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HEAT BALANCE IN ARAB'S GULF OF EGYPT

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ABSTRACT

Monthly heat balance components were estimated for the Arab's Gulf of Egypt in 1977 calender year.

The annual radiation balance Qr was 118.7 K cal/cm^2. The annual heat loss due to evaporation Qe was 108.2 K cal/cm^2. The heat exchange due to conduction between the sea and the atmosphere Qc was very small (about 0.0 K cal/m^2).

Results reveal that the annual heat balance through the sea surface in 1977 was positive (10.5 K cal/cm^2). This heat gain is consumed by the horizontal heat transport to the east.

INTRODUCTION

Surface heat exchange is but one mechanism of water body heat transport. It is important in the hydrothermal analysis of temperature distribution resulting from waste heat discharges. Three other important heat transport processes are heat storage within the water column, heat advected with currents, and heat dispersed by turbulent transport processes.

In the present paper, the surface heat exchange in the Arab's Gulf of Egypt is discussed, and the summation as a net rate of surface heat exchange is defined.

The Arab's Gulf

It is a large indentation between El-Daba and Alexandria, about 90 miles long (Fig. 1). It lies between longitude 28° 27' and 29° 50' E. The investigated area covers the continental shelf to a depth of 100 m. The total area covers about 783 square nautical miles (about 2625 square kilometers), with a maximum width of about 14 nautical miles.

During 1977 and February 1978, six longitudinal sections were covered monthly in the area of investigation (24 stations, Fig. 2). At every station the meteorological and hydrographical parameters were measured. For the present study, the mean monthly meteorological parameters at the sea surface and the mean hydrographic parameters were calculated.

The hydrography and meteorology of the Arab's Gulf were studied by Maiyza, 1979. The heat budget of the different Mediterranean basins were computed by Ovechinikov et al.,1976.

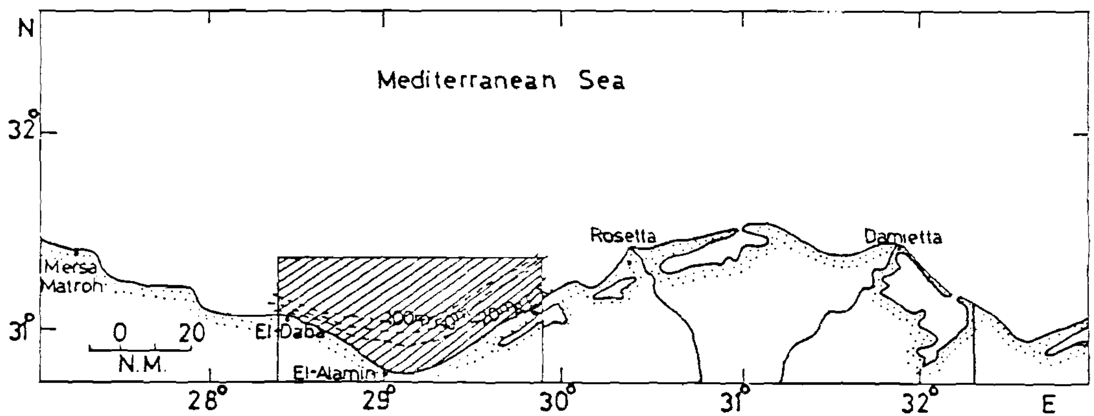

Fig. (1)
The Egyptian Mediterranean Coast.

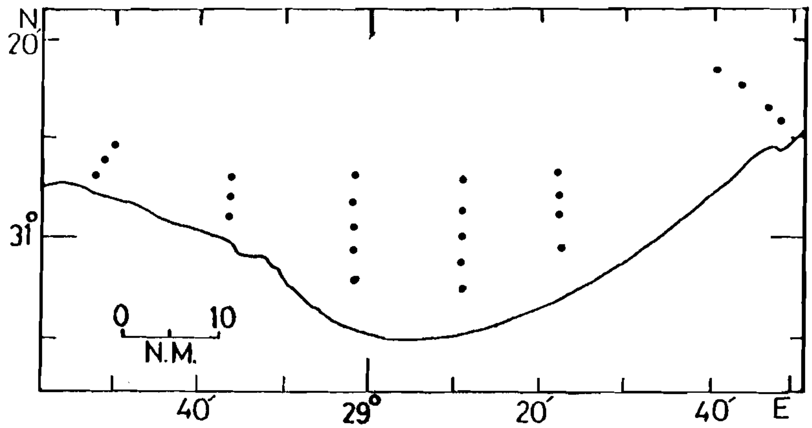

Fig. (2)
Map showing the stations occupied in the Arab's Gulf of Egypt in 1977.

FORMULATION

The heat balance of the water column (Q) equation for the shelf area can be written in the form of algebratic sum of all components, causing gain or loss of heat into or from the sea:

$$Q = Q_r + Q_e + Q_c + Q_o + Q_b + Q_w \qquad (1)$$

where,

Q_r: the observed solar radiation. This is the difference between the heat penetration the sea surface and the back radiation from the sea to the atmosphere,

Q_e: the heat loss due to evaporation,

Q_c: the heat loss or gain due to conduction at the sea surface,

Q_o: the heat loss or gain due to precipitation,

Q_b: the heat loss or gain due to contact with the bottom, and

Q_w: the heat loss or gain due to the turbulent vertical and horizontal movements of water bodies.

The surface heat exchange (Q_s) can be written in the form:

$$Q_s = Q_r + Q_e + Q_c \qquad (2)$$

Also the monthly heat balance of the water column relative to the yearly mean temperature is computed.

a) Absorbed Solar Radiation or Radiation Balance (Q_r)

Water temperature is mainly dependent upon the solar radiation absorbed at the sea surface. The radiation balance equation for a unit area of the sea surface in a unit interval of time is:

$$Q_r = Q(1 - \quad) F(N) - E^* \qquad (3)$$

where,

Q : the amount of heat penetrating to the sea surface,

: the albedo of the sea surface,

F(N): factor depends on the cloud ness, and

E* : the net loss of heat from the sea surface due to long wave radiation.

b) Loss of Heat Due to Evaporation (Q_e)

The estimation of Q_e was made using the following equation:

$$Q_e = L\,E = L\,B\,U\,(e_o - e_a),$$

where,

L : the latent heat of evaporation,

E : the rate of evaporation,

B : evaporation coefficient, calculated for the investigated area = 8.3×10^{-6},

U : surface wind speed,

e_o : saturated vapour pressure at the sea surface temperature, and

e_a : actual vapour pressure.

c) Heat Loss or Gain to Conduction (Q_c)

Heat enters or leaves the sea through the sea surface by conduction if the air temperature is greater or less than the water temperature. The rate of such process is proportional to the temperature difference between the two media.

$$Q_c = A\,U\,(t_o - t_a),$$

where, A: the senible heat exchange coefficient. This coefficient depends on the saturated vapour pressure at surface water temperature (t_o) and the difference between the surface water and the air temperature ($t_o - t_a$).

d) Heat Content of the Water Column (Q_w)

Q_w relative to 0°C is given by:

$$Q_w = \rho \; C_p \; t \; dz, \quad (4)$$

ρ : density of sea water,
t : water temperature, and
h : depth to the bottom.

In the present work, the monthly heat content relative to the annual mean temperature (t) is determined. The equation will be in the form:

$$Q_w = \rho \; C_p \,(t - t)\, dz \quad (5)$$

For each depth interval, the amount of heat is given by:

$$\rho_i \; C_{pi} \,(t - t)_i \; dz \quad i = 1,2,3,\ldots\ldots, n \quad (6)$$

The total heat content relative to t of the water body in the Arab's Gulf is given by:

$$Q_w = \Sigma \rho_i \; C_{pi} \,(t - t)_i \, dz_i \quad (7)$$

RESULTS

Table (1) and figure (3) illustrate the monthly computed values of Q_r, Q_e, Q_c, Q_s and Q_w in the Arab's Gulf in 1977.

a) Radiation Balance (Q_r)

The area of investigation received an amount of 118.7 k cal/cm^2 in 1977, with a mean monthly of 9.9 k cal/cm^2. The maximum absorption observed in June (14.9 k cal/cm^2), while the minimum value occurred in December (2.5 k cal/cm^2). These values showed that the extreme values of heat absorption occur in early summer and early winter.

These values are in the orders of the Levantine Sea (The hydrography of the Mediterranean Sea, 1976), where the annual radiation balance is 115.7 k cal/cm^2 with extreme values, also, in June and December (16.9 and 1.9 K cal/cm^2, respectively).

Rate of Evaporation (E):

From the surface of the Arab's Gulf of Egypt, an amount of 1811.5 mm evaporated in 1977. The maximum monthly evaporation occured in December, while the minimum one was observed in February. In general, the monthly amount of water evaporated from the Arab's Gulf is irregular, since it depends upon the wind speed which was variable in 1977.

b) Heat Loss Due to Evaporation (Q_e)

The heat abstracted by evaporation is the most important factor controlling

Table (1)

Monthly surface heat balance parameters (Q_r, Q_e, Q_c, and Q_s), monthly evaporation (E) and the monthly heat balance in the water column (Q_w) in the Arab's Gulf of Egypt in 1977.

Month	Q_r Q_r	E	Q_e	Q_c	Q_s	Q_w
January	4.50	122.1	-7.29	1.09	-1.70	-0.81
February	6.63	106.7	-6.34	-0.41	-0.12	- 1.08
March	10.04	146.8	-8.76	+0.08	+1.36	- 1.02
April	13.19	169.8	-10.13	-0.98	2.08	-[illegible].71
May	14.45	144.6	-8.65	-0.69	5.11	-[illegible].64
June	14.88	110.2	-6.58	-0.36	7.94	[illegible].45
July	14.84	178.1	-10.63	-0.83	3.38	1.58
August	13.50	189.6	-11.33	-0.40	1.77	[illegible].27
September	10.88	155.5	-9.31	-0.73	0.84	[illegible].95
October	8.25	194.7	-11.62	-0.21	-3.58	[illegible].65
November	5.05	93.3	-5.57	-0.03	-0.55	[illegible].04
December	2.46	200.1	-11.95	+3.47	-6.02	-[illegible].39
Sum (1977)	118.67	1811.5	-108.16	0.0	10.51	[illegible].29
Mean (1977)	9.89	151.0	-9.01	0.0	0.88	[illegible].02

Q_r, Q_e, Q_c, Q_s, and Q_w in k cal / cm^2. E in mm.

the heat balance between the sea and the atmosphere. The heat loss was maximum in December 1977 (11.95 k cal/cm^2). In general, the heat loss from the sea due to evaporation and also the rate of evaporation in 1977 were irregular and this may be due to the coastal effect as well as the irregularity of the wind field over the investigated area.

The area of investigation lost 108.2 k cal/cm^2. The heat loss due to evaporation as estimated by Ovechinikov et al. (1976) was maximum in December (8.15 k cal/cm^2) with a mean annual heat loss of 55.1 k cal/cm^2.

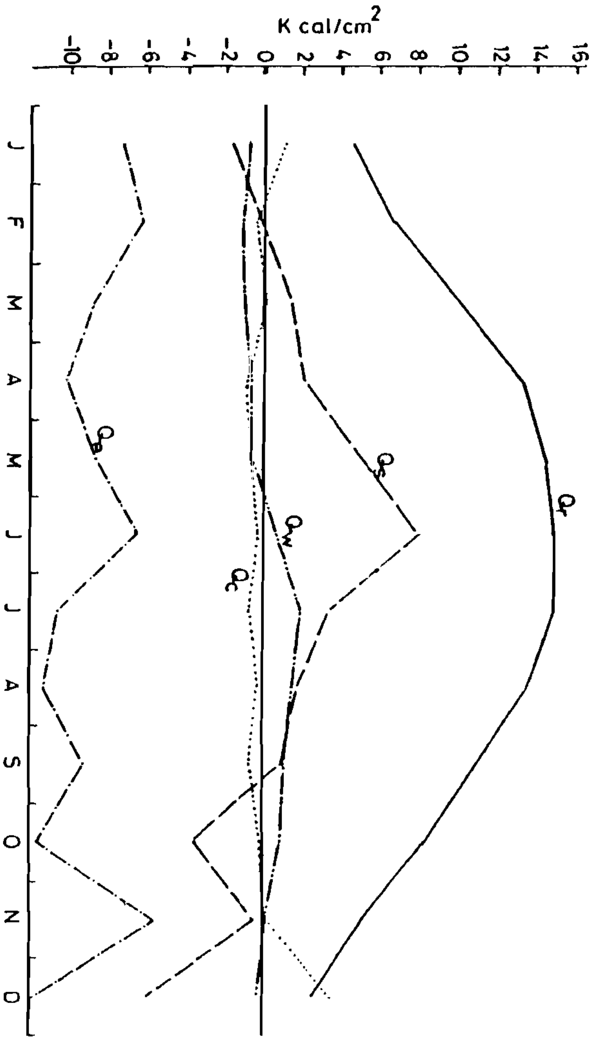

Fig. (3)
The monthly surface heat balance components.

The large difference between the present results and the results of Ovechinikov et al. (1976) may be due to:

- The location of the Arab's Gulf in the extreme southern, warmer area of the Levantine Sea.
- The investigated period (1977 calendar year) was expected to be a warm year in which the prevailing wind was the hot and dry continental air masses from the south (Maiyza, 1984).

c) Heat Loss or Gain due to Conduction (Q_c):

Q_c in the Arab's Gulf in 1977 was very interesting, since the heat loss was equal to the heat gain. The heat gain occurs only in winter, while the heat loss occurs in the other seasons. In general, the monthly Q_c is very small compared with Q_e. Q_c ranged between -0.98 k cal/cm^2 in April and 3.47 k cal/cm^2 in December.

d) The Heat Balance of the Water Column (Q_w):

The water body in the Arab's Gulf loses heat from November to May while it gains heat during the rest of the year. The maximum monthly Q_w was observed in July (1.6 k cal/cm^2), while the minimum one was in February (-1.1 k cal/cm^2).

e) The Heat Balance at the Sea Surface (Q_s):

Q_s has a value of about zero in February and September. From March to August, the sea stores heat through the sea surface, while from October to January the sea loses heat to the atmosphere. The maximum value of heat loss from the Arab's Gulf was observed in December (-6.0 k cal/cm^2) whereas, the maximum value of heat gain occurred in June (7.9 k cal/cm^2).

DISCUSSION AND CONCLUSION

The annual heat balance through the sea surface in the Arab's Gulf shows that the values of the summer heat gain are higher than the winter heat loss. Hence, the net heat gain in 1977 was 10.5 k cal/cm^2. This positive value of Q_s may be transported to the east as a horizontal heat loss from the investigated area. In the western part of the Gulf, the seawater is colder than in the eastern part allover the year. Also the water current in the Arab's Gulf is mainly eastward following the north African Atlantic Current (Maiyza, 1979). Moreover, the positive heat balance in the investigated area may be due to the fact that 1977 calendar year was a warm year in which the monthly air and water temperatures were higher than the monthly mean values in the whole Levantine Sea (Maiyza, 1984).

Figure (4) shows the sea surface heat balance (Q_s) and the heat balance of the water column in the Arab's Gulf during 1977. From this figure, it is clear that the heat gain through the sea surface began in March while

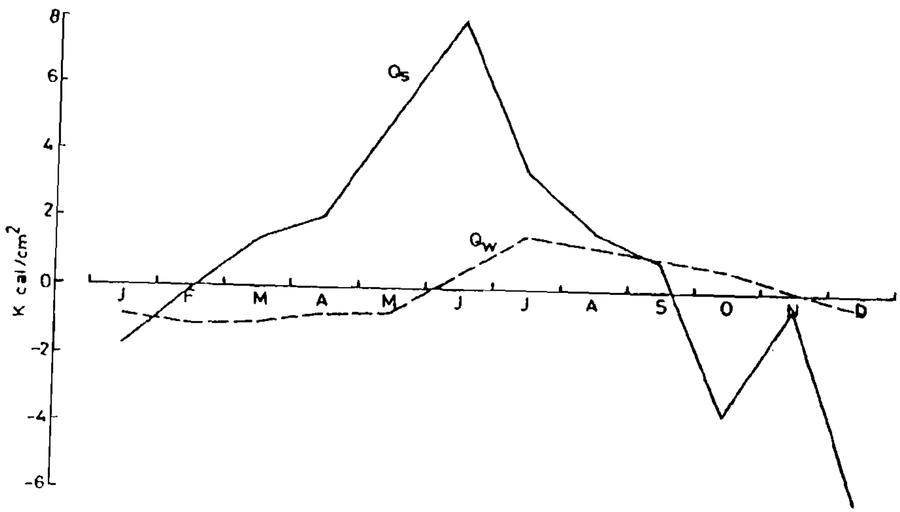

Fig. (4)
The monthly surface heat balance (Q_s) and the monthly heat content in the water column in 1977.

the heat gain in the water column began three months later; i.e., in June. The heat loss through the sea surface to the atmosphere began in October while it began in the water column two months later; i.e., in December. This time lag is mainly due to the consumption of Q_r at the upper surface by Q_e in the transitional seasons (spring and autumn) and the heat gain or loss from the water body began later depending on the positive or negative differences between Q_r and Q_e.

The correlation coefficient between the heat balance components of the present study and the results of Ovchinikov et al. (1976) shows good significant correlations for Q_r (0.9775), Q_c (0.6960) and Q_s (0.8848). However, there is no significant correlation for Q_e (0.1659) and this may be due to the location of the area underinvestigation; i.e., in the shallow coastal zone and also due to the peculiar behavior of evaporation during the warm 1977 calendar year.

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