Solar Diffuse Radiation & Its Relation with Cloud Discharges

S K SARKAR & A B BHATTACHARYA
Department of Physics, University of Calcutta, Calcutta 700009

and

M K DAS GUPTA
Institute of Radio Physics & Electronics, Calcutta 700009

Received 24 July 1979; accepted 31 January 1981

Diffuse solar radiation (sky radiation) due to dust particles, water vapour and clouds in the atmosphere is related to the electrical discharges from clouds. The monthly values of the local solar diffuse radiation and the monthly ratios of local diffuse to global solar radiation \( D/G \) have been examined in relation to the noise levels of atmospherics recorded at Calcutta at three frequencies (10, 20 and 30 kHz). The results exhibit some definite seasonal changes which appear to be in close agreement with one another. Further, the values have been found to increase with local activity of nor' westers, maximum value being observed during the rainy season.

1. Introduction

The relationships between solar activity and meteorological phenomena formed an interesting subject of study during the last few decades but the data obtained so far are not enough. Solar radiation can be broadly divided into three categories, viz. direct, diffuse and global. Diffuse solar radiation, also known as the sky radiation, represents the shortwave energy of solar origin, scattered and diffused downwards by the (i) gas molecules, (ii) dust particles, (iii) water vapour and (iv) clouds in the atmosphere. In fact, clouds are visible symbols of atmospheric activity and these are the seats of atmospheric electricity. No detailed analysis has yet been made between the solar diffuse radiation and cloud discharges. We were thus prompted to study the variation of diffuse radiation with that of the cloud discharges appearing in the form of atmospherics over the tropical station Calcutta.

2. Collection of Data

Solar radiation data including the diffuse radiation, global radiation, sunshine hours, etc. recorded by the Alipore Meteorological Observatory, Calcutta, have been collected through the Meteorological Observatory, Poona, after being properly processed. These solar data for a period of two years from Oct. 1976 to Sep. 1978 have been extensively analyzed in conjunction with our recorded data of atmospherics in the VLF band. Three TRF receivers at 10, 20 and 30 kHz were used to record the atmospherics round the clock. The receivers used were designed suitably to ensure a large dynamic range with a view to handling a fairly wide range of field intensities.

3. Analysis and Results

3.1 Monthly Variations

The monthly means of the hourly values of local diffuse radiation \( D \) in cal/cm\(^2\)/hr are plotted in Fig. 1. The median noise level of the integrated field intensity of atmospherics (IFIA) corresponding to each observing hour of solar radiation was first noted wherefrom the mean value for each month has been calculated; this mean value is also shown in Fig. 1. We see from Fig. 1 that the variation of diffuse radiation closely resembles the variation of atmospherics at all the three frequencies. The intensities of diffuse radiation and of atmospherics are predominant during the hot summer and early monsoon months, May to August, while a
minimum value is noticed during the clear winter months, November to February.

An analysis of the correlation coefficients between the plots of diffuse radiation and IFIA at each of the frequencies has been made. The results obtained are presented in Table 1.

It is seen from Table 1 that there is a positive correlation coefficient of value ~ 0.8 in all the cases.

### 3.2 Ratio of Diffuse to Global Radiation

Global solar radiation is the downward flux of shortwave radiation from the sun and sky on a horizontal surface, affected by cloud amount, aerosols and atmospheric absorptions. The monthly values of the daily ratios of diffuse to global solar radiation, \((D/G)\), are shown in Fig. 2. Taking into account all days, clear as well as cloudy, it is seen that for the whole year the trend of \((D/G)\) has a close similarity to that observed for IFIA, being predominant during the monsoon months, June to August. The monthly means of the difference, \((G - D)\), received on a horizontal surface when plotted show highest values during the premonsoon months and least in monsoon, showing an almost inverse relation with the variation of IFIA during the monsoon months.

### 3.3 Seasonal Changes of Diffuse Radiation & IFIA

The seasonal values of diffuse solar radiation per hour for the three main seasons—winter (October to February), premonsoon (March to May) and monsoon (June to September) have been calculated. The results are shown in Table 2.

It appears from Table 2 that the diffuse radiation during the premonsoon and monsoon seasons are much higher than that during the winter season.

For comparison, the mean hourly median noise level of IFIA at 10, 20 and 30 kHz for the three seasons are calculated. The results are shown in Table 3.

It is found from the Table 3 that the values of IFIA during the winter is least, intermediate during the premonsoon and highest during the monsoon season at all the three frequencies.

### 3.4 Sunshine Hours, Normalized \(D\) and IFIA

A normalized curve for the diffuse radiation obtained from the mean values is plotted monthwise in Fig. 3. A similar normalized curve for IFIA has also been plotted in Fig. 3 by considering the median noise
It is interesting to see that the trends for the two curves are similar with a little more fluctuation for the D values. Another curve exhibiting the mean actual hours of sunshine has been superimposed in Fig. 3. It is seen that the curve for sunshine hours is almost a mirror image of the other two curves with a minimum during the cloudy monsoon season and a maximum during the remaining clear months.

3.5 Test of Significance

Using the normalized values of diffuse radiation and IFIA the test of significance (t) has been calculated by the usual relation

\[ t = \frac{\bar{X}_d - \bar{X}_d}{\sigma_d / \sqrt{n}} \]

where \( d \) is the difference between the two mean values of a pair and \( n \) is the number of samples for which \( \Sigma d \) has been calculated. In our analysis, the three main seasons of the year, viz. winter, premonsoon and monsoon have been considered for 5, 3 and 4 months, respectively, giving the values of \( n \) for three different sets of \( t \). The seasonal values of the significance ratio (t) and also its corresponding level of significance (p) are presented in Table 4. The level of significance (p) has been obtained from a knowledge of significance ratio (t) and degrees of freedom \((f) = n - 1\).

It appears from Table 4 that the level of significance is sufficiently small during the winter months and there is a marked rise of its value during the premonsoon and monsoon seasons. The significance ratio during the latter two seasons is of the order of 2 only.

4. Discussion

The phenomena of scattered radiation in the atmosphere are very complex and varied. Numerous factors determining the quantity of scattered radiation change continuously in time and space and make computation difficult. The amount of diffuse radiation received for a particular geophysical location on the earth's surface depends mainly on the solar altitude, turbidity in the atmosphere and cloudiness. On the other hand, the noise level in the integrated field intensity of atmospherics at a place is solely controlled by lightning discharges around the observing station. The seasonal variation of both the phenomena noted will be governed by the activity of their sources. In our experimental results, a close similarity of the variation of diffuse radiation with the variation of IFIA indicates that the common causes are more responsible for their variation. In the winter months when the local sky is almost free from clouds but dust particles are present diffuse radiation is least. Due to the poor activity of the sources the noise level of IFIA also exhibits a minimum value during these months. As the year advances, there is a general increase of both diffuse radiation and IFIA due to an increase of cloudiness accompanied by nor' westers at the premonsoon months. With the establishment of monsoon, both diffuse radiation and IFIA further increase. Both the phenomena attain a maximum value during the monsoon months as a result of the increased cloudiness over the region. With the withdrawal of the monsoon in October and setting in of winter conditions, there is again a fall of D and IFIA. An examination of the ratio of diffuse to global solar radiation (D/G) considered for all the days of a year, similarly exhibits higher values during the monsoon months. It, therefore, appears that the higher values of (D) as also (D/G) in summer and monsoon months are due to the increased cloudiness during this period which again governs the noise level of atmospherics originating in the lightning discharges in the upper atmosphere. In our observations, the close agreement of the mean values of (D) and (D/G) with the atmospheric noise level at all the frequencies indicates that both of them are dominated primarily by the activity of local clouds.

The correlation coefficients between the values of diffuse solar radiation and the intensities of atmospherics is quite good. Besides the activity of clouds some other parameters like pollution also contribute to the diffuse radiation either simultaneously or in succession, while the record of IFIA is influenced by a large number of natural sources over a very wide range. The positive sign associated with a high correlation coefficient between D and IFIA indicates that in producing those values the common causes are distinctly more effective than the contribution due to independent causes.

The lack of significance level in the winter season is understandable as the D values at such times is governed mainly by the characteristics of dust particles, gas molecules, etc. This is as a result of high local industrial pollution and partly by the activity of

| Table 4—Significance Ratio (t) and Level of Significance (p) |
|----------------|-------------------|------------------|
| Season         | Degrees of freedom | Significance ratio (t) | Level of significance (p) |
| Winter         | 4                 | 6.5              | 0.002 < p < 0.003 |
| Premonsoon     | 2                 | 2.6              | 0.15 < p < 0.20  |
| Monsoon        | 3                 | 2.4              | 0.15 < p < 0.20  |
local clouds. During the overcast cloudy months, on the other hand, there is a reduction of industrial pollution as a result of rainfall and wash-out in precipitation. The low level of significance during the winter season thus might be due to the combination of weak clouds and dust particles, while their high values during the premonsoon and monsoon months are perhaps caused by the vigorous activity of clouds at such times.

Acknowledgement

The authors are thankful to Prof. C K Majumdar, Head of the Department of Physics, Calcutta University, Calcutta, for his kind interest in this work and to the Director of Meteorological Observatory, Poona, for providing the relevant solar radiation data.

References