VEÐURSTOFA ÍSLANDS
THE ICELANDIC METEOROLOGICAL OFFICE

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GLOBAL RADIATION IN ICELAND

REYKJAVÍK 1969

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1. INTRODUCTION

Global radiation or short wave radiation from sun and sky, falling on a horizontal surface has been recorded in Reykjavík since 1st July 1957, when registrations started as a part of the program for the International Geophysical Year. They have continued since then, only with an intermission due to instrument damage, which lasted the whole year 1961. Pyranometers of the Eppley type have been in use from the beginning. As the records are now available for a period of more than 10 years it must be considered timely to give a relatively good picture of the radiation conditions in Reykjavík.

In a former publication (Einarsson, 1966) the author discussed the first 3½ years of registrations and used the data to compute equations of regression between global radiation and some other meteorological elements. It was found that duration of sunshine and cloud cover gave the best correlation. In this paper these equations are tested against the new data for Reykjavík, and then used to compute mean global radiation in the period 1958—1967 for 5 stations recording duration of sunshine and 30 stations observing cloud cover at 08, 14 and 20 IMT (Icelandic Mean Time). The results of the computations are then used to draw a radiation chart for Iceland for each of the months March-October, thus giving the very first approximation to the radiation climate of the country.

2. RADIATION STATION AND INSTRUMENTS

Reykjavík is situated in Southwest-Iceland on the south side of Faxaflói. To the west there is open sea but in other directions the town is surrounded by a low mountain range lying about 20—30 km apart.

The radiation station is located in a rather free and high location near the office of the Icelandic Meteorological Office, and where the sky is free in all directions above 2° except for the mountain Esja and two nearby towers. The position is 64° 08′ N and 21° 54′ W and the height of the pyranometer above sea level is 56 m.

As already mentioned the station is equipped with Eppley pyranometers, and as a rule a "10-junctions" instrument has been in use, but in some years an instrument of the type "50-junctions" has been operated in the darkest months of the year.

The instruments, their constants and periods of use have been as follows: (Standardization coefficients are referred to the International Pyrheliometric Scale.)

Eppley nr. 3278: This instrument is of the type "50-junctions" and has a standardization coefficient 8.05 mV per cal $\cdot$ cm^{-2} $\cdot$ min^{-1}. It is the most sensitive instrument and has therefore only been used during winter months as follows:

26th Nov. 1957 — 27th Feb. 1958
15th Oct. 1958 — 28th Feb. 1959
7th Nov. 1959 — 25th Feb. 1960
20th Oct. 1960 — 10th March 1961
2nd Oct. 1967 — 31st Dec. 1967.

Eppley nr. 1715: This instrument is of the type "10-junctions" and has a standardization coefficient 2.326 mV per cal $\cdot$ cm^{-2} $\cdot$ min^{-1}. It was in use as follows:

1st July — 25th Nov. 1957
28th Feb. — 14th Oct. 1958
1st March — 6th Nov. 1959
26th Feb. — 19th Oct. 1960.

Eppley nr. 4235: This instrument is of the type "10-junctions" and has a standardization coefficient 2.48 mV per cal. $\cdot$ cm^{-2} $\cdot$ min^{-1}. It was in use continuously during the relative long period:

3rd Jan. 1962 — 22nd April 1967.

Unfortunately the instrument was damaged on 22nd April 1967. A little later or in the period 25th May — 2nd Oct. 1967 special resistances were connected to Eppley nr. 3278 so it could be used with the same instrument constant as Eppley nr. 4235.

3. CALIBRATION OF INSTRUMENTS

The instruments have been calibrated by comparison with Ångström Pyrheliometer nr. 503. Unfortunately calibrations for the years 1958–63 are not very reliable due to instrument problems, but calibrations of Eppley nr. 4235 are considered very good and may serve as a basis for any kind of comparison between the instruments. Results of calibrations and comparisons will now be described shortly.

a. Calibrations with Ångström Pyrheliometer.

Eppley nr. 3278: Correction of radiation values according to two calibrations made on 24th Feb. 1958 and 20th Oct. 1960 is: *–9.2%.*

Eppley nr. 1715: Mean correction according to three calibrations made on 30th April 1958, 11th Sept. 1959 and 20th Oct. 1960 is: *8.6%.*

Eppley nr. 4235: Mean correction according to calibrations 24th March 1965, 4th May 1965 and 29th March 1967 is: *7.5%.*

Eppley nr. 3278 (used during the summer 1967 with special resistances): Mean correction from two calibrations: *–2.7%.*

As already mentioned the calibrations from 1958–63 are not very reliable. However as the instrument E. 3278 has only been used in the dark winter months, when radiation is very low, it is justifiable to omit any correction for this instrument rather than use a doubtful one.

More important is to find a correction for E. 1715, which was in use 1957–60. The correction 8.6% is not reliable and must be controlled, and therefore an attempt will be made to compare the values of E. 1715 with those of E. 4235 on clear days. This will be discussed below.

In 1964 the Ångström Pyrheliometer was repaired and recalibrated in Sweden. All calibrations of E. 4235 should therefore be reliable, and the correction 7.5% will be used on radiation values recorded with this instrument.

Only two calibrations were made for E. 3278 (with resistances) and the corrections are small and do not deviate much from each other, so it is hardly opportune to correct the values.

b. Comparison of instruments on clear days.

As a correction of 7.5% has been adapted to the values of E. 4235 it may now be of value to compare this instrument with E. 1715 to get a reliable correction for the latter. The author (Einarsson, 1966) has shown that a very good relation exists between hourly values of global radiation and solar altitude on clear days for the period 1957–1960. The correlation coefficient was found to be $r = 0.995$. At that time E. 1715 was in use except for the winter months November to February. A corresponding relation for the period January 1962 — April 1967, in which E. 4235 was in use, could give a valuable comparison between the instruments. Accordingly a similar equation of regression has been computed for this latter period, giving a correlation coefficient $r = 0.993$. It must be noted, that the radiation values are not corrected in these equations.

Fig. 1 shows the regression lines for both periods. It is seen that the line for E. 1715 is lying a little lower than that for E. 4235. The difference be-

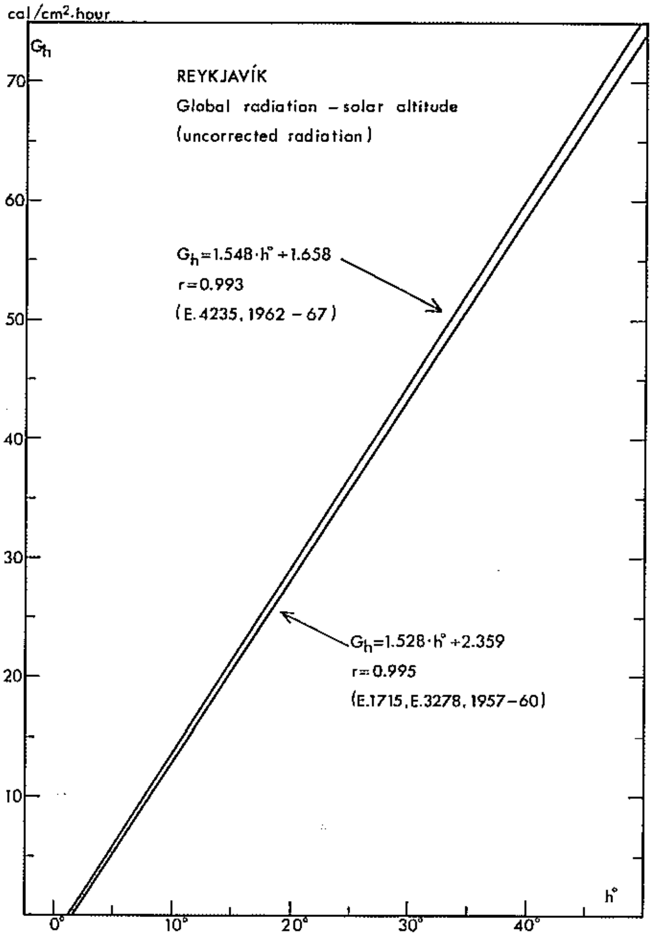

Fig. 1:
Regression lines between hourly values of global radiation and solar altitude on clear days for the two periods July 1957 — Dec. 1960 and Jan. 1962 — April 1967. Uncorrected radiation.

tween them, given in per cent of the radiation values of E. 4235 is for different solar altitudes:

solar altitude	*difference*
10°	5.8%
20°	3.8%
30°	2.9%
40°	2.5%
50°	2.3%.

In the former period E. 3278 was used during the winter, when the sun's declination is always less than –8° and the solar altitude consequently never reaches 20°. For this reason and the fact that radiation measurements are inaccurate in winter the value for solar altitude 10° will not be taken into account. It can also be shown on a scatter diagram that single values do not fit very well in the extreme low part of the line.

The mean value for the other solar altitudes is 2.9%, which then gives an estimate of the correction of E. 1715 compared with E. 4235. The correction for E. 4235 is already determined as 7.5%, and the correction for E. 1715 should therefore be 10.4%. Calibration with Ångström Pyrheliometer gave the correction 8.6% as we remember. As a consequence a correction of *10.0%* will be used for all radiation values recorded with E. 1715. As will be shown later comparison of daily values of global radiation on clear days confirms this result.

In accordance with the foregoing discussion the following corrections are applied for the different instruments:

E. 3278:	correction:	0.0%
E. 1715:	„	10.0%
E. 4235:	„	7.5%
E. 3278: (with resistances)	„	0.0%

4. GLOBAL RADIATION IN REYKJAVÍK 1958–1967

a. Global radiation on clear days.

For the period July 1957 — Dec. 1960 a curve has been found, describing the annual variation of the global radiation on clear days (G_0), (Einarsson, 1966). A day is here considered as clear when the sum of the cloudiness (in eighths) for eight daily observations is not more than 12 eighths. The curve was based on uncorrected values of the radiation. The instruments in use were E. 1715 and during the winter E. 3278, and consequently mean values of G_0 for the months March — October are now corrected, i.e. increased by 10%. For the months November — February the values should strictly be unchanged. However it appears that the original curve was drawn a little too low in winter, so it has been decided to apply the 10% correction also to the winter months in order to correct this roughly.

Corrected mean values of G_0 for each month of the year are shown in table 1.

TABLE 1

Mean values of global radiation in Reykjavik on clear days (cal/cm² · day).

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
23	107	270	502	726	829	754	568	353	152	38	7

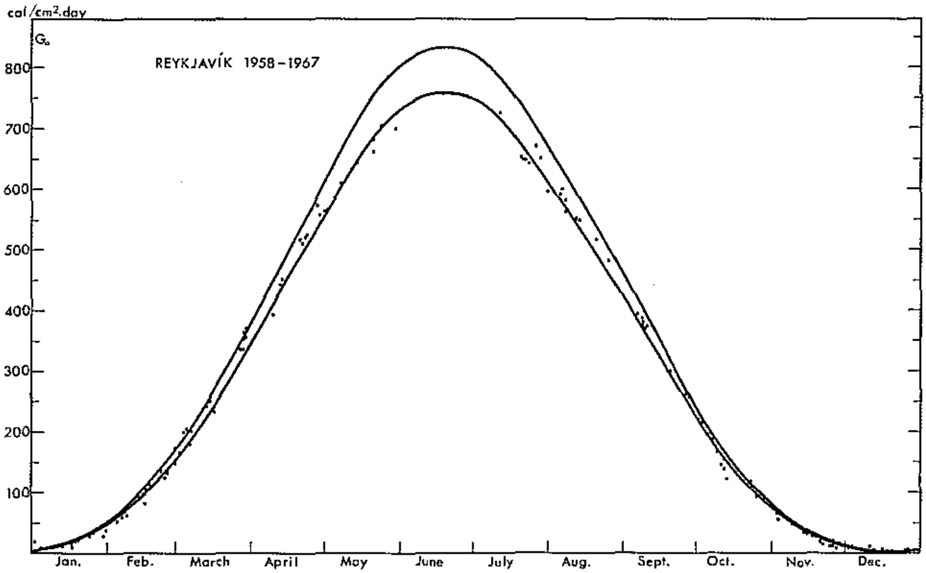

Fig. 2: Uncorrected and corrected (higher curve) curves for global radiation on clear days G_0, together with single uncorrected values from the period 1962—1967.

In fig. 2 the former uncorrected curve for G_0 is shown together with single uncorrected values for the latter period and the new corrected curve. The single points show that the values in the latter period are a little higher than the older curve, but the form of the curve does not change appreciably. This confirms the difference between the two pyranometers E. 1715 and E. 4235, which was discussed in last chapter.

Later in this paper one will need values of G_0 to compute relative radiation, G/G_0, which is used as a variable in the equations of regression between global radiation and duration of sunshine or cloud cover.

b. Global radiation 1958–1967.

To describe the radiation conditions in Reykjavík I have chosen the 10 years period 1958–1967. As already mentioned records were lacking for the year 1961 and for April and May 1967. Values for these months have been computed with the aid of equations of regression which are discussed later.

In table 2 are given corrected radiation values for each of the years 1958–1967 and decade mean values. In fig. 3 are shown the mean curves for absolute and relative global radiation (G and G/G_0).

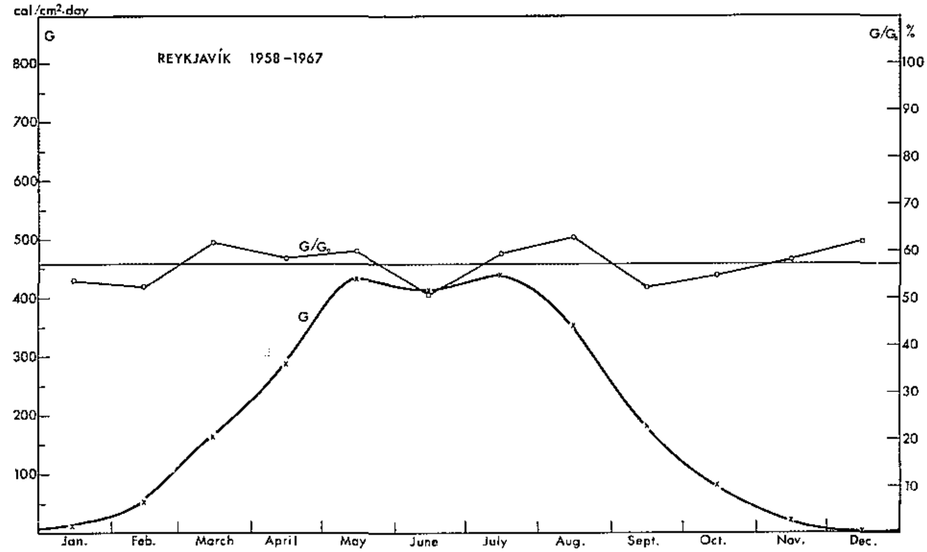

Fig. 3: Monthly means of absolute and relative global radiation in Reykjavik 1958—1967 (G and G/G_0).

TABLE 2

Global radiation in Reykjavik 1958—1967 in cal/cm² · day (corrected values).

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1958:	13	61	168	270	575	414	486	382	153	80	15	5	219
1959:	13	41	129	327	359	411	348	315	150	59	21	5	182
1960:	11	66	158	275	375	383	505	428	184	106	25	4	210
1961:	14[1])	55[1])	141[1])	310[1])	353[1])	482[1])	458[1])	308[1])	183[1])	80[1])	19[1])	6[1])	201[1])
1962:	11	47	209	285	426	373	430	356	204	62	23	3	202
1963:	10	48	157	254	433	409	457	311	195	70	28	2	198
1964:	8	45	126	310	395	462	359	387	186	81	14	4	198
1965:	14	44	181	324	399	427	419	366	226	65	23	4	208
1966:	13	75	182	280	436	381	454	353	151	113	20	4	205
1967:	13	52	190	259[1])	554[1])	380	462	300	171	96	25	4	209
Decade mean.	12	53	164	289	431	412	438	351	180	81	21	4	203

1) Computed values.

The first thing one notices when examining fig. 3 is that the month of highest solar altitude, i.e. June, has a lower mean global radiation than both May and July. This was also the case for the shorter period 1957–1960 and was then considered as exceptional. It must however now be stated that weather conditions in Reykjavík have in a whole decade been such as to reduce the global radiation to values lower than in the nearest two months. As a striking example it may be mentioned that only one clear day was found in June during the ten years period in question. It will be shown later that this rather unusual shape of the radiation curve in summer is only found in the southwest corner of Iceland. With this exception the radiation curve for Reykjavík has a rather regular shape.

The annual mean values given in the last column of table 2 show, that radiation does not vary very much from year to year. Only in 1959 does the annual mean value deviate 10% from the decade mean. However the variation from year to year of each month's values is considerable. This is especially the case in May where the highest value is 575 $cal/cm^2 \cdot day$, and the lowest one 353 $cal/cm^2 \cdot day$, the difference being more than 50% of the decade mean. July and August show also rather great variability, whereas in June the good years are lacking.

The relative global radiation gives an estimate of the part of the clear sky radiation which reaches the ground. It is seen that the annual mean value of G/G_0 is 57% with a maximum of 62.9% in August and a minimum of 50.8% in June. Except for June the summer months have relatively high values. In general 43% of the clear sky radiation is therefore lost due to clouds.

5. RELATIONS BETWEEN GLOBAL RADIATION, SUNSHINE AND CLOUDINESS

For the period July 1957 — Dec. 1960 the author computed equations of regression between relative global radiation G/G_0 and some meteorological elements for Reykjavík (1966). It was found that relative duration of sunshine S/S_0, mean cloud cover in second power N_d^2, based on observations at 08,14 and 20 IMT, and N_d gave the best linear correlation. For the months March to October the correlation coefficients between G/G_0 and S/S_0 varied from $r = 0.906$ to $r = 0.963$, but between G/G_0 and N_d^2 from $r = -0.774$ to $r = -0.933$, with the best correlation in July in both cases. For N_d the coefficients varied between $r = -0.773$ and $r = -0.904$.

By computing multiple linear equations of regression some improvement was achieved, but on such a small scale that the simpler method of linear regression will be used in this investigation. All equations were originally computed on the basis of daily values of S/S_0, N_d and N_d^2. However it is recommended that they are used only to compute mean values of G/G_0 such as monthly means.

New radiation data from the years 1962–1967 have now made it possible to test these equations. Mean monthly values of global radiation, were calculated in three ways, i.e. by using respectively S/S_o, N_d and N_d^2. The resulting values were then compared with the measured values G. The result of the comparison is given in table 3.

TABLE 3

Average differences between computed radiation values and measured radiation G, in per cent of G, using respectively S/S_0, N_d and N_d^2 as variables. Mean deviation from the average is also given.

	J	F	M	A	M	J	J	A	S	O	N	D
Calculated from S/S_0:												
Difference, %:	15.1	5.7	-2.7	-0.8	2.6	3.9	0.3	-0.9	0.2	1.0	0.6	28.2
Deviation:	±11.8	±4.4	±4.2	±1.6	±2.6	±2.9	±2.5	±1.9	±3.7	±4.5	±10.9	±24.7
Calculated from N_d:												
Difference, %:	14.7	2.9	-4.6	-4.2	-0.6	2.4	-0.6	-2.0	2.8	0.3	-1.9	26.1
Deviation:	±15.8	±4.6	±8.3	±2.5	±4.1	±4.2	±2.9	±3.1	±7.1	±4.9	±16.2	±25.2
Calculated from N_d^2:												
Difference, %:	24.3	10.0	-0.3	2.6	7.5	7.3	7.7	5.6	12.0	7.1	7.5	34.0
Deviation:	±16.5	±5.7	±7.8	±3.3	±4.8	±4.8	±2.6	±3.1	±7.3	±4.7	±17.0	±26.5

During the winter, especially in November, December and January correlation between radiation and the above mentioned parameters is not good at all. Radiation instruments become less sensitive when sun is low (See f. example Robinson, 1966, pp. 263) and measurements of duration of sunshine are not very accurate either. This can be seen from the table, as the deviations are rather great in those months.

During the months March–October the situation is quite different. It can be seen from table 3 that the difference between computed and measured values is then within 4% with a deviation up to ±4.5%, when using S/S_o as variable. This must be said to be very satisfactory. When using N_d the result is also rather good but N_d^2 seems to give too high values except in March. This is surprising as N_d^2 gave better correlation coefficients than N_d. The reason is that the relation between G/G_o and N_d^2 is curvelinear, and the curve tends to lie a little too high just in the part where monthly mean values usually lie.

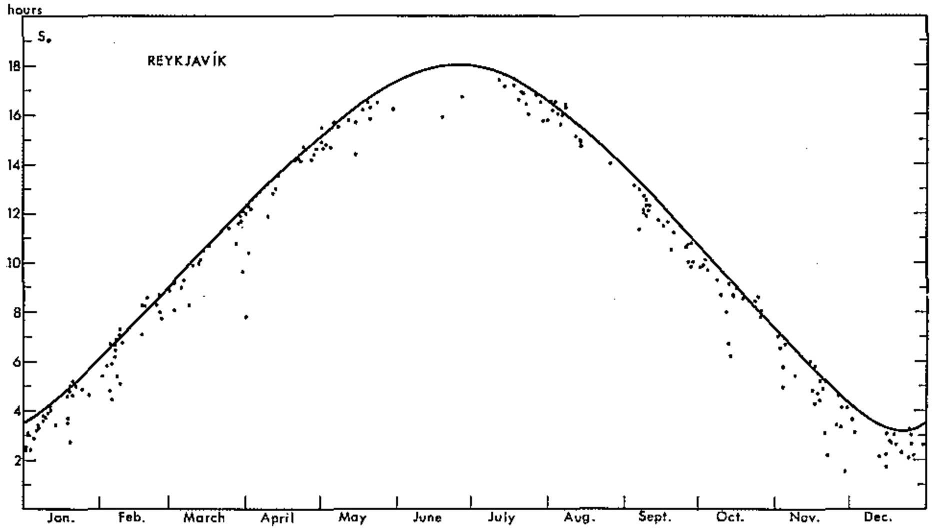

Fig. 4: Duration of sunshine in Reykjavík on clear days S_o.

The testing shows that the equations of regression give radiation values very close to the measured ones especially when using S/S_o and N_d as variables. N_d^2 gives somewhat better values than N_d only in March and April, but in other months N_d is so much better that it will be used in all months rather than having two types of equations for cloud cover. It must at last be born in mind that the testing is strictly valid for Reykjavík only.

When S/S_o is used as a variable it is necessary to find a curve describing the duration of sunshine on clear days S_o. This was done for the period July 1957 — Dec. 1960 by plotting all clear days values on a diagram and drawing the best fitting curve (Einarsson, 1966). For the latter period 1961–1967 it has now been tested, whether it is necessary to alter this S_o-curve, by plotting the new values on the diagram. It turned out that the majority of the points were lying above the original curve. A new one was therefore drawn, now in such a way that the majority of the single values are lying on or below the curve as can be seen in fig. 4. The values of S_o are used to compute values of S/S_o, and it is therefore entirely a matter of definition how the curve is drawn.

As a consequence of this new S_o-curve for Reykjavík all equations of regression with S/S_o had to be corrected before they could be used elsewhere. The corrected equations and also equations with N_d are shown in table 4 together with the corresponding correlation coefficients. These are the equations used in the next section.

TABLE 4

Equations of regression and correlation coefficients.

month	equations	r	equations	r
Jan.	$G/G_0 = 0.6706 \cdot S/S_0 + 42.60$	0.781	$G/G_0 = -7.768 \cdot N_d + 99.74$	-0.703
Feb.	$G/G_0 = 0.7280 \cdot S/S_0 + 33.96$	0.898	$G/G_0 = -9.530 \cdot N_d + 107.38$	-0.797
March . .	$G/G_0 = 0.7585 \cdot S/S_0 + 34.26$	0.906	$G/G_0 = -10.985 \cdot N_d + 123.32$	-0.773
April . . .	$G/G_0 = 0.7750 \cdot S/S_0 + 30.17$	0.958	$G/G_0 = -11.302 \cdot N_d + 123.32$	-0.884
May . . .	$G/G_0 = 0.7640 \cdot S/S_0 + 28.74$	0.962	$G/G_0 = -10.646 \cdot N_d + 120.16$	-0.870
June . . .	$G/G_0 = 0.8317 \cdot S/S_0 + 28.93$	0.919	$G/G_0 = -13.112 \cdot N_d + 135.17$	-0.815
July . . .	$G/G_0 = 0.7418 \cdot S/S_0 + 31.64$	0.963	$G/G_0 = -11.155 \cdot N_d + 122.49$	-0.904
Aug. . . .	$G/G_0 = 0.7586 \cdot S/S_0 + 31.16$	0.949	$G/G_0 = -11.353 \cdot N_d + 125.58$	-0.855
Sept. . . .	$G/G_0 = 0.7974 \cdot S/S_0 + 29.16$	0.941	$G/G_0 = -11.628 \cdot N_d + 123.97$	-0.866
Oct.	$G/G_0 = 0.8002 \cdot S/S_0 + 31.10$	0.918	$G/G_0 = -11.149 \cdot N_d + 118.59$	-0.818
Nov. . . .	$G/G_0 = 0.7951 \cdot S/S_0 + 37.43$	0.805	$G/G_0 = -11.119 \cdot N_d + 116.16$	-0.792
Dec.	$G/G_0 = 0.7053 \cdot S/S_0 + 58.38$	0.546	$G/G_0 = -9.529 \cdot N_d + 118.39$	-0.553

6. CALCULATIONS OF GLOBAL RADIATION IN ICELAND 1958–1967

The equations of regression discussed in the last section are now used to calculate a mean value of G/G_0 for each month for 5 stations measuring duration of sunshine and 30 stations estimating cloud cover at the three hours of observation 08, 14 and 20 IMT. The calculations are based on monthly mean values for the 10 years period 1958–1967.

It must be emphasized that it is not to be expected that relations which are originally found for Reykjavík can be used with the same accuracy for stations where climatic conditions are different. It is probably so that conditions in the southern and western parts of the country do not vary considerably from those in Reykjavík. On the other hand this assumption is more questionable when considering the northern and eastern parts. Furthermore one decade is a rather short period. The calculated values are therefore approximate, although they must be said to give a valuable first picture of the radiation climate in Iceland, a picture which of course must be completed with direct measurements in the future.

Fig. 5 shows the stations used in the calculations. The 5 stations measuring duration of sunshine S, are Reykhólar, Akureyri, Höskuldarnes, Hallormsstaður and Hólar í Hornafirði. On the other stations cloud cover N_d was used.

For the stations measuring S, a curve for S_0 had to be drawn. This was

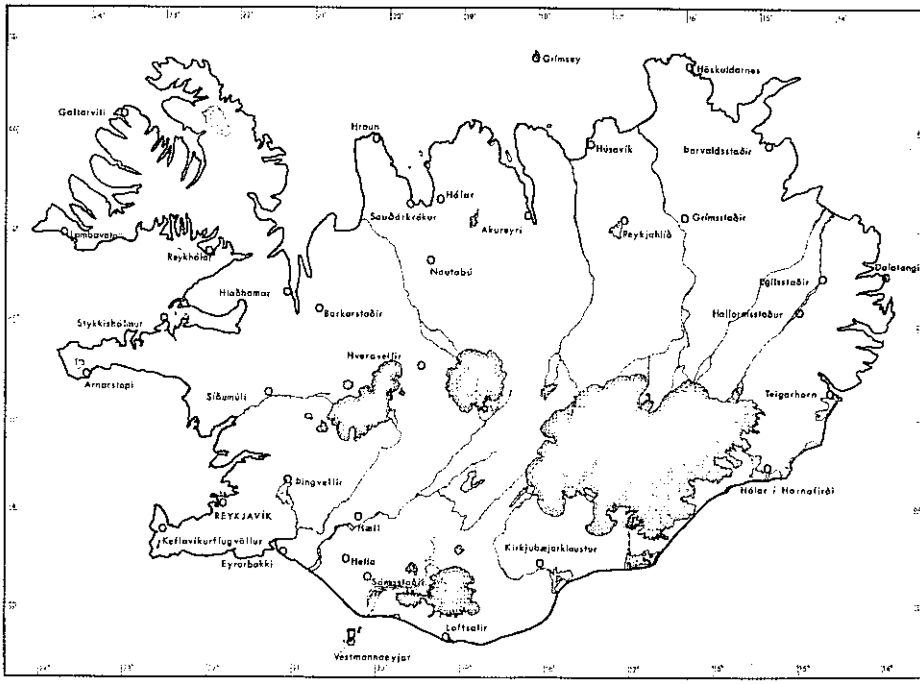

Fig. 5: Stations used for computations of global radiation in Iceland.

done in the same way as for Reykjavík, by plotting clear days' values on a diagram and then drawing the best fitting curve in such a way that the majority of the points where lying on or below the curve. S/S_0 could then be computed.

After computing G/G_0 the next step was to find values for G_0 which again could be used to compute the absolute global radiation G, for each station. G_0 varies with latitude and this variation had to be found. This was done with the aid of tables for "Total daily direct solar radiation reaching the ground with various atmospheric transmission coefficients", found in Smithsonian Meteorological Tables (List, 1951). To these values were added values for diffuse radiation, and the total radiation computed for 60° N and 70° N for the different dates given in the tables, and for different transmission coefficients. The values were then compared with measured values of G_0 in Reykjavík and it was found that an average of the computed values for transmission coefficients $a = 0.8$ and $a = 0.9$ did fit best to the measured ones. Consequently one could find in per cent of radiation at 60° N the mean difference in G_0 between 60° N and 70° N for each month. A table was then made, giving the values of G_0 for ½° intervals from 63½° N to 66½° N, according to the computed differences (table 5).

TABLE 5

Global radiation on clear days G_0 for different latitudes (cal/cm² · day).

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
63.5° N	25	115	279	509	730	829	755	573	361	160	42	8
64.0° N	23	109	272	504	727	829	754	569	355	153	39	7
64.5° N	21	103	265	498	724	828	753	565	349	147	36	7
65.0° N	20	97	258	493	722	828	752	561	343	141	33	6
65.5° N	18	91	251	488	719	827	750	557	337	135	30	5
66.0° N	16	84	245	483	717	827	749	553	330	129	28	5
66.5° N	14	78	238	478	714	827	748	549	324	123	25	4

According to the G_0-values given in table 5, G was calculated for all stations as presented in table 6.

TABLE 6

Global radiation in Iceland 1958—1967.
cal/cm² · day.

	J	F	M	A	M	J	J	A	S	O	N	D
Calculated from S/S_0:												
Reykhólar	9	44	147	283	407	463	442	308	173	63	14	3
Akureyri	9	44	141	271	390	456	414	282	173	66	14	3
Höskuldarnes	7	37	132	254	369	470	384	259	163	56	12	2
Hallormsstaður	9	54	157	280	408	473	419	288	188	72	15	4
Hólar í Hornafirði	12	61	163	280	413	432	400	313	190	80	22	5

Calculated from N_d:	J	F	M	A	M	J	J	A	S	O	N	D
Síðumúli	11	50	153	264	407	392	418	311	168	70	18	4
Arnarstapi	11	50	156	280	445	468	477	355	180	71	17	4
Stykkishólmur	10	44	136	256	390	416	418	296	162	61	14	3
Reykhólar	10	46	150	288	412	467	433	314	167	63	14	3
Lambavatn	10	47	152	282	435	446	450	333	179	65	15	3
Galtarviti	7	36	129	262	403	467	416	292	159	53	11	3
Hlaðhamar	11	52	160	283	421	478	442	309	188	71	17	3
Barkarstaðir	10	47	149	256	383	424	401	283	169	61	14	3
Hraun	9	42	143	268	403	489	391	273	178	62	12	3
Sauðárkrókur	9	45	153	292	427	489	417	300	181	67	14	3
Nautabú	9	41	139	244	343	381	341	250	152	58	13	3
Hólar í Hjaltadal	9	40	140	259	381	413	367	269	162	59	12	3
Akureyri	9	44	148	275	405	456	408	281	177	67	14	3

	J	F	M	A	M	J	J	A	S	O	N	D
Grímsey	7	34	120	238	356	435	340	247	153	51	10	2
Húsavík	9	44	151	290	419	565	466	330	210	65	12	3
Reykjahlíð	10	50	170	297	442	521	442	313	197	75	14	3
Grímsstaðir	10	49	157	297	427	521	450	313	197	73	14	3
Raufarhöfn1)	7	37	132	244	371	446	357	253	157	56	10	2
Þorvaldsstaðir	9	45	148	257	373	456	374	274	175	65	13	3
Hallormsstaður	11	56	164	290	429	490	426	303	201	77	17	4
Egilsstaðir	11	53	157	272	405	478	409	290	192	71	15	3
Dalatangi	10	47	137	255	375	424	367	264	172	65	14	3
Teigarhorn	12	57	162	292	430	479	410	317	192	78	20	5
Hólar í Hornafirði	13	60	169	284	423	435	402	319	195	81	22	5
Kirkjubæjarklaustur	14	63	173	298	418	425	453	354	207	91	25	5
Loftsalir	15	63	176	306	474	512	504	394	213	90	25	6
Sámsstaðir	14	65	183	339	510	544	504	399	211	88	24	5
Vestmannaeyjar	14	57	158	277	419	414	445	356	179	81	22	5
Hæll	14	58	176	296	448	425	461	366	188	84	23	5
Hella	14	61	172	292	449	425	453	366	198	89	24	5
Eyrarbakki	13	55	157	269	410	392	419	334	181	78	21	5
Þingvellir	13	56	163	295	447	425	461	352	183	78	21	5
Keflavíkurflugvöllur	13	54	150	263	401	381	427	333	176	74	19	4
Hveravellir2)	11	46	149	247	392	392	359	265	167	60	15	4

1) Raufarhöfn is only 3—4 km from Höskuldarnes.

2) Values were estimated from only 3 years of observations.

In table 6 radiation could be calculated in two ways for the 5 stations recording duration of sunshine, using S/S_0 and N_d respectively, and these two calculations can therefore be compared. It is seen that the difference between them is surprisingly small indeed. Except for the winter months Nov. — Feb. the difference exceeds 5% of the radiation only in June and July at Höskuldarnes (Raufarhöfn) and in May and Aug. — Oct. at Hallormsstaður, and in general it is much less.

7. DISCUSSION

It has already been pointed out that the radiation values presented in table 6 must for many reasons be looked upon as preliminary. The calculations are based on relations found in Reykjavík, and they can obviously not be used with the same accuracy in other parts of the country. Furthermore an estimate of cloud cover is rather inaccurate and systematic differences in the estimate are likely to occur between different observers. In the third

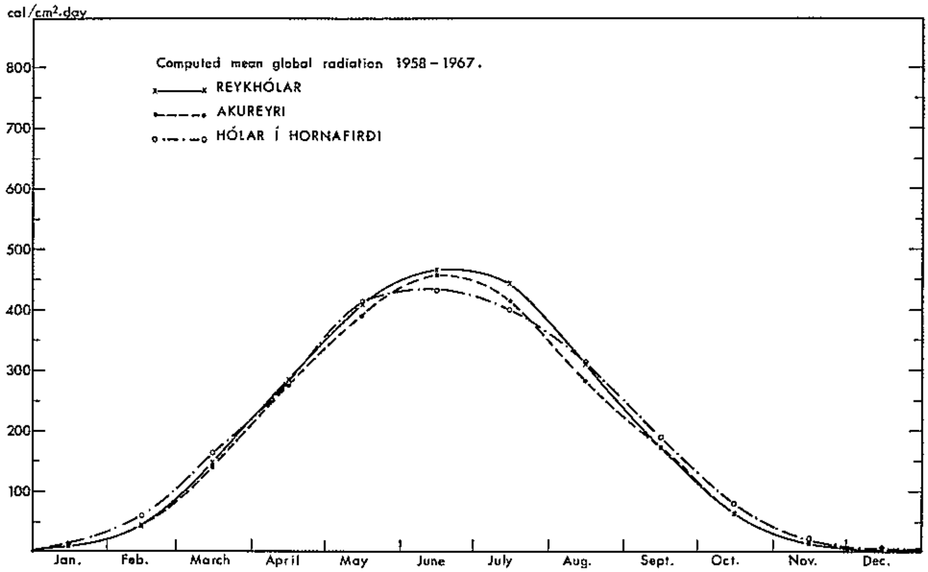

Fig. 6: Computed mean global radiation for Reykhólar, Akureyri and Hólar í Hornafirði.

place a 10 years period is not a very long one compared with the normal period of 30 years. Unfortunately the lack of data made it impossible to use a longer period as registrations of global radiation in Reykjavík started in 1957, and the same was the case for three of the stations measuring duration of sunshine. In spite of these shortages the computed radiation gives a valuable first picture of the radiation climate in Iceland.

The calculated radiation presented in table 6 will now be discussed and the values applied to draw maps showing the distribution of global radiation in Iceland.

It was shown in fig. 3 that June had a lower radiation in Reykjavík than May and July, probably due to bad weather conditions. It is now of interest to see if this also applies to other parts of the country. An examination of table 6 shows that this is not the case. June has a lower value than May and July in the southwestern corner of the country represented in the table by stations as Síðumúli, Keflavíkurflugvöllur, Þingvellir, Eyrarbakki, Hella, Hæll and Vestmannaeyjar. Farther to the east and north the radiation curve changes its shape to a form with a maximum in June.

In fig. 6 are shown the mean smoothed curves of global radiation for Reykhólar, Akureyri and Hólar í Hornafirði. In all the places the maximum is found in June, although the form of the curves differs in other ways. At Hólar í Hornafirði May has a value comparable with June, and at Reykhólar July has a relatively high value. However, at Akureyri in North-Iceland

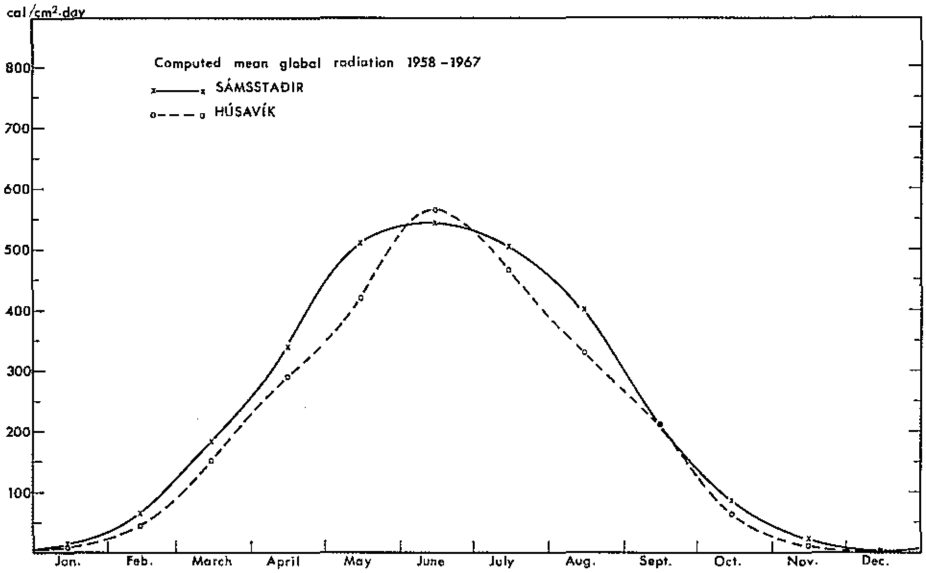

Fig. 7: Computed mean global radiation for Húsavík and Sámsstaðir.

the maximum in June is more pronounced compared with May and July. In fact a significant difference in the shape of the radiation curve in summer is found between North- and South-Iceland. This is seen more clearly in fig. 7, where curves for the two stations having the highest global radiation in June, Húsavík in North-Iceland and Sámsstaðir in South-Iceland, are presented. Húsavík has an absolute maximum with its 565 cal/cm^2 · day in June.

The figure shows that the summer maximum is more pronounced and narrower at Húsavík than at Sámsstaðir, where the curve has a broader form with high radiation not only in June but in all summer months. There is indeed a latitudinal difference in radiation on clear days between North- and South-Iceland, which almost disappears in June, but increases towards spring and autumn. As can be seen from table 5 however this difference is so small that it can only explain a part of the difference between the two stations. Significant difference in cloud cover and weather conditions must be present.

Maps describing the distribution of global radiation in Iceland 1958–1967 for each of the months March–October are presented in fig. 8 a–h.

In *March* a maximum area of about 180 cal/cm^2 · day is found in South-Iceland with a relative high area spreading out to the west and also to the northeast.

In *April* the maximum zone in South-Iceland is much more pronounced with a maximum 340 cal/cm^2 · day in Fljótshlíð to the west of the glacier

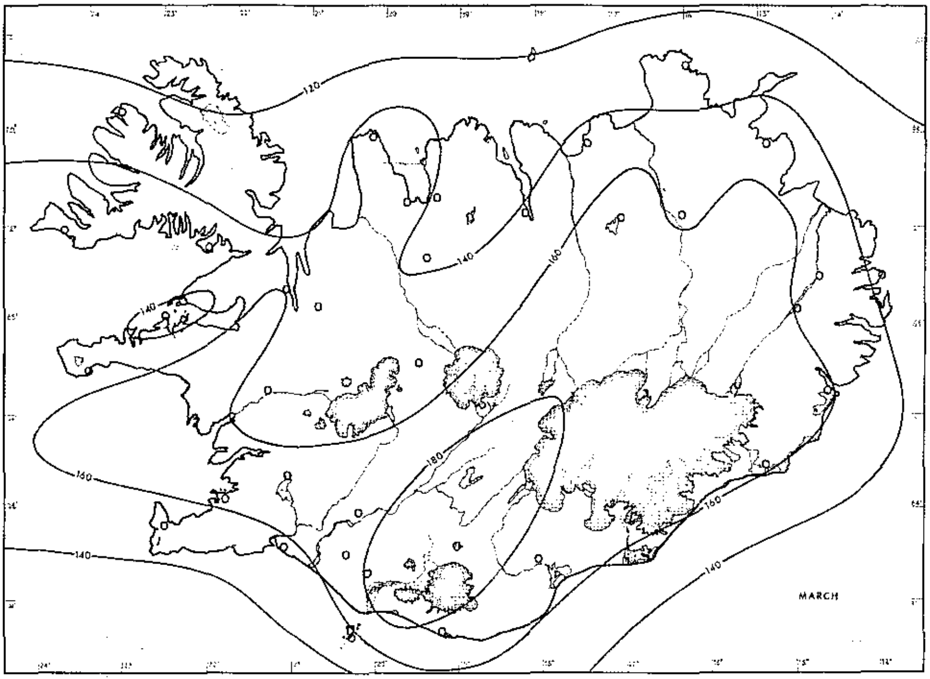

Fig. 8a: Distribution of global radiation in Iceland 1958—1967 in March. expressed in cal/cm^2 · day.

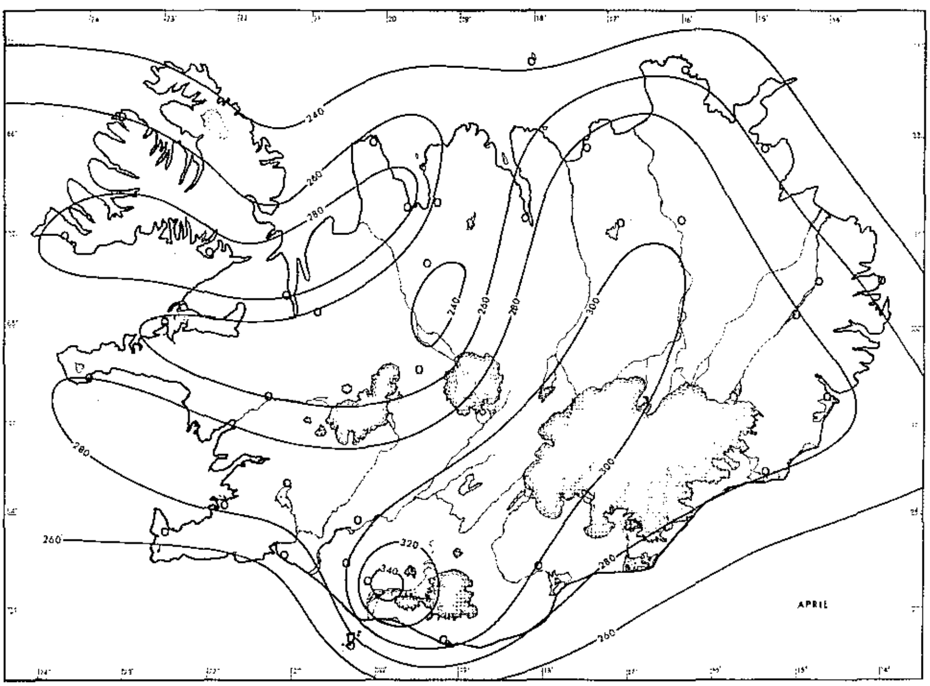

Fig. 8b: Distribution of global radiation in Iceland 1958—1967 in April, expressed in cal/cm^2 · day.

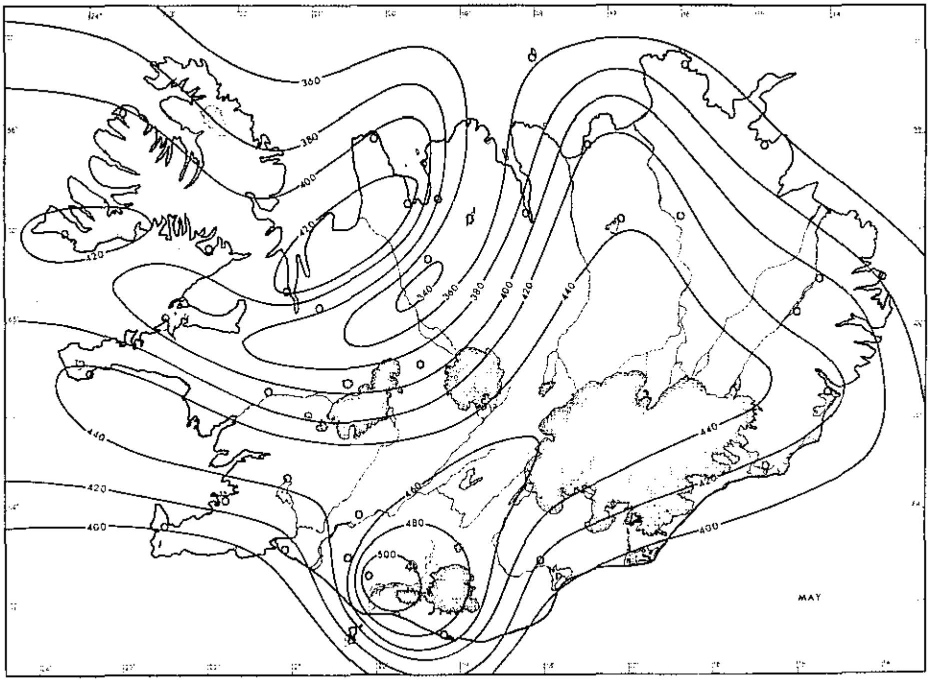

Fig. 8c: Distribution of global radiation in Iceland 1958—1967 in May, expressed in cal/cm^2 · day.

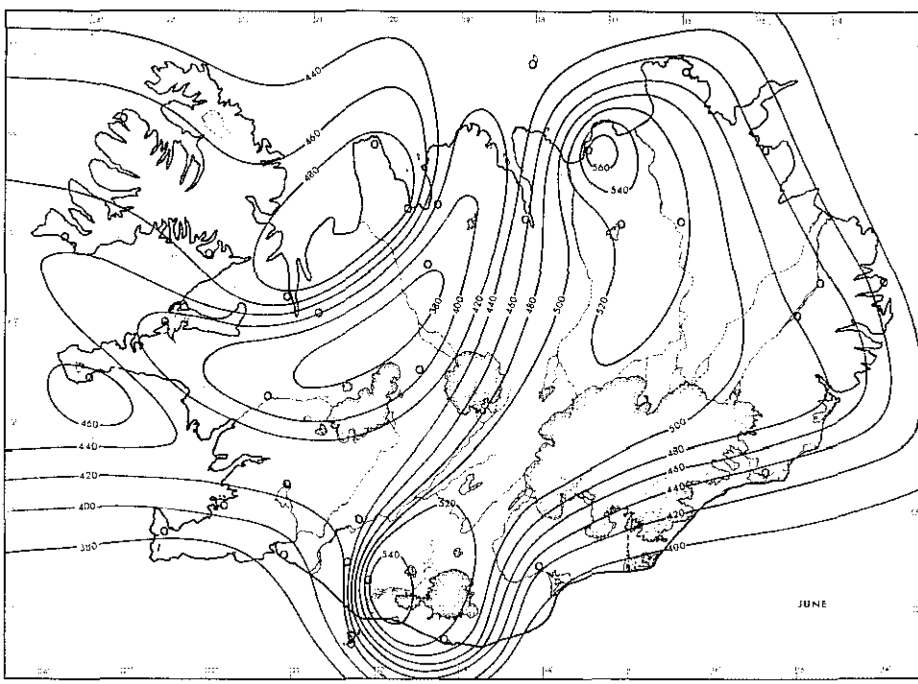

Fig. 8d: Distribution of global radiation in Iceland 1958—1967 in June, expressed in cal/cm^2 · day.

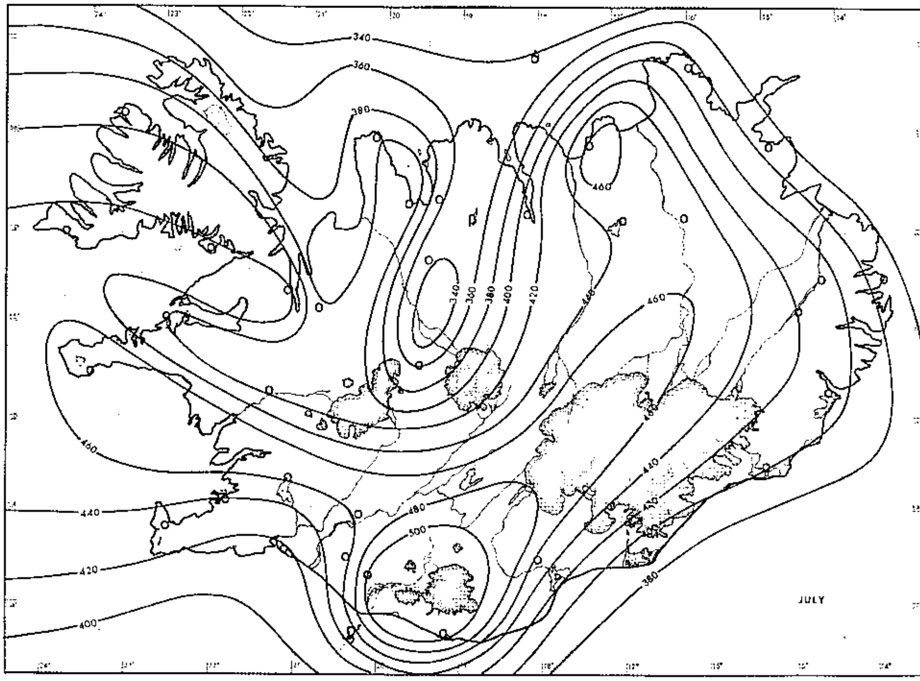

Fig. 8e: Distribution of global radiation in Iceland 1958—1967 in July, expressed in cal/cm^2 · day.

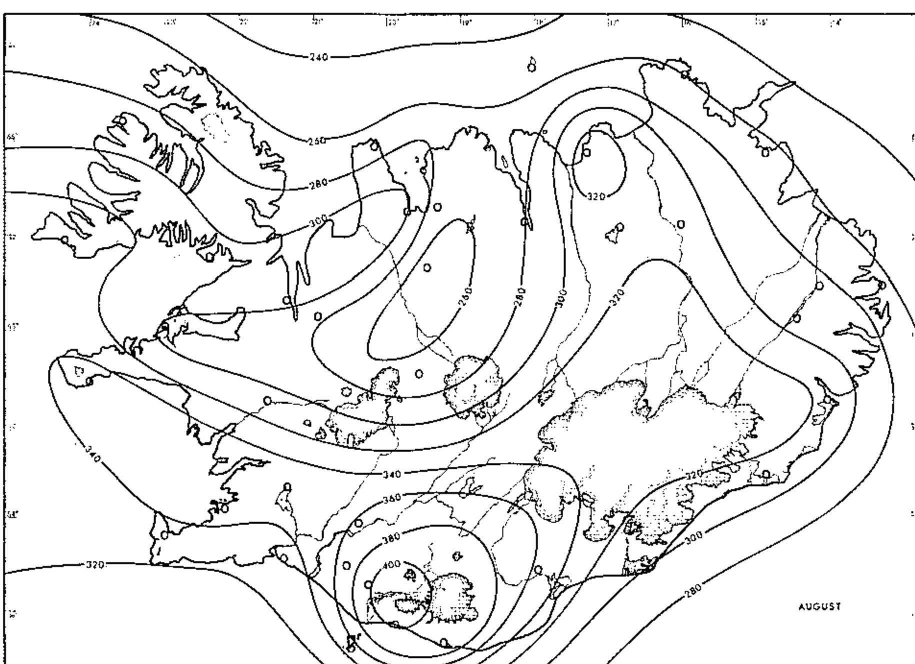

Fig. 8f: Distribution of global radiation in Iceland 1958—1967 in August, expressed in cal/cm^2 · day.

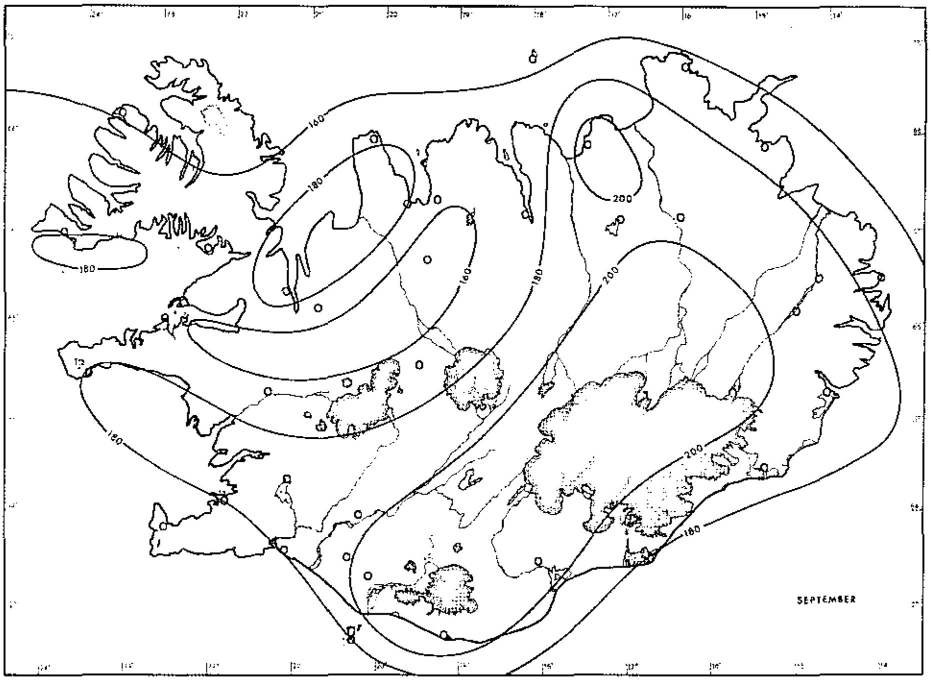

Fig. 8g: Distribution of global radiation in Iceland 1958—1967 in September, expressed in cal/cm² · day.

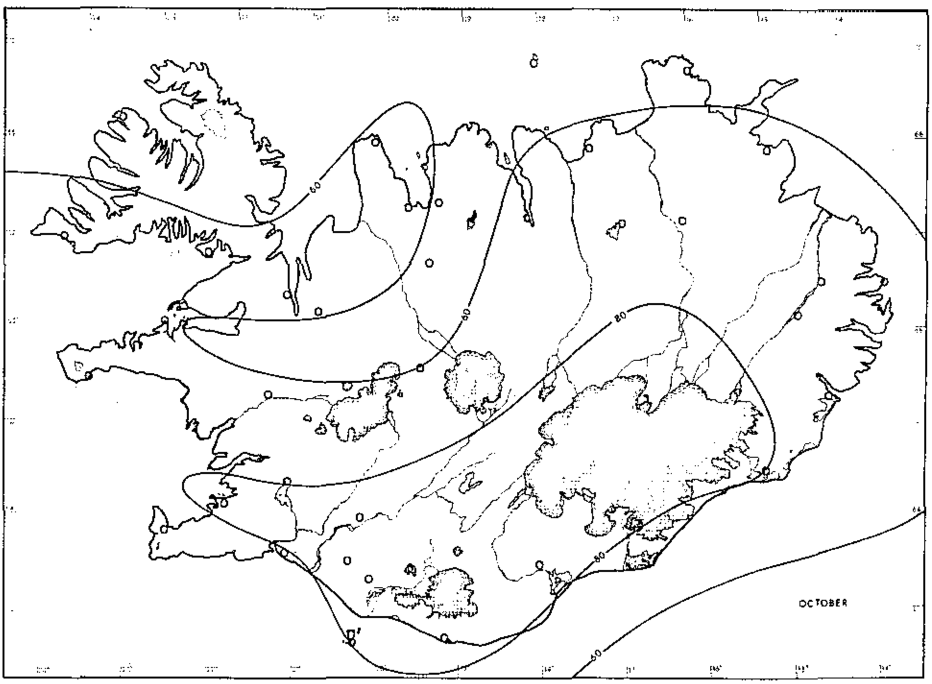

Fig. 8h: Distribution of global radiation in Iceland 1958—1967 in October, expressed in cal/cm² · day.

Mýrdalsjökull. From this maximum a zone of relatively high radiation reaches to the northeast and later north to the highlands north of the huge glacier Vatnajökull. This is not surprising as the area north of Vatnajökull is in a precipitation shadow and cloud cover is therefore probably low.

A surprising feature is the distinct minimum zone reaching from the inside of the district Skagafjörður to the highland area Kjölur, and from there turning to the west to inner Húnavatnssýsla and Dalir. The minimum is 240 cal/cm^2 · day in inner Skagafjörður. It is not easy to find a satisfactory explanation of this minimum. However, a possible one is the following: When the wind blows from the east, which is a frequent direction in Iceland, a low, partly due to heating during the day, partly of orographic origin, is often found in the inner parts of Northeast-Iceland. As a consequence the wind blows from a southeasterly direction in the eastern part and reduces the cloud cover, while to the west in the Skagafjörður area the wind is from north or even northwest, and thus carries moisture from the coast to the inland. This could at least partly explain the maximum area in the Mývatn area (see also fig. 8 c–h) and the much less radiation farther west. However in the westernmost part of North-Iceland this influence is not pronounced, and in the lee for the east and northeast wind a zone of high radiation is found in inner Húnaflói and Barðaströnd in April.

The map for *May* shows in general the same patterns as April, but the differences in the radiation values between maximum and minimum areas are larger. The maximum in Fljótshlíð is now 500 cal/cm^2 · day and secondary maxima are found in inner Húnaflói and Barðaströnd. Relatively high values are also found in Faxaflói, and as before north of Vatnajökull and in the Mývatn area, on the border of which the station Reykjahlíð is lying.

June shows yet steeper gradients. The absolute maximum of 560 cal/cm^2 · day is now found in Northeast-Iceland between Húsavík and Mývatn, and the Fljótshlíð-maximum is distinct as before. In this month the latitudinal difference in insolation with clear sky almost disappears and differences in the radiation are therefore almost entirely due to differences in local weather conditions.

July shows again a similar picture as May and June, but the main maximum has now returned to South-Iceland.

It might be mentioned that the difference between maximum and minimum global radiation in May, June and July is of the order 160–180 cal/cm^2 · day which is a similar amount as the total radiation received in March in the maximum zone.

August and *September* are similar to the other summer months, but now the radiation as well as the differences are decreasing, and in *October* the absolute variation is small.

According to the distribution maps global radiation shows a considerable variation and is highly influenced by local differences in cloud and weather conditions, as has been pointed out by Wallén (1966). The need for further registrations of radiation is therefore obvious.

The radiation values seem to be rather reasonable compared with values from neighbouring countries (Lindholm 1958, Schieldrup Paulsen 1952, Spinnangr 1968 and Wallén 1966).

The present investigation is the first attempt to describe the radiation climate of Iceland. Although the results must be considered as preliminary, they can form a basis for further radiation research. Knowledge of the radiation energy is also the key to studies concerning energy- and water-balance conditions.

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SUMMARY

Records of global radiation in Reykjavík, Iceland, in the period 1958–1967 are presented and discussed.

Mean global radiation for the same decade is then calculated for 5 stations in Iceland recording duration of sunshine and 30 stations observing cloud cover, on basis of equations of regression previously found for Reykjavík (Einarsson, 1966). The computed radiation values are applied to draw radiation maps for Iceland for each of the months March–October.

A distinct zone of maximum insolation is found in Fljótshlíð in South-Iceland and from there a zone of relatively high radiation reaches to the north of the glacier Vatnajökull to an other maximum in the Mývatn area in summer. Characteristic is also a minimum zone reaching from the inside of the district Skagafjörður to the highland area Kjölur, and from there turning to the west to inner Húnavatnssýsla and Dalir. According to the distribution maps global radiation shows a considerable variation and is highly influenced by local differences in cloud cover and weather conditions.

ÁGRIP Á ÍSLENZKU

Í ritgerð þessari er fjallað um mælingar á geislun frá sól og himni í Reykjavík á árabilinu 1958–1967.

Á grundvelli fylgnilíkinga, sem höfundur hefur áður fundið milli geislunar í Reykjavík annars vegar og fjölda sólskinsstunda eða skýjahulu hins vegar (Einarsson, 1966), er síðan reiknuð meðalgeislun áranna 1958–1967 á 5 veðurstöðvum, sem mæla fjölda sólskinsstunda og 30 stöðvum, þar sem skýjahula er áætluð. Niðurstöður útreikninganna eru að lokum notaðar til þess að teikna geislunarkort fyrir Ísland mánuðina marz til október.

Þessi kort sýna, að hámark geislunar er í flestum mánuðum að finna á svæðinu vestan Mýrdalsjökuls, einkum í Fljótshlíð. Þaðan liggur belti hárrar geislunar til annars hámarkssvæðis nærri Mývatnssveit, og er það hámark einkum greinilegt yfir sumarmánuðina. Einkennandi fyrir kortin er einnig allmikið lágmarkssvæði, sem liggur úr innanverðum Skagafirði til Kjalsvæðisins, þar sem það beygir til vesturs um innanverða Húnavatnssýslu, allt til Dala.