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Résumé de l'article

La climatologie de la péninsule Labrador-Ungava vient de nous apparaître dans une nouvelle perspective grâce à des recherches récentes sur le bilan calorifique et hygrométrique à la surface du sol ainsi que sur les divers types de courants atmosphériques en rapport avec les conditions météorologiques locales.

Le bilan énergétique du Labrador-Ungava, bien que typique de ces latitudes, témoigne de températures beaucoup plus basses que celles que Von rencontre habituellement dans des régions semblables. Au cours de l'été, on a observé un rayonnement net quotidien de 0.258k cal/cm ^{2} en moyenne. Durant la saison végétative, l'évapotranspiration utilise à peine 40% du rayonnement net ; ceci permet de penser qu'une part considérable de l'énergie disponible peut être utilisée dans les mouvements convectifs de réchauffement. Ainsi s'expliquerait le développement si répandu de cumulus typiques de l'ensemble de la région en été.

On est moins renseigné sur le bilan hygrométrique. Les précipitations sont abondantes et au cours de la période de fonte des neiges, en mai et en juin, le ruissellement est considérable. Il semble probable que le déficit total en eau est de loin inférieur a celui des bassins forestiers situés plus au sud. On n'a guère étudié la climatologie synoptique de *l'* Ungava-Labrador, mais l'auteur fait mention des rapports qui auraient pu exister entre les courants atmosphériques et l'accumulation de la neige pendant la dernière glaciation.

RECENT CLIMATOLOGICAL RESEARCH IN LABRADOR-UNGAVA

by

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The word « climatology » has come to cover several loosely-related fields of science, some strongly geographical in nature, others more akin to the parent discipline of meteorology. Among professional meteorologists, in fact, climatology is often regarded simply as book-keeping, i.e., as the process whereby standard meteorological data are put onto punch-cards for storage. This pessimistic view is without any historical justification. It arises from two facts : first, that the official organizations are all faced with the monumental problem of recording the data for posterity, and second, that so much of what passes by the name « climatology » is obviously of inferior intellectual quality. The tendency of geographers to lay stress on the importance of climatology, accompanied by an unwillingness to face up to the mathematical and physical rigors of its methodology, merely accentuates this attitude.

If climatology is the scientific study of climate, then the problem of defining the field reduces to one of defining climate. The idea that climate is average weather is quite inadequate, since there are many different sorts of average (of which the arithmetic mean is only one of the useful sorts), and since the word « weather » does not comprehend mainly what we must now regard as climatic elements (for example, the net radiation at the earth's surface). Informally, it can be said that climate, as defined at a fixed point, is the *characteristic* assemblage of meteorological phenomena experienced at that point, which may, of course, be at the earth's surface or at any level in the atmosphere.

In practice climatological research shows little signs of being directed at such sophisticated objects. Broadly it falls into three major categories :

(*i*) studies of the energy and moisture balances of the earth's surface, which are connected with plant-growth, evaporation, run-off and ground-water supplies ;

(*ii*) studies of the general circulation of the atmosphere (dynamic climatology) and its effect on local weather (synoptic climatology) ; and

(*iii*) studies of past-climates, or palæoclimatology.

All three types of research have been recently applied to the Labrador-Ungava region, principally by workers at McGill University in the case of categories (*i*) and (*ii*), and by Potzger and Courtemanche in (*iii*). Palæoclimatology, however, is for all practical purposes a study in itself, depending as it does on non-climatological methods of research. Accordingly we shall confine ourselves in this chapter to the first two fields of research.

Standard Climatologies

We may first dispose of standard climatologies, written in the traditional manner. These define what is sometimes called the regional macroclimate. Labrador-Ungava is, of course, covered by the standard national or continental climatologies, notably the *Climatological Atlas of Canada* (1), published jointly by the Division of Building Research, National Research Council, and the Department of Transport. There have also been specific studies of the macroclimate of Labrador-Ungava itself. Hare's 1950 study (2) was revised and rearranged by Longley, and issued as a regional climatic report by the Department of Transport (3). All these studies are based on the very thin station network maintained since about 1937 by the federal meteorological system (with assistance along the southern margin from provincial stations). The network has been so thin that by no stretch of the imagination can it be described as adequate. All that it permits is a description of the gross distribution of the standard elements — temperature, precipitation, and cloudiness in particular.

In view of the monotony of the plateau surface of the interior, it may be assumed that the distribution of air temperatures, cloudiness and humidity are well enough known, since interpolation is easy. But the precipitation distribution is very inadequately known. Much of the fall takes the form of dry, heavily drifted snow, whose precise measurement is at present impossible. It is highly probable, for example, that annual precipitation is much higher along the crest of the Laurentide scarp, 50 to 75 miles inland, than it is along the coast of the Gulf of St. Lawrence. But no stations are available in this zone, and precipitation maps normally indicate a steady northward decrease of annual falls from the coastal stations (for example, Sept-Îles, Natashquan and Harrington Harbour) to the southernmost group on the plateau (Lake Manouan, Ashuanipi, Eon Lake). The lack of adequate precipitation maps is serious in view of the present hydro-electric power developments on several of the largest streams (including the Hamilton). Measured regional run-off annual yields in the southern part of the peninsula usually exceed 1.8 cubic feet per second (cfs) per square mile, and may exceed 2.0 cfs. These imply annual excess of precipitation over evapotranspiration of over 25 inches. Existing precipitation maps suggest a lower figure, implying that they generally underestimate the true precipitation.

The Heat and Moisture Balance

Modern climatology has shifted interest from the traditional parameters of temperature and precipitation to the budgets of energy and moisture at the earth's surface. It is especially true in arctic and subarctic regions that radiation incomes at soil level may be very high in spring when air temperatures are still near the freezing point. Hence a false impression is obtained if one concentrates wholly on temperature as a means of assessing the growth potential for vegetation. Significantly the major initiatives in the new climatology have come largely from a northern country, Russia.

The heat balance at the earth's surface can be written

$$I\ (1-\alpha)+R'-R''+S-N=O$$

where I is insolation (direct and diffuse), α is the albedo (i.e., reflectivity over all the solar spectrum), R′ is infra-red radiation received from clouds and atmosphere, R″ is the infra-red radiation emitted from the surface, S is the heat flux into or out of the soil and N is the consumption of heat by photosynthesis, less the release of heat during fermentation and decay processes in the soil. N is usually much smaller than the other terms, and is neglected here. S is directed downward in spring and summer and upward in autumn. Under deep snow-cover it becomes negligible, and even in summer rarely exceeds 5 per cent of the solar flux. Hence to a good degree of approximation the energy supply at ground level is given by the net radiation R, where

$$R=I\ (1-\alpha)+R'-R''$$

I and R are both capable of direct measurement, the former by means of actinographs, solarimeters or pyrheliometers, the latter by means of net radiometers measuring the total radiative flux.

The annual value of I over eastern Canada (Budyko, 4 ; Mateer, 5) can be inferred indirectly (by reference to cloudiness statistics) to vary from about 75 kilogramme-calories per square centimeter (usually called kilolangleys, kcal cm^{-2}) along the shores of Hudson Strait, to about 100 kcal cm^{-2} in Gaspé and the Clay Belt (these figures being comparable with the range observed over Great Britain). The central plateau has values between 85 and 95 kcal cm^{-2}. These are high incomes for so cold a climate, reminding us that the cold is maintained by advection of cold airmasses, and by the coldness of the seas. The income is very low in late autumn (less than 2 kcal cm^{-2}) because of the short days and excessive cloudiness. In June it lies between 10 and 15 kcal cm^{-2} in most areas. At Schefferville, Qué. (in 54°48′N. latitude), monthly average totals are given in Table 1. These are based on actinograph observations at the McGill Sub-Arctic Research Laboratory. Since the station is near the centre of the peninsula, its readings are representative.

Table* 1** ***Measured Mean Total Solar Radiation Income, Schefferville, Qué.

	kcal/cm²		*kcal/cm²*	
January	1.9	July	11.6	
February	3.6	August	9.3	
March	9.0	September	6.8	Year 88.0
April	12.1	October	3.9	
May	12.8	November	2.2	
June	13.2	December	1.6	

(*After* Orvig, 6 : MS records)

(Period 1957-61, some breaks)
[Meteorological Service of Canada type G bi-metal actinograph]

As Table 1 shows, the solar radiation income has a maximum in late spring and early summer (because of relatively clear skies), and decreases substantially before the temperature maximum is reached in late July. The great vigour of plant growth in June, in spite of low temperatures, reflects this asymmetry.

Some part of this solar energy is reflected, and hence does not enter the heat balance. The proportion so lost is α I, where α is the albedo. The albedo of sub-arctic surfaces is fairly high, and in recent years attempts have been made to measure it in Labrador-Ungava. Jackson (7) made airborne determinations in the woodland and forest-tundra sub-zones, and Davies (8) conducted a similar study, primarily over the woodland zone north of the Hamilton River. Ground checking in Davies' area was carried out by Morrison and Œsterreich (9). Albedo depends on the solar zenith angle as well as on the surface type, but the figures in Table 2 seem reasonably representative for central Labrador-Ungava.

Table 2 Measured Albedos of Cover Types, Labrador-Ungava

Type	*Tundra*	*Burns*	*Open Woodland*	*Bog & Muskeg*	*Close Forest*	*Open Water*
Modal albedo	.114	.117	.105	.097	0.85	.048

(Total absorption is zero albedo : perfect reflection is 1.000.)
After J. A. DAVIES (8)

The net solar income, I $(1-\alpha)$, is hence about 10 to 15 per cent less than the figures given in Table 1, since the surface types given are typical of vast areas of the plateau.

The net radiation (R) is the energy available to heat the soil, to create convection in the air above, to bring about evapotranspiration, to melt snow, to permit photosynthesis and ultimately to provide the power for geomorphic processes. Hence its magnitude is of crucial importance to many people. According to Budyko's climatological estimates (4), the annual value of R is below 20 kcal cm^{-2} in northern parts of Labrador-Ungava, and is about 30 kcal cm^{-2} along the southern margin. It is negative (greater than -1 kcal cm^{-2} in December) in winter, and positive from March until September. In June it lies near 8 kcal cm^{-2}, and tends to be geographically very uniform.

There are as yet very few climatological observations of net radiation, though efficient instruments integrating the various fluxes have been available for some years. In Labrador-Ungava the only available study was carried out by Orvig (6) at the McGill Sub-Arctic Research Laboratory at Schefferville. Confining himself to the growing season of 1958 Orvig used a Suomi-Kuhn net radiometer (10). For the period June 9 – September 7 he found a mean daily net radiation of .258 kcal cm^{-2}, or a monthly average of 8.7 kcal cm^{-2}, rather higher than Budyko's computed value. Figure 1 shows the diurnal variation of R. It is positive during the growing season from 0600 hrs. to 1800 or 1900 hrs.,

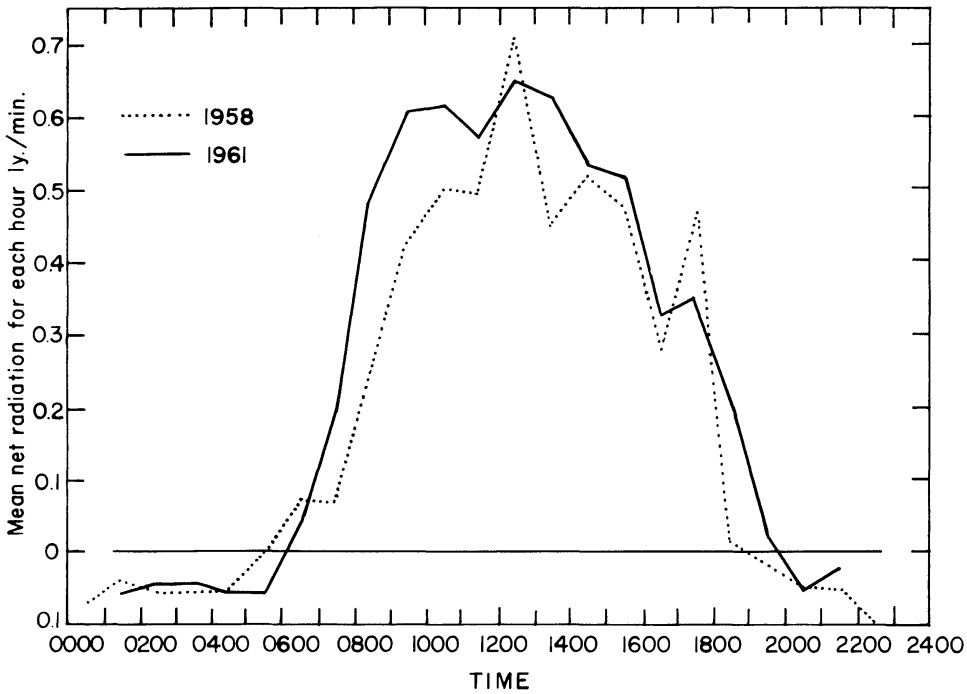

Figure 1 Mean net radiation for each hour near Schefferville, Québec. (*After* DAVIES and ORVIG.)

reaching highest intensities of over 0.5 cal cm^{-2} per minute between 1030 hrs. and 1500 hrs. It is of course highly variable from day to day. A later study by Davies (8) confirmed these results in all essentials.

This energy is used in several different ways. In April and May, much of it is used in snow melt. In June and early July, heat flux to the soil is large relative to other seasons, but remains small by comparison with the other uses. Budyko assumes that evapotranspiration uses most of the rest, because of the wetness of the surface. But measured evapotranspiration rates from some northern areas to be discussed below, correspond to only about 40 per cent of the net radiation. If these are representative there must be a large consumption of heat in convective heating of the atmosphere. The widespread development of cumulus so typical of Labrador-Ungava in summer is consistent with this guess.

To sum up, Labrador-Ungava may be said to have an energy balance typical of its latitudes, but associated with much lower air temperatures than is usual for such a régime. During the growing season, there is more than a hint that a considerable part (perhaps almost half) of the net radiation goes into convective heating.

The moisture balance is far less perfectly known. The best available rainfall maps are, as we have seen, inadequate. Run-off stations compiled from stream-gauges maintained by *la Commission des Eaux Courantes* and by

certain private companies, indicate annual discharges of 21 to 26 inches in northern districts, implying evapotranspiration values of 10 to 15 inches over the basins concerned [Cavadias (11)]. The net radiation, if all used for evaporation, could account for 13 to 20 inches. Over the southern half of the peninsula, a regional evaporation of 13 inches and a net radiation equivalent to about 17 inches seem typical. Hence a quarter of the available energy is used for other purposes, chiefly convective heating with cumulus skies. Further north, although data are very scarce, it may be estimated that evapotranspiration falls to 40 percent, or even less, of the potential value represented by the net radiation. Similarly reduced values of evaporation were also reported by Hare (12) from studies conducted on the Finnish plateau, in a similar radiation climate but in higher latitudes. He suggested that the widespread occurrence of bare rock, and of cryptogam floor cover (mosses and lichens) with rudimentary capacity to draw on soil water, reduced the evapotranspiration.

Nebiker and Orvig (13) attempted a proof of this hypothesis. They installed Thornthwaite-style evapotranspirometers beneath a lichen cover (primarily *Cladonia alpestris*) in the summer of 1956, choosing open woodland sites at Schefferville, Qué. For the period July 1 – August 31 the tank lost only 5.4 cm by evaporation. The basal layer of the lichen (consisting of dead and decaying fruiting bodies) remained saturated while the top few centimetres of the non-vascular lichen dried out to form a dry mulch. Radiation measurements were not available but it may be assumed that the net radiation was not less than the equivalent of 30 cm for the two-month period. Hence only a sixth of the available energy went into evaporation, presumably due to the resistance imposed by the lichen cover. Somewhat larger losses have been observed subsequently, but all values fall short of the net radiation by a wide margin. It must be recalled, however, that the scattered trees and shrubs of the woodland zone suffer excessive transpiration due to their exposed position, which enables them to acquire extra energy by advection. Signs of dessication in the trees and shrubs abound even in moist areas. We conclude that the moss-lichen floors are very poor evaporators but that water losses off the vascular cover are excessive. Integrated over area (though no measurements exist), the probability is that water losses fall far below those typical of forested watersheds further south.

This means, of course, that to Labrador-Ungava's abundant precipitation must be added an anomalously low loss due to evaporation. This is an admirable situation for power development, and the 1.5 to 2.0 cfs per square mile annual average yields in southern areas are very good. Against this must be set the excessive concentration of run-off in May and June due to winter snow melt.

Dynamic and Synoptic Climatology

The special interest of the Labrador-Ungava peninsula to the climatologist is that it was one of the final refuges of the Wisconsin ice sheets ; the last ice disappeared from the central plateau not much more than 6,500 years before present. The peninsula has still, for its latitude, the harshest climate on earth,

and the regional snowline lies not far above the summits ; small glacierettes survive in the cirques of the Torngats. It offers, in fact, the nearest thing we have today to a mid-latitude glacial climate, accessible to study and inviting conclusions as to the past. For this reason alone we might expect considerable interest among dynamic climatologists in the peninsula.

About twenty years ago there arose a controversy as to the probable climate of the peninsula during the growth phase of the Laurentide ice sheet in early Wisconsin times. Enquist (14) had assumed that easterly moist circulation from the Atlantic was responsible for the snow accumulation, a hypothesis revived in more modern dress by Antevs in 1945. Flint and Dorsey (15) on the other hand concluded that the necessary snowfall was provided by disturbances from the west and south-west, as at present, though with the characteristic position of the westerly jet-streams displaced considerably southward. Hare (16) confirmed this view, although he emphasized the possible rôle of Hudson's Bay as a moisture source during the autumn months.

A most elaborate study of the synoptic climatology of Labrador-Ungava has since been completed by Barry (17), who sought to obtain answers to these questions by uniformitarian methods. Working on analyzed sea-level and 500 millibar chart series provided by the Arctic Forecast Team, Meteorological Branch, Department of Transport, Edmonton, he established the existence of ten airflow pattern types. He then analysed by season the characteristic cloudiness, precipitation and temperature distributions appropriate to each type. This was done objectively, using machine methods.

Barry's main conclusion is that the control of surface weather by airflow types is much more complicated than simple theories of the above kind can permit. He does, however, conclude that easterly flow leads to definitely non-glacial climate and finds himself broadly in agreement with Flint and Dorsey, and also with Leighly (18), that cyclones from the south and southwest are the crucial elements in the snow accumulation.

No other work of significance has come to the writer's attention. Most research in dynamic climatology is now conducted on the continental or even planetary scales. It is this that makes the work of Barry all the more a model of its sort : for, as it has been said, the eyes of the fool are on the ends of the earth. We can only hope that more climatologists will try to do as well with the manifold unsolved problems still presented by the climate of this bleak peninsula.

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RÉSUMÉ

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