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Heat Budget of the Southeastern Part of the Arabian Gulf

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تقدير التدفق الحراري في الجزء الجنوبي الشرقي من الخليج العربي

سلطان و الجهريبي
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تم تقديـر التدفق الحراري عبر سطح البحر بفعل العمليات المختلفة في الجزء الجنوبي الشرقي للخليج العربي بإستخدام معادلات الجملة (Bulk Formulas) بحيث كان المتوسط السنوي لكل من الحرارة بالتوصيل والمصاحبة للبخر والإشعاع المنبعث من البحر على التوالي 4، 153، 57 W/m² بينما كان المتوسط السنوي للإشعاع الشمسي المقاس 200 W/m² . وعليه فإن محصلة التبادل الحراري الرأسي تؤدي إلى فقدان المياه الساحلية 7 W/m² وهذه الحرارة المفقودة يجب أن تعوض بواسطة حركة التيارات البحرية.

Key Words: Heat Budget – Southeastern Arabian Gulf

ABSTRACT

The surface heat fluxes through the air-sea interface for the coastal water of the southeastern part of the Arabian Gulf have been estimated using the bulk formulas. The annual mean values of the sensible, latent and back radiation fluxes are 4, 153 and 57 W m^{-2} respectively. The annual mean of recorded solar radiation is 200 w m^{-2}, thus, giving an annual heat flux deficit of 7 W m^{-2}. This heat deficit must be compensated by that advected by the currents.

INTRODUCTION

Heat balance studies are of fundamental importance as the changes in ocean temperature in any locality occurs in response to heat transfer across the air-sea interfaceand the advected by the water masses. The water temperature is an important parameter in the ecology of the marine environment. Over short periods a balance may not be achieved and this results in temperature changes. In the long term and on an annual basis it is expected that a balance is accomplished and the water temperature maintains a constant value. However, global warming and its impact on the ocean temperature may offset this fact. Global warming directly affects water temperature and causes expansion of the ocean volume.

The Arabian Gulf (Fig.1) is a semi-enclosed water body situated in an arid zone where evaporation greatly exceeds precipitation and river runoff. In addition to its large contribution in the heat budget, evaporation plays an important role in maintaining the circulation of the Gulf. This renders the Gulf to act like an inverse estuary with a surface inflow and a subsurface outflow. Evaporation in the Gulf has been estimated by a number of authors. Privett (1959) estimated the evaporation rate to be 144 cm y^{-1} with the highest rate in winter. Meshel and Hassan (1986) used data from Doha and Manama for 1984 and estimated evaporation to be 202 cm y^{-1}. Ahmad and Sultan (1991) estimated the evaporation for the whole Gulf to be 228 cm y^{-1} while Sultan and Ahmad (1994) gave a value of 208 cm y^{-1} for the coastal water of Kuwait. It appears from recent estimates that the evaporation averages to 200 cm y^{-1} with the highest rate in summer. These findings are in contrary to those of Privett (1959) where evaporation is higher in winter.

The freshwater input is mainly from the Shatt-Al-Arab River Estuary with a minor contribution from the Iranian rivers in the north (Hughes and Hunter, 1979). Estimates of the annual river runoff vary over a wide range from 5 to 100 $km^3\ a^{-1}$ (Hartmann et al., 1971; Grasshoff, 1979; Ezzat; 1985). Thest estimates are equivalent to a range from 2.1 to 42 cm y^{-1}. These figures indicate that most of the water balance of the Arabian Gulf is accomplished through exchange with the Gulf of Oman. Recent agricultural and industrial developments in the countries situated along the main rivers have reduced the level of fresh water input significantly into the Arabian Gulf. Additionally the cessation of deredging activities in the Shatt-Al-Arab river due to the gulf war has affected the level of fresh water greatly. In fact local dwellers have experienced a great change in the salinity of the river.

Recent study of the heat budget of the Arabian Gulf indicated an annual mean heat deficit of 21 W m^{-2} due to the air-sea interface processes (Ahmad and Sultan, 1991). In contrast the adjacent Gulf of Oman is a great heat recipient water body (55 W m^{-2}) (Sultan and Ahmad, 1993). Part of this heat gain is advected through water exchange at the Strait of Hormuz to compensate the heat deficit in the Arabian Gulf. In studying the heat budget of the coastal water of Kuwait, Sultan and Ahmad (1994) found that the air-sea interface processes result in an annual heat flux surplus of 28 W m^{-2}. An unpublished similar exercise conducted by the authors in the coastal water of Al-Jubail area, Saudi Arabia, shows that the annual heat flux is negative (53 W m^{-2}).

The objectives of the present study is to calculate the heat fluxes at the surface water of the southeasternpart of Gulf (Doha-Qatar) and compare the results with that of the whole Gulf and other areas in the region.

Methods :

The data used in this study were obtained from the Department of Civil Aviation and Meterology, Doha. Monthly means of air temperature were taken over a 35-year period. The monthly means of wind speed and relative humidity were obtained for a period of 23 years. Monthly means of solar radiation were obtained for a 22-year period. The monthly means of sea surface temperature were obtained over a period of 11 years. The meteorological parameters were measured on an hourly basis. Daily means were obtained from hourly values and monthly means from the daily ones.

Evaporative and sensible heat fluxes:

The Bulk Aerodynamic method is used to estimate evaporative and sensible heat fluxes Q_e and Q_h. The bulk formula for the evaporative heat flux is

$$Q_e = \rho_a .L.C_E.(q_s - q_a).W$$

where L is the latent heat of evaporation, C_E is the exchange coefficient, q_a is the specific humidity at the air temperature, and w is the wind speed.

The upward sensible heat flux is

$$Q_h = \rho_a.C_T.C_p.(T_w - T_a).W$$

where ρ_a is the density of air, C_T is the heat flux coefficient, C_p is the specific heat of air at constant temperature, T_w and T_a are the sea surface and air temperatures respectively.

The coefficients of exchange, C_E and C_T play a key role in the calculation of the evaporative and sensible heat fluxes. The choice of these coefficients for the Arabian Gulf has been discussed in details in previous studies (Ahmad and Sultan, 1991; Sultan and Ahmad, 1994). A similar value is suggested for both coefficients (Masagutov, 1981). For the Arabian Gulf the value of CE and CT is 1.3x10-3 (Ahmad and Sultan, 1991). With the appropriate numerical values the equations for the evap-ortive and sensible heat fluxes become,

$Q_e = 2.4 \cdot (e_s - e_a).W$ $\quad W.m^{-2}$

$Q_h = 1.5 \cdot (T_w - T_a) \cdot W$ $\quad W.m^{-2}$

where e_s is the saturation vapor pressure at the sea surface and e_a is the vapor pressure in the air both expressed in millibars (mb).

Radiative fluxes:

The net long-wave radiation Q_b is computed using Budyko's formula (Budyko, 1974)

$$Q_b = \delta.\sigma.T^4_w \cdot (0.254 - 0.005.e_a) + 4.\delta.\sigma.T^3_w \cdot (T_w - T_a) \quad W.m^{-1}$$

where δ is the emissivity of the sea surface relative to a black body and is (0.95) σ the Stefan-Boltzman constant 82 x 10^{-12} cal min^{-1} cm^{-2} deg^{-4}, T_w and T_a are the absolute sea surface and air temperatures respectively.

The cloud cover reduces the net long-wave radiation by a factor (1-nc), where n is the cloudiness in fraction of unity and c is a factor the varies with latitude from 0.5 at the equator to 0.82 at 75°N. Substituting for the numerical values the equation for the net long-wave heat flux as given by Ahmad and Sultan (1991) becomes,

$$Qh = 5.4.10^{-8} \cdot (T4w \cdot (0.254 - 0.005e_a) \cdot (1 - 0.6n) + 4T^3_w.(T_2 - T_a) \; W.m\text{-}2$$

Results and dicsussion :

The result of the calculations of surface heat fluxes togetherwith the recorded solar radiations are given in the table and displayed in fig.2. Based on the monthly means of meteorological data and sea surface temperature the investigation shows that the sensible heat flux is positive (gain) in summer and neagative (loss) in winter. The annual average is about 4 $W.m^{-2}$. This value agrees with the results of the coastal water of Kuwait in the sense it is positive (Sultan and Ahmad, 1994). On the other hand the value for the whole Gulf is negative (-1 $W.m^{-2}$) (Ahmad and Sultan, 1991).

The latent heat flux varies considerably, being higher in summer and lower in winter with an annual average of 153 $W.m^{-2}$. The pattern of variation does not agree with that of Privett (1959) where everaporation is higher in winter. However, the present results agree very well with the recent estimates of evaporation from the Gulf (Meshal and Hassan, 1986; Ahmad and Sultan, 1991; Sultan and Ahmad, 1994). The numerical value of evaporation at the coastal water of the southeastern part of the Arabian Gulf agree with that of the Kuwait region, but is slightly less than that for the whole Gulf (168 $W.m^{-2}$).

The net upward long-wave radiation averages to about 57 W.m-2 with a pattern that displays low values in summer and higher values in winter. This pattern agrees with the results of recent studies. Despite higher surface temperature, the net long-wave radiation is low in summer. This is intimately related to the variation of the vapor pressure in the air. The difference between sea surfaces and air temperatures seem to be less effective than the vapor pressure.

The annual mean of the recorded short-wave radiation Q_s absorbed at the surface is 200 $W.m^{-2}$. This is slightly less than the value for the whole Gulf. This is expected as the amount of cloud cover is higher in the Qatar area. This leads to a heat deficit of 7 $W.m^{-2}$. The result of the present study agree with that of the whole Gulf in the sense that there is a heat deficit due to the air-sea interface processes, though the numerical value is smaller (7 $W.m^{-2}$). The net heat loss due to air-sea interface processes must be compensated by het gain due to advection. The present results reflect the importance of the currents in maintaining the heat balance of the study area and invites a detailed study of the current pattern in the area in order to quantify its contribution to the heat budget.

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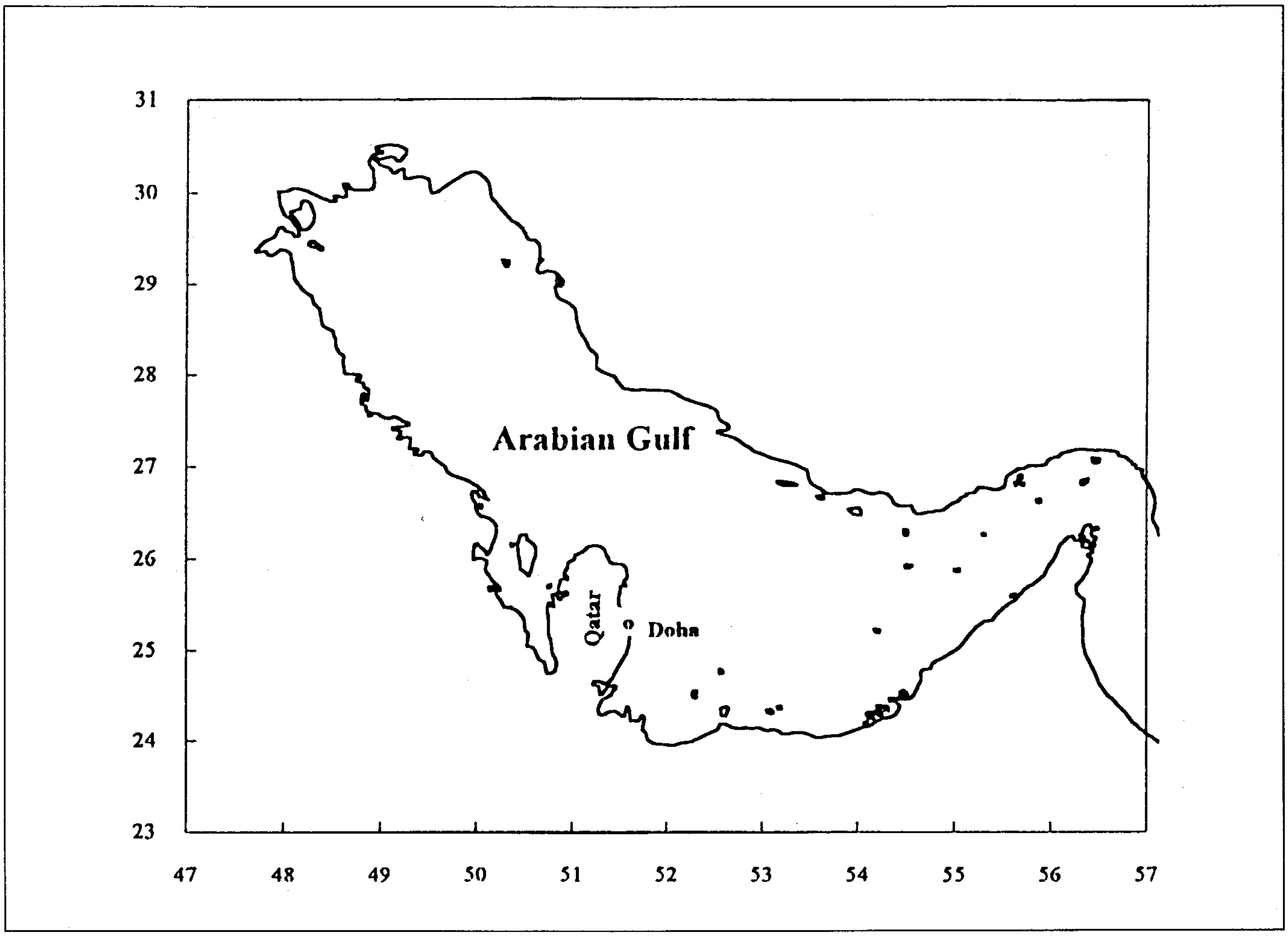

Fig 1

Map of the Arabian Gulf showing Qatar peninsula and the coastal meteorological station

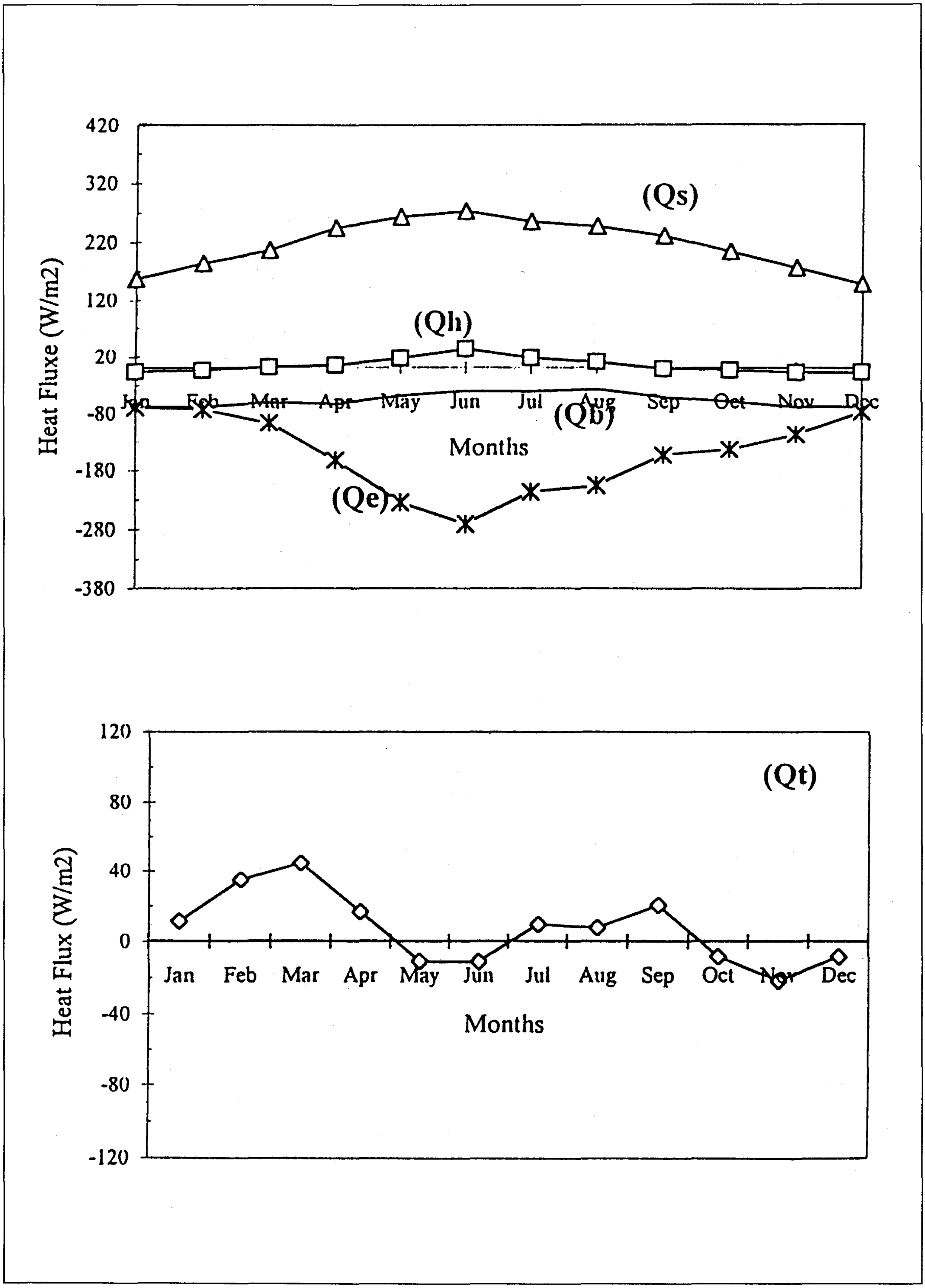

Fig 2

Monthly means of the various heat flux components: solar radiations (Qs), back radiations (Qb), latent heat flux (Qe) and sensible heat flux (Qh) and net heat flux (Qt).