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PROCEDURES IN USING A LIGHT AIRCRAFT FOR THE REMOTE SENSING OF SURFACE RADIATIVE TEMPERATURES

by

B. J. Garnier*

Remote sensing devices are being increasingly used in climatology and other sciences concerned with observing and analysing conditions on the surface of the earth. One reason for this is the increasing availability of instruments at a reasonably low price. However, for such instruments to be fully used it is necessary that their operation should be simple and low-priced also. Ground observations present little difficulty in this respect. However, many scientifically useful observations are best made from the air; but instrumented remote sensing aircraft are expensive to hire and require specialized and skilled operational crews. The purpose of this article is to offer an account of how a series of remote sensing experiments was undertaken at low cost by using a light aircraft. It is hoped that to report on how the work was undertaken will be useful to others interested in similar or related types of observation.

The objective of the experiments was to obtain information on the topographical variations in surface radiative temperatures. For this purpose a precision radiation thermometer (PRT-5) of the Barnes Engineering Company was used. This instrument consists of an optical head, an electronic control unit, and interconnecting power cables. The optical head collects infrared radiation from the target surface, and generates an electrical signal which is proportional to the difference between the radiation from the surface and that from a precisely temperature-controlled internal black-body source. This signal is further processed by electronic circuits to produce a precise DC signal which is displayed on a panel-meter graduated in absolute temperature units. The signal can also be fed into a recorder unit. The standard PRT-5 has a spectral range of 8-14μ. However, spectral modules are available to alter the spectral band, particularly so as to be able to narrow the band to provide higher sensitivity. The instrument normally has a 2° field of view, which provides a target area 35 ft. in diameter from a distance of 1,000 ft.

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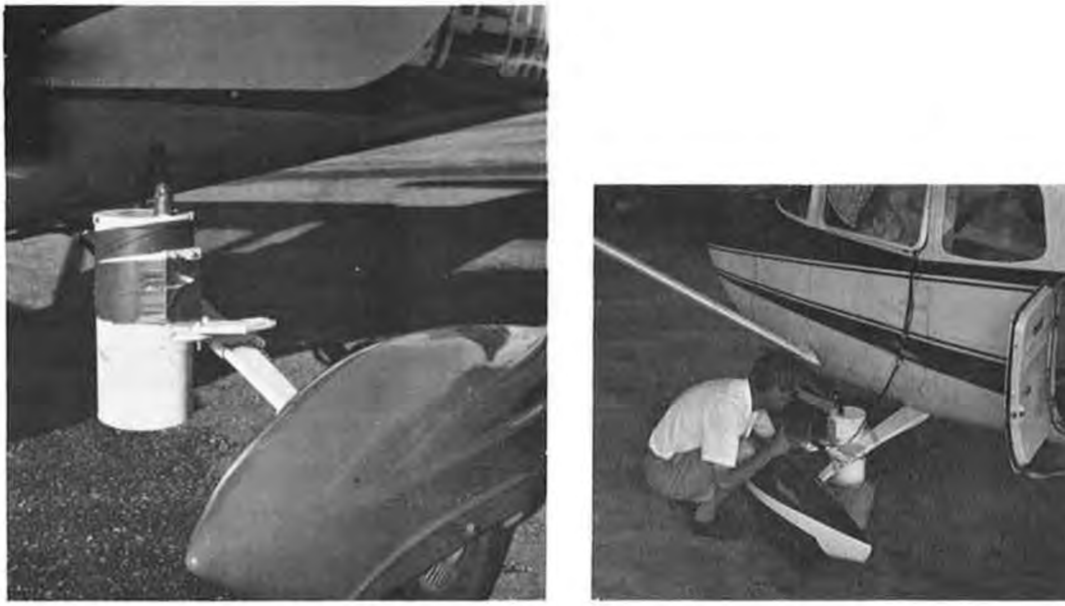
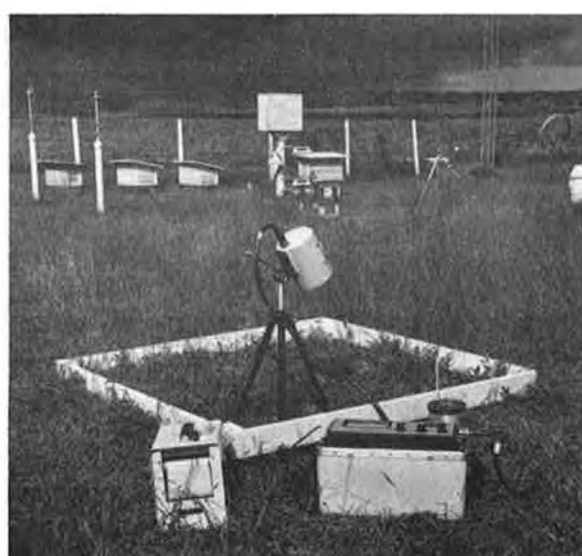


(a) PRT-5 installed on aircraft step.

(b) Metrodata recording system
in aircraft.



(c) Ground truth observations.

Fig. 1 Instrumentation for Airborne Observations.

The observational programme was carried out in Barbados during 1969 and over parts of southern Quebec during three separate weeks of the summer of 1971. There were two weeks of observation in Barbados: the last week of June and the first week of December. In the first period a single engined Cessna 172 was used, and during the second period, a single engined Cessna 150. All the observations over southern Quebec were made from a Cessna 150. The aircraft in Barbados was supplied by Aero Services (Barbados) Ltd., and that for southern Quebec by Wondel Aviation Ltd. located at St. Hubert airport. Both types of aircraft are particularly suitable for remote sensing purposes. The fact that the wings are across the top of the aircraft means that both the pilot and the instrument operator can obtain a clear view of the ground below. This is important when flying without precise navigational instruments since it enables the pilot to see easily and to pass accurately over the control points on the ground. Of the two aircraft used, the Cessna 150 proved the most practical in that the pilot has a rather better view from it than from the larger, 4-seater Cessna 172.

For installation on the aircraft the optical head of the PRT-5 was mounted in a cylindrical housing, approximately 12 inches high and 6 inches in diameter, with a hole 2 inches in diameter through which the radiometer viewed its target area. A right-angled bracket was fixed to the outside of the housing. This bracket had two bolt holes in it which enabled the cylinder, with the PRT-5 inside it, to be bolted to the step of the aircraft. To enable this to be done, two holes had to be drilled in the step of the aircraft. No other modification to the aircraft was required since the lead wires from the optical head were passed through the window of the pilot's cabin (fig. 1a). The electronic unit for the PRT-5 head, and also the recorder being used were installed in the baggage compartment of the aircraft (fig. 1b).

Although the observational procedures adopted in both Barbados and southern Quebec were essentially the same, the Barbados work will be described first since the procedures followed in southern Quebec were modified somewhat in the light of the experience gained in Barbados.

Observations over Barbados

In June 1969, one PRT-5 was used. It was a standard instrument observing in the 8-14μ region. During December, two PRT-5s were used, one mounted on each step of the aircraft. One instrument was the standard one used in June, but the other had been modified to observe in the 10-12μ region in order to obtain an idea of the effect of atmospheric attenuation on the results being recorded. The instruments, together with another PRT-5 and a

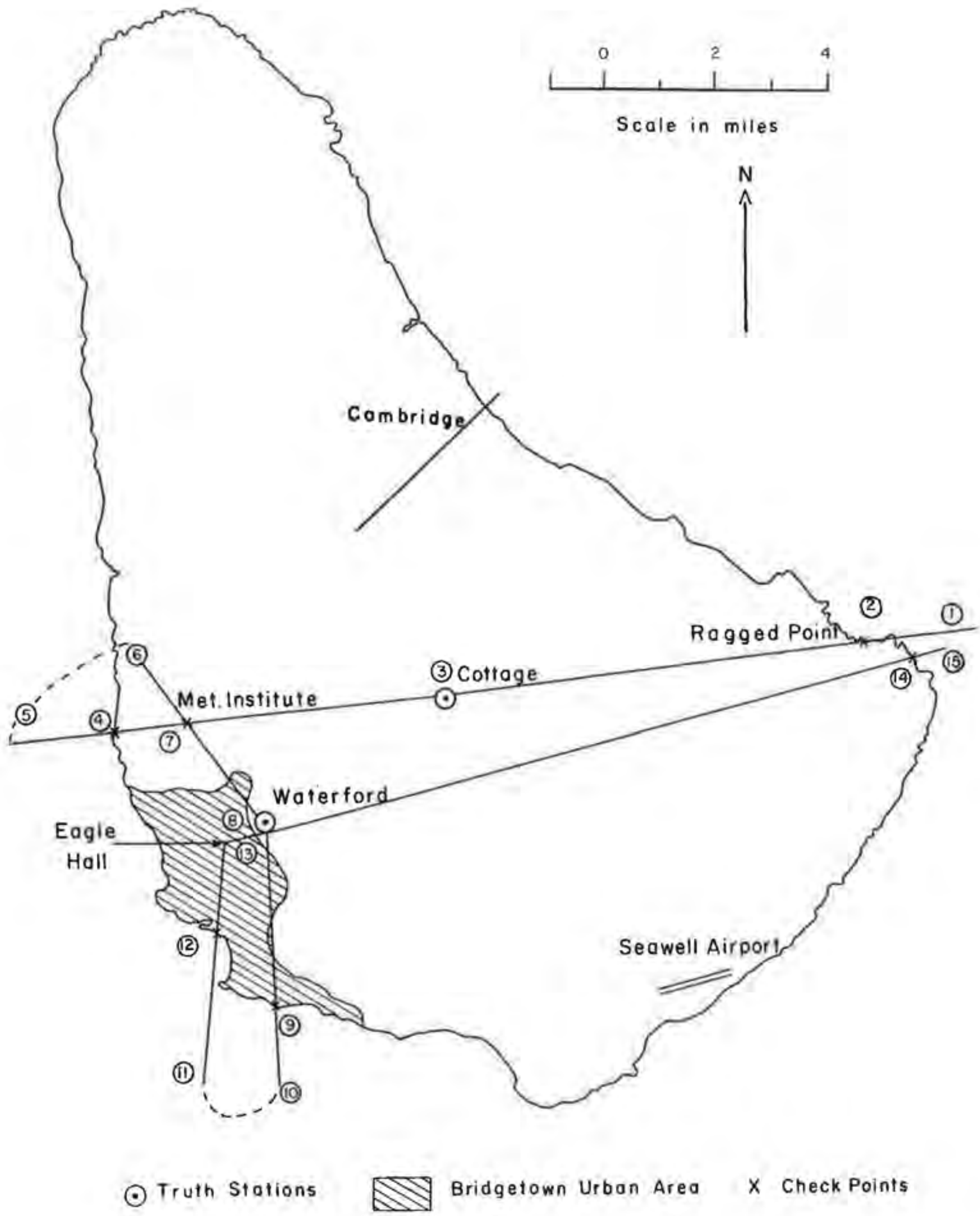


Fig. 2 Flight Lines and Ground Control over Barbados.

PRT-10 for ground observations, were manufactured and supplied by the Barnes Engineering Company of Stamford, Connecticut. Data in Barbados were recorded in the aircraft on a DL620A Digital Data System supplied by Metrodata Systems Inc. of Norman, Oklahoma. This system accepts 18 channels of analog data plus two channels of time data. It records 48 observations a second, including the two time channels. In the aircraft it was operated on 12VDC using a 12VDC to 110V-60 inverter. Data from the PRT-5 used for ground control observations were recorded on the standard 29-401 portable strip-chart recorder supplied and adapted for PRT-5 use by the Barnes Engineering Company (fig. 1c).

The basic observational procedure followed consisted in making a series of traverses over the island at selected times of day. The various flight lines are shown in fig. 2. They comprise a main traverse which took in the island's major terrain or surface variations, and special traverses designed to provide particular samples of conditions over the steep and variable relief of the east coast (Cambridge area) and over the Bridgetown urban area. Ground control points were established at Waterford, Cottage, and Cambridge. Here, at the appropriate times, suitable surface observations were made which were intended as checks on the airborne data. In addition, check points were identified at different places on the traverse routes. As the aircraft passed over the different ground control or check points, the fact was indicated by means of a coding system which would subsequently appear in the recorded magnetic tape data. In this way it was hoped to be able to identify the position of the aircraft from the data output and so correlate the observed values with the different surface conditions.

The subsequent difficulties in carrying out the data analyses provides one of several lessons learnt as a result of the Barbados work. The PRT-5 is a fast-response instrument of high sensitivity. Thus, surface temperature variations due to the passage of a cloud, or a change in surface wind conditions, are reflected in the recorded observations as well as variations due to the physical character of the surface itself. This high sensitivity to changing surface conditions was faithfully recorded on the DL620A Digital Data System with its capability of 48 observations a second. As a result, a mass of data was acquired which proved extremely difficult to analyse from the viewpoint of the experiment's primary objective: understanding the topographic variations of surface radiative temperatures. The problem was not a question of numbers, which can be handled by a computer. The problem was to distinguish clearly between the effect of cloud or wind as opposed to surface, and to identify precisely the points on the ground corresponding to the points in the data record.

The latter difficulty reveals another error made in Barbados: generally speaking, the distances between control or check points were too long, and these points were themselves not sufficiently distinguishable from the characteristics of the surfaces surrounding them, except in the case of the coastline which could always be clearly identified on the data printout. Even Waterford, over which great care had been taken as the principal ground control station, proved difficult to identify. This was largely because its distinctiveness had been concentrated on too small an area. The station comprised a grassed plot, some 30 yards square, surrounded by ploughed land. It was not always easy for the pilot flying 1,500 ft. above sea level (1,200 ft. above station level) to go over such a small area, especially when the wind was strong or the air turbulent. Equally, it was difficult for the observer to push the code control button at exactly the right moment, since a timing error of one 2/5 second at the aircraft speed of between 50 and 60 yards a second, could easily put the "station" on the data output off target. The latter factor also arose in the case of check points like Cottage or the Caribbean Meteorological Institute buildings at Husbands (fig. 2), both of which could be accurately flown over without difficulty but the identification of which proved difficult if the code button had been pressed either too early or too late. Tests of the potential time lapse in this respect were made in respect of coastal check points, which could be easily identified from the data. By comparing the actual crossing time given by the code for the point, an error of ±0.5 sec. in the time of pushing the code button had to be accepted as a normal expectation. This implies an error of ±25 to 30 yards on the ground. In retrospect, shorter traverses and/or more frequent control points, and better use of the coast as a control point, would have greatly improved the observational procedures adopted in Barbados, at least insofar as the analysis of surface variations in radiative temperatures is concerned.

Faced with these difficulties, several systems of data analysis were tried. These are explained fully elsewhere (Garnier, 1971). The most generally useful procedure proved to be to convert the digital data to a graphical printout of temperature profiles. The practical scale of these was almost identical to the profile obtainable directly on a 29-610 strip-chart recorder running at 3 inches a minute.

Calibration checks on both the PRT-5 and the recorder used were undertaken before and after each flight. These indicated that steady instrumental conditions were maintained during each flight but that there were differences between one flight and another. The latter were not sufficiently pronounced to warrant adjusting the data by a calibration factor for each individual flight. Instead, it was possible to use a single calibration factor for the experiments of a given week. However, each experimental period required its separate conversion equations. This was true despite the fact that the same PRT-5 (S/N 149) observing in the 8-14μ region was used in both June and December.

Another factor found to be important as a result of the Barbados work concerns the influence of atmospheric attenuation on instrument performance. Tests for this were carried out, particularly during the December experimental period. These tests showed the effects of atmospheric attenuation in the Barbados area to be virtually linear, at least below 3,000 ft. elevation above sea level (Weiss, 1971). As might be anticipated, the influence of the atmosphere on the PRT-5 observing in the 10-12μ region was less than on that observing in the 8-14μ region. In the former case a temperature decrease of 0.5°C/1,000 ft. was observed and in the latter case it was 0.8°C/1,000 ft. The data for both instruments suggest, however, that below 3,000 ft. a simple calibration for atmospheric conditions can be undertaken if a level flight at two or three different altitudes can be made over a stable target, such as water. Such calibration was not, in fact, undertaken during either of the Barbados experimental periods, since the principal tests for atmospheric influence were not, unfortunately, taken until the very end of the observational programme.

Observations over Southern Quebec

The observational programme over southern Quebec took place during the summer of 1971: it covered the last week of June, a week in mid-July and a week in mid-August. The areas of interest comprised the city of Montreal, an area centred on Mont St. Hilaire, and part of the upper Eaton river basin some twenty miles east of Sherbrooke. For all these flights a PRT-5 observing in the 8-14μ region was used. It was attached to a Cessna 150 aircraft, and the recorder used was a 29-610 strip-chart recorder running at 3 inches a minute.

The basic observational procedures used were like those adopted in Barbados, but improved in the light of the experience gained in that experiment. One major improvement was in the length of the traverse lines adopted. These were kept short and as far as possible passed over surfaces which could be easily recognized on the strip-chart record. In the vicinity of Mont St. Hilaire and over Montreal there was no difficulty over this owing to the presence of the rivers Lawrence and Richelieu, and of lac Hertel in the centre

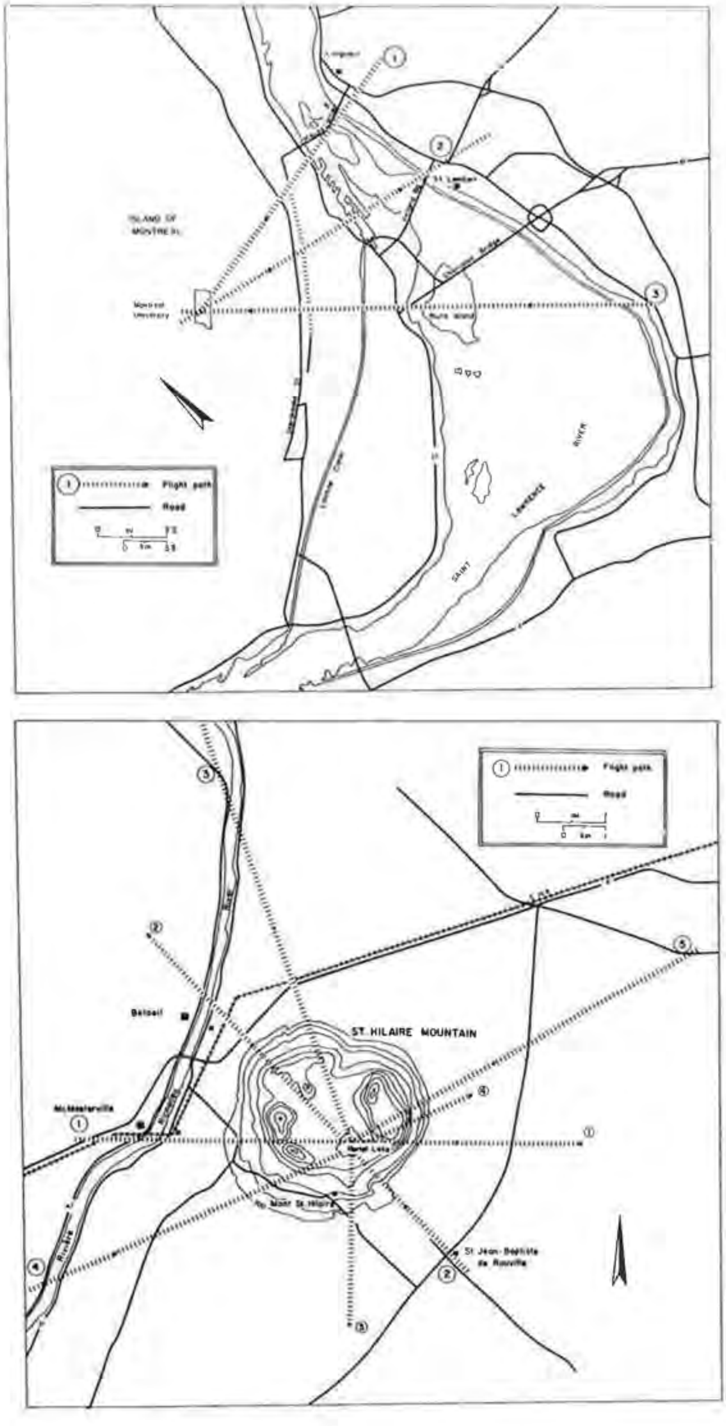


Fig. 3 Flight pattern over Montreal (upper) and Mont St. Hilaire (lower).

of Mont St. Hilaire (fig. 3). No such water bodies existed in the Eaton river basin, however. Here it was necessary to make use of ground parties led by professors Bonn and Clemens of the University of Sherbrooke. These parties took up positions on roads as shown in fig. 4. Each traverse began at the village of Island Brook and continued in a straight line for a specified time. The observer in the aircraft noted the position of each ground party on the strip-chart recorder as the aircraft flew over, and the ground parties made records of surface temperature (one PRT-5 was available on the ground, and thermometers were used in other cases) to compare with those observed from the aircraft.

The combined use of short traverses and a strip-chart recorder greatly facilitated data analysis, and also ensured that a continuous and immediate check of the experiment as it progressed could be maintained. Moreover, the response of the recorder was sufficient to indicate essential surface influences but not so fast that it confused the picture by too much detail. In particular the influence of wind changes or passing cloud was not revealed unless they were sufficiently persistent to become integrated into the total surface radiative temperature picture. Thus, from the viewpoint of the experimental objectives the strip-chart recorder provided a more convenient recording system than had the magnetic tape system adopted in Barbados.

As in Barbados, instrument and recorder calibrations were undertaken before and after each flight. The method adopted was the same as had been used previously: a saucepan of water, well stirred, was held close to the PRT-5 optical head. The water temperature was read by a mercury thermometer and compared with the PRT-5 reading. In Barbados this system had worked well with water at two or three different temperatures. In southern Quebec the system was not so successful. The temperature gradient between water and air, and also the wind--except where calibration could be undertaken in a hangar--made a steady thermometer reading of the water surface temperature impossible except for water which had been left standing long enough to become adjusted to air temperature. Consequently in practice it proved possible to use only one thermometer-read water temperature. The recorder calibration, however, could be undertaken at several temperatures since the PRT-5 recorded a steady surface temperature as long as the water was not stirred. Thus the scale of the strip-chart record could be readily noted before and after each flight, but the response of the PRT-5 at different temperatures was not so easy to obtain in the field. It was necessary to maintain laboratory checks on the instrument before and after each experimental period, in addition to

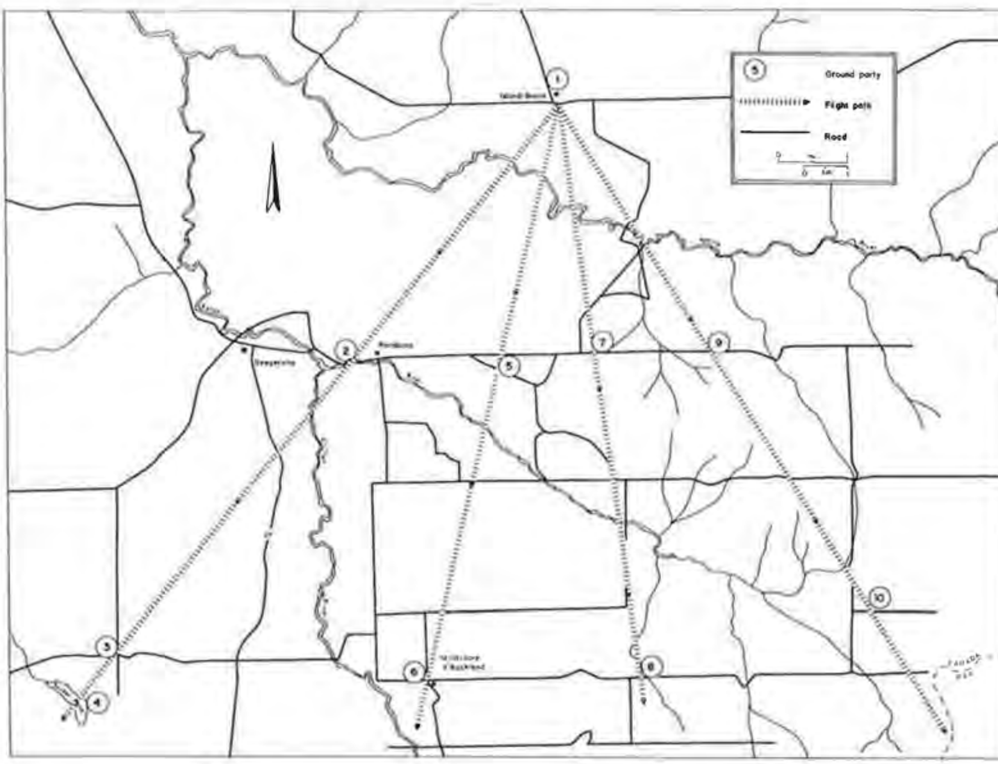


Fig. 4 Flight Paths over the Upper Eaton Basin.

The circled points indicate the position of ground parties. Two parties were used, one moving successively from points 2, 5, 7, to 9, and the other from points 3, 6, 8, to 10. Flights were made in one direction only along each path to give the ground parties time to move from one point to another.

monitoring the field performance as well as possible. As in Barbados, it was found that the instrument performed well during each week of observations, but that the calibration factor changed between each week of observation during the summer.

The influence of atmospheric attenuation on the performance of the PRT-5 was also monitored regularly during each week of observation. This was done by flying above the same stretch of the Richelieu river successively at 3,000 ft., 2,000 ft., and 1,000 ft. above sea level. On one occasion a flight at an altitude of 10 ft. above the water was also made. In general the effect of altitude on the recorded surface water temperature was small, and rarely reached more than 0.5°C/1,000 ft. Moreover, the largest differences tended to occur between the observations at 3,000 ft. and 2,000 ft., indicating that atmospheric attenuation below 2,000 ft. was negligible nearly all the time. Since the traverse flights were normally below 1,500 ft. above sea level, except in the Eaton river basin where they were 500-700 ft. above the surface at an altitude of 1,800 ft., little correction for altitude was necessary. However, on one or two occasions this was required, as, for example, on July 19 (a humid morning) and again on August 18 when steady differences of 0.5°C/1,000 ft. and 0.6°C/1,000 ft. respectively were observed. Tests for atmospheric attenuation are, therefore, to be recommended even in middle latitudes.

Conclusion

The general conclusion arising from the observations made in Barbados and southern Quebec is that a light aircraft, such as a Cessna 150, can be effectively used in remote sensing work. An instrument such as a PRT-5 can be simply attached to the step of the aircraft and even in winter it would probably be practical to run the lead wires through the window, which can be blocked against cold by foam rubber. Indeed, this procedure was adopted in southern Quebec to avoid inconvenience to the observer because of the wind.

Experience has shown that the length of traverses and the system of recording need to be carefully considered in the light of experimental objectives. Where small temperature differences over small distances are important, such as in water pollution monitoring, a recording system such as the DL620A used in Barbados is appropriate and can be easily operated. For more general resource-survey work, however, the strip-chart recorder supplied with a PRT-5 is quite suitable in terms of the detail of the results portrayed and very convenient in that it enables the experiment to be readily monitored as it progresses. The chief problem of data analysis in the experiments described proved to be in the precise identification of ground points on the strip-chart record or magnetic tape printout. Some form of photographic record taken from a camera mounted beside the PRT-5 would have greatly helped with this. However, this would add instrumentation which might encumber the cheapness and simplicity of the experiment as it was, in fact, undertaken.

ACKNOWLEDGEMENTS

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WEATHER AND HUMAN COMFORT IN MONTREAL: AN EXAMPLE OF SUMMER CONDITIONS

by

Daniel LaFleur*

A great deal of attention is currently being given to different aspects of urban climatology. This is not surprising in view of the high proportion of the population living in cities at the present time, and also because of the effect urban agglomerations are known to be having upon various environmental problems, either directly through air pollution, for example, or indirectly through their possible influence on conditions in the surrounding countryside. One aspect of urban influence which needs investigating is the effect the city has upon the actual living conditions for man. Or to put the matter in the form of a question, what kind of climatic environment has the building of a city produced for the people who live and work there as they walk on its streets in the normal course of business?

In an attempt to throw some light on the answer to this question, a pilot study into aspects of the physiological climatology of Montreal has been undertaken. The aim of the study is to investigate certain aspects of the human comfort and thermal strains experienced by people when outside, walking the streets of the urban area.

There is a considerable literature on comfort and thermal stress indices in relation to climatic environmental conditions (Landsberg, 1970). The general principles underlying the evaluation of these indices is to recognize that human health and comfort depend upon the maintenance of a stable internal body temperature at 37° C. and a skin temperature of 33° C. Since the human body generates heat internally through metabolic processes and gains and loses heat from and to the environment, it follows that heat gains and losses must balance if stable health and comfort conditions are to be maintained. Heat gain from metabolism depends on human activity; heat relationships with the environment depend on the nature of the environment and are intimately connected with environmental radiation, temperature, humidity,

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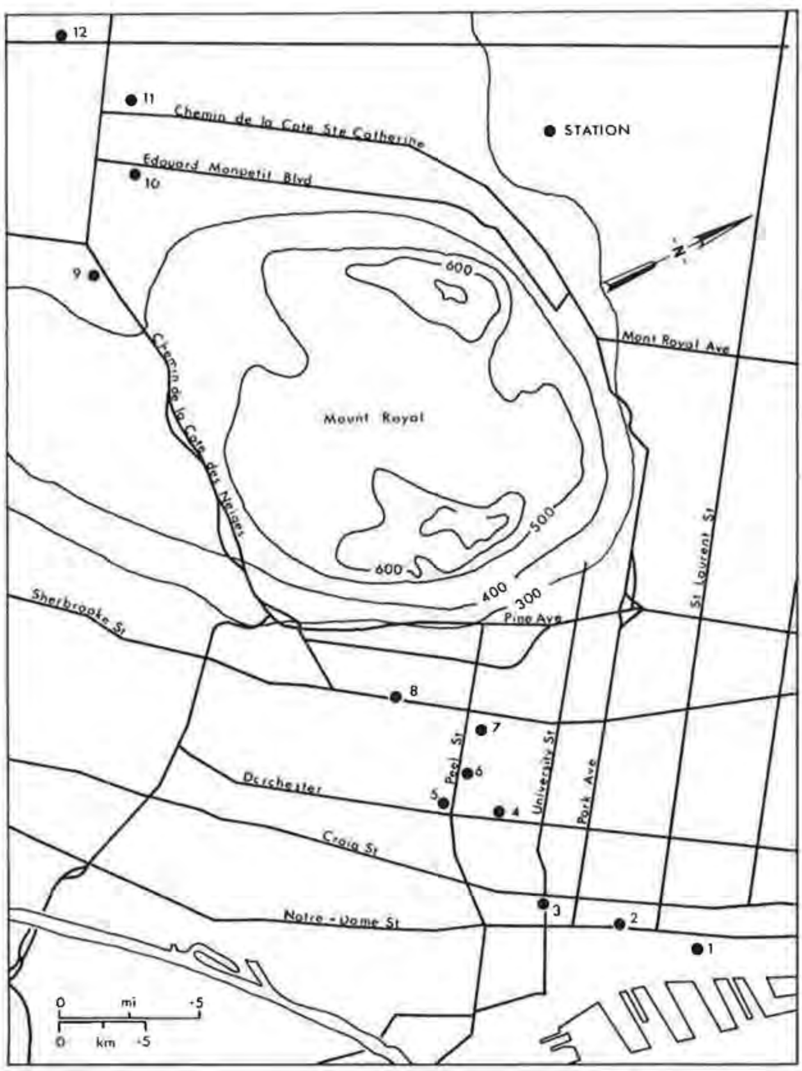

Fig. 1 Location of Observation Stations in Montreal.

and wind. Thus, climatic indices of human strain and comfort consider particularly these elements. In general, stresses are set up either if the body cannot lose heat rapidly enough or if the body loses heat too rapidly. The rates of gain and loss are related partly to activity and partly to thermal and humidity gradients between the body and its environment. Stress indices in physiological climatology, therefore, are based upon these considerations and are designed to evaluate those gradients which are dependent on radiative and atmospheric conditions (Buettner, 1951).

In general, climatic stress indices can be thought of as falling into two classes: those which emphasize the idea of "sensation", such as the wind chill index or the effective temperature index, and those which centre upon biological activity such as heart rate, evaporative heat loss from the lungs, or the levels of involuntary sweating or shivering.

The observations needed to calculate these different indices comprise the four elements referred to above: radiation, air temperature, moisture content of the air, and wind speed. In the present study only observations of the latter three elements have proved practical for the time being, and the indices discussed in the present article have, accordingly, been limited to those involving primarily these three elements. As the study progresses it is planned to incorporate a radiative term in the results, but in the results reported here this term has been neglected. Furthermore, only seven summer days of observation will be considered. In future work, care will be taken to correct the fluctuations in time from noon to two o'clock for temperature and humidity, so as to compare spatially the data. Discussion of observations made through the autumn and winter months will also be reserved for later presentation.

The instruments used for making the observations consisted of an Assmann ventilated psychrometer and a Casella sensitive cup anemometer. Both instruments were mounted on a rack on the roof of a car. Calibration tests were made to ensure the most efficient way to mount the instruments so that the effect of the car was minimized. Simultaneous tests of car observations and observations from matched instruments away from the car influence showed that the effect of the car never produced a variation resulting in a difference greater than one degree F. of effective temperature, a difference which is considered to be insignificant, at least in the analysis given here of summer conditions.

Twelve observation stations were chosen to represent the city climate (fig. 1). Their choice and precise location were determined by five factors:

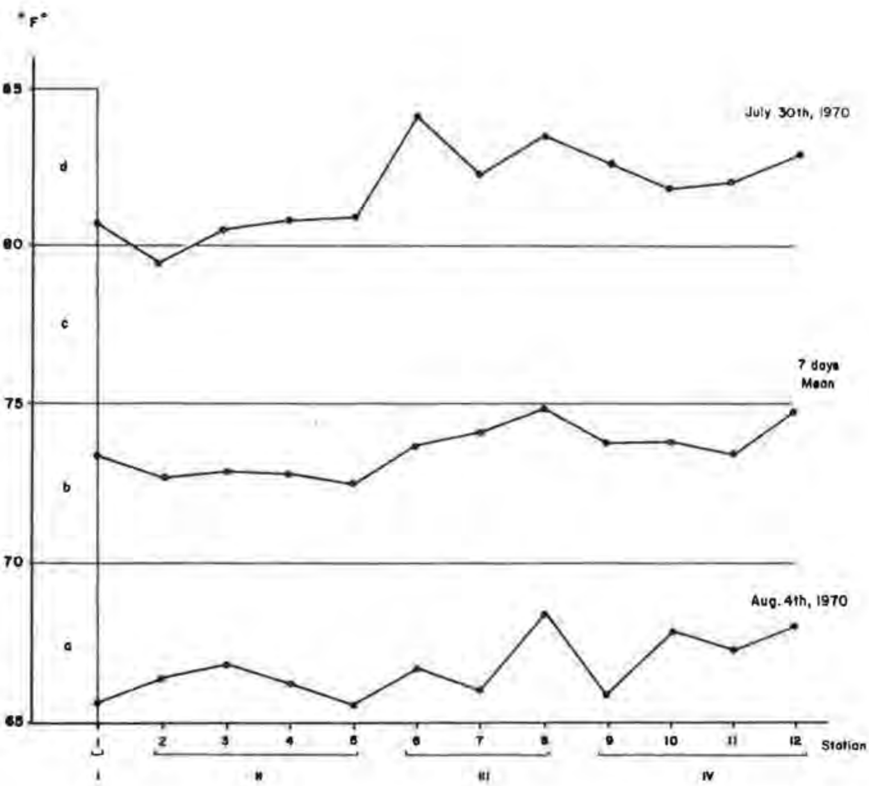

Fig. 2 Temperature - Humidity Index.

(a) no discomfort;
(b) some persons are uncomfortable;
(c) 50% or more persons are uncomfortable;
(d) most people show signs of discomfort.

Note: In this, and subsequent figures, the stations are grouped as:

I Tourist region.
II Business area.
III Commercial area.
IV Residential area.

(1) The urban structure: the stations covered the area from "Old Montreal" (the tourist zone), through the business district of St. James street, the business and commercial zones of Dorchester boulevard and St. Catherine street, and across Mt. Royal via Cote des Neiges to residential areas in Van Horne street.

(2) The human presence: care was taken to make observations at sites where large numbers of people are normally walking, although the residential area is an obvious exception to this rule.

(3) Wind direction: prevailing winds in Montreal are predominantly from the south, southwest, and west all year, with a secondary direction, especially in winter, of predominance from north or northeast (Longley, 1954); observation sites were accordingly arranged in a series of "stair-like steps" from the harbour to Van Horne street along an east-west axis.

(4) Montreal City physiography: three stations are sited on the flat land bordering the St. Lawrence river, five are in the region of terraces rising from this flat land towards Mt. Royal, and the remaining four sample the mountain itself and the land on the side away from the river.

(5) Experimental continuity: since the car was moving generally from east towards west, all observations were made on the right-hand side of the street; also "no parking" areas were chosen to avoid bad generalization of the intersection in people's minds and to ensure that the same spot would be available for observations on each traverse.

The time taken to cover the traverse from start to finish was two hours. Observations at each site lasted four minutes, this being the minimum time necessary to achieve stabilization with an Assmann psychrometer. Wind speeds were averaged over two-and-a-half minute periods within the four-minute observation period. Traverses were made between noon and 2 p.m. This is a time when many people are in the streets at lunch-time, and is also a time when temperature fluctuations are usually minimal during the heat of the day (Powe, 1969).

The seven days of summer midday observations analyzed here comprise those of July 30 and 31 and August 3 - 7 inclusive, 1970. The first two days represent days of high temperature and humidity during an invasion of humid, tropical air from the south, while the remaining days represent the cooling trend which set in with the arrival of polar air following the frontal passage.

Computer calculations of several indices were undertaken. From these, four have been chosen for illustration in fig. 2 to 5. The first two of these represent "sensation-type" indices, whereas the second two are more

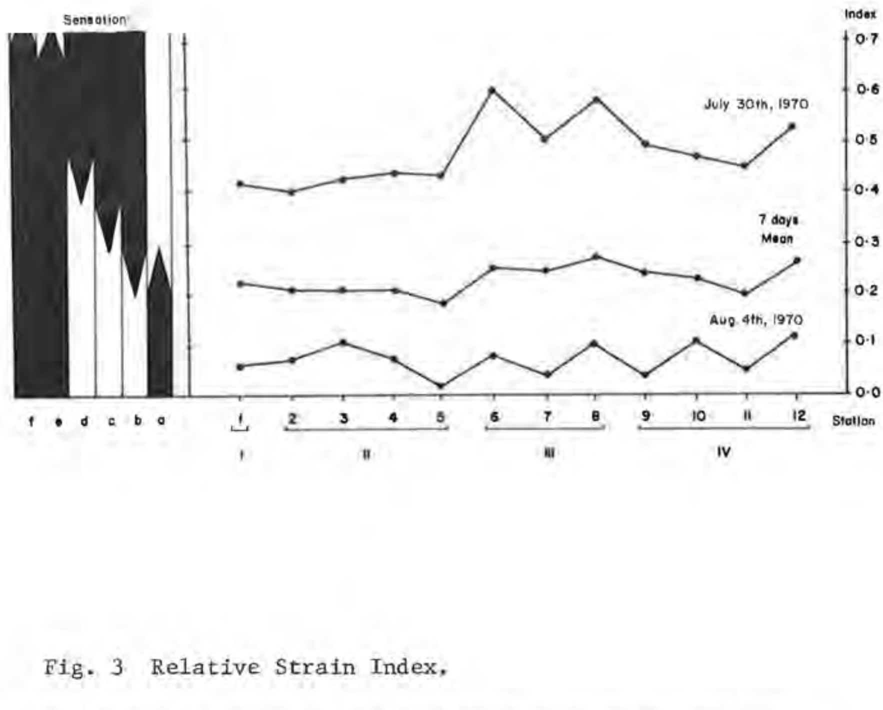

Fig. 3 Relative Strain Index.

The index is shown on the righthand side of the diagram. On the left is an indicator of sensations felt, the black shading indicating in what part of the index scale the majority of people respond. For example, the diagram shows that comfort (column a) is felt by all people below an index of 0.2 and by no people above an index of 0.3, and that some distress (column c) begins to be felt by some above an index of 0.3 and is felt by all above an index of 0.4. The sensation zones are: (a) comfort; (b) discomfort; (c) distress; (d) failure; (e) performance; (f) tolerance.

biological in character. Each figure shows the two extreme days and the mean for the seven days.

Of the indices contained in the first group, the "discomfort index", also called the "temperature-humidity index", is perhaps the best known. It is a form of effective temperature index and is calculated from an empirical formula (Thom 1957, 1958)

$$DI = 0.4(T_a + T_w) + 15.0$$

in which T_a and T_w are dry bulb and wet bulb temperatures respectively in degrees F. The resulting values of the discomfort index (DI) are related to a subjective scale based on reported sensations of people in different experimental groups (fig. 2).

A rather more sophisticated treatment of the same basic idea of conditions influencing feelings of comfort and discomfort is given by the "relative strain index" devised by Lee and Henschel (1966). This index is designed for conditions in a hot environment and assumes the metabolism of a person wearing a light business suit, and walking at 2 m.p.h. in air moving at about 1 m.p.h. This index was corrected for various wind speeds. Under these conditions, the relative strain (RS) is given by the formula

$$RS = [10.7 + 0.74(T_a - 35)] / [44 - vp]$$

where T_a is air temperature in deg. C, and vp is vapour pressure in mmHg. Corrections for non-standard conditions, that is, the conditions which do not meet the specifications, can be applied for specific situations. The authors of the index have interpreted their relative strain values for both healthy and unhealthy persons. Only the scale for healthy persons has been attached to this diagram (fig. 3).

The two biological-type formulae chosen for illustration concern the lungs and heart-rates respectively. An index concerning the former was devised by LeRoy (LeRoy, unpub.) working in West Africa. It is based primarily, but not solely, on the fact that equilibrium temperature of the lungs can only be maintained by evaporative cooling, the rate of which depends on the vapour pressure gradient between the lungs and inspired air. By considering this gradient, along with other factors, notably the connection between vapour pressure and the movement of air into and out of the blood stream, LeRoy devised a pulmonary index which could be simply interpreted in

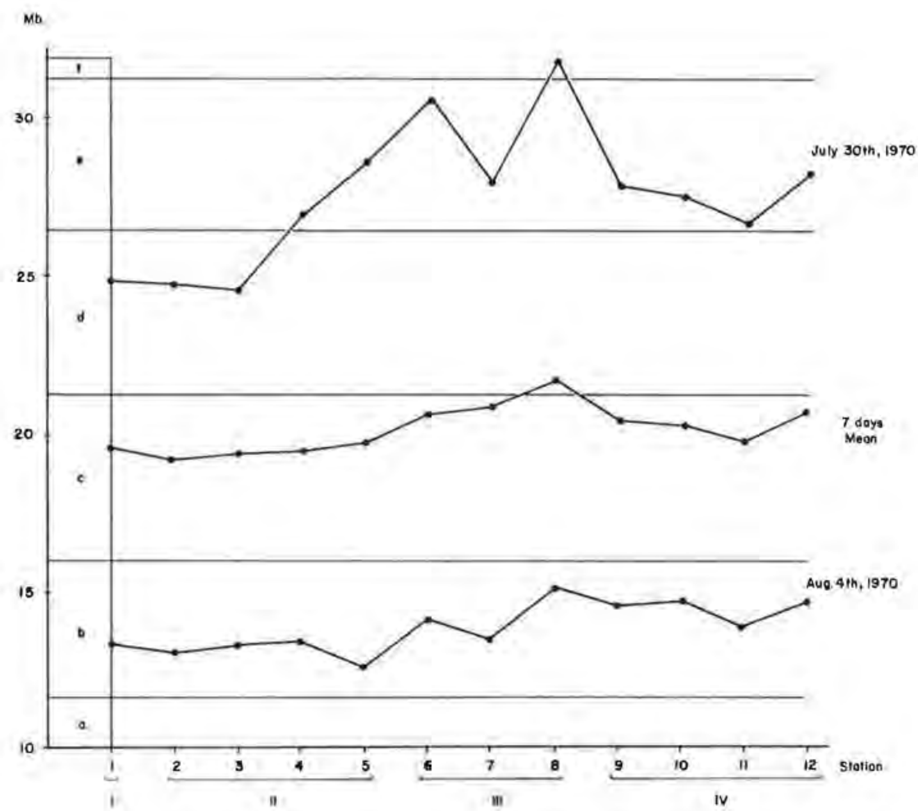

Fig. 4 Pulmonary Climatic Index.

Key to letter classification:

(f) very unhealthy
(e) slightly unhealthy
(d) very debilitating
(c) slightly debilitating
(b) comfortable - healthy
(a) invigorating - healthy

relation to vapour pressure. Thus, healthy and unhealthy, and comfortable and uncomfortable conditions, can be specified by atmospheric vapour pressure given in millibars. That part of LeRoy's index scale relevant to Montreal summer vapour pressures is shown in fig. 4 as a guide to interpreting the data of the diagram.

The fifth diagram (fig. 5) shows data for heart rates in relation to weather conditions calculated from a formula developed by Fuller and Brouha (1966). This formula reads

$$HR = 0.029\ MR + 0.7(T_a + vp)$$

where HR is the heart rate in beats per minute, MR is the metabolic rate in BTU/hr. for a given activity, T_a is air temperature in deg. F and vp is atmospheric vapour pressure in mmHg. For the calculations illustrated a metabolic rate for a person walking on a level surface at 3 m.p.h. was used. For interpretation the calculated heart rates should be referred to a "safe limit" for healthy persons, which varies according to the air temperature and atmospheric vapour pressure, and also in respect to how a person is dressed. The calculation of the "safe limit" for persons normally dressed and in good health may be approximated from the formula

$$SHR = (206.4 - 0.63X) - 10$$

where SHR is the safe limit of heart rate in beats per minute, and $X = (T_a + vp)$ in the units of the previous formula. The "safe limit" is defined as being a condition in which physical effort without frequent rest periods, approximately every 15 to 20 minutes, could be dangerous to health. Under the conditions encountered in our work (MR = 10.50 BTU/hr.) this limit is of the order of 110 beats per minute, as indicated in fig. 5.

The results presented in this article indicate that weather conditions during the summer period analysed produced considerable differences in the physiological sensations experienced from one station to another and one day to another. It would appear that the commercial area of Montreal was the area where the physiological stresses and subjective discomfort tended to be the greatest. This is perhaps a reflection of the influence of the building structures and high incidence of automobile traffic. The latter probably increased to local heating, while the former were probably reflected in the relatively low wind speeds and higher temperatures recorded at the

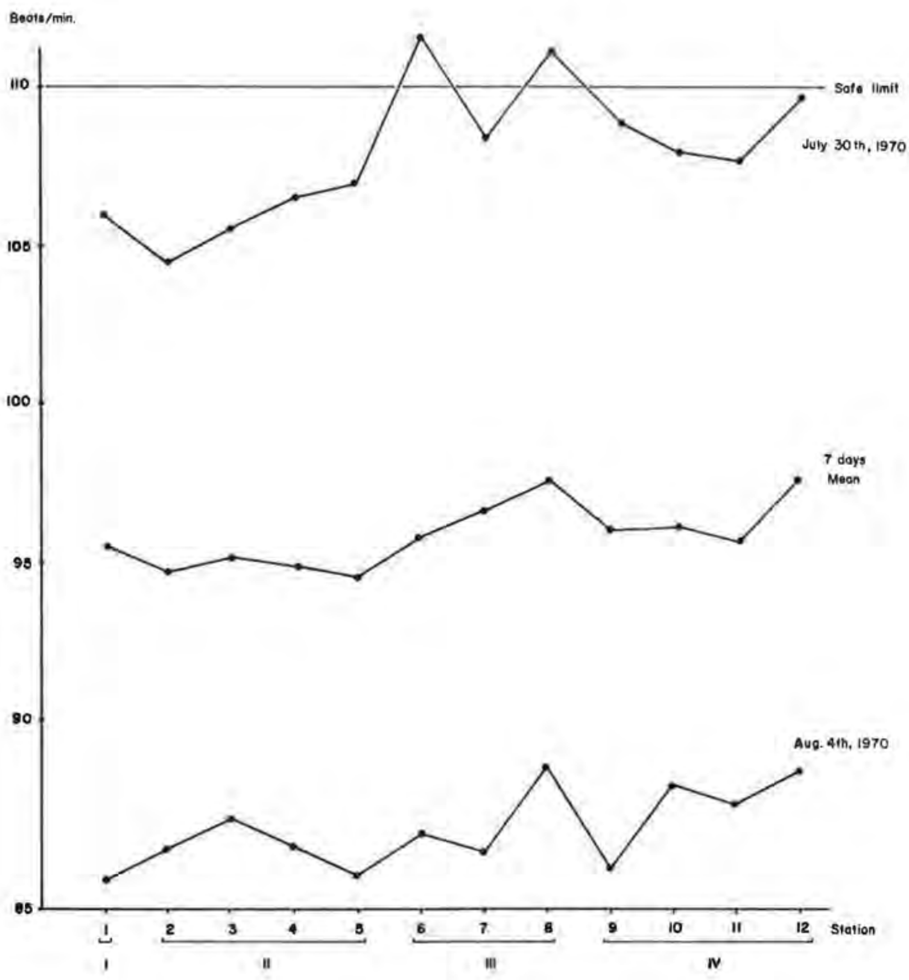

Fig. 5 Heart Rate Index.

stations in this part of the city. In any case, it seems that the pilot study undertaken shows the need to examine further the influence of the city's microclimates upon the welfare, if not of the people living in them, at least upon the "man in the street".

ACKNOWLEDGEMENT

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PSYCHOLOGY AND CLIMATE: A BRIEF REVIEW OF SOME SUBJECTIVE VIEWS

by

Simon Kevan*

Introduction

This essay is an attempt to present an essentially historical outline of the personal and subjective views of a wide variety of authors concerning the effects of climate and/or weather upon the mental processes of man. For the present purpose a subjective view is considered to be an opinion that has been expressed without the support of statistical or experimental observation. Consequently,so as not to inadvertently misrepresent an author's view, the citations used and their interpretations are largely restricted to those from the works of authors most of whom were well aware of the difficulties encountered in trying to separate influences such as political systems, economic and technological standards of living, dietary habits, and the effects of endemic diseases from the influences of the climatic conditions themselves upon the psychological processes of man.

Climate and National Characteristics

One of the earliest works to discuss the effect of atmospheric conditions upon the psychological processes of man is the treatise on "Airs Waters and Places", attributed to Hippocrates of Cos (c. 460 - 357 B.C.). Hippocrates realized that there was an inter-relationship among the meteorological, hydrological and topographical properties of the environment and believed that these factors influenced a human being both physiologically and psychologically. He maintained that in places where the climate is "favourable" and is uniform throughout the year the people are fleshy, inarticulate, lazy, cowardly, and dull, but that in areas where the climate is less amicable and is prone to variations that shock the mind, the inhabitants are lean, articulate, energetic, brave, and intelligent(Jones,1923).

It would appear from the research undertaken for the present essay that Aristotle (c. 384 - 322 B.C.) subscribed to a modified version of Hippocrates' views when he stated that those who live "in cold climate and in Europe are full of spirit, but wanting in intelligence and skill; and

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therefore they retain comparative freedom, but have no political organization, and are incapable of ruling over others. Whereas the natives of Asia are intelligent and inventive, but they are wanting in spirit, and therefore they are always in a state of subjection and slavery. But the Hellenic race, which is situated between them, is likewise intermediate in character, being high-spirited and also intelligent"(Hutchins, 1952). Pliny the Elder (c. 62 - 113 A.D.) held the same opinion as Aristotle. He stated, however, that it is the climate that induces the differences in temperament among people and that these differences arise because of the climatic influences upon physiological processes (Rackham, 1938).

In the literature of mediaeval and early renaissance times several authors, such as Fulke among others, wrote treatises on meteorology. A few of these authors must undoubtedly have discussed the effect of weather and climate upon the psychological processes of man; however, for the present essay it has not been possible to adequately peruse those treatises, largely on account of the difficulty of access and interpretation.

With the advent of "The Age of Reason" in the eighteenth century, Montesquieu (1748) analyzed the past and present governments of European nations and tried to relate the laws of a particular country to its climate. He advanced the hypothesis that if different climates produced different emotions and temperaments, then the laws of the region would be adjusted to those psychological stipulations. In order to justify the premise of this hypothesis he presents personal observations that concern the effect of hot and cold climates upon human nature. He argued that the vigorous nature of the inhabitants of colder regions is physiologically induced, and that such stamina created courage, cunning, and mental activity. Hot climates, on the other hand, enervate the people and cause laziness, deceit, and a mind so dull that "scarsely any punishment is so severe as mental employment; and slavery is more supportable than the force and vigor of mind necessary for human conduct."

Almost a century before, Burton in his "The Anatomy of Melancholy" wrote, with reference to climate and temperament: "as the Air is, so are the inhabitants, dull, heavy, witty, subtile, neat, cleanly, clownish, sick and sound" (Shilleto, 1893). He ascribed the conceited and merry characteristics of the Egyptians to the serenity of the air in which they lived. Congreve (1670 - 1729) attributed the discontent "saturnine, dull, and melancholic" disposition of the English people to the uncertainty of the English weather. Dumas (1844) also attributed the "dark countenance" of the English to their weather. Hartwig (1874) believed that it was the "mild and moist insular climate" of Britain that caused the British to have a "sedate" character. In a similar vein, but carrying the hypothesis a stage further, Geikie (1904), himself a Scot, emphasized that it was the gloomy atmosphere of Scotland that helped to produce the subdued and "grim" nature of the Scots. Hartwig also stated that the large fluctuations in temperature and the dry climate of North America have helped to induce "the 'go-ahead' activity which has done so much for their [the Americans'] peosperity, but at the same time it is the cause of the painful neuralgic diseases to which they are subjected" (Hartwig, 1874). It is interesting to note this particular observation made so long in advance of the well-known obsession with neuroses and psychoanalysis among present day north Americans. Somewhat later, Ward (1918) suggested that the differences between the northern and southern north Americans are caused, in part, by the difference in climate. He reasons that northerners who live in a duller, harsher climate that has a long and dreary winter, are, as a result of these climatic conditions "more serious, more industrious, more enterprising, and act after more mature deliberation". The southerners, on the other hand, "reflecting their brighter skies, are more cheerful, more emotional, more impulsive, more genial, more generous, but also less energetic and more easy-going." More recently Okadu (1935) produced a report that attributes the regional differences in the character and customs of the Japanese people to the climatic environment of each area: his findings were not so very different from those of Ward.

In the late 1930's and early 1940's Mills (1939, 1942), Markham (1942) and Huntington (1945) published works devoted to the study of the effects of meteorological conditions on human activity. Mills tried to determine the physiological basis for the effect of climate on human behaviour. Both Markham and Huntington attempted to relate the rise and fall of civilizations to climatic changes. Markham stresses man's adaptation to the climatic environment, whereas Huntington emphasizes macroclimatic changes. Two of the latter author's theories that are notable suggest that (a) solar cycles are closely related to such social cycles as migration, labour unrest, and business activities, and (b) that climate and the distribution of religious denomination are related in terms of cause and effect.

In contrast to many other authors, Claiborne (1970) is sceptical about the relationship between climate and human behaviour. He points out that most of the observations made may apply to the Western Hemisphere but that most of the theories break down when they are applied to the Eastern Hemisphere.

The Atmosphere and the Individual

Both Burton and Inwards et al. (1950), three hundred years later, lead the reader to believe that Virgil (70 - 19 B.C.) thought that changes in the atmospheric composition brought about emotional changes in man. These authors quote statements by Virgil, however, that refer to the activities of birds and their emotional response to the atmospheric environment. It would appear, therefore, that Virgil's statements should be treated as anthropomorphisms. Celsus (c. 24 B.C. - ?), a Roman physician, was of the opinion that symptoms of melancholy, madness, and epilepsy were at their most intense during spring. He also believed that the south wind was detrimental to the senses and made the body "heavy, moist and languid" and that heat enervated the mind(Grieve, 1838).

Burton wrote "In a thick and cloudy air (saith Lemnius) men are tetrick, sad, and peevish: and if the Western Winds blow, and that there be a calm, or a fair sunshine day, there is a kind of alacrity in men's minds; it cheers up men and beasts: but if it be a turbulent, rough, cloudy, stormy weather, men are sad, lumpish and much dejected, angry, waspish, dull, and melancholy" (Shilleto, 1893). He also claims that winter weather, which is "ugly, foul, [and] squalid ... works on all men more or less, but especially on such as are melancholy, or inclined to it, ..."

Jansen, who is quoted extensively by Maury (1859), obviously believed that seamen were affected mentally by the various weathers and climates through which they travel. He wrote "If all the outbreathings and heartfelt emotions which the contemplation of nature forces from the sailor were recorded in the log-books, how much farther should we be advanced in the knowledge of the natural state of the sea!" Jansen also discusses the land and sea breezes of southeast Asia and their effect on the psychological processes of seamen. He maintains that there is a predictable cycle of meteorological events that occur during the day and that there is an equally predictable mental reaction that corresponds to and is caused by the particular atmospheric condition.

Ward found, as did Celsus, that the south winds [in the Northern Hemisphere] were disagreeable. He also mentions the effect of some of the more regional winds upon the inhabitants. He reports "the sirocco has been described as 'not fatal to human life', but 'deadly to human temper'. In Spain there is a proverb, 'Ask no favours during the salano'. The nervous effect of the dry foehn and chinook of western North America are well known. The zonda of the Argentine is reported as not infrequently making people temporarily insane, and leading to suicide" (Ward, 1918, p. 310). Markham (1942) believed that very dry air caused nervousness and sleeplessness and that moist air produces nervous depression and lethargy.

Both Mills (1939, 1942) and Huntington (1945) maintained that barometric pressure and cyclonic activity are associated with seasonal and daily fluctuation of emotions and moods. Mills found that a low pressure centre produced a feeling of futility, prevented normal mental efficiency and caused an inability to accomplish difficult tasks. The result was that children became restless and irritable and adults became more quarrelsome and fault-finding. After a frontal storm had passed causing a decrease in temperature and a rise in pressure the opposite feelings occurred. Huntington was affected in a similar manner by the passage of fronts, but he reported that the feeling of exhilaration commenced towards the end of the storm, even though the rain may still have been falling. He also introduced the theory that an increase in atmospheric ozone stimulates mental activity (Huntington, 1945).

A book about climatology, written for the layman, by Neuberger and Stephens (1948) points out that abrupt changes in the weather, especially if they disrupt the routines of daily life, break down the conventional human reserve and tend to make people more friendly. On p. 139 of their study they write: "a group seeking shelter from a passing summer shower will freely discuss the current weather situation and its effect upon their plans. Strangers trudging through a heavy snow will cheerfully exchange comments, whereas normally they would pass each other in silence."

Benuzzi (1952) noticed that there is an inter-relationship among a man's mood, his perception of the environment because of varying light intensities, and meteorological conditions. He vividly described men's gaiety while the sun is shining, and the sudden feeling of fear when the sky becomes overcast and the air becomes calm, then the sudden relief felt when rain starts.

Tromp (1963) has mentioned the need for more intensive studies on the effect of weather and climate upon the psychological processes of man. He believes that many psychological changes are related to physiological changes that occur in the circulatory system and to differences in light intensity. Tromp also suggests that differing styles of northwestern European and Italian artists may partially be explained by "the differences in climatologically determined temperament and actual differences in light and shade effects surrounding the painted objects" (Tromp, 1963, p.3). A similar opinion concerning the effect of light intensity upon psychological processes is also held by Critchfield (1966).

Last, but not least, is the psychiatrist (Rosenbaum, 1971) who maintains that our psychological reactions to certain types of weather are related to our childhood memories of reactions to that type of weather. However, this opens up yet another field of speculation about which there is not space for discussion here.

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RESEARCH REPORT

During the past summer R. Wilson and S. Kevan participated in a joint McMaster - McGill evapotranspiration project at Simcoe, Ontario. Evapotranspiration was measured by the Bowen Ratio technique in adjoining irrigated and non-irrigated grass fields. The purpose of the study was to compare the evapotranspiration differences between the fields and to assess the performance of complex and simple forms of the combination model for evaluating evapotranspiration. The latter is particularly important in applied problems since detailed measurements are rarely available. For example, it is desirable to know the magnitude of the error in the calculated potential or equilibrium evapotranspiration as the number of approximations and assumptions is increased. The study at Simcoe will allow assessment of the following: (1) the effect of applying measurements of net radiation and soil heat flux for a dry field to a wet condition; (2) the effect of calculating net radiation from a measurement of solar radiation; (3) the effect of using half-hourly, hourly, or daily measurements of screen temperature and humidity rather than continuous "on site" measurements; (4) the effect of calculating roughness lengths from measurements of vegetation height; (5) the best daily sequence for applying the potential and equilibrium models; and (6) possible simplified procedures for estimating surface resistance to evapotranspiration.

Within the context of his programme of radiation balance studies over southern Quebec, B. J. Garnier undertook a series of measurements of surface radiative temperatures. These were effected by means of a precision radiation thermometer (PRT-5) attached to the step of a light aircraft (see pp. 1-12 of this number of Climatological Bulletin). The experiments were conducted at different times of day and night, and under different weather conditions, during June, July, and August 1971. Flights were made over Montreal, the Mont St. Hilaire region, and in the upper Eaton river basin, some 20 miles east of Sherbrooke.

The flights over Montreal were undertaken as a start to a systematic investigation of the city radiation balance, with particular reference to: (a) conditions at different seasons; (b) the effect of different types of buildings, and of open spaces within the city; and (c) contrasts between the downtown area and suburban districts.

The survey of surface radiative temperatures over the Mont St. Hilaire region was made to examine topographic variations in the value of L↑ in a rural context. Surface observations were maintained at the Mont St. Hilaire climatological station. By comparing these with the aircraft observations it appears that the topographic variation of L↑ over natural surfaces rarely exceeds ±5% of the values measured over grass at a representative site. Since the net short-wave radiation balance can be evaluated in terms of its topographic variations to at least this degree of accuracy from single, representative site observations, the results of the Mont St. Hilaire survey suggest that a rational way to evaluate topographic variations of net radiation through the equation $R_n = (Q+q)(1-a)+L\downarrow-L\uparrow$ may have been found.

Similar results were obtained from the airborne surveys undertaken over the Eaton river basin. These surveys were made in co-operation with staff and students from the University of Sherbrooke, who were responsible for ground truth measurements in the study area. A particular reason for selecting the area investigated was to see if the results could be incorporated into a simple formula to evaluate potential evapotranspiration from net radiation estimates, and then use the results to estimate basin run-off by water balance techniques.

NEWS AND COMMENTS

Richard G. Wilson, assistant professor of climatology at McGill University, has been awarded the Ph.D. degree by McMaster University. His thesis was entitled: "Evapotranspiration Estimates from the Water Balance and Equilibrium Models."

Recent theses in climatology accepted by McGill University include:

(a) "Topography and Solar Radiation in Barbados," by B. K. Basnayake, Ph.D.

(b) "Weather Systems and Precipitation Characteristics over the Arctic," by Stephen Fogarasi, M.Sc.

(c) "Spatial and Temporal Variations in Urban Air Temperatures," by Brett G. Maxwell, M.Sc.

Professor B. J. Garnier visited St. Vincent in July 1971, to attend the XIth Meeting of the Caribbean Meteorological Council and also the meeting of the Advisory Committee to the Caribbean Meteorological Institute.

In Barbados, the climatological station at Waterford is currently being managed by Mr. B. da C Ifill. Now that the Caribbean Meteorological Institute, no more than a mile away, is functioning well, it is probable that the Waterford station will be closed during 1972. The station came into being in 1959 and has performed a useful service in providing basic agroclimatological data as well as a base for special research from time to time. These activities can now be undertaken at the Institute, and the need for Waterford no longer exists. For long term values, observations at the station will be maintained until at least May 1972, which will provide more than a year of overlap with the Institute observations.

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