INSTITUT ZA OCEANOGRAFIJU I RIBARSTVO — SPLIT
SFR JUGOSLAVIJA

No. 70 BILJEŠKE - NOTES 1988

The empirical correlation coefficient between temperature and salinity in some areas of the Mediterranean Sea

Empirijski koeficijent korelacije između temperature i saliniteta u nekim područjima Sredozemnog mora

Mohamed A. Said

Institute of Oceanography and Fisheries, Kayet Bey, Alexandria, Egypt

INTRODUCTION

In some areas of the Eastern Mediterranean, the surface waters under the influence of intense cooling by evaporation taking place at the sea surface over which dry and cold winds (often 10°C colder than the sea surface) blow, become more saline, somewhat colder and consequently more dense than their surroundings. These waters sink downward to depth ranging from 200—250 m for Levantine intermediate water, to 1000—1200 m in the Adriatic Sea and the North Aegean Sea and up to 2000 m in NW Mediterranean (Unesco Rep., 1984).

The aim of the present work is to study the phenomena of formation of deep waters in selected areas of the Eastern Mediterranean through statistical calculations, by evaluating the correlation coefficient between temperature and salinity values along standard surfaces. These areas are shown in Fig. 1.

OBSERVATIONAL DATA AND METHOD OF ANALYSIS

The calculations are of the winter season. Oceanographic data used were those from several Mediterranean expeditions (obtained from hydrographic data centre B, Moscow), including R/V Shikmona (1965 & 1968), R/V Ichtiolog (1966 & 1971), R/V Akademik Petrovsky (1977) R/V Vasily Golovnin (1977) and R/V Yakov Gakkel (1977, 1981 & 1982). Vertically unstable stations were either corrected for temperature or salinity or rejected if many instabilities

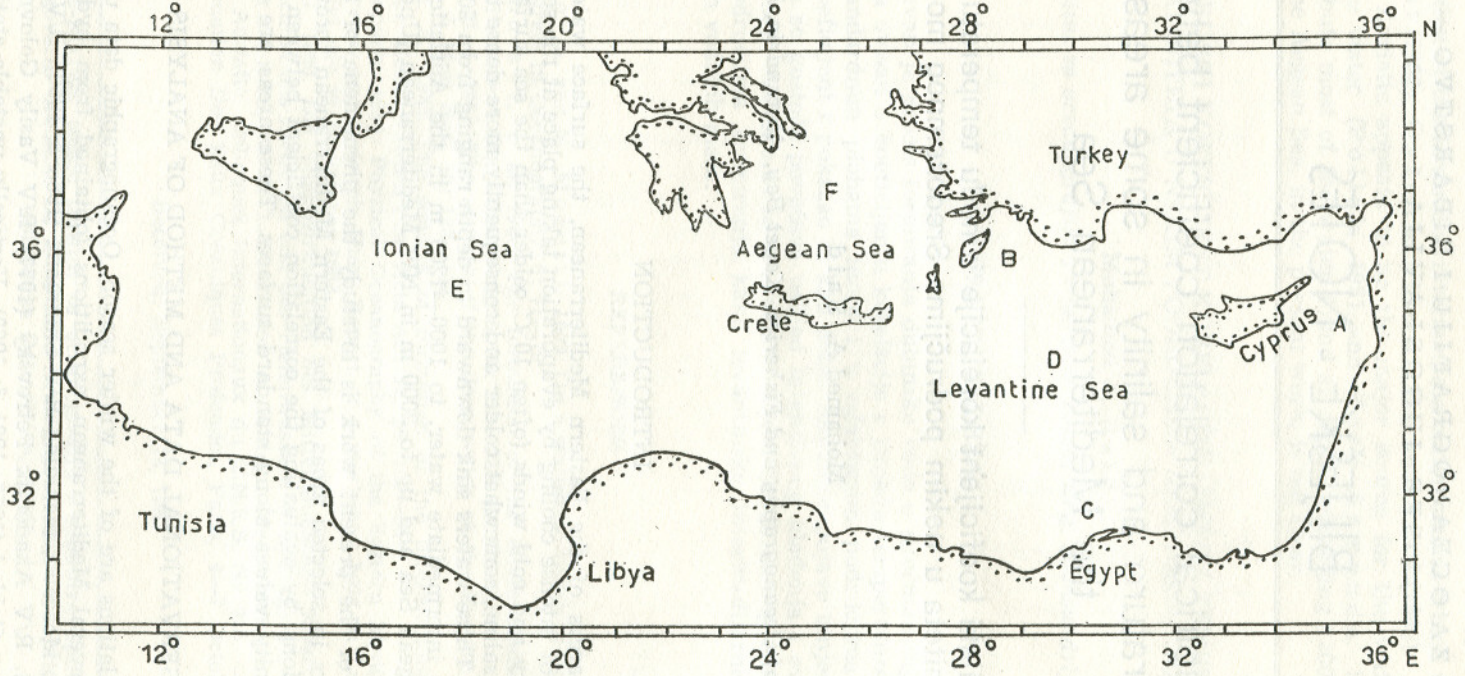

Fig. 1. The Eastern Mediterranean Sea and the locations of the areas under study

were observed. The locations of the areas under study and the number of the used hydrographic stations are shown in Table 1.

Table 1. Locations of the areas under study and the number of the used hydrographic stations.

Area	Latitude		Longitude		Number of stations
	from N	to N	from E	to E	
A	32° 20'	36° 33'	32° 50'	35° 13'	18
B	33° 44'	36° 28'	25° 19'	25° 12'	30
C	31° 09'	32° 49'	25° 30'	33° 37'	30
D	31° 33'	35° 30'	23° 30'	34° 31'	47
E	35° 00'	38° 30'	15° 41'	20° 41'	25
F	35° 31'	39° 05'	23° 19'	27° 15'	32

The standard deviation analysis of both temperature and salinity of the study areas are shown in Tables 2 & 3. The greatest variation of temperature is confined to the areas A & B, while the least variation belongs to the area D. Generally, the whole set of data are within the acceptable range of accuracy.

RESULTS AND DISCUSION

The first attempt to study the surface water sinking through statistical calculations, by evaluating the correlation coefficient between temperature and salinity values along standard the faces was made by De Maio and Moretti (1969). They computed the correlation coefficient in the south-central Tyrrhenian Sea, in the Ligurian Sea and in selected areas of the Atlantic and Pacific Oceans.

The calculated correlation coefficients r for the data taken from several Mediterranean expeditions, gave the results represented graphically in figures 2 & 3, which show how r changes as a function of depth. Fig. 2. shows the r-variation with depth in the north-easternmost part of the Eastern Mediterranean (area A) during the period 19 February — 9 March 1965. Positive values of r are observed in the upper 30 m. Between 30 and 90 m, r is negative. Deeper than 100 m, positive values of r are observed. The high positive value of r is observed between 200—400 m depth.

For the northern Levantine Sea (area B), the correlation coefficient was based on the data collected during 3 January — 17 February 1968. The correlation coefficient between T and S is negative in the uper 300 m layer and positive down to the bottom (1500 m) as shown in Fig. 2.

For the Egyptian Mediterranean coast (area C), the used hydrographic data were taken from the R/V Ichtiolog during 11—18 February 1966 and 1—9 February 1971. The r-curve for the data collected in February 1971 indicates that the correlations between T and S are positive in the upper 150 m, they have negative values in the layer between about 150 and 240 m and come back to positive values down to a depth of 1000 m (Fig. 2). The correlation coefficient r for the Egyptian Mediterranean coast has variations similar to those of Fig. 2. for the north-easternmost part of the Eastern Mediterranean.

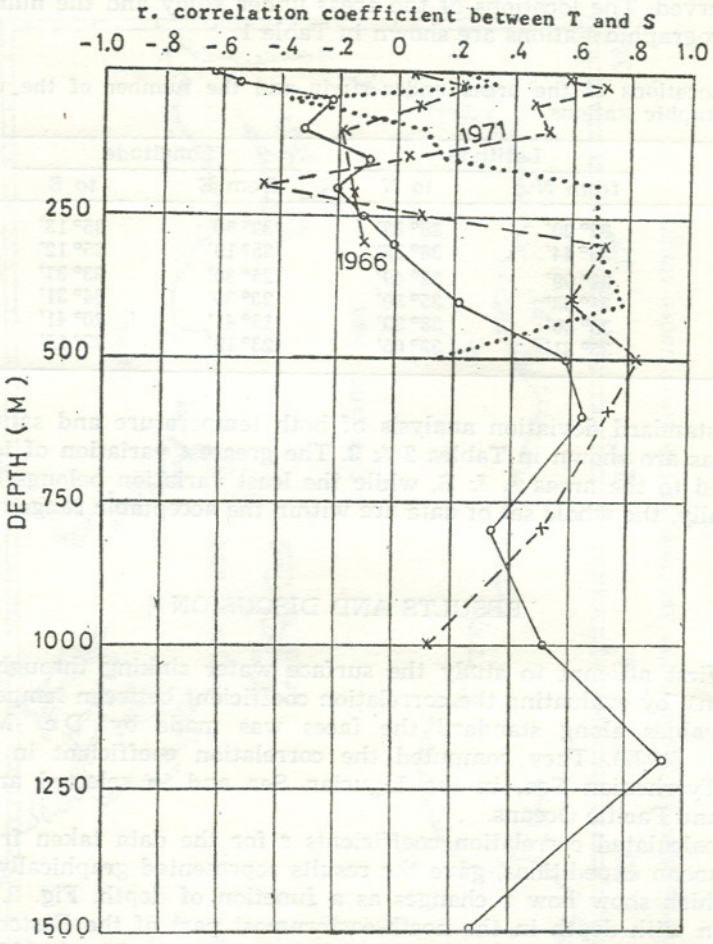

Fig. 2. Correlation coefficients for temperature and salinity during the winter in the: ... area, A, o--o--o area B and - - -x- - -x area C.

For the whole Levantine Sea (area D), the data used in the calculation were collected by the Russian R/V Vasily Golovnin during the period 3—20 March a strong wind with a velocity of about 18 cm/sec. was recorded. This of investigation. During this period the meteorological studies showed that northwestern winds prevailed accompanied with a continental polar air masses coming from the Balkan Peninsula and from the eastern Europe. From 9—12 March a strong wind with a velocity of about 18 cm/sec. was recorded. This strong cold wind decreased the air temperature to 6—8°C (O v t c h i n n i k o v, 1984). The calculated correlation coefficients r for the hydrographic data are represented graphically in Fig. 3. Small negative correlations between T and S are observed in the upper 125 m. Below that depth the correlations between them become positive to a depth of 1325 m, they have negative values from 1325 to 2325 m and become again positive at 2500 m.

Table 2. Standard deviation analysis of temperature at standard depths

Area	A	B	C		D	E	F
Depth m	1965	1968	1966	1971	1977	1977	1977—1981—1982
0	17.24 ± 0.520	16.19 ± 0.642	17.36 ± 0.443	17.31 ± 0.375	16.19 ± 0.603	15.60 ± 0.881	15.17 ± 0.687
20	17.15 ± 0.373	16.16 ± 0.631	17.18 ± 0.378	17.30 ± 0.453	16.14 ± 0.600	15.28 ± 0.582	15.13 ± 0.687
50	16.97 ± 0.319	16.12 ± 0.633	17.07 ± 0.397	17.34 ± 0.490	16.06 ± 0.559	14.95 ± 0.729	15.07 ± 0.644
100	16.78 ± 0.338	16.04 ± 0.691	16.89 ± 0.414	17.21 ± 0.503	15.98 ± 0.602	14.71 ± 0.562	15.01 ± 0.615
150	16.62 ± 0.483	15.94 ± 0.709	16.57 ± 0.414	16.91 ± 0.609	15.67 ± 0.598	14.67 ± 0.277	14.94 ± 0.583
200	16.38 ± 0.643	15.76 ± 0.700	16.26 ± 0.736	16.31 ± 0.816	15.27 ± 0.559	14.57 ± 0.282	14.84 ± 0.556
250	16.05 ± 0.366	15.44 ± 0.626	15.83 ± 0.600	15.50 ± 0.580	15.02 ± 0.535	14.38 ± 0.256	14.72 ± 0.527
300	15.72 ± 0.484	15.14 ± 0.562	15.41 ± 0.588	15.04 ± 0.428	14.74 ± 0.458	14.26 ± 0.224	14.61 ± 0.477
400	15.50 ± 0.867	14.57 ± 0.440	—	14.57 ± 0.397	14.33 ± 0.336	14.09 ± 0.175	14.36 ± 0.309
500	15.00 ± 0.691	14.20 ± 0.352	—	14.18 ± 0.247	14.04 ± 0.223	14.02 ± 0.175	14.23 ± 0.224
600	—	13.98 ± 0.264	—	14.00 ± 0.170	13.86 ± 0.024	13.90 ± 0.149	14.16 ± 0.240
800	—	13.78 ± 0.134	—	13.77 ± 0.082	13.71 ± 0.116	13.74 ± 0.081	14.06 ± 0.274
1000	—	13.71 ± 0.146	—	13.66 ± 0.042	13.62 ± 0.063	13.67 ± 0.057	14.02 ± 0.351
1200	—	13.69 ± 0.155	—	—	13.59 ± 0.034	13.64 ± 0.040	—
1500	—	13.63 ± 0.014	—	—	13.60 ± 0.016	13.61 ± 0.033	—
2000	—	—	—	—	13.60 ± 0.019	13.62 ± 0.018	—
2500	—	—	—	—	13.72 ± 0.038	13.65 ± 0.024	—
3000	—	—	—	—	—	13.70 ± 0.013	—

Table 3. Standard deviation analysis of salinity at standard depths

Area	A	B	C		D	E	F
Depth m	1965	1968	1966	1971	1977	1977	1977—1981—1982
0	38.980 ± 0.056	38.930 ± 0.107	39.280 ± 0.077	38.803 ± 0.150	39.014 ± 0.190	38.250 ± 0.257	38.770 ± 0.151
20	39.023 ± 0.031	38.930 ± 0.106	39.280 ± 0.077	38.805 ± 0.145	39.015 ± 0.190	38.284 ± 0.236	38.761 ± 0.145
50	39.036 ± 0.028	38.966 ± 0.164	39.280 ± 0.077	38.812 ± 0.144	39.030 ± 0.184	38.380 ± 0.178	38.770 ± 0.148
100	39.037 ± 0.033	38.960 ± 0.105	39.280 ± 0.077	38.832 ± 0.107	39.032 ± 0.155	38.516 ± 0.219	38.780 ± 0.126
150	39.037 ± 0.032	38.999 ± 0.072	39.290 ± 0.063	38.877 ± 0.064	39.035 ± 0.117	38.702 ± 0.175	38.770 ± 0.125
200	39.020 ± 0.040	39.002 ± 0.086	39.300 ± 0.063	38.912 ± 0.036	39.020 ± 0.064	38.780 ± 0.098	38.760 ± 0.124
250	39.005 ± 0.022	38.976 ± 0.078	39.300 ± 0.063	38.920 ± 0.028	38.995 ± 0.057	38.793 ± 0.064	38.760 ± 0.111
300	38.990 ± 0.034	38.940 ± 0.087	39.300 ± 0.063	38.924 ± 0.041	38.969 ± 0.054	38.798 ± 0.052	38.780 ± 0.109
400	38.966 ± 0.059	38.907 ± 0.069	—	38.878 ± 0.053	38.904 ± 0.059	38.783 ± 0.056	38.770 ± 0.084
500	38.934 ± 0.048	38.860 ± 0.065	—	38.830 ± 0.053	38.852 ± 0.049	38.769 ± 0.058	38.780 ± 0.079
600	—	38.840 ± 0.063	—	38.793 ± 0.050	38.816 ± 0.041	38.759 ± 0.052	38.780 ± 0.085
800	—	38.820 ± 0.037	—	38.757 ± 0.043	38.776 ± 0.034	38.730 ± 0.048	38.790 ± 0.067
1000	—	38.790 ± 0.048	—	38.721 ± 0.044	38.747 ± 0.028	38.711 ± 0.044	38.820 ± 0.080
1200	—	38.790 ± 0.055	—	—	38.736 ± 0.018	38.702 ± 0.042	—
1500	—	38.770 ± 0.015	—	—	38.725 ± 0.020	38.684 ± 0.044	—
2000	—	—	—	—	38.710 ± 0.016	38.664 ± 0.034	—
2500	—	—	—	—	38.700 ± 0.015	38.657 ± 0.040	—
3000	—	—	—	—	—	38.643 ± 0.004	—

For the Ionian Sea (area E), a curve relative to observations taken down to 3000 m during 11 February — 10 April 1977 by the Russian R/V Akademik Petrovsky was evaluated (Fig. 3). The behaviour of the Ionian Sea waters is similar to that observed for the Levantine Sea with small differences in the r-values.

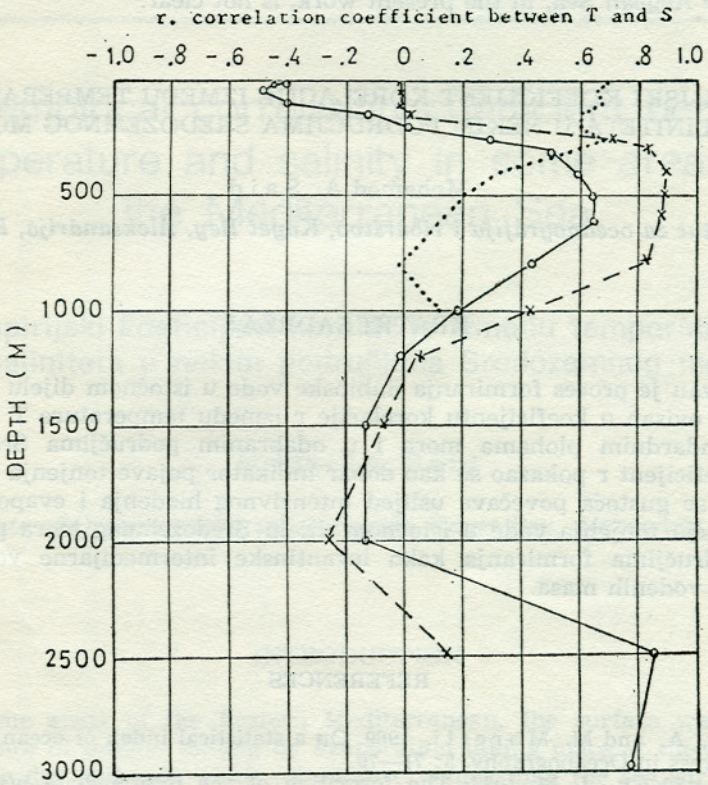

Fig. 3. Correlation coefficients for temperature and salinity during the winter in the: - - -x- - - -x area D, o--o--o area E and ..... area F.

In order to study the behaviour of the Aegean Sea waters (area F), only a curve was calculated for the observations taken during the winter months of 1977, 1981 and 1982 by the Russian R/V Yakov Gakkel. Fig. 3. illustrates the r-variations with depth. The r-curve lies completely in the positive section. The higher positive values are observed in the upper 300 m and decrease with increasing depth down to 1000 m.

CONSLUSION

In the present work, the areas of water sinking in the Eastern Mediterranean are the northern and central parts of the Levantine Sea and the Ionian Sea. The areas of water sinking in the Levantine Sea coincide with the regions

of formation of the Levantine intermediate water masses which were suggested by Wüst (1960), Ovtchinnikov (1984) and Said (1985).

The Adriatic appears to be the major source for the waters below the Levantine water (Pollak, 1951 and Zore-Armanda, 1972). It seems to contribute most of the water found at depths exceeding 1200—1300 m. The role of the Aegean Sea, in the present work, is not clear.

EMPIRIJSKI KOEFICIJENT KORELACIJE IZMEĐU TEMPERATURE I SALINITETA U NEKIM PODRUČJIMA SREDOZEMNOG MORA

Mohamed A. Said

Institut za oceanografiju i ribarstvo, Kayet Bey, Aleksandrija, Egipat

KRATKI SADRŽAJ

Izučavan je proces formiranja dubinske vode u istočnom dijelu Sredozemnog mora ovisan o koeficijentu korelacije r između temperature T i saliniteta S na standardnim plohama mora i u odabranim područjima Sredozemnog mora. Koeficijent r pokazao se kao dobar indikator pojave tonjenja površinske vode čija se gustoća povečava uslijed intenzivnog hlađenja i evaporacije.

Područja tonjenja vode u istočnom dijelu Sredozemnog mora podudaraju se sa područjima formiranja kako levantinske intermedijarne vode tako i dubinskih vodenih masa.

REFERENCES

De Maio, A. and M. Moretti. 1969. On a statistical index of ocean variability. Progress in Oceanography, 5: 71—79.

Ovtchinnikov, I. M. 1984. The formation of the intermediate waters in the Mediterranean Sea. Okeanologyia, 26: 217—225. (In Russian).

Pollak, M. J. 1951. The sources of the deep water of the Eastern Mediterranean Sea. J. Mar. Res., 10: 128—152.

Said, M. A. 1985. The sources of formation of the intermediate water masses in the Mediterranean Sea. Acta Adriat., 26: 191—201.

Unesco Reports. 1984. Physical Oceanography of the Eastern Mediterranean : an overview and research. Plan. Report of a workshop held in Lerici, La Spezia (Italy), N° 30, September 1983.

Wüst, G. 1960. Die Tiefenzirkulation des Mittelländischen Meers in den Kernschichten das Zwischen und des Tiefenwassers. D. hydrogr. Z., 13: 105.

Zore-Armanda, M. 1972. Formation of Eastern Mediterranean deep water in the Adriatic. Colloques Internationaux du C.N.R.S. N° 215. — Processus De Formation Des Eaux Océaniques Profondes, Paris, 4—7 Octobre 1972.

Received: September 18, 1987

BILJEŠKE-NOTES, izdaje Institut za oceanografiju i ribarstvo Split; izlazi povremeno. Odgovorni urednik: Dr Mira Zore-Armanda. Naklada 600 primjeraka. Tisak: »Slobodna Dalmacija«, Split