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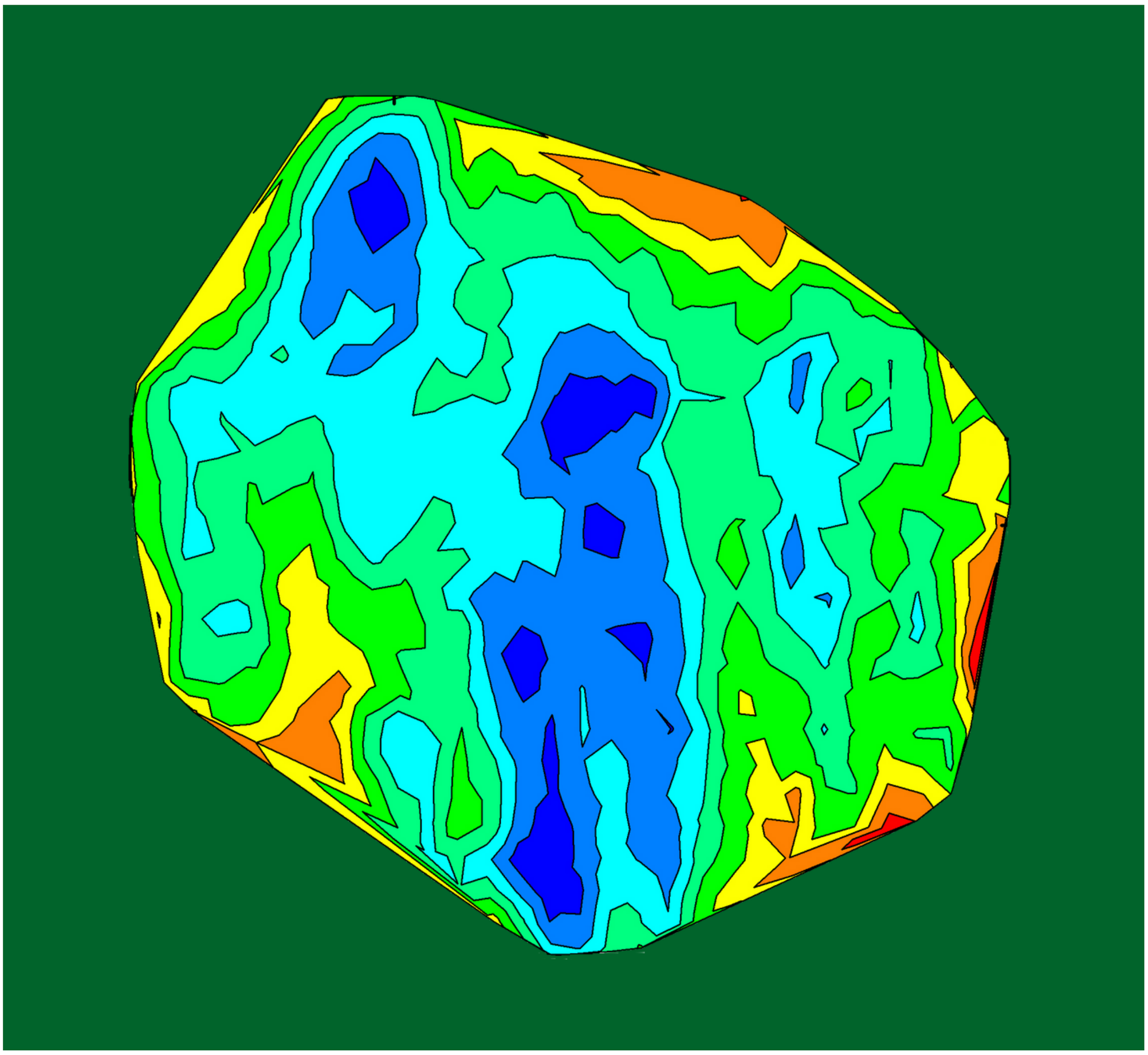

Department of Physics, Prithvi Narayan Campus, Pokhara
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Himalayan Physics

Study of Affecting Factors of Meteorological Parameters on Solar Radiation on Pokhara

Research Article

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Abstract: Solar radiation data are of great significance for solar energy systems. This study aimed to estimate monthly and seasonal average of daily global solar radiation on a horizontal surface in Pokhara (Lat.:28.21° N, Long.: 84°E and alt. 827 m above sea level), Nepal, by using CMP6 pyranometer in 2015. As a result of this measurement, monthly and yearly mean solar radiation values were 20.37 ± 5.62 MJ/m^2/ day in May, 11.37 ± 2.38 MJ/m^2/ day in December and 16.82 ± 5.24 MJ/m^2/ day respectively. Annual average of clearness index and extinction coefficient are 0.51 ± 0.14 and 0.53 ± 0.31 respectively. There is positive correlation of maximum temperature and negative correlation of with global solar radiation.

Keywords: • Clearness index • extinction coefficient • global solar radiation • meteorological parameters

1. Introduction

Sun is the closest star from the Earth and hence solar energy is the fundamental as well as renewable energy. Main source of energy of Sun is thermonuclear fusion reaction. In this reaction, four hydrogen atoms fuse to form one helium atom and two positrons emitting 26.7 MeV energy. Sun emits 3.846×10^{26} W energy in form of electromagnetic wave. Solar energy 1367 W/m^2 (solar constant , I_{sc}) incidents on upper surface of atmosphere when distance between Sun and Earth is 1.49×10^8 km [1] . Solar energy is free energy, clean and free of harmful environmental effects sources. Study of solar radiation and its effect of different meteorological parameters are used in Agriculture, Hydrology, Climate change.

Nepal is a land-locked south east mountainous Asian country with a large area of beautiful landscape. Within this small and beautiful setting it possesses diversity in biosphere and variation of climate. Nepal lies in

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sunbelt (15° to 35° latitude). Annual solar isolation is 3.6−6.2 kWh/m^2/ day and sunshine duration is 300 days in Nepal [2]. In fiscal year 2010/011, 425 TJ energy is consumed in Nepal in which, tradition fuel is 83.7 percentage, commercial fuel is 15.5 percentage and renewable energy is 0.8 percentage [3]. Large foreign currency is waste to import petroleum product. Study of solar radiation is important for agriculture and energy transformation.

Pokhara (Lat.: 28.21° N, Long.: 84° E and alt. 827 m a.s.1.) lies in the western region, covers area 464.24 km^2 is shown in Figure 1. Population and population density are 600,759 and 868.074 km^{-2} respectively [4]. Yearly mean daily solar radiation is 16.499 MJ/m^2/ day from 2007 to 2012 in Pokhara [5]. Maximum solar radiation is 23.21 MJ/m^2/ day in June and minimum is 12.04 MJ/m^2/ day in December from 2009 to 2010 in Pokhara [6].

Figure 1. Map of Pokhara [source: www.travelnewsnepal.com]

2. Methodology and material

The solar radiation on a horizontal surface of upper atmosphere (H_o) passes through the earth's atmosphere to ground surface attenuated exponentially due to scattering, reflection, and absorption by the atmospheric constituents like air molecules, aerosols, water vapor, ozone and clouds. Hence, solar radiation on a horizontal

surface of ground (H_g) is affected by physical and meteorological parameters.

According to Bougure-Lembert law [7–9], normal solar radiation on ground is function of extinction coefficient(K) and optical air mass(m),

$$H_g = H_o e^{-Km}$$

Where

$$H_0 = \frac{24}{\pi} I_{sc} \left[1 + 0.033 \cos\left(\frac{360}{365} n_d\right)\right] (\omega_s \sin\delta \sin\phi + \cos\delta \cos\phi \sin\omega_s)$$

$$\delta = \text{ solar declination } = 23.45 \sin\left(\frac{360}{365}(284 + n_d)\right)$$

n_d = no. of day of year (DOY)

ω_s = sunshine hour angle = $\cos^{-1}(-\tan\delta \tan\phi)$

Optical air mass (m) depends on atmospheric pressure (P), solar zenith angle (θ_z), solar hour angle (ω), latitude (ϕ) of the place [10, 11].

$$m = \frac{P}{101325} \quad \frac{1}{\cos\theta_z + 0.15\,(93.885 - \theta_z)^{-1.253}}$$

Global solar radiation (GSR) is sum of direct solar radiation and diffused solar radiation. Daily GSR and meteorological data are collected from Department of Hydrology and Meteorology (DHM) for year 2015. GSR is measured by CMP6 first class pyranometer [12], as shown in Figure 2.

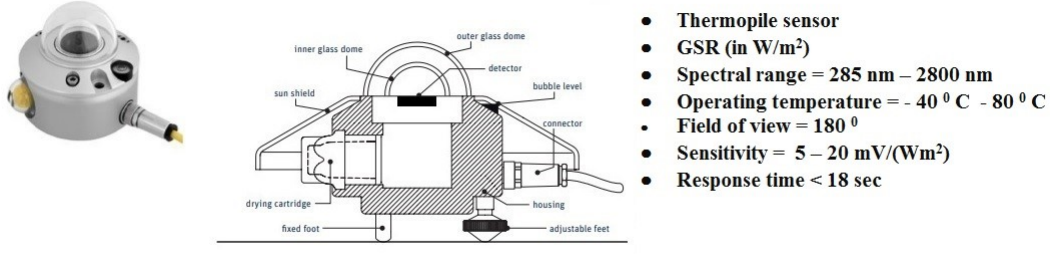

Figure 2. CMP6 pyranometer [source: www.kippzonen.com]

Open source software Python 3.7 is used to analysis and plot graph. Mean ($\bar{x}$), standard deviation (σ), correlation coefficient (r) are used as statistical tool. Data are presented in form mean ± standard deviation. Standard error (SE) is used as error bar in graph.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$

$$SE = \frac{\sigma}{\sqrt{n}}$$

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

Here n is no. of data. Correlation coefficient is used to find relation between two variables.

3. Results and Discussion

Figure 3 (a) indicates the measured data of daily variation of GSR .There is high fluctuation of solar energy in Pokhara. GSR is maximum 28.57 MJ/m^2/ day and minimum 1.15 MJ/m^2/ day are found in 124th day of year and in 307th day of year respectively. Variation of clearness index ($K_T = H_g/H_o$) with day number of year (DOY) is shown in Figure 3 (b) .Clearness index is maximum 0.72 and minimum 0.04 are found in 68th day of year and in 307th day of year respectively. Number of cloudy days ($K_T < 0.34$) is 47 and number of clear days ($K_T > 0.65$) is 60. Variation of extinction (K) with day number of year (DOY) is shown in Figure 3 (c). Extinction coefficient is maximum 2.70 and minimum 0.17 are found in 90th day of year and in 281th day of year respectively.

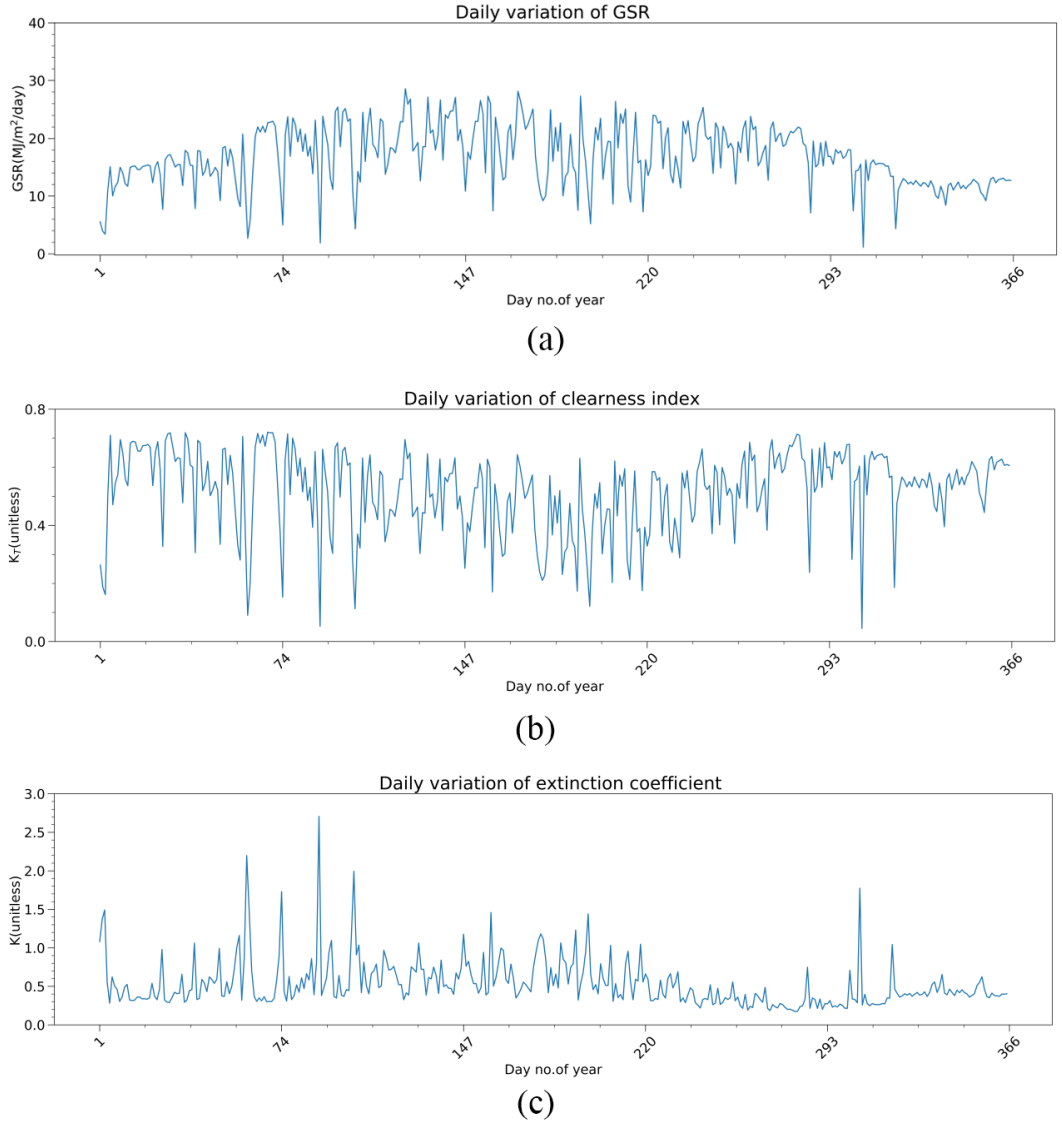

Figure 3. Daily variation of parameters (a) GSR, (b) Clearness index, and (C) Extinction coefficient

Figure 4 (a) shows monthly variation of GSR. GSR is maximum value 20.37 ± 5.62 MJ/m^2/ day in May due to less solar declination and high temperature and is minimum 11.37 ± 2.38 MJ/m^2/day in December due to less solar declination and low temperature . Variation of GSR is large in June whereas less in December. Figure 4 (b) shows monthly variation of clearness index. It is maximum 0.58 ± 0.15 in October and minimum 0.39 ± 0.15 in July. Variation is large in March and less in December. Figure 4 (c) shows monthly variation of extinction coefficient. It is maximum 0.69 ± 0.35 in April and minimum 0.30 ± 0.11 in September. Variation is large in March and less in December.

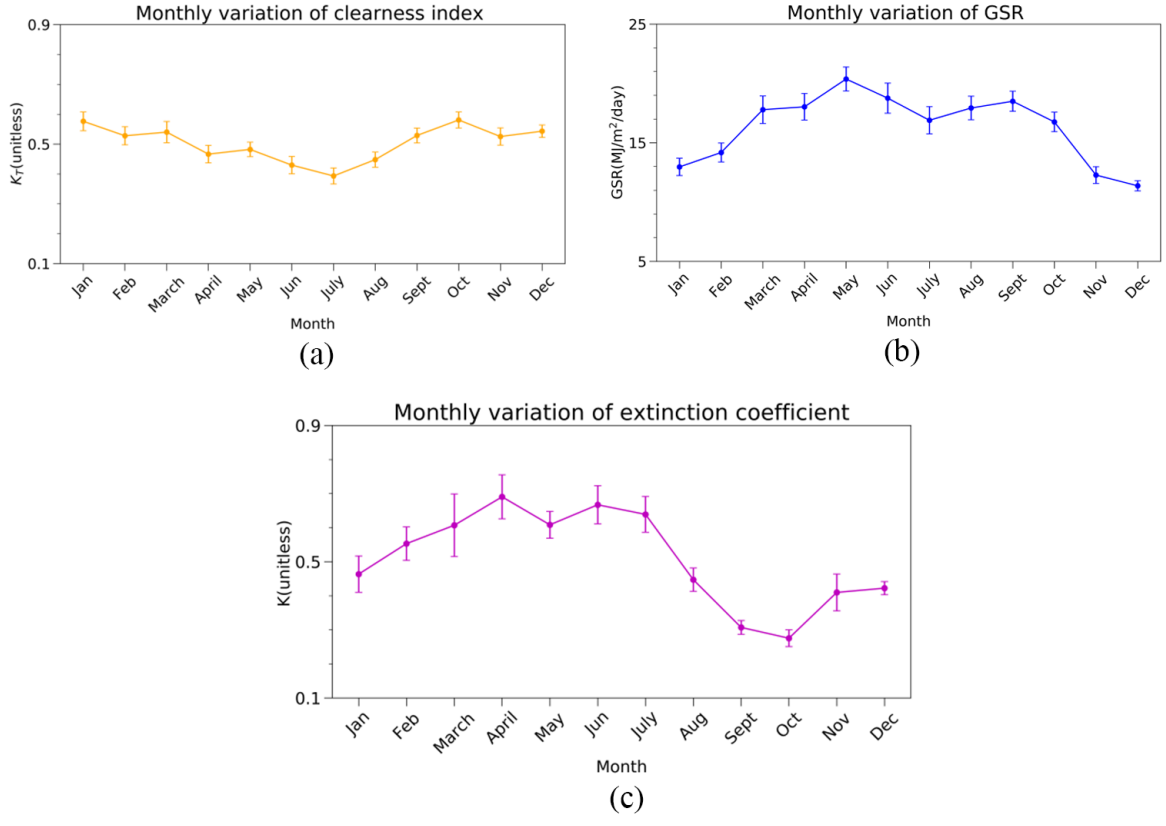

Figure 4. Monthly variation of parameters (a) GSR, (b) Clearness index, and (C) Extinction coefficient

Figure 5 (a) shows seasonal variation of GSR. GSR is maximum in 18.73 ± 6.077 MJ/m^2/day in spring and minimum 12.79 ± 3.57 MJ/m^2/day in winter. GSR varies large in summer but less in winter. Figure 5 (b) shows seasonal variation of clearness index. Clearness index is maximum 0.54 ± 0.15 in winter and minimum 0.42 ± 0.15 in summer. Clearness index varies large in summer but less in autumn. Figure 5 (c) shows seasonal variation of extinction coefficient. Extinction coefficient is maximum 0.63 ± 0.38 in spring and minimum 0.33 ± 0.19 in autumn. Extinction coefficient varies large in spring but less in autumn.

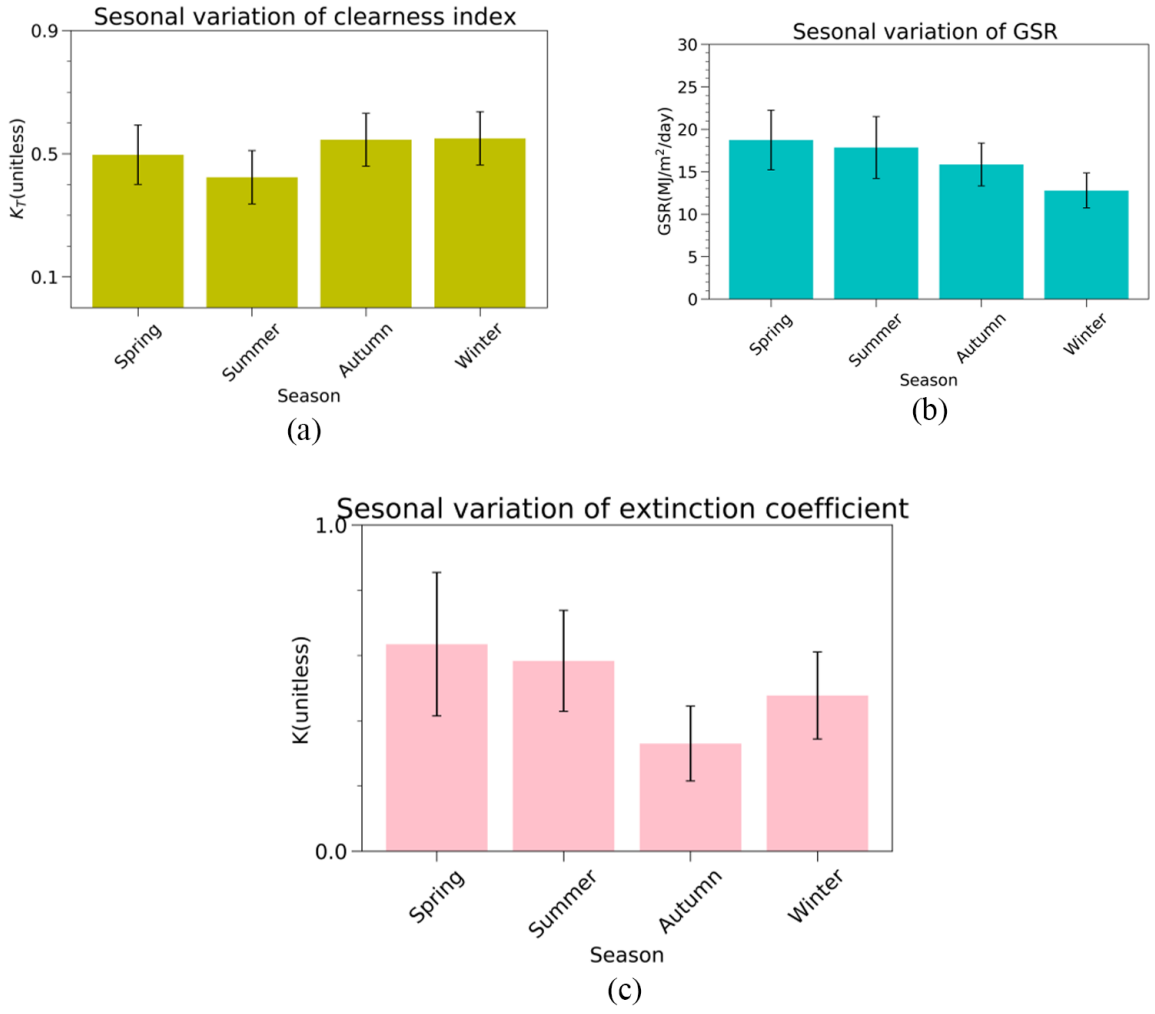

Figure 5. Seasonal variation of parameters (a) GSR, (b) Clearness index, and (C) Extinction coefficient

Temperature of hottest day is 34.2 °C in 160th of day of year and that of coldest day is 4.0 °C in 359th day of year. Figure 6 (a) show variation of GSR with maximum temperature. Correlation coefficient (r) is 0.89. Figure 6 (b) show variation of GSR with minimum temperature. Correlation coefficient (r) is 0.80. Annual mean of maximum and minimum temperature of Pokhara in 2015 are 27.32 ± 4.39 °C and 16.46 ± 5.40 °C respectively. Number of rainy days is 159 and total rain fall is 3727.2 mm. Figure 6 (c) show variation of GSR with rainfall. Correlation coefficient (r) is 0.54. Annual mean of relative humidity is $76.13 \pm 9.43\%$. Figure 6 (d) show variation of GSR with relative humidity (RH). Correlation coefficient (r) is -0.37. The precipitable water content (w) were estimated by using Leckner equation (1978) in terms of the relative humidity as a fraction of one (RH) and the ambient temperature in Kelvin (T). Figure 6 (e) show variation of GSR with water contend (w). Correlation coefficient(r) is 0.67. Annual mean od water contend is 3.42 ± 1.02 cm.

N is day length ($2\omega_s/15$) and n is sunshine hour. Annual mean of relative sunshine hour (n/N) is 0.59 ± 0.25.

Figure 6 (e) show variation of GSR with relative sunshine hour. Correlation coefficient (r) is −0.42. There is positive correlation of GSR with max. temp., min. temp., rainfall and water contend but negative correlation with relative humidity and relative sunshine hour.

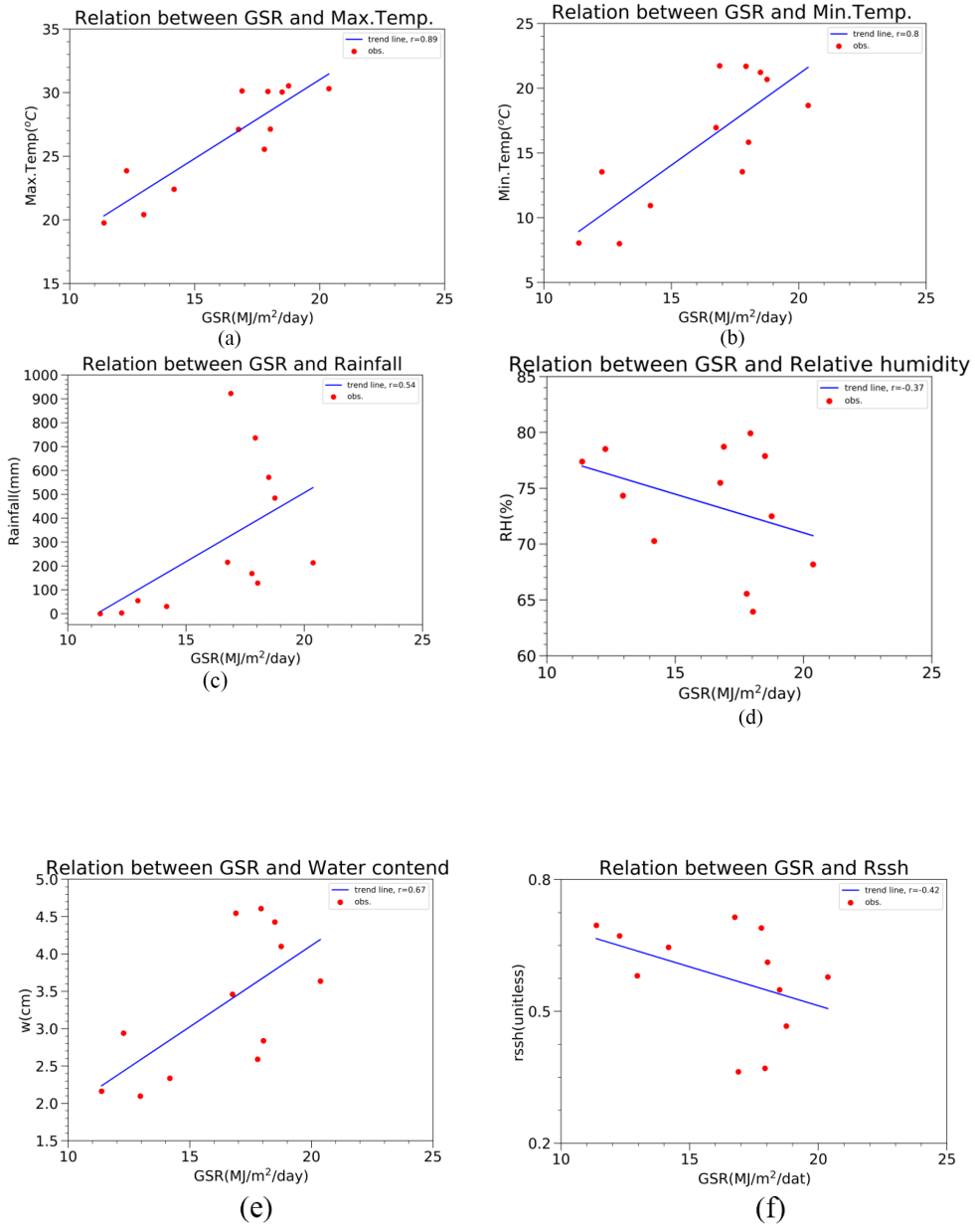

Figure 6. Relation of Linke turbidity with of parameters (a) Max. temperature, (b) Min. temperature, (C) Rainfall, (d) Relative humidity, (e) water contend and (f) Relative sunshine hour

4. Conclusions

Annual mean of GSR and clearness index for 2015 in Pokhara are 16.82 ± 0.24 MJ/m^2/ day and 0.51 ± 0.14 respectively. Annually 2.85×10^6 TJ (791 TWh) solar energy incidents in Pokhara in 2015. Yearly mean of extinction coefficient is 0.53 ± 0.31. About 50% of solar energy is absorbed by atmosphere.

5. Acknowledgements

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