Geostrophic current patterns off the Egyptian Mediterranean coast

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Abstract

Using objectively analysed hydrographic data, currents have been calculated off the Egyptian Mediterranean coast at the surface and at 30, 50, 75, 100, 200 and 300 m depths for the four seasons.

The surface circulation is dominated by an anticyclonic circulation off Salum Bay in winter, spring and summer. In nearshore areas, the current flows eastwards at the shallower levels but westwards at the deeper levels.

Off the Nile Delta, the current is almost eastward with a higher velocity in summer and autumn, while in spring it is very weak. Off the area between Port Said and Rafah, there is a clear cyclonic circulation appearing in all seasons except winter. At 50 and 75 m depth, the velocity of the circulation is weak. At 100 m depth, the circulation that appeared between Matruh and Alamen in summer decreases in area and magnitude at the former depths.

At 200 and 300 m in winter, the current velocity is quite low. In spring the current flows southwards off the area between Rafah and Port Said. In summer, the current off the area between Port Said and Rafah is quite strong and flows to the south. The situation in autumn is quite similar to that in summer, except in the eastern area, where the current is a westward one.

The complete text of the paper is available at http://www.iopan.gda.pl/oceanologia/

1. Introduction

The Egyptian Mediterranean coast extends between longitude 25°30′E and 34°15′E and extends northwards to latitude 33°N, Figure 1. It has a surface area of about 154 840 km^2 and its water volume is 224 801 km^3 (Said & Rajkovic 1996).

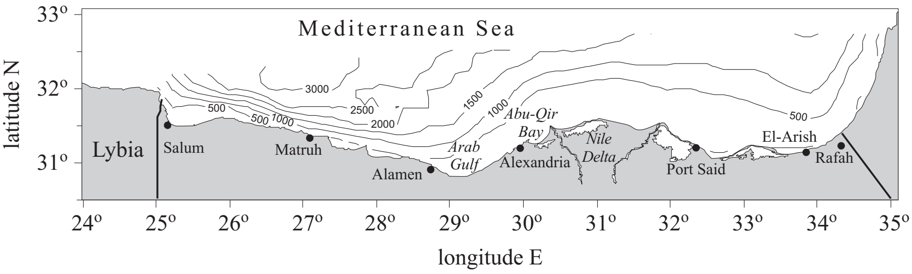

Figure 1. The Egyptian Mediterranean coast

The shoreline between Salum and Abu-Qir Bay is more or less straight with slight undulations forming small embayments. The depths of the continental shelf edge generally increase with increasing shelf width. The widest continental shelf in the southern Mediterranean is found in front of the Nile Delta, where a shelf more than 70 km wide has been built up by the sediments of the River Nile.

Different water masses are found off the Egyptian coast: a surface water mass of high salinity, a subsurface water mass of minimum salinity and maximum oxygen content of Atlantic origin that extends below 50–150 m, an intermediate water mass of maximum salinity extending below 150 m to about 300–400 m depth, and deep waters of Eastern Mediterranean origin (Said & Karam 1990).

Direct current measurements in the south-eastern sector of the Mediterranean Sea are very scarce. This has led to the use of indirect methods such as T-S diagrams and distributions of some physical properties of sea water. Many investigators have studied the circulation pattern in different areas of the Mediterranean Sea using indirect methods during different seasons (Sharaf El-Din 1972, Morcos & Hassan 1976, Sharaf El-Din & Karam 1976, Gerges 1976, Kamel 1993 and Said & Eid 1994). Kamel (1998, 1999) revealed the circulation pattern of the Mediterranean Sea through the distribution of salinity and density fields and illustrated the surface circulation pattern of the eastern Mediterranean Sea.

The feature common to the entire current system is a westward flow, although during winter, the current pattern is different from that in the summer. This difference is attributed primarily to wind action (Sharaf

El-Din 1972). Hamad et al. (2006) showed that the most of the Atlantic Water (AW) flow concentrates in the southern Ionian Sea along the western Egyptian slope.

Investigation of the circulation pattern in Egyptian Mediterranean water is obviously of great importance for discovering the distribution of coastal pollution and the possibility of Intermediate water formation.

The aim of this study was to produce water circulation maps at different levels for the four seasons. The geostrophic current was computed in the southern part of the Levantine basin (off the Egyptian coast). The dynamic topography at the different levels was studied using temperature, salinity and density observations in a rectangular area extending from 24°E to the Middle Eastern coast and from 33°N to the Egyptian coast. The current was computed for the surface, 50, 75, 100, 200 and 300 m levels in each of the four seasons.

2. Material and methods

Seasonal climatological hydrographic data covering the area off the Egyptian coast for the period from 1975 to 2001 were used. These data were obtained from the National Oceanographic Data Center Washington (NODC) and the Mediterranean Oceanic Data Base. Using the above randomly distributed hydrographic data, the values at nodal quarter degree grid points were calculated for each season.

Geostrophic velocity profiles were computed for different pairs of adjacent stations and were plotted for the four seasons. The dynamic computation depends to a great extent on the choice of reference level. In the present study the reference level was taken to be 1000 m.

The method of computing the geostrophic current used here is described in detail in Pond & Pickard (1983). The final geostrophic x-and y-equations are

$$(v_1 - v_2) = (1/2\,\Omega \sin\varphi)\partial(\Delta\Phi)/\partial x \text{ and}$$

$$(u_1 - u_2) = -(1/2\,\Omega \sin\varphi)\partial(\Delta\Phi)/\partial x,$$

where

$\Delta\Phi = \alpha\partial p$ is the change in geopotential over the vertical distance ∂z, $(z_2 - z_1)$;

α is the specific volume;

u_1 and u_2 are the velocity components in the zonal direction (positive towards the east) in m s^{-1}, subscripts 1 and 2 refer to depth levels z_1 and z_2;

v_1 and v_2 are the velocity components in the meridional direction (positive towards the north) in m s^{-1};

subscripts 1 and 2 refer to depth levels z_1 and z_2;
φ is the geographical latitude;
Ω is the angular speed of rotation of the Earth, equal to 7.29×10^{-5} rad s^{-1}.

3. Results and discussion

It is clear from the figures that in nearshore areas the current is directed eastwards at the upper levels (from the surface to 75 m); this is AW flow. At deeper levels (100, 200 and 300 m depth), the current begins to reverse direction, becoming westward (intermediate water).

The surface circulation in the study area is shown in Figure 2 for the four seasons. In the upper layers, the general current runs eastwards along the coast and is dominated by some circulation patterns and gyres.

An anticyclonic gyre is located off Salum Bay in winter and spring (Figures 2a,b), whereas in autumn the entire feature weakens and the eastward current dominates. The Mersa Matruh gyre appears clearly off the Arab Gulf. It varies from cyclonic in winter, summer and autumn to anticyclonic in spring (Figure 2). In summer and autumn this circulation has a high current velocity at its southern edge, covering the area between Salum and Alamen in summer. Said & Rajkovic (1996) showed that the Mersa Matruh gyre exhibits a strong winter to summer variability, reversing from an anticyclonic to a cyclonic circulation. Gerin et al. (2009) described the surface circulation as an eastward flow along the western Egyptian slope that continues in a cyclonic circuit along the Middle East slope.

Figures 2a,c,d and 3a,c,d show the eastward Atlantic Water (AW) flows close to the Egyptian coast in winter, summer and autumn. This result agrees well with Millot & Taupier-Letage (2005), who demonstrated that the main feature of the surface current is the AW that flows all along the eastern basin following the slope. Off the Nile Delta, the current is almost eastward, with a higher velocity in summer and autumn, while in spring it is very weak. The El-Arish gyre is distinct off the area between Port Said and Rafah. It is cyclonic in all seasons except winter, when the current is very weak. Said & Rajkovic (1996) also demonstrated the existence of this gyre in winter only; in summer it disappeared completely.

At 50 m depth (Figure 4), the circulation is very similar to that at the surface although velocities are a little lower. At 75 m depth, the current velocity decreases and the direction of the current off western Salum is to the south-east (Figure 5). At 100 m depth (Figure 6), the El-Arish gyre, which appears at the previous levels (50 and 75 m) between Port Said and Rafah, disappears at 100 m and is replaced by an eastward current in winter, a south-westward one in spring and summer, and a north-westward one in autumn. The circulation in the area between Mersa Matruh and Alamen is less extensive and slower mainly during summer.

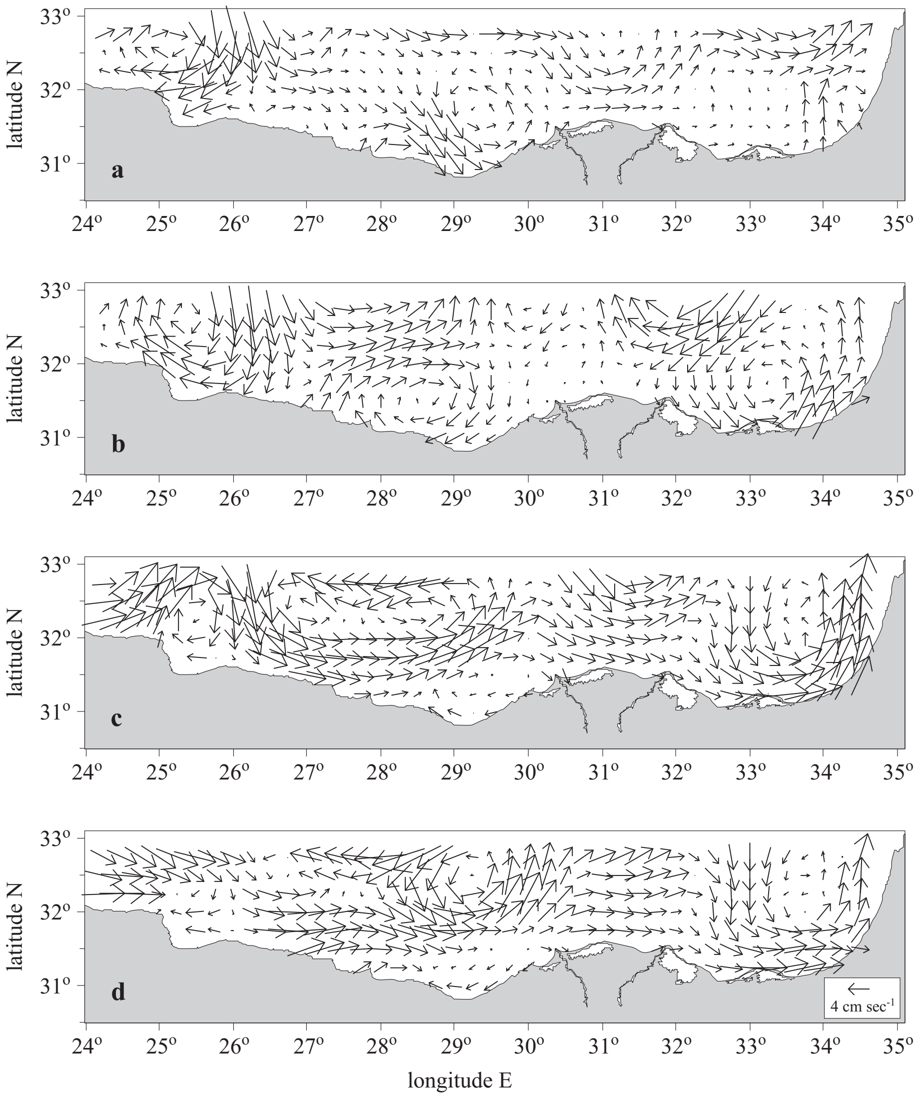

Figure 2. Distribution of surface currents off the Egyptian coast in winter (a), spring (b), summer (c) and autumn (d)

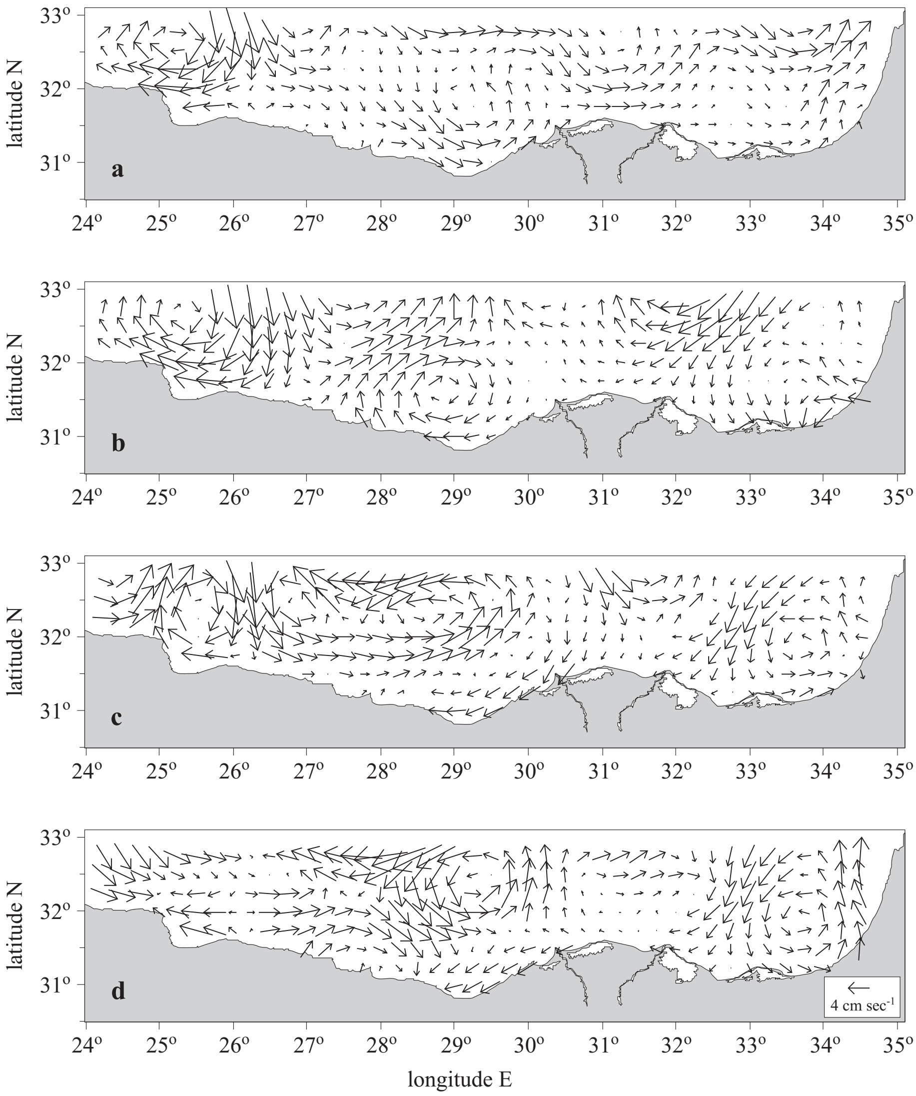

Figure 3. Distribution of currents at 30 m depth off the Egyptian coast in winter (a), spring (b), summer (c) and autumn (d)

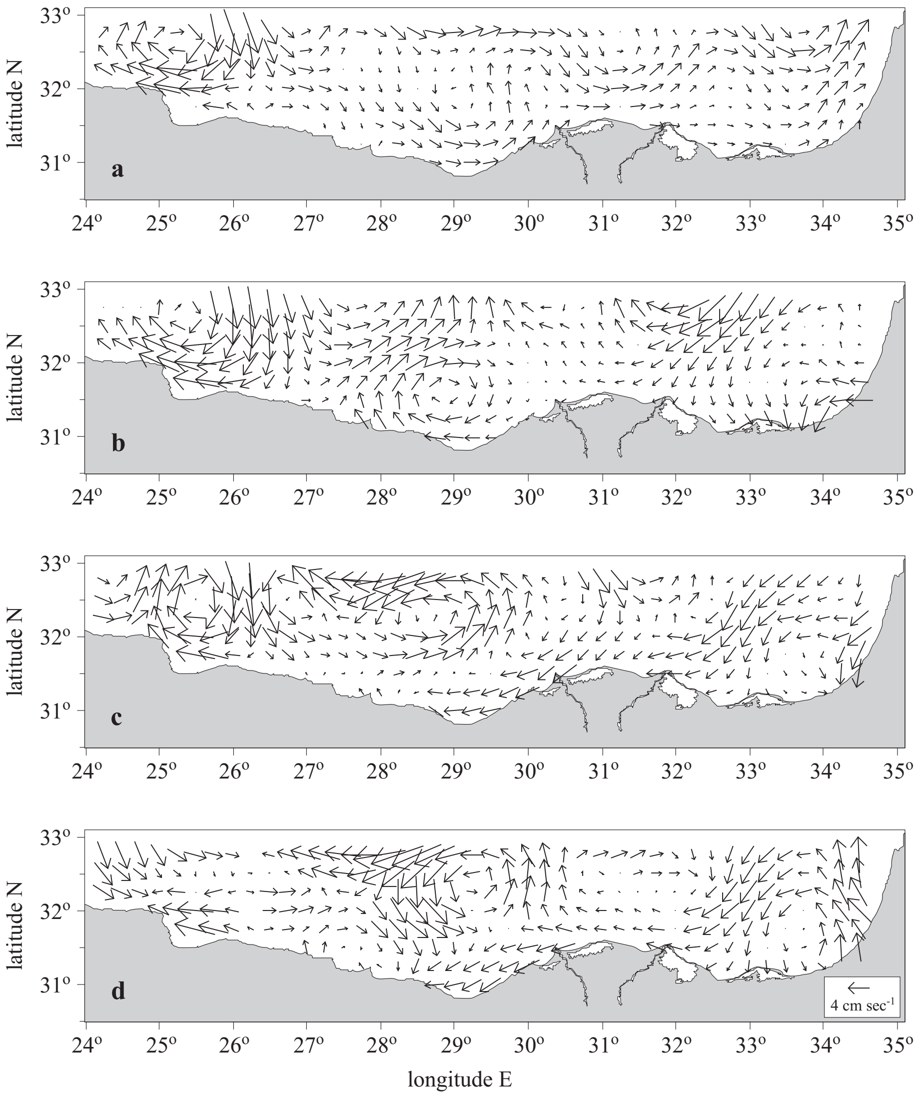

Figure 4. Distribution of currents at 50 m depth off the Egyptian coast in winter (a), spring (b), summer (c) and autumn (d)

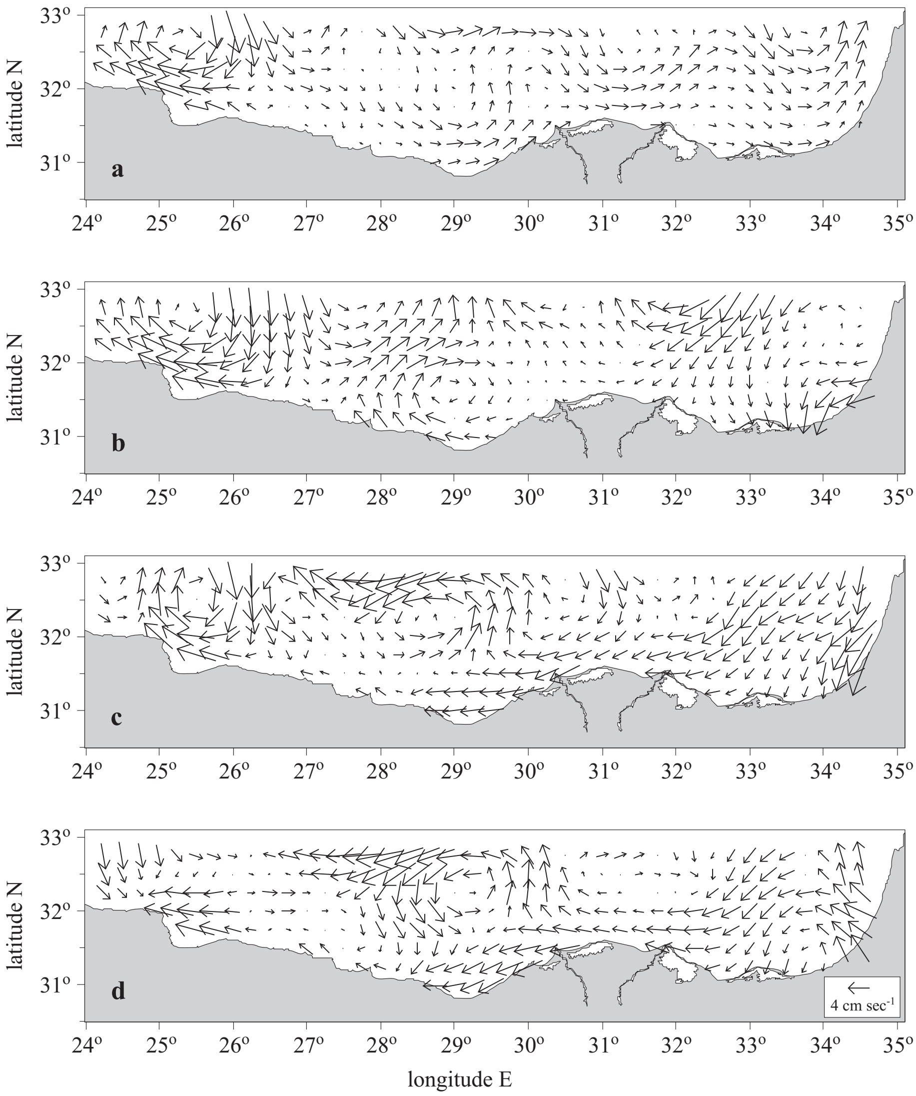

Figure 5. Distribution of currents at 75 m depth off the Egyptian coast in winter (a), spring (b), summer (c) and autumn (d)

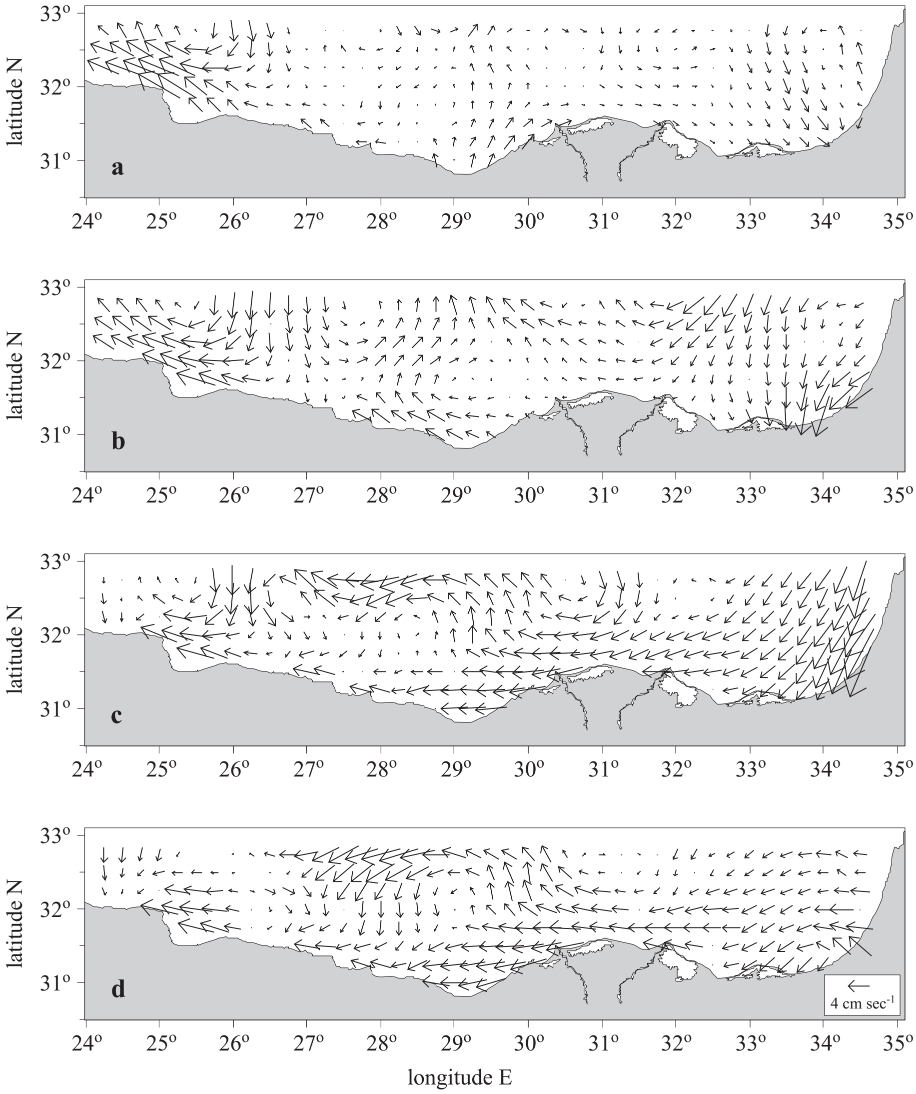

Figure 6. Distribution of currents at 100 m depth off the Egyptian coast in winter (a), spring (b), summer (c) and autumn (d)

At 200 and 300 m depth (Figures 7 and 8) in winter, the current velocity is less than in the other seasons. Off Rafah a high-speed cyclonic circulation appears on its western border in winter, while in spring the current flows to the south off the area between Rafah and Port Said. In summer, off the area between the Arab Gulf and Matruh, there are two parallel westward currents near the shore and offshore. The current off the area between

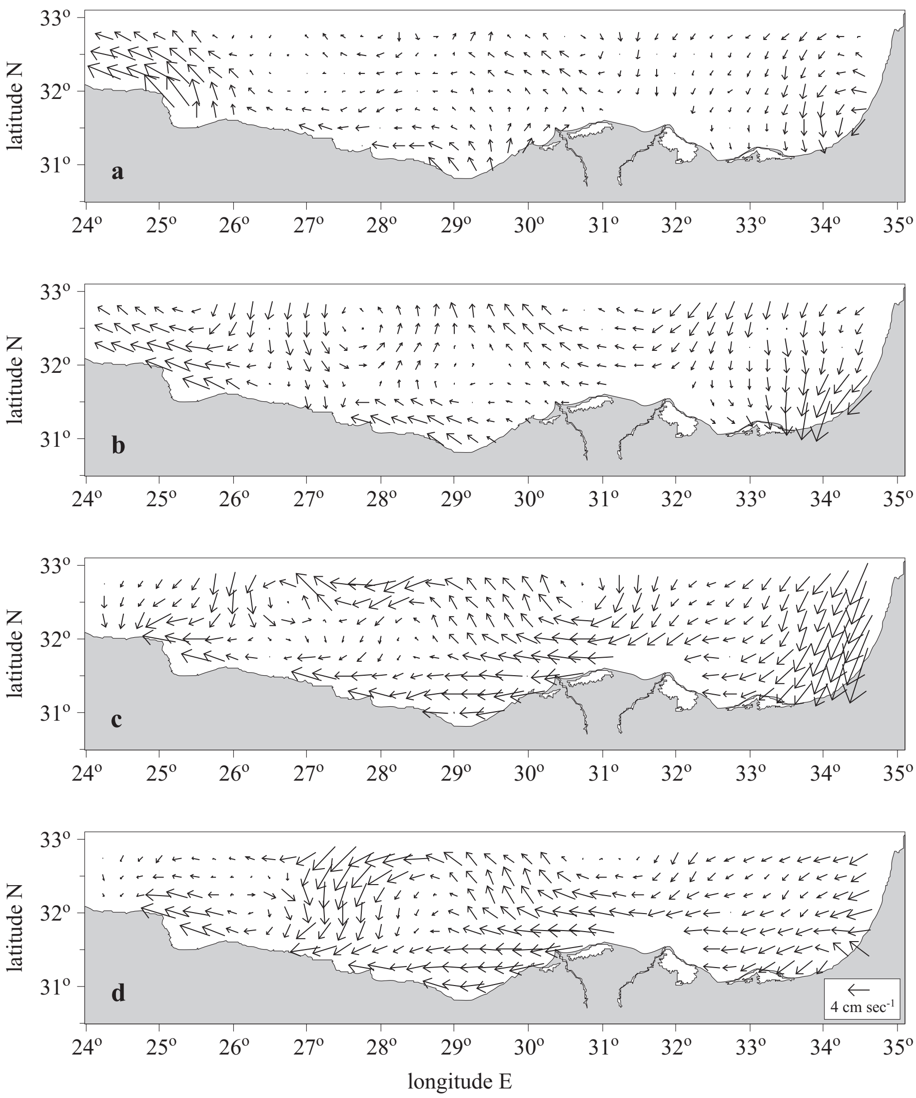

Figure 7. Distribution of currents at 200 m depth off the Egyptian coast in winter (a), spring (b), summer (c) and autumn (d)

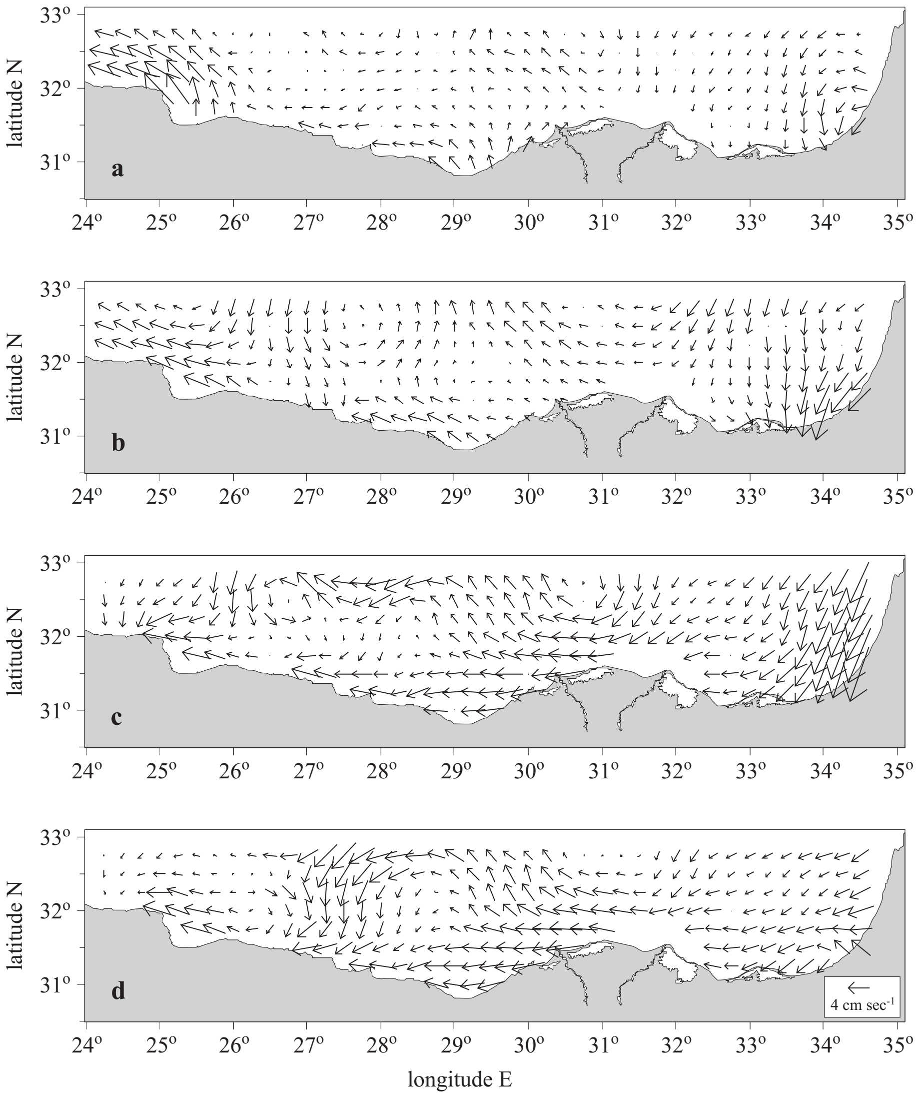

Figure 8. Distribution of currents at 300 m depth off the Egyptian coast in winter (a), spring (b), summer (c) and autumn (d)

Port Said and Rafah is stronger than at any other season but flows southwards only off Rafah and then westwards as far as 25°E.

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