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Altitudes Variation of Solar Energy in Himalaya region, Nepal

Bed Raj K.C.[1], Surendra Shrestha[2] and Khem N Poudyal[3]

[1]*Mahendra Multiple Campus Tribhuvan University, Nepalgunj, Nepal*
[2]*Department of Electronics and Computer Engineering, Pulchok campus, Institute of Engineering, Tribhuvan University, Lalitpur, Nepal*
[3]*Institute of Engineering, Central Campus, Pulchowk, Tribhuvan University, Kathmandu, Nepal*

bedrajkc@yahoo.com

Abstract

In this study, global solar radiation in some locations in Nepal measured by calibrated pyranometer at Biratnagar (26.45°N, 87.27°E, 74.0m), Pokhara (28.20°N, 83.98°E, 800.0m) and Jumla(29.27°N to 82.18°E, 2514.0m) since 2015. The influence of physical as well as meteorological parameters on global solar radiation was analyzed. The measured global solar radiation data shows that there is about 7.35% per km increase in Jumla in comparision with Pokhara and Biratnagar. This result conformed that there is strong correlation found in between global solar radiation and altitude. In addition, the GSR varies with environmental pollution and local weather condition.

Keywords: *Global solar radiation, seasonal variation, altitude, atmospheric pollution, potential, application.*

1. Introduction

All energies either being naturally or artificially yielded on the areas belonged to planet earth come primarily from solar source as light (Adam, April 2013). It is renewable, inexhaustible, pollution free and environment friendly type of resource among many renewable energy options in the world [1]. The global solar radiation reach on earth is the most fundamental renewable energy resource in nature. Solar energy, radiant light and heat come from the sun. The sun could play key role in de-carbonizing the global economy alongside improvements in energy efficiency and imposing cost on greenhouse gas emitters. In the studies of solar energy, data on solar radiation and its components at a given location are a fundamental input for solar energy applications such as photovoltaic, solar-thermal systems, solar furnaces and passive solar design [2]. Solar radiations are becoming increasingly appreciated

Corresponding Author : Bed Raj K.C.
Author's affiliation : Mahendra Multiple Campus Tribhuvan University, Nepalgunj, Nepal
Email: bedrajkc@yahoo.com
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because of their influence on living matter and feasibility of its application for useful various purpose. The electromagnetic radiation emitted by the sun covers a wide range of wavelength from radio waves through the infrared, visible and ultraviolet to x-rays and gamma rays. [3] Nepal is located at the latitude (27.5^0 N), it is closer to solar belt (lat. 15^0 - 35^0), it receives abundant solar radiation through the country which varying from 1293MJ/m^2/day to 2248MJ/m^2/day. The average global solar radiation varies from 3.6 to 6.2KWh/m^2/day, and the sunshine's for about 300 days in a year. The national average sunshine hours and solar energy are 6.8/day and 4.7KW/m^2/day respectively [4].

Nepal is presently facing against an energy crisis of unprecedented proportions in daily supplies of the same category about fuel resources [5]. The 706 MW total installed capacity of Nepal Electricity Authority Board, supplemented by net purchase through power trade market of India, is inadequate to meet national demand. Load shedding has thus become the rule of the day and night, with ever seriously attended economic consequences to the national scopes of enrichment. In this situation renewable energy development is a high priority program of the government that has been supported through the enactment of sole relevant developmental policies and national plans to attract private sector participation [5]. These strategic plans have included targeted subsidies and funding mechanisms; tax and duty concessions; and exemption of mini, micro and Pico hydro projects from royalties and licensing requirements. Renewable sources of energy is taken as a high priority sector of the governmental department. Which has a goal to increase the share of changeable parameter from less than 1% to 10% of the total energy in supply, and to increase the access to electricity from alternative energy sources from 10% to 30% within the next 20 years [5]. To Complete these goals, the government has plan to invest USD 1,076 million in renewable energy by 2020. The government include support for hydropower, solar PV and biogas technologies. In the past several donors assisted programs have been initiated in the renewable energy sector through many projects. However, most of them were completed during 2011-12, and development partners are presently designing cooperation programs in consultation with government. The SREP is a part of the larger program and add value to the overall renewable energy development of the country [6]. Solar energy is at present becoming more and more popular as the oil prices are getting so kept as for increasing [7]. The demand of coal, oil and gas continues to grow on a daily basis the worldwide. These types of inflammable fuel are increasing global warming, ozone depletion and air pollution too because of heat and temperature allied with carbon dioxide in the smokes formed after burning hydrocarbons and other organic substances as fuel. So, solar power is one of the best alternatives which provides solutions of above problems to living in a modern ecological setting.

2. The factors, which affects global solar radiation

The amount of solar energy arriving on the earth's surface varies because of changing atmospheric conditions and the changing position of the sun, both during the day and throughout the year. Geophysical and atmospheric constituents are mainly two factors which affects the solar radiation. Clouds are the most atmospheric condition that determines the amount of solar radiation that reaches the earth. The variability is due to both local effects such as water vapor, clouds, pollution and seasonal variations, as well as other effects such s length of the day at particular latitude. Desert regions tend to have lower variations due to local atmospheric phenomena. [8] For the practical purposes, solar radiation at the top of the atmosphere can be taken as a constant. However, the precise location of a site on Earth and atmospheric effects drastically change the level of radiation at the surface of Earth. The most common factors affecting the solar radiations are latitude, cloud cover, Aerosols, elevation etc. [9]

Sunshine duration or sunshine hours is climatologically indicator, measuring duration of sunshine in given period (usually, a day or a year) for a given location on Earth, typically expressed as an averaged value over several

years. It is a general indicator of cloudiness of a location, and thus differs from insolation, which measures the total energy delivered by sunlight over a given period. It is climate indicator. To estimate ratio of recorded bright sunshine duration and daylight duration, it is used. In the case of Nepal very few sunshine recorders installed in many places due to financial constraints [10].Sunshine duration has been taken as a climatological indicator, measuring period of solar insolation toward this dwelling planet, usually during a day or a year for the given location on ground. It is defined as an average value of several years. It is an indicator of cloudiness in sky which measures the total energy level delivered by sunlight over a given period of time [10].. It is the parameter to forecast whether the area is feasible to let a milieu generate solar energy or not to the earth [11]. It is defined as the period during which direct solar irradiance exceeds its threshold value of 120W/m² [10]. Sunshine period has become used to determine percentage ratio of recorded duration bright sun's emission and day light hours for the estimation of GSR in empirical models [10]. The sunshine duration parameter is found as the most important dint of accurate measurement of GSR on the earth. However, there is no sufficient numbers of sunshine recorders installed in many places in the world including in our country Nepal. From various measurements it has been reported that there are about 6.8 sunny hours per day having high potential of GSR in the country [12].

The fact is thus been told that the lighter gases might be expected to become more abundant in the upper layer of airy region. In the middle latitudes of earth, the intensity of incident solar radiation increases by 5 to15 percent for each 1000.0m increase in an elevation in the downward level of troposphere. The overall effects of solar radiation on earth are in a variably complicated manner by the greater cloudiness of weather associated with the state of climate even at some few hundred-meter altitude of mountains. Therefore, it is done a tough task to generalize the altitudinal variation and global solar radiation, however some ground measurement data and meteorological parameters are helpful to estimate the global solar radiation at similar altitudes as well as climatic conditions in our Himalayan region.

The altitude is important for the understanding GSR in lower level to high mountain regions. The variation of GSR with altitude can be predicted using the relation given as

$$\text{Altitude effect(a)} = 100\left(\frac{R_{high}\,R_{low}}{R_{high}}\right)\frac{1000}{h_{high}\,h_{low}} \quad (1)$$

where, Rhigh and Rlow are the solar radiation at high altitude and low altitude, likewise, h_{high} and h_{low} are height of high altitude and low altitude respectively. The altitude effect 'a' is measured in percentage per km relation [13].

3. Materials and Methods

The device which measures the radiation coming from the sun through sky is called pyranometer [14]. CMP6 Pyranometer measured the solar radiation on a horizontal surface. The CMP6 Pyranometer are installed at shadow fewer open places with data logger. A CMP6 Pyranometer is shown in Figure 1.

The word Pyranometer comes from Greek language 'pyr' which means 'fire' and ' ano' means 'sky' and meter refers to the measurement. The device which measures the radiation coming from sun is called Pyranometer [15]. The Pyranometer consists of black surface and gets heated exposed to the solar radiation then we get global solar radiation in the form of W/m^2. The operating temperature of CMP6 Pyranometers ranges from -400 C to 800 C. It has wide spectral range of instrument from 310 nm to 2800 nm. The sensitivity of instrument and field of

view are 5 to 15 µV/W/m^2 and 1800 respectively. In CMP6 Pyranometer, the measuring data is recorded by LOGBOX SD data logger within a minute resolution for 24 hours.

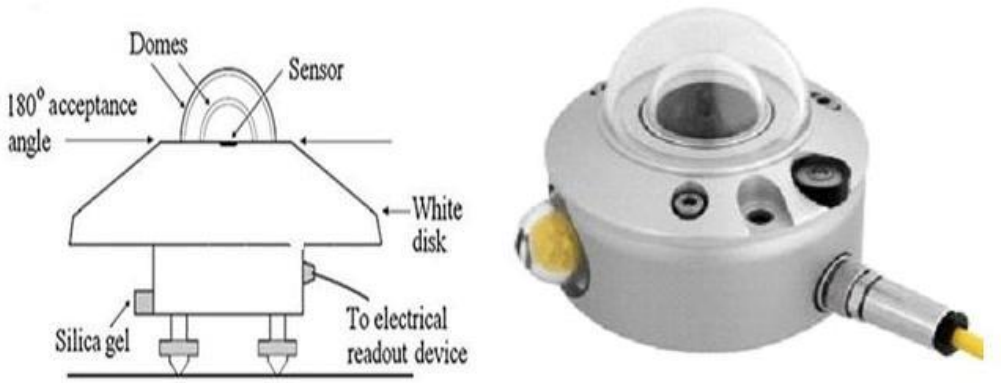


Figure 1. Pyranometer.

The special features of device are low noise, high resolution and low power consumption. It works in all-weather condition. It collects the data at real time for the needs of meteorology and slow signal analysis. For long-term data storage, we can use SD memory card. For the communication, LOGBOX uses either RS232 or RS485 communication port. The global solar radiation (Hg) is measured using CMP6 Pyranometer on the horizontal surface [16-17]. The instruments are installed on the top of Buildings of at Biratnagar (74m), Pokhara (800m) and Jumla (2514m) locations.

4. Experimental Results

4.1 Monthly variation of Solar radiation

Monthly mean measured value of GSR is shown in figure 1 for the years 2015 in Biratnagar. The maximum and minimum value of GSR is observed to be 21.05 and 10.31 MJ/m/day in April and December respectively. The annual average measured value of GSR 15.36 MJ/m^2/day which is sufficient to generate the solar energy (Shrestha, 1998). The coefficient of determination is obtained as 0.940. It indicates about 94.0 percent of the data is closer to the best fit line**.** The p-value is also found within the range of permissible limit. The trend line of fifth degree polynomial is fitted with measured data of GSR in Biratnagar and is shown in figure 2. Monthly mean measured value of GSR is shown in figure 1.2 for the years 2015 in Pokhara.

The maximum and minimum value of GSR is observed to be 23.94 and 11.85MJ/m2/day in June and December respectively. The annual average measured value of GSR 17.29 MJ/m2/day which is sufficient to generate the solar energy (Shrestha, 1998). The coefficient of determination is obtained as 0.89. The value of coefficient of determination is about 89 percent which is the lowest among the three sites. It may be due to frequently changing local weather condition in this site. The p-value is also found within permissible range of acceptance. The trend line of fifth degree polynomial is fitted with measured data of GSR in Pokhara and is

shown in figure 3.

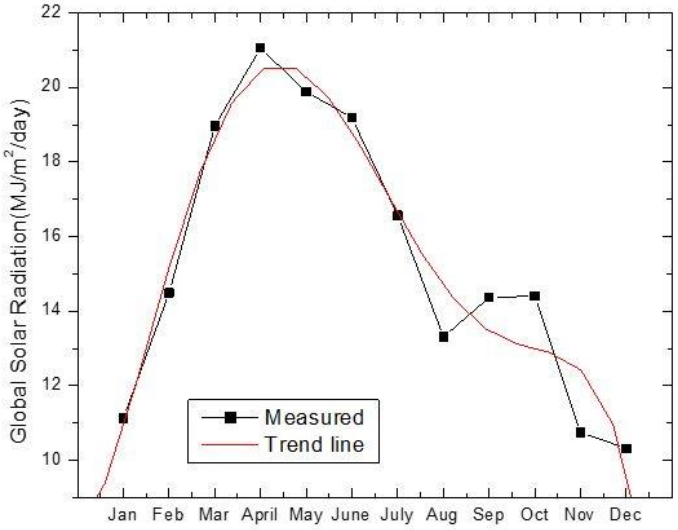


Figure 2. Monthly variation of Solar radiation in Biratnagar 2015.

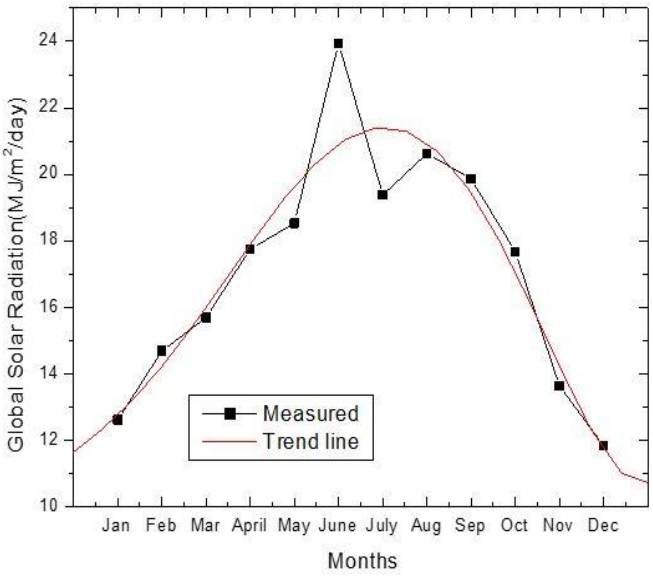


Figure 2. Monthly variation of Solar Radiation in Pokhara, 2015.

Monthly mean measured value of GSR is shown in figure 3 for the year 2015 in Jumla. The maximum and minimum GSR of 24.15 and 12.97 MJ/m^2/day were observed in June and December respectively. The annual average measured value of GSR 18.72 MJ/m^2/day which is sufficient to generate the solar energy (Shrestha, 1998). The coefficient of determination i s obtained as 0.84. The Fourth-degree polynomial closely fitted with measured data of GSR in Jumla which is shown in figure 4.

4.2 Seasonal Variation of Solar radiation

Figure 5 shows that the global solar radiation significantly fluctuates from season to season. The Nepalgunj region is part of the Terai area of Nepal. The measured solar energy for winter, spring, summer and autumn are 14.86, 20.04, 14.74 and 11.82 MJ/m2/day respectively. High value of GSR in spring is found due to less solar

zenith angle and maximum clear sky days. The daily average global solar radiation is 15.36MJ/ m2/day is found at Biratnagar.

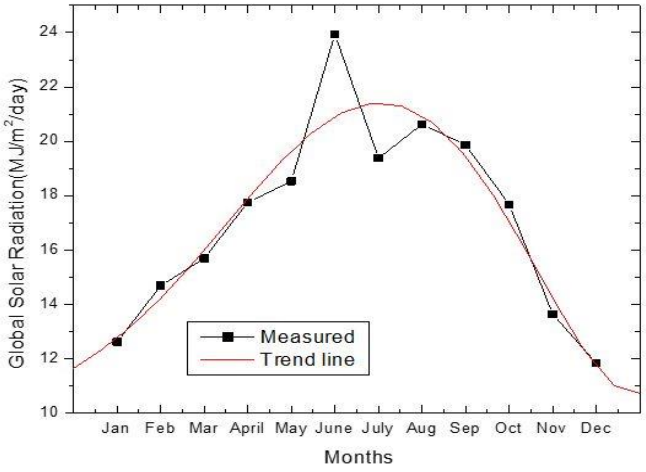


Figure 4. Monthly variation of Solar radiation in Jumla, 2015.

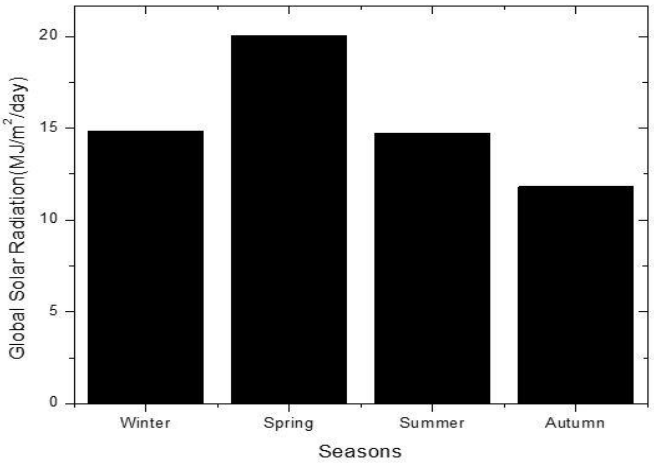


Figure 5. *Seasonal variation of Solar radiation in Biratnagar, 2015.*

Figure 6 shows the seasonal variation of GSR in Pokhara in the year 2015. The GSR of 14.39, 20.47, 19.95 and 14.34 MJ/m^2/day were found in winter, spring, summer and autumn seasons respectively. In this region, the maximum and minimum amount of GSR are obtained in Spring and Autumn which is similar as in Biratnagar. High value of GSR in spring is attributed due to less solar zenith angle, less cloud and less rainfall. The annual average GSR of 17.28 MJ/m^2/day is obtained in Biratnagar.

Figure 6 shows the seasonal variation of GSR in Jumla. The GSR of 17.46, 23.12, 19.03 and 15.28MJ/m2/day were obtained in winter, spring, summer and autumn seasons respectively. The GSR should be higher in spring, summer season and lower in winter, autumn season due to the SZA. Since there is excess cloud and rainfall in summer. So that the lower value of GSR is found in summer than in spring season. The minimum and maximum values of GSR were found in autumn and spring season respectively. This trend is similar to Pokhara and Biratnagar.

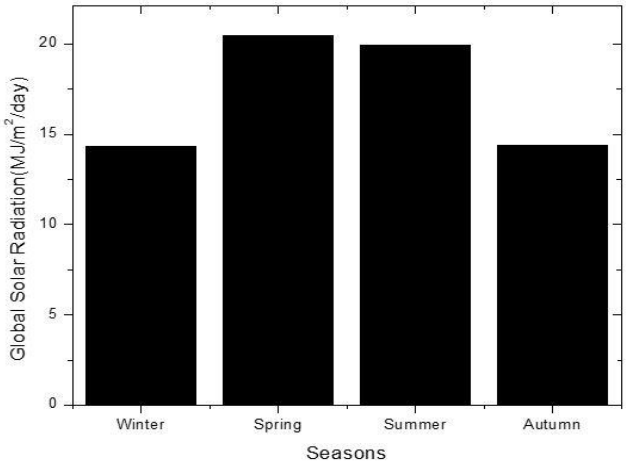


Figure 6. Seasonal variation of Solar radiation in Pokhara,2015.

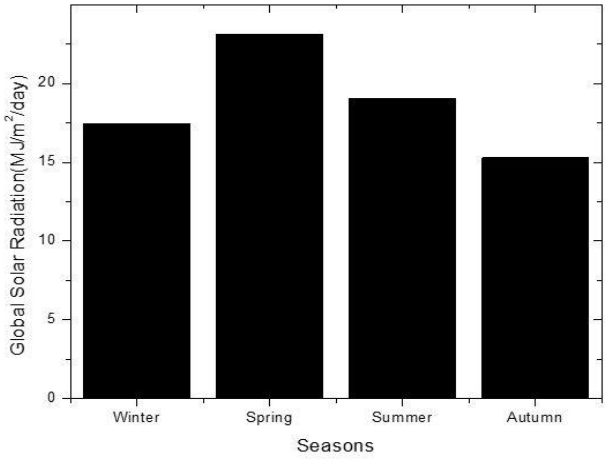


Figure 7. Seasonal Variation of Solar radiation in Jumla,2015.

4.3 Variation of Solar radiation with Altitude

The annual GSR in the three observed sites: Biratnagar, Pokhara, and Jumla were 15.36, 17.29, and 18.72 MJ/m^2/day respectively. The bar diagram of monitored data is shown in figure 8. The measured data shows 7.35% increment in GSR per km is found. It indicates that measured data of global solar radiation increases with increase in altitude.

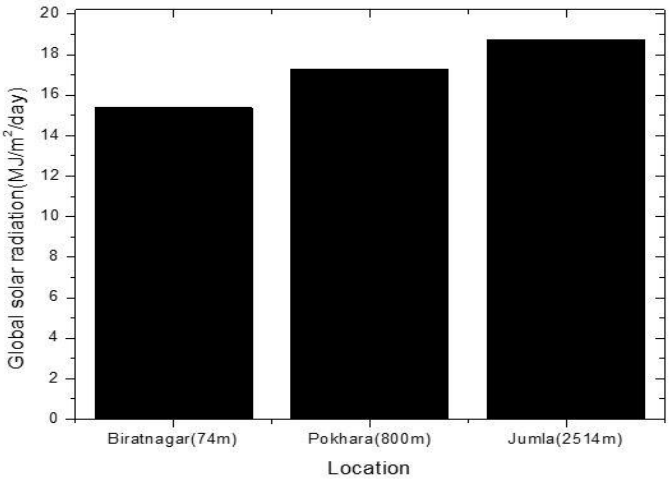


Figure 7. Variation of Solar radiation with altitude.

5. Conclusion

It is concluded that the global solar radiation increases with increase in altitude. It is found that there is 7.35% increment in GSR per km altitude. The solar radiation is comparatively low at the low altitude site Biratnagar and higher values are found in Pokhara and Jumla due to higher altitude.

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