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Estimating Atmospheric Precipitable Water from Common Variables

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Abstract:- **Knowledge of precipitable water content in the atmosphere is an important ingredient in the modeling and development of solar radiation and solar devices. The objectives of this article are to evaluate the precipitable water content for the various vegetation zones in Nigeria, using existing common expressions and to develop monthly linear regression models to be determined between longitude and altitude. The monthly models are compared with the existing expression. This comparison is made to determine whether a common relation could be used estimate precipitable water content within the various vegetation zones in Nigeria.**

Key words:- Precipitable water, model, solar radiation, vegetation.

INTRODUCTION

Precipitable water content is an essential ingredient in the developmental of solar radiation models for estimation of solar energy under clear sky radiations. The depth of solar energy studies and increase applications of solar radiant energy has necessitated the theoretical analysis of the attenuation of solar radiation passing through the atmosphere.

Total precipitable water, ω, is defined as the vertically integrated water vapor in a column extending from the surface to the top of the atmosphere [1]. Precipitable water is an important atmospheric parameter that is needed when using physical or empirical models to predict solar radiation [2]. The atmospheric precipitable water content is usually obtained from radiosonde data . However, in the absence of atmospheric sounding or solar spectral measurements, one of the most suitable options for computing the precipitable water content is from accurate empirical formulae[1, 2], among others.

Studies carried out on the analysis of monthly mean atmospheric precipitable water content [2, and 3]

The purpose of the study is to alleviate this shortcoming and to equally widen the horizon on precipitable water content within the various vegetation zones in Nigeria.

MATERIALS AND METHODS

Study Area

Nigeria has a tropical climate with sharp regional variances depending on rainfall. Nigerian seasons are governed by the movement of the intertropical discontinuity, a zone where warm, moist air from the Atlantic converges with hot, dry, and often dust-laden air from the Sahara known locally as the harmattan. Vegetation zones in Nigeria parallel the climatic zones. Three types of vegetation prevail: forest (where there is significant tree cover), savannah (insignificant tree cover, with grasses and flowers located between trees) and montane land. Both the forest zone and the savannah zone are divided into three parts as shown in fig 1.

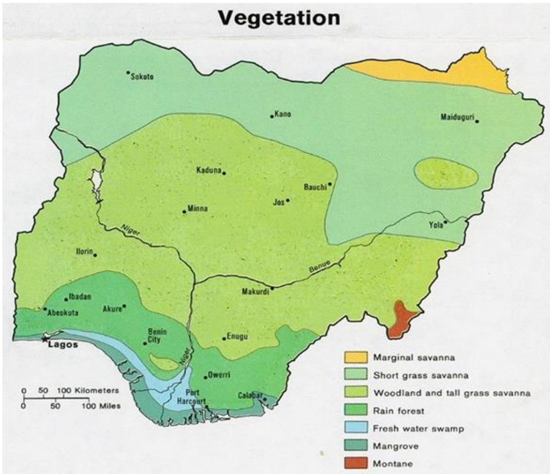

Figure 1: Vegetation map of Nigeria [4]

Data sets

Daily measured data for thirty years (1981 – 2010) obtained from archives of Nigerian Meteorological Agency (NIMET) data centre, were averaged to obtain the monthly yearly values. Table 1 showed the geographical locations and the date of measurement used in this present study. The stations are located in areas characterized by different climatic conditions. The measurement includes relative humidity and temperatures.

Table 1: Characteristics of geographical locations

Serial Number	Station	Longitude	Latitude	Height above sea level
1	Kaduna	7.45	10.6	645.38
2	Kano	8.53	12.05	7 14
3	Sokoto	5.25	13.02	350.75
4	Ibadan	3.9	7.43	227.23
5	Enugu	7.55	6.47	141.5
6	Port-Harcourt	7.02	4.85	195.51

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METHODOLOGY

In order to estimate solar radiation under clear sky radiation knowledge of precipitable water content in the atmosphere is very important. In the absence of radiosonde data or solar spectral measurements, variety of techniques are available [4, 5, and 6] for computing the parameter. Among those, the Leckner's and Gueymard formulation are common expression for estimating total precipitable water in the atmosphere.
Leckner's empirical formulation expresses the precipitable water content in terms of relative humidity as [6]:

$$\omega_L = 49.3\frac{RHP_s}{T} \quad (1)$$

$$P_s = 0.01exp\left(26.23\ \frac{5416}{273.15+T}\right) \quad (2)$$

Gueymard [4] introduced a new expression in terms of water vapor scale, surface temperature and relative humidity as:

$$\omega_G = 21.67H_v\frac{RH\,P_s}{T} \quad (3)$$

$$\ln P_s = 22.33 - 49.14\frac{1}{T_o} - 10.922\frac{1}{T_o^2} - 0.3902T_o \quad (4)$$

$$H_v = 0.4976 + 1.5265\theta + \exp\left(13.6897\theta - 14.9188\theta\right)^2$$

Where
T Absolute temperature in Kelvin,
RH Absolute humidity,
P_s Vapor pressure,
H_v Apparent water vapor scale height in kilometers,
T_o=T/100, θ=T/273.15
The results of precipitable water content estimated using the above two expressions, indicate that the two empirical models estimated the water vapor content with similar remarkable results.
However, the results are obtained are for the various vegetation zones considered under this particular study, in cm.

DISCUSSION OF RESULTS

Table 2 shows the different degrees of correlation between the monthly mean water vapour, longitude and altitude. The months of May, June, September and October had correlation coefficients of less than 0.50 while the remaining months had correlation coefficients greater than 0.50. There was a clear joint dependence on longitude and altitude for the monthly values.

The highest water vapor content was recorded in tropical rain forest and fresh water swamp vegetation zones with fresh water swamp vegetation having the highest monthly averages most times followed by Tropical rain forest, Guinea and Sudan vegetations. Highest precipitable amounts were obtained in the months of May through October for the Guinea and Sudan vegetations. It is pertinent to mention that in Guinea and Sudan zones, cloudy and rainy season's lies between the months with highest water content.

From figures 2 to 5, it is evident that the two empirical models estimated the water vapor content with similar remarkable results. However, the regressed model estimated the water vapor content with high degree of accuracy for Guinea and Tropical rain forest vegetations, although the model fairly over estimated and under estimated the amounts for Sudan and fresh water swamp zones, respectively.

The graph of figures 2 and 3 (representative of guinea and vegetation zones) show marginal increment of precipitable water content from the beginning of the year, it then rose steadily to May where it attains it maximum value. It stabilizes at that until September until it falls out for the remaining part of the year. However, for case of figures 4 and 5 (tropical rain forest and fresh water swamp vegetation zones), maximum values of precipitable water content are obtained in the months of May to September (for regressed parameters), whereas March, April May and November are months of with highest precipitable water content (for case of empirical equations).

Therefore, the monthly precipitable water content for the vegetation zones in Nigeria have been obtained through the use of an empirical relation that makes use of monthly average temperature and relative humidity. The results indicate longitudinal and altitudinal influence on the distribution of water vapor in these vegetation zones.

Table 2: Monthly regression equations for evaluating precipitable water content at all zones

Equation	R-Squared value
Jan = 6.33 - 10.7 L - 0.00471 A	R-Sq = 64.2%
Feb = 7.10 - 12.3 L - 0.00519 A	R-Sq = 63.9%
Mar = 8.62 - 24.4 L - 0.00388 A	R-Sq = 59.5%
Apr = 7.62 - 15.8 L - 0.00218 A	R-Sq = 50.8%
May = 6.33 - 4.2 L - 0.00139 A	R-Sq = 41.6%
Jun = 5.74 - 0.0 L - 0.00126 A	R-Sq = 47.9%
Jul = 5.05 + 4.76 L - 0.00127 A	R-Sq = 59.1%
Aug = 4.97 + 4.63 L - 0.00100 A	R-Sq = 60.4%
Sep = 5.32 + 2.57 L - 0.00112 A	R-Sq = 43.9%
Oct = 6.51 - 8.8 L - 0.00176 A	R-Sq = 45.2%
Nov = 7.63 - 17.0 L - 0.00404 A	R-Sq = 57.8%
Dec = 7.03 - 12.6 L - 0.00492 A	R-Sq = 72.6%

Where,
L Longitude
A Altitude

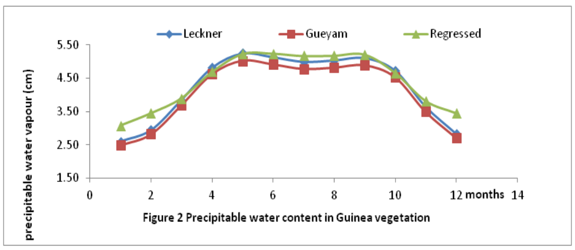

Figure 2 Precipitable water content in Guinea vegetation

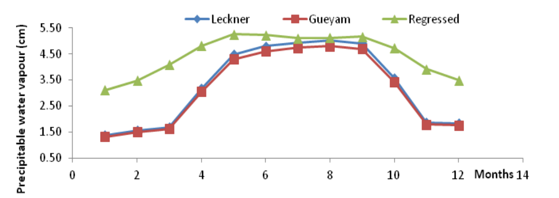

Figure 3 Precipitable water content in Sudan vegetation

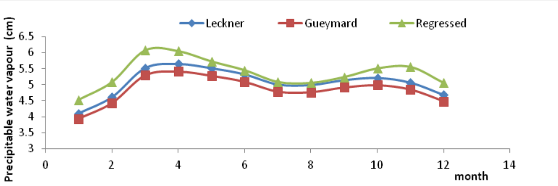

Figure 4: Precipitable water vapour in Tropical rain forest

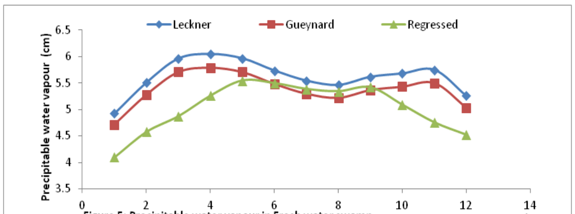

Figure 5: Precipitable water vapour in Fresh water swamp

CONCLUSION

In this paper, overall monthly average precipitable water for four vegetation zones have been obtained through use of longitude and altitude. The results of regressed monthly mean precipitable water content indicate the distribution of water vapour with respect to vegetation.
Also, the distribution was fairly represented for all the vegetation zones considered under this study.

REFERENCES

[1] López, **G.** and Baffle, F. J (2004), “Estimate of the atmospheric turbidity from three broad-band solar radiation algorithm.. A comparative study”. Annales Geophysics,. 22, pp 2657-2668

[2] Maduekwe, A. A. L. and Iheonu, E. E. (1999), “Emperical Determination of the Monthly Average Atmospheric Precipitable Water Distribution for Nine Nigerian Locations”. Nigerian Journal of Renewable Energy, 7, pp 26-30

[3] Gueymard, C (1994), “Analysis of Monthly Atmospheric Precipitable Water and turbidity in Canada and North United States”. Solar Energy, 53, pp 57-71

[4] http://www.images.nationwide.com/images/motoo/africa/nigeria_veg_1979.opg-window

[5] Iqbal, M (1983), An Introduction to solar Radiation. Academic press, Toronto

[6] Leckner, B (1978), “The spatial distribution of solar radiation at the earth’s surface – elements of a model”. Solar energy, 20, pp 143-150