THE MAIN ENERGETICALLY ACTIVE ZONES OF THE BLACK SEA

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The intensive vertical water exchange between the deep and surface waters takes place in the middle of large-scale quasi-stationary cyclonic gyres in the central part of the Black Sea. The rising of deep waters results from a kinematic effect. Their average perennial volume is equal about 3000 km /year. In winter, when the cyclonic circulation becomes more active, the upper boundary of the deep waters in the centres of cyclonic gyres may rise to the depth of 25-30 m. With the deep waters biogenous elements and hydrogen sulfide surplus produced in the water column, rise into the surface layer where H_2S is oxidized. In such a way the biological productivity of the upper layer and the dynamical balance between the processes of producing and oxidation of H_2S are maintained. The deep water rising forms a vast central divergence zone (CDZ) passing through the centres of cyclonic gyres (OVCHINNIKOV *et al.*, 1993).

In the centres of cyclonic gyres where the thickness of the upper active layer and its heat reserve are minimal (due to deep water rising), during the autumn-winter cooling (thermohalinic convection) the intensive mixing and sinking of surface waters down to the pycnocline dome occurs. In the process of their interaction with the deep waters (5/1 or 6/1) the waters of cold intermediate layer (CIL) are formed, and at the same time the oxigen for the rising H_2S oxidation is supplied. This process is accompanied by the intensive energy exchange between the sea and atmosphere, that gives the reason to consider these regions to be the Black Sea energetically active zone (OVCHINNIKOV *et al.*, 1993).

The internal waves with mesoscale periods which are actively developed on the main pycnocline domes, contribute to the most energetic interaction between the surface and deep waters.

In the nearshore zone, between the midstream of the Rim Cyclonic Current (RCC) and the shore, there is a quasi-stationary system of nearshore anticyclonic eddies (NAE) covering the whole sea coast along its perimeter (OVCHINNIKOV, TITOV, 1990; OGUZ *et al.*, 1992). They are formed owing to anticyclonic vorticity of the current field at the expense of the lateral shear (horizontal gradient) of velocity between the RCC midstream and the steep nearshore slope of the bottom. The nearshore convergence zone (NCZ) where the kinematic sinking of water takes place, is passing through the centres of the NAE having convergence properties. On the other hand, the nearshore area is a periphery of quasi-stationary cyclonic gyres where the kinematic sinking of water occurs. The superposition of NCZ upon this area stipulates the intensive sinking of the nearshore waters there (OVCHINNIKOV, TITOV, 1990).

The regions of deep water rising in the CDZ and surface water sinking in the NCZ are communicated and form a single closed system of the transverse circulation. In this system of circulation the water rising in the CDZ is compensated by the water sinking in the NCZ. Yet the compensation of rising waters is not carried out by their direct transport from the region of sinking, but through a complex lateral turbulent exchange in the system of eddies of various size.

The fundamental importance of the transverse circulation system for the ecology of the Black Sea consists in the following. If the extent of the anthropogenous contamination does not exceed the natural capability of the sea to the self-purification, the contaminated waters, sinking in the nearshore zone, are purificated gradually during their moving to the centre of the Basin and improve the ecological conditions of waters in the region of their rising. If the extent of the anthropogenous contamination exceeds the natural potential of self-purification, then the sinking contaminated waters having passed through the system of transverse circulation, will close the cycle of the whole sea contamination including its deep waters, that may lead to the irreversible ecological catastrophe of the Black sea (OVCHINNIKOV, TITOV, 1990; TITOV, 1992).

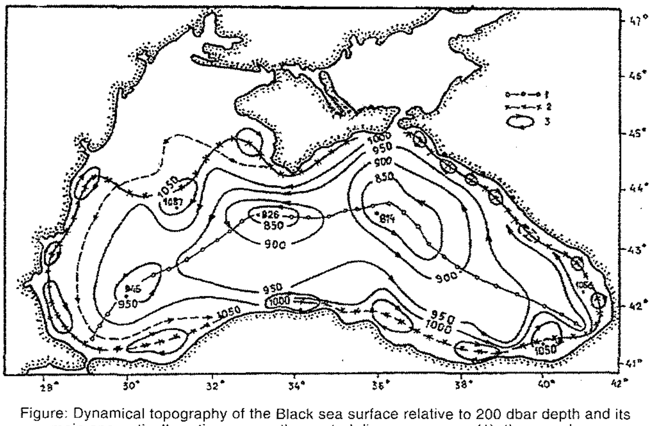

Figure: Dynamical topography of the Black sea surface relative to 200 dbar depth and its main energetically active zones: the central divergence zone (1), the nearshore convergence zone (2) and the nearshore anticyclonic eddies (3).

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THE SECULAR VARIATION OF WINTER TEMPERATURE OF AIR IN THE NORTH-EASTERN PART OF THE BLACK SEA

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Secular series of the mean monthly temperature of air at four points of observations on the coasts of the Crimea and North Caucasus, and for comparison in Odessa and Sukhumi, were assumed as basis of studies of winter climatic conditions in the north-eastern part of the Black Sea. The most cold months of January and February were assumed to be the typical pure winter months and their mean temperature (T°) to be the winter temperature of air (Figure 1, a). The graphic and spectral analysis of T°secular series at each point of observations showed that climatic peculiarities of the Black Sea in the cold season are characterized by a well-defined short-period variation from 2.2 to 4.4 years, weak manifestation of eleven-year sun cycle and distinet twenty-year fluctuations (19.2 years). In order to get the most clear regularities in the secular variation of T°we had to turn to its filtration by the five-year sliding averaging. The graphs of smoothed winter temperature of air (T*°) appeared to be similar for all six points of observations, and correlation coefficients of T*°between the different points of observations are close to 1. It is indicative of the unity of atmospheric processes not only over the north-eastern part of the Black Sea but also over the most its aquatory. That is why for the further analysis of climatic variation the smoothed winter temperature of air in the port of Novorossiisk is given by way of example (Figure 1,b).

As is seen from Figure 1,b, in T*°variation one can also trace the long-time periodicity which is nearly 20 years. In this case the duration of its positive and negative deviations (warm and cold cycles) from the mean secular winter temperature of air (from a "standart" TN°= 2.7°C) equals about 10 years. So in more than secular (121 years) series of winter temperature of air under study in the port of Novorossiisk, five complete and well-defined twenty-year fluctuations are traced with ten-year warm and cold cycles. That is why the processes of vertical interaction between the surface and deep waters in the centres of main cyclonic gyres of the Black Sea, being in direct relation with the "severity" of winter conditions, undergo mostly the same long-time variation in the cold intermediate water (CIW) formation. During cold cycles a considerable intensification of winter convection, kinematic deep water rising and other hydrophysical processes take place here which favour the active formation of the cold intermediate layer in the Black Sea. In this case the volume of anomally cold intermediate water (CIW; 5-6°C) is sharply increased, hydrogen sulphide oxidation grows, and its upper boundary is noticeably lowered, much more biogenic elements are withdrawn from the deep waters into the surface layer, and therefore its productivity is considerably increased. At the same time the surface waters are replenished and renewed due to rising of relatively clean deep waters. Such a cold cycle favourable for the whole ecosystem of the Black Sea is supposed to start at the beginning of the nineties. On the contrary, during the warm cycles all the proces- ses become weak that has a negative influence upon the ecosystem of the whole Basin. Such a warm cycle with the total positive deviation of T*°equal to 13.2°C was observed in the first half of the eighties and brought a lot of troubles into the Black Sea ecosystem.

But the warm and cold cycles in twenty-year T*°fluctuations are revealed irregularly that is well reflected in the total deviations of T*°from TN°in these cycles (Figure 1,b). As the result of such irregular T*° fluctuations in the period under discussion, a considerable surplus of its positive deviations was accumulated which is equal to +11.2°C. In this case a stable trend (Figure 1,b; a broken line) is traced from the thirties to nineties which is characterized by the winter temperature of air rising by 2.25°C in Novorossiisk area. Such T*°rising during the last 60 years had to be reflected in the weakening of thermodynamical processes and, as a consequence, in the oppression of the Black Sea ecosystem.

Considering winter processes in the Black Sea, we must notice that in this season 3000 km^3 of deep water on an average penetrate into the surface layer through a weakened pycnocline (OVCHINNIKOV, POPOV, 1987). This volume exceeds by the order of magnitude the largest components of this Basin water balance. Hence it is obvions how important is the role of the deep waters in the formation of the Black Sea upper active layer.

In this way, the revealed regularities of variation of winter climatic conditions make possible the long-period prognosis of hydrogen sulphide contamination of the deep water and the ecological situation of the Black Sea as a whole.

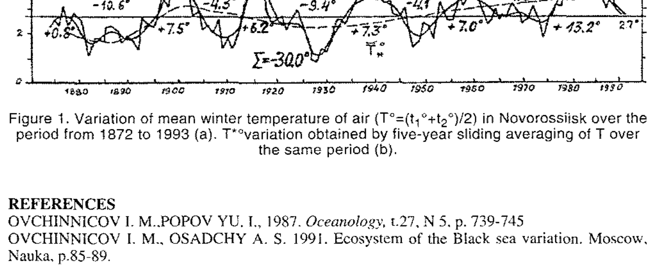

Figure 1. Variation of mean winter temperature of air (T°=(t$_1$°+t$_2$°)/2) in Novorossiisk over the period from 1872 to 1993 (a). T*°variation obtained by five-year sliding averaging of T over the same period (b).

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