Global solar radiation flux measurements over India during the IQSY

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ABSTRACT. Results of measurements of global solar radiation made at a network of 14 stations including 2 island stations in India during the IQSY have been studied. The radiation climate of India relating to global radiation and the monthly and seasonal variation of global radiation over India are discussed.

1. Introduction

The energy received from the sun in the form of radiation and the different radiation fluxes to and from the earth's surface, are among the most important factors which govern the heat economy of the earth and its atmosphere, and consequently all meteorological phenomena in the earth-atmosphere system. Necessary radiation measurments on a global scale for framing an adequate radiation climate of the world came to be organised only during the International Geophysical Year and augmented in the years ending with the International Years of the Quiet Sun. The global network of radiation stations cannot, however, still be considered to be satisfactory even today.

Global solar radiation or the downward flux of shortwave radiation from sun and sky on a horizontal surface is the most important component of the radiation balance and a knowledge of the seasonal and spatial distribution of this quantity is essential in understanding the radiation climate of a region. Maps depicting the spatial distribution of global solar radiation for various regions and for the whole world have been prepared by various workers. In the absence of radiation observations from a satisfactory network of stations in India, Ramdas and Yegnanarayanan (1954) calculated global solar radiation values at 22 stations from the values of duration of sunshine. The distribution of global radiation over India on the basis of these estimates have been discussed by Mani, Swaminathan and Venkiteshwaran (1962) as well as the results of the measurements of global radiation made during the IGY and the International Indian Ocean Expedition (Mani, Chacko and Venkiteshwaran 1962, and Mani, Chacko, Desikan and Krishnamurthy 1967 a, 1967 b).

The radiation network during the IQSY, consisted of 14 stations measuring global solar radiation in addition to other radiation components, both shortwave and longwave. This network though not adequate, may be considerd to be fairly satisfactory and representative of the different climatic zones of the country. The present paper summarises the results of global solar radiation measurements at 14 stations in India during the IQSY.

2. Instrumental equipment

The instrumental equipment at ten stations, Poona, New Delhi, Calcutta, Madras, Nagpur, Jodhpur, Visakhapatnam, Kodaikanal, Trivandrum and Ahmedabad, consisted of Moll-Gorczynski thermoelectric pyranometers with Cambridge thread recorders for the continuous record of global radiation. At two stations, Port Blair and Mangalore, Eppley 180° pyranometers with Brown Electronik recorders, installed by the Michigan University in connection with their IIOE programme of radiation measurements, were in use. Goa was equipped with an Eppley 180° pyranometer with Leeds and Northrup potentiometric recorder and Minicoy with a bimetallic pyranograph. All pyranometers were installed at the highest points available on the roofs of the observatory buildings so as to provide as free an exposure as possible to the entire sky.

The mean daily values of global radiation in cal/cm^2/day for all the months January 1964 to December 1965 have been taken into consideration for all the stations, except for Mangalore and Port Blair, for which 1964 values and Minicoy, for which values from July 1964 to June 1965 have been used.

3. Analysis of the results and discussion of data

3·1. *Monthly and seasonal variations of T*

The mean daily values of global solar radiation T in cal/cm^2/day, month by month for all days and separately for clear, cloudy and overcast days have been computed from the records. The number of occasions of each type, the maximum

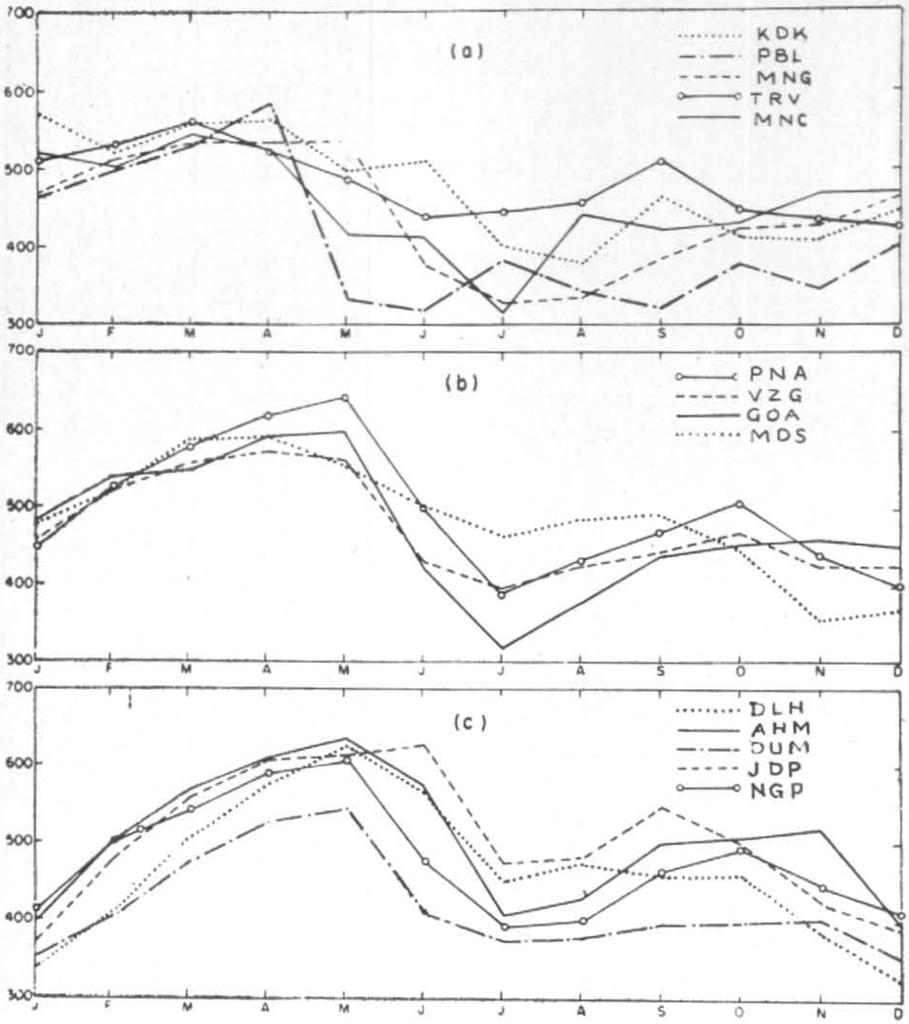

Fig. 1. Annual march of global solar radiation (cal/cm²/day)

NGP—Nagpur
DLH—Delhi
KDK—Kodaikanal
TRV—Trivandrum
VZG—Visakhapatnam
AHM—Ahmedabad
PBL—Port Blair
MNC—Minicoy
GOA—Goa
DUM—Dum Dum
MNG—Mangalore
PNA—Poona
MDS—Madras
JDP—Jodhpur

and minimum values of global radiation for each month and their ratios have also been derived.

(*i*) *All days*

The annual march of global solar radiation at all 14 stations is shown in Fig. 1 [(a), (b) and (c)]. The variations during the year at different stations are generally similar, with high values in summer and low values during monsoon/winter. At most of the stations, maximum values are reached in April or May. Minicoy and Trivandrum, however, attain the maximum in March, and Jodhpur reaches the highest value only in June, due to the early/late onset of monsoon clouding at these stations. For Ahmedabad, Delhi, Poona, Nagpur and Jodhpur situated in the arid or semi-arid regions of the country with less of monsoon clouding, the maximun mean daily global radiation is over 600 cal/cm²/day while for Dum Dum it is as low as 527 cal/cm²/day. It is significant that barring Kodaikanal, the maximum daily value of T is also higher at these five stations. Kodaikanal being a high altitude station characterised by a clear atmosphere with low turbidity, receives more radiation than all the other stations on cloud free days.

At Ahmedabad, Delhi, Trivandrum, Dum Dum and Jodhpur the minimum value of mean global radiation is reached in December to January while at the remaining stations it is reached in the monsoon months, June to August. The minimum T lies between 350-400 cal/cm²/day for most of the stations. For Trivandrum it is 425 cal/cm²/day and for Delhi, Mangalore, Goa, Port Blair and Minicoy, the minimum mean daily value is of the

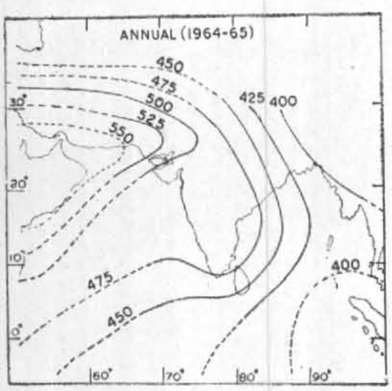

Fig. 2(a)

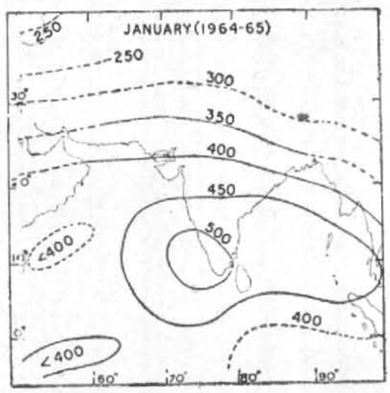

Fig. 2(b)

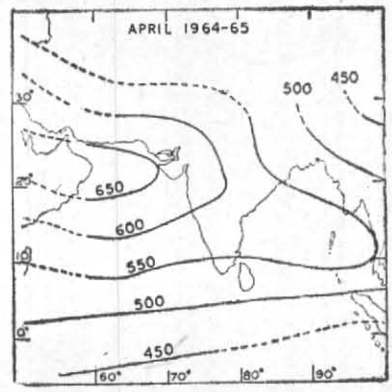

Fig. 2(c)

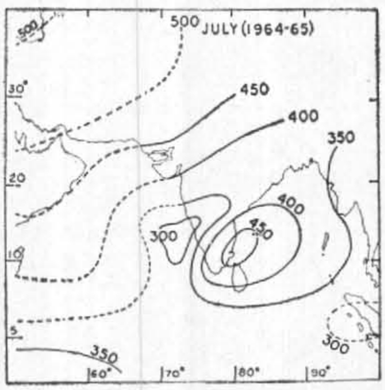

Fig. 2(d)

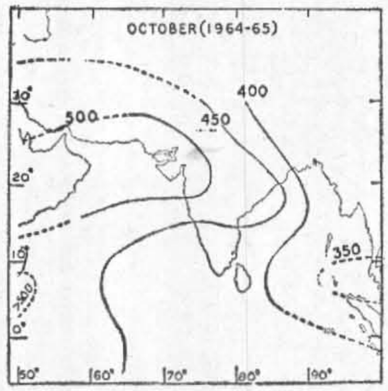

Fig. 2(e)

Fig. 2. Global radiation (cal/cm^2/day)

order of 320 cal/cm^2/day. In contrast to all the other stations, Trivandrum shows only a small variation in the values of mean T during the different months.

(*ii*) *Clear days*

Considering the mean value of T on clear days only, the difference between the maximum and minimum values is higher for the stations situated in the arid or semiarid regions, *viz.*, Nagpur, Jodhpur, Poona, Ahmedabad and New Delhi. For these stations, the maximum occurs in May and the minimum in December, except for Jodhpur where the maximum is in April. The clear day value for Kodaikanal is high even in December (604 cal/cm^2/min).

(*iii*) *Overcast days*

The mean annual value of T on overcast days, lies between 176 cal/cm^2/day and 232 cal/cm^2/day for all the stations, except for Mangalore and Port Blair where the values are as low as 98 and 93 cal/cm^2/day respectively. At these two stations, the values for overcast days during the different months are also low. Values of global radiation recorded on an overcast day become significant when one has to compute values of global radiation from values of duration of sunshine, using Ängstrom's formula (Ängstrom 1956). The value of α in the formula refers to the relative global radiation on an overcast day and is among other things highly dependent on the frequency of high or low clouds and absorption by the clouds. The different values of global radiation recorded on overcast days at different stations and the very low values at Port Blair and Mangalore, indicate that in the computation of global radiation from the duration of sunshine, the adoption of a uniform value of α for all the regions in the country, may lead to erroneous results.

3.2. *Spatial distribution of global solar radiation over India*

Monthly maps for India and its neighbourhood showing the spatial distribution of global radiation have been prepared for the whole year as well as for the individual months. Only 5 maps, for the whole year and for four representative months, January, April, July and October corresponding to the two solstices and equinoxes are presented in Figs. 2 (a) to 2(e). The isolines are drawn for every 50 cal/cm^2/day. While the distribution

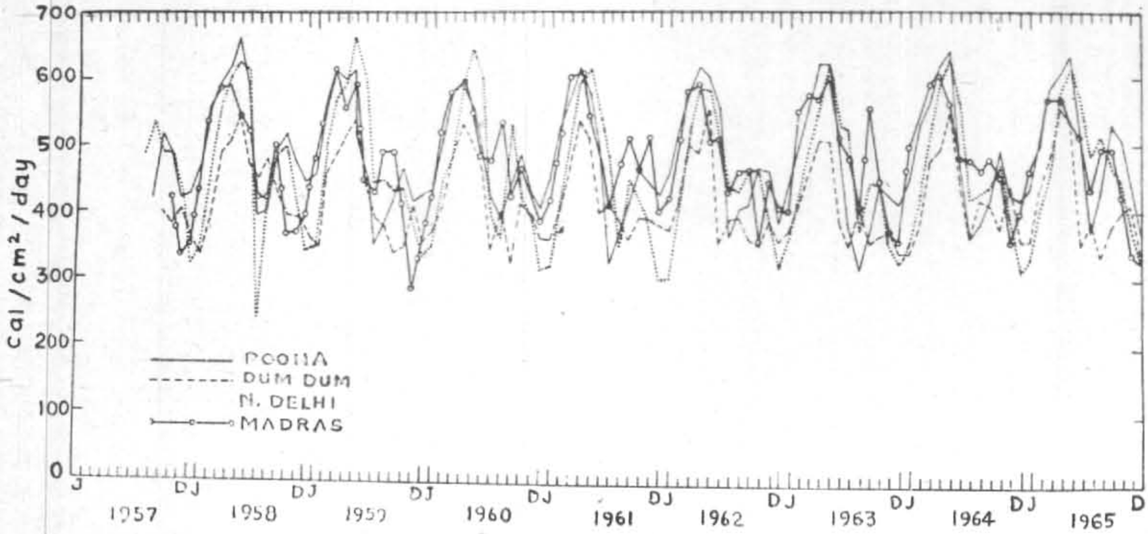

Fig. 3. Monthly distribution of global radiation during 1957 to 1965

is basically similar to that obtained during the IGY, the actual values are somewhat different. The global radiation varies from 400 to 500 cal/cm²/day with the highest values in the arid/semiarid regions of Rajasthan. The major portion of the country receives global radiation between 450 and 500 cal/cm²/day.

The maps for the different months present gradual change in the pattern from January to December. The maximum shifts from south to north from January to June, with the apparent movement of the sun to the north. The pattern is distorted during the monsoon months July to September, and the maximum again shifts southwards during October to December. This southward shift is less marked compared to the northward movement, since during October to December the pattern is modified by the northeast monsoon and global radiation is mainly controlled by cloud amount.

Mani *et al.* (1967b) have studied the distribution of global radiation over the Indian Ocean and the adjoinging continents. The data were based partly on computed values and partly on available observations and the present distribution maps for India agree well with the patterns presented by them.

3·3. *Year-to-year variation of T*

Fig. 3 shows the year-to-year variation of the monthly distribution of global radiation from 1957 (IGY) to 1965 (IQSY) at four stations Poona, Delhi, Madras and Calcutta. There are systematic variations in global radiation from year-to-year at all four stations. Global radiation is affected not only by cloud amount, but also by atmospheric turbidity and its influence on the earth's albedo, as well as the albedo of the clouds themselves. The variations are a maximum in Central and North India, where dust plays an important role and least in South India. The variations cannot, however, be considered to be significant as they are roughly of the same order as the accuracy of measurement itself.

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