

Characteristics of the Egyptian Mediterranean water masses during the cold and warm winters

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Two winter sets of hydrographic data representing warm and cold winters for 1989 and 1990 respectively were used to study the characteristics of Egyptian Mediterranean water masses. The classification was based on the variations of air and surface water temperatures.

Four water masses were observed during winter; (i) the surface water mass of temperature 17-19 °C, salinity maximum 39.0-39.2 occupies the upper 200 m layer; (ii) the Levantine intermediate water mass of temperature 15-17 °C and salinity 38.8-39.0 occupies depths between 200 and 400 m, (iii) a mid-depth water mass lies between 400 and 800 m of temperature 14-15 °C and salinity range 38.75-38 and (iv) the deep water mass of potential temperature range 13.3-13.5 °C, salinity 38.6-38.75 and density $\sim 29.1 \sigma_t$.

By analyzing the water temperature and salinity distributions, we found that the average surface water temperature are 18.88 °C and 16.73 °C during the warm and cold winters, respectively with an average difference of 2.1 °C. The difference reached the maximum value of 2.32 °C at 50 m depth. It decreases with increasing depth to reach 0.12 °C at 200 m depth. At the depth of 250-500 m, the difference was negative and varied between -0.42 and -0.17 °C. The difference of average salinity at the surface was about 0.07 and decreased to reach 0.03 at 50 m depth. At depth of 100 m and down to 500 m, the difference values were negative and varied between -0.03 and -0.09.

Vertically, the variations in the water temperature and salinity were observed not only on the surface, but also to a deeper layers (>200 m). The surface layer (0-150 m) represents a water mass of high positive temperature difference (up to 2.5 °C) and low positive salinity difference (~ 0.06). The intermediate layer showed a nuclei of negative difference (-1.4 °C and -0.2 salinity) in the eastern side of the study area at depth of 200-300 m.

Key words: water masses, thermohaline characteristics, east Mediterranean

INTRODUCTION

The Eastern Mediterranean, and in particular southeastern part off the Egyptian coast, was one of the least understood parts of the world Ocean. Recent observations made possible through the national programs of bordering countries and planning under the POEM research program (Physical Oceanography of the Eastern Mediterranean, UNESCO, 1984, 1985, 1987; MALANOTTE-RIZZOLI & ROBINSON, 1988; OZSOY *et al.*, 1989, 1991; ROBINSON *et al.*, 1991; POEM GROUP, 1992, ROBINSON & MALANOTTE-RIZZOLI, 1993; MARULLO *et al.*, 1999), have made significant contributions to a much needed understanding of the Eastern Mediterranean circulation. A new hypothesis about the movement of the Atlantic water in the Eastern Mediterranean has been described by HAMAD *et al.* (2005).

The southeastern part of the Mediterranean Sea off the Egyptian coast was one of the least investigated areas until the last two decades. Our early knowledge on the hydrography of this area started with the information obtained by GEORGY & SHAHEEN (1964), HALIM *et al.* (1967) and HASSAN (1969). Most of the known characteristics of the water masses have been obtained by constructing T-S diagram, and sections of horizontal and vertical distributions of some physical and chemical properties of sea water such as salinity, temperature and oxygen (MORCOS & HASSAN, 1973, 1976; GERGES, 1976; SHARAF EL-DIN & KARAM, 1976; MAIYZA, 1979; SAAD, 1984; ABDEL-MOATI & SAID, 1987; SAID, 1993; SAID & EID, 1994).

Although knowledge of the hydrographic structure of the deltas is very important, the Nile Delta which is focal points for the trade, agriculture and fisheries of coastal peoples has poorly studies till recent time. The Nile River, although its discharge has been considerably decreased since 1965, and is now controlled by Aswan High Dam, is still the main river, discharging into the southeastern Mediterranean. It is thus contributing to the overall river pollution input in this area of the Mediterranean Sea. The average total discharge for the preceding 9 years (1956-1964) amounted to 48.03 km³ (GERGES,

1976). From 1965 on, the discharge remarkably decreased. Information on the yearly discharge of the River Nile, measured at Edfina (30 km south of Rosetta outlet), indicated that the average annual discharge amounted to 3.76 km³.

The aim of the present work is to study the characteristics of Egyptian Mediterranean water masses off the Nile Delta through two winter sets of hydrographic data representing warm and cold winters for 1989 and 1990 respectively.

MATERIAL AND METHODS

The data used in this study were taken from the joint Soviet-Egyptian expeditions carried out along the Egyptian Mediterranean sector during December 20-27, 1988 aboard RV Academic Levrentyev, and March 7-15, 1990 aboard RV professor Bogorov. Fig. 1 illustrates the area of investigation and locations of the sampling stations. During the two expeditions, two data sets were collected. Hydrographic data were taken from 31 stations during 1988 and from 30 stations during 1990 using MARK-III NBIS CTD (USA) for 1 m intervals from surface to bottom. Standard meteorological measurements, such as wind speed and direction, atmospheric pressure and air temperature were taken every four hours during the study period using an automatic weather station.

These two sets of hydrographic data were used for determination the characteristics of the warm and cold winters. The classification was based on calculating the deviation of monthly average air temperature from the mean values taken from the Atlas (MIDDELANDSE ZEE, 1957) of the corresponding months. The negative temperature anomaly identified as a cold month and the positive as a warm one. In the present work, 1989 was identified as a warm winter and 1990 as a cold one. This method was applied to identify the cold and warm years by LAMAKEN (1984), MAIYZA (1984), MAIYZA *et al.* (1995) and GUERGESS (2006).

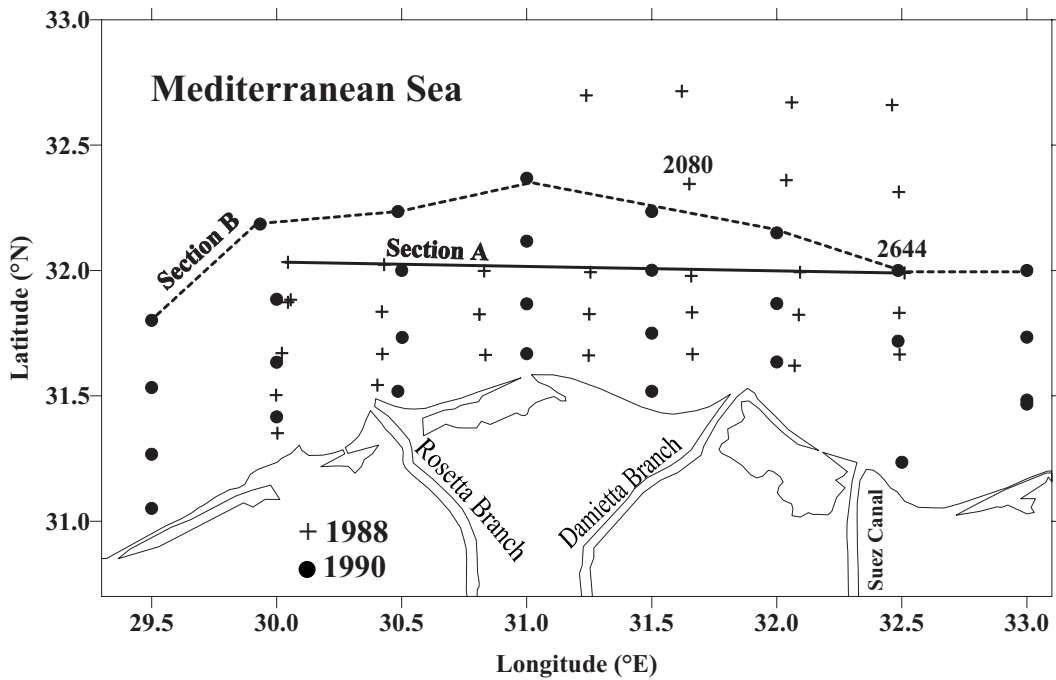


Fig. 1. Area of investigation and locations of the sampling stations

RESULTS AND DISCUSSION

Bottom topography of the Nile Delta area based on observations taken during the present study is shown in Fig. 2. From the figure, the continental shelf off the Nile Delta is broadening while on the both sides it is a little

bit shorter. The 50 m isobath is more or less dividing the continental shelf into two equal halves. Isobaths between the two contour 100 and 500 m are squeezed offshore central part of the delta.

During 1989 cruise, moderate northwesterly winds were prevailed with a velocity range of

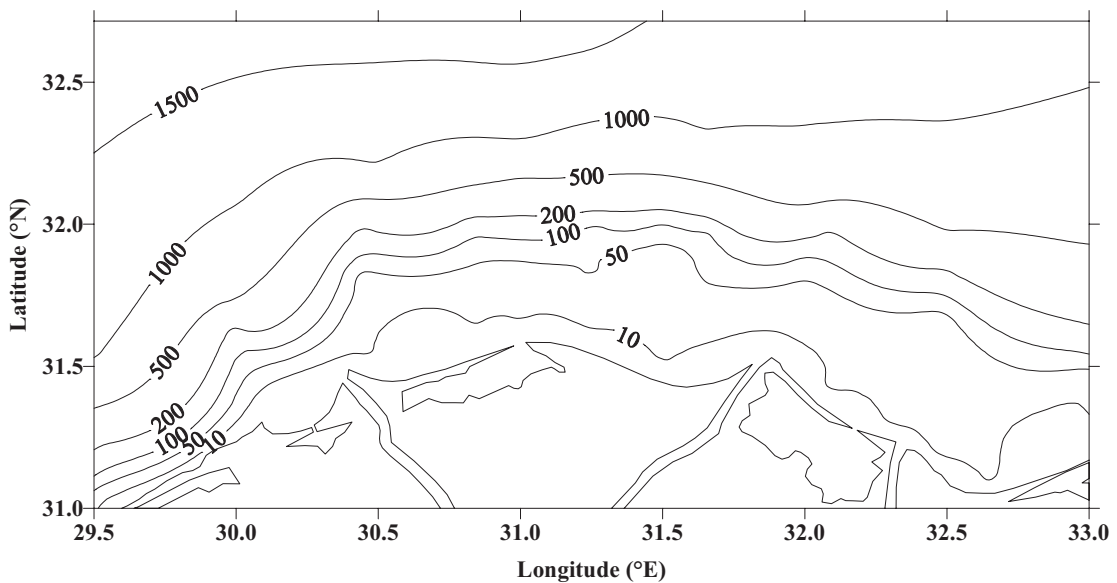


Fig. 2. Bottom topography of the Nile Delta area based on the observations taken during the present study

1-10 m sec^{-1} . The air temperature changed from 15.0 to 19.0 $^{\circ}\text{C}$ through out the study period. While, in 1990 cruise, the prevailing wind was also in the northwest direction with a velocity range is 4-12 m sec^{-1} . The air temperature fluctuated between 13.0 and 17.0 $^{\circ}\text{C}$ through out the period of investigation.

A - Hydrographic structure of the water masses during the warm winter

In winter 1989, the surface water temperature varied between 17.78b $^{\circ}\text{C}$ and 19.47 $^{\circ}\text{C}$ with few slightly colder or warmer spots (Fig. 3a). Lowest values of water temperature (<18.0 $^{\circ}\text{C}$) are observed in the western part of

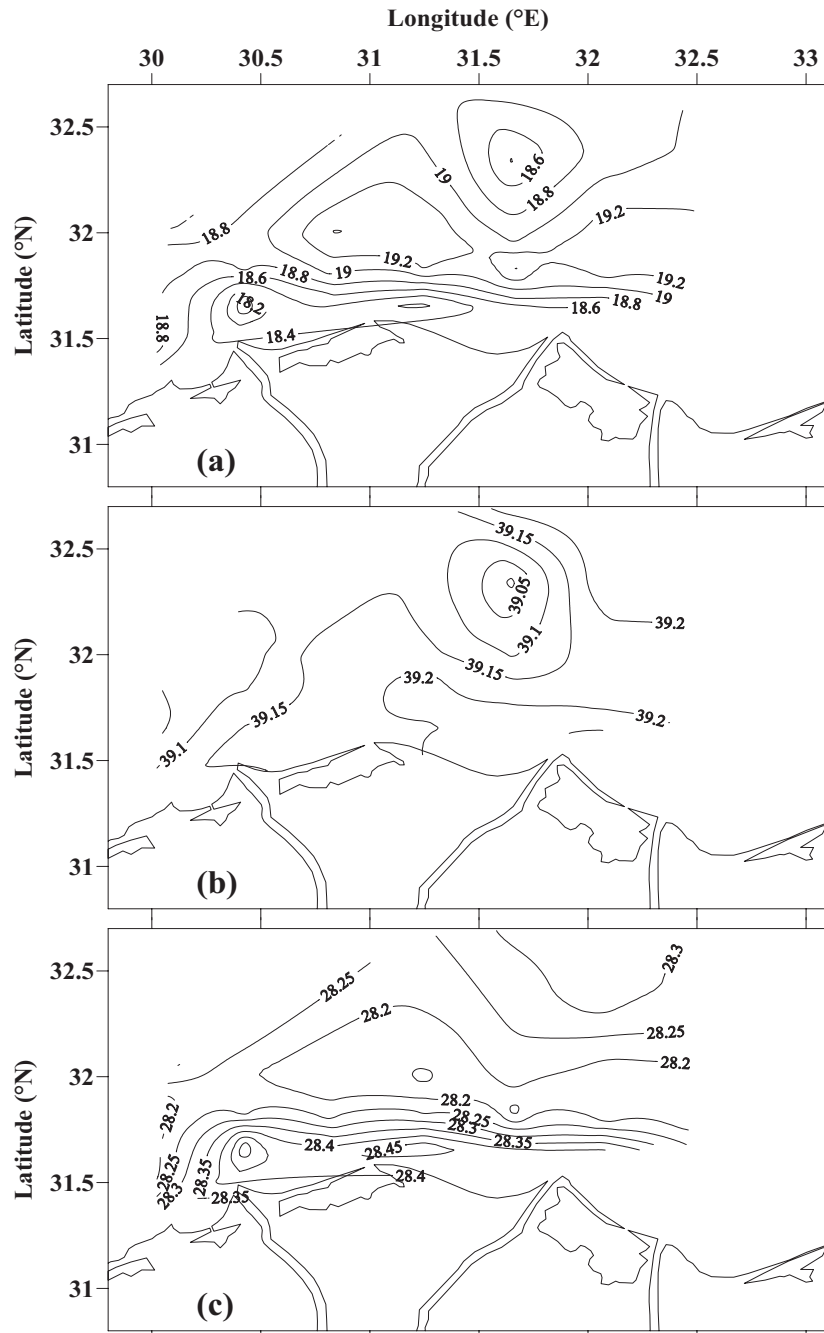


Fig. 3. Horizontal distribution of surface (a) water temperature (b) salinity and (c) density (σ_t) during the warm winter (1989)

the study area near Rosetta mouth of the Nile River. A region of water temperature (18.4-18.8 °C) is observed in the offshore stations off Damietta branch of the Nile River. It lies between Latitudes 32° and 32°30' N and Longitudes 31° 30' and 32° E. From (Fig. 3a), it is important to mention that there is an indication of a spreading of warm water of temperature (19-19.2 °C) from the eastern part of the study area flows westwards.

The surface salinity during the study period changes between 38.99 and 39.26, with a general trend of increasing salinity eastward (Fig. 3b). The most conspicuous features of the salinity distribution at the surface are the presence of a wide area of salinity 39.05-39.10. This area is characterized by relatively low temperature (18.4-18.8 °C) and density $> 28.25 \sigma_t$ and occupies the offshore area off Damietta branch of the Nile River.

The surface density (σ_t) values vary between 28.2 and 28.4. Higher values of σ_t are observed in the coastal area due to the low temperature

and high salinity values. The horizontal distribution of surface σ_t values (Fig. 3c) indicates the existence of in flowing water of 28.2 σ_t from the east. This water has a temperature of more than 19.0 °C and salinity 39.15-39.20.

Profiles of temperature, salinity and density (Fig. 4a) at station No 2080 located in the center of the closed area off Damietta indicated that, the water temperature decreases from 18.40 °C at the surface to 16.56 °C at 150 m depth. Below the 150 m and to 400 m the temperature rapidly decrease to about 14°C, and then it slowly decreases to reach 13.50 °C at 1000 m. Salinity values of ~39.00 are observed in the upper 30 m layer and decrease to reach 38.89 at 150 m. With increasing depth, the intermediate water characterized by a secondary maximum of salinity (38.93-38.95) and occupies depths between 150 and ~300 m was observed. Below this layer, salinity values slightly decrease with depth to reach 38.63 at 1000 m. Values of σ_t increase with increasing depth from 28.1 at the surface to about 29.12 near the bottom (Fig. 4).

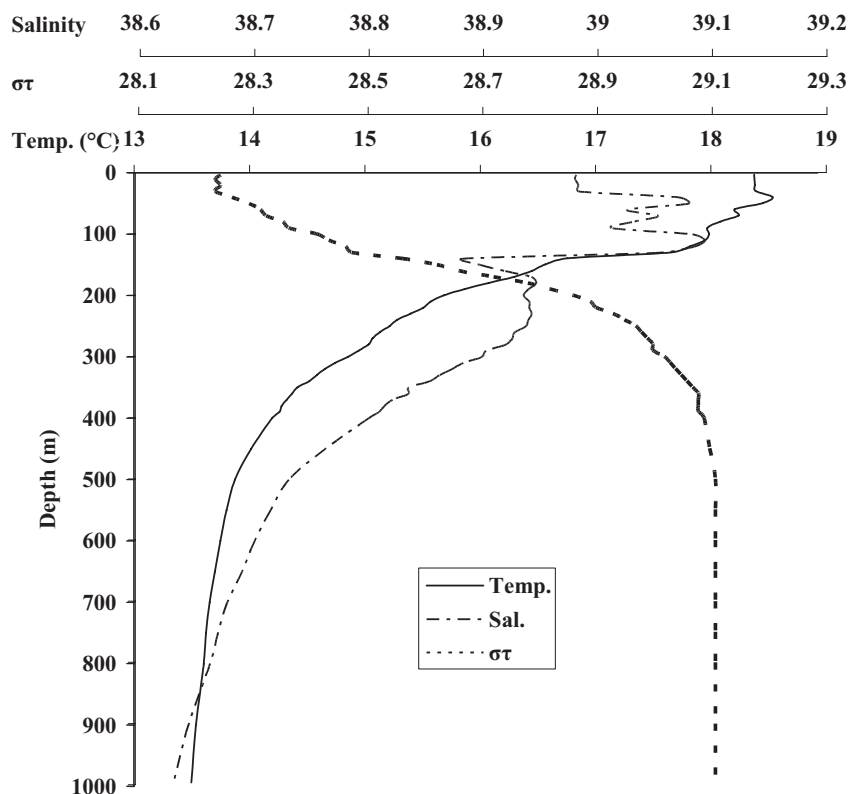


Fig. 4. Vertical profiles of temperature (°C), salinity and density (σ_t) for station 2080 during winter 1989

The offshore stations are represented in a section parallel to the Nile Delta coast to study the vertical space variability of the hydrographic parameters. The location of this section (section A) is shown in Fig. 1. During (1989) warm winter, the water temperature varies between 19.35 °C and 16 °C in the upper 200 m layer (Fig. 5a). At the central part of Nile Delta, the water temperature is approximately homogenous (19.0-19.35 °C) from surface to about 200 m depth i.e. values slightly decrease by about 0.35 °C. This homogeneity may be due to the vertical mixing by winter convection. Below this layer, the water temperature decreases to reach 14 °C at 400 m depth, and

slowly decreases with increasing depth to reach 13.58-13.59 °C at 1000 m depth.

Salinity values show a great homogeneity in the whole area due to the vertical mixing. It varies between 39.0 and 39.16 in the upper 200 m layer (Fig. 5b). At the central part of the area the salinity varies within a very narrow range of about 0.06 between 39.10 and 39.16. This layer has a temperature range of 19-19.35 °C and density 28.20 σ_t . Below this layer, salinity decreases with increasing depth to reach about 38.65 at 1000 m depth. Values of σ_t increase with increasing depth from 28.2 at the surface to about 29.13 near the bottom (Fig. 5c).

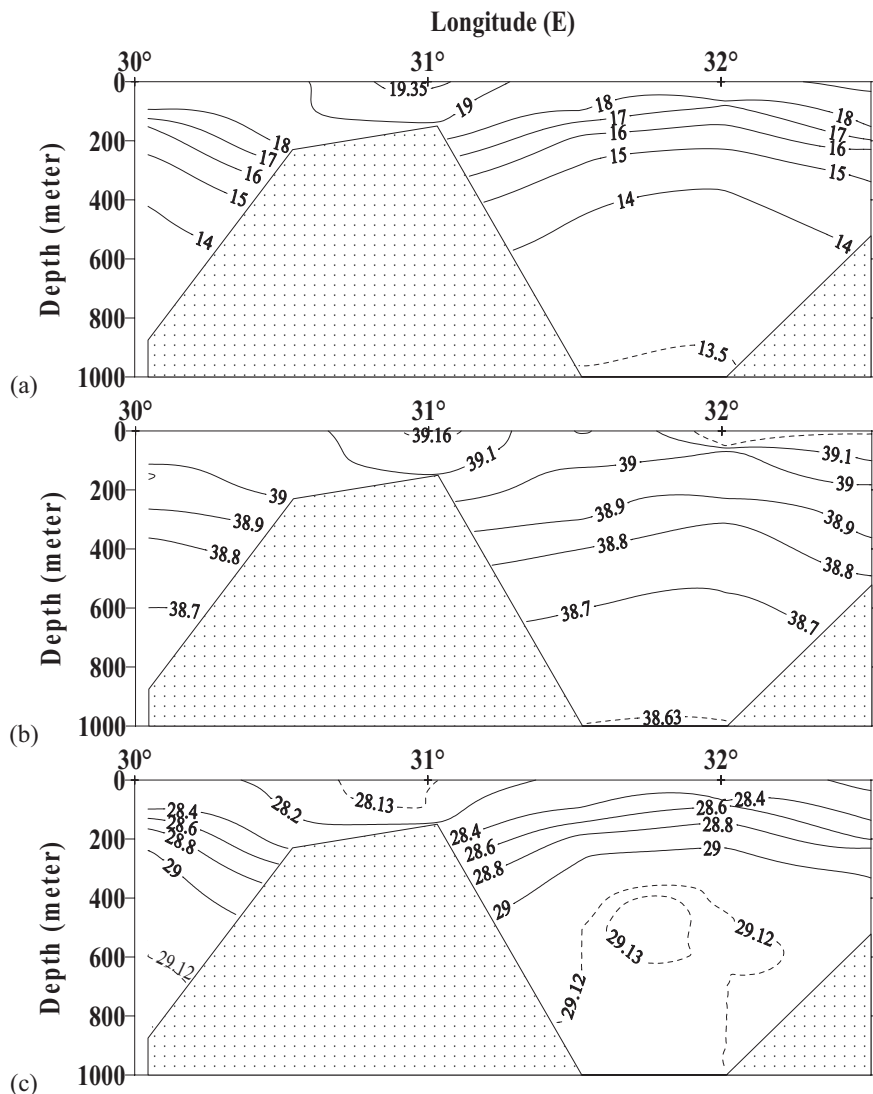


Fig. 5. Vertical distribution (a) water temperature (b) salinity and (c) density (σ_t) during the warm winter (1989)

B - Hydrographic structure during the cold winter

The surface water temperature during the 1990 cold winter varies between 16.13 °C and 17.33 °C. The most conspicuous features of temperature distribution at the surface are the presence of two small eddies of temperatures 16.5-16.7 °C and 16.9-17.1 °C in the eastern part of the study area (Fig. 6a).

The surface salinity changes between 38.64 and 39.27 lowest values of salinity (<38.80) are observed in the coastal zone of the eastern part of the study area off Lake Manzalah (Fig. 6b). This area is also characterized by low values of temperature (<16.30 °C) and σ_t (<28.60). A region of water salinity 39.00 is observed in the western part of the Nile Delta off Rosetta mouth. This

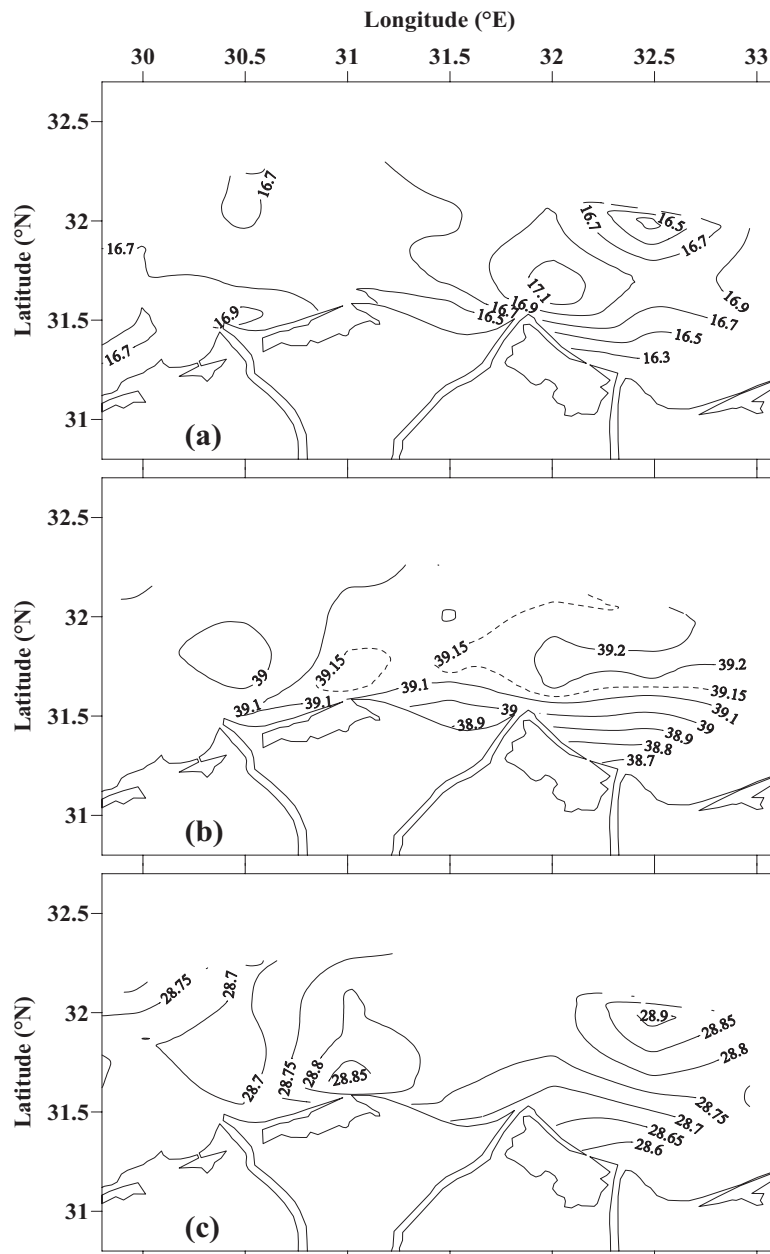


Fig. 6. Horizontal distribution of surface (a) water temperature (b) salinity and (c) density (σ_t) during the cold winter (1990)

region is characterized by temperature $16.7\text{ }^{\circ}\text{C}$ and density $28.7\text{ }\sigma_t$. A water with salinity $39.1\text{-}39.2$ seems to flow westward in high-salinity tongue.

The surface density varies between 28.6 and 28.9 . The region of high σ_t values ($28.8\text{-}28.9$) is observed in the north-eastern part of the area and is characterized by low temperature ($16.5\text{-}16.7\text{ }^{\circ}\text{C}$) and high salinity (39.20).

Profiles of temperature, salinity and density (Fig. 7) at station No 2644 in the center of the closed area show a great homogeneity in the upper 50 m layer. The values are $16.1\text{ }^{\circ}\text{C}$ for temperature, 39.15 for salinity and 28.94 for σ_t . Below that depth, temperature and salinity decrease with depth to reach $13.57\text{ }^{\circ}\text{C}$ and 38.86 at 500 m depth respectively. Den-

sity increases with increasing depth to reach $29.28\text{ }\sigma_t$ at 500 m depth.

The vertical distribution of the hydrographic parameters along a section (B) parallel to the Nile Delta coast is shown in Fig. 8. In the upper 200 m layer, the water temperature changes in a narrow range from 16.9 to $16.0\text{ }^{\circ}\text{C}$. This layer is characterized by high salinity values ($39.0\text{-}39.15$) and density $28.7\text{-}28.9\text{ }\sigma_t$. Below that depth, the water temperature decreases to about $14.0\text{ }^{\circ}\text{C}$ at 500 m depth and slowly decreases with depth to reach $13.60\text{ }^{\circ}\text{C}$ at 1000 m depth. Salinity also decreases downward from 39.0 at 200 m level to reach 38.72 at 1000 m depth. Meantime density increases with increasing depth from 28.9 at 200 m depth to $29.2\text{ }\sigma_t$ at 1000 m depth.

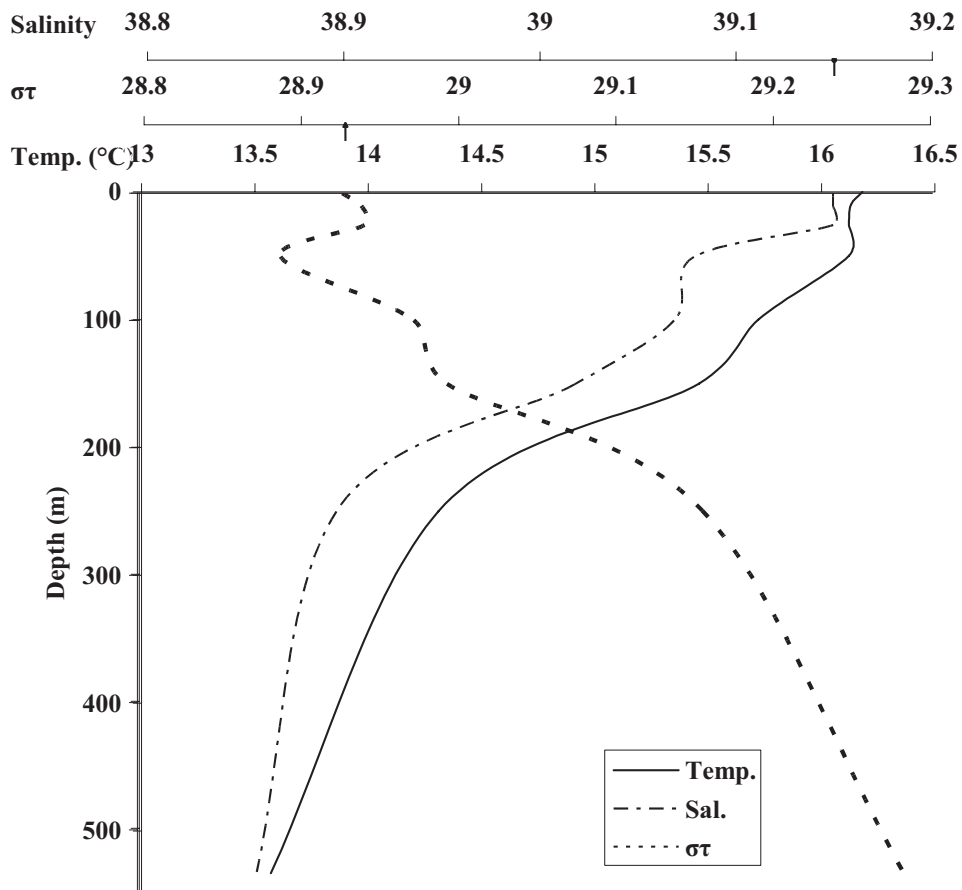


Fig. 7. Vertical profiles of temperature ($^{\circ}\text{C}$), salinity and density (σ_t) for station 2644 during winter 1990

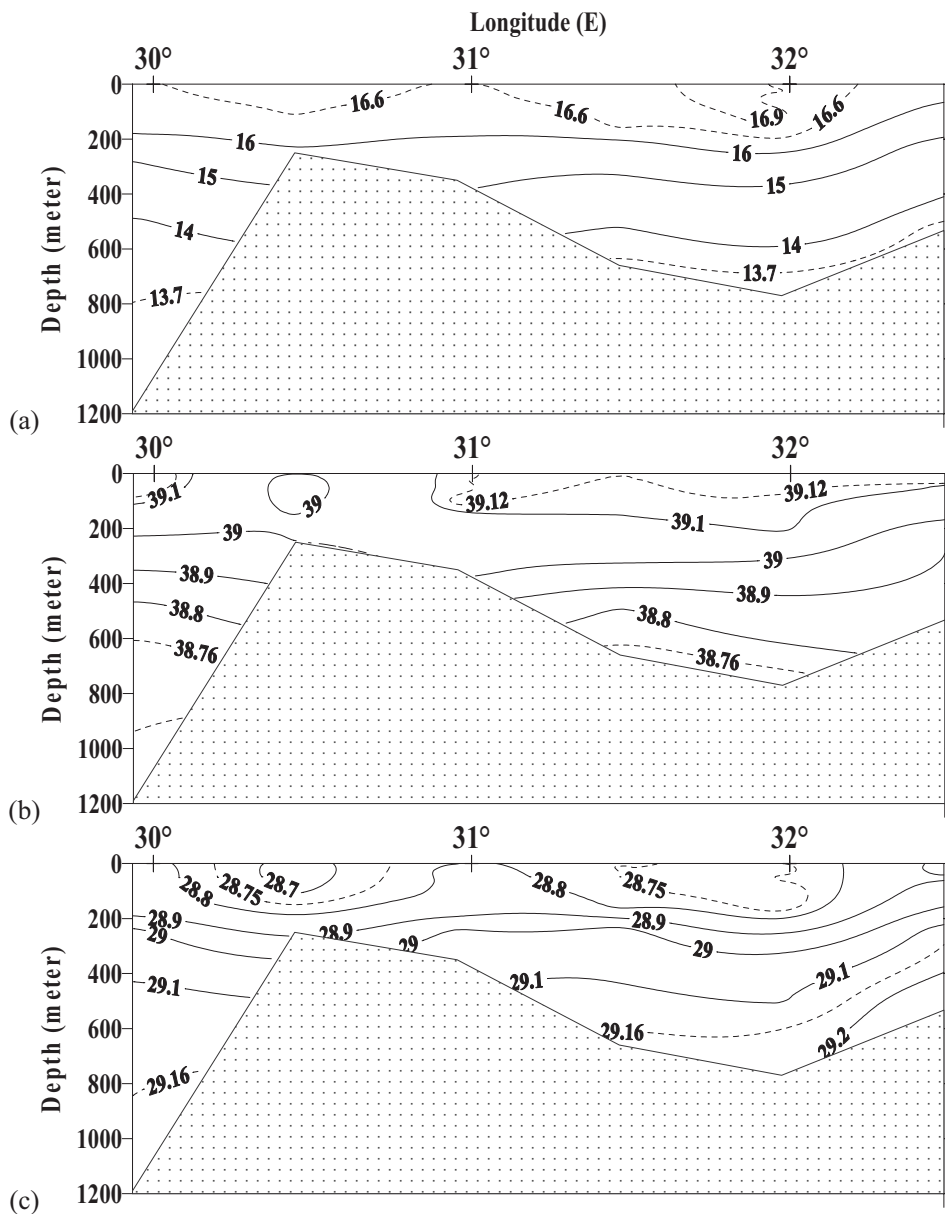


Fig. 8. Vertical distribution (a) water temperature (b) salinity and (c) density (σ_t) during the cold winter 1990

C - Water masses along the Egyptian coast

The results reveal that, four water masses could be observed during winter (Fig. 9). The surface water mass which is characterized by the temperature range 17-19 °C and the salinity maximum 39->39.2 and σ_t values between 28.1-28.4 occupies the upper 200 m layer. The Levantine intermediate water mass identified

by a secondary maximum of salinity 38.8-39.0 occupies depths between 200 and 400 m. This water mass has a temperature range of 15-17 °C and density 28.5-28.9 σ_t . This water mass is formed in some regions of the Eastern Mediterranean, from where it spreads in the core layer of what WUST (1960) has called Levantine Intermediate Water (LIW). Regions of formation of LIW have been already more or less identified in the Eastern Mediterranean by WUST (1960), MOR-

COS (1972), OZTURGUT (1976), OZSOY *et al.*, (1981), OVCHINNIKOV (1984), SAID (1985), ABDEL-MOATI & SAID (1987) and SAID & KARAM (1990).

Between 400 and 800 m a water mass of temperature 14-15 °C and salinity range 38.75-38.87 and density 28.8-29 σ_t is observed. This water mass is called a mid-depth water mass. Below 1000 m down to the bottom, the deep water mass of potential temperature range 13.3-13.5 °C, salinity 38.6-38.75 and density ~ 29.1 σ_t is observed. These water masses are generally a typical structure of the Mediterranean shelf waters off the Egyptian coast and are also observed by SAID (1993) and SAID & EID (1994).

By analyzing the water temperature and salinity distributions, we found that the aver-

age surface water temperature are 18.88 °C and 16.73 °C during the warm and cold winters, respectively with an average difference of 2.1 °C. Vertical profiles of average temperature and salinity difference (Fig. 10) show that the difference reaches its maximum value of 2.32 °C at 50 m depth, and decreases with increasing depth to reach 0.12 °C at 200 m depth. At the depth of 250-500 m, the average water temperature during the cold winter was higher than those of the warm one. The difference varies between -0.42 and -0.17 °C. The difference of average salinity at the surface was about 0.07 and decreases to reach 0.03 at 50 m depth. Below this level down to 500 m, the differences are negative and vary between -0.03 and -0.09.

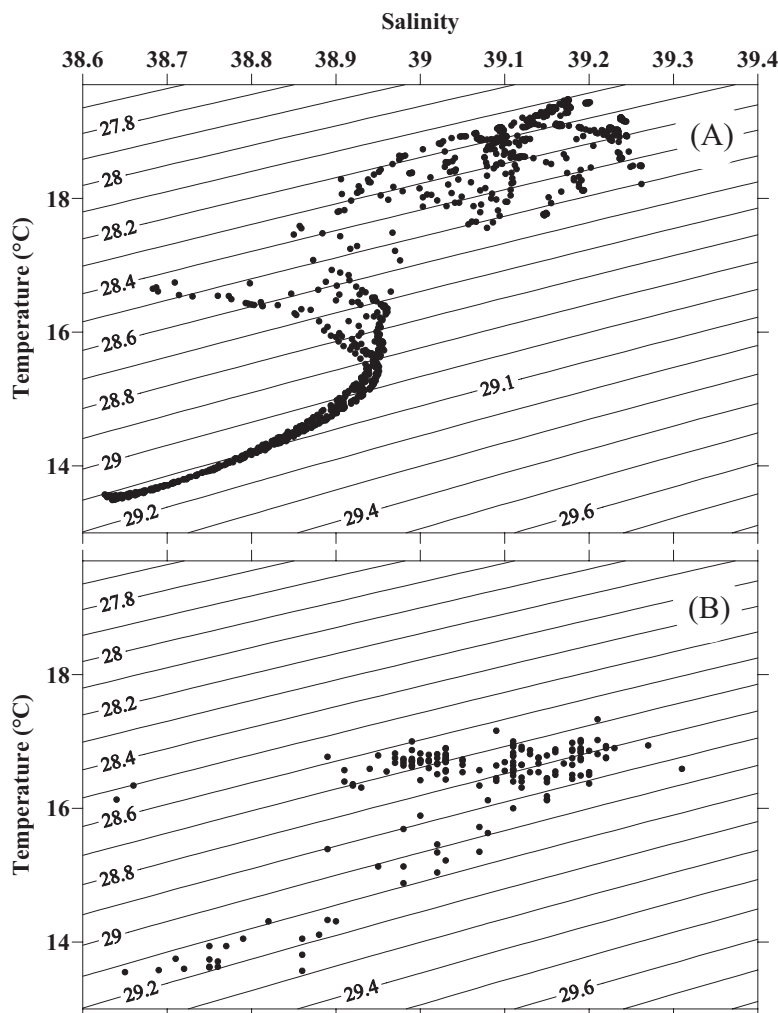


Fig. 9. T-S relationship during winter of (a) 1989 and (b) 1990

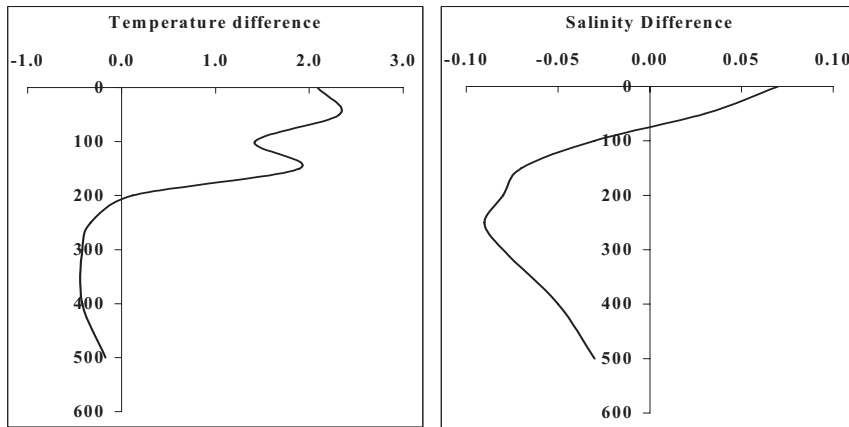


Fig. 10. Vertical profiles of average temperature and salinity differences between the warm and cold winters

The vertical distribution of the difference in water temperature and salinity between warm winter represented by section (A) and cold winter represented by section (B) is shown in Fig.

11. The variations in the water temperature and salinity (A) and (B) are observed not only on the surface, but also at deeper layers (>200 m). The surface layer (0-150 m) represents a water

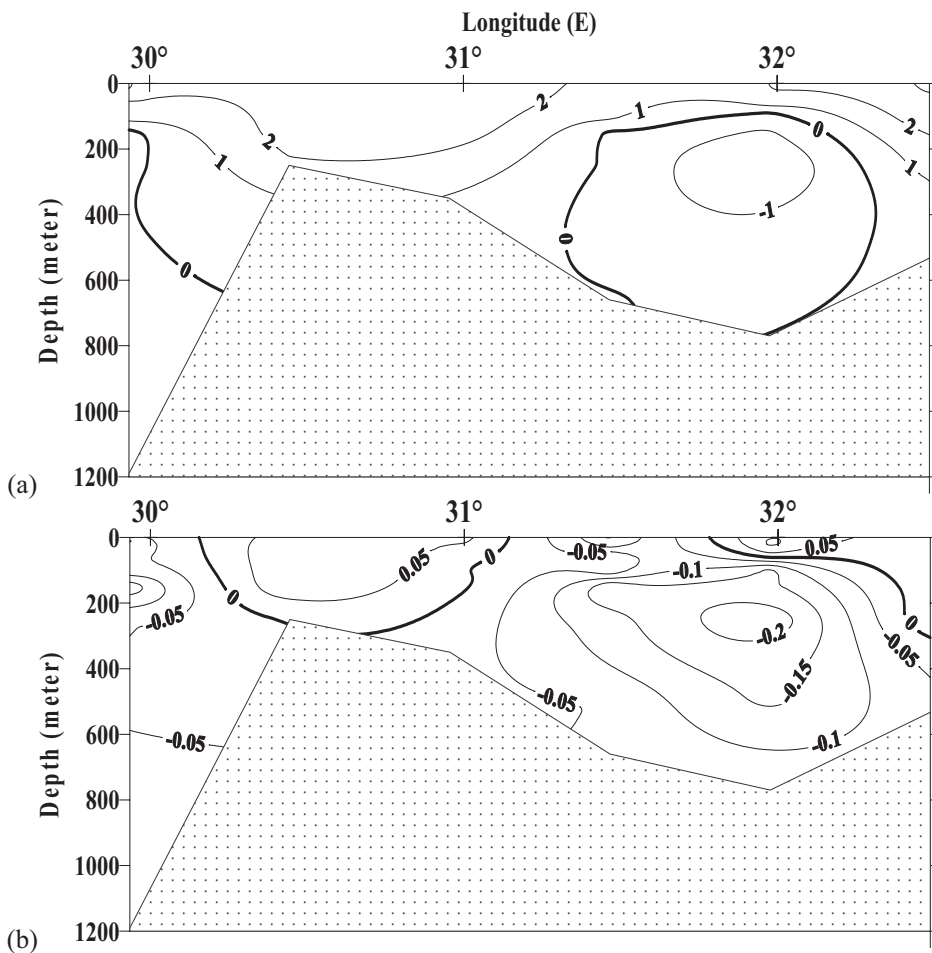


Fig. 11. Vertical distribution of (a) water temperature and (b) salinity differences between the

mass of high positive temperature difference (up to 2.5 °C) and low positive salinity difference (~0.06). The intermediate layer shows a nuclei of negative differences (-1.4 °C and -0.2 salinity) in the eastern side of the study area at depth of 200-300 m.

CONCLUSIONS

The data used in this study were taken from the joint Soviet-Egyptian expeditions carried out along the Egyptian Mediterranean sector during December 20-27 1988 aboard RV Academic Levrentyev, and March 7-15, 1990 aboard RV professor Bogorov. These two sets of the hydrographic data were used for determination the characteristics of the Egyptian Mediterranean waters off the Nile Delta during warm and cold winters.

In winter 1989, the surface water temperature varied between 17.78 °C and 19.47 °C and salinity between 38.99 and 39.26. The surface density (σ_t) values varied between 28.2 and 28.4. While during the 1990 cold winter the surface water temperature varies between 16.13 °C and 17.33 °C and salinity changes between 38.64 and 39.27. The surface density varies between 28.6 and 28.9 σ_t .

Four water masses could be observed during winter, these are; the surface water mass which is characterized by temperature range 17-19 °C, salinity maximum 39.0->39.2 and σ_t

values between 28.1-28.4 occupies the upper 200 m layer. The Levantine intermediate water mass identified by a secondary maximum of salinity 38.8-39.0 occupies depths between 200 and 400 m. This water mass has a temperature range of 15-17 °C and density 28.5-28.9 σ_t .

A mid-depth water mass lies between 400 and 800 m of temperature 14-15 °C, salinity range 38.75-38.87 and density 28.8-29 σ_t . Below 1000 m down to the bottom, the deep water mass of potential temperature range 13.3-13.5 °C, salinity 38.6-38.75 and density ~29.1 σ_t is observed.

In the present study, the maximum depth of vertical salinity mixing during the warm winter 1989 is 100-150 m and in the upper 250 m layer in the cold winter 1990, (i.e. the depth of salinity mixing was deeper in 1990 than that in 1989). The simple comparison between the vertical profiles of average temperature and salinity of the two winters show that, the difference reaches its maximum value of 2.32 °C at 50 m depth, and decreases with increasing depth to reach 0.12 °C at 200 m depth. At the depth of 250-500 m, the average water temperature during the cold winter was higher than those of the warm one. The difference varies between -0.42 and -0.17 °C. The difference of average salinity at the surface was about 0.07 and decreases to reach 0.03 at 50 m depth. Below this level down to 500 m, the differences are negative and vary between -0.03 and -0.09.

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Karakteristike egipatskih vodenih masa tijekom hladnih i toplih zima

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SAŽETAK

Dva seta hidrografskih podataka, sakupljena tijekom toplih i hladnih zima 1989. i 1990. godine, korištena su pri proučavanju karakteristika egipatskih sredozemnih vodenih masa. Njihova klasifikacija je načinjena prema varijacijama temperature zraka i površinskih temperatura mora.

Proučavane su četiri vodene mase tijekom zimskog perioda: (i) površinska vodena masa s temperaturom od 17-19 °C i maksimalnim salinitetom od 39.0-39.2, koja je obuhvaćala površinski sloj do 200 m, (ii) Levantinska intermedijarna voda s temperaturom od 15-17°C i salinitetom od 38.8-39.0, zamijećena na dubinama između 200 i 400 m, (iii) vodena masa srednjih dubina (400-800 m) s temperaturom od 14-15 °C i salinitetom od 38.75-38, te (iv) duboka vodena masa s potencijalnom temperaturom koja je varirala između 13.3-13.5°C, salinitetom između 38.6-38.75 te gustoćom od $\sim 29.1 \sigma_t$.

Analizirajući vrijednosti temperature mora i saliniteta, ustanovljeno je da je prosječna površinska temperatura mora iznosila 18.88 °C tijekom toplih, te 16.73 °C tijekom hladnih zima, to jest s razlikom od 2.1 °C.

Razlika je dosegla maksimalnu vrijednost od 2.32 °C na dubini od 50 m, smanjujući se s povećanjem dubine te dostižući 0.12 °C na dubini od 200 m. Na dubini od 250-500 m razlika je bila negativna i varirala je između -0.42 and -0.17 °C. Razlika kod prosječnih vrijednosti saliniteta na površini iznosila je 0.07 i smanjivala se do 0.03 na dubini od 50 m. Na dubini od 100 m te dublje prema 500 m, razlika je postala negativna te varirala između -0.03 i -0.09.

Vertikalne promjene u temperaturi mora i salinitetu su primijećene ne samo na površini, već i u dubljim slojevima (>200 m). Površinski sloj (0-150 m) predstavlja vodene mase s izrazitim pozitivnom temperaturnom razlikom (do 2.5 °C) i s malo povišenim salinitetom (~ 0.06). Srednji sloj pokazuje (jest) jezgra negativne razlike (-1.4 °C u temperaturi i -0.2 salinitetu) na istočnoj strani istraživanog područja na dubini od 200-300 m.

Ključne riječi: vodene mase, termohalina svojstva, istočno Sredozemlje