

The use of the Bellani Spherical Pyranometer for the measurement of total solar radiation

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1. Introduction

The measurement of the total short-wave radiation falling from the sun, the sky and the surroundings on freely exposed objects, such as a plant, is of special interest in biology, bioclimatology and agricultural meteorology since radiation plays an important part in controlling the growth features and physiological processes in plants like photosynthesis, photoperiodism etc. There are several instruments for the measurement of solar radiation. However, for use at agricultural farms, the important prerequisites of an instrument are simplicity of operation and maintenance, low cost and acceptable accuracy.

The commonly used instruments for the measurement of solar radiation at radiation stations are the Angstrom pyrhelimeter for the measurement of instantaneous values and the Moll-Gorczynski solarimeter, the Eppley pyrbelimeter, Robitzsch bimetallic actinograph and the Bellani spherical pyranometer for the measurement of integrated values of radiation. Of these, the cheapest instrument and the simplest from the point of operation and maintenance is the Bellani spherical pyranometer. It was, therefore, decided to see how far the measurements of radiation made with this instrument are comparable with those obtained with a standard instrument like the Moll-Gorczynski solarimeter and also to

check up the belief that for tropical regions the ratio of the indications of a spherical pyranometer with those of a horizontal surface pyranometer may be nearly constant.

2. Brief description of the instrument

The Bellani spherical pyranometer consists of a glass sphere filled with alcohol which distils into a graduated glass tube below, when warmed by the solar radiation falling on the sphere. The rate of distillation of the alcohol from the sphere is proportional to the intensity of radiation falling on the sphere. Therefore, the integrated radiation during any given interval of time is proportional to the quantity of alcohol which condenses in the glass tube. The inner sphere is metal coated (grey) for becoming a non-selective absorber of radiation. It is protected from the effects of wind and weather by an outer glass sphere, the space between the two being evacuated for reducing the heat exchanges between the two spheres to a minimum.

The constants of the instruments are expressed in units of calories per square centimetre per centimetre and the difference between the two readings on the glass tube during a given interval of time multiplied by the calibration factor gives the energy of radiation (in cal/cm²) during the interval. As the amount of alcohol that evaporates is also a function of temperature, the constants are given for every 10°C.

TABLE 1

Month	Madras		Poona		Calcutta		New Delhi	
	R	Z	R	Z	R	Z	R	Z
Jan	0.496	34°22'	0.518	39°50'	0.541	43°57'	0.609	49°53'
Feb	0.485	26°04'	0.484	31°32'	0.502	35°39'	0.556	41°35'
Mar	0.481	15°35'	0.452	21°03'	0.471	25°10'	0.502	31°06'
Apr	0.474	3°39'	0.429	9°07'	0.463	13°14'	0.497	19°10'
May	0.475	5°34'	0.408	0°06'	0.427	4°01'	0.503	9°57'
Jun	0.477	10°12'	0.426	4°44'	0.455	0°37'	0.507	5°19'
Jul	0.467	8°37'	0.435	3°09'	0.466	0°58'	0.507	6°54'
Aug	0.469	1°18'	0.438	4°10'	0.452	8°17'	0.497	14°13'
Sep	0.475	9°40'	0.463	15°08'	0.470	19°15'	0.514	25°11'
Oct	0.480	21°13'	0.477	26°41'	0.511	30°48'	0.541	36°44'
Nov	0.499	31°18'	0.507	36°46'	0.546	40°53'	0.625	46°49'
Dec	0.511	36°17'	0.535	41°45'	0.579	45°52'	0.645	51°48'

R—Ratio of radiation recorded (Bellani \div Moll's)

Z—Zenithal distance of the sun

3. Comparison

The radiation data collected at the following radiation stations of the India Meteorological Department were used in the present study—

Stations	Period of data
Madras (Lat. 13°00' N Long. 80°11' E)	2 years (1958-59)
Poona (Lat. 18°32' N Long. 73°51' E)	3 years (July 1957 to June 1960)
Calcutta (Lat. 22°39' N Long. 88°27' E)	2 years (1958-59)
New Delhi (Lat. 28°35' N Long. 77°12' E)	2 years (1958-59)

For all the stations, the daily values of total solar radiation (sun and sky) obtained with the Moll-Gorczyński solarimeter were

tabulated side by side with those computed from the readings of the Bellani spherical pyranometer. The ratios of the radiation values obtained with the spherical pyranometer to those with Moll's solarimeter were then worked out. They were then averaged for each month and the means for each month for the three-year or two-year period, as the case may be, were worked out. The mean ratios are given in Table 1.

As the ratios were found to vary from month to month even for the same station, it was decided to see whether they show any relationship with the positions of the sun in the sky with respect to the station. For this purpose the mean zenithal distances of the sun for each place for each month were computed. These are also given in the table for each station against the corresponding ratios. The ratios and the zenithal

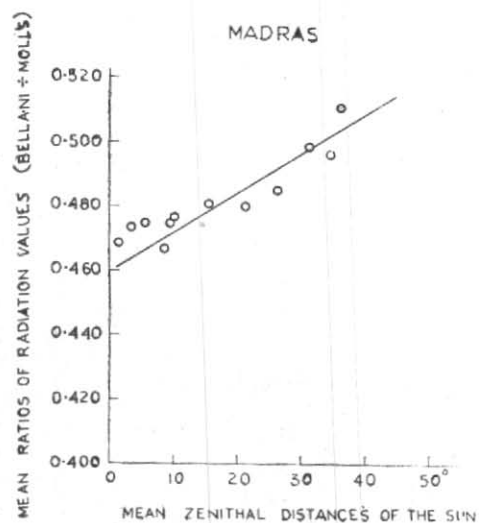


Fig. 1

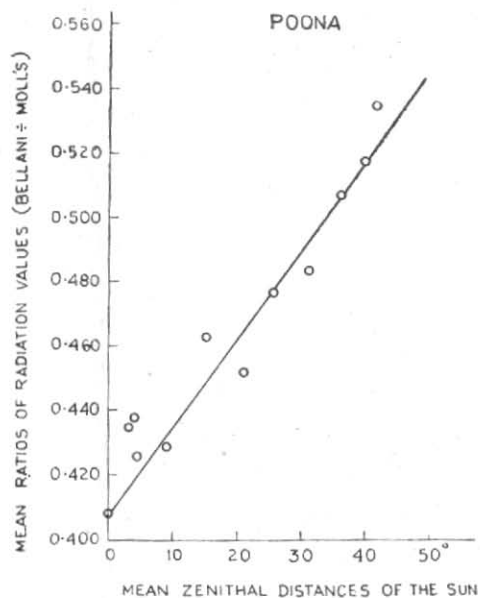


Fig. 2

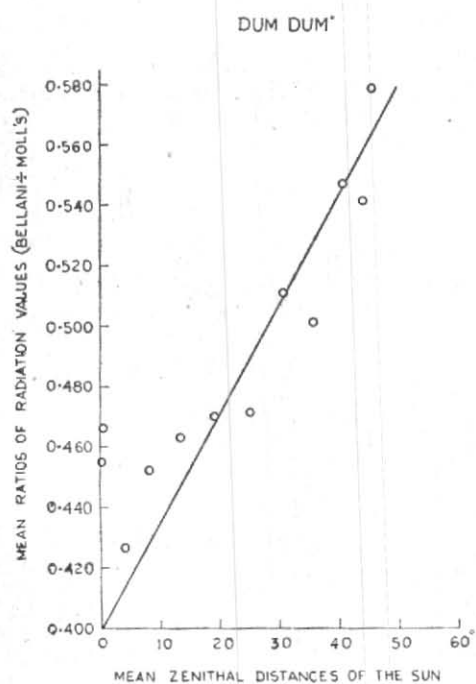


Fig. 3

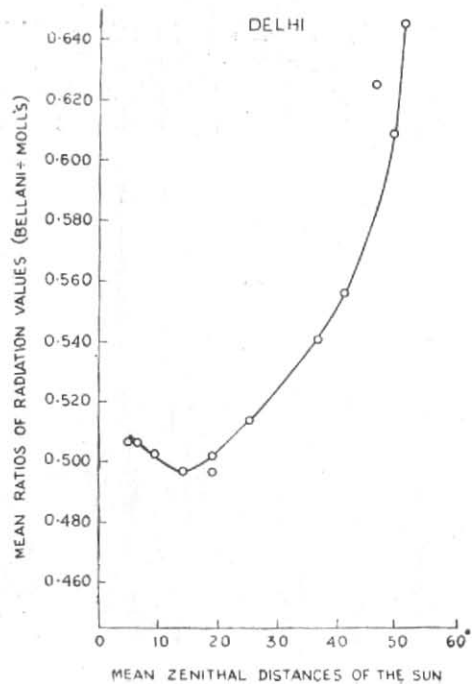


Fig. 4

distances for each station were also plotted on graphs. These are given in Figs. 1, 2, 3 and 4 respectively for Madras, Poona, Calcutta and Delhi.

4. Results

(1) It is seen that, the mean ratios of the radiation values obtained with the Bellani spherical pyranometer to those with the Moll solarimeter are not constant even for the same station but show a systematic variation from month to month depending upon the zenithal distances of the sun, the ratios, in general, increasing with increasing zenithal distances.

(2) For the same station, when the zenithal distances are small the ratios do not show systematic variation with the zenithal distances.

(3) The relationship between the ratios and zenithal distances is more or less linear for Madras, Poona and Calcutta, but for Delhi, the northernmost station, it is not quite linear.

(4) The slopes of the straight lines which could be drawn, connecting the ratios and zenithal distances increase with the increasing latitude suggesting that perhaps near

the equator, the ratios may not show any appreciable changes from month to month.

(5) The belief that for tropical regions the ratio may be constant is not correct.

5. Conclusion

The results of the analysis given above indicate that the Bellani spherical pyranometer can be used for the measurement of total (short-wave) solar radiation to a fair degree of accuracy.

The values obtained with the instrument cannot directly give actual values of the radiation but have to be corrected for the zenithal distances of the sun. These corrections can be derived by comparative observations with any absolute instrument for an year or so. Even if this is not possible the corrections can be derived to a fair degree of accuracy from comparative observations at some reference stations to the north and south.

6. Acknowledgement

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REFERENCE

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