

## Study of Linke Turbidity Factor on Solar Radiation over Jumla

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### Abstract

*Population growth, mechanization, and industrialization are the by product of human civilization and its resultant impacts goes to degrade the natural environment by the affecting of air-pollution and also associated with climatic change. Linke turbidity factor ( $L_T$ ) is an important parameter for assessing the air pollution at Jumla (Lat.:29.28° N, Long.: 82.16° E and Alt. 2300 masl). Because of the unavailability of spectral measurements data, a model has been used to estimate the Linke turbidity factor ( $T_L$ ) from broadband measurement of Global Solar radiation in 2012. The annual average solar insolation, clearness index ( $K_T$ ) and extinction coefficient ( $K$ ) are  $5.11 \pm 2.34 \text{ kWh/m}^2/\text{day}$ ,  $0.71 \pm 0.12$  and  $0.25 \pm 0.13$  respectively. Similarly, the annual average value of Linke turbidity factor ( $L_T$ ) and visibility  $1.97 \pm 0.47$  and  $28.09 \pm 21.08$  km are found. Finally it is found that there is strong relation between Linke turbidity factor and meteorological parameters i.e. relative humidity, temperature, water content, ozone and rain fall.*

**Keywords:** air mass, clearness index, extinction coefficient, Linke turbidity, meteorological parameters

### Introduction

Sun is the closest star from the Earth. Solar energy has been identified as the largest renewable resources on earth. This energy is passing through the atmosphere and at the same time some part of energy is scattered and some part is absorbed by the gas molecules. In addition, that this solar energy interacts with large particles of atmosphere such as water droplets, dust and aerosols. The attenuation of solar energy through a real atmosphere verse that through clean, dry atmosphere gives atmospheric turbidity. Study

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of atmospheric turbidity and its dependence on different meteorological parameters are important to study in agriculture, Hydrology, Climate change.

Nepal is a land-locked mountainous country with a large area of beautiful landscape situated between latitudes of 26.36<sup>0</sup> N to 30.45<sup>0</sup> N and longitudes of 80.06<sup>0</sup> E to 88.2<sup>0</sup> E. The elevation of the country ranges from 60.m to 8848.m within a span of 200 km from south to north and about 800 km from east to west (Majupuria T C ,1999).Nepal is situated between two giant industrial countries India and China and their industrial byproduct can directly affect the concentration of air pollutants and depletion of ozone concentration over Kathmandu Valley. That is why it is urgent to study the level of ground atmospheric ozone and other pollutants concentration at this mega city Kathmandu.

Nepal lies in sunbelt (latitude 15° to 35° ). Thus, it receives huge amount of solar radiation at the most of the parts of the country. It varies from 12.93MJ/m<sup>2</sup>/day to 22.48 MJ/m<sup>2</sup>/day. Annual average solar insolation and sunny days are 3.6- 6.2 kWh/m<sup>2</sup>/day and 300 respectively in Nepal (Shrestha et al. ,2003). The latest research result showed that there is about 4.23 kWh/m<sup>2</sup>/day solar radiation is found in Nepal (Poudyal, 2015). In fiscal year 2016/017, 538.6 TJ energy is consumed in which tradition fuel is 73%, commercial fuel is 25% and renewable energy is 2%( MoF, 2016/017). This data showed that there large amount foreign currency are inverted to import petroleum product. Petroleum fuel based vehicle make air pollution due to emission of carbon dioxide and other unburned gases. So study of atmospheric turbidity is required.

Jumla (Lat.29.28<sup>0</sup> N, Lon. 82.16<sup>0</sup> E and alt. 2300 m above sea label ) in the mid-western region ,covers area 2,531 sq. km is shown in Figure 1 .Population and population density are 108,921 and 43/sq.km. , respectively (CBS, 2011). This area lies in alpine climatic zone (Adhikari et al., 2013). The largest Rara Lake is situated at an altitude of 2,990 m above sea label. Large amount of energy will be required to promote tourism trade and other commercial activities in that area.).The annual average measured value of global solar radiation (GSR) is 19.90 ± 0.66MJ/m<sup>2</sup>/day was found in Jumla for the year 2011(KC et al. ,2016).



**Figure 1:**Map of Jumla [source:[www.lahistoriaconmapas.com/atlas/](http://www.lahistoriaconmapas.com/atlas/)]

**Methodology and Material**

The extraterrestrial solar radiation above the atmosphere ( $H_o$ ) is attenuated exponentially in atmosphere. According to Bougure-Lembert law (Iqbal ,1983),direct normal solar radiance on ground ( $H_g$ ), is

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

Where

$$H_o = I_{sc} \left[ 1 + 0.033 \cos \left( \frac{360}{365} n_d \right) \right] \cos \theta_z \dots \dots \dots (1)$$

$$\text{solar zenith angle}(\theta_z) = \cos^{-1}(\sin \delta \sin \phi + \cos \delta \cos \phi \cos \omega)$$

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

$I_{sc}$  = solar constant = 1367 W/m<sup>2</sup> (Duffie and Beckman ,2013)

$n_d$  = no. of day of year(DOY)

$\phi$  = latitude of the place

$K$  = extinction coefficient

$m$  = optical air mass

$\omega$ =solar hour angle

Clear ness index is

$$K_T = \frac{H_g}{H_o} = e^{-Km} \dots \dots \dots (2)$$

According to Bason (Bason ,2004)(Eftimie,2009), Linke turbidity( $L_T$ ) is

$$L_T = \frac{K}{0.8662 Dr(m)} \dots \dots \dots (3)$$

$Dr(m)$  is Rayleigh optical thickness as a function of the optical air mass( $m_a$ ).The optical air mass( $m_a$ ) is described by Kasten (1966) using the solar zenith angle ( $\theta_z$ ) ,altitude and atmospheric pressure(P) .

$$Dr(m)$$

$$= \frac{1}{6.6296 + 1.7513m_a - 0.1202m_a^2 + 0.0065m_a^3 - 0.00013m_a^4} \dots \dots \dots (4)$$

$$m_a = \frac{P}{101325 \cos \theta_z + 0.15(93.885 - \theta_z)^{-1.253}} \dots \dots \dots (5) \text{(Wang et al. ,2017)}$$

Global solar radiation (GSR) is the sum of direct or beam solar radiation and diffused solar radiation. This GSR and meteorological data are collected from Department of Hydrology and Meteorology (DHM), Government of Nepal for year 2012. The GSR is measured by CMP6 First Class Pyrometer (Kipp and Zonen,2008) shown in Figure 2.Total ozone column (TOC) data are collected from

[http://data.ceda.ac.uk/badc/toms/data/omi/ ]for the 2012.The Total Ozone Mapping Spectrometer (TOMS) is an instrument which built and operated by the National Aeronautics and Space Administration (NASA). Out of five TOMS instruments which were built, four entered successful in orbit. The Ozone Monitoring Instrument (OMI) has replaced Earth Probe TOMS since January 1, 2006.Solar insolation data are collected from [ https://power.larc.nasa.gov/data-access-viewer/].MATLAB 2015 software are used to analysis data and plot graph. In this research work, mean, standard deviation and correlation coefficient are used as statistical tool. Standard deviation is used as error bar in graph. Data are presented in for mean ± standard deviation.

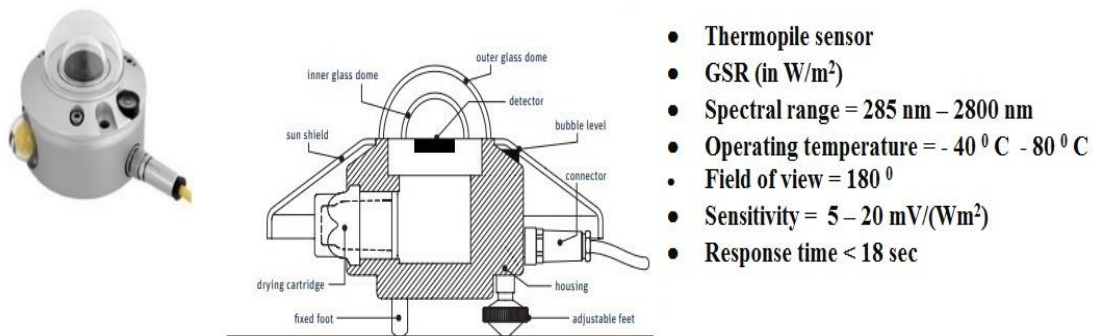


Figure 2: CMP6 pyranometer [source: [www.kippzonen.com](http://www.kippzonen.com)]

### Results and Discussion

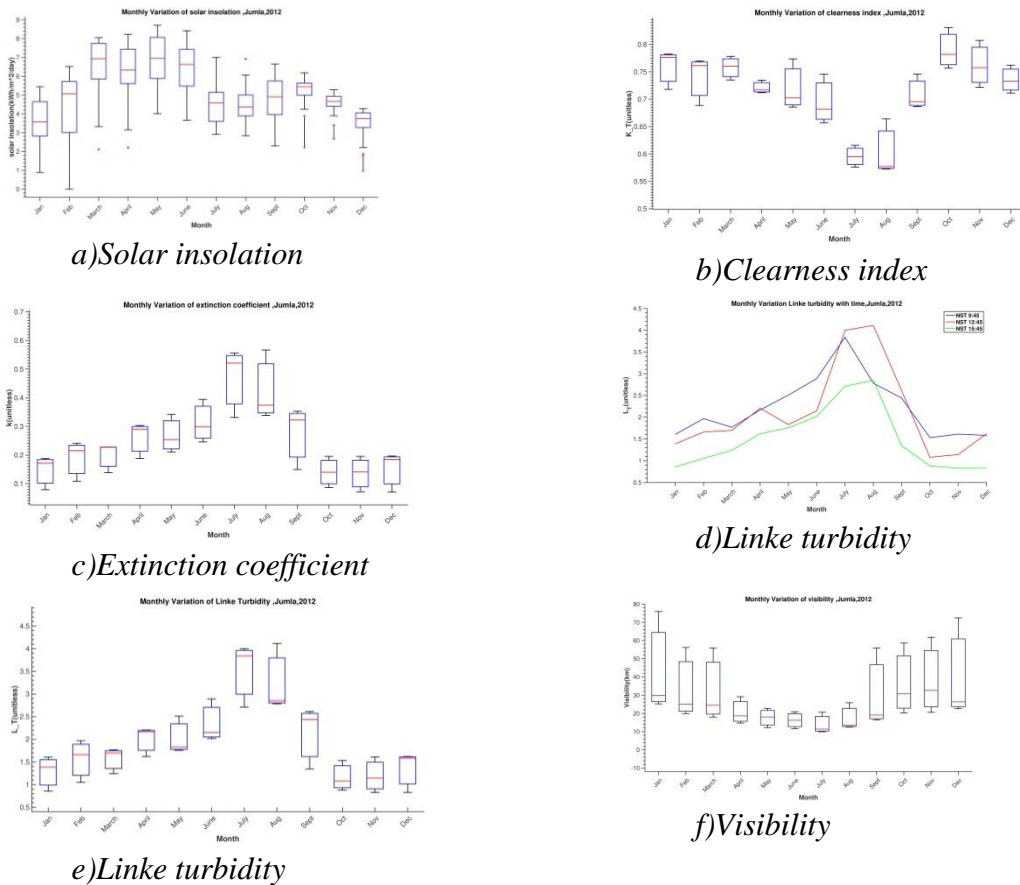
The monthly variation of solar insolation is shown in Figure 3(a).Solar insolation is maximum  $6.87 \pm 1.28 \text{ kWh/m}^2/\text{day}$  in May due to long day length and minimum  $3.46 \pm 0.80 \text{ kWh/m}^2/\text{day}$  in December due to small day length. The monthly variation of clearness index ( $K_T$ ) is shown in Figure 3(b).It is maximum  $0.78 \pm 0.06$  in October that means sky is clear where as minimum  $0.59 \pm 0.17$  in July due to rainy season. Similarly the solar insolation varies large in July and lesser in October due to the less cloudy at July and high cloudy fog in October. . Figure 3(c) shows the monthly variation of the extinction coefficient. It is maximum ( $0.47 \pm 0.24$ ) in July and minimum ( $0.13 \pm 0.04$ ) in November. It is due to the local weateher condition.

Figure 3(d) shows the monthly variation of Linke turbidity. Its maximum and minimum value of Linke turbidity  $3.83 \pm 1.87$  and  $1.53 \pm 1.14$  are found at NST 9:45 amin July and in October. It values due to local weather condition. .Maximum and

minimum value at 12:45 are  $4.12 \pm 2.24$  in August due to rain and  $1.07 \pm 0.47$  in October due to clear sky and  $7.30 \pm 1.21$  in August respectively. Maximum and minimum value at 15:45 are  $2.85 \pm 1.44$  in August and  $0.82 \pm 0.45$  in November respectively. Figure 3(e) shows monthly variation of Linke turbidity. Maximum value of Linke turbidity  $3.57 \pm 1.83$  is in July and minimum value  $1.16 \pm 0.37$  is in October. It varies less in October whereas large varies in July.

According Koshmeider's formula (Horvath, 1971), visibility in km is  $R = 3.912/K$ .....(6).

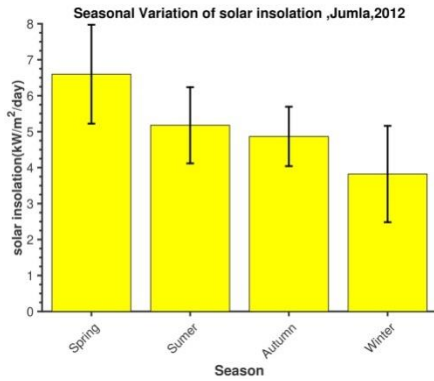
Figure 3(f) show the monthly variation of visibility. It is maximum  $43.51 \pm 20.81$  km in January and minimum  $12.57 \pm 9.33$  in July due to variation of the extinction coefficient



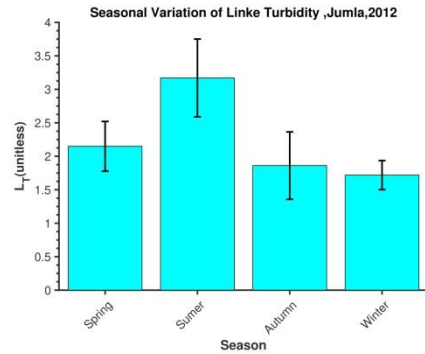
**Figure 3: Monthly variation of parameters**

Figure 4(a) shows the seasonal variation of solar insolation. Spring has large solar insolation  $6.59 \pm 1.37$  kWh/m<sup>2</sup>/day whereas winter has minimum value  $3.82 \pm 1.22$  kWh/m<sup>2</sup>/day. Figure 4(b) show the seasonal variation of Linke turbidity. Summer has

more Linke turbidity  $3.17 \pm 0.58$  than in winter Linke turbidity  $1.71 \pm 0.21$  due to the local weather condition.



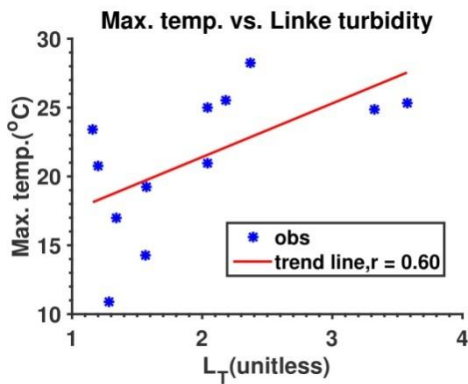
a) Solar insolation



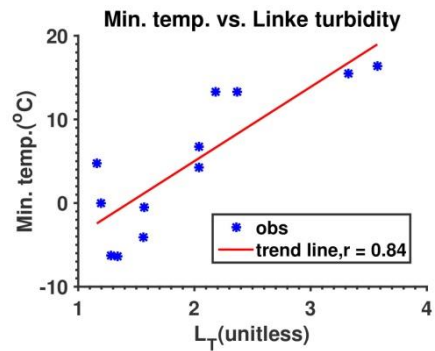
b) Linke turbidity

**Figure 4:** Seasonal variation of parameters

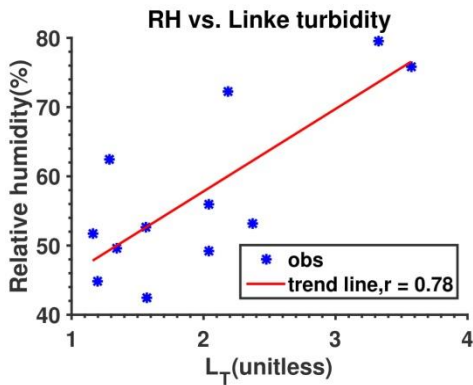
Figure 5(a) show correlation between maximum temperature and Linke turbidity. Correlation coefficient of them is 0.06. Annual mean of maximum temperature is  $21.29 \pm 5.17^{\circ}\text{C}$ . Figure 5(b) show correlation between minimum temperature and Linke turbidity. Correlation coefficient of them is 0.84. Annual mean of minimum temperature is  $4.74 \pm 8.41^{\circ}\text{C}$ . Figure 5(c) show correlation between relative humidity and Linke turbidity. Correlation coefficient of them is 0.78. Annual mean of relative humidity is  $57.47 \pm 12.21\%$ . Figure 5(d) show there is strong correlation ( $R^2=0.90$ ) between water content and Linke turbidity.



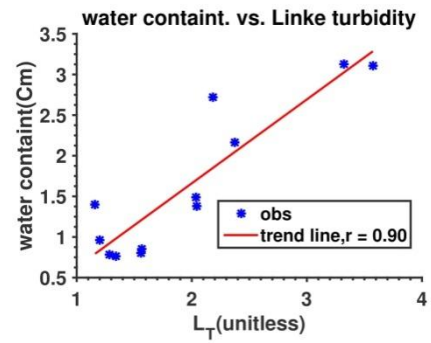
a) Maximum temperature



b) Minimum temperature



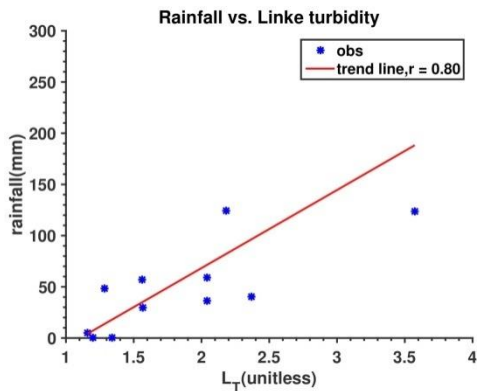
c) Relative humidity



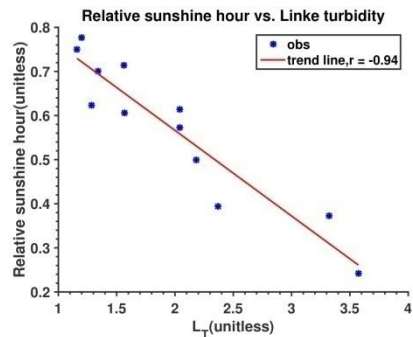
d) Water content

**Figure 5:** Relation of Linke turbidity with of parameters

Figure 6(a) shows correlation between rainfall and Linke turbidity. Correlation coefficient of them is 0.80. Annual rainfall 792.20 mm. Rainy day is 129. Where N is day length ( $2\cos^{-1}(-\tan\delta\tan\phi)/15$ ) and n is sunshine hour. Figure 6(b) show correlation between relative sunshine hour (n/N) and Linke turbidity. Correlation coefficient of them is -0.94. Annual mean of relative sunshine hour is  $0.57 \pm 0.16$ . Figure 6(c) shows correlation between Total Ozone Column (TOC) and Linke turbidity. Correlation coefficient, r of them is 0.81. Yearly mean of total ozone column (TOC) is  $250.42 \pm 8.60$  DU. There is positive correlation of Linke turbidity with maximum temperature minimum temperature, relative humidity, water content, rainfall and TOC. But there is negative correlation of Linke turbidity with relative sunshine hour.

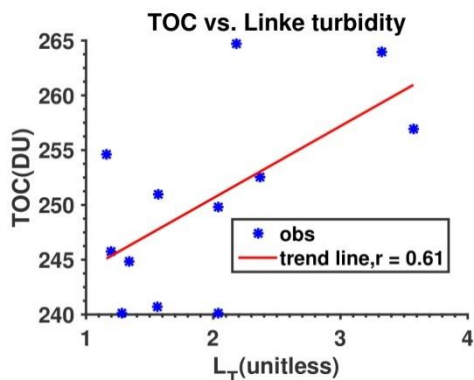


a) Rainfall



b) Relative sunshine hour





c)TOC

Figure 6: Relation of Linke turbidity with of parameters

### Conclusions

Annual average solar insolation in Jumla for year 2012 is  $5.11 \pm 2.34$  kW/m<sup>2</sup>/day was found which is very much significant to harvest the solar energy at that location. Likewise the yearly mean of clearness index  $0.71 \pm 0.12$  was found. It means that there is comparatively more clear days than other parts of Nepal. The mean of extinction coefficient  $0.25 \pm 0.13$  was found. Similarly the annual average of Linke turbidity are  $2.22 \pm 0.70$ ,  $2.12 \pm 1.00$  and  $1.49 \pm 0.71$  at 9:45, 12:45 and 15:45 NST respectively. Annual mean of Linke turbidity is  $1.97 \pm 0.47$ . Annual mean of visibility is  $28.09 \pm 21.08$  km. Relative sunshine hour affect negatively on Linke turbidity. Water content effects positively on Linke turbidity.

According to Wang (Wang et al. ,2017) ,Linke turbidity values is 3.3 to 7.7 in Wuhan (latitude 30°32'N, longitude 114°21'E and 30 m a.s.l.), Central China from 2010 to 2011. According to Laxmi Narain and S.N. Garg (Narain and Garg ,2013),on eight years (1993–2000) study, Linke turbidity for four cities of India are  $T_L = 7.5$  for Kolkata (26.93° N, 88.45° E,431 ma.s.l.) , $T_L = 4.6$  for Poona (18.53° N, 73.85° E,559 ma.s.l.) , $T_L = 6.4$  for Jaipur (26.93° N, 88.45° E,431 ma.s.l.) and  $T_L = 6.8$  for New Delhi (22.65° N,88.45° E, 216 ma.s.l.). The comparison of all results showed that the our values of Linke turbidity result are verymuch similar with major cities of the China and India. Finally it is concluded that Jumla is comparatively less polluted to compare as data of the different cities of India and China.

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