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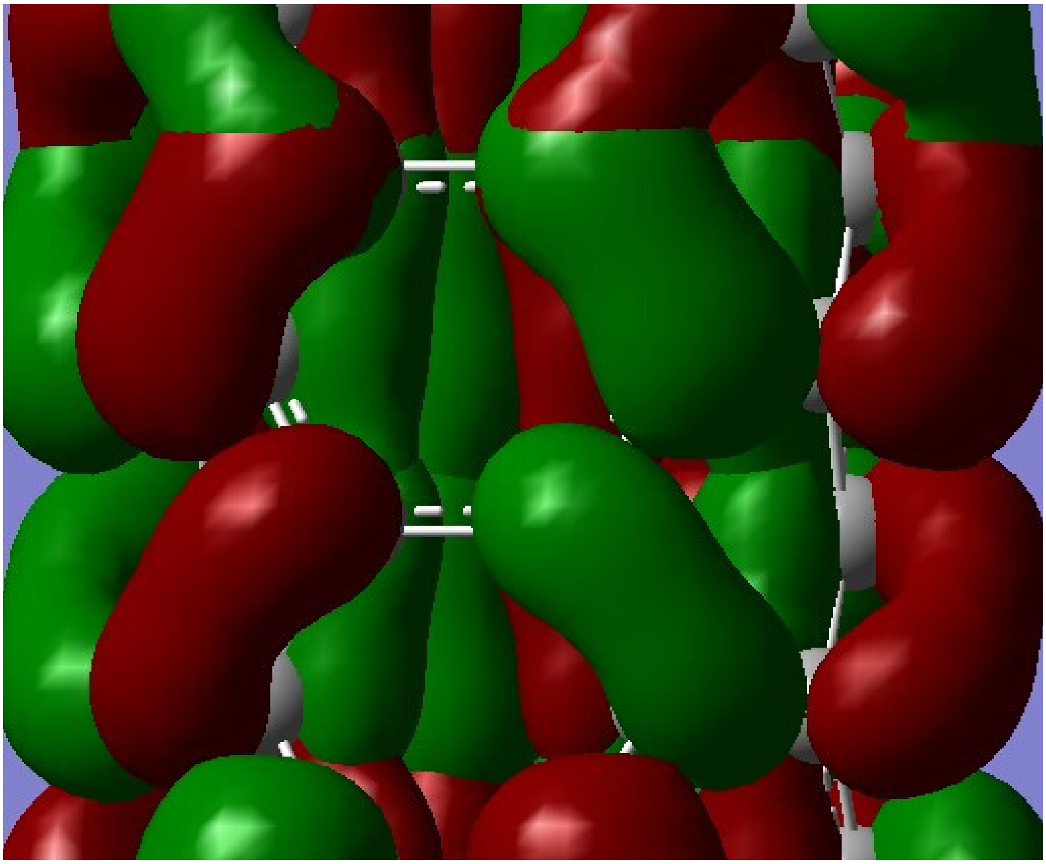

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Estimation of solar energy in Pokhara, Nepal

Research Article

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Abstract: The main aim in this research work is to predict the daily global solar radiation (GSR) using the instrument CMP6 Pyranometer at mid-land altitude of Pokhara (28.22°N, 83.32°E, 800m) Nepal. The solar radiation primarily depends on rainfall, temperature, sunshine hour and local weather condition. The empirical model is based on the metrological parameters like temperature; rainfall and sunshine hour are determined by using regression technique. Empirical constants are found to be (0.43, 0.20) and (0.11, 0.55) in modified Angstrom model and Gariepy empirical model respectively at the year of 2016. The average global solar radiation (GSR) in Pokhara was 15.90 MJ/m^2 /day for the year of 2016. This empirical constant can be utilized to predict the global solar radiation for the year to come. At the end the measured GSR and predicted GSR are utilized on statistical tools and all the error are very low and within the significant range.

Keywords: Global solar radiation • Meterological parameter • Regression technique • Emperical constants

1. Introduction

Energy is the primary and most universal measure of all kinds of work by human beings and nature. The sun is the source of all sorts of energy and remains as principal deity since human thinking began. In Hindu scriptures, people begin with "Ekam,Adityam" which means only one is Aditya, meaning Aditya or the sun was only god when civilization began. A Hindu begins his ritual with Surya Namaskar. In Greek mythology, Apollo, the sun god was one of the principal gods. Therefore, the sun remains as the principal deity right from the beginning and even today [1]. Advancement in technology has made for increased energy demand of people. The sources of energy are varied according to the technological achievements. In the beginning, wood has been used to provide energy and then coal is replaced instead of wood. It is very crucial to all kind of development aimed at human welfare covering agriculture, household, transportation, industrial, commercial and educational sectors. It really helps to improve the quality of life. The rate of energy consumption per capita is considered as one of the vital

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parameter of civilization. Energy has been the lifeblood for continual progress of human civilization [2]. Energy is central to achieving the interrelated economic, social, and environmental aims of sustainable human development. But if we are to realize this important goal, the kinds of energy we produce and the ways we use them will have to change. Otherwise, environmental damage will accelerate, integrity will increase, and global economic growth will be jeopardized [3].Solar energy is the bright light and heat from the sun that is harnessed using a range of ever-evolving technologies such as solar heating, solar thermal energy, photo voltaic solar architecture, molten salt power plants and artificial photosynthesis [4, 5]. Solar energy comes to the earth in the form of radiation, or sunlight with spectral components mostly in the visible, near infrared, and near ultraviolet.Energy from the sun in the form of solar radiation supports almost all life on earth as it drives the earth's climate and weather. Almost all the forms of world's energy we know are solar in origin. Solar radiation is one of the major fuel sources, occurs abundantly in Nepal. Nepal is close to solar belt (latitude 15° to 35°). Nepal receives ample global solar radiation varying from 12.93 MJ/m^2 days to 22.48 MJ/m^2 days and the sun shines for about 300 days a year, the number of sunshine hour's amounts almost to 2100 hours per year and average insulation intensity of about 4.7 $kWhm^{-2}day^{-1}$(=16.92 MJ/m^2/day) .The various research work confirmed that the average global solar radiation is 3.6-6.2 KWh/m^2day in Nepal [6, 7].

Many papers have been published regarding the global solar radiations. The National Academy of Science and Technology (NAST) and New Energy Industrial Technology (NEDO) had recently done research work in the field of Global Solar Radiation and its mapping in Nepal. These models are not yet abundance to design and forecast the value of global energy in Nepal. Also, National Renewable Energy Laboratory (NREL) displayed that early about 4.5 to 5 kWh/m^2/day of solar energy is measured around the country. However, Solar and Wind Energy Resources Assessment (SWERA) was the project launched by AEPC in 2003. The German Satellite showed about 3.5-4 kW/m^2/day amount of solar radiation in central and mid hill region of Nepal [3]. Likewise, [8] was to present a good model to present monthly global solar radiation based on regression technique. In this case, different model like linear, quadratic, linear-logarithmic, logarithmic, and power equations were observed. The measured data of global solar radiation on a horizontal surface along with sunshine hours, maximum and minimum temperature relative humidity, and wind speed were elucidated using the nonlinear Angstrom type model and able to predict the annual average of daily global solar radiation with more accuracy. Then the long term performance of the solar energy was estimated and compared with measured data and local correlation the different errors were also presented and this shows the light deviation from the experimental result. So to study the solar energy and design the energy conversion devices [9] used Angstrom Prescott model to calculate average global solar radiation and some errors were also calculated. This will help to advance the state of knowledge in estimation of global solar radiation.

2. Theory

The core of the sun which extends from the center to about 20%of the solar radius is at an extremely high temperature of around 15.7×10^6K and pressure of 340 billion times earth's air pressure at sea level. Under these condition, a nuclear fusion reaction takes place that merge four hydrogen nuclei or protons into an α-particle (helium nucleus), resulting in the production of energy from the net change in mass due to the fact that the alpha particle is about 0.7% less massive than the four protons. This energy is carried to the surface of the sun in about a million years, through a process known as convection, where it is released as light and heat [10, 11].The sun emits the energy at the rate of 3.9 ×$10^2$6 J/sec(Watts) in all directions. It is attributed to the fact that sun is continuously changing its own mass into energy at the rate of 4.5 ×10^9 kg/sec. Sun is able to create energy because it is essentially a massive fusion reaction.

3. Instrument and Methods

The global solar radiation on horizontal surface was measured using CMP6 pyranometer .It has wide spectral range of instrument from 310 nm to 2800 nm. The operating temperature is from -40°C to 80°C. The sensitivity of instrument and field of view are 5 to 15 μV/W/m^2 and 180° respectively [12].The global solar radiation (H_g) is measured using CMP6 pyranometer on the horizontal surface at Pokhara. However the extraterrestrial global solar radiation (H_0) is in joule per square meter and I_sc is in W/m^2. H_0 is calculated using equation.

$$H_0 = \frac{24}{\pi} I_{sc} \left(1 + 0.033 \cos \frac{360n}{365})(\cos\phi \cos\delta \sin\omega + \omega \frac{\pi}{180} \sin\phi \sin\delta\right) \tag{1}$$

where ϕ is the latitude (rad) and δ is the solar declination angle (rad), ω is sunset hour angle for typical day and n is mean day of each month, where n is the day of year, January first n =1 to 365 days.

$$\delta(degree) = 23.45 \sin\left(\frac{360}{365}(284 + n)\right) \tag{2}$$

The earth rotates about an axis which makes an angle of approximately 66.5° with the plane of its rotation around the sun. The declination angle varies from maximum value of +23.45° on June 21 to minimum value of 23.45° on December 22. The relation of day length is,

$$N = \frac{2}{15} \cos^{-1}(-\tan\phi \tan\delta) \tag{3}$$

$$\omega = \cos^{-1}(\tan\Phi \tan\delta) \tag{4}$$

where ω = sunset hour angle

Then many methods have been tried to deduce its value. Among several parameter, sunshine (n) data is taken as the best one which depends on declination angle and of course cloudiness [13]. One of the models which are used to predict average global solar radiation in a particular place is given by an equation called as Angstrom's equation which is linear [14]. In this research work following equations are used.

$$\frac{H_g}{H_0} = a + b\frac{n}{N} \tag{5}$$

$$\frac{H_g}{H_0} = c + d\frac{n}{N} \tag{6}$$

where c = 0.3791-0.0041Tav-0.0176P and d = 0.4810-0.0043Tav+0.0097P. The values of a,b and c,d are the regression coefficients of the modified Angstrom model and Gariepy empirical model, where H_g is the monthly average global solar irradiance on a horizontal surface and H_0 is monthly average daily extraterrestrial solar irradiance [15, 16].

4. Results and Discussion

The seasonal variation of global solar radiation at Pokhara in 2016, the GSR for winter, spring, summer, and autumn were 14.52, 18.65, 17.64 and 12.81 MJ/m^2/day are clearly shown in Fig. 1(a). The annual average of GSR in 2016 is 15.90 MJ/m^2/day. High value of GSR in spring is attributed due to less solar zenith angle, less cloud and less rainfall also less precipitation whereas lower value of GSR in autumn is found due to large solar zenith angle.

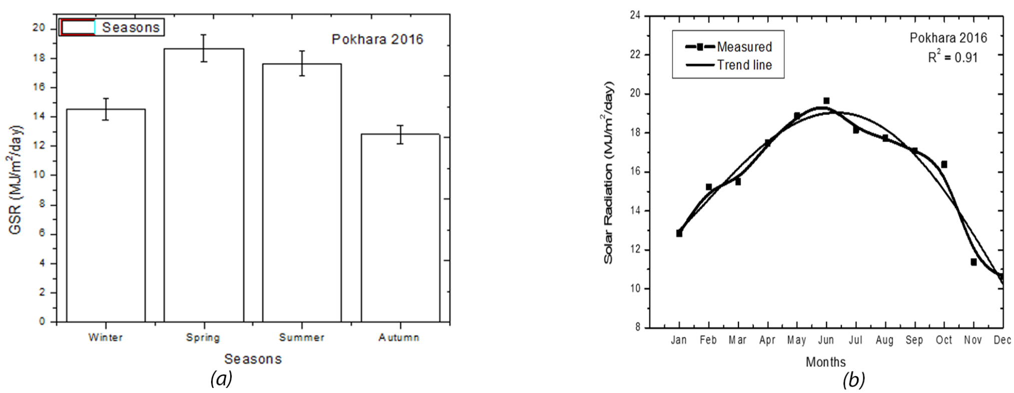


Figure 1. (a) Seasonal Variation, and (b) Monthly Mean Variation of GSR in Pokhara in 2016

Fig. 1(b) shows the trend of global solar radiation at Pokhara, with high value during the dry season. During rainy season, the minimum radiation is obtained as the rain bearing clouds hide the sky. There were two maxima and two minima for GSR during the year with major maxima between February-April i.e. dry and pre-monsoon season and minor maxima during August-October. The major minima occur between May-July sometimes up to August due to the rain carrying clouds pervading radiation in the sky while the minor minima occurs during winter season especially in January and December mainly due to dust, haze covering the atmosphere at that period of the year. The relationship between sunshine hour and measured GSR is strong implying that sunshine hour changes according to the season because of annual motion of the earth which directly affects GSR.

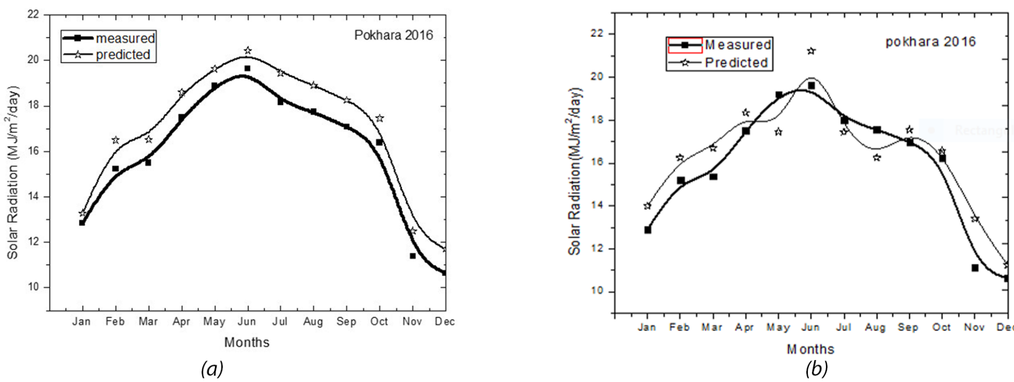


Figure 2. Comparison between the measured and predicted GSR of Pokhara in 2016 using model given by, (a) Eq. 5, and (b) Eq. 6

The Fig. 2(a) and Fig. 2(b) indicate that the measured and estimated values of global solar radiation in Pokhara for year 2016 are very much similar tentatively. However, there is slight variation of GSR due to the different weather conditions. The regression coefficients a,b and c,d are called empirical constants which depends upon different factors such as sunshine hour, relative humidity, latitude and maximum temperature of air. Clearly, the value of MBE and RMSE using sunshine hour as a meteorological parameters in two years were minimum than values using other parameters. Furthermore, it can be observed that the measured and estimated values of GSR are in close agreement while using sushine hour as a meteorological parameter.

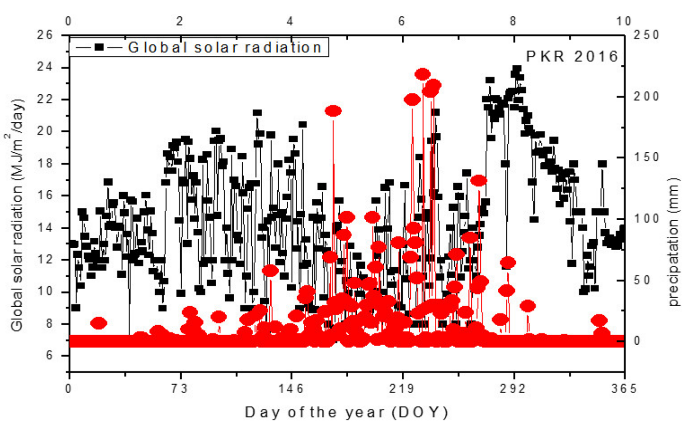
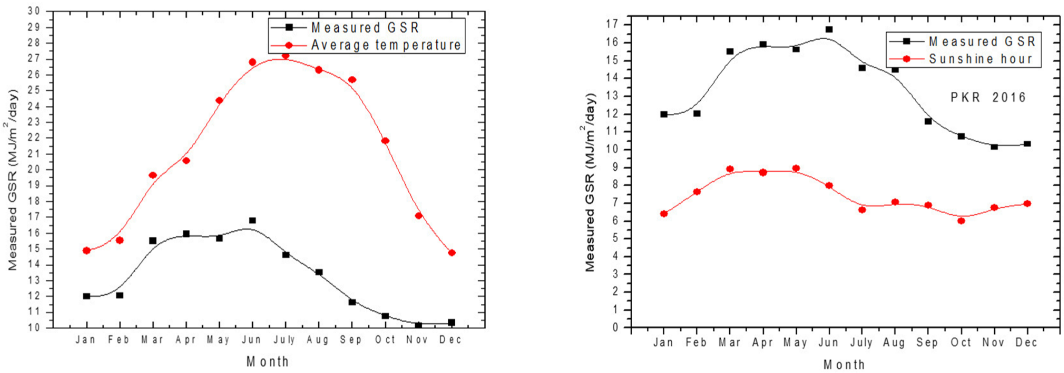


Figure 3. Mean variation of rainfall with GSR of Pokhara in the year of 2016

Fig. 3 shows the relation that at rainy season the GSR decreases because of cloud, fog and moisture present in the atmosphere. Maximum rainfall occur during rainy season where as GSR slightly decreases.



(a) (b)

Figure 4. Variation of, (a) GSR with temperature, and (b) Sunshine with GSR (Pokhara, 2016)

Fig. 4(a) shows the relation between monthly variation of solar radiation and average temperature and it is found that global solar radiation increases with the increase of average temperature. Fig. 4(b) shows the monthly variation of global solar radiation with sunshine hour. It is found that global solar radiation increases with the increase of sunshine hours.

5. Conclusions

It is concluded that the global solar radiation varies from month to month due to local weather condition and precipitation. The maximum and minimum value of GSR was found on spring and autumn due to presence of fog, dust particles, cloud and position of Sun etc. In this study, empirical constants of modified Angstrom empirical model and Gariepy empirical model were found to be respectively (0.43, 0.20) and (0.11, 0.55). Finally it is concluded that modified Angstrom empirical model is better than Gariepy empirical model with higher degree of accuracy for the prediction of GSR in Pokhara. The obtained empirical constants can be employed to predict the GSR in upcoming years at similar geographical location of Nepal.

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