McGILL UNIVERSITY
Department of Geography

CLIMATOLOGICAL BULLETIN

NO 11
APRIL 1972

McGILL UNIVERSITY, MONTREAL

CLIMATOLOGICAL BULLETIN is published twice a year in April and October. The subscription price is THREE DOLLARS a year.

Please address orders and inquiries to:

Department of Geography (Climatology)
McGill University
P.O. Box 6070
Montreal 101, Quebec
Canada

CLIMATOLOGICAL BULLETIN

CONTENTS

No. 11 April 1972

CLIMATOLOGY IN ENVIRONMENT CANADA - 1972

by

Morley K. Thomas*

The Atmospheric Environment Service, part of Canada's new Department of the Environment, is probably best known to most people as the Meteorological Service. Regardless of nomenclature - the Service actually bore three different official names in 1971 - climatology and climatological work, both services and research, have always been an integral part of meteorology in Canada.

LAST CENTURY

What we now think of as climatology is much older than the national meteorological service. There were some earlier observations, but the first official ones were those taken at the Toronto Magnetic and Meteorological Observatory by British military personnel early in the 1840's. Responsibility for the Toronto Observatory passed to the Canadian government in the early 1850's, and it was around it that a national service was subsequently organized. Meanwhile individual scientists and hobbyists were taking observations in other parts of the country and laying the foundations for Canada's climatological network. One in particular, Dr. Charles Smallwood of Montreal, built his own observatory in the 1850's and subsequently established the McGill Observatory in 1862. A century ago, on May 1, 1871, the new federal government passed an order-in-council appropriating funds for government meteorological work. The new Service, which was soon officially called the Meteorological Service of Canada, was organized by Professor G. T. Kingston, Director of the Toronto Observatory, as part of the Department of Marine and Fisheries where it was to remain for more than 60 years.

By 1872 Professor Kingston had recruited more than 100 stations for Canada's first official network, and by the turn of the century, 300 stations had been established across Canada. Each Annual Report of the Service contained dozens of pages of historical climatic data, but it was not until Mr. R. F. Stupart, later to become Sir Frederic, became Director of the

---

* Morley K. Thomas is Superintendent of Operations in the Climatology Division of the Atmospheric Environment Service, Toronto.

Meteorological Service in 1893 that progress was made in compiling and publishing a comparative climatology of the country. Mr. H. A. Payne, the Dominion Climatologist, was responsible for the two first statistical climatic data publications, while Stupart published several reports on the climate of different sections of the country. After Mr. Payne's death in 1911, Mr. A. J. Connor was promoted to his position and was to remain Canada's Chief Climatologist until his retirement in 1950.

When weather analysis and forecasting techniques were under development a century ago, it was thought that climatological data would prove invaluable to meteorologists and would allow the setting up of systems of analogues or models. It was further believed that after the weather had been observed and recorded for a few years the patterns that undoubtedly would be discovered would make forecasting that much easier. The atmosphere, however, turned out to be exceedingly complex, and by the early days of this century, climatology had been practically dismissed as an aid to weather forecasting. During and immediately following World War I Scandinavian meteorologists developed new theories and techniques by which weather analysis and forecasting could be undertaken on a much better scientific basis than that previously used. While this was a tremendous boost for meteorology in general, it did lead to a decade or two of relatively bleak conditions for climatology since most resources in money and men were devoted to research and development of the new techniques and in enlarging the evolving forecasting system.

THIS CENTURY

After World War II the relative importance of climatology in meteorological services was greatly improved. Meteorology had been found to be of great importance to the armed forces through day-to-day forecasting for operations and by the use of climatology in strategic planning. It was also during this period that punched card systems were being developed thus laying the groundwork for future computer developments. Meteorologists and climatologists also began to realize that many advances in modern statistical theory could be advantageously used with climatological data. But perhaps of more importance was the fact that planners and designers in government and industry were beginning to comprehend that climatological data and information could be of great value to them in their planning for operations and for capital investment. This demand for new services is well illustrated by the increase in staff of the Meteorological Branch's Climatology Division at Headquarters from 12 people in 1945 to more than 100 by 1960.

In 1950 the Division began experimenting with punched cards, and over the next two decades succeeded in bringing modern methods of data processing to most of its routine operations. Computers were introduced in the mid-1960's and the only limitations today to the number of statistical projects which can and should be undertaken are financial resources and the ability of professional and technical personnel to make significant use of the computer outputs. Nor was the entire development of climatology during the 1950's and 1960's limited to better routine processing of data and an increase in the production of climatic data periodicals. In the early 1950's Canada suffered several disastrous floods, and one result was that resources became available to begin hydrometeorological work in 1955. About 20 years ago the Service began assigning or seconding professionals to other government departments - Agriculture, Forestry, National Research Council, etc. - to work in the various fields of applied climatology, but a change in policy in the 1960's led to increased capabilities at Headquarters in such fields as arctic climatology, microclimatology, industrial climatology, agricultural climatology, as well as in hydrometeorology. By the end of 1971, the Climatology Division's staff totalled about 150, with an annual budget of just less than two million dollars.

Thirty-five years ago, in November 1936, the Meteorological Service officially became the Meteorological Division of the Department of Transport. In 1956 the title was changed to the Meteorological Branch, and early in 1971 when the Department of Transport was reorganized into a ministry, the Service became known as the Canadian Meteorological Service. Finally, in June 1971 when Meteorology, Water Management, Fisheries, Forestry, and other smaller services of the federal government were brought together to form a new Department of the Environment, a brand new name - "The Atmospheric Environment Service" - was created.

Along with a new name in 1971 the Service received a new Headquarters building, its third since 1871. For four decades the observatory on the University of Toronto Campus served as national headquarters, but lack of office space and the university's need for space led to the construction of a new building at 315 Bloor Street West, which was occupied during the summer and fall of 1909. Thirty years ago, in 1941, the Climatology Division moved from 315 Bloor Street West to a nearby building beginning an exodus that was only completed in the summer of 1971 when all Meteorological Headquarters' staff were reunited at a new building at 4905 Dufferin Street on the edge of Metropolitan Toronto, some 11 miles NNW of the downtown area (fig. 1). During the 1950's and 1960's different Headquarters' Divisions and Sections had been

Fig. 1 The New Buildings of the Atmospheric Environment Service at 4905 Dufferin Street, Downsview, Ontario.

Fig. 2 A Selection of Publications of the Atmospheric Environment Service.

located in as many as six different buildings - the Climatology Division was successively in the old McMaster building, the Medical Arts building at 77 Admiral Road, at 260 Richmond Street, and, finally, from 1960 to 1971 in the Mackenzie Building in downtown Toronto.

1972 ORGANIZATION

Although a relatively extensive reorganization of the entire Atmospheric Environment Service is expected to take place in 1972, the current Headquarters' Divisions are - Administration, Basic Weather Climatology, Forecast, Instruments and Research and Training - each administered by a Chief who reports directly to the Assistant Deputy Minister. Besides the Toronto-based activities, where more than 600 are employed, the Central Analysis Office in Montreal and other smaller units are administered directly from Headquarters. Most field operations, however, are administered by six Regional Directors of the AES who also report to the ADM. The total number of AES employees is about 2500.

At Headquarters most climatological matters are the responsibility of the Climatology Division. The Division is staffed by approximately 150 employees and is divided into the Operations, Climatic Data Processing, Climatological Applications and Hydrometeorological Sections. The Operations Section is responsible for the collection and technical quality control of all data, the preparation and publication of historical climatic data periodicals and of statistical climatological summaries, the archiving of publications and documents, and the general provision of information and data (fig. 2). The Climatic Data Processing Section transfers specific climatic data to punched cards and other computer accessible media, participates in the quality control and publication activities, undertakes computer projects originating both from within and outside the Service and maintains the official Canadian climatic archive of tapes, cards and film. The Climatological Applications Section is responsible for applying meteorology for the benefit of all economic activities in the country and for the health and well being of Canadians, while the Hydrometeorology Section carries out similar activities in connection with hydrometeorology and water. In addition, this latter Section is primarily responsible for the participation by AES in such activities as the International Hydrological Decade and the International Field Year for the Great Lakes.

SERVICES

The Atmospheric Environment Service provides three services to the public of Canada - a) forecasting, b) climatological, and c) applications and consultation services. Of these, the forecasting service is by far the most extensive and is provided by a system consisting of a Central Analysis Office, Regional Weather Centrals and several dozen smaller Weather Offices. These offices provide the Canadian public with information on today's and tomorrow's weather, 24 hours a day, 7 days a week. Several hundred meteorologists and technicians are employed directly in providing forecast services and more money is spent on this type of work than any other, except the observational programs.

On the other hand, climatological services are provided by relatively few people and it has only been in recent years that personnel have been trained as specialists in this field. Both forecast and climatological services are provided from all weather offices, and at most of the major offices there is at least one climatological services specialist who is responsible for handling requests for climatological data and information. A larger unit in the Climatology Division at Headquarters is responsible for handling those enquiries that are national in scope and those that are too complex for servicing in Regional offices. Guides and manuals have been circulated for use in all field offices in an attempt to standardize and improve climatological services across the country.

The third type of service, meteorological applications and consultation, may be considered to be just in its infancy, although by 1972 there were eight such specialists, known as Scientific Services Officers, in Regional offices providing consultation services to other government departments and to the public in such fields as hydrometeorology, agriculture, forestry, and industrial siting. In addition, both the Climatology and Research and Training Divisions at Headquarters have groups of such specialists who are responsible not only for advising and assisting Regional personnel, but also for undertaking those national and complex projects which cannot be done in the field.

CLIMATIC DATA

The biggest single set of responsibilities of the Headquarters' Climatology Division is the collecting, processing and quality controlling of all current Canadian climatic data, the publishing of historical climatic data periodicals and the archiving of the data for future use. In the Regional offices about a dozen employees are responsible for preliminary data control work, while at Headquarters about 50 technicians and data processors complete the job. When modern methods of data processing were introduced more than 20 years ago, punched cards were used to process and store the data, but in recent years magnetic disks and magnetic tape have been used for this work (fig. 3). The archives now contain the equivalent of about 80,000,000 punched cards, of which 40,000,000 are on magnetic tape.

More than 20 years of hourly data from about 150 stations are in the card and tape library, while such daily climatological data as temperature extremes and precipitation amounts are available in similar format for those 8,000 stations that have existed for 10 years or more.

TABLE ONE

Decadal Census of Climatological Stations

year	BC	YT	NWT	ALTA	SASK	MAN	ONT	PQ	NB	NS	PEI	NFLD	TOTAL
1861	0	-	0	-	-	-	2	1	1	0	0	0	4
1871	1	-	0	-	-	1	48	40	8	26	0	2	126
1881	8	-	13	-	-	5	70	15	12	19	3	4	149
1891	19	-	26	-	-	76	165	24	16	17	3	4	350
1901	54	0	54	-	-	37	117	19	12	13	3	8	317
1911	81	2	0	66	59	29	96	26	10	20	3	6	398
1921	138	3	6	88	54	33	135	76	22	29	2	9	595
1931	221	2	21	80	88	36	150	118	20	29	3	9	777
1941	219	6	23	101	98	42	166	120	59	33	3	37	907
1951	241	12	37	135	167	68	306	196	46	56	4	30	1298
1961	397	14	80	291	252	106	412	247	51	83	13	56	2002
1971	467	33	59	410	240	159	430	406	64	87	16	63	2434

Currently there are approximately 2,500 climatological stations across Canada, of which 240 are principal or first-order stations reporting data periodically each day for analysis and forecast purposes. Of these approximately 170 are hourly reporting stations where a weather watch around the clock 7 days a week is maintained. Most of the 2,200 climatological stations report both temperature extremes and precipitation totals while a number of principal and climatological stations have additional equipment which enable them to report such parameters as rainfall intensity, soil temperature, bright sunshine, and solar radiation. In addition to surface data the Atmospheric Environment Service has 32 upper air stations where twice daily balloon flights are made to report on temperature, humidity and pressure conditions to heights exceeding 100,000 feet. Historical upper air data are available since the

Fig. 3 Data Recording and Magnetic Tapes in the Atmospheric Environment Service.

1940's, but it is only since 1950 that the data series are considered homogeneous and complete. An indication of the development of climatological stations over the country is given in Table One.

DATA PUBLICATIONS

There are three separate and distinct kinds of climatic data. "Historical climatic data" are the official published data which appear in such periodicals as the Monthly Record, the Monthly Bulletin, and the Monthly Radiation Summary. These are checked and processed data from specific places at specific times and might be considered to be the basic building blocks in our climatic archives. On the other hand, "statistical climatic data" are those which are found in summaries or tables of Climatic Normals and other publications where the data have been statistically treated. A third kind, "current climatic data," might also be called weather information since these are data that have only recently been reported, are immediately available but have not been quality controlled. The data in the locally published Monthly Meteorological Summaries and in the Canadian Weather Review are examples of current data.

Appendix III following this article gives some information on both the current and historical climatic data periodicals being published in 1972. The best sources of statistical climatic data in 1972 are the Temperature and Precipitation Tables (6 Regional volumes), and the Climatic Normals series (6 volumes according to climatological elements). Work is currently underway on the new 1941 - 1970 normals, and before the end of 1972 it is hoped that the first volumes of statistical climatic data based on this period will be published. Over the past few years 10 series of climatic maps have been published, and in 1970 these were bound into an Atlas of Climatic Maps. Upper air averages of temperature, humidity and altitude based on observations from the 1951 - 1960 decade are available in either tabular or map form.

In this account of the AES' Climatology Division, the organizational history and the current operational activities have been stressed at the expense of providing more information about climatological and hydrometeorological research, modern methods of data processing and the very large and highly promising field of meteorological applications. It is hoped, however, that knowledge of the basic history will set the stage for a better understanding of all climatological activities in Environment Canada today.

APPENDIX I

PRINCIPAL OFFICERS RESPONSIBLE FOR AES CLIMATOLOGICAL WORK
MARCH 1972

Assistant Deputy Minister, Atmospheric Environment Service	- J.R.H. Noble
Chief, Climatology Division	- C.C. Boughner
Superintendents:	
Climatology Operations	- M.K. Thomas
Climatic Data Processing	- B.S.V. Cudbird
Hydrometeorological and Marine Applications	- T.L. Richards
Climatological Applications and Consultation	- G.A. McKay

APPENDIX II

CLIMATOLOGICAL ELEMENTS, NETWORKS AND STATIONS - JANUARY 1972

Elements	No. of Stations
Daily temperature extremes	1895
Daily precipitation totals	2375
Precipitation intensities	428
Hourly wind mileages	188
Daily soil temperatures	58
Daily evaporation	118
Hourly sunshine	280
Hourly radiation	46

Networks	
Principal stations	
- total	278
- synoptic	235
- hourly (24 hr.)	163
Climatological stations	2156
Upper air stations	36

APPENDIX III

SELECTED AES CLIMATOLOGICAL PUBLICATIONS

A - CLIMATIC DATA PERIODICALS

CANADIAN WEATHER REVIEW (monthly)

An interim review of the month's weather available three weeks after the close of each month. Contains text, maps and data from principal stations.

MONTHLY RECORD - METEOROLOGICAL OBSERVATIONS IN CANADA

The complete monthly summary of temperature, precipitation, wind, sunshine, etc., from all official Canadian stations. Available within 6 months of the close of each month.

MONTHLY BULLETIN - CANADIAN UPPER AIR DATA

Data from 34 stations for 20 standard pressure levels for 2 ascents per day are listed. Available within six months.

MONTHLY METEOROLOGICAL SUMMARY

Summaries are currently issued from about 50 local Weather Offices and are available between the 5th and 15th of the following month.

ANNUAL METEOROLOGICAL SUMMARIES

About 25 local Weather Offices produce these summaries.

B - STATISTICAL CLIMATIC PUBLICATIONS

TEMPERATURE AND PRECIPITATION TABLES

A set of six Regional volumes containing mean monthly and annual values based on the 1931-1960 period.

CLIMATIC NORMALS

A set of six volumes containing mean and extreme values of temperature, precipitation, sunshine, cloud, pressure, sunshine, thunderstorms, humidity, wind and frost data based on the 1931 to 1960 period as far as possible.

THE CLIMATE OF CANADA

Complete climatic data tables are listed for 45 stations in this reprint from the Canada Year Book.

UPPER AIR CLIMATE OF CANADA

Maps and tables based on data from 34 stations over the period 1951-60.

C - REGIONAL CLIMATOLOGICAL STUDIES

Volumes are available on Central Canada, Southern Ontario, Northern Ontario, Quebec, Saskatchewan, Newfoundland, Montreal, Winnipeg, Vancouver, Toronto, Hudson Bay and the Arctic.

D - CLIMATIC MAPS AND ATLASES

ATLAS OF CLIMATIC MAPS

Thirty sheets containing about 130 maps illustrate the patterns of climate throughout the country.

E - REFERENCE LISTS

Guide to the Climatic Maps of Canada
Guide to Canadian Climatic Data
Climatological Station Catalogues
Bibliography of Canadian Climate
Inventories of Data on Cards and Tapes

(For complete information write for A Selected List of Climatological Publications to Atmospheric Environment Service Headquarters, 4905 Dufferin Street, Downsview, Ontario).

APPENDIX IV

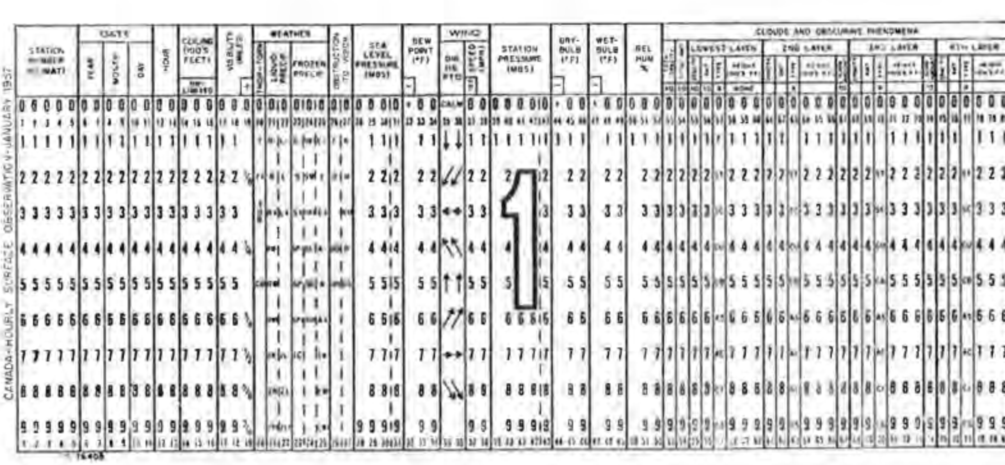
DATA AVAILABLE ON CANADIAN CLIMATIC DATA PUNCH CARDS

CARD NO. 1: Hourly Surface Observations.

This card format documentation was prepared for use with punched cards produced from hourly surface observations, including non-24-hourly reports, from January 1, 1947. All revisions in reporting and punching procedures, as well as changes in time standards, are documented as required. Annually up-dated inventories are maintained by the Climatology Division.

The weather elements reported comprise: ceiling, visibility, weather, obstruction to vision, sea level pressure, dew point temperature, wind, station pressure, dry bulb temperature, wet bulb temperature, relative humidity, clouds and obscuring phenomena - amount, type and height.

Cards are punched for each regularly scheduled observation. Cards are missing for those hours when observations were not recorded. However, when only the occasional hour was not recorded an observation missing card may be punched containing indicative information, station number, year, month, day, and hour. Prior to June 1958, missing data were indicated by "Y" or a blank, but since June 1, 1958, blanks only are used for missing data.



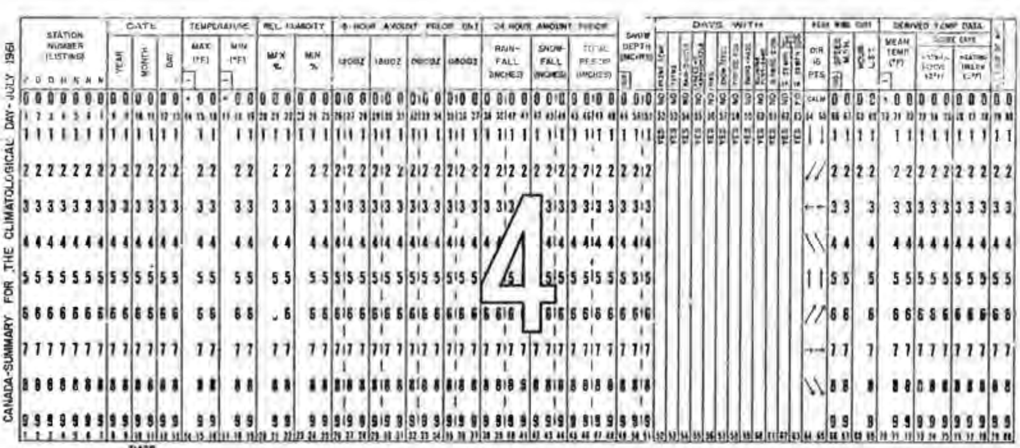
CARD NO. 4: Summary for the Climatological Day.

This card format documentation was prepared for use with punched cards produced from summaries of climatological day observations dating back to January 1, 1947. Data from earlier years are available for a few stations. All revisions in reporting and punching procedures, as well as definitions of a climatological day as they existed from time to time are documented. Revised inventories are up-dated annually by the Climatology Division.

The elements reported comprise: maximum and minimum temperatures, 24-hourly amounts of rainfall, snowfall and total precipitation and, where available, maximum and minimum relative humidity, 6-hourly precipitation totals, snow depth, peak wind gust, and whether or not various phenomena such as thunderstorms, hail, freezing rain, smoke, etc. occurred.

For first order stations only computed data are available concerning mean daily temperature, growing degree days above 42°F, and heating degree days below 65°F.

Various round-off procedures have been adopted for recording temperatures in whole degrees. Snowfall is punched to a tenth of an inch.



Further Information: The foregoing provides a general indication of the nature and content of the card-punched data available. For complete details of the contents of the more than 20 cards in current use, please write to the Atmospheric Environment Service.

DAILY SOLAR RADIATION DIFFERENCES BETWEEN STATIONS IN SOUTHERN CANADA: A PRELIMINARY ANALYSIS

by

R. G. Wilson and D. E. Petzold*

1. Introduction

It is well known that the amount of solar radiation received at the earth's surface during any short time interval can vary considerably within a short distance. This variation arises primarily because the same weather conditions, particularly clouds, are not experienced at the same time in all parts of a region. The degree and nature of the variability are still unknown factors but they must be understood before we can rationally extend the point measurements which we already have and before we can properly design new networks of radiation stations.

Without a very dense network, this problem essentially concerns the assumption that data from a "representative" site are directly applicable to another site in the same region. Consideration must be given to three factors: error, distance, and time. The error, represented by the difference in the amount of radiation received at the two sites, can be expected to increase as the distance between the sites increases and to decrease as the time interval increases. Thus one might visualize the answer to this problem being presented as a series of graphs which would indicate the probabilities of exceeding certain errors as functions of both distance and time.

An analysis of this problem might be separated into three steps: (1) determining the relationship between the magnitude of the error and distance; (2) determining the frequency distribution of the errors; and (3) recalculating the error for longer time intervals. This paper presents some preliminary results for steps (1) and (2) using solar radiation data for stations in southern Canada.

2. Procedure

A list of the stations chosen for the analysis, their locations,

* R. G. Wilson is Assistant Professor of Climatology at McGill University. D. E. Petzold is a graduate student in climatology in the Department of Geography at McGill University.

TABLE ONE

Radiation stations used in the analysis

STATION	ABBREVIATION	LATITUDE (N)	LONGITUDE (W)
Elora Res. Stn.	EL	43°39'	80°25'
Guelph OAC	GU	43°31'	80°14'
Mont St. Hilaire	SH	45°32'	73°10'
Montreal Jean Brébuf	ML	45°30'	73°37'
Ottawa N.R.C.	OT	45°27'	75°37'
Suffield A	SU	50°16'	111°11'
Swift Current CDA	SC	50°16'	107°44'
Toronto	TO	43°40'	79°24'
Toronto Met. Res.	TM	43°48'	79°33'
Toronto Scarborough	TS	43°43'	79°14'

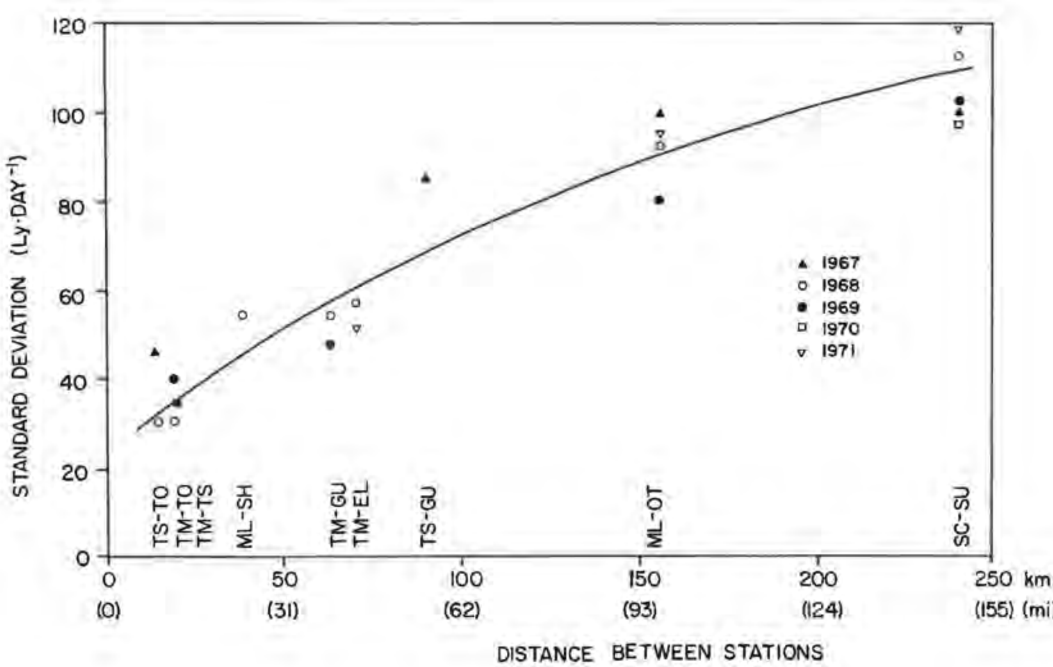


Fig. 1 Variation of Standard Deviation with Distance.

and station abbreviations to be used here are presented in Table One. The Mont St. Hilaire data were available at McGill and data for the other stations were extracted from the "Monthly Radiation Summary" which is published by the Atmospheric Environment Service. In the present analysis we have used daily data for 4-month summer periods (June to September) from 1967 to 1971. Summer periods were chosen to minimize the possibility of urban air pollution effects since many of the stations are located in or near large cities. Pairs of stations which provided simultaneous records were selected and the difference in the recorded totals was calculated for each day of the 4-month period.

3. Results

a) Average differences between stations

Mean and standard deviations of the differences for each period are shown in Table Two. Most of the average differences were small, indicating that the general radiation conditions were the same at the two stations concerned. In order to make a definite decision we have assumed that the recorded value of solar radiation at any station might be in error by as much as ±5.0%. Thus the difference between two stations would not be significant unless it exceeded ±7.1% (= $\sqrt{(5.0)^2 + (5.0)^2}$) of the average amount of radiation received at the two stations. The four values which exceeded this limit are indicated by stars in Table Two. It is possible that the high TO-TS value could have been caused by air pollution effects since both stations are located in urban areas of Toronto, and the two high SU-SC values might indicate that the 238 km distance is near the margin of the homogeneous radiation region for this four-month period. No explanation has been found for the high TS-GU value for 1967.

b) Variation of standard deviations with distance

As shown in Fig. 1, the standard deviation of the differences between stations was closely related to the distance between the stations. The correlation coefficient between the standard deviation (S, ly day^{-1}) and distance (D, km) was 0.95, and a polynominal fitted to the data gives

$$S = 26.5 + 0.541\ D - (8.4 \times 10^{-4}\ D^2).$$

The intercept value of 26.5 ly day^{-1} corresponds closely to the estimated error in mean differences between stations with a solar radiation average of about 400 ly day^{-1}.

It should be noted here that it was necessary to choose pairs of

TABLE TWO

Solar radiation differences between stations for June - September periods (radiation values in ly day^{-1}), 1967-71.

STATIONS[1]	DISTANCE (km)	YEAR	DAYS	MEAN SOLAR	DIFFERENCES $\bar{d}$	S
TO - TS	14	1967	122	478	-38*	46
		1968	121	468	-12	30
TM - TO	19	1968	121	462	24	29
		1969	116	450	2	41
		1970	104	461	13	35
		1971	118	458	-10	35
TM - TS	27	1968	121	468	12	41
ML - SH	37	1968	103	401	12	54
TM - GU	64	1968	113	471	-15	54
		1969	111	441	16	48
TM - EL	71	1970	107	451	26	56
		1971	118	455	0	49
TS - GU	84	1967	122	471	40*	83
ML - OT	156	1967	114	420	26	99
		1968	121	423	-17	93
		1969	120	427	4	80
		1971	94	439	-14	94
SU - SC	238	1967	104	541	58*	101
		1968	122	466	46*	113
		1969	115	498	7	103
		1970	118	477	26	97
		1971	100	472	17	121

[1] See Table One for station abbreviations.

* Stations with significantly different radiation values (see text, p. 17).

stations which have a greater east-west separation than north-south. Slightly larger standard deviations might occur in north-south directions if an imaginary line joining the stations lies across primary storm paths rather than along them. Larger mean differences would also be expected in north-south directions because of natural latitudinal variations in solar radiation.

c) Frequency distributions of differences between stations

Each data set was subjected to a chi-square test to determine if the daily differences between stations had a normal distribution. Data were divided into eight groups about the mean difference ($\bar{d}$): six of these covered spans of 0.5S between $\bar{d}$ - 1.5S and $\bar{d}$ + 1.5S, and the remaining two categories covered data which fell below $\bar{d}$ - 1.5S and above $\bar{d}$ + 1.5S. The calculated chi-square values for each data set are shown in Table Three and examples of the distributions are shown in Fig. 2. Of the 22 data sets tested, 12 gave positive results at a 5% level and this number increased to 16 at a 1% level. It is significant that 5 of the 6 sets which tested negatively at both levels concerned the stations TO-TS and SU-SC. Both of these had sets in which the test for mean differences also failed, and it is felt that the suggestions advanced above to explain this failure are also applicable here.

As is apparent from Fig. 2, the observed distributions tended to have a higher peak than the normal distributions. This occurred in nearly every case and it means that there is a slightly greater chance of finding small differences than would be predicted on the basis of a normal distribution. It was first thought that this feature might be related to the use of the 4-month period, such that a larger number of small differences would be produced during August and September when radiation totals are lower than in June and July. With this possibility in mind, we analysed the data for ML-OT, TM-TO, and SU-SC for individual months as shown in Table Four. The standard deviations in June and July were greater than those in August and September in each case. This indicates that it might be better either to use 2-month periods or to express the standard deviation of the differences as a ratio of the mean total solar radiation. However, the observed distributions still had higher peaks than the corresponding normal distributions, so it would seem that this feature is characteristic of these data.

TABLE THREE

Calculated chi-square values for June - September periods and decisions of tests for normality. (Critical values of chi-square: 5% level = 12.59; 1% level = 16.81)

STATIONS	YEAR	CALCULATED CHI-SQUARE	DECISION 5% level	DECISION 1% level
TO - TS	1967	22.35	no	no
	1968	22.25	no	no
TM - TO	1968	7.84	yes	yes
	1969	4.40	yes	yes
	1970	5.25	yes	yes
	1971	4.60	yes	yes
TM - TS	1968	6.18	yes	yes
ML - SH	1968	13.04	no	yes
TM - GU	1968	8.00	yes	yes
	1969	11.80	yes	yes
TM - EL	1970	18.81	no	no
	1971	12.12	yes	yes
TS - GU	1967	16.55	no	yes
ML - OT	1967	5.07	yes	yes
	1968	2.39	yes	yes
	1969	13.35	no	yes
	1971	4.13	yes	yes
SU - SC	1967	25.12	no	no
	1968	8.40	yes	yes
	1969	26.62	no	no
	1970	22.81	no	no
	1971	16.81	no	yes

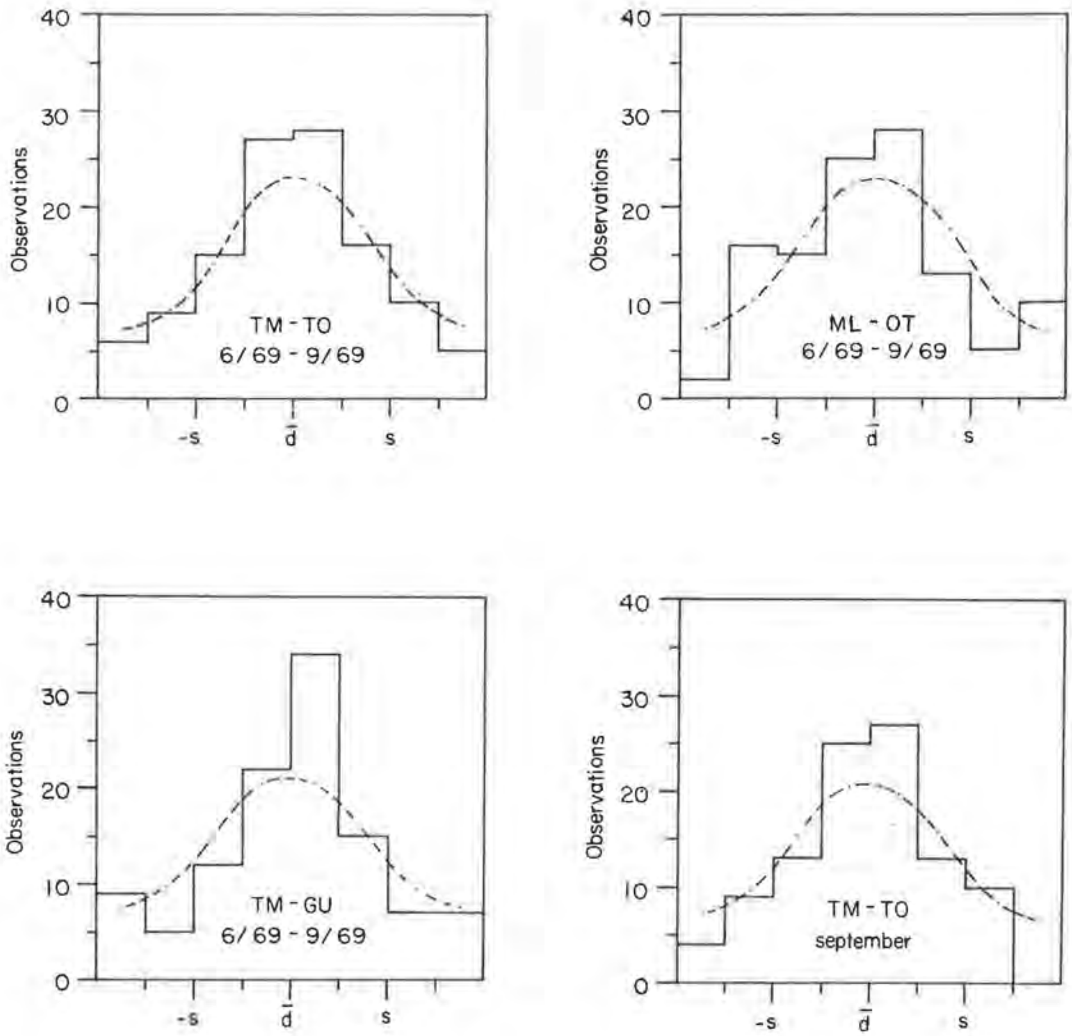


Fig. 2 Frequency Distributions of Differences between Stations.

TABLE FOUR

Solar radiation differences between stations for individual months (radiation values in ly day^{-1})

STATIONS	MONTH	DAYS	MEAN SOLAR	DIFFERENCES $\bar{d}$	DIFFERENCES s
ML - OT (1967-71)	June	127	475	- 2	106
	July	148	492	14	104
	August	119	425	- 6	83
	September	111	312	13	80
TM - TO (1968-71)	June	114	496	9	45
	July	118	528	8	36
	August	121	477	10	31
	September	107	315	1	35
SU - SC (1967-71)	June	140	543	35	140
	July	140	575	52	106
	August	137	502	26	86
	September	142	342	10	90

4. Conclusions

This preliminary analysis has indicated that the magnitude of daily solar radiation differences between stations in Southern Canada varies in a predictable manner according to the distance separating the stations, and that the differences are distributed normally. From this stage it is a simple operation to determine the probabilities of exceeding any error limits when solar radiation data are extended from one station to points in the surrounding region. The third step of the problem posed in the Introduction, that of using longer time intervals to decrease the errors, can be approached by using the Central Limit Theorem. The mean difference between stations will remain the same in any data set whether 1-day, 2-day, or 3-day, etc. values are used, but the standard deviation will decrease when the averaging interval is increased. According to the Central Limit Theorem, the standard deviation for n-day intervals should be given by dividing the 1-day standard deviation by $\sqrt{n}$. New probability levels then could be calculated for the increased time intervals.

It is now expected that the analysis will be performed for other periods of the year, and the possible existence of a single annual standard deviation-distance relationship will be tested by expressing the standard deviation as a ratio of the mean solar radiation. Similar tests also will be performed for stations in the subarctic region of Labrador-Quebec.

RESEARCH REPORT

The programme of research into the energy budget and microclimate of Barbados, directed by B. J. Garnier and sponsored by the Office of Naval Research (Geography Branch), Washington, D.C., has now been completed. The work was begun in July 1968 with a field programme which lasted until the end of December the following year. This field work comprised a series of special periods of observation, including a programme of remote sensing using a PRT-5 installed on a light aircraft, against a background of the continuous observation of standard meteorological parameters in different parts of the island, but especially at Waterford. The work is evaluated in a series of Technical Reports and a comprehensive summary of the results achieved is available in a Final Report, issued December 1971 and entitled "The Energy Budget and Microclimate of Barbados."

A general conclusion arising from the work is that the energy budget and microclimatic conditions over Barbados represent the interrelationships between: (a) the overall synoptic atmospheric situation; (b) the pattern of cloud and precipitation; and (c) the topographic (surface) variations in net radiation which are, themselves, closely related to surface variations of incoming short-wave radiation. The first two of these three factors have been, and continue to be, intensively studied by meteorologists, particularly those associated with Florida State University and also the BOMEX programme. The third factor is one which, although realised perhaps in a general way, could do with a more intensive scrutiny. Only its potential significance has been brought out by the recently-concluded work on the energy budget which has concentrated mainly on local surface variations in the radiation balance. A particularly interesting feature of the study of these variations has been the revelation of the intense and rapid heating of east-facing slopes over the island during the early hours of the day. It has been shown that the heating of these slopes responds rapidly to the rising sun and is at a maximum by 0900 to 1000 hours, whereas elsewhere on the island the maximum is delayed to 1100 hours or later. Moreover, the high atmospheric transmissivity of early morning hours contrasts with the lower atmospheric transmissivity normal from 1000 hours onwards, and means that west-facing slopes are not normally heated by the afternoon sun to the same extent as are east-facing slopes by the morning sun. This contrast is further accentuated by the fact that the steepest slopes and most rugged terrain in Barbados are east-facing. The contribution of this differential heating in time and space to the cloud streets and precipitation patterns across the island, more particularly under weakly disturbed atmospheric conditions, is a matter which may well repay further study.

Another result of the Barbados work is to show that surface variations in L↑ over the island at a given time rarely exceed ±5% of the values observed at a level grassed site centrally, or representatively, located on the island. The same feature is becoming apparent in the analysis of the results of the remote sensing experiment (see Bulletin No. 10, October 1971, pp. 1-12) undertaken over southern Quebec in the summer of 1971. These combined results, from a tropical and a mid-latitude location, encourage the belief that topographic variations in net radiation can now be rationally evaluated by means of observations taken at a single representative site, as has been shown to be the case for short-wave radiation in numerous reports arising from the climatology programme at McGill University. For evaluating net radiation, it is necessary to observe at the representative site all the components of the equation

$$R_n = (Q+q)(1-a) + L\downarrow - L\uparrow.$$

All of these except L↓ are easy to measure. This value can be, and is normally, evaluated as a residual in the basic equation. Moreover, since L↓ is an atmospheric phenomenon it can be treated as valid for the area for which the site is representative. Albedo may be obtained and inserted on an appropriate base map by reference to land-use maps or air photographs. The completed research in Barbados and the currently continuing research in southern Quebec and, more recently, research in the sub-Arctic centred on the McGill University Sub-Arctic Laboratory at Knob Lake (Schefferville), seem to have opened up a rational approach to solving spatial variations in the net radiation balance, with all that such knowledge implies for energy budget and microclimatic studies.

A second piece of completed research which can now be briefly reported on here is that undertaken by Daniel LaFleur into some aspects of the human environment of the city of Montreal. The last number of this Bulletin (see Bulletin No. 10, October 1971, pp. 13-23) contained an account of the study's principal aims and the observation methods used, together with some comments on conditions during one week in summer. The whole survey, however, sampled autumn and winter conditions as well as those of summer. The results show that at all seasons there is considerable spatial variation in human comfort conditions across the city. The differences, moreover, were normally large enough to embrace at least one and often two human comfort or stress classes during the course of a single two-hour traverse. Data analyses indicated that differences in wind speed made the greatest contribution (80%) to these variations during autumn and winter months. Wind was also an important contributor to spatial variations of the comfort indices of summer, but at this time of year radiation appeared to be a greater cause of variation from one station to another. In general, it was found that temperature and humidity conditions did not vary greatly in a spatial sense within the city and consequently contributed little to variations in the wind chill factor in winter or to comfort indices and thermal and biological stress in summer. Their function appears to be that of providing a uniform base level for the detailed spatial variations. Moreover, their characteristics seem to follow the nature of mesoscale conditions at large, correlating in a general way with the values recorded at Dorval airport. This suggests that the particular influence exerted by the city *per se* upon conditions of human comfort is through local wind and radiation factors, with the former being the more important of the two for most, but not all, of the year. There is a lesson here perhaps for urban planning.

Early in the past winter Auguste Blanchais started a series of observations aimed at examining the distance to which urban influences are felt in the local climates of the surrounding countryside. The observations have concentrated mainly on short-wave radiation. This element has been chosen initially because the atmospheric attenuation of direct radiation can be considered as integrating the major city influence on climate through atmospheric pollution, while the distance to which this attenuation extends over the surrounding countryside indicates the influence of the transport of city pollutants by the wind. The latter factor is related both to the wind speed and direction and the degree of instability in the atmosphere.

The observational procedure has consisted of making traverses with instruments mounted on a car. A Kipp solarimeter was used for short-wave radiation measurements. An adjustable shade-ring was devised to permit the observation of diffuse radiation as required and the instrument was mounted on a stand with a counter-weight so as to ensure that it remained horizontal whatever the angle of the car's roof. The output from the solarimeter was read on a Comark millivoltmetre. Temperature and humidity were observed by means of an Assmann ventilated psychrometer, wind speed by a Casella sensitive cup anemometer, and wind direction by means of a nylon "wind-sock" fixed to the radio antenna of the car.

The general procedure was to take observations at fixed points, the points being the same for each traverse made, along the traverse routes. The principal route accorded with the dominant wind direction from the west. The traverse began at the corner of Sherbrooke and Atwater Streets, continued east across Victoria Bridge and then followed route 9 towards Mont St. Hilaire. There were 12 observation points along this route: five on Montreal Island and seven on the other side of the St. Lawrence river. A secondary traverse was in a north-south direction, along Sherbrooke Street and across the Champlain Bridge: there were five observation stations within the city on this traverse.

A total of eleven traverses was made in the winter months. They were undertaken on fine days under clear skies or under conditions of light, stratified high cloud which could be considered as supplying a uniform sky coverage across the city and surrounding countryside. Of the eleven experiments, six were between 0900 and 1100 hours, three from 1100 to 1300 hours, and the remaining two between 1300 hours and 1500 hours EST. Since each experiment lasted approximately two hours it was necessary to adjust the results to some standard. For the direct short-wave radiation observations (evaluated by comparing global and diffuse observations at each observation point) this was achieved by adjusting all values to the same sun angle, using for this purpose the transmissivity derived at each point from the actual sun angle and the direct short-wave radiation at the time of observation. Other adjustments were made against such continuous observations of temperature, humidity, and wind as were available from the McGill University campus observatory, the Forces base at St. Hubert airport, and the CBC tower on Mt. Royal.

Data analyses are currently proceeding with, to begin with, special reference to the variation of direct short-wave radiation along the traverse lines. Initial results indicate a marked diminution of this element over the city in comparison with the surrounding countryside. The urban area in general has values of short-wave radiation equal to 65% of rural values. However, within the city area considerable variation is observable, with some areas appearing regularly to have higher or lower values than others. Higher values were consistently recorded in the vicinity of the Dow Planetarium, for example, where wind observations indicate marked local turbulence and variation in direction. By contrast, observations on the city bank of the St. Lawrence river indicated a regular diminution in direct short-wave radiation, at times showing lower values than anywhere else in the city, in contrast to the south shore where direct solar radiation values are commonly close to those of the countryside at large. A thorough investigation of the causes of these variations is being attempted in the light of other meteorological elements and the local conditions at individual stations.

R. Wilson and D. Petzold have begun a study of solar and net radiation in the Churchill River basin, Labrador. The work is being done for Churchill Falls (Labrador) Corporation (contract no. 509.08) and will provide background information for using radiation measurements in snowmelt forecasts. At the present time the only permanent radiation station in the region is maintained by the Atmospheric Environment Service at Goose Bay. Three additional stations for measuring solar radiation are being established by the Churchill Falls Corporation and a series of measurements in and around Schefferville have been undertaken by McGill. The project includes studies of solar radiation variations with distance and of the relationship between solar and net radiation over melting snow. Auxiliary projects, being financed by other agencies, will investigate radiation conditions in forested areas and on lakes with the objective of producing maps of the net radiation over snow surfaces in small basins.

B. J. Garnier
Professor of Climatology
McGill University

NEWS AND COMMENTS

R. G. Wilson attended the 1972 Eastern Snow Conference at Oswego, New York. Papers and discussions were scheduled for February 3 and 4, but a heavy snowstorm forced the participants to engage in informal sessions until the 6th. Dr. Robert Sykes, the local snow expert, reported a total snow fall of 50 inches during the 2-day storm.

Daniel LaFleur has been awarded the M.Sc. degree in Geography (Climatology) at McGill University. The title of his thesis was: "Une Etude Bioclimatique de la Ville de Montréal."

The 1972 meeting of the Friends of Climatology was held in Toronto on Friday and Saturday, March 10 and 11. Co-sponsors for the meeting were the Atmospheric Environment Service Headquarters and the Centre for Research on Environmental Quality at York University. The theme of the meeting was Climate and the Biosphere, and sixty-six Friends registered for the sessions which were held in suburban Downsview at both York University and AES Headquarters.

The featured speaker for the meeting was Professor G. Courtin of Laurentian University, who described his climatological and biological research programmes on Devon Island, Northwest Territories. Shorter presentations were given by Dr. W. Rouse of McMaster University, who described some of his work on evapotranspiration from lichen in the James Bay area, Dr. W. Frisken of York University, who examined the potential environmental impact of man's input of heat into the atmosphere, and Dr. R. E. Munn, who discussed the subject of scale and the need for modelling in bioclimatological work. The Saturday morning session was devoted to an informal discussion of numerous topics affecting the development and usefulness of climatological work in Canada.

The meeting for 1973 will be held in Montreal, probably in March. Interested persons not already on the mailing list are invited to contact B. J. Garnier at the Department of Geography, McGill University, P.O. Box 6070, Montreal 101, Quebec.

Robert Proulx, a graduate of the Université de Québec at Trois Rivières, has been awarded a National Research Council Scholarship and will undertake graduate work in climatology at McGill University.

B. J. Garnier attended the Technical Conference on Hurricanes and Tropical Meteorology held in Barbados in the first week of December 1971.

Since March 1959, McGill University has maintained a climatological station at Waterford, Barbados, using land generously provided by the Barbados Government. The station has been oriented towards agroclimatology and has provided a base for numerous workers in this and related fields. Now that the Caribbean Meteorological Institute (a WMO/UNDP sponsored project) is fully functioning and is situated less than a mile from Waterford, there is no longer a need for the Waterford station. Consequently the station will be closed on May 31, 1972, after a final year of observations to parallel with those at the Meteorological Institute has been completed so as to enable the transfer of statistics for long-term averages.

B. J. Garnier and R. G. Wilson are preparing a "Handbook on Radiation Mapping." The Handbook is designed to bring together the results of the past five years' research in this field which has been going on, and still continues, at McGill University. The contents of the Handbook will be strictly practical and concentrate on methods of mapping surface variations in short-wave and net radiation at different scales and for different purposes. Although examples will be confined mainly to southern Canada and sub-Arctic or Arctic conditions, it is hoped that the Handbook will offer a methodology useful to all concerned with or interested in surface radiation conditions. The Handbook is being sponsored by the Atmospheric Environment Service.

McGill University

Department of Geography

CLIMATOLOGICAL RESEARCH SERIES

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

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

No. 3 Climate of the Rupununi Savannas - A study in Ecological Climatology, by David B. Frost, 92 pp., December 1967 - out of print.

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

No. 5 Topographic Influences on a Forest Microclimate, by R. G. Wilson, 109 pp., September 1970, price $10.00.

No. 6 Estimating the Topographic Variations of Short-Wave Radiation Income: The Example of Barbados, by B. J. Garnier and Atsumu Ohmura, 66 pp., December 1969, price $7.50.

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

Prices of RESEARCH SERIES vary, but subscribers to the BULLETIN are entitled to a 50% reduction on the published price, provided they hold or held a current subscription for the year in which the relevant number of the RESEARCH SERIES appears.

Send orders and inquiries to:

Department of Geography (Climatology)
McGill University
P.O. Box 6070
Montreal 101, Quebec
Canada