Research Journal of Chemical Sciences E-ISSN 2231-606X
Vol. **6(8),** 24-28, August **(2016)** *Res. J. Chem. Sci.*

Variation of Global Solar Radiation at different altitudes of Mid-Western Region, Nepal

Bed Raj K.C.[1*], Khem N. Poudyal[2] and Shekhar Gurung[3]
[1]Mahendra Multiple Campus, Tribhuvan University, Nepalganj, Nepal
[2]Institute of Engineering, Tribhuvan University, Kathmandu, Nepal
[3]Central Department of Physics, Tribhuvan University, Kathmandu, Nepal
bedrajkc@yahoo.com

Available online at: www.isca.in, www.isca.me
Received 16th May 2016, revised 20th July 2016, accepted 14th August 2016

Abstract

The experimental results on global solar radiation in some locations in Nepal measured by calibrated pyranometer at Jumla(29.27°N to 82.18°E, 2514.0m), Dang (28.70°N, 82.18°E, 603.0m) and Nepalgunj (28.05°N, 81.62°E, 150.0m) since 2011. The influence of different meteorological as well as physical parameters to the intensity of global solar radiation was analyzed. This research highlighted fluctuation of the measured value of global solar radiation with local weather condition. Measured global solar radiation data shows that there is about 7.5% per km increase in Jumla in comparision with Dang and Nepalgunj. This result conformed that there is strong correlation found in between altitude and global solar radiation. In addition the GSR varies with environmental pollution and local weather condition.

Keywords: Altitude, Global solar radiation, Atmospheric pollution, Potential, Application.

Introduction

Global Solar Radiation: Sun is a source of heat and light for life on Earth. Solar energy is electromagnetic radiation concentrated in infrared, visible, and ultraviolet rays. Solar radiation originates in the sun's core and is eventually sent to Earth. This radiation is created deep within Sun's core where the temperature ($15x10^6$ °C) and pressure (340 billion times Earth's air pressure at sea level) is so intense that nuclear reaction takes place. This reaction causes four hydrogen nuclei to fuse together so as to form one helium nucleus.The helium particle is about 0.7 per cent less massive than the four hydrogen nuclei. The released energy is 26.7MeV from this nuclear process which is carried to the surface of the Sun through convection, in the form of heat and light.

On a surface normal to the solar beam, outside the Earth's atmosphere, power density is 1,365W/m^2 which is known as 'Solar Constant'. As solar radiation passes through the atmosphere, depending on the length of the atmospheric path traversed by the solar radiation and the quantity of dust, water vapour, CO_2, ozone, and other aerosols present, some amount of the radiation is scattered and absorbed. The diffused irradiance plus the direct irradiance from the sun are together termed as Global Irradiance. It is well established that the solar radiation is not equally available in all regions of the world as it is governed by the earth-sun geometry. On a clear sky day in the tropics, when the sun is overhead, the global irradiance can exceed 1000 W/m^2 but in high latitude it rarely exceeds 850 W/m^2. Similarly, daily solar radiation may be 5-7 kWh/m^2/day in the tropics but could be less than 0.5 kWh/m^2/ day in high latitudes[1].

Energy is important to all development processes. The rate of energy consumption today is taken as indicator civilization which really helps to improve the quality of life of the people. The energy consumption is directly linked with all round development of the people. In the contest of our country Nepal, about 75% of the total populations still live in rural areas and they don't have access to modern forms of energy like petroleum product, hydroelectricity and solar photo voltaic and so on. For lighting purpose, they should use the kerosene lamp. Living standard of remote rural people is difficult. At the remote areas of our country the cost of one litre kerosene is more than NRs 100 to NRs 200 in 2010. According to this data, the prices of the petroleum product are beyond the capacity of the rural Nepali citizens.

At the present time about 85% of total energy is obtained from fuel wood, agriculture residue and cow dung which are used for cooking and heating purposes in the rural areas of Nepal. Similarly about 12.5%, 1.5%, and 1% energy is obtained by the petroleum products, hydroelectricity and renewable energy resources respectively. So nation should spend huge amount of money on importing the few percent of energy demands, hence government spends little money in educations, public health and security. This is the real ground situation of Nepal, thus, it is the time to explore the global solar radiation potential for the sustainable development of the nation. The average global solar radiation in Nepal varies from 3.6-6.2 kWh/m^2 day, sun shines for about 300 days a year. Thus, Nepal lies in a favorable insolation zone in the world[2]. Solar energy technology has good economic and social potential.

This will improve living standard of people by creating opportunities for higher income generation. The level of development and application in Nepal today is such that tremendous benefits are obtained from agricultural output in Nepal if solar energy is effectively harnessed for on farm utilization. Since Nepal lies within a high sunshine belt of the world, it should use this as a turning point for solution in energy utilization problems, which will create more efficient, more hygienic environmental friendly technology.

Factors Affecting Global Solar radiation: There are mainly two types of affecting factors of global solar radiation on the earth. One of them is geophysical parameters which are nearly constant over and over in years. The others directly and indirectly affect on incoming GSR due to the interaction with atmospheric constituents and local environment. Those constituents may vary from place to place. The Solar Zenith angle is the angle between local Zenith and line joining the observer and Sun. This angle is between 0° to 90°. Smaller the Zenith angle greater is the Solar intensity on the earth's surface[3]. Clouds are formed from small water droplets or ice crystals. Rainfall occurs when moisture in the atmosphere condenses in to drops. When the water droplets in the cloud become too heavy then it falls from the cloud towards the earth in the form of rain. During rainfall there is formation of cloud in the sky which typically blocks sunlight from reaching to the earth surface resulting to decrease in solar energy. About half of the earth is covered by cloud which helps to maintain the global temperature. Clouds appear with a wide range of shapes, sizes and microphysical properties. The cloud is highly dynamic because of its close relationship to circulation. They reflect radiation back to space in a large fraction of incident solar radiation, which is concentrated at visible wavelengths. Clouds and black carbon shield the major part of planet from solar radiation, which plays the important role in the earth's energy budget. Cloud's role is important in the budget of terrestrial radiation that emitted in the infrared radiation by the planet's surface and atmosphere to offset solar heating. Cloud cover is a significant barrier to penetration of insolation. How much radiation is actually reflected depends on the types of clouds, amount of cloud cover and thickness[4]. The attenuation of global solar radiation by cloud varies with wavelength[5].

The annual precipitation in Nepal varies from place to place. In the summer season, the sky is partly or fully covered by cloud. Thus the solar radiation decreases with increase in rainy and cloudy days. It might be due to the absorption and reflection of radiation due to the presence of rain droplets in the atmosphere, clouds and aerosols[6,7].

The relative humidity is one of the major effecting factors of solar radiation. It gradually decreases from lowland, midland to highland regions of Nepal. It has been found that the places at higher altitudes are generally less humid than at low altitude region of Nepal. In addition, the northern, mid-western, western and far western region, there is very less humidity, about 21 to 33 percent, because of less rainfall and less forest. Geographically, the north eastern region seems to be more humid. In mid hills and low land regions there is about 80 to 90 percent RH except winter season. It is known that higher rainfall locations have higher value of humidity. On the other hand, the relative humidity absorbs the solar radiation in the atmosphere. Thus lower value of GSR is found at a location of higher relative humidity. GSR compared with relative humidity and it is found that the high value of GSR at low value of relative humidity and vice versa[8].

The fact that the lighter gases might be expected to become more abundant in the upper atmosphere. In middle latitudes the intensity of incident solar radiation increases by 5 to 15 percent for each 1000 m increase in elevation in the lower troposphere[9]. The overall effects is invariably complicated by the greater cloudiness associated with variation of climate even few hundred meters altitude of mountain. Therefore, it is difficult to generalize the altitudinal variation and global solar radiation, however some ground measurement data and meteorological parameters help to estimate the global solar radiation at similar altitude as well as climate condition in Nepal.

Sunshine duration is a climatological indicator, measuring duration of sunshine in given period, usually a day or a year for a given location on Earth. It is expressed as an average of several years. It is a 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 the parameter to forecast whether the area is feasible to generate solar energy or not. It is defined as the period during which direct solar irradiance exceeds a threshold value of 120 W/m² [9]. Sunshine duration is used to measure percentage ratio of recorded bright sunshine duration and daylight duration for the estimation of GSR in empirical models. The sunshine duration parameter is the most important for accurate measurement of GSR on the earth[10]. The lighter gases are found in the upper atmosphere. In middle latitudes the intensity of incident solar radiation increases 5 % to 15% for each 1000.0 m increase in elevation in the lower troposphere[8].

The altitude is an importance factor for the variation of GSR from low land area to mountain region. The GSR changes with altitude and it can be calculated by using the given relation as [11,12].

$$(Altitude\ \ effect\ (a\ \ ) = 100\left(\frac{R_{high} - R_{low}}{R_{high}}\right)\frac{1000}{h_{high} - h_{low}}$$

Materials and Methods

The device which is used to measure the radiation coming from the sun through sky is called pyranometer. Its main components are glass dome, metal body, radiation screen, black sensor, level and cable. This pyranometer requires power for operation.

The solar radiation is absorbed by black coated thermopile sensor and the radiation is converted into heat. The heat flows through the sensor to the pyranometer housing. The thermopile sensor creates the temperature difference and this temperature difference is directly proportional to the potential difference which is a voltage output. When the output terminal connects to the data logger then it converts the voltage into intensity of radiation directly in W/m^2 unit. This pyranometer is used to measure the global solar radiation within one minute interval of time for 24 hours at three different geographic, climatic and physical conditions for throughout the years. For the measurements reported in this paper portable Pyranometer Kipp and Zonen CMP 6 model was used. It is a type of actinometer which is used to measure global solar radiation on a planar surface and shadow-less open space. There is a sensor that is designed to measure the global solar radiation flux density (in watts per meter square) from a field of view of 180° [13]. The instruments are installed on the top of Buildings of at Nepalgunj (150m), Dang (603m) and Jumla (2514m) locations.

Results and Discussion

Monthly variation of solar radiation: Monthly mean measured value of GSR is shown in Figure-1 for the years 2011 in Nepalgunj. The maximum and minimum value of GSR is observed to be 19.7 and 8.2 MJ/m^2/day in June and December respectively. The annual average measured value of GSR (13.8 ±1.25) MJ/m^2/day which is sufficient to generate the solar energy. The coefficient of determination and p-values are obtained as 0.945, and < 0.0001. It indicates about 94.5 percent of the data is closer to the best fit line**.** The p-value is also found within the range ofpermissible limit. The trend line of fifth degree polynomial is fitted with measured data of GSR in Nepalgunj and is shown in Figure-1.

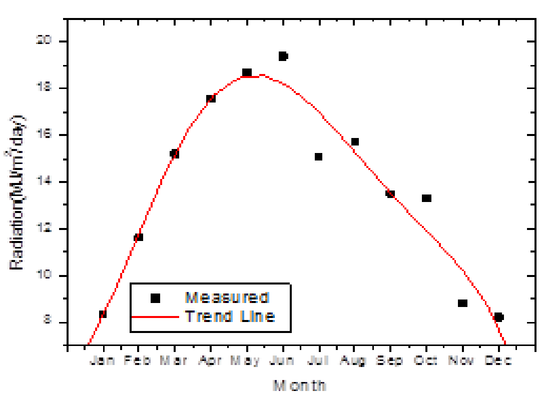

Figure-1
Monthly variation of Solar radiation in Nepalgunj 2011

Monthly mean measured value of GSR is shown in figure 1.2 for the years 2011 in Dang. The maximum and minimum value of GSR is observed to be 22.7 and 10.08 MJ/m^2/day in June and January respectively. The annual average measured value of GSR (16.7 ±1.3) MJ/m^2/day which is sufficient to generate the solar energy. The coefficient of determination and p-values are obtained as 0.92, and < 0.0028. The value of coefficient of determination is about 92 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 Dang and is shown in Figure-2.

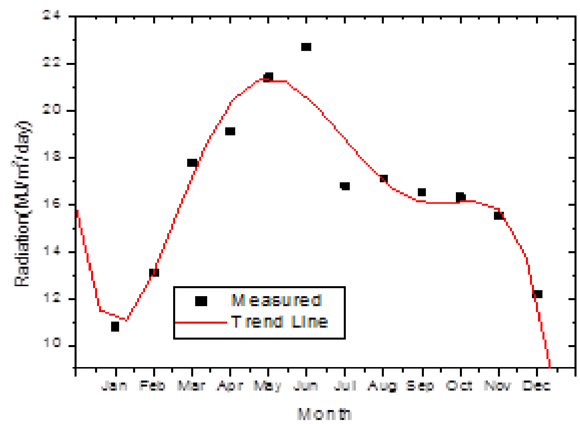

Figure-2
Monthly variation of Solar Radiation in Dang, 2011

Monthly mean measured value of GSR is shown in figure 1.3 for the year 2011 in Jumla. The maximum and minimum GSR of 25.3and 14.6 MJ/m^2/day were observed in May and January respectively. The annual average measured value of GSR (19.9 ±0.66) MJ/m^2/day which is sufficient to generate the solar energy (Shrestha, 1998). The coefficient of determination and p-values are obtained as 0.98, and < 0.001.The Fifth degree polynomial closely fitted with measured data of GSR in Jumla which is shown in figure 3.

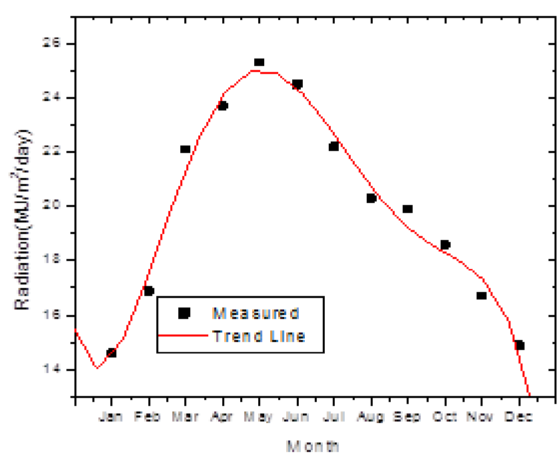

Figure-3
Monthly variation of Solar radiation in Jumla, 2011

Seasonal Variation of Solar radiation: Figure-4 shows seasonal variation of the global solar radiation. The Nepalgunj area is part of the Terai region of Nepal. The measured solar energy for winter, spring, summer and autumn are 13.02, 19.31, 17.86 and 14.68 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 found at Nepalgunj is 12.9MJ/ m2/day.

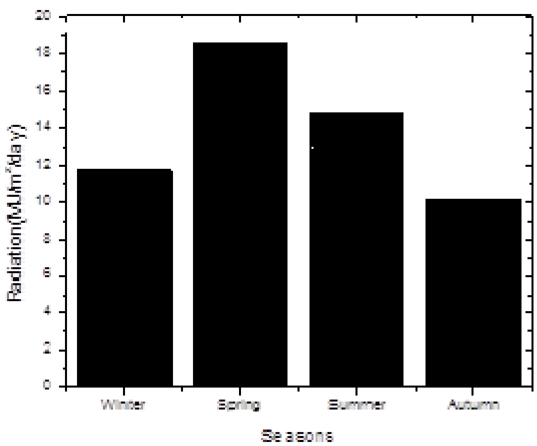

Figure-4
Seasonal variation of Solar radiation in Nepalgunj, 2011

Figure-5 shows the seasonal variation of GSR in Dang in the year 2011. The GSR of 13.9, 21.1, 16.8 and 14.7 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 winter and Autumn which is similar as in Nepalgunj. High value of GSR in spring is attributed due to less solar zenith angle, less cloud and less rainfall. The annual average GSR of 16.7 MJ/m^2/day is obtained in Dang.

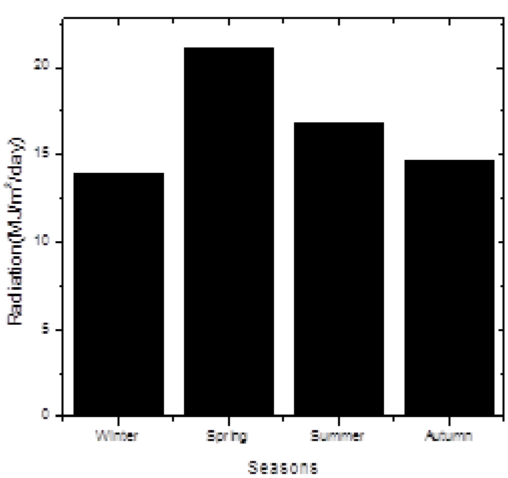

Figure-5
Seasonal variation of Solar radiation in Dang, 2011

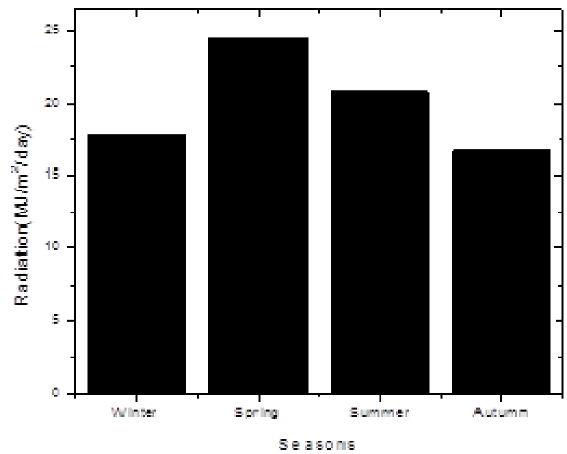

Figure-6
Seasonal Variation of Solar radiation in Jumla, 2011

Figure 6 shows the seasonal variation of GSR in Jumla. The GSR of 17.8, 24.5, 20.8 and 16.7 MJ/m^2/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 Dang and Nepalgunj.

Variation of Solar radiation with Altitude: The ground based monitored data of GSR in the three observed sites: Nepalgunj, Dang, and Jumla were 20.22, 21.52, and 24.9 MJ/m^2/day respectively in clear sky day on 17 July 2011. The bar diagram of monitored data is shown in Figure-7. The measured data shows 7.53% increment in GSR per km is found. This result indicates that measured data of global solar radiation increases with increase in altitude.

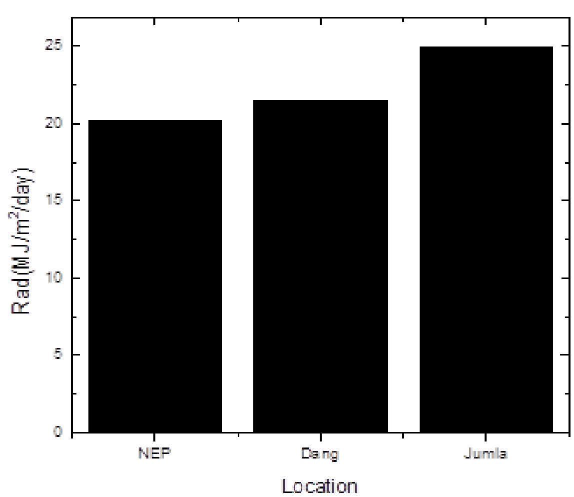

Figure-7
Variation of Solar radiation with altitude

Conclusion

It is concluded that the trend of global solar radiation is maximum at March, April and May at all three measuring sides. Likewise there is less amount of GSR is found at summer season because of clouds, wind blow and too much rain fall. Similarly there is maximum amount of solar radiation found in spring season and minimum at winter season because at the spring season there is no more wind, clouds and rainfall however, at the winter season the fog and clouds covered the sky and the sunshine hour is also very small to compare in other seasons.

The most important clue is found that the GSR directly related to the altitude of the measured locations. It showed that the GSR increases with increase in altitude. The solar radiation is comparatively low at the low altitude site Nepalgunj and higher values of GSR is found in Dang and Jumla due to less rain fall zone, less humid area and higher altitude.

Acknowledgments

Authors are grateful to express their gratitude to Department of Hydrology and Meteorology (DHM), Government of Nepal for providing all necessary meteorological data. We are thankful to NAST for installing Pyranometer in M.M. Campus, T.U. Nepalgunj for measurement of Solar radiation. Authors would like to give special thanks to faculty member and staffs of Dept. of Physics Mahendra Multiple Campus, Tribhuvan University, Nepalganj, Nepal.

References

1. Shashaank Shekhar I.P. (2012). Direct Normal irradiance. New Delhi: Compendium of National Training Programme On RETScreen International Software for Evaluationof Renewable Energy Projects.

2. WECS (2010). Water Energy Commission Secretariat. Energy sector Synopsis Report.

3. Kerr J.B. (2003). Understanding the factors for affect surface UV radiation. *Ultraviolet Ground andspace based measurements,Model, and effects*, 1-14.

4. Salby M. (1996). Fundamentals of Atmospheric Physics. 61, International Geophysics Series, Academic Press.

5. Seckmeyer G.E. (1996). Transmittance of a cloud is wavelength dependent in UV Range. *Geophys, Res, Lett.*, 23(20), 2753-2755.

6. RECAST TU. (2001). Development of Solar Dryers in Nepal. 10-11.

7. Thapa M.K., Bhattarai B.K.,Gurung S.,Sapkota B.K. and poudyal K.N.(2016). Diurnal and Monthly Variation of Aerosol optical Depth and Angstrom's parameters in Kathmandu valley,Nepal. *Research Journal of Chemical Sciences Volume,* 6(2), 40-44.

8. Barry R.G. and Chorley R.J. (1978). Atmosphere, Weather and Climate. 40-41.

9. WMO (2003). Scientific Assessment of Ozone depletion. Global Ozone research and Monitoring Project Report, 47.

10. Schmucki. D.A. and Philipona Rolf (2002). Ultraviolet radiation in the Alps:the altitude effect. *Opt. Eng.,* 41, 5369-5383.

11. Poudyal K.N., Bhattarai B.K., Sapkota B. and Kjeldstad Berit (2012). Estimation of Global solar Radiation using Sunshine duration in Himalaya Region.*Research Journal of Chemical Sciences,* 2(11), 20-25.

12. Kipp and Zonen (2008). CMP series instruction manual. Kipp and Zonen B.V., Delftech park 36, Netherlands.