PRELIMINARY STUDIES ON GLOBAL SOLAR RADIATION IN MBALMAYO, CAMEROON

by

Louis E. AKPABIO, Akpan B. UDOIMUK, and Sunday E. ETUK

Original scientific paper
UDC: 536.25:551.524/.525:504.7
DOI: 10.2298/TSCI0904207A

This paper presents preliminary studies on the global solar radiation in a horizontal surface along with the prevailing meteorological conditions measured during the period 1999-2001 in Mbalmayo, Cameroon. Hourly, daily, and mean monthly values of global solar radiation and meteorological data were obtained from the International Institute of Tropical Agriculture automatic weather station of Mbalmayo. The data were processed as daily, hourly, sum of 10-day data for 8.00/12.00/16.00/20.00 hours, decadal hourly, decadal daily, and mean monthly data. The highest measured daily, decadal hourly, decadal daily, and mean monthly data for global solar radiation in Mbalmayo was found to be 29.7, 2.76, 21.8, and 20.1 MJm^2, respectively. The highest hourly global solar radiation value up to 182.44 MJm^2 was observed between March 21-31, 1999. Apart from the global solar radiation measurements, the main observed meteorological parameters were, soil temperature, temperature, wind speed, precipitation, and relative humidity. The results show that there exist seasonal tendencies in the variation of global solar radiation. The range of variation of these radiations and the distribution puts Mbalmayo has a high potential for solar energy utilization.

Key words: *global solar radiation, Mbalmayo, Cameroon*

Introduction

Knowledge of global solar radiation is essential in the prediction, study, and design of the economic viability of systems which use solar energy. Information on global solar radiation received at any site should be useful not only to the locality where the radiation data is collected but also for the wider world community [1]. A global study of the world distribution of global solar radiation requires knowledge of the radiation data in various countries and for the purpose of world wide marketing, the designers and manufactures of solar equipment will need to know the average global solar radiation available in different and specific regions [2, 11].

Obviously measured data is the best form of the knowledge. Unfortunately, there are very few meteorological stations that measure global solar radiation, especially in developing countries. For such stations where no measured data are available, the common practice is to estimate global solar radiation from other measured meteorological parameters like relative sunshine duration [3-10].

While designing solar energy systems, one also needs to know insolation values at hourly intervals for inclined and horizontal surfaces [12-14]. Hourly values of solar radiation allow us to derive very precise information about the performance of solar energy systems. For example, hourly radiation values are more useful in calculating the performance of flat plate col-

lectors than daily global solar radiation values. Several meteorological stations present their data in terms of monthly-averaged values of daily global irradiation. Where there are no such data available, it may be possible to obtain them from long-term sunshine data via models [15-19].

The mean objective of this paper is to analyze the measured global solar radiation of Mbalmayo, Cameroon and also contribute significantly to global solar radiation available in this part of the world.

Geography of the site and data

Cameroon is broadly divided into two climatic domains namely: equatorial and tropical climate. Mbalmayo, the town in which this project is located lies in the centre province of Cameroon which experiences equatorial climate. Its coordinates are latitude 11°30'E, longitude 3°31'N; altitude 641 m. Mbalmayo specifically is situated in the Guinea type of equatorial climate. This is characterized by its four seasons in a year (two rainy and two dry) with abundant rains. This type of climate is characterized by high and fairly constant temperature, 25 °C on the average.

The prevailing winds in Cameroon and of course, Mbalmayo are the South-Westerly and North-Easterly trade winds. The SW wind blows from the Atlantic Ocean and brings rain while the NE wind, a very dry wind, blows across the country bringing the Harmattan dust with it – this is the dry season period. The data utilized herein were obtained courtesy of the International Institute of Tropical Agriculture (IITA) station of Mbalmayo.

Results and discussion

Figure 1 shows the variation of global solar radiation for the year 1999; there are two maxima (major and minor) and two corresponding minima (major and minor). The major maximum occurred between January-March and the minor maximum occurred in September. The major minimum is in the month of August while the minor minimum is in December. The above result shows that the best month March, with global solar radiation of 20.1 MJ/m^2, contributes about 10.7% of the annual total while the worst month, August, with global solar radiation of 12.7 MJ/m^2 contributed about 6.8% of the annual total.

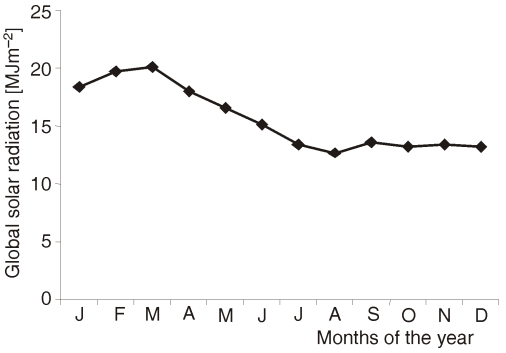

Figure 1. Variatian of global solar radiation for Mbalmayo

Figure 2 presents the overall average of global solar radiation for three years under review (1999-2001). From the figure, the major and minor maximum occurred in the months of April and September, respectively. The major and minor minimum is, respectively, in the month of October and August.

Figure 3 shows the mean decadal daily global solar radiation variation, again we have two major maximum occurring between March-April (major maximum) and the minor maximum in September. The major minimum is in the month of October, while the minor minimum is in August.

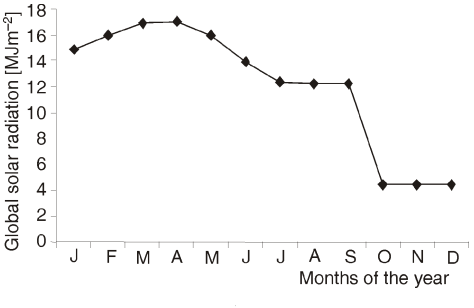

Figure 2. Variation of monthy mean global solar radiation

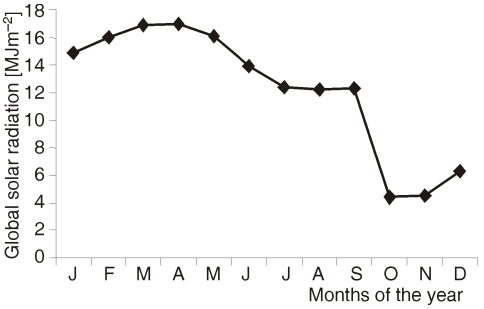

Figure 3. Variation of mean of decadal daily global solar radiation

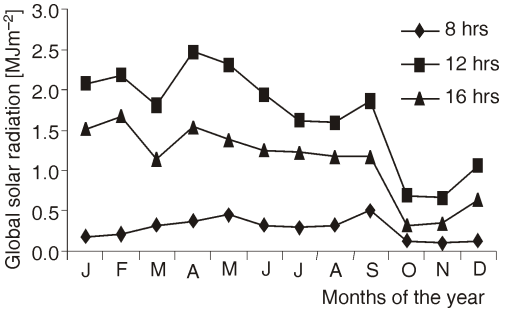

Figure 4. Variation of mean decadal hourly global solar radiation

Figure 4 presents the mean decadal hourly global solar radiation in each month of the years under review. As expected, the 12 hours pattern has the highest values of global solar radiation followed by the 16 hours pattern and the least as 8 hours pattern. This is due to the fact that on the Earth's surface; the highest value of global solar radiation intensity is received about the local solar noon, while 8 hours and 16 hours represent the local sunrise and sunset, respectively. Also fig. 4 generally shows that; in the months of February, April, May, and September when the Harmattan dust haze is either just setting in or clearing off and the atmosphere has less cloud activity that is when we have peak values from the hour patterns. Hence the hour pattern variation observed from month to month could be divided into two distinct groups: two maxima (major and minor) with two corresponding minima (major and minor).

Further more; from figure 4 the major and minor maximum during 8 hours occurred in September and May, respectively, while the major and minor minimum was in January and November, respectively. For 12 hours values, the major and minor maximum occurred in February and April, respectively, while that of major and minor minimum was in March and October, respectively. Finally, during the 16 hours , the major and minor maximum occurred in April and September, respectively with the major and minor minimum in March and October, respectively.

Analysis of the results show that high values of global solar radiation are associated with months when the atmosphere has less clouding activity and the Harmattan haze is just setting in or clearing out. This can be observed in the month of January, February, March (long dry season) and August (short dry season). Therefore, there are two distinct groups of variation – the high radiation value being associated with less turbid and cloudy months while the low values has to do with cloudy and turbid months (long wet season September to December and short wet season between April and June).

The relative importance of local climatic factors and movement of the Sun in the sky on the amount of global solar radiation received on the ground at Mbalmayo is further highlighted by the variation of monthly mean decadal hourly radiation. The February-April maxi-

mum due partly to the Sun being almost directly overhead at noon at this time of the year and partly due to Harmattan haze clearing off with little clouding.

The highest measured daily, decadal hourly, decadal daily, and mean monthly data for global solar radiation was found to be 29.7, 2.76, 21.8, and 20.1 MJ/m^2, respectively. The highest hourly global solar radiation value up to 182.44 MJ/m^2 was observed between March 21-31, 1999. Apart from the global solar radiation measurements, other observed meteorological parameters were: the highest maximum soil temperature of 30.9 °C in March 2000, highest maximum temperature of 31.5 °C in March 2000, the highest rainfall recorded in September 2000 was 337 mm, highest panevapouration was recorded in April 1999 as 125 mm and the highest recorded relative humidity was 102.9 in January 1999.

The results obtained have been compared with Udo *et al*. [20] for Ilorin a tropical region like Mbalmayo. It is interesting to note that two maxima (major and minor) with two corresponding minima (major and minor) were also observed [20]. In their reports; they also had the best month as March with global solar radiation of 20.4 MJ/m^2 contributes about 9.9% to the annual total. While their worst month, July, had 14.5 MJ/m^2 leading to 7.0% of the annual total. From the compared results, our value for the best month of March is almost the same as that reported in [20]. While for the worst month, they had July and the value for global solar radiation is till very close. Those values are within the range of global solar radiation expected in the tropics [21-23].

Conclusions

Seasonal variation of global solar radiation at Mbalmayo is observed. The two maxima (major and minor) are in the months of March-April and September, respectively, while the corresponding minima (major and minor) were in the months of October and August, respectively. Mbalmayo has two types of global solar radiation – high radiation values due to low turbid and cloudy months while low value is associated with cloudy and less turbid months. This seasonal variation implies that, local climatic factors have more effect on the amount of solar radiation received on the horizontal surface than the Sun's position in the sky. The high value of global solar radiation makes Mbalmayo a high potential for solar energy utilization.

Acknowledgments

The authors are grateful to the International Institute of Tropical Agriculture station at Mbalmayo for providing the data. They also appreciate the financial support of LASE Radiation/Radon group for the project.

References

[1] Massaquoi, J. G. M., Global Solar Radiation in Sierra Leone (West Africa), *Solar Wind Technol., 5* (1988), 1, pp. 281-283
[2] Ibrahim, S. M. A., Predicted and Measured Global Solar Radiation in Egypt, *Solar Energy, 35* (1985), 1, pp. 185-188
[3] Nguyen, B. T., Pryor, T. L., The Relationship between Global Solar Radiation and Sunshine Duration in Vietnam, *Renewable Energy, 11* (1997), 1, pp. 47-60
[4] Akpabio, L. E., Comparison between Solar Radiation Energy and the Characteristic of Wind Power Calculations in South Eastern Nigeria, *Nig. J. Phys., 4* (1992), 1, pp. 15-20
[5] Akpabio, L. E., Eno, E. E., Monthly Average Daily Global and Diffuse Solar Radiation in Uyo, Nigeria, *Integrated Journal of Sciences and Engineering*, *3* (2001), 1, pp. 7-15

[6] Akpabio, L. E., Ukpong, U. A., Etuk, S. E, Analysis of Solar Radiation at Uyo, Nigeria, *JAS, 6* (2003), 2, pp. 3607-3613
[7] Akpabio, L. E., Udoimuk, A. B., Characteristic Distribution of Total, Diffuse and Direct Solar Radiation at Calabar, *GJPAS, 9* (2003), 1, pp.139-145
[8] Akpabio, L. E., Etuk, S. E, Relationship between Global Solar Radiation and Sunshine Duration for Onne, Nigeria, *Turk. J. Phys., 27* (2003), 2, pp. 161-167
[9] Akpabio, L. E., Udo, S. O., Etuk, S. E, Empirical Correlations of Global Solar Radiation with Meteorological Data for Onne, Nigeria, *Turk. J. Phys., 28* (2004), 3, pp. 205-212
[10] Akpabio, L. E., Udo, S. O., Etuk, S. E., Modeling Global Solar Radiation for a Tropical Location: Onne, Nigeria, *Turk. J. Phys., 29* (2005), 1, pp. 63-68
[11] Udo, S. O., Aro, T. O., Akpabio, L. E., Characteristic of Diurnal Pattern of Global Photosynthetically Active Radiation at Ilorin , Nigeria, *Nig. J. Phys., 18* (2006), 2, pp. 223-226
[12] Gopinathan, K. K., Polokoana, P., Estimation of Hourly Beam and Diffuse Solar Radiation, *Solar and Wind Technology*, *3* (1986), 3, pp. 223-229
[13] Dragicevic, S. M., Vuckovic, N. M., Evaluation of Distributional Solar Radiation Parameters of Cacak Using Long-Term Measured Global Solar Radiation Data, *Thermal Science*, *11* (2007), 4, pp. 125-134
[14] De Miguel, A., *et al*., Solar Radiation and Sunshine Hour Maps in Castilla and Leon Region (Spain), *Renewable Energy*, *4* (1994), 8, pp. 933-940
[15] Aksakal, A., Rehmann, S., Global Solar Radiation in Northeastern Saudi Arabia, *Renewable Energy*, *17* (1999), 2, pp. 461-472
[16] Raja, I. A., Twidell, J. W., Distribution of Global Insulation over Pakistan, *Solar Energy*, *44* (1990), 3, pp. 63-71
[17] Muneer, T., Solar Radiation and Daylight Models for the Energy Efficient Design of Buildings, Architectural Press, Oxford, UK, 1997
[18] Elagib, N. A., Alvi, S. H., Mansell, M. G., Correlationships between Clearness Index and Relative Sunshine Duration for Sudan, *Renewable Energy*, *17* (1999), 2, pp. 473-498
[19] Udo, S. O., Contribution to the Relationship between Solar Radiation and Sunshine Duration in the Tropics: A Case Study of Experimental Data of Ilorin, Nigeria, *Turk Journal of Physics*, *26* (2006), 3, pp. 229-236
[20] Udo, S. O., Aro, T. O., Measurement of Global Solar Radiations, Global Photosynthetically – Active and Downward Infrared Radiation at Ilorin, Nigeria, *Renewable Energy*, *17* (1999), 1, pp.113-122
[21] Frangi, J. P., Yahaya, S., Piro, J., Characteristics of Solar Radiation in the Sahel; Case Study; Niamey, Niger, *Solar Energy*, *49* (1992), 3, pp.159-166
[22] Ododo, J. C., Usman, A., Correlation of Total Solar Radiation with Common Meteorological Parameters for Yola and Calabar, Nigeria, *Energy Conversion and Management*, *37* (1996), 5, pp. 521-530
[23] Kuye A., Jagtap, S. S., Analysis of Solar Radiation Data for Port Harcourt, Nigeria, *Solar Energy*, *49* (1992), 2, pp. 139-145

Authors´ affiliations:

L. E. Akpabio (**corresponding author**)
Department of Physics, University of Uyo,
Uyo, Akwa Ibom State, Nigeria
E-mail: leabio2002Žyahoo.com

A. B. Udoimuk
Department of Physics, University of Calabar,
Calabar, Cross River State, Nigeria

S. E. Etuk
Department of Physics, University of Uyo,
Uyo, Akwa Ibom State, Nigeria

Paper submitted: May 16, 2008
Paper revised: August 28, 2008
Paper accepted: September 12, 2008