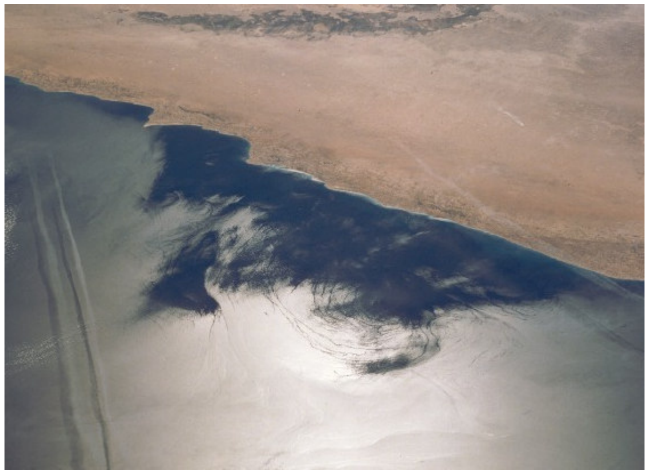

HYDROGRAPHIC STRUCTURES AND CIRCULATION OUTLINE OF THE SOUTHEASTERN MEDITERRANEAN OFF THE EGYPTIAN COAST

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SOMMARIO:

1. Introduction

The knowledge of the hydrographic structures of the eastern Mediterranean, and in particular of the Levantine basin, is very scarce and it is due to the lack of direct measurements near the Egyptian coast. Moreover, little is known about the circulation pattern of the Egyptian Mediterranean waters.

This short outline resumes what has been done by the Egyptian oceanographers in this area in the last 20 years.

Additional references on the oceanographic research carried out by Egyptian scientists in the southeastern Mediterranean can be found in the appendix.

2. Area of study

The Egyptian Mediterranean coast lies between longitude 25° 30′ E and 34° E and extends northward to latitude of 33° N; Fig.1 shows the Egyptian coastline and the most important cities.

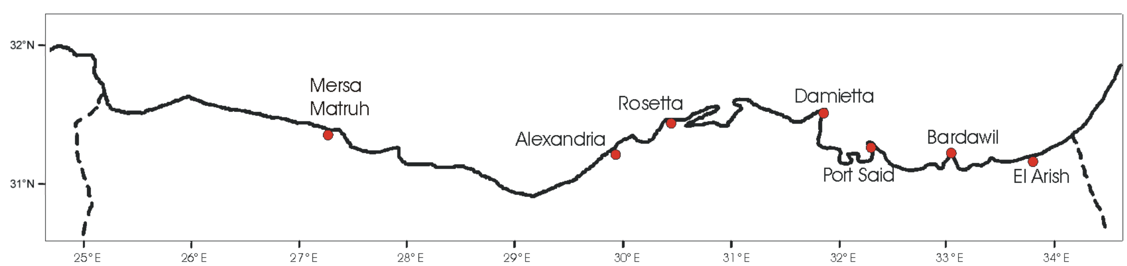

Fig. 1: Egyptian Mediterranean coast.

3. Hydrographic parameters

The 3D interpretation of the hydrographic parameters of the southeastern Mediterranean off the Egyptian coast reveals horizontal and vertical movements of various water masses (three in winter and five in summer) (Said and Eid, 1994a). In winter, the upper 400 m layer is characterized by temperature between 15 and 17 °C and a salinity maximum of 38.9-39.2, while, in summer, the warming effect increases the temperature of the surface water (the upper 30-50 m) up to 28 °C and a strong thermocline is developed. The salinity maximum of this layer reaches 38.8-39.2. The temperature and the salinity of the subsurface layer (50-100 m) range between 17.0 and 22.0 °C and between 38.6 and 38.8 respectively and is identify as the Atlantic Water Mass (AWM) (El-Din and El-Gindy, 1987). Below the AWM layer the Levantine Intermediate Water (LIW) is identified by a salinity maximum of 38.9-39.1 at 150-400 m, where the temperature varies between 15 and 17 °C.

During both seasons, between 400 and 800 m a mid-depth water mass, characterized by temperature values between 13.6 and 14.5 °C and by salinity range of 38.75-38.87, is detected. This mid-depth layer is observed throughout the East Mediterranean basin (Karam and Said, 1988) and is generally shallower in the Levantine (400-700 m) than in the Ionian basin (1200-2000 m).

Finally, below 1000 m and down to the bottom, the deep water mass is characterized by temperature and salinity values that fluctuate respectively between 13.3-13.5 °C and between 38.68-38.75.

In winter, sea surface temperature off the Egyptian coast generally increases in winter moving away from the near-shore (Said and Abdel-Moati, 1992). The values range between 16 and 18 °C, the lowest values are observed between longitude 28°-29° E, while the highest values are confined to the eastern coast (Said and Karam, 1990). In summer, the water temperature at sea surface is steady almost everywhere (26-29 °C); cold spots (< 25 °C) appear only off the Nile Delta (Said and Abdel-Moati, 1992) and between 27-29°E (Said and Rajkovic, 1996). In autumn, summer values decrease by 3-5 °C, with a minimum close to the Bardawil coast (22.3 °C) and a maximum off Port Said (24 °C) (see Fig. 1 for the location).

4. Levantine Intermediate Water

The presence of an intermediate water characterized by a secondary maximum of salinity in the Mediterranean Sea (Fig. 2) was studied since 1912 when Nielsen prompted that the main sources of this layer take place near the northern region of the Levantine basin from where it extends to the south and west. Wüst (1960) pointed out that, along the coasts of Asia Minor, the temperature drops in late winter and simultaneously the salinity value at the surface reaches its maximum (39.1). These conditions allow the formation, on both sides of Rhodes, of an homogeneous water mass (Levantine Intermediate Water LIW) in the upper 250 meters, characterized by a relatively dense surface water. Moreover Said (1985) indicated that, in cold winters, the formation of LIW arises nearly everywhere in the Levantine Sea with the exception of the southern and the extreme eastern parts, while, in mild winters, the formation occurs only at the boundaries of the cyclonic gyre of the Levantine Sea and north of Crete.

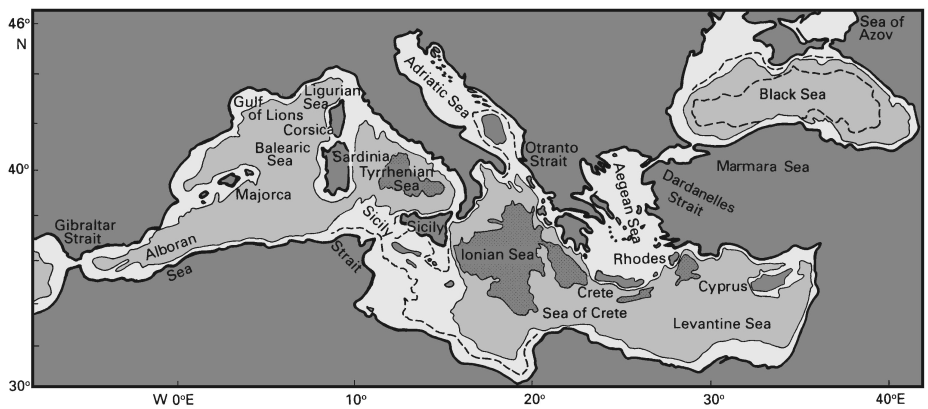

Fig. 2: Mediterranean Sea.

According to Morcos (1972), comparing the climatological and the hydrological situations during winter, the offshore water of the Egyptian coast in the upper 200 meters fits together with the Levantine one in the same layer. Therefore, he suggested that the regions to the east of longitude 29°E and the west of Alexandria are to be considered a secondary source of formation of the intermediate water. This dense water formed off the Egyptian coast in winter occupies the broad continental shelf and a part of the continental slope which creates the best conditions to slope down and to spread as an intermediate water to the north and west.

Another study (Abdel-Moati and Said, 1987) found that the area in front of Damietta reveals a process of formation of the intermediate water similar to that suggested by Morcos and therefore is another area of formation of this salty water. Moreover, the highly salinity tongue of the eastern Mediterranean water comes into Damietta area from the north to the south and deflects toward the west and again towards the north, creating a small anticyclonic eddy (Fig. 3) (Said, 1993b).

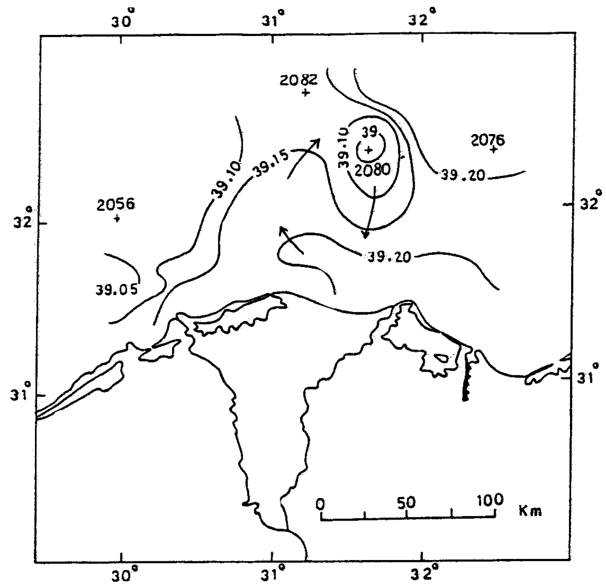

Fig. 3: Surface salinity during December 1988 (Said,1993b) .

5. General circulation

A cyclonic general circulation was proposed by El-Gindy and El-Din (1986) in the Levantine Sea as well as in the Ionian Sea. In particular, the patterns of the surface circulation in the Levantine Sea manifest a cyclonic gyre in the north and in the central parts, while, in the southern part, an anticyclonic eddy is detected (El-Nady and El-Gindy, 1987). Moreover, the autumn pattern shows cyclonic eddies in the north and south area and an anticyclonic gyre in the central part of the basin.

The water budget on the Egyptian Mediterranean coast has been calculated by Said (1993a) computing the amount of water circulation through it. He found that the water, after passing the Strait of Sicily, follows a cyclonic gyre along the coasts of the Eastern basin, according to the previous knowledge on the circulation in the Eastern Mediterranean. The same author (Said, 1990) pointed out that the geostrophic circulation of the central and eastern Mediterranean waters demonstrates a considerable stability in both seasons (winter and summer) and is mainly characterized by (Figs. 4 and 5):

- a vast cyclonic gyre in the Levantine Sea, enclosing also the southern part of the Aegean Sea;
- a cyclonic gyre in the Ionian Sea;
- an anticyclonic gyre in the south Ionian Sea and near the Egyptian coast.

In winter the cyclonic gyres are better defined than in summer; probably this is related to the atmospheric cyclones that circulate over the Mediterranean Sea mostly in the cold season.

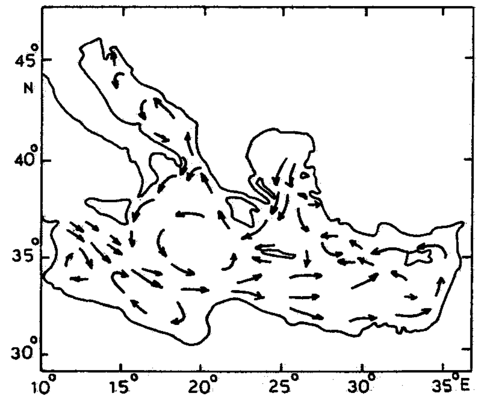

Fig. 4: General circulation of the Mediterranean Sea (Nielsen, 1912).

Considering the 1000 dbar surface as the level of no motion, the geostrophic current velocity ranges between 5-10 cm/s in the south Ionian Sea, 15-25 cm/s near the Egyptian coast, between 35-40 cm/s in the eastern part of the Levantine Sea and 15-30 cm/s at the strait of Crete.

According to Said (1990), the circulation of the intermediate water masses remains close to that of the surface layers. The LIW formed in the Levantine Sea is involved in the Levantine cyclonic gyre and in the Aegean Sea the intermediate water moves through the eastern strait of Crete. In the center of the basin, this water is carried by the cyclonic gyre of the Ionian Sea to the north, while the south Ionian (Libyan) anticyclonic moves intermediate water westward.

The isopycnal analysis of the Egyptian Mediterranean coast, studied by Said (1993a), showed that the inflowing intermediate water from the Levantine basin and the water formed on the Egyptian Mediterranean shelf flow away from the continental shelf to the northwest in a high salinity tongue.

Evaluating the irregular distribution of the steric height, for a water column of 1000 m, off the Egyptian coast, Eid and Said (1995) determined that the investigated area, in addition to be considered an extension of the North African current flowing to the east, leads to form an anticyclonic gyre off Mersa Matruh and a cyclonic one off El-Arish. While the Mersa Matruh gyre is observed in winter and in summer, the El-Arish gyre is well defined in winter and completely disappears in summer.

The surface circulation is dominated by the Atlantic water inflow along the north African coast and by the Mersa Matruh anticyclonic gyre in the western part of the Egyptian coast. More recent studies (Said and Rajkovic, 1996 and Said and Eid, 1994b) proved that the Mersa Matruh gyre displays an extreme variability among the two seasons, reversing from anticyclonic (winter) to cyclonic (summer) circulation (Said and Rajkovic, 1996) and, during summer, can also split into two (Said, 1998) or three (Said and Rajkovic, 1996) smaller eddies at 200 meters. Moreover, the surface current, that flows eastward parallel to the Egyptian coast, bifurcates in two branches near the Nile Delta (Said and Eid, 1994b; Said, 1994 and Said and Rajkovic, 1996). One turns back and follows the Egyptian coast towards the west. This first branch is well observed in winter in the entire water column near the coast, while in summer the reversing circulation is very weak and could be found only westward of Alexandria. The other branch circulates into the cyclonic gyre (Said and Eid, 1994b) off El-Arish in winter and disappears in summer. To the east of El-Arish gyre, the Shikmona gyre is observed in both seasons (Fig. 5).

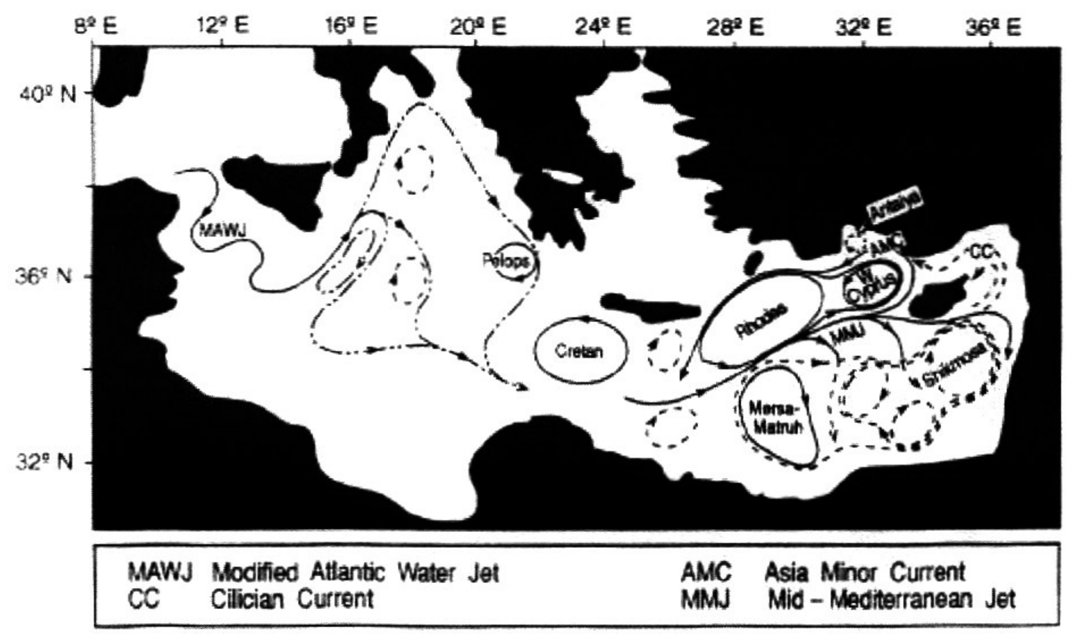

Fig. 5: Gyres, eddies and near-surface circulation in the eastern Mediterranean Sea according to Robinson and Golnaraghi (1993).

The averaged current speed at the surface, off the Egyptian coast, during winter is slightly higher than the one measured during summer. In winter it fluctuates between 1 and 50 cm/s, while in summer it varies between 1 and 24 cm/s. The geostrophic current velocity at the edge of Mersa Matruh gyre varies between 12 and 29 cm/s in winter and between 6 and 13 cm/s in summer. The current velocity reaches its maximum values (>40 cm/s) at the El-Arish gyre in winter. The current velocity of both gyre decreases with increasing depth (Said and Eid, 1994b).

The dynamic pattern of the sub-surface layer (50-100 m) is very similar to that observed at the surface in winter and summer, while, at the deeper layer, small edges appear within the gyre and between them.

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