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CONTENTS

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CLOUDINESS AND GLOBAL RADIATION AT THE HEAD OF INUGSUIN FIORD, N.W.T., IN THE SUMMER OF 1968

by

S. Fogarasi and M. Boakes*

Introduction

Radiation conditions in Canada have been investigated by Mateer (1955) for clear skies, and by Vowinckel and Orvig (1962) for clouded skies at radiation stations associated with open topography. Little information is available on radiation in closed valleys, where the depletion of clear-sky radiation by local cloudiness is different from the results shown by the two studies mentioned above.

This article is a contribution to the understanding of the relationship between cloudiness and global radiation over a rugged topography. Inugsuin Fiord (Fig. 1)(63 35'N and 70 02'W) at the east coast of Baffin Island, N.W.T., was selected for investigation. This little known site became a location for climatological study because a flat section of the beach, at the head of the fiord, was suitable for weather observation, some of the major ice fields of Baffin Island were accessible from the fiord and, finally, weather data collection could support glaciological studies on adjacent glaciers. It can also be mentioned that for the support of glaciological and geological investigations the Department of Mines and Technical Surveys of Canada erected a depot and a base camp at the head of the fiord in 1964.

Global radiation and synoptic weather observations have been recorded at the base camp during the summer of 1968 as part of the glaciological program. The short stay of field personnel at Inugsuin Fiord limited the collection of radiation and cloud data to a portion of the

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summer. However, it proved possible to extend the characteristics of radiation and cloud conditions for the whole summer, by studying existing data so as to portray global radiation as a function of solar elevation for various cloud conditions. By converting solar elevation into time the general relationship between cloudiness and radiation can be determined for any time of the summer, even for days when no observation of radiation is available. By knowing the general relationship between cloudiness and radiation the depletion of global radiation by clouds can be obtained for any day of the summer. With the knowledge of the depletion of radiation, the role played by weather systems in climatic variation can then be assessed.

Observation Program

As part of the regular synoptic program for the station, cloud observations were made four times a day at 0100, 0700, 1300 and 1900 EST, from 25 May to 13 August, 1968. It was assumed that the observed cloud cover was the average of the period from half an hour before to half an hour after the observation, and that the four observations represented the diurnal march of cloudiness. Multi-layered cloud structures were not visible to the ground observer when overcast clouds formed the lowest layers. In the presence of a scattered or broken cloud cover this observation error was diminished since the observer could recognize a stratified cloud structure.

Sunshine duration was recorded with a Campbell-Stokes Sunshine Recorder and the global radiation was measured with a Casella model Robitsch Actinograph. Global radiation was measured from 2 June to 14 August, a period shorter than that of the cloud observation. At midnight, radiation was intercepted by a mountain peak of 762 m (2500 ft) height, north of the observation site (Fig. 1). For the rest of the day global radiation was not obstructed by local topography. However, it has been shown by Pyatnenkov (1959) that global radiation is indirectly affected by the joint influence of the solar azimuth and the topography. Unfortunately, in the present study, due to the lack of measurements of the albedo, direct and scattered radiation, it has been necessary to disregard any effect of the topography on the global radiation.

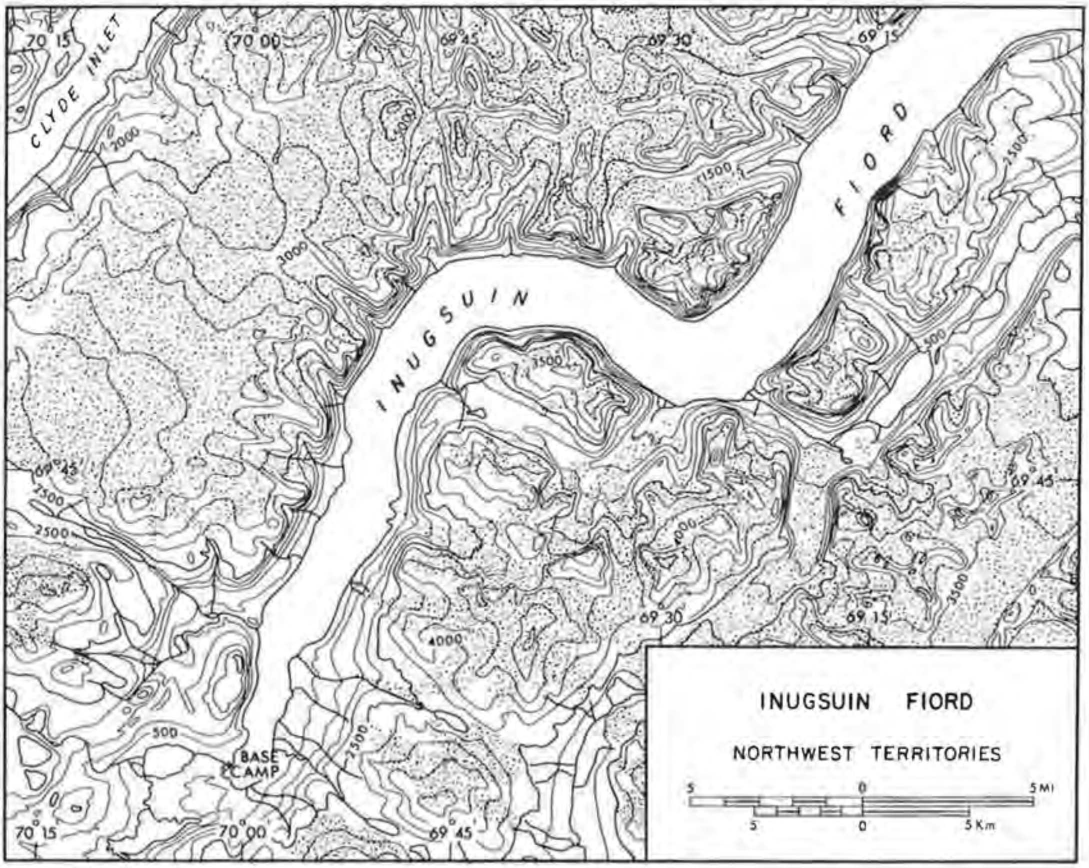

Fig. 1. Topography along Inugsuin Fiord, Baffin Island, N.W.T. Dotted areas represent permanent ice covers.

Analysis of the Cloud Data

Cloud records have been grouped into four classes according to the time of observation and the main cloud types. The cloud ammounts were grouped into three classes: scattered (1/10-5/10 cloud cover), broken (6/10-9/10 cloud cover), and overcast (10/10 cloud cover) (Fig. 2). The percentage of the amount of clouds is presented in the form of a cumulative frequency distribution.

For a generalization of the local cloudiness, both the single and multi-layered total (low, middle, and high-level) cloud cover were taken into consideration. The frequency distribution of the total cloudiness indicated a J shape distribution (Fig. 2). In 49% of all observations the sky was overcast at the observation site and clear siies were recorded for only 10% of the observations.

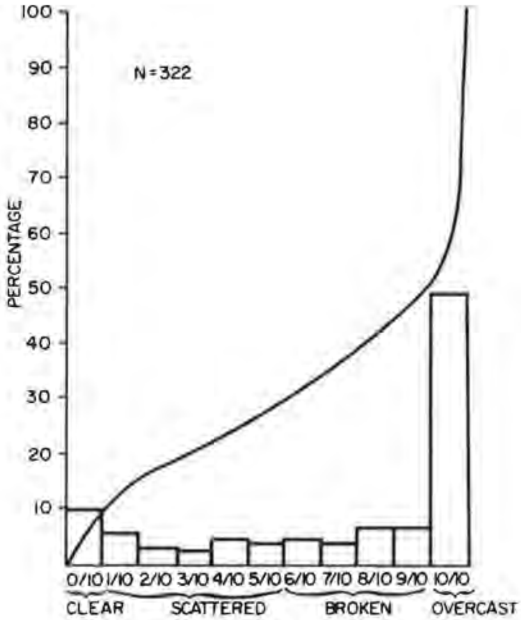

Fig. 2. Cumulative frequency distribution of total cloudiness for 290 clouded and 32 clear-sky conditions.

TABLE ONE

Generalization of the cloud frequency distribution.

Time	Clear %	Scattered 1/10 - 5/10 %	Broken 6/10 - 9/10 %	Overcast 10/10 %
All-day cloudiness	10	20	21	49
Morning (0700 h)	10	15	28	47
Noon (1300 h)	10	20	28	42
Evening (1900 h)	10	23	21	46
Midnight (0100 h)	11	18	16	55
Average	10	19	23	48

Histograms of the total cloudiness were drawn for each of the four daily observations, and the conclusions are summarized in Table One. The J shape of the frequency distribution persists for the four observations, and the predominance of overcast conditions, the persistence of the 10% clear sky, and the occurence of scattered and broken cloud cover in approximately 20 % of the observations are clearly shown. A slight diurnal variation in the amount of clouds is also revealed by the Table. A detailed account of the behaviour of the main cloud types during the summer of 1968 in the area is being developed in a separate paper (Fogarasi, in preparation).

To demonstrate the relative importance of the various cloud types in the local climate, the partial contribution of the cloud forms to the total cloudiness is shown in Figure 3. The time-variation of the single and multi-layered cloud cover was plotted in tenths (Fig. 3a) while the partial contribution of the individual cloud types to the total cloudiness was recorded in percentages (Figs. 3b, c, d, e, and f). Areas formed by the graphs b, c, d, e, and f were measured with planimeter, and the sum of the partial areas was considered 100%. A 4/10 total cloud cover (Fig. 3a), for example, at 1900 EST 10 June 1968 can be seen to have been produced entirely by cumulus clouds (Fig. 3d). The percentage contribution of each cloud type is shown for each day according to cloud type (Fig. 3b, c, d, and e). The overall contribution of each type is given as a percentage on the right of the diagram. The contribution by stratocumulus (44%) and stratus (30%) is dominant while the rest of the cloud types appeared less frequently and consequently contributed much less to the total cloud cover.

Global Radiation and Cloudiness

A general relationship between local cloudiness and global radiation is demonstrated by means of a diagram showing actinograph data and the sunshine curve (Fig. 4a and b). A statistical analysis shows that, on the average, the normalized five-day running means of the sunshine curve and global radiation correlated with an $r = 0.8$ at the $<0.1\%$ significance level. The use of five-day running means in the correlation was used because comparison with other values, e.g. four, eight, and ten-day running means, showed that the five-day period optimized the significance level and the correlation coefficient. This correlation value is a qualitative approximation of the relationship, because the effect of

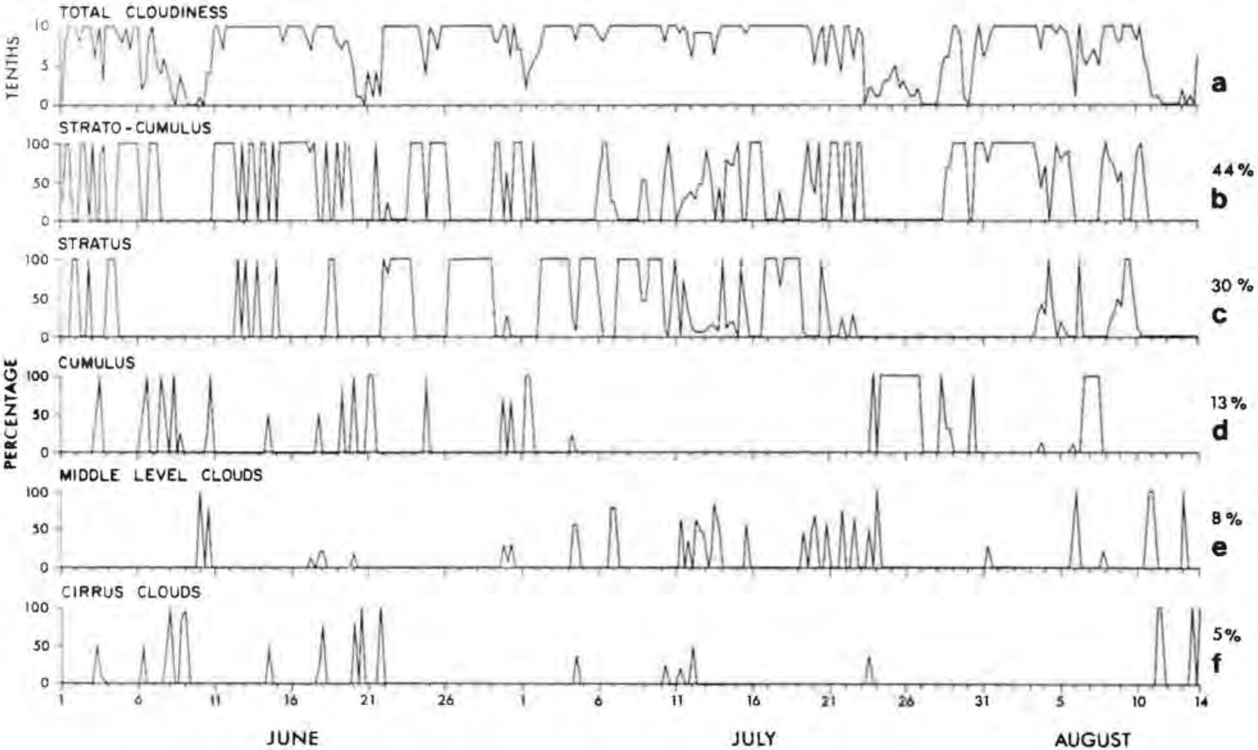

Fig. 3. Composite diagram of cloudiness from 1 June to 14 August 1968, Inugsuin Fiord, N.W.T. a) Total, that is, single and multi-layered cloudiness; b), c), d), e), and f) Percentage distribution of Sc, St, Cu, middle-level, and high-level cloud types to the total cloudiness. The partial contributions of the cloud types to the total cloudiness are indicated on each curve.

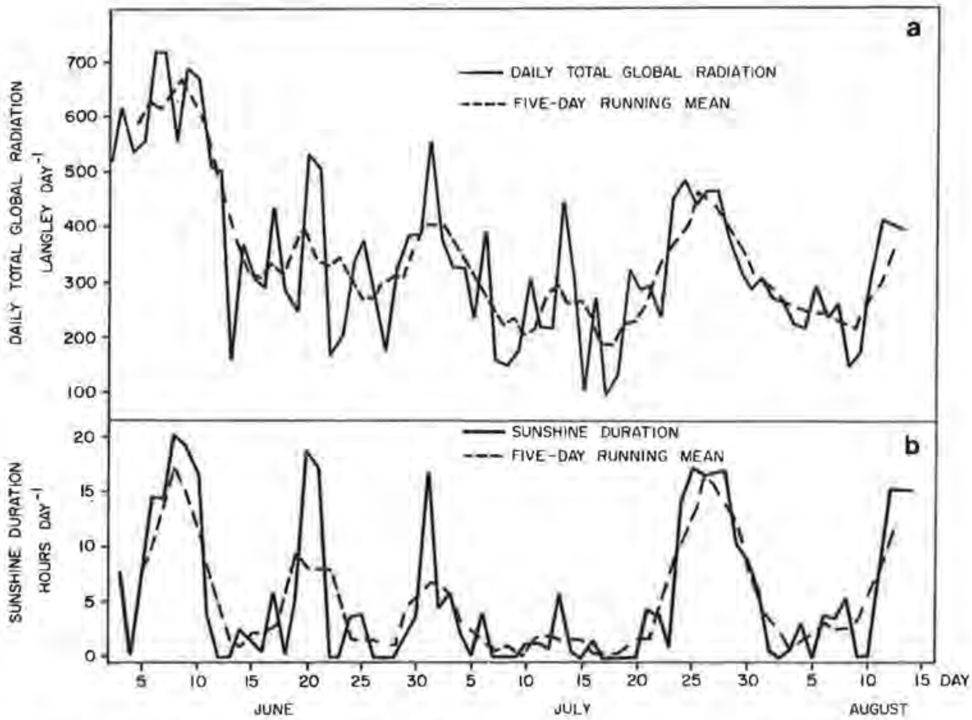

Fig. 4. a) Daily total global radiation with five-day running mean of the global radiation. b) Daily total sunshine duration with five-day running mean values.

cloudiness on global radiation varies largely with the time of day.

As indicated in the introduction, the aim of this study is to deduce diurnal radiation patterns for each cloud category for some selected days during the summer even when actual observations are not available. It is assumed for each radiation pattern, that cloud conditions remain the same for the whole day and that the global radiation at identical morning and afternoon solar elevations is the same; in other words, the diurnal pattern of the radiation distribution is regarded as symmetrical about noon if the cloud cover does not change during the day. To obtain the relevant diurnal radiation patterns solar elevations were calculated for each observation with a nomogram (Mateer and Godson, 1959). For this calculation the times of the observations, made according to Eastern Standard Time, were converted to local true time by adding 20 minutes and the relevant values of the equation of time to the local standard time, because Inugsuin Fiord is east of the centre (75°W) of the time zone by 4°58', that is, by 19 min 51.6 sec.

The hourly radiation totals recorded at the four daily

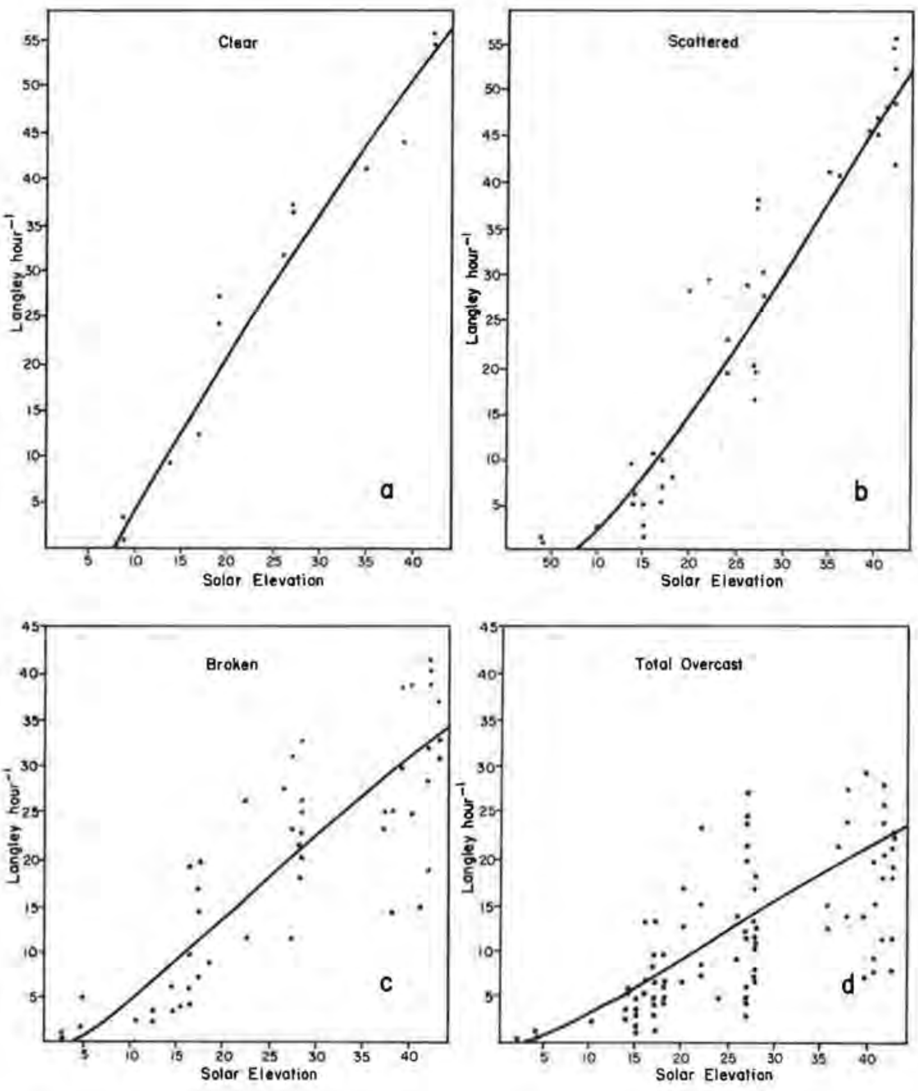

Fig. 5. Variation of global radiation as a function of solar elevations for: a) clear, b) scattered, c) broken sky conditions, and d) for all the single-layered and nine more multi-layered overcasts. Curves were fitted to equation (2). Some dots represent several data points.

observations were related to the relevant solar elevations for cases when the cloud conditions were classified as clear, scattered, broken and overcast (Fig. 5), to see how the amount of cloud can influence radiation. Investigation was also extended to cases when: a) the two most frequent cloud types, stratocumulus and stratus, as shown in Figure 3, occurred; b) the thickest cloud type, nimbostratus (Fig. 6), was observed; and c) when precipitation had fallen half an hour before or half an hour after the observation (Fig. 6). The analysis presented in Figure 6 shows the effect of the selected cloud types on global radiation. In the selection of the cloud types the availability of a sufficient number of data played a major role. In Figure 5 single and also single plus multi-layered cloud covers were included. In Figure 6 only single types and single-layered clouds forming overcast conditions were examined. This was done to eliminate the composite effects of multiple cloud types on global radiation.

The morning and afternoon radiation values of the whole summer were plotted against the solar elevations (Figs. 5 and 6) because a symmetric radiation distribution was assumed. The first of these diagrams, the clear sky radiation, indicates the smallest scatter (Fig. 5a). The scatter of dots, under clear sky conditions could be caused by changes in sky conditions during the hour about the observation time and possibly by seasonal decreases in the depletion of solar radiation by precipitable moisture from spring to the end of the summer. Furthermore, the effects of the diurnal change of albedo due to the topography have been disregarded and a constant pattern of diffuse radiation assumed. The scatter of data can be seen to increase with cloud cover and solar elevation (Figs. 5b, c and d). Under scattered cloud cover, possibly because of the additional reflection from clouds, the actinograph in some cases recorded even higher radiation values than indicated under clear sky conditions. The wide range of scatter under overcast conditions was possibly caused by the varying transmissivities of the contributing cloud types. Overcast might be formed by a thin stratus, a thick nimbostratus, or a multi-layered cloud structure. Such variability of cloud density resulted in a wide range of scatter (Fig. 5d).

A wide scatter of dots was recorded for overcast stratocumulus (Fig. 6a). This scatter can be explained by the variation of cloud density within the stratocumulus layer ranging from almost clear sky conditions to quite dark clouds. The actinograph under a stratocumulus ceiling could

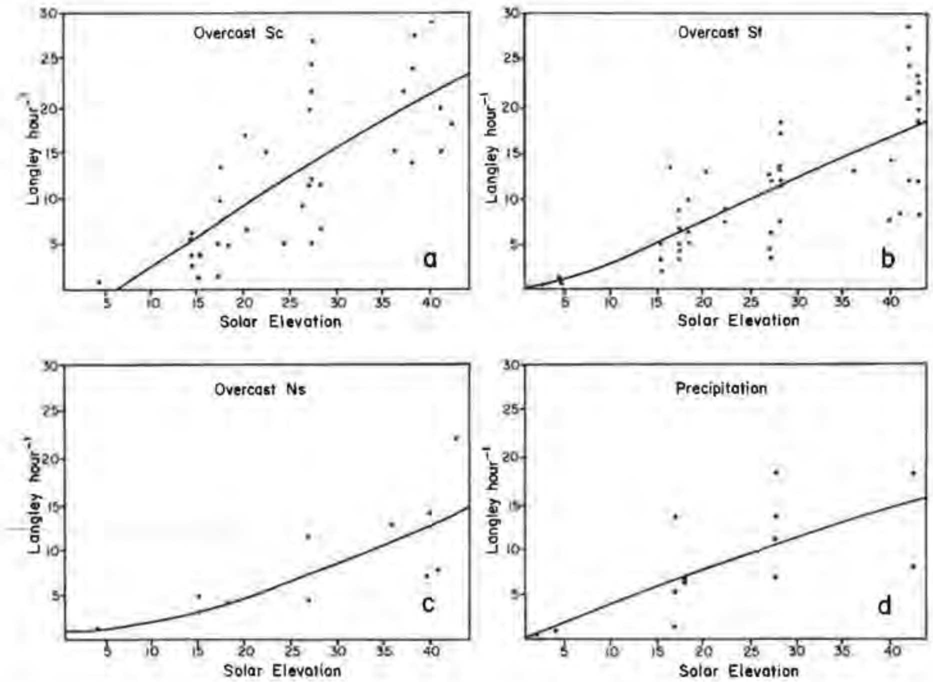

Fig. 6. Variation of global radiation as a function of solar elevation when overcast skies were formed by: a) single-layered stratocumulus, b) single-layered stratus, c) nimbostratus and d) when precipitation had fallen. Curves were fitted to equation (2). Some dots represent several data points.

TABLE TWO

Detailed account of the curve fitting equation (2)

Cloudiness		Correlation Coefficient	Standard error of estimate langley/h	A Ly/h	B	C
Clear Sky		0.96	4.99	-14.09	0.85	0.00
Single	Scattered	0.94	6.01	-3.12	1.46	0.80
and	Broken	0.82	7.87	-0.74	0.51	0.15
multi-layered	Overcast	0.66	7.89	-0.40	0.36	0.20
Single	Stratocumulus	0.72	5.59	-2.72	0.34	0.06
layered	Stratus	0.79	4.47	0.15	0.27	0.20
	Nimbostratus	0.73	4.19	1.31	0.62	2.00
single or multi-layered	with precipitation	0.67	4.47	-0.02	0.18	0.00

be exposed to various intensities of global radiation.

The scatter of dots for stratus conditions (Fig. 6b) indicates the presence of various transmissivities of stratus clouds. It is always possible that some cloud layers existed and varied in time above a strato-cumulus or stratus overcast during the one hour period of observation. Possibly the great vertical thickness of the nimbostratus overcast (Fig. 6c) was responsible for the fact that this cloud form produced the smallest scatter. A reasonably small scatter was recorded also for those hourly periods when precipitation occurred half an hour before and half an hour after the cloud observation (Fig. 6d).

To show the general relationship between global radiation and solar elevation, curves were fitted to the data for each of the separate diagrams. Barashkova's formula (Barashkova, et al., 1961), developed for the presentation of the clear sky radiation, was used for this curve fitting:

$$Q_\circ = 0.95 \frac{J_\circ \sin h^\circ}{1 + 0.2 \operatorname{cosec} h^\circ} \text{ cal/cm}^2 \text{ min} \qquad (1)$$

where $Q_\circ$ is the global radiation, $J_\circ$ is the solar constant (1.98 cal/cm^{2}min), and h° is the solar elevation. Equation (1) is in a general form for detailed analysis and applicable where the maximum amplitude can be reached at 90° solar elevation.

The data in the present study were less detailed than those used by Barashkova; therefore equation (1) was converted here to a form suitable for use on the basis of a time interval of an hour instead of a minute. The equation now takes the form:

$$y = A + B \frac{118.8 \sin^2 h^\circ}{\sin h^\circ + C} \text{ langley/h} \qquad (2)$$

where A, B and C are constants. It can be seen that for any given values of h° and C, equation (2) assumes the form:

$$y = A + Bx \qquad (3)$$

where $x = \dfrac{118.8 \sin^2 h^\circ}{\sin h^\circ + C}$. Equation (3) can then be solved for A and B

TABLE THREE

Effect of cloudiness on global radiation at Inugsuin Fiord, N.W.T., during the summer of 1968

Cloudiness		Daily Total Global Radiation langley/day				Percentage of Clear-sky Radiation Transmitted				Percentage of Clear-sky Radiation Depleted			
		21 June	31 May 13 Jul	13 May 1 Aug	30 Apr 16 Aug	21 June	31 May 13 Jul	13 May 1 Aug	30 Apr 16 Aug	21 June	31 May 13 Jul	13 May 1 Aug	30 Apr 16 Aug
Clear Sky		603	571	476	396	100	100	100	100	0	0	0	0
Single	Scattered	516	488	396	320	86	85	83	81	14	15	17	19
and mu	Broken	385	369	309	267	64	65	65	67	36	35	35	33
multi-layered	Overcast	259	246	208	174	43	43	44	44	57	57	56	56
Single	Stratocumulus	258	248	207	176	42	43	43	44	57	57	57	56
layered	Stratus	203	193	164	138	34	34	35	35	66	66	65	65
	Nimbostratus	161	153	132	110	27	27	28	28	73	73	72	72
Single or multi-layered	with precipitation	195	187	159	137	32	33	33	34	68	67	67	66

The values of the daily radiations and the percentages were rounded up to the nearest integer.

by the method of least squares. For the initial approximation a constant $C = 0.2$ was used; this initial value having been taken from the multiple of cosec in equation (1). Constant C was then increased or decreased recursively until the standard error of estimate reached a minimum. This optimal value of C derived separately for each cloud condition was then used to compute the relevant values of A and B. The process was performed on a PDP 10 computer and the data and the curves were plotted on a Hewlett-Packard 1900B calculator with HP 9125B plotter attached.

Table Two shows the details of the results of the curve fitting process using equation (2). As would be expected from the scatter of the dots in Figures 5 and 6 the coefficient of correlation was highest for clear sky radiation and lowest for single and multi-layered overcast. The constant A in equation (2), representing the intercept on the y axis, was in an inverse relationship to the amount of the cloud cover. For stratus and nimbostratus overcast the intercepts were positive and this is probably due to reflected short-wave radiation from cloud bases at low or even negative solar elevations. At high latitudes clouds can reflect some radiation when the sun is only a few degrees under the horizon or behind the obstructing mountains due to the depression of the surface horizon (Pyatnenkov, 1959). The overcast stratocumulus resulted in a slightly more negative intercept than single and multi-layered broken cloudiness and overcast.

Barashkova's formula has also been applied previously with success to curve fitting of clear-sky radiation data obtained in Sweden (Chróścicki, 1971). Chróścicki's curves agreed well with Barashknva's clear-sky radiation lines fitted to data from Russian stations. The scatter in Chróścicki's diagrams increased with increasing geographical latitude. The most northerly station in Chróścicki's analysis, Kiruna at 67°53'N, 20°18'E, yielded a scatter similar to the scatter at Inugsuin Fiord shown in Figure 5a.

The primary purpose of the curve fitting process was to show the general relationship between global radiation and local cloudiness in terms of solar elevations. It was assumed that this relationship deduced for the middle of summer was also valid both for the early and late summer. If converted as a function of time, the fitted curves for diurnal radiation types and also daily total global radiation can be deduced for any day of the summer. Therefore, solar elevations as used for the curve fitting analysis were reconverted into Eastern Standard

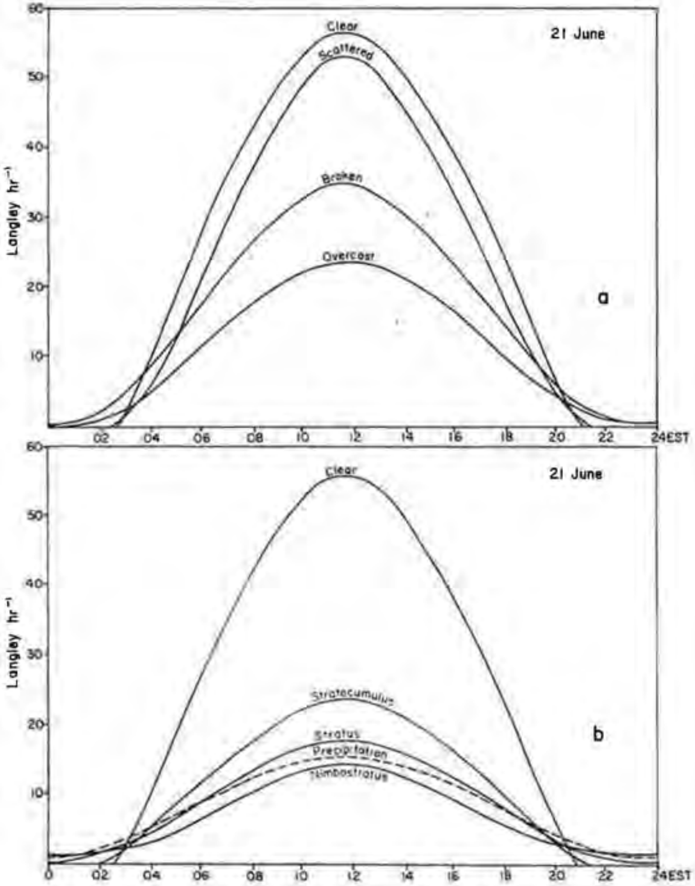

Fig. 7. Diurnal types of global radiation at Inugsuin Fiord, N.W. T. for 21 June.

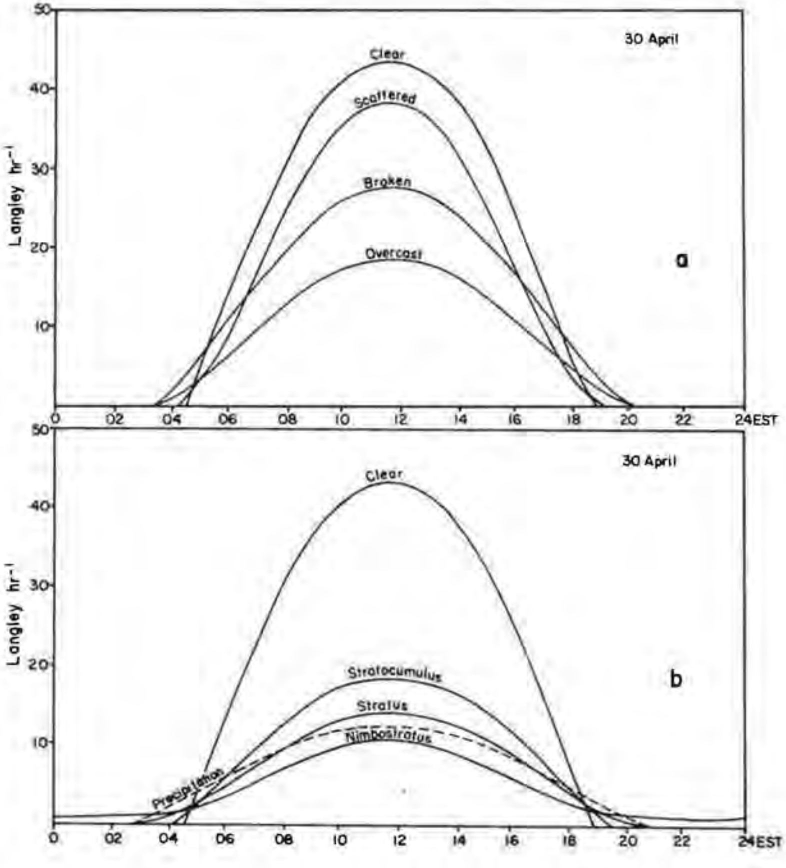

Fig. 8. Diurnal types of global radiation at Inugsuin Fiord, N.W.T. for 30 April.

Note: In both figures: a) is in terms of the amount of clouds and b) is when overcast skies were formed by single-layered strato-cumulus, stratus, nimbo-stratus, and when precipitation had fallen. In the precipitation category both single and multi-layered clouds were included.

time by using Mateer and Godson's technique (1959) as described earlier.

Diurnal radiation types were thus calculated for 21 June and 30 April (Figs. 7 and 8). The curves so obtained are well separated during most of the day; but during morning and evening they overlap and intersect each other. When the sun was either below the horizon or was obstructed by a mountain, the global radiation was zero at clear sky; but small global radiation was indicated under clouded sky. Areas formed by the curves and the time axes of the diagrams (Figs. 7 and 8) were proportional to the daily total global radiation. The latter decreased with the increase of cloud cover (Figs. 7a and 8a) and with the increase in the thickness of the overcasts formed by various types of clouds (Figs. 7b and 8b).

The possible amount of daily total global radiation is shown for selected days under various sky-conditions in Table Three. Daily total radiations were measured with a planimeter on 21 June (Fig. 7) and on 30 April (Fig. 8); and also on two more sets of curves constructed for 13 and 31 May (not shown). Radiation values for days other than shown in Table Three can be obtained by interpolation.

The transmission of the clear-sky radiation for the selected days and cloud categories was estimated next. The percentage of transmission was obtained by dividing values of the daily total global radiation for clouded skies, as listed in Table Three, by the theoretical clear sky radiation. The value of transmission subtracted from 100% yielded the magnitude of depletion (Table Three). The tabulation reveals that overcast clouds depleted more than half of the global radiation measured under clear skies.

The daily total global radiation was almost identical both for single and multi-layered overcast and also for single-layered stratocumulus overcast. The thickest cloud cover, nimbostratus, depleted most of the global radiation incident on the instrument under clear skies. All the cloud categories, with the exception of scattered cloudiness, transmitted the clear sky radiation in an inverse relationship to the declination of the sun whereas the depletion of the clear sky radiation was directly proportional to the declination with the exception of scattered cloud conditions. This relationship reveals that the optical thickness of the local clouds is at a maximum with high solar declination, or that clouds become thicker when spring progresses to summer.

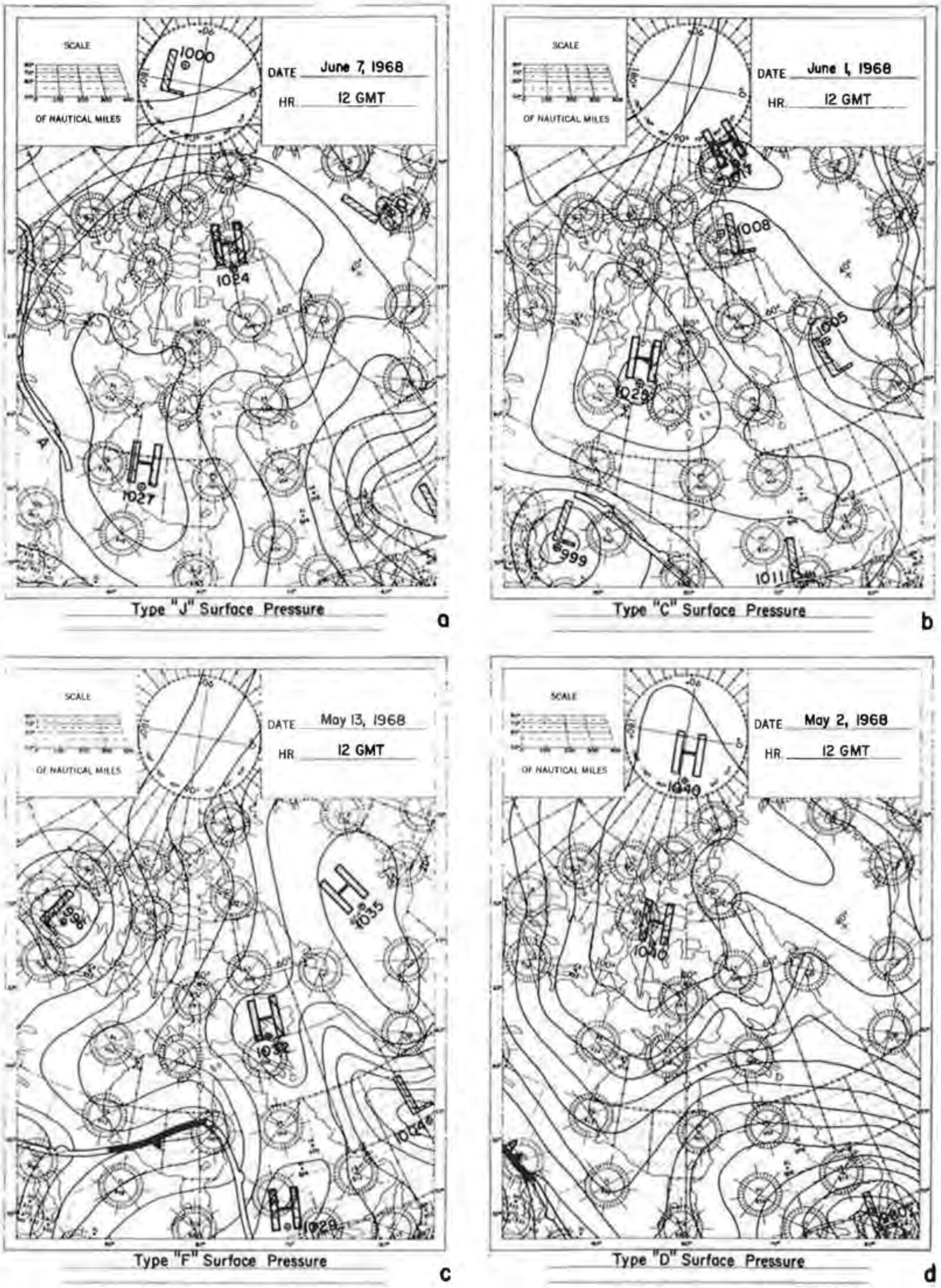

Fig. 9. Four anticyclonic surface weather types producing the highest radiation at Inugsuin Fiord. Each actual weather condition shown here is the best representative of a pressure pattern. a) Weather type J; b) Weather type C; c) Weather type F; d) Weather type D.

The diurnal patterns of global radiation indicate that the daily global radiation varies greatly under clear or partially clear skies, while under overcast skies the bulk of global radiation spreads over the whole day with a smaller daily variation. Figure 4b shows that clear weather spells formed five peaks during the summer and that the daily total global radiation varied much less during cloudy conditions than with clear skies. It can be seen from Figure 4a that a few clear weather conditions are very important contributors to the summer total radiation and that the rest of the weather types substantially decrease radiation. Hence attention is drawn to the effect of atmospheric circulation on the daily total global radiation.

Weather Types, Cloudiness, and Global Radiation

Global radiation and sunshine duration (Fig. 4) were compared with the relevant surface pressure maps and surface weather types. The weather types were derived previously by a quantitive classification of the surface pressure patterns (Fogarasi, 1971) and were identified with a letter code. By this classification 20 surface pressure types were derived for the period 2 June - 14 August 1968. Twice daily weather maps, issued for 0000 and 1200 GMT (0700 and 1900 EST), were used in the classification. The assumption was made that weather maps used in the analysis represented the actual weather conditions for a period of 12 hours, that is, from 6 hours before to 6 hours after the issue of the weather maps. Hence sunshine and cloud conditions observed at 0100 and 0700 EST were related to the 1200 GMT surface weather maps, while the 1300 and 1900 EST data were compared with the 0000 GMT surface weather charts of the previous day.

The comparison of the weather maps and sunshine data revealed that high sunshine values occurred when a surface pressure ridge occupied the eastern coastal region of Baffin Island or when a small-scale ridge developed over Cumberland Peninsula in Baffin Island. Four typical weather types associated with the highest amount of sunshine and radiation were selected and their weather maps are shown in Figure 9.

Despite the outstanding sunshine and radiation values, clear skies infrequently occurred with these high pressure systems at Inugsuin Fiord. Type J weather, (Fig. 9a) for example, never appeared without cloud, while type C weather (Fig. 9b) was in only 32% of the observations

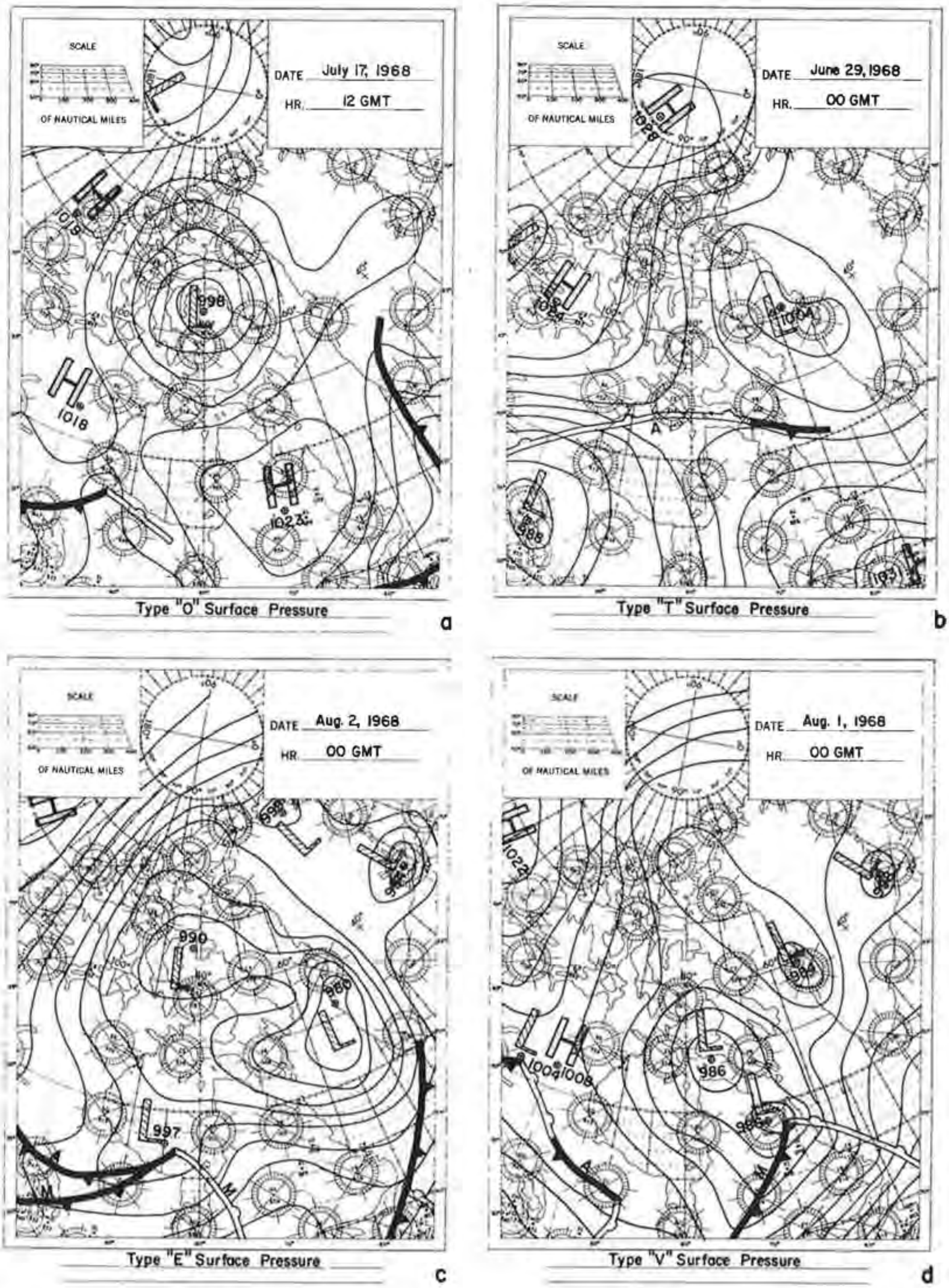

Fig. 10. Four cyclonic surface weather types depleting the most of the clear-sky radiation at Inugsuin Fiord. Each actual weather condition shown here is the best representative of a surface pressure pattern. a) Weather type O ; b) Weather type T; c) Weather type E; d) Weather type V.

associated with clear skies (Table Four). Table Four shows that stratocumulus always occurred with a broken ceiling in each weather type. Stratus cloud in general formed overcast at type C and D weather, while the rest of the cloud types were scattered. High daily total radiation of the clouded skies was due to high solar declination (Table Three) and to a particular association of the night and day cloudiness. Broken stratocumulus with an average of 35% depletion at higher solar elevation resulted in relatively high daily total global radiation. This particular association of cloudiness at low and high solar elevations is not an average condition of a weather type. This association does, however, occur in a random way within the sparsely occurring weather types. The periods within which the high pressure types occurred are indicated in column 2 of Table Four, and the diurnal variation of cloudiness at the four observations are shown in column 5 of the same table.

The contribution of an anticyclonic weather type to the summer total radiation increases if the weather type occurs in mid-June either with clear skies or with a particular diurnal cloud distribution described already. This favourable condition occurred infrequently during the periods when particular high-pressure systems persisted. The four weather types and their partial contribution to the summer total radiation is presented in Table Five. These weather types did not last very long yet they contributed 31% of the summer total radiation. There were six other anticyclonic weather types that contributed 19% to the total summer radiation. Infrequent high pressure systems provided half of the incoming global radiation.

The other half of the global radiation was transmitted by frequent low-pressure systems with variable cloud cover. For convenience only four low pressure types are shown in Figure 10. There occurred ten more classifiable and some more unclassifiable weather types that really did not affect the summer radiation climate in the fiord. Two low pressure systems, types O and T, were consistently associated with nimbostratus cloud cover, while weather types E and V appeared most frequently with stratocumulus and stratus overcast (Table Five). The rest of the low pressure patterns were not consistent in cloudiness.

TABLE FOUR

Cloud conditions associated with the four anticyclonic weather types, 25 May - 14 August 1968, at Inugsuin Fiord, N.W.T.

Weather type	Period of occurrence	Cloud conditions		Hourly % of the total cloud occurrences at EST				Daily total % of cloud occurrences
				01	07	13	19	
J	6 - 8 June	Sc	Broken	20	10	-	10	40
		Cu	Scattered	-	10	20	10	40
		Ci	Scattered	-	10	-	10	20
		Clear	-	-	-	-	-	Nil
C	30 May- 10 June	Sc	Broken	4	7	7	2	20
		Cu	Scattered	4	8	4	4	20
		St	Overcast	2	-	-	5	7
		Asc	Scattered	5	-	-	2	7
		As	Scattered	-	2	-	-	2
		Ci	Scattered	4	4	2	2	12
		Clear	-	7	7	9	9	32
F	19 June- 21 June	Sc	Broken	8	17	8	9	42
		Cu	Scattered	8	17	-	-	25
		Ci	Scattered	9	-	8	-	17
		Ac lent	Scattered	8	-	-	-	8
		Clear	-	-	-	-	8	8
D	5 June- 13 August	Sc	Broken	4	4	8	9	25
		Cu	Scattered	-	-	-	4	4
		Ac	Scattered	8	-	8	4	20
		St	Overcast	-	-	8	5	13
		Ci	Scattered	-	4	8	-	12
		Clear	-	4	-	4	9	26

TABLE FIVE

Partial contribution of four clear and four cloudy weather types to the total global radiation in summer.

	Anticyclonic Weather				Overcast			
					NB		SC.ST	
	J	C	F	D	O	T	E	V
Type total radiation ly	1388	2542	1192	2435	460	530	1774	916
Contribution (%) to the summer total = (25, 457 ly)	6	10	5	10	1.8	2	7	4
Mean daily total radiation, ly/day	694	565	477	443	153	353	229	262
Life span of the weather types in days, 2 June-13 Aug., 1968	2	4.5	2.5	5.5	3	1.5	6.7	3.5

Table Three shows that clear sky radiation can increase from the end of April to the middle of June by as much as 50%. Table Three and Five also reveal that type J weather can increase the local summer total radiation in June much more than in late fall or early spring.

The total contribution of each weather type to the summer total global radiation depends on the frequency of occurrence of the weather types and also on the dates of occurrence. Finally, it can be concluded that an extended dominance of a weather type in the second part of June, either with clear skies or with scattered cloud cover during the day and broken cloudiness at night, can substantially increase the annual climate. Thus it can be seen that a relatively small proportion of the weather types, if associated with a special type of diurnal cloud distribution, can be responsible for the modification of the radiation climate.

Conclusions

Gavrilova (1966) pointed out that the monthly possible total clear-sky radiation for May, June, July and August decreases only up to 67°N latitude and increases again further north. This increase, according to Gavrilova, was due to the continuous radiation during the polar day. The feasibility of extending and extrapolating the depletion values and the radiation characteristics of weather types to locations with a geographical latitude different from that of Inugsuin Fiord, seems improbable, because of the latitudinal variation of global radiation and great horizontal cloud variations within identical pressure types. However, the local depletion values and the weather type characteristics can be extended to the fiords adjacent to Inugsuin Fiord.

Interdisciplinary studies on climatic variations frequently explain climatic changes solely with the annual occurrences of certain surface pressure patterns. This study relating cloudiness and radiation with weather types, and an earlier investigation of arctic precipitation and weather types (Fogarasi, 1972) suggest that a particular weather condition which occurs relatively infrequently but at critically important times may significantly influence the climate, whereas the annual total occurrence of a weather type may be a less significant factor in climatic variation.

Acknowledgements

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REFERENCES

Barashkova, E.P., W.L. Gayevsky, L.N. Dyatchenko, K.M. Lugina and Z.J. Pivovarova, 1961: "Solar Radiation Conditions of the Territory of Soviet Union", Glavnaya Geofizicheskaya Observatoriya, Leningrad, Gidromet, Izdatel'stovo, 527p.

Chróścicki, W., 1971: "Solar Climate of the Swedish Territory. Selected Problems", Tellus, Vol. 23, No. 3, pp. 232-246.

Fogarasi, S., 1972: "Weather Systems and Precipitation Characteristics over the Arctic Archipelago in the Summer of 1968", Canada Department of the Environment, Inland Waters Directorate, Scientific Series, No. 16, 116 p.

Fogarasi, S., 1973: "Cloud Climate at the Head of Inugsuin Fiord, N.W.T. in the Summer of 1968", in preparation.

Gavrilova, M.K., 1966: "Radiation Climate of the Arctic", Main Administration of the Hydrometeorological Service of the USSR Council of Ministers, (Gidrometeorologicheskoe Izdatel'stwo), Leningrad 1963. Translated from Russian by the Israel Program for Scientific Translations, Jerusalem 1966, 178 p.

Mateer, C.L., 1955: "Average Insolation in Canada during Cloudless Days", Canadian Journal of Technology, Vol. 33, pp. 12-32.

Mateer, C.L., and W.L. Godson, 1959: "A nomogram for the Determination of Solar Altitude and Azimuth", Monthly Weather Review, Vol. 87, No. 1, pp. 15-18.

Pyatnenkov, B.A., 1959: "Effect of Albedo on Incoming Total Radiation in the Arctic", (Vliyanie al'bedo na prikhod summarnoi radiatsii v Arktike) Arkticheskiy Nauchno-Issledovatel'skiy Institut Trudy., Leningrad, Vol. 217, pp. 157-173.

Vowinckel, E., and S. Orvig, 1962: "Relation between Solar Radiation Income and Cloud Types in the Arctic", Journal of Applied Meteorology, Vol. 1, pp. 552-559.

A BRIEF INTRODUCTION TO SYNTHETIC CLIMATOLOGY AND DETERMINISTIC MODELING STRATEGY

by

Sam I. Outcalt*

Introduction

The author's intention is to introduce a complex topic and to demonstrate the location of climatonomy in the realm of possible analytical strategies. Readers with a more technical interest in the topic are urged to consult a recent article by the author (Outcalt, 1972). The author hopes that his biased approach to the subject will be recognized and compensated for by the intelligent reader.

I. Definition

The word climatonomy was introduced in a paper by Dr. H Lettau at the 1954 meeting of the American Geophysical Union in Washington, D.C. It was chosen to "indicate a study of man's physical environment that is significantly more numerically oriented than conventional climatology" (Lettau, 1969). Etymologically the comparison is between nomy (law) and logy (word, talk, knowledge) indicating that climatonomy is the natural child of climatology as the older discipline became more worldly and sophisticated with advancing age. In short, the word in current usage specified "a mathematical explanation of the basic elements which determine the physical environment of any planetary surface" (Lettau and Lettau, 1969).

II. The Problem in General Terms

The problem is to establish a precise relationship between a forcing (time dependent input) function and a response (time dependent

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output) function utilizing the fundamental laws of physics as a vehicle (Lettau and Lettau, 1969). In this paper the forcing function of solar radiation outside the atmosphere, a pure function dependent only on time of year and latitude and the time-dependent response regime of surface temperature are used frequently as illustrations. In actual practice the mathematical relationships which transform the forcing function into the response function may contain empirical parameters; but their functional structure is dictated by physical reasoning. It is obvious that the mathematical representation of heat conduction within a homogeneous solid with a semi-infinite plane surface is more fertile territory for the application of physical "law" than the turbulent transfer of heat and water within the atmospheric boundary layer.

III. The Evolution of Synthetic Climatology (Climatonomy)

The nature and character of the evolution of research in any discipline is limited and often dictated by the availability of hardware and software. Hardware is the sum total of physical equipment which is available, whereas software is the theoretical and conceptual framework which transforms hardware into a set of research tools.

Early investigations in deterministic synthetic climatology relied primarily upon analytical solutions to the sets of differential equations which described the gross features of the energy transfer environment at the earth's surface (lettau, 1951). A classic example is the early work of Brunt on the analytical estimation of the nocturnal minimum temperature (Brunt, 1934). His parabolic radiation cooling model was the departure point for many early pioneers in deterministic modeling (Sutton, 1953). Lonnqvist (1962, 1963) abstracted the diurnal solar radiation and surface thermal regimes into Fourier series and developed a methodology for transforming the parameters of the forcing series into those of the response series. His parameter transform method was based upon a physical interpretation of the relationship between the two sets of series parameters and contained information about the energy transfer environment of both the atmosphere and the soil.

Myrup (1969) programmed an analog computer to provide solutions to the surface energy balance equation which yielded a surface temperature solution when all the other boundary conditions were specified. His method hinges on the fact that each of the components of surface energy transfer (net radiation, soil, sensible and latent heat flux) is a function, nonlinear in detail, of the surface temperature. There is a value of surface temperature which will bring the sum of the equation set describing the individual components to zero. This temperature which is the solution to the rather complex and nonlinear transcendental energy summation equation is termed the equilibrium surface temperature. The equilibrium surface temperature will converge with time-dependent measured surface temperatures in cases where the model is faithfully duplicating nature or compensating errors due to incorrect environmental parameterization and/or model structure. Once the equilibrium temperature solution is achieved by a search at an iteration in model time, which represents a real time step in the diurnal cycle, the components of the energy transfer systems as well as substrate thermal data may be acquired and retained.

It is possible to recognize two distinct stages in the initial evolution of synthetic climatology: (1) the development of analytical models (software) and (2) the marriage of analog computer hardware with the theory of equilibrium temperature (software). Another obvious step is the mating of flexible digital computer hardware with equilibrium temperature software using numerical algorithms (software) to carry out the search for the equilibrium temperature at each iteration, as forcing solar radiation is generated for 15 minute intervals in the synthetic diurnal cycle and Fickian diffusion in the soil produces thermal lag (Outcalt, 1972). This is an ideal application of digital hardware as the surface energy balance equation must be solved over 20,000 times to yield one set of diurnal information. A single solution of this equation takes approximately a quarter of an hour at a desk calculator with tables. Representative digital central processor times are in the realm of 20 seconds of real time for 20,000 calculations. In the future the application of hybrid (analog-digital) hardware in deterministic climatology appears to hold great promise for even further speeding solutions to the energy balance equation. This step will become increasingly important as thermal response maps of complex terrain blocs are synthesized from geographic data matrices.

IV. Methodological Considerations

Climatonomy differs from traditional climatology by virtue of its deterministic analytical framework. The operational differences between ideal physical and empirical models were highlighted by Epstein (1971) and are presented in Table One.

TABLE ONE

Ideal Model Comparison

Model Type	Mathematical Structure	Data Requirements	Application Region
Empirical	Linear or arbitrary	All system information	Data region only
Physical	Dictated by system physics	Limited-selected system information	Universal

There are numerous mathematical series which can be employed to precisely regenerate any set of discrete time series observations when these series are extended toward a limit, at which the parameter number equals the number of observations. However, the discontinuous function which is sampled at discrete points may behave differently from the empirically generated version between data points (Rayner, 1971). This is in fact the likely outcome when the data variance spectrum has a significant portion of its integral at frequencies higher than the sampling frequency. It may therefore be argued that the mathematical structure of a well "fitting" empirical equation does not contain process information independently. In fact, since there are an almost infinite number of mathematical structures which might be selected for a precise data "fit," it can be demonstrated that information is minimized by the condition of simi-infinite suitability. If the suitability of a large number of candidate structures is equal, their probability of selection equals the reciprocal of their number. This is precisely the condition which minimizes the information content for any finite number of choices as information varies with the sum of the product of state probabilities and their natural logarithms (Tribus and McIrvine, 1971). Somewhat more formally, since the level of information entropy (uncertainty) may be expressed as uncertainty (S) dependent upon the question (Q) and knowledge (x) in terms of the probability of distinct states (P_i), in our case selections of a suitable mathematical structure, where (K) is a scale factor here considered to be unity, the relationship is (Goldman, 1968):

$$S(Q/x) = -K \sum_{i=i}^{n} P_i \ln (P_i) \tag{1}$$

In our case the probability of the selection of any specific mathematical structure by a "universal genius" (a strawman akin to Maxwell's Deamon) is 1/n where (n) is the number of suitable candidate structures. Thus, equation (1) becomes:

$$S(Q/x) = -1 \cdot n \cdot (1/n) \cdot \ln(1/n) = -\ln\,(1/n) \qquad (2)$$

It follows that as the number of suitable and equally selectable structures becomes large (approaches infinity):

$$\lim_{n \to \infty} \{S(Q/x)\} \qquad \text{when } P_i = 1/n \qquad (3)$$

An additional result is now indicated. As the number of suitable and equally selectable structures approaches infinity, the information content of "fitting" approaches nil.

The comparison may be further elaborated by the example of an empirical worker observing the net thermal radiation flux between the surface and the sky hemisphere. He defines "radiative conductivity" (K_r) based upon the slope of a regression line running through the point cloud created by his observations of net thermal radiant flux (N) and the difference between the radiation temperature of the sky hemisphere (Ts) and the surface (T_o). His equation has the form:

$$N = K_r\,(T_s - T_o) \qquad (4)$$

Whereas the more "universal" physical relationship is well known as:

$$N = S(T_s^4 - T_o^4) \qquad (5)$$

where (S) is the Stefan-Boltzman constant. It is easily demonstrated by the expansion of equation (5) that the "radiative conductivity" of equation (4) is in fact the first derivative of a mean environmental temperature (T_m):

$$N = S(T_s^2 + T_o^2) \cdot (T_s + T_o) \cdot (T_s - T_o) \tag{6}$$

But as: $Tm = 0.5\ (T_s + T_o) \simeq T_s \simeq T_o$

It follows: $N = S(T_m^2 + T_m^2) \cdot (T_m + T_m) \cdot (T_s - T_o)$

$$N = 4ST_m^3\ (T_s - T_o)$$

Therefore:

$$K_r = S4T_m^3 = dR_m/dT_m \quad \text{where:} R_m = \sigma T_m^4$$

It is now painfully apparent that the empirical "radiative conductivity" varies with the mean environmental temperature in a strongly nonlinear manner. The linear empirical model will only be satisfactory over a constructed portion of universal data space, its own data region defined by the mean environmental temperature, and would not withstand spatial-temporal dislocation to another distant location, season or planet. Further, it is believed that the parameters derived from statistical analysis do not contain noise-free mathematical structural information due to autocorrelation, intercorrelation and non-homogeneity in normal geophysical data (Outcalt, 1972).

Finally, the information content of empirical and physical deterministic models is vastly different and dictates their range of application. Empirical models are frequently excellent predictive devices but are vastly deficient as models for the analysis of environmental manipulation, a major modeling task in our times. An empirical investigator can successfully predict runoff from a temperate mountain glacier by parametric regression analysis of historical runoff data and temperature data from a weather screen at a nearby valley village. However, when faced with the task of designing a strategy for increasing runoff, the empirical worker would have only the option of setting a fire beneath the weather screen as he is operating within the rather constricted analytical framework cast by regression analysis. A micrometeorologist who has been modeling the energy transfer environment of the glacier surface would probably select the option of dumping lampblack over the surface, particularly the highly reflective snow areas, and thus lower the integrated albedo of the entire glacier basin.

In summary, the major operational difference between deterministic physical and empirical models of geophysical systems is that the transfer function or operator between the input-forcing time series and the output-response series is at best "translucent" and often "opaque" within an empirical model, whereas the transfer operator is "transparent" in physical variables which are built into the transfer operator as guided by physical "law" or reasoning, which is a major advantage in the analysis of environmental manipulation. In the example above, the student of energy transfer can vary surface albedo and examine runoff-response within his model structure, whereas the empirical worker has no "knob" named albedo to fiddle.

Traditionally geophysical scientists have relied upon historical data for their information about the natural world. The concept of an experiment is vastly different in these areas of investigation compared to the experimental mode in the "pure sciences". Natural scientists have waited for nature to act, and have observed and recorded these actions. However, it has been an extremely nasty problem to structure observational data in a manner which will yield information about "unobserved" natural responses. Question: The mean wind speed today is 1 meter/second and the lawn thermal response is recorded. What would be the effect of doubling the wind speed on the lawn thermal regime, all else being equal? One could wait patiently for that similar windy day. The wait might be infinite. In fact, some would state flately that the wait would be infinite. However, the owner of a deterministic physical surface climate simulator need only alter one variable in his input data field to "experiment". This presumes that his model has in the past demonstrated a respectable degree of convergence with the real world. This synthetic type of experimentation is called simulation-sensitivity analysis and enables workers in the geophysical sciences to approach the experimental investigation mode which is a characteristic of the "pure" sciences. The step liberates investigators from the severe methodological restrictions of a historical data base.

V. The Power of Simulation-Sensitivity Analysis

Initially the very act of synthetic model production forces the model builder to abstract nature in such a way that he gains new insights about the system under study. It is possible to study systems empirically without <u>any</u> knowledge of their mechanics, although this approach somewhat diminishes the investigator's ability to interpret the resulting empirical parameters. By the process of introducing students to synthetic climatology, the individuals learn about the system by tinkering with the simulator and are forced to construct rigorous experimental designs to optimize the transfer of their results to the real world. Simulation-sensitivity testing and modeling at the outset of the investigation of a system will often play a major part in dictating the experimental design and is an aid in avoiding the "data overload" which frequently haunts the empirical workers after the data collection phase of the investigation. Often at this stage the investigator has a good idea of the realm of environmental variables because he knows the limits dictated by the physical environment of his test cases and can sensitivity-test over these regions.

In short, simulation-sensitivity analysis appears to be the ideal vehicle for rationally estimating the response magnitude of the environmental alterations which are the impacts of human technology. Synthetic climatologies and hydrologies offer planners a powerful strategy for the comparison of the ecological effects anticipated from the implementation of competing land-development and environmental manipulation schemes.

VI. Summary

The general concept of climatonomy is extremely powerful as it is capable of integrating the effects of complex natural systems containing atmospheric, geomorphic and biological elements. In its present stage of evolution, operating synthetic climatological simulators are valuable tools for instructing students in the behavior of complex natural systems and gaining an analytical knowldege of the nature of the diurnal thermal regime at the earth's surface. The ability of the methodology to handle problems of environmental manipulation makes it unique from other analytical structures in the age of ecology.

REFERENCES

Brunt, D., 1934: Physical and Dynamical Meteorology, Cambridge University Press.

Epstein, E., 1971: personal communication.

Gates, D., 1962: Energy Exchange in the Biosphere, Harper and Row Biological Monographs, 151 pp.

Goldman, S., 1968: Information Theory, New York: Dover, 385 pp.

Lettau, H., 1951: "Theory of Surface-Temperature and Heat-Transfer Oscillations near a Level Ground Surface", Trans. Amer. Geophys. Union, 32, 189.

Lettau, H., 1969: "Evaporation Climatonomy", Monthly Weather Review, Vol. 97, No. 10, pp. 691-699.

Lettau, H. and K. Lettau, 1969: "Shortwave Radiation Climatonomy", Tellus, Vol. 21, No. 2, pp. 208-222.

Lonnqvist, O., 1962: "On the Diurnal Variation of Surface Temperature", Tellus, Vol. 14, No. 2, pp. 96-101.

Lonnqvist, O., 1963: "Further Aspects on the Diurnal Temperature Variation at the Surface of the Earth", Tellus, Vol. 15, No. 1, pp. 75-81.

Myrup, L. O., 1969: "A Numerical Model of the Urban Heat Island", Journal Applied Meteorology, Vol. 8, No. 6, pp. 908-918.

Outcalt, S., 1972: "The Development and Application of a Simple Digital Surface Climate Simulator," Journal Applied Meteorology, Vol. 11, No. 7, pp. 629-636.

Outcalt, S., 1973: "A Note on Degree-Day Accumulation and Clacier Run-off Simulation", Climat. Bulln. (McGill University), No. 13, April, pp. 27-32.

Rayner, J., 1971: An Introduction to Spectral Analysis, London: Pion Ltd., 174 pp.

Sutton, O.G., 1953: Micrometeorology, New York, London and Toronto: McGraw-Hill Book Co.

Tribus, M. and E.C. McIrvine, 1971: "Energy and Information", Scientific American, Vol. 224, No. 3, September, p. 164.

AN ECONOMICAL ELECTROPLATING BATH AND ITS USE IN THE CONSTRUCTION OF THERMOPILES

by

W.J. Kyle*

1. Introduction

Several applications in microclimate work require the manufacture of "home-made" sensors. These include devices to measure soil heat flux, standard thermopiles, and linear radiation instruments such as those described by Szeicz, Monteith and dos Santos (1964) and Denmead (1967). All require the construction of a thermopile sensor by electroplating copper on constantan. As such, an electroplating bath with an appropriate control unit is necessary. Although available commercially the cost of electroplating units tends to be prohibitive for most applications of this type. This note explains the construction and use of an economical electroplating bath (ECPB) which can be made in the laboratory, at small cost, from materials readily available.

2. Construction of electroplating bath

The electroplating bath is constructed from ¼" sheet plexiglass. Two pieces 48" x 9", two pieces 12" x 9", and one piece 48½" x 12" are required, the latter forming the base of the bath. These dimensions are for a bath suitable for the construction of linear thermopiles. A considerably smaller bath or even a beaker would be adequate for soil heat flux plates. These are bonded together by plexiglass cement as shown in Figure 1. For additional strength brass machine screws are inserted along the seams. After construction the bath is made watertight by coating the inside seams with silicone sealant.

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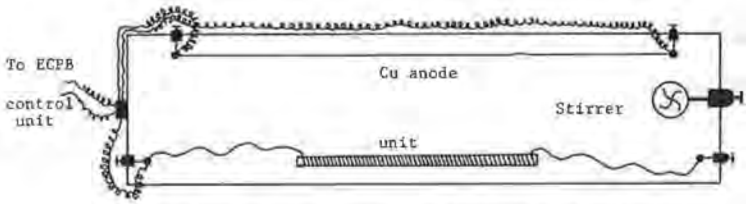

Fig. 1. Schematic diagram of ECPB.

The bath employs a linear copper anode one metre long which is placed along its length. To avoid attack by the electrolyte the anode is supported by glass tubes (Fig. 2) held to the side of the bath by standard laboratory clamps. Both ends of the anode are connected to a terminal block on the side of the bath which serves as the input socket from the control unit. The cathode lead from the unit to be plated is wired to the negative side of the terminal block.

3. Construction of ECPB control unit

This unit (Fig. 4) controls the plating current by means of a simple resistance circuit (Fig. 3). For added convenience the unit is constructed so that internal battery power (9V DC) or an external DC source may be used. A 250 ohm resistance pot, an SPDT switch, a 0 - 15 V panel meter, a 0 - 500 mA panel meter, and a two-pin connector are required. These are housed in a small chassis box. Output from the control unit to the plating bath is by means of standard banana plugs and jacks (Fig. 5).

4. Construction of thermopiles

The ECPB may be used for any application requiring the plating of constantan wire with copper. A suitable former is wound with constantan wire. Since only one half of this is to be plated to form a thermopile, the other half is masked to ensure that it remains unplated. This may be achieved easily by painting with coloured nail polish. The whole unit is cleaned with carbon tetrachloride to ensure that no grease remains on the wire. After cleaning, the wire should not be touched with bare hands. The former is then connected to the cathode lead of the ECPB. To ensure a uniform deposit of copper the cathode lead takes the form of a bare copper wire laid lengthwise along the centre of the unit to be plated and in good contact with each turn.

The total area to be plated must be known. This is calculated

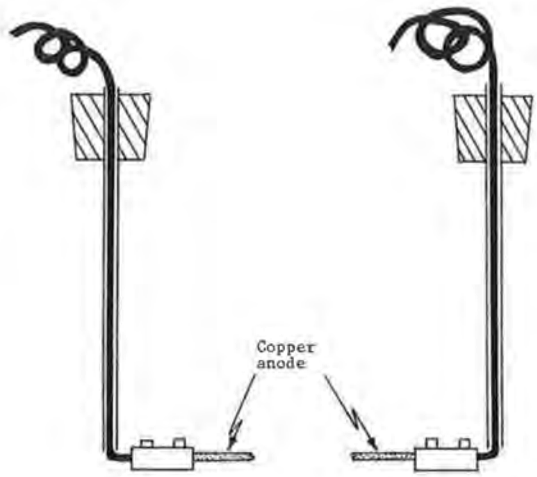

Fig. 2. Anode supports.

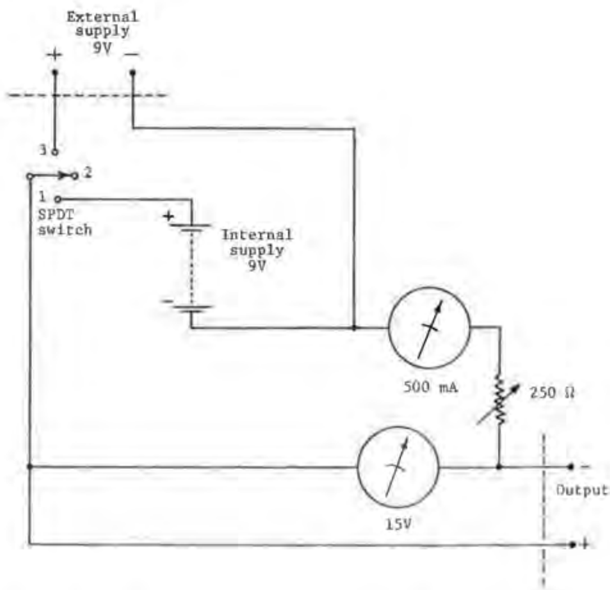

Fig. 3. Circuit diagram of ECPB control unit.

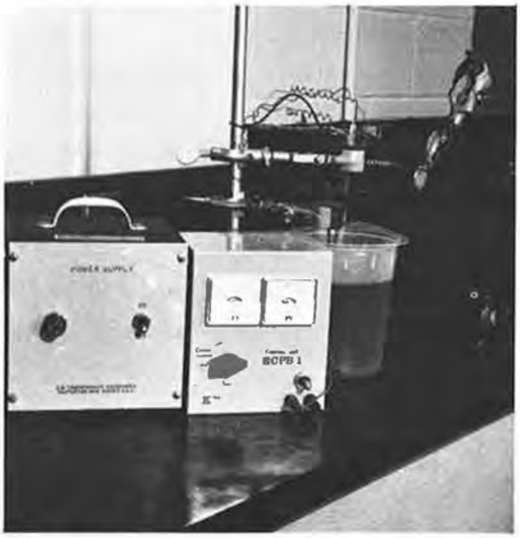

Fig. 4. ECPB control unit.

Fig. 5. The complete electrochemical plating system.

simply from the known length of the wire and its diameter (d). The total surface area of the wire is then the length of the exposed part multiplied by π d. The thermopile is now immersed in the electrolyte (200 g $CuSO_4.5H_2O$ plus 50 g H_2SO_4 per litre of water).

During plating three important points must be borne in mind. First, the input potential must at all time exceed the decomposition potential of copper (1.25 V) otherwise no plating will take place. Second, the plating current density should not exceed 15 mA $cm^{-2}hr^{-1}$. Above this density, plating is heavy and large flakes are deposited. Below this density, plating is light and even (salmon pink colour) resulting in a more robust thermopile. In general, low plating density and longer time periods give a better product. Appropriate adjustment of the control unit will ensure that these two requirements are met. Third, the electrolyte should be kept in constant motion. This is best done with a laboratory stirrer.

After plating the power is switched off before the completed thermopile is removed from the bath. The thermopile is washed and the protective mask is removed carefully from the unplated constantan using acetone. When dry it is advisable to protect the newly-plated surface from damage by spraying with an acrylic spray. The thermopile is then ready for assembly into the design instrument.

5. Acknowledgements

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REFERENCES

Denmead, O.T., 1967: "A Strip Net Radiometer", Austr. J. Instr. Control Vol. 23, p. 61.

Szeicz, G., J.L. Monteith and J.M. dos Santos, 1964: "Tube Solarimeter to Measure Radiation among Plants", J. Appl. Ecol., Vol. 1, pp. 169-174.

RESEARCH NEWS

Sub-Arctic Research

During the past two years a significant portion of McGill's climatology research has been concentrated in the sub-arctic regions of Labrador and Quebec under the direction of R. Wilson. The development of large hydroelectric facilities in these areas (Churchill Falls and James Bay) certainly has been the primary motivating factor behind much of the research and, understandably, many of the studies have been concerned with snowmelt.

We have been fortunate to have the Sub-Arctic Research Laboratory at Schefferville for a base of operations, and to have snowmelt hydrology studies being conducted under the direction of T. Dunne in conjunction with our climatology program. The significance of these two elements cannot be overestimated; we all have had access to base station data and comfortable accommodations, and it has been possible to share data, experience, and sometimes workload. The five graduate students who have been involved in the climatology-hydrology efforts (J. FitzGibbon, S. Mathewson, D. Petzold, A. Price, and M. Rinaldi) will benefit by having more and better data than they could have collected if they had been working individually.

The basic philosophy of the program has been to investigate problems having both scientific and practical merit. Contracts with industrial personnel have allowed us to inform them of the results and significance of our research, and to be indormed of the problems they are facing.

Some of the results of the climatology studies are: (a) incoming solar and net radiation over snow can be related by simple linear regressions for both open and woodland areas; (b) the amount of solar radiation that reaches the snowpack in the woodland is dependent upon the tree structure and woodland density (see paper by R.G. Wilson and D.E. Petzold in December 1973 issue of Journal of Applied Meteorology); (c) the net radiation available to the snowpack in the woodlands is nearly independent of the woodland density between 16% and 50% coverage, apparently because longwave radiation gains from the trees tend to offset the shortwave losses; and (d) the concept of solar radiation differences between stations which was reported in a previous issue of the BULLETIN (No. 11, pp. 15-22) has been tested in the Churchill Falls Basin with almost the same results as applied to southern Canada. The significance of these results in a practical sense are that net radiation can be estimated from a base station measurement of incoming solar radiation, a solar radiation measurement could be used as one element of an index - or regression-type snowmelt calculation without allowing for woodland density, and the necessary solar radiation network can be rationally planned to allow for the effects of error, distance, and time.

The measurements were extended in the spring of 1973 to consider the fluxes of sensible and latent heat to the snowpack, but the data have not been completely analysed yet. This aspect will be continued in 1974 and it is hoped that a program can be initiated to consider summertime evaporation from the numerous lakes in the area.

Research in Southern Quebec

Climatological research in southern Quebec from within the Department of Geography at McGill University over the past few years has been mainly concentrated on the summer months. This has resulted in the accumulation of a large amount of data for the warm months of the year covering various aspects of the radiation balance - data which have been used for developing methods of analysing surface variations in the radiation balance components, and which have been applied to the analysis of water resources in the Eaton river basin. Winter work has been mainly confined to urban studies, particularly in respect of the work of Tim Oke and his associates before he left McGill to take up his present position in the University of British Columbia.

An attempt is currently being made to rectify this seasonal imbalance in radiation studies by a concentrated effort based on Mont St. Hilaire. Under the general direction of B.J. Garnier and R. Wilson, graduate students in the department will help maintain an intensive programme of observations covering all components of the radiation balance through the autumn, winter, and spring months. These ground observations will be supplemented by regular airborne observations of surface radiative temperatures, and, if possible, surface albedo, using a Cessna 150 aircraft supplied by Won-Del Aviation, St. Hubert Airport. Fifty hours of flying time have been reserved covering the period September 1 to May 31. During September and October ten hours of flying were undertaken using a PRT-5 attached to the step of the aircraft. The main concentration has been in the area of Mont St. Hilaire, but flights across downtown Montreal have also been made. The whole programme aims to obtain reliable data on surface variations in radiation balance conditions covering the autumn leaf fall, pre-snow fall and immediately post-snowfall conditions, the depth of winter (including the January thaw if the weather co-operates), and, finally, the periods immediately before and after snowmelt and into the early summer regrowth period. In addition to continuing observations at Mont St. Hilaire and the remote sensing observations, periodic ground studies are planned using hand observations of net radiation and surface temperatures (using a PRT-10) over different slopes and surfaces.

Research in Barbados

During the past summer, B.J. Garnier carried out a programme of field studies in Barbados in support of an investigation into the radiation balance of east-facing slopes on the island. Previous work has shown that under weakly-disturbed atmospheric conditions the early morning heating of the slopes might significantly affect the subsequent development of cloud streets across the island. The present work is to study this possibility more intensively by examining radiation balances in detail and under varied weather conditions.

The programme consisted of (a) continuing base-station observations at the Caribbean Meteorological Institute, (b) periods of intensive observations at east coast locations, and (c) an investigation into surface radiative temperatures by means of observations from a light aircraft. The programme lasted from the last week of June until the middle of August.

The base station observations comprised the standard meteorological observations taken at the Institute, supplemented for the period of field work by continuous recording of global and sky-diffuse short-wave radiation, albedo and net radiation measurements over grass, and surface temperature measurements using thermistors at the soil surface. The periods of intensive observations lasted 3-4 days according to circumstances, and were undertaken at regular intervals. During these periods, continuous recordings were made at an east coast site of surface temperatures and the other radiation balance components listed above for the Institute. In addition, from 0430 to 1200 hours on each day of the observation period hand observations of net radiation (using a portable net-radiometer), surface temperatures (using a PRT-10), and atmospheric humidity (using an Assmann ventilated hygrometer) were made every half hour. The net radiation and surface temperature observations were made at different points representing different slopes, surfaces, and elevations. Some similar hand observations were also made at the Institute over level suffaces with different kinds of vegetation.

The remote sensing programme was carried out between July 23 and August 1. A PRT-5 attached to the step of a Cessna 150 aircraft was used for this purpose and the procedures followed were as described in a recent number of this BULLETIN (No. 10, pp. 1-12). A total of 27 hours of observation was flown. The greater part of the observations covered the period 0600 - 1300 hours. Most flights were over the east coast area, but some inland flights over areas of gentle relief were made for purposes of comparison. The most striking preliminary result of these observations is to see the regular, daily growth of a "surface heat bubble", in the same spot of the east coast (not its entire length) during the first 90 - 120 minutes after sunrise. This occurred even on a cloudy morning when the island configuration appeared to contribute to a local coastal break in the cloud such that the sun's rays reached only a limited part of the coast. The details and implications of this "heat bubble" are currently being examined.

NEWS AND COMMENTS

Dr. Geza Szeicz is spending the academic year, 1973-74 in the Geography Department at McGill University where he will give two undergraduate courses and assist in the graduate climatology programme. Dr. Szeicz will be well-known to readers of the BULLETIN for his many contributions in books and scientific journals to the fields of radiation studies, environmental physics, and agricultural and plant climatology. Dr. Szeicz was born and educated in Hungary, and has spent most of his professional career as a member of the research team at the Rothampstead Experimental Station at Harpenden, England. This is his second professional visit to north America: his first was from September 1970 to December 1971 when he was attached to the Soil and Crop Science Department of Texas A & M University.

Simon Kevan has been awarded the degree of M.Sc. at McGill University in Geography (Climatology). His thesis was entitled: "A Study of Evaporation over a Short-Grass Surface". He is currently on the staff of the John Abbott CEGEPS at Ste Anne de Bellevue, Quebec.

Recent publications of interest include:

(a) "The Climate of the Mackenzie Valley - Beaufort Sea", Vol. 1 by B.M. Burns, Climatological Studies No. 24, Atmospheric Environment Service, 1973.

(b) "The Tourist and Outdoor Recreation Climate of Ontario: Vol. One - objectives and definitions of seasons" by R.B. Crowe, G.A. McKay, and W.M. Baker, Pubn. in Applied Meteor. REC-1-73, Atmospheric Environment Service, 1973.

(c) "Types de Temps Synoptiques en Belgique et Climats Locaus à Liège" by André Hufty, Bulln de la Soc. Belge d'Etudes Géogrs., Vol. 71 & 72, 1972, 1973, Mémoire No. 23, 80 pp.

The 1974 Congress of the Canadian Meteorological Society will be held at York University, Toronto, in the period May 29-31. This will coincide with the meetings of the Learned Societies at the University of Toronto from May 26 to June 8, 1974.

Seven graduate students in climatology are currently in residence in the Department of Geography at McGill University. Four of these are doctoral candidates, and three are preparing for the M.Sc. degree. Of the seven students, three are Canadian (two French Canadian and one of Italian immigrant origin) and the remaining four comprise citizens of the United States, Trinidad, New Zealand, and Hong Kong.

A recent report produced in connection with studies on the projected oil pipeline in the Mackenzie Basin contains articles covering much material of interest to climatologists, especially those who have hydrological interests. The report is entitled: "Hydrologic Aspects of Northern Pipeline Development" published by the Environment-Social Committee Northern Pipeline, Task Force on Northern Oil Development, Report No. 73-3, April 1973 (Information Canada Catalogue No. R27-172). Articles of particular interest to climatologists include: "Documentation of an Extreme Summer Storm in the Mackenzie Mountains, N.W.T." by D.K. Mackay, Stephen Fogarasi and M. Stitzer; "Precipitation Frequencies and Intensities along Northern Pipeline Routes in the Mackenzie Valley, N.W.T." by Kala Swami; "Mackenzie Basin Water Balance Study" by J.C. Anderson; and "Hydrologic Processes in a Subarctic Upland Watershed" by C.D. Sellars.

Patrice Paul recently completed his doctoral dissertation entitled "La Climatologie de la région de Montréal". He has now left his post with the University of Quebec at Montreal and is currently on the teaching staff of the Institute of Geography in the University of Strasbourg.

FRIENDS OF CLIMATOLOGY

The 1974 meeting will be held in Ottawa. It is being organized by Dr. Wolfgang Baier, Agrometeorological Section, Plant Research Institute, Central Experimental Farm, Ottawa.

OBITUARY

CAMERON DOUGLAS ALLEN, B.Sc., M.Sc.

Cam Allen died in a car accident on 9 July, 1973 near Elora, southern Ontario, en route to his research site at the University of Guelph Research Farm. He had an outstanding record both as an undergraduate and as a graduate student at McMaster University. This was highlighted by his placement on the Dean's Honour List in 1971 and his receipt of a National Research Council award in 1972. At the time of his tragic death he was engaged in the collection of micrometeorological data for a dissertation to complete his Ph.D. requirements at McMaster. His research interest in evapotranspiration (J. Appl. Meteor., 1973, 12, 649-657) had focussed on separating the evaporation and transpiration components. Climatology has lost a most able student. Those who knew him have lost a dear friend. He was an exceptional person with an unparallelled sense of humour. He is survived by his wife, Kelly, to whom we offer our deepest sympathy and support.

John Davies
McMaster University

McGill University

Department of Geography

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No. 1 Two Studies in Barbadian Climatology, by W. R. Rouse and David Watts, 65 pp., July 1966, price $6.50.

No. 2 Weather Conditions in Nigeria, by B. J. Garnier, 163 pp., March 1967, out of print.

No. 3 Climate of the Rupununi Savannas - A Study in Ecological Climatology, by David B. Frost, 92 pp., December 1967, 2nd printing in process.

No. 4 Temperature Variability and Synoptic Cold Fronts in the Winter Climate of Mexico, by J. B. Hill, 71 pp., February 1969, price $7.50.

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No. 7 The Remote Sensing of Surface Radiative Temperatures Over Barbados, by B. J. Garnier, 52 pp., May 1972, price $6.50

No. 8 Moisture Conditions in the Savanna Region of West Africa, by Kala Swami, in press.

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