

On the Distribution and Variation of Solar Radiation in Japan

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Abstract

Records of daily total of solar radiation measured on a horizontal surface for consecutive three to seven years are available for about forty stations in Japan. Using these data, yearly and seasonal mean isopleths of solar radiation are drawn.

In the results the following features are to be pointed out:

- 1) The distributions are affected by the meteorological factors rather than by latitude.
- 2) The amount of solar radiation is larger in the inland district than near the sea.
- 3) The minima of solar radiation in the Tokyo and Osaka districts are remarkable.
- 4) The seasonal variation of the amount of solar radiation is largest in summer and then in spring, autumn and winter in the order of magnitude.
- 5) The annual variations of solar radiation are mainly brought about by the conditions in summer.

1. Introduction

Solar radiant energy is the source of all living things and activities on the earth and the investigation of the amount of solar radiation reaching the earth's surface has a fundamental importance on human life. In a meteorological context, too, solar radiation is the origin of all phenomena. It has long been well known that non-uniform and irregular distributions of solar radiation and of atmospheric outgoing infrared radiation over the earth are the origins of motion of the atmosphere (SIMPSON, 1928; HOUGHTON, 1954; PHILLIPS 1956). Both solar and atmospheric radiations are affected by the meteorological factors, of which, to our regret, we have not yet satisfactory knowledge, and many questions about them still remain unsolved. The investigations of them may be one of the important problems in future meteorology. It is also important from the standpoint of solar energy utilization to know the geographical distribution and time variation of solar radiation.

Recently S. FRITZ has given the distribution pattern of solar radiation in U.S.A. (FRITZ, 1955), and J. N. BLACK has given the same pattern of the world (BLACK, 1956). BLACK's map is most convenient as it gives the world-wide monthly distribution but as the number of stations where solar radiation is measured is limited,

his map is based on a rather rough assumption of the relation between solar radiation and cloud amount.

It is desirable to draw a map of solar radiation in Japan as accurate as possible on the basis of actual measurement. In our country the data of measurement with the Robitzsch actinograph are available at many meteorological stations, and are given in the Actinometric Bulletin published by the Japan Meteorological Agency.

It is only during the last few years that the network and the work of standardization of solar radiation measurement have been recovered from the war-time destruction. The data used here cannot therefore be free from more or less uncertainties. But nevertheless this kind of statistical research is desirable since it gives fundamental knowledge of radiation climate in Japan and also gives conversely a necessary criticism upon the post-war network of radiation measurement in Japan.

2. Method of calculations

The data used in this work are the mean values for a period of five days of solar radiation during the years from 1948 to 1954 in Japan, which are printed in the "Actinometric Bulletin" published by the Japan Meteorological Agency (formerly the Central Meteorological Observatory). These data, therefore, are the daily integrated values of solar radiation falling on the earth's horizontal surfaces measured with the Robitzsch actinograph. In order to show the general aspects of the distribution of solar radiation, distribution-maps are drawn, where mean

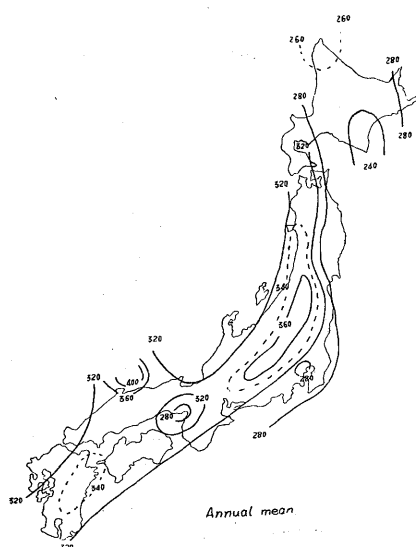


Fig. 1. Annual mean distribution of solar radiation in Japan, curves are the lines of equal intensity (cal/cm². day).

values of four to seven years from 1948 to 1954 and of about forty stations were used as basic data (Fig. 1). These data are used because there seem to be no other data that cover a longer period and are so reliable. To see the seasonal dependency, the same procedures are taken for each season, namely for the mean values for three months of the year, and the maps for each season are obtained (Fig. 2). In order to see the range of variations and to see if the solar radiation has any correlation to the anomalous low temperatures in summer or to the high temperatures in winter experienced in the years under review, the distribution-maps of the annual means for each successive year are desired, but they cannot be prepared owing to the lack of data, and the inter-annual variations of the seasonal means of solar radiation at the given stations of varying latitudes are graphically shown (Fig. 3). The daily amount of solar radiation depends not only upon its intensity, but also upon the

duration of sunshine. So we also examined the variation in the duration of sunshine and in the solar radiation per unit duration of sunshine.

3. Results obtained and discussions

(a) *The distribution of solar radiation in Japan*

The outstanding feature of the distribution of solar radiation is that it is mostly affected by the meteorological factors rather than by the latitude (Figs. 1

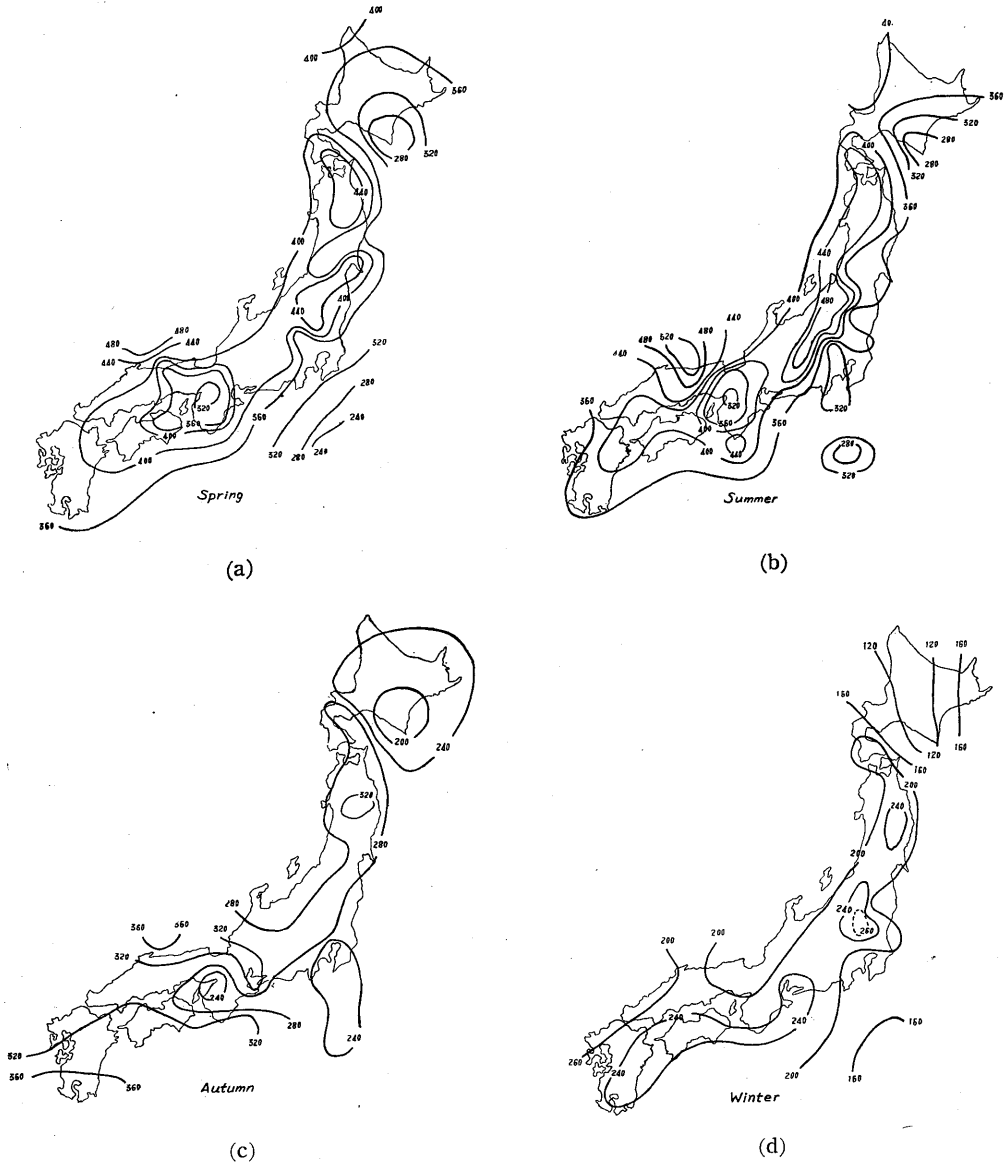


Fig. 2. Seasonal mean distribution of solar radiation in Japan.

and 2). The extra-terrestrial solar radiation, of course, is larger in the lower latitudes than in the higher in all seasons in Japan, but this is not the case with the distribution pattern of solar radiation at ground level. This is presumably because the amount of the water vapor, dust and mean effective cloudiness, which contribute to the extinction of solar radiation by scattering and absorption, are greater in the lower latitudes than in the higher by so much that they mask or disturb the tendencies of the distribution of the extra-terrestrial solar radiation. Comparing the distribution of solar radiation in the inland with that near the sea (Figs. 1 and 2), the amount of solar radiation in the former is generally larger than that in the latter. This is probably due to the fact that the effective total amount of dust, water vapour etc. that tend to reduce solar radiation, is smaller in the inland than near the sea. As expected, Figs. 1 and 2 show that the minima of solar radiation in the Tokyo and Osaka districts are remarkable. This probably shows the influence of the two typical great cities in Japan containing more smog or haze than other districts. Observing the distribution of the seasonal means of solar radiation (Fig. 2), we see the amount is largest in summer, and then follow spring, autumn and winter in the order of magnitude. It may be said that the "turbidity" of the atmosphere which depends upon the water vapor, dust and effective mean cloudiness is not large enough to mask the effect of seasonal variation of the extra-terrestrial solar radiation. We also examine the solar radiation per unit duration of sunshine, but no outstanding feature seems to exist.

(b) *The inter-annual variation of solar radiation in Japan*

Fig. 3 shows that the annual variations of the amount of solar radiation are mainly brought about by the conditions in summer. This is probably due to the fact that the amount of solar radiation is largest in summer, in which the rainy season, the so-called "Baiu," sets in and that the situation of "Baiu" fluctuates from year to year. Observing Fig. 3, we see the amount of solar radiation seems to fluctuate from year to year. According to the statistical testing, however, these variations are not statistically significant in 95% of the confidence limit.

4. Conclusion

As mentioned above, the data are not sufficiently abundant and also may not be accurate enough to produce satisfactory results. Nevertheless, the following conclusions or suggestions for future research may be noticed as the results of this study. In Japan the solar radiation reaching the earth's surface is much affected by the meteorological conditions rather than by the latitude. The studies of solar radiation on the earth's surface must be done simultaneously with the examinations of the amount and distribution of the water vapour, dust and effective mean cloudiness. The effects of dust on solar radiation have not been well investigated either theoretically or experimentally (HOUGHTON, 1954). And the studies on the effects of non-Rayleigh scattering and the examination of the amount and size distribution of dust must be done in future. As for the effect of cloudiness, we have a few theoretical and experimental studies (HOUGHTON, 1954; HEWSON, 1943; FRITZ and MACDONALD, 1951), but these studies are not satisfactory

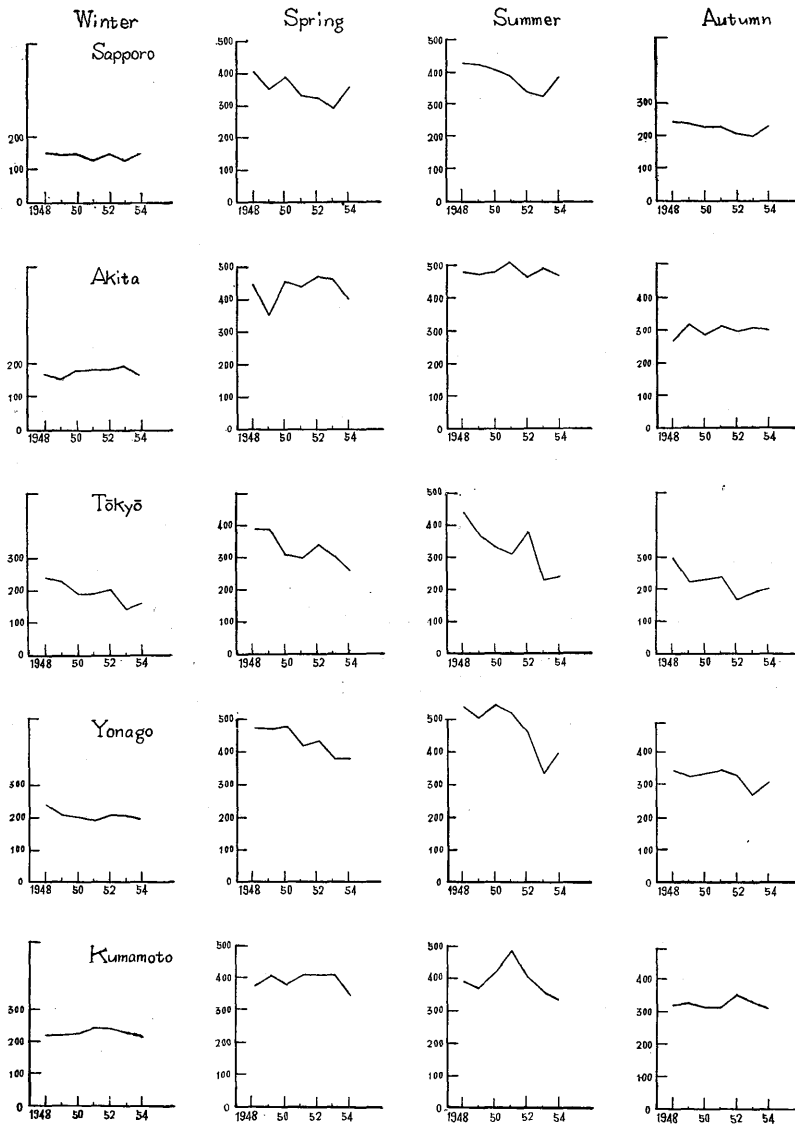


Fig. 3. Inter-annual variation of seasonal mean intensity of solar radiation various stations in Japan during the period from 1948 to 1954. Ordinates show the intensities (cal/cm² day) and abscissas shows time of the year.

either. Such studies should be carried through in future in connexion with the problem of radiation climate discussed in this paper.

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