METEOROLOGICAL
ANALYSIS OF EVAPORATION RATE IN UYO

ISSN: 2141 – 3290

AKPAN, U. E and BILLY, U. A
Department of Physics, University of Uyo, Uyo
+2348132335245, udosenakpan@yahoo.com

ABSTRACT: The rate of evaporation in Uyo had been estimated using meteorological parameters. Average monthly data collected over five years were used. The data includes; sunshine hours, relative humidity, air temperature, solar radiation and wind speed. Multiple regression and correlation were adopted for the analysis. The study reveals that solar radiation has the highest correlation coefficient with evaporation R = 0.998. Combination of other parameter such as with solar radiation gives the same correlation coefficient of R = 0.998. The estimated evaporation correlates highly with observation evaporation with R = 0.998.

INTRODUCTION

Many studies show that rate of evaporation correlates variously with some meteorological factors. Some of the parameters used by various researchers include air temperature, wind speed, relative humidity, solar radiation, sunshine hour and air pressure. Surinder and Mahesh(2008) employed linear regression modeling technique to study the influence of different combinations of meteorological parameters on evaporation from a reservoir using several input combinations to find out the importance of different input parameters in predicting evaporation. They used air temperature, wind speed, sunshine hours, and mean relative humidity. For single parameter they found out that temperature had the highest correlation coefficient of 0.91, while sunshine hours had the least with 0.168. A multiple parameters correlation showed that the four parameters correlation gave the highest coefficient of 0.96 with the RMSE of 0.865. In another study, Thompson (1988) using four meteorological parameters, solar radiation, air temperature, wind speed and vapour pressure deficit concluded that there was a weak correlation between temperature and evaporation. He also showed that temperature differences between the water body and surrounding air are apparently much more pertinent to evaporative losses that air temperature on its own, since they control the vital vapour pressure deficit. Working on three different tanks, he correlated between various evaporimeters and daily variation of meteorological factors and observed that when water body temperature and air temperature are identical, the vapour pressure deficit is minimal and evaporation proceeds slowly. He confirmed that the vapour pressure deficit in the evaporation process had a correlation coefficient of 0.70 for two evaporimeters. Johnson and Sharma (2008) analyzing evaporation records in Australia at 29 locations revealed that there was no significant changes in relationship between monthly average solar radiation and sunshine duration showing that the trend derived with sunshine duration was a representative of the solar radiation trend. He obtained a high correlation coefficient of 0.95 between Penman trends and advection component trend. However, the study revealed a weak correlation between the Penman trend estimates and the pan evaporation trend estimates with a coefficient of 0.42. Some other studies that correlated rate of evaporation with meteorological factors in various places were that of Ovadia and Pegg (1979), Berlner and Agam (2004), Barry and Chorley (1999) among others.

This study seeks to establish the relationship between rate of evaporation and five meteorological factors namely, air temperature, wind speed, air pressure, relative humidity and solar radiation for Uyo, Nigeria with the air method determining the most significant parameter that affects evaporation.

METHODOLOGY

The daily data on evaporation, wind speed, relative humidity, solar radiation, maximum and minimum temperature and sunshine hours were obtained from Nigeria Meteorological Agency in Uyo, Nigeria. The data covered the period of five year (2004 – 2008). Uyo lies on latitude 5°18’53.7’’N, longitude 7°59’39’’E and on the altitude of 180m above the level. As a town in equatorial region, it is endowed with much rains between March and October and dryness falling between November and February. Monthly averages of the data were computed and used for the analyses. Correlation with each parameter and regression analysis with those meteorological factors were carried out.

RESULTS AND DISCUSSION

The relationship between the observed evaporation and other meteorological parameters are presented in Eqs. 1-30. Table 1 shows different average data obtained and the estimated evaporation over the period of five years.

Table 1: 5-years average meteorological data for Uyo.

Month	Evaporation (mm/day)		Solar radiation		Pressure (mb)	RH (%)	Wind speed (km/day)	Average Temp (^{0}c)
	Observed	Estima-ted	(mm /day)	(MJm^{-2} day^{-1})				
Jan	3.72	3.75	3.7	31.6	29.6	70.6	36.9	28.3
Feb	3.54	3.54	3.5	29.9	29.3	72.0	41.5	29.7
Mar.	2.74	2.73	2.7	28.5	29.4	79.6	45.1	29.3
April	1.98	2.02	2.0	17.1	29.7	82.8	43.1	28.3
May	1.64	1.62	1.6	13.7	29.8	83.6	32.9	27.7
June	1.36	1.42	1.4	12.0	30.0	86.2	26.1	26.9
July	1.10	1.11	1.1	9.4	29.7	89.2	22.9	26.3
Aug	1.28	1.31	1.3	11.1	30.0	88.4	21.7	26.1
Sept	1.24	1.18	1.2	10.25	30.0	86.4	21.7	26.7
Oct	1.48	1.52	1.5	12.8	29.8	84.8	23.0	27.4
Nov	2.20	2.02	2.0	17.1	30.1	82.2	24.5	28.0
Dec	2.50	2.53	2.5	21.35	30.2	80.8	28.5	28.2

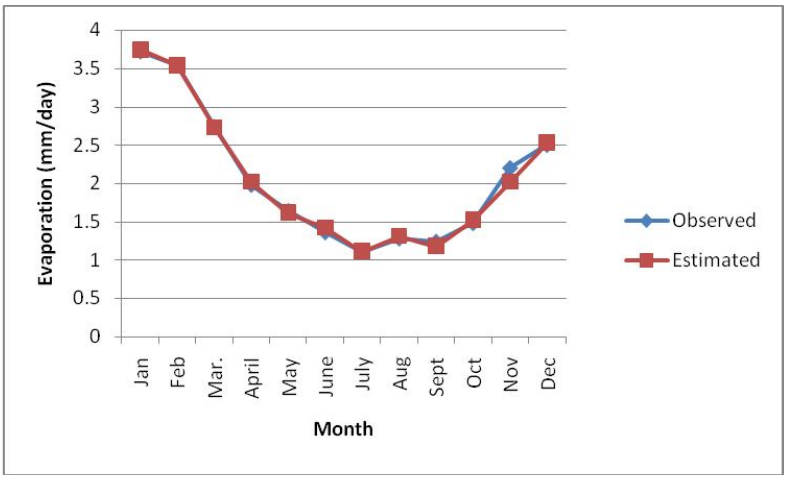

Figure 1: Comparison of observed and estimated evaporation for Uyo

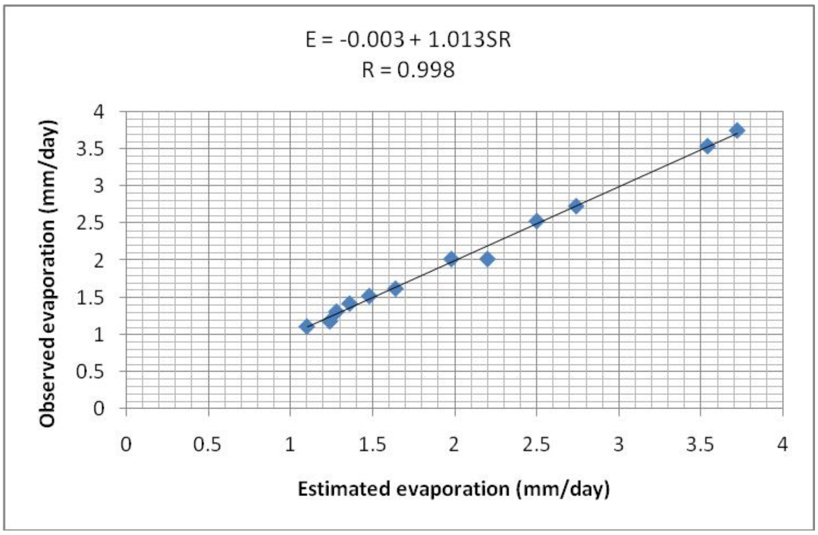

Figure 2: Regression plot of observed and estimated evaporation for Uyo.

Fig. 1 shows the comparison between the observed average monthly data and the estimated data of evaporation. Fig.2 gives the regression plot of the observed and the estimated average monthly evaporation in Uyo.

Relationship Using One Variable Correlation

E = Observed evaporation, T = Average air temperature, P = Air pressure, RH = Relative Humidity, SR = Solar Radiation, WS = Wind speed.

$E = -16.767 + 0.679\,T$ ($R = 0.853$, $\sigma = 0.49505$) (1)

$E = 54.64 - 1.764\,P$ ($R = 0.541$, $\sigma = 0.78856$) (2)

$E = 14.410 - 0.150\,RH$ ($R = 0.981$, $\sigma = 0.17939$) (3)

$E = -0.03 + 1.013\,SR$ ($R = 0.998$, $\sigma = 0.06453$) (4)

$E = -0.108 + 0.071\,WS$ ($R = 0.708$, $\sigma = 0.66357$) (5)

Relationship Using Two Variable Correlations

$E = -11.855 + 0.657T - 0.145P$ ($R = 0.851$, $\sigma = 0.52064$) (6)

$E = -10.444 + 0.097T - 0.135RH$ ($R = 0.984$, $\sigma = 0.17647$) (7)

$E = -0.666 + 0.026T + 0.98SSR$ ($R = 0.998$, $\sigma = 0.06578$) (8)

$E = -17.598 + 0.715T - 0.005WS$ ($R = 0.850$, $\sigma = 0.52110$) (9)

$E = -13.324 + 0.039P - 0.151RH$ ($R = 0.982$, $\sigma = 0.18883$) (10)

$E = -1.952 + 0.065P + 1.024SR$ ($R = 0.998$, $\sigma = 0.06603$) (11)

$E = 3.557 - 0.120P + 0.68WS$ ($R = 0.709$, $\sigma = 0.69903$) (12)

$E = 1.047 - 0.011RH + 0.941SR$ ($R = 0.998$, $\sigma = 0.06663$) (13)

$E = 13.641 - 0.143RH + 0.007WS$ ($R = 0.983$, $\sigma = 0.18305$) (14)

$E = 0.031 - 0.002WS + 1.029SR$ ($R = 0.998$, $\sigma = 0.06640$) (15)

Relationship Using Three Variable Correlations

$$E = 6.150 + 0.112T + 0.134P - 0.136RH \ (R = 0.985, \sigma = 0.18404) \quad (16)$$

$$E = -3.782 + 0.037T + 0.094P + 0.990SR \ (R = 0.998, \sigma = 0.06548) \quad (17)$$

$$E = -8.769 + 0.722T - 0.295P - 0.013WS \ (R = 0.853, \sigma = 0.54904) \quad (18)$$

$$E = -10464 + 0.097T + 0.00WS - 0.135RH \ (R = 0.984, \sigma = 0.18717) \quad (19)$$

$$E = 0.386 + 0.026T - 0.011RH + 0.913SR \ (R = 0.998, \sigma = 0.06823) \quad (20)$$

$$E = -0.942 - 0.012RH + 0.945SR + 0.070P \ (R = 0.998, \sigma = 0.0684) \quad (21)$$

$$E = -1.379 + 1.029SR + 0.046P - 0.001WS \ (R = 0.998, \sigma = 0.06971) \quad (22)$$

$$E = 6.570 + 0.235P + 0.012WS = 0.144RH \ (R = 0.984, \sigma = 0.18746) \quad (23)$$

$$E = -0.923 - 0.02WS - 0.009RH + 0.966SR \ (R = 0.998, \sigma = 0.06935) \quad (24)$$

Relationship Using Four Variable Correlations

$$E = -2.762 + 0.038T + 0.100P - 0.013RH + 0.907SR \ (R = 0.998, \sigma = 0.06763) \quad (25)$$

$$E = 5.020 + 0.082T + 0.997P - 0.137RH + 0.005WS \ (R = 0.985, \sigma = 0.19508) \quad (26)$$

$$E = -1.110 + 0.068T - 0.006RH + 0.949SR - 0.006WS \ (R = 0.998, \sigma = 0.06311) \quad (27)$$

$$E = -2.353 + 0.069T + 0.023P - 0.006WS + 0.987SR \ (R = 0.998, \sigma = 0.06338) \quad (28)$$

$$E = -0.757 + 0.062P + 0.00WS + 0.951SR - 0.012RH \ (R = 0.998, \sigma = 0.07280) \quad (29)$$

Relationship Using Five Variable Correlations

$$E = -1.940 + 0.066T - 0.005WS + 0.033P - 0.007RH + 0.942SR \ (R = 0.998, \sigma = 0.06770) \quad (30)$$

It was observed that solar radiation is the parameter that had the best single correlation result with R = 0.998 as obtained in Eq. 4, and pressure has the least correlation coefficient with R= 0.541. This implies that the estimation of the rate of evaporation based on solar radiation as a single parameter is preferred to other single parameter models. Considering the two variable regression models (Eqs.6 – 15) it was observed that four different models shared the highest correlation coefficient with R = 0.998. These were the models containing solar radiation combined with any other parameter (Eqs.8, 11, 13 and 15). This shows that the presence of solar radiation in any relationship creates much impact in the relationship and increases the chances of good estimation of evaporation rate. When three variable regression was considered, five separate models shared the highest value of the correlation coefficient with R =0.998. These models are that of Eqs. 17, 20, 21, 22, and 24). It was also observed that the presence of solar radiation with combined parameters in all these models contributed largely to the effective estimation of the rate of evaporation. For the four variable regression, four separate models with highest value of the correlation coefficient of R = 0.998 were observed. The models are given in Eqs. 25, 27, 28, and 29. When these models are used separately, they would provide very effective way of estimating the rate of evaporation in Uyo and places with the similar meteorological parameters. The five variable regression had a correlation coefficient of R = 0.998. This is given in Eq. 30. If all the data are available, this model when used would provide an accurate estimation of the rate of evaporation. It was observed that the relationship between evaporation and solar radiation had the same correlation coefficient as that of combination of meteorological factors. This implies that other parameters may not be needed for the estimation of evaporation rate except for minor variations. This study however seems to be at variance with the observation by Surinder and Mahesh (2008) who noted that temperature as a single parameter had the highest correlation coefficient with evaporation.

It would be noted that multiple linear regressions were used for correlations and the standard errors of estimate were also obtained through the correlation. The Mean Bias Error (MBE), the Root Mean Square Error (RMSE) and the Mean Percentage Error (MPE) were calculated using the formulae:

$$MBE = \sum(S_{pred} - S_{obs})/n \quad (31)$$

$$MPE = \sum \frac{(S_{pred} - S_{obs})}{S_{obs}}/n \quad (32)$$

$$RMSE = \left[\frac{\sum(S_{pred} - S_{obs})^2}{n}\right]^{1/2} \quad (33)$$

Where S_{pred} is the predicted values of evaporation or the estimated values and S_{obs} is the observed values of evaporation.

Since the MPE gives information on the long term performance of the examined regression equation, a positive MPE value provides the average amount of overestimation in the calculated values while a negative MPE value provides underestimation. On the whole, a low MPE is desirable.

Table 2: Variations in Error Calculations.

MONTH	MBE	RMSE	MPE
January	0.004	0.0144	0.114
February	0.008	0.0289	0.240
March	0.000	0.0000	0.000
April	0.010	0.0346	0.505
May	0.020	0.0693	1.220
June	0.005	0.0202	0.430
July	- 0.006	0.0202	– 0.530
August	- 0.013	0.0462	– 1.040
September	0.008	0.0260	0.604
October	0.012	0.0404	0.790
November	- 0.016	0.0548	– 0.720
December	- 0.013	0.0462	– 0.530

Table 2 shows the variation of error as computed using Equs 31-33. The test on RMSE conveys information on the short term performance of the equations since it enables a term by term comparison of the actual variations between the estimated and measured values. A low value of RMSE predicts more accurate estimation. From the error calculations, it was observed that the mean values for the month of March has the lowest RMSE value of 0.00, signifying that the estimate obtained were accurate. It was also observed that the MPE values were positive for other months except the months of July, August, November and December. This shows that the computed values of evaporation for the months which MPE were positive provided average information of underestimation in the calculated values. However, the RMSE having lower values showed that the estimations were within the acceptable limit.

CONCLUSION

The correlation of five meteorological factors which are sunshine hour, solar radiation, pressure, air temperature and relative humidity with evaporation has led to the observation that solar radiation is a major factor with which evaporation can be estimated. The contribution of other parameters though significance are not as pronounced as that of solar radiation. Single parameter correlation shows that solar radiation correlated highly with evaporation with coefficient R = 0.998. Other parameters have the following correlation coefficients: Temperature, R=0.853, Pressure, R = 0.541, Relative humidity, R = 0.981 and Wind speed, R = 0.708. The combination of solar radiation with other parameters gives a high correlation coefficient of 0.998. The correlation coefficient is less in any other combination without solar radiation. It is also observed that the estimated evaporation correlates highly with observed evaporation with R = 0.998.

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