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Dew Point Temperature, Relative Humidity and Sunshine Hours in Jos, Nigeria: Their Relationship and Predictive Model

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Abstract: The objective was to examine the relationship between dew point temperature, relative humidity of the air and sun shine hours in Jos, Nigeria and derived the predictive model. The 10 years (2001 to 2010) of measurements were obtained from the weather observatory at the University of Jos, for analyses. The sunshine duration (in hours and tenths) were fundamentally measured while the dew point temperature and the relative humidities were derived from the Mason's psychrometer with the aid of the Blundell Harling humidity slide rule. Regression analysis techniques were then used to analyse and examine the relationships between the weather elements. The coefficient of regressional analysis R^2 and R_a^2 (R^2 adjusted) were calculated. An empirical equation which was derived was used to compare the measured dew point temperature values and the predicted. That of R^2 gave 98.5% while that of R_a^2 registered 88.0%. It was discovered that the developed model can be used for the prediction of dew point temperature on a short and long-term basis.

Key words: Temperature, empirical, regression, weather, Jos

INTRODUCTION

Dew and frost are not actually forms of precipitation because they do not fall from the atmosphere. Dew consists of tiny beads of water that form as water vapour condenses onto surfaces near the ground (such as blades of grass) when the surface's temperature drops to below the air's dew-point temperature. When the dew-point temperature is below freezing, water vapour changes directly into ice without becoming a liquid first. The white, delicate ice crystals that form in this manner are called frost (Ahrens, 2009).

The dew-point hygrometer measures relative humidity by means of the dew point. A small amount of ether is placed in a highly polished, thin, metallic cup and the evaporation of the ether, accelerated by blowing air through it, lowers the temperature of the cup. When the dew point of the surrounding air is reached a film of moisture suddenly appears on the surface of the cup. The temperature is read by means of a thermometer and a table accompanying the instrument gives the relative humidity in terms of the atmospheric and dew-point temperatures.

Studies relevant to the availability of the solar energy resources in Nigeria (Swartman and Ogunlade, 1967; Ideriah and Suleman, 1989; Sambo, 1986, 1988, 1996; Folayan, 1988; Ojosu, 1990; Burari and Sambo, 2003) have indicated its viability for practical purpose. If solar energy appliances with just 5% efficiency are used to cover 1% of the country surface area thus 2.54×10^6 MWh of electrical energy can be obtained from the solar energy (Sambo, 1996). This amount of electrical energy is equivalent to 4.66 million barrels of oil per day (Sambo, 1996). Bala and Muhammad (1999) proposed a model for the prediction of daily average total solar radiation and temperature for Bauchi in the form:

$$Hi = Ai+Bit+Cit^2 \quad (1)$$

And:

$$Ti = Li+Mit+Nit^2 \quad (2)$$

In this research, an empirical model was developed to calculate the measured and predicted dew point temperature values for Jos using sunshine duration and relative humidity.

MATERIALS AND METHODS

The 10 years (2001 to 2010) weather elements from the university of Jos weather observatory/station were collected. The elements include: dew point temperature in °C, sunshine duration in hours and tenths and relative humidity in percentage.

The geographical area of study is the University of Jos weather observatory (9.9°N, 8.9°E) at a height/altitude of 1,159 m above mean sea level. The instruments used for

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data collection include the Mason's Psychrometer which combines the dry and the wet bulb thermometers. The dew point temperature and the relative humidity were derived from the Mason's hygrometer with the aid of the humidity slide rule and the hygrometric tables. The Campbell-Stokes sunshine recorder measures directly the duration of bright sunshine in hours and tenths. The general model equation is as shown:

$$T_d = \sum_{i,j=0} \alpha_{ij} S^j R^i \tag{3}$$

Where:

- α_{ij} = The parameters to be determined using regression analysis techniques
- S = The sunshine duration
- R = The relative humidity

The data collected spanned for a period of ten.

RESULTS AND DISCUSSION

The data collected are shown in Table 1. The data from 10 years of measurements (2001 to 2010) were then analyzed to determine the monthly, annual and decade averages of the three elements considered. Generally, the sunshine duration, the relative humidity and the dew point temperature values are not the same, hence, the dew point temperature values were compared with the sunshine duration and the relative humidity by a correlation equation. The variation between the minimum Temperature values (T_d) and each of the other variables, Relative humidity (R) and Sunshine duration (S) were obtained. Furthermore, an empirical relationship between the dew point temperature values (also known as the independent variable, T_d), sunshine duration (S) and relative humidity (R), also known as the dependent variables were derived for the station as shown below. The general empirical equation is:

$$T_d = \alpha_{00}+\alpha_{01}R+\alpha_{10}S+\alpha_{11}SR+\alpha_{02}R^2+\alpha_{20}S^2+ \alpha_{12}RS^2+\alpha_{21}R^2S+\alpha_{22}(RS)^2+\alpha_{03}R^3+\alpha_{30}S^3 \tag{4}$$

Where:

- α_{ij} = Constants for any particular weather station
- T_d = The independent variable
- S and R = The dependent variables of the correlated elements

In order to know the utility of the model, the following goodness-of-fit tests were carried out. The coefficient of determination, R^2:

Table 1: Monthly mean values of dew point Temperature (T_d) in °C, Sunshine in hours (S) and Relative humidity in percentage (R) for Jos

	Unijos Met. Station		
Months	T_d	S	R
Jan.	1.6	7.3	25
Feb.	2.9	7.9	21
Mar.	3.2	6.9	22
Apr.	11.7	5.9	41
May	17.4	5.5	54
Jun.	18.7	5.4	61
Jul.	19.4	4.2	65
Aug.	19.0	3.4	66
Sep.	18.7	4.4	61
Oct.	17.2	6.3	50
Nov.	12.1	6.2	36
Dec.	5.1	7.8	31

$$R^2 = \frac{\sum\left(\hat{T}_i - \bar{T}_i\right)^2}{\sum\left(T_i - \bar{T}_i\right)^2} \tag{5}$$

The adjusted coefficient of determination, R_a^2:

$$R_a^2 = \frac{(n-1)R^2 - (K-1)}{n-K} \tag{6}$$

The Root Mean Square Error, RMSE in °C:

$$RMSE = \sqrt{\frac{\sum_i\left(T_i - \hat{T}_i\right)^2}{n}} \tag{7}$$

Where:

- T_i = Observed values
- $\hat{T}_i$ = Fitted values
- $\bar{T}_i$ = The mean of the observed values
- n = The number of data points
- K = The number of parameters determined in the regression analysis

From the regression equation of the station carried out, it was discovered that the coefficient of regressional analysis (R^2) and the adjusted coefficient of regressional analysis (R_a^2) values recorded 99.0 and 88.5%, respectively (Table 2). This shows that the correlation strength, of the dew point temperature (T_d), the Relative humidity (R) and the Sunshine duration (S) are quite high and strong. This is further demonstrated from the plotted line graphs and the column graphs of the measured dew point temperature values and the predicted values against the months (Fig. 1-4). The curves and the column graphs run concurrently to each other as shown in Fig. 1-4. The minimum dew point temperature value of 1.6°C occurred in January while the maximum dew point temperature value of 19.4°C occurred in July.

Table 2: Values of regressional parameters

Parameters	Station (Jos)
α00	-1589
α10	580
α01	26
α11	-4.6
α02	-73
α20	-0.13
α12	-0.024
α21	0.13
α22	0.00540
α30	0.00068
α03	3.2
R^2	0.9900
R_a^2	0.8850
RMSE	0.04628
MSE	3.4948

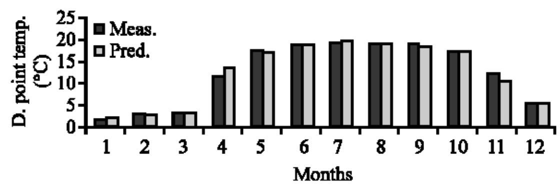

Fig. 1: Column graph of Meas. and Pred. Dew point temp. value for Jos

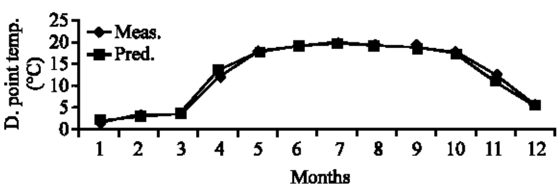

Fig. 2: Line graph showing Meas. and Pred. Dew point temp. value for Jos

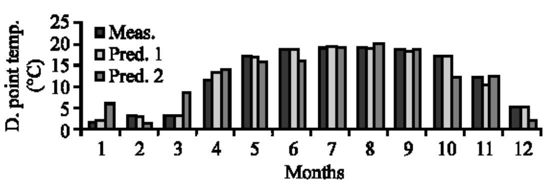

Fig. 3: Column graph showing Meas. and Pred. 1 and 2 dew point temp. value for Jos

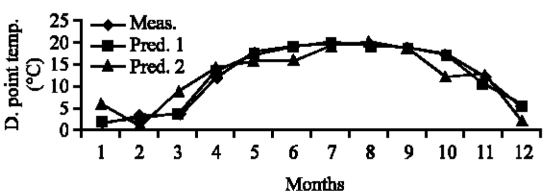

Fig. 4: Line graph showing Meas. and Pred. 1 and 2 dew point temp. value for Jos

Comparing the curves and the column graphs with that of Bala and Muhammad (1999) there is a slight deviation in their concurrency. This goes further to show that this derived model is an improved version compared to that of Bala and Muhammad (1999). However, the Root Mean Square Error (RMSE) and the Mean Square Error (MSE) values were 0.04628 and 3.4948°C, respectively.

CONCLUSION

Excellent correlation relationships were established between the dew point temperature values and the other two parameters which are relative humidity and the sunshine duration. Moreover, the developed model gave an improved result compared to that of Bala and Muhammad (1999) study in the semi-arid environment of Nigeria. The developed empirical formula of this research can be applied to long and short term predictions of other meteorological elements.

IMPLICATIONS

Dew point is an element of sunshine. Sunshine determines dew point. When sun shines researchers have evaporation. Evaporation leads to cloud formation. Clouds condensation is a product of dew point. When cloud condenses, it gives rainfall. Therefore, the observed positive relationship between sunshine and dew point suggests that there is an increase in relative humidity which is the percentage water in the atmosphere. Thus, the environment is humid.

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