THE BLACK SEA THERMAL STRUCTURE

L.I. Ivanov*, A.S., Samodurov,

*Marine Hydrophysical Institute, Ukrainian National Academy of Sciences, Sevastopol, Ukraine -max777@ukrcom.sebastopol.ua

Abstract

A peculiar thermal structure of the Black Sea is characterised by a gradual increase of temperature interrupted by a quasi-isothermal layer from 500 to 650-m. A stationary one-dimensional model is applied to explain the existence of this layer. It is shown that the total upward heat flux from the Black Sea thermocline notably exceeds the value of the geothermal heat revealing the dependence on thermal properties of the Bosphorus inflow. The geothermal heat is important below the quasi-isothermal layer where the inflow is a cold water pattern compared with the bulk water mass.

Key words: Black Sea, temperature, vertical profile, models.

Introduction

Vertical distribution of the potential temperature in the Black Sea below the core of the Cold Intermediate Layer is characterised by a gradual increase, approximately, down to 500 m. From 500 m to about 650 m, the potential temperature is quasi-uniform, both in the vertical and horizontally [1]. Spatial variations within the layer do not exceed 0.005°C. The layer, same as the pycnocline, is dome shaped with. The potential temperature vertical gradients within the layer are close to zero or have small negative values in the centre of the sea, and have small positive values over continental slopes.

The structure and a comparative role of the sources of heat in maintaining the observed temperature stratification in the interior of the basin are not immediately clear. At the exit of the strait, the Marmara Sea water constitutes a source of heat. However, over the shelf, the effluent comes into direct contact with the Black Sea waters. Through mixing with the Cold Intermediate Water, the temperature of the Marmara Sea water decreases from 14°C at the exit of the strait to about 8°C at the shelf edge [2].

What is an average integrated effect of the upper layer on the thermal regime of the effluent? Ozsoy *et al.* [3] have shown that, due to entrainment, the flowing down fluid can become cooler than the waters of the thermohalocline, and relatively cold (less saline) isopycnal intrusions are well noticeable in the depth range 100 – 500 m. However, a continuously cooled thermocline could not be stationary. On the other hand, observations do not reveal any trends in the thermohaline properties of the Black Sea on a century scale [4] suggesting stationarity of the system. Our paper is an attempt to resolve this contradiction, and to explain the peculiar thermal structure of the Black Sea in the framework of a one-dimensional stationary model. The objective of the work is to estimate contribution of different sources of heat in the formation of the Black Sea water column thermal structure.

Formulation of the model. We consider a stationary one-dimensional model based on mass, salt and heat balances for the Black Sea. The uppermost layer of the sea is excluded from our consideration. This does not need a special justification because inputs of salt occur only below a certain depth. The lower boundary of the uppermost layer is set at the upper boundary of the Bosphorus inflow. Since the Black Sea is characterised by steep continental slopes one may suggest that the considered processes take place in a basin with vertical boundaries and a plane bottom.

The domains of the plume and of the interior are distinguished in the basin. The influence of the plume on the interior is realised in the form of a source or sink of water distributed over the vertical. At the upper boundary we set a source of water with the volume transport of the Bosphorus inflow. This source of water determines vertical velocity in the interior domain. In the vertical, the system consists of three layers. In the first layer, the interaction of the water masses of the plume and of the interior occurs as pure entrainment of the ambient fluid to the inflow. The second layer models the thermohalocline, intermediate and deep layer. The interaction between the plume and the interior in this layer is characterised by disintegration of the plume through the formation of isopycnal intrusions. A separate examination of the fluxes in the third layer is necessary to tune the model. This layer is the Bottom Homogeneous Layer. Thus, the third phase of the plume – interior interaction is characterised by a flow down of a 'remainder part' of the plume into BHL, and its subsequent mixing within the layer by thermal convection. To sustain stationarity of the system the amount of salt that penetrates into BHL is set in agreement with the outward salt flux across the upper boundary of the layer. The conditions of continuity of heat, salt and water fluxes hold at the boundaries between the layers.

The vertical exchange in the interior domain of the basin has two components. The advective transport occurs due to the existence of the vertical velocity, , determined, in its turn, by the lateral source of water. The diffusive transport is maintained by the mechanism of turbulent diffusion in the pycnocline and intermediate layer, by double diffusion at the top boundary of BHL and by convective mixing in BHL. Conceptually the exchange processes modelled here were basically described by Ozsoy *et al.* [3].

Results

The approach to the solution of the problem was found useful to reveal the role of the geothermal heat flux in the formation of the thermal structure of the deep part of the water column of the Black Sea. It is shown that the Marmara Sea water downflow is a warm water pattern above 500 m. Below, the plume penetrates further downward as a cold water pattern. Thus, the lateral source of heat, together with the geothermal heat flux, determines the thermal regime of the Black Sea.

The calculated total vertical heat flux out of the Black Sea thermohalocline is, approximately, 17 times the value of the geothermal heat flux. Consequently, on average, the plume warms up the interior domain of the sea. Estimating the upward heat fluxes at 500 m we got a negligibly small value, 20 times less than a value for the geothermal heat flux. Consequently, the geothermal heat is almost entirely spent below 500 m in compensation for the negative lateral heat flux. Model results thus shed light on the nature of the conspicuous quasi-isothermal layer observed in the Black Sea in the layer, approximately, from 500 to 650 m.

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References.

1. Murray, J.M., Top, Z., Ozsoy, E., 1991. Hydrographic properties and ventilation of the Black Sea. *Deep-Sea Res.*, 38, Suppl. 2A: 663 – 689.
2. Ozsoy, E., Unluata, U., 1997. Oceanography of the Black Sea: a review of some recent results. *Earth-Science Reviews*, 42: 231-272.
3. Ozsoy, E., U.Unluata, Z.Top, 1993. The evolution of Mediterranean water in the Black Sea: interior mixing and material transport by double diffusive intrusions. *Progress in Oceanography*, 31: 275-320.
4. Ivanov, L.I., Belokopytov, V., Ozsoy, E., Samodurov, A., 2000. Ventilation of the Black Sea Pycnocline on Seasonal and Interannual Time Scales. *Journal of Mediterranean Marine Science*, 1 / 2: 61-74.