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CONTENTS

METEOROLOGICAL TEACHING IN SCHOOL PROGRAMS[1]

L.K. McGlening
Canadian Meteorological Service, Toronto

1. INTRODUCTION

The author is not a teacher, nor is he directly connected with the educational field; however, for the past 25 years he has been indirectly associated with students and teachers who have been seeking help in the teaching and learning processes of meteorology in elementary and secondary schools across Canada. As a result of this experience a historical survey of past and present-day efforts exerted by the Canadian Meteorological Service in the field of meteorological education for schools is outlined; comments and opinions in regard to improving the teaching of meteorology in schools are then presented.

2. PUBLICATIONS FOR SCHOOLS

In the Weather Services Section of the Canadian Meteorological Service each day's mail brings enquiries on weather topics. Some are simple and direct: "Please tell me everything you know about meteorology". Others are more selective, like the student who wrote: "Would you kindly provide me with information on weather forecasting and weather instruments. Don't send anything on clouds as I already know too much about clouds." More sophisticated requests are received too. For example a recent writer stated: "As a science project I wish to build a meteorological computer. Please send me the plans for one."

The Meteorological Service's involvement in providing material for teaching meteorology in schools really began immediately after World War II, during which the publication of the "Daily Weather Map" was suspended for security reasons. At the end of the war it was decided that printing and mailing information which is essentially only useful on a real-time basis, was impractical. However, numerous requests arose from teachers who wished to use daily maps for teaching weather in a practical way. Many of these teachers were former RCAF aircrew who had received meteorological instruction during their military careers and were anxious

1. Paper presented at the Fourth Annual Congress of the CMS,held at the University of Manitoba, Winnipeg, June 17-19, 1970.

to introduce their students to the mysteries of "met". To meet this need, Gilmour Clark, a staff meteorologist, produced the "Weather Map Series for High Schools" - a series of six surface charts depicting conditions 12 hours apart over a period of 3 days. A Guide Book accompanied the maps and was intended for the teacher's use, primarily so that the teacher would know a little more about the subject than the student - always a good arrangement, even today. This series was an instant success: the first printing was 5,000 sets, designed as a 2-year supply. A somewhat similar series in use today is printed in lots of 100,000 which rarely lasts 12 months.

In many schools the maps were used and re-used by successive classes until they became dog-eared and illegible. Many teachers apologetically asked for replacements after over 5-years use. Obviously, the students pored over the data on the maps and missed nothing. One map in the series contained a plotted synoptic where the wind was calm and was represented by the usual circle. This symbol had not been defined in the legend, with the result that every month at least a half dozen letters asked for an explanation. One student said, "My teacher says that circle means a ring around the moon, but I want to be sure."

A few years ago the "Weather Map Series" was revised and updated by Syd Buckler. Consideration was given at first to a series using hypothetical data which could be selected to illustrate specific principles, without many of the complications so often encountered in actual fact. Anyone attempting to fake a surface chart should be warned - don't try! Just at the point when temperatures and pressures have been neatly selected to illustrate a textbook situation, other data which are ludicrously in error have been overlooked. The final maps were chosen from an actual series of archive weather maps which showed the progression of systems across the continent in a reasonably simple pattern; Syd laboured manfully to explain all the anomalies in a logical and reasonable fashion. This new series used the world-renowned Canadian three-front model and very likely its godfathers would be gratified to know that 100,000 more potential converts are being reached every year.

Information leaflets

In 1949 the Service undertook to design, construct and man a weather display at the Canadian National Exhibition in Toronto. This was the first of a series of displays which continued annually for 12 years. The practice was to design each display around a central theme or weather phenomenon - lightning, hurricanes, the Arctic, etc. To complement the display a one-page leaflet was prepared dealing with that year's theme. It soon became evident that these leaflets were extremely useful in answering enquiries from teachers and students and as a result they became a part of the portfolio of educational publications. Untold hours and money have been saved by mailing out one or more of these leaflets to answer a query which would otherwise require a special letter. A set of 12 such leaflets has been prepared and in 1969 about 1,200,000 were distributed.

Cloud charts

One of the most difficult demands to meet was the provision of a cloud chart with good photographs of common cloud types clearly reproduced (preferably in colour). An attempt was made to assemble such a series of photographs,but it proved impossible to acquire a complete set which was available without copyright, which could be successfully reproduced, and which illustrated single cloud types rather than a complex sky condition. At one stage the help of the National Film Board was enlisted. They agreed to provide the required shots, so that over 500 photographs were submitted for examination and classification at the end of a year. Unfortunately the photographers were enamoured of cumulus clouds and cirrus formations, so that from the multitude of samples only a half dozen good typical cloud photographs were obtained. The costs for reproducing a chart of sufficient quality to illustrate cloud formations were extremely high, and would not permit supplying the chart free-of-charge or even at a reasonable price.

Eventually a happy solution was found in a Cloud Chart illustrating 35 types in colour, copyright by Louis Rubin of Denver, Colorado and complete with captions assisting the laymen to predict the future weather with complete confidence. Mr. Rubin was in his late seventies and almost completely paralysed. His hobby of collecting cloud pictures and of studying weather has turned into a profitable source of income for him after a compulsory retirement. Weather Services around the world purchase his charts and many commercial firms use the pictures as promotional giveaways.

Changing Demands for Information

It is interesting to note how the demand for information reflects the current topics of interest. 1954, the year of Hurricane Hazel, focussed attention on hurricanes; weather modification was very big in 1960, and 1965 was the year for long-range forecasting. In 1970 the vogue is for data on pollution and on satellite pictures. To meet these surges of interest appropriate publications are developed. Each year the level of scientific content and complexity has increased to reflect the obvious desire on the part of students and teachers alike for authentic and informative aids.

A rather complete booklet on weather satellites is in preparation. A requirement for a publication on setting up and operating a school weather station has yet to be satisfied. Without doubt, something about the role of computers in meteorology will become necessary as more and more enquiries are received.

3. EDUCATIONAL VARIATIONS FROM PROVINCE TO PROVINCE

Education in Canada is a provincial responsibility, so that the extent to which meteorology, or weather,is incorporated in school curricula varies a great deal from province to province. A few years ago a summer student, Miss Margaret Johns (whose father is a Canadian meteorologist) undertook a project to review the curricula at all grade levels across Canada to determine how much meteorology was included, at what grade it was introduced, and in what detail. The purpose of the project was to see whether material more directly related to the prescribed courses could be made available from the Meteorological Service.

The task turned out to be a formidable one. Meteorology,or weather, in some provinces is introduced at Grade 1 with topics like - what does a snowflake look like? - and extends to the higher grades where detailed and somewhat outmoded theories of frontal analysis are taught. In other provinces meteorology receives only scant mention and then only in relation to geography or physics. It was difficult to extract a clear pattern from province to province, but the most extensive treatment of meteorology at the secondary school level appears to be in Alberta and Ontario followed by British Columbia. The other provinces also include meteorology as an optional topic, but in a much less detailed and formal manner. These differences are reflected in the volume of requests for information received from teachers and students, and in the nature of these enquiries.

It is interesting to note that for many years there were very few requests for material received from Quebec province. The provincial prerogative in the educational field was jealously guarded and it was not considered politic to seek assistance from a federal service such as the Canadian Meteorological Service. This situation has been rapidly changing, and a sizable volume of enquiries from Quebec is now received. Part of this is a result of the fact that the number of publications in the French language has progressively increased;in 1970 the objective of having all the educational series available in both languages has been reached.

4. IMPROVING THE TEACHING OF WEATHER IN SCHOOLS

These remarks concerning educational publications and their relationship to the curricula of primary and secondary schools are just an introduction to what I <u>really</u> want to propose today.

My first suggestion is that we capitalize on the revolt of youth against the Establishment. I think many of the educators at this Congress will agree that part of the current student protest is against the irrelevancy of much that is taught in schools. But what could be more relevant to everyday life than weather and climatology? Let us exploit the obvious and vital relationship between weather and pollution, weather and population, weather and sports, weather and food - all the subjects in which modern youth is interested, and considers of primary importance. Let's forget about physics and mathematics and statistics as the handmaidens of meteorology and emphasize that meteorology is not an isolated, cold, theoretical science, but rather a part of the real day-to-day world of living and breathing, languishing and dying, regressing and progressing.

To accomplish this shift in emphasis, some attention must be diverted from the graduate and post-graduate levels where so much of the image-making and "recruiting" has been done; some attention must be turned to the primary and secondary school levels where life-long impressions are formed and where the revolt against orthodoxy will soon be as evident as it now is on University campuses. We must convince government and educational authorities and private enterprises too, that one of the most effective ways to improve and expand the economy and well-being of Canadians is to teach them, while they are young, how to understand the effects of weather, how to take advantage of this knowledge and how to help in improving this knowledge. This program will, I feel sure, as a spin-off, help to create a greater interest in meteorology as a career; but even if it doesn't, it will serve as a worthwhile long-range contribution to Canada's economy.

5. INTRODUCING WEATHER INTO SCHOOL CURRICULA

There are a number of ways in which weather (rather than meteorology) can be effectively introduced into school curricula. One of the foremost is for interested groups (the Canadian Meteorological Society, University staff members and Meteorological Service representatives) to meet with provincial educational officials and offer to assist them to incorporate weather into their curricula at appropriate levels associated with the appropriate parallel studies. For example, weather fits beautifully into a study of exploration, into an analysis of population migrations, and into an examination of historical events. It can be related to drama, literature, art, social economics, and resource studies. At this stage meteorology should not be identified directly with physics and mathematics. As a genuine interest develops in the wonder of weather, questioning minds will want to look deeper into why things occur as they do, and the opportunity will be provided to lead students into the discovery of the science of meteorology for themselves.

Next, these same groups should take every opportunity to write articles, leaflets, booklets and books on the relevance of weather to life. I hope to develop within the Service a series of such leaflets to be used as educational aids - each with a title beginning "Weather and ...."

Another suggestion is to program, at the local level, visits to schools from Meteorological Service staff from University meteorological faculty and from experts in other disciplines who can relate meteorology to their own fields. These visits can take the form of seminars, round-table discussions, film showings and anything else which will capture the student's interest and imagination. I believe that the basic principles of meteorology can be explained to students without using a single equation or law of physics. By example, and by illustrations based on the experience of the student himself, a speaker can teach without being pedantic.

Finally, I'd like to emphasize that this introduction of weather into the schoolroom can start at the primary level. The booklet "How to Become a Meteorologist" published by the World Meteorological Organization*, expresses it much better than I can. The section entitled "The Child Discovers His World" states in part:

"Heat and cold, rain and snow, wind and waves .... at a very early age the child discovers the world around him through these simple elements. The wind may make him feel cold and perhaps unsteady on his feet - but it helps to fly his kite. The rain makes him wet and perhaps miserable but the snow makes the world look different and provides amusing games. The sea waves may make him ill on a sea journey but are fun when bathing in the sea. Experts in child psychology consider that such perception is already active when the child is only a few months old. To the child, atmospheric phenomena must surely be a source of wonder. The ever-moving and ever-changing patterns of a cloudy sky;the attention and, with other simple activities he observes, such as the flight of birds,the activity of insects,and the rest of nature's varied spectacle, they constitute his outside world - a world of wonder. Curiosity is then awakened and the questions of How? and Why? present themselves.

"Thus, at a very elementary stage in a child's education and without becoming involved in long words like "meteorology", his teacher may give him a simple and direct introduction to the teaching of natural sciences. Explanations of simple phenomena lead naturally to interest in methods of observing and measuring the weather - and such activities are in fact the basis of practical meteorology. Nature thus provides the material that the teacher may use even at an early stage."

What I am suggesting is really not new or radical. It is just a shift in emphasis towards the primary and secondary schools, where I think we can create in young people a fascination about weather which will remain for them a source of pleasure and profit for the rest of their lives.

*WMO - No. 257.TP.143 - Geneva 1970.

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ON THE VARIATION OF THE 500-MB WIND AND ITS EFFECT ON THE RELEASE OF INSTABILITY IN THE LEE OF THE ALBERTA ROCKIES [1]

E.R. Reinelt
University of Alberta

1. INTRODUCTION

The effect of the upper wind on the release of instability,in particular with respect to the formation of hail, has engaged the continued attention of many investigators since Dessens (1960) found that winds of jet intensity were associated with severe hailstorms in Southwestern France. The results of subsequent investigations to date are, at best, inconclusive if not contradictory. Ratner (1961), studying the winds in the 500- to 250-mb layer for all RAWIN stations in the U.S., found that neither the speed of the winds aloft, nor the wind shear between 500 and 250 mb appeared to be determining factors in the occurrence of hail. Das (1962) claims that strong wind shear aloft favours the formation of hail, but suppresses the maximum size attainable for a given temperature and liquid water distribution. Schleusener (1962) concluded that hail fell when a wind maximum moved southward across hail-prone Colorado, such as would occur when a jet associated with an approaching trough moved into the area. Schönbächler and Zenone (1965), examining hail fall on the southern slopes of the Alps, close to the area studied by Dessens, found that the maximum speed of the upper wind was, on the average, higher with thunderstorms than without them, but were unable to conclude that the upper winds had decisive effects on the triggering of thunder and hailstorms. Proppe (1965), investigating Alberta storms, showed that vertical wind shear may in fact hinder most hailstorm development. However, Malkowski (1965) claims that the horizontal extension of storm cells depends on the vertical wind distribution, to the extent that strong vertical shear favours large cell size. Rosinski and Kerrigan (1969), examining hailstones from severe Colorado storms, suggest that the character and intensity of a hailstorm may well depend on the size and concentration of the ingested aerosol particles, linking, in particular,giant nuclei ($>75\ \mu$ diameter) with the leading edge of intense

1. Presented at the Fourth Annual Congress of the CMS, held at the University of Manitoba, Winnipeg, June 17-19, 1970.

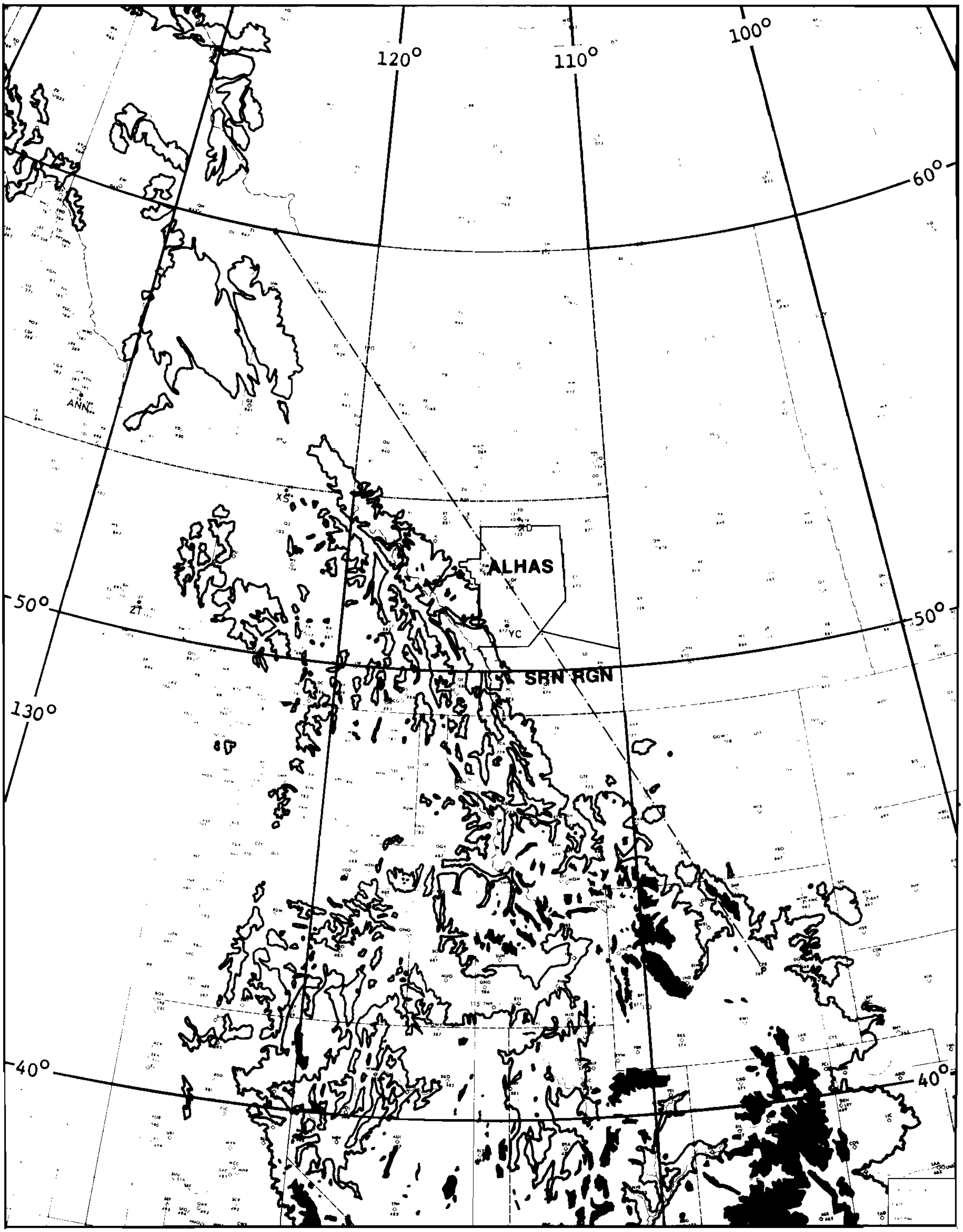

Figure 1. Locations of the Alberta Hail Studies Regions, and the Base Line used in the Time Sections.

storms. Thompson (1970), studying hail-swath patterns of Alberta storms, found that wind directions in the 700- to 200-mb layer are nearly constant with height, thus providing no support for the hailstorm models of Newton and Newton (1959), and of Browning (1964), which require veering winds throughout the troposphere. Thompson concludes also that strong upper winds may be only a condition, but not a requirement for the production of long hail swaths, usually associated with the most intense and persistent storms.

In the light of the foregoing it is only too clear that the issue is far from settled. The present investigation, while in a sense an extension of the work of Schleusener, comes in essence to a different conclusion. Even so, there can be little difference of opinion with Schleusener's contention that it is important to consider the broadscale circulation in connection with studies of local phenomena, such as hail.

2. THE CONSTRUCTION OF TIME SECTIONS

Time sections are convenient devices for presenting masses of meteorological data in time and space. On a synoptic scale, they are particularly useful for depicting variations of the zonal wind, day-to-day changes in the temperature and moisture fields along chosen reference lines, and the like. Schleusener (1962) prepared time sections of the 500-mb zonal wind speeds along the 110°W meridian for the spring and summer seasons of 1959 through 1961.

In assessing the effect of the Rocky Mountains on the release of instability in the Alberta hail study areas, the space coordinate is conveniently oriented parallel to the Continental Divide. Since the air flow is most strongly affected by mountains when crossing within an angle of some thirty degrees from the normal to a barrier ridge, this choice of orientation should show any effect to the best advantage. Figure 1 shows the location of the line of the space section with respect to the Rockies and the two hail study areas: the principal Alberta Hail Study Project Area (ALHAS) centred at Penhold, and the Southern Region including Lethbridge and Medicine Hat. The line extends from a point on the B.C.-Yukon boundary (60°N, 125°W) to Casper, Wyoming, and crosses the two hail study areas about mid-way.

The 500-mb geostrophic wind component normal to the Continental Divide was computed from analysed 0000Z and 1200Z 500-mb maps, using the interpolated contour gradients along the line of the section at intervals of one fifth (0.2) of a degree of latitude. The normal geostrophic component for May, June, July and August, 1967, is shown in the time sections of Figures 2 through 5.

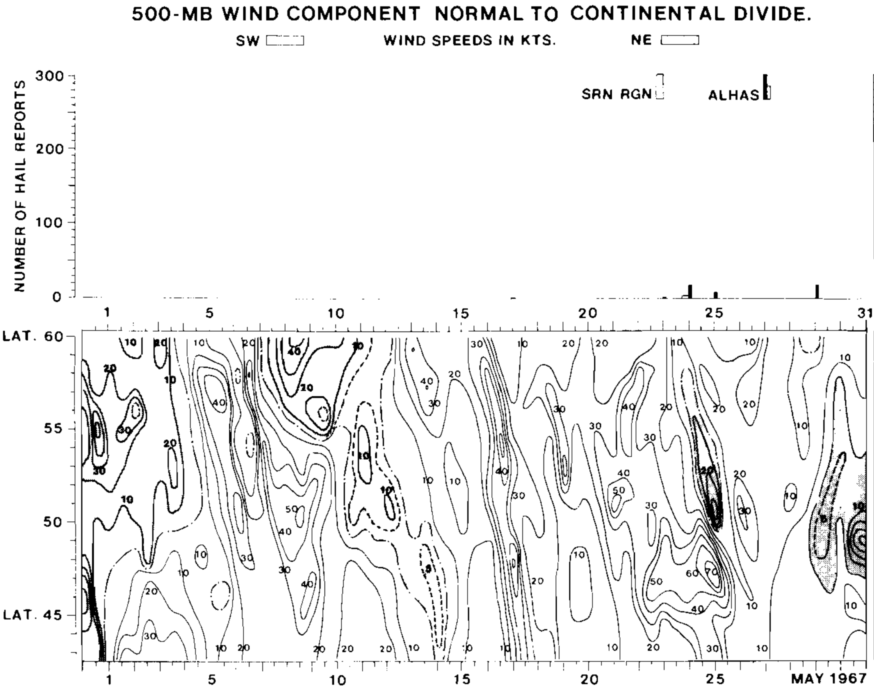

Figure 2

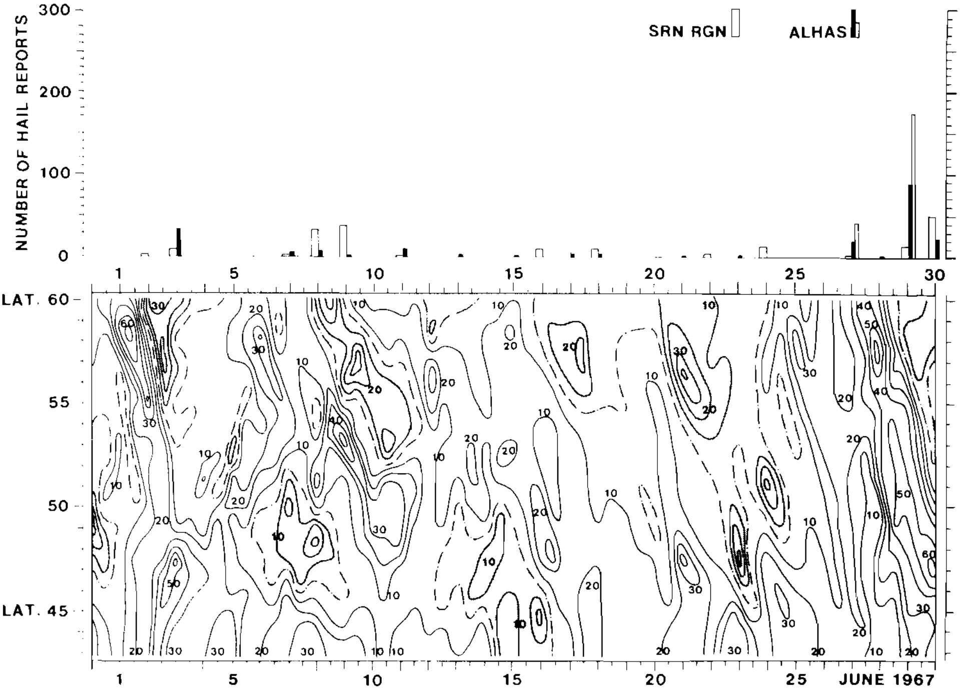

Figure 3

3. RELATION OF SYNOPTIC PATTERNS WITH THE OCCURRENCE OF HAIL IN ALBERTA

Longley and Thompson (1965), in their detailed study of the causes of hail in Alberta, list seven meteorological conditions favourable to the formation of hail, but found that no single condition was by itself sufficient or necessary. They were " ... forced to conclude that the margin between hail or no hail is apparently very small ... ".

An examination of the surface and 500-mb synoptic patterns of hail days,carried out in connection with the time sections of the geostrophic wind, laads to much the same conclusions. It seems in particular that the synoptic features at the surface are of very little consequence, except perhaps in the release of isolated and sporadic instability by moving frontal waves and cold fronts. If anything, high surface pressures are the rule, rather than the exception: highs, building in from the Pacific or even the Arctic are more likely to be present on days with hail than frontal or thermal lows.

Referring specifically to the twenty cases of major hail days of the 1967 season with clearly discernable storm tracks (Summers, 1968), the dominant surface feature on eleven days was a Pacific high over most of British Columbia and Alberta, or at least a well-defined ridge, an offshoot of the Pacific high, over Southern and Central Alberta. Arctic highs were in evidence on three days, one supporting a "backdoor" cold front which moved westward to the Rockies. Lows, waves and indefinite isobaric configurations were present on the remaining six days.

The contour and isotherm configurations at the 500-mb level fell into more consistent patterns, but not without leaving some stubborn and vexing exceptions. On fourteen days with major hail tracks there were cold troughs, cold lows, or at least definite indications of cold air advection over the southern half of Alberta. On most of these occasions the jet stream, when present, was to the south of Alberta, or at least south of the area of hail-fall. Cooling aloft then seems to be particularly conducive to the large-scale release of instability in the lee of the Rockies, but it must be noted immediately that the remaining six cases of major hail occurred with well-developed anticyclonic flow aloft, with quite high 500-mb temperatures (-10°C to -12°C),and apparently weak warm-air advection.

Examination of the 47 hail situations not characterized by well-marked tracks shows a trend toward a more equal distribution of surface highs and lows. At the 500-mb level, cold troughs and cold-air advection are still the dominant features on 20 days, but well-developed ridges are present on 10 days, and various other configurations, from strong zonal flow to weak, indefinite circulations prevail on the remaining 17 days. These cases include several occurrences of widespread hail of grape to golfball size.

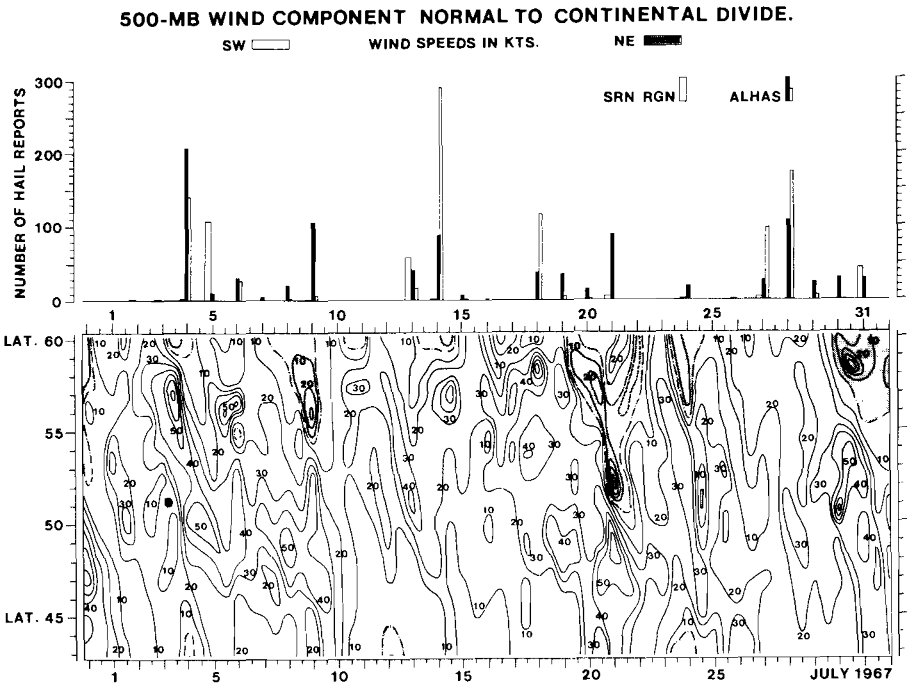

Figure 4

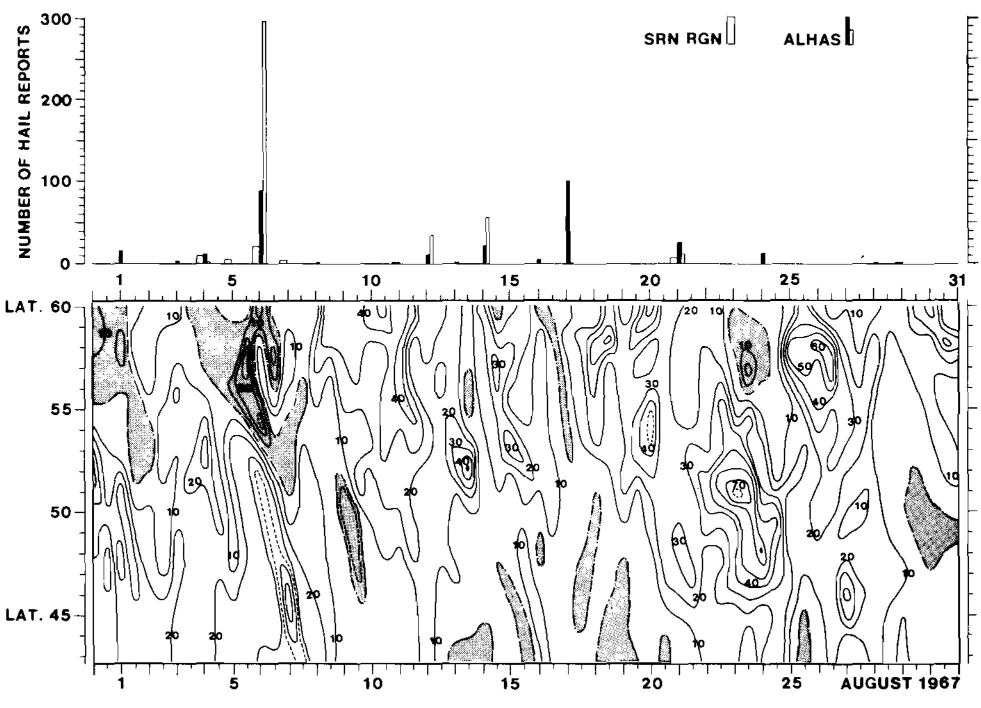

Figure 5

4. PATTERNS IN THE 500-MB NORMAL WIND COMPONENT ON DAYS WITH HAIL

Even a casual inspection of the time sections readily reveals the banded structure of the pattern of isotachs, moving generally from north to south with the passage of time. The cellular pattern of the moving wind extrema, described by Schleusener, is also clearly discernable. The progress of major troughs and cold lows is shown by the change in the normal component from southwest to northeast, and the strong horizontal shear reflected in the gradients of the isotachs. But strong horizontal shear usually implies also strong vertical shear,and the presence of jet streams. In this sense, cores of high winds aloft traversing the hail study areas from north to south, are certainly present on most of the major hail days, e.g., June 2, 8, 9, 29 and 30; however, there is little in the pattern to account for the hail on June 27. Examining the time sections for July and August only confirms what is found in June. There is hail with high winds aloft on many days, but the severe and extensive hail on July 27 and 28, developed in a 500-mb ridge, with at most only slight cold-air advection. Similar conditions prevailed on August 17 when 100 reports of hail noting stones as large as golfballs were received from the ALHAS area alone. In this instance, the 500-mb temperatures were a warm -10^{o}C, but a cold front pushed westward to the Continental Divide.

5. CONCLUSIONS

The use of time sections of upper winds in the investigation of the incidence of hail is clearly valuable in that it provides a synopsis of the broad-scale feature of the atmospheric circulation in the area of interest. Troughs, ridges, moving wind maxima and gradients show up clearly, and may be correlated easily with other meteorological data, such as reports of hail.

However, the question as to whether hail will or will not occur cannot be settled on the basis of an examination of the upper wind field alone. Judicious extrapolation of trends of moving features may prove of value in short-term forecasting, but is not likely to shed much light on the fundamental problem of the generation of intense storms. It may well be that the creation of intense instability is primarily dependent on the thermodynamic condition of the air mass, and on the nature of the underlying terrain, rather than on the aerodynamics of the broad-scale flow. This appears to be the case even in the hail-prone regions to the lee of major mountain ranges. Thus the release of instability in the presence of mountain waves has been investigated with great care,notably by Booker (1963), but the cause-effect relationship has not been adequately resolved to date.

It seems quite feasible that,in the release of lee-side instability, a mountain range acts primarily as a physical barrier separating two potentially unstable, but still internally consistent masses of air. The barrier inhibits or prevents altogether the movement of the lower layers of the air masses, but offers little hindrance to the flow of air aloft. Thus a cool current of air may move in freely aloft and override a warm unstable air mass which has formed in the leeward shelter of the barrier ridge. The ensuing sudden disturbance of the vertical equilibrium would lead to an overturning of the highly unstable column of air, with rapid penetration of warm, moist air to great heights. Since the advection of cold air aloft would be most marked and rapid on the cold side of a jet stream, the development of intense thunderstorms should most readily occur with the passage of cold troughs aloft. However, the passage of well-defined cold troughs is clearly not a necessary condition for the release of intense instability. Mesoscale systems,too small to be detected by existing synoptic networks, may well produce sufficient localized cooling aloft, on crossing the barrier, to upset a precarious equilibrium in the lee of the Continental Divide.

ACKNOWLEDGEMENTS

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PRECIPITABLE WATER OVER CANADA

I Computation[1]

John E. Hay
Department of Geography
University of Canterbury
Christchurch, New Zealand

1. INTRODUCTION

The water vapour present in the earth's atmosphere plays an important role in many of the processes operating in that atmosphere. A significant portion of the shortwave radiation entering the earth's atmosphere is either scattered or absorbed by water vapour, which itself is a strong absorber and radiator of longwave radiant heat energy. In addition the latent heat energy released when atmospheric water vapour is condensed and the possible appearance of some of this water at the earth's surface as precipitation both indicate other areas where a knowledge of the atmospheric water vapour content is, or should be, of immediate concern.

Information on the total depth of precipitable water (the depth to which liquid water would stand if all the water vapour in a vertical column, of uniform cross-section, extending from the earth's surface to the top of the atmosphere were condensed)was required in a study of the radiation climatology of Canada (Hay, 1970).

This ultimate use of the precipitable water data dictated certain characteristics of the present study. Monthly mean values of precipitable water were required for the 165 first-order surface synoptic weather stations used in the radiation study referenced above. In Canada, as in most other countries, the density of the upper air station network is low because of the high costs of operating such facilities. During the study period (1957-1964) only 34 Canadian upper air stations were operating.

1. Paper presented at the Fourth Annual Congress of the CMS, held at the University of Manitoba, Winnipeg, June 17-19, 1970.

The problem which forms the basis of this particular study is to produce monthly mean values of the total depth of precipitable water above not only the 34 Canadian upper air stations but also above the 134 Canadian surface synoptic stations and 28 selected United States upper air stations (see Fig. 1). This will enable the distribution of precipitable water over Canada to be determined to the necessary high degree of spatial resolution, a result which would have been impossible to obtain from a study of the upper air data alone.

The distributions derived in this study will be presented (in Part II) in the form of maps of mean monthly values for the period 1957 to 1964.

2. COMPUTATIONAL PROCEDURES

(a) For Upper Air Stations

For the 62 upper air stations located in Canada, Alaska and the northern contiguous United States monthly mean 1200 GMT temperatures and relative humidities for the surface and standard pressure levels were used to calculate the depth of precipitable water between all adjacent levels by means of the following equation for a layer bounded by levels 1 and 2:

$$u_{p_1-p_2} = \frac{(621.9)(0.5)(e_{s_{p_1}} + e_{s_{p_2}})(0.5)(U_{p_1} + U_{p_2})(p_1-p_2)}{980(0.5)(p_1+ p_2)} \qquad (1)$$

where u is the depth of precipitable water vapour (cm), p the atmospheric pressure (mb), e_s the saturation water vapour pressure (mb), and U the relative humidity (%).

The monthly mean values were considered valid if they were computed from at least half the daily ascents, even though statistical values of relative humidity (due to "motor-boating") might be included in these ascents. The total depth of precipitable water at these upper air stations was computed by summing the values for individual layers of either 50- or 100-mb thickness, except in the case of the near-surface layer.

The highest (altitudinally) pressure level used in the computations was either the 400-mb level or the last level attained before the monthly mean temperature achieved a value below -40 deg C. In all cases the water vapour content of another 100-mb layer was added, with the assumption that the water vapour concentration was zero at the next pressure level above. This assumption is considered valid since, except in the Great

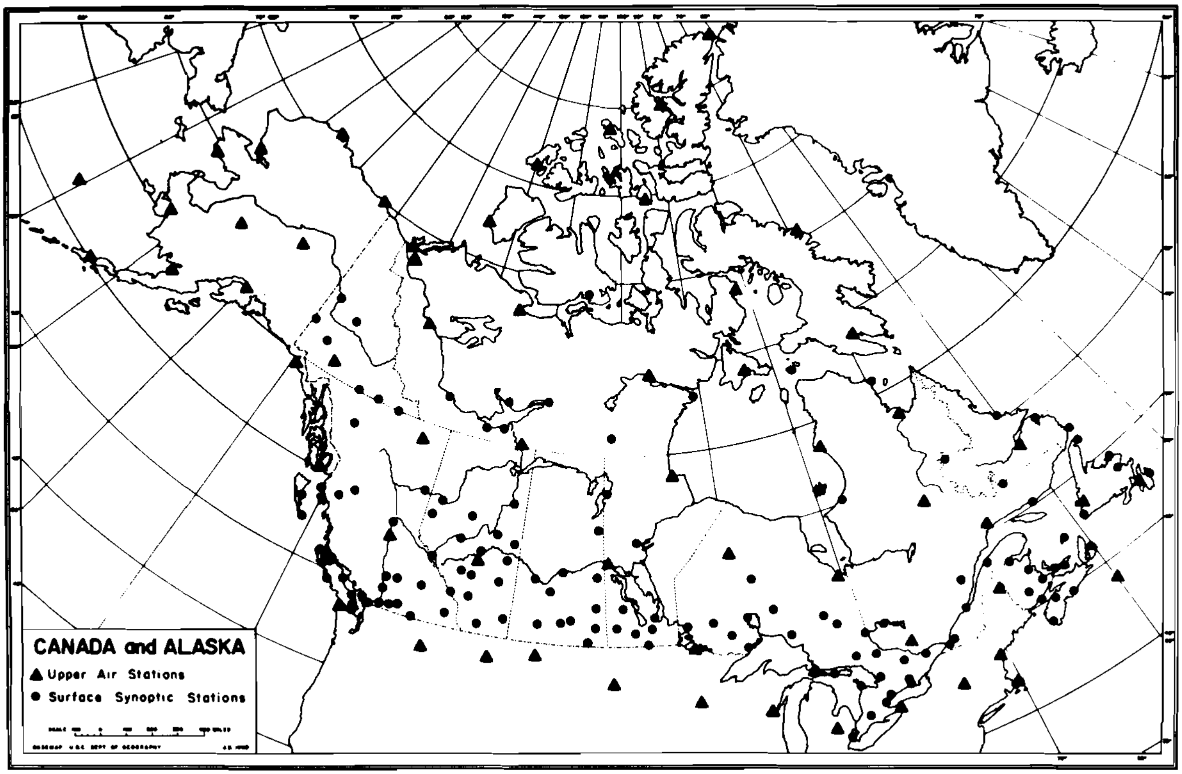

Fig. 1. Locations of stations used in study.

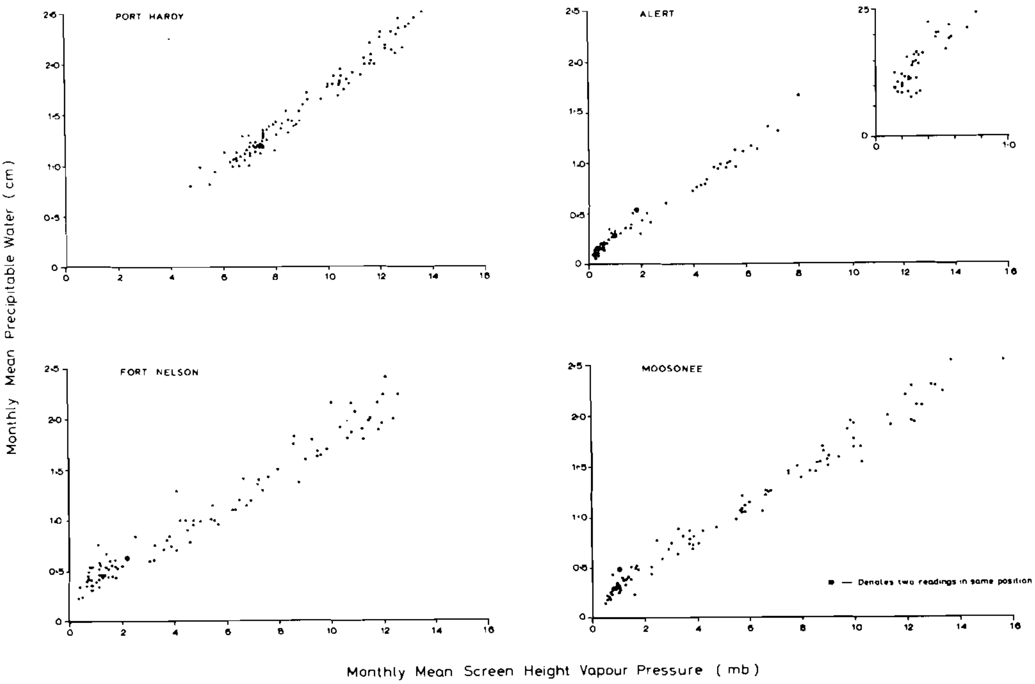

Fig. 2. Relationships between screen-height vapour pressure and total precipitable water for four selected locations.

Lakes area in mid-summer, the monthly mean temperature is normally less than -40 deg C at or above the 400-mb level (Titus, 1967), and at such temperatures the water vapour content is effectively zero, e.g., for a 100-mb layer with a mean temperature of -45 deg C, a relative humidity of 100 per cent and a mean pressure of 350 mb, the depth of precipitable water equals 0.0002 cm. Bannon and Steele (1966) similarly concluded that the amount of water vapour above the 500-mb pressure level generally made an insignificant contribution to the total depth of precipitable water.

(b) For Surface Synoptic Stations

Numerous authors, e.g., Reitan (1963), Goss and Brooks (1956), Monteith (1961) and Shands (1949),have reported the existence of a relationship between the amount of water vapour at screen height and that in the total depth of the atmosphere. A study of the relationship between the monthly means of screen-height vapour pressure and the total depth of precipitable water at the 62 upper air stations indicated that a significant correlation (at the 0.01 level), existed for all 62 stations. Thus the following relationship could be used to predict monthly mean precipitable water vapour from the monthly mean surface vapour pressure (a frequently observed climatological variable):

$$u = a + be \tag{2}$$

where e is the screen-height water vapour pressure and a and b are regression coefficients. The names of the Canadian stations used in this particular study, along with details of their respective correlation and regression statistics, appear in Table 1 and the graphical relationships for four stations are shown in Fig. 2.

An inspection of the regression coefficients revealed a spatial variability in the values. Such a variation could be ignored by grouping all the data and accepting the introduction of increased and systematic errors in the calculated precipitable water. Alternatively, if a coherent spatial pattern is detected, the interpolation of values of the regression coefficients for intervening stations may be made on the assumption of spatial coherency in the variation of these parameters.

Figs. 3 and 4 indicate that there is a coherence in the spatial patterns for both the slope and intercept terms. Therefore, the values for the intervening surface synoptic stations were interpolated using similar, but larger scale maps.

3. SPATIAL VARIATION OF SLOPE TERM "b"

In the interpretation of this coefficient it is useful to realize that, during the seasonal change in atmospheric water vapour content, a

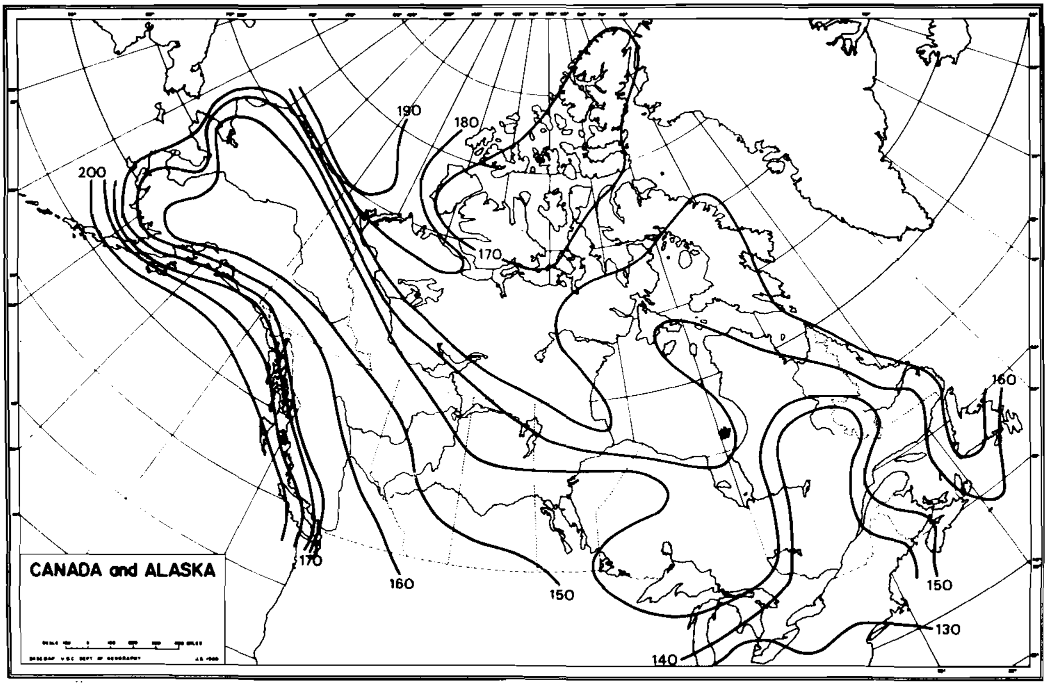

Fig. 3. Distribution of "b" the slope term (x 10^3) in the precipitable water - vapour pressure relationship.

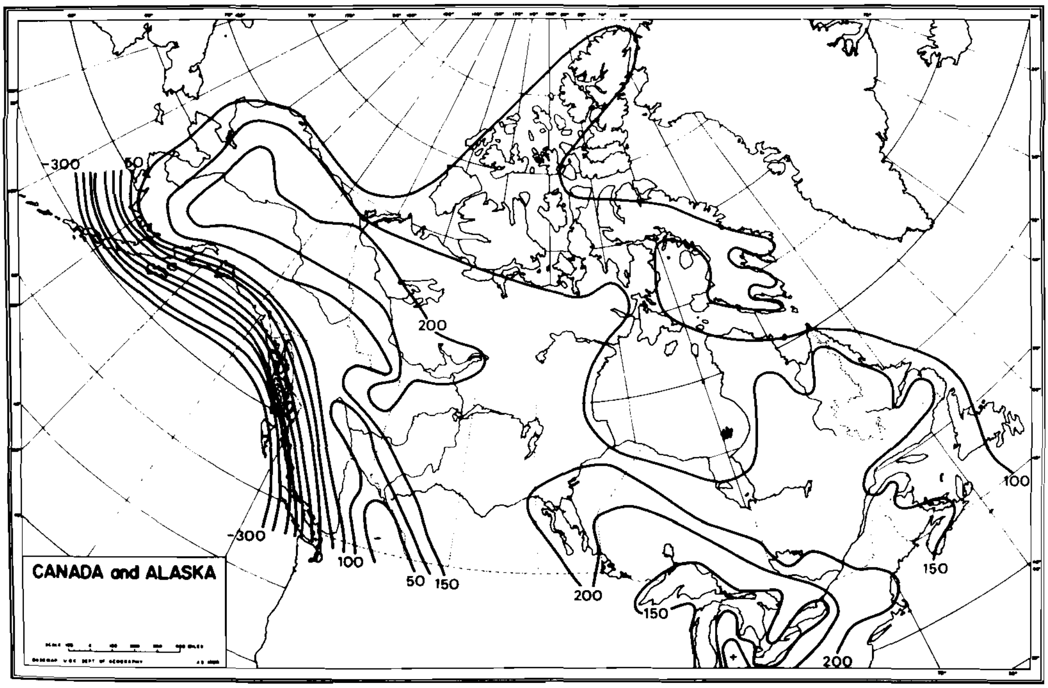

Fig. 4. Distribution of "a" the intercept term (x 10^3) in the precipitable water - vapour pressure relationship.

Table 1. Vapour pressure - precipitable water regression results

Station	a	b	r^2	SE (cm)
Aklavik/Inuvik	0.210	0.165	0.98	0.09
Alert	0.100	0.170	0.98	0.05
Argentia	0.070	0.157	0.92	0.16
Baker Lake	0.159	0.163	0.98	0.08
Churchill	0.143	0.172	0.98	0.10
Clyde	0.083	0.169	0.96	0.08
Coppermine	0.152	0.175	0.96	0.11
Coral Harbour	0.122	0.159	0.98	0.08
Edmonton	0.181	0.149	0.98	0.09
Eureka	0.134	0.166	0.98	0.06
Fort Chimo	0.120	0.158	0.98	0.08
Fort Nelson	0.281	0.151	0.96	0.12
Fort Smith	0.187	0.155	0.98	0.08
Frobisher Bay	0.091	0.169	0.98	0.08
Goose	0.169	0.162	0.98	0.08
Hall Lake	0.103	0.170	0.98	0.08
Isachsen	0.225	0.166	0.98	0.04
Maniwaki	0.221	0.142	0.98	0.10
Moosonee	0.189	0.157	0.98	0.09
Mould Bay	0.114	0.171	0.98	0.06
Nitchequon	0.154	0.137	0.98	0.08
Norman Wells	0.211	0.163	0.98	0.08
Port Hardy	-0.200	0.195	0.98	0.08
Port Harrison	0.128	0.157	0.96	0.09
Prince George	0.135	0.160	0.96	0.10
Resolute	0.090	0.166	0.98	0.07
Sable Island	0.076	0.158	0.94	0.19
Sachs Harbour	0.121	0.167	0.98	0.07
Sept Iles	0.125	0.164	0.98	0.10
Stephenville	0.113	0.174	0.98	0.09
The Pas	0.215	0.147	0.98	0.08
Trout Lake	0.200	0.140	0.98	0.07
Whitehorse	0.125	0.160	0.96	0.08

r : simple correlation coefficient
SE: standard error of estimate

high value reflects a proportionately greater increase in the total atmospheric water vapour content compared to the increase in the near surface layer, while a low value reflects a proportionately smaller increase.

A relatively large increase in the near surface air temperature in the continental interior from winter to summer creates the potential for a relatively large increase in the water vapour content of the lower atmospheric layers compared with changes that take place at higher altitudes. It is apparent that a large proportion of this potential water vapour increase actually occurs since summer relative humidity values are generally the same or higher than the corresponding winter values.

Due to the greater influx of water vapour into the lower levels to satisfy this higher potential for water vapour increase, a distribution in the slope term which reflects the continentality of the area is to be expected, with low values in the continental interior and higher values in coastal areas. Similarities between Fig. 3 and the map of continentality produced by MacKay and Cook (1963) are indeed apparent. However, dissimilarities do occur, a notable one being the appearance of minimum values in southeastern Canada and northeastern U.S.A. where much higher values would be expected if the continental versus oceanic temperature regime were the only influence.

Reitan (1963) found relatively low slope values in eastern and central U.S.A. and higher values west of 100^{o}W. Unfortunately, since he used screen-height dew point temperature as the independent variable,the actual values are not numerically comparable. His results and the obvious modifications to a solely thermally induced pattern are compatible with the existence of the low level influx of water vapour in eastern and central U.S.A. associated with the circulation around the western end of the subtropical high, which is most pronounced in summer (Rasmusson, 1966). Such a flow greatly increases the proportion of water vapour in the lower layers of the atmosphere and will thereby account for the low values of the slope terms found in the eastern and central U.S.A. and southeastern Canada.

By comparison, the remaining areas of Canada and the U.S.A. are under the influence of air with Pacific or Arctic origins and with less tendency for water vapour to be concentrated in the lower layers of the atmosphere during summer months.

The validity of this argument is greatly substantiated by the work of Reitan (1960)who showed the existence of the above-mentioned regional differences in the vertical distribution of water vapour when the eastern and central distributions were compared with those in the remaining areas of the United States.

The spatial variation in the slope term will thus reflect the thermal influence to a large degree, but with a local modification due to circulation patterns. Of interest in this respect is the southeastward penetration of a secondary maximum in the slope term with an axis running from Coppermine through Churchill to the southern part of Hudson Bay. This pattern is probably a result of the reduction in continentality due to the intrusion of maritime arctic air in the lee of the Rockies, the vertical distribution of water vapour in this air also assisting to create the secondary minimum.

Hence the spatial distribution of the slope term may be considered to reflect the integrated influence of aspects of the physical and dynamical climatologies of Canada.

4. SPATIAL VARIATION OF THE INTERCEPT TERM "a"

The spatial distribution of the intercept term may be accounted for by the influence of altitude and the presence of large water bodies. The altitudinal trend, which is apparent in Fig. 4, cannot be attributed to the pressure dependency of vapour pressure, since such a dependency would result in increasing intercept values with increasing altitude. This is opposite to the observed trend. The pressure dependency is overriden because, though surface humidities at high altitudes are frequently similar to those at lower elevations, the lapse rate of water vapour is much greater in the former due to the shallower depth of the atmosphere. Therefore at high elevations the surface vapour pressures are associated with lower values of total precipitable water, and there will be a tendency for the intercept value to decrease with increasing altitude.

A second influence, which may be used to explain the tertiary minimum in the Great Lakes area and the primary minimum on the Pacific Coast, is associated with the fact that the intercept value is most strongly controlled by the water vapour conditions prevailing in winter. At such a time warmer temperatures and higher surface vapour pressures occur in proximity to large water bodies. Such an influence will be restricted to the lower surface layers and hence these areas, similar to high altitude localities, are characterized by high surface vapour pressures, but not by correspondingly high values of the total precipitable water.

Therefore the spatial distributions of the intercept term in Eq. 2 reflects the control of both altitude and the proximity of large water bodies.

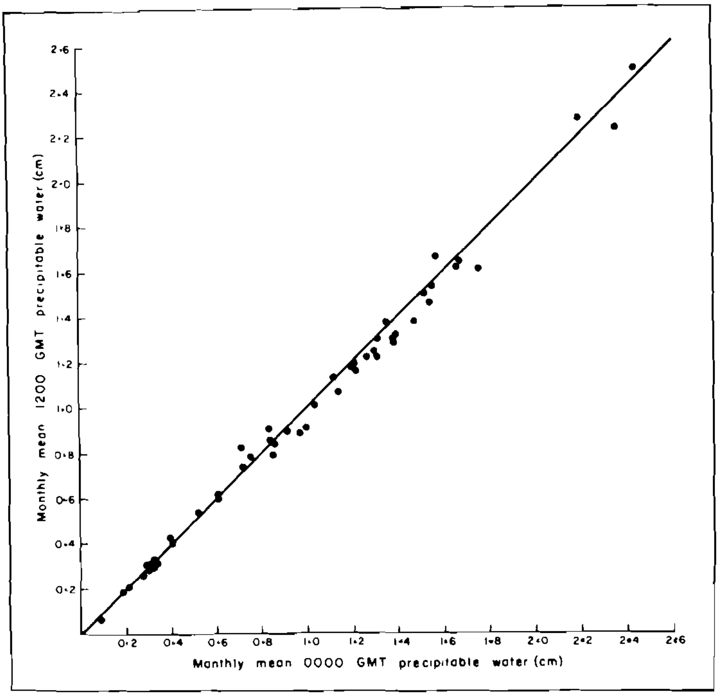

Fig. 5. Comparison of 0000 and 1200 GMT precipitable water values.

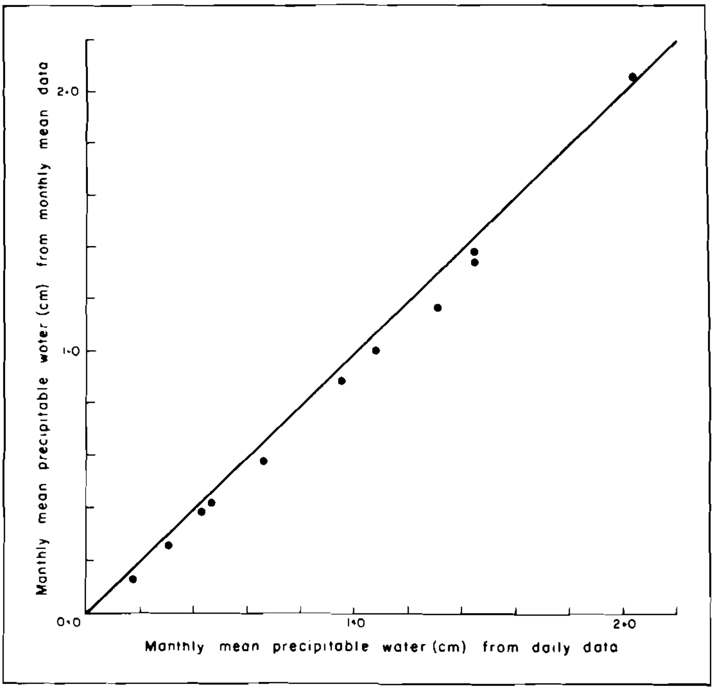

Fig. 6. Comparison of monthly mean precipitable water calculated from daily and monthly mean data.

5. RELIABILITY OF RESULTS

(a) Standard Error of Estimated Values

Table 1 shows that the largest standard error in the total depth of precipitable water estimated from screen-height vapour pressure was 0.19 cm for Sable Island. Barry (1965) has estimated that the errors arising from the computation of precipitable water from upper air data yield a reliability of ±5 per cent or ± 0.08 cm at a representative value of 1.5 cm. It is acknowledged that the error in estimated values will normally increase with increasing distance from an upper air station.

(b) Use of 1200 GMT Values

In all computations requiring temperature or humidity data monthly mean 1200 GMT values were used. In order to test the representativeness of this observation time a comparison was made with data for 0000 GMT by taking a random sample of 50 values of monthly mean total precipitable water for the two observation times. These data, which are presented in Fig. 5, tend to confirm the contention of Rasmusson (1966) that there is no significantly persistent diurnal variation in the depth of precipitable water over North America. A hypothesis to this effect could not be rejected at the 0.05 significance level with the present data.

Thus an assumption that the monthly mean precipitable water field could be adequately deduced from either of the two times for radiosonde ascents appears tenable.

Both physical and financial constraints on data acquisition made it impossible to obtain data for both 0000 and 1200 GMT. Since the upper air data for the United States stations, which were used to improve the knowledge of the precipitable water field in the border areas, are published in the "Climatological Data National Summary"(U.S.Weather Bureau) for 1200 GMT only, observations made at that time were used to determine the precipitable water field over Canada.

(c) Effect of Time Averaging

The "Monthly Bulletin Canadian Upper Air Data", published by the Canadian Meteorological Service,provides tabulations of both temperature and relative humidity for the surface and the standard pressure levels for individual days and mean values for each month. Limited resources again placed a restriction on data acquisition such that monthly mean values were used to compute the monthly mean depth of precipitable water, rather than values from daily ascents. The two means so derived differ due to the non-linearities which exist in the formulation of Eqn. (1) used to compute precipitable water from temperature and humidity data.

Fig. 6, which is based on a random sample of eleven months, indicates that by using the monthly mean upper air data the precipitable water is underestimated for low values and overestimated for high values. The extent of this error inherent in the computed monthly mean values (as judged from the root mean square error of ± 0.07 cm) is similar to that associated with the other errors which arise in computing precipitable water (Barry, 1965).

(d) Length of Study Period

Since a restricted time period is used to derive the mean values it is necessary to verify the long term representativeness of the study period (1957-1964) and to indicate the reliability of a mean based on eight observations.

For three reasons Edmonton Industrial Airport was chosen for this special study. Minns (1970) found that of four Canadian locations, viz., Fort William, Fort Simpson, Winnipeg and Edmonton, the latter appeared to respond more definitely to an hypothesized decrease in the strength of the zonal circulation between 1820-1834 and the present. Secondly, the station is located in an area which has experienced considerable urban development in the last half century. Finally, high interannual variability in the monthly mean precipitable water values also meant that the mean monthly values would be less reliably defined at this location.

Tarnizhevskii (1959) states that the accuracy of determining mean monthly values of climatological parameters may be determined from:

$$e' = \overline{X}_s - \overline{X} \qquad (3)$$

such that

$$-\frac{\sigma}{\sqrt{N}}t < \overline{X}_s - \overline{X} < \frac{\sigma}{\sqrt{N}}t. \qquad (4)$$

where $\overline{X}$, $\overline{X}_s$ are the population and sample means, respectively, σ the standard deviation of the sample, N the number of observations, and t is Student's t. Thus e' represents the limits within which the difference between the population and sample means should lie with a certain probability, the latter being determined by the value chosen for t. In the present case the standard deviation was that for the 30-year period 1939 to 1968; N equalled eight; and a probability level of 0.90 with seven degrees of freedom was selected.

This analysis requires that the monthly means of the parameters be normally distributed, a fact which was verified for the present study using the Kolmogorov-Smirnov test with a 0.20 significance level.

The number of years N' for which observations of specific climatological parameters are required before the population mean may be established within certain limits with a given probability has been studied by Black (1961) and Budyko and Drozdov (1966). The value of N' may be determined from the following equation:

$$N' = (z\sigma/e')^2 \qquad (5)$$

where z is the critical value or confidence coefficient. In the calculation of N' the limits were set at ± 0.1 cm of the true mean 90 per cent of the time.

Finally Student's t-test was used to test for a significant difference between the means for the 30-year and 8-year (1957-1964) periods.

The analyses for January and June (Table 2) indicated that in both cases there was no significant difference between the long- and short-term means and that the mean monthly precipitable water could be adequately defined by the eight years of data.

Table 2. Analysis of computed precipitable water at Edmonton Industrial Airport

	January	June
Thirty-Year Mean	0.43	1.70
Eight-Year Mean	0.44	1.65
e'	0.04	0.06
N'	2	3

(e) Mesoscale Reliability

The power of the computational procedures used in the present study to increase the spatial sampling density would be severely reduced if large horizontal discontinuities in the monthly mean precipitable water field were indicated by the analysis. To test for this possibility two case studies were undertaken. The first was for the Toronto area where

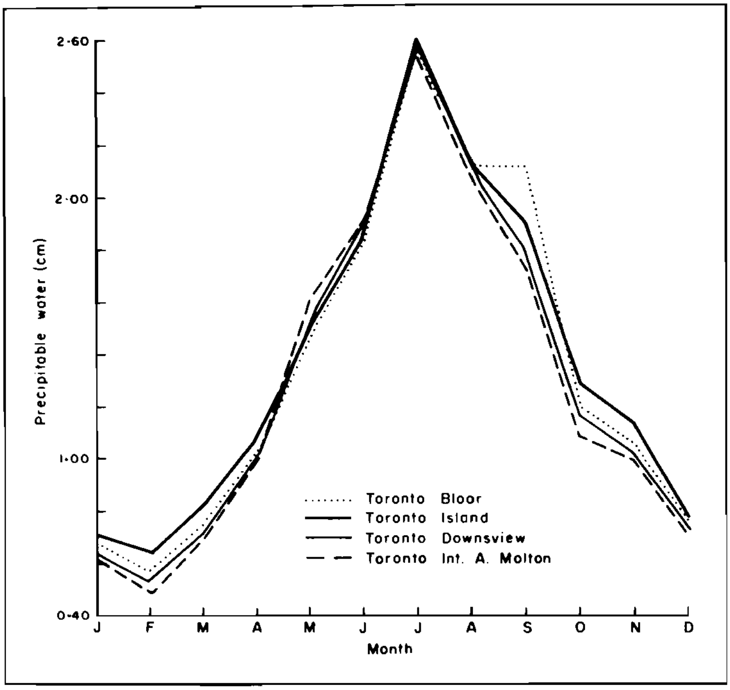

Fig. 7. Seasonal variation in precipitable water at four Toronto locations for 1964.

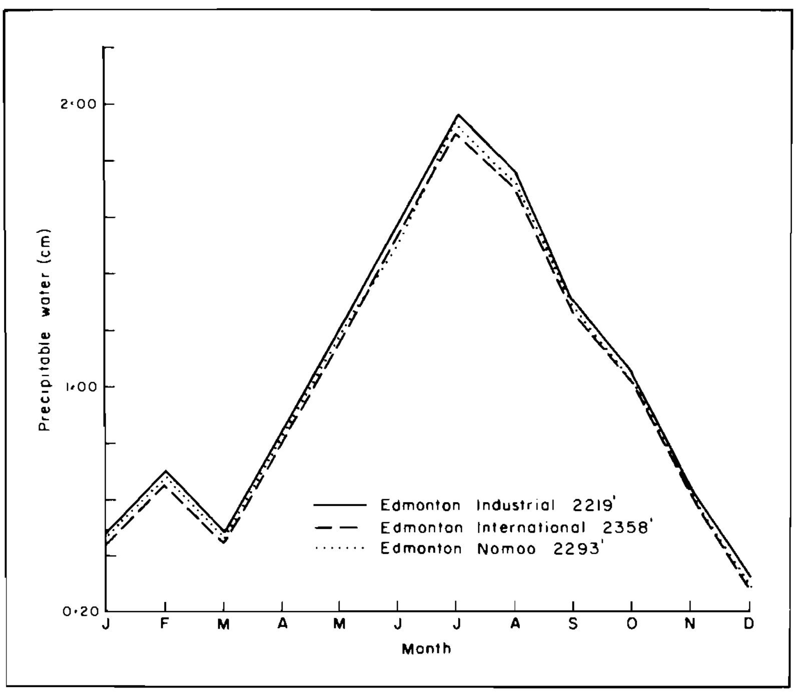

Fig. 8. Seasonal variation in precipitable water at three Edmonton locations for 1964.

four stations recording screen-height temperature and relative humidity on a synoptic basis were located.

Fig. 7 shows the seasonal variation in total precipitable water at these four locations for 1964. The coefficients in Equation 2 were assumed to be the same for all four stations. Despite their different locations the mean values of total precipitable water were very similar. Moreover, the small but persistent trends which are apparent may well have a physical meaning though caution must be exercised in the interpretation since the differences are within the probable limits of accuracy of the computations.

Between October and April the values suggest a gradient in precipitable water away from the shore of Lake Ontario, a pattern in keeping with the tendency for the lake to act as a heat and water vapour source in winter. In May and June it appears that the gradient was partly reversed as the city and lakeside areas became less important as water vapour sources. In July the similarity in values at all four locations must lead to the conclusion that any local differences were not sufficiently well developed to be reflected in persistent differences at screen-height. The gradient in August and September was opposite (and greater) than that for May and June possibly reflecting the renewed influence of the city as a heat source and the lake as a heat and water vapour source. This autumn trend subsequently merged into that typical of the winter months when the influence of the city relative to the lake was apparently lessened.

The implied seasonal variations in lake-to-land screen-height vapour pressure gradients are in agreement with the results of Richards and Fortin (1962) and Jackson (1963).

A second series of data (presented in Fig. 8) are for the Edmonton area where observations in 1964 were available for the Edmonton Industrial, Edmonton International and Namao Airports. The largest difference in total precipitable water between any of these locations occurred in July when a value of 1.89 cm was recorded at Edmonton International and 1.97 cm at Edmonton Industrial Airports. Urban-rural and altitudinal differences are thought to account for the consistent differences in the total depth of precipitable water between these three locations.

From these two studies it is apparent that despite the use of stations from widely diverse environments but in the same general locality, no large discontinuities in the total precipitable water field will arise. This further suggests that the screen observations, in accordance with the original purpose for establishing such an instrumental exposure, are more sensitive to the characteristics of the macroclimate than those of the microclimate.

6. SUMMARY AND CONCLUSIONS

The preceding sections have discussed both the reasons for, and the methods used in computing values of the depth of precipitable water over Canada. Empirical methods have made it possible to extend the analysis of the precipitable water fields into areas where upper air data are unavailable. Not only is it possible to define the characteristics of the precipitable water field in such areas to a satisfactory degree of accuracy,but it is also possible to gain insight into aspects of the physical and dynamical climatologies of Canada when studying the distributions of the empirical regression coefficients used to extend the analysis.

In Part II of this paper maps of mean monthly precipitable water over Canada will be presented and discussed along with a brief description of actual or potential applications for the results of the present study.

ACKNOWLEDGEMENTS

Grateful thanks are due to Mrs. E. Lay and Miss C. Herring who typed the first and final drafts of this paper, respectively;to the University of British Columbia, the University of London King's College, the University of Canterbury and McMaster University,and particularly to the Heads of the Geography Departments of these institutions, where portions of this study were undertaken; and finally to Dr. F.K. Hare, Geography Department, University of Toronto for his constant interest and guidance.

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BOOK REVIEW

DESCRIPTIVE METEOROLOGY. By H.C. Willett and F. Sanders. Academic Press Inc., New York, 2nd Edition, 1959, xix, 355 pp., 72 Fig. $9.50.

Descriptive Meteorology has been extensively used in Colleges and Universities throughout North America and Europe as a basic text for introductory courses in Meteorology. The subject matter builds up gradually and systematically from elementary properties of the atmosphere to the General Circulation, so that teachers using the book find their work neatly organized.

Probably the text's greatest asset lies in the fact that the authors have managed to describe a very complex system in simple language. Unlike other introductory texts the mathematical and physical treatment of the material is sufficiently elementary so that any student with competence in High School Physics and elementary calculus should be able to follow the development of the subject matter readily. For this reason, the text is now being adopted to introduce the Science of Weather to non-specialist students in Agriculture, Geography, Forestry and Engineering.

Although simplicity is the greatest asset of the text, it certainly contributes to some major weaknesses, e.g., the text tends to be circumlocutous, wordy and repetitious. Identical explanations are found in several sections of the book (thirty-one at last count). A more mathematical treatment could refer to an equation developed previously rather than repeating the substance of a thought associated with it. One wonders at the number of readers who might feel insulted by the style.

While one agrees with the authors that the book is not a reference text, it would be useful to give the curious student a more extensive bibliography to more advanced works, if he should wish to continue self-enquiry (after student days are over).

A great deal of effort is expended to describe the atmospheric system which could be summarized by a concise schematic representation. More illustrations and diagrams would be desirable in future editions; this suggestion is not a request for a pictoral text. Even though the type of student who uses this book would probably have difficulty visualising systems, especially if these were in more than two dimensions, the diagrams could help him a great deal.

One really valuable feature of the text is the inclusion of problems at the end of several chapters. Students at Calgary have made it a point to solve these problems to test their understanding of the material. This trend should be encouraged. However, future editions should provide answers at least to odd- or even-numbered problems, in order to save the student the trouble of searching for an often elusive instructor to verify his answers. It should also be possible to precede each set of problems with a worked example.

Descriptive Meteorology is a good textbook and one that I would recommend to all students and teachers in Meteorology and allied fields.

L.C. Nkemdirim,
The University of Calgary.

NOTES FROM COUNCIL

The following was elected to membership at the November 26, 1970, meeting of Council:

Graduate Student Member

Yoondae (David) Ahn

APPOINTMENT OF COMMITTEES

Council appointed Committees for the ensuing year at the October 28, 1970 meeting, as given below. The President is an ex officio member of all Committees.

Nominating Committee:	T.L. Wiacek, Chairman D.K.A. Gillies J.D. Holland
Membership Committee:	H.L. Ferguson, Chairman G.A. McPherson (ex officio) J.D. McTaggart-Cowan Chairman or appointee from each Centre
Awards Committee :	J. Clodman, Chairman K.L.S. Gunn K.D. Hage
Editorial Committee :	E.J. Truhlar, Chairman J.A.W. McCulloch H.B. Kruger R.E. Munn
Centres Committee :	C.M. Penner, Chairman With power to add

FIFTH ANNUAL CONGRESS

Second Canadian Conference On Micrometeorology

The Second Canadian Conference on Micrometeorology, and the Fifth Annual Congress of the Canadian Meteorological Society will be held May 10-12 and 12-14 respectively, at the Macdonald College Campus of McGill University.

The Campus, which houses the Faculty of Agriculture, is located at Ste. Anne de Bellevue, at the western tip of the Island of Montreal, about twenty miles from downtown Montreal, and about twelve miles from Montreal International Airport, Dorval. It can be easily reached from downtown Montreal, and from the airport, via Highway 2 and 20, and via the Trans-Canada Highway (number 40).

Double occupancy rooms, and meals, are available on the Campus for approximately $10 per day per person. There are a number of motels and restaurants within a radius of 5-10 miles, the nearest restaurants being in St. Anne de Bellevue, a 10-15 minute walk from the Campus.

The Annual General Meeting of the CMS will be held on the evening of Wednesday, May 12, and a banquet on the following evening, Thursday, May 13. Details concerning registration, program,etc.,will be announced later.

MEETINGS

CENTRE DE QUEBEC

Mardi soir, le 27 octobre dernier, avait lieu à la Faculté d'Agriculture de l'Université Laval la deuxième réunion d'information de l'année 1970-71.

A cette occasion, le conférencier invité était le docteur Denis J. Lamberts, docteur en sciences agronomiques et chef des travaux de recherche à l'Université de Louvain qui nous a parlé du sufet suivant: "Les changements de climat réflétés dans le développement des sols." Dans cet ordre d'idées, le docteur Lamberts nous a fait un exposé de paléo-climatologie en rapport avec la pédologie des sols fossiles en Belgique. Ce sujet dont on a eu peu souvent l'occasion d'entendre parler jusqu'a présent a su piquer la curiosité des auditeurs.

Le conférencier fut présenté par M.R. Perrier, président, et remercié par le docteur L.-J. O'Grady, de la Faculté d'Agriculture de l'Université Laval.

CANADIAN SCIENTIST ATTENDS INTERNATIONAL SYMPOSIUM ON CROPS AND CLIMATE

Scientists from around the world investigating the effects of climatological factors on crop production met at the University of Uppsala in Sweden, September 15 to 20, 1970. Mr. G. W. Robertson, a Canadian, and a CMS member, presented one of the seven key-note papers at the UNESCO Sponsored Symposium on PLANT RESPONSE TO CLIMATIC FACTORS. Some 150 scientists attended the symposium and presented 60 supporting papers. Topics discussed were concerned with such problems as: the effects of drought and freezing temperatures on the water stress within plants; the influence of radiant energy and temperature on water use,photo-synthesis, and the formation of leaf and floral buds; the importance of carbon dioxide on net assimilation, crop growth and yield;and the use of climatological data for appraising the probability of maturing crops and of their yield in various climatic areas of the world.

A method for determining the probability of maturing crops in given climatic zones was discussed by Mr. Robertson. His technique is based on simple and readily available climatic factors and provides a biometeorological time scale which is superior to the heat unit system for determining the rate of crop development. It appears to be universal in scope and, although developed from information gathered in Canada, has been successfully tested on data for wheat grown in the Argentine. The technique has been used for mapping those areas in Northwestern Canada where wheat might be matured without excessive risk of crop damage by freezing temperature.

It was suggested that the method could be used in many situations to determine the probability of maturing and harvesting grain under conditions where there is a risk of freezing temperature, drought, or wet weather at the time of critical growth periods and at the time of harvest. The technique will be valuable where new crops are being introduced in new areas, whether it is for replacement of wheat in the Canadian Prairies, for new rice strains in Southeast Asia,or for corn or other cereals in parts of the world where these crops have never been grown before.

Mr. Robertson was formerly Chief of the Agrometeorology Section of the Plant Research Institute, Canada Department of Agriculture from 1959 to 1969. He has recently served as an expert on agricultural meteorology with the United Nations Development Program in the Philippines where he has worked with a World Meteorological Organization team of experts which is assisting the Philippine Government with the organization and development of a research and training program in Meteorology. The work consists of both in-service training at the Philippine Weather Bureau and post-graduate training in the Department of Meteorology at the University of the Philippines.

SOMAS MEETING 29 OCTOBER 1969

The 21st meeting of the NRC Subcommittee on Meteorology and Atmospheric Sciences was held at Ottawa on October 29, 1970.

SOMAS continued to discuss weather modification legislation and was pleased to note the passage of Bill 6 by the Quebec National Assembly. However, the Committee was of the opinion that the Quebec law covered only the stimulation of precipitation and not the suppression of precipitation and resolved to continue to press for legislation in this area in all provincial capitals.

SOMAS noted that the National Research Council had responded positively to its efforts with respect to the Global Atmospheric Research Programme and sent forward a resolution encouraging NRC to continue to do so. The committee also established a Canadian Scientific Committee for GARP with the following terms of reference. The CSC for GARP is a subcommittee of SOMAS, and, acting on behalf of SOMAS, will a) give scientific support to the Coordinating Committee for GARP of NRC; b) communicate directly with the Joint Organizing Committee for GARP on scientific matters; c)coordinate the scientific content of Canadian GARP programmes. The chairman of this subcommittee is Dr. Andre Robert, and its other members are Dr. R.W. Stewart, Dr. M. Miyake, Dr. W.L. Godson, Dr. W. Hitschfeld, Dr. C.L. Mateer, Dr. R.E. Munn.

The Committee also discussed the question of student needs and prospects in meteorology in the future, and resolved to communicate with the Science Council concerning a possible survey of meteorological manpower needs in the next 5 to 10 years.

CONFERENCE ON GREAT LAKES RESEARCH

The 14th Conference on Great Lakes Research will be held in Toronto, Canada, on April 19, 20 and 21, 1971.

Sponsored by the International Association for Great Lakes Research, the 14th Conference is co-hosted by the Canada Centre for Inland Waters, Burlington, and the Great Lakes Institute, University of Toronto.

Further information may be obtained by writing to Mrs. J.S. Seddon at the Great Lakes Institute, University of Toronto, Toronto 5, Ontario, Canada. Telephone 928-2995.

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Section C: General Subject Index

EDITORIAL NOTE

The first issue of ATMOSPHERE (Volume 9 Number 1) in the new format should be distributed during March, 1971.

INFORMATION FOR AUTHORS

Articles may be contributed either in the English or French language. Authors may be members or non-members of the Canadian Meteorological Society. Manuscripts for ATMOSPHERE should be sent to the Editor, ATMOSPHERE, P.O. Box 851, Adelaide Street Post Office, Toronto 210, Ontario. After papers have been accepted for publication, authors will receive page proofs along with reprint order blanks.

Manuscripts for ATMOSPHERE, should be submitted in duplicate, typewritten with double-spacing and wide margins, each page numbered consecutively. Headings and sub-headings should be clearly designated and distinguished. Each article should have a concise, relevant and substantial abstract.

Tables should be prepared on separate sheets, each headed with a concise explanatory title and number.

Figures should be provided in the form of two copies of an original which should be retained by the author for later revision if required after review. A list of legends for figures should be typed separately on one or more sheets. Authors should bear in mind that figures must be reduced for reproduction, to be printed alone or with other figures. Labelling should be made in a generous size so that characters after reduction are easy to read. Line drawings should be drafted with India ink at least twice the final size on white paper or tracing cloth, and adequately identified. Photographs (half tones) should be glossy prints at least twice the final size.

Units. The International System (SI) of metric units is preferred. Units should be abbreviated only if they are accompanied by numerals, e.g.,"10 m", but "several meters."

Footnotes to the text should be avoided.

Literature citations should be indicated in the text by author and date. The list of references should be arranged alphabetically by author, and chronologically for each author, if necessary. Forms of abbreviation may be obtained by studying past issues of ATMOSPHERE.

Italics should be indicated by a single underline.

THE CANADIAN METEOROLOGICAL SOCIETY
La Société Météorologique du Canada

The Canadian Meteorological Society came into being on January 1, 1967, replacing the Canadian Branch of the Royal Meteorological Society, which had been established in 1940. The Society exists for the advancement of Meteorology and membership is open to persons and organizations having an interest in Meteorology. There are local centres of the Society in several of the larger cities of Canada where papers are read and discussions held on subjects of meteorological interest. ATMOSPHERE is the official publication of the Society. Since its founding, the Society has continued the custom begun by the Canadian Branch of the RMS of holding an annual congress each spring, which serves as a National Meteorological Congress.

For further information regarding membership,please write to the Corresponding Secretary, Canadian Meteorological Society, P. O. Box 851, Adelaide Street Post Office, Toronto 210, Ontario.

There are three types of ordinary membership - Member, Student Member and Corporate Member. For 1971, the dues are $14.00, $2.00 and $40.00, respectively. ATMOSPHERE is distributed free to all types of member. Applications for membership should be accompanied by a cheque made payable at par in Toronto to the Canadian Meteorological Society.