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MODELING OF THE THERMOHALINE PROCESSES IN THE ACTIVE LAYER IN THE CENTRAL AND EASTERN PARTS OF THE MEDITERRANEAN.

HASSAN M. HASSAN

Institute of Oceanography and Fisheries, Kayet-Bey, Alexandria, Egypt.

ABSTRACT

Using the model of Doronin (1964) for studying the formation of the active layer in different seas and oceans, the process of the formation of this layer in the central and eastern part of the Mediterranean Sea was investigated.

The thickness of the surface active layer and its changes with time and location were obtained. The data obtained by calculation were compared by actual observations and found to be in close agreement.

The effect of mixing on the salinity structure was clearly indicated from the results.

INTRODUCTION

The study of different processes forming the active layer in the seas and oceans represents a very important problem in oceanography. The majority of the atmospheric processes affecting the deeper water layers take place through this layer.

A through study of this layer is essential to predict or explain the dynamics of all other processes taking place in deeper layer. Using the model of Doronin, Y.P. (1964) for studying the formation of the active layer in different seas made it possible to investigate the process of formation of this layer in the centeral and eastern parts of the Mediterranean Sea.

THE MODEL

The fundamental equations in this model are the following

1) The heat balance equation for the quasi-homogenous layers

$$\int_{t_i}^{t_{i+1}} \varphi_a(t)\,dt = C[\int_0^{h} \rho_i\, T_i\, dz + \int_{h_i}^{h_{i+1}} T_i\, dz - \int_0^{h_{i+1}} \rho_{i+1}\, T_{i+1}\, dz + \rho \int_{t_i}^{t_{i+1}} a \frac{\partial T}{\partial t}\, dt], \quad \ldots (1)$$

Where:

c = The specific heat capacity of the sea water.
h = The thickness of the quasi-homogenous layer.
φ_a = The heat flow between the sea surface and the atmosphere.
$\partial T/\partial z$ = The temperature gradient at depth $z = h$ and
ϑ = The coefficient of turbulent thermal conduction.

In the right hand-side of the equation the first term represents the heat reserve of the quasi-homogenous layer h_i and at the moment t_i. The second term represents the increase in the heat reserve as a result of the increase in the thickness of the quasi-homogenous layer from h_i to h_i+1. The third term is the heat reserve of the quasi-homogenous layer at moment t_i+1. The fourth term determines the heat flow as a result of the turbulent mixing between the quasi-homogenous layer and the underlying ones in a time period.

$$\tau = t_{i+1} - t_i$$

2) The salt balance equation for the same layer

$$\int_0^{h_{i+1}} \rho_{i+1} S_{i+1}\, dz = \int \rho_i S_i\, dz + \int_{h_i}^{h_{i+1}} \rho S_i\, dz + \int_{t_i}^{t_{i+1}} \varphi_S\, dt , \qquad (2)$$

Where φ_S is the salt flow in the quasi-homogenous layer.

The thickness of the quasi-homogenous layer in the case of its formation as a result of the mixing with a free convection, is determined by the relationship between the density of the convected layer $[\rho_{i+1}]$ and the underlying layer

$$\rho_{[h_{i+1}]} \qquad [3]$$

Where. $\rho_{i+1} \lesssim \rho_{[h+1]}$

The thickness of the upper quasi-homogenous layer - in case of mixing by wind effect - is changing from h_i to h_i+1. For determination of the wind mixing depths we use the equation of Kutagourski (1970).

$$h = 0.2\ V^2 \qquad [4]$$

Where,V is the wind velocity in m/s. If both the transfere of heat and salt in the layer of convective mixing are known, it is possible to solve the problem of mixing covection using the [1-4] system of equation when convection is due to continuous cooling.

To use the above model it is necessary to know the initial temperature and salinity profiles at the end of the heating period at each point of the network Fig. 1. It is necessery to know the atmospheric pressure, the wind velocity, the air tempperature and the radiation balance at each of these points for the cooling period. These meterological elements are given as the average values for 14 points in the area of investigation Fig. 1, while the hydrographic data used are obtained from the observations. As a result of the calculation we obtained the hydrographic features for the cooling period [from 20th August to 20th April] to get the following:

1- The thickness of the quasi-homogenous layer.
2- The temperature and salinity within this layer.
3- The heat exchange between the sea surface and the atmosphere.

To take into consideration the effect of advection it was necessery to know the current speed and directions. That was obtaind using a three dimension circulation model for the same area.

In cheking the validity of the obtained information a comparison was made between the calculated values and observed ones.

RESULTS AND DISCUSSION

The minimum value of the thickness of the quasi-homogenous layer is observed in the beginning of the autumn season, where the thickness is approximately the same all over the investigated area. The development of this layer is continued with time and its maximum thickness reached at the end of March when convection is stopped, Fig. 2.

Fig. 3 shows the horizontal distribution of the thickness of the quasi-homogenous layer during the cooling period from September to April. The quasi-homogenous layer starts to be more restricted in September in the south-western part of the area as a result of the western current flowing through Cicily strait of small vertical density gradient. Convection in this part starts early and the thickness of the homogenous layer reaches 15 m, where in the north-eastern part it is only of 6 m and water layers still exhibit strong vertical gradient giving rise to delaying of the convection.

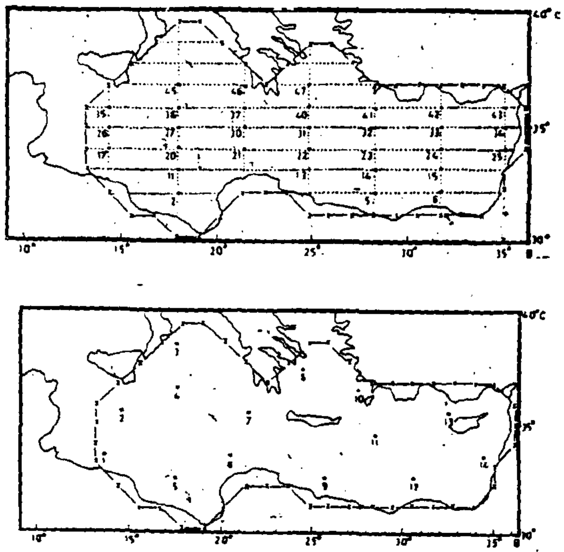

Fig. (1). Upper: Position of the points of calculation.
Lower: Position of the meteorological points.

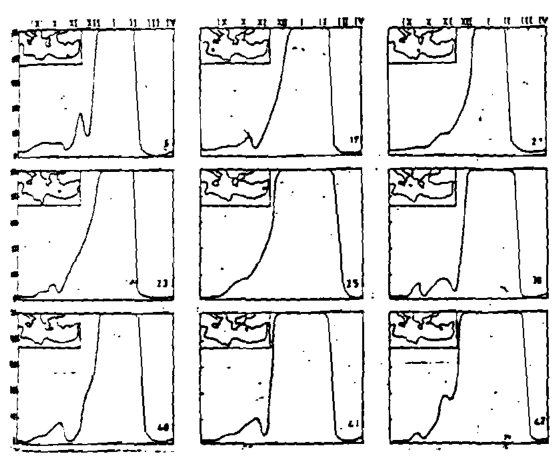

Fig. (2). The development of the thickness of the homogenous layer in the cooling period.

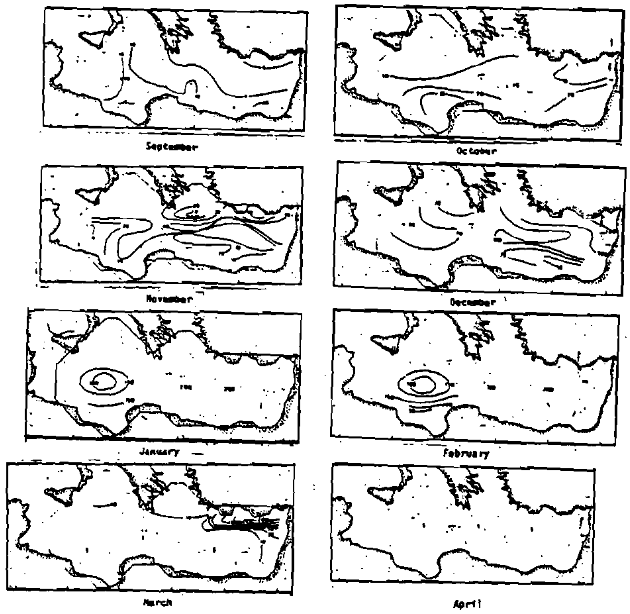

Fig. (3). Horizontal distribution of the thickness of the active layer in the cooling period.

The thickness of the layer in October is increasing in the south-western part of the area to more than 30 m. In the eastern and centeral parts it is only of 10 and 15 m, respectively and water layer still keeping stratification. An intensive convection starts to take place in November in the north-eastern parts, where the thickness of this layer ranges between 50 and 70 m. in other parts it is from 10 to 30 m. During December a very intensive convection takes place in the north-eastern part where the thickness of the homogenuos layer reaches 200 m. In the central and western parts it is of less than 100 m.

With the exception of the south-western parts - where the thickness of this layer reaches only 100 m or less with relative stratification-all over the area of investigation the thickness of the homogenous layer in January is the same [200 m]. In February, the convection is generally of the same features as that observed in January. Only in the sout-western parts of the area the thickness of the layer decreases from 100 m in January to 50 m in February. In March, except the north-eastern parts of the investigated area, where an intensive convection still observed and the thickness of the homogenous layer reaches 200 m, in the rest of the area the thickness of the homogenous area decreases to 5 m. This explains the process of heating and the formation of a new quasi-homogenous layer of wind-origin. The process of convection which was observed in the cooling period is absent in April.

The data obtained by calculation concerning the thickness of the homogenous layer were compared with that collected from the observations on R/V Ichthyolog dealing with the vertical distribution of temperature and salinity profiles in addition to the Bathythermograph data. The comparison shows a complete coincidence.

Very interesting results were received which show the effect of mixing on salinity. Fig. 4 shows that the salinity of the quasi-homogenous layer at the beginning of the cooling period decreases as a result of the mixing of upper layer which has a maximum surface salinity with the underlying layer of minimum salinity. The decrease of salinity continues until the convection reches the layer of secondary maximum salinity, where salinity increases as a result of the convective mixing as well as the intensive evaporation in winter.

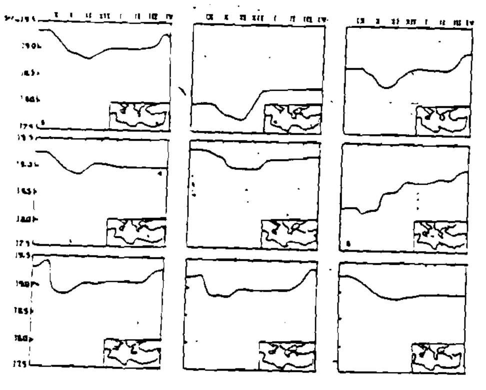

Fig. (4). The effect of mixing on salinity structure.

REFERENCES

Doronin, Y.P., 1969. **Heat interaction between the atmosphere** and **hydrosphere in the Arctic Sea**. Leningrad, 1969 (In Russian).

Doronin, Y.P., C.G. Balincekove and L.N. Karlin, 1974. Formation of the thermocline as a product of the interaction of the ocean and the atmosphere. **AANII,** 315.

Dzukov, L.A., 1970. Calculation of the vertical motion in the non-homogenous ocean. **Physics of the atmosphere** and **the ocean,** 1, ANCCP.

Ovchinikov, I.M., 1966. Circulation in the surface and intermeditae layer of the Mediterranean Sea. **Oceanography,** 6.