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NUMERICAL INVESTIGATION OF THE UPPER BIOLOGICALLY ACTING TURBULENT LAYER OF THE BLACK SEA

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Summary: *As it is known, the Black Sea ecosystem a dramatically changed during the last few decades. Upper mixed layer of the Black Sea, which is biologically active is polluted by many highly toxic substances. They are getting in the Black Sea by inflow of rivers and ground waters. These substances heavily loaded with nutrients containing nitrogen and phosphorus and contaminated with industrial and mining wastes. Anthropogenic eutrophication developed in the Sea a dramatically destroys the marine food chain and living biological organisms. Besides, the oil floods became intensive in last years as sea transportations have significantly increased. It is clear, that the process of transport and evolution of any polluting substance is closely connected to dynamic processes (circulation, wind-driven turbulence , etc.) Thus the modeling of spreading of the substances with underlying some biochemical transformations are a complex problem, which in turn includes the modeling of marine dynamic processes.*

In this paper some features of the Black Sea upper mixed layer (UML) are numerically investigated by using 3-D basin-scale model of the Black Sea dynamics (BSM-IG, Tbilisi, Georgia). For this goal this model is functioned with variable coefficients of vertical turbulent eddy viscosity and diffusion (VTV-VTD during) one modelling year. These coefficients as last version of the Pacanovsky -Philande parameterization (PP-P) developed by Bennis are embedded in the model. The Black Sea UML depth variability is estimated by using a well known criteria of temperature Dt-0.2 .

Using criteria of temperature the results analysis shows: : On the one hand the mixed layer has physically different configuration and variable depths which is undergoes a significant variability in the inner annual time scale ; on the other hand it is combined to the following results: In wintertime the intense wind-driven turbulence promotes strong mixing. Mixed layer has almost same homogenous structure when above Black sea the strong wind was replaced by weak wind. Besides, it is characterized by the clear tendency to deepen mixed layer depth approach to 26m especially in Georgian water area . In the same time gradient of Richardson numbers at the Sea upper levels varied in the ranges 0 <R <<1 and R >> 1 are in a good agreement according to these strong and weak wind respectively. This result demonstrates that: In wintertime similar alternation of the winds affect and change circulation of the Sea. It in turn in small time does not have the ability to transform the structure of the mixed layer . This result is in direct connection of the thermohaline impact, which plays the additional role to grows UML depth in the Black Sea.

Key words: *Black Sea, Biologically active Layer, Wind-Driven Turbulence*

1 Introduction

The UML of seas and oceans is one of the important water areas, the thermodynamic state of which defines many important physical, chemical and biological processes in the sea-atmosphere environment. The same can be note concerning the Black Sea turbulent mixed layer which is the object of our investigation. The thermo-dynamical state of the upper mixed layer of the Black Sea significantly influences on the living marine organisms. Turbulent flows affect biological productivity. It controlling the distribution of nutrients in the upper mixed layer and the light exposure of phytoplankton.

It is well known that the depth of the UML in the sea and ocean is determined by measurements of water properties: temperature and sigma-t (density) [1]. Besides its determination is progressed using of the numerical modeling.

Many aspect of the Black Sea UML features was studied by some authors [2,3,4,5,6] using difference numerical models and processing of the measured date. Among they more complex parameterizations of the vertical turbulent mixing the Mellor and Yamada formulation and k- ε model was used by Korotaev at al., [4] and Stanev at al., [5] respectively in the contest to develop of the Black Sea ecosystem and biogeochemical models.

The main object of this study is investigate numerically some features of the Black Sea UML characterized by homogenous temperature fields . In addition here we consider the relation between the Black Sea UML and the gradients of Ruchardson number when above black sea the nonstationary atmospheric circulation and thermohaline action are developed.

2 Model Description

To achieve this goal the numerical experiment are cared out using average several climatic data's and 3-D basin-scale z-level model of the Black Sea dynamics of M. Nodia Institute of Geophysics (BSM-IG, Tbilisi, Georgia). This BSM-IG is based on a primitive equation system of ocean hydrothermodynamics in hydrostatic approximation, which is written for deviations of thermodynamic values from their standard vertical distributions [7].

3. Parameterization of the VTV and VTD processes

The variable coefficients of the VTV and VTD are included in the model as the last version of the classical Pacanovsky -Philande parameterization (PP-P) [8] developed by Bennis at al.,[9] , which difference from previous version of PP-P is numerically stable in terms of the Gradient Richardson number -R, when the ratio between stabilizing buoyancy forces and de-stabilizing shear forces is characterized by R<0.

During the investigation the total vertical eddy viscosity ν_1 and diffusion coefficient $\nu_{T,S}$ of temperature and salinity stand in this model as functions of the gradient Richardson number $\nu_1(R) = f_1(R) = a_1 + \dfrac{b_1}{(1+\alpha R)^2}$ and $\nu_{T,S}(R) = f_2(R) = a_2 + \dfrac{f_1(R)}{(1+\alpha R)^2}$ respectively [9].

Where $R = \dfrac{g}{\rho_r} \dfrac{\partial_z \rho}{[(\partial]_z u)^2 + [(\partial]_z v)^2}$, g is the gravity constant and ρ_r is a reference density for the sea water. This model is very loyal for the negative gradient Richardson numbers .

Our experiments cared out with the same constants a_1; a_2 (units: cm^2s^{-1}) as PP model [8], $b_1 = 50\ cm^2s^1$, α adjustable coefficient of the functions $f_1(R)$ and $f_2(R)$ are selected at the range [0,0001,10] and [0.00001, 1] according to Richardson number ranked as several diapasons: R>=1000, 100<=R<1000; 10<=R<100; 1<=R<10; 0.1<=R<1; 0.01<=R<0.1 and 0<R<0.01. This variability of the α parameter in computed processes regulated the VTV and VTD coefficients in the following diapasons 30-70 cm2s-1 , 5-15 cm2s-1 respectively.

4. Results of numerical Investigation

In numerical experiment on inner-annual simulation of the Black Sea hydrological regime the integration started on the 1st of January and proceeded one modelling year. This investigation is carried out for four seasons on an example middle period of January, April, July and October . This allows to carry out continuous control the mixed layer features and its flexibility related to the Richardson Number from cold winter season to end of the Autumn . Here in this paper this relation on the single of January are presented , because of restriction of paper's volume).

4.1 Results of numerical experiment for January

To define the main features of UML for winter season in the inner-annual time scale we chose the time interval 342-378 hours. This period is characterized by alternation of the very strong and calm winds above the Black Sea[10], (Eastern wind (15-20m/s) and Northeastern (0-1m/s)corresponding to the time intervals (January): t=342-366h and 366-378h.)

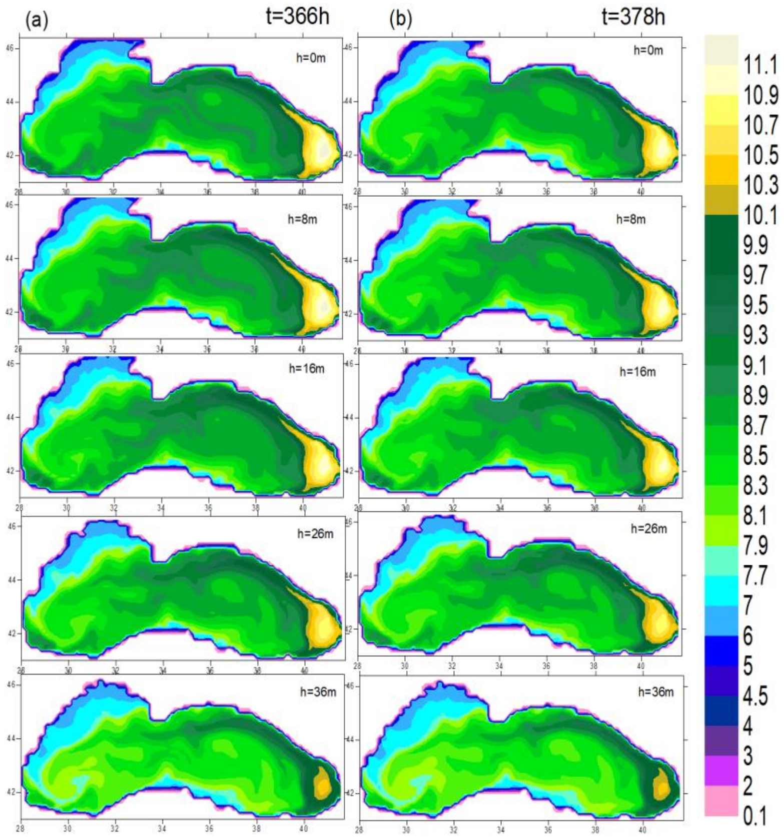

Fig.1. Calculated temperature fields (^{0}C) at the time moments: t=366 and t=378 h (January)

The temperature (deg.C), fields on different horizons, the entire depth 0-36 m at the time T= 366h and 378h presented on the Figs.1 characterize well the general peculiarities of the UML in January. The analysis of this Figure 1a. shows that in wintertime (January) the intense wind-driven turbulence promotes strong mixing . According to criteria of temperature (Dt-0.2) UML depth approach 26m in all most part of the Black Sea. Mixed layer depth does not exceed 16m in the narrow zone of the north-west and near of Georgian shoreline is fixed at the time t = 366h (see Fig 1a). It has same homogenous structure within depth 0-16m when above Black sea the strong wind is replaced by weak wind and it is characterized by the clear tendency to deepen mixed layer approach to 26m, especially in the Turkish and Georgian sea line at the time t=78h, (see Fig. 1b). This result is in direct connection of the thermohaline impact accompanied by Sea cooling processes , which plays the additional role to grows UML depth in the Black Sea.

In the same time gradient of Richardson number at the upper levels of sea varied in the ranges 0 <R <<1 and 1<<R<100 are in a good agreement according to these strong and weak winds respectively see Fig.2 and Fig.3. It is well know when 0<R<<1 slightly stratified layer takes place, which does not exclude the mean features is expressed as homogenous layer of temperature. Difference from it 1<<R <10 is observed in computed processes, when mixed layer depth has increased requires more careful study of these processes.

This result demonstrates that: the similar alternation of the winds (strong wind is replaced by weak wind) affect and change circulation of the Sea, which in turn in small time does not have the ability to transform the structure of the mixed layer .

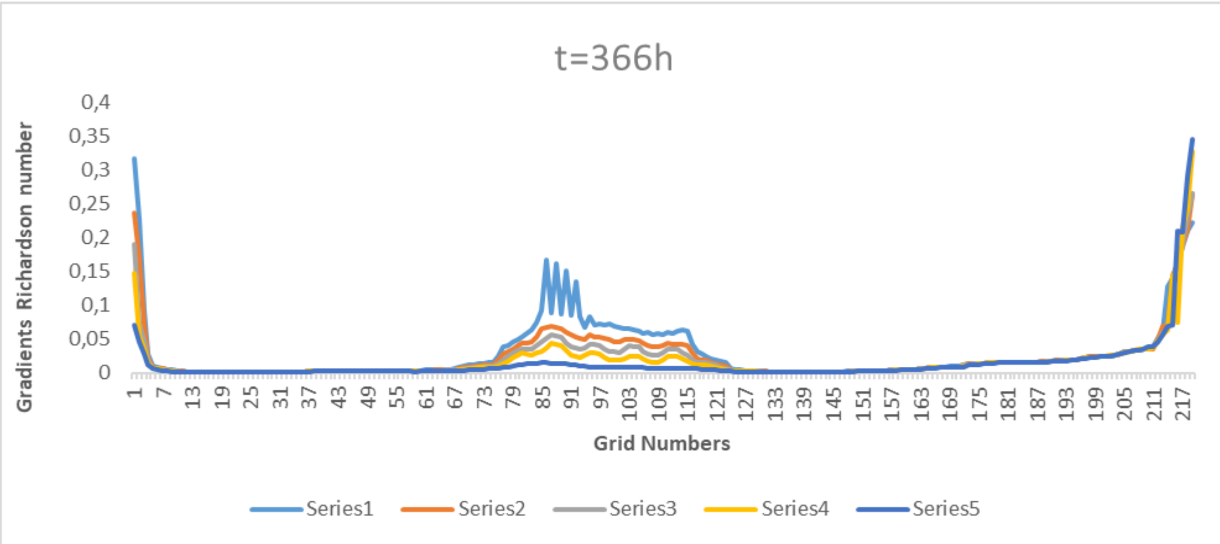

Fig. 2. The Richardson Number variability in sections along $41^0 9'$ N and $42\ ^0 5'$N at t= 366h .

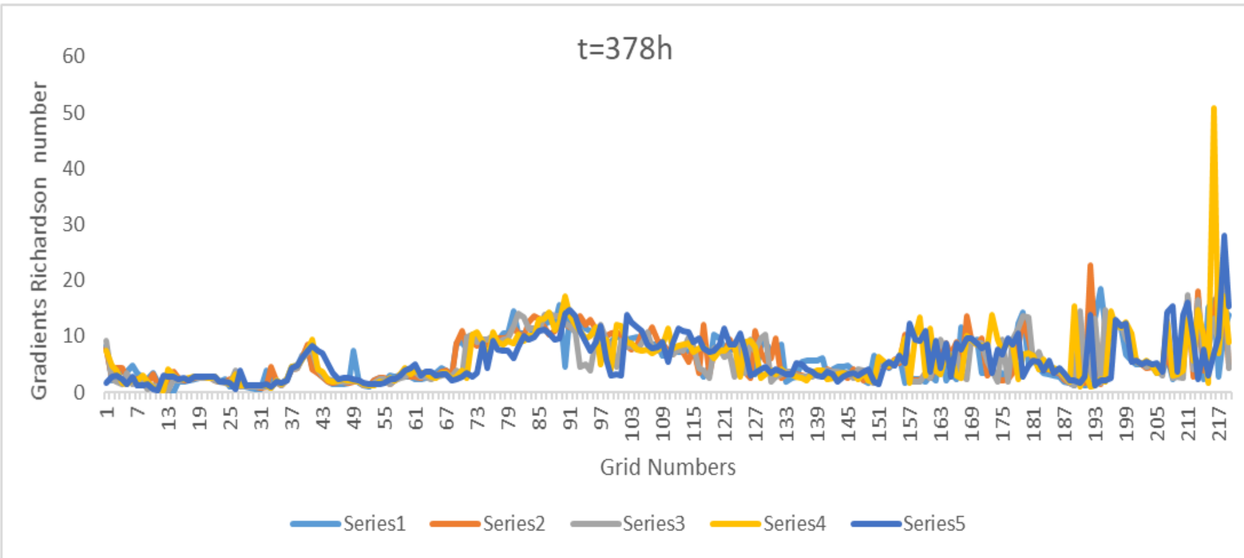

Fig.3. The Richardson Number variability in sections along $41^0 9'$N and $42\ ^0\ 5'$N at t= 378 h.

Conclusion.

The numerical experiment carried out on the basis BSM-IG improved by PP-P allow us to demonstrates that, UML in the Black Sea despite of the weak wind and physical configuration is characterized by 1<<R< 100 keeps of the same strong structure of temperature fields, which homogenized by influence of previous strong wind and Sea cooling processes also.

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