APC for calculate of the vertical distribution of temperature and salinity fields in the active layer of the Black Sea by satellite and hydroacoustic data could serve as a basis for the establishment of a «System for analysis and monitoring of the fields of thermohaline characteristics in the Black Sea based on the remote measurements». With the help of which the dynamics of processes in the marine environment, the features of the spatio-temporal variability of thermohaline characteristics and effects of their change on hydrobiological, hydrochemical, hydrophysical processes and the ecosystem of the sea in general can be evaluated.

The developed methods and principles of building an the APC for calculation of vertical distribution of temperature and salinity fields of water according to satellite and hydroacoustic data can be applied also to others water area of the World Ocean, taking into account their hydrological conditions.

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