Investigating thermal energy equilibrium in the Persian Gulf

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Abstract

Iran is connected to the global oceans and other countries through the Persian Gulf, Oman Sea and Caspian Sea. Generally, the total amount of all thermal radiuses entered to the oceans and exited from them should be zero; otherwise, the oceans will be either freeze over or grown hot. The goal in this paper is to survey the thermal equilibrium in the Persian Gulf. Since the rainfall rate and the waters entered the Persian Gulf was about 90cm/a, and evaporation rate was about 213cm/a, therefore, the evaporation rate of 20-25cm/a, in one year was more than the rainfall in the Persian Gulf. Considering this point that the volume of output and input waters in the Persian Gulf were equal to 0.186×10^6 m^3/s and 0.169×10^6 m^3/s respectively, the net heat transfer of the Persian Gulf estimated to be 25W/m^2. It was tried to justify this amount of extra heat of the Persian Gulf by the term of surface heat flux. In this research, the annual average of short waves observed on the surface of the Persian Gulf was about 245 W/m^2, the flow of the surface heat, the flow of the latent heat, and also infrared radiation flux were calculated as -4, 179, and 92 W/m^2, correspondingly. Thus, a shortage of heat about 22 W/m^2 related to the additional heat entered the Persian Gulf was observed.

Keywords: Evaporation; Solar radiation; Sensible heat; Infrared radiation fluxes; Persian Gulf.

1. Introduction

The survey of thermal energy equilibrium in the Persian Gulf is important. Having knowledge about the Persian Gulf distribution and transformation of heat, one can forecast the meteorology, fishery, the place of aquatics life, and exact information of the sea behavior.

The Persian Gulf weather is dry and evaporation is more than rainfall there. The entrancing water stream of the Oman Sea from the surface with normal temperature of 24.5 ^{o}C and the salinity of

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37.1/1000 to the Persian Gulf, while the Persian Gulf water out stream with the temperature of 19.5 ^{o}C and 40.2/1000 salinity from bottom moves outward the Persian Gulf (Reissosadat, 2003).

Vertical mixture often occurs in the North part of the Persian Gulf in winter. In summer, the heat surface of the Persian Gulf is more than in winter, but because the water with the maximum salinity and maximum density goes deep, in the lower layers one can see similar qualities in summer and winter. There has not been much measures about thermal energy in the Persian Gulf, but based on the Privett's studies in 1959, and Hassan's studies in 1986 in the Persian Gulf, the evaporation rate had been estimated in order of 144 and 202cm/a, and in their climatic atlas of the Indian Ocean, Hastenrath *et al.* (1979) represented the surface heat fluxes tables. The annual averages of short-wave radiation, net long-wave radiation, and latent heat flux for the Gulf appear to be 230, 75 and 110 W/m^2, respectively. On the Red Sea, there are more accomplish scientific researches in this field. Bunker in 1979 calculated the rate of latent heat flow of the Red Sea as 183W/m^2 and Sultan in 1989 estimated it as 165W/m^2 for the central region of the Red Sea and 169 W/m^2 for the sea as a whole (Hastenrath *et al.*, 1979).

Several studies estimated the annual mean value of net surface heat flux in Persian Gulf. This amount varies between 66W/m^2 to -21W/m^2. A study calculated the net surface heat flux about 45 W/m^2, the latent heat flux value of 110W/m^2, and evaporation rate about 1.39 m/year (Hastenrath *et al.*, 1979). Furthermore, in another research, the net surface heat flux was reported about -21W/m^2 with the latent heat flux value of 168W/m^2 and evaporation rate of 2.12m/year (Ahmad and Sultan, 1991). Moreover, Prasad and the colleagues achieved the value of net surface heat flux in about 66W/m^2 (Prasad *et al.*, 2001). Another study obtained the net surface heat flux of -7W/m^2, the latent heat flux value of 145W/m^2 and evaporation rate of 1.83m/year (Johns *et al.*, 2003). In addition, the mean value of evaporation rates of 1.57 and 1.61 m/year were estimated by observing two different sites of Iran; Busher, and Bandar Abbas, located near northern coast of Persian Gulf (Sabziparvar *et al.*, 2011& 2013).

2. Materials and methods

The temperature of the Persian Gulf water differs from one place to another and from time to time. These differences demonstrate heat transfer by currents sun energy absorption, evaporation, and so on. For classifying the heat transfer, following parameters can be used:

Q_s: Heat flux with short wavelength, the amount of entered sun energy, which is received through the Persian Gulf surface.

Q_b: Net heat flux with long wavelength, the estimated net upward long wave radiation between Persian Gulf surface and atmosphere.

Q_h: Heat flux due to conduction, the amount of heat taken or lost from the water, which is exchanged between Persian Gulf and atmosphere due to the thermal differences.

Q_e: The heat flux loses through the evaporation in the region

Q_v: The amount of taken or lost heat flux by aquatic environment that is usually horizontal

Q_T: Net heat flux, the heat added to or reduced from the Persian Gulf surface

Apparently, there are other sources such as the earth inner heat, changes of kinetic energy, chemical or nuclear reactions, and so on, but they are too small to mention. The equation used for the thermal equilibrium of these rates is:

$$Q_s + Q_b + Q_h + Q_e + Q_v = Q_T \qquad (1)$$

which Q_T is the total amount of earned or lost heat, thus the positive amounts of this parameter is the taken thermal energy and the negative amount is the lost thermal energy by the Persian Gulf.

When the water temperature does not change in a time interval, it does not mean that there is not the heat fluxes in that water. However, this means that

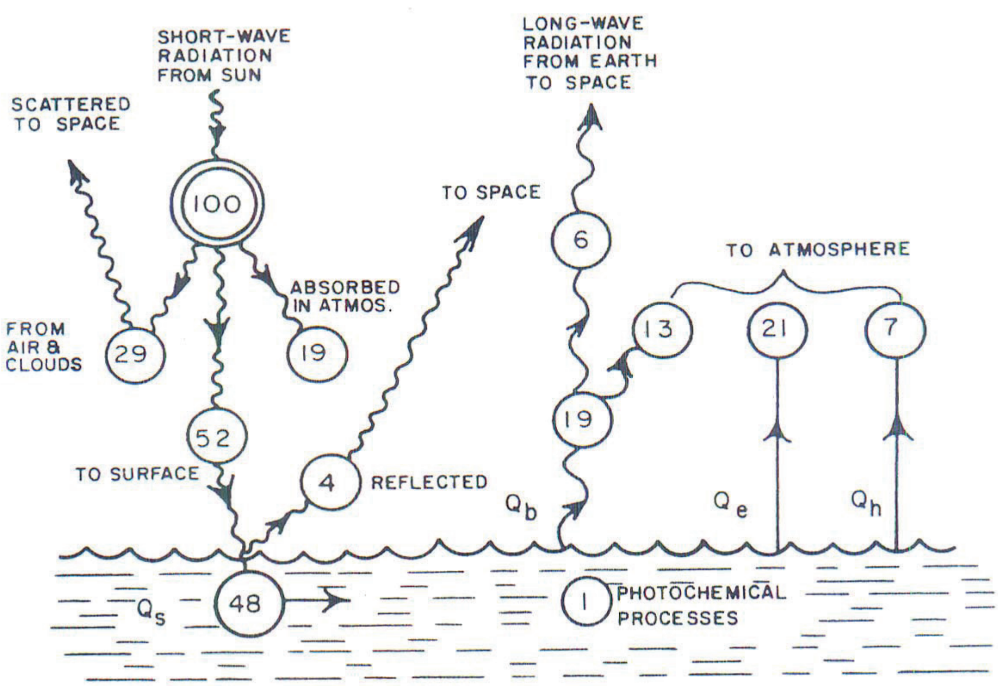

Figure 1. The radiated solar energy and its conversion to different terms in the thermal equation

the algebraic amount of the left side of the Equation (1) is equal to zero, in other words the pure entrance of the heat is equal to its pure external.

In the world oceans, the annual average of Q_s, Q_b, Q_e, and Q_h are in order of 150, -50, -90, and -10W/m^2, and the annual average of Q_v is equal to zero, because the heat moves inside the water through the syndrome, and it remains with no exchange by the outside. The Figure1 shows the radiated solar to the atmosphere and sea surface, and its exchange rate to different rates of thermal Equation (2) [Emery *et al*., 1987].

Thus, the pure thermal equilibrium in the air-sea boundary layer in all of the oceans is calculated with following formula:

$$Q_T = Q_s - Q_h - Q_e - Q_b \qquad (2)$$

2.1. Q_s

This term, Q_s is the entered solar energy rate influenced by different parameters through the Persian Gulf surface. The parameters are as follows: The first parameter shows the clouds and atmosphere that absorbs the solar energy and caused less energy to reach the sea surface. Different factors influence on this parameter as below:

- ❖ Clouds caused the absorption and distribution of radiation
- ❖ The length course of atmosphere depends on the angle of the sun with horizon
- ❖ The gas molecules such as O_2, O_3, and H_2O absorb radiation in many layers of atmosphere.
- ❖ Dust and the other factors in the atmosphere spread out the radiation
- ❖ The surface reaction depends on the sun altitude and the purity rate of the sea surface

This influence is measured by the following equation (Hirose *et al*., 1996):

$$Q'_s = Q_{so}\,(1\text{-}0.0012\ c^3) \qquad (3)$$

In this formula Q'_s is the rate of radial energy got to the sea surface, and Q_{so} is the rate of initial radial energy, c is the cloud coverage. If the sky is absolutely cloudy, then c =8, and if the sky is absolutely clear, c =0. Thus, in absolute cloudy weather:

$Q'_s = Q_{so} (1\text{-}0.0012\times8^3) = 0.39Q_s$ (4)

and if the weather is absolutely clear $Q'_s = Q_s$.

The next effective parameter in Q_s is the tilt of the sun, as it goes up in the latitude, the received energy by the ocean's surface decreases. This parameter is under influence of the bellow factors:

- ❖ The height of the sun when it is up the horizon, which depends on the latitude and seasons
- ❖ The length of the day that depends on the latitude and seasons
- ❖ The segment's surface on which the sun shines and depends on the distance of the sun from the horizon

Another parameter is the effect of changing seasons caused a change to the length of a day, so the longer the day, the more time will the sun be above the horizon, so the absorbed energy by oceans will increase.

The next parameter is the rate of light reflection from the sea surface. This factor depends on vibrations of the sea surface and the changes of tilt angle of the sun.

There is a tentative relation for this reflection as follow:

$Q_r = 0.\ 15Q'_s - (0.01Q'_s)^2$ (5)

For example in Table 1, the following proportion of shining angle is defined by the reflection and absorption amounts (Blance, 1985).

Using the Equations of (3) and (5), one can get the amount of short-wave radiation into the water through the Sun by Equation (6) presented by Levastu in 1963:

$Q_s = Q'_s\text{-}Q_r = 0.85Q'_s\text{-}10\ Q'_s$ (6)

In clear sky, this amount is too high and to get close to the reality amount, it is multiplied by coefficient of 0.7, which is the atmosphere conductivity coefficient (Hirose *et al*., 1996). Figure 2 shows the different amounts of radiation energy of short waves to the oceans' surface in the absence of clouds.

Table 1. Proportion of sun angle and the reflected and absorbed values

Angel of sun	90°	60°	30°	20°	10°	5°
Reflected value	2	3	6	12	35	40
Absorbed value	98	97	94	88	65	60

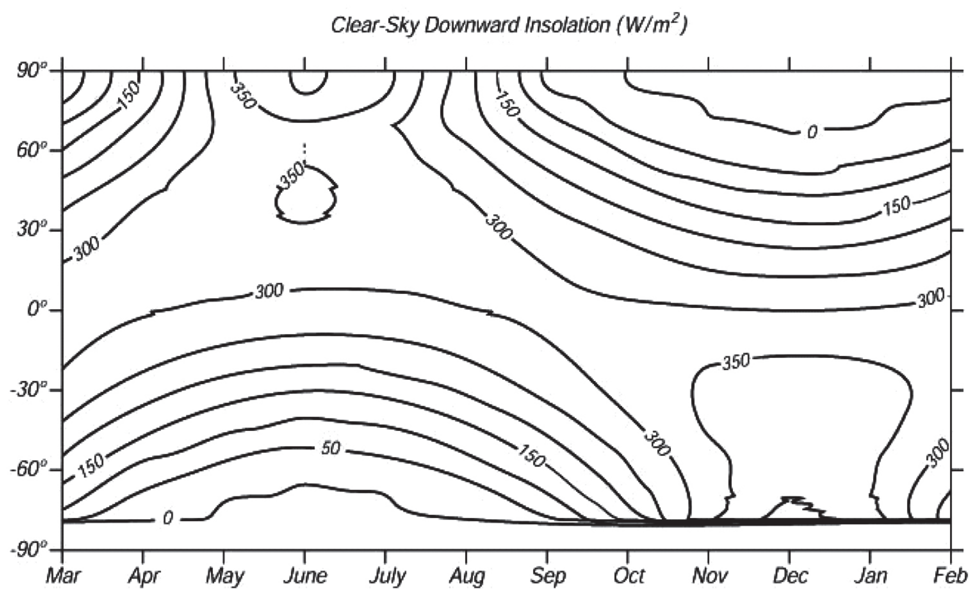

Figure 2. Daily average of the short waves energy radiation to the oceans' surface in the absence of clouds

2.2. Q_b

Everything that has temperature higher than absolute zero emits thermal energy and it can be determined by the Estephan Battzman equation (McLellan, 2013):

$$Q = \varepsilon \, б \, T^4 \quad (7)$$

In this equation, ε is the emission constant of the object which is between 0 and 1, and depends on flatness and unevenness of the body surface and its color. For black body surface ε = 1. The б is Boltzman constant and is equal to 5.67×10^{-8} W/m^{2}k^4, and T is the absolute temperature of the object. Q_b is the total amount of lost energy from the sea as long radiation, which shows the difference between radiated energy to outside of the sea surface and the received energy by the sea.

Angestrom in 1920 showed that the rate of losing this energy depends on both the absolute temperature of the sea surface, and the content of atmosphere water vapor. Angestrom presented the different amounts of Q_b in different figures, tables and graphs (McLellan, 2013). The Q_b can be also calculated by Levastu formula (Equation 8).

$$Q_b = (143 - 0.9T_w - 0.46\, e_a)\,(1 - 0.1C) \quad (8)$$

In the formula, C is the portion of cloud covering, e_a is the relative moisture above the sea surface, and T_w is the water temperature measured in centigrade. The rate of long waves radiation is calculated Equation (9) by Budyko (1974)

$$Q_b = \delta\, б t_w^{\,4}(0.254 - 0.005e_a) + 4\delta\, б T_w^{\,3}(T_w - T_a) \quad (9)$$

In this formula δ =0.95 and T_a is the air temperature. If one considers the rate of covering cloud:

$$Q_b = 5.4\times 10^{-3}\,[T_w^{\,4}(0.254 - 0.0005\, e_a)\,(1 - 0.6c) + 4T_w^{\,3}(T_w - T_a)] \quad (10)$$

2.3. Q_e

The evaporation term is one of the most important thermal terms in the Persian Gulf, but its direct determination is not simple. For evaporation, one needs to provide thermal energy from an outside source. This thermal energy can also be provided by taking heat from the rest of the liquid, and this way is more usual in the oceans. It is obvious that evaporation causes the loss of thermal energy. An approximate amount of heat (4200-Joule) is necessary to evaporate one-gram of water, and this rate changes with salinity and temperature.

Budyko (1974) estimated that each year the oceans lose their water about 1.2 meters through the evaporation, and the heat value was approximately equal to 100 W/m^2. However, there are different formulas to measure the evaporation. The first one is:

$$Q_e = F_e .\, L_t \quad (11)$$

In this formula, F_e is the evaporation rate of water in kg/s.m^2 and L_t is the latent heat of the evaporation, which can be achieved from the Equation (12) [Hodges, 1999]:

$$L_t = (2500 - 2.39t)\ \text{kj/kg} \quad (12)$$

which "t" is water temperature measured in Centigrade.

To calculate F_e in different times, one can put a dish of water on the deck and then calculate the massive difference of water. However, this contains many errors because firstly pressure of water vapor on deck is less than that on the sea surface. Secondly, the blow of wind on the sea surface can be different from the wind-blown on the deck. In addition, the semi experimental formula as bellow is applicable:

$$F_e = 1.4\,(e_s - e_a)\,w \quad (13)$$

In this relation e_s is the saturated vapor pressure above the sea surface and e_a is the vapor pressure in the 10-meter height above the water surface in air and "w" is the wind speed in height of 10 meters above the water surface. In combination of the Equations (12) and (13), the result will be:

$$Q_e = F_e .\, L_t = 1.4(e_s - e_a)\, w\, (2500 - 2.39t) \times 10^{-3} \quad (14)$$

In the formula, "e_s" is the saturated pressure of water vapor over the sea surface, "e_a" is the real water vapor pressure in the height of 10 meters on the water surface (kilo-Pascal), and "w" is the wind speed in the height of 10 meters above the water surface.

The amount of "e_s" above the sea surface is a little less than the amount of which on the distilled water

Table 2. Some values of "C_T" related to different temperature and wind speed values.

W (m/s) / $(T_w\text{-}T_a)$ °K	2	5	10	20
-10			0.75	0.96
-3		0.62	0.93	0.99
-1	0.34	0.87	0.98	1.00
+1	1.30	1.10	1.02	1.00
+3	1.50	1.19	1.06	1.01
+10	1.87	1.35	1.013	1.03

surface (e_d). In addition, the amount of "e_d" is available in the meteorological tables. For example for salinity of 35 ppt:

$$e_s = 0.98\ e_d \quad (15)$$

To calculate Q_e, one can also use the Smith formula in 1988 (Simonsen and Haugan, 1996).

$$Q_e = L\ C_e\ \rho_a\ (e_s - e_a)\ w \quad (16)$$

which "L" is the latent heat of water vapor (2.5×10^6 j/Kg) and C_e is the coefficient of latent heat flux which obtains from the relevant tables based on the wind speed and temperature difference between air and sea (Kara, 2000).

2.4. Q_h

Generally, most oceans have higher temperature than the surrounded air temperature; thus, the conduction term will be negative. In fact, to calculate "Q_h" following formula similarly to evaporation formula is used (Smith formula in 1988):

$$Q_h = \rho_a\ C_T\ C_P\ L_T\ (T_w\text{-}T_a)\ w \quad (17)$$

which "ρ_a" is the air density, "C_T" is the coefficient of thermal flow, "C_p" is the specific heat capacity of the air in the constant pressure, "w" is the wind speed ,"T_w" is the surface temperature in Kelvin, and "T_a" is the air temperature above the water (in Kelvin). Whereas the air temperature decreases upward, then the heat from the sea surface is led up and the Q_h will be negative. In addition, if the temperature decreases downward, the heat will be directed from air into the water and in this case "Q_h" is an energy receiver term and it is positive as well. The Blance experiments in 1985 showed that the C_T and C_e coefficients are not constant and they depend on the wind speed and thermal difference between the air and the sea surface (Blance, 1985; Kara, 2000). Furthermore, Masag and Utov in 1981 suggested that these coefficients are equals whenever the wind speed is between 2 to 21 m/s, and the thermal difference between water and air is from zero to ±4 C. For the Persian Gulf these coefficients are considered equal, $C_T = C_e = 1.3\times10^{-3}$. Furthermore, Smith presented some graphs and tables for the C_T as a function of temperature and wind speed, a sample of which is shown in the Table 2 (Michuald and Drome, 1991). In addition, for calculating Q_h, :Dirtkey formula in 1965 is also applicable

$$Q_h = -1.88\ w\ (T_w - T_a) \quad (18)$$

3. Results and data analysis

The average values of the oceanography and meteorology parameters have been calculated in the Persian Gulf for 15 years (1991-2006). The air temperature, surface heat flux, the relative moisture, wind speed, and the data for cloud have been presented in Table 3. The table shows the results related to the observation of sun radiation, the perceptible heat flux, the latent heat flux, the calculated of the long wave radiations, and the pure heat flux in the air-sea boundary layer.

Table 3. Different parameters' values during months in Persian Gulf

Month	T_w (^{o}C) Water surface temperature	T_a (^{o}C) Air temperature	Percent humidity	W (m/s) wind speed	C Cloudy coefficient	e_s (KPa) Water surface vapor pressure	e_a (KPa) Water surface vapor pressure in 10-m height	A_n (^{o}C) Sun average tilt	T_d (H) Average day length
Jan	19.8	15	65.3	7.5	2.4	12.5	4.4	36	10.5
Feb	19.2	16.5	67.3	8	2	13	5.5	44	11
Mar	20.1	20.1	81	7.5	1.8	14.5	8.4	52	11.5
Apr	23.8	25	68.3	7	2.3	17.5	13	60	12
May	26.4	30	70.6	7	1.4	21.5	19	69	13
Jun	29	33.9	76.6	6.5	1.1	26	21	77	13.5
Jul	31.6	35	70	6.5	1.4	30	21	79	13.5
Aug	33	33.9	82	7	1.6	32	19.5	77	13
Sep	31.8	31.4	72.6	6	1.2	28.5	17	68	12
Oct	29.7	27.1	66.6	5.5	1.3	23	13.6	60	11.5
Nov	24.8	21.8	62	6.5	3	17	9	52	11
Dec	20.5	16.6	55	7	2.7	14	5	44	10.5
Average	25.81	25.53	69.78	6.83	1.85	20.79	13.03	59.83	11.92

3.1. Q_s

Using Table 3 and Equations (3) and (4), the amounts of Q_s for different months and its annual average were calculated and they are available in Table 4. The variations of Q_s during different months are shown in Figure 3.

Table 4. The amounts of short waves flux in different months in the Persian Gulf

Month	A_n(^{o}C) Average angel sun	T_d (H) Average day length	C Cloudy coefficient	Q_{so}	Q'_s	Q_s
Jan	36	10.5	2.4	151.20	148.69	126.37
Feb	44	11	2	193.60	191.74	162.96
Mar	52	11.5	1.8	239.20	237.53	201.87
Apr	60	12	2.3	288.00	283.80	241.20
May	69	13	1.4	358.80	357.62	303.94
Jun	77	13.5	1.1	415.80	415.14	352.82
Jul	79	13.5	1.4	426.60	425.20	361.37
Aug	77	13	1.6	400.40	398.43	338.63
Sep	68	12	1.2	326.40	325.72	276.83
Oct	60	11.5	1.3	276.00	275.27	233.95
Nov	52	11	3	228.80	221.39	188.16
Dec	44	10.5	2.7	184.80	180.44	153.35
Average	59.83	11.92	1.85	290.80	288.41	245.12

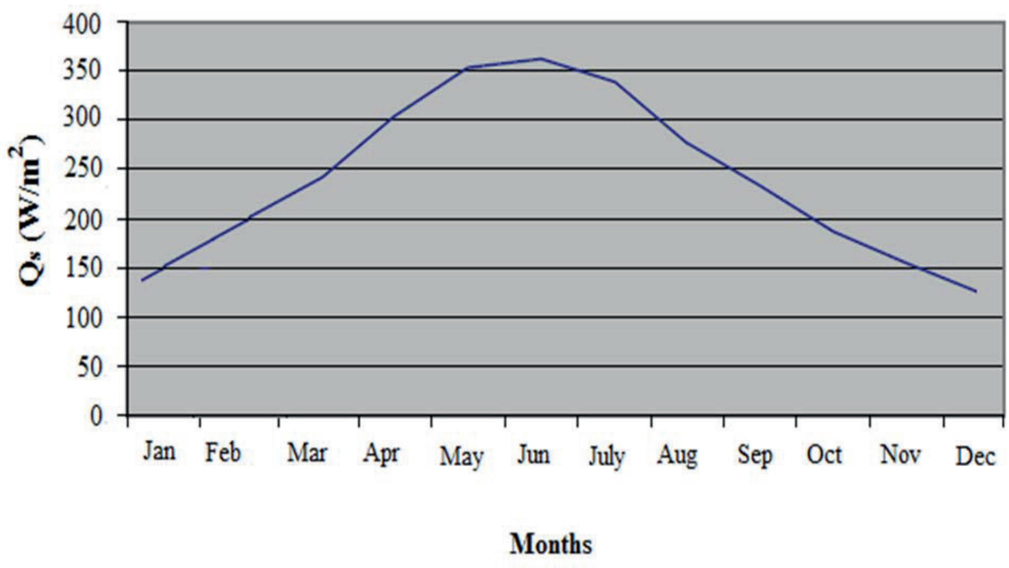

Figure 3. The variations of Q_s during different months in Persian Gulf

3.2. Q_b

Using Table 3, and Equations of (9) and (10), the amounts of Q_b for different months that radiate from the sea surface to the air and its annual average were calculated and they are presented in Table 5. In addition, Figure 4 shows the variations of Q_b in different months.

Table 5. The amounts of long wave flux in different months

Month	T_w (^{o}C) Water surface temperature	e_a	C Cloudy coefficient	Q_b
Jan	19.8	4.4	2.4	93.60
Feb	19.2	5.5	2	98.55
Mar	20.1	8.4	1.8	99.26
Apr	23.8	13	2.3	89.01
May	26.4	19	1.4	95.03
Jun	29	21	1.1	95.44
Jul	31.6	21	1.4	90.21
Aug	33	19.5	1.6	87.64
Sep	31.8	17	1.2	93.77
Oct	29.7	13.6	1.3	95.71
Nov	24.8	9	3	81.58
Dec	20.5	5	2.7	89.24
Annual average	25.81	13.03	1.85	92.42

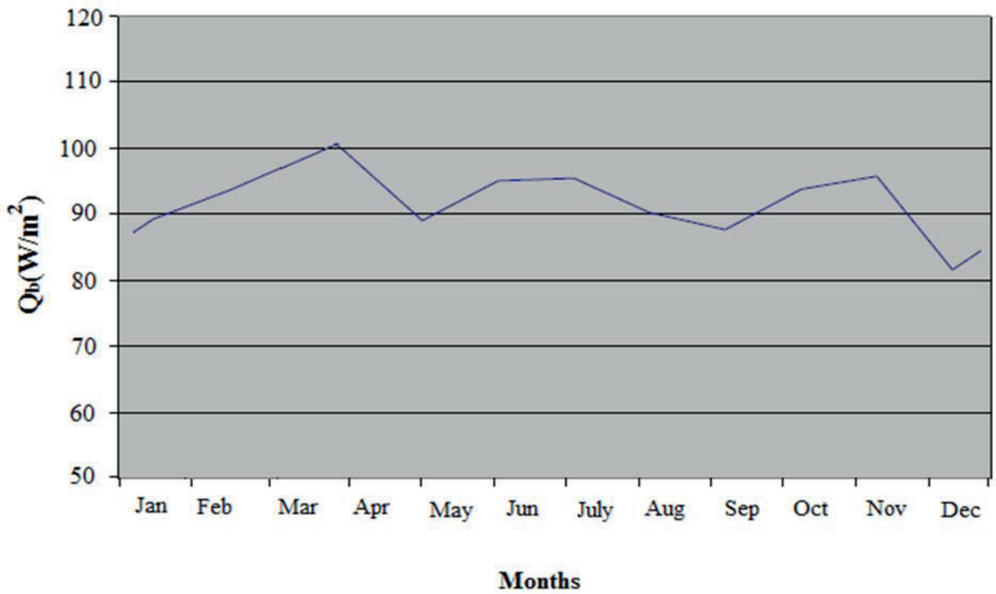

Figure 4. The variations of Q_b in different months in Persian Gulf

3.3. Q_e

Using Table 3 and Equations (14) and (16), the amounts of Q_e for the different months and its annual average have been calculated and they are presented in Table 6. Figure 5 shows the variations of Q_e in different months.

Table 6. Values of Q_e, heat from evaporation, in different months in Persian Gulf

Months	W(m/s) Wind speed	T_w (^{o}C) Water surface temperature	T_a (^{o}C) Air temperature	e_s	e_a	Q_e
Jan	7	20.5	16.6	14	5	216.75
Feb	7.5	19.8	15	12.5	4.4	209.31
Mar	8	19.2	16.5	13	5.5	206.45
Apr	7.5	20.1	20.1	14.5	8.4	156.91
May	7	23.8	25	17.5	13	107.56
June	7	26.4	30	21.5	19	59.49
July	6.5	29	33.9	26	21	110.08
Aug	6.5	31.6	35	30	21	197.95
Sep	7	33	33.9	32	19.5	296.38
Oct	6	31.8	31.4	28.5	17	234.25
Nov	5.5	29.7	27.1	23	13.6	176.20
Dec	6.5	24.8	21.8	17	9	178.07
Annual average	6.83	25.81	25.53	20.79	13.03	179.12

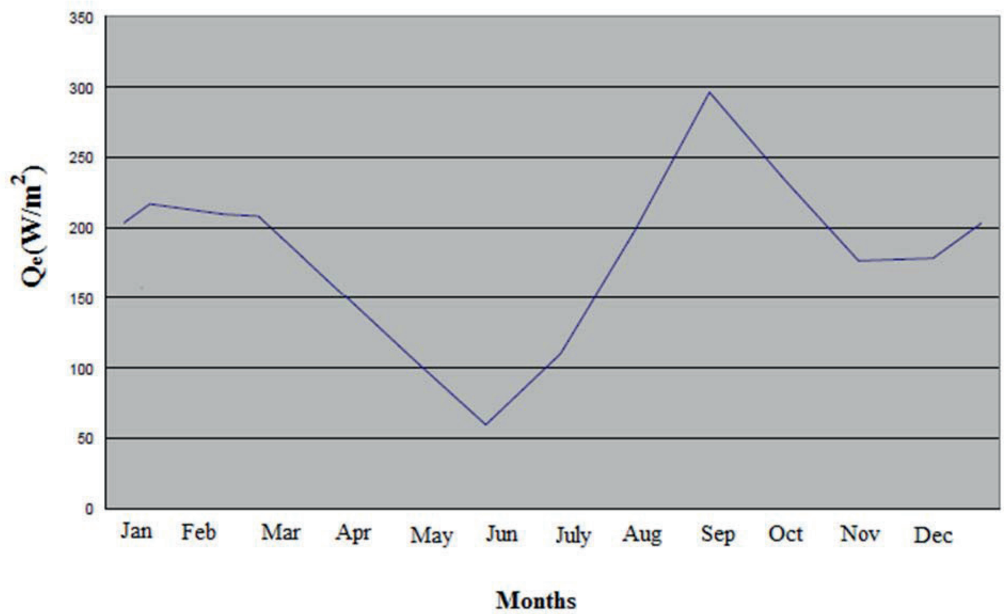

Figure 5. The variations of Q_e in different months in Persian Gulf

3.4. Q_h

Using Table 3 and Equations (17) and (18), the amounts of Q_h for the different months and its annual average were calculated and they are presented in Table 7.The changes of Q_h in different months during the years is drawn in Figure 6.

Table 7. The Q_h exchanged between the Persian Gulf and the atmosphere in different months

Months	W(m/s) wind speed	T_w(° C) Water surface temperature	T_a(° C) Air temperature	Q_h
Apr	7.5	20.1	20.1	0.00
May	7	23.8	25	15.79
June	7	26.4	30	47.38
July	6.5	29	33.9	59.88
Aug	6.5	31.6	35	41.55
Sep	7	33	33.9	11.84
Oct	6	31.8	31.4	-4.51
Nov	6.5	29.7	27.1	-26.88
Dec	6.5	24.8	21.8	-36.66
Jan	7	20.5	16.6	-51.32
Feb	7.5	19.8	15	-67.68
Mar	8	19.2	16.5	-40.61
Annual average	6.83	25.81	25.53	-4.27

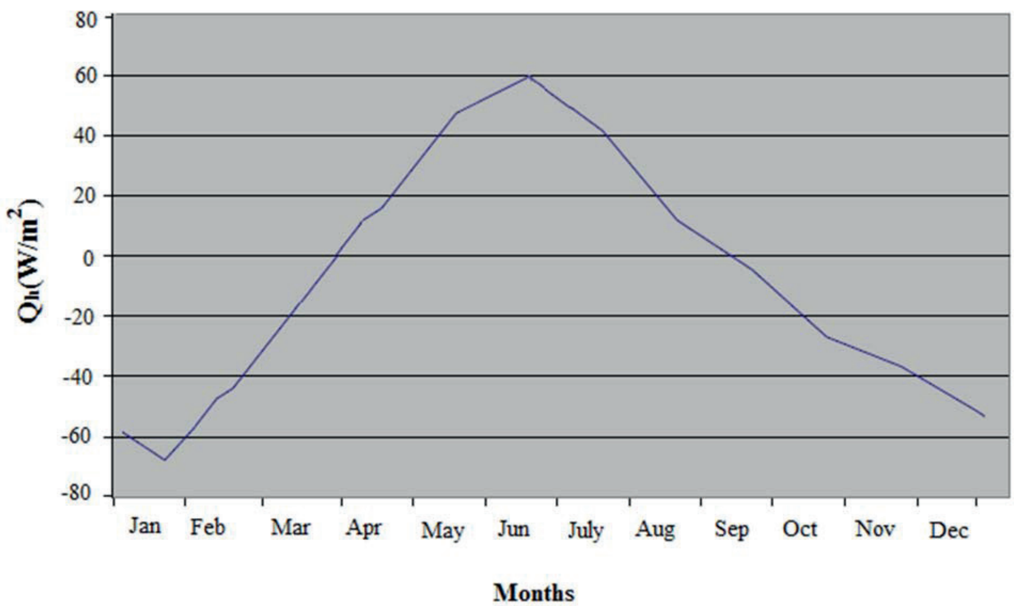

Figure 6. The variations of Q_h in different months in Persian Gulf

4. Discussion and Conclusion

Considering the amounts of Q_s from Table 4 and Figure 3, show that the Q_s had the maximum amounts in June, July, and August. According to the Table 3, one can understand that the solar angle and the day length had the most values, while the amount of the clouds was less in those months, and obviously the Q_s was high. The lowest values of Q_s were in December, January, and February, because the amount of clouds increased and the sun angle and the length of the day decreased.

Table 5 and Figure 4 show that the Q_b had the maximum values in February and March. Table 5 illustrates that in these months the amounts of the surface temperature was minimum. Therefore, the high amount of Q_b was quite natural. Moreover, the Q_b had the lowest values in November, and December, of course the difference between the highest and the lowest values of Q_b was about 17 W/m^2 annually.

Table 6 and Figure 5 show that the amount of Q_h had the highest values in May, June, and July. The table also illustrates that the temperature difference between the air and the surface of the Persian Gulf was more than the other months that was a normal case. The amounts of Q_h were negative in September, October, November, December, January, and February, because the water temperature was higher than the air temperature. Moreover, there was no temperature difference between the air and the surface of the Persian Gulf in March, so the amount of Q_h was zero.

Table 7 and Figure 6 show that the Q_e had the highest values in August and September. Table 7 proves that in these months the amount of e_s-e_a was the maximum, so it was normal that Q_e was high as well. The lowest amounts of Q_e were in March and April thus, in these months the amount of e_s-e_a was minimum.

4.1. Q_T

The use of Table 3 and Equation (2), calculated the amounts of Q_T for different months of the years (1991-2006) and the annual average indicated in Table 8. In addition, Figure 7 shows the amount of Q_T in different months of the years.

In the Figure 8 using a deductive figure, all different terms of the thermal equation (Equation

Table 8. The heat added to or lost from the surface of Persian Gulf

Heat parameter / Months	Q_s	Q_b	Q_h	Q_e	Q_T
Apr	201.87	99.26	0	156.91	-54.30
May	241.2	89.01	15.79	107.56	28.84
June	303.94	95.03	47.38	59.49	102.04
July	352.82	95.44	59.88	110.08	87.42
Aug	361.37	90.21	41.55	197.95	31.66
Sep	338.63	87.64	11.84	296.38	-57.23
Oct	276.83	93.77	-4.51	234.25	-46.68
Nov	233.95	95.71	-26.88	176.2	-11.08
Dec	188.16	81.58	-36.66	178.07	-34.83
Jan	153.35	89.24	-51.32	216.75	101.32
Feb	126.37	93.6	-67.68	209.31	108.86
Mar	162.96	98.55	-40.61	206.45	101.43
Annual average	245.12	92.42	-4.27	179.12	-22.15

2) are compared. The figure clarifies that the annual differences of Q_b are very low and the annual differences of Q_s are high.

The Table 8 and the Figures 7 and 8 the annual average of net heat flux in the Persian Gulf was equal to -22.15W/m^2. As it was mentioned before, the transmission of the pure heat through the Hormuz strait to the Persian Gulf was equal to 25 W/m^2 that is relevant to this shortage, so, the thermal equilibrium in the Persian Gulf is absolutely established.

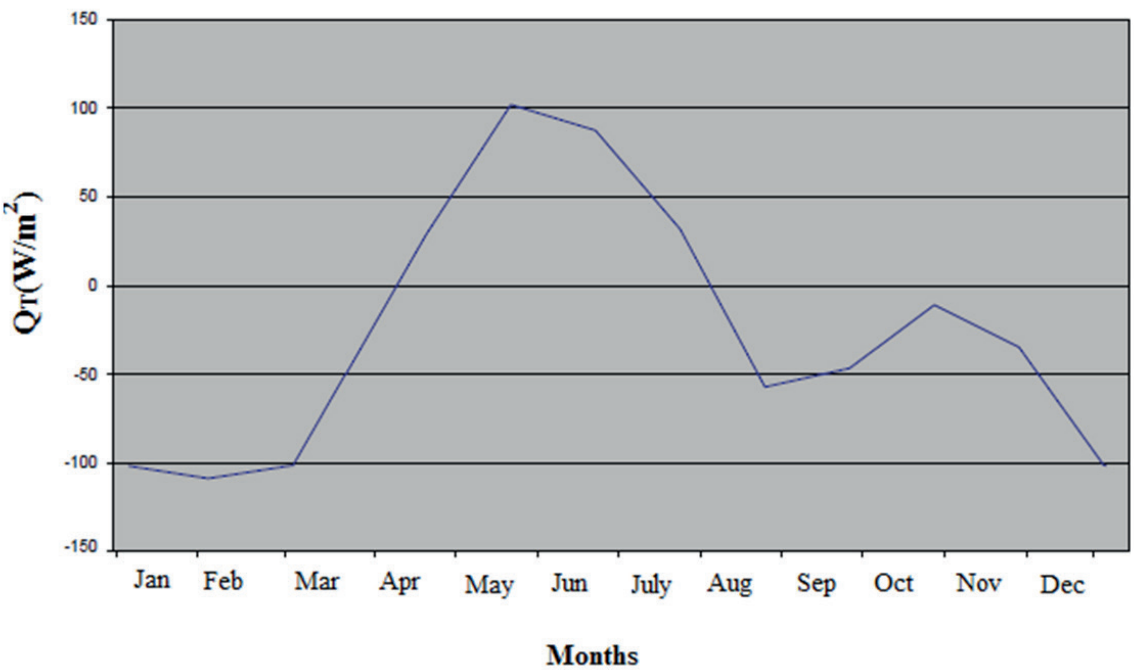

Figure 7. The annual average of Q_T during different months of the years

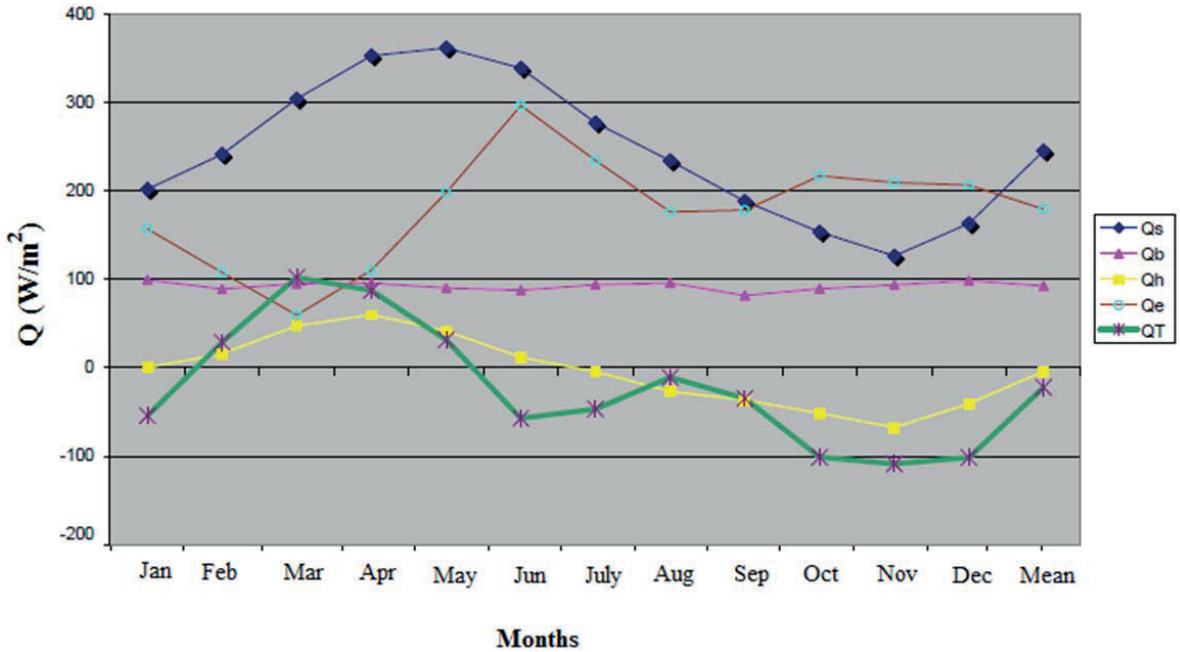

Figure 8. Annual average of the thermal parameters during different months of the years

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