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THE DISTRIBUTION OF TERRESTRIAL RADIATION

BY

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In a recent *Memoir* entitled "Further Studies in Terrestrial Radiation"[1] I described a method which enables us to calculate the outgoing long-wave radiation from the earth and its atmosphere. In the present *Memoir* I apply the method there described to calculate the distribution of incoming and outgoing radiation at different parts of the earth at different times of the year, and in this way obtain a picture of the radiation balance both in time and space. It is not necessary to repeat the method of calculation; it will be sufficient to recall that the outgoing radiation depends on four factors only, namely (*a*) the surface temperature, (*b*) the temperature of the upper surface of the clouds, (*c*) the temperature of the stratosphere, and (*d*) the amount of cloud.[2] Given the values of these four factors, the intensity of the outgoing radiation is first calculated for clear skies, R_1, then for overcast skies, R_2; then the actual intensity of the outgoing radiation is given by

$$R = R_1 (1 - C) + R_2 C$$

in which C is the cloud amount expressed as the fraction of the sky covered by clouds.

In the previous paper it was not necessary to calculate the incoming radiation in any detail. For the purpose of that paper it was only necessary to consider the albedo of the earth as a whole, and Aldrich's value of 0·43 was adopted. In this paper it is necessary to calculate the amount of incoming solar radiation reflected in different localities, and for this purpose it is necessary to know the relationship between the albedo and the cloud amount. For no cloud Aldrich[3] gives 0·08 reflection from the surface and 0·09 from the atmosphere, a total of 0·17; for a cloud amount of 0·52, the mean cloud amount for the earth as a whole adopted by him, Aldrich gives 0·43 as the amount reflected; for completely overcast skies Aldrich gives 0·78, or probably a little more if one considers the small amount of reflection from the air above the clouds.[4] These values

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[1] *London, Mem. R. Meteor. Soc.*, **3**, 1928, No. 21.

[2] In the previous paper the small amount of radiation of wave lengths less than $5\frac{1}{2}\mu$ was neglected as being quite insignificant.

Some of the surface temperatures dealt with in this paper are, however, sufficiently high to give rise to significant amounts of short-wave radiation, some of which is transmitted and some absorbed by the atmosphere. To allow for this half the radiation of wave lengths shorter than $5\frac{1}{2}\mu$ emitted by the ground has been added to the outgoing radiation. For the method of computation see the Appendix to this paper.

[3] *Washington, D.C., Smithsonian Inst. Ann. Astroph. Obs.* **2**, 1908, p. 162.

[4] *Washington, D.C., Smithsonian Inst. Ann. Astroph. Obs.* **4**, 1922, p. 379.

do not lie on a straight line; but in Fig. 1, the three points have been connected by a simple curve.

A. Ångström[5] has discussed the variation of the albedo with cloud amount and gives the following linear relationship:

$$a = 0{\cdot}70C + 0{\cdot}17\ (1 - C).$$

This straight line is shown on Fig. 1, and it will be seen that there is little difference between Aldrich's and Ångström's values of the albedo except

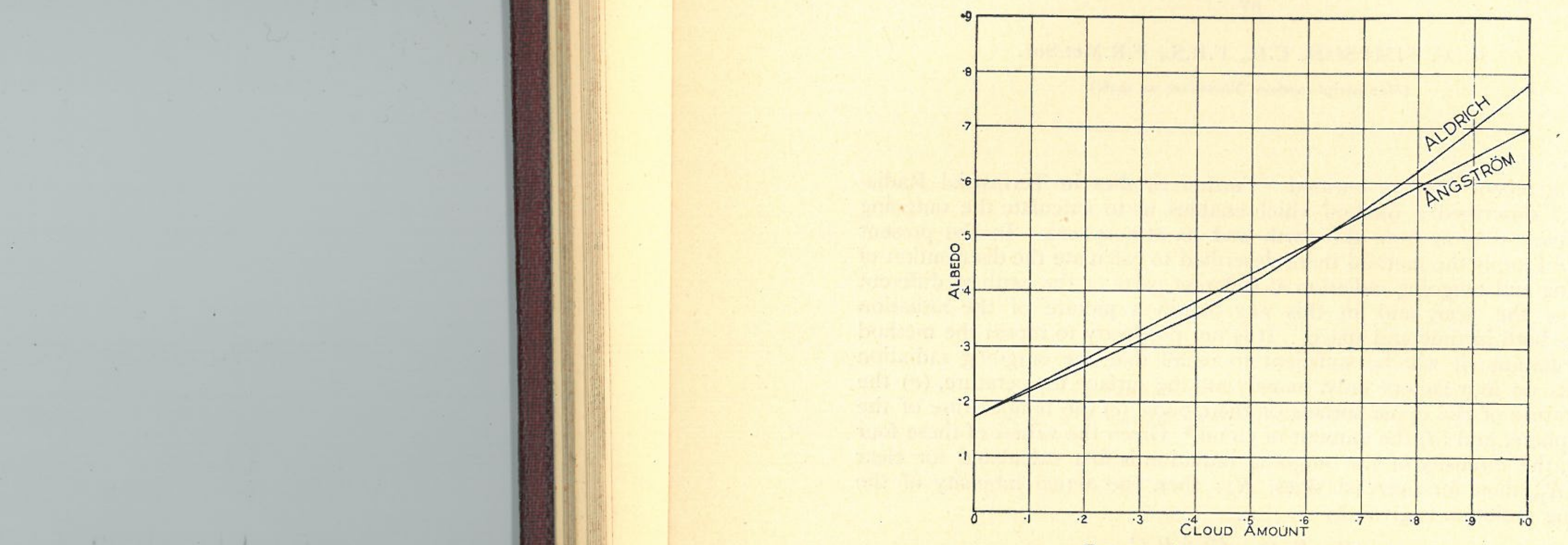

FIG. 1.—Albedo and cloud amount.

in the neighbourhood of overcast skies. Not wishing to judge between the values of these two authorities, I have simply adopted the mean of the two determinations as follows:

TABLE A—ALBEDO AND CLOUD AMOUNT.

Cloud amount	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
Albedo	0·17	0·22	0·27	0·32	0·37	0·43	0·48	0·54	0·61	0·67	0·74

With these values of the albedo, a, and an incoming solar radiation intensity of S' we have

$$\left.\begin{array}{l}\text{Intensity of solar radiation absorbed}\\ \text{by the earth and its atmosphere}\end{array}\right\} = S = S'\ (1 - a).$$

PART I. GEOGRAPHICAL DISTRIBUTION OF RADIATION DURING JANUARY AND JULY.

INTENSITY OF OUTGOING TERRESTRIAL RADIATION.

The surface of the earth between latitudes 70° N. and 70° S. was divided into "10° squares," for each of which Dr. C. E. P. Brooks determined the mean temperature and the mean cloud amount for each

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[5] A. Ångström, *Beitr. Geophysik, Leipzig*, **16**, 1926, H. 1.

of the two months, January and July. The values are shown on Figs. 2, 3, 4 and 5. The temperature of the stratosphere has been taken to be simply a function of the latitude and not to change during the year; the values adopted are the following:

TABLE B—TEMPERATURE OF THE STRATOSPHERE.

Latitude	0°-10°	10°-20°	20°-30°	30°-40°	40°-50°	50°-60°	60°-70°
Stratosphere temperature	204	207	211	214	217	219	220

For reasons given in the previous *Memoir*, the temperature of the upper surface of the clouds has been taken to be 260a in all parts of the earth.

With these values the intensity of the outgoing terrestrial radiation was calculated, with the results shown in Figs. 6 and 7. I do not propose to discuss the results in any great detail in this paper, as they are in many respects so novel and raise so many problems that much time and investigation will be required before their true significance can be grasped. The following important characteristics of the outgoing radiation, however, may be noted.

The great uniformity in the intensity of the outgoing radiation in all parts of the world and at both seasons of the year is remarkable. On the two maps practically the whole area has radiation between ·26 and ·30 cal. per cm.^{2} per min.; this uniformity would come out much more clearly if equal area maps had been used instead of maps on Mercator's projection.

Both maps show two belts of relatively high radiation, one on each side of the equator, the equatorial region itself sending out radiation only a little more intense than that from the polar regions. This latter fact is due to the low stratosphere temperature and the large amount of cloud in equatorial regions.

On comparing Figs. 6 and 7 with the corresponding charts showing the temperature distribution in January and July, it will be seen that there are large differences, due mainly to the effect of the cloud. Desert regions are the sources of the most intense outgoing terrestrial radiation.

INCOMING SOLAR RADIATION.

In order to examine the heat balance it is necessary to compare the intensity of the outgoing radiation with the intensity of the radiation received from the sun. The intensity of the solar radiation at the limits of the atmosphere have been computed by Angot.[6] Using these values and applying the albedo corresponding with the cloud amount in each square, values of the intensity of the "effective solar radiation" have been computed for each 10° square.

RADIATION BALANCE.

The difference between the intensities of the terrestrial radiation and of the effective solar radiation represents the rate of accumulation or loss of heat due to radiation. This is a very important meteorological factor, for on it depends nearly every process which takes place in the atmosphere. Values for the difference, $S - R$ are plotted on Figs. 8 and 9. In these diagrams the italic figures indicate negative values, that is, the outgoing

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[6] *Ann. bur. cent. météor., Paris*, 1883, partie I., pp. B 136-161.

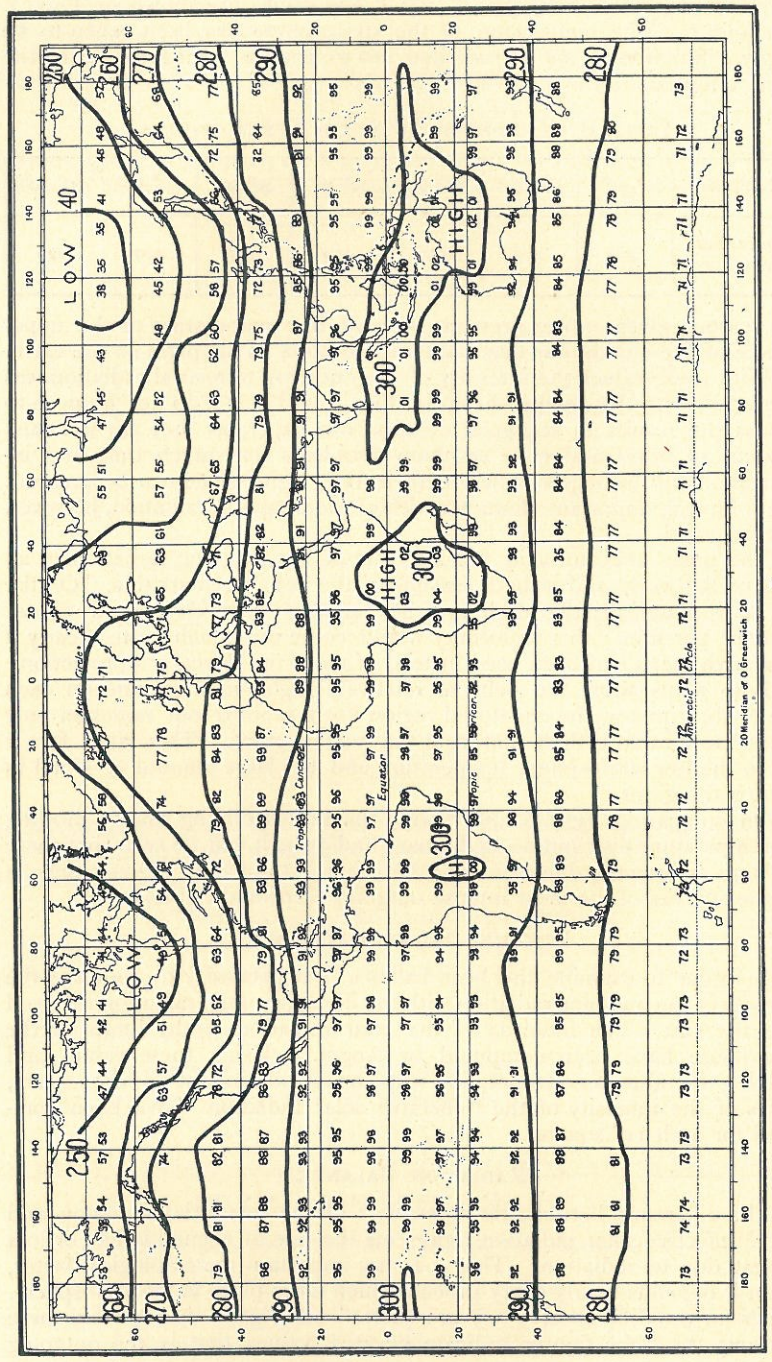

FIG. 2.—Mean temperature, January.
The mean temperatures of the 10° squares are expressed in the absolute scale with the first figure, 2 or 3, omitted.

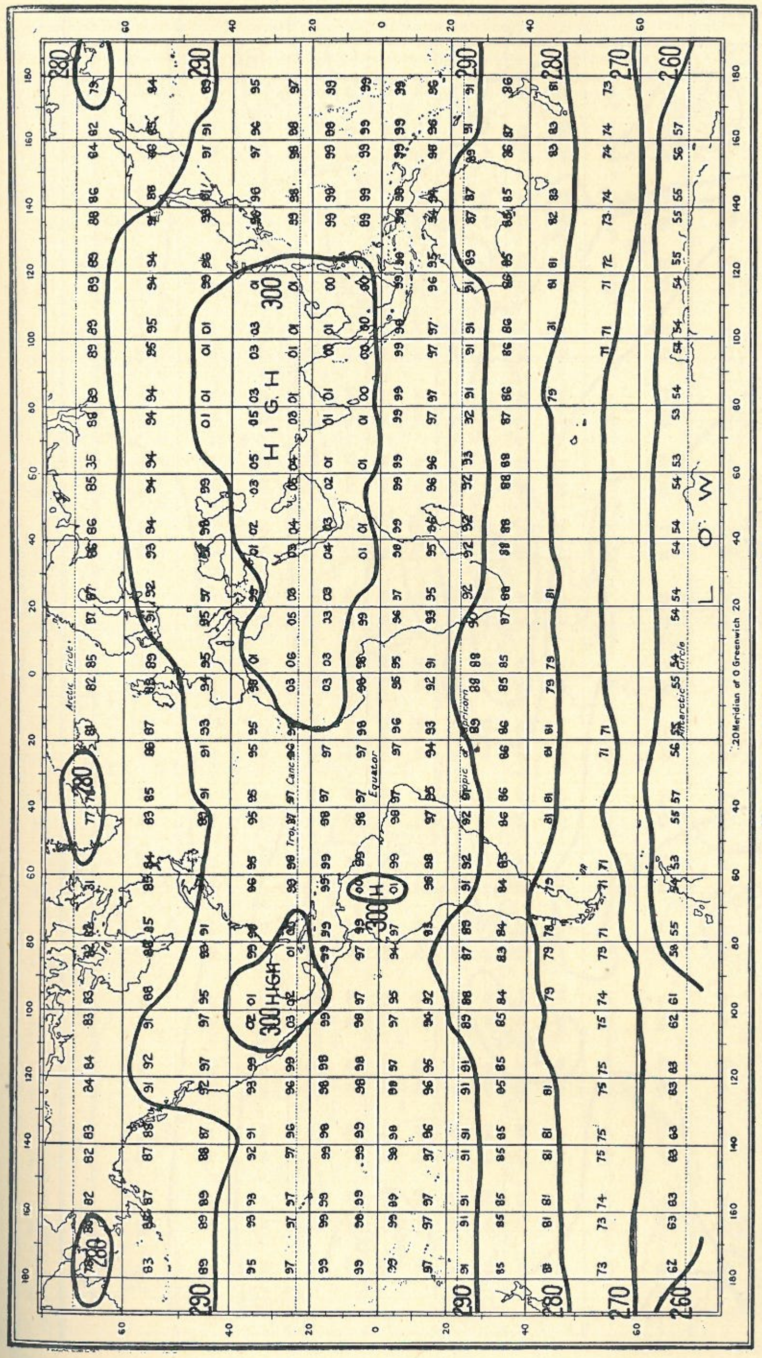

FIG. 3.—Mean temperature, July.
The mean temperatures of the 10° squares are expressed in the absolute scale with the first figure, 2 or 3, omitted.

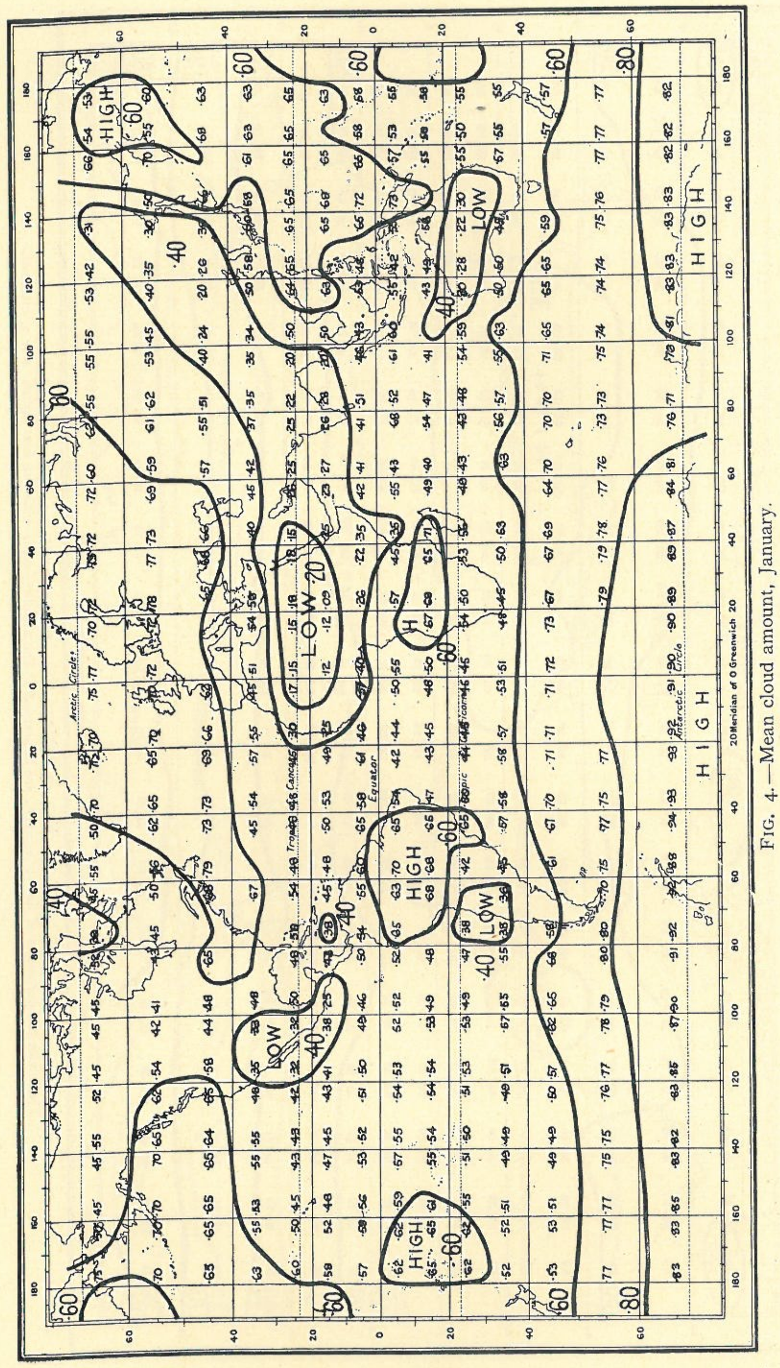

FIG. 4.—Mean cloud amount, January. Clear sky=·00, overcast sky=1·00.

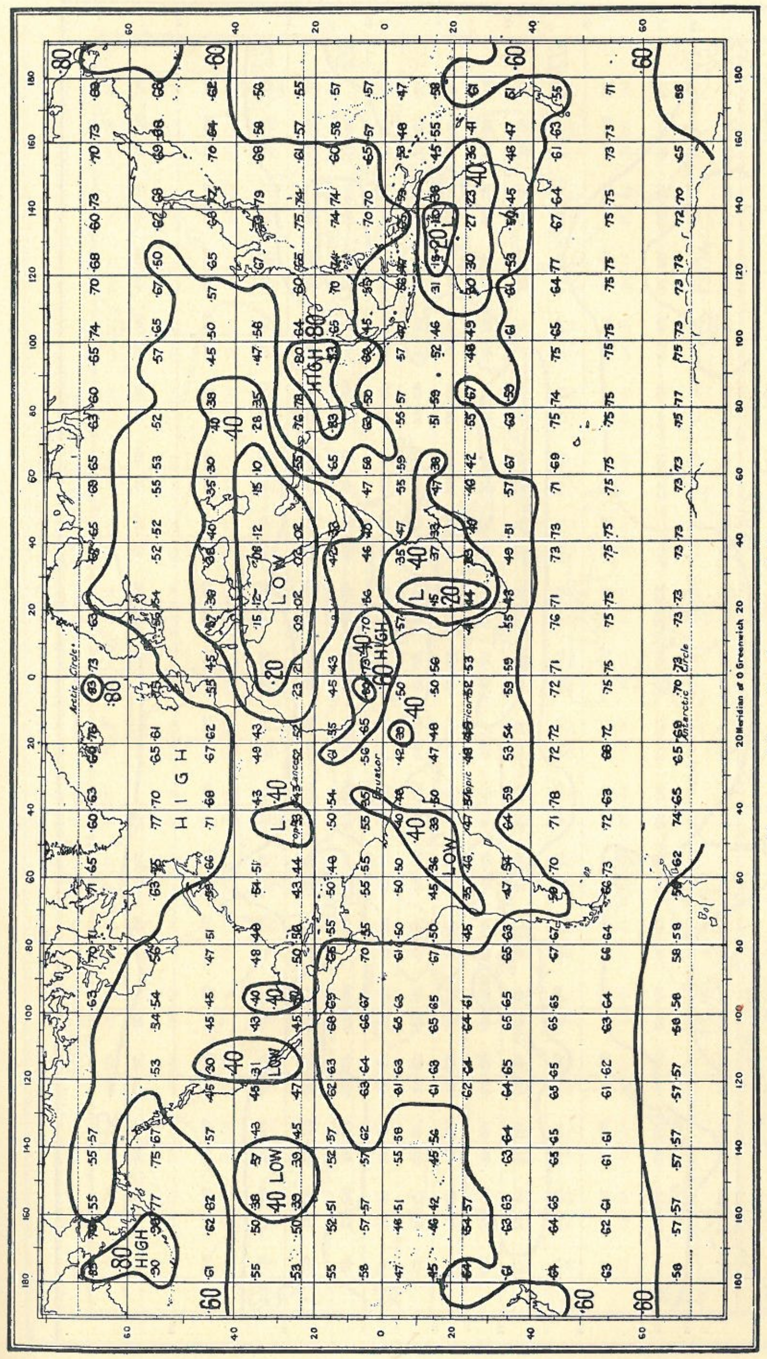

FIG. 5.—Mean cloud amount, July. Clear sky=·00, overcast sky=1·00.

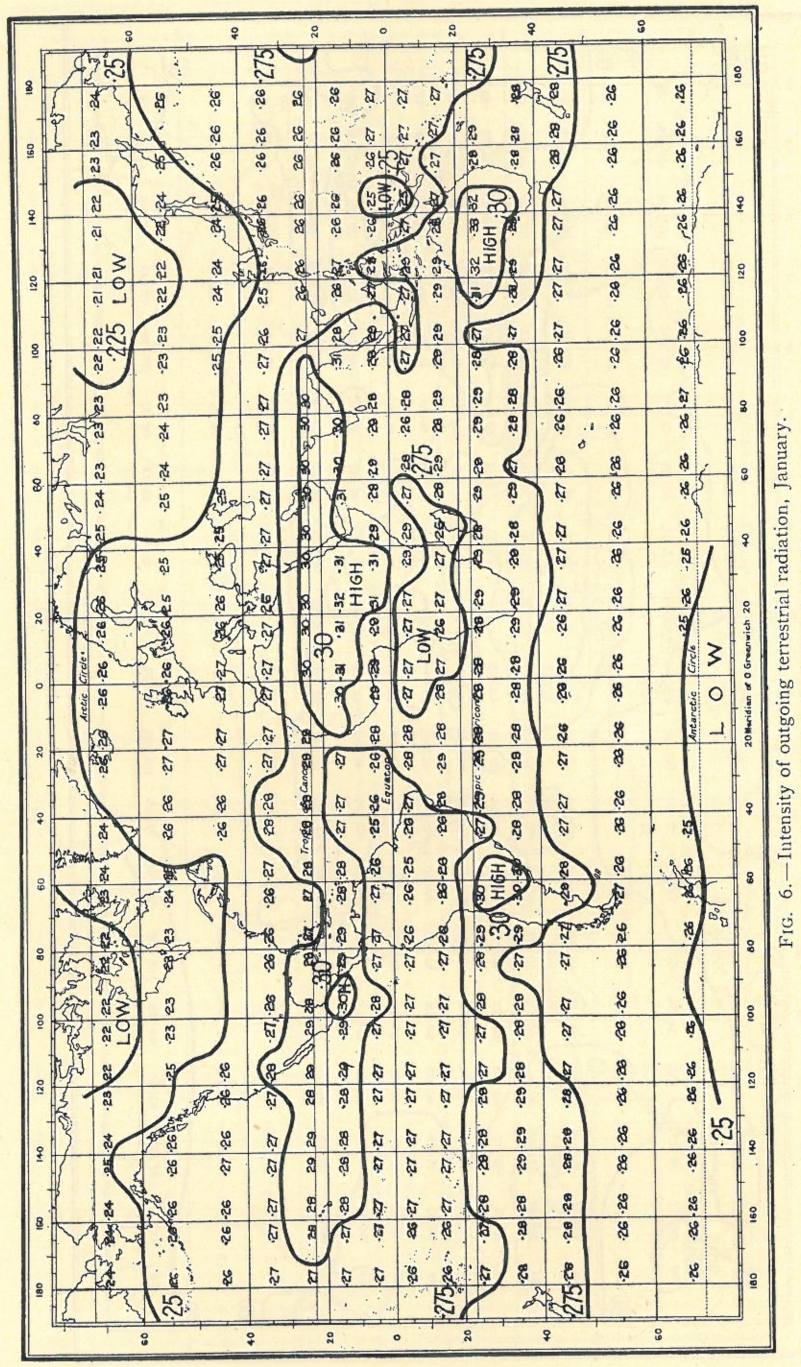

FIG. 6.—Intensity of outgoing terrestrial radiation, January.
Unit: gram calorie per sq. cm. per min.

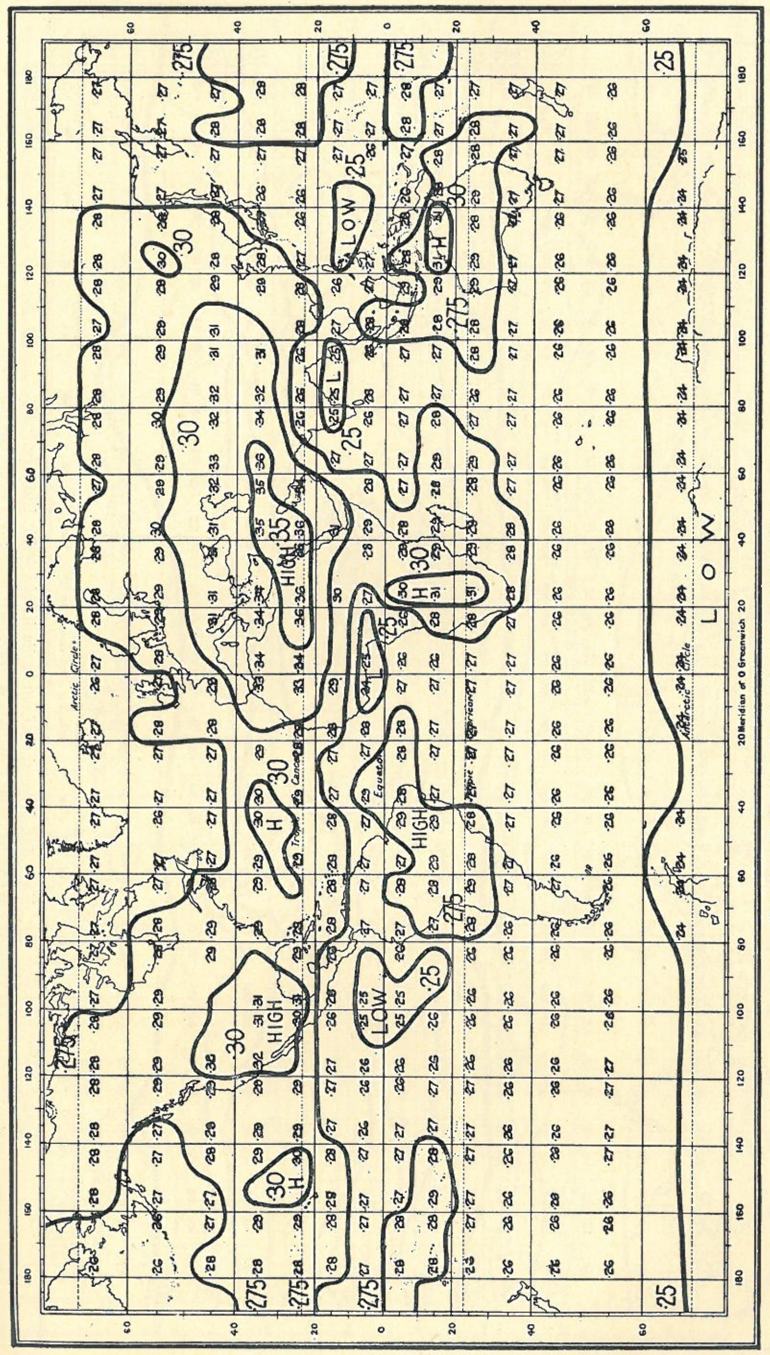

FIG. 7.—Intensity of outgoing terrestrial radiation, July.
Unit: gram calorie per sq. cm. per min.

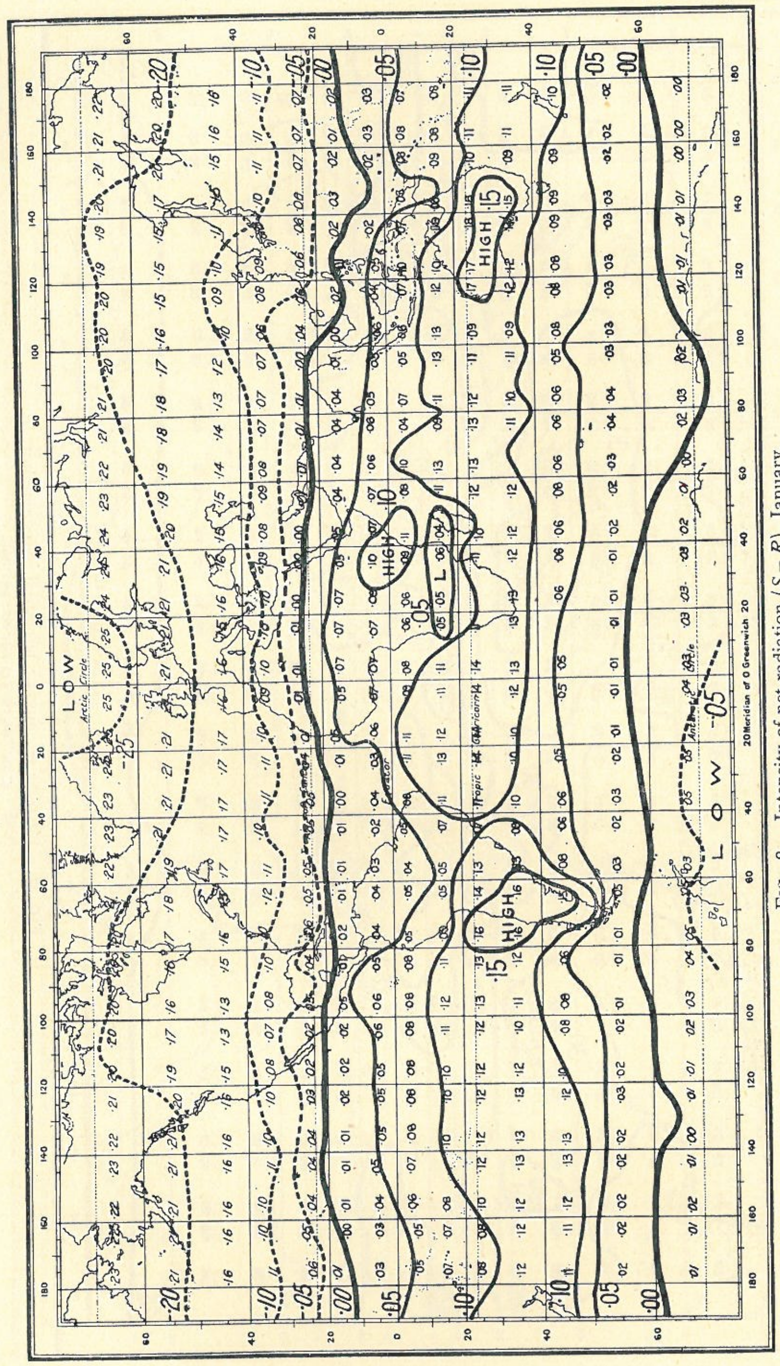

FIG. 8.—Intensity of net radiation ($S-R$), January.

S = intensity of effective solar radiation, R = intensity of outgoing terrestrial radiation.
Unit: gram calorie, per sq. cm. per min.
Negative values are shown in italics, and by broken lines.

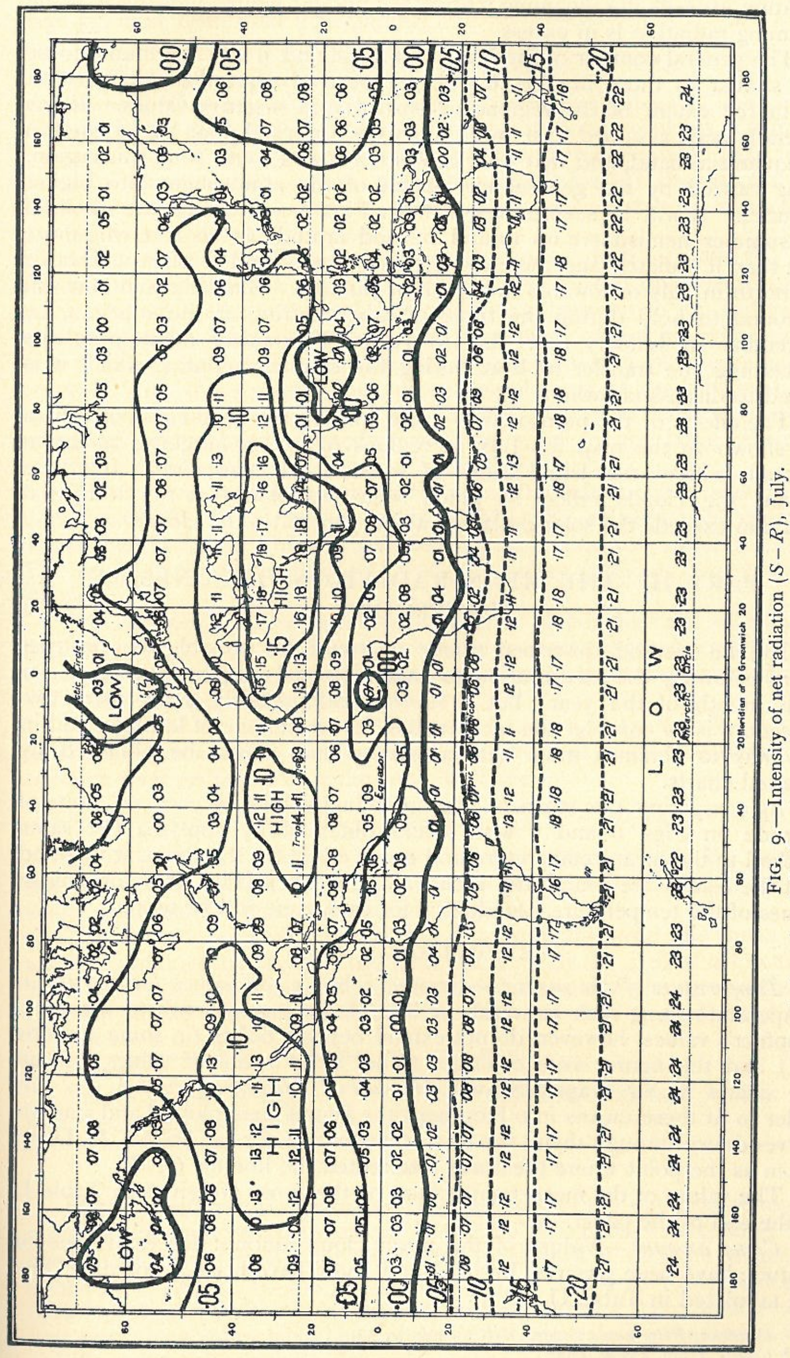

FIG. 9.—Intensity of net radiation ($S-R$), July.

S = intensity of effective solar radiation, R = intensity of outgoing terrestrial radiation.
Unit: gram calorie, per sq. cm. per min.
Negative values are shown in italics, and by broken lines.

radiation exceeds the incoming; while the upright figures indicate that the incoming radiation is in excess.

The general contour of the lines in Figs. 8 and 9 will be found to be very similar to those in Figs. 6 and 7 respectively, but the chief interest lies in the extent of the regions of positive and negative values. It has generally been assumed that more energy is absorbed than is radiated in an equatorial band, and that heat passes north and south from this region, being carried by the general circulation of the atmosphere into higher latitudes. It will be seen, however, from Figs. 8 and 9, that the whole of the summer hemisphere up to and beyond latitude 60° is receiving more heat than it radiates, and therefore there can be little flow of heat towards the north in July or towards the south in January. Similar conditions will be found to hold during the three months centring at the solstices, *i.e.* November to January and May to July. This raises many problems concerning the transfer of heat during the summer months, which it is hoped to discuss elsewhere.

The effects of the monsoons in India and on the west coast of Africa are shown in the map for July as regions of excess outgoing radiation isolated within the large band of excess solar radiation. In these regions the clouds reflect so much solar radiation that the terrestrial radiation exceeds the solar radiation which penetrates the clouds.

PART II. THE MEAN RADIATION OF ZONES OF LATITUDE.

By the method described above it would be possible to construct charts showing the distribution of incoming and outgoing radiation for each month of the year; but a shorter and probably more instructive procedure is to consider the mean values for each zone of latitude, and in this way to obtain a more general survey than would be obtained by detailed charts.

By comparing the mean of the individual values in each 10° zone of latitude on Figs. 6 and 7 with values obtained by applying the same method to the mean temperature and mean cloud for the zones, it is found that the results are practically identical. In this section, therefore, mean values of the temperature, cloud, etc., for each zone will be used.

METEOROLOGICAL DATA.

Temperature of the surface.—Hopfner[7] has given values for the mean temperature along each 10° circle of latitude for each month of the year. Hopfner's values, however, do not extend beyond 60° S. (in some months 50°), and the figures were extended to 80° S. by means of values read off the charts in Sir Napier Shaw's *Manual of Meteorology*,[8] Vol. II. In order to fit these means into Hopfner's the figures were plotted and smooth curves drawn through them, the mean temperature for say 70°-60° N. being taken as the point where the curve intersected the line for 65° N.

The values of the mean temperature of the zones are given in Table I. at the end of the paper.

Cloud amount.—Values of the mean cloud amount for each zone of latitude have been given by Brooks,[9] and these have been adopted. They are tabulated in Table II.

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[7] Hopfner, *Peterman's Geogr. Mitt.*, 1906, p. 33.

[8] Camb. Univ. Press, 1928.

[9] C. E. P. Brooks, *London, Mem. R. Meteor. Soc.*, **1**, 1927, No. 10, Table II., p. 129.

Temperature of the stratosphere and clouds.—The values given above, page 55, have been used throughout.

SOLAR RADIATION DATA.

Intensity of solar radiation.—Table III. contains values of the mean intensity of the solar radiation at the confines of the atmosphere. A mean "solar constant" of 1·952 has been adopted, and the variations have been based on Angot's tables. From the last line of Table III. the effect of the sun's varying distance is clearly shown, the variation due to this cause during the year being 7 per cent.

Albedo.—From the values of the cloud amount given in Table II., and the relationship between cloud amount and the albedo given in Table A above, the mean albedo for each zone of latitude between 70° N. and 70° S. was calculated. The albedo gives the proportion of the incoming radiation which is reflected, while we are more interested in the radiation absorbed; for this reason values of the complement of the albedo $(1-a)$ have been tabulated in Table IV. For the two polar caps a constant albedo of ·65 has been adopted, in order to allow for the large reflection of solar radiation from the extensive surfaces of snow.

Effective solar radiation.—By multiplying the values of the solar radiation given in Table III. by the values in Table IV., we obtain the intensity of the solar radiation which is absorbed by the earth and its atmosphere. The values of the intensity of this "effective solar radiation" are given in Table V.

Total effective solar radiation.—In order to obtain the total solar radiation absorbed by the earth it is necessary to multiply the intensity of the effective solar radiation in each zone by the area of the zone, and then sum the products for all the zones.

The area of the zone between latitudes θ_1 and θ_2 is $2\pi r^2(\sin\theta_1-\sin\theta_2)$, in which r is the radius of the earth. If $\bar{S}$ is the mean intensity of the effective solar radiation over the zone, we have

$$\text{Total effective solar radiation over zone } \theta_1-\theta_2=F=2\pi r^2 S(\sin\theta_1-\sin\theta_2).$$

Values of $S(\sin\theta_1-\sin\theta_2)$ for each zone are given in Table VI., and the last line of the table contains the total effective solar radiation for the whole earth derived from the sum of the zones.

The average value of the effective solar radiation over the world as a whole is obtained by dividing the total radiation by the area of the surface. Thus if $\bar{S}$ is the average effective solar radiation, and F the total radiation as given in the last line of Table VI. (the unit of F is $2\pi r^2$) we have:

$$\bar{S}=\frac{F\times 2\pi r^2}{4\pi r^2},\ \textit{i.e.}\ \bar{S}=\tfrac{1}{2}F \text{ cal. per cm.}^2 \text{ per min.}$$

Values of the average effective solar radiation obtained in this way have been added in the last line of Table V.

TERRESTRIAL RADIATION.

Outgoing terrestrial radiation.—The intensity of the outgoing terrestrial radiation for the zones between 70° N. and 70° S. has been calculated from the meteorological data given in Tables I., II. and B, and the values are tabulated in Table VII. and plotted on Fig. 10. Satisfactory meteorological data do not exist for the polar zones, therefore values of the outgoing radiation from these zones have been obtained by extrapolating the curves from 70° N. and 70° S. towards the poles. The extrapolated values are probably correct, but in any case the area of these zones is so small that they contribute little to the heat balance of the earth as a whole, and therefore accurate values of the radiation intensity here are not of prime importance. A discussion of the curves on Fig. 10 will be taken up later in this paper.

Total terrestrial radiation.—From the values of the intensity of the terrestrial radiation given in Table VII. and the area of the zones, the values of the total outgoing terrestrial radiation from each zone have been calculated and reproduced in Table VIII.

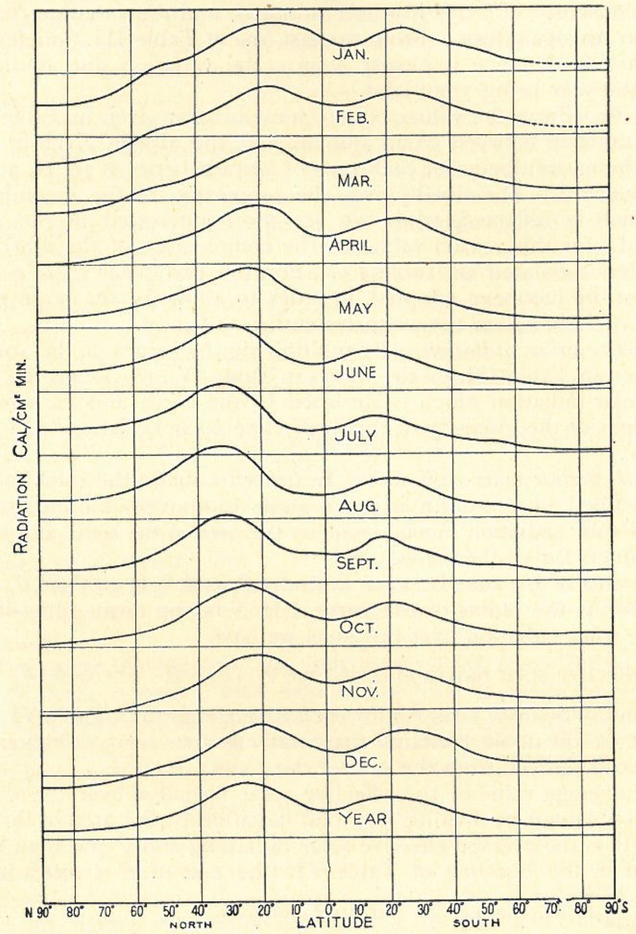

FIG. 10.—Intensity of outgoing terrestrial radiation.

The horizontal line below the equatorial portion of each curve represents ·250 cal./cm.^{2} min. for that curve. The distance between horizontal lines is ·050 cal./cm.^{2} min. Thus the top line of the diagram represents ·300 cal./cm.^{2} min. for the January curve, and the bottom line of the diagram ·200 cal./cm.^{2} min. for the year curve.

Net radiation.—By net radiation is meant the balance of incoming and outgoing radiation; it is obtained by taking the difference between the incoming and outgoing radiation ($S - R$).

In Table IX. are given values of the intensity of the net radiation obtained by subtracting the values of the intensity of the outgoing terrestrial radiation given in Table VII. from the values of the intensity of the effective solar radiation given in Table V. Positive values indicate that the intensity of the effective solar radiation is greater than the intensity of the terrestrial radiation, and therefore the net effect is an accumulation of heat due to radiation. Similarly negative values indicate a net loss of heat due to radiation.

The values from Table IX. are plotted on Figs. 11 and 12.

Total net radiation.—The total net radiation, that is the difference between the total incoming and the total outgoing radiation, can be obtained in two ways, both of which give the same result: (*a*) by multiplying the values given in Table IX. by the area of the zones, or (*b*) by taking the difference between the values in Tables VI. and VIII. The values obtained are given in Table X., and represent the total gain or loss of heat due to radiation in each zone and over the earth as a whole.

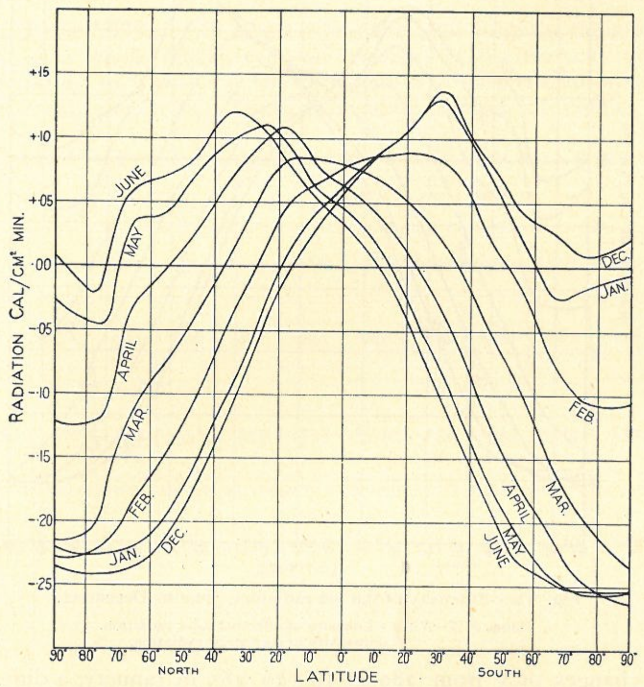

FIG. 11.—Intensity of the net radiation, December to June.

Values of $S - R$: S = intensity of effective solar radiation.
R = intensity of terrestrial radiation.

DISCUSSION OF RESULTS.

Intensity of Outgoing Terrestrial Radiation.

The values of the intensity of the outgoing radiation in each zone for each month (Table VII.) are plotted on Fig. 10. The horizontal line immediately below the equatorial portion of each curve represents ·250 cal. per cm.^{2} per min. and the horizontal line above ·300. We notice at once the great similarity in all the curves. Each curve shows two zones of maximum radiation, one on each side of the equatorial regions where the radiation is relatively low. Throughout the year, even in the summer of the southern hemisphere, the zone of maximum radiation is on the north of the equator. This maximum increases from the winter to the summer, but the change is very small, the variation being only from ·289 in December to ·308 in August, a change of 7 per cent. The maximum in the southern hemisphere changes only from ·280 in July to ·285 in January, a difference of less than 2 per cent.

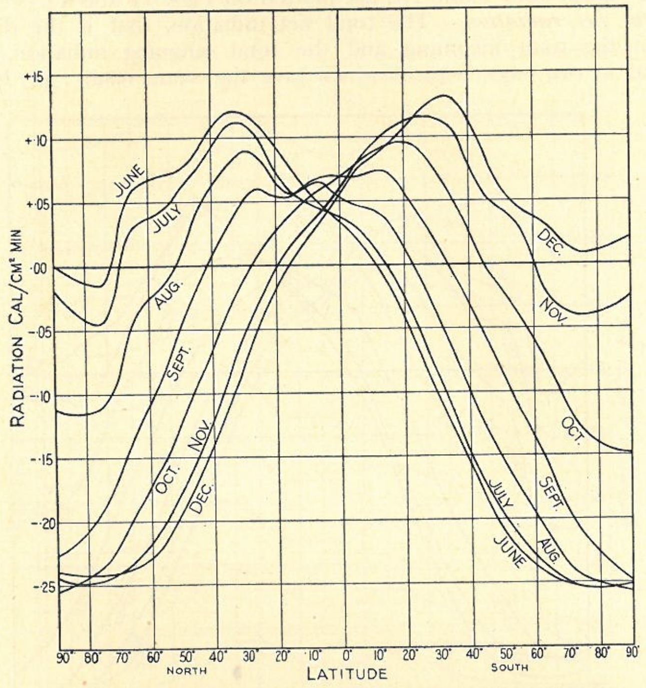

Fig. 12.—Intensity of the net radiation, June to December.

Values of $S-R$: S = intensity of effective solar radiation.
R = intensity of terrestrial radiation.

The belts of maximum radiation move slightly with the declination of the sun, being furthest north in July and furthest south in January.

INTENSITY OF THE NET RADIATION.

With almost uniform outgoing radiation, as shown in Fig. 10, the net radiation must be mainly determined by the effective solar radiation, which has a very large variation with latitude. Figs. 11 and 12 show the variations of the intensity of the net radiation with latitude (Table IX.) for each of the twelve months. Where any curve on these figures is below the zero line the outgoing radiation exceeds the incoming radiation, while the reverse is the case where the curve is above the zero line. It will be noticed that in December the curve is above the line from latitude 16° N. to the South Pole, while in June it is above the line from 11° S. to the North Pole, except for a small region around latitude 80° N. where, however, the values are very uncertain.

Thus in these two months the whole region from the Pole which has summer, to more than 10° beyond the equator, receives more heat from the sun than it radiates to space; while the remainder of the earth emits more radiation than it receives. It is only during the equinoctial months, September and March, that the region which receives more heat than it emits is even approximately central.

Considering the great difference between the two hemispheres as regards the distribution of land and sea, the symmetry of the curves in Figs. 11 and 12 is surprising.

THE BALANCE BETWEEN INCOMING AND OUTGOING RADIATION.

From Table VIII. it will be seen that the total outgoing radiation from the earth as a whole during the year averages $\cdot 548 \times 2\pi r^2$ cal. per min., while according to Table VI. the total effective solar radiation averages $\cdot 536 \times 2\pi r^2$ cal. per min. These two values should, of course, be the same; but the difference is only 2 per cent, and considering the uncertainty of many of the data used, especially of the cloud amounts, the agreement is much better than could have been expected, in fact no better confirmation of the correctness of the assumption made could be expected. The difference of 2 per cent may be due to many causes; it may be due to insufficient observations of the temperature and cloud amount, to slight errors in determining the absorption of water vapour, or to inaccurate relationship between the amount of cloud and the albedo. Of all these the values of the albedo are the most uncertain, and neither Aldrich nor Ångström claim an accuracy of anything like 2 per cent for their determinations. In any case an error of 2 per cent in the absolute value of the radiation is quite insignificant, but it is awkward when we come to discuss the small differences between the incoming and outgoing radiation at different times of the year, and therefore it is convenient to remove it. The best way to do this is to assume that our values of the albedo are all

TABLE C—TOTAL RADIATION OVER THE EARTH AS A WHOLE.

Unit: $2\pi r^2$ cal. per min. ($2\pi r^2 = 2\cdot 56 \times 10^{18}$ sq. cm.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Incoming solar radiation above atmosphere.	1·010	1·000	·982	·966	·952	·944	·944	·952	·966	·982	1·000	1·010	·976
Effective solar radiation.	·550	·562	·559	·558	·539	·532	·529	·544	·553	·554	·552	·545	·548
Outgoing terrestrial radiation.	·540	·542	·547	·551	·552	·552	·551	·552	·554	·549	·545	·542	·548
Difference solar-terrestrial.	+·010	+·020	+·012	+·007	-·013	-·020	-·022	-·008	-·001	+·005	+·007	+·003	·000

2 per cent too great and then to increase the effective solar radiation by this amount.

I do not propose to apply this correction to the values in the tables in the Appendix, which are much better left exactly as they have been calculated directly from the observed data. In Table C, however, the correction has been applied, purely as a matter of convenience so that there will be no small numerical differences, which have no significance when the total incoming and outgoing radiations are compared.

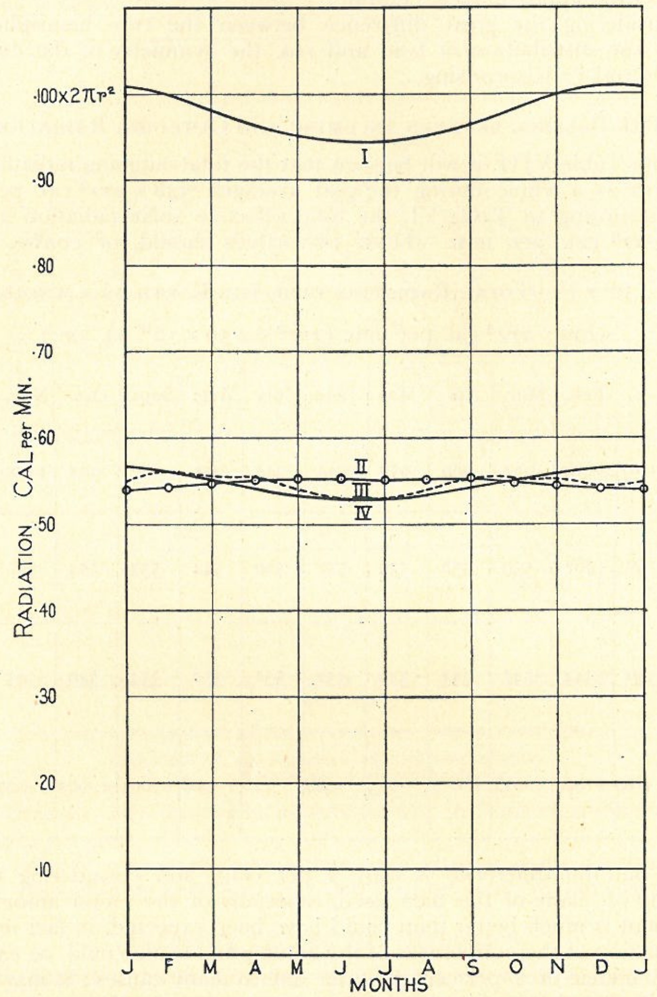

FIG. 13.—Annual variation of radiation to and from the whole earth.

Curve. I.—Incoming solar radiation above atmosphere.
Curve II.—Terrestrial radiation.
Curve III.—Effective solar radiation.
Curve IV.—Effective solar radiation if albedo remained constant and equal to its mean value.
Unit : $2\pi r^2$ calories per min.

In the first line of this table are given the values of the solar radiation at the limits of the atmosphere, based on an average "solar constant" of 1·952. The values are those given in the last line of Table III. multiplied by 2, because the unit adopted in Table C is $2\pi r^2$ cal. per min. As already remarked, the variation during the year is the consequence of the varying distance of the earth from the sun. The next line gives the amount of solar radiation absorbed by the earth and its atmosphere; the values are those given in the last line of Table VI. increased by 2·24 per cent. The third line gives the values of the terrestrial radiation taken from Table VIII. The last line gives the difference between the effective solar radiation and the outgoing terrestrial radiation, for each month and for the year.

In Fig. 13 the values contained in Table C are plotted, the zero for each of the curves being the bottom line of the figure, so that the variation may be compared with the absolute values. At the top of the diagram we have Curve I giving the values of the solar radiation on reaching the atmosphere.

Curve II gives the annual variation of the outgoing radiation. The regularity of this curve is surprising, the total variation throughout the year being only from ·540 to ·554, *i.e.* 2·6 per cent. It will be noticed, however, that what little annual variation there is, is opposite to that of the solar variation. Whether this is a real effect or not cannot be decided at present.

Curve III, a dotted curve, gives the effective solar radiation. It will be noticed that although this curve follows the solar radiation in its main features, the variation is not so great. To bring this out Curve IV has been added, which shows what the effective radiation would be if the albedo of the earth remained constant from month to month. That Curve III is flatter than Curve IV shows that the variation in the cloud amount is such as to counteract to some extent the variation in the intensity of the solar radiation. I do not wish to enlarge on this aspect or even to stress it, because the variations in Curves II and III are so very small, and the data on which they are based are so uncertain, that the small annual variation shown may have no real significance.

The general result, however, is clear: except for small uncertain irregularities the total outgoing radiation from the earth as a whole just balances the incoming solar radiation in every month, there being no period of the year during which the earth as a whole receives more radiation than it emits.

SUMMARY.

(*a*) The geographical distribution of incoming and outgoing radiation during January and July is determined and exhibited on maps.
(*b*) The incoming and outgoing radiations for each 10° zone of latitude are calculated for each month of the year.
(*c*) The result indicates great uniformity in the intensity of the outgoing terrestrial radiation, both in time and space, and that except for small uncertain irregularities the total outgoing radiation from the earth as a whole just balances the incoming solar radiation at all periods of the year.

TABLE I.—MEAN TEMPERATURE.

Degrees absolute. 200+ or 300+·

Zones.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
70–60 N	51·1	53·2	57·9	65·1	73·5	79·9	83·4	81·7	77·0	67·9	60·1	54·0	67·1
60–50 N	61·3	62·6	68·2	74·8	81·1	86·6	89·1	88·3	83·1	76·5	69·7	65·1	75·5
50–40 N	72·3	73·0	77·6	82·4	87·1	91·4	94·0	93·5	89·2	83·9	79·1	74·7	83·2
40–30 N	83·9	82·8	86·5	89·8	93·1	96·2	99·0	98·3	95·4	92·0	87·9	84·6	90·8
30–20 N	92·0	91·0	93·5	95·7	97·8	99·4	00·5	00·2	99·1	97·4	94·5	92·6	96·1
20–10 N	97·5	97·1	98·4	99·3	00·1	00·5	00·7	00·2	00·0	99·7	99·1	97·1	99·1
10– 0 N	99·2	99·5	99·7	00·0	00·2	99·9	99·4	99·2	99·8	99·7	00·2	99·0	99·6
0–10 S	99·6	99·7	99·7	99·3	99·2	98·8	97·8	97·8	98·9	99·2	99·3	99·4	99·1
10–20 S	99·3	99·0	99·1	98·0	97·3	95·9	94·8	95·0	96·4	97·2	97·7	99·1	97·4
20–30 S	96·2	96·1	96·3	94·7	92·8	91·0	89·9	91·1	92·2	93·7	94·1	95·6	93·6
30–40 S	91·2	90·6	90·6	88·6	86·9	85·2	84·4	85·0	86·7	87·9	88·4	90·5	88·0
40–50 S	84·9	84·7	84·1	82·0	80·4	79·1	78·9	79·0	80·8	81·6	82·1	83·9	81·8
50–60 S	78·2	78·7	77·3	75·1	73·4	71·6	71·0	72·3	75·0	75·2	75·6	77·2	75·1
60–70 S	72·8	74·2	73·1	70·4	66·2	61·0	57·9	63·0	69·0	69·5	69·4	72·7	68·3

TABLE II.—MEAN CLOUD AMOUNT.

Zones.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
70–60 N	·57	·56	·54	·59	·65	·66	·66	·68	·71	·72	·67	·60	·63
60–50 N	·59	·57	·57	·59	·64	·63	·63	·62	·62	·67	·67	·64	·62
50–40 N	·59	·57	·57	·57	·56	·56	·54	·49	·49	·54	·58	·61	·56
40–30 N	·50	·49	·49	·48	·48	·43	·42	·39	·39	·43	·45	·48	·45
30–20 N	·41	·41	·41	·39	·41	·43	·45	·44	·40	·39	·38	·40	·41
20–10 N	·40	·39	·39	·40	·47	·53	·59	·58	·54	·46	·44	·44	·47
10– 0 N	·50	·48	·49	·53	·54	·56	·57	·55	·53	·53	·53	·53	·53
0–10 S	·54	·53	·53	·52	·50	·50	·50	·52	·53	·53	·53	·55	·52
10–20 S	·54	·52	·52	·49	·46	·45	·43	·44	·43	·47	·49	·54	·48
20–30 S	·49	·50	·50	·47	·48	·48	·47	·45	·48	·47	·49	·50	·48
30–40 S	·53	·52	·54	·53	·55	·56	·56	·54	·55	·56	·55	·52	·54
40–50 S	·64	·65	·63	·64	·64	·67	·69	·64	·66	·67	·67	·66	·66
50–60 S	·76	·69	·71	·74	·73	·72	·70	·69	·68	·71	·71	·75	·72
60–70 S	·86	·80	·80	·72	·72	·66	·68	·74	·75	·77	·83	·80	·76

TABLE III.—INTENSITY OF SOLAR RADIATION AT CONFINES OF ATMOSPHERE: *S'*.

Gram. cal. per sq. cm. per min.

Zones.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
90–80 N	·000	·000	·070	·360	·630	·740	·670	·430	·120	·010	·000	·000	·250
80–70 N	·000	·030	·150	·380	·610	·720	·650	·440	·200	·050	·000	·000	·270
70–60 N	·031	·104	·253	·439	·609	·689	·634	·480	·296	·139	·043	·018	·311
60–50 N	·108	·202	·347	·505	·632	·685	·648	·533	·382	·235	·125	.084	·374
50–40 N	·206	·300	·431	·562	·652	·689	·664	·580	·460	·329	·223	·178	·440
40–30 N	·305	·392	·505	·601	·664	·685	·668	·613	·525	·417	·323	·278	·498
30–20 N	·403	·476	·560	·623	·656	·668	·658	·628	·570	·493	·415	·378	·544
20–10 N	·491	·546	·599	·630	·636	·632	·632	·625	·603	·554	·501	·472	·576
10– 0 N	·566	·599	·619	·615	·595	·583	·589	·605	·615	·599	·570	·554	·593
0–10 S	·628	·636	·623	·587	·542	·517	·529	·568	·607	·628	·628	·621	·593
10–20 S	·672	·654	·607	·538	·472	·442	·458	·515	·583	·636	·664	·675	·576
20–30 S	·701	·652	·570	·472	·390	·354	·374	·448	·542	·628	·687	·711	·544
30–40 S	·711	·636	·519	·397	·300	·260	·284	·366	·480	·599	·689	·730	·498
40–50 S	·705	·599	·452	·309	·206	·166	·190	·276	·407	·554	·677	·734	·440
50–60 S	·685	·546	·370	·215	·112	·076	·100	·182	·323	·495	·652	·728	·374
60–70 S	·672	·484	·280	·117	·035	·018	·029	·088	·229	·423	·623	·734	·311
70–80 S	·680	·440	·180	·040	·000	·000	·000	·020	·130	·360	·620	·760	·270
80–90 S	·700	·420	·100	·000	·000	·000	·000	·000	·050	·320	·640	·780	·250
Whole Earth.	·505	·500	·491	·483	·476	·472	·472	·476	·483	·491	·500	·505	·488

TABLE IV.—VALUES OF $(1-a)$.

a = Albedo.

Zones.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
90–80 N	·35	·35	·35	·35	·35	·35	·35	·35	·35	·35	·35	·35	(·35)
80–70 N	·35	·35	·35	·35	·35	·35	·35	·35	·35	·35	·35	·35	(·35)
70–60 N	·53	·54	·55	·52	·49	·48	·48	·47	·45	·44	·47	·52	·50
60–50 N	·52	·53	·53	·52	·49	·50	·50	·50	·50	·47	·47	·49	·50
50–40 N	·52	·53	·53	·53	·54	·54	·55	·58	·58	·55	·53	·51	·54
40–30 N	·57	·58	·58	·58	·58	·61	·62	·63	·63	·61	·60	·58	·60
30–20 N	·62	·62	·62	·63	·62	·61	·60	·61	·63	·63	·64	·63	·62
20–10 N	·63	·63	·63	·63	·59	·56	·52	·53	·55	·60	·61	·61	·59
10– 0 N	·57	·58	·58	·56	·55	·54	·53	·55	·56	·56	·56	·56	·56
0–10 S	·55	·56	·56	·56	·57	·57	·57	·56	·56	·56	·56	·55	·56
10–20 S	·55	·56	·56	·58	·60	·60	·61	·61	·61	·59	·58	·55	·58
20–30 S	·58	·57	·57	·59	·58	·58	·59	·60	·58	·59	·58	·57	·58
30–40 S	·56	·56	·55	·56	·55	·51	·54	·55	·55	·54	·55	·56	·55
40–50 S	·49	·49	·50	·49	·49	·47	·46	·49	·48	·47	·47	·48	·48
50–60 S	·42	·46	·45	·43	·44	·44	·46	·46	·47	·45	·45	·42	·44
60–70 S	·35	·39	·39	·44	·44	·48	·47	·43	·42	·41	·37	·39	·42
70–80 S	·35	·35	·35	·35	·35	·35	·35	·35	·35	·35	·35	·35	(·35)
80–90 S	·35	·35	·35	·35	·35	·35	·35	·35	·35	·35	·35	·35	(·35)

TABLE V.—Intensity of the Effective Solar Radiation: *S*.

Gram. cal. per sq. cm. per min.

Zones.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
90–80 N	·000	·000	·025	·126	·220	·259	·234	·150	·042	·004	·000	·000	·088
80–70 N	·000	·011	·052	·133	·214	·252	·228	·154	·070	·018	·000	·000	·094
70–60 N	·016	·056	·139	·228	·298	·331	·304	·226	·133	·061	·020	·009	·156
60–50 N	·056	·107	·184	·263	·310	·348	·324	·266	·191	·110	·059	·041	·187
50–40 N	·107	·159	·228	·298	·352	·372	·365	·336	·267	·181	·118	·091	·238
40–30 N	·174	·227	·288	·349	·385	·418	·414	·386	·331	·254	·194	·161	·299
30–20 N	·250	·295	·347	·392	·407	·407	·395	·383	·360	·311	·266	·238	·337
20–10 N	·309	·344	·377	·397	·375	·354	·329	·331	·332	·332	·306	·288	·340
10– 0 N	·323	·347	·359	·344	·327	·315	·312	·333	·344	·335	·319	·310	·332
0–10 S	·345	·356	·349	·329	·309	·295	·302	·318	·340	·352	·352	·342	·332
10–20 S	·370	·366	·340	·312	·283	·265	·279	·314	·356	·375	·385	·371	·334
20–30 S	·407	·372	·325	·278	·226	·205	·221	·269	·314	·371	·398	·405	·316
30–40 S	·398	·356	·285	·222	·165	·140	·153	·201	·264	·323	·379	·409	·274
40–50 S	·345	·293	·226	·151	·101	·078	·087	·135	·195	·260	·318	·352	·211
50–60 S	·288	·251	·167	·092	·049	·033	·046	·084	·152	·223	·293	·306	·165
60–70 S	·235	·189	·109	·051	·015	·009	·014	·038	·096	·173	·231	·286	·131
70–80 S	·238	·154	·063	·014	·000	·000	·000	·007	·046	·126	·217	·266	·094
80–90 S	·245	·147	·035	·000	·000	·000	·000	·000	·018	·112	·224	·273	·088
Average for Whole Earth.	·269	·274	·273	·272	·264	·260	·258	·266	·270	·271	·270	·266	·268

TABLE VI.—Total Effective Solar Radiation: *F*.

Unit $=2\pi r^2$ cal. per min. ($2\pi r^2=2{\cdot}56\times10^{18}$ sq. cm.).

Zones.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
90–80 N	·000	·000	·000	·002	·003	·004	·004	·002	·001	·000	·000	·000	·001
80–70 N	·000	·000	·002	·006	·010	·011	·010	·007	·003	·001	·000	·000	·004
70–60 N	·001	·004	·010	·017	·022	·024	·022	·017	·010	·005	·001	·001	·012
60–50 N	·006	·011	·018	·026	·031	·035	·032	·027	·019	·011	·006	·004	·019
50–40 N	·013	·020	·028	·037	·043	·046	·045	·041	·033	·022	·015	·011	·029
40–30 N	·025	·032	·041	·050	·055	·060	·059	·055	·047	·036	·028	·023	·043
30–20 N	·039	·047	·055	·062	·064	·064	·062	·061	·057	·049	·042	·038	·053
20–10 N	·052	·058	·063	·067	·063	·059	·055	·056	·056	·056	·051	·048	·057
10– 0 N	·056	·060	·062	·060	·057	·055	·054	·058	·060	·058	·056	·053	·058
0–10 S	·060	·062	·061	·057	·054	·051	·053	·055	·059	·061	·061	·060	·058
10–20 S	·062	·061	·057	·052	·048	·045	·047	·053	·060	·063	·065	·062	·056
20–30 S	·064	·059	·051	·044	·036	·032	·035	·043	·050	·059	·063	·064	·050
30–40 S	·057	·051	·041	·032	·023	·020	·022	·029	·038	·046	·054	·058	·039
40–50 S	·042	·036	·028	·019	·012	·010	·011	·017	·024	·032	·039	·043	·026
50–60 S	·029	·025	·017	·009	·005	·003	·005	·008	·015	·022	·029	·031	·016
60–70 S	·017	·014	·008	·004	·001	·001	·001	·003	·007	·013	·017	·021	·010
70–80 S	·011	·007	·003	·001	·000	·000	·000	·000	·002	·006	·010	·012	·004
80–90 S	·004	·002	·001	·000	·000	·000	·000	·000	·000	·002	·003	·004	·001
Whole Earth.	·538	·549	·546	·545	·527	·520	·517	·532	·541	·542	·540	·533	·536

TABLE VII.—Intensity of Outgoing Terrestrial Radiation: *R*.

Gram. cal. per sq. cm. per min.

Zones.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
90–80 N	·225	·228	·240	·250	·257	·265	·270	·265	·260	·253	·247	·240	·256
80–70 N	·227	·232	·243	·252	·260	·267	·272	·266	·261	·255	·248	·242	·257
70–60 N	·235	·239	·249	·257	·263	·270	·273	·270	·264	·258	·252	·246	·259
60–50 N	·252	·253	·259	·265	·270	·276	·279	·279	·272	·264	·258	·255	·264
50–40 N	·258	·259	·264	·270	·277	·284	·289	·294	·286	·275	·266	·260	·272
40–30 N	·271	·269	·275	·281	·287	·298	·305	·307	·301	·289	·281	·273	·286
30–20 N	·285	·283	·288	·295	·297	·298	·298	·299	·300	·298	·293	·286	·294
20–10 N	·289	·289	·292	·293	·287	·280	·274	·275	·278	·288	·288	·284	·285
10– 0 N	·275	·278	·277	·273	·273	·270	·268	·269	·273	·273	·274	·271	·272
0–10 S	·271	·273	·273	·273	·275	·274	·272	·271	·272	·272	·272	·266	·273
10–20 S	·276	·279	·279	·280	·283	·281	·280	·280	·284	·281	·280	·277	·281
20–30 S	·285	·284	·285	·285	·280	·277	·275	·279	·279	·283	·281	·284	·281
30–40 S	·280	·279	·278	·276	·271	·268	·267	·270	·271	·272	·274	·279	·274
40–50 S	·269	·268	·269	·265	·264	·261	·261	·262	·263	·264	·264	·267	·264
50–60 S	·262	·265	·263	·261	·259	·259	·259	·260	·263	·261	·261	·261	·261
60–70 S	·257	·259	·259	·260	·257	·254	·254	·254	·259	·258	·257	·258	·257
70–80 S	·255	·257	·258	·260	·256	·254	·253	·253	·258	·258	·257	·258	·257
80–90 S	·255	·255	·258	·260	·255	·253	·253	·253	·257	·258	·257	·258	·257

TABLE VIII.—Total Terrestrial Radiation.

Unit $=2\pi r^2$ cal. per min. ($2\pi r^2=2{\cdot}56\times10^{18}$ sq. cm.).

Zones.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
90–80 N	·003	·003	·004	·004	·004	·004	·004	·004	·004	·004	·004	·004	·004
80–70 N	·010	·010	·011	·011	·012	·012	·012	·012	·012	·011	·011	·011	·012
70–60 N	·017	·018	·018	·019	·019	·020	·020	·020	·020	·019	·019	·018	·019
60–50 N	·025	·025	·026	·026	·027	·028	·028	·028	·027	·026	·026	·026	·026
50–40 N	·032	·032	·032	·033	·034	·035	·036	·036	·035	·034	·033	·032	·033
40–30 N	·039	·038	·039	·040	·041	·043	·044	·044	·043	·041	·040	·039	·041
30–20 N	·045	·045	·046	·047	·047	·047	·047	·047	·047	·047	·046	·045	·046
20–10 N	·049	·049	·049	·049	·048	·047	·046	·046	·047	·048	·048	·048	·048
10– 0 N	·048	·048	·048	·048	·048	·047	·047	·047	·048	·048	·048	·047	·048
0–10 S	·047	·048	·048	·048	·048	·048	·047	·047	·047	·047	·047	·046	·048
10–20 S	·046	·047	·047	·047	·048	·047	·047	·047	·048	·047	·047	·047	·047
20–30 S	·045	·045	·045	·045	·044	·044	·043	·044	·044	·045	·044	·045	·044
30–40 S	·040	·040	·040	·040	·039	·038	·038	·038	·039	·039	·039	·040	·039
40–50 S	·033	·033	·033	·033	·032	·032	·032	·032	·032	·032	·032	·033	·032
50–60 S	·026	·026	·026	·026	·026	·026	·026	·026	·026	·026	·026	·026	·026
60–70 S	·019	·019	·019	·019	·019	·019	·019	·019	·019	·019	·019	·019	·019
70–80 S	·012	·012	·012	·012	·012	·011	·011	·011	·012	·012	·012	·012	·012
80–90 S	·004	·004	·004	·004	·004	·004	·004	·004	·004	·004	·004	·004	·004
Whole Earth.	·540	·542	·547	·551	·552	·552	·551	·552	·554	·549	·545	·542	·548

TABLE IX.—Intensity of the Net Radiation : $S-R$.

Gram. cal. per sq. cm. per min.

Zones.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
90–80 N	−·225	−·228	−·215	−·124	−·037	−·006	−·036	−·115	−·218	−·249	−·247	−·240	−·168
80–70 N	−·227	−·221	−·191	−·119	−·046	−·015	−·044	−·112	−·191	−·237	−·248	−·242	−·163
70–60 N	−·219	−·183	−·110	−·029	+·035	+·061	+·031	−·044	−·131	−·197	−·232	−·237	−·103
60–50 N	−·196	−·146	−·075	−·002	+·040	+·072	+·045	−·013	−·081	−·154	−·199	−·214	−·077
50–40 N	−·151	−·100	−·036	+·028	+·075	+·086	+·076	+·042	−·019	−·094	−·148	−·169	−·034
40–30 N	−·097	−·042	+·013	+·068	+·098	+·120	+·109	+·079	+·030	−·035	−·087	−·112	+·013
30–20 N	−·035	+·012	+·059	+·097	+·110	+·109	+·097	+·084	+·060	+·013	−·027	−·048	+·043
20–10 N	+·020	+·055	+·085	+·104	+·088	+·074	+·055	+·056	+·054	+·044	+·018	+·004	+·055
10– 0 N	+·048	+·069	+·082	+·071	+·054	+·045	+·044	+·064	+·071	+·062	+·045	+·039	+·060
0–10 S	+·074	+·083	+·076	+·056	+·034	+·021	+·030	+·047	+·068	+·080	+·080	+·076	+·059
10–20 S	+·094	+·087	+·061	+·032	·000	−·016	−·001	+·034	+·072	+·094	+·105	+·094	+·053
20–30 S	+·122	+·088	+·040	−·007	−·054	−·072	−·054	−·010	+·035	+·088	+·117	+·121	+·035
30–40 S	+·118	+·077	+·007	−·054	−·106	−·128	−·114	−·069	−·007	+·051	+·105	+·130	·000
40–50 S	+·076	+·025	−·043	−·114	−·163	−·183	−·174	−·127	−·068	−·004	+·054	+·085	−·053
50–60 S	+·026	−·014	−·096	−·169	−·210	−·226	−·213	−·176	−·111	−·038	+·032	+·045	−·096
60–70 S	−·022	−·070	−·150	−·209	−·242	−·245	−·240	−·216	−·163	−·085	−·026	+·028	−·126
70–80 S	−·017	−·103	−·195	−·246	−·256	−·254	−·253	−·246	−·212	−·132	−·040	+·008	−·163
80–90 S	−·010	−·108	−·223	−·260	−·255	−·253	−·253	−·253	−·239	−·146	−·033	+·015	−·169

TABLE X.—Total Net Radiation (Effective Solar − Terrestrial).

Unit $=2\pi r^2$ cal. per min. ($2\pi r^2=2{\cdot}56\times10^{18}$ sq. cm.).

Zones.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
90–80 N	−·003	−·003	−·003	−·002	−·001	·000	·000	−·002	−·003	−·004	−·004	−·004	−·003
80–70 N	−·010	−·010	−·009	−·005	−·002	−·001	−·002	−·005	−·009	−·011	−·011	−·011	−·008
70–60 N	−·016	−·014	−·008	−·002	+·003	+·005	+·002	−·003	−·010	−·015	−·017	−·018	−·008
60–50 N	−·020	−·015	−·008	·000	+·004	+·007	+·004	+·001	−·008	−·015	−·020	−·021	−·008
50–40 N	−·019	−·012	−·004	+·003	+·009	+·011	+·009	+·005	−·002	−·012	−·018	−·021	−·004
40–30 N	−·014	−·006	+·002	+·010	+·014	+·017	+·016	+·011	+·004	−·005	−·012	−·016	+·002
30–20 N	−·006	+·002	+·009	+·015	+·017	+·017	+·015	+·013	+·009	+·002	−·004	−·008	+·007
20–10 N	+·003	+·009	+·014	+·017	+·015	+·012	+·009	+·009	+·009	+·007	+·003	+·001	+·009
10– 0 N	+·008	+·012	+·014	+·012	+·009	+·008	+·008	+·011	+·012	+·011	+·008	+·007	+·010
0–10 S	+·013	+·014	+·013	+·010	+·006	+·004	+·005	+·008	+·012	+·014	+·014	+·013	+·010
10–20 S	+·016	+·015	+·010	+·005	·000	−·003	·000	+·006	+·012	+·016	+·018	+·016	+·009
20–30 S	+·019	+·014	+·006	−·001	−·009	−·011	−·009	−·002	+·006	+·014	+·018	+·019	+·006
30–40 S	+·017	+·011	+·001	−·008	−·015	−·018	−·016	−·010	−·001	+·007	+·015	+·018	·000
40–50 S	+·009	+·003	−·005	−·014	−·020	−·023	−·021	−·016	−·008	·000	+·006	+·010	−·007
50–60 S	+·003	−·001	−·010	−·017	−·021	−·023	−·021	−·018	−·011	−·004	+·003	+·004	−·010
60–70 S	−·002	−·005	−·011	−·015	−·018	−·018	−·018	−·016	−·012	−·006	−·002	+·002	−·009
70–80 S	−·001	−·005	−·009	−·011	−·012	−·011	−·011	−·011	−·010	−·006	−·002	·000	−·007
80–90 S	·000	−·002	−·003	−·004	−·004	−·004	−·004	−·004	−·004	−·002	·000	·000	−·003
Whole Earth.	−·002	+·007	−·001	−·006	−·025	−·032	−·034	−·020	−·013	−·007	−·005	−·009	−·012

APPENDIX

As it is possible that other investigators may wish to use the methods of this paper, it seems desirable to publish a description of the procedure which has been used in carrying out the actual calculations.

In the following the symbol $[R]_a^b$ means the energy in the black-body radiation between the wave lengths a and b. Subscripts are given to R to indicate the temperature for which the radiation must be taken—these are: G for the temperature of the ground, C for the temperature of the upper surface of the clouds, and S for the stratosphere. Thus $[R_S]_{5\frac{1}{2}}^{7}$ means the energy in the radiation from a black body at the temperature of the stratosphere between the wave-lengths $5\frac{1}{2}\mu$ and 7μ.

The total outgoing radiation with clear skies is:

$$R=[\tfrac{1}{2}R_G]_0^{5\frac{1}{2}}+[R_S]_{5\frac{1}{2}}^{7}+[\tfrac{1}{2}(R_G+R_S)]_7^{8\frac{1}{2}}+[R_G]_{8\frac{1}{2}}^{11}+[\tfrac{1}{2}(R_G+R_S)]_{11}^{14}+[R_S]_{14}^{\infty}$$
$$=\left\{[\tfrac{1}{2}R_G]_0^{5\frac{1}{2}}+[\tfrac{1}{2}R_G]_7^{8\frac{1}{2}}+[R_G]_{8\frac{1}{2}}^{11}+[\tfrac{1}{2}R_G]_{11}^{14}\right\}+\left\{[R_S]_{5\frac{1}{2}}^{7}+[\tfrac{1}{2}R_S]_7^{8\frac{1}{2}}+[\tfrac{1}{2}R_S]_{11}^{14}+[R_S]_{14}^{\infty}\right\}$$
$$=\Sigma[R_G]+\Sigma[R_S].$$

With overcast skies we have a similar expression:

$$R=\Sigma[R_C]+\Sigma[R_S].$$

With a cloud amount C, expressed as a fraction, we have:

$$R=\left\{\Sigma[R_G]+\Sigma[R_S]\right\}(1-C)+\left\{\Sigma[R_C]+\Sigma[R_S]\right\}C$$
$$=(1-C)\Sigma[R_G]+C\Sigma[R_C]+\Sigma[R_S].$$

The following tables give the values of $\Sigma[R_G]$ or $\Sigma[R_C]$, and $\Sigma[R_S]$:

TABLE XI.—Values of $\Sigma[R_G]$ or $\Sigma[R_C]$.

Cal. per. sq. cm. per min.

Temp.	$\Sigma[R]$	Temp.	$\Sigma[R]$	Temp.	$\Sigma[R]$	Temp.	$\Sigma[R]$
a.		a.		a.		a.	
230	·051	250	·080	270	·123	290	·180
231	·052	251	·082	271	·126	291	·184
232	·053	252	·084	272	·128	292	·187
233	·055	253	·086	273	·130	293	·191
234	·056	254	·088	274	·133	294	·194
235	·057	255	·090	275	·136	295	·198
236	·059	256	·092	276	·138	296	·202
237	·060	257	·094	277	·141	297	·205
238	·062	258	·096	278	·144	298	·209
239	·063	259	·098	279	·146	299	·212
240	·064	200	·100	280	·149	300	·216
241	·066	261	·102	281	·152	301	·220
242	·067	262	·104	282	·155	302	·224
243	·068	263	·106	283	·158	303	·228
244	·070	264	·108	284	·162	304	·231
245	·072	265	·111	285	·164	305	·235
246	·073	266	·113	286	·167	306	·239
247	·075	267	·116	287	·170	307	·243
248	·076	268	·118	288	·174	308	·248
249	·078	269	·121	289	·177	309	·252

TABLE XII.—VALUES OF $\Sigma[R_S]$.

Cal. per sq. cm. per min.

Temp.	$\Sigma[R_S]$	Temp.	$\Sigma[R_S]$	Temp.	$\Sigma[R_S]$	Temp.	$\Sigma[R_S]$
a.		a.		a.		a.	
200	·112	206	·123	212	·135	218	·148
201	·114	207	·125	213	·137	219	·151
202	·116	208	·127	214	·140	220	·153
203	·117	209	·129	215	·142	221	·156
204	·119	210	·131	216	·144	222	·158
205	·121	211	·133	217	·146	223	·161

CORRIGENDA

I should like to take this opportunity of correcting two errors which have been found in the previous *Memoirs*.

(1) In the first *Memoir* ("Some Studies in Terrestrial Radiation") the humidity of the standard atmosphere was based on Hergesell's formula:

$$\log r = 1{\cdot}8333 + 1{\cdot}603\,\frac{t}{T}$$

in which r = relative humidity, t = temperature in degrees centigrade, and T = temperature in degrees absolute. Unfortunately when computing the values according to this formula, T was taken to be 273 throughout instead of $273+t$. In consequence the relative humidity used for the different layers is not that which would have been given by Hergesell's formula. The difference, however, is only small, and entirely disappears where the temperature of the standard atmosphere is 0°C. The error makes no difference to the argument used, and there would be no need to refer to it except for the possibility that someone might quote the figures given as being the values obtained from Hergesell's formula. It is to guard against this contingency that the correction is recorded.

(2) On page 13 of the second *Memoir* ("Further Studies in Terrestrial Radiation") it is stated that the length of a column of air containing ·3 mm. of precipitable water is given by the following expression:

$$L = 21/p \text{ metres.}$$

This expression should have been:

$$L = 380/p \text{ metres approximately.}$$

Again the error has no effect on the argument, for the expression was only introduced to show that in the lower atmosphere a column of air containing ·3 mm. of water-vapour is generally sufficiently short to be considered to be at a uniform temperature. This conclusion is still true except when the vapour pressure is very low.