Computation of the Surface Heat Flux by means of bulk formulas in El-Max Bay, Alexandria (Egypt)

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El-Mex Bay, west of Alexandria, extends for about 15 km and has a mean depth of 10m. It's surface area is of about 19.4 km^2 and its volume 190.3 x 10^6 m^3. It receives a heavy load of wastewater (2.4 x 10^9 m^3 / year) both directly from industrial outfalls or indirectly from Lake Maryut via El-Mex Pumping Station.

Throughout the period from January to December 1988, 12 trips were carried out in El-Mex Bay area using a motor boat. Temperature and salinity were measured at discrete depths from seven hydrographic stations. In particular, monthly data were there given as function of depth describing the mass field characteristics of the water column through a year of 1988. The monthly mean climatological data from Ras El-Tin Meteorological Station at Alexandria for the 15 years (1970-1984) have been used for the computations of the heat flux.

The total upward heat flux Q from the sea surface consists of the upward flux of long wave radiation Q_l, latent heat flux Q_e and the sensible heat flux Q_c less the absorbed global irradiation Q_s :

$$Q = Q_l + Q_e + Q_c - Q_s \quad (1)$$

Formulas for computation of Q_l, Q_e and Q_c are taken from Stravisi and Crisciani (1986) which are given according to Gill (1982). A detailed discussion of the formulas is presented in Stravisi and Crisciani (1986). Rate of absorption of global solar irradiation Q_s is given by

$$Q_s = (1 - A_n) Q_n.$$

where A_n is the sea surface albedo and can be calculated from tables (Kolesnikov, 1970). Q_n is the global solar irradiance calculated at the sea level using Timofeev's equations (1970). The heat flux (1) released from the sea surface is the difference $Q = Q_b - Q_\theta$ between an input flux Q_b through the other boundaries, mainly due to advection,

and $$Q_\theta = C_w \rho h \frac{\partial \theta}{\partial t}$$

representing the rate of heat storage in the sea, in a vertical water column of depth h and unit horizontal surface; θ is the vertical mean seawater temperature, C_w = 3.98 x 10^3 JKg^{-1} K^{-1} is the average seawater specific heat at constant pressure. The boundary heat flux Q_b in a basin can be computed once Q and Q_θ have been evaluated.

The monthly mean values of the computed heat flux are listed in table 1.

Table (1). Monthly and annual surface heat fluxes (Watts / m^2) from El-Mex Bay.

	January	February	March	April	May	June	July	August	September	October	November	December	Year
Q_l	76.15	79.55	82.97	83.34	79.18	72.86	66.24	64.42	66.95	69.12	71.64	73.79	73.85
Q_e	96.05	100.38	108.58	109.48	115.91	130.42	148.67	152.17	149.93	119.43	103.45	103.27	119.83
Q_c	18.20	10.90	-0.64	-7.70	-9.46	-9.03	-7.28	-4.40	00.00	3.55	7.91	16.93	1.58
Q_n	109.81	158.21	223.82	290.67	315.48	368.29	355.87	318.55	255.03	186.90	132.28	103.56	234.87
A_n	0.080	0.073	0.066	0.061	0.062	0.054	0.054	0.054	0.060	0.068	0.077	0.082	0.066
Q_s	101.02	146.66	209.05	272.94	295.92	348.40	336.65	301.35	239.73	174.19	122.09	95.07	220.26
Q	89.38	44.37	-18.14	-87.82	-110.29	-154.15	-129.02	-89.16	-22.85	17.91	60.91	98.92	-25.00
Q_θ	-18.00	14.98	15.64	24.97	61.66	56.10	21.20	-15.36	-28.40	-21.40	-52.11	-59.28	00.00
Q_b	71.38	59.35	-2.50	-62.85	-48.63	-98.05	-107.82	-104.52	-31.25	-3.49	8.80	39.64	-25.00

For a better comprehension of the "heat sink" character of El-Mex Bay, the flux Q_θ of heat stored in the Bay has been computed, using a mean depth h = 10m, together with the heat Q_b advected from the Bay (Fig.1). The heat storage values vary from -59.28 in December to 61.66 W m^{-2} in May. The flux Q_b is negative during the period from March to October with an average of -59.89 W m^{-2}. From November to February, it varies between 8.80 and 71.38 W m^{-2}.

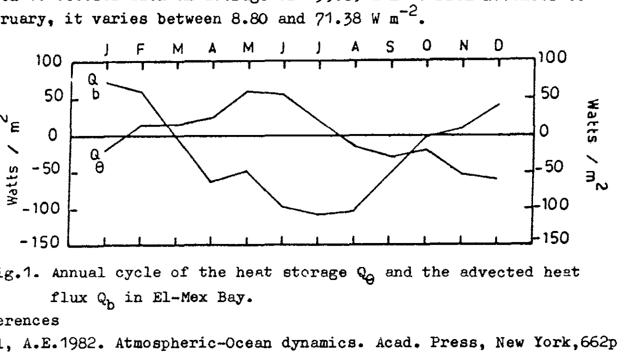

Fig.1. Annual cycle of the heat storage Q_θ and the advected heat flux Q_b in El-Mex Bay.

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Seasonal Heat Budget of the Southeastern Mediterranean Waters off the Egyptian Coast during 1983-1986

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Heat-budget components of the Mediterranean waters off the Egyptian coast were studied from August 1983 to July 1986. During this period, eight cruises were carried out to the southeastern Mediterranean between longitudes 29° 45'E and 33° 45'E using RV Noor Ya Nabi. Two separate data sets were used in this study : standard meteorological measurements and hydrographic data. These meteorological measurements were taken every 3h while the ship was on station and used to compute the surface heat budget. During each cruise, temperature and salinity were measured at discrete depths from 24 stations located along eight sections extending perpendicular to the coast. Temperature corrections were made using calibration curves. Salinity was measured on a Beckman induction salinometer (Model RS-7C).

The components of the heat budget of the shelf waters of the Egyptian Mediterranean coast were computed using Timofeev's equations (1970 & 1983), for details refer to Said (1987). From the calculations, the amount of heat loss through the sea surface due to back radiation is not more than -68.11 to -83.73 W m^{-2}. The heat loss due to conductive heat exchange ranged between -0.47 and -50.85 W m^{-2}, and that due to evaporation varied between -91.17 and 205.57 W m^{-2}. Hence, evaporation was the main component affecting the monthly and seasonal fluctuations in the heat budget. Table 1 indicated the quantity of heat loss through the sea surface due to evaporation at the offshore stations.

Table 1 . Heat loss (W m^{-2}) due to evaporation from the sea surface at the stations off the Egyptian coast.

	1983	1984		1985			1986	
	August	February	July	October	April	July	February	July
El-Agami (AG)	-	-98.69	-	-113.88	-113.15	-152.62	-104.46	-165.74
Rosetta (RS)	-153.40	-101.19	-147.15	-112.16	-117.83	-159.80	-108.44	-163.87
Burullus (BR)	-151.68	-102.53	-143.72	-114.19	-126.87	-158.09	-108.44	-
Damietta (DM)	-112.47	-97.35	-123.09	-114.66	-129.62	-134.97	-103.42	-122.78
Port Said (PS)	-121.22	-	-120.13	-114.19	-132.04	-133.40	-104.81	-118.72
El-Tina (TN)	-154.80	-	-154.18	-155.27	-146.73	-173.86	-134.55	-163.87
Bardawil (BD)	-	-	-161.99	-	-150.44	-183.86	-	-154.49
El-Arish (AS)	-	-	-143.56	-	-	-	-	-156.37

Computed values of heat content (expressed as Kg W m^{-2}) from surface to 100m for the offshore stations using the formula described by Pattullo et al (1969) are listed in table 2.

Table 2 . Heat content, surface to 100 m depth, at stations off the Egyptian coast. Values in kg W m^{-2}.

	1983	1984		1985			1986	
	August	February	July	October	April	July	February	July
El-Agami (AG)	-	82.95	-	104.95	83.87	100.77	86.20	104.93
Rosetta (RS)	98.67	83.73	100.81	98.68	86.71	106.64	87.85	106.17
Burullus (BR)	98.02	83.39	97.93	100.42	86.34	98.85	87.58	-
Damietta (DM)	99.72	82.82	95.17	98.45	87.19	100.50	88.64	100.36
Port-Said (PS)	-	-	107.55	102.25	86.62	106.22	89.71	97.68
El-Tina (TN)	104.80	-	105.44	101.44	84.92	101.59	88.48	100.33
Bardawil(BD)	-	-	99.13	-	86.62	118.71	-	104.95
El-Arish (AS)	-	-	96.40	-	-	-	-	100.83

In the present work, the most important results are contained in tables 1 & 2. In order to compare the time series of evaporation and heat content, a mean value was obtained for each parameter for each cruise (Fig.1); the heat loss from the sea surface due to evaporation increases with increasing heat content.

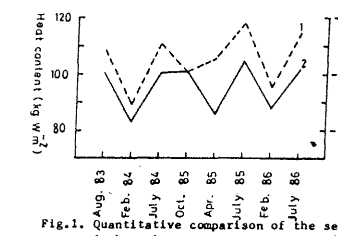

Fig.1. Quantitative comparison of the series of :
1- heat loss due to evaporation (W m^{-2}),
and 2- heat content (Kg W m^{-2}) for Mediterranean waters off the Egyptian coast.

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