

**SPACE-TIME SCALE DEPENDENCE OF THE HORIZONTAL EXCHANGE COEFFICIENTS****Diaconu Vasile**

Romanian Marine Research Institute-Constanța

**ABSTRACT:**

Using sea current time series recorded over the Romanian Black Sea shelf, the increase of the horizontal exchange coefficients from nearshore to offshore waters, as well as the differences in their values above and below the seasonal thermocline were shown. Their dependence on the  $2/3$  power of the averaging period was proved valid for period up to 12 hours.

The Reynolds stresses in the momentum equation for the turbulent motion can be expressed in terms of the mean velocity gradient using the turbulent exchange coefficients (3). Introduction of the "mixing length" concept (1) allows the coefficients to be computed from the measured sea current velocity fluctuations using the method proposed by ERTEL (4).

With a view of quantitatively evaluating the turbulent exchange coefficients for the Romanian Black Sea shelf waters, five sea current time series recorded in the summer period were used (Tab. 1).

During the recording period, there was a sharp seasonal

Table 1

Location and characteristics of sea current records

No.	Offshore distance (nmi)	Water depth (m)	Currentmeter depth (m)	Sampling interval (min)	Record length (hours)
1	30	52	10	10	90
2	30	52	10	5	50
3	30	52	30	5	50
4	1	10	1	15	160
5	1	10	9	15	160

thermocline at the depth of about 20 m in the offshore sites. There were no temperature profile data available for the nearshore sites. All currentmeters were of the ALEXAEV type, attached to sub-surface buoy moorings.

A computer program for processing the data in order to obtain the turbulent exchange coefficients was written for the Felix C-256 system. The program calculates the velocity components, their average values over a selected period of time, the deviations of the actual velocity components and, eventually, the exchange

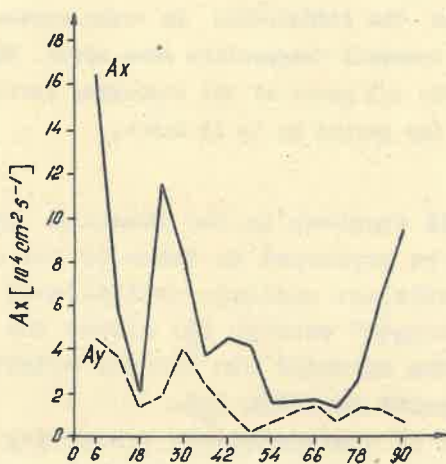
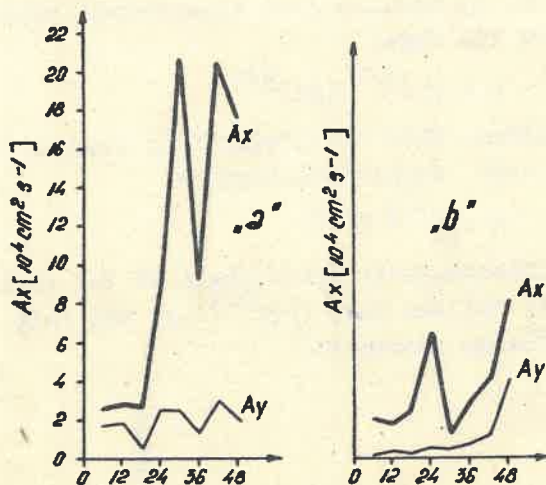


Fig. 1 - Time evolution of the turbulent exchange coefficients for the series no. 1.



**Fig.2** - Time evolution of the turbulent exchange coefficients for the series no.2 (a) and 3 (b).

coefficients by the ERTEL's algorithm.

The results obtained using a 6 hours period for averaging showed a high time variability for all the records used in computations (Fig.1-3), the values of the maximum exchange coefficient  $A$  being confined within  $2.9 \times 10^4 - 34.6 \times 10^4 \text{ cm}^2/\text{s}$  in the offshore sites, and within  $1.0 \times 10^4 - 30.5 \times 10^4 \text{ cm}^2/\text{s}$  in the nearshore ones. It can also be seen that for the simultaneous records no.2 and no.3 (Fig.2) the coefficients below the thermocline are 3-4 times smaller than those in the upper layer, where the kinetic energy turbulent transfer from the atmosphere takes place.

For all the series, the computed coefficients increased with the increase of the averaging period and of the sampling interval (Fig.4-6). According to GEZENTZVEI (1) there is a "2/3 power" relationship between coefficients and the averaging period:

$$A = CT^{2/3} \quad (1)$$

where  $A$  is the horizontal turbulent exchange coefficient,  $T$  is the averaging period and  $C$  is a constant. Furthermore, assuming

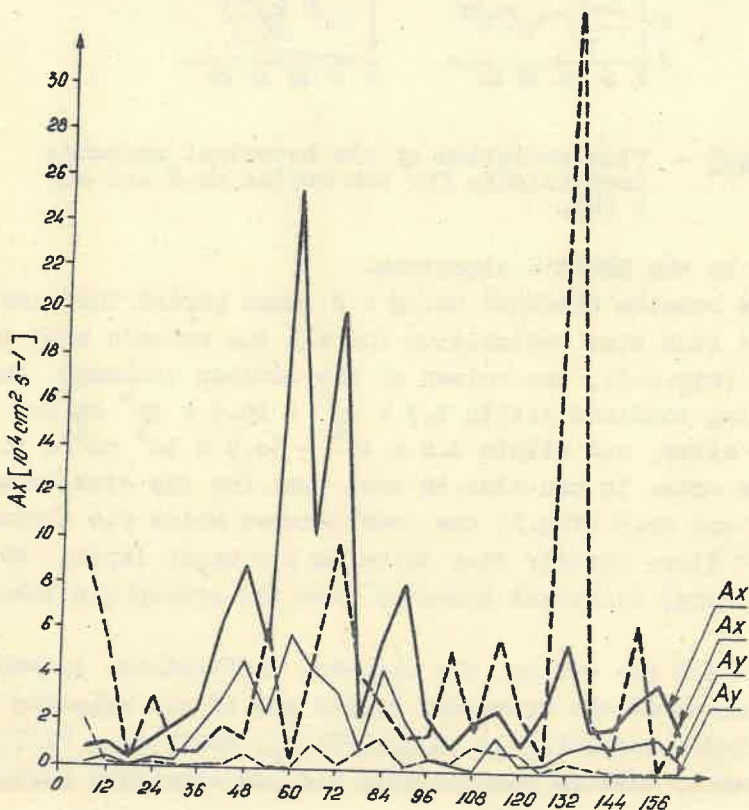
that  $C$  depends on the molecular viscosity  $\mu$  and on the energy dissipation rate  $\mathcal{E}$ , it results from dimensional considerations that (1) must have the form:

$$A = m \mathcal{E}^{1/3} (\mu T)^{2/3} \quad (2)$$

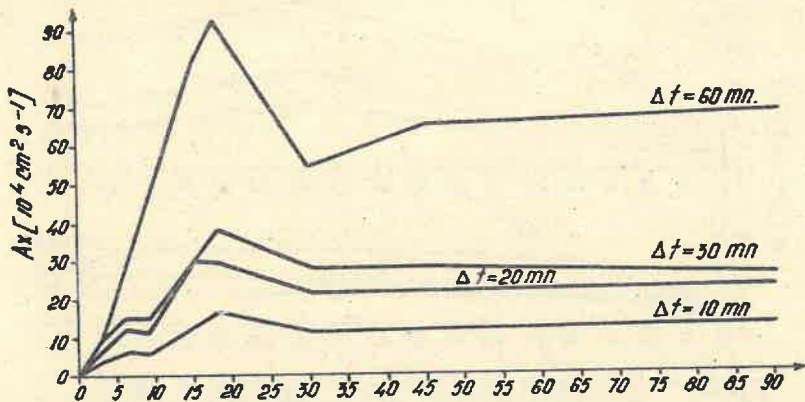
where  $m$  is a constant. This relationship is similar to the well known "4/3 power law" RICHARDSON-OBUKHOV:

$$A = c \mathcal{E}^{1/3} L^{4/3} \quad (3)$$

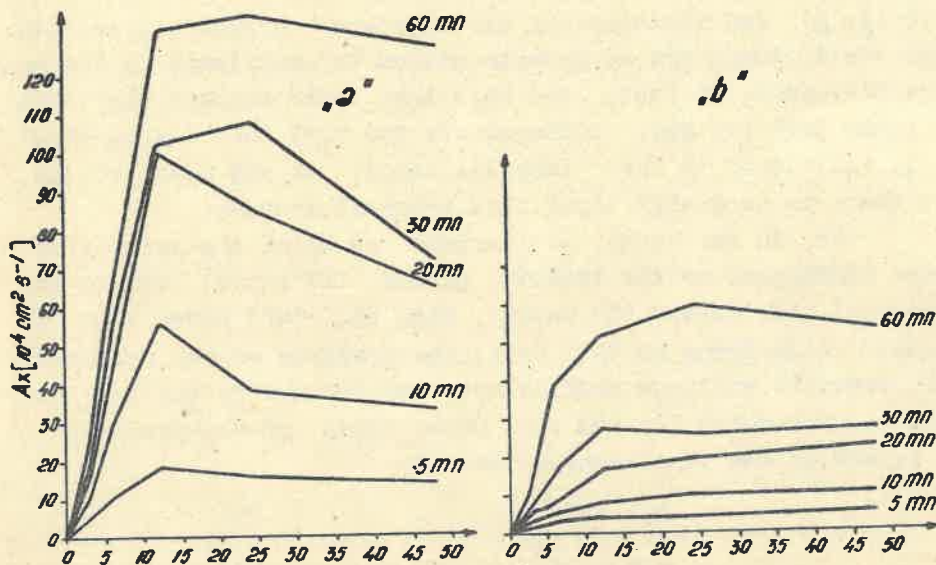
where  $L$  is the characteristic space scale of the phenomenon. From this similarity it follows that  $(\mu T)^{2/3}$  has the role of a length scale for the exchange processes.



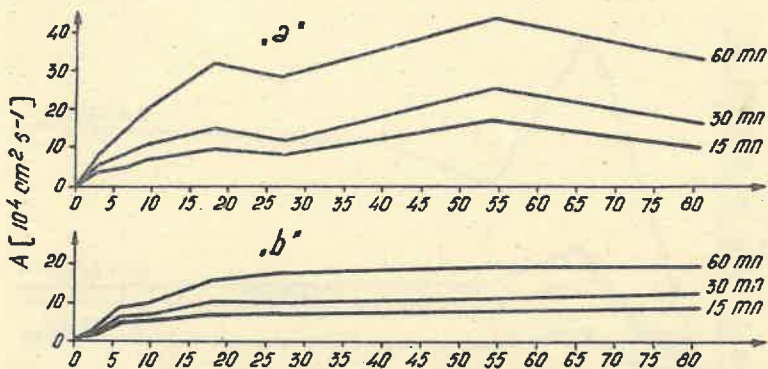
**Fig.3** - Time evolution of the turbulent exchange coefficients for the series no.4 (a) and 5 (b).



**Fig. 4** - Exchange coefficients variation as a function of the averaging period and sampling interval-series no. 1.



**Fig. 5** - Exchange coefficients variation as a function of the averaging period and sampling interval-series no. 2 (a) and 3 (b).



**Fig. 6** - Exchange coefficients variation as a function of the averaging period and sampling interval-series no. 4 (a) and 5 (b).

But, for all the five analysed series the increase of the horizontal exchange coefficients is limited to averaging periods of about 12-18 hours. This "saturation effect" was observed before (2; 6) and explained by the fact that beyond a specified length scale there are no greater eddies to contribute to the exchange processes. In fact, one must take into account that the "4/3 power law" (4) and, consequently the "2/3 power dependence" (3), is valid only in the "inertial range" of the space scales, where there is no energy input from external sources.

Or, in our cases, the periods at which the saturation appears correspond to the inertial period (17 hours) and to the semidiurnal tide period (12 hours), when the "4/3 power law" is no longer valid. Owing to this fact, the analysis of the variation of the computed exchange coefficients was limited to the 1-12 hours range, for which (2) and two other types of relationships were fitted by the least squares method:

$$A = aT^m t^n \quad (4)$$

$$A = b T^m \quad (5)$$

where  $t$  is the sampling interval.

The results showed little change in  $m$  between the series, but its values were still close to 0.67. The values for the  $n$  exponent were within 0.7-0.8 for the offshore series and within

0.4-0.5 for the nearshore records, for sampling intervals of the order of 5-30 minutes. The analysis of the scattering of the computed values of the coefficients on both sides of the fitted curves showed that using a particular  $m=0.67$  for each series did not sensibly improve the fit quality. Thus, it can be stated that the "2/3 power" relationship expressed by (2) is well suited for describing the horizontal exchange coefficients dependence on the averaging period, if the latter does not exceed 12 hours (Fig.7).

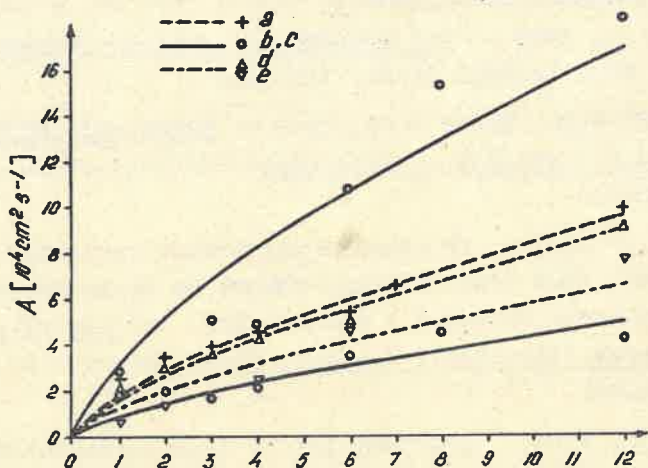


Fig.7 - Turbulent exchange coefficients dependence on the averaging period-series 1-5 (a-e).

The observed scattering can be further reduced by using a digital filter for smoothing the original record (2; 7; 8) but in this case the coefficients are smaller by 1-2 orders of magnitude due to the fact that the contribution of the small eddies to the velocity component fluctuations is "filtered out".

The results obtained in the Romanian shelf waters show that the coefficients computed by ERTTEL method can properly describe the turbulent energy transfer if the averaging period does not exceed 12 hours. The sampling interval must be of 5-15 minutes if one wishes to investigate small scale phenomena (5). Also, there is a further need of more data in order to assess the influence of the hydrological conditions such as wind effect, water

mass stratification, sea state and shore and bottom limiting effect on the horizontal exchange coefficients.

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