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Radiant Energy During Clear Weather in the Growing Season at Poste-de-la-Baleine (Great Whale), Nouveau-Québec

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Résumé de l'article

Dans un article antérieur, nous avons présenté pour les types de surface principaux à Poste-de-la-Baleine des coefficients de régression par temps clair, de sorte qu'il est possible d'estimer le rayonnement net à partir de données sur le rayonnement solaire global reçu en surface. Les buts du présent article complémentaire sont les suivants :

(i) établir une courbe pour fournir des estimations rapides des flux du rayonnement solaire global par temps clair ; (ii) donner des coefficients quotidiens de la transmissivité atmosphérique pour

des conditions synoptiques type par temps clair ; (iii) essayer de définir à partir de données sur l'ensoleillement et d'observations météorologiques horaires « une heure de beau temps », pour évaluer la fréquence et la durée de temps clair dans la saison de croissance pour lesquelles toutes ces courbes d'énergie rayonnante sont valables ; (iv) présenter une brève climatologie de beau temps pour la période 1971 à 1975.

Les renseignements fournis dans ces deux articles pourraient être utiles dans l'écologie, la gestion des ressources et dans le développement du chauffage solaire et des serres, mais son utilisation doit être limitée à la zone côtière.

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RADIANT ENERGY DURING CLEAR WEATHER IN THE GROWING SEASON AT POSTE-DE-LA-BALEINE (GREAT WHALE) NOUVEAU-QUÉBEC

by

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INTRODUCTION

During the greater part of the growing season, the weather along the east coast of Hudson's Bay remains a prey to cold advection from the Bay associated with the cooling influence of the ice and icy waters on the prevailing onshore westerly atmospheric flow. Fog, low cloud banks, temperatures most frequently below 10°C, high relative humidities, rain, drizzle and penetrating winds are major ingredients (cf. Wilson, 1972), and over the long term form the general ecological setting and lower limits of energy to which coastal life has had to adjust at this season in order to survive. The overall greyness of the scene is matched by the minimal spatial contrast in the amount of daytime radiant energy (net all wave radiation) available from one kind of surface to another (cf. Wilson and MacFarlane, 1971). Although the daytime ratio of net radiation to incoming solar radiation is high for all surfaces below the cloud blanket, the total solar energy (diffuse radiation) received at the ground is small, while long-wave atmospheric radiation assumes a greater importance. These are all summer characteristics of an Arctic coastal climate and appear to be largely responsible for the southward extension of the tundra (and Arctic climate) along the east coast of Hudson's Bay.

A change in wind direction, and the scene is rapidly transformed. With drier, northerly flow it can become a cool, brilliantly sunlit landscape, with exceptional visibility and colour definition. When the regional flow is from the SE quadrant, the warmer, more humid and more turbid air masses produce a hazier sunlight and frequently strong, searing surface winds which cause drifting and blowing sand. In clear weather, solar energy characteristics are not entirely those of the Arctic. At latitude 55°17N, the sun's altitude reaches 58° at noon on June 22, and although midsummer days are long, there is still a marked daily rhythm (maximum daylength 17h14).

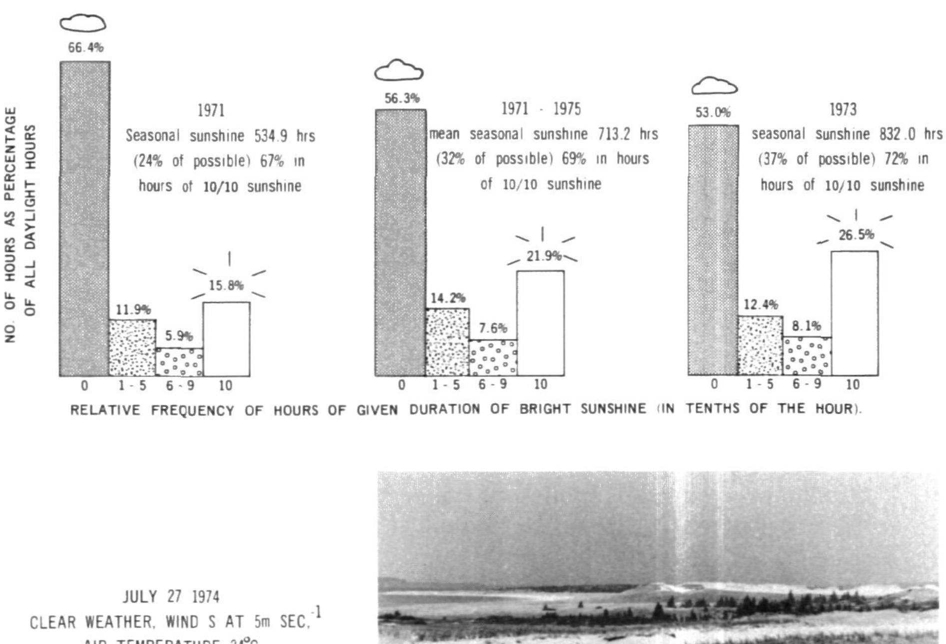
The dual nature of the climate at Poste-de-la-Baleine is suggested in Figure 1 by the frequencies of « clear » and « over-cast » hours (10/10 and zero bright sunshine) registered by the Campbell-Stokes recorder during the growing seasons 1971-1975. Although the mean seasonal total of sunshine,

Figure 1

THE DUAL NATURE OF THE WEATHER AT POSTE - DE - LA - BALEINE

Relative frequency of hourly duration of bright sunshine, May 16 to October 15, 1971 - 1975

JUNE 4 1972
HEAVY STRATOCUMULUS COVER, WIND NW AT 6m SEC^{-1}, AIR TEMPERATURE -1°C



JULY 27 1974
CLEAR WEATHER, WIND S AT 5m $SEC.^{-1}$
AIR TEMPERATURE 24°C

713.2 hours, was barely a third of the possible hours of daylight, 69% of this total was concentrated in hours of « continuous »[1] sunshine. This general pattern holds for the individual seasons ; 1971, a cool season in which the monthly mean daily temperature never reached 10°C and 1973, one of the warmest seasons on record.

In quantitative terms, Figure 2 illustrates the contrast in solar energy input and surface net radiation at noon for selected clear, dry situations and for occasions with low overcast, fog and generally damp conditions. On June 5, 1974, in clear, dry, NE flow, the incoming solar radiative flux at noon was 731.5 Wm^{-2} greater than during the low overcast, fog and dampness of May 30, 1970. With clear, dry weather the differences in the radiative properties of dry and wet sites and of various surface materials are accentuated, so that the daytime net radiation for any given solar input varies quite widely from one type of surface to another ; on June 5, the horizontal variation with surface type was as great as 212.0 Wm^{-2} at noon (Figure 2). Spatial differences are further emphasized in clear weather by the wide variation at any given time in the direct solar energy input with respect to slope, aspect the geometry of surface structures.

Although the frequency of clear weather is limited, its importance in seasonal climate, in the creation of favourable microclimates near the ground and in ecology appears to be greater than the frequency might suggest. For example :

1. In addition to the larger quantity of solar energy reaching the ground, there is an important increase in the amount of high-intensity radiation received, such as in the biologically effective ultraviolet-B wavelengths (cf. Caldwell, 1972), the latter fluctuating in relation to atmospheric ozone and levels of turbidity.

2. Miller and Tieszen (1972) concluded that primary production in the Arctic tundra increased with solar radiation, but was not affected by infrared radiation from the sky or ground. Savile (1971) found that modest differences in total bright sunshine duration between Mould Bay and Isachsen were significant in explaining the better growth at Mould Bay, where most plant activity is confined to the lowest 3 to 10 cm. At Poste-de-la-Baleine, the abnormally sunny growing seasons of 1973 and 1974 resulted in a surge of plant growth especially on the more sheltered sites, which could profit most from the increase in solar energy received. Discussing « warming devices » in a number of Arctic plants and insects, Corbet (1972) emphasizes that they rely on direct radiation and stresses the importance of the proportion of sunny days in summer as a climatic statistic.

3. While these periods of clear weather provide necessary energy for certain ecological processes, at Poste-de-la-Baleine such times may also be associated with limiting heat stress and dessication. For example, in light

[1] The limitations of the sunshine recorder are discussed later.

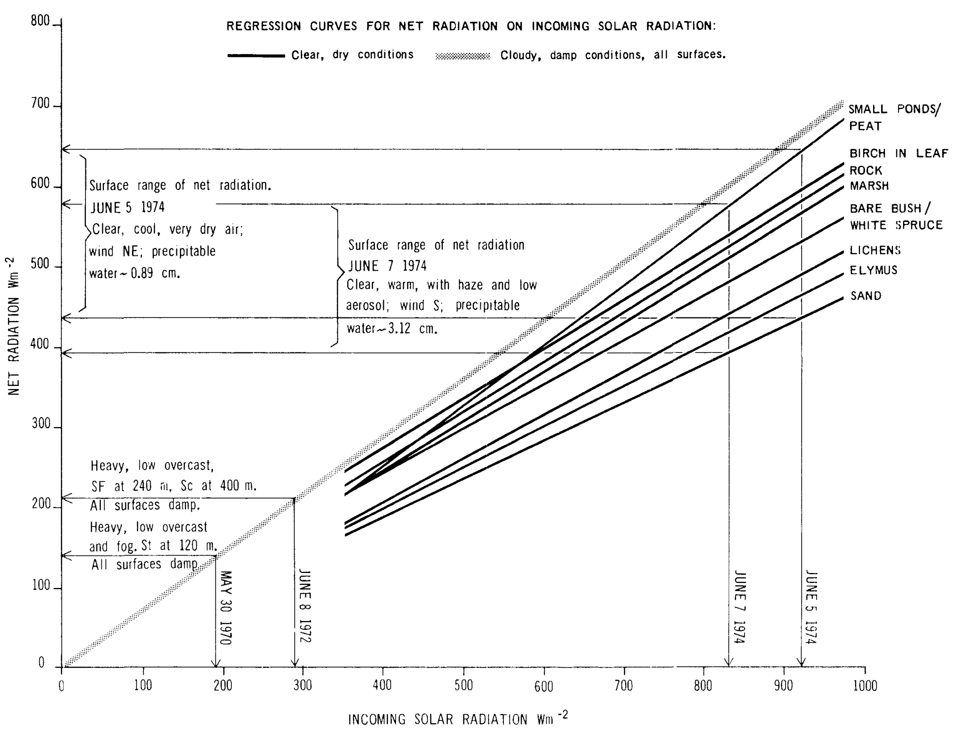
WNW flow at noon on June 26, 1974, the temperature of sand, lichen soil and lichen surfaces measured 45.7 to 51.1C, 25° to 30° higher than the air temperature of 21.1°C. The relative humidity was only 32%. With strong southerly flow (13-18 m sec^{-1}) relative humidities as low as 15% have been recorded. Similar dessicating conditions have been reported on the Kola and Taimyr peninsulas, near the Lena delta and in NE Siberia by Dolgin (1970).

4. The year-by-year fluctuations at Poste-de-la-Baleine in the mean temperature of the warmest month around 10°C (Köppen's ecologically significant Arctic/sub-Arctic limit) are associated with the variation in seasonal frequency of clear weather.

In a previous article (Wilson, 1975), the relationship between net radiation and incoming solar radiation at Poste-de-la-Baleine was determined for the major surface types during clear weather (cf. Figure 2). The regression analyses were based on series of measurements of point fluxes made during the growing seasons 1972-1975. The curves permit the estimate of net radiation from incoming solar radiation. In the present complementary study, an attempt is made to determine :

Figure 2

POSTE - DE - LA - BALEINE : Range of global and net radiation fluxes (horizontal surface) for clear, dry weather and damp, cloudy conditions. Some extreme noon values.



a) the incoming solar radiation fluxes for given solar heights during clear weather and their variability and limits with respect to atmospheric attenuation ;

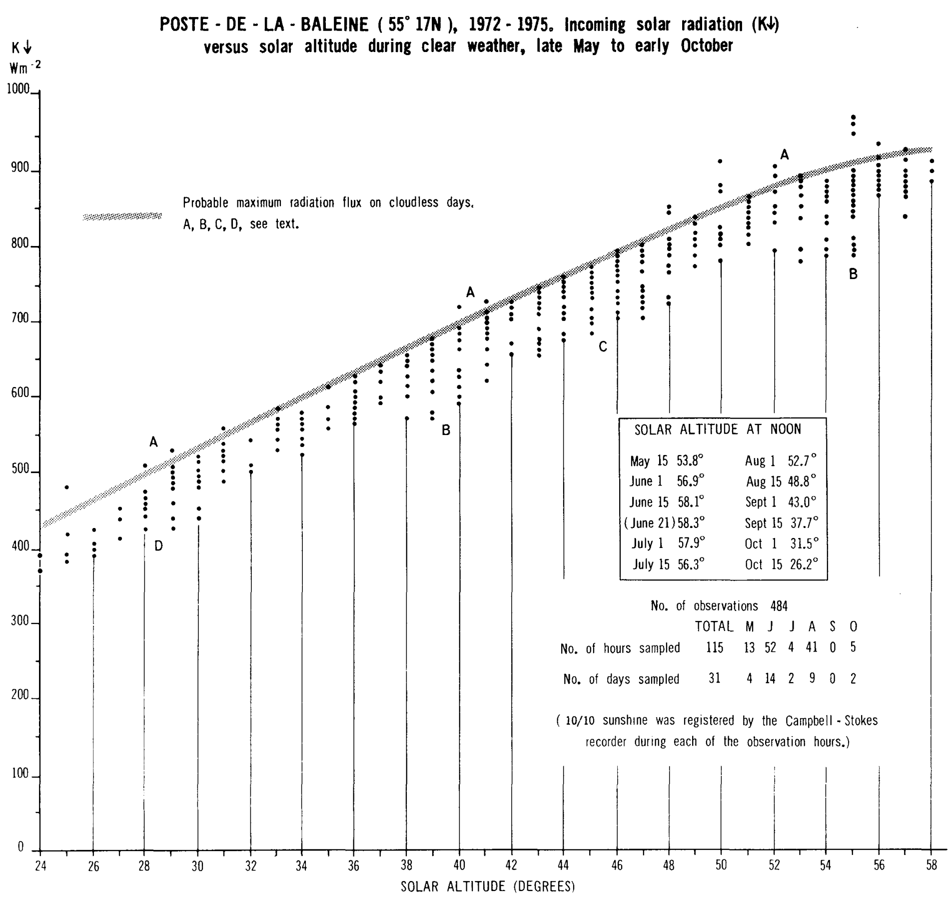
b) the frequency and duration of such periods of clear, dry conditions for which all these curves are valid.

For background information on the natural setting, surface conditions and atmospheric considerations for the study area, as well as discussion of the intrumentation and measurement, the reader is referred to the earlier article.

CLEAR WEATHER SOLAR INPUT

Point fluxes of incoming solar radiation measured during the growing seasons 1972-1975 are plotted against solar altitude in Figure 3. Owing to the poor cosine response of the Dirmhirn pyranometer at low sun, no obser-

Figure 3



vations were made when the sun was below 24° above the horizon. At Poste-de-la-Baleine the sky is rarely completely free from cloud, but as far as could be determined visually and by the stability of the recording needle, the sky seemed clear in the broad vicinity of the sun at all observations.

The variability of clear-weather downward solar radiation is principally [2] related to changes in the quantity and vertical distribution of aerosol and precipitable water, and to the presence or absence of very light cloud often difficult to observe from the ground. Along the coast near Poste-de-la-Baleine there are a number of factors which tend to accentuate such fluctuations.

1. Oscillations in the position of the jet stream overhead with variable development and dissipation of cirrus. Very thin cirrus may not be clearly visible at the ground.

2. Modification of the atmospheric temperature, humidity and aerosol profiles in the lowest 100 m or so over the coastal region during local cold air advection from the Bay, as in the case of a sea breeze. At times an almost invisible low-level veil or rafts of cloud are present.

3. Strong, dessicating winds from the ESE to S, which lift the sand particles along the exposed coastal terraces. These strong land winds also appear to carry a certain amount of organic matter from the interior.

4. Occasional smoke pollution from forest fires — for example in mid-July 1974, from fires burning in Northern Ontario. To what extent urban-industrial pollution from regions to the south affects Poste-de-la-Baleine is not known. On flights into this post under regional anticyclonic conditions over southern Canada and the eastern United States (for example, August 15, 1973), drift of air pollution in the layer below the tropopause has been seen to extend at least as far as the coast (cf. Flowers et al., 1969). There are now frequent contrails over and following this coast, as the zone become an international air lane.

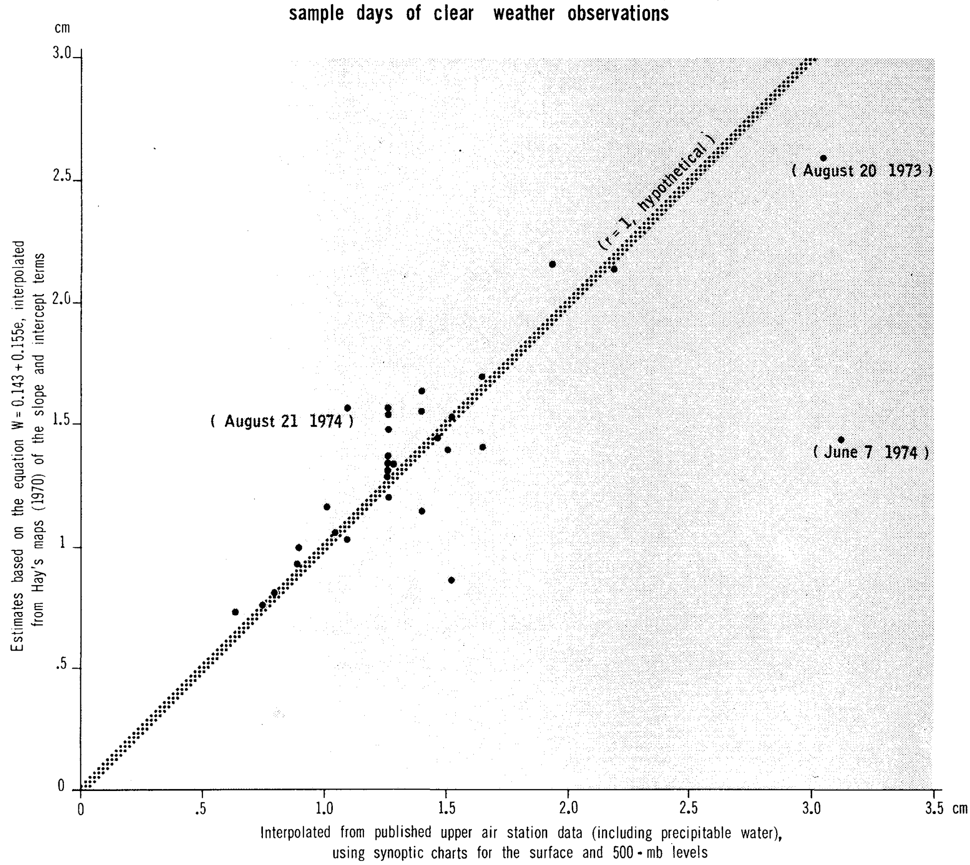
Precipitable water for the observing days was interpolated from values published for neighbouring upper air stations, together with the upper air soundings [3] and corresponding synoptic charts for the surface and 500 mb. As a trial check on these values, the coefficients of the linear regression of mean monthly precipitable water (w) on mean vapour pressure (e) at the surface were interpolated for Poste-de-la-Baleine from Hay's maps (1970). Although it is understood that these coefficients apply specifically to *monthly mean* values, an earlier study in the United States by Bolsenga (1965) had

[2] Variation in the ultra violet is related to ozone as well as atmospheric turbidity. In the absence of information on total ozone, MacDonald (1963) found that the best single indicator of its variability in July and October was the 100-mb height field — a negative correlation, significant at the 95% level.

[3] *Monthly Bulletin, Canadian Upper Air Data,* Atmospheric Environment Service (AES), Downsview. Copies of synoptic charts were kindly supplied by AES personnel at Montréal and Québec airports.

Figure 4

POSTE - DE - LA - BALEINE : Estimated precipitable water (7a. m.) for the 31 sample days of clear weather observations



indicated that a linear relationship also holds for hourly values, although the reliability of estimate is lower. Figure 4 shown a plot interpolated « synoptic » values for 7 am EST against those estimated from the surface vapour pressure for the same hour. The major discrepanies occurred with regional flow southerly (cf. June 7, 1974, August 20, 1973), when there is some evidence that a low-level humidity inversion was present in this coastal zone, resulting in an underestimate of total precipitable water. Conversely, overestimates seem to occur with a stronger humidity gradient near the surface, for example with low-level flow from the Bay and drier regional flow aloft (cf. August 21, 1974). Table 1 offers some measure of the range of precipitable water for the days sampled, and includes monthly mean values, 1957-64, interpolated from Hay's (1971) maps.

Incoming solar radiation fluxes

An analysis of the flux values for Poste-de-la-Baleine (Figure 3) suggests the following :

Table 1

Precipitable water estimated for Poste-de-la-Baleine (7 a.m.)

Month	*No. of days*	*Range (cm)*	*Remarks*	*1957-64 monthly mean (after Hay, 1971) (cm)*	
Late May	4	0.64 – 1.02		May	0.97
June	14	0.81 – 3.12		June	1.20
July	2	1.40 – 1.65	(NE/NNE flow only)	July	1.77
August	9	1.09 – 3.05		August	1.75
September	0			September	1.38
Early October	2	1.27 – 1.52	(Essentially SW flow only)	October	1.03

1. *Maximum solar radiation* is associated with the drier, cleaner air masses or northern origin, especially in late May and early June when the sea surfaces remain mostly ice-covered (cf. June 5, 1974). Later in the summer, stable fluxes of incoming solar radiation occasionally approached similar values (with respect to solar elevation) in clear NW/WNW flow following the passage of a cold front ; at such times these fluxes may be effectively enhanced in the coastal zone by cloud reflection, when light low-level cumulus, drifting in from the sea, *almost* dissipates over the sandy terraces to reappear over the granite hills behing (cf. August 21, 1974). A curve of probable maximum radiative flux in clear weather is shown in Figure 3. Precipitable water was estimated at 0.65 to 1.10 cm on these occasions (see Table 1).

2. *The extreme values above the curve (A)* indicate further enhancement of incoming solar radiation by reflection, when fair-weather cumulus or the edge of a cirrus sheet or streak is just within the influence of the sun's rays. The highest instantaneous flux recorded was 1315.7 Wm^{-2} on May 30, 1972 (solar elevation 54°), in relation to white, well-defined stratocumulus cloud of 3/10 opacity and amount at 610 m. This was associated with westerly flow off the Bay at 5 m sec^{-1}. Within 2 minutes the flux had fallen to 645.4 Wm^{-2} below the centre of the white cloud base. The total daily energy received was possibly higher than that given by the curve shown on Figure 3. When the cloud is slightly greater in opacity and amount, for example 4/10 under similar conditions on June 4, 1974, the enhanced fluxes of 1241.7 and 1183.8 Wm^{-2} registered from the side and between clouds were offset 2-3 minutes later by considerably lower values of 391.6 and 319.7 Wm^{-2} below the grey centre of the cloud base. However, the daily total may still fall within the general limits for « clear weather » radiation suggested by Figure 3.

3. *Greatest atmospheric attenuation* occurred with the warm, humid, hazy and apparently more polluted air masses from the south (for example, (B), June 7, 1974 and August 20, 1973). Frequently transparency was further decreased at those times by the presence of an almost invisible veil of jet-stream cirrus, and locally by increased aerosol related to the remarkable dryness and speed of ESE to SSW low-level flow, causing blowing sand. The precipitable water was estimated at 3.05 to 3.10 cm. Low flux values (C) also occurred with upper NW and SW flow and light, variable surface winds on August 18 and 19, 1973. Precipitable water was less, about 1.95 and 2.15 cm. However these days were very warm and drying, and followed a very dry period. Many surfaces along the sandy coastal terraces were quite dessicated, so that the amount of low-level natural aerosol was probably an important contributing factor (cf. Piggin, 1972). The air was hazy on both days. Low level of « clear weather » transparency grade into those when the sun is veiled by light but clearly visible cirrus. With the jet stream so frequently overhead, clear weather is often associated with cirrus cloud (cf. Conover, 1960). On many occasions it is extremely difficult to define the full extent of this cloud from the ground, while oscillations in the position of the jet can lead to subtly changing sky conditions from hour to hour. On June 9, 1974 (D), a marked halo around the sun earlier in the day supported the belief that very thin cirrus was present at the time of observation.

Figure 3 could therefore be of practical value in estimating clear-weather fluxes of incoming solar radiation, K ↓ (horizontal surface) at Poste-de-la-Baleine, given the date, time of day and the hourly weather observations from the AES station. Given an estimate of K ↓, the net (all-ware) radiation fluxes, Q*, for the different surface types can then be evaluated using the regression equations already established.

Atmospheric transmissivity

For many purposes estimates of total daily incoming solar radiation amount are required. These can be calculated if the daily coefficient of atmospheric transmissivity is known.

On those days when measurements had been made over extended periods, the curves were extrapolated below 24° to the horizon, and integrated over hourly intervals to give an estimate of the total daily solar energy received at the surface (Table 2). Since is was rare to have a complete day without synoptic or local change in sky conditions, the « daily » estimates are based in most cases on either clear-weather morning or afternoon values, in order to obtain some idea of the limits and variation of the coefficient of atmospheric transmissivity.

As part of a current programme to map the solar radiation received at Poste-de-la-Baleine in relation to local topography, direct solar radiation on a

Table 2

Coefficients of atmospheric transmissivity, Poste-de-la-Baleine

Date	*Period of obs. used*	*Daily K* ↓ (Whm^{-2})	*Atmospheric transmissivity*	*% diffuse radiation*	*Precipitable water (cm)*	*500-mb wind*
June 5 1974	Morning	9025	0.791	15.4	0.89	N
June 7 1974	Morning	7192	0.630	25.3	3.12	SW
June 8 1975	Morning	8839	0.774	16.5	1.27	NE
June 22 1974	Afternoon	8886	0.778	16.3	1.47	NE
Aug. 8 1974	Afternoon	7285	0.779	19.3	1.52	NW
Aug. 19 1973	a) Morning	5939	0.691	27.9	2.18	SW
	b) Afternoon	6194	0.721	25.5		
	c) Day	6067	0.706	27.0		
Aug. 21 1974	Afternoon	6705	0.780	20.9	1.09	WNW
Aug. 22 1973	Afternoon	6403	0.745	23.6	1.27	SW [1]
Oct. 3 1973	Morning	3573	0.725	42.2	1.52	NW [2]

[1] Flow around a cold low to the NW.

[2] Essentially SW air stream.

Table 2 (continued)

Coefficients of atmopheric transmissivity : corresponding surface weather.

Date		*Hourly Surface Weather Data*				
		Wind (m sec⁻¹)	*Temp. (°C)*	*Vap. press. (mb)*	*VPD (mb)*	*Cloud reported*
June 5 1974		E-NE, 0–5	2–11	5– 6	1– 9	Ci
June 7 1974		SSE-S, 9–11*	17–28	6–12	13–26	Ci
June 8 1975		WNW-NW, 0–3	4– 9	8– 9	1– 3	Cu, Ci
June 22 1974		NNE-NNW, 6–1	12– 7	8– 9	6– 1	Cu, Ci
Aug. 8 1974		N-NE, 3–5	13–15	13–10	3– 7	Sc, Cu, Ci
Aug. 19 1973	a)	ESE-W, 5–3	17–29	11–14	7–30	(Haze)
	b)	NNW-SE, 2–0	21–24	16–13	9–16	(Haze)
	c)					
Aug. 21 1974		NW-WNW, 3–2	11–10	9– 8	3– 4	Sc, Cf
Aug. 22 1973		WNW-NE, 3–0	12–10	9	5– 2	Sc, Ci
Oct. 3 1973		E-ESE, 2–5	4– 8	4	4– 6	Ac, Ci

* Gusting to 15m sec^{-1}. VPD, Vapour pressure deficit.

horizontal surface was calculated[4] for a series of days and for different coefficients of atmospheric transmissivity (solar constant, 1353 Wm^{-2}). The coefficient for a given day was then obtained by comparing the total solar radiation estimated from the observations with the calculated value for a perfectly transparent atmosphere (coefficient, 1.0). The results are shown in Table 2. Values ranged from 0.80 to 0.60. A further comparison of the observed daily totals with the calculated total direct radiation for the appropriate transmissivity then offered an estimate[5] of the proportion of diffuse radiation received. These values are included in the Table.

Table 2 also indicates some relevant weather information for the days concerned. The synoptic situation and hourly weather data for four of these days are illustrated in Figure 5 and commented upon below.

1. *June 5 1974 (atmospheric transmissivity, 0.791),* an example of high transparency of late May/early June. During the morning both upper air and surface flow were generally northerly, visibility excellent, and air temperatures not much above 10°C (Figure 5a, b). Optical phenomena were noted over the ice-covered Bay near noon. However, the upper air ridge was

[4] The calculations for Poste-de-la-Baleine (after Sellers, 1965) were carried out by Michel Lecarpentier of the Department of Geography, Université Laval, based on a programme incorporated in his Master's Thesis (Lecarpentier, 1973).

[5] As the residual, this estimate incorporates any instrumental or measurement error.

shifting rapidly eastward and strengthening, while the surface high moved southeastward over central New Québec/Labrador. By 1 p.m., surface winds at Poste-de-la-Baleine had shifted to SE and freshened, with immediate rise in air temperature and drying power, and increasing cirrus. The estimate of the coefficient was based on the morning period ; the associated « daily » total solar radiation input of 9025 Whm^{-2} is probably close to the maximum available at this season.

2. *June 7 1974 (atmospheric transmissivity, 0.630)*, an example of low transparency during southerly flow and increased turbidity. With the continued eastward shift of the upper ridge over the east coast of Hudson Bay on June 6, the intensification and southward extension of the surface high over central Québec-Labrador, and the development of a trough over the western side of the Bay, a very strong pressure gradient had built up over this coastal area. In the southerly air stream aloft, warm moist air was being advected from the southern United States. Near the surface, hourly winds from the SSE of up to 18 m sec^{-1}, gusting to 24 m sec^{-1} were recorded, perhaps in part accelerated by the marked surface temperature differential between the ice on the Bay and the heated dry sand, lichen and rock, and by the alignment of the coastal topography. Vapour pressure at screem level was only 4-5 mb, with relative humidity as low as 15%. Drifting and blowing sand occurred together with haze, stratocumulus, slight altocumulus and cirrus streaks, partially obscuring the sun. By the morning of June 7 (Figure 5a), the ridge had shifted slightly to the east, otherwise the synoptic situation was essentially the same. During the morning period the hourly winds had moderated to 9-11 sec^{-1}, but were still gusting up to 15 m sec^{-1} (Figure 5b). Although vapour pressure and relative humidity had more than doubled, the actual drying power of the air had increased owing to higher temperatures and surfaces were dessicated. Although there was some cirrus present, the sun appeared essentially unobstructed by cloud at the time of observation, as far as could be determined from the ground. Although the precipitable water was estimated at over 3 cm, and there may well have been some high-level urban and industrial aerosol advected from southern regions, the major attenuating factor appeared to be the haze created by low-level aerosol. Near noon, an Electra flying at about 900 m was scarcely visible from the ground. The daily total solar input, based on the morning period, was about 20% less than for June 5, the decrease in the noon flux about 10%. The amount of diffuse radiation was 31% greather than on June 5 (cf. Table 2). These results are similar to those of Idso (1972) for the case of a significant dust storm in Arizona, except for the higher percentage of diffuse radiation in the latter case. This type of synoptic situation appears to be an element in the weather of the growing season at Poste-de-la-Baleine, and is being studied further.

3. *August 21 1974 (atmospheric transmisssivity, 0.780)*, an example of higher transparency later in the summer, with slight enhancement of the total solar input in the presence of low-level cumulus. With strong flow aloft of NW origin (Figure 5c), the precipitable water was low for the season (Table 1). During the afternoon period (Figure 5d), winds at the surface were light,

NW-WNW, off the Bay and relatively humid ; air temperature over the coastal terraces was a cool 10-11°C, probably close to that of the water surface. Visibility was excellent. Light Sc and Cu cloud were present over the sea and over the hills inland, as it drifted in over the coast it generally dissipated, or almost dissipated to leave only feint wafts, over the sandy coastal terraces. Temperatures of 29° and 39°C were recorded just below the exposed sandy surface and bare sandy soil ($\sim$ 6° southerly slope) during the early hours of the afternoon. The frequent formation of a clear « hole » over this coastal area appears to be another element in the seasonal radiation climate, although the causes are probably multiple.

4. *August 19 1973 (atmospheric transmissivity, 0.706)*, an example of a very warm hazy, late summer's day, with sea breeze. In a situation of relatively light regional flow of southerly origin, both aloft and near the surface (Figure 5c), the sky was cloudless over the whole 24-hour period. The day had been preceded by a number of days of hot, dry weather, surfaces were dried out and a haze hung over the coast, reducing horizontal visibility to 16 km (Figure 5d). Precipitable water was estimated at over 2 cm. About noon, there was a shift in wind direction from ESE to an onshore drift from NNW, accompanied by an 8°C drop in air temperature and a 5-mb increase in vapour pressure. Near sunset, the wind changed back to ESE. Fluxes of incoming solar radiation were correspondingly lower in the morning than in the afternoon - a type of asymmetry already commented upon by Piggin (1972). Natural aerosol appears to be more effective than water vapour in atmospheric attenuation, and the cleaner if more humid air drifting in from the sea increases the transparency over the coastal zone. (See also Monteith, 1966, and Unsworth and Monteith, 1972.) Based on the morning period, transmissivity was estimated at 0.691, against 0.721 for the afternoon (Table 2). The estimated solar input for the day was 6067 Whm^{-2}, about 10% less than for August 21 1974 (above).

DEFINITION OF A CLEAR HOUR

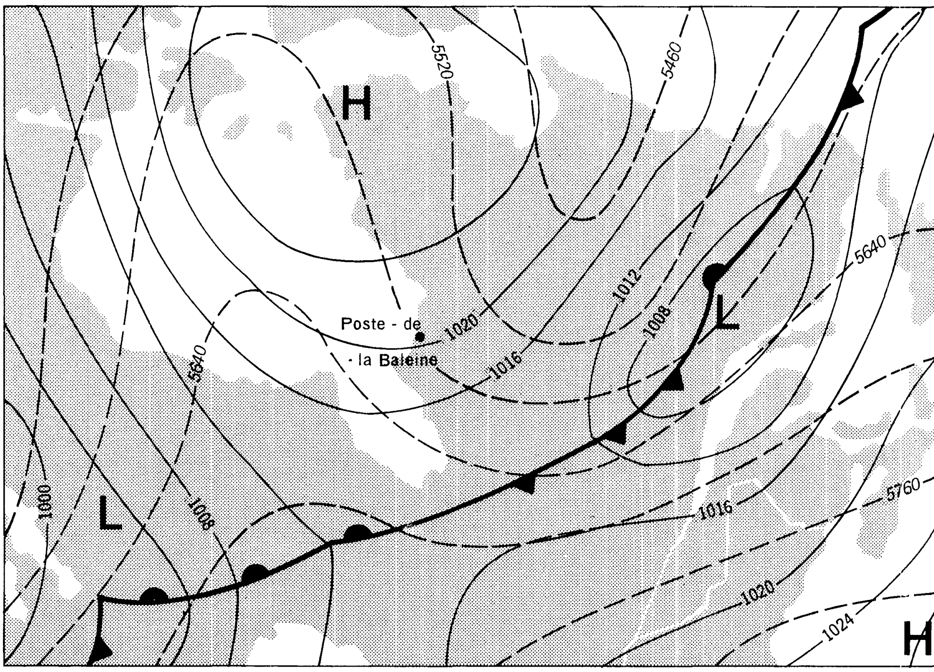
Considering the rapidity with which local and regional weather can change at Poste-de-la-Baleine, the direct, rapid response of the surface to variations in incoming solar radiation and the importance of shorter spells of sunshine, the *hour* rather than the day seems to be a more useful working unit for climatological purposes. To determine for the growing season the frequency and duration of periods of clear, dry weather, for which the curves relating insolation and net radiation are valid, an attempt is made to define a « clear hour » in terms of the regular observations recorded at the Poste-de-la-Baleine AES weather station.

State of the sky

Since it is unrealistic in this mid-latitude, maritime situation to equate clear weather with cloudless skies, the major consideration must be the

Figure 5a

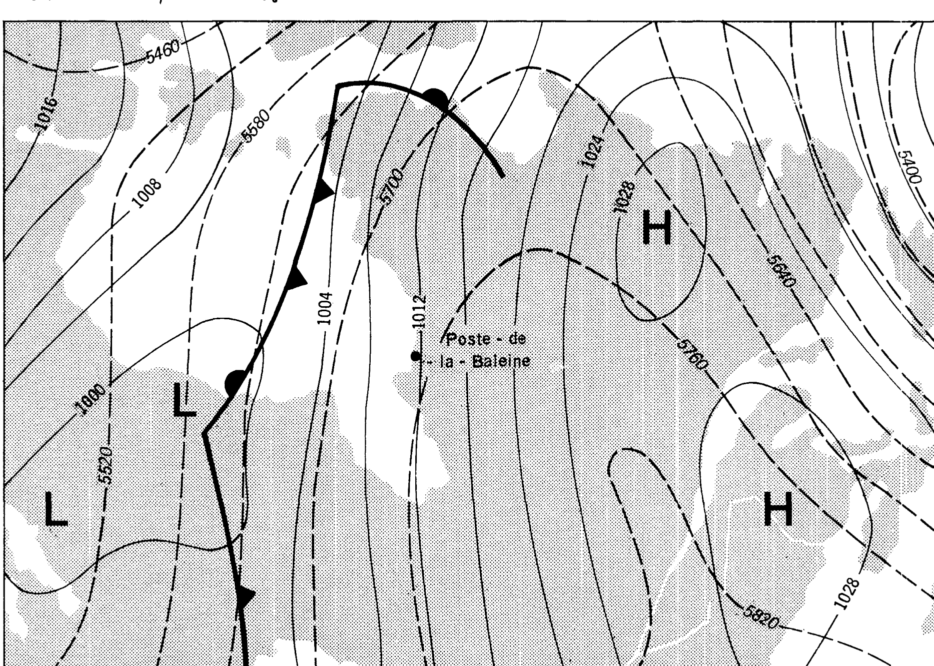
JUNE 5 1974, 0700 EST.



—1020——— Surface pressure, mb.

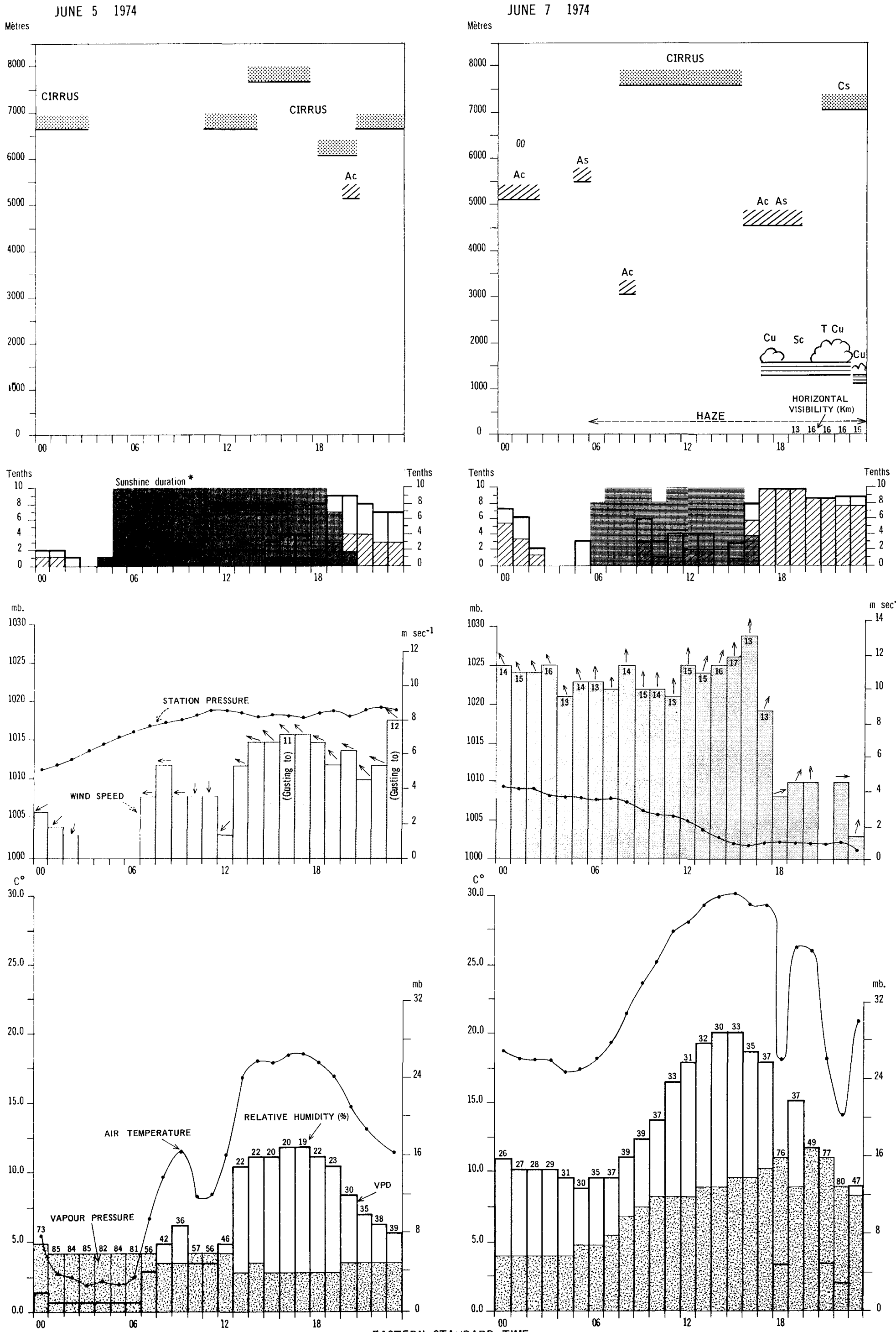
— —5460—— 500 - mb height, m.

JUNE 7 1974, 0700 EST.



Courtesy Canadian Weather Service, CAO, Dorval, Québec.

Figure 5b HOURLY WEATHER DATA: Poste-de-la-Baleine



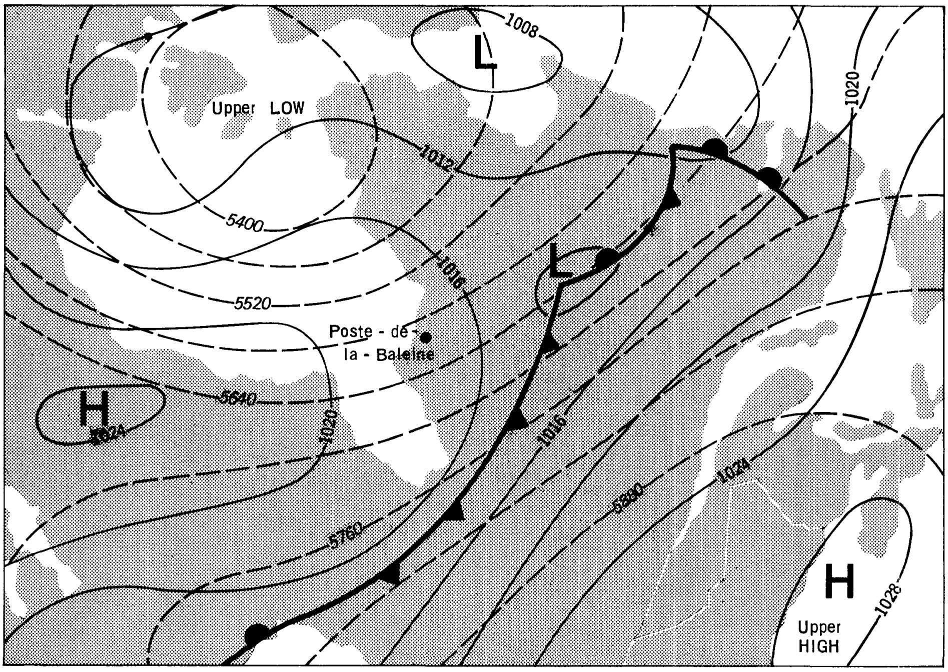
EASTERN STANDARD TIME

* Data observed on the hour, except sunshine which refers to duration over the 60 minutes ending at the hour.

(Data courtesy of the A.E.S. weather station)

Figure 5c

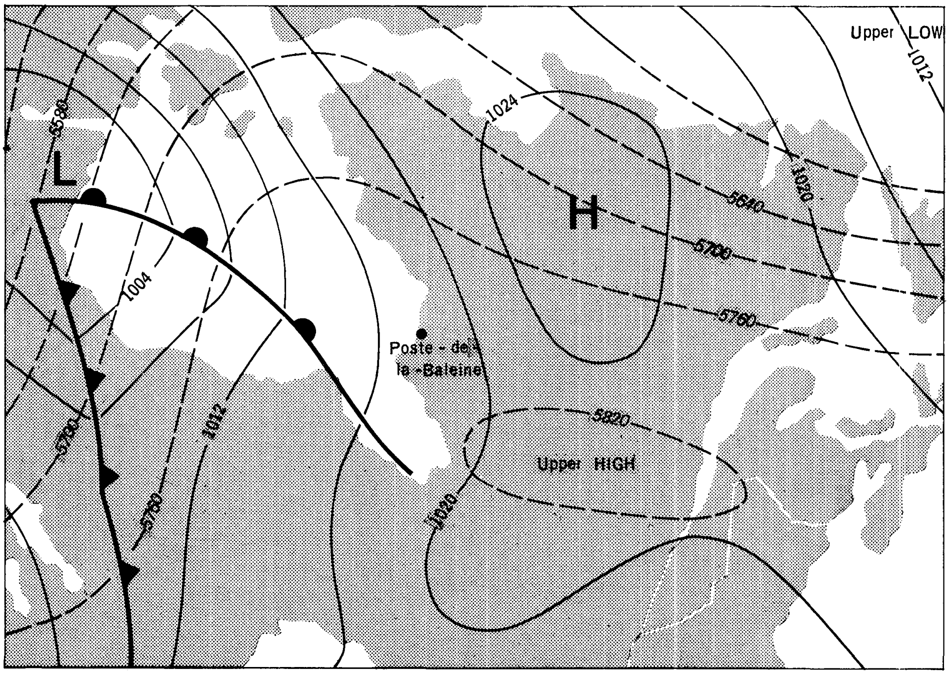
AUGUST 21 1974, 0700 EST.



—1016——— Surface pressure, mb.

— —5640 — 500 - mb. height, m.

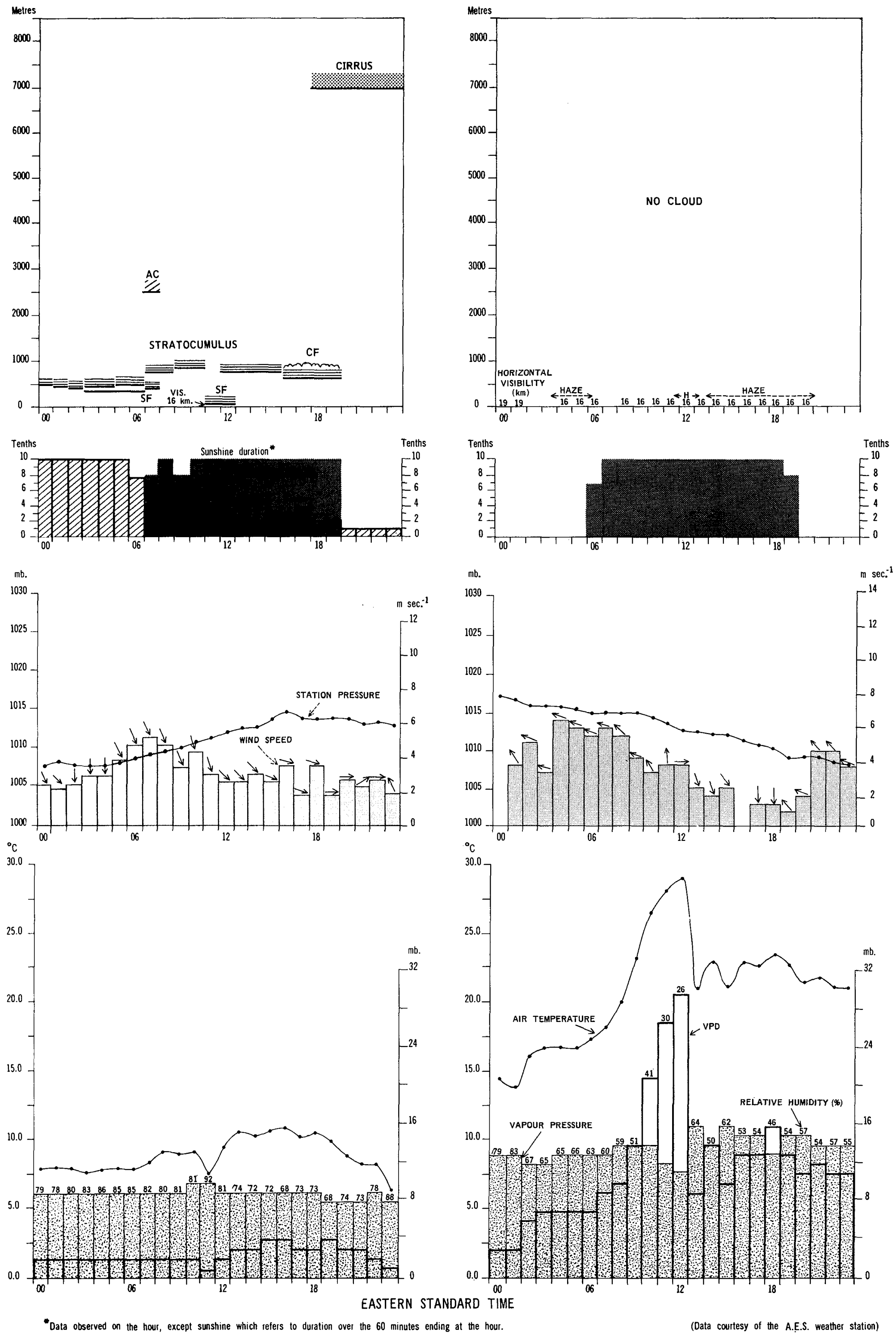
AUGUST 19 1973, 0700 EST.



Courtesy Canadian Weather Service, CAO, Dorval Québec.

Figure 5d HOURLY WEATHER DATA: Poste-de-la-Baleine

AUGUST 21 1974



*Data observed on the hour, except sunshine which refers to duration over the 60 minutes ending at the hour.

(Data courtesy of the A.E.S. weather station) determination of the state of the sky. The best available basis for a definition is probably the hourly duration of bright sunshine as measured by the Campbell-Stokes sunshine recorder. The linear relationship between total K ↓ and the duration of sunshine is already well-established on both a monthly basis, and in the case of clear weather on a daily basis also (cf. Durand, 1974). The limits and possible errors in the Campbell-Stokes sunshine records may be of greater significance when the hourly values are used *per se*, as this offers little opportunity for the type of compensation which may take place within a day. They have been described in detail in the following references : British Meteorological Office (1956), Perl (1948), Bider (1958), Cook (1971) and WMO (1972), and are discussed briefly below.

Sources of error can be grouped into three : those concerned a) with the basic design of the instrument and its construction ; b) with installation, maintenance and operational procedures, and c) with the interpretation of the burns on the charts. For b) and c), standard instructions have been set out, following WMO recommendations, but given careful installation of the instrument, they still require a certain discipline and experience to follow through. At present the only check on the data received is to make sure that the observations do not fall outside the possible hours of daylight (Buss, 1976). The quality of the data may therefore vary substantially from station to station and from observer to observer.

The instrument, a glass sphere used to burn a trace on a graduated paper card according to the intensity of the direct radiation, has a lower limit of sensitivity averaging about 200 Wm^{-2} ; the value can vary from about 140 to 280 Wm^{-2} with respect to the instrument and to the temperature and dampness of the paper. This implies a solar elevation of $\sim$ 5°, in clear weather, before a burn is registered in the morning and a similar cut-off point before sunset ; that is, a possible shortening of the daily record by up to 1½ hrs in the growing season at Poste-de-la-Baleine. During the day the cut-off point (some critical value of K ↓ minus diffuse radiation) is related both to the degree of atmospheric transparency in cloud and haze and to solar elevation, but also to the narrow width ($\sim$ 2 cm) of the hourly gradation of the chart. For intermittent cloud, this gives a poor resolution in relation to the response time required for changes in the burn, and is aggravated when radiation is strong by a spread of the burn (overburn).

Checking the AES sunshine records for the 115 hours during which the « clear » weather radiation observations were taken (1972-1975), it was found that all these hours had registered continuous (10/10) sunshine. The frequency of cloud amount and opacity reported at these hours is shown in Figure 6a, b. For comparison, similar data are presented for all 10/10 sunshine hours of the snow-free season (May 16-October 15) 1974.

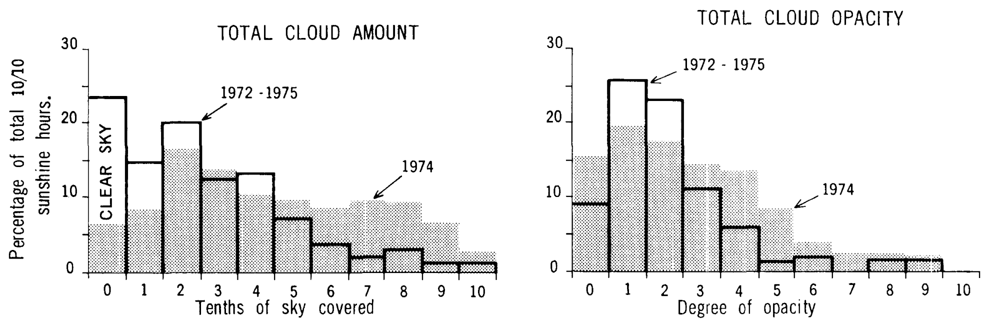
With respect to the *total amount of sky covered* (Figure 6a), the 1972-75 sample shows that nearly three quarters of the hours had 3/10 or less cloud, and only 9% more than a 5/10 cover. For the 1974 season, however, there is a higher proportion of greater cloud amounts, with about a third of all 10/10 sunshine hours reporting a cover in excess of 5/10. These total values frequently include more than one level of cloud. In the case of *total opacity*, there is less difference ; for 1972-75, over 90% of the hours reported 3/10 or less, for the 1974 season nearly 70%. Much can be explained by reference to Figures 6b, c :

1. Some of the observations of 9/10 and 10/10 sky cover are for *cirrus* with opacity reported as 0 or 1/10 ; alternatively, the same condition may be reported as clear, with opacit 1/10. This difficulty in describing an almost invisible cloud veil has been noted in the Antarctic. The predominance of very low *opacity* for cirrus is seen in Figure 6b, In the field sample, it never exceeded 3/10 ; in 1974, 94% of the hours with cirrus were at 3/10 or less. This may be an approximate critical transparency for the cut-off of the burn. It has been noted that there is usually no « trace » even when a cirrus layer is still so thin that the sun casts faint shadows at the ground (Thomas, 1963). Over the 1974 season, nearly two-thirds of the 10/10 sunshine hours occurred with some cirrus present. There was a bias in the 1972-75 field sample away from southerly days owing the frequent difficulties in measurement caused by very light but variable cirrus, often with strong winds and drifting sand. Figure 6c suggests that this explains the lower total frequency of cirrus for the sample hours compared with the 1974 season.

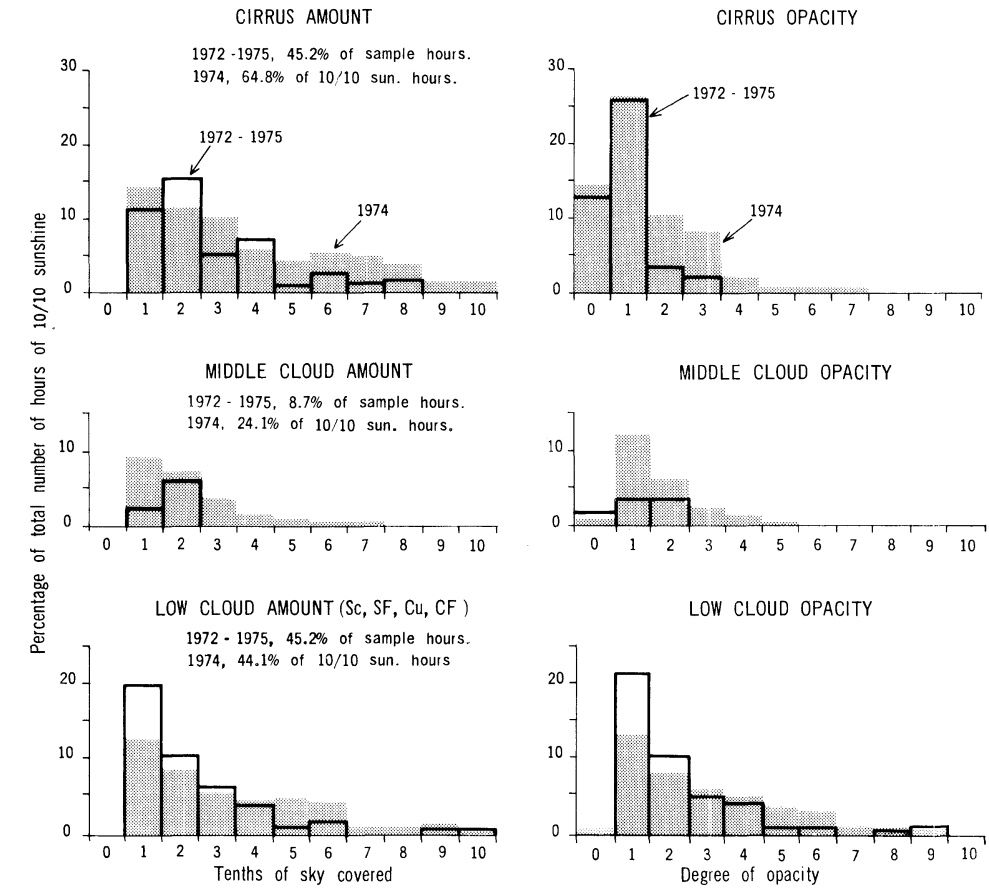
2. In the case of *large amounts* of *low-level cloud* with 10/10 sunshine, it is frequently a matter or turbulence and stronger surface heating over the sandy coastal terraces opening up and maintaining larger « holes » of clear sky, during mostly cloudy conditions. This feature of the climate at Poste-de-la-Baleine is well-known to local pilots. When such relatively small clear areas remain *in situ*, the intensity of solar radiation may be considerably enhanced by reflection from cloud sides. Figure 6b shows that the *opacity* of the Sc, SF, Cu, CF cloud is generally low : for the 1972-75 sample, 3/10 or less for 83% of the hours with low cloud ; the corresponding proportion for the 1974 season was 66%. The *rate of passage* of intermittent low-level cumulus, together with their opacity, is crucial to the spread and continuity of the burn over the hour. Comparing the Campbell-Stokes trace with those of a new sunshine detector and tracking pyroheliometer, Cook (1971) found no visible reaction in the burn to 2 to 4 minute « drop-outs », but a narrowing of the trace at a 6-minute lapse. This resulted in a small over-reading of sunshine duration for the sample period. However, with more variable sky conditions (intermittently greater opacity), the slower response of the Campbell-Stokes burn resulted in an under-reading. During two cases of advection of shallow stratocumulus from the Bay at Poste-de-la-Baleine (amount/opacity 3/10 to 4/10, high sun) the interval between the maximum and minimum radiative fluxes was 2 to 3 minutes, and 10/10 sunshine was recorded ; winds were W and NW at 5 m sec^{-1}. Although surface winds off the Bay during the « clear » weather sample 1972-75 were generally lighter (Table 3e), this would still imply many occasions when such cloud of this amount

Figure 6a, 6b

POSTE - DE - LA - BALEINE: Cloud during "clear" weather. (Data courtesy AES)

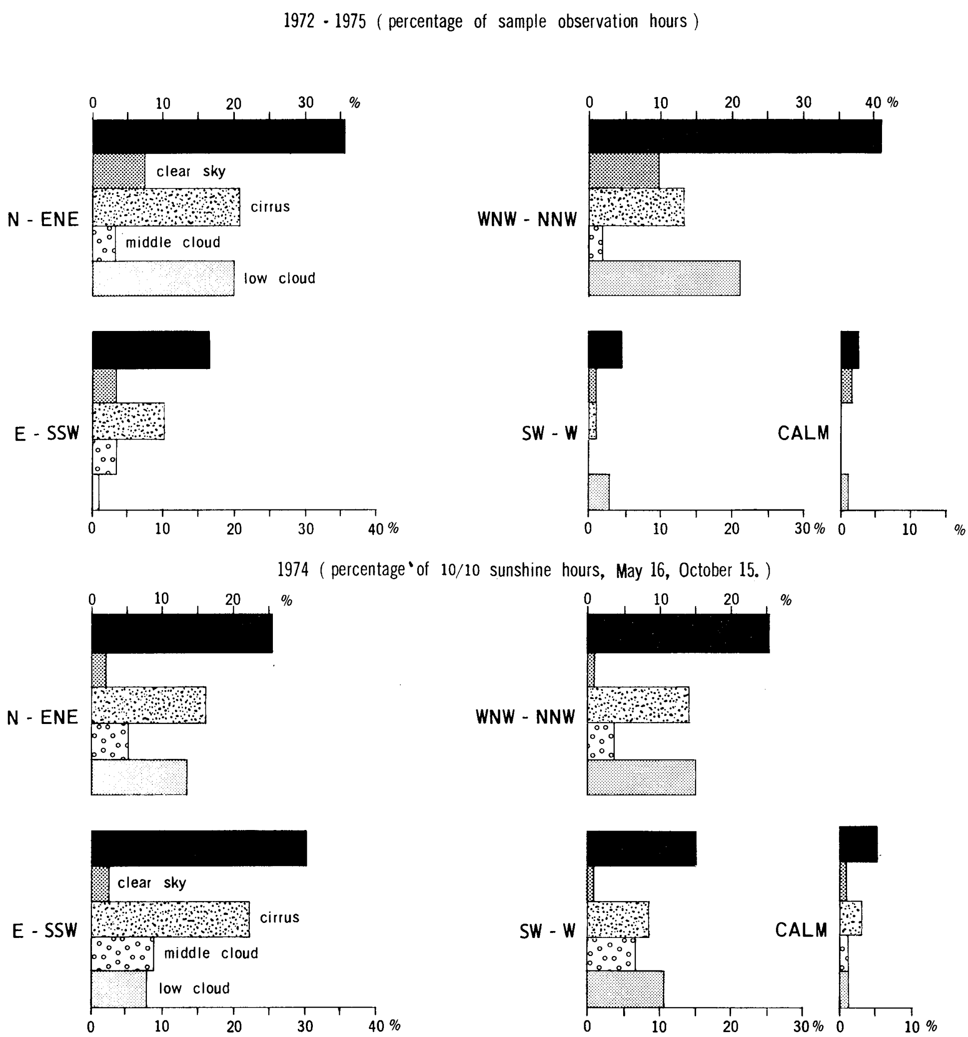


6a. Total amount and opacity for hours of continuous (10/10) bright sunshine: at field observation hours, 1972 - 75, N = 115, solar elevation ≥24°; for the growing season, May 16 - October 15, 1974, N = 503, solar elevation ≥ 5°.



6b. As above, but by cloud type (all reported levels)

Figure 6c



6c. Relative occurence of cloud types by surface wind direction for hours of continuous **10/10** bright sunshine : 1972 - 1975 sample observation hours and the 1974 season (all reported cloud levels)
Black bars indicate the percentage of the total **10/10** sunshine hours with winds from the given direction (cf. figure 8)

and opacity is not recorded in the burn. Owing to the delicate interaction between timing, amount, opacity and location of cloud with respect to the solar zenith, it is difficult to suggest a « clear hour » cut-off for low-level cloud with respect to amount and opacity. It is perhaps worth nothing that once a grey shadow became apparent at the cloud base (opacity $\sim$ 4/10), there was a steep depletion of the solar flux below the cloud centres by a further 250 Wm^{-2} or more.

3. As *middle cloud* is usually associated with an approaching frontal system and preceded by cirrus, this type of cloud was rarely an active consideration during the sample hours. The amount and opacity never exceeded 2/10, a limit which covers most of the corresponding hours of the 1974 season (Figure 6b).

4. Wagner (1927) stressed the influence of *solar elevation* on the sunshine burn. Acording to its height, location and geometry, small amounts of cloud can more effectively cut down direct radiation at low sun. This restriction would apply increasingly as the season progresses. For the field sample, solar height was never less than 24° ; for the 10/10 sunshine hours in the 1974 season the lower limit is close to 5°. During periods of clear weather at Poste-de-la-Baleine, the early morning hours are at times foggy. Frequently, the sun may be cut off in late afternoon/early evening by cirrus or middle cloud on the SW/W horizon. On the other hand, much of the low cloud is related either to diurnal advection from the Bay or convection over land and is not present during the early and late daylight hours.

5. There is a possible source of error arising from the use of hourly observations for weather characteristics, while the sunshine duration refers to the whole hour ending at that time. In addition the sunshine records refer to local apparent time, the « hourlies » to Eastern Standard Time. For climatological purposes (and in practice) these differences are small. Perhaps of greater importance is the dependence of the cloud observations on the care and good judgement of each observer.

Figure 6c shows a simple breakdown of the cloud data for continuous sunshine hours into four major flow situations, based on surface winds (cf. Figure 5). A comparison of the 1972-75 data with those for 1974 indicates that within the flow types the field sample was representative of the cloud type to be expected.

The limiting sky conditions for hours of continuous (10/10) bright sunshine appear to correspond well with those observed during the clear-weather field measurements of incoming solar radiation. The 10/10 sunshine hour was therefore accepted as the basic unit in assessing clear-weather frequency and duration on a climatological basis, while bearing in mind :

a) a tendency at this season and in this climate towards an overestimate owing to the frequency of intermittent low cloud (and overburning) ;

b) the sharp differences in sky cover which can occur between the coast and the hills inland, prohibiting extrapolation beyond the coastal zone ;

Table 3

Frequency of hourly surface weather characteristics during the 1972-75 field sample hours, according to wind direction

a) Air temperatures (°C). Absolute range : – 1° to 30°C.

°C	*≤0*	*1-4*	*5-9*	*10-14*	*15-19*	*20-24*	*25-29*	*≥30*	*Total*
N - ENE		3	6	14	9	9			41
E - SSW			5	1	7		4	2	19
SW - W	1	2		1			1		5
WNW - NNW	1	3	17	23		3			47
Calm		1		1		1			3
Total	2	9	28	40	16	13	5	2	115
°C	≤0	<5	<10	<15	<20	<25	<30	≤30	Total
Lands winds	0%	5%	23%	48%	75%	90%	97%	100%	60
Bay winds	4%	13%	46%	92%	92%	98%	100%		52

b) Vapour pressure (mb). Absolute range : 4 to 16mb.

mb	*4-5*	*6-7*	8-9	*10-11*	*12-13*	*14-15*	*16-17*	*Total*
N-ENE	5	6	14	5	8	3		41
E-SSW	11	2			3	2	1	19
SW-W	4			1				5
WNW-NNW	8	2	29	2	3	1	2	47
Calm	1		1			1		3
Total	29	10	44	8	14	7	3	115

C) Vapour pressure deficit (mb). Absolute range : 1 to 30mb.

mb	*1-5*	*6-10*	*11-15*	*16-20*	*21-25*	*26-30*	*Total*
N-ENE	19	10	7	5			41
E-SSW	3	3	3	4	2	4	19
SW-W	3	1				1	5
WNW-NNW	37	9	1				47
Calm	2		1				3
Total	64	23	12	9	2	5	115

d) Relative humidity (%) : Absolute range : 19 to 86%.

%	*<20*	*20-29*	*30-39*	*40-49*	*50-59*	*60-69*	*70-79*	*80-89*	*Total*
N-ENE		1	1	12	12	8	4	3	41
N-SSW	1	4	7	7					19
SW-W		1		1		2	1		5
WNW-NNW			1	3	4	14	16	9	47
Calm					1		2		3
Total	1	6	9	23	17	24	23	12	115

Table 3 (continued)

Frequency of hourly surface weather characteristics during the 1972-75 field sample hours, according to wind direction

e) Wind Speed (m sec^{-1}). Absolute range : Calm to 11 m sec^{-1}.

m sec^{-1}	*0-1*	*2-3*	*4-5*	*6-7*	*8-9*	*10-11*	*Total*
N-ENE	1	6	12	15	7		41
E-SSW		2	8	6	1	2	19
SW-W	1		4				5
WNW-NNW	8	28	10		1		47
Calm	3						3
Total	13	36	34	21	9	2	115

m sec^{-1}	*⩽1*	*⩽3*	*⩽5*	*⩽7*	*⩽9*	*⩽11*	*Total*
Land winds	2%	15%	48%	83%	97%	100%	60
Bay winds	19%	71%	98%	98%	100%		52

c) that although these 10/10 hours account for two thirds or more of the total sunshine hours (Figure 1, Table 5a), from the point of view of total direct solar energy received, the partial hours of bright sunshine are not negligible.

Other weather characteristics

AES weather data indicating the atmospheric humidity, the drying power of the air, and the lifting and carrying capacity of the wind are grouped according to flow patterns in Table 3, for the field sample hours. In Table 4, the humidity and wind speed information has been regrouped with respect to air temperature. This gives some indication of the relative precipitable water and aerosol content, and of the dryness of the surfaces.

The regression curves relating incoming solar radiation and net radiation refer to dry surface conditions. In relation to clear weather, surface wetting can occur as a result of radiation or advection effects (early morning dew, fog or light drizzle) or through instability showers, especially those associated with cold frontal weather, and in the period immediately following the snowmelt. However, once the sun is shining brightly, the drying out of the surfaces, especially sand and lichens, takes place very rapidly. So much so, that it was very difficult to sample clear weather/damp surface conditions for the « dry » sites. At all the observing hours, the immediate surface layer felt dry to the touch, although sub-surface conditions were more variable. At the hours studied, relative humidity was generally well below 90% and the vapour pressure deficit (VPD) ⩾ 2 mb. In the five cases in which the VPD was less, four occurred with air temperature ⩽ 0°C, and one followed light early morning fog. The lower values of VPD were mainly associated with lighter

Table 4

Frequency of atmospheric humidity characteristics and wind speed according to air temperature : 1972-1975 field sample hours

a) Vapour Pressure.

°C *mb*	*< 5*	*5-9*	*10-14*	*15-19*	*20-24*	*25-29*	*≥ 30*	*Total*
4-7	11	15	5	8				39
8-11		13	30	7	1	1		52
12-15			5	1	10	3	2	21
>16					2	1		3
Total	11	28	40	16	13	5	2	115

b) Vapour Pressure Deficit.

°C *mb*	*< 5*	*5-9*	*10-14*	*15-19*	*20-24*	*25-29*	*≥ 30*	*Total*
1-6	11	25	34	1				71
7-12		3	6	8	2			19
13-18				7	11			18
19-24						2		2
25-30						3	2	5
Total	11	28	40	16	13	5	2	115

c) Relative Humidity

°C *%*	*< 5*	*5-9*	*10-14*	*15-19*	*20-24*	*25-29*	*≥ 30*	*Total*
> 80		7	5					12
60-79	10	8	26	1	2			47
40-59	1	13	7	7	10	2		40
20-39			2	7	1	3	2	15
< 20				1				1
Total	11	28	40	16	13	5	2	115

d) 'Wind Speed.

°C *m sec⁻¹*	*< 5*	*5-9*	*10-14*	*15-19*	*20-24*	*25-29*	*≥ 30*	*Total*
≤ 3	2	20	19	1	6	1		49
4-5	7	6	13	4	2	2		34
6-7	2	1	4	8	5	1		21
8-9		1	4	3			1	9
10-11						1	1	2
Total	11	28	40	16	13	5	2	115

winds from the Bay (Table 3). From a climatological viewpoint, it is probably reasonable to assume that for 10/10 sunshine hours the surfaces are dry.

OCCURRENCE OF CLEAR WEATHER, 1971-75 *(daylight hours)*

For this study, the *growing season is* considered to extend from May 16 to October 15. Normal dates (1931-60) for the season free from snow cover and for periods with selected temperature characteristics are given in Table 5. The 1941-70 temperature normals show little difference. The variability form one year to the next is however considerable, especially in the early part of the season when much depends on the direction of the prevailing winds and the persistence of ice in the Bay. This shows clearly in the extreme dates and length of the frost-free period and in the standard deviation of the monthly temperature (Tables 5 and 6). The influence of wind direction can

Table 5

Poste-de-la-Baleine : snow-free season/growing season 1931-1960

Characteristics	*M* *Date*	*J* *Date*	*J* *Date*	*A* *Date*	*S* *Date*	*O* *Date*
Free from snow cover (medium volues)	28	—	—	—	—	25
Mean daily temp. >0°C	13	—	—	—	—	23
>5°C		9	—	—	26	
>10°C			7	27		
Mean frost-free period (daily min. temp. >0°C)		28	—	31		
Last spring frost* : earliest/latest		7	14			
First fall frost :* : earliest/latest			16			4
Longest frost-free season		7	—	—	28	
Shortest frost-free season			13 — 18			
Mean hours of sunshine 1971-75	176	183	164	167	90**	47

Sources : *Climatic normals*, vol. 6, *Snow cover data* (J. G. Potter, 1965), AES. (See also : Frost data 1941-1970. G. M. Hemmerick and G. R. Kendall, 1972, AES.)

* Season divided arbitrarily at July 15.
** 10 days missing.

Table 6

Poste-de-la-Baleine : temperature and wind characteristices during 1971-1975 compared with the normals

a) Mean daily temperature (°C).

	M	*J*	*J*	*A*	*S*	*O*
1931-60	0.4	6.6	10.6	10.8	7.4	1.9
Standard deviation	2.1	2.6	1.8	1.8	0.9	1.6
1941-70	0.9	6.3	10.6	10.3	7.5	2.3
1971	0.1	5.8	8.4	8.8	7.5	4.3
1972	−1.9	5.5	9.6	8.8	5.7	−0.8
1973	2.9	6.9	10.8	14.3	8.1	3.8
1974	2.0	9.8	12.5	11.1	4.9	−0.7
1975	4.6	10.3	10.7	11.6	7.2	2.9

b) Mean daily maximum temperature (°C)

	M	*J*	*J*	*A*	*S*	*O*
1931-60	4.6	11.6	15.6	14.8	10.7	4.6
1941-70	5.2	11.3	15.6	14.3	10.9	5.2
1971	4.3	10.7	13.2	12.7	11.2	7.7
1972	3.0	10.8	15.1	12.9	9.3	1.9
1973	7.3	11.9	14.9	19.8	11.8	7.0
1974	6.5	15.1	17.3	15.1	8.1	1.7
1975	9.9	15.6	15.5	15.7	11.0	5.7

c) Hourly prevailing wind direction

	M	*J*	*J*	*A*	*S*	*O*
1962-71	N	N	WSW	WSW	W	W
1971	NNE	W	WSW	W	W	SSE
1972	WNW	NNW	W	WSW	WNW	S
1973	NNE	NNE	W	SE	WNW	ESE
1974	ESE	S	W	SE	W	NW
1975	ESE	WNW	W	W	NNE	SSE

Sources : *Climatic normals*, vol. 1 (1968), *Temperature and precipitation, Québec, 1941-70, Monthly Record, Hourly data summaries, no 101, AES.*

be seen in the contrast between the cold and warm spring months of 1972 and 1974 (Table 6) : in the former case, the high frequency of WNW/NW winds was a controlling factor in the late persistence of ice and snow and low air temperatures along the coast ; in 1974, the situation was reversed with an unusually high frequency of warm, drying winds from the ESE/S. Although May 16 appears early, during the second half of May the mean daily temperature is usually above 0°C, with daily maximum temperatures above 5°C. The snow cover along the coast is very irregular owing to the strong winds, and over broad areas of the terraces is soon destroyed.

Hourly frequency of clear weather

On the average, clear weather (10/10 sunshine) occurred during 22% of the daylight hours for the five growing seasons 1971-75 (Table 7a). This percentage varied from a low 16% (359 hours) during the cold summer of 1971 to 27% (518 hours) for the warmer season of 1973. Within the season, the lateness of the spring melt and the higher probability of anticyclonic flow in late May and early June result in a characteristic asymmetry with highest frequencies of clear hours during the first few weeks of the growth period (Table 7b). This appears to compensate to some extent for the late start : for example, in 1974 and 1975 the birch leaf canopy was complete by June 10 ; mid-June the alder and willow in the coastal gullies were in leaf, and many of the flowering plants in bloom. Although there is a greater likelihood of clear weather in late spring, Table 7b indicates considerable variation in the number of clear hours for a given month from year to year, depending on the frequency and degree of persistence of the major circulation patterns. Most remarkable is the large number of hours in August 1973, a month more usually characterized by westerly flow, depressions and fog.

The seasonal and monthly occurence of clear weather for different hours of the day is shown in Figure 7. For those hours ending at 9.00 to 16.00, the total possible number of days is similar for each hour throughout the season ; beyond, the total number becomes less owing to the variation in the hours of sunrise and sunset. Over the 1971-75 seasons, clear weather was most frequent around noon with a rather higher probability during the afternoon hours than in the morning. The relatively high mean values for August reflect the anomaly of 1973.

Duration of periods of clear weather

The high proportion of the total bright sunshine received in 10/10 sunshine hours was noted in the introduction (Figure 1, and see Table 7). Although the total number of clear hours is restricted by local air flow and surface conditions, these hours of continuous sunshine still tend to occur consecutively in response to the general synoptic situation. In Table 8, the number of days per season and by month with periods of clear weather equalling or exceeding given numbers of hours are shown for 1971-75. Over the

Figure 7

POSTE - DE - LA - BALEINE : Diurnal occurrence of 10/10 sunshine hours, May 1 to October 31, 1971 -75

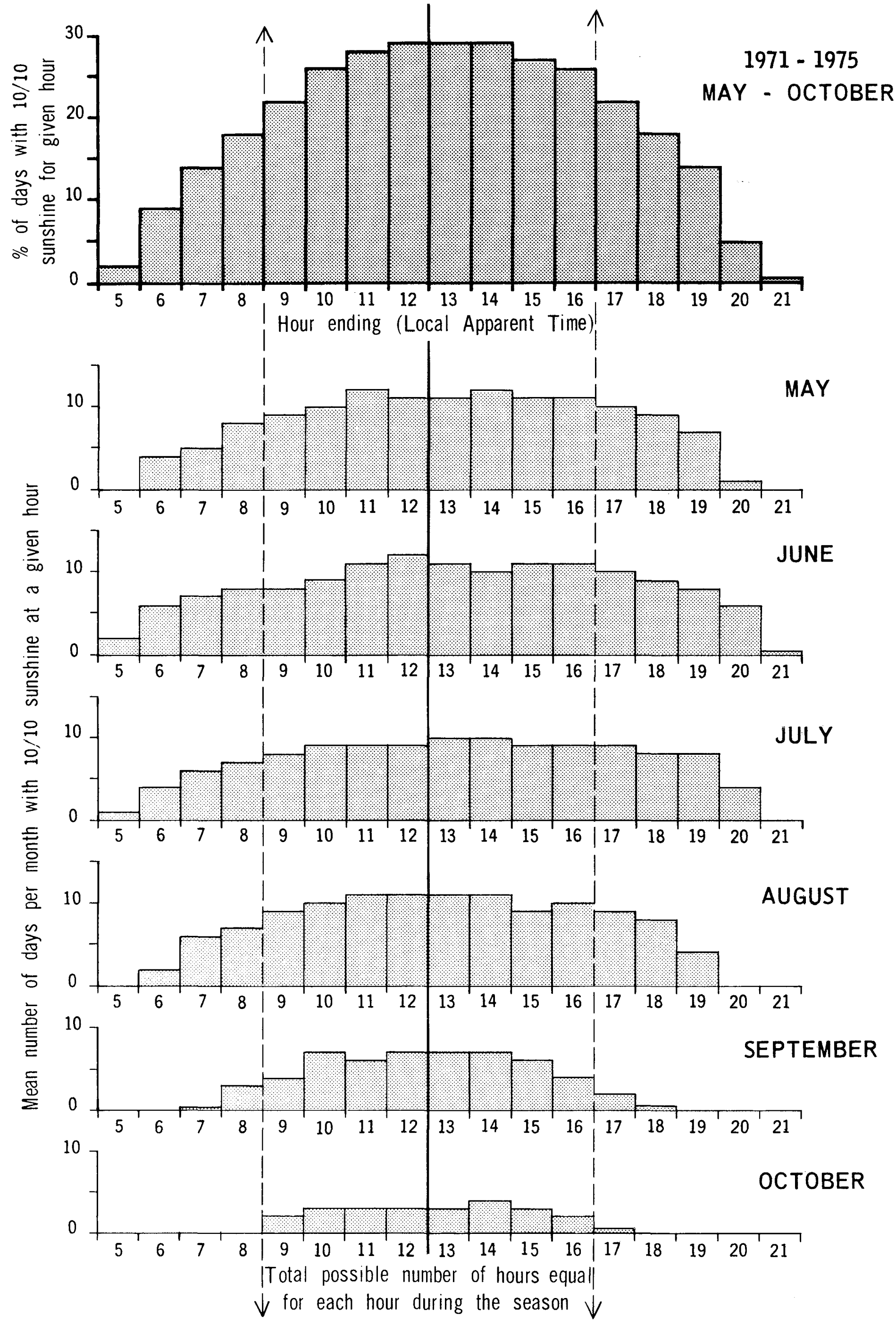


Table 7a

Relative frequency of hours of given duration of bright sunshine, 1970-75, May 16 — Ocober 15, as a percentage of daylight hours

Year	Hourly sunshine duration				Total sunshine			
	0/10	*1/10 - 5/10*	*6/10 - 9/10*	*10/10*	*Hours*	*% possible*	*Total in 10/10 hours*	*% of total sunshine in 10/10 hours*
1971	66.4	11.9	5.9	15.8	534.9	23.5	359	67.1
1972	58.1	13.6	6.5	21.8	695.6	30.5	496	71.3
1973	53.0	12.4	8.1	26.5	832.0	36.7	600	72.1
1974	49.8	17.2	9.8	23.2	765.9	35.3	503	65.7
1975	53.7	15.9	7.7	22.7	737.6	32.4	518	70.2
1971-75	56.3	14.2	7.6	21.9	713.2	31.6	495	69.4

Table 7b

Total number of hours of continuous (10/10) sunshine per month

Year		*May 16–31*	*June*	*July*	*August*	*Sept.*	*Oct. 1–15*	*Season*
1971	a	49	117	72	80	35	6	359
	b	18.7%	22.9%	14.0%	17.5%	9.3%	3.7%	15.8%
	c	70.2	154.7	110.3	120.4	60.4	18.9	534.9
1972	a	84	160	125	76	44	7	496
	b	32.1%	31.4%	24.4%	16.6%	11.7%	4.3%	21.8%
	c	109.9	199.1	173.4	110.7	81.5	21.0	695.6
1973	a	40	129	136	197	74*	24	600
	b	15.3%	25.3%	26.5%	43.1%	20.3%	14.8%	26.5%
	c	69.7	176.5	178.0	258.7	118.5	30.6	832.0
1974	a	69	143	137	119	28	7	503
	b	26.3%	28.0%	26.7%	26.0%	10.6%	4.3%	23.2%
	c	103.5	187.2	205.2	174.4	68.0	27.6	765.9
1975	a	57	147	118	112	78	6	518
	b	21.8%	28.8%	23.0%	24.5%	20.7%	3.7%	22.7%
	c	78.6	199.2	150.8	168.3	122.3	18.4	737.6

* 9 days missing.

a) Total number of 10/10 sunshine hours;

b) % of daylight hours

c) Total bright sunshine duration in hours.

Table 8a

Number of days per season with periods (consecutive 10/10 hours) of continuous sunshine equalling or exceeding certain values : 1971-75, May 16 – October 15

Year	⩾ 2 hrs days	%	⩾ 5 hrs days	%	⩾ 10 hrs days	%	⩾ 15 hrs days	%
1971	47	30	28	18	13	8	5	3
1972	70	46	46	30	22	14	4	3
1973	86	57	51	34	27	18	5	3
1974	70	48	42	29	24	17	5	3
1975	70	46	50	33	22	14	3	2
1971-75	69	45	43	29	22	14	4	3

Table 8b

As above : mean monthly number of days

Month	⩾ 2 hrs	⩾ 5 hrs	⩾ 10 hrs	⩾ 15 hrs
May	17	11	7	1
(May 16-31)	(8)	(5)	(3)	(< 1)
June	16	11	7	3
July	17	10	5	2
August	16	11	5	
September	10	5	1	
October	6	2		
(Oct. 1-15)	(2)	(1)		

five seasons, 45% of the days had at least 2 hours of sunshine, and 29%, 5 hours or more. There was an interesting difference between the more extreme summers of 1971 and 1975. The data period is too short for more general comment, but a glimpse at Thomas (1963) 10-year values for other stations across Canada suggested that although the mean number of days with 5 or more consecutive hours of sunshine is relatively low, there may be less difference for the periods of 10 or more hours between the Hudson Bay site and such eastern centres as Quebec City and Fredericton.

Total bright sunshine amounts

To complete the analysis, Tables 5, 7 and 9 show seasonal, monthly and daily values of total bright sunshine duration, which includes the partial hours. Again, the August 1972 anomaly is apparent in all the tables.

Table 9a

Average daily duration of bright sunshine, 1971-75, in hours

May	*June*	*July*	*August*	*Sept.*	*Oct.*	*Season*
5.7	6.1	5.3	5.4 *	3.2	1.5	4.5

* Excluding 1973, the 4-year mean is 4.6 hrs.

Table 9b

Relative frequency of daily sunshine totals, May 16 – October 15, as a percentage of the total number of days

Year	*Daily sunshine totals (hrs)*					
	< 0.5	*⩽ 2*	*⩽ 4*	*⩾ 5*	*⩾ 10*	*⩾ 15*
1971	40%	59%	71%	29%	13%	4%
1972	29	46	61	39	20	4
1973	25	37	49	51	22	5
1974	21	40	53	47	22	6
1975	23	45	56	44	22	5
1971-75	28	46	58	42	20	5

Table 9c

Mean monthly number of days with total daily sunshine of specified amounts, 1971-1975

Month	*Daily sunshine totals (hrs)*					
	⩽ 0.5	*⩽ 2*	*⩽ 4*	*⩾ 5*	*⩾ 10*	*⩾ 15*
May	8	12	16	13	9	1
May 16-31	4	6	8	8	4	1
June	7	12	15	15	9	3
July	8	12	17	14	7	2
August	8	13	15	16	7	1
September *	9	15	19	9	2	
October	15	23	28	3		
Oct 1-15	7	11	13	2		

* 10 days missing.

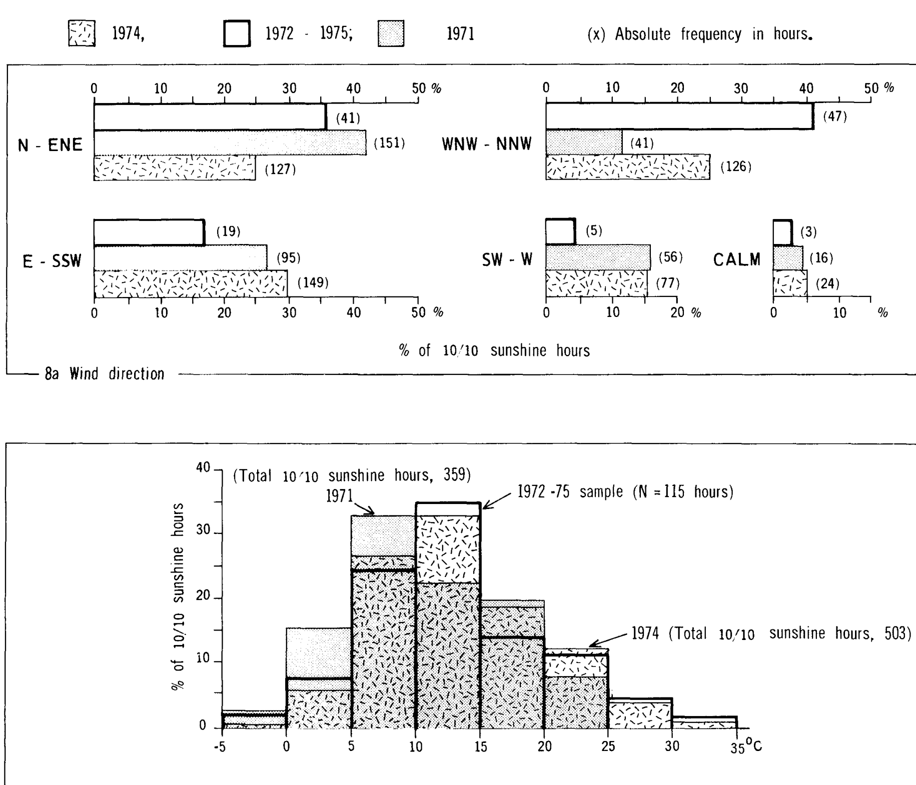
Clear weather and warm season climate

Sunshine records are available from October 1970 for Poste-de-la-Baleine. Table 6 offers some indication of the extent to which weather during the 1971-75 period differed from the long-term means. On the average, late spring/early summer was warmer, autumn colder and July marginally cooler than the previous 30 to 40 years. The colder summers of 1971 and 1972 represent those years when the mean daily temperature for the warmest month fails to reach 10°C, with attendant ecological implications for growth. For the 1973 to 1975 seasons, monthly temperatures were generally well above normal.

During the warmer seasons, there were not only more hours of clear weather than in 1971, 1972 (Table 7), but interesting differences in the frequency of the related flow patterns. As an example, Figure 8 compares wind direction and temperature distribution for clear hours in 1971 and 1974.

Figure 8

POSTE - DE - LA - BALEINE : Wind direction and air temperature at the end of 10/10 sunshine hours, for the 1972 - 75 sample and the 1971 and 1974 seasons (May 16 - October 15).



In 1971, the predominant winds during clear weather were N/NNE and the greater proportion of hours with temperature below 10°C were associated with winds from those directions. Above 20°C, the higher frequency for 1974 is closely associated with the large number of hours with winds from the E to SSW, including a significant increase in the occurence of strong southerly flow. The directions NW/WNW also take on a greater importance in 1974. Clear conditions in this sector are related not only to cold front weather, but to those often warmer occasions when a sea-breeze may develop. Characteristic humidity and wind speed for the different wind sectors and temperature classes were given in Tables 3 and 4. As Namias (1958) put forward nearly a generation ago, the character of the individual seasons at high latitudes appears to be dominated by certain large-scale flow patterns which once established tend to persist and recur throughout that season.

CONCLUSION

The information for Poste-de-la-Baleine provided here and in the companion article (Wilson, 1975) is relevant in ecology and resource management, and in the development of solar heating and greenhouses, but it applies strictly to the coastal zone.

1. Rapid estimates can be made for the different clear-weather situations of the incoming solar radiation and net radiation fluxes according to surface type.

2. Using the coefficient of atmospheric transmissivity appropriate to the synoptic situation, daily totals of incoming solar radiation can be calculated, and the corresponding daytime totals of all-wave radiation input can be assessed for the various surfaces. A study of this kind is concurrently under way in which slope and aspect are incorporated.

3. The importance of the quality and duration of clear weather can be assessed as a factor in the variability of the seasonal climate in this otherwise cool, cloudy, damp coastal margin, dominated by depressions and Hudson's Bay.

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ABSTRACT

WILSON, Cynthia : Radiant energy during clear weather in he growing season at Poste-de-la-Baleine (Great Whale) Québec.

In a previous article, regression coefficients were determined for the major surface types during clear weather at Poste-de-la-Baleine, to permit estimates of net radiation given the incoming solar radiation. In the present complementary study :

(i) a curve is set up to provide a quick estimate of the incoming solar radiation fluxes in clear weather ;

(ii) daily coefficients of atmospheric transmissivity are given for characteristic clear-weather synoptic situations ;

(iii) an attempt is made to define a clear hour in terms of bright sunshine and hourly weather observations, to assess the frequency and duration of clear weather in the growing season for which all these radiant energy curves are valid ;

(iv) a brief climatology of clear weather is presented for the period 1971 to 1975.

The information provided in these two papers is relevant in ecology and resource management, and in the development of solar heating and greenhouses, but it applies strictly to the coastal zone.

KEY WORDS : Climatology, radiation, sunshine, New Quebec.

RÉSUMÉ

WILSON, Cynthia : Energie rayonnante par temps clair pendant la saison de croissance à Poste-de-la-Baleine (Great Whale), Québec.

Dans un article antérieur, nous avons présenté pour les types de surface principaux à Poste-de-la-Baleine des coefficients de régression par temps clair, de sorte qu'il est possible d'estimer le rayonnement net à partir de données sur le rayonnement solaire global reçu en surface. Les buts du présent article complémentaire sont les suivants :

(i) établir une courbe pour fournir des estimations rapides des flux du rayonnement solaire global par temps clair ;

(ii) donner des coefficients quotidiens de la transmissivité atmosphérique pour des conditions synoptiques type par temps clair ;

(iii) essayer de définir à partir de données sur l'ensoleillement et d'observations météorologiques horaires « une heure de beau temps », pour évaluer la fréquence et la durée de temps clair dans la saison de croissance pour lesquelles toutes ces courbes d'énergie rayonnante sont valables ;

(iv) présenter une brève climatologie de beau temps pour la période 1971 à 1975.

Les renseignements fournis dans ces deux articles pourraient être utiles dans l'écologie, la gestion des ressources et dans le développement du chauffage solaire et des serres, mais son utilisation doit être limitée à la zone côtière.

MOTS CLÉS : Climatologie, rayonnement, ensoleillement, Nouveau-Québec.