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Evaluation of Some Dynamical Parameters at the Central Red Sea during Early Summer

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Abstract. The horizontal circulation pattern of the Red Sea shows that the maximum turbulent mixing zone is in the central area. The dynamical computation of the turbulent vertical mixing parameters: Richardson Number (Ri), Reynolds Stress (J_m) and Diffusive Salt Flux (J_s) have been carried out at the central area of the Red Sea. The Ri values show the occurrence of dynamical stability with magnitude greater than 1/4 along the three selected stations. The Reynolds stress results show an upward vertical flux at station II between surface and 40m and near surface at station III. The maximum value of upward momentum flux is -4.71 x 10^{-3} Pa. The distribution pattern of J_s is analogous to that of K_s as both distributions reveal that the magnitude of these two mixing parameters decreases relatively with depth.

Keywords: Vertical mixing, dynamic instability.

Introduction

The horizontal circulation pattern of the Red Sea appears to consist of a number of gyres or eddies distributed along the length of the Sea and has its maximum turbulent mixing zone at the centre of it (Quadfasel and H. Baudner, 1993). Therefore, the study of mixing parameters at this area is important to explore the dispersion of pollution, biological productivity assessment which is necessary for fishery industry and turbulent flow controls exchanges of both mass and momentum between the corals and the overlying water.

The vertical turbulent mixing has been carried out by many scientific studies. Sharaf El-Din (1964) investigated the mixing process in the

North Sea and computed the Eddy coefficient of viscosity. Johnson (1996) studied mixing in the Gulf of Cadiz, Libya by carrying out viscous dissipation measurements. Other scientists as Rossa and Lueckb (2005) estimated turbulent dissipation rates from high frequency (10 KHz to 1 MHz) acoustic backscatter. Munka and Wunschb (1998) studied the energetic of tidal and wind mixing and estimated the tidal energy by about 3.7 TW (2.5 TW from M2 alone). Most of this energy is dissipated in the turbulent bottom boundary layers of marginal seas.

Kobayashia *et al.,* (2006) estimated the total dissipated energy for the M2 at Seto Inland Sea, Japan to be about 3.4×10^9 W, and found that the tidal stirring has an essential role in controlling density stratification.

Tidal currents generate an upwelling mechanism which enhances the dynamical processes of vertical turbulent mixing. Hornea *et al.,* (1996) used measurements of velocity microstructure to confirm that vertical mixing rates at Georges Bank, Canada are primarily due to tide, although wind forcing also contributes significantly.

Data and Analysis

A scientific expedition was launched to explore the marine natural resources at the central area of the Red Sea during the period from 28th April to 20th May 1979. The research program was planned to extend for one year; unfortunately, it was terminated after only one month. Measurements of the vertical distribution of temperature, salinity and current field utilized in this investigation, were obtained at five neighboring stations as shown in Fig. 1 and Table 1.

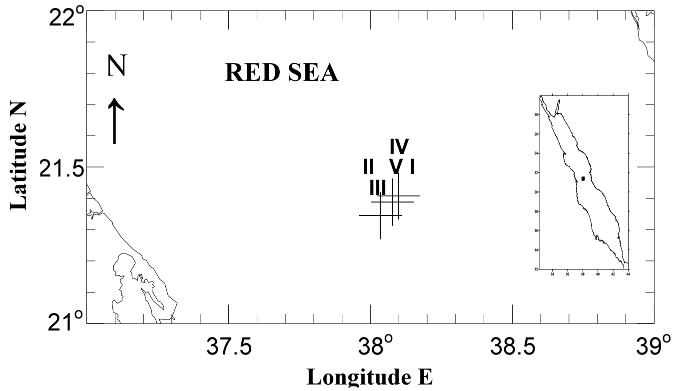

Fig. 1. Study area and stations.

Table 1. Date and geographical position of stations.

Station No.	***Longitude***	***Latitude***	**Date**
I	38° 5.95' E	21° 24.47' N	28/4/1979
II	38° 2.1' E	21° 20.7' N	28/4/1979
III	38° 2.1' E	21° 20.7' N	8/5/1979
IV	38° 4.7' E	21° 23.3' N	11/5/1979
V	38° 4.7' E	21° 23.3' N	20/5/1979

Results and Discussion

A- Richardson Number

In oceanography the Richardson number has a more general form which takes stratification into account. It is a measure of relative importance of mechanical and density effects in the water column.

$$Ri = N^2 / (du / dz)^2$$

where *N* is the Brunt-Vaisala frequency.:

The Richardson number defined above is always considered positive. An imaginary *N* indicates unstable density gradients with active convective overturning. Under such circumstances, *N* does not have an accepted physical meaning and the magnitude of negative *Ri* is not generally of interest. When *Ri* is small (typically considered below 1/4), then velocity shear is considered sufficient to overcome the tendency of a stratified fluid to remain stratified, and some mixing will generally occur. When *Ri* is large, turbulent mixing across the stratification is generally suppressed (Pond and Pickard, 1983).

Figure 2 shows the vertical distribution of Ri at three selected stations. The Ri values show the occurrence of dynamical stability with magnitude greater than 1/4. The minimum value of Ri is -1.2×10^{-1} at 5m; the maximum value is 4.68×10^{3}. The small negative value of Ri detected near the surface indicates that vertical mixing process has occurred at this layer.

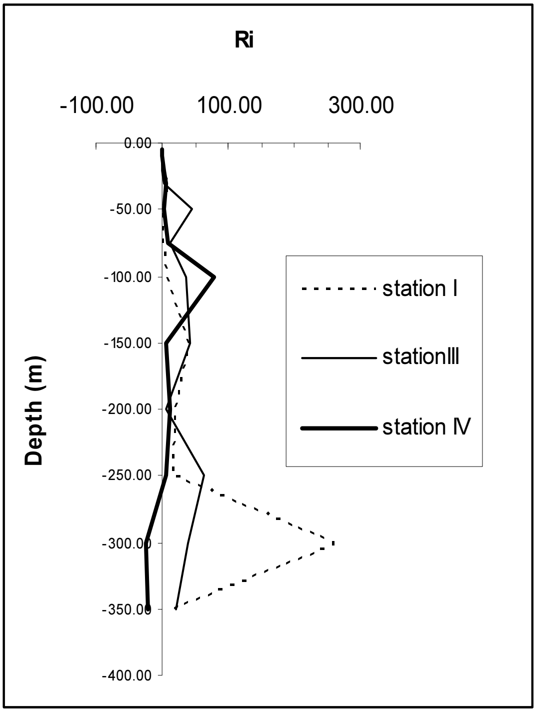

Fig. 2. Vertical distribution of Richardson Number.

B- Reynolds Stress

Reynolds Stress is the stress tensor in a fluid due to the random turbulent fluctuations in fluid momentum. So, the Reynolds Stress profile illustrates the vertical turbulence flux of momentum and is defined by:

$$J_m = -\rho K_m \frac{\partial \left\| \vec{V} \right\|}{\partial z}$$

The Eddy viscosity (K_m) is defined in terms of the molecular viscosity (μ) and density (ρ) by:

$$K_m = \mu / \rho$$

The vertical transport of momentum is generally directed downwards as shown in Fig. 3. As the negative sign of flux indicate that the vertical transport is directed upwards and vice versa, upward vertical flux can be detected at station II between surface and 40m and near surface at station III. The maximum value of upward momentum flux is -4.71×10^{-3} Pa while the maximum value of downward momentum flux is 1.25×10^{-3} Pa. The average vertical flux of momentum is 1.01×10^{-3} Pa.

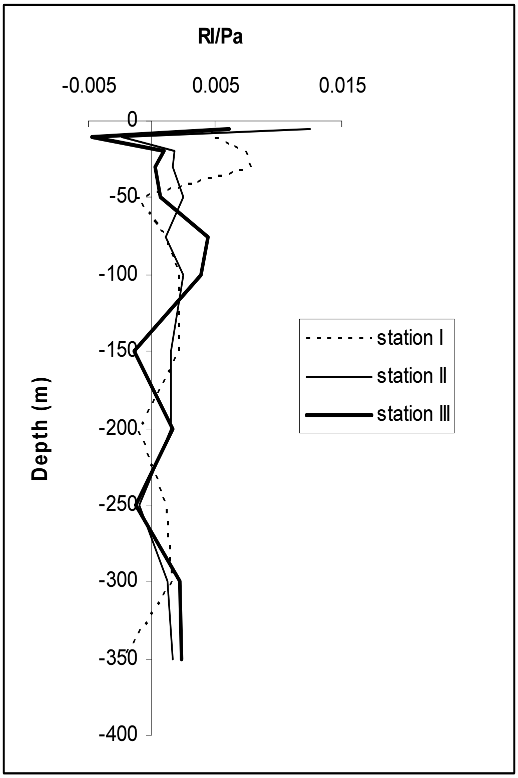

Fig. 3. Vertical distribution of Reynolds stress.

C- Diffusive Salt Flux

This dynamical mixing parameter resembles the vertical turbulent transport of salt and is defined by:

$$J_s = 10^{-3}\,\rho\,K_s\,(\partial S / \partial Z)$$

As $K_s = 0.2(\epsilon / N^2)$

K_s is Eddy coefficient of diffusivity of salt and ϵ is Viscous Dissipation

The numerical results, Fig. 4, shows that the distribution of J_s is analogous to that of K_S as both distributions reveal that the magnitude of these two mixing parameters decreases relatively with depth. All station except station I have relatively strong salt vertical fluxes near the surface which is probably a result of excess process of evaporation. The minimum vertical salt flux is -5×10^{-7} kg m^{-2} s^{-1} attained at station I at depth 75m.; the maximum vertical salt flux is 3.44×10^{-5} kg m^{-2} s^{-1} at station III. The average vertical salt flux is 9.35×10^{-7} kg m^{-2} s^{-1}.

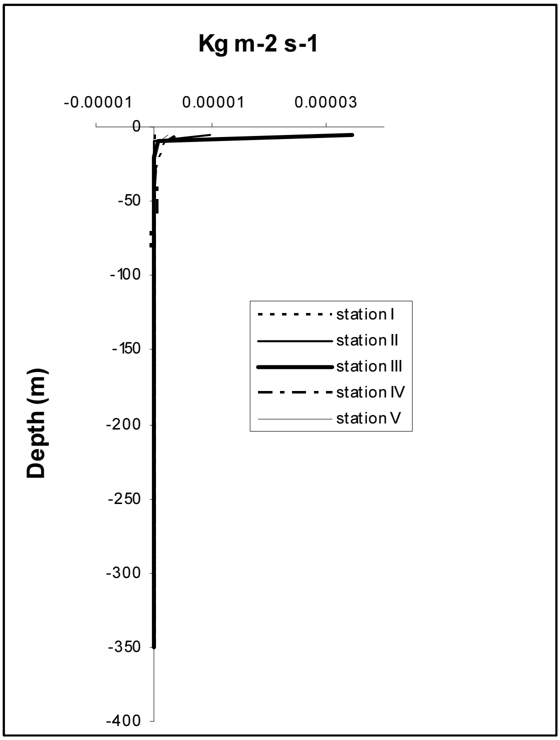

Fig. 4. Vertical distribution of Diffusive Salt Flux.

Summary and Conclusions

Measurements of the vertical distribution of temperature, salinity and current are used to calculate the dynamical computations of the vertical turbulent mixing parameters. The Ri values show the occurrence of dynamical stability with magnitude greater than 1/4 along the three stations selected. The small negative value of Ri detected near the surface indicates that vertical mixing process occurred at this layer. Upward vertical flux can be detected at station II between surface and 40m and near surface at station III. The maximum value of upward momentum flux is -4.71×10^{-3} Pa while the maximum value of downward momentum flux is 1.25×10^{-3} Pa. All stations except station I have relatively strong salt vertical fluxes near the surface which is probably a result of excess process of evaporation. The minimum vertical salt flux is -5×10^{-7} kg m^{-2} s^{-1} attained at station I at depth 75m; the maximum vertical salt flux is 3.44×10^{-5} kg m^{-2} s^{-1} at station III. The average vertical salt flux is 9.35×10^{7} kg m^{-2} s^{-1}.

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تقييم لبعض العناصر الديناميكية لمنطقة وسط البحر الأحمر في وقت مبكر من فصل الصيف

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المستخلص. إن دراسة الدورانات المائية لمنطقة وسط البحر الأحمر تتطلب حساب ودراسة العناصر الديناميكية للاضطراب الخلطي الرأسى لهذه المنطقة. لذلك تم استخدام قياسات درجة الحرارة و الملوحة وسرعة التيار لمنطقة وسط البحر الأحمر لحساب بعض عناصر الخلط والاضطراب الرأسية مثل:
Richardson Number (Ri), Reynolds Stress (J_m) and Diffusive Salt Flux (J_s).
إن دراسة Ri تعتبر مقياسًا نسبيًا لأهمية التأثيرات الميكانيكية وتأثير الكثافة على عمود الماء فقد أظهرت قيم Ri استقرارًا ديناميكيًا بمقدار يعد أكبر من ٤١١ خلال عمود الماء لثلاث محطات. أيضًا ظهرت بعض القيم السالبة ل Ri قرب الطبقة السطحية، وهذا يدل على وجود خلط رأسي خلال هذة الطبقة. وحيث أن حسابات (J_m) تظهر كمية الضغط الشاذ الناتج عن الاضطراب الخلطي الجزافي لطاقة الحركة لعمود الماء، فقد أظهرت المحطة رقم ٢ وجود تيار رأسي متجه إلى أعلى في الطبقة ما بين السطح وعمق ٤٠ مترًا وبالقرب من السطح في المحطة رقم ٣. كما أظهرت النتائج الرقمية لتوزيعات (J_s) تطابقًا كبيرًا مع التوزيعات الناتجة عن حساب K_s من حيث الانخفاض النسبي للقيم مع العمق. أيضًا أظهرت كل المحطات ماعدا المحطة رقم١، وجود تيار ملحي رأسي بالقرب من السطح ناتج عن زيادة البخر في هذه المنطقة.