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# Computation of Solar Radiation for Various Climatic Regions of India

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**Abstract:** The historical weather datasets of different locations of India were complied for solar radiation, maximum and minimum temperatures and sunshine hours. Solar radiation is vital parameter, measured only at 35 meteorological stations all over the India. Our country, with diverse agro climatic zones, although covered by huge network of 550 Automatic Weather Stations but still faces the problem of acquisition of data related to key meteorological parameters. This paper aims to calibrate the coefficient of two equations: 1) Angstrom Prescott Equation [Rs= (a+b*n/N) Ra], which has input of sunshine hours data 2) Supit–Van Kappel Equation [H=Ho (a √Tmax-Tmin +b√ (1-Cw/8) +c), with the inputs of easily available temperature and cloud cover data, on the basis of 25 stations all over India representing diverse agro climatic zones. Extrapolation technique was used for the stations that are located within radius of 200 km. The relationship of solar radiation with square root of the difference in maximum and minimum temperatures was significant. The northern region showed greater range of predictability, i.e. 0.43 to 0.86 in winter; 0.19 to 0.82 in pre monsoon; 0.25 to 0.84 in monsoon and 0.40 to 0.89 in post monsoon which was statistically significant. The degree of prediction was higher for locations in northern and western regions, which was poor for all location in southern and eastern regions. The transmissivity of the atmosphere for global solar radiation under perfectly clear sky conditions is given as the sum of the regression coefficient a & b of Angstrom Prescott Equation. Also, the transmissivity of an overcast atmosphere is interpreted as the value of the intercept, a. From our regression constants (a = 0.23 and b = 0.38), it is observed that the atmospheric transmissivity under clear skies is 0.61. This result compares well with the value of 0.67 to 0.70 reported for the humid tropics [4]. The clear-sky transmissivity of most tropical regions in general seems to lie between 0.68 and 0.75 [1, 8].

**Keywords**: Solar radiation, Angstrom-Prescott (A-P), calibration, Supit–Van Kappel, agro climatic zone.

## INTRODUCTION

Solar radiation is the dominant, directly energy input the terrestrial ecosystem; and it affects all physical, chemical and biological processes. In order to understand the solar radiation as related to climate change, there is need to develop a simple method for the determination of this solar radiation from easily available datasets. The intensity of solar radiation varies temporally and spatially over locations along with a diurnal course of variation. Extra terrestrial radiation, at the top of the atmosphere, is primarily a function of latitude and day of the year [1-2]. The atmospheric composition, which happens to be highly dynamic diurnally as well as seasonally, influences the extent of absorption, reflection and transmission of the solar radiation (Photosynthetically active radiation). Accordingly the temperature also rises from an early morning minimum to afternoon.

Increased demand for radiation data has led to the development of numerous predictive methods ranging from simple empirical methods [3] to complex numerical models, depending on the available input data. Parameters used in such models include, air temperature, coldness, relative humidity, precipitation etc [4-5]. Interaction between solar irradiance and the highly variable atmospheric constituents is extremely complex and not well documented, particularly for cloudy sky [6]. The relationship of ratio of solar radiation to square root of temperature range with Julian day for various diverse locations could account for 30-64 percent variability, which was statistically significant [7]. There is a need to evaluate radiation from the dynamic temperature range as several locations in the country record temperatures and rainfall. Solar radiation, received during the daytime, is usually related to diurnal variation in temperature and thus range of temperature can predict the solar radiation. A useful relationship exists between solar irradiance and the range in daily temperature extremes [8].

Solar radiation arriving at the earth's surface is the fundamental energy source driving various crop growth processes like seed germination, leaf expansion, growth of stem and shoot, flowering, fruiting and essential thermal conditions for assimilation of nutrient and dry matter distribution. Solar radiation is also acts as facilitator for many applications in various natural earth processes, solar heating, cooking, drying and interior illumination of buildings are observed by geologist, solar engineers, architects, agriculturists and hydrologists. Despite its significance, solar radiation is not widely measured directly due to the cost, maintenance and calibration requirements of the equipments [9]. Even at stations where solar radiation is being observed having large gap of missing data or erratic values due to inconsistency, of measuring instruments and improper functioning of equipment [9-11]. However, sunshine hours the length of periods that the ground surface has irradiated by direct solar radiation has measured in most of station in India. WMO defined sunshine duration as the period during which direct solar radiation exceeds a threshold value of 120 watts per square meter ($W/m^2$) [12]. This value is equivalent to the level of solar irradiance shortly after sunrise or shortly before sunset in cloud-free conditions. Efforts have been made in past to estimate solar radiation in absence or failure of equipment using various meteorological parameters like sunshine [13, 14], ambient temperature and Relative humidity [15], rainfall [16], Temperature [17, 18], cloud cover [19], both temperature and precipitation based [16] inputs in empirical model. Reliable radiation information is needed to provide input data in crop growth modelling and a good data base on the radiation is thus needed to understand the crop-weather relations.

To overcome the problems we have tried in this paper to deduce solar radiation coefficients using 1) Angstrom Prescott Equation: sunshine based (2) Supit–Van Kappel Equation: temperature and cloud cover of 25 stations representing different agro climatic regions of India. However, the basic limitation of these regression models is that the accuracy and suitability is based on region specific and are highly depends upon the data from which the regression coefficient has been derived. A–P models do not physically account for radiative extinction processes in the atmosphere, and thus the model parameters have to be calibrated locally [20]. It is calibrated Angstrom–Prescott coefficients (a, b) under different time scales and their impacts in estimating global solar radiation in the basin [9]. He was used data from 1957 to 1978 to estimate hourly values of global diffuse and direct solar radiation [21]. By using regression analysis they derived Angstrom and Prescott coefficient for 16 stations in India [15]. He also worked out global radiation on ambient temperature and relative humidity for 14 Indian stations [22]. He was tested the applicability of substituted missing Rs data by the values measured in a nearby station [23]. The precision of the radiation estimated in this way decreased with increasing distance between the two stations: Rs decreased from 0.95 to 0.60 as the distance increased from 17 to 369 km.

## MATERIALS AND METHODS

### Meteorological data

National Data Centre (NDC) of India Meteorological Department, Pune provided the dataset of 25 stations that included daily observed global solar radiation ($MJ\ m^{-2} day^{-1}$) and sunshine duration (hours), cloud cover (octa) and temperature ($^{o}$ C). The data scrutiny was done using FORTRAN programme. Daily values for the required variables were available for 25 sites, for varying lengths of records between 1980 and 2012 in Table 1. The dataset of 25 sites were divided into four seasons (Winter, Pre-Monsoon, Monsoon and Post-monsoon).

### Agro climatic Sites

A total of 127 agro-climatic zones have been identified in India under Agricultural Meteorology Division of India Meteorological Department. The data of 25 stations covered across the India from North to south and East to west with altitudinal variation representing the diverse agroclimatic region. The different equations can be used in given below

### Angstrom-Prescott Equation

A linear regression relationship between the ratio of average daily global radiation to the corresponding value on a completely clear day and the ratio of average daily sunshine duration to the maximum possible sunshine duration was proposed [13]. To solve the difficulty in obtaining the clear sky radiation data [14]. He suggested using the extraterrestrial radiation to replace it, and the modification in this way led to the formation of the A–P equation:

$$R_s = R_a (a + bS)$$

Where,

$R_s$ and $R_a$ are the global and extraterrestrial solar radiation ($MJ\ m^{-2}\ d^{-1}$), respectively, a and b the A–P coefficients, the sum of which is the clear sky transmissivity, S= ratio of n and N the actual and maximum possible sunshine duration respectively.

**Hargreaves Equation**

He has suggested that the solar radiation (Rs) can be estimated from the difference between maximum and minimum air temperature using simple equation [23]. The model has also been validated for the Senegal River basin [24].

$$Rs=a.\ Ra\ (T_{max} - T_{min})^{0.5}$$

Where,

Rs and Ra are the global and extraterrestrial solar radiation (MJ $m^{-2}day^{-1}$), respectively, $T_{max}$ and $T_{min}$ are daily maximum and minimum air temperature in Celsius and a is an empirical coefficient, the value of a to be 0.16 for interior regions and 0.19 for coastal regions.

**Supit –Van Kappel Method**

The Angstrom Prescott method is easy to apply provided that the constant values are available, but unavailability of sunshine data in many stations restricts applicability of Angstrom and Prescott in many regions [19]. To estimate solar radiation without the sunshine data, He suggested the equation in which difference between maximum and minimum temperature was used [24]. Correlated cloud amount to global radiation in square root equation as the analysis of cloud cover and global radiation showed a non-linear relationship [19]. He proposed one empirical model which was used [19].

$$H=Ho\ [a\ \sqrt{T_{max}-T_{min}} + b\ \sqrt{(1-C_w/8)}] +c$$

Where,

$C_w$ is the mean of the total cloud cover of the daytime observations (octa) and a, b and c are empirical constants. Cloud-cover data are usually not available and are also less reliable, because the observation of cloudiness is somewhat subjective [25].

**MODELS AND CALIBRATION**

To calibrate and validate the Angstrom-Prescott model, historical records from each weather station were used for corroborated periods in which parallel information on incoming solar radiation and sunshine hours were available. The values of Ho and N were calculated according to the day of the year and the latitude of each locality [26]. The database was split into two parts. The first subset, 66% of the total data, was used to calibrate the model, using a linear regression equation to find the empirical coefficients (a&b) of the Angstrom-Prescott model and the remaining data were used to validate the model. The adequacy of the model was assessed by calculating the Pearson product moment correlation coefficient r, relative error and mean-square error (MSE). Analyses of residuals, as well as normal plots, were used to identify possible inadequacies in the models or problems in the data.The empirical coefficients show high variation in terms of spatial distribution;

**COEFFICIENT APPLICATION IN SAME AGRO CLIMATIC ZONE**

Spatial interpolation methods are employed to predict values at unknown locations from a set of point data where the property under investigation is known to exhibit spatial dependency [22].

**RESULTS AND DISCUSSION**

**LINEAR RELATIONSHIP DEVELOPED BETWEEN SOLAR RADIATIONS**

The calibration and validation from actual radiation from A-P formula showed in Table-2. The mean actual radiation is always greater than more station. The radiation R square is 0.92 in Jailsamer station in winter season and the value of RMS is 0.40 at Jaipur and the highest of SD is 1.84 at Santacruz and the highest 4.500 radiation at Chennai in Winter season.

Some station of calibration and validation of winter seasons the result showed in Table-2. The mean actual radiation was always less than estimated radiation but some stations are vis-versa. The result showed that winter season was less value of actual radiation and estimated radiation as compared with pre monsoon i.e. summer season due to temperature is maximum in the season. The maximum radiation value was 20.1 at Goa location and minimum radiation 11.7 MJ $m^{-2}day^{-1}$ in Deharadun locations and RMS value 0.40 in Jaipur and highest value 0.82 at Ranchi but pre monsoon is the maximum value 25.5 MJ $m^{-2}day^{-1}$ at Bhavnagar location and the lowest value of 19.6 MJ $m^{-2}day^{-1}$ at Portblair and RMS value 0.15 at Pune and highest value 0.79 at Deharadun location from pre-monsoon. The maximum mean actual value was 22.9 MJ $m^{-2}day^{-1}$and minimum value was 13.9 MJ $m^{-2}day^{-1}$ at Portblair location in monsoon season. The RMS value was lowest 0.694 at Jailsamer and highest value was 0.87 at Bhavnagar location in monsoon season in Table-2. The maximum actual value was 19.4 MJ $m^{-2}day^{-1}$at Bhavnagar and minimum value of radiation was 13.9 $MJm^{-2}$ with RMS is 0.60 to 0.90 in post monsoon season in Table-2.The standard deviation value of all four season was presented in Table-2.

**Table-1: Data of different stations with available years**

| S No | Station | Latitude (Degree Centigrade) | Longitude (Degree Centigrade) | Elevation (Meter) | Data period |
|---|---|---|---|---|---|
| 1 | Srinagar | 34.1 | 74.8 | 1693 | 1986-2010 |
| 2 | Dehradun | 30.33 | 78.3 | 670 | 1982-2010 |
| 3 | Patiala | 30.33 | 76.4 | 252 | 1993-2010 |
| 4 | Delhi | 28.63 | 77.2 | 229 | 1980-2011 |
| 5 | Jaipur | 26.91 | 75.8 | 429 | 1982-2010 |
| 6 | Jaislmer | 26.9 | 77.91 | 293 | 1982-2010 |
| 7 | Patna | 25.6 | 85.13 | 48 | 1985-2007 |
| 8 | Shillong | 25.57 | 91.88 | 1525 | 1980-2012 |
| 9 | Varanasi | 25.31 | 83 | 78 | 1982-2010 |
| 10 | Ranchi | 23.36 | 85.33 | 635 | 1994-2003 |
| 11 | Dum-Dum | 22.62 | 88.42 | 16 | 1982-2010 |
| 12 | Bhopal | 23.3 | 77.4 | 488 | 1982-2010 |
| 13 | Ahmadabad | 23.33 | 72.58 | 60 | 1980-2007 |
| 14 | Bhavnagar | 21.76 | 72.15 | 26 | 1980-2007 |
| 15 | Nagpur | 21.13 | 79.83 | 312 | 1980-2007 |
| 16 | Bhubaneswar | 20.26 | 85.83 | 45 | 1984-2004 |
| 17 | Pune | 18.5 | 73.86 | 568 | 1980-2009 |
| 18 | Santacruze | 18.55 | 72.54 | 11 | 1980-2008 |
| 19 | Vishakhapatnam | 18.11 | 83.4 | 60 | 1980-2007 |
| 20 | Hyderabad | 17.32 | 78.38 | 542 | 1980-2003 |
| 21 | Machillipatnam | 16.17 | 81.13 | 14 | 1985-2003 |
| 22 | Goa | 15.29 | 74.12 | 1167 | 1980-2009 |
| 23 | Chennai | 13.6 | 80.23 | 7 | 1980-2011 |
| 24 | Portblair | 11.61 | 92.72 | 16 | 1980-2007 |
| 25 | Kodiakonal | 10.23 | 77.48 | 2133 | 1980-2011 |

Source: Agricultural Meteorology Division of India Meteorological Department

**Table-2: Calibration of radiation ($MJm^{-2}day^{-1}$) in season using Angstrom- Prescott equation of different station of India**

| Station | | Mean radiation ($MJm^{-2}day^{-1}$) | SD | RMS |
|---|---|---|---|---|
| **Winter** | | | | |
| Patna | Actual | 14.1 | 4.2 | 0.51 |
| | Estimated | 14.1 | 3.0 | |
| Ranchi | Actual | 18.3 | 3.0 | 0.82 |
| | Estimated | 18.3 | 2.8 | |
| Dum-Dum | Actual | 14.3 | 3.2 | 0.73 |
| | Estimated | 14.3 | 2.7 | |
| Jaipur | Actual | 15.8 | 2.7 | 0.40 |
| | Estimated | 16.0 | 1.7 | |
| Jailsamer | Actual | 15.9 | 3.2 | 0.85 |
| | Estimated | 15.8 | 2.9 | |
| Bhopal | Actual | 17.3 | 3.3 | 0.43 |
| | Estimated | 17.3 | 2.5 | |
| Varanasi | Actual | 14.0 | 3.9 | 0.69 |
| | Estimated | 14.0 | 3.0 | |
| Deharadun | Actual | 11.7 | 3.6 | 0.79 |
| | Estimated | 11.7 | 3.0 | |
| Patiala | Actual | 12.2 | 4.3 | 0.74 |
| | Estimated | 12.2 | 3.7 | |
| Bhavnagar | Actual | 18.3 | 2.5 | 0.80 |
| | Estimated | 11.1 | 1.7 | |
| Santacruz | Actual | 17.4 | 2.5 | 0.66 |

| | | | | |
|---|---|---|---|---|
| | Estimated | 17.3 | 1.8 | |
| Goa | Actual | 20.1 | 2.6 | 0.71 |
| | Estimated | 20.0 | 2.1 | |
| Ahmadabad | Actual | 17.2 | 2.6 | 0.81 |
| | Estimated | 17.2 | 2.2 | |
| Pune | Actual | 18.2 | 2.7 | 0.75 |
| | Estimated | 18.1 | 2.2 | |
| Vishakhapatnam | Actual | 18.7 | 3.1 | 0.81 |
| | Estimated | 18.7 | 2.7 | |
| Chennai | Actual | 17.9 | 4.3 | 0.81 |
| | Estimated | 17.8 | 3.8 | |
| Portblair | Actual | 18.5 | 4.1 | 0.51 |
| | Estimated | 18.5 | 2.8 | |
| **Pre monsoon** | | | | |
| Patna | Actual | 22.2 | 3.5 | 0.56 |
| | Estimated | 22.2 | 2.9 | |
| Ranchi | Actual | 23.8 | 3.8 | 0.71 |
| | Estimated | 23.8 | 3.5 | |
| Dum-Dum | Actual | 20.6 | 4.0 | 0.73 |
| | Estimated | 20.6 | 3.5 | |
| Jaipur | Actual | 23.5 | 2.9 | 0.68 |
| | Estimated | 23.5 | 2.8 | |
| Jailsamer | Actual | 24.2 | 3.7 | 0.51 |
| | Estimated | 24.2 | 2.8 | |
| Bhopal | Actual | 23.9 | 3.9 | 0.57 |
| | Estimated | 24.0 | 3.2 | |
| Varanasi | Actual | 22.2 | 3.1 | 0.57 |
| | Estimated | 22.2 | 2.7 | |
| Deharadun | Actual | 20.8 | 4.6 | 0.79 |
| | Estimated | 20.8 | 4.4 | |
| Patiala | Actual | 21.8 | 4.7 | 0.72 |
| | Estimated | 21.8 | 4.3 | |
| Bhavnagar | Actual | 25.5 | 2.5 | 0.79 |
| | Estimated | 25.5 | 2.6 | |
| Santacruz | Actual | 23.6 | 2.6 | 0.51 |
| | Estimated | 23.6 | 1.8 | |
| Goa | Actual | 24.0 | 2.7 | 0.67 |
| | Estimated | 23.9 | 2.4 | |
| Ahmadabad | Actual | 24.4 | 2.9 | 0.50 |
| | Estimated | 24.4 | 2.5 | |
| Pune | Actual | 24.5 | 3.2 | 0.15 |
| | Estimated | 24.4 | 1.4 | |
| Vishakhapatnam | Actual | 23.4 | 2.8 | 0.66 |
| | Estimated | 23.4 | 2.4 | |
| Chennai | Actual | 23.3 | 3.1 | 0.66 |

| | | | | |
|---|---|---|---|---|
| | Estimated | 23.3 | 2.6 | |
| Portblair | Actual | 19.6 | 5.3 | 0.55 |
| | Estimated | 19.6 | 4.0 | |
| **Monsoon** | | | | |
| Patna | Actual | 17.2 | 5.8 | 0.76 |
| | Estimated | 17.2 | 5.0 | |
| Ranchi | Actual | 16.2 | 5.2 | 0.83 |
| | Estimated | 16.2 | 4.7 | |
| Dum-Dum | Actual | 15.9 | 5.3 | 0.72 |
| | Estimated | 15.9 | 4.5 | |
| Jaipur | Actual | 20.7 | 4.5 | 0.71 |
| | Estimated | 20.7 | 3.9 | |
| Jailsamer | Actual | 22.9 | 3.5 | 0.64 |
| | Estimated | 22.8 | 2.8 | |
| Bhopal | Actual | 16.5 | 6.6 | 0.78 |
| | Estimated | 16.6 | 5.9 | |
| Varanasi | Actual | 17.6 | 5.5 | 0.76 |
| | Estimated | 17.6 | 4.9 | |
| Deharadun | Actual | 15.9 | 5.6 | 0.76 |
| | Estimated | 15.9 | 5.0 | |
| Patiala | Actual | 19.2 | 6.0 | 0.70 |
| | Estimated | 19.2 | 5.2 | |
| Bhavnagar | Actual | 18.5 | 5.1 | 0.87 |
| | Estimated | 18.4 | 5.1 | |
| Santacruz | Actual | 16.1 | 5.9 | 0.71 |
| | Estimated | 16.1 | 4.9 | |
| Goa | Actual | 16.8 | 5.8 | 0.81 |
| | Estimated | 16.8 | 5.3 | |
| Ahmadabad | Actual | 17.8 | 5.4 | 0.83 |
| | Estimated | 17.7 | 4.9 | |
| Pune | Actual | 17.5 | 5.0 | 0.82 |
| | Estimated | 17.5 | 4.6 | |
| Vishakhapatnam | Actual | 17.6 | 6.2 | 0.80 |
| | Estimated | 17.5 | 5.6 | |
| Chennai | Actual | 19.4 | 4.6 | 0.80 |
| | Estimated | 19.4 | 4.1 | |
| Portblair | Actual | 13.9 | 5.6 | 0.66 |
| | Estimated | 13.9 | 4.6 | |
| **Post monsoon** | | | | |
| Patna | Actual | 15.2 | 3.4 | 0.74 |
| | Estimated | 15.2 | 2.8 | |
| Ranchi | Actual | 17.3 | 4.0 | 0.76 |
| | Estimated | 17.2 | 3.4 | |
| Dum-Dum | Actual | 15.2 | 3.6 | 0.80 |

| | | | | |
|---|---|---|---|---|
| | Estimated | 15.1 | 3.1 | |
| Jaipur | Actual | 17.3 | 2.5 | 0.79 |
| | Estimated | 17.3 | 2.1 | |
| Jailsamer | Actual | 18.1 | 2.2 | 0.85 |
| | Estimated | 18.1 | 1.8 | |
| Bhopal | Actual | 18.3 | 3.3 | 0.60 |
| | Estimated | 18.2 | 2.3 | |
| Varanasi | Actual | 15.4 | 3.0 | 0.79 |
| | Estimated | 16.7 | 2.5 | |
| Deharadun | Actual | 15.1 | 3.1 | 0.77 |
| | Estimated | 15.0 | 2.4 | |
| Patiala | Actual | 13.9 | 3.5 | 0.80 |
| | Estimated | 13.8 | 2.9 | |
| Bhavnagar | Actual | 19.4 | 2.7 | 0.90 |
| | Estimated | 19.4 | 2.4 | |
| Santacruz | Actual | 17.6 | 2.9 | 0.71 |
| | Estimated | 17.5 | 2.2 | |
| Goa | Actual | 19.3 | 3.5 | 0.78 |
| | Estimated | 19.3 | 3.0 | |
| | Actual | 17.8 | 2.7 | 0.78 |
| Ahmadabad | Estimated | 17.8 | 2.3 | |
| Pune | Actual | 18.6 | 3.3 | 0.86 |
| | Estimated | 18.5 | 2.9 | |
| Vishakhapatnam | Actual | 18.4 | 4.6 | 0.88 |
| | Estimated | 18.4 | 4.3 | |
| Chennai | Actual | 15.5 | 5.5 | 0.82 |
| | Estimated | 14.7 | 4.4 | |
| Portblair | Actual | 15.8 | 5.2 | 0.66 |
| | Estimated | 15.7 | 4.1 | |

**Table-3: Calibration of radiation ($MJm^{-2}day^{-1}$) in season using Supit–Van Kappel of different station of India**

| Station | | Mean radiation ($MJm^{-2}day^{-1}$) | SD | RMS |
|---|---|---|---|---|
| | | **Winter** | | |
| Patna | Actual | 14.1 | 4.2 | |
| | Estimated | 14.1 | 3.3 | 0.61 |
| Ranchi | Actual | 18.3 | 3.0 | |
| | Estimated | 18.3 | 2.3 | 0.61 |
| Dum-Dum | Actual | 14.3 | 3.2 | |
| | Estimated | 14.3 | 2.4 | 0.54 |
| Jaipur | Actual | 15.8 | 2.7 | |
| | Estimated | 15.8 | 1.9 | 0.53 |
| Jailsamer | Actual | 15.9 | 3.2 | |
| | Estimated | 15.5 | 2.2 | 0.72 |
| Bhopal | Actual | 17.3 | 3.3 | |
| | Estimated | 17.3 | 1.8 | 0.30 |
| Varanasi | Actual | 14.0 | 3.9 | |
| | Estimated | 14.0 | 3.2 | 0.68 |
| Deharadun | Actual | 11.7 | 3.6 | |
| | Estimated | 11.7 | 3.1 | 0.74 |
| Patiala | Actual | 12.2 | 4.3 | |
| | Estimated | 12.2 | 3.4 | 0.61 |
| Bhavnagar | Actual | 18.3 | 2.5 | |
| | Estimated | 18.3 | 2.1 | 0.70 |

| | | | | |
|---|---|---|---|---|
| Santacruz | Actual | 17.4 | 2.5 | |
| | Estimated | 17.4 | 1.6 | 0.43 |
| Goa | Actual | 20.1 | 2.6 | |
| | Estimated | 20.1 | 1.8 | 0.45 |
| Ahmadabad | Actual | 17.2 | 2.6 | |
| | Estimated | 17.2 | 2.1 | 0.64 |
| Pune | Actual | 18.2 | 2.7 | |
| | Estimated | 18.2 | 2.1 | 0.64 |
| Vishakhapatnam | Actual | 18.7 | 3.1 | |
| | Estimated | 18.7 | 2.3 | 0.57 |
| Chennai | Actual | 17.9 | 4.3 | 0.67 |
| | Estimated | 17.9 | 3.6 | |
| **Pre monsoon** | | | | |
| Patna | Actual | 22.2 | 3.47 | |
| | Estimated | 22.2 | 2.18 | 0.40 |
| Ranchi | Actual | 23.77 | 3.81 | |
| | Estimated | 23.77 | 2.64 | 0.48 |
| Dum -Dum | Actual | 20.64 | 3.97 | |
| | Estimated | 20.64 | 2.40 | 0.36 |
| Jaipur | Actual | 23.50 | 2.87 | |
| | Estimated | 23.50 | 1.91 | 0.45 |
| Jailsamer | Actual | 24.20 | 3.73 | |
| | Estimated | 24.80 | 2.59 | 0.46 |
| Bhopal | Actual | 16.55 | 6.64 | |
| | Estimated | 16.55 | 5.48 | 0.68 |
| Varanasi | Actual | 22.21 | 3.07 | |
| | Estimated | 22.21 | 2.04 | 0.44 |
| Deharadun | Actual | 20.79 | 4.63 | |
| | Estimated | 20.79 | 3.76 | 0.66 |
| Patiala | Actual | 21.80 | 4.66 | |
| | Estimated | 21.80 | 3.44 | 0.54 |
| Bhavnagar | Actual | 25.47 | 2.54 | |
| | Estimated | 25.47 | 1.90 | 0.56 |
| Santacruz | Actual | 23.77 | 3.81 | |
| | Estimated | 23.77 | 2.64 | 0.48 |
| Goa | Actual | 23.97 | 2.74 | |
| | Estimated | 23.97 | 1.46 | 0.29 |
| Ahmadabad | Actual | 24.41 | 2.86 | |
| | Estimated | 24.39 | 1.99 | 0.48 |
| Pune | Actual | 25.71 | 55.49 | |
| | Estimated | 25.80 | 55.55 | 1.00 |
| Vishakhapatnam | Actual | 23.38 | 2.79 | |
| | Estimated | 23.38 | 1.35 | 0.27 |
| Chennai | Actual | 23.35 | 3.08 | 0.38 |
| | Estimated | 23.35 | 1.89 | |
| **Monsoon** | | | | |
| Patna | Actual | 17.2 | 5.8 | |
| | Estimated | 17.2 | 4.3 | 0.5 |
| Ranchi | Actual | 16.2 | 5.2 | |
| | Estimated | 16.2 | 3.6 | 0.5 |
| Dum-Dum | Actual | 15.9 | 5.3 | |
| | Estimated | 15.9 | 3.7 | 0.5 |
| Jaipur | Actual | 20.7 | 4.5 | |
| | Estimated | 20.7 | 2.9 | 0.4 |
| Jailsamer | Actual | 22.9 | 3.5 | |
| | Estimated | 22.9 | 2.4 | 0.5 |
| Bhopal | Actual | 23.9 | 3.9 | 0.4 |

| | | | | |
|---|---|---|---|---|
| | Estimated | 23.9 | 2.4 | |
| Varanasi | Actual | 17.6 | 5.5 | |
| | Estimated | 17.6 | 4.2 | 0.6 |
| Deharadun | Actual | 15.9 | 5.6 | |
| | Estimated | 15.9 | 4.8 | 0.7 |
| Patiala | Actual | 19.2 | 6.0 | |
| | Estimated | 19.2 | 4.8 | 0.6 |
| Bhavnagar | Actual | 18.5 | 5.1 | |
| | Estimated | 18.5 | 4.1 | 0.6 |
| Santacruz | Actual | 16.1 | 5.9 | |
| | Estimated | 16.1 | 4.6 | 0.6 |
| Goa | Actual | 16.8 | 5.8 | |
| | Estimated | 16.8 | 4.3 | 0.6 |
| Ahmadabad | Actual | 17.8 | 5.4 | |
| | Estimated | 17.7 | 4.4 | 0.7 |
| Pune | Actual | 17.5 | 5.0 | |
| | Estimated | 17.5 | 3.9 | 0.6 |
| Vishakhapatnam | Actual | 17.6 | 6.2 | |
| | Estimated | 17.6 | 4.9 | 0.6 |
| Chennai | Actual | 19.4 | 4.6 | 0.6 |
| | Estimated | 19.4 | 3.5 | |
| **Post monsoon** | | | | |
| Patna | Actual | 15.2 | 3.45 | |
| | Estimated | 15.2 | 2.50 | 0.52 |
| Ranchi | Actual | 17.3 | 3.95 | |
| | Estimated | 17.3 | 3.05 | 0.60 |
| Dum-Dum | Actual | 15.2 | 3.62 | |
| | Estimated | 15.2 | 2.53 | 0.49 |
| Jaipur | Actual | 17.3 | 2.54 | |
| | Estimated | 17.3 | 1.89 | 0.55 |
| Jailsamer | Actual | 18.1 | 2.19 | |
| | Estimated | 18.1 | 1.88 | 0.73 |
| Bhopal | Actual | 18.3 | 3.28 | |
| | Estimated | 18.3 | 2.08 | 0.40 |
| Varanasi | Actual | 15.4 | 3.04 | |
| | Estimated | 15.4 | 2.04 | 0.45 |
| Deharadun | Actual | 15.1 | 3.11 | |
| | Estimated | 15.1 | 2.75 | 0.78 |
| Patiala | Actual | 13.9 | 3.54 | |
| | Estimated | 13.9 | 2.81 | 0.63 |
| Bhavnagar | Actual | 19.4 | 2.69 | |
| | Estimated | 19.4 | 2.29 | 0.73 |
| Santacruz | Actual | 17.6 | 2.89 | |
| | Estimated | 17.6 | 1.90 | 0.49 |
| Goa | Actual | 19.4 | 3.49 | |
| | Estimated | 19.4 | 2.05 | 0.35 |
| Ahmadabad | Actual | 17.8 | 2.72 | |
| | Estimated | 17.8 | 2.09 | 0.33 |
| Pune | Actual | 18.6 | 3.26 | |
| | Estimated | 18.4 | 2.27 | 0.49 |
| Vishakhapatnam | Actual | 18.4 | 4.64 | |
| | Estimated | 18.4 | 3.74 | 0.65 |
| Chennai | Actual | 15.5 | 5.46 | 0.62 |
| | Estimated | 15.5 | 4.29 | |

**Table-4: The Angstrom- Prescott coefficient (a, b) calibrated through daily values data**

| S No | Station | Winter | | | Pre-monsoon | | | Monsoon | | | Post Monsoon | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | a | b | $R^2$ | a | b | $R^2$ | a | b | $R^2$ | a | b | $R^2$ |
| 1 | Srinagar | 0.36 | 0.511 | 0.77 | 0.284 | 0.561 | 0.825 | 0.263 | 0.515 | 0.729 | 0.248 | 0.505 | |
| 2 | Dehradun | 0.244 | 0.414 | 0.960 | 0.273 | 0.467 | 0.939 | 0.23 | 0.465 | 0.466 | 0.297 | 0.382 | 0.830 |
| 3 | Patiala | 0.265 | 0.467 | 0.915 | 0.31 | 0.448 | 0.876 | 0.263 | 0.475 | 0.900 | 0.269 | 0.431 | 0.492 |
| 4 | Delhi | 0.269 | 0.489 | 0.901 | 0.32 | 0.47 | 0.820 | 0.28 | 0.48 | 0.863 | 0.246 | 0.499 | 0.663 |
| 5 | Jaipur | 0.286 | 0.456 | 0.666 | 0.355 | 0.372 | 0.855 | 0.292 | 0.416 | 0.863 | 0.284 | 0.441 | 0.895 |
| 6 | Jaislmer | 0.296 | 0.461 | 0.975 | 0.399 | 0.332 | 0.835 | 0.368 | 0.345 | 0.876 | 0.314 | 0.427 | 0.963 |
| 7 | Patna | 0.394 | 0.25 | 0.783 | 0.302 | 0.432 | 0.883 | 0.252 | 0.486 | 0.908 | 0.241 | 0.47 | 0.901 |
| 8 | Shillong | 0.226 | 0.564 | 0.920 | 0.209 | 0.600 | 0.904 | 0.271 | 0.523 | 0.831 | 0.253 | 0.564 | 0.881 |
| 9 | Varanasi | 0.288 | 0.362 | 0.924 | 0.282 | 0.417 | 0.863 | 0.24 | 0.426 | 0.925 | 0.274 | 0.453 | 0.872 |
| 10 | Ranchi | 0.258 | 0.54 | 0.946 | 0.246 | 0.545 | 0.899 | 0.252 | 0.512 | 0.923 | 0.249 | 0.512 | 0.698 |
| 11 | Dum-Dum | 0.335 | 0.328 | 0.868 | 0.282 | 0.447 | 0.818 | 0.263 | 0.482 | 0.885 | 0.267 | 0.421 | 0.902 |
| 12 | Bhopal | 0.246 | 0.488 | 0.931 | 0.227 | 0.547 | 0.778 | 0.225 | 0.541 | 0.936 | 0.305 | 0.412 | 0.875 |
| 13 | Ahmadabad | 0.281 | 0.438 | 0.925 | 0.341 | 0.402 | 0.764 | 0.259 | 0.462 | 0.905 | 0.251 | 0.456 | 0.896 |
| 14 | Bhavnagar | 0.030 | 0.428 | 0.881 | 0.321 | 0.429 | 0.850 | 0.286 | 0.459 | 0.920 | 0.29 | 0.435 | 0.931 |
| 15 | Nagpur | 0.224 | 0.502 | 0.868 | 0.274 | 0.46 | 0.694 | 0.24 | 0.515 | 0.829 | 0.27 | 0.451 | 0.817 |
| 16 | Bhubaneswar | 0.324 | 0.398 | 0.859 | 0.246 | 0.503 | 0.662 | 0.258 | 0.453 | 0.860 | 0.295 | 0.409 | 0.945 |
| 17 | Pune | 0.303 | 0.395 | 0.906 | 0.568 | 0.106 | 0.687 | 0.287 | 0.454 | 0.914 | 0.274 | 0.453 | 0.925 |
| 18 | Santacruze | 0.36 | 0.299 | 0.875 | 0.395 | 0.308 | 0.423 | 0.27 | 0.496 | 0.868 | 0.323 | 0.341 | 0.861 |
| 19 | Vishakhapatnam | 0.299 | 0.417 | 0.792 | 0.351 | 0.394 | 0.858 | 0.278 | 0.499 | 0.894 | 0.263 | 0.474 | 0.947 |
| 20 | Hyderabad | 0.242 | 0.480 | 0.858 | 0.306 | 0.448 | 0.891 | 0.296 | 0.441 | 0.877 | 0.247 | 0.455 | 0.886 |
| 21 | Machillipatnam | 0.248 | 0.441 | 0.77 | 0.28 | 0.397 | 0.83 | 0.267 | 0.462 | 0.85 | 0.255 | 0.425 | 0.81 |
| 22 | Goa | 0.315 | 0.406 | 0.871 | 0.309 | 0.429 | 0.858 | 0.258 | 0.519 | 0.906 | 0.299 | 0.426 | 0.926 |
| 23 | Chennai | 0.245 | 0.452 | 0.915 | 0.298 | 0.431 | 0.432 | 0.312 | 0.409 | 0.901 | 0.227 | 0.438 | 0.872 |
| 24 | Portblair | 0.308 | 0.365 | 0.882 | 0.26 | 0.439 | 0.887 | 0.248 | 0.488 | 0.740 | 0.257 | 0.425 | 0.883 |
| 25 | Jodhpur | 0.315 | 0.405 | 0.865 | 0.331 | 0.389 | 0.859 | 0.287 | 0.409 | 0.869 | 0.275 | 0.442 | 0.879 |

**Table-5: The Supit–Van Kappel coefficients (a, b, c) calibrated through daily values data**

| S No | Station | Winter | | | | Pre-monsoon | | | | Monsoon | | | | Post Monsoon | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | a | b | c | $R^2$ | a | b | c | $R^2$ | a | b | c | $R^2$ | a | b | c | $R^2$ |
| 1 | Srinagar | 0.012 | 0.433 | 5.439 | 0.434 | -.001 | 0.492 | 9.434 | 0.205 | 0.017 | 0.444 | 7.216 | 0.651 | 0.061 | 0.391 | 0.913 | 0.781 |
| 2 | Deharadun | 0.129 | 0.242 | -2.848 | 0.481 | 0.087 | 0.279 | 1.413 | 0.519 | 0.101 | 0.273 | -0.68 | 0.579 | 0.142 | 0.267 | -3.857 | 0.893 |
| 3 | Patiala | 0.037 | 0.457 | 1.688 | 0.255 | 0.023 | 0.379 | 7.531 | 0.187 | 0.014 | 0.455 | 6.513 | 0.730 | 0.048 | 0.381 | 1.961 | 0.390 |
| 4 | Delhi | 0.084 | 0.428 | -1.22 | 0.778 | 0.032 | 0.342 | 8.362 | 0.724 | 0.021 | 0.479 | 7.274 | 0.832 | 0.079 | 0.353 | -0.238 | 0.667 |
| 5 | Jaipur | 0.068 | 0.290 | 3.840 | 0.803 | 0.068 | 0.170 | 8.673 | 0.677 | 0.061 | 0.222 | 7.763 | 0.597 | 0.090 | 0.213 | 3.137 | 0.842 |
| 6 | Jailsamer | 0.093 | 0.357 | 0.252 | 0.475 | 0.055 | 0.298 | 6.854 | 0.680 | 0.053 | 0.259 | 7.607 | 0.249 | 0.100 | 0.290 | 0.535 | 0.837 |
| 7 | Patna | 0.092 | 0.379 | -2.306 | 0.551 | 0.050 | 0.263 | 6.914 | 0.451 | 0.033 | 0.469 | 4.664 | 0.506 | 0.100 | 0.322 | -1.402 | 0.693 |
| 8 | Shillong | 0.035 | 0.454 | 4.472 | 0.620 | 0.595 | 0.438 | 2.802 | 0.733 | 0.073 | 0.308 | 4.043 | 0.540 | 0.032 | 0.466 | 5.059 | 0.437 |
| 9 | Varanasi | 0.111 | 0.283 | -2.664 | 0.745 | 0.053 | 0.198 | 8.489 | 0.577 | 0.034 | 0.396 | 5.980 | 0.642 | 0.061 | 0.254 | 3.328 | 0.685 |
| 10 | Ranchi | 0.070 | 0.385 | 2.415 | 0.777 | 0.029 | 0.398 | 7.967 | 0.748 | 0.058 | 0.451 | 3.142 | 0.639 | 0.093 | 0.389 | 0.119 | 0.775 |
| 11 | Dum-Dum | 0.062 | 0.309 | 1.669 | 0.715 | 0.025 | 0.270 | 10.68 | 0.501 | 0.021 | 0.479 | 7.274 | 0.619 | 0.033 | 0.318 | 5.803 | 0.660 |
| 12 | Bhopal | 0.043 | 0.284 | 6.545 | 0.835 | 0.041 | 0.466 | 4.554 | 0.820 | 0.049 | 0.330 | 6.601 | 0.790 | 0.075 | 0.257 | 4.083 | 0.698 |
| 13 | Ahmadabad | 0.081 | 0.303 | 1.671 | 0.782 | 0.047 | 0.262 | 8.945 | 0.638 | 0.045 | 0.421 | 4.373 | 0.847 | 0.038 | 0.344 | 5.114 | 0.616 |
| 14 | Bhavnagar | 0.084 | 0.307 | 1.981 | 0.805 | 0.044 | 0.304 | 8.822 | 0.563 | 0.044 | 0.374 | 4.956 | 0.833 | 0.042 | 0.400 | 4.209 | 0.703 |
| 15 | Nagpur | 0.081 | 0.307 | 1.012 | 0.805 | 0.044 | 0.297 | 7.666 | 0.712 | 0.361 | 0.511 | 4.210 | 0.80 | 0.044 | 0.317 | 5.754 | 0.798 |
| 16 | Bhubaneswar | 0.116 | 0.196 | 0.402 | 0.439 | 0.046 | 0.312 | 6.441 | 0.306 | 0.052 | 0.480 | 2.183 | 0.774 | 0.142 | 0.266 | -3.856 | 0.823 |
| 17 | Pune | 0.146 | 0.097 | 2.859 | 0.779 | 0.266 | -.004 | 17.19 | 0.590 | 0.415 | 0.065 | 5.215 | 0.668 | 0.194 | 0.081 | 5.245 | 0.636 |
| 18 | Santacruze | 0.038 | 0.291 | 6.015 | 0.662 | -0.05 | 0.222 | 22.52 | 0.477 | 0.017 | 0.601 | 5.972 | 0.784 | 0.009 | 0.310 | 9.205 | 0.526 |
| 19 | Vishakhapatnam | 0.043 | 0.305 | 7.504 | 0.60 | -0.02 | 0.227 | 19.06 | 0.513 | 0.015 | 0.632 | 5.781 | 0.636 | 0.038 | 0.463 | 5.279 | 0.810 |
| 20 | Hyderabad | 0.178 | 0.253 | -0.09 | 0.68 | 0.026 | 0.263 | 12.69 | 0.712 | 0.045 | 0.521 | 4.222 | 0.60 | 0.094 | 0.329 | 0.733 | 0.794 |
| 21 | Machillipatnam | 0.084 | 0.307 | 3.184 | 0.668 | 0.003 | 0.376 | 10.59 | 0.681 | 0.017 | 0.513 | 7.556 | 0.582 | 0.008 | 0.436 | 7.27 | 0.622 |
| 22 | Goa | 0.1 | 0.1 | 5.3 | 0.6 | 0.0 | 0.1 | 16. | 0.4 | 0.0 | 0.5 | 7.6 | 0.6 | 0.0 | 0.2 | 11.7 | 0.4 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 02 | 72 | 60 | 08 | 29 | 85 | 11 | 83 | 39 | 37 | 89 | 39 | 30 | 56 | 55 | 46 |
| 23 | Chennai | 0.1<br>03 | 0.3<br>60 | 0.5<br>99 | 0.8<br>53 | 0.0<br>01 | 0.3<br>04 | 15.<br>20 | 0.6<br>37 | 0.0<br>33 | 0.4<br>23 | 8.3<br>73 | 0.7<br>45 | 0.0<br>65 | 0.4<br>93 | 1.62<br>5 | 0.7<br>48 |
| 24 | Portblair | 0.0<br>50 | 0.3<br>70 | 6.5<br>82 | 0.7<br>4 | 0.0<br>28 | 0.4<br>28 | 7.1<br>00 | 0.4<br>76 | -<br>0.0<br>3 | 0.5<br>43 | 10.<br>62 | 0.4<br>57 | 0.0<br>02 | 0.5<br>47 | 7.17<br>4 | 0.5<br>38 |
| 25 | Jodhpur | 0.0<br>80 | 0.2<br>62 | 2.4<br>28 | 0.8<br>59 | 0.0<br>70 | 0.1<br>71 | 7.7<br>28 | 0.7<br>45 | 0.0<br>51 | 0.3<br>21 | 6.2<br>55 | 0.7<br>71 | 0.0<br>74 | 0.2<br>71 | 2.92<br>3 | 0.8<br>55 |

The Supit-Van Kappel equation showed mean actual and estimated radiation value, standard deviation and RMS value in also Table-3. The mean actual and estimated radiation and standard deviation was the value and RMS value in Table-3. The mean radiation value was ranged between 11.7 at Deharadun to 20.1 at Goa location with RMS value was ranged 0.43 Santacruz to 0.74 Deharadun in winter season and in pre monsoon radiation ranged 20.6 Dehardun to 25.7 Pune with RMS ranged 0.27 Visakhapattanam to 1.00 Pune. The mean radiation ranged 15.9 Dumdum to 23.9 at Bhopal with RMS ranged 0.42 at Bhopal to 0.72 at Deharadun in monsoon. The mean actual and estimated radiation was ranged between 13.9 at Patiala to 19.4 at Bhavnagar and Goa with RMS ranged 0.33 at Ahmadabad to 0.78 at Deharadun in post monsoon (Table-3).

The linear relationship developed between solar radiation and temperature range for the different season as well as for annual is reported in Table 4 for selected stations. In pre monsoon, the value of a was relatively higher in southern location when compared with the locations falling in the north, whereas the reverse in trend was noticed for b. The degree of predication was relatively better for locations in the south[7-9]. In kharif (monsoon) season, the degree of predication of solar radiation was relatively poor in the southern location, whereas the predictability in northern locations got improved. For Jaislmer (Rajasthan), the value of a was the highest compared with other locations and thereby resulting in relatively smaller value of b. The result was quite contrasting due to relatively higher value of b for the other locations. In pre monsoon; similar trend was noticed for Pune, where b was large along with higher slope for a. In the pre-monsoon; similar trend was noticed for higher value of Pune location of a but smaller value of same location of b. The degree of predication for solar radiation in all season was statistically significant at all locations. The result was quite contrasting due to relatively higher but positive value of b for the other locations. In post monsoon; similar trend was noticed for Santacruze, where b was large along with higher slope for a. The result was quite contrasting due to relatively higher but positive value of b for the other locations. On the basis of all monsoons ranged from 0.42 in pre monsoon (Santacruze location) to 0.98 in winter (Jailsamer location) [7-9] in Table-4.

## RELATIONSHIP AS QUADRATIC FUNCTION OF THE DAY

The relationship developed as per equation two for selected stations of India presented in Table-2. It may be seen that the value of regression coefficient are different monsoon for different location and $R^2$ ranged from 0.43 to 0.86 in winter; 0.19 to 0.82 in pre monsoon; from 0.25 to 0.84 in monsoon and from 0.40 to 0.89 in post monsoon which were statistically significant in Table-5. The value of $R^2$ is lower in Jaislmer location in monsoon and Patiala and Srinagar in pre monsoon was not significant. The monsoon and post monsoon was similar coefficients [7-9]. The degree of predication was higher for locations in the northern and western regions, where it was poor for all locations in southern and eastern regions. The actual and predicated data was calibrated through daily value using Supit-Van Kappel coefficient. The value of empirical constant c was more positive value in locations except winter and post monsoon season. In winter season decrease in radiation was noticed but all season increasing in radiation was noticed. The empirical value of a and b was positive for all season except pre monsoon. The coefficients were statistically significantly. This method of radiation determination can be engaged successfully for simulation exercises [7-9]. The chances of error propagation with this simple approach are also reduced when the radiation estimates are integrated over a period of time, viz. for monsoon, pre monsoon, post monsoon and winter monsoon. The empirical value of c was negative value in Deharadun and a is also negative value and $R^2$ value is very low (0.47) in Portblair location in monsoon season [7-9].

## TREND ANALYSIS

Trend of solar radiation variation in different season over locations indicated mixed trend of increase or decrease in the rate variation. Regions in Western Himalayas showed an increase in all monsoons in Table-4 and Table-5. On kharif basis, the decrease in the rate of variation of radiation per year was noticed in most locations excepting parts of Rajasthan, Gujarat, Maharashtra and Andhra Pradesh [7-9], where increased values were noticed [3, 5, 7, 8, 10]. During the winter season, decrease in radiation was noticed in all most parts of the country (excepting parts of western Himalayas, Gujarat and Maharashtra). During the pre monsoon, increased variation in radiation was noticed in almost all parts of the country, excepting in Maharashtra, Karnataka, Madhya Pradesh, Gujarat and Uttarakhand. Since these trends have been worked out from the historic datasets collected over years (15-30 years) for all locations, these results should be used with caution. These are a need to in depth work out the extent of the radiation change for various locations of the country.

The validation, F test, T test, P value and Z value has computerized. The t test is used to identify if two independent groups of data was significantly different or not. When the calculated values satisfy: t <t0.05 (critical value), the two groups of data differ insignificantly, and vice versa has computed. The transmissivity of the atmosphere for global solar radiation under perfectly clear sky conditions is given as the sum of the regression coefficient a&b. Also, the transmissivity of an overcast atmosphere is interpreted as the intercept a.From our regression constants (a = 0.23 and b = 0.38), it is observed that the atmospheric transmissivity under clear skies for one is 0.61. This result compares well with the value of 0.67 to 0.70 reported for the humid tropics [4]. The clear-sky transmissivity of most tropical regions in general seems to lie between 0.68 and 0.75 [1, 8].

The smaller the value of t, the better is the model's performance. To determine whether a model's estimates are statistically significant, one simply has to determine a critical t value obtainable from standard statistical tables, i.e., α / 2t at the level of significance and (n-1) degrees of-freedom. For the model's estimates to be judged statistically significant at the 1-α confidence level, the calculated t value must be less than the critical t value with computerised. Using Angstrom- Prescott Calibration of the two samples are significantly different at Bhopal and both calibration and validation the two samples are significantly different at Bhavnagar with p<0.0001.Validation of the two samples are significantly in F test different with computerised & Visakhapatnam and Portblair with p<0.0001 and except above stations are non-significantly in winter season with computerised. Using Supit–Van Kappel formula the validation of two samples are significantly different of F test but P value is p> 0.9999 at Patna, Ranchi, Dumdum, Deharadun, Santacruze, Goa, Visakhapattanam and Chennai in winter season with computerised. Using Angstrom- Prescott validation of the two samples are significantly different in F test at Patna, Dumdum, Jaipur, Jailsamer, Bhopal, Varanasi, Deharadun, Bhavnagar, Goa, Pune and with p<0.0001 and except above stations are non significantly in pre season. Using Supit–Van Kappel formula validation of two samples are significantly different of F test but P value is p> 0.0001 at Patna, Dumdum, Deharadun, Patiala, Bhavnagar, Visakhapattanam and Chennai in pre monsoon season with computerised. Using Angastron validation of the two samples are significantly different in F test at Dumdum, Jailsamer, Deharadun, Portblair and with p value 0.0001 and except above stations are non significantly in monsoon season [3, 5, 7, 8, 10]. Using Supit–Van Kappel formula validation of two samples are significantly different of F test but P value is p> 0.0001 at Dumdum, Jailsamer, Deharadun, Bhavnagar, Santacruz, Pune, Visakhapattanam and Chennai in monsoon season. Using Angstrom- Prescott validation of the two samples are significantly different in F test at Bhopal, Deharadun and calibration of Varanasi, Dumdum, Ahmadabad, Chennai and with p value 0.0001 and except above stations are non significantly in post season with computerised also. Using Supit–Van Kappel formula validation of two samples are significantly different of F test but P value is p> 0.0001 at Ranchi, Dumdum, Deharadun, Patiala, Santacruz, Goa, Pune, Visakhapattanam and Chennai in post monsoon season with computerised also [3, 5, 7, 8, 10].

## CONCLUSION

The A–P and Supit –Van Kappel coefficients are greatly affected by location as well season. In general, the calibration by using monthly mean daily data tends to have a higher a and lower b values following A-P approach, compared with that by using daily data, and it also tends to have larger variations spatially. There is no satisfactory explanation why some sites showed large differences, while others did not have much variations. On a yearly scale, the relationship between n/N and Rs/Ra at most of the sites can no longer be described by the linear A–P equation. Computation of solar radiation on the basis of sunshine hours or square root of temperature range was satisfactory over representative locations over the country, and the coefficients developed could be satisfactorily used for computation of solar radiation on the basis of easily determinable and available weather parameters.

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