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HEAT BALANCE OF LAKE BOROLLUS, EGYPT.

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ABSTRACT

Monthly heat balance components were estimated for Lake Borollus of Egypt in the period January, 1987-January, 1988.

The annual radiation balance (Qr) was + 384.21 x10^{12} k cal. The annual heat loss due to evaporation (Qe) was -424.43 x 10^{12} k cal. The heat exchange due to conduction (Qc) was + 20.86 x 10^{12} k cal. The resultant annual surface heat balance (Qs) was -19.36 x 10^{12} k cal. The annual heat gain through six drains was +46.50 x 10^{12} k cal. Through the outlet, the Lake loses annually -17.22 x 10^{12} k cal. Through the Lake's bottom, it loses -16.18 x 10^{12} k cal annually.

Results reveal that the annual heat balance was negative (-1.27 x 10^{12} k cal.). This small negative heat balance might be compeansated by the direct contact with the Lake's bottom or it was due to the year to year varaitions of the amount of solar radiation reaching the Lakes's surface.

INTRODUCTION

The heat balance of lakes has various applications limnologically and meteorologically in revealing many processes deal with heat exchanges. This balance is governed by the contribution of the different factors affecting the heat budget of a certain system.

The present work tends to study the puantitative contribution of different processes controlling the heat budget of Lake Borollus .

Lake Borollus (Fig. 1) is located at the northern part of the Nile Delta, between the two branches of the Nile. It extends latitudinally between 30^{o} 30′ and 31^{o} 10′ E. The Lake is rather narrow and its breadth varies between 5 and 17 km. The present area of the Lake is about 350 km^2 (Maiyza, 1989). The Lake is separated from the sea by a strip of land of different widths and hights. The sole connection with the sea is through a narrow opening known as Al-Boghas outlet, located at the north-eastern corner of the Lake. The depth of the Lake varies from 0.42 to 2.07 m increasing from east to west and from south to north.

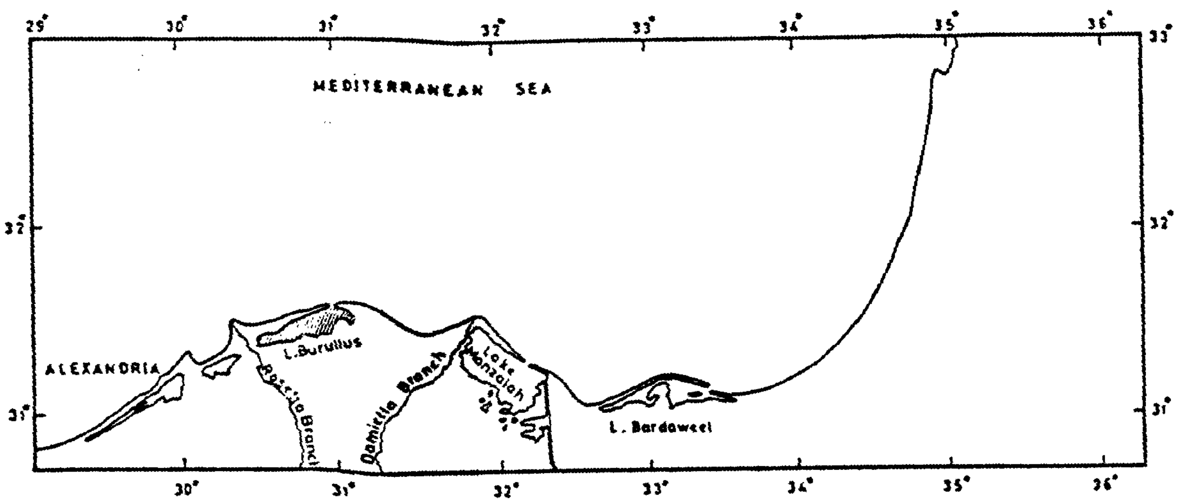

Fig. 1

Area under study.

The wind has a great effect on the movement of the water in the Lake. A considerable amount of the Lakes water is shifted eastwaed or westwards under the influence of the westerly or easterly winds, respectively.

Along the southern and eastern boundries of the Lake, there are 6 drains (Fig. 1). These drains discharged 2.16 km^3 of water in 1987.

There is no published work about the heat balance of Lake Borollus, except for the surface (Maiyza et al., 1988).

FORMULATION

The equation of the heat balance of any water body (Q) can be written in the form:

$$Q = Qr + Qe + Qc + Qo + Qb + Qw$$

where:

- Qr : the absorbed solar radiation . This is the difference between the heat reaching the surface of the Lake and the back radiation from the Lake's water to the atmosphere (Radiation balance),
- Qe : the heat loss due to evaporation,
- Qc : the heat loss or gain due to conduction at the Lake water surface,
- Qo : the heat loss or gain due to precipitation,
- Qb : the heat loss or gain due to contact with the bottom, and
- Qw : the heat loss or gain due to vertical turbulence and horizontal movements of the water body.

For Lake Borollus, the heat balance equation can be written in the form:

$$Q = (Qr + Qe + Qc) + (Qd + Qex) + Qb$$

or

$$Q = Qs + Qw + Qb$$

where:

Qs = Qr + Qe + Qc (surface heat balance), and
Qw = Qd + Qe x (heat gain and loss due to the discharged drainaged water trough drains and Lake's water outflow from the Lake through the outlet, respectively.

a) Radiation balance (Qr):

Water temperature mainly depends upon the solar radiation absorbed at the surface. The monthly radiation balance equation (Jerdak & Malevcke, 1973), for the Lake is:

$$Qr = A (Q'(1 - \alpha) F (n) - E^*)$$

where:

ρi : drainage water density,
Cpi : specific heat,
Vi : monthly discharged water, and
Ti : drainage water temperature (drain i).

e) Heat loss through the outlet (Qex):

The monthly amount of Qex was calculated using the follwing equation:

$$Qex = \sum \rho_i \;\; Cpi \;\; Si \;\; \cos\theta\, i.\; RT \qquad i=1,\ldots\ldots,n$$

where:

Si cos θ i: the flow component along the axis of the outlet (Lake-ward is positive), and
R : the cross - section area of the outlet,

In order to get the amount of water discharged from the Lake in a unit time recording currentmeter was moored at the Lake-sea connection for about 4 days a month. A 10 minute time interval was adjusted to permit recording current speed and direction. The results were converted to a monthly amounts of Qex as the other heat components.

f) The heat loss or gain through the bottom (Qb):

The monthly amount of the Lake's water lost or gained due to seepage in Lake Borollus (Maiyza, 1989) was used to estimate Qb:

$$Qb = \rho \; Cb \;\; T \;\; V$$

where:

ρ, C, T : are the mean monthly values of density, specific heat and water temperature, respectively, and
V : the monthly water exchange through the bottom (Maiyza, 1989).

Qb, here, is considered as the heat exchange with the Lake's water seepage as a result of water leakout or leakinto the Lake rather than the direct contact between water and bottom of the Lake.

DATA AND METHODS OF ANALYSIS

During 1987 and January 1988, 19 hydrographic stations were monthly covered in the area of investigation (Fig. 2). At every station the mean monthly meteorological and hydrographical parameters were measured. At st. 1(Fig. 2) direct measurements of evaporation were carried out at the same time with recording of the meteorological and hydrographical parameters in order to get the evaporation coefficient of the area under study.

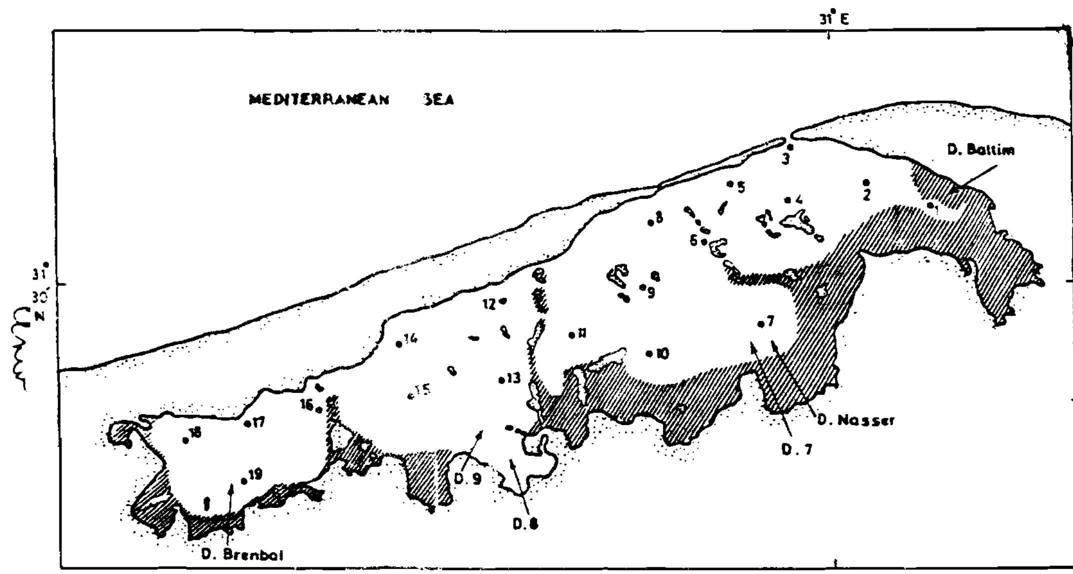

Fig. 2

Present Situation of Lake Borollus
D : Drain   o : Hydrographic station.

The amount of discharged drainage waters into the Lake was obtained from the General Works and Water Resources Directorate, Kafr El-Shikh Governorate.

The water exchange through the outlet was computed using an AANDERAA recording currentmeter. The instrument was moored at the Mid-depth (1.4 m) of the deepest point (2.8 m) in the outlet. The instrument recorded the current speed and direction, beside the water temperature and salinity at 10 minute time interval. The current along the outlet axis was considered.

RESULTS

Figures 3, 4 and 5 illustrate the monthly computed values of Qr, Qe, Qc, Qs, Qd, Qex, Qw, Qb and Q

a) Radiation balance (Qr):

During 1987, through the surface, the Lake absorbed $\pm 384.21 \times 10^{12}$ k cal. from the solar radiation, with a monthly mean of $+32.02 \times 10^{12}$ k cal. The maximum monthly value of Qr was recorded in late spring and early summer (May, June and July) averaging $+47.28 \times 10^{12}$ k cal., while the minimum value of absorption was found in early winter (December, $+8.86 \times 10^{12}$ k cal.).

(Evaporation (E))

During 1987, a Lake's surface layer water layer of 2,031 mm thickness was evaporated. The maximum monthly evaporation occurred in August, while the minimum was obseved in December. Generally, the monthly amount of water which evaporated from Lake Borollus was irregular, since it depends upon the wind speed which was also irregular.

b) Heat loss due to evaporation (Qe):

The heat loss by evaporation is the most important factor controlling the heat balance between the water and the atmosphere. The high monthly heat loss due to evaporation was observed in spring and reached its maximum value in August (-66.11×10^{12} k cal.), while the minimum value of Qe occurred in December (-17.81×10^{12} k cal.) and January (-10.19×10^{12} k cal.). In general, the heat loss due to evaporation was irregular. This may be due to the morphology of the Lake (presence of large number of small islands).

In 1987, Lake Borollus lost -424.43×10^{12} k cal. with a mean monthly heat loss equals to -35.37×10^{12} k cal.

c) Heat loss or gain due to conduction (Qc):

Due to conduction, Lake Borollus gained $+20.86 \times 10^{12}$ k cal. in 1987. Qc was positive in the period from April to October and negative in the other time of the year except in

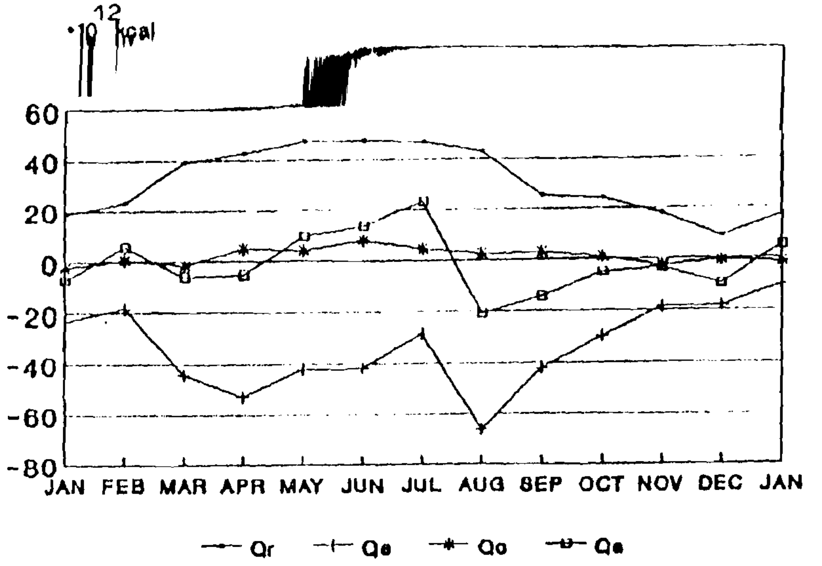

Fig. 3

Monthly surface heat balance
Lake Borollus (Jan. 1987-Jan. 1988).

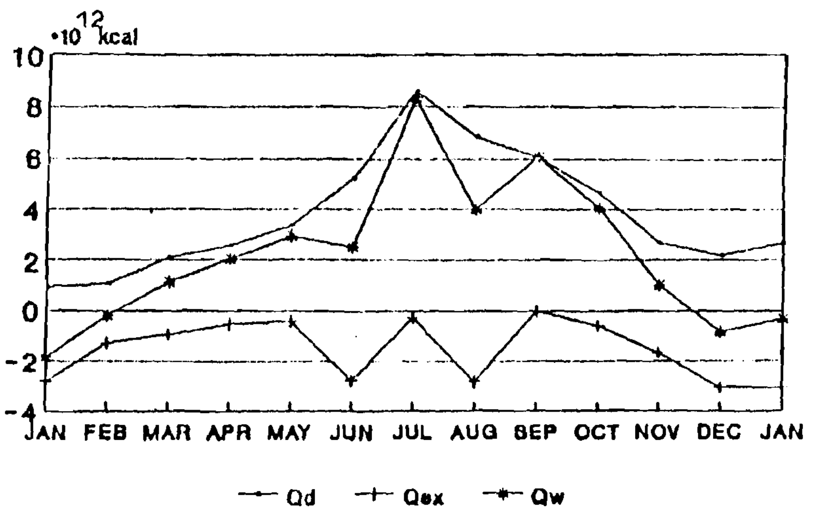

Fig. 4

Monthly Horizontal heat Advection
Lake Borollus (Jan. 1987-Jan. 1988).

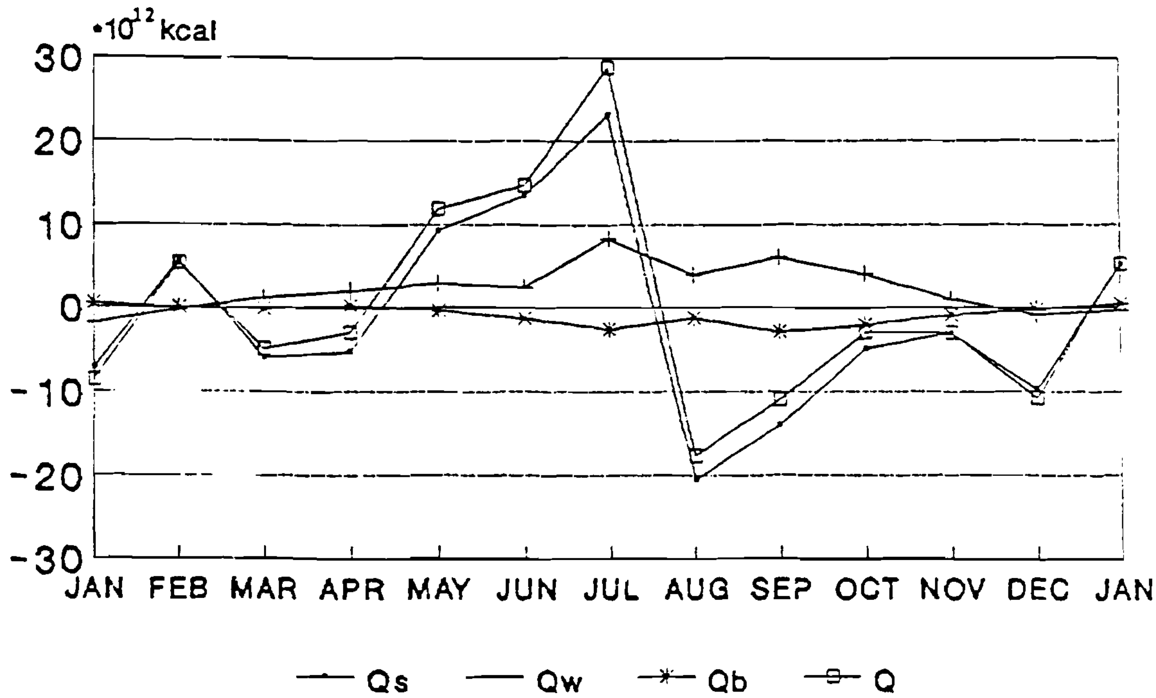

Fig.5

Monthly heat balance components
Lake Borollus (Jan. 1987-Jan. 1988).

February. The maximum monthly heat gain was observed in June ($+7.88 \times 10^{12}$ k cal.), while the maximum one occurred in November (-2.59×10^{12} k cal.).

Surface heat balance (Qs):

The annual surface heat balance of the water of Lake Borollus shows that, the value of the heat gain in summer season is less than that in autumn and winter seasons.The net surface heat loss in 1987 was calculated to be 19.36×10^{12} k cal. The main factor affecting the surface heat balance in Lake Borollus was Qe as shown in Fig. 3.

d) Heat gain through drains (Qd):

The discharged draiunage water, through 6 drains, transported total heat of $+46.50 \times 10^{12}$ k cal. during 1987 with mean monthly of about $+3.88 \times 10^{12}$ k cal. The maximum monthly value of heat gained to the Lake through drains was observed in summer ($+8.63 \times 10^{12}$ k cal. in July), while the minimum one was occurred in winter ($+0.96 \times 10^{12}$ k cal. in January, 1987).

e) Heat loss through the outlet (Qex):

During 1987, and by the water going to the sea through the outlet, Lake Borollus lost -17.22×10^{12} k cal., with mean monthly of -2.44×10^{12} k cal. The maximum monthly heat loss, through the outlet, was observed in December (-3.03×10^{12} k cal., while there was no heat transport to the sea during September.

The horizontal advection to and from the Lake (Qw = Qd+Qex):

The annual value of Qw was greater than Qs and reached to $+22.28 \times 10^{12}$ k cal / 1987. The maximum heat loss was observed in January 1987 and reached to -1.88×10^{12}k cal., while the maximum gain was recorded in July ($+8.35 \times 10^{12}$k cal.). It was found that the main factor affecting Qw is Qd as shown in Fig. 4.

f) The heat exchange through the Lake's bottom (Qb):

The calculations revealed that through the bottom, Lake Borollus lost about $-16.18 \times 10\ 10^{12}$k cal./ 1987, with mean monthly value of -1.35×10^{12}k cal.

DISCUSSION AND CONCLUSION

The annual heat balance of Lake Borollus shows that the amount of the heat gain in summer season is slightly less than that of the heat loss in autumn and winter seasons. The net heat loss in one year (1987) was calculated to be -1.27×10^{12}k cal. The main factor affecting the heat balance in Lake Borollus was Qs as shown in Fig. 5. This small negative value of heat balance might be compensated by the direct contact with the Lake's bottom. Also, the year to year variation in the amount of solar radiation reaching the Lake's surface might be the reason of such negative heat balance. There is an eleven year variation cycle in the temperature in the Eastern Mediterranean region estimated by Maiyza (1984). The recorded anomalous hot years were 1955, 1966, 1977 and consequently 1988. The years between the anomalous warm years were relatively cold. The negative heat balance of 1987 might be compensated in the next 1988. This conclusion is true when comparing Qs and Q in January 1987 and 1988. They were possitive in January 1988 (+5.14 and +5.26 x 10^{12}k cal.) and negative in January 1987 (-7.23 and -8.66 x 10^{12}k cal. respectively, (Fig. 5).

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