

The Seasonal Changes of the Circulation Pattern in the Arabian Gulf Deduced from the Field of Mass

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ABSTRACT. Hydrographic data, collected in the period 1933-1992 (from NODC, USA), in the Arabian Gulf and the area near the Strait of Hormuz in the Gulf of Oman, are used for the evaluation of the surface density current in the Arabian Gulf relative to 50 decibar level. The current speed has attained its highest value in summer where it reaches a value of 19 cm/sec, whereas the lowest values are found in winter and autumn with a range of 2-8 cm/sec. This is explained by the strong horizontal and vertical mixing in late autumn and winter, which causes lower density current values while in summer, more stratification is established. The cyclonic eddies are deduced in the north and the south of the study area in winter and summer; this agrees with the previous current measurements and the ships drift data. The present model suggests also anticyclonic gyre in spring and autumn.

The Arabian Gulf lies between the latitudes 24° and 30° 20'N and longitudes 48° and 56° 30'E (Fig. 1). It is a shallow water basin where its mean and maximum depths are 35 and 100 m respectively. The Arabian Gulf is characterized by a high evaporation rate where the evaporation rate exceeds the precipitation falls on the Gulf and the runoff from the adjacent lands. Hence, it represents a negative estuary with an inflow from the Gulf of Oman "Indian Ocean surface water" and a deep outflow at the Strait of Hormuz towards the Gulf of Oman (Hunter 1984). The dominant wind direction in the area is from the N to the NW, but during September when the Monsoon of Indian Ocean reaches the eastern side of Qatar with E to NE winds (El-Gindy and Sabra 1992).

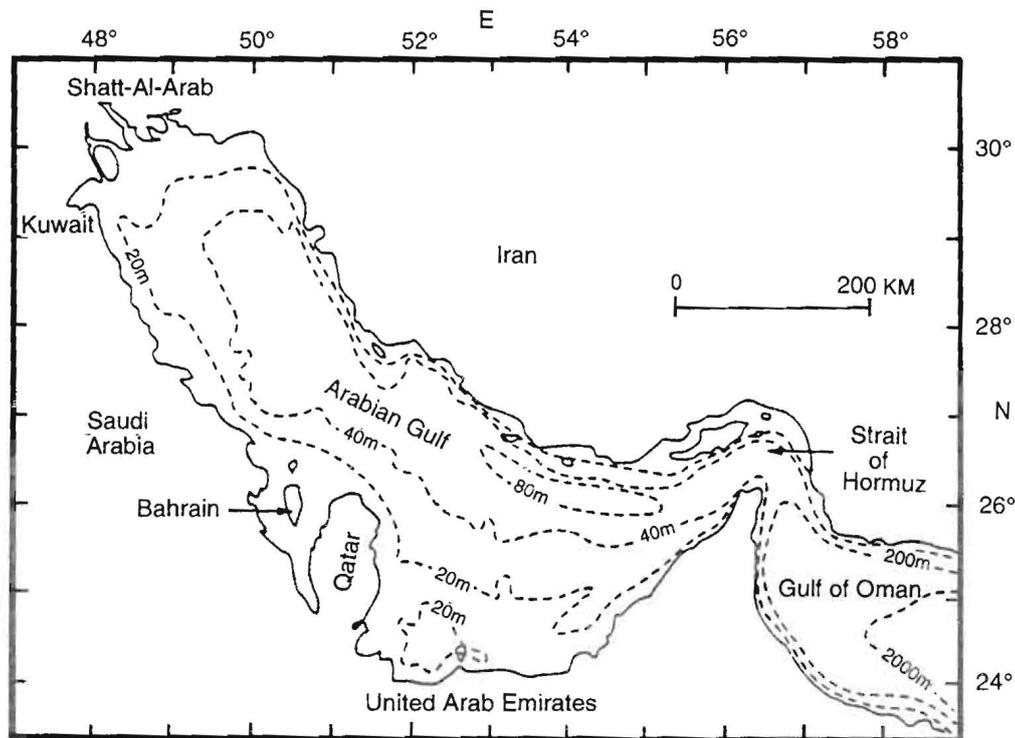


Fig. 1. Arabian Gulf and its bathymetry.

The investigation of the circulation pattern in this area is important in different fields such as pollutant transport as well as in biological, chemical and geological studies. The non-tidal current, including wind driven and density currents, has been studied by several authors. The ships drift data were used by Szekiolda *et al.* (1972), Szekiolda (1976) and Hunter (1982). The hydrographic distributions were used as tracers of water motion by Schott (1918), Sewell (1934), British Admiralty (1941), Emery (1956), Sugden (1963), Duing and Koske (1967), Leveau and Szekiolda (1968), Hartmann *et al.* (1971), Szekiolda *et al.* (1972), Grasshoff (1976), Szekiolda (1976), Brewer *et al.* (1978) and Hassan and El-Samra (1986). These studies showed cyclonic residual currents associated with the pressure gradient due to the mass distribution.

Numerical models have also been applied to simulate the circulation pattern in the region (Hunter 1982). Assuming the geostrophic balance across the Gulf axis and frictional balance along the axis, it was found that the two layer pattern of exchange

at the Strait of Hormuz between the Arabian Gulf and the Gulf of Oman is due to the high evaporation rate in the Arabian Gulf (Hunter 1982). Hunter (1983) predicted a surface current 10 cm/sec along the Iranian coast. Al-Hajri (1990) found that the wind stress has an important influence on the current system. The density current was calculated using hydrographic data collected in February and May 1992 (R/V Mount Mitchell) and in February, 1977 (R/V Atlantis II), Lardner *et al.* (1993). Near the Strait of Hormuz, the maximum surface velocities were ranging between 10-12 cm/sec as indicated from Mount Mitchell data whereas the maximum surface velocity was found to reach 17 cm/sec as indicated from Atlantis II data. This evidence raises the question of annual variations. According to El-Gindy and Habashi (1993), the sea surface temperature has annual variations correlated to those of air temperature. Cold and warm winters were identified with a temperature difference of about 2 °C. The Mount Mitchell data were collected during a cold winter and the Atlantis cruise was in a warm winter. The changes in the density current could be related to these temperature variations.

The most important direct current measurements were done during the cruise of R/V Mount Michell (February-May 1992), using recording Aanderaa current meters in different localities from the Strait of Hormuz to a longitudinal section passing by Qatar Peninsula. The residual surface and bottom currents for the whole period was less than 6 cm/sec. The two opposite flows, deduced from indirect estimates at the Strait of Hormuz, and the anti-clockwise gyre in the southern part of the Arabian Gulf were confirmed, Saad and Ahmed (1993).

The different authors agreed about the pattern of exchange at the Strait of Hormuz and the cyclonic eddy in the southern part of the Arabian Gulf. The current system in the NW of the study area is not well known. The objective of this paper is to study the seasonal variations of surface density currents in the Arabian Gulf relative to 50 decibar level.

Data Collection and Method of Analysis:

Hydrographic data collected by different cruises in the period 1933-1992 (obtained from National Oceanographic Data Center, at Washington, USA, and Oceanographic data records in Qatar University) are analyzed (Table 1). These data were grouped to represent the different seasons; winter which includes January, February and March; spring which includes April and May; summer which includes June, July, August and September, and autumn which includes October, November and December. The annual variations in these data were investigated by El-Gindy and Habashi (1993). They concluded that the relevant annual changes occur in winter season; the cold winter is typically represented by the data in February 1992

(Mount Mitchel NOAA cruise), while most of the winter data were collected in a warm period with an increase about 2 °C in sea water temperature. In this paper only the warm winter data are used. Figure (2) shows the location of the hydrographic stations in the Arabian Gulf during different seasons. These data were edited by checking of the vertical stability and the horizontal distributions of temperature, salinity and density. The odd values were either replaced by an interpolated value or deleted from the data set. The temperature and salinity at the irregularly distributed stations were grided at different six levels (0, 10, 20, 30, 40 and 50 m) to get the values at the same grid nodal points in the different seasons (El-Gindy and Hegazi 1996).

The steric components (thermal, haline and total steric departures from mean sea level) are calculated in the Arabian Gulf using Pattullo *et al.* (1955) equations. The average values of these components are calculated in three regions:

- i) Region 1, the northwestern region, is located from longitude 48° E to 51.25° E.
- ii) Region 2, the central region, lies between longitudes 51.25° E and 54.25° E.
- iii) Region 3, the eastern region, lies between the longitude 54.25° E to the strait of Hormuz at 56.25° E.

To calculate the current velocity in the Arabian Gulf from the field of mass the following method is used. Starting with the hydrostatic equation the total water height (Z) due to the variation of density can be expressed by:

$$Z = g^{-1} \int_{p_a}^{p_0} \Delta\alpha \, dP$$

where:

g is the acceleration of gravity.

p_a is the atmospheric pressure.

p_0 is the pressure at the reference isobaric surface. In this study the reference surface is taken at 50 db surface. Hence,

$$\Delta\alpha = \alpha - \alpha_0$$

where α is the specific volume at a given level at the station and α_0 is its value at the reference depth.

Table 1. Sources of hydrographic data used in the present study.

Month	Year	Country	No. of casts	Total No. of casts
January	1961	USA	103	121
	1969	UK	3	
	1987	Qatar	15	
February	1960	USA	13	270
	1961	USA	30	
	1967	UK	36	
	1977	USA	29	
	1984	Qatar	14	
	1987	Qatar	28	
March	1961	USA	9	68
	1965	USA	2	
	1965	Germany	38	
	1967	UK	5	
	1969	UK	5	
	1984	Qatar	9	
April	1950	USA	1	59
	1965	Germany	45	
	1986	Qatar	13	
May	1961	France	24	144
	1966	USSR	4	
	1967	UK	41	
	1992	USA	75	
June	1968	USSR	5	5
July	1968	USSR	36	54
	1984	Qatar	18	
August	1968	USSR	102	102
September	1962	India	4	106
	1968	USSR	32	
	1985	Qatar	26	
	1986	Qatar	44	
November	1933	UK	5	49
	1963	USA	5	
	1968	UK	25	
	1983	Qatar	3	
	1984	Qatar	11	
December	1933	UK	1	17
	1949	USA	3	
	1984	Qatar	13	

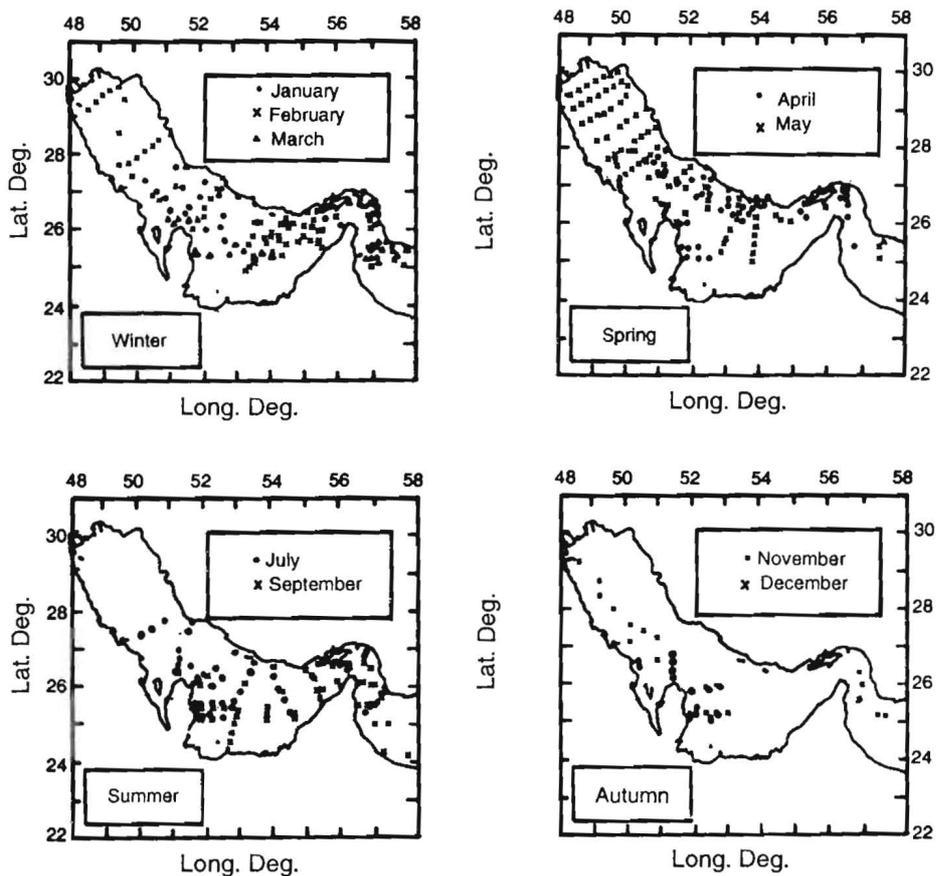


Fig. 2. Location of hydrographic stations used in the present study (after El-Gindy and Hegazi, 1996).

To estimate the relative current, it is supposed that the sea surface is inclined to the level surface by an angle θ degree. This can be achieved by the balance of two forces: the pressure force and the Coriolis force, and the bottom friction is ignored. This can be expressed by:

$$2\Omega \sin\phi V = g \tan\theta$$

Therefore, the current can be given by the equation:

$$V = g \tan\theta / 2\Omega \sin\phi$$

where:

ϕ is the geographical latitude; and Ω is the angular speed of the earth's rotation.

The slope of the sea surface can be determined by:

$$\tan\theta_x = \Delta Z / \Delta X ; \quad \tan\theta_y = \Delta Z / \Delta Y$$

in x- and y- directions respectively. The x-direction is taken to the east and the y-direction to the north. ΔZ is the difference in steric height between two stations. ΔX and ΔY are the distances between the stations (or the points of the data interpolation) in the x- and y- directions. In this work, they were chosen as a half degree longitude and a half degree latitude respectively.

Thus, the x- and y- current components can be expressed by:

$$\begin{aligned} v &= g \tan \theta_x / 2 \Omega \sin\phi \\ u &= -g \tan \theta_y / 2 \Omega \sin\phi \end{aligned}$$

The total current speed C is the vector sum of the above two components, *i.e.*

$$C = (u^2 + v^2)^{1/2}$$

and the direction D is given by:

$$D = \tan^{-1} v / u$$

To estimate the current velocity at the center of each grid, the average values of u and v at the sides of the grid were estimated and then the total current velocity was computed.

Results and Discussion

1) Steric heights in Arabian Gulf:

i) Thermal departure:

The thermal departures from mean sea level are shown in Fig. (3). Due to the low temperature during winter, Fig. 3a indicates that the thermal component is variable between -2 and -6 cm. This depression is deeper in the northwestern part than in southern part.

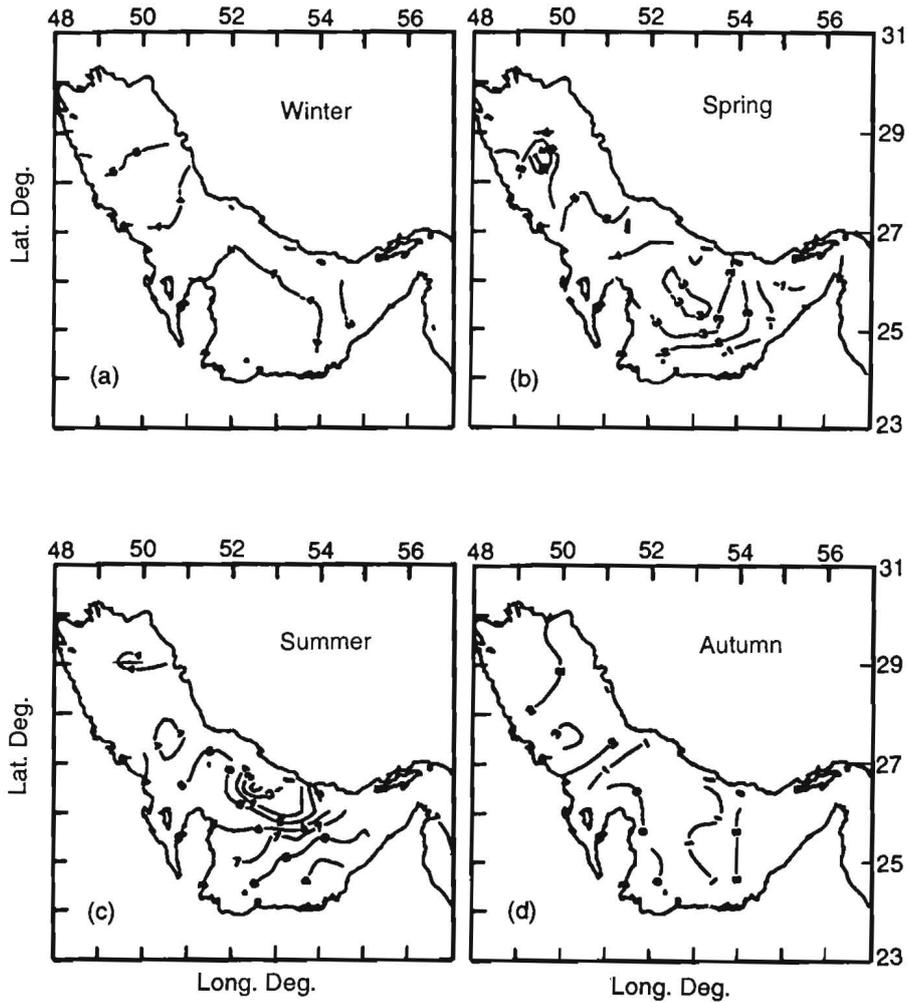


Fig. 3. The distribution of thermal departures from mean sea level (cm) in the Arabian Gulf during different seasons.

The thermal departure during spring (Fig. 3b) changes between -6 and 0 cm. Also, the sea level is depressed at the northern side and raised gradually up stream.

In the Arabian Gulf, due to the increase in water temperature during summer, the thermal height becomes positive and relatively large. It is changed from 4 to 9 cm as shown from Fig. 3c, with higher level in the SE of the Gulf.

During autumn, the water temperature decreases, and consequently the thermal height decreases. The sea level due to thermal departure varies between -0.5 and 2.9 cm as shown in Fig. 3d.

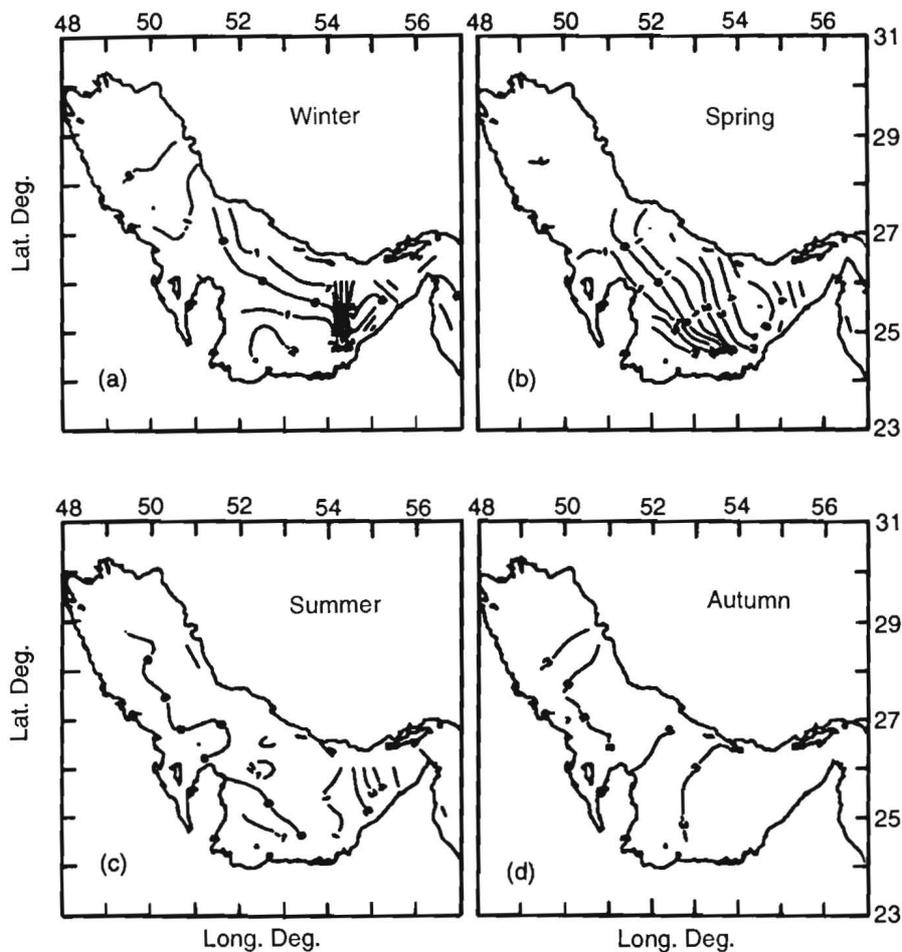


Fig. 4. The distribution of haline departures from mean sea level (cm) in the Arabian Gulf during different seasons.

ii) Haline departure:

The distribution of haline departures from mean sea level in the Arabian Gulf during different seasons are shown in Fig. (4). During winter, Fig. 4a, the haline

component is more effective than the thermal ones specially at Strait of Hormuz due to the effect of diluted Oman water. The haline height oscillates between -2.5 cm at the northern part and 10 cm near to the Strait of Hormuz, this trend reflects the salinity distribution in the Arabian Gulf.

During spring, Fig. 4b, the sea level changes due to the haline departure fluctuates between -3 and 9 cm, with low values in the north and south of the Gulf and higher values along the Iranian side.

During summer, Fig. 4c, the sea level changes due to salinity varies between -2 and 4 cm, and it is lower along the Arabian side than that of the Iranian side.

During autumn, Fig. 4d, the sea level changes due to haline departure shows that the sea level is depressed by about -4 cm at the northern boundary and raised by about 13 cm near the Strait of Hormuz.

iii) Total steric departure:

The distribution of the total steric departures from mean sea level in the Arabian Gulf are shown in Fig. (5). The steric component is the situation of sea level in Arabian Gulf under the effect of both temperature and salinity together, *i.e.* under the effect of water density. During winter, Fig. 5a shows the influence of both temperature and salinity on sea level changes which ranges between -8 cm at the northern boundary of the Gulf and 8 cm near to the Strait of Hormuz.

During spring, Fig. 5b represents the total steric departure which is considered to be large. The sea level is depressed due to density by about -6 cm at the northern boundary of the Gulf and raised by about 10 cm near the Strait of Hormuz. Thus, the steric effect during spring is mainly thermal at the northern and central regions of Arabian Gulf, while it is mainly haline along the eastern boundaries.

The total steric effect on sea level variation during summer is relatively strong (Fig. 5c). The steric height fluctuates between 4.5 and 12 cm. By comparing the contribution of both temperature and salinity on sea level fluctuations during summer, it is clear that, the steric effect is mainly thermal.

During autumn (Fig. 5d) the steric height is small and varied between -2.5 and 1.5 cm. Thus it is clear that, the steric height during autumn is mainly haline.

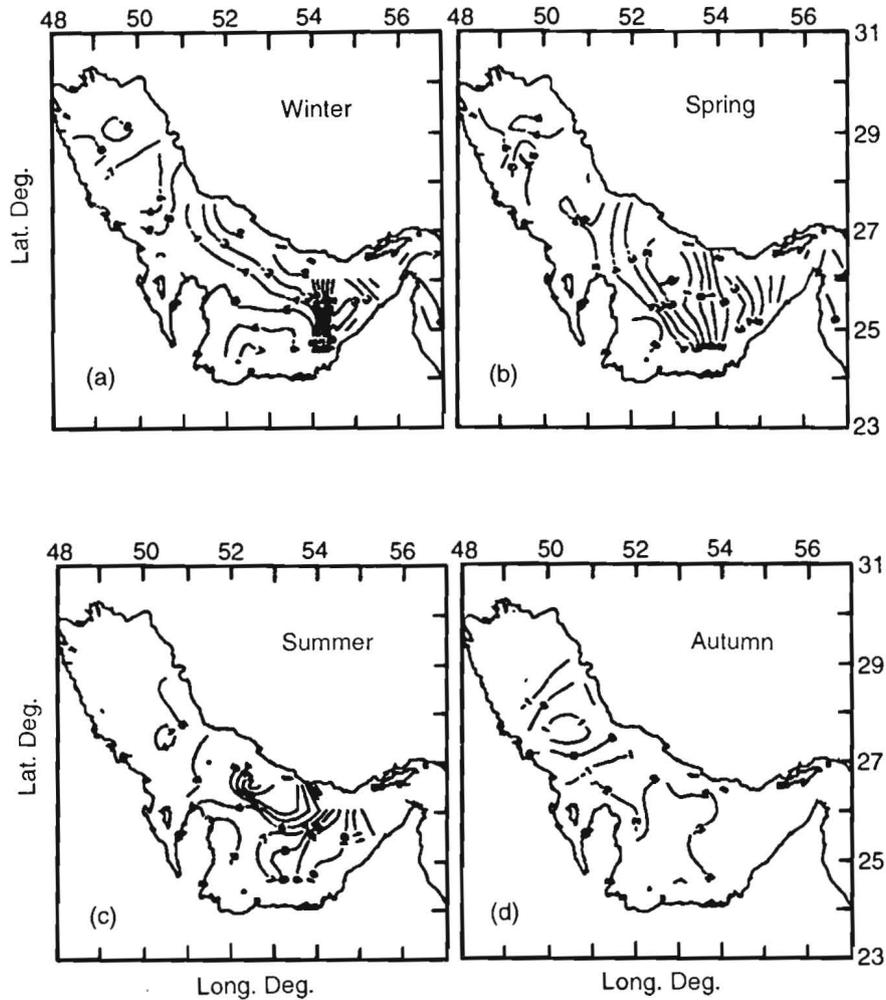


Fig. 5. The distribution of total steric departures from mean sea level (cm) in the Arabian Gulf during different seasons.

Table (2) shows the average values of the steric heights in Arabian Gulf. From this table, it is clear that, in the north-western and central regions, the steric height is mainly thermal except during autumn. While in the eastern region, it is mainly haline except during summer. In the Arabian Gulf, as a whole, it is seen that, the temperature variations play an effective role in the variability of sea level. The salinity variations affected only during autumn and near the strait of Hormuz.

Table 2. The average seasonal steric heights (cm) in the Arabian Gulf.

Region	Steric	Winter	Spring	Summer	Autumn
North-western	Thermal	-4.61	-4.98	4.64	1.93
	Haline	-1.48	-0.54	0.06	-2.62
	Total	-6.08	-5.52	4.70	-0.68
Central	Thermal	-3.99	-3.01	6.12	0.70
	Haline	-0.34	0.57	0.09	-2.65
	Total	-4.33	-2.45	6.22	-1.95
Eastern	Thermal	-2.43	-0.66	7.71	2.46
	Haline	5.66	6.34	3.65	9.80
	Total	3.23	5.68	11.36	12.26
Arabian Gulf	Thermal	-3.95	-3.33	5.86	1.43
	Haline	-0.10	0.98	0.23	-1.11
	Total	-4.05	-2.35	6.09	0.31

2) Density Currents in Arabian Gulf:

The surface density currents in the Arabian Gulf during the different seasons are represented in Fig. (6). During winter, (Fig. 6a), whose data represent the warm winter (with a temperature higher than climatic mean, El-Gindy and Habashi, 1993, El-Gindy and Hegazi 1996), the ranges of the current speed at the sea surface are 2-5 cm/sec, 2-10 cm/sec and 2-15 cm/sec in the northwestern part of the Arabian Gulf (west of 52° E), south of the Gulf (52° - 55° E) and at the Strait of Hormuz respectively. Inside the Arabian Gulf, two cyclonic eddies are manifested in the north and the south of the area.

During spring (Fig. 6b) the ranges of the current speed are 2-10 cm/sec, 2-15 cm/sec and 2-5 cm/sec in the above mentioned sub-regions respectively. The two cyclonic eddies in the northwest and the south of the region, observed in Winter, are replaced by anticyclonic ones, with a dominant current from east to west in the southern part.

During summer (Fig. 6c) it is seen that, strong currents are generated by density field. The speed ranges at the above mentioned sub-regions in study area are 2-19

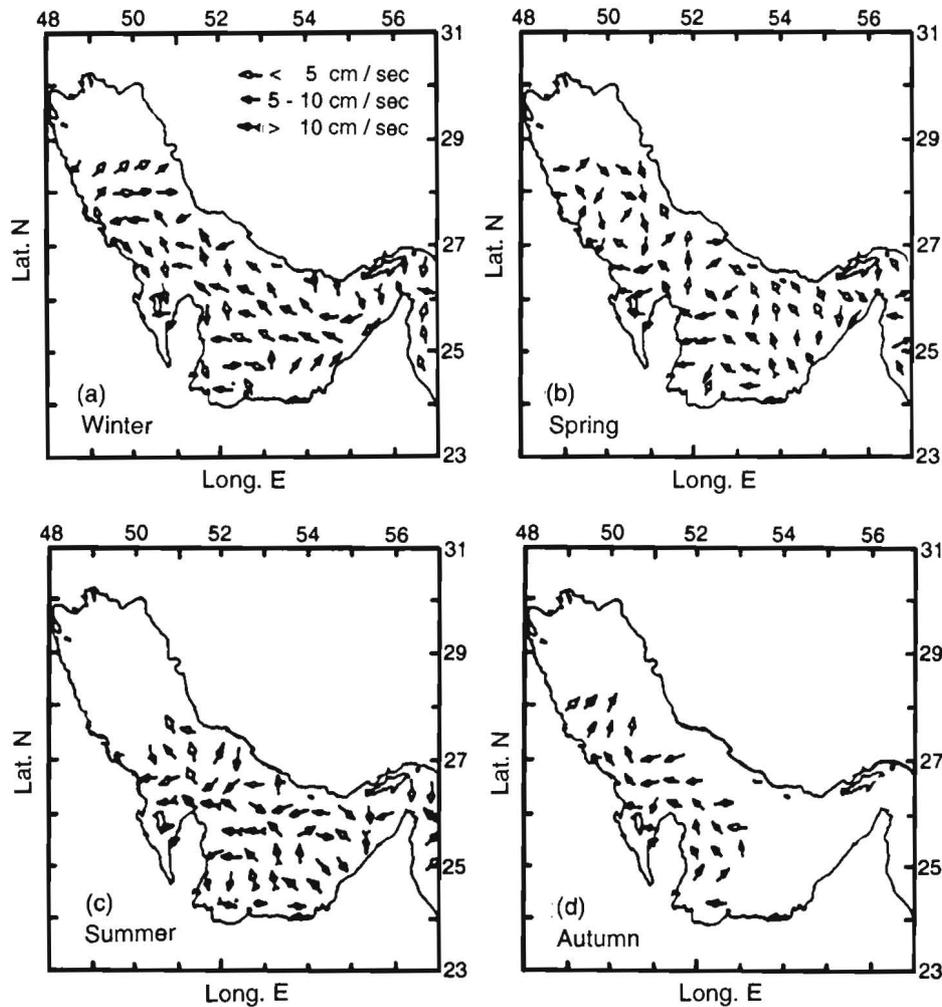


Fig. 6. Surface density currents in the Arabian Gulf during different seasons.

cm/sec, 2-18 cm/sec and 2-15 cm/sec respectively. The cyclonic eddies are again generated in the southern part. In the north, at the surface, the flow is dominated by currents from southeast to northwest direction, with no gyral motion.

During autumn (Fig. 6d) where few data are available, it can be shown that, the current speed at its lowest values of the year. It varied between 2-8 cm/sec between longitudes 50° and 54° E near the Arabian side of the Gulf.

Conclusions

The seasonal steric components (thermal, haline and steric heights) are calculated in the Arabian Gulf for the upper 50-m layer. From the variability of sea level due to the steric height distributions, the circulation pattern in the Arabian Gulf is estimated. The results revealed that:

Temperature variations have the most significant effect on sea level variations. The effect of salinity on sea level changes is significant only near the Strait of Hormuz. The fluctuation of sea level due to the density distributions is relatively large. The seasonal distribution of steric height showed that the sea level is depressed during winter and spring and it is raised during summer and autumn. The minimum value of steric height (about -4 cm) is found during winter and the maximum one (about 6 cm) is observed during summer.

The density current speed has the highest value in summer, where it reached 19 cm/sec. While, its lowest values (2-8 cm/sec) are found in winter and autumn, which are the seasons of the active water mixing.

The cyclonic eddies are well demonstrated in winter and summer, in the north and south of the Arabian Gulf, while anticyclonic eddies are shown in spring.

At the Strait of Hormuz, the flow is always towards the Arabian Gulf, but sometimes there is an indication of opposite flow near the Arabian coasts. These results coincide with the residual currents obtained from Aanderaa recording current meters, taken during Mount Mitchell cruise 1992 (Saad and Ahmed 1993), and the flow deduced from the ship drift reports analyzed by Hunter (1982). Therefore, although the friction term is neglected in the present model, the model gives reasonable good results confirmed by the observations.

References

- Al-Hajri, K.R.** (1990) *The circulation of the Arabian (Persian) Gulf: a model study of its dynamics*. Ph.D. Thesis, Catholic University of America.
- British Admiralty** (1941) Water movement and related information. Persian Gulf sheet 11, oceanographic chart no. 13 C 6120.
- Brewer, P.G., Fleer, A.P., Kadar, S., Stafar, D.K. and Smith, C.L.** (1978) Chemical oceanographic data from the Persian Gulf and Gulf of Oman. Report WHO 1-78-82 Woods Hole Oceanographic Institution, USA.
- Duing, W. and Koske, P.K.** (1967) Hydrographic observations in the Arabian Sea during the NE monsoon period 1964-65. *"Meteor" Forschungsergebnisse series A*(8): 1-43.
- El-Gindy, A.A.H. and Sabra, A.** (1992) Variability of wind system and its expected effects on oil slick movement in the Arabian Gulf. *Qatar Univ. Bull.*, 7: 215-221.
- El-Gindy, A.A.H. and Habashi, B.B.** (1993) Hydrographic conditions in ROPME Sea Area; Calibration of Mt. Mitchell, 1992 cruise data and annual variations. Proceedings of the Scientific Workshop on Results of the R/V Mt. Mitchell Cruise in ROPME Sea Area, January 24-28, 1993, Kuwait, 204-229 pp.
- El-Gindy, A.A.H. and Hegazi, A.** (1996) Atlas on the hydrographic conditions in the upper 50 meters in the Arabian Gulf and the Gulf of Oman. Published by Scientific Applied Research Center, Qatar University.
- Emery, K.** (1956) Sediments and water of Persian Gulf. *Bulletin of the American Assoc. of Petroleum Geologists*, 40(10): 2354-2383.
- Grasshoff, K.** (1976) Review of hydrochemical conditions in the Gulf region. *UNESCO Technical papers in Marine Sciences*, 26: 39-62.
- Hassan, E.M. and El-Samra, M.I.** (1986) Physical and chemical characteristics of ROPME Sea Area. ROPME proceedings of the workshop on Regional Marine and Research Program, Al-Ain, 1985, UNESCO publication, 46-67 pp.
- Hartmann, M.H., Seibold, L.E. and Walger, E.** (1971) Surface sediments in the Persian Gulf and Gulf of Oman I. Geologic-Hydrologic setting and first sedimentology results. *"Meteor" Forschungsergebnisse, series C*(4): 1-96.
- Hunter, J.R.** (1982) Aspects of the dynamics of the residual circulation of the Arabian Gulf. Paper presented at NATO Advanced Research Institute, Norway, 6-11 June 1982.
- Hunter, J.R.** (1983) A review of the residual circulation and mixing processes in the KAP region with relation to applicable modelling techniques. Symposium Workshop on oceanographic modelling of Kuwait action plan region, at University of Petroleum and Minerals, Dhahran, Saudi Arabia, Oct. 15-17.
- Hunter, J.R.** (1984) A review of the residual circulation and mixing process in the KAP region with reference to applicable modelling techniques. *UNESCO reports of Marine Sciences*, 28: 37-45.
- Lardner, R.W., Rabeh, A.H., Gunay, N., Hussein, N., Reynolds, R.M. and Lehr, W.J.** (1993) Computation of the residual flow in the ROPME Sea Area using the Mt. Mitchell data and the KFUPM/RI hydrodynamic models. Proceedings of the Scientific Workshop on Results of the R/V Mt. Mitchell Cruise in ROPME Sea Area, January 24-28, 1993, Kuwait, 116-151 pp.

- Leveau, M. and Szekiolda, K.H.** (1968) Situation hydrologique et distribution du zooplankton dans le NW de la mer d'Arabie. *Sarsia*, **34**: 285-298.
- Pattullo, J., Munk, W., Revelle, R. and Strong, E.** (1955) The seasonal oscillations in sea level. *J. Mar. Res.*, **14**: 88-156.
- Saad, M. and Ahmed, F.** (1993) The residual currents at mooring positions in the ROPME Sea Area (RSA). In the Scientific ROPME workshop on the results of Mt. Mitchell cruise, Kuwait, Jan. 24-26.
- Schott, G.** (1918) Oceanographie und Klimatologie des Persischen Golfes und des Golfes von Oman. *Annalen der Hydrographie und Maritimen Meteorologie*, 1-46 pp.
- Sewell, R.B.S.** (1934) The John Murray Expedition to the Arabian Sea. *Nature*, London, **133**: pp. 86-89.
- Sugden, W.** (1963) The hydrology of the Persian Gulf and its significance in respect to the evaporite deposition. *American J. of Sci.* **261**: 741-755.
- Szekiolda, K.H., Salomonson, V. and Allison, L.J.** (1972) Rapid variation of sea surface temperature in the Persian Gulf as recorded by Nimbus 2 HRIR, *Limnology and Oceanography*, **17**(2): 807-809.
- Szekiolda, K.H.** (1976) Space oceanography, *Oceanography and marine biology annual review*, **14**: 99-166.

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التغيرات الموسمية لنظام حركة المياه في الخليج العربي المستنبطة من مجال الكتلة

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ان دراسة نظام حركة المياه في الخليج العربي له أهمية كبرى في مجالات مختلفة مثل انتقال الملوثات في الخليج بالإضافة إلى أهميتها لمجالات علوم البحار المختلفة سواء كانت البيولوجية أو الكيميائية أو الجيولوجية . ونظراً لعدم توافر قياسات حقلية للتيارات البحرية بصورة مستديمة لمنطقة الخليج العربي ، فان هذا البحث يقوم باستنتاج سرعة واتجاه التيارات البحرية الناشئة من اختلاف كثافة المياه من مكان إلى آخر . لذا ينقسم هذا البحث إلى جزئين أساسيين :

- ١- حساب التغير في ارتفاع عمود الماء نتيجة اختلاف الكثافة . وبما أن كثافة ماء البحر تعتمد على درجة الحرارة والملوحة ، فان ارتفاع عمود الماء نتيجة الكثافة يمكن تقسيمه إلى جزئين : جزء ناتج من تأثير درجة الحرارة (ويسمى الانحراف الحراري) ، والجزء الآخر ناتج من تأثير الملوحة (ويسمى الانحراف الملحي) . مجموع التأثيرين معاً يعطي تأثير الكثافة (ويسمى الانحراف الأستيركي الكلي) .
- ٢- نتيجة اختلاف الانحراف الأستيركي الكلي من منطقة إلى أخرى ينتج عنه

ميل في مستوى سطح البحر مما يولد حركة للمياه . وبالتالي بمعلومية هذا الانحراف أمكن حساب سرعة واتجاه حركة المياه في منطقة الخليج العربي .

لاتمام هذه الدراسة تم تجميع كل البيانات الهيدروجرافية (درجة الحرارة والملوحة ومن ثم تم حساب كثافة مياه البحر) من كل الرحلات التي تمت في منطقة الخليج العربي وفي المنطقة القريبة من مضيق هرمز في خليج عمان في الفترة ما بين ١٩٣٣ و ١٩٩٢ . تم تنقية هذه البيانات البحرية وحذف البيانات الغير صالحة والشاذة منها . ثم تم تجميع هذه البيانات وأخذ المتوسطات لها على شبكة أبعادها نصف درجة لخط العرض x نصف درجة لخط الطول ، وتم تجهيز هذه البيانات على ستة أعماق هي : صفر ، ١٠ ، ٢٠ ، ٣٠ ، ٤٠ ، ٥٠ متر ، وذلك للفصول الأربعة المختلفة . باستخدام هذه البيانات البحرية تم حساب سرعة التيارات السطحية الناتجة من اختلاف كثافة مياه البحر في الخليج العربي بالنسبة لمستوى ضغط ٥٠ ديسيبار .

أظهرت نتائج هذه الدراسة أن درجة حرارة مياه الخليج لها التأثير الأكبر على تغير مستوى سطح البحر (أي على تغير ارتفاع عمود الماء) ، بينما كان تأثير الملوحة أكبر ما يمكن بالقرب من مضيق هرمز وذلك نتيجة دخول مياه خليج عمان الأقل ملوحة إلى الخليج العربي . . مجموع التأثيرين معاً (الارتفاع الأستيركي الكلي) في منطقة الخليج العربي كان كبيراً نسبياً . أظهرت الدراسة أيضاً أن هناك تأثير موسمي للانحراف الأستيركي الكلي في منطقة الخليج العربي ، حيث كان هذا الانحراف سالباً (أي أقل من متوسط مستوى سطح البحر) خلال فصلي الشتاء والربيع ، بينما كان الانحراف موجباً (أي أكبر من متوسط مستوى سطح البحر) خلال فصلي الصيف والخريف . أقل قيمة للارتفاع الأستيركي الكلي كان حوالي - ٤ سم في فصل الشتاء ، بينما أكبر قيمة لوحظت في فصل الصيف وكانت حوالي ٦ سم .

أوضحت الدراسة أيضاً أن التيارات البحرية الناتجة من توزيع كثافة المياه في الخليج العربي كانت سرعتها أكبر ما يمكن خلال فصل الصيف حيث وصلت إلى ما يقرب من ١٩ سم/ ثانية - بينما أقل سرعة للمياه تراوحت ما بين ٢-٨ سم/ ثانية وقد لوحظت خلال فصلي الشتاء والخريف .

أيضاً ظهرت الدوامات السيكلونية في شمال وجنوب الخليج العربي في فصلي الشتاء والصيف ، وهذا كان موافقاً تماماً مع قياسات التيارات البحرية السابقة . كما أظهرت الدراسة الحالية عن وجود دوامة أنتيسايكلونية في فصلي الربيع والخريف .