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Contribution of Water Density to Sea Level Fluctuations in Red Sea

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ABSTRACT. The temporal and spatial variations of steric components and their contribution to the fluctuations of Red Sea level are calculated for the upper 300m layer during different seasons using all available climatologically hydrographic data. The temporal variations of steric components showed that the sea level of the Red Sea as a whole is depressed by about 4.5cm during winter (due to higher density) and raised by about 3cm during summer (due to lower density). The spatial variations showed that the sea level of the Red Sea is depressed at northern regions by about 8-14cm (due to lower temperature and higher salinity) and raised at southern regions by about 11-16cm (due to higher temperature and lower salinity) during the different seasons. In general, the total steric departure from mean sea level is mainly thermal at most regions of the Red Sea except at southern ones where it is haline. The relations between the steric components and the hydrographic parameters are linear. It is positive for thermal departures and negative for haline and total steric departures.

Introduction

The density of sea water *in situ* is an important parameter not only for the dynamics processes, but also as one of considerable significance with regard to study of variation in sea level. Pattullo *et al.* (1955) introduced the term "steric" sea level. The steric sea level is defined in terms of the seasonal fluctuations in specific volume of the sea water. The steric sea level is high when the water is warm, low when it is cold. Conversely, a high steric level corresponds to a low value of salinity. Thus, the seasonal variations of the density within the water column, from which steric departures from mean sea level can be calculated, are dependent on the seasonal variations of thermal and haline structure of that column.

Morcos (1970) found that the level of the sea in the Red Sea is strongly influenced in the long-term by the rate of evaporation and the balance between inflowing and outflowing water.

Patzert (1972) discussed the principal causes of sea level fluctuations in the Red Sea. He concluded that the predominant factors affecting the sea level fluctuations are winds, circulation patterns and hydrographic structure of the sea. In the northern and central regions of the sea, evaporation, atmospheric pressure and steric variations are not the controlling factors in the oscillation of the mean sea level in these regions, their net effect is to diminish the rise and fall in the monthly mean sea level. In the southern Red Sea, the atmospheric pressure and steric variations account for almost all of the variations in mean sea level. He considered the seasonal variations of steric sea level as seasonal variations of monthly mean geopotential relative to the level where there are no seasonal variations (300m level).

Abdallah and Eid (1989) studied the distribution of steric components at different regions in the Red Sea during winter and summer seasons. The steric sea level in the southern regions of the sea is higher than that in the northern parts by estimated values of about 19cm in winter and 23cm in summer. Also, they found that the steric factor is considered to be one of the controlling factors that affect sea level fluctuations in the northern Red Sea during the summer and in the southern regions in winter.

Eid and Abdallah (1994) studied the relations between the steric components and the hydrographic parameters in the Red Sea. They found a linear relation between them. It was positive for thermal components and negative for haline and total steric components. These linear relations slightly differ with depth.

The present work is an attempt to study the seasonal distribution of steric compounds (thermal, haline and total steric departures) over the Red Sea and try to get relation between the hydrographic conditions and the steric fluctuations in the different regions of the Red Sea.

Materials and Methods

All the available hydrographic data, concerning temperature and salinity, taken in the Red Sea up to 1998 were used to calculate the steric components in the sea. Data were obtained from World Ocean Atlas 1998 (WOA98), CD-Rom Documentation, version 1.0, Ocean Climate Laboratory, National Oceanographic Data Center, April 1999.

It is known that, the seasons in the Red Sea considered as two main seasons, winter (from December to March) and summer (from June to September), and two transitional periods, spring (April-May) and autumn (October-November). In this study we choose one month to represent each season, February represents winter season, May represents spring, August represents summer and November represents autumn.

The data were measured at standard depths. To obtain better quality hydrographic data, the unstable stations were corrected for temperature and/or salinity. It is worthy to mention that only a few observations were rejected because of their poor quality, perhaps due to personal, instrumental and/or location error. Using the above randomly distributed temperature and salinity data, the values at nodal grid points were calculated for each season. The Red Sea was covered by 20 gridded stations. Figures 1a&b show the stations taken at each season and the grid stations used in this analysis. The latter gridded data are used in the calculation of steric components using Pattello *et al.* (1955) equations:

$$Zt = \frac{1}{g}\int_{pa}^{po}\left(\frac{\partial\alpha}{\partial T}\right)\Delta T dp$$

$$Zs = \frac{1}{g}\int_{pa}^{po}\left(\frac{\partial\alpha}{\partial S}\right)\Delta S dp$$

$$Z\alpha = \frac{1}{g}\int_{pa}^{po}\Delta\alpha dp$$

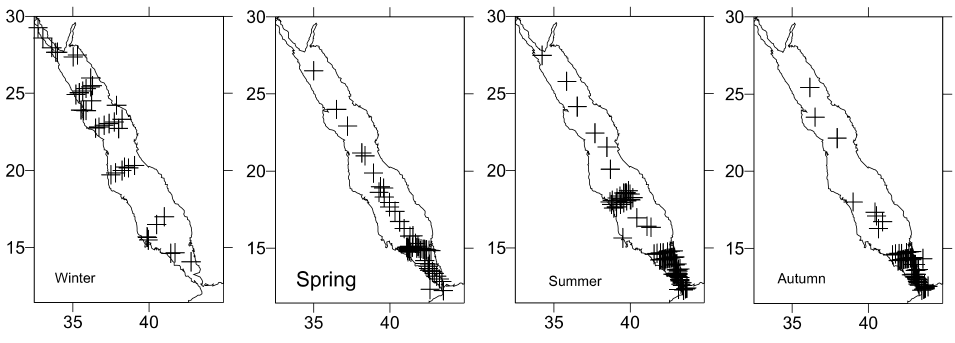


FIG. 1(a). Location of hydrographic stations used in the present study.

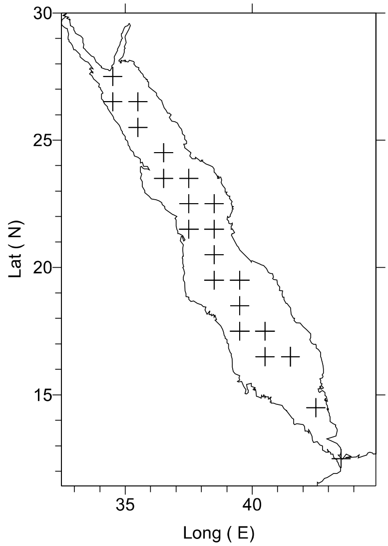


FIG. 1(b). Location of grid stations.

Where Zt, Zs and Zα are thermal, haline and total steric departures from mean sea level respectively, g is the acceleration of gravity, p_a is the atmospheric pressure, p_o the pressure (depth) where all seasonal effects vanish (300 db), Δt and ΔS for any depth designate the seasonal departures in temperature and salinity from their long period annual averages TB and SB. $\Delta\alpha$ is the departure in specific volume (steric departure) due to small ΔT and ΔS and is given by:

$$\Delta\alpha = \alpha(T,S,P) - \alpha(TB,SB,P) = (\partial\alpha/\partial T)\,\Delta T + (\partial\alpha/\partial S)\,\Delta S + \ldots$$

where $(\partial\alpha/\partial T)$ and $(\partial\alpha/\partial S)$ are to be evaluated at TB(P) and SB(P).

The above equations are programmed in Fortran language and the program is run three times.

I) The first run is done by taking TB and SB as the annual mean at each grid station at different levels (average four seasons). This method is useful to compare the steric fluctuations from one season to another at each station and each region. We called this way the seasonal variation of steric components (or temporal variations).

II) The second run is done by taking TB and SB as the average values of temperature and salinity for each season at different levels (average 20 grid stations). This way is carried out to compare the steric heights from one region to another (from north to south) at each season. We called this way the regional variations of steric components (or spatial variations).

III) The third run carried out for TB and SB represented as the average temperature and salinity for all data at different levels *i.e.* average 80 grid stations

(4 seasons × 20 grid stations). This run is taken to compare the steric components from season to season as well as from region to another at each grid station (*i.e.*, run I + run II). This way is called seasonal and regional variations of steric components (or temporal and spatial variations).

The steric heights are calculated at each grid station and then it averaged at four regions to give a quick picture to their variations over the Red Sea. The regions are chosen according to latitudes and represented as:

Region I lie between 22-28ºN; Region II lies between 20-22ºN; Region III lies between 17-20ºN and Region VI lies between 13-17ºN (Fig. 1c).

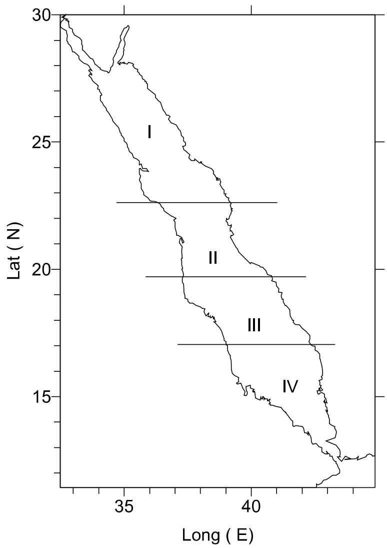


FIG. 1(c). Selected regions of Red Sea.

For obtaining the relationship between steric components (thermal, haline and total steric departures) and the hydrographic parameters (temperature, salinity and water density), the results of calculation of spatial variations (Run II) and results of temporal and spatial variations (Run III) of steric components during different seasons are fitted with the hydrographic parameters using the least square method.

Results and Discussion

1) Horizontal Distributions of Steric Components

a – Temporal Variations of Steric Components

The steric components (thermal, haline and total steric departures) are calculated for the upper 300m layer at each grid station relative to the annual mean values of hydrographic data (Run I). The computed values give the variability of steric components at each station from season to season, *i.e.* a temporal variations of steric components at each station. The horizontal distributions of these components (in cm) in the Red Sea during different seasons are shown in Fig. 2-4.

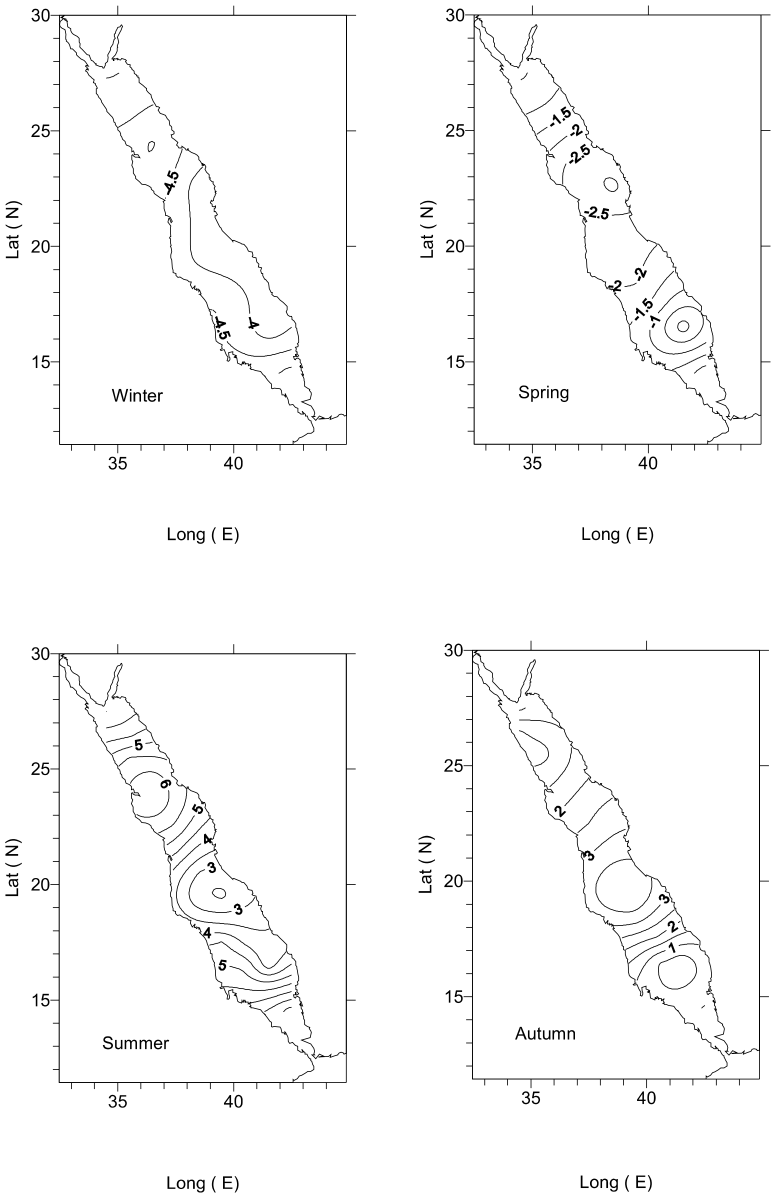


FIG. 2. Temporal variation of thermal departures from mean sea level in Red Sea during different seasons.

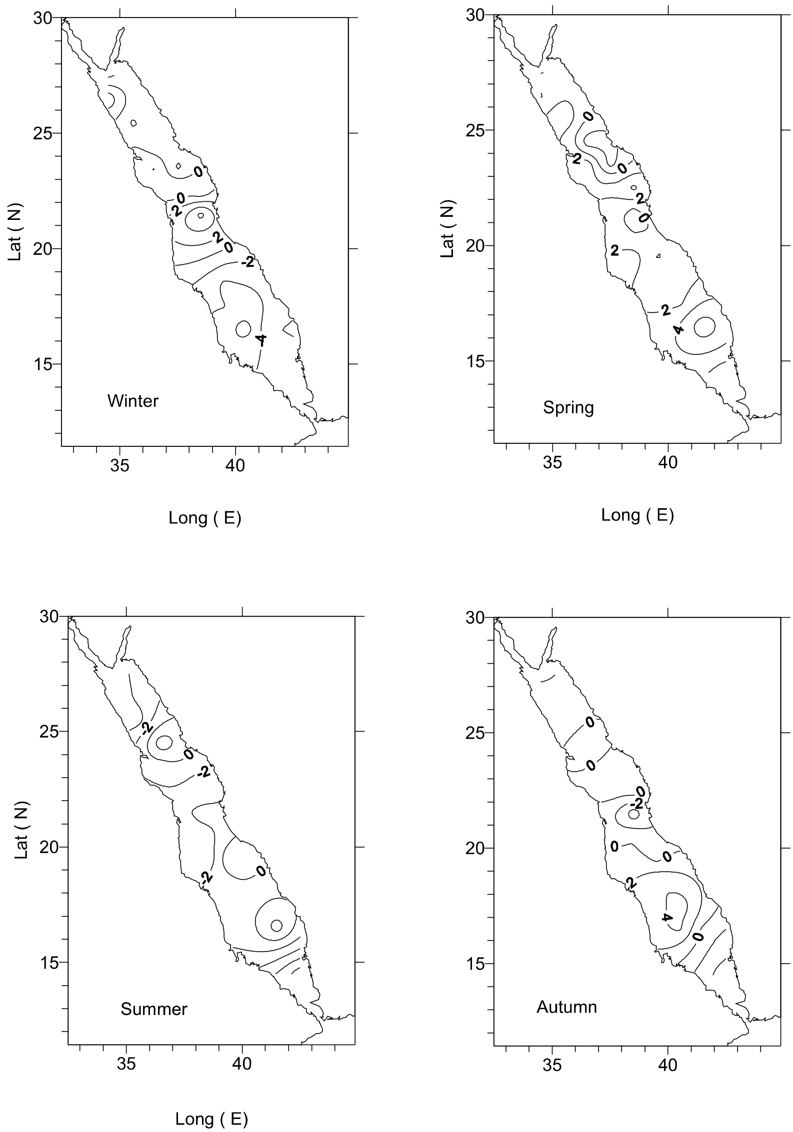


FIG. 3. Temporal variation of haline departures from mean sea level in Red Sea during different seasons.

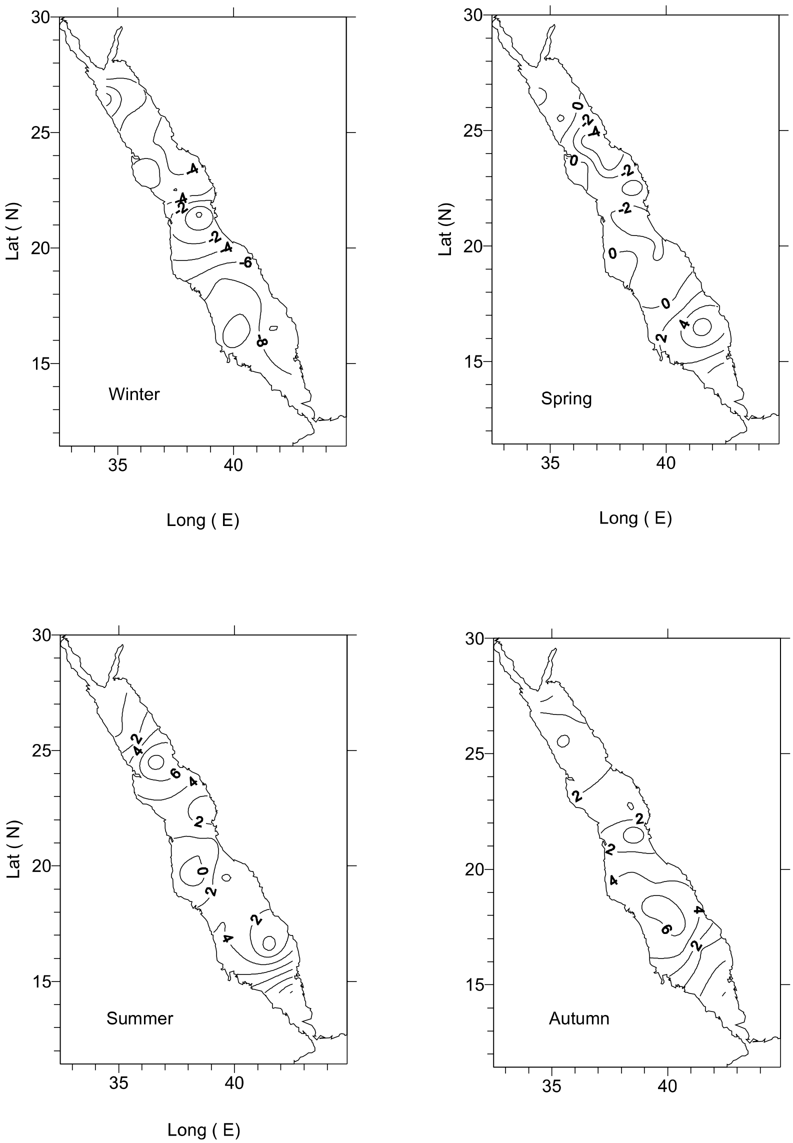


FIG. 4. Temporal variation of total steric departures from mean sea level in Red Sea during different seasons.

i. Thermal Departures

Figure 2 shows the distribution of thermal departures from mean sea level (Zt) in Red Sea during different seasons. It is clear that the values of (Zt) are negative during winter and spring, while they are positive during summer and autumn. Negative thermal departure results when water temperature is lower than the annual mean temperature and vice versa. Thus, the contours of (Zt) reflect the temperature distribution (for 300m layer) over the Red Sea.

During winter, the values of (Zt) fluctuated between –3.7cm (at central regions) and –5cm (at northern and southern regions). On average, the sea level over the Red Sea is depressed by about 4cm.

During spring, the (Zt) values varied between –3cm (at central region II) and 0.25cm (at southern region IV) with average value of –1.8cm for Red Sea as a whole. During summer, the sea level is raised due to the thermal component of steric departures. The thermal height ranges between 2.5cm (at central regions) and about 6cm (at northern region) and 7cm (at southern region). The average value of thermal height for the whole Red Sea is about 4.5cm.

During autumn, the water temperature slightly decreases and consequently the thermal height decreases. The sea level due to thermal departure changed between 0.2cm (at southern region) and about 4cm (at region III). The average value of thermal departure from mean sea level during this season for the Red Sea is about 2cm.

ii. Haline Departures

The distribution of haline departures from mean sea level in Red Sea during different seasons are shown in Fig. 3. A decrease in salinity will be accompanied by a decrease in density which will, in turn, be responsible for the increase in the volume occupied by a given mass of water. Consequently, a negative departure of salinity from the annual mean salinity will result in a positive haline departure from mean sea level, and vice versa.

During winter, the haline height (Zs) oscillates between –6.7cm (at region IV) and 6.7cm (at region II). It is seen that the positive values occupied the northern regions of the Red Sea, while the positive ones occurred at southern regions. It means that the salinity in the northern regions is lower than the annual mean values during this season, while it is higher at southern regions. This pattern reflects the salinity distribution within the upper 300m layer (Table 1). The Red Sea depressed, as a whole, by about 0.5cm during winter.

During spring, in general, the haline departures over the whole Red Sea is positive except at few stations, *i.e.*, its mean salinity is lower than the annual mean. It changed between –3cm in region I and 7.4cm in region IV. The Red Sea is raised by about 1.5cm due to the salinity effect on sea level during this season.

During summer, the sea fluctuated due to haline departure between –5cm and 7cm. The low value is observed in northern regions, while the higher one is found at southern region near Bab El-Mandab strait. The mean salinity during this period is generally higher than the annual mean over the most regions of the Red Sea. Thus, the sea as a whole, is depressed (by about 1.5cm) during summer.

During autumn, the haline departures from mean sea level vary between –8cm and 5cm. The lower values are observed at region II and region IV, while the higher value is found at region III. The average values of haline departures over the whole Red Sea showed an increase in sea level height during this season by about 0.5cm.

iii. Total Steric Departures

The distributions of total steric departures from mean sea level in the Red Sea are shown in Fig. 4. The total steric component is the situation of sea level in Red Sea under the effect of both temperature and salinity together, *i.e.*, under the effect of water density. The total steric departure is negative (high density) during winter and spring seasons, while it is positive (low density) during the rest of the year.

During winter, the total steric effect on sea level variation is relatively strong. It varies between –11cm at southern region and 2.7cm at central region. The Red Sea is depressed as the total effect of both temperature and salinity by about –4.8cm.

During spring, the steric height is relatively small especially at northern and central regions of the Red Sea. It changed between –5cm in northern region and 7cm in southern one. On average, the sea level depressed by about 0.2cm.

During summer, the total steric height is positive at most stations in Red Sea. It fluctuated between –1cm at northern stations and 14.5cm at southern station. The Red Sea is raised during this season under the effect of water density by about 2.9cm. During autumn, the steric height oscillated between –2cm and 7cm. Also, the Red Sea as a whole is raised by about 2.7cm.

The average values of steric components at different regions of the Red Sea as well as for the Red Sea as a whole are shown in Table 1. It is clear that, the steric effect during winter is mainly thermal at all four selected regions. The haline component has a notable effect only at southern regions. The contribution of both thermal and haline departures is counter phase during spring, so their effect on the total steric height is relatively small, except at southern region where the haline height is more effective. During summer, the steric effect is mainly thermal. The effect of haline component, especially at northern regions, is decreasing the rise of sea level due to the thermal component. Again, the steric height during autumn is mainly thermal.

TABLE 1. Temporal variation of steric components (in cm) at different regions of the Red Sea.

Component	Region	Seasons			
		Winter	Spring	Summer	Autumn
Thermal (Zt)	23-28ºN	–4.56	–1.54	5.14	1.58
	20-23ºN	–4.02	–2.63	4.28	2.99
	17-20ºN	–4.06	–1.83	3.35	3.07
	13-17ºN	–4.33	–0.93	5.30	0.59
	Red Sea	–4.27	–1.79	4.50	2.15
Haline (Zs)	23-28ºN	1.08	0.72	–2.39	0.60
	20-23ºN	1.83	1.47	–2.44	–0.84
	17-20ºN	–0.03	1.36	–0.73	2.42
	13-17ºN	–3.80	4.08	0.24	–0.51
	Red Sea	–0.49	1.57	–1.59	0.53
Total steric ($Z\alpha$)	23-28ºN	–3.48	–0.82	2.75	2.18
	20-23ºN	–2.19	–1.16	1.84	2.15
	17-20ºN	–7.09	–0.47	2.62	5.49
	13-17ºN	–8.13	3.15	5.54	0.08
	Red Sea	–4.76	–0.22	2.91	2.68

b – Spatial Variations of Steric Components

To compare between the variability of steric components from one region to another along the Red Sea through a certain season, the steric components are calculated on the basis of the deviation of hydrographic parameters at each station from the average values of all data during this season at different depths. This method gives no oscillation of sea level over the Red Sea as a whole due to the steric effect at each season because the summation of positive and negative values of steric departures are equal. Figures 5, 6 & 7 show the horizontal distribution of these spatial variations of steric components during different seasons.

i. Thermal Departures

The distribution of spatial variation of thermal departures from mean sea level for each season is shown in Fig. 5. It is seen that, the thermal height is almost negative at northern region (I) of Red Sea and positive at the rest. The positive

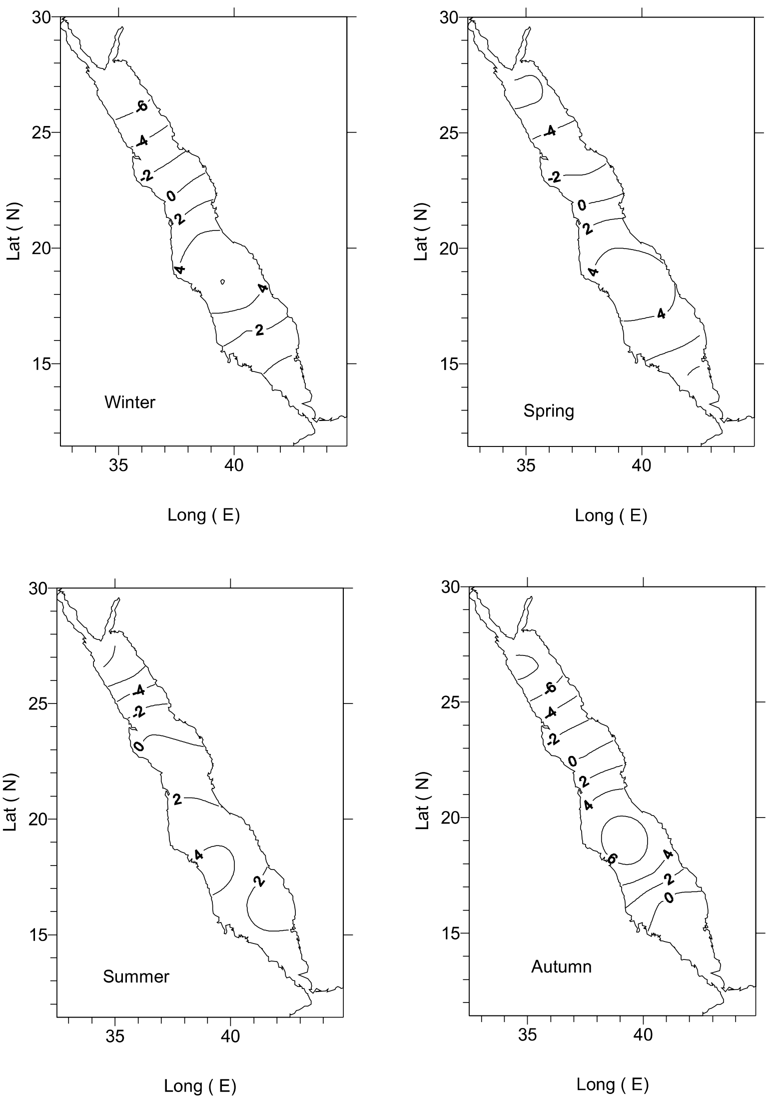


FIG. 5. Spatial variation of thermal departures from mean sea level in Red Sea during different seasons.

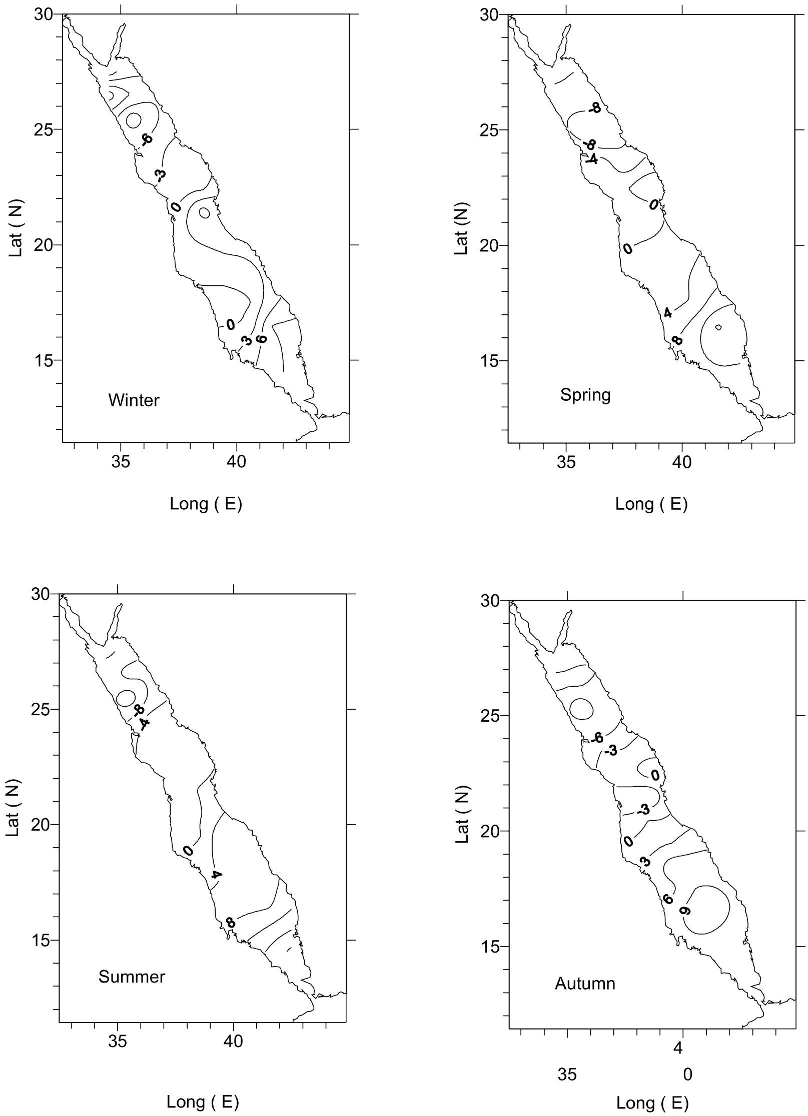


FIG. 6. Spatial variation of haline departures from mean sea level in Red Sea during different seasons.

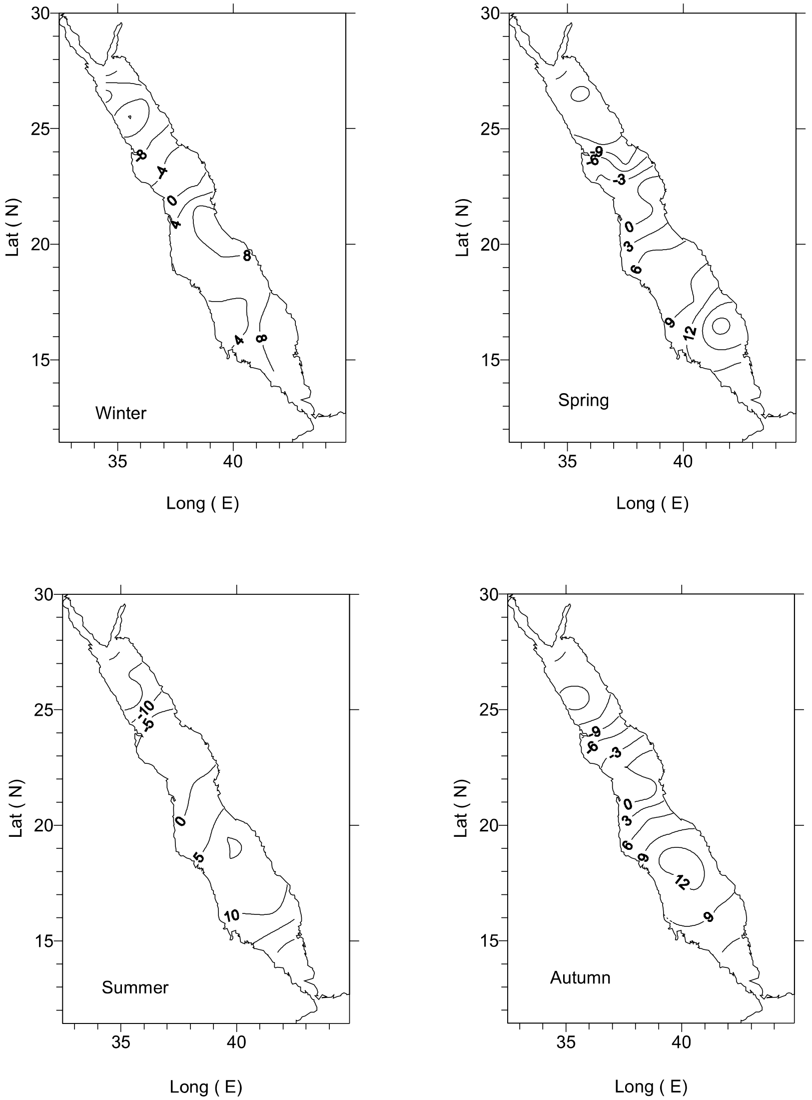


FIG. 7. Spatial variation of total steric departures from mean sea level in Red Sea during different seasons.

values are higher at southern central region (III). This pattern indicated that the temperature of water column extending from the surface to 300m depth is low in northern region and increasing southward to reach its maximum value at region (III). The maximum negative and maximum positive values of thermal height are about –8.8cm and 7.2cm as observed during autumn.

ii. Haline Departures

Figure 6 shows the distribution of haline heights (Zs) over the Red Sea at different seasons. The haline height is negative (due to high salinity) at northern regions I and II, while it is positive (due to low salinity) for the other regions. This pattern reflects the salinity distribution over the Red Sea. The Zs values varied between –11cm and 10cm during winter, –11cm and 16cm during spring, –15cm and 21cm during summer and finally between –10cm and 10cm during autumn.

iii. Total Steric Departures

The distribution of spatial variation of total steric departures from mean sea level in the Red Sea during the different seasons is shown in Fig. 7. It is negative (high density) at northern regions and positive (low density) at southern regions of Red Sea (as thermal and haline departures). This distribution reflects the distribution of water density over the Red Sea. The extreme values of the total steric departures are –22cm and 23cm as observed during summer season.

Table 2 shows the average values of steric components at each region as well as the annual mean values. It is clear that, the contribution of thermal and haline components on total steric component during the winter are the same in magnitude especially at region I and II, while the steric component is mainly thermal at region III (due to the higher temperature) and mainly haline at region IV (due to lower salinity). During the rest of the year, the total steric departure is affected by both thermal and haline departures at region I with higher effect of haline component. At region II, the thermal and haline departures have nearly the same height but with different sign (positive for thermal and negative for haline). At region III, the total steric departure is affected by both thermal and haline departures by almost the same magnitude. At region IV, the total steric departure is mainly haline.

c – Temporal and Spatial Variations of Steric Components

The steric components are calculated on the basis of the deviation of hydrographic parameters at each level for a given station from their annual and regional mean (average values of all used data at different levels). These calculations of steric departures give a clear picture for steric variations at each station from one season to another as well as from one region to another. The horizontal distributions of these calculations over the Red Sea during different seasons are shown in Fig. 8, 9 & 10.

TABLE 2. Spatial variation of steric components (in cm) at different seasons in the Red Sea.

Component	Season	Seasons			
		23-28ºN	20-23ºN	17-20ºN	13-17ºN
Thermal (Zt)	Winter	–4.97	1.82	5.00	1.01
	Spring	–4.43	0.73	4.75	1.99
	Summer	–4.09	1.34	3.65	1.89
	Autumn	–5.22	2.42	5.73	–0.44
	Year	–4.68	1.58	4.78	1.11
Haline (Zs)	Winter	–4.59	1.72	0.76	6.57
	Spring	–7.00	–0.71	3.08	12.37
	Summer	–6.94	–1.45	4.14	11.69
	Autumn	–6.08	–1.96	5.18	8.82
	Year	–6.15	–0.60	3.29	9.86
Total steric (Zα)	Winter	–9.55	3.54	5.76	7.58
	Spring	–11.44	0.02	7.83	14.36
	Summer	–11.03	–0.11	7.80	13.68
	Autumn	–11.30	0.45	10.90	8.39
	Year	–10.83	0.98	8.07	10.97

i. Thermal Departures

Figure 8 shows the temporal and spatial variations of thermal departures during different seasons. It is clear that the thermal departures over the Red Sea are negative during winter (due to lower temperature) and positive during summer (due to higher temperature). During the transitional period (spring and autumn), the thermal departures are negative in the northern regions and positive in the southern ones. Also, it is seen that, the values of thermal height increase from north to south. The maximum negative value is almost –11.5cm (at northern region (I) during winter), while the maximum positive value is about 9.4cm (at central region (III) during summer). On an average, over the Red Sea as a whole, the sea level is depressed by about 4.2cm during winter, while it is raised by about 4.5cm during summer under the effect of water temperature only.

ii. Haline Departures

Figure 9 shows the temporal and spatial variations of haline departures during different seasons. The sea level is depressed at the northern regions (due to higher salinity) and raised at southern regions (due to lower salinity). During

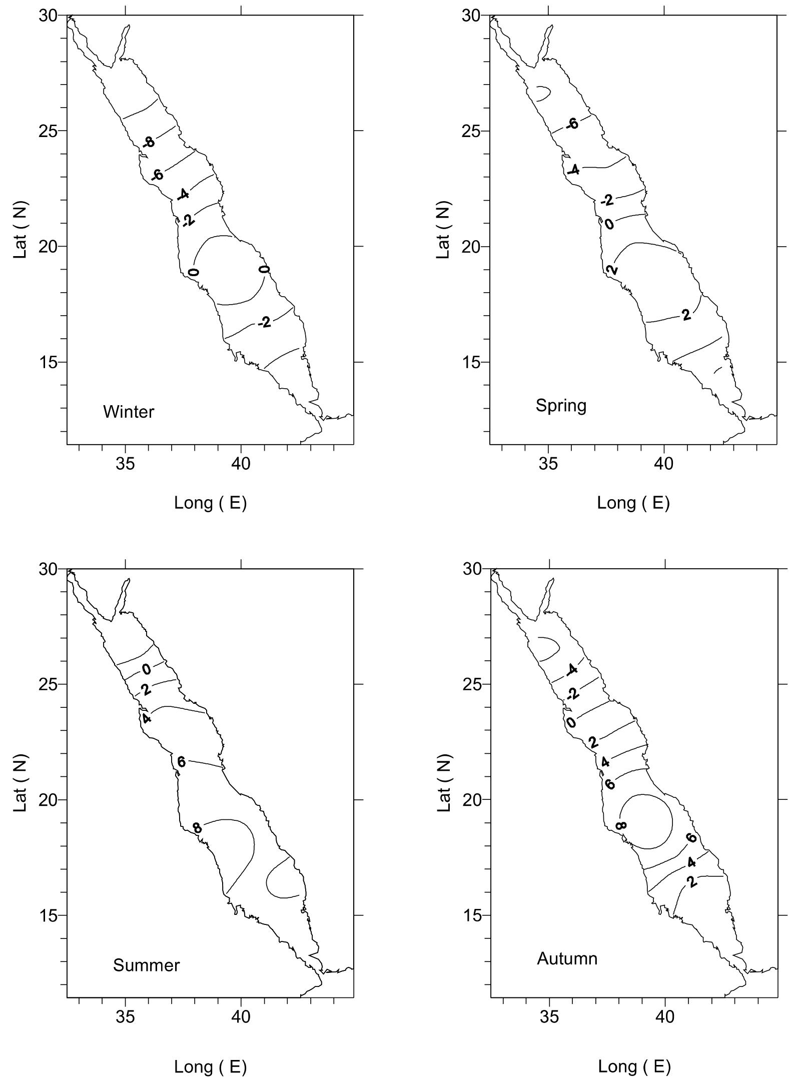


FIG. 8. Temporal and spatial variations of thermal departures from mean sea level in Red Sea during different seasons.

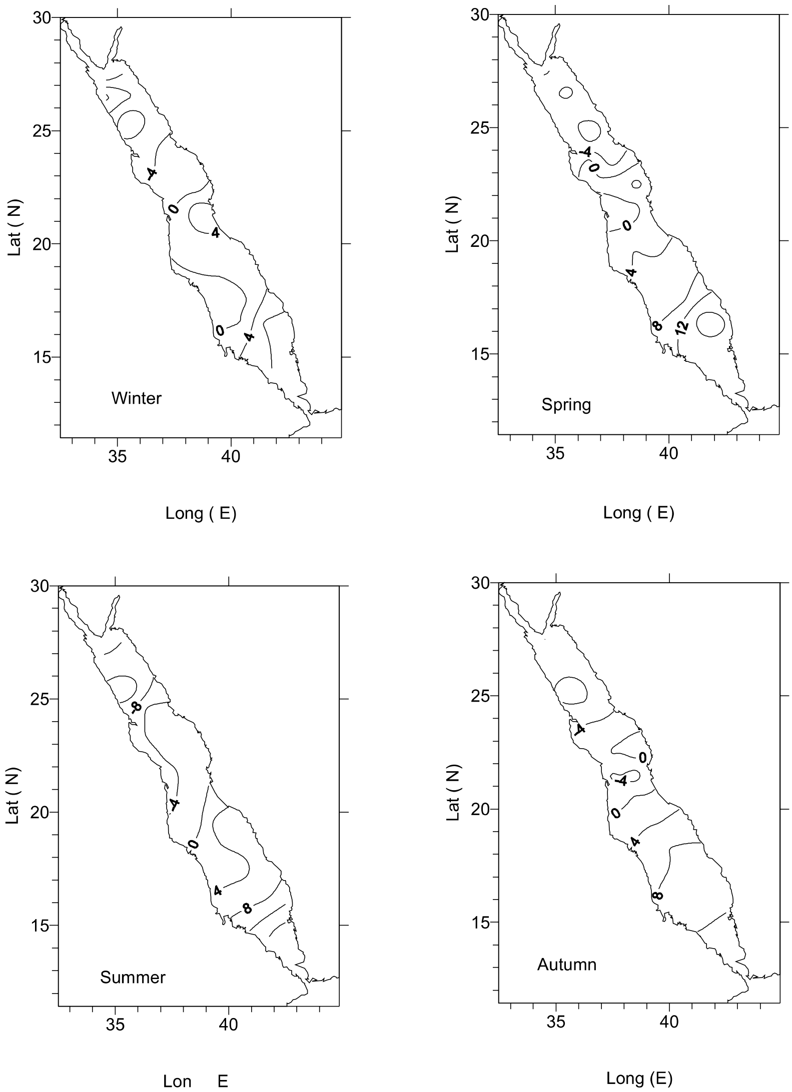


FIG. 9. Temporal and spatial variations of haline departures from mean sea level in Red Sea during different seasons.

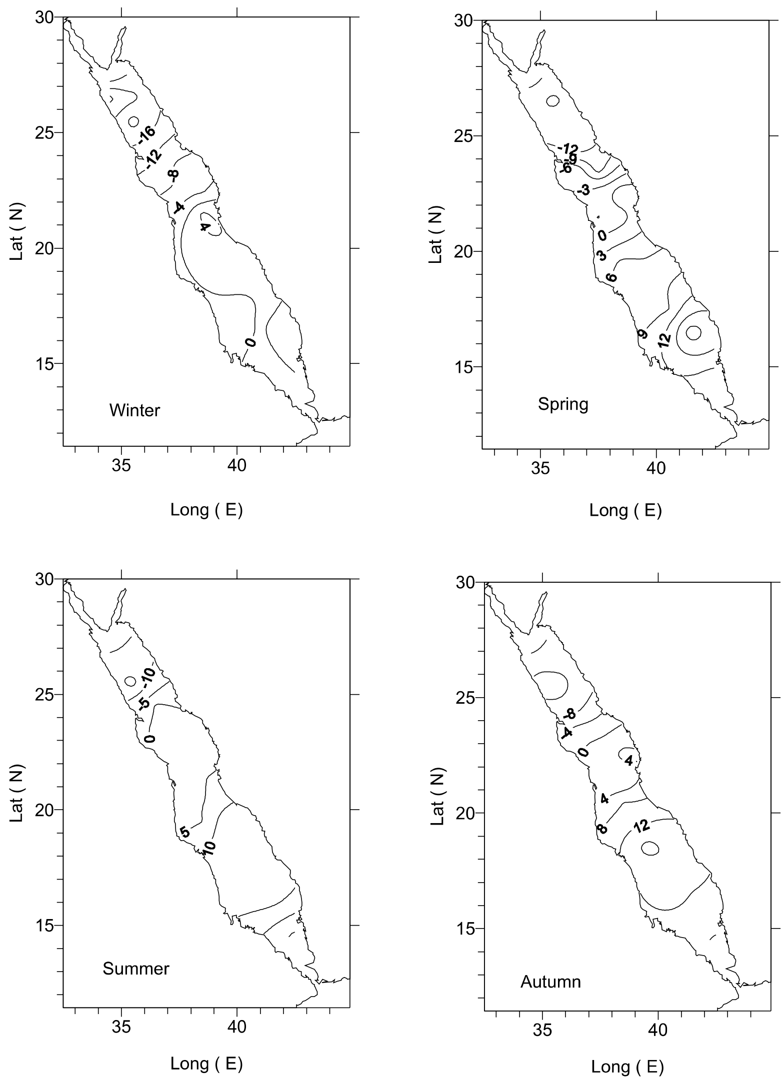


FIG. 10. Temporal and spatial variations of total steric departures from mean sea level in Red Sea during different seasons.

winter, the haline departures from mean sea level varied between –11.5cm and 9cm, while during spring, it changed between –9cm and 18cm. During summer, the sea level due to haline effect oscillated between –16cm and 19cm, while during autumn, it fluctuated between –9.8cm and 9.5cm.

iii. Total Steric Departures

The distribution of temporal and spatial variations of total steric heights during different seasons is shown in Fig. 10. This distribution showed a negative height at northern regions (due to higher density) and positive ones at southern regions (due to lower density). This distribution reflects the distribution of water density over the Red Sea. The values of total steric height fluctuated between –23cm and 6cm during winter, between –15cm and 19cm during spring, between –19cm and 25cm during summer and between –14cm and 15cm during autumn.

Table 3 shows the average values of steric components at different regions of the Red Sea during different seasons. It is seen that, the total steric departures in the Red Sea is mainly thermal at northern region and mainly haline at southern region during winter and spring. While during summer and autumn, the total steric departures are mainly haline at northern and southern regions, and it is mainly thermal at central regions.

TABLE 3. Temporal and spatial variations of steric components (in cm) at different regions and seasons of Red Sea.

Component	Region	Seasons				
		Winter	Spring	Summer	Autumn	Year
Thermal (Zt)	23-28ºN	–9.07	–6.17	0.27	–3.17	–4.53
	20-23ºN	–2.49	–1.08	5.88	4.58	1.72
	17-20ºN	0.56	2.89	8.26	7.95	4.92
	13.17ºN	–3.30	0.15	6.47	1.70	1.26
	Red Sea	–4.15	–1.68	4.60	2.28	–
Haline (Zs)	23-28ºN	–5.09	–6.44	–8.53	–5.55	–6.15
	20-23ºN	1.22	0.86	–3.05	–1.44	–0.60
	17-20ºN	0.26	4.64	2.55	5.70	3.29
	13-17ºN	6.07	13.94	10.09	9.35	9.86
	Red Sea	–0.50	1.56	–1.60	0.52	–
Total steric ($Z\alpha$)	23-28ºN	–14.15	–11.60	–8.27	–8.72	–10.69
	20-23ºN	–1.27	–0.22	2.83	3.14	1.12
	17-20ºN	0.62	7.53	10.82	13.65	8.21
	13-17ºN	2.76	14.10	16.56	11.05	11.12
	Red Sea	–4.65	–0.12	3.00	2.80	–

3) The Relations between Steric Components and Hydrographic Parameters

The relationship between the steric components (Zt, Zs and Zα) and the hydrographic parameters (T, S and σt) for the upper 300m layer are determined for spatial variations of steric components (Run II) as well as for temporal and spatial variations of steric components (Run III). The relations for spatial steric components are shown in Fig. 11. It is seen that, these relations are linear. Its gradient is positive for the thermal component and negative for the haline and total steric components. Also, it is clear that, these relations are slightly differing from one season to another. The relations for temporal and spatial variations of steric components are identical with that for spatial variations, but the difference from one season to another is very small. The linear equations for these relations are evaluated for each season. These equations may be written in the form:

$$Zt\ (cm) = m \times T\ (^{o}C) + c$$

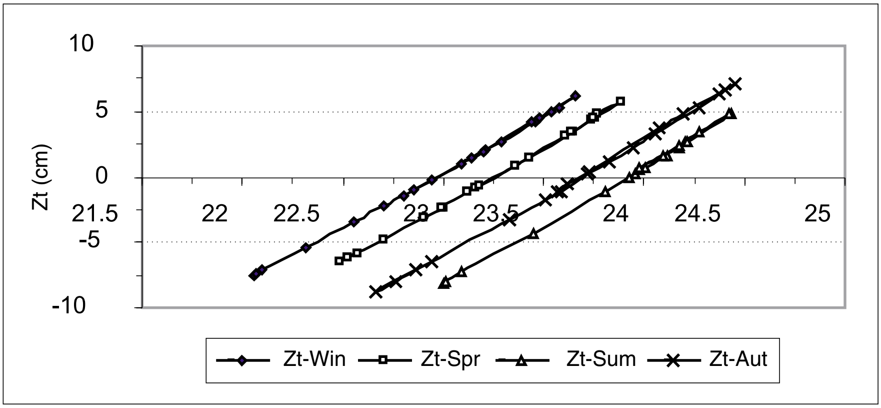
$$Zs\ (cm) = m \times S\ (‰) + c$$

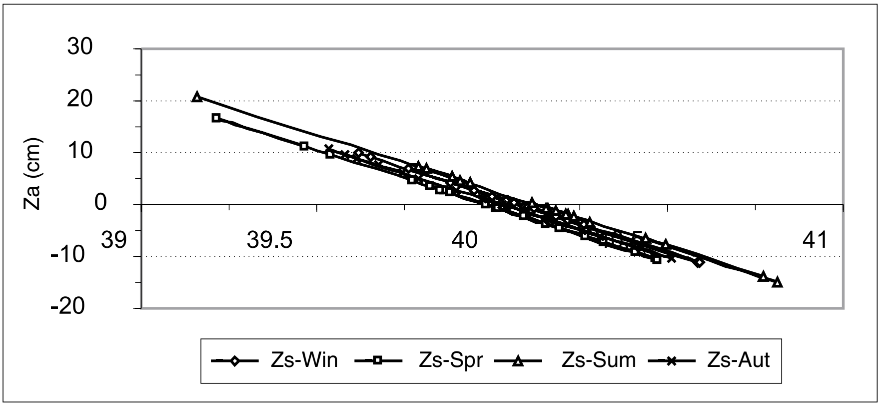
$$Z\alpha\ (cm) = m \times \sigma t + c$$

Where m is the slope of the straight line and c is the intercept part from y-axis. Table 4 shows the values of (m) and (c) for the two runs at different seasons.

TABLE 4. Slope (m) and intercept (c) values of linear equations.

Spatial variation results (Run I)					
Variables	Parameters	Winter	Spring	Summer	Autumn
Zt, t	Slope (m) Intercept (c)	8.44 –193.82	8.77 –203.82	8.96 –214.38	8.91 –211.06
Zs, S	Slope (m) Intercept (c)	–21.61 865.94	–21.58 862.75	–21.57 865.38	–21.56 863.12
Zα, σt	Slope (m) Intercept (c)	–28.66 797.27	–28.88 798.89	–29.00 799.57	–29.17 804.10
Temporal and spatial variations results (Run II)					
Variables	Parameters	Winter	Spring	Summer	Autumn
Zt, T	Slope (m) Intercept (c)	8.17 –191.77	8.65 –202.82	9.24 –216.59	9.05 –212.05
Zs, S	Slope (m) Intercept (c)	–21.61 865.44	–21.57 864.12	–21.56 863.74	–21.56 863.48
Zα, σt	Slope (m) Intercept (c)	–28.66 792.54	–28.88 798.74	–28.99 802.35	–29.16 806.73





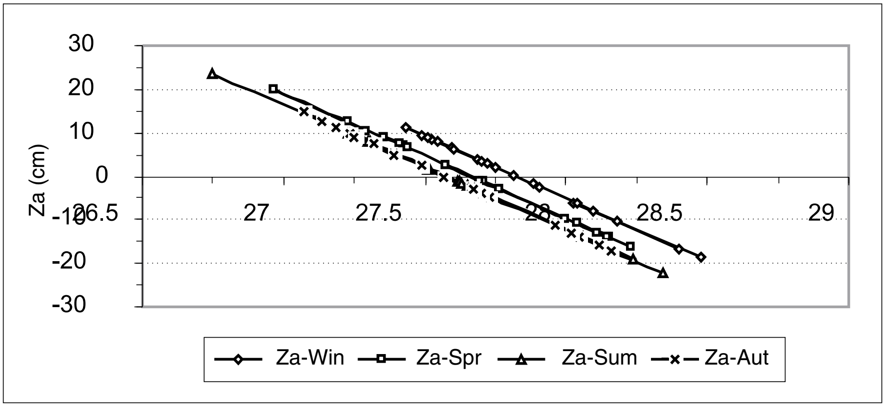


FIG. 11. Relationship between spatial steric components and hydrographic parameters for different seasons in Red.

All the results obtained from temporal and spatial variations of steric departures. Figure 12 are fitted together to get general equations for direct prediction of steric components by knowing the average hydrographic parameters within the upper 300m layer in the Red Sea. These equations are written in the form:

$$Zt = 8.91\ T - 208.71$$

$$Zs = -21.57\ S + 864.04$$

$$Z\alpha = -29.11\ \sigma t + 805.13$$

Where:

Zt, Zs and $Z\alpha$ are the thermal, haline and total steric departures (in cm) respectively. T, S and σt are the temperature, salinity and water density within the upper 300m layer respectively.

Conclusion

Using all the available hydrographic data taken from the International Data Center, the seasonal steric components (thermal, haline and total steric departures) are calculated for the upper 300m layer at 20 grid stations which covered the Red Sea. The results revealed that the general distribution of steric components over the Red Sea reflects the distribution of hydrographic parameters.

The thermal departures from mean sea level play an active role on the fluctuations of Red Sea level especially at the northern part of the sea during winter and spring seasons and at central region during summer and autumn seasons.

The contribution of haline departure is more effective on sea level oscillations at southern part of the Red Sea near the strait of Bab El-Mandab.

In general, the sea level of the Red Sea as a whole is depressed under the effect of water density by about 4.5cm during winter and raised by about 3cm during summer.

The sea level oscillates between these two values during the transitional periods (spring and autumn seasons).

The thermal departures correlate by a linear positive relation with water temperature, while the haline and the total steric departures correlate by a linear negative relation with salinity and water density respectively. To predict the steric components directly by knowing the hydrographic parameters (for the upper 300m layer), linear equations are prepared using the least square method.

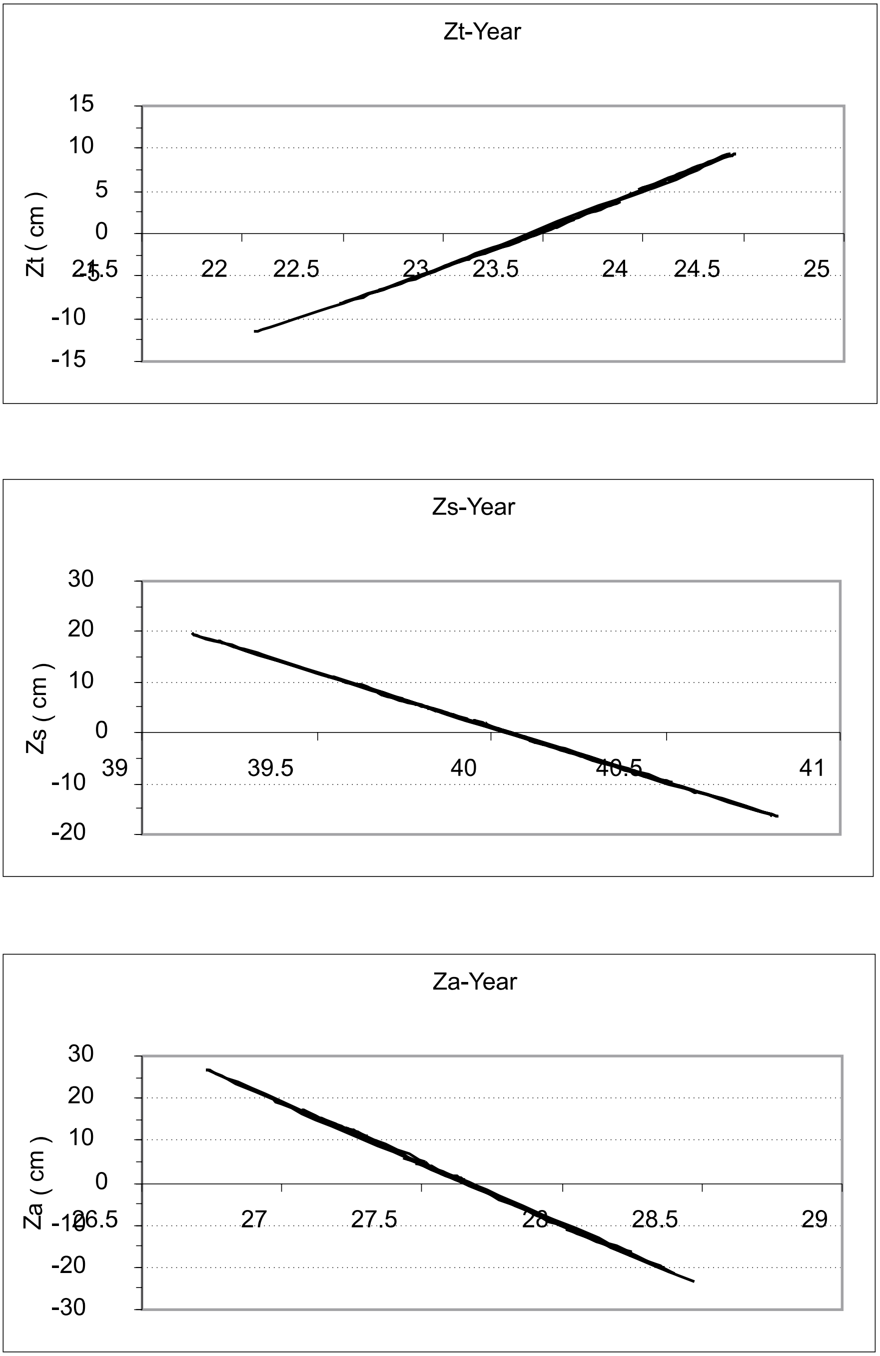


FIG. 12. Relationship between steric components (temporal and spatial) and hydrographic parameters in Red Sea.

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مساهمة كثافة المياه في تذبذب مستوى سطح البحر الأحمر

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المستخلص. استخدمت كل البيانات البحرية المتاحة في البحر الأحمر، والتي تم جمعها من مركز البيانات العالمي (واشنطن)، وتم حساب التغيرات الزمنية والتغيرات المكانية للمركبات الاستيريكية (الانحراف الحراري ، الانحراف الملحي والانحراف الاستيريكي الكلي) للطبقة الممتدة من سطح البحر وحتى عمق ٣٠٠ متر خلال فصول السنة المختلفة، وتمت دراسة مساهمة هذه المركبات في تذبذب مستوى سطح البحر الأحمر.

أظهرت التغيرات الزمنية للمركبات الاستيريكية أن البحر الأحمر ككل ينخفض بمقدار ٤,٥ سم خلال فصل الشتاء (نتيجة الكثافة العالية) ويرتفع بمقدار ٣ سم خلال فصل الصيف (نتيجة الكثافة المنخفضة). بينما أظهرت التغيرات المكانية أن مستوى سطح البحر الأحمر ينخفض عند المنطقة الشمالية بمقدار يتراوح مابين ٨ – ١٤ سم (نتيجة انخفاض الحرارة وارتفاع الملوحة) ويرتفع عند المنطقة الجنوبية للبحر بمقدار يتراوح مابين ١١ – ١٦ سم (نتيجة ارتفاع الحرارة وانخفاض الملوحة) خلال الفصول المختلفة.

عموما الانحراف الاستيريكي الكلي (مجموع الانحراف الحراري والانحراف الملحي) الناتج من تغير الكثافة كان سببه الأساسي هو الانحراف الحراري عند معظم مناطق البحر الأحمر فيما عدا المنطقة الجنوبية ، حيث أن الانحراف الملحي هو المؤثر الأكبر.

أظهرت الدراسة أن العلاقات بين المركبات الاستيريكية والعناصر الهيدروجرافية علاقات خطية. كانت هذه العلاقات خطية موجبة بالنسبة للانحراف الحراري وعلاقات خطية سالبة بالنسبة للانحراف الملحي والانحراف الاستيريكي الكلي.