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Ultraviolet radiation measurements at Pune

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सार — वर्ष 1972-73 के दौरान पुणे (18° उ०, 73° पू०) में एप्ली पराबैंगनी विकिरणमापी का प्रयोग करके क्षैतिज सतह पर सूर्य और आकाश से प्राप्त 290-390 नो० मी० तरंग दैर्ध्य वाले भूमण्डलीय सौर पराबैंगनी विकिरण (जी०यू०वी०आर०) के माप प्रस्तुत हैं।

वर्ष भर में प्रतिदिन औसतन लगभग 16 कैल०/सें० मी०^2 माप जी० यू० वी० आर० के रूप में प्राप्त हुए हैं। प्रतिदिन के मापों की सीमा 12-20 कल०/सें० मी०^2/घं० है जो शीतकाल में सूर्य के निम्न उत्थापन कोणों के कारण अपेक्षाकृत कम है। जी० यू० वी० आर० और भूमण्डलीय सौर विकिरण (जी० आर०) का अनुपात 4 प्रतिशत के लगभग है और शीतकाल में यह और कम है। अनुपात पूरे दिन बदलता रहता है तथा दोपहर को अधिकतम होता है।

जी० यू० वी० आर० का घंटेवार औसत मान ग्रीष्म में दोपहर को 3.9 कैल०/सें० मी०^2/घंटा और शीतकाल में 2.0 कैल०/सें० मी०^2/घंटा के लगभग है। सामान्यत : अपराह्न की तुलना में पूर्वाह्न में ज्यादा जी० यू० वी० आर० प्राप्त होता है।

जी० यू० वी० आर० पर आविलता का कोई स्पष्ट प्रभाव दृष्टिगोचर नहीं हुआ। तथापि, दोपहर के आसपास के घंटेवार मानों में आविलता वृद्धि के साथ पराबैंगनी विकिरण में कमी की प्रवृत्ति देखी गई।

ABSTRACT. Results of measurements of global solar ultraviolet radiation in the wave length range 290—390 nm received from the sun and sky on a horizontal surface (GUVR) using an Eppley ultraviolet radiometer at Pune (18 N, 73 E) during 1972-73 are presented.

During the year on an average about 16 cal/cm^2 are received daily as GUVR, the daily values ranging from 12-20 cal/cm^2/day with lower values in winter, due to the lower solar elevation angles at this time. The proportion of GUVR to global solar radiation (GR) is about 4 per cent with lower values, again in winter. This ratio also varies during the day, being a maximum at noon.

The mean hourly values of GUVR is about 3.9 cal/cm^2/hour at noon in summer and about 2.0 cal/cm^2/hour in winter. In general more GUVR is received in the forenoon than in the afternoon.

No marked influence of turbidity on the GUVR has been observed. However, the hourly values around noon show a decreasing trend with increasing turbidity.

1. Introduction

Although ultraviolet radiation, contained in the wavelength range 290-390 nm, forms an insignificant portion of the total solar radiative energy flux, its measurement is of vital importance in many fields. It is responsible for the dissociation of ozone molecules in the upper atmosphere and plays a role in determining the equilibrium amounts of stratospheric ozone layer. Ultraviolet radiation is also biologically important, being an effective bactericide, causes hemolysis and erythema, acts as an albumen coagulant and affects living organisms in other ways.

Considerable work has been done, since Rodinov *et al.* (1936) and Stair (1951, '52) made extensive measurements, to study the energy distribution in the ultraviolet radiation at sea level and higher, in the location of the lower boundary of the ultraviolet spectrum, its diurnal and annual variation, the energy distribution at various altitudes etc. The subject has been extensively studied at Davos for over sixty years (Bener 1962, 1964) using photo-electric cadmium cells and later ultraviolet spectrometers.

The most recent and apparently the most reliable of the mountain based extrapolations of the extra terrestrial solar fluxes are due to Stair and Ellis (1968) working at Mauna Loa (3400 m) and Labs and Nackel (1968) at Jungfraujach (3600 m). Measurements have also been made recently by Drummond and Hickey (1972) using high altitude aircraft and X - 15 rocket research aircraft at heights ranging from 11 - 15 km and 78 - 83 km respectively. The NASA Nimbus IV satellite Monitor of Ultraviolet Solar Energy (MUSE) and Backscattered Ultraviolet (BUV) experiments (Heath 1969, '71), have given extensive data on ultraviolet radiation for the first time on a global scale. Subbaraya *et al.* (1972) have made direct measurements of ultraviolet radiation from a sounding rocket over India up to heights of 100 km.

While considerable amount of work has been done at high mountain stations and from high altitude aircraft, balloons and rockets, elsewhere, systematic measurements of the ultraviolet radiation reaching the earth's surface have not been made over the Indian subcontinent. The present paper summarises results

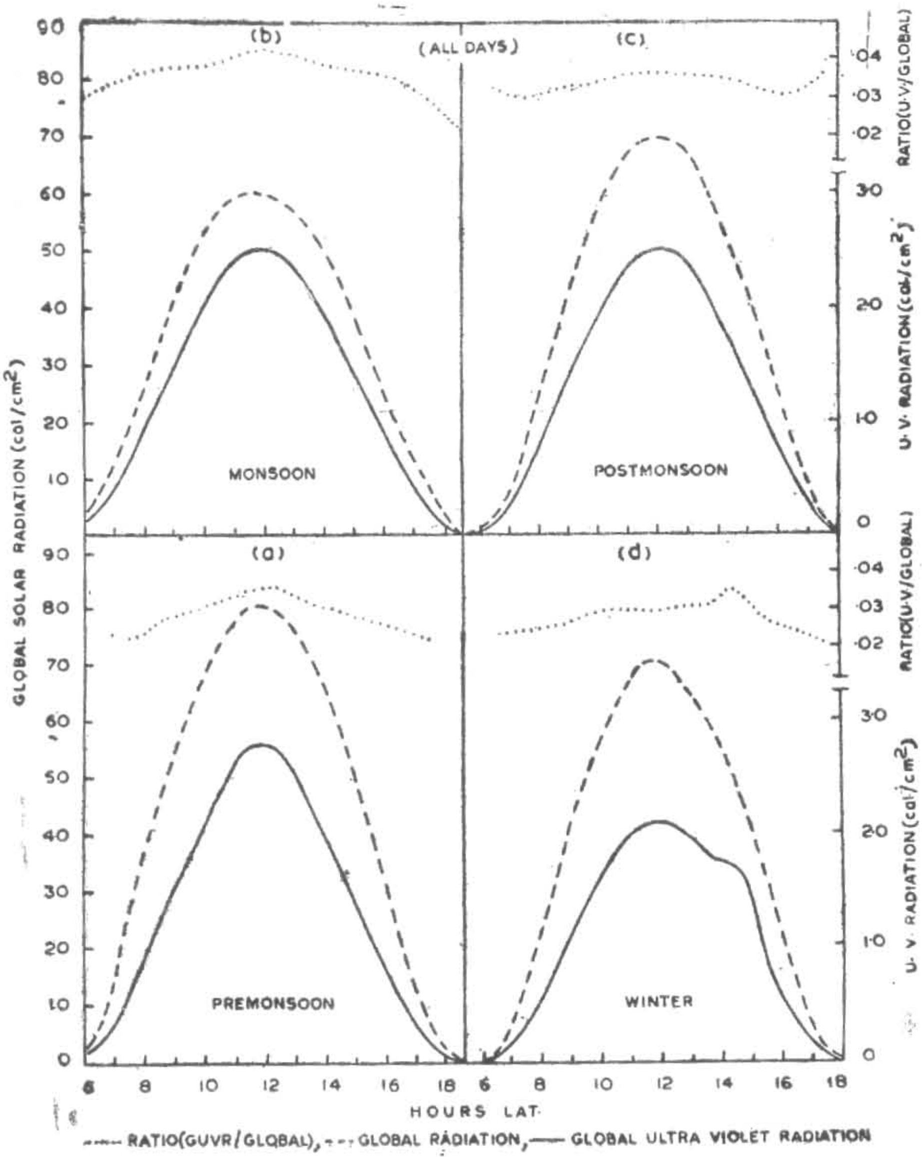

Fig. 1. Hourly values of ultraviolet and global solar radiation and their ratio (all days)

of global ultraviolet radiation (GUVR) measurements made at Pune during 1972 to 1973.

2. Method of measurements

The measurements of ultraviolet radiation contained in the global solar radiation (GR) were made with an Eppley ultraviolet radiometer responding to the wavelength range from 290 -390 nm. The radiometer consists essentially of a Weston selenium barrier layer photoelectric cell with a sealed-in quartz window, a band pass filter to restrict the wavelength response of the photocell to the desired value and a diffusing disc of opaque quartz, which reduces the light intensity incident on the photocell and improves the cosine response of the instrument. The terminals of the photocell are connected through a precision resistor (1,500 ohms) and the voltage drop across this resistor is measured. The linearity and cosine response of the instrument are of the order of $\pm$ 2 per cent. The calibration of the instrument was periodically checked with a tungsten-in-quartz iodine vapour lamp.

The instrument was exposed on the roof of the Central Radiation Laboratory at Pune at a height of 11 m above ground, where a practically free exposure to the sky is available. The output of the radiometer was connected to a Honeywell potentiometric recorder having a range of 0 - 15 mV. The global solar radiation values were also recorded on the same instrument.

The instrument was originally calibrated at the Eppley Laboratory against a calibrated thermopile detector using appropriate filters. The calibration value of the instrument is 0.189 millivolts per cal/cm²/min. The hourly and daily sums of ultraviolet radiation were computed from the records.

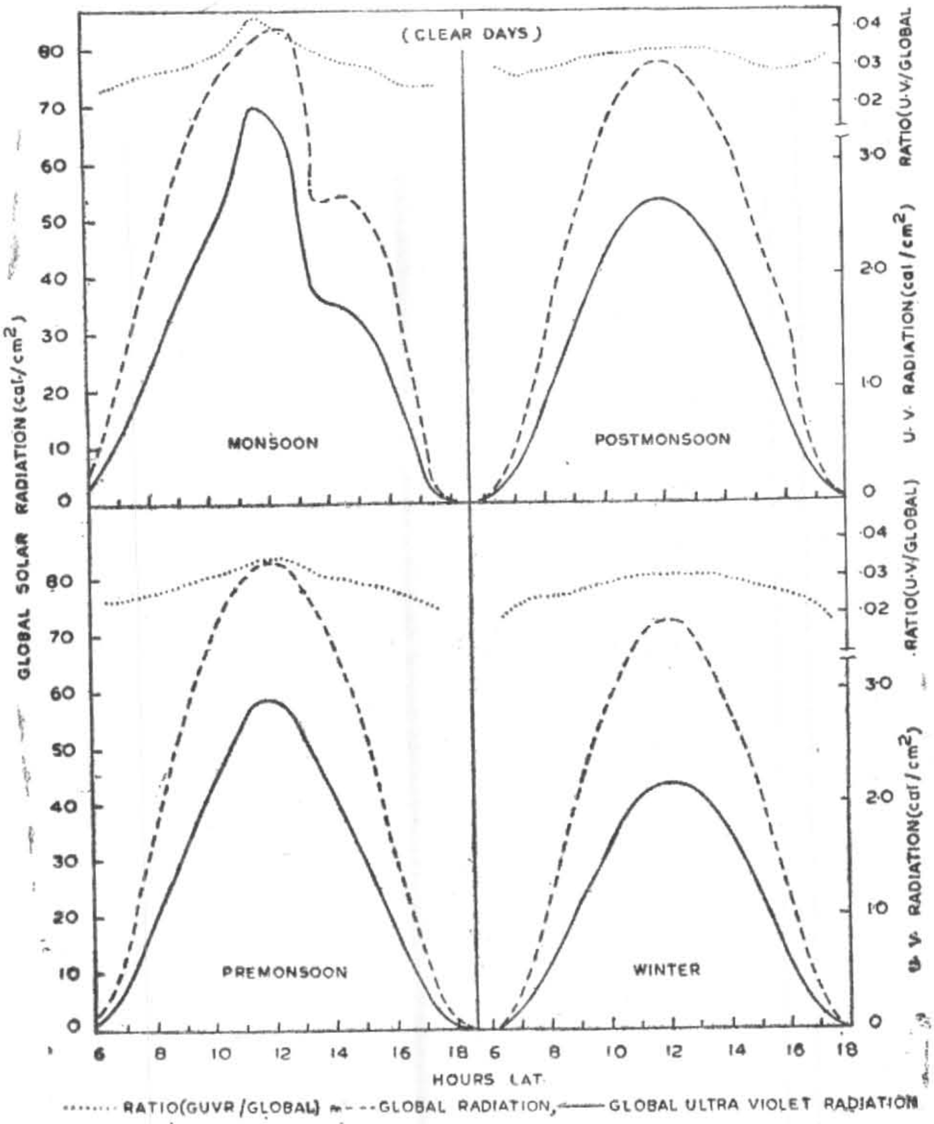

Fig. 2. Hourly values of ultraviolet and global solar radiation and their ratio (clear days)

3. Discussion of results

During the year on an average about 16 cal/cm² are received daily as GUVR forming nearly 4 per cent of the GR. The individual daily values range between 12 & 20 cal/cm²/day, the lower values occurring in winter due to low solar altitudes.

3.1. *Daily variation*

The hourly values of ultraviolet and global solar radiation and the ratio of GUVR to GR for the seasons pre-monsoon (March - May), sonsoon (June - August), post monsoon (September - November) and winter (December - February) are plotted in Fig. 1 (a - d). Similar values for clear days alone and overcast days alone are plotted in Figs. 2 and 3. As small values of total solar radiant energy corresponds to small solar heights, the portion of ultraviolet radiation in it will increase with increase of solar height. The daily range of ultraviolet radiation thus shows a marked maximum at about noon, the maximum flux being generally observed somewhat earlier than that at true noon. This is true except during the cloudy monsoon months, August and September when the maximum occurs just after noon. The diurnal variation is of the order of 0.001 to 3.018 cal/cm²/hour. The ratio GUVR/GR is fairly constant during the day with values ranging less than 2 per cent of the mean. The ratio is however invariably a maximum just before noon, with the maximum amount of GUVR being received at that time. During the day, the hourly value of GUVR reaches 3.0 cal/cm²/hour just before noon in May. The corresponding value for winter is 1.96 cal/cm²/hour. The proportion of GUVR in the GR

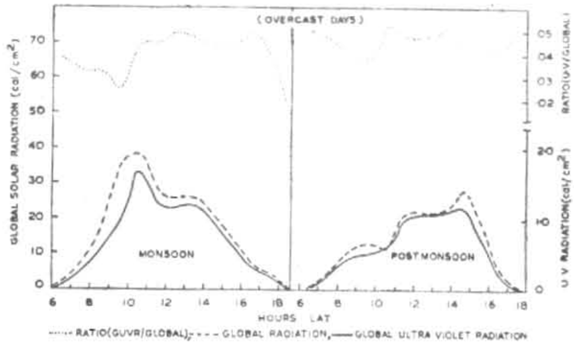

Fig. 3. Hourly values of ultraviolet and global solar radiation and their ratio (overcast days)

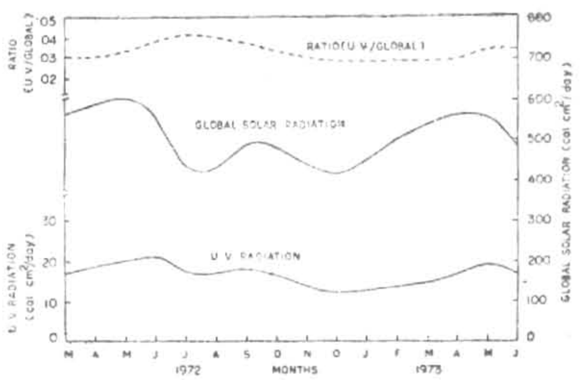

Fig. 4(a). Variation of global solar and ultraviolet radiation and the ratio (UV/global) month by month (all days) at Pune

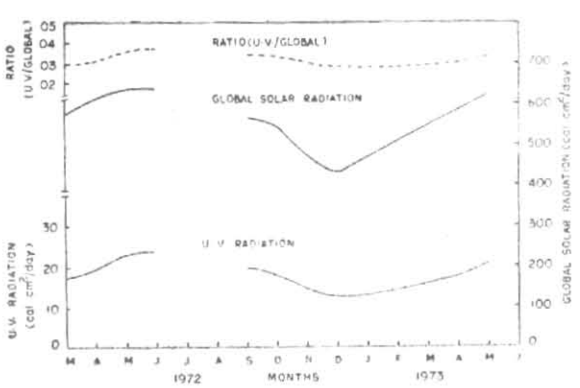

Fig. 4(b). Variation of global solar and ultraviolet radiation and the ratio (UV/global) month by month (clear days) at Pune

during July is a maximum at noon being about 4.5 per cent and 3.6 per cent early in the morning and late in the evening. The daily variation of this ratio is less than 10 per cent.

3.2. *Seasonal variation*

The maximum amount of GUVR 19 - 21 cal/cm²/day is received in the pre-monsoon summer months May and June, unlike the extra-tropical regions where the maximum ultraviolet is received in autumn, because of the minimal ozone content in the atmosphere. The minimum amount is received in December and January

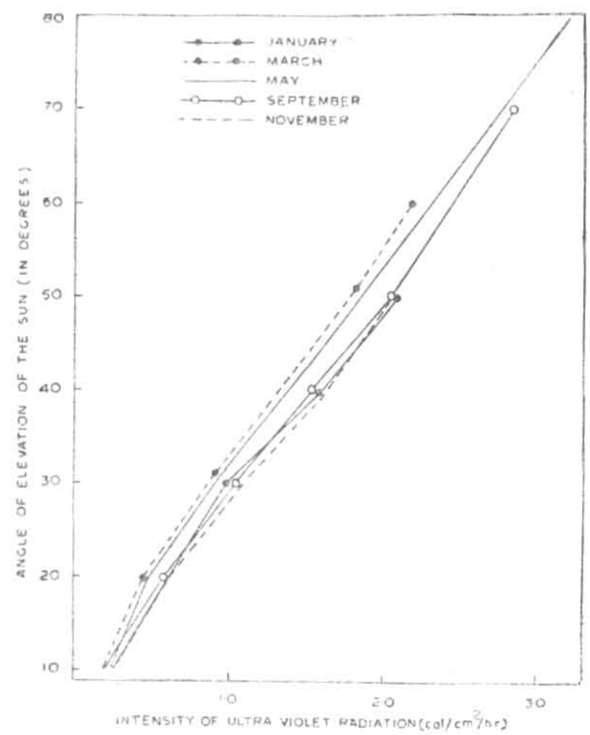

Fig. 5. Variation of UV radiation with angle of solar elevation (Clear days)

11.7 to 13.0 cal/cm²/day, as a result of the lower solar elevation in these months.

The diurnal variation curve is smooth, with a steady rise and fall except during the cloudy monsoon months July and August when presumably as a result of clouding two maxima are observed at 1130 and 1300 IST with a minimum around noon.

The proportion of GUVR in GR shows an annual variation with values ranging from 0.028 to 0.041, the lower values occurring in winter due to lower solar altitudes. The diurnal variation of the ratio GUVR to GR is least during the cloudy days in July and August.

The annual march of ultraviolet and global solar radiation and the ratio ultraviolet to global solar radiation is plotted in Fig. 4 (a). The peak in GR is, however, seen to be reached a month before GUVR.

Similar curves for clear days alone are plotted in Fig. 4 (b). The effect of clouding being eliminated, the maximum is observed with highest solar altitude in June and the minimum in December.

The maximum observed is 3.3 cal/cm²/hour in May at an angle of elevation of 82 deg. In Fig. 5 hourly values of GUVR intensity in cal/cm²/hour are plotted against angles of elevation for alternate months. The slope is the same although the actual values vary from month to month. It will be seen that for the same solar altitudes, GUVR is higher for the winter months when the turbidity is lower.

Isopleths of hourly values of ultraviolet and global solar radiation for all days were drawn and studied. Values exceeding 3 cal/cm²/hour are received from 11 to 13 L.A.T. in April and May and exceeding 2.5 cal/cm²/hour from May to October around noon, except during June and July, the cloudy monsoon months. The largest proportion, 4.5 per cent is found in July - August around noon.

On cloudy days the hourly values of GUVR are invariably low of the order of 1.0 cal/cm²/hour and the daily suns are also of the order of 6 - 8 cal/cm²/day.

The ratio of GUVR/GR is, however, uniformly high with values of the order of 4 - 5 per cent throughout the day in July and August. The highest proportion is found in July with a value of 6.0 per cent.

The mean value of GUVR received on all days and on clear days alone are 16.4 and 17.2 cal/cm²/day. The corresponding ratios are 3.3 and 3.2 per cent respectively.

3.3. *Effect of clouds on ultraviolet radiation from sun and sky*

Bener (1964) carried out extensive spectroscopic studies of GUVR and its dependence on various meteorological parameters in the wavelength region 330 - 370 nm. He has discussed the dependence of ultraviolet radiation on solar altitude, the amount of atmospheric ozone, ground reflection and atmospheric turbidity. He found the ratio q between the intensity of ultraviolet radiation with and without clouds as 0.65 - 1.75 for low clouds, 0.70 - 1.47 for middle and 0.90 - 1.47 for high clouds. A detailed study for Indian conditions is under way and is to be presented elsewhere.

On clear days the hourly value of GUVR reaches values of 3.6 cal/cm²/hour in June. The lowest value reached is 2.0 cal/cm²/hour in December. The daily sum is again highest in June 23.4 cal/cm²/day and the minimum in December 12.1 cal/cm²/day.

3.4. *Effect of turbidity on ultraviolet radiation*

Values of turbidity were plotted against the hourly values of GUVR for the exact hour of observation of turbidity. The results show a tendency for the GUVR to be lower when the turbidity is higher. This tendency is not clearly evident since GUVR measured includes diffuse radiation as well. No marked influence of turbidity on GUVR has been noticed, although turbidity is very high in summer. This may be due to the fact that a turbid atmosphere causes an increase in the diffuse ultraviolet radiation.

However, the hourly values around noon with higher solar elevations show a decreasing trend with increasing turbidity.

3.5. *Effect of ozone on ultraviolet radiation*

No influence of ozone on the ultraviolet radiation could be detected since the ultraviolet radiation measured is integrated over the spectral range 0.29 to 0.39 μ.

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