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SOLAR RADIATION OVER NEW GUINEA AND ADJACENT ISLANDS

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ABSTRACT

Maps showing the distribution of solar radiation over New Guinea and adjacent islands have been prepared for January, April, July and October and for the year as a whole. These maps are based on a modified Ångström equation, $Q = Q_A (0.25 + 0.55\ n/N)$, derived from data for Port Moresby, Rabaul and Djajapura-Sentani, which was applied to sunshine data for 38 stations and cloud cover data for another 12 stations. The maps presented show considerably more detail than the world maps and regional maps published so far. Although based on sparse data, the distribution patterns found are consistent with published patterns of related climatic variables.

INTRODUCTION

Very little information is readily available on the geographical distribution of solar radiation over New Guinea and adjacent islands. Hounam (1963, 1969) has prepared maps for Australia, but for the region directly to Australia's north only large-scale world maps (*eg* Budyko, 1958; Ashbell, 1961; Löf *et al*, 1966) or regional maps (Mani *et al*, 1967) are available. Such maps are, because of their scale, inadequate for many purposes and sometimes even misleading. New Guinea, in common with many areas, lacks data derived from direct measurements of incoming solar radiation. More widely available climatic parameters, such as cloudiness and hours of bright sunshine are therefore sought.

This paper presents maps of annual and monthly solar radiation over New Guinea and adjacent islands. Although the preliminary nature of these maps should be stressed, they provide insight in the distribution of this very significant climatic parameter.

METHODS AND RESULTS

Solar radiation records were available for Port Moresby, Rabaul and Djajapura-Sentani. For both Port Moresby and Djajapura, long-term records of hours of bright sunshine were available, while for Rabaul, the records used were those obtained at nearby Kerevat. Details on stations, measurements and sources of the data are given in Table 1. A modified Ångström equation was used, of the form

$$Q = Q_A\ (a + b\ n/N) \qquad \ldots 1$$

where Q = total radiation received on a horizontal surface on earth

Q_A = radiation received on a horizontal surface extraterrestrially

n = actual duration of bright sunshine

N = maximum possible duration of bright sunshine

a, b = constants to be found by linear regression

For all three stations long-term averages of mean daily solar radiation and duration of bright sunshine for all months were used and the three sets of 12 pairs of data were pooled, in order to calculate a linear regression of Q/Q_A on n/N, as shown in Fig 1. Values for extra-terrestrial radiation were obtained from McCullough (1968) and for maximum possible duration of bright sunshine from the Smithsonian Tables (List, 1958). The results of linear regression were

$$Q = Q_A\ (0.25 + 0.55\ n/N) \qquad \ldots 2$$

with $r = 0.89$

As the three individual stations fit the above relationship reasonably well, regression equation 2 has been used in this study to estimate monthly values of solar radiation for 27 stations in West Irian and for 11 stations in Papua New Guinea and islands, with observations of actual duration of bright sunshine. For all stations n/N was converted into Q/Q_A for all months of the year.

Spatial cover on the eastern side of New Guinea was still inadequate for a study of the geographical distribution of solar radiation throughout the year. The part of the day that direct solar radiation is intercepted by clouds is $1-n/N$. For 16 stations in New Guinea, both twice-daily cloud cover observations (usually at 9 am and 3 pm) and measurements of the duration of bright sunshine were available; and by pooling all long-term data it was calculated by linear regression that

$$n/N = 1.101 - 0.884\ c_{av} \qquad \ldots 3$$

with $r = -0.71$

Using equation 3, mean monthly cloud cover data from another 12 stations mainly in Papua New Guinea were converted to n/N values and hence to monthly values of Q/Q_A. Annual values of global radiation were calculated as the sum of 12 monthly values. (Equation 3 is in fact an approximation since the relationship between n/N and c_{av} also depends on the state of the atmosphere and the type of clouds).

The distribution of mean daily shortwave solar radiation in mW-h/cm^2 for January, April, July and October is shown in Fig 2, 3, 4 and 5 respectively. In Fig 6 the distribution of total annual global solar radiation is shown in W-h/cm^2. In all figures different symbols have been used to indicate the type of information used for a particular station in drawing the maps.

Table 1 Details of stations and measurements used for establishing relationship between hours of bright sunshine and solar radiation

Station	Lat.	Long.	Elevation	Pyranometer or Actinograph	Heliograph	Years	Source
Port Moresby	$9^\circ 29'$	$147^\circ 09'$	41	Eppley		1966-71	CSIRO, Building Research
					Campbell Stokes	1957-69	Bureau of Meteorology
Rabaul	$4^\circ 13'$	$152^\circ 15'$	13	Robitzsch		1956-68	Bureau of Meteorology
Kerevat	$4^\circ 19'$	$152^\circ 02'$	10		Campbell Stokes	1955-67	Bureau of Meteorology
Djajapura-Sentani	$2^\circ 34'$	$140^\circ 29'$	98	Kipp		1957-60	Meteorol. and Geoph. Service, Irian Barat
					Campbell Stokes	1956-65	Meteorol. and Geoph. Service, Irian Barat

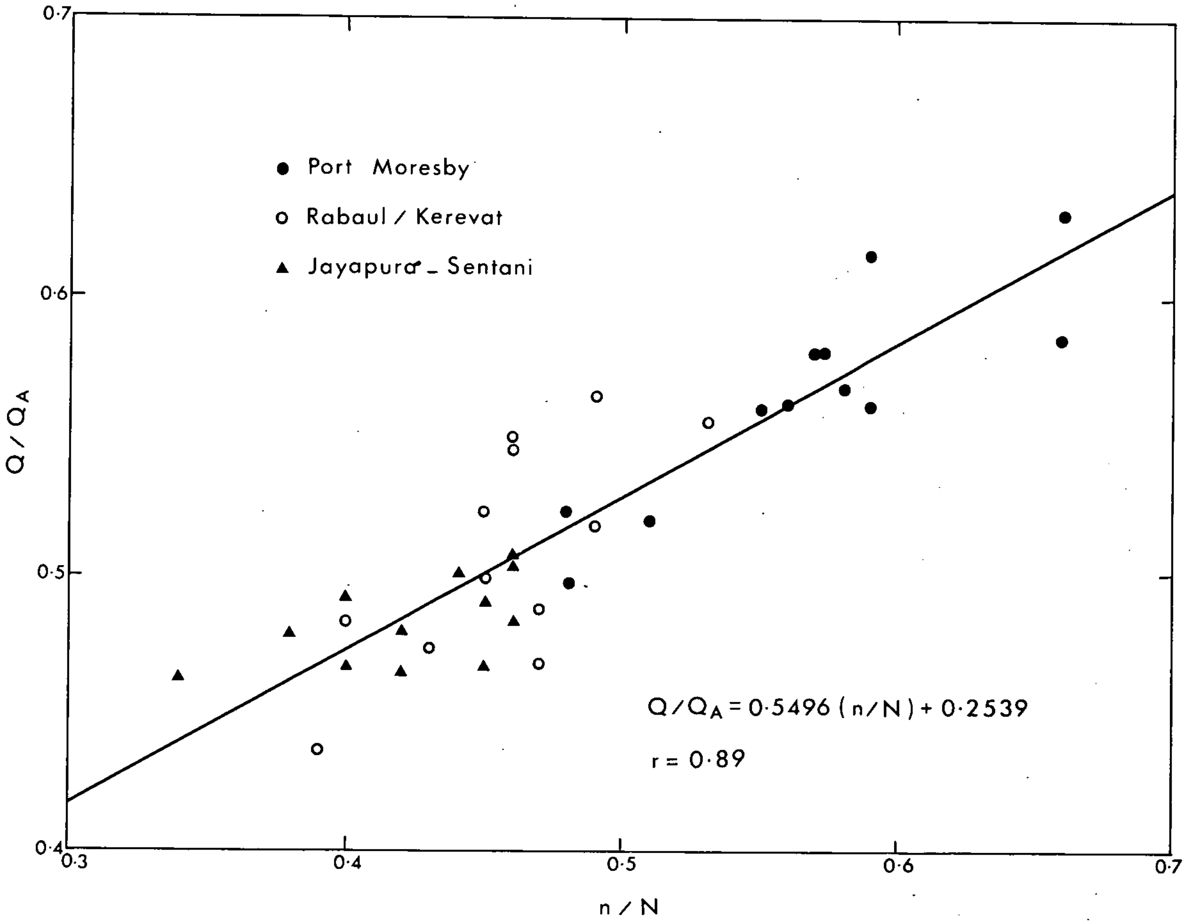

Fig 1 Relationship between monthly values of Q/Q_A and n/N for Port Moresby, Rabaul/Kerevat and Djajapura-Sentani

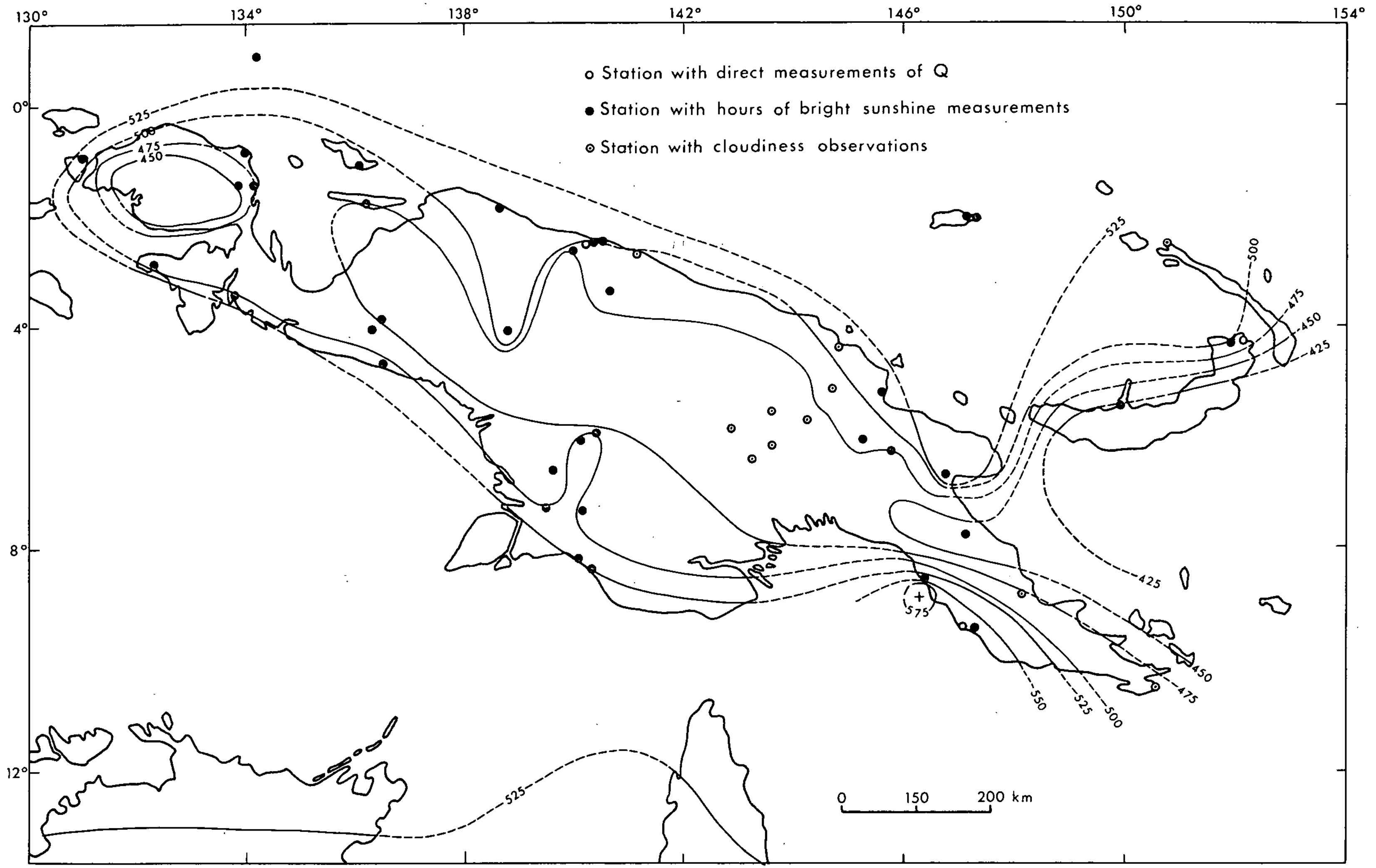

Fig 2 The distribution of global solar radiation for January expressed as mean daily values in $mW\text{-}h/cm^2$

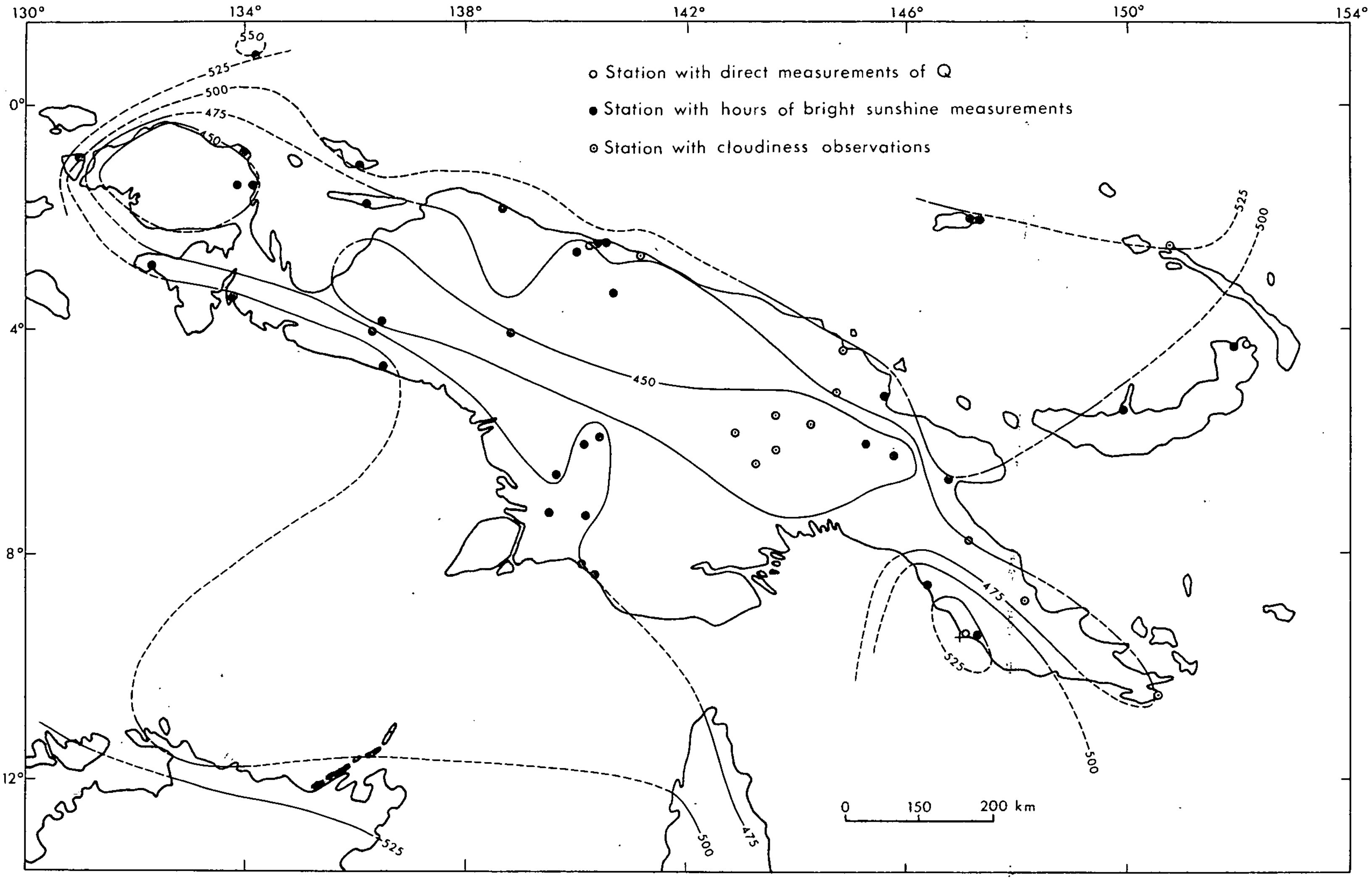

Fig 3 The distribution of global solar radiation for April expressed as mean daily values in mW-h/cm^2

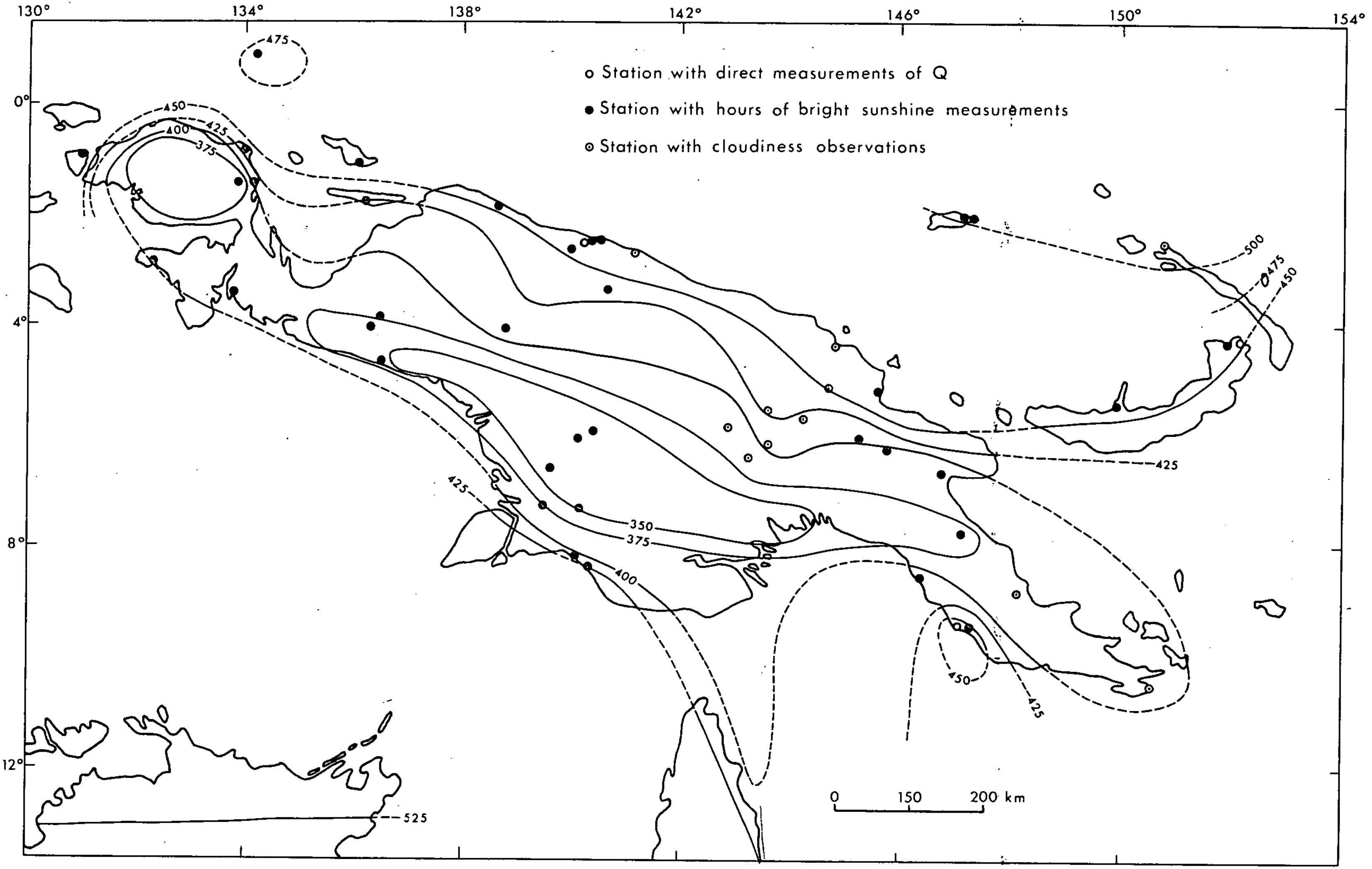

Fig 4 The distribution of global solar radiation for July expressed as mean daily values in mW-h/cm^2

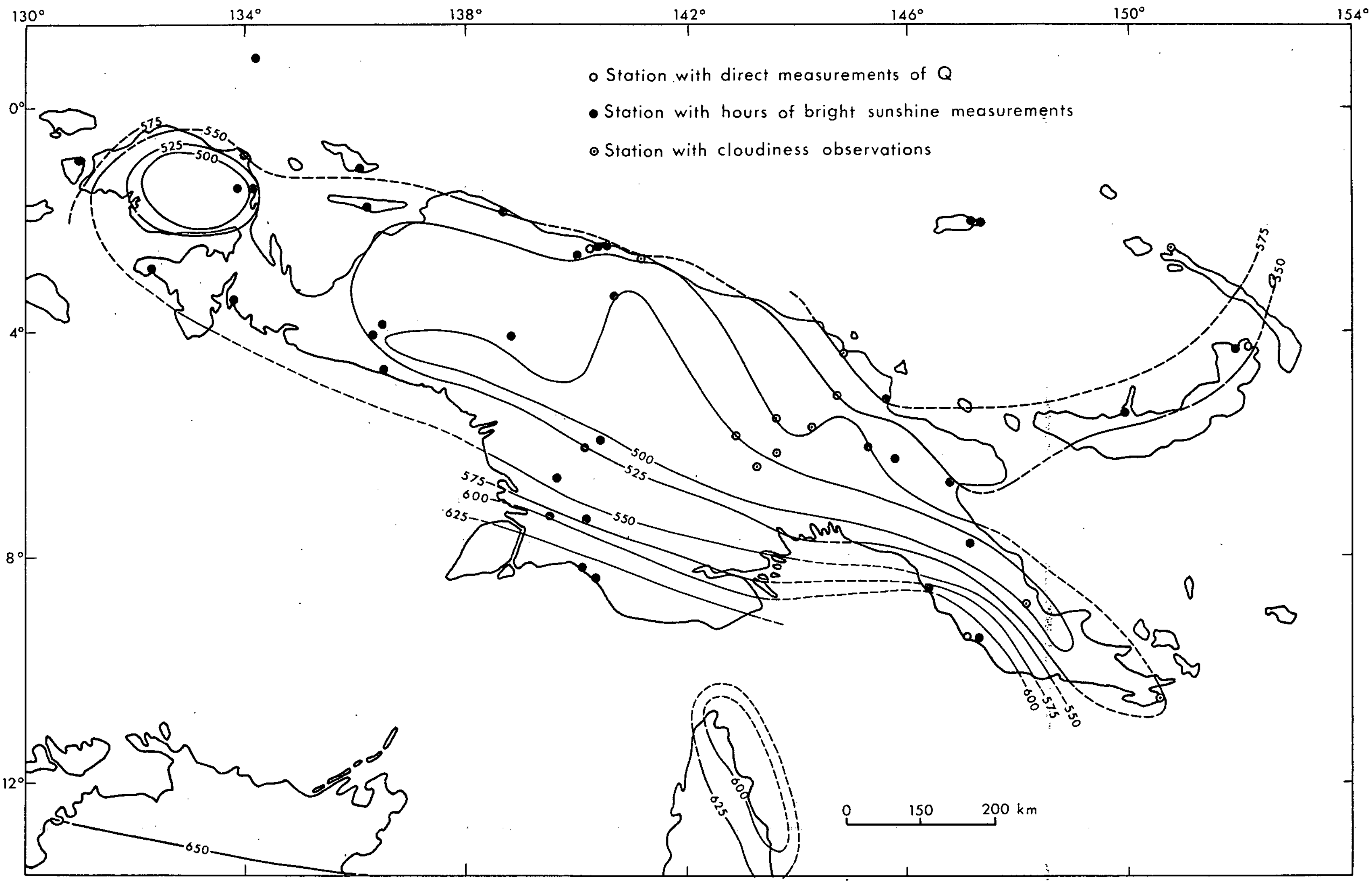

Fig 5 The distribution of global solar radiation for October expressed as mean daily values in mW·h/cm^2

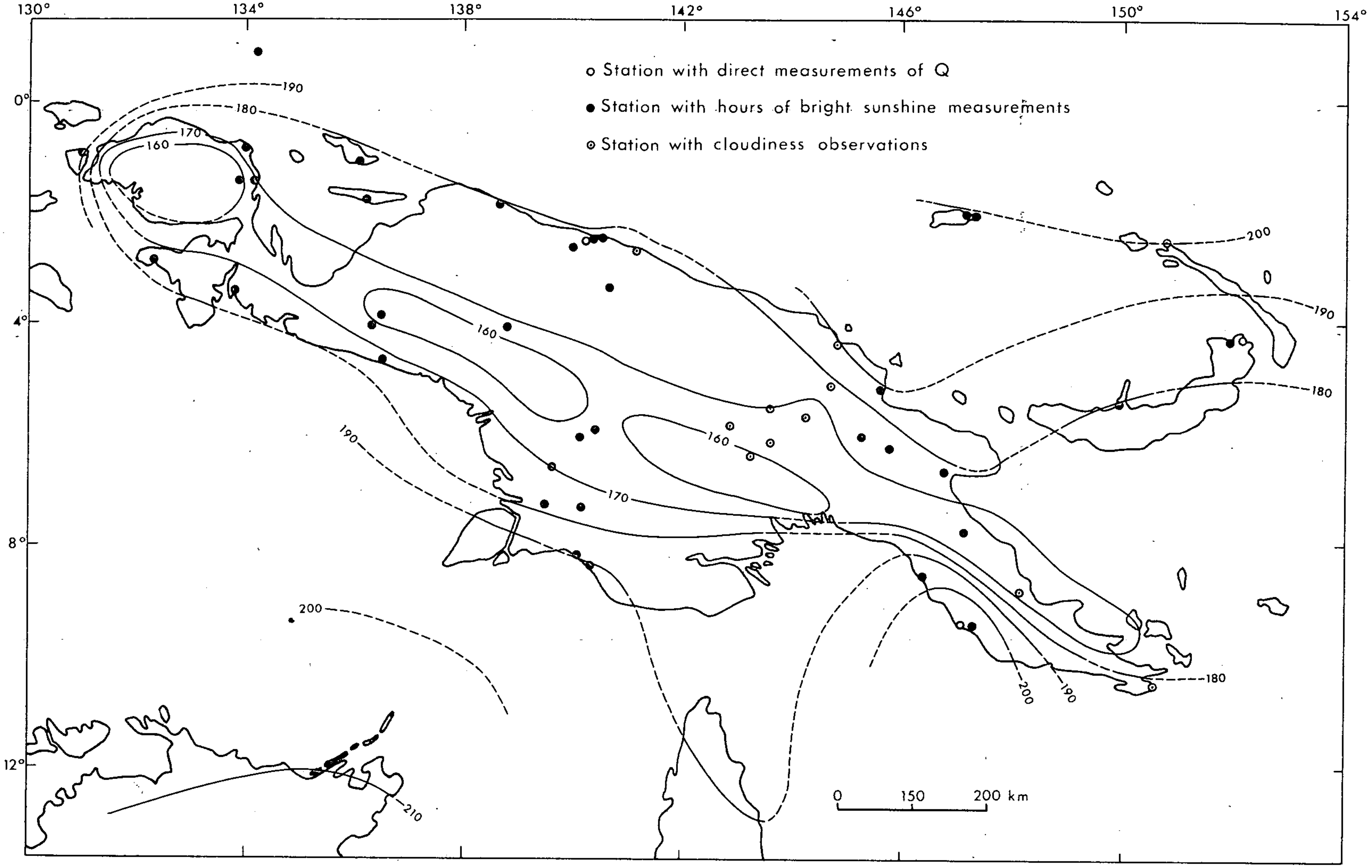

Fig 6 The distribution of the annual total of global solar radiation reaching the earth's surface, expressed in W-h/cm^2

The January and July distributions approximate to the summer and winter solstices, while the April and October distributions are roughly those for the equinoxes. All isolines over sea surfaces have been dashed to indicate the tentative nature of those divisions. Distributions of solar radiation over northern Australia, as derived from Hounam's (1963) maps have been included. Much more data will be needed to extrapolate isolines over the Timor, Arafura and Coral Seas, than is available at present.

DISCUSSION

The values for intercept a and coefficient b given in equation 2, *viz* 0.25 and 0.55 respectively, are slightly different from those obtained for six stations on the Australian continent by Hounam, who reported values of 0.26 and 0.50 in 1963 for 458 pooled monthly data and values of 0.27 and 0.50 in 1969 for 890 pooled monthly values. De Vries (1958) reported a and b values of 0.27 and 0.55 respectively for two years of measurements at Deniliquin (New South Wales). The values found here are also not greatly different from those reported by Black *et al* (1954) for Dry Creek (South Australia) *viz* $a = 0.30$ and $b = 0.50$, and for Mt Stromlo (Australian Capital Territory), *viz* $a = 0.25$ and $b = 0.54$. In a review of world data, Glover and McCulloch (1958) suggested $a = 0.29 \cos$ (latitude) and $b = 0.52$. This would have given for the equator $a = 0.29$ and for 12°S, $a = 0.28$. In view of these relatively small differences, which are partly due to different types of pyranometers used in the above studies, the locally obtained values for the constants a and b will be used. It is pointed out that, while the data in Fig 1 do not go beyond $0.34 \leq n/N \leq 0.66$ and $0.44 \leq Q/Q_A \leq 0.63$, there are virtually no values calculated on the maps which go outside those limits.

On the basis of experience elsewhere (Stanhill, 1965), the accuracy of the monthly values of solar radiation presented in this paper is estimated to be between ±10 and ±15%. This accuracy is comparable with the desirable limit of accuracy of second-class pyranometers, that is ± 5% (World Meteorological Organization, 1965) and with the estimate of Nicolet (1948), who stated that the accuracy expected in a network of such pyranometers is not better than 10%.

A zonal pattern in the distribution of solar radiation would be expected from the seasonal migration of the zone of maximum extra-terrestrial insolation. However, a dominant feature of all four monthly distributions and the annual distribution of solar radiation presented here is that the orientation of belts of equal insolation is roughly NW-SE. The pattern is similar to the orientation of rainfall regimes as noted by Fitzpatrick *et al* (1966). They stated that the asymmetric distribution in rainfall is caused by contrasting effects on the general atmospheric circulation of the proximity of the Australian continent, the vast sea surfaces of the Pacific and the major meteorological barrier of the Central Cordillera of New Guinea. These considerations apply also to cloudiness and insolation.

In January (Fig 2), minimum daily values of about 410 mW-h/cm^2 are reached over New Britain, except for the Gazelle Peninsula. Maximum values occur in the Bereina-Port Moresby coastal strip, with values at Bereina reaching about 600 mW-h/cm^2. A small area of low radiation levels occurs over the Vogelkop (about 540 mW-h/cm^2), while most of the Central Cordillera receives between 450 and 475 mW-h/cm^2. A minor area of high radiation lies over the island of Mappia, north of Manokwari, which is a coral atoll, clear of any orographic effect.

In April (Fig 3), maximum daily values occur in the Port Moresby area (540 mW-h/cm^2), around Kavieng (540 mW-h/cm^2) and at Mappia (550 mW-h/cm^2). Minimum values occur over most of the Central Cordillera and in the Vogelkop (425 mW-h/cm^2).

The distribution for July (Fig 4) shows maximum daily values of about 520 mW-h/cm^2 in the Kavieng area, of 490 mW-h/cm^2 at Mappia and of 470 mW-h/cm^2 in the Port Moresby area. The belt of minimum insolation (325-350 mW-h/cm^2) has shifted southward and lies between Kokenau and Kikori. Most of the Vogelkop receives between 360 and 375 mW-h/cm^2 in this month.

Maximum daily values of insolation in October (Fig 5) are reached in the Koembe-Merauke-Daru coastal strip (625-650 mW-h/cm^2). Minimum values occur over the Vogelkop and over much of the Central Cordillera (475-500 mW-h/cm^2).

On an annual basis (Fig 6) most of the area, except Mappia, Kavieng and the Port Moresby area, receives less than 200 W-h/cm^2 solar radiation per year. Minima are reached over considerable parts of the Central Cordillera (about 160 W-h/cm^2).

Most world maps of solar radiation clearly show for the Southern Hemisphere an increase in annual solar radiation income with increasing latitude till maxima are reached about 20-30°S. Yearly totals over the Great Sandy Desert in Australia exceed 230 W-h/cm^2. Neither Budyko (1958) nor Mani *et al*(1967) clearly show the secondary minimum in annual solar radiation income over New Guinea and adjacent islands, associated with the insular character of the region.

Latitudinal differences in extra-terrestrial radiation over the year throughout the area are relatively small. The ratio of extra-terrestrial radiation at 12°S to that at the equator is 1.10 in January, 0.92 in April, 0.85 in July and 1.03 in October. Cloud cover is apparently the major control for latitudinal and longitudinal differences in Q/Q_A. Many of the present distribution patterns and larger scale spatial differences can qualitatively be explained on the basis of average cloudiness data derived from satellite observations as provided by Sadler (1969). The period covered by satellite cloud observations so far, is not long enough to make detailed quantitative predictions of insolation over the area.

Seasonal changes in cloud cover and radiation level are closely linked to the seasonal latitudinal shifts of the subtropical high-pressure belt and the intertropical convergence zone. A clear example lies in the position of the belt of low radiation over New Guinea with respect to the Central Cordillera.

In January, at the height of what is called the northwest monsoon, the belt of low radiation occupies its most northerly position. In July, during the southeast trade season, the belt has shifted to its most southerly position. In April and October intermediate positions of the belt correspond more closely with most of the Central Cordillera.

It may be noted that important additional differences in insolation may occur on a local scale on the Central Cordillera because of significant differences in elevation-dependent air mass.

In conclusion the tentative character of the monthly and annual maps presented in this paper must be emphasized. There is a great need for expanding the present network of stations recording solar radiation in the area as well as the number of stations recording hours of bright sunshine, especially for inland areas. A shortcoming of the present study is that the relation between solar radiation and hours of bright sunshine has been based on data from three coastal stations. Future improvement on the present maps will depend on the availability of data from stations at higher altitude and inclusion of such data in establishing this relationship.

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