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Estimation of evaporation rates in the north west Arabian gulf based on sea surface temperature and Meteorological data

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Abstract:-

Bulk aerodynamic formula (Singh's equations) was used to study the evaporation in the north west Arabian gulf. Evaporation was estimated for the region. The annual averages of evaporation in the area are (mm /yr) for two years (2014-2015) 23, 22 respectively. Evaporation is higher in the region during June, July, August, September and October. The correlation between the humidity gradient (e_w-e_a) and monthly averages of evaporation were high in all regions being approximately 0.8, whereas the correlation between monthly averages of evaporation and wind speed were about 0.6. The main cause of higher evaporation was the humidity gradient (e_w-e_a), i.e., higher humidity gradient. These variations were related to the changes in humidity and the wind speed at this location.

Keywords: North west Arabian Gulf, Evaporation rate.

Introduction:

The Arabian gulf contains a semi-enclosed system of water that covers an area of approximately 226 000 (km^2) and ranges in length between (990-1000) km and width (56-338) Km, and because of shallower waters, it was characterized with high temperature significantly and increases in evaporation rates and the marked increases in salinity that link between values (40-50) part per thousand in the coastal areas of gulf (Ismail *etal*., 2007) because of the study area site was characterized by a very dry and warm. Summer begins in April and lasts until October. During the hot dry months, the degree of the daily average temperature is about 33°C, it was recorded on some days of (June, July and August) as 51°C, with very low humidity. Whereas the months of March, April, May, October and November (thermal inversions months) less harsh with low temperatures slowly under 40°C to 30°C (Abdul-Razzak, 1984). There is a lack in rainfall during summer months of June to September, and when the winter begins. During November to February, the average temperature is around 13°C, the minimum to -2°C and a maximum temperature of 27°C in the month of January. The record rainfall compound during winter month was between 25-175 mm. When the favorable conditions for rains occurred especially when warm, moist air from the gulf blocks cold air from Europe (Al-Mahmood *etal.*, 2014). Sometimes thunderstorms occur accompanied by a cold air during these months which may causes the high rainfall compound rate for the quarter equinox (Spring and Autumn), it was difficult to distinguished the overlapped seasons (Summer and Winter), it appears in the Spring months of March to May, and occurred during this season aerial fluctuations may cause a state of dust and sand storms known among local such as the names (Sarayat), with moderate temperatures, and thunderstorms also occur (ROPME,2004), it was very common that the rain falling during the spring and be heavy rains sudden and short time often. Thus affecting navigation in marine and coastal areas (Ramsar.wetland.org). Studies of evaporation process in the northern part of the Arabian gulf are scarce in comparison with the southern part of the gulf. So, the present work was one of the few investigations carried out for the estimating the evaporation rate from the northern part of the Arabian gulf based on meteorological data taken during the period of 2014 to 2015. In addition, SST data collected about study region.

Evaporation estimates were essential for water balance studies, irrigation and land resource planning, etc. all the components of the hydrological cycle, evaporation was perhaps the most difficult to estimate owing to complex interactions between the components of the land, plant atmosphere system. There exists a multitude of methods for the measurement and estimation of evaporation. Overviews of many of these methods were found in review papers or books (Singh,1989: Morton, 1994). The methods for determining evaporation can be grouped into several categories, including: (1) empirical (Kohler, *etal* 1955), (2) water budget (Guitjens, 1982), (3) energy budget (Fritschen,1966), (4) mass transfer (Herbeck, 1962), (5) combination (Shuttleworth and Wallace, 1984). In a recent paper by (Singh is equation)**.** An inspection of these equations reveals that the only meteorological factors having a major influence on evaporation are vapor pressure gradient, wind speed and temperature (Singh and Xu, 1997).

Data and Method of calculation:-

The standard meteorological measurements such as; air temperature, relative humidity and wind speed for the study region were taken from the (I.R.I.M.O, 2014-2015). The SST data are from Physical Oceanography distributed active archive center (SOC, 2014). Figure (1) illustrates the location of the study area. The water vapor pressure was estimated from daily observations of SST and air temperature for the period of 2014 to 2015. The evaporation rate was estimated by using the bulk aerodynamic method which given by (Singh and Xu, 1997) as follows:

$$E = K\,(e_w - e_a)\,w \qquad (1)$$

Where;

E = evaporation (mm/day).

$K = 10.137\times10^{-2}$ (Osman, 1984).

w = wind speed (m/sec).

e_w = saturated vapor pressure at water temperature (mb), and

e_a= water vapor pressure of air (mb)

The saturated vapor pressure at water temperature (e_w) and vapor pressure at air temperature (e_a) are calculated from the following equations (Csanady, 2001).

The vapor pressure at air temperature is estimated using the following equation:

$$e_a = 6.112 \times \exp\,(17.67T/273.15 + T) \qquad (2)$$

T is the air temperature in °C.

where e_w is the saturation vapor pressure in (mb), using the equation.

$$e_w=e_a \times \text{relative humidity} \qquad (3)$$

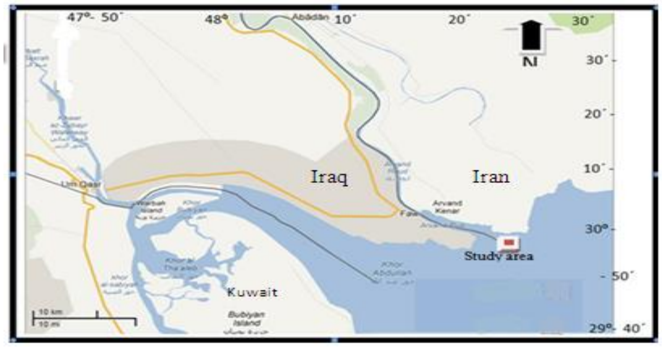

Fig. (1). The study region in north west of Arabian gulf

The plots of monthly SST and meteorological data from 2014 to 2015 for the region was shown in Fig. 2 (a to e).

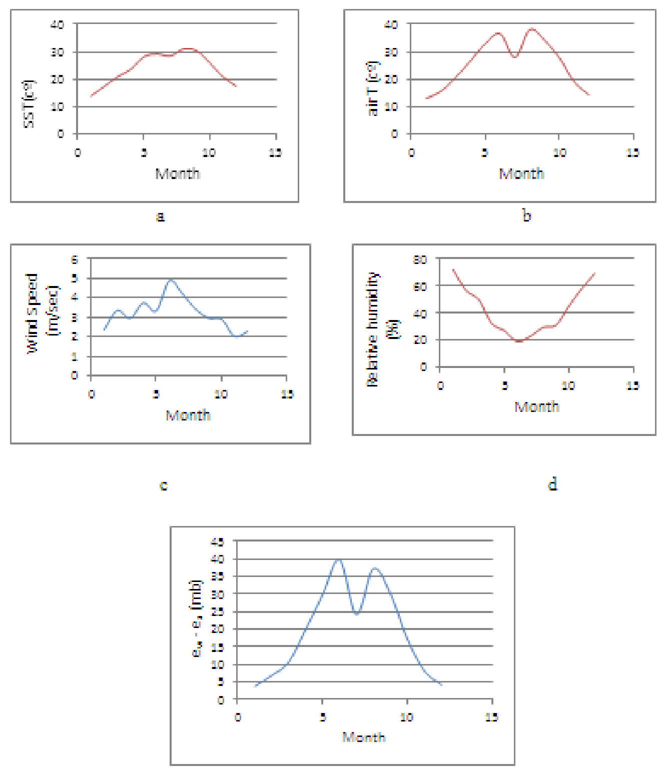

Fig. (2). Monthly sea surface temperature and meteorological data along with computed monthly values of (e_w – e_a) in the region for the study period from 2014 to 2015

Based on monthly values of SST, air temperature and relative humidity, the humidity gradient (ew-ea) was calculated and the monthly values of humidity gradient from 2014 to 2015 for the region were given in Table

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(1) and plotted in Fig. 2(e). The computed monthly values of evaporation from 2014 to 2015 are given in Table (2) also and plotted in Fig. (3).

Table (1). Monthly average of sea surface temperature (SST), air temperature, wind speed. Values humidity gradient ($e_w - e_a$ in mb) and relative humidity of studied region during the period from 2014 to 2015

Month	Relative humidity (%)	Wind Speed(m/sec)	Air Temperature(c°)	SST(c°)
Jan.	72.1	2.36	13.15	14
Feb.	56.9	3.36	15.75	17.44
Mar	50	2.95	20.85	20.94
April	32.55	3.75	26.8	23.65
May	27.1	3.33	33	28.16
June	19.15	4.88	36.55	29.2
Jul	23.05	4.21	27.9	28.4
Aug.	29.5	3.43	38	31.08
Sep.	31.1	2.95	34.2	30.38
Oct.	45.1	2.9	27.85	25.92
Nov.	58.1	2.03	19.2	20.92
Dec.	69.25	2.28	14.35	17.5

Table (2) Monthly average values of humidity gradient (e_w - e_a) and evaporation rates estimated by using bulk aerodynamic method for the period (2014 – 2015)

Month	Humidity gradiant e_w- e_a (mb)	Mean Evaporation mm / month
Jan.	3.825	0.915
Feb.	6.90	2.35
Mar.	10.696	3.209
April	19.973	7.592
May	29.90	10.09
June	39.75	19.66
Jul.	24.17	10.31
Aug.	37.25	12.92
Sep.	30.07	8.999
Oct.	17.23	5.09
Nov.	8.16	1.679
Dec.	4.22	0.975

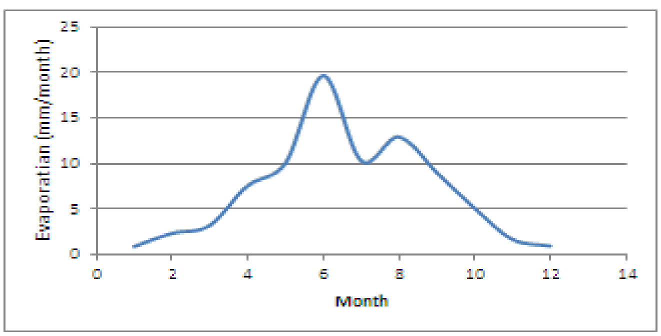

Fig .(3). Monthly average values of evaporation rates (mm/month) of studied region during the period (2014 – 2015)

The annual average evaporation for the region in 2014 and 2015 were given in Table (3).

Table (3). The annual average evaporation for the region in 2014 and 2015

year	Evaporation (mm/ year)
2014	23
2015	22

Table (4). correlation coefficients between evaporation rate, wind speed and humidity gradient for the studied region

	Correlation
wind speed	0.6
humidity gradient	0.9

Results and Discussion:-

The meteorological measurements over the study area were indicated that air temperature during winter was less than sea surface temperature, while in summer it was higher (Fig. 2). The wind speed was varies from one season to another, the high value of wind speed was recorded in the study region at June with (4.44m /sec), based on monthly values of sea surface temperature and air temperature and relative humidity, the declined in monthly humidity (e_w-e_a) which was calculated from the year 2014 to 2015 for the region and given in Table (1) and Fig. 2(a to e). From the table it was clear that, a decrease in the values of November, December, January and February was recognized. The computed monthly values of evaporation from 2014 to 2015 were given in Table (2) and Fig. (3). It was found that the high values of evaporation during the study period is recorded in June (19.66 mm). This corresponding with (Al- Muhyi, 2015).

The average annual value of evaporation was (23 mm/yr) at 2014 in the area was up because the relative humidity was relatively little and wind speed as shown at Table (3).

During the study period, there was a fluctuation in the monthly values of evaporation rates for study area, as a result of wind speed and air temperature and sea surface temperature.

Correlation of monthly averages of evaporation with wind speed and the difference (e_w-e_a) was shown in Table (4). The correlation between the humidity gradient (e_w-e_a) and monthly climatology of evaporation were strong and was approximately 0.9, whereas the correlation between the monthly average of evaporation and wind speed was weak in all regions (~ 0.6).

Conclusion:-

Bulk aerodynamic formulas (Singh's equations) was used to study the evaporation on the north west of Arabian gulf. In the region evaporation was greater (June - Agust) than the rest of the year. Evaporation was higher at 2014 during the study period. The correlation between the humidity gradient (e_w-e_a) and monthly climatology of evaporation was strong in all regions and approximately with a correlation coefficient of 0.9, while the correlation with the wind speed was about 0.6. Therefore, the evaporation mostly was depends on the humidity gradient over the region and the wind speed.

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