EXPERIMENTAL AND NUMERICAL INVESTIGATION OF EDDY EXCHANGE COEFFICIENTS IN THE SURFACE LAYER OF THE MIDDLE ADRIATIC SEA

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Abstract

Vertical eddy exchange coefficients in the surface layer in the middle Adriatic Sea were studied using boundary conditions for the heat and salt fluxes and one dimensional modeling. Results for experimental data are in concordance with those obtained from the model.

Key-words: turbulence, models, Adriatic Sea

Scope and methods

The main scope of this work was to study vertical eddy exchange in the surface layer of the middle Adriatic using boundary conditions for heat and salt fluxes and one dimensional modeling. The results brought up vertical eddy exchange coefficients for the surface layer.

Data from the period January 1961 to December 1980 were used for calculating vertical exchange coefficients on the seasonal scale. Data were collected on the regular monthly or seasonal basis at oceanographic stations of the transect Split-Gargano (Fig. 1). Measurements were done mostly once a month (only exceptionally few times) but on different dates. Data were analyzed on an annual time scale, so that the data set extended from t=1 to t=365 days. Only the data with the same number of measurements for standard oceanographic depths (0, 10, 20, 30, 50, 75 and 100 m) at stations 8,9,10,11,12 and 13 (Fig.1.) were used, while the data from the depths below 100m were rare, and were not considered. On the basis of the monthly mean values of bulk variables, heat and water fluxes were calculated for meteorological station Hvar.

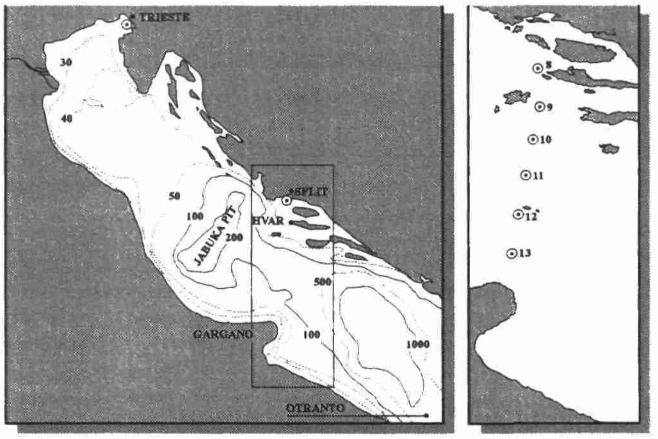

Figure 1. The transect Split-Gargano in the middle Adriatic Sea.

The situation on the 5th August 1972, when measurements were performed every six hour was used for numerical experiment. Experimental area includes station 9 on the transcect Split-Gargano. Both temperature and salinity at standard oceanographic depths were measured as well as the bulk variables. Hourly mean sum of incoming solar radiation was taken from the Split station (1).

Eddy exchanges coefficient obtained from climatological data

Using boundary conditions in finite difference form and climatological mean values for heat and water fluxes, and temperature and salinity for surface and at 10 m depth, it was possible to determine vertical eddy exchange coefficients in the surface layer: K_T and K_S.

To smooth seasonal variability, introduced using data from different years and different stations, the function of the form:

$$Y(t) = A_0 + A_1 \sin(\frac{2\pi}{T} t + \varphi_1) + A_2 \sin(\frac{4\pi}{T} t + \varphi_2), \qquad 1$$

was least-square fitted to temperature data as well as to climatological heat values. It was not possible to approximate salinity data by a harmonic function (2), so salinity means were determined averaging between months.

Eddy exchange coefficients obtained from 1D model

It is supposed that the surface layer turbulence mainly depends on the wind forcing. The divergence and vorticity of the wind induced currents in the open middle Adriatic are small (3). The wind induced currents in this case may be described with the one-dimensional model. Only the vertical mixing and the Coriolis force should be included in the model. The defined boundary conditions at sea surface describing air-sea interaction will be the governing factors in the model. The simplest method to describe air-sea interaction using the measured meteorological data is the bulk method. It is important to split this problem from a general three-dimensional model to obtain the clear idea how the boundary equations and the closure model work for the vertical exchange.

The Mellor and Yamada (4; 5) Level II closure model was taken for the closure. The Nihoul form (6) for the turbulent length scale including surface and bottom boundary layers is used. The bulk method is applied (7;8) to obtain surface boundary conditions for the heat exchange. Short wave radiation attenuation coefficients are introduced according Jerlov (9) for the optical water type IB. The trapezoidal scheme (10) is used for the Coriolis term and turbulent exchange of momentum is obtained from the implicit scheme (11). The scheme for the temperature and salinity continuity equations is the implicit scheme, the same as for the turbulent exchange of momentum.

Results

Coefficients of vertical turbulent exchange in the surface layer were first determined for both heat and salt. Surface boundary conditions were applied and climatological means were taken for heat and water flux. Function (1) was fitted to the data of heat flux and sea temperatures at 0 and 10 m. Vertical heat and salt gradients were determined from the difference between the surface and 10 m depth. Correlation coefficient between the vertical heat gradient and heat flux is 0.91 (significant at the 0.001 level). It allowed us to determine vertical exchange coefficient for heat using the least square method. Seasonal course of the vertical heat exchange coefficient is shown in Fig.2. The value obtained by the least square method is:

$K_T = (3.05 \pm 0.09) \cdot 10^{-4}\ m^2\ s^{-1}$

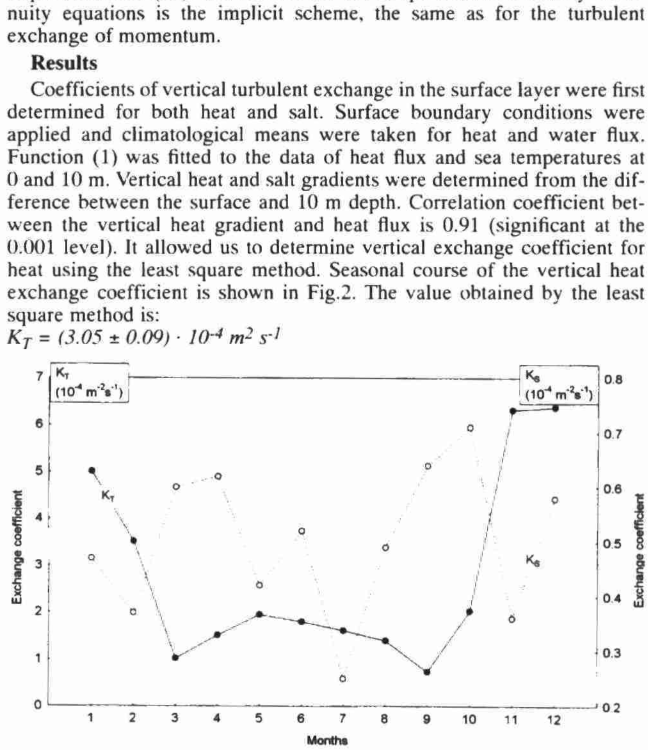

Figure 2. Monthly mean values of eddy exchange coefficients for heat and salt for the surface layer.

Salinity in the surface layer during the heating season is proportional to the differences P-E, while in autumn and winter salinity and P-E are opposed in phase. Earlier investigation (12) proved that north Italian rivers, especially the Po River, influenced waters of the Jabuka Pit. When the thermocline is well developed, lighter north Italian waters reside in the surface layer and are transported by the SE current to the Split-Gargano transect (13). They cause decrease of salinity in the surface layer. As a consequence of ice melting, the largest Po runoff is observed in May which coincides with salinity spring minimum at the transect (14; 15). Less saline water resides at the surface, since the mixing is prevented by the fully developed thermocline and it seems that the influence from the Po River inflow could be observed. For this reason, vertical coefficient of salt exchange for the surface layer is determined using different relations throughout the year, as indicated in the schema:

$$E - P = \begin{cases} E - P & \text{September - April} \\ E - (P + R) & \text{May - August} \end{cases}$$

where R denotes the quotient between the Po river inflow and the Adriatic shelf area. Taking the Po river into account, correlation coefficient between