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Estimate net heat flow using equilibrium temperature in the sea-air interface of the northwestern Arabian Gulf

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Abstract:

Equilibrium temperature in addition to the thermal exchange coefficient has been used as a reference to appreciation of the net thermal interchange rate on the water's surface in the northwest Arabian Gulf for the year 2019, both of which are based on meteorological elements. Results show that the waters northwest Arabian Gulf earn heat from October to January and lose heat from February to September. Most months of the year in the northwestern section of the Arabian Gulf, the equilibrium temperature, which indicates the net heat loss, is lower than the sea surface temperature. The importance of this study is due to the effect of the thermal budget on the weather and changes in water temperature which affect the marine environment.

Keywords: Northwest Arabian Gulf, Equilibrium temperature

1. Introduction:

Heat interchange across the border layer at the interface between air-sea is quite significant to investigate several scientific implementations like; weather predicting, the dynamics of climate, the atmosphere, investigation of oceanic circulation, and thermal modifications in the upper atmosphere and lower circumference. Changes in heat stocked at the sea surface's upper layers could be prescribed by balancing between fallen solar radiation flow, longwave radiation flow release for the sea surface, and latent heat flow to the atmosphere from the sea surface. At the air-sea interface, heat exchange operations occur between the atmosphere and water. Included methods of defining those operations that were summed up by [1] and [2], bulk aerodynamic, dissipation, and the eddy correlation method, every one of them demands registering a different kind of independent environmental data involving oceanographic information and hourly meteorological.

Studies of thermal equilibrium in the region are scarce, as there is one study related to the estimation of evaporation rates [3], where the study showed that the annual averages of evaporation in the region are (mm /yr), for two years (2014-2015) 23, 22 respectively. Another study shows the relation between some atmospheric elements and marine phenomena in the northwest Arabian Gulf [4]. In this paper, the concept of equilibrium temperature (T_e) is applied for calculating net thermal interchange on the water's surface, and equilibrium temperature is the virtual temperature at which the net surface heat interchange rate is zero, in theory. This method utilizes many heat flux exchanges which include back radiation, evaporative flow over the surface of the sea, and the air above it. Mean sea surface temperature (Ts) replies to these operations through a heat exchange coefficient [k] ($w / m^2 C^o$), As the rate of sea surface temperature response to heat flow exchanges is described by the mean of this factor. Figure (1) shows the location of the investigation zone.

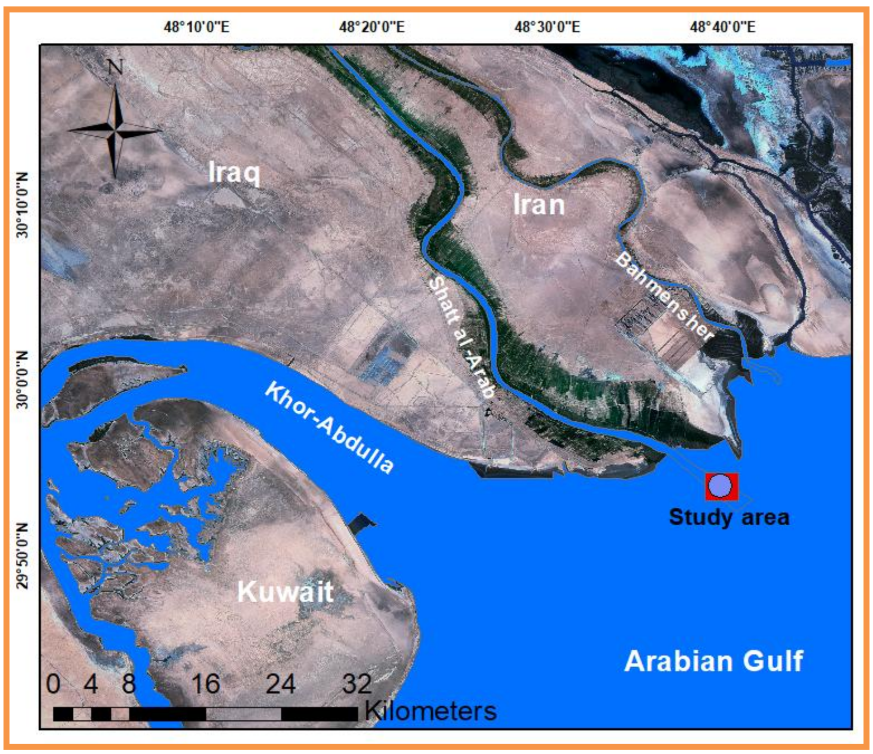

Figure 1: The study region in the north-west Arabian Gulf

2. Derivation of Equilibrium Temperature:

If (T_s) is a symbol for the sea surface temperature, then the amount of heat interchange per unit area upon the water's surface ($K (T_e - T_s)$) emulates variation in heat stock per unit area over time ($\rho C_p H \frac{\partial T_S}{\partial t}$) during the column of water.

$$\rho C_p H \frac{\partial T_S}{\partial t} = K(T_e - T_s) \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Whereas (C_p), and (ρ) is the specific heat, and density of water respectively, (H) is the depth. Over time, temperature (T_s) decreases or increases, building on if the sum of heat outputs with inputs (Q_t) is negative or positive.

$$\frac{\partial T_S}{\partial t} = \frac{Q_t}{\rho C_p H} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

By substitution relationship (1) in (2), we get

$$Q_t = K\,(T_e - T_s) \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

This equation has been introduced by [5].

So, the main parameter denoting the total of the temperature-dependent heat interchange operations inclusive sensible, evaporative, besides return radiative fluxes. Has displayed [6] that the successful approach for (T_e) explain by the following relationship.

$$T_e = T_d + \frac{Q_S}{K} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where (Qs) is defined as the amount of arriving solar radiation absorbed per unit area, and the dew point temperature is the prevailing participant in the seasonal variations of (Te).

Introduced [7] :

$$K = 4.5+0.05\ T_s + (\beta + 0.47)\ f(W) \ldots\ldots\ldots(5)$$

where $\beta = 0.35 + 0.015\ Tm + 0.0012\ T_m^2$

$$T_m = 0.5(T_s + T_d) \ldots\ldots\ldots\ldots\ldots\ldots..(6)$$

[7] summarize many mathematical formulas for f(w), one of them is f (W) = 3.3 W, where wind velocity (W) is recorded with (m/s). There are two points that the thermal interchange parameter (K) is involved in straightly as the proportion factor to convert temperature variance (Te - Ts) to the equivalent amount of heat exchange and as a splitter of the solar radiation ingredient at approximating to (Te) and indirectly, show the diversity of this factor that represents the collective amount of conduction, back radiation, and evaporation at the concept of equilibrium temperature. Dew point temperature was calculated from relative humidity and air temperature according to the formula [8].

$$T_d = \left(\frac{R_h}{100}\right)^{\frac{1}{8}} * (112 + (0.9 * T_a)) + (0.1 * T_a) - 112 \ldots\ldots\ldots(7)$$

Where T_a = air temperature, R_h = relative humidity

The incident solar radiation (Q_s) under cloudy conditions was calculated by [9] depending on total cloud cover data in the study area,

$$Q_s = Q_{os}\ (1 - aC - bC)\ (1 - \sigma) \ldots\ldots\ldots..(8)$$

A = b= 0.38 [10]

σ = Albedo= 0.06

C = (1-0) Fraction of cloud cover in tenths [11]

Q_{OS} = Total solar radiation incoming from a clear sky, and calculated using the following equation [12]:

Q_{OS} = 0.014 An Tℓ (gm al cm-2 day-1)

An= The sun's altitude at noon (degrees).

T_ℓ = Day's Length from sunrise to sunset (minutes)

A_n and T_ℓ are calculated using the Page equation [13]

Table (1): Monthly average of solar radiation absorbed Q_S; Wind velocity w; Relative humidity Rh; Sea surface temperature T_S; Dew point temperature T_d; Equilibrium temperature T_e; Thermal interchange parameter K; Net surface heat flow at the air-sea interface Q_t.

Month	Q_s W/m^2	W m/s	Rh %	T_s °C	T_d °C	T_e °C	K W/m. °C	Q_t W/m^2
Jan.	156	2.38	61.3	14	5.80	15.30	16.41	21.45
Feb.	188	3.38	55.4	17.44	6.77	15.48	21.58	-42.25
Mar.	217	2.97	50.1	20.94	10.02	20.80	20.12	-2.65
April	246	3.77	28.1	23.65	6.82	16.84	24.55	-167.08
May	250	3.35	26.4	28.16	11.26	22.03	23.22	-142.31
June	266	4.9	19.5	29.2	9.77	18.19	31.57	-347.49
July	249	4.24	24.2	28.4	5.61	14.53	27.92	-387.26
Aug.	240	3.46	28.6	31.08	16.82	26.67	24.36	-107.31
Sep.	228	2.97	35.2	30.38	16.72	27.27	21.61	-67.07
Oct.	219	2.91	52.4	25.92	17.21	27.80	20.67	39.01

Nov.	186	2.06	60.3	20.92	11.27	23.14	15.67	34.83
Dec.	165	2.3	71.9	17.5	9.30	19.35	16.41	30.46

3. Data Analysis:

This study considered primary variables of mean monthly meteorological such as air temperature (Ta), relative humidity (Rh), and wind velocity (W), which were collected from two weather stations [14], [15] for verification and comparison also was obtained Sea Surface temperature data (SST) from the scientific team for the Marine Center Science, University of Basrah 2019. To confirm the ability of the equilibrium temperature in addition to the coefficient of thermal exchange to provide estimates of net heat flow at the air-sea interface in the northwestern Arabian Gulf, the current research was conducted. Knowing Q_s, W, T_d, T_s are enough for K and Te to appreciate. Table (1) provides the monthly average sea surface temperature, wind velocity data, dew-point temperature, and relative humidity. Also, shows the calculated amounts of the heat interchange coefficient, the equilibrium temperature, and the net heat flux of the surface estimated at the air-sea interface, as well as that, it was plotted as in Figure (2). The temperature of the sea surface is greater than the equilibrium temperature from (February - September) and is lower from (October - January).

Figure 2: Net Heat Flow of Surface at the Air-Sea Interface

4. Discussion and Results:

Heat exchange at the air-sea interface is the critical factor that controls the temperature of the water body. Based on observable meteorological variables, can estimate the net rate utilizing a thermal interchange parameter and equilibrium temperature. Net heat exchange values in an air-water interface in the northwest Arabian Gulf show net gains starting (October - January) whilst the net loss (February - September). The current study agrees with the findings of [16], which focused on a long-term emulation of the Gulf hydrodynamics, where results concluded that water evaporation in the Gulf is controlled by meteorological forcing (i.e., humidity, air temperature, cloud cover, and wind) and warm water inflow from the Sea of Oman throughout the Strait of Hormuz in winter. As a result, it can be concluded that the equilibrium temperature and thermal interchange coefficient can be reliably used to compute the net rate of heat interchange on the sea surface of the northwestern Arabian Gulf.

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