Solar Radiation Maps for the Southern African Region

K.K. Gopinathan
Physics Department, National University
of Lesotho, Roma-180, Lesotho

ABSTRACT

Monthly iso-radiation lines are drawn for the Southern African region using the global radiation data for sixty-one locations. The data are presented in the form of 12 monthly maps and the results are discussed. Yearly mean daily global radiation values are also calculated for these locations and the results are presented.

INTRODUCTION

The most important parameter in utilizing solar energy is the radiation data. They must be accurate and available prior to any solar energy utilization. The most important solar radiation measurement is that of global radiation on a horizontal surface. In this paper, global radiation values on a horizontal surface reported for various locations in Southern Africa are utilized to prepare detailed monthly iso-radiation maps for the region. Most of the Southern African countries have no oil resources and it will be worthwhile for these countries to concentrate on solar energy for their energy needs. The climate of Southern Africa is almost ideal for solar energy utilization. Not only does a greater part of the subcontinent have a summer rain fall, but during winter the sky over the interior is usually cloud free and solar energy is thus available when it is most required.

The Southern African region occupies a geographical zone of approximately 10°E to 40°E longitude and zero to 35°S latitude. The data on measured and estimated values of monthly mean daily global radiation reported by various authors for 61 locations in Southern Africa are utilized to prepare the iso-radiation maps of the subcontinent. The distribution of average daily solar radiation throughout the subcontinent has been compiled in the form of 12 monthly maps.

In an earlier attempt, Drummond and Vowincker[1] prepared a seasonal map of global radiation for Southern Africa, with only two radiation maps, one for the winter and the other for the summer season. They employed data from 30 locations for preparing the maps. Lof et al.[2] prepared the world distribution map of solar radiation and some of the countries in the Southern African region were included in the map. However, they did not include data from countries like Zambia, Tanzania, and Lesotho and only one station from Zimbabwe was considered.

In the present study, results from many locations in these countries are also included. Furthermore, it is felt that a detailed regional map will be more useful for solar energy application in the region than a general global map. Iso-radiation maps have been prepared therefore for the 12 months of the year and the results are discussed.

DATA AVAILABLE FOR MAPPING

The data on monthly mean daily global radiation for the sixty-one locations were obtained from reports published by various authors[2-7]. Measured or estimated values of global radiation were used for drawing the iso-radiation lines. From the radiation values contours for total radiation on a horizontal surface were drawn. The monthly mean daily global radiation values shown in the figures are in MJ m^{-2}. The yearly mean daily solar radiation for each station was calculated by adding monthly mean daily radiation and dividing the sum by 12. Seasonal maps were not drawn as they can be obtained from the monthly maps, by considering the months included in the season.

RESULTS AND DISCUSSION

The iso-radiation lines for the 12 months of the year are shown in Figs. 1-12. Yearly mean daily global radiation lines are shown in Fig. 13. The following salient features emerge from a study of the radiation maps.

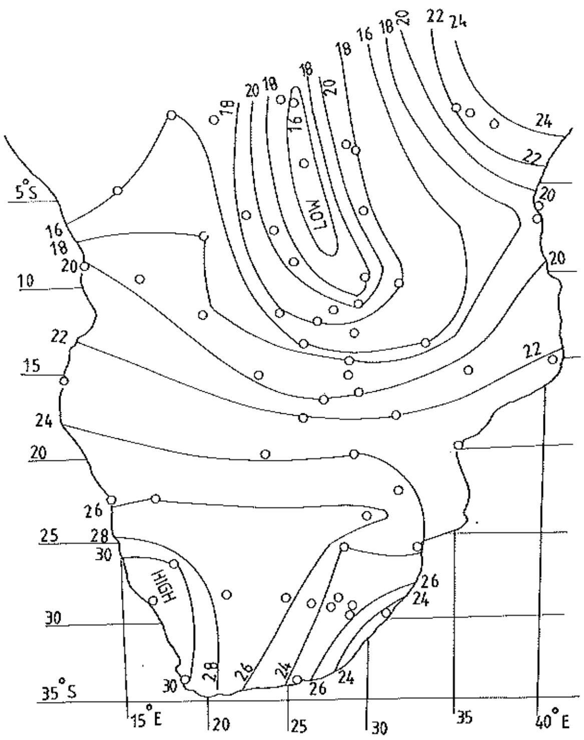

Fig. 1 Isoradiation lines for January (MJ m^{-2} day^{-1})

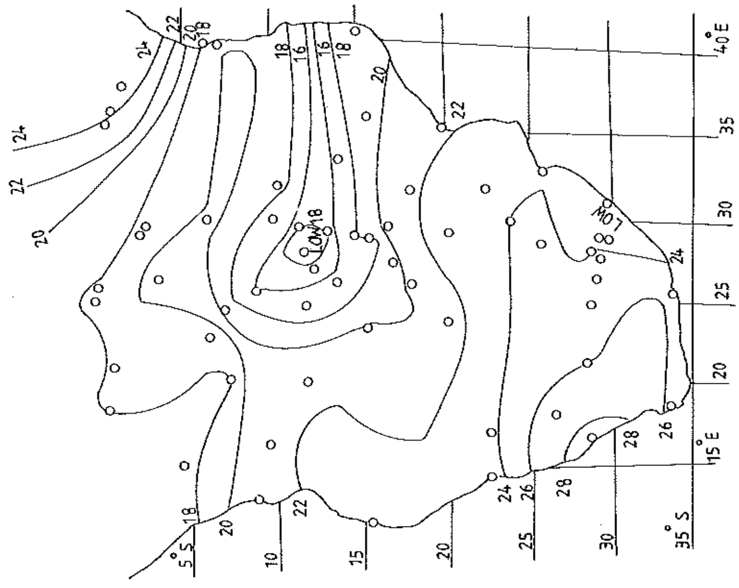

Fig. 2 Isoradiation lines for February (MJ m^{-2} day^{-1})

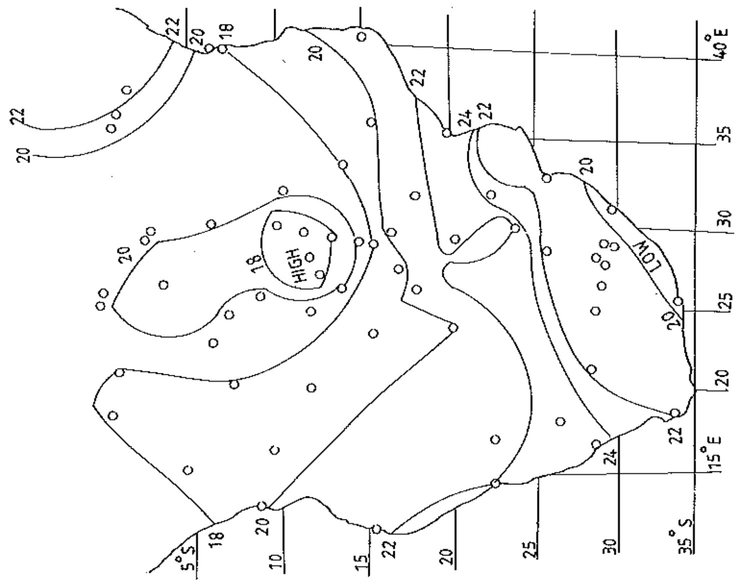

Fig. 3 Isoradiation lines for March (MJ m^{-2}day^{-1})

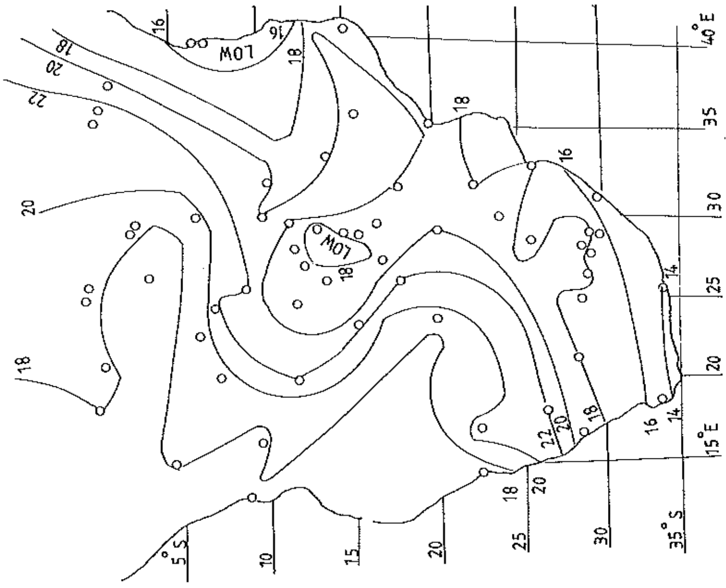

Fig. 4 Isoradiation lines for April (MJ m^{-2} day^{-1})

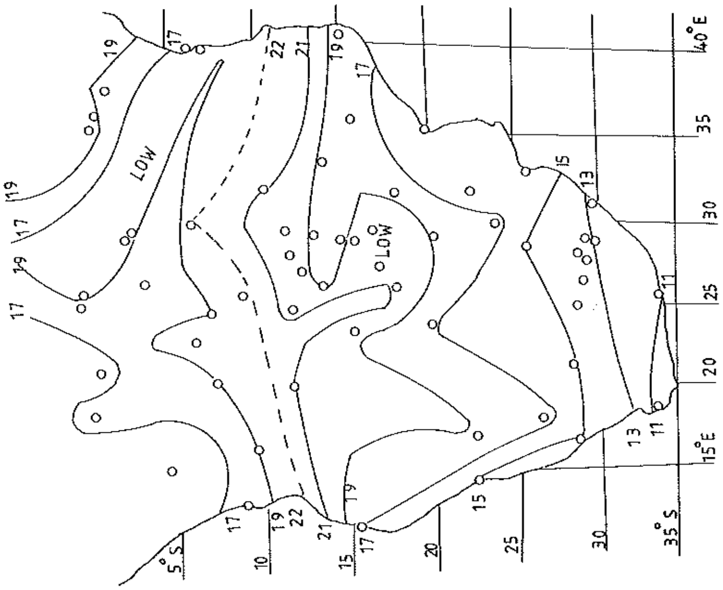

Fig. 5 Isoradiation lines for May (MJ m^{-2} day^{-1})

Solar radiation for January (Fig. 1) has a strong gradient from north to south and is predominant in the western part of the continent. In the western part, it has a value of 16 MJ m^{-2} day^{-1} in the north and 31 MJ m^{-2} in the south, with the maximum radiation line passing through about 30°S latitude. There is also an east-west gradient showing more radiation for the western stations as compared to the eastern stations located at the same latitude, in the region from 15°S to 35°S. The north-south gradient for February (Fig. 2) is slightly less, though still significant. The east-west gradient is still maintained and has extended further to the north during this month. However, the north-south and east-west gradients seem to have weakened during March (Fig. 3). The level of solar radiation has decreased by about 20-25 percent in the southern region, as compared to the previous months. March has the most uniform distribution of solar radiation and the variation for the whole subcontinent is between 18 to 23 MJ m^{-2} day^{-1}, during this month. The solar radiation has considerably decreased in the southern part of the continent in April (Fig. 4). There is a further 20-30 percent decrease in solar intensity in the southern part in the month of May (Fig. 5), still showing a weak east-west gradient. The maximum radiation zone has moved further northward.

The decrease in solar radiation from January to June is about 60-70 percent in the south and about 5-10 percent in the north. During June (Fig. 6), the north-south variation in radiation intensity is from 15 MJ m^{-2} day^{-1} in the northern part to 10 MJ m^{-2} day^{-1} in the southern part. The maximum radiation line has moved to around 12°S latitude. An east-west slope is still observed in the central region. The north-south variation is more predominant in the east during July (Fig. 7) and the east-west gradient has reversed its direction with the stations in the eastern region having more solar radiation than in the west of the same latitude. The interior of the subcontinent receives more solar radiation during this month as compared to the coastal stations. The trend observed in July is repeated in August (Fig. 8). The radiation intensity values have gone up slightly during this month as compared to July. A strong north-south gradient is again observed in September (Fig. 9) with the line of maximum radiation again being observed around 30°S latitude. In the east-west slope, the eastern locations have higher radiation intensity in the northern part and the western locations have higher intensity in the southern part of the subcontinent. Radiation intensity variation in October (Fig. 10) is almost similar to that observed in September. The intensity of solar radiation increases in November (Fig. 11) and varies from 17 MJ m^{-2} day^{-1} in the north to 31 MJ m^{-2} day^{-1} in the south. The trend of increasing solar intensity is continued in December (Fig. 12) with an east-west gradient similar to that observed in January.

Yearly mean daily solar radiation values (Fig. 13) show a clear north-south gradient, both in the eastern and western parts. In the west, the radiation intensity first increases in the region from zero to 30°S latitude, and then decreases. In the east, this decrease is observed from 15°S latitude onwards. The east-west slope is also observed, with high irradiation for the east, in the northern part of the subcontinent and higher values for the west in the southern part.

The above observations can be interpreted as follows: In Southern Africa, winter months are June, July and August and the summer months are December, January and February. These two seasons are characterized by very marked climatic differences except in the latitude north of 5°S, where the rainy (and accordingly the most cloudy) seasons occur during the transition months of March to May and September to November. Over the bulk of the interior of the subcontinent, the winter months are cloudless, or very nearly so and the summer months are much more cloudy. Most of the rainfall occurs during the summer months. In the region of the western province of South Africa, the regimes are reversed and the winters are cloudy and wet whereas the summers are dry and sunny.

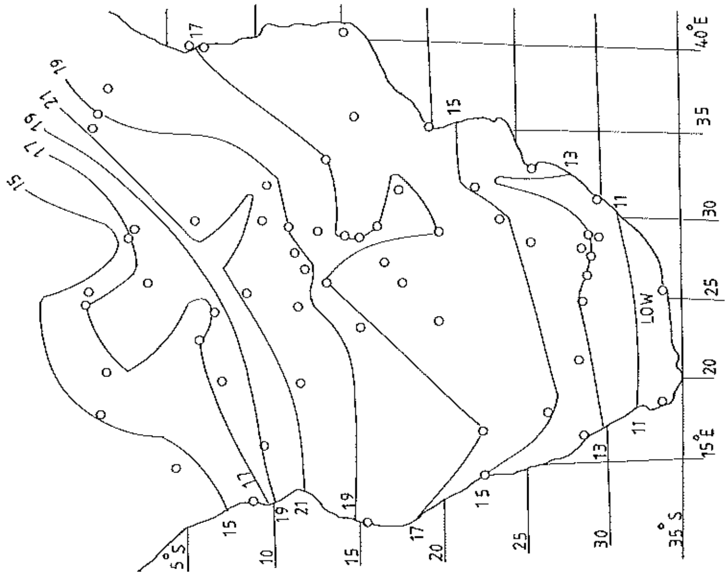

Fig. 6 Isoradiation lines for June (MJ m^{-2} day^{-1})

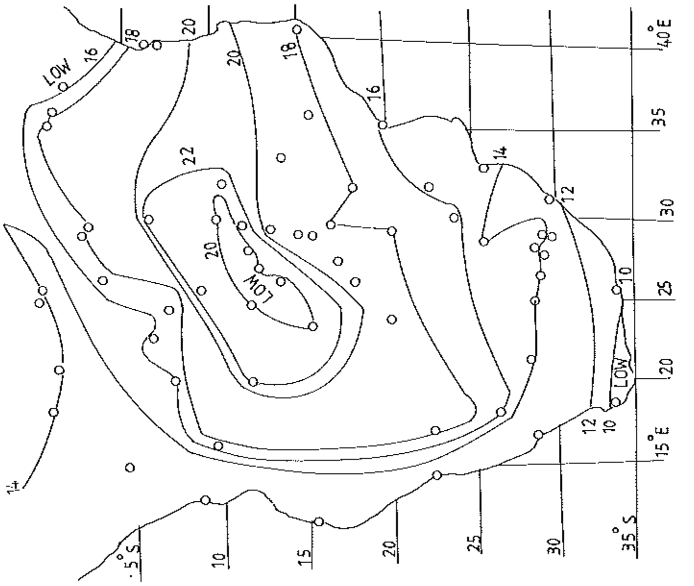

Fig. 7 Isoradiation lines for July (MJ m^{-2} day^{-1})

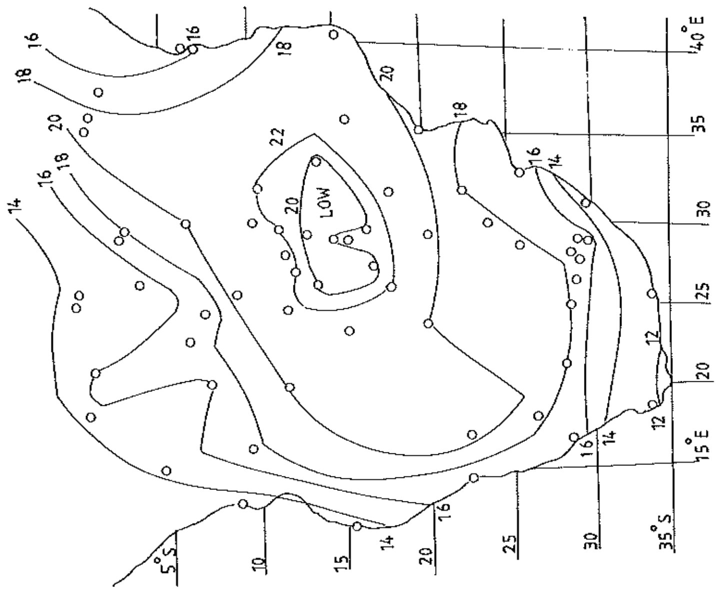

Fig. 8 Isoradiation lines for August (MJ m^{-2} day^{-1})

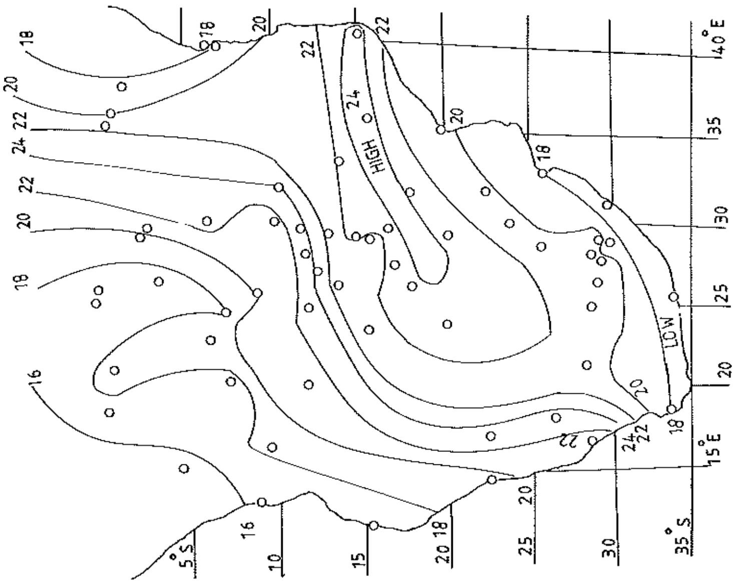

Fig. 9 Isoradiation lines for September (MJ m^{-2} day^{-1})

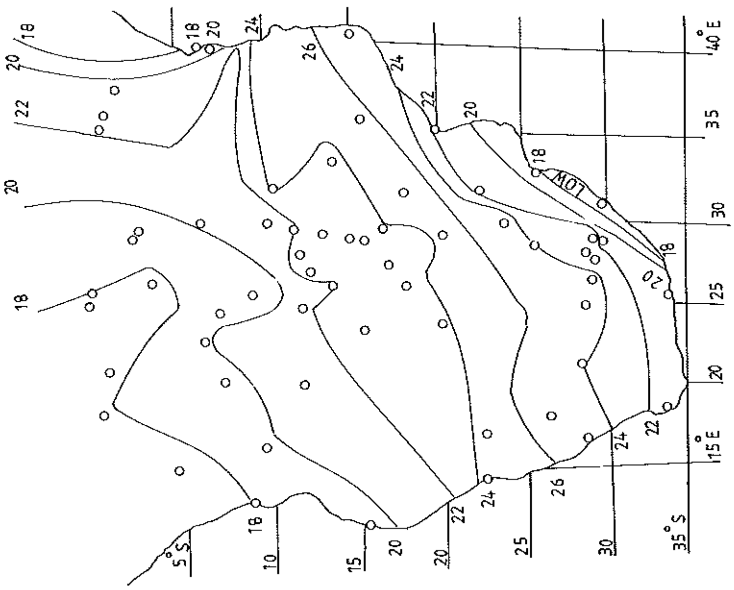

Fig. 10 Isoradiation lines for October (MJ $m^{-2} day^{-1}$)

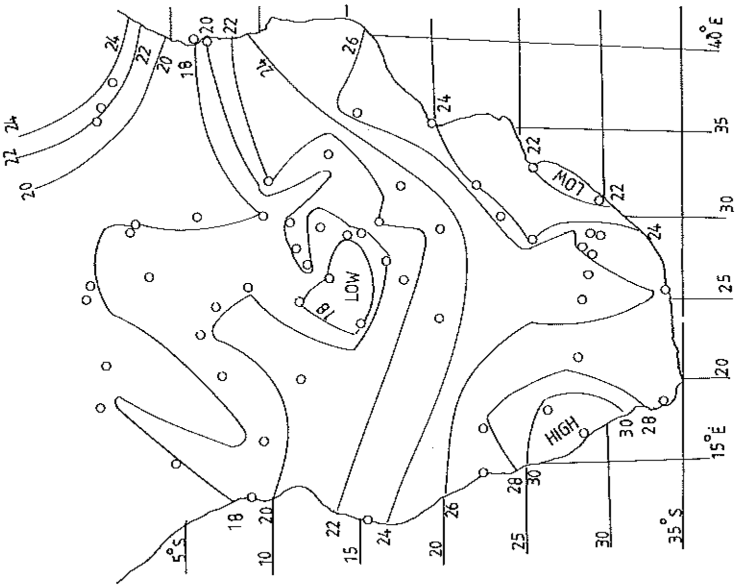

Fig. 11 Isoradiation lines for November (MJ $m^{-2} day^{-1}$)

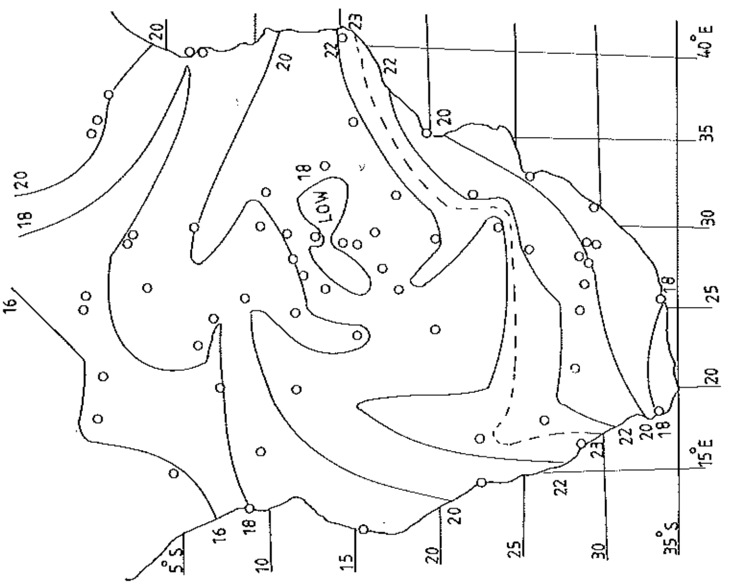

Fig. 13 Yearly mean daily isoradiation lines (MJ m^{-2} day^{-1})

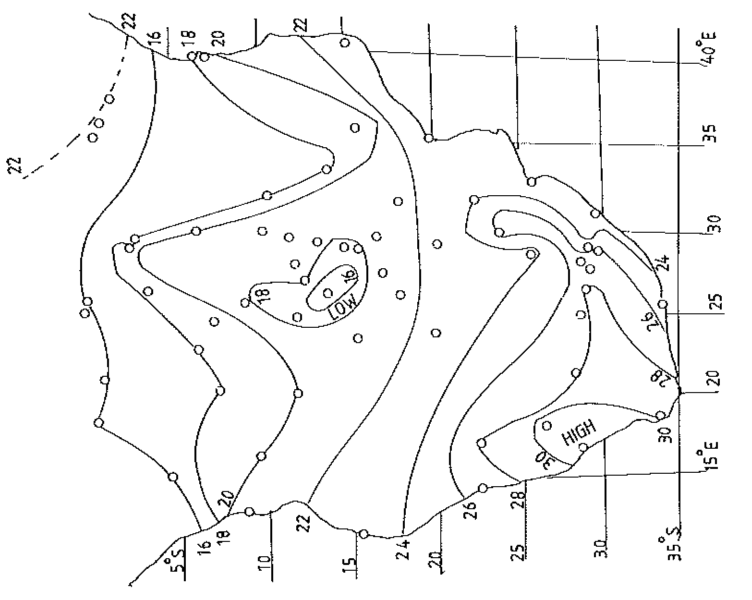

Fig. 12 Isoraddiation lines for December (MJ m^{-2} day^{-1})

During the summer months the sun is at its southernmost position and at the outermost limits of the atmosphere the highest radiation is received between 30° and 40°S. Accordingly, the zone of maximum intensity at the surface is found around 30° to 40°S latitude during the summer months. During the winter months there is an increase in sunshine duration northward and an increase in cloudiness to the south of 30°S and to the north of 10°S. Accordingly, maximum radiation is found in a zone extending from 10°S to 30°S. In the northerly region radiation values are usually higher, for the same latitude, in the east rather than in the west during this season. The possible reason is that in the west the moisture content of the air and the density of clouds are higher than in the east. Further south of the zone of maximum radiation, the western sector of the continent receives distinctively more radiation than the eastern sector. The main factor determining this strong radiation in the west is again the low values of cloud cover. In the extreme south, radiation decreases drastically in winter months. Large amounts of cloud cover may again be the main factor.

CONCLUSION

The main features of global radiation on a horizontal surface in the Southern Africa region are as follows:

1. The extreme south of the western region of the subcontinent has an annual variation of over 200 percent in solar intensity. It varies from 10 MJ m^{-2} day^{-1} in June and July to 31 MJ m^{-2} day^{-1} in December and January. The annual variation in the north of the western region is only of the order of 50 percent, from 12 MJ m^{-2} day^{-1} in July to 18 MJ m^{-2} day^{-1} in February.
2. There is a strong radiation gradient from north to south which stretches in summer and weakens in winter months. The most uniform distribution of solar radiation throughout the subcontinent is during March.
3. An east-west gradient is observed during most of the months.
4. Yearly mean daily solar radiation values show both north-south and east-west gradients.

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