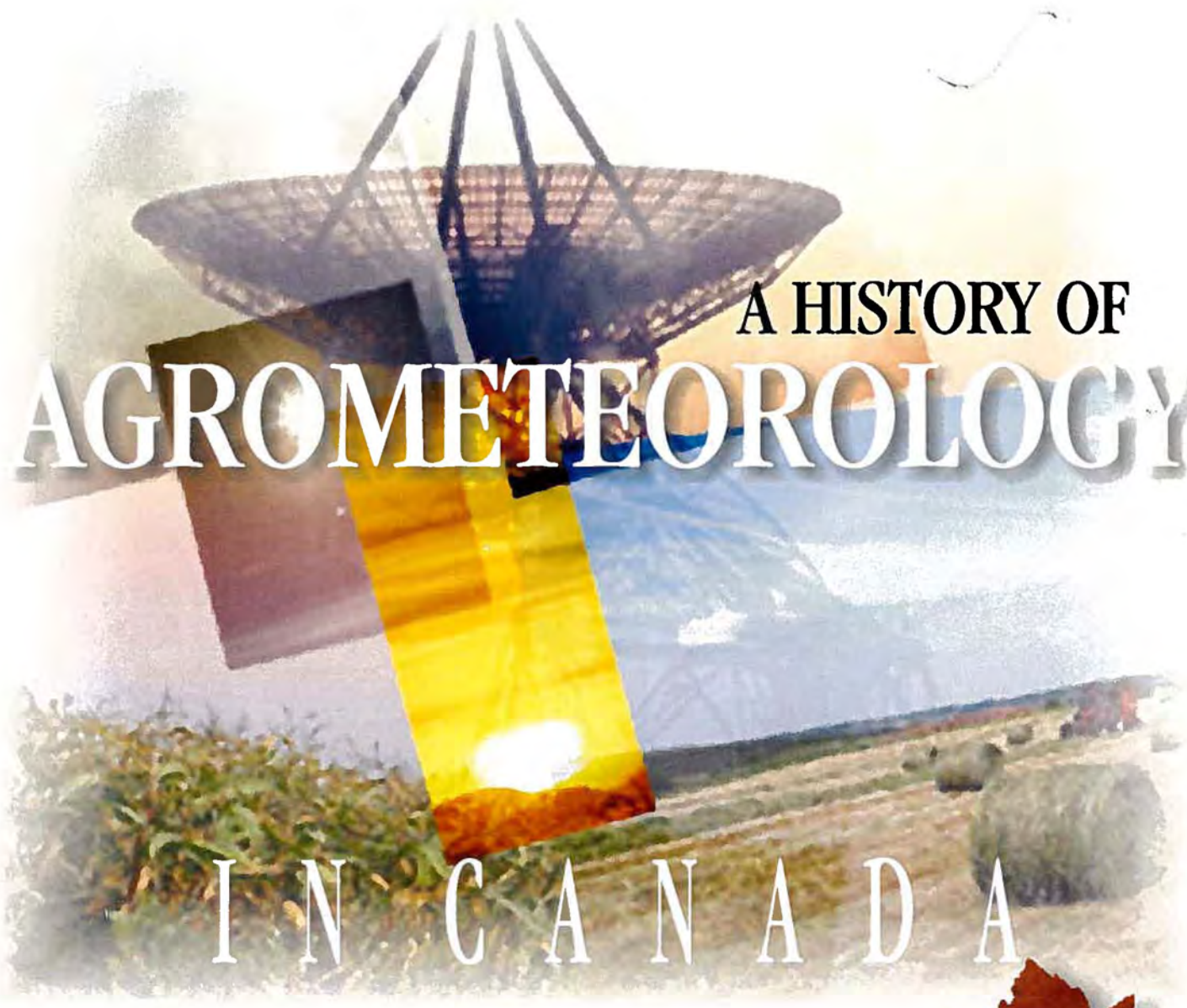
Environment Canada Environnement Canada



A HISTORY OF AGROMETEOROLOGY IN CANADA

By George W. Robertson

Canada

A HISTORY OF AGROMETEOROLOGY IN CANADA

By GEORGE W. ROBERTSON

Unpublished Report,
Atmospheric Environment Program,
Environment Canada, 1998.

TABLE OF CONTENTS

FORWARD

The World Meteorological Organization is a specialized agency of the United Nations. Its Commission for Agricultural Meteorology, to which most of the world's countries belong, promotes the application of meteorology to enhance world food production. At its Ninth Session in 1986 the Commission "encouraged members to prepare for individual countries a 'History of Agricultural Meteorology' that was linked to international work and the work of the Commission." (WMO, 1987.)

In response to this request, and in recognition of the valuable contributions of a substantial number of Canadians to the discipline, Agriculture Canada and Environment Canada agreed to produce "A History of Agrometeorology in Canada". A joint project was developed by the two Departments, and George Robertson was commissioned to prepare the manuscript.

Robertson is a well-know, well-respected agrometeorologist, both in Canada and internationally. He headed Agriculture Canada's Agrometeorological Section for 18 years, served two years as a consultant in a WMO assignment in the Philippines, then returned for another two years to the Swift Current Research Station as Head of the Soil Science Section. After his retirement in 1973 he undertook a variety of consulting jobs, including missions sponsored by WMO and the Food and Agriculture Organization to strengthen agrometeorology in developing countries. His more than 30 years of experience as a researcher, teacher, manager, consultant and coordinator give him a perspective that few others could match.

Dr. Wolfgang Baier, retired Director of Agriculture Canada's Plant Research Centre, provided leadership and support for the preparation of the manuscript, in cooperation with Mal Berry, former Chief of the Analysis and Impact Division of Environment Canada.

Environment Canada's Joan Masterton managed manuscript completion and publication. Ed Truhlar and Mal Berry edited the document.

PREFACE

Agrometeorology in Canada has had a long and varied development. The first concerns for the effects of weather on agriculture were probably by agriculturists themselves who had to live with the weather and make the best of it. Early, serious studies involved drought and frost and how these hazards affected the survival of crops. Action was taken by plant breeders who learned to live with the climate as best they could by developing or selecting crops that required a short growing season to fit the limited frost-free season in many parts of Canada. The development and selection of drought-resistant varieties was also of concern to early agriculturists. As time went on, the management of land, irrigation, and harvesting of cereals and hay had to be adapted to the climate and its variability. Even the fight against insects and diseases peculiar to the environment of Canada had to be geared to the prevailing weather conditions. Thus it was only natural that agriculturists studied climate and its effects on all facets of crop production.

At an early stage, meteorologists, or more specifically climatologists, were quick to realize the importance of weather to agriculture and assisted agriculturists with a better understanding of the climate of the country and its variability. They also undertook, or encouraged the taking of, weather observations and made these available to those wishing to do their own analyses. As the science of weather forecasting developed, meteorologists became concerned with providing farmers with advanced notification of forthcoming weather events. First attempts were not too successful but as the science progressed so too did the usefulness of forecasts. This development involved a better understanding of the earth's atmosphere and its movement, better measuring techniques, improved national and global communication networks, faster handling of multitudes of data, better understanding of farmers' requirements and what could be provided, and finally an improved and acceptable means of distributing information to the farmer.

When I took on this task of reviewing the progress of agrometeorology in Canada, I envisioned about 300 pages of double-spaced manuscript. As more and more information was uncovered in old reports and from respondents to letters and notices about this effort, it gradually became obvious that agrometeorology in Canada developed on many fronts. These included agricultural and forestry research institutions, the Canadian Meteorological Service, universities, research councils, and provincial governments. That chaotic development of the science didn't occur is due largely to international, national, regional and provincial commissions, committees and societies which brought people together and provided the opportunity to discuss problems and their solution.

Throughout the report I have attempted to include sufficient material so that any one thread of a complicated agrometeorological fabric may be traced. Included are such items as the development of farm-weather services, communications, farmers' feedback, crop-production monitoring, the micro-environment of crops, integrated pest management, land capability assessment, climatic resource management, crop environment physiology, remote sensing of agrometeorological events, and a host of other problems. These problems have been identified by groups and individuals who followed through to a successful conclusion or are still working on unsolved problems. One of my objectives here was to identify those groups and individuals who made contributions to one or more of these threads that make up the fabric.

To identify those who took part in the development of agrometeorology several dozen letters were sent to individuals asking for specific information from them and their colleagues. Also, the assistance of the Canadian Meteorological and Oceanographic Society (CMOS) and the Canadian Society of Agrometeorology (CSAM) was solicited in bringing this project to the attention of their members and in seeking information from them. At this point I want to thank these two Societies for their cooperation

regarding this matter. Much of the material for the History also was obtained from the annual reports of the NCAM (ECA), other annual progress reports, and other histories and reports.

I owe a debt of gratitude to a number of people who helped to make this History possible. First I want to thank Dr. Wolfgang Baier and Mr. Mal Berry for making it possible for me to work on this project. I greatly appreciate the valuable information provided by many individuals in response to my letters and the announcements in the monthly newsletters of CMOS and CSAM. Many of these letters provided valuable information on early events and developments over time. My thanks to all of you who so generously responded. Especially I want to acknowledge the assistance provided by Mr. Morley Thomas who prepared the chapter (Ch. 2) on "The Early Years" and to Dr. Graham Walker and Mr. Ray Garnett who prepared the section on the development of the Weather and Crop Surveillance Section of the Canadian Wheat Board. (Ch. 7, Part 5). Lastly, my sincere gratitude to my wife, Lucille, who helped with the typing, sorting of material and proofreading, and who stood by me while I spent endless hours on the word processor when we should have been out enjoying the weather and gardens at our summer cottage in the forests of the Gateneau. Thank you one and all.

George W. Robertson,
Ottawa, 1990

CHAPTER 1
INTRODUCTION

The Climatic Scene

The climates of the agricultural areas of Canada, both within and between regions, are as variable as any found in most agricultural areas of the temperate climatic zones of the world. Large regional variations are the result of a long coastline exposed to both the Atlantic and Pacific Oceans and to the Great Lakes, a vast continental interior, and deep valleys between high mountain ranges. Precipitation may occur at any time in all regions, although it is most important and heavier east of the rocky Mountains during the summer months. Along the west coast winter precipitation is much heavier than summer rainfall, which may be quite scanty in many areas. Conditions are arid in some of the interior valleys of the Rocky Mountains and semi-arid in the Prairie Provinces, where severe droughts are not uncommon.

Winter conditions have a profound influence on soil characteristics and on the survival of perennial crops. Winter precipitation ranges from heavy rainfall along the west coast and heavy snowfall in the mountains, to scant snowfall on the prairies, and a mixture of rain, snow or freezing rain in Ontario and Quebec, and moderately heavy snow along the east coast.

There is a wide range of temperature both seasonally and geographically. Winters are moderately mild along the West Coast but elsewhere are generally below freezing. Coldest temperatures occur on the prairies where, along with scant snow cover on the ground, deep freezing of the soil occurs. Elsewhere, where snow offers good insulation, soil temperatures are usually uniformly near or just above freezing during the winter months. Summer temperatures are more uniform across Canada during the growing season but range from moderate along the east and west coasts and in northern regions, to hot and humid (almost tropical) in southern regions (Ontario) and hot and dry in the valleys of the Rocky Mountains.

Climatic variability within regions is equally important to agriculture in Canada. By far the greatest, and most common to all regions, variability is from winter snow and subfreezing temperatures to summer heat. In fact the beginning, duration and end of the growing season in Canada is determined by the annual march of temperature. Spring sowing takes place when the soil has warmed sufficiently to support seed germination and harvesting must be completed before freezing temperatures and snowfall come in the autumn.

The West Coast has the longest growing season in Canada with the least variation of temperature from summer to winter. The mountain valleys and the prairies have the greatest annual range of temperature, and a relatively short growing season accompanied by a high risk of untimely freezing temperatures in both spring and autumn. There is a risk of snow before harvest on the prairies. The beginning of the growing season in the eastern provinces is about the same as for the prairies, but the end of the season extends well into autumn because of the moderating effects of large bodies of water, resulting in longer growing seasons.

Temporal changes in climate or abnormalities are extremely important to Canadian agriculture as they determine the degree of risk involved in various farming activities. Variability in winter snowfall has a bearing on the availability of irrigation water, the survival of over-wintering crops and plants, and for recharging soil water. This is particularly important in the prairies and those mountain valleys that depend on runoff for irrigation. Untimely freezing temperatures in the early spring may cause damage to

emerging seedlings and particularly to the flowers of fruit trees. Summer droughts occur from time to time and are particularly severe on occasion over the prairies. Occasional hail, windstorms, tornadoes and flooding are also problems in some areas.

These variations in Canadian climate have created a keen awareness of weather and climate amongst all levels of personnel involved in the agricultural industry, and by agricultural scientists and meteorologists. As a consequence many studies have been made of Canada's climate, its variability and risks in relation to agricultural land-use planning and management, and crop productivity. Also, a great deal of effort has been devoted to the development of short-term weather forecasting services specifically for agricultural operational purposes.

Canadian Agriculture

Farming in Canada is as varied as the climate. Arable land is generally confined to a narrow strip just north of the Canada-United States border, ranging in width from less than 200 km to over 500 km. Although some horticultural crops are grown in the Yukon and the Northwest Territories, the northern extent of commercial farm land is in Alberta, where it almost reaches the 60th parallel of latitude.

Animal husbandry is practised in every province where pasture and forage crops can be grown. Beef cattle are raised on large ranches, mainly in Alberta and the interior of British Columbia. Dairy cattle are raised in all provinces but the main dairy industry is in Ontario and Quebec. The Great Plains Area of western Canada is noted for its high protein spring wheat, barley, canola and other small grain crops. Corn and soya beans are grown extensively in southern and central Ontario, while tobacco is grown in a small area of southern Ontario and in New Brunswick. Tree fruits, small fruits and wine are produced chiefly in British Columbia, the Niagara Peninsula of Ontario and in southwestern Quebec. The Maritime Provinces are noted for their potatoes, although this crop can be grown in almost all regions of the country. Market gardening is carried out in most areas of Canada near large cities where there is a ready market for produce. Canning crops such as tomatoes, green peas and corn are produced mainly in southern Ontario and southern Alberta.

Irrigation is confined chiefly to the interior valleys of British Columbia, and in southern parts of Alberta and Saskatchewan. Supplemental irrigation is applied in many other areas of the country where water is available and special high-value crops such as small fruits and market garden crops are grown.

Forestry is practised in all provinces but the major operations are in British Columbia, Northern Ontario, Quebec, New Brunswick and Nova Scotia.

This brief background of the climate and agriculture of Canada will provide a backdrop against which the science of agrometeorology developed over the past 100 years or so in Canada.

Agrometeorological Services in Canada

In the area of meteorology, Canada follows a "single service" policy, in a general sense, for providing meteorological services to the public and industry, including agriculture and forestry.

The Canadian Meteorological Service (CMS), or as it is currently known, the Atmospheric Environment Program (AEP) of the Department of the Environment (Environment Canada) is responsible for a number of programs.. These include networks of official weather stations, the preparation of weather forecasts, the archiving and publication of climatological data and summaries, telecommunications systems for the exchange of data and weather information, the official representation of Canada in international meteorological activities, and research work associated with these activities.

The AEP has encouraged weather-sensitive areas in industry and the public to undertake problem-oriented research, to provide specialized services, and to undertake training programs from the farmer level up to postgraduate level. In these endeavors the AEP has often been an active partner.

In the field of agriculture, the Canadian Department of Agriculture is responsible for agricultural policies, price control for certain commodities, subsidies and insurance, marketing, the Canada land inventory, and research in many areas of food production, transportation and storage. Research is also carried out at the universities along with teaching programs. Extension services at the farm level is usually left to the responsibility of the provinces.

Forestry activities are shared by the Canada Department of Forestry and provincial departments. In general the federal department is responsible for research while the provinces are responsible for forest protection and reforestation.

Climate is an important resource for consideration in all phases of agriculture and forest activities.

Modus Operandi

In this history of Canadian agrometeorology, it is shown how research and services provided to agriculture and forestry developed from the earliest of times to the present complex system of individual and institutional activities and cooperation. The activities of the Canadian Meteorological Service, the Canadian Departments of Agriculture and Forestry, provincial government departments, and the universities are traced. The roles of the Expert Committee on Agrometeorology, the Canadian Federation of Agriculture, scientific societies and international organizations, in encouraging agrometeorological research and service in Canada are considered. Lastly, many individuals have played a very important role in developing agrometeorology and this is portrayed throughout the text.

CHAPTER 2
THE EARLY YEARS

by Morley K. Thomas

The Meteorological Service of Canada

Before the Meteorological Service was organized in 1871-72, Prof. G.T. Kingston, Director of the Toronto Observatory attempted to have an observatory established in the Red River Settlement to measure the climate and thus learn more about the possibilities for agriculture and settlement. But Kingston was rebuffed, and so he turned his attention to promoting a scheme for a network of climatological observing station in the East, and was successful.

Weather forecasting followed immediately and public weather forecasts were first issued in 1876, a by-product of analyses done in preparing storm warnings for shipping. No special attention to agriculture was given in the forecast until 1879 when "probabilities" were in demand so farmers could benefit from them during haying and wheat harvest. The Ontario newspapers were publishing weather forecasts by this time but there was a real problem in getting timely information to the farmers. Attempting to solve this the Meteorological Service made arrangements with several railroads to have the morning trains in summer carry a "weather disc" or symbol indication the forecast for the next 24 hours - i.e., fair cloudy, or rain. Successful for a while, the program was discontinued after 10 years or so because so often railroad workers neglected to change the disc each day.

Provincial Interests

Another milestone in developing agrometeorology during the 1880's was the interest shown by the three provincial governments in setting up and maintaining networks of precipitation measuring stations. In Ontario it was Archibald Blue of the Board of Industry; in Manitoba Acton Burrows, Deputy Minister of Agriculture and Statistics; and in British Columbia J.R. Anderson, Deputy Minister of Agriculture who were the enthusiasts in promoting the acquisition of precipitation data in their provinces. Burrows, in Manitoba, first wrote to the Meteorological Service Director in January 1883 and within three years scores of new precipitation stations had been opened in the province.. That year one third of the 250 precipitation stations in Canada were located in southern Manitoba.

Weather and Agricultural Connections

More developments in the 1880's marked the beginnings of an appreciation for the connection between agriculture and weather-climate. In April 1886 Wm. Johnston, President of the Ontario School of Agriculture at Guelph wrote to the Service about the possibility of the School operating a paid or salaried observing station. There being no chance of this, the School purchased instruments to aid in teaching meteorology and became a cooperative, volunteer climatological station. In the 1888 Annual Report of the Service, the director thanked Prof. H. H. Panton of the School "who, in addition to taking charge of the observations at that station, has induced several of the students on leaving the college, to keep a register of rainfall at their own residences."

Also, during this decade the Dominion Department of Agriculture established the first five Experimental Farms where meteorological observations were taken from the start. Dr. Wm. Saunders, founder and first Director of the Experimental Farms Service corresponded with Mr. Charles Carpmael, Director of the Meteorological Service, Department of Marine and arranged for instruments to be supplied to the Farms by the Meteorological Service.

Some phenological reports were published through action by the Royal society of Canada but it was to be 20 years later before there was again important action in the field of agrometeorology. By about the turn of the century daily weather forecasts were available for all regions of southern Canada - published in the daily newspapers and in some areas obtainable from the local telephone central. Some years later the Meteorological Service experimented with frost warning services for fruit growers in the Niagara Peninsula and and in the Annapolis Valley. British Columbia Fruit Growers demanded a similar service in 1919 although it was not begun until 1935.

International Considerations

Just before World War I, a rivalry between Agriculture and Meteorology began to develop over whom should be allowed to expand to provide additional services for the farmers. In March 1911, T.K. Doherty of the Department of Agriculture at Ottawa, was appointed Canadian Commissioner of the International Institute of Agriculture and named to represent Canada at the 1911 General Assembly in Rome.

It appears that this Assembly formed a Committee on Agricultural Meteorology to fill a vacuum created by the inaction on the matter by the International Meteorological Organization. This caused some concern amongst the meteorologists, both in Canada and internationally, and led to the setting up a Section for Agricultural Meteorology (CAgM) by the International Meteorological Organization (IMO) in 1913.

R.F. (Later Sir Frederic) Stupart, by then the Director of the Meteorological Service, was a leading proponent for the CAgM and became a charter member of the Commission in 1913 (IMO, 1914, Cannegiester, 1963).

Increasing Activity by CMS

R.W. Mills served as agrometeorologist in Toronto from February 1914 until November 1916 during which time he cooperated with the Domion Experimental Farms Service at 14 of their stations in a field experiment on spring wheat in relation to weather. Much of this experiment appears to have been based on the work of Russian agrometeorologist as several Russian publications on the subject were translated about this time. Mills became ill, however, and resigned. Some of his work was taken over by E.G. McDougal who succeeded Mills but publication did not come until 1918 when A.J. Connor, the Dominion Climatologist, wrote "Agricultural Meteorology - Relation of the Weather to the Yield of Wheat in Manitoba" (Connor, 1918) and others (Connor, 1922, 1926). Later, McDougal published a report on weather and sugar beet yields (McDougal, 1920).

In 1920 the Meteorological Service set up an office at the Grain Exchange in Winnipeg and soon the Winnipeg Daily Weather Map publication was begun. Later this accompanied the Western Bulletin that was first issued several years earlier. During the 1920's there appears to have been somewhat of a stand off between Agriculture and Meteorology, probably through lack of resources.

Spurred on by the developing drought situation in the Prairies during the 1930's, agrometeorology received an increasing amount of attention. Connor became the agrometeorological expert in the Meteorological Service and Canada's representative on the CAgM of IMO. He became interested in the prairie drought situation and published a number of papers on the matter in the Canada Yearbook and other governmental reports (Connor, 1931, 1933, 1939, 1941).

Activities Elsewhere

Dr. F.T. Shutt, Dominion Chemist with the Canadian Department of Agriculture made several studies of climatology and the effect of environment on wheat quality and growth. Measurements of the fertilizer value of chemicals in precipitation were also made (Shutt, 1894, 1908, 1910, 1915).

The drought of the 1930's inspired a great deal of thought about the influence of weather on crop yields. The man who published most in the sector was Dr. J.W. Hopkins, Biologist of the National Research Laboratories (Council), Ottawa. His dozen or so papers dealt more with climatic elements for the benefit of agriculturists (Hopkins, 1935, 1936, 1938a, 1938b, 1939, 1941).

Others were also thinking of the effect of weather and climate on agriculture. An attempt to relate wheat yield to tree rings was made (Powell, 1932); soil temperatures were investigated (Thomson, 1934); water conservation was considered (Main, 1935); and the leaching in the higher rainfall area of eastern Canada was studied (McKibbon, 1933). Research work at a more basic level was also being undertaken at the universities in regard to frost injury to plants at McGill (Siminovitch and Scarth, 1938) and plant growth at Alberta (McCalla et al., 1939).

Little attention was paid to agrometeorology during World War II although the publication of the 1941 US Department of Agriculture Yearbook "Climate and Man" must be noted.

Early Research

Some pre-WW-II research is illustrated by the following publications listed in chronological order.

1894 SHUTT, F.T. Observations on the quality of air at Ottawa. Trans. Roy. Sec. Of Canada, Sect. III, p. 47-49 .

1908 SHUTT, F.T. The fertilizing value of snow. Trans. Royal Soc. Of Canada, Section III, pp. 181-185.

1909 SHUTT, F.T. The influence of environment on the composition of wheat. J. Soc. Chem. Ind. pp. 12-15.

1910 SHUTT, F.T. The nitrogen compounds of rain and snow. Roy. Soc. Of Canada, Sect. III, pp. 55-59.

1914 IMO. Report of the Tenth Meeting, Rome, 1913. His Majesty's Printing Office, London, M.O. 216, 95 pp.

1915 SHUTT, F.T. and HOUSTON, G.N. Report of the climate and soil conditions in C.P.R. Company's Irrigation Project, Western Section, near Calgary, Alberta. Canadian Dep. of the Interior, Irrigation Br. Bull. No. 3.

1918 CONNOR, A.J. Relation of the weather to the yield of wheat in Manitoba. Mon. Bull. Agric. Statist. April, 11 pp.

1920 MCDOUGHAL, E.G. Influence of climate on the yield and quality of sugar beets in Canada. Mon. Bull. Agric. Statist. 13:295-301.

1922 CONNOR, A.J. Modal atmospheric streaming in wet and dry seasons in the Canadian wheat region. Bull. Am. Meteorol. Soc. 3:35-36.

1926 CONNOR, A.J. The distribution of precipitation in Canada. The Canada Year Book. pp. 42-46.

1931 CONNOR, A.J. Agriculture, climate and population of the Prairie Provinces of Canada. Dominion Bureau of Statistics. pp. 9-21.

1932 CONNOR, A.J. Droughts in Western Canada, The Canada Year Book. 128 pp.
POWELL, L.B. Tree rings and wheat yields in southern Saskatchewan. Mon. Weather Rev. 60:22-221.

1933 McKIBBON, R.R. Climate and soil leaching variation in Quebec. Sci. Agric. 13:413-425.

1934 SHUTT, F.T. The quality of wheat as influenced by environment. Empire J. Exp. Agric. pp. 119-138.

THOMPSON, W.A. Soil temperatures at Winnipeg, Manitoba. Sci. Agric. 15:209-217.

1935 HOPKINS, J.W. Weather and wheat yields in western Canada. I. Influence of rainfall and temperature during the growing season on plot yields. Can. J. Res. 12:306-334.

MAIN, T.C. Weather conservation in the Prairie Provinces. Eng. J. Montréal. 18:212-218/221-231.

HOPKINS, J.W. Agricultural Meteorology: Some characteristics of precipitation in Alberta and Saskatchewan. Can. J. Res. C, 14:319-346.

1937 ROSE, J.K. Weather and wheat yield in Western Canada, Geogr. Rev. 27:140-142.

1938a HOPKINS, J.W. Agricultural Meteorology: Correlation of air temperatures in central and southern Alberta and Saskatchewan with latitude, longitude and altitude. Can. J. Res. C, 16:16-26

b HOPKINS, J.W. Influence of air temperatures and soil moisture subsequent to flowering on the nitrogen content of wheat. Can. J. Res. C, 16:135-144.

1938 SIMINOVITCH, D. and SCARTH, G.W. A study of the mechanism of frost injury to plants. Can J. Res. C, 16:467-481.

1939 CONNOR, A.J. The Climate of Manitoba. Economic Survey Board, Winnipeg. Rep. No. 16. 163 pp. + tables + maps.

HOPKINS, J.W. Estimation of leaf area in wheat from linear dimensions. Can. J. Res. C, 17:300-304.

McCALLA, A.G., WEIR, J.R. and NEATBY, K.W. Effects of temperature and sunlight on the rate of elongation of stems of maize and gladiolus. Can. J. Res. C, 17:388-409.

1941 CONNOR, A.J. Snowfall maps of Canada. Proc. Cent. Snow Conf., Michigan State College, East Lansing. 1:153-159.

HOPKINS, J.W. Agricultural Meteorology: Seasonal incidence of rainless and rainy periods at Winnipeg, Swift Current and Edmonton. Can. J. Res. C, 19:267-277.

RIPLEY, P.O. Observations on snow cover as affecting crops. Proc. Cent. Snow Conf., Michigan State College, East Lansing. 1:116-126.

CHAPTER 3
CANADIAN METEOROLOGICAL SERVICE

PART 1 - ORGANIZATION AND POLICY

Background

A number of factors contributed to the development of agrometeorology during the early years following the Second World War. Chief among these were the restraint of scientific research, development and services in the public sector during the war; and scientific developments in the areas of weather forecasting and applied meteorology resulting from military activities during the war. When peace was declared, the dam burst and a flood of knowledge was released for public use.

Two factors helped to direct a part of this flow of knowledge to the area of agrometeorology.

International Influence

The first of these factors was at the international level. The International Meteorological Organization (IMO) was formally established in 1878 at a conference in Utrecht, the Netherlands. It was composed of directors of meteorological services of countries and territories throughout the world and, although they did not have the full official backing of governments, they nevertheless pursued ambitious programmes of perfecting and standardizing meteorological activities. This Organization showed very little interest in agrometeorology except to obtain observations from experimental agricultural sites wherever possible. In 1912 the Institut international d'agriculture, during its regular meeting in Rome, formed a Committee on Agricultural Meteorology. This caught the IMO unawares and at their 10th meeting in Rome on April 7, 1913 the matter was fully discussed. Although some members thought that agrometeorology belonged within the sphere of agriculture, it was agreed that the IMO should form a permanent Commission for Agricultural Meteorology (CAgM/IMO). As noted earlier, Canada was represented at this meeting by Sir Frederic Stupart, the Director of the CMS, who became a charter member of the Commission.

Eight meetings were subsequently scheduled by CAgM/IMO, but two intervening wars and financial problems prevented much serious activity.

The 8th and last meeting of the IMO/CAgM was held in Toronto, August 11- 23, 1947, at the invitation of the Canadian Meteorological Service (CMS) and was hosted by them (IMO, 1949). Following this and other Commission meetings, the IMO was reorganized as the World Meteorological Organization (WMO), one of the Technical Organizations of the United Nations, and CAgM/IMO became the Commission for Agricultural Meteorology (CAgM/WMO), one of eight Technical Commissions of the WMO.

This last meeting of CAgM/IMO in Toronto was an important one for Canada and undoubtedly inspired many individuals in attendance to think more about the role of meteorology in agriculture. It was attended by 18 representatives from 16 countries. The official delegates from Canada were Mr. C.C. Boughner, Chief of the Climatology Division of the CMS, Dr. D.L. Putnam of the Ontario Research Foundation, and Dr. P.O. Ripley of the Experimental Farm Service of the Canada Department of Agriculture (CDA) in Ottawa.

Boughner had joined the Climatological Division of the CMS in 1934, shortly after graduating from the first M.A. course in meteorology offered by the University of Toronto. He succeeded Mr. Connor as Chief of the Climatology Division when the latter retired.

Two other members of the CMS attended the meeting as observers: Mr. A. Thomson, Assistant Director, and Mr. F.D. Thompson both from the CMS Headquarters. Three other Canadian Scientists attended as observers: Mr. J.S. Smith, physics lecturer, at the Ontario Agricultural College, Guelph; Dr. W.G. Wellington, entomologist with the Canadian Forestry Service; and Dr. J.L. Doughty, Officer-in-Charge of the Soil Research Laboratory of CDA in Swift Current, Saskatchewan. The three official delegates (Boughner, Putnam and Ripley) were essentially administrators, not agrometeorologists, but were leaders in areas where agrometeorology was to develop in the future. All three appeared to have been inspired by this meeting.

Surplus of Meteorologists

The second factor encouraging the development of agrometeorology was an apparent abundance of meteorologists left over from war activities. During the war a large number of meteorologists had been recruited and trained for service in the British Commonwealth Air Training Plan. Afterwards there was, temporarily, a surplus of them. Many wished to continue in meteorology as a career. Furthermore, meteorology had made great technical advances during the conduct of the war, not only in the fields of climatology and weather forecasting but also in the application of meteorology to many weather-sensitive planning and technical problems. It was only natural then, that the Director of the Meteorological Service, Dr. Andrew Thomson, should look further afield for expanding the science of meteorology other than in the field of weather forecasting. It was not difficult to foresee economic and social potential for research in regard to the role of meteorological in such applied areas as agriculture, forestry, hydroelectric power transmission, the National Building Code, railroad and highway transportation and aircraft engine design.

The CMS had operated unofficially under a Single Service System for several years. In keeping with this system, CMS encouraged the loan of individual meteorologists on a secondment basis to various organizations which had a real need. Keeping the seconded meteorologists on the staff of the CMS gave them direct access to the Service's technical knowledge (through workshops and staff meetings), services, and material (such as climatological data and instrumentation). In some cases the CMS loaned technicians and summer students to assist the seconded personnel. Another advantage of the secondment scheme was that some areas required a meteorologist for only a short term. The policy provided assurance of a continuing career as the seconded individual could return to CMS at the completion of his secondment. According to the policy, the CMS paid the salary of the seconded individual while he worked in the environment of the agency to whom he was seconded. The later identified problem areas, provided general direction, and looked after housekeeping expenses. The policy was a great success and was kept in force for over 20 years.

A Period of Secondment (1951-1968)

In the fall of 1951 Mr. G.W. Robertson was seconded to the Experimental Farms Services of CDA where he worked under the Direction of Ripley (see Chapter 4). Since this position was of a liaison and coordinating nature on a national scale, Robertson reported directly to Boughner in AES. He made frequent trips to CMS Headquarters in Toronto to confer with Boughner, Thomson (the Director), McTaggart-Cowan (Assistant Director and later Director) and others in the Service.

By 1953 several other meteorologists had been seconded to various agencies and the Single Service System became recognized officially as a mode of operation by Treasury Board under Minute TB 460968 dated 19 November 1953 and TB 523066 dated 10 December 1957 as being the most appropriate for Canada.

To keep up with the additional workload brought about by the secondment policy and the increasing demand in the area of applied climatology, a new group was established in 1953 within the Climatology Division called Climatology Operations with M.K. Thomas as Superintendent.

Thomas had already worked for the CMS for 12 years. He joined the Service in 1941 shortly after graduating from the University of Western Ontario with a B.A. with Honours in Mathematics and Physics. He was given assignments with the RCAF (1942-1945), with the Climatology Division in Toronto (1946-1950), and with the Division of Building Research of the National Research Council in Ottawa (1951-1953). During this period he found time to earn an M.A. degree in Meteorology from the University of Toronto (1949).

Seconded meteorologists reporting to Bougner and Thomas at this time included H.C. Cameron in the Canadian Department of Forestry, Ottawa, G.W. Robertson, Plant Research Institute, CDA, Ottawa and J.A. Turner in the BC Forestry Service, Victoria. Later Cameron was replaced by L.B. MacHattie and M. Webb; S.N. Edey and G.D.V. Williams joined Robertson; and G.A. McKay was seconded to PFRA, Regina.

During the next 13 years there was little major change in organization. The introduction in the 1950's of electronic data processing by means of punch cards introduced a significant change in the way climatological data was verified, processed, published and archived. It also created a large demand for data from the seconded meteorologists who now could analyze and interpret the information for user-oriented purposes on a "wholesale" basis (Robertson, 1968).

Mr. G.A. McKay was seconded, in 1959, to the CDA's Prairie Farm Rehabilitation Administration (PFRA) in Regina to serve as an agricultural hydrometeorologist on projects in the prairie provinces.

McKay received a B.Sc. from the University of Manitoba in 1943 and an M.Sc. from McGill University in 1953. From 1943 to 1946 he work as a CMS weather forecaster at several RCAF field establishments and as meteorological scientist for the Canadian Army's Arctic "Exercise Muskox" operational force. From 1946 to 1959 he served as weather forecaster successively at major weather offices in Montreal, Gander, and Winnipeg.

The Secondment Policy served its purpose for some 18 years. By 1966 the Meteorological Branch of the Department of Transport (as the CMS was then known), under its director, Mr. J.R.H. Noble, began a careful review of the Secondment Policy. It was decided secondment had outlived its usefulness, and by Treasury Board Minute 677535 dated 28 February 1968 the policy was relaxed to allow civilian departments and agencies of the Federal Government to acquire meteorological staff of their own. But while allowing other agencies to embark into meteorology, this Minute stated that the Meteorological Branch was responsible for operating the basic observing network, including the climatological station network. Thus according to government policy, the Meteorological Branch had a responsibility for the national meteorological and climatological observing programs.

In anticipation of this change, Robertson was offered a position in CMS headquarters in Toronto in 1966, but he elected to stay with CDA as Chief of the Agrometeorological Section. He, Williams and Edey were officially transferred from the CMS to CDA on April 1, 1968. At the same time MacHattie and Webb were transferred from the CMS to the Department of Forestry in Ottawa.

Climatic Applications Division of the CMS

In 1966 the CMS made several organizational changes. The former Climatological Division of which Boughner was Chief absorbed into The Central Services Directorate of which he became Director General. Within this Directorate the Meteorological Applications Branch was formed with Thomas as Director. Previously he had been Superintendent of Climatological Operations in the Climatological Division since 1953.

A new division was formed under this Branch, viz. the Climate Applications Division and McKay was appointed as Chief, following his return from PFRA in 1966. This new Division was responsible for developing applied climate service programs for non-hydrological sectors of the Canadian economy. In particular, support was given to agriculture, construction, and arctic development. As well as support services to CDA, support to agriculture embraced the undertaking of regional climate studies, with agricultural emphasis where appropriate. The climatic studies of regions and provinces were a major agricultural support initiative. In 1970 a new section, Agriculture and Forest Meteorology (AFMS), was established in the Climatic Applications Division in response to the change in the Secondment Policy.

Strategic Plan for Developing a Basic Climatological Network

In 1970 the CMS prepared a "Strategic Plan for the Development of Climatological Networks to Observe Temperature and Precipitation". This plan was presented to the 1971 Annual Meeting of the Canadian Committee on Agrometeorology (CCAM) by McKay.

In the report, CMS pointed out that several agencies had been pressing for increased climatological data:

1. The Canadian Agricultural Services Coordinating Committee (CASCC) had noted, at its 1968 meeting, the shortcomings of available climatic data for agriculture and had recommended more observations from remote areas and the need for expertise to analyze and interpret climatic data for use by agriculture in resource development and planning. In this connection the Agricultural Rehabilitation and Development Administration (ARDA) had contributed, over the past three years, about $250,000 to support the Meteorological Branch in its efforts to transfer historical climatic data to punch cards for processing in connection with the Canada Land Inventory (CLI).

2. Provincial government agencies in nearly all provinces had been urging the CMS to expand and extend its climatic networks into areas of sparse population wherever there was potential agricultural land. Again the data was required for resource development and planning purposes.

3. The forest industry had indicated a requirement for climatic data for its long-range planning and the management of forests, whether productive or non-productive. The existence of widespread forest cover was considered essential for the maintenance of the balance in nature: in protecting water-catchment areas, in assuring supplies of water, in reducing wind and protecting land against drought and erosion, and in providing shelter for birds and animals. CMS recognized that a major expansion of the climatological observing network in forested areas would be essential for the acquisition of the basic data required for the provision of meteorological support for forestry.

4. Universities were showing an increasing interest in the use of climatic data for research and instructional purposes. Several institutions had their own climatic observatories and were interested in exchanging data and building up their own archives with at least local or regional data.

The abstract of McKay's report follows:

"One of the responsibilities of the Meteorological Branch is to acquire data to define the climate of Canada and to provide climatic data and advice to assist government agencies, commerce and industry, and the general public. During the past two decades this responsibility has intensified as a result of the ever-increasing emphasis on the use of climatological data for planning and operational purposes. Accordingly, the Meteorological Branch must plan, organize and administer climatological networks to ensure that the present and future needs of Canada for climatic data and information are met.

"For the purpose of this plan, Canada is divided into three parts: (a) settled areas; (b) fringe areas: and (c) isolated areas.

In the settled areas of the country, an increase in station density is necessary and will be brought about by adding more cooperative stations, by instituting contract stations and by providing autographic equipment at selected stations.

"It is necessary to develop and install autographic weather stations for the fringe areas where facilities to meet the need for climatological data are sparse. Such stations would be visited weekly or monthly for servicing of the equipment and collection of the recorded data. Data from the autographic stations will be supplementary to those obtained from manual observing stations.

"For the isolated areas in the arctic and subarctic regions of the country, it is necessary to develop and install autographic weather stations capable of recording climatological data for periods up to eight months. Data from these stations, as in the fringe areas, will be supplementary to those obtained from manned observing stations."

It appeared that the studies and recommendations of the NCAM/CCAM over the past 10 years regarding climatic stations and networks were beginning to bear fruit.

Scientific Service Units were established at various Regional Offices across Canada in 1971. Scientific Service Officers were appointed to the Toronto and Winnipeg Regional Offices. It was suggested that these officers would serve the important agricultural areas of Ontario and Manitoba/Saskatchewan, respectively. They were expected to develop their knowledge of agrometeorology, to act as liaison between agricultural interests and the CMS, to determine the requirements of the agricultural industry in their regions for meteorological information and advice, to develop plans to meet such requirements and, as time permitted, to advise or assist in agrometeorological projects or investigations initiated by other agencies.

Staff Changes

From 1966 to 1971 Mr. E.I. Mukammal was the only meteorologist working full time on problems related to agrometeorology at CMS Headquarters in Toronto.

Mukammal received a B.A. in Mathematics from the American University of Beirut in 1939, a D.I.C. in Meteorology from the Imperial College of Science and Technology in London, England in 1947, and an M.Sc. in Meteorology from the University of London, England, in 1948. Before joining the CMS in 1956 he worked as an assistant meteorologist and meteorologist for the Iraqi Government (1938-42) and for the British Meteorological Office in the Middle East (1942-46). He was a teacher of Senior Mathematics, Whittengehame College, Brighton, England (1948-53) and a meteorologist with the British Colonial Office (seconded to the Government of Ghana) (1953-56).

After joining the CMS in 1966 he undertook research on the micrometeorological aspects of air pollution, evapotranspiration and lysimetery and mesoclimatology. Eventually he gained international recognition in these areas of research. In 1971 he was appointed Head of the Biometeorology Research Section.

Dr. R.A. Treidl was appointed Head of the new Agricultural and Forestry Meteorology Section in 1970.

These two appointments really marked the beginning of the expansion of active research work in agrometeorology at CMS Headquarters. Prior to this most of the research by CMS was undertaken by the meteorologists seconded to Forestry, PFRA and CDA.

Boughner retired in 1973 and in 1976 Thomas became Director General of the Central Services Directorate and subsequently, McKay became Director of the Meteorological Applications Branch, under which most of the agrometeorological research was conducted.

In March 1973 the AFMS was strengthened by the addition of Mr. E.C. Birch. He received a degree in agronomy from the University of Guelph before becoming a meteorologist with the AES in 1962. Before joining the Section he was duty forecaster at the North Bay Meteorological Office for 11 years.

Agroclimatological Services within AES

A major organizational change took place during 1971. The CMS, which had been a Branch of the Federal Ministry of Transport for the past 35 years, became one of the principal components under the new Department of the Environment and was to be known in future as the Atmospheric Environment Service (AES).

By 1974 agroclimatic work in the AES had settled into a definite pattern of responsibility and service. AES recognized the requirements of Canadian agriculture and forestry for meteorological support services and responded to these at three levels: the headquarters area; the Regional Offices; and various City Weather Offices across the country. The new Centrre Services Directorate at Headquarters contributed significantly at two levels, namely through the Applications Division and its AFMS, and the Training Branch. Agrometeorological activities were underway in all six Regional Offices (Vancouver, Edmonton, Winnipeg. Toronto, Montreal and Moncton). Each Regional Office maintained a staff of professional meteorologists to answer the specific problems of the region. Since user groups and their weather-sensitive interests vary from region to region, so do their requirements for meteorological support. To provide this support each region was staffed with a supervisor, and supporting meteorologists. . This staff could expect professional guidance and assistance from AES Headquarters if required. Their activities in 1973 ranged from land use and impact studies to support projects for individual users or user groups. Forecast services were supplied by regional and local offices.

In 1973 and 1974 the Canadian Meteorological Centre at Montreal provided daily World Weather Watch (WWW) data to the Canadian Wheat Board (CWB) on magnetic tape on a trial basis. This was in response to a proposal initiated by Robertson, then consultant on climatological matters with the CWB, suggesting that the Board might use WWW data for monitoring weather conditions and their variability as they affected crop production and marketing on a global basis. Preliminary trials were encouraging, and in collaboration with the Regional Prairie Weather Central at Winnipeg, the Wheat Board made a formal request in 1975 for WWW data on a routine basis. The WWW program had been designed to provide global data to the national meteorological services of the world for preparing weather forecasts. This is probably the first time in history that such data were used for something other than weather forecasting purposes.

In the spring of 1974, Robertson was invited to give a seminar to staff of AES in Toronto in order to acquaint personnel with the world shortage of wheat, the role of the Canadian Wheat Board in monitoring global wheat production, and their requirements for WWW data in connection with this monitoring exercise. This seminar, undoubtedly, had a bearing on the future developments within the Meteorological Applications Branch of AES.

A generally deteriorating world food situation and a fluctuating world climate that became evident in 1972 (Robertson, 1973b) was cause for alarm in both agricultural and meteorological circles by the summer of 1974. Spurred on by this double threat, the AES increased its research activities aimed at a better understanding of the mechanics of climatic fluctuations and climatic change, with the hope of improving medium- and long-range forecasts to aid agriculture in increasing food production through better planning.

Organization for Climate-Change Research

In 1974 a new group, involving five research scientists, was established within the Central Services Directorate. Its sole area of interest was the prediction of phenomena lasting one month to 10 years, within the time span of 100 years.

The CCAM, at its 1975 Annual Meeting, considered the matter of climatic variability in regard to food production. Baier presented a position paper to that meeting on the subject (Baier, 1975).

By 1977 research included studies of climatic changes and variability in the past, and an attempt to develop predictive skills in relation to climate. Up to this time the only conclusive result was confirmation of findings elsewhere that the variability of most climatic factors had increased significantly since the mid-1960's. Speculation as to the impact of climatic change continued for several years (CCA, 1977; Treidl, 1978a; McKay, 1979; Treidl, Birch and Sajecki, 1981).

The Canadian Climate Centre (CCC)

In April 1978, the Canadian Climate Centre (CCC) was established, not only to consolidate many of the climatological activities of various units of AES, but to meet the growing demands of many sectors of the Canadian economy in a period of apparent climatic instability.

Dr. B.W. Boville became its first Director-General. The organization of the CCC included two branches and six divisions. Of interest to agrometeorology was the Climatological Applications Branch with McKay as Director, and the Applications and Impact Division of which Mr. M.O. Berry was Chief. The Agriculture and Forest Meteorology Section (Treidl as Head) fell under this Division.

The responsibilities of CCC included the development of climatic monitoring and predictive capabilities, and provision of a focal point for the activities under the Canadian Climate Program (CCP) (see below). The CCC was responsible for providing timely information to user groups. This was accomplished through a new weekly publication "Climatic Perspectives". The first issue was released in September 1978 on an experimental basis. This was to replace several former publications of the AES and provide more timely and useful material on a regular basis.

Earlier studies of climatic change and its predictability led to the evolution of the concept of a Canadian Climate Program (CCP) within the framework of the World Climate Program organized by WMO.

The CCP was formally established on November 23, 1978 under the initiative of the Department of the Environment. The administrative and operational structure of the CCP included three groups of individuals with representatives from agriculture on each.

The Climate Planning Board was composed primarily of senior managers from those federal government departments with climatic concerns. The Board was responsible for overseeing the development of policy as well as providing liaison and guidance to ensure the successful operation of the CCP on national and international scales. The representative from agriculture was Dr. E. LeRoux, Assistant Deputy Minister (Research) of Agriculture Canada.

The Climate Advisory Committee was to evaluate the Program, consult with and advise the Director General of the CCC, make recommendations to the Board and coordinate CCP activities. The Committee originally had federal government, university, private sector, and professional society representation. The representative from agriculture was Dr. W. Baier, Assistant Director of the Land Resources Research Institute, CDA and from Forestry Dr. L.W. Carlson of the Canadian Forestry Service.

A Task Force on the Design of the CCP was established for planning purposes. Departmental representatives worked with designated experts in the CCC to coordinate the design of the Program on a sectorial basis. The representative for agriculture was Dr. R. Halstead of CDA and for forestry, Dr. L.W. Carlson.

The CCC was to provide a central focus for CCP activities. In addition to functioning as the lead agency for the Program, the Centre was to undertake basic climatic functions relating to data management, research, information services, applications, impacts, monitoring, and prediction. Boville retired in 1979 and Thomas succeeded him as Director-General of the CCC.

Mr. G.D.V. Williams joined the AFMS of CCC in 1979. Previously he had spent 19 years with the Agrometeorology Section in the Research Branch of CDA. He worked with CCC on problems dealing with climate as a natural resource, and the impact of its variation on crop production and land-use zonation. He retired in 1985.

AES activities contributing to the development of the CCP included a number of meetings, seminars, and workshops held in cooperation with other departments, agencies, and the private sector in order to establish the requirements of the various users of climatic information. To this end a CCP Agriculture-Climate Workshop was held in Ottawa on 22-23 November 1979. Four Working Groups were established, dealing with:

- Strategic Planning and Policy
- Data Requirements and Access.
- Impact and Monitoring.
- Techniques, Applications and Models.

Some 36 recommendations were made by these four working groups (CCP, 1979). Based on these recommendations and those from other seminars and working groups a plan of action for the CCP was prepared by the Climate Planning Board. The Board was to act as an umbrella under which agencies could request funding for specific projects on an integrated basis. Individual agencies were given full responsibility for obtaining and managing resources and for setting internal priorities.

The Canadian Council of Resource and Environment Ministers made a recommendation in 1981 that the Climate Planning Board be reorganized to increase provincial participation: the provinces taking a lead role in the organization of regional climate advisory committees, and federal-provincial consultation in areas such as climate network expansion, technology transfer, and the undertaking of special studies on climate change and its impacts.

Accordingly, four provinces (Alberta, Ontario, Québec and Newfoundland) became members of the Climate Advisory Board in 1982. Although documentation for new resources required by various federal agencies for the CCP was completed, due to federal monetary restraints, no new money was available for projects. Two provinces (Saskatchewan and Nova Scotia) established provincial Climate Advisory Committees in 1983. Many activities were carried out successfully but several areas suffered from lack of resources.

Thomas retired in 1983 and McKay acted as Director General of CCC until his retirement a year later. Treidl also retired in 1983.

By the end of 1984 all provinces but Ontario and Prince Edward Island had named Provincial Climate Advisory Committees. Funding was received for a few projects, one of which was of interest to agriculture, viz. socio-economic impact of climatic change on food production which was scheduled to start in the fall.

In 1983, the AES commissioned an independent task torce to investigate the level of meteorological services required in Canada. This was a major undertaking, and involved months of work interviewing AES's clients. In May 1986, the Minister of the Environment gave approval to an AES Level of Service Policy based on the results of the task-force study. Implementation of this policy included a detailed examination of the services AES provides with a view to differentiating between basic services (which were provided from general tax revenues) and those above the basic level (for which recovery of costs was to be effected in accordance with an AES Schedule of Charges). Separate "sectorial" policies were developed, based on the level of Service Policy, in the following areas: agriculture, forestry, marine, and services to Canadians through the media.

The draft of the AES Policy on Meteorological Services for Agriculture was review by all AES Regions, the Expert Committee on Agrometeorology (ECA), the CFA, deputy ministers of provincial agriculture, and CDA. All reviews were thoroughly studied and considered in the final draft, which was put into effect for the 1988 growing season. The policy contained a statement concerning the role of the private sector relative to future service to the farm industry. AES was expected to encourage and nurture this development, however, the area where AES left off and the private sector took over was still somewhat hazy in 1988.

A Memorandum of Understanding

The preparation of a Memorandum of Understanding (MOU) between Agriculture Canada and Environment Canada began in 1978. The necessity for this was brought about by recent and proposed legislation defining the responsibilities of the two Departments. According to government legislation, the Minister of the Environment was given the responsibility for all matters relating to meteorology, including climatology (Department of the Environment Act, 1970; the Government Organization Act 1979). Similarly, the Minister of Agriculture was given responsibility for all matters relating to agriculture over which the Parliament of Canada has jurisdiction (Department of Agriculture Act, 1979). The purpose of the MOU was to specify the cooperative arrangements agreed to between Environment Canada and Agriculture Canada with respect to meteorological services and associated research in support of agriculture in Canada. The MOU was drafted by a small task force consisting of L.T. Campbell and A.G. MacVicar of AES, and W. Baier and S.N. Edey of CDA.

The original MOU was approved in 1981. It spelt out in broad terms the roles of AES and CDA as well as the method of coordination between the two agencies regarding the provision of meteorological services to agriculture and the undertaking of research relative to these services. The framework was provided for two coordination committees. One was a national committee to be established by CDA (Research Branch) to coordinate agrometeorological and related meteorological research in Canada. Membership was to involve all agencies undertaking such research. A second national committee was to be established to coordinate and ensure the exchange of information between federal and provincial agencies and producers on producer requirements, communication systems, new technology, and services in support of farm-weather services. Provision was also made to review annually the terms of the MOU and make revisions as conditions warranted.

The MOU served its purpose for eight years but underwent revision in 1988-89. The new MOU was approved in 1989. It spelt out in more detail the roles of CDA and AES, and the coordination of their activities in the area of agrometeorology. The former policy of secondment was re-established. The organization and role of the Expert Committee on Agrometeorology was given in more detail. Special attention was given to the responsibilities for environmental quality, and for cost-recovery for certain services and the free exchange of other services between the two agencies.

PART 2 - CLIMATOLOGICAL SERVICES

General

It should be noted that prior to 1970, there was no statutory or other authority for the CMS to carry out a climatological observation program. However, ever since a Minute of the Privy Council, dated 1 May 1871 authorized the Minister of Marine and Fisheries to spend $5000 for meteorological and climatological purposes, the national meteorological organization has had the prime responsibility for climatological observations in the country. By the Department of Transport Act of 1936, the management and direction of Canadian meteorological services were vested in the Minister of Transport. Although the scope of these services was not defined in this or any other Act, parliamentary approval of annual estimates constituted the specific authorization for the nature and extent of meteorological services provided.

Most of the work in the Climatological Division up to 1950 was directed towards climatological statistics: managing climatological stations, verifying the data, publishing it in the Monthly Meteorological Record, preparing and publishing climatological analyses and summaries, and providing information to individuals upon request. Agriculturist, including soil scientists, were among the early users of climatic data, particularly monthly and annual summaries and long-term averages. There were two routine user groups which catered directly to agriculture: a) the Agricultural Division of the Dominion Bureau of Statistics published weekly and monthly weather summaries in their regular crop condition reports throughout the growing season; b) Mr. Troop, a CMS meteorologist at the Winnipeg Grain Exchange, prepared and distributed several hundred copies of a Daily Weather Map consisting of a synoptic weather chart, a 36-hour weather forecast, and daily temperature and rainfall information for a number of stations throughout Canada. This was prepared primarily for the use of members of the Grain Exchange, but other interested parties were on the mailing list. Reports for these two publications were supplied by the Climatology Division from synoptic weather reports and special weekly weather reports mailed in by observers at climatic stations during the growing season.

Climatic Analyses

Prior to World War II, climatic normals were prepared by hand calculations using, at best, mechanical calculators. In keeping with WMO recommendations, CMS updated climatic normals every ten years, using data for the previous 30 years. Normals for the 30-year period, 1931-60, were the first to be prepared by electronic data processing. There was some delay in preparing the manuscript as all daily data had to be transferred from report forms to punch cards. Precipitation and temperature normals for 1941-70 were issued in 1973 and 1975 respectively.

The next set of normals were prepared by the CCC and issued in four series. The normals were based on the WMO 30-year Standard Normal Period of 1951-80.

During the period 1955 to 1970 the Climatological Division prepared and published a number of climatic summaries of interest to agriculture: growing degree-days (Boughner, 1964); Climate of Canada (Boughner and Thomas, 1959); temperature distribution (Cudbird, 1963); frequency of thunderstorms (Kendall and Petrie, 1962); prairie snow cover (McKay and Thompson, 1968); soil temperature summary (Potter, 1962); record drought and hot spell in 1961 (Thomas, 1961); and Canadian climatic maps (Thomas and Anderson, 1968).

In 1962 the Government of Canada passed the Agriculture Rehabilitation and Development Act (ARDA). One of the programs under this act was the Canada Land Inventory (CLI). It was understood from the beginning that the CLI should include climatic data and information. To this end the Ontario Research Foundation (Chapman and Brown, 1966) was awarded a contract to prepare a preliminary study of the agroclimate of Canada. A more detailed analysis was required later and for this purpose daily climatic

data on punch cards for 30 years were required for several dozen stations. The CMS was in the midst of transferring its archives to punch cards and needed financial assistance to meet ARDA's early requirements. ARDA put up some $250,000 for punch card preparation. To oversee the ongoing CLI projects in agroclimatology, a steering committee was formed. Thomas was the CMS representative on this committee along with Hodges of ARDA, and Ripley and Robertson from CDA.

Agroclimatic Data Publication

For several years the NCAM had recognized the importance of the weather observations taken at CDA Research Stations and other agricultural establishments, and had recommend that these be published regularly in order to make the data readily available to agricultural researchers. In 1965 the CMS responded to a request that these daily data be published. They established a monthly publication entitled "Daily Agrometeorological Data". The data consisted of 12 elements including regular climatic data plus other information of special interest to agriculture such as soil temperature, leaf wetness duration, evaporation, wind speed at two metres, and grass minimum temperature.

One of the sad changes during 1974 was the demise of the monthly publication of Daily Agrometeorological Data. This report always suffered from production difficulties. The information it contained was to be provided in a new publication which, however, did not become available until the release of the weekly report, "Climatic Perspectives", late in 1978 by the Canadian Climate Centre.

Handbook on Agriculture and Forest Meteorology

The project on the preparation of a Handbook on Agriculture and Forest Meteorology was initiated in 1971 by Treidl shortly after he was appointed to head the AFMS. Work progressed steadily on this over the next eight years. Much of the contents evolved during Treidl's travels to agrometeorological establishments across the country. Brown, of the University of Guelph, was awarded a contract to prepare a chapter dealing with plant-weather relationships.

The main part of the Guide consisted of tables of averages and frequencies of various climatic factors, both observed and derived, for 200 to 500 stations across Canada. Ample explanation of the tables was provided.

Part I of the Guide was published and released in October, 1978. It consisted of four text chapters and ten tables comprising over 600 bilingual pages. The tables contained information on 226 climatological stations at strategic locations within the agricultural and forest belts of Canada. The 2nd and 3rd parts were released within the next three years. (Treidl, 1978b, 1979, 1981).

Activities in the 1980's

A pilot study was established in 1984 in the Beaver Valley near Thornbury, Ontario to improve the understanding of topographic influences on the variation of climatic factors in order to assess the representativeness of weather stations, and to provide improved means of interpolating between them. Five sites were established to observe temperature, humidity, precipitation and wind in relation to land-form orientation, land use, and elevation. Mobile surveys between stations were planned. This study originated from a request by Chapman of ORF (see Ch. 7).

The CCC developed a Station Information System (SIS) computer database which showed the details regarding the observing program. SIS information could be examined through a microcomputer, permitting the user to obtain information on any station, group of stations for a given area, or any observation program. The system was put into operation in 1987.

The Monitoring and Prediction Division (CCRM) of CCC undertook to prepare, on an experimental basis, starting in 1986, thirty-day and seasonal forecasts of temperature and precipitation.

PART 3 - FORECAST SERVICES TO AGRICULTURE

Situation Immediately after World War II

Just prior to World War II, the CMS had expanded its weather observing network and forecasting operations, primarily for the benefit of Trans-Canada Airlines. Forecast centres were located at airports at Moncton, Montreal, Toronto (Malton), Winnipeg, Lethbridge, and Vancouver.

During the war years there were severe restrictions on the availability and distribution of weather information, including weather forecasts. Although the technology of weather forecasting advanced significantly in this period, the use of forecasts was restricted primarily to military and aviation usage.

Establishment of Public Forecasting Offices

Immediately after the war, these restrictions were lifted and once again the media were permitted to release forecasts to the public. It was not long afterwards that the aviation forecasting staff at forecasting offices of CMS were supplemented by a staff of public weather forecasters, and Public Weather Offices were established at the main forecast centres (Vancouver, Edmonton, Winnipeg, Toronto, Montreal and Halifax). Public weather forecasts were primarily directed to the general public through the radio and the press, and eventually through television when it became available in the early 1950's.

Although there was no special mandate for the Public Weather Offices to issue farm-oriented forecasts, special reference to weather-sensitive farm operations were not overlooked. For example, the public forecasts frequently contained information regarding dry spells for haying and harvesting operations, and reference to untimely freezing conditions in the spring and fall.

The Okanagan Valley Frost Warning Service, started in 1935 for fruit growers, was probably the first and only regular forecast service for farmers at this time. Every spring a meteorologist was sent from Toronto Head Office, and then after the war, from the Toronto, then after the War, from Vancouver Public Weather Office, to Penticton to organize a special temperature network in the Valley, and to prepare on-the-spot forecasts of freezing temperatures. This service was soon extended to include wind forecasts for orchard spraying operations.

Experimental Farm-Weather Forecasts

By the end of the 1950's, there was a growing demand for specialized farm-weather forecasts. The NCAM was organized in 1959 and one of its main concerns for several years was the improvement of farm- weather services including better communication with the farmer (see Chapter 5). Through the efforts of the NCAM, experimental farm-weather forecasts were undertaken by CMS in cooperation with provincial departments of agriculture in New Brunswick, Saskatchewan and Alberta. The most successful of these experiments was in New Brunswick in connection with forecasting favourable weather for the outbreak of late potato blight. The reason for this success was the fact that the farmer could withhold spraying until the forecast indicated a period of weather favourable for the spread of the blight, at which time he could take immediate preventative action. Carefully following a spray program based on the weather forecasts provided better and more economical protection than conventional spraying at regular intervals. Dickison of the Fredericton City Weather Office became heavily involved in the potato-late-blight weather program.

Working Group on Agrometeorological Services in Alberta (1964)

The Director of CMS had frequently said that if agriculture could say exactly what was required in regard to farm-weather services, the CMS would provide it. The NCAM made several attempts to spell out agriculture's requirements but CMS was not entirely satisfied with the requests. In 1964 a Working Group

was established by CMS to devise improved methods for determining the requirements for meteorological services in support of agriculture.

It was decided to make a pilot survey in Alberta where keen interest in farm-weather services had been demonstrated (see Chapters 5 and 8). Members of the Working Group consisted of A. MacVicar, Assistant Superintendent of Public Weather in the Forecast Division (Chairman), M.K. Thomas, Superintendent of Operations for the Climatological Division, and M. Monsinger of Basic Weather Services, all from CMS headquarters in Toronto; D. Smith, Chief of the Edmonton Weather Office; and G.W. Robertson, Chief of the CDA Agrometeorological Section in Ottawa. Meetings were held in Edmonton, Lacombe, Olds, Calgary, and Lethbridge in the fall of 1966. These meetings were attended by a representative cross section of Alberta Agriculture including: farmers and ranchers; research specialists from the Universities, CDA research establishments, and the Alberta Research Council; CMS meteorologists; food processors and handlers; provincial soil surveyors; district agriculturists; and administrators in the provincial Department of Agriculture.

The ensuing report contained comments on a number of topics: short, medium, long-range and seasonal weather forecasts, including the forecasting of special agrometeorological elements; weather modification and hail suppression; climatic observations and the provision of data; research requirements including special instruments and observations, data interpretation and crop-pest weather relationships and financing; education at both the professional and farmer levels; and the requirements for professional agrometeorologists.

Regional Centres and City Weather Offices

By the early 1970's Regional Weather Centres were established at Vancouver, Edmonton, Winnipeg, Toronto, Montreal and Moncton. Each Centre soon included a Scientific Service Officer and a small support staff. These units provided much needed special services to farms although actual forecasting was done by the regional forecasting offices, and modified and released for local use through the City Weather Offices.

Communications and Forecasting Services

During 1969 the CMS continued to adapt computer techniques to improve the operation of certain systems. Communications networks controlled by computers were expected to be standardized, and to improve the flow of data between international, national, regional and local areas, thus making data more readily available to the end-user. The increasing use of computers for weather analysis and forecasting procedures led to increased production of a greater variety of support to agriculture and to freeing professionals to devote more time to examine agrometeorological problems in greater depth, and to develop more appropriate services through increased coordination with agricultural personnel.

In spite of developments in the computer and communications fields, however, there still remained a serious problem of communication with the farmer concerning the most appropriate content of farm-weather advisories, and the method of their delivery to the end-user.

Farm-Weather Services, 1972

In June of 1972 the AES initiated a major project with the objective of obtaining a clearer definition of requirements of the agricultural industry for weather information (particularly forecasts) and of recommending ways and means of satisfying such requirements. Interviews were held with growers, and government and university officials. In most parts of Canada and the USA, agricultural weather services were reviewed in detail.

By this time ongoing farm-weather services included, in addition to the routine public weather forecasts provided by all forecast offices, a number of special programs for agriculture such as: the Ontario

Farm-Weather Service; limited programs for the Lower Fraser Valley in BC and in southwestern Quebec; frost and spraying forecasts for the Okanagan Valley, the Niagara fruit belt, and the Lake Erie tobacco belt; and the potato blight forecasts in New Brunswick.

Collaboration with the CANFARM Project was initiated in 1972. The aim was to provide relevant climatic data to the Canadian farming community. Initially, climatic data as required in yield-prediction models for barley was provided on a longitude-latitude based grid-point system. It was also considered that CANFARM would be an efficient channel for the dissemination of AES five-day forecasts when they became available in the near future.

Extended Forecasts

Experimental 5-day forecasts were issued from the Prairie Weather Centre (Winnipeg) for the first time in 1974. A general forecast was prepared and released each Thursday foru the general public, and a special agriculturally oriented one was prepared and released daily for the Rosetown-Kindersley area of Saskatchewan. Although the outlooks often were not reliable towards the end of the 5-day period they were, nevertheless, well received by the farming community. By 1976 5-day weather forecasts were issued regularly by all regional offices, and an experimental 10-day outlook was prepared for AES internal use only.

Another service to agriculture, started in 1976, was the preparation, in collaboration with the Agrometeorological Section of CDA, of "Climatological Planning Information for the Prairies". This document gave predictions of the soil-water reserves at planting time, the precipitation trend during the summer months, and probable harvest weather conditions.

Fire-Weather Service

A significant change was made in forecasting services in 1974 when the Fire-Weather Service was transferred from the Canadian Forestry Service to AES, providing a more uniform service across Canada. In keeping with this change, AES collaborated with the Ontario Ministry of Natural Resources by loaning a forecaster to the Forest-Fire Control Branch. Mr. M. Newark of AES was moved into an office at Queen's Park and, aided by a teletype drop and facsimile printer, provided forecasts and guidance throughout the 1974 season during which extremely heavy fire outbreaks occurred in Northern Ontario. By 1976 all forecast offices were providing forest-fire damage-index predictions to the forestry services of the provincial governments.

In connection with fire-weather services, the first CFS-AES coordination meeting hosted by AES was held in Toronto on November 2, 1977.

Weatheradio

Weatheradio Canada stations were first installed in Toronto, Vancouver, Montreal, and Halifax in 1978. These radio stations were operated continuously, 24 hours per day and seven days per week, on VHF/FM using one of three fixed frequencies. They broadcast, exclusively, weather information for the use of anyone with a suitable radio capable of receiving the broadcasts. The information was repeated about every 5 minutes and included statements on present weather, general and user-oriented forecasts, weather warnings, and climatological information.

One of the most significant advances in farm-weather forecasts was made in 1978 when AES and the Government of Nova Scotia cooperated to extend the Weatheradio Canada network to Nova Scotia, where three stations were opened to serve both farming and marine interests. Five more stations were opened in 1979, which extended coverage to most of Nova Scotia and part of Prince Edward Island.

This development appeared to be the answer to the problem of transmitting to the farmer timely forecasts and information. This problem had plagued the NCAM and its successors the CCAM/CCA and ECA in attempting, over the years, to improve agrometeorological services for farmers.

In 1985 AES cooperated with the Ontario Ministry of Agriculture and Food (OMAF) in undertaking a feasibility study in regard to expanding Weatheradio Canada into southern Ontario and using satellites as a means for Weatheradio signal transmission.

Canadian Federation of Agriculture

For several years the Canadian Federation of Agriculture (CFA) had passed resolutions at annual meetings, requesting the CMS to improve and extend its services to farmers. Although these resolutions kept the requirements for farm-weather services before the CMS, apparently no special action was taken until the ECA considered the problem of climatic variability at its 1977 Annual Meeting (Dr. Ferguson, Chairman) and made several recommendations to the Canada Agricultural Services Coordinating Committee (CASCC).

Later in 1977, a contract study was undertaken for the Agrometeorological Section of CDA by Dr. P Shanker, who prepared a position paper in 1977 on Farm-Weather Forecasting and Climatic Advice in Canada with proposals for revitalizing agricultural-weather services, Furthermore, the theme for the 1978 early spring meeting of the ECA, with Baier as Acting Chairman, was on the topic of Farm-Weather Services. This theme continued at the 1978 fall meeting of ECA.

As a result of discussions and recommendations made by ECA to CASCC, the latter authorized the formation of a Task Force on Agricultural-Weather Services to study and implement the proposals of ECA. Baier of CDA was named Chairman of the Task Force and Mr. L.A. Campbell of AES was named Vice-Chairman. Other members were Edey of the Agrometeorology Section of the Research Branch, Dr. Bursa of CFA, and Robertson, consultant who had been retained to prepare a report (1979) on Agricultural-Weather Services, with special reference to Operational Farm-Weather Services.

Based on the recommendations of the 1977 ECA annual meeting, CASCC had authorized holding a workshop on Farm-Weather Services involving the AES, CFA and the Agrometeorological Section of CDA. This Workshop did not materialize until 1979 when CFA undertook to sponsore it. The workshop was held in Ottawa on March 22-23, 1979, and was attended by representatives from AES, CFA, CDA, provincial departments of agriculture and the universities.

The most important recommendation from this workshop was the recognition that there was a lack of dialogue between the farmer and the meteorologist. To remedy this it was suggested that provincial subcommittees of the local CFA groups be formed with representation, not only from farmers, but from the regional and city weather offices of AES, and from provincial and university people interested in bettering farm-weather services.

The recommendations of the workshop appeared to have the necessary effects. Not only were CFA subcommittees formed in all provinces, but CFA (Bursa) was given a membership in the ECA in 1980. This was the first time in some 20 years that an ECA member was appointed from the private sector.

During the next four years AES made substantial changes in its Farm-Weather Service programs.

Farm-Weather Activities, 1984

A review of Farm-Weather Services at the end of 1984 indicated a very active program by AES during the growing season (April-October) across Canada. Each Weather Centre prepared a Farm-Weather Forecast containing predictions of wind, drying conditions, and probability of precipitation; indices relevant to farming operations within the region; and weather outlooks for the next three to five days.

These forecasts were issued two or three times daily, and were also broadcast on Weatheradio Canada continuously, covering most of the agricultural areas of Canada. Additional farm-weather services and communications to disseminate the information to growers varied from province to province, meeting regional needs.

A good rapport had developed between AES regional managers on the one hand and farmers, farm groups, producers, agricultural scientists, and colleagues in provincial departments of agriculture on the other, through regular meetings at Provincial Farm-Weather Service Committees. These Committees had as their objective improvement of farm-weather services, resolution of problems, exchange of information, and the education of the farmer. Senior AES Managers attended the national meetings of the CFA Farm-Weather Service Committee.

Summary of Farm-Weather Services at the End of 1989

As the decade drew to a close, farm-weather services provided by the AES from Regional Offices, Weather Centres and City Weather Offices had settled into a fairly static routine, although there was provision for local adjustments and changes depending on changes in communications and meteorological technology, and in local user requirements. AES Regions issued farm/rural weather bulletins for some 80 agricultural regions across Canada two to four times a day during the growing season (April through October). Approximately 8,000 agricultural forecasts were prepared during the period. These were disseminated to farmers by local radio stations and on Weatheradio Canada. Farmers were able to telephone some local Weather Offices to listen to a recorded abbreviated farm forecast. Limited consultation services were provided by some Weather Offices for local areas.

Basic agricultural forecasts and services included the information normally included in the public weather forecast, as well as additional information on wind speed and direction, frost occurrence, and precipitation amounts and intensity. Some elements in farm forecasts were mandatory, while others were regional in nature, such as the drying index, potato-blight index, growing-degree days, and corn-heat units. Specialized services also included warnings of severe weather (sometimes in separate bulletins), extended (3- to 5-day) forecasts, current weather information, and daily, weekly and monthly summaries.

Future Farm-Weather Service

The AES Policy on Meteorological Services for Agriculture, approved in 1988, was intended for implemention over the next 20 years. The plan was designated to modernize AES, utilize new technology and major advances in communications, improve forecasting of weather phenomena, and permit the Service to continue operating an effective national weather, climate, ice and air quality service while living with reduced resources and fewer staff. Some impacts on agricultural-weather services will likely result from implementing this strategic plan.

PART 4 - AIR POLLUTION

Air pollution studies in Canada, particularly of sulfur dioxide, predate WW II. CMS become involved in a study at Trail, BC with the objective of reducing the impact on agriculture (Hewson, 1945).

Tobacco Leaf Fleck

An increasing problem with injury of an unknown cause to tobacco leaves was noticed in the tobacco-growing area around Delhi in southern Ontario during the mid-1950s. This appeared to be associated with wet-weather, rain and dew, and became know as "wet-weather leaf fleck". Several studies were conducted, but no direct causative relationship could be established. In 1958 Robertson was given a report on the matter to review. He was unhappy with the instrumentation used and the data

analyses. He took the matter up with the Director of the CMS, Dr. A. Thomson, and it was agreed that CMS should cooperate with the committee working on the problem and supply staff and instrumentation to undertake a thorough micrometeorological study to complement the physiological and air-quality studies being planned for 1959. Mr. E.I. Mukammal was given the task of doing the field work on micrometeorology at the tobacco experimental site near Delhi. His work on tobacco leaf fleck led to several years of research on the micrometeorological aspects of air pollution and the development of air-pollution expertise within CMS.

With the discovery that there are many pollutants in the atmosphere, and also many different sources, an Air Quality Network was established in 1974. A joint OMAF-AES Symposium was hosted by AES at Toronto on March 7, 1977. The theme was air pollution and its impact on agricultural and forest productivity. Lectures were presented by E.I. Mukammal, S.N. Linzon and Marlene Stewart. Since then air pollution monitoring and research has continued.

Joint Research with the University of Guelph

In 1978 the Biometeorological Research Section (Mukammal) and the University of Guelph (Gillespie and Hofstra) developed a joint project on the effect of the environment on the spatial variations in ozone damage to crops along the shores of Lake Erie and Lake Huron. Past experience had shown a gradation in severity of ozone injury to white beans from Lake Erie northward to Southampton on Lake Huron. The study involved detailed measurements of wind, temperature, and ozone profiles at varying distances from the lake shore within the region. Another similar cooperative project was with Thurtell and Ormrod of the same university, concerning damage to corn caused by actual ozone uptake by the plant.

In 1980 two vehicles were used to undertake a mobile survey of ozone concentration in southwestern Ontario, in order to find a less susceptible area for ozone injury to white beans. Additional ozone data was collected to assess crop damage in southwestern Ontario in 1981 (Mukammal et al., 1982). The study was expanded in 1982 to included the synoptic climatology of ozone in central Canada. It was hoped that such a study would allow a better understanding of how ozone is transported (Mukammal, 1985).

The ozone research in Ontario was reviewed in 1983 and the objectives redefined under four headings:

- to compile a statistical summary of spatial and temporal ozone concentrations, and of persistence of episodes and their association with meteorological factors;
- to characterize the various synoptic weather conditions of ozone episodes;
- to determine the source of local and long-range transported ozone;
- to delineate the geographical areas potentially subject to ozone episodes.

Acid Rain

Prior to 1985 maple-sugar producers noted an unexplained decline in sugar-maple groves. There was a suggestion that this might be caused by acid rain. The AES Ontario Region undertook a study of the impact of acid rain in relation to the problem.

PART 5 - RESEARCH AND ANALYSIS (INTERPRETATION)

Topoclimatology

Mukammal started a project in 1960 in cooperation with the Ontario Research Foundation concerning the effect of topography and proximity to lakes on temperature and humidity in Southern Ontario. In 1975

these studies were renewed and intensified in southern Ontario together with mesoscale evaluations of the agroclimate when Dr. R.B. Stewart joined the AES as an NRC Post-Doctorate Fellow.

Stewart had received a B.A. degree (Honours Geography) from the University of Windsor in 1971; an M.Sc. (Micrometeorology) from McMaster University in 1972; and a Ph.D. (Micrometeorology) also from McMaster University in 1975. He had received an Ontario Graduate Fellowship tenable at McMaster during the period 1971-75. During both of his postgraduate programs at McMaster he had worked on evaporation problems (Stewart and Rouse, 1976).

At AES he worked with staff of the AFMS for two years on several of their ongoing research projects. In 1975 topoclimatic studies were extended to parts of the District of Mackenzie and the Yukon in connection with an agroclimatic survey being conducted in collaboration with the Department of Northern Affairs and the Agrometeorological Section of CDA. The database for this study was completed in 1976.

Forest Micrometeorology

At the onset of the International Biological Program (IBP) in 1965, CMS and the Canadian Department of Forestry cooperatively initiated, under the leadership of Mukammal, in a Forest Microclimatology Project in Petawawa. In this connection he became a member of the Canadian Project on Production Processes of the IBP (1966-70). Experience during this research made him the main bioclimatic contributor to the Canadian phase of IBP, and his expertise was sought after, not only in connection with the siting of forest experiments, but also in connection with grassland and other ecosystem productivity experiments.

Lysimetric Research

In 1969 CMS, under the leadership of Mukammal, put into service a large lysimeter for measuring evapotranspiration. The lysimeter was 20 ft. in diameter, three ft. deep and weighed 60 tons. The weighing scale had a sensitivity to detect a change in water content equivalent in depth of 0.015 mm. The tank contained heating and refrigerating units to maintain the thermal properties of the soil in the lysimeter similar to those in the surrounding field.

This lysimeter was eventually used to test and develop equipment and standard procedures for measuring evaporation, evapotranspiration, and soil-water. It was also used to study processes of snow melting, deposition of frost and dew, and divergence of radiant energy. Some of these studies were undertaken for WMO (Mukammal et al., 1971; Mukammal and Neumann, 1977).

The Spruce Budworm and Weather

In 1970 AES assisted with a project to evaluate the meteorological factors affecting the spread of the spruce budworm from data gathered in collaboration with the Canadian Forestry Service in the Maritimes. The study progressed for several years. From 1976 to 1978 the effect of the seabreeze over the area was studied. By 1980 the emphasis was on the effect of mesoscale convergence lines in the wind pattern on budworm-control strategies (Neumann and Mukammal, 1981).

Frost Studies in Southern Ontario

A project on low-level inversions and their breakup by wind machines and helicopters in connection with frost protection in southwestern Ontario was started in 1970. This study continued until 1976 in the London area. A similar study underway in the Niagara Peninsula was modified in 1976 to include detection of the infrared radiation temperatures of the ground. Also 15 special minimum temperature stations, and some 30 locations with grass minimum thermometers, were established. Four towers were used to help determine the depth of surface inversions (Stewart et al.,1977, 1978).

Soil-Water Measurement

In 1974 a study was initiated to determine the performance of various neutron meters for soil-water measurement, and also to test other techniques, especially those for measuring soil-water potential. In 1976 the 20-ft. lysimeter water budget was used to test the performance of five different kinds of neutron soil-water meters in an international comparison study sponsored by WMO.

Soil Temperature

In 1974 a cooperative project was begun with the Soil Research Institute of CDA and Prof. Williams at Carleton University, to provide a complete description of the thermal and hydraulic characteristics of the soil at some 60 observation sites in the AES soil-temperature network.

A study of the relation between soil temperature and snow depth at various sites across Canada, started in 1981, and was completed in 1983.

PART 6 - RESEARCH UNDER THE CCC PROGRAM

Drought in Western Canada

An extensive drought study in western Canada was begun in 1980 in cooperation with the Inland Waters Directorate of Environment Canada, and with agencies from CDA, DREE (PFRA), the provincial governments and universities. Initially the study was to address the physical controls on drought, including the climatological time series during the past century (Berry and Williams, 1985).

Up to the end of 1980 the project centred on the simulation of soil moisture. Daily data from some 140 stations measuring temperature and precipitation since 1925 were used. The station data were transferred to a grid system by an objective procedure. Alberta wheat yields were correlated with soil-moisture deficit and other climate-related elements (Williams and Masterton, 1983; Williams, 1985). A study of the synoptic features associated with dry spells was also started in 1981.

Forestry

A new Forest Meteorology Project (FARMFOR) was initiated in 1982 in cooperation with the Province of Ontario in connection with "tree farming" for an energy production feasibility study. This was expected to become a major initiative with involvement on an international scale within the Forest Energy Agreement of the International Energy Agency. A pilot project addressing synoptic weather typing and a preliminary study of the application of phenology as a forest-climate tool were started in 1983.

The Applications and Impact Division of AES also became involved, in 1984, in a project to develop methodologies for integrating synoptic climate information into forest-fire management decision-making processes. The project investigated the relationship between drought and forest-fire incidence and other forest operations. A drought index based on the Shear and Steila Index for real-time forest-fire management purposes was developed (Loiselle, 1984).

Climatic Impact Studies - High Latitude Agriculture

The International Institute for Applied Systems Analysis (IIASA) investigated the feasibility of an international climatic impact study on agriculture in 1983. The high latitude part of this study included parts of Canada, Iceland, Finland and the USSR. The Canadian part of the study took place in Saskatchewan with CCC, the Regional Development Branch of CDA, PFRA, and the Saskatchewan Research Council collaborating. The Applications and Impact Division of AES coordinated the study.

Canadian participants under the leadership of Williams met with their international counterparts in Austria in early 1984 (Williams et al., 1988).

Climatic Impact Studies - Southern Ontario

A second impact study was initiated in 1984 by the Applications and Impact Division. This project examined the impact of climate and climate variability on the quality and yield of cash crops, particularly field tomatoes in southern Ontario.

Corn Heat-Unit Climatology

A climatological study of corn-heat units for Ontario was completed in 1984. This was based on temperature data for the standard period, 1951-1980 (Bhartendu, 1984).

The AES Regional Office in Quebec was also doing research on corn-heat units in 1985. In cooperation with the Upper St-Lawrence Crop Management Club, the Quebec Department of Agriculture, and universities, corn-heat units were being investigated on a mesoscale basis. Consideration was being given to soil and air temperatures for various soil types, where differences were noted in corn maturity.

CCC Research Summary at the End of 1989

By 1987 CCC had become involved in a number of short- and longer-term research projects. The range and scope of these during the 3-year period 1987-1990 is indicated by the following list:

- sensitivity and response of winter wheat production in Ontario, and the effect of CO2 doubling
- relationships between climate and climatic variability and the occurrence of potato blight
- relationships between primary vegetation cover and climate.
- testing of commercial farm weather software
- study on outbreaks of western encephalitis in Manitoba
- software development for access to archived climatic data.
- review of techniques to predict drought conditions in western Canada.
- study of the frequency and intensity of droughts in Saskatchewan.
- examination of mid-tropospheric circulation patterns and wet and dry spells.
- a study of the severity and duration of water and thermal stress in the Island Lake Tree Improvement Area.
- the climatology of the Dryden tree nursery using a system of climatic stations and mobile survey techniques.
- modeling vegetative accommodation to climate, including a study of shifts in the Canadian boreal forest under possible "greenhouse warming".

Thirty-Day Anomaly Forecasts

On May 15, 1988, the CCC began releasing experimental 30-day temperature anomaly forecasts on the 15th and last day of each month in "Climatic Perspectives".

PART 7 - MISCELLANEOUS

Research Grants (1961)

In 1961 Mr. P.D. McTaggart-Cowan, Director of the CMS, met with Dr. E.W.K. Steacie, President of the National Research Council and Dr. D.G. Hamilton, Director (Crops) of the Program Directorate of the Research Branch of CDA and Chairman of the NCAM, to discuss grants to universities for

agrometeorological research. McTaggart-Cowan pointed out that the CMS administered a small sum of money for this purpose. Although NRC had no control over the distribution of the money, there was close liaison between NRC and the CMS regarding the allotment of grants. There was heavy competition for available funds from both agencies, and the request for funds had to be well justified. Available funds were granted to those establishments which had demonstrated interest, ability, accomplishment, and which had an important problem on which to work.

In 1962 the CMS made the first annual grants available for research on agrometeorological problems. King at the Ontario Agricultural College received $11,000 to study energy fluxes in crops, and the University of Alberta received $5,000 to study micrometeorology at the University Farm at Ellerslie.

Cooperation with the University of Guelph

In 1964 Mukammal was invited to become a member of the Agricultural Meteorology Advisory Committee on Education of the University of Guelph. He continued this activity for 14 years. A few years later, in 1966, he was requested to undertake part-time lecturing in bioclimatology at the University of Guelph, an undertaking he continued until his retirement.

Activities in NCAM (CCAM, CCA, ECA)

Up to 1970 there was no direct representation from the CMS Headquarters in Toronto on the NCAM. The Committee considered that Robertson, in his capacity as liaison meteorologist from CMS served adequately as the spokesman for the CMS. Furthermore, Barks, Regional Meteorologist, District Aviation Forecast Office, CMS Moncton, served as representative from the Atlantic Region as well as spokesman for the CMS field activities during the first four meetings of the NCAM. Unfortunately he transferred to another field of interest in 1962 and was no longer eligible for membership on the committee.

In 1965 Mr. A.G. MacVicar had attended the Sixth Annual Meeting of the NCAM and submitted the report on the CMS Working Group, which investigated the requirements for meteorological services in support of agriculture in Alberta.

In 1967 Mr. M. K. Thomas was invited to attend the Eighth Annual Meeting of the NCAM, particularly to report on such matters as the publication of daily agroclimatic data, and the expansion of the meteorological data archives on punch cards, particularly to meet the requirements of the Agriculture Rehabilitation and Development Administration (ARDA) for the Canada Land Inventory. In 1964, Thomas was appointed, along with Hodges, Ripley and Robertson, to a steering committee in regard to this matter. He was again invited to attend the Ninth Annual Meeting of NCAM in 1968.

Two representatives from the CMS were invited to attend the 1969 Annual Meeting of the NCAM. Mr. K.T. McLeod, Superintendent of Public Weather Services, and Mr. J.D. Holland participated in special topics for discussion at the meeting: Farm-Weather Forecasts and Weather Modification. At this meeting the members decided that the CMS should have a permanent membership in the Committee in order to ensure a continuing and meaningful liaison between agriculture and meteorology. It was noted that the policy of seconding meteorologists by the CMS was due to terminate in April 1969, thus increasing the need for permanent representation of the CMS on the Committee to strengthen relationships between the two groups. Mr. K.T. McLeod became the first permanent representative from the CMS on the NCAM (now the Canadian Committee on Agrometeorology - CCAM) in 1970, when he attended the Eleventh Annual Meeting. Throughout the ensuing years several individuals from CMS contributed greatly to the success of the CCAM (see Chapter 5).

In 1974, AES hosted the Annual Meeting of the CCA for the first time in its history. The Fifteenth Annual Meeting was held at AES Headquarters in Downsview, Ontario at the invitation of Mr. J.R.H. Noble, the Assistant Deputy Ministry of AES, who formally opened the meeting with comments on the current energy and food crisis and the role of agrometeorology in connection with the unprecedented world

demand for wheat. He also outlined the role and contributions of the World Meteorological Organization in regard to this same problem.

Agrometeorological Training Courses and Workshops

Two 2-week training seminars were held in 1975. One was for meteorologists and the other for meteorological technicians. Both seminars were aimed at upgrading the understanding of regional personnel of subjects in applied meteorology. Agrometeorology received special consideration in the course for professional employees.

The recently established CCC arranged three meetings in 1980: a workshop for forest-meteorology at AES headquarters in Toronto in January, a seminar on horticulture and meteorology at Vineland in February, and an agrometeorological seminar at the University of Guelph in May.

The Ontario Region of AES cosponsored a workshop and published the proceedings for "Role of Long-Range Transport and Weather in Agriculture". This was held at the Arboretum Centre at the University of Guelph in October 1983.

A workshop on Evapotranspiration, Irrigation, and Plant-Moisture Stress in Agriculture and Forestry was held at Kortright Centre in Kleinburg, Ontario in October 1984. This was sponsored jointly by the AES, the Ontario Ministry of Natural Resources and the CMOS Special Interest Group on Agricultural and Forestry Meteorology.

Metrification

The AES began to use the metric system in the provision of information to the public on April 1, 1975, when temperatures began to be reported in degrees Celsius. Precipitation reports were made in metric units starting October 1, 1975. These changes necessitated many changes and re-definitions. Of interest to agriculture were the changes in the base temperatures for growing degrees-days and other critical temperature thresholds. Other elements were converted gradually.

PART 8 - PUBLICATION HIGHLIGHTS (in chronological order)

1914 IMO. Report of the Tenth Meeting, Rome 1913. M.O. No. 216. *His Majesty's Printing Office, London*. 95 pp.

1945 HEWSON, E.W. The meteorological control of atmospheric pollution by heavy industry. Quart. J. Roy. Meteorol. Soc., 71:266-282.

1949 IMO. Commission for Agricultural Meteorology, 8th Session at Toronto, Canada from 11th to 23rd August, 1947 - Abridged Final Report. *International Meteorological Organization*, Publ. No. 63, Imprimerie la Concorde, Lausanne, Suisse. 32 pp.

1959 BOUGHNER, C.C. and THOMAS, M.K. The Climate of Canada. Meteorological Branch. In: *Canada Year Book of the Dominion Bureau of Statistics*, Ottawa. 74 pp.

1961 THOMAS, M.K. June 1961 - a record hot dry month on the Canadian prairies. *Meteorol. Br., Tech. Cir.* 372. 6 pp.

1962 KENDALL, G.R. and PETRIE, A.G. The frequency of thunderstorm days in Canada. *Meteorol. Br. Tech. Cir.* 418. 21 pp.

POTTER, J.G. Soil temperature records at eight localities in Canada, 1959-1960. *Can. Dept. Agric., Res. Br.* 31 pp.

1963 CUDBIRD, B.S.V. Means, standard deviations, tendencies, and extremes of pressure and temperature at selected Canadian Stations. *Meteorol. Br. Tech. Cir.* 448. 44 pp.

1964 BOUGHNER, C.C. The distribution of growing degree-days in Canada. *Meteorol. Br., Canadian Meteorological Memoirs No. 17.* 40 pp.

1965 MUKAMMAL, E.I. Ozone as a cause of tobacco injury. *Agric. Meteorol.,* 2:145-165.

1966 CHAPMAN, L.J. and BROWN, D.M. The climates of Canada for agriculture. *Can. Dept. Forestry and Rural Develop., Can. Land Inventory,* Rep. No. 3. 24 pp. + maps.

MUNN, R.E. Descriptive meteorology. Advances in Geophysics, Supplement, 1. *Academic Press, New York.* 245 pp.

1968 THOMAS, M.K. and ANDERSON, S.R. Guide to climatic maps of Canada. *Meteorol. Br., Climatic Cir.* Cli-1-67. 79 pp.

McKAY, G.A. & THOMPSON, H.A. Snow cover in the prairie provinces of Canada. *Trans. Amer. Soc. Agr. Eng.* 11:812-815.

ROBERTSON, G.W. National summary of pertinent information from "Probability Analyses of Weekly Climatic Data for Irrigation and Agricultural Planning" prepared for the Annual Meeting of the National Soil Survey Committee, Edmonton, Alberta, 22-26 April 1968. *Internal Report No. 10 of the Ag. Met Section, Research Branch CDA, Ottawa,* 12 pp.

1969 MUKAMMAL, E.I. Air pollutants, meteorology, and plant injury. *Tech Note No. 96. WMO No. 234.* 73 pp.

1971 MUKAMMAL, E.I., MCKAY, G.A., and TURNER, V.R. Mechanical balance - electrical-read-out weighing lysimeter. *Boundary-Layer Meteorology,* 2:207-217.

1973 ROBERTSON, G.W. Weather and world food production. *Weekly Letter, Agriculture Canada, Swift Current, Saskatchewan,* March 2, 1973. 2 pp.

1975 BAIER W. The role of agricultural meteorology in the new world food situation as related to weather/climate variability. *Sixteenth Annual Report of the Canada Committee on Agrometeorology to the Canadian Agricultural Services Coordinating Committee.* App. 13, 25 pp.

1976 MUKAMMAL, E.I. Review of present knowledge of plant injury by air pollution. *Tech. Note No. 147, WMO No. 431.* 27 pp.

STEWART, R.B. and ROUSE. W.R. Simple models for calculating evaporation from dry and wet tundra surfaces. *Arctic and Alpine Res.* 8:236-274.

1977 CCA. Climatic Variability in relation to agricultural productivity and practices. Theme papers prepared for the 1977 CCA Meeting, Winnipeg, Manitoba, 11-12 January 1977. *Canada Committee on Agrometeorology, Research Branch,* CDA, Ottawa. 222 pp.

MUKAMMAL, E.I. and NEUMANN, H.H. Application of the Priestley-Taylor evaporation model to the influence of soil moisture on the evaporation from a large weighing lysimeter and Class A pan. *Boundary-Layer Meteorol.* 12:243-256.

STEWART, R.B., WIEBE, J., AND MUKAMMAL, E.I. Delineation of frost prone areas in the Niagara fruit belt. *Tech. Bull., Ont. Ministry of Food and Agriculture.* pp. 29

1978 CANADIAN FORESTRY SERVICE. Proceedings of the Symposium on Forestry Meteorology sponsored by the World Meteorological Organization and hosted by the Canadian Forestry Service and the Atmospheric Environment Services of the Departments of Fisheries and Environment at the University of Ottawa, Ottawa, Ontario, Canada, August 21-25, 1978. *Published on behalf of WMO by the Canadian Forestry Service.* WMO - No. 527. 234 pp.

TREIDL, R.A. Climatic variability and wheat growing in the Prairies, p. 347-365 in: Essays on Meteorology and Climatology in Honour of Richmond W. Longley. Eds. K.D. Hage and E.R. Reinelt, *Department of Geography, University of Alberta*, Monograph 3.

TREIDL, R.A. Handbook on Agricultural and Forest Meteorology - Part I. Atmospheric Environment Service, Fisheries and Environment Canada; *Supply and Services Canada* No. En. 56-1/51. 75 pp. + 10 tables.

STEWART, R.B., WIEBE, J., AND MUKAMMAL, E.I. The use of thermal imagery in defining frost prone areas in the Niagara fruit belt. J. Remote Sensing and Environ. 7:187-202.

1979 CCP. Proceedings of the CCP Agriculture-Climate Workshop, November 22-23, 1979, Ottawa. *Sponsored by: Agriculture Canada (Research Branch) & Environment Canada (Atmospheric Environment Service).* 87 pp.

McKAY, G.A. Perceptions of the economic implications of climate variability. *Environ. Can. Atmos. Environ. Serv., Can. Cli. Centre,* Report No. 79-11E. 12 pp.

TREIDL, R.A. Handbook on Agricultural and Forest Meteorology - Part II. Atmospheric Environment Service, Fisheries and Environment Canada; *Supply and Services Canada* No. En. 56-1/52. 14 tables.

1981 NEUMANNM H.H. and MUKAMMAL, E.I. Incidence of meso-scale convergence lines as input to spruce budworm control strategies. *Inter. J. Biometeorol.* 25:175-187

TREIDL, R.A., BIRCH, E.C. and SAJECKI, P. Blocking action in the northern hemisphere: A climatological study. *Atmosphere-Ocean,* 19:1-23.

TREIDL, R.A. Handbook on Agricultural and Forest Meteorology - Part III. Atmospheric Environmental Service, Environment Canada; *Supply and Services Canada* No. En. 56-1/53. 11 tables.

1982 NEUMANN, H.H. Recent developments in research on air pollution and plant injury. CAgM Report No. 9.

MUKAMMAL, E.I., NEUMANN, H.H. and GILLESPIE, T.J. Meteorological conditions associated with ozone in southwestern Ontario. *Atmos. Environm.,* 16:2095-2106.

1983 WILLIIAMS, G.D.V. and MASTERTON, J.M. An application of principal component analysis and an agroclimatic resource index in ecological land classification for Alberta. *Climatol. Bull.* 17:3-28.

1984 BHARTENDU, S. A climatology of corn-heat units in Ontario. *Ontario Region, AES,* SSD-84-1

LOISELLE, M. An on-line drought index for forest-fire management purposes. *Ontario Region, AES,* SSD-84-2.

1985 BERRY, M.O. and WILLIAMS, G.D.V. Thirties drought on the prairies: how unique was it? In: C.R. Harington (Ed.), Climatic Change in Canada 5, *Sylloques,* 55:63-74. National Museum of Canada.

MUKAMMAL, E.I. Some features of the ozone climatology of Ontario, Canada, and possible contributions of stratospheric ozone to surface concentrations. *Arch. Met. Geoph. Biokl.* Ser. A, 34:179- 211.

WILLIAMS, G.D.V. Estimated bioresource sensitivity to climatic change in Alberta, *Canada. Climatic Change*, 7:55-69.

1986 WILLIAMS, G.D.V. Land use and agrosystem management in semi-arid conditions, pp. 70-90; and Land use and agrosystem management in cold regions, pp. 138-161. In: *Land Use and Agrosystem Management Under Severe Climatic Conditions.* Tech. Note 184, WMO No. 633. 161 pp.

1988 WILLIAMS, G.D.V., FAUTLEY, R.A., JONES, K.H., STEWART, R.B. and WHEATON, E.E. Estimating effects of climatic change on agriculture in Saskatchewan, Canada. In: Perry, N.L., Carter, T.R. and Konijn, N.T. (Eds.) *The Impact of Climatic Variations on Agriculture, V. 1, Assessment in Cool Temperate and Cold Regions.* Kluwer, Dordrecht, The Netherlands. pp. 219-379.

CHAPTER 4
CDA RESEARCH BRANCH, OTTAWA

PART 1 - EARLY POST WORLD WAR II DEVELOPMENTS

As pointed out in Chapter 3, two factors operated to encourage the development of agrometeorology within the Canada Department of Agriculture during the early post-WW-II years: the last meeting of IMO/CAgM held in Toronto in 1947 (IMO, 1949); and the existing surplus of meteorologists.

Canadian Inspiration from the Final IMO Meeting - 1947

The last meeting of IMO/CAgM, held in Toronto in 1947 (IMO, 1949), was an important one for Canada. Besides the official delegates from the CMS, the Canada Department of Agriculture was also invited to send delegates. Dr. P.O. Ripley, then Director of the Division of Field Husbandry, Soils and Agricultural Engineering of the Experimental Farms Service (EFS), and Dr. J.L. Doughty, Officer-in-Charge of the Soils Research Laboratory (SLR) of the Service at Swift Current were selected to attend.

Both gentlemen were familiar with the general influence of weather and climate on soil formation and agricultural production, and must have been impressed with the proceedings of the meeting and the possibilities of developing a better understanding of the influence of weather and climate on agricultural activities. When they returned from the meeting, plans were drawn up to recruit a full-time soil scientist who had about fifty percent of his training or experience in meteorology or climatology.

Post-War Surplus of Meteorologists

The second factor was the existence at the time of a surplus of meteorologists. This encouraged the CMS to look further afield than aviation in an attempt to place meteorologists in weather-sensitive areas where they might help the economy of the country. Agriculture was only one of several areas in which meteorologists might play an important role in post-war development.

PART 2 - STAFF, POLICY and DEVELOPMENT

Meteorologist Seconded to Agriculture - 1951

The EFS position for a soil scientist-climatologist went unfilled for over a year. In 1951, G.W. Robertson, a meteorologist with the CMS, heard of the opening and applied. He had neither the soils training nor experience, although he had worked on a committee (A.G. McCalla, W.E. Bowser, W. Odynsky) of the Alberta Soils Survey Group (Ch. 8). He had also taken a course in Field Crops Management from Dr. A.G. McCalla, Dean of Agriculture at the University of Alberta. He had a B.Sc. degree in Mathematics and Physics (Alberta, 1939) and an M.A. degree in Physics/Meteorology (Toronto, 1948). He had 12 years experience in the CMS as a weather observer, lecturer and forecaster with the British Commonwealth Air Training Plan, aviation and public weather forecaster at the Edmonton Weather Office and meteorologist at the newly formed Central Analysis Office in Ottawa. His appointment was almost certain when it was learned that he had been born and raised on a farm in Alberta and it was clinched by the offer of the CMS to second him to CDA, Ottawa, providing that the EFS would fill their position with a suitable agricultural scientist to work with him in the field of agrometeorology.

This was the beginning of the Agrometeorological Section, headed by Robertson for the next 18 years. He worked under the direction of, in succession, Dr. Ripley (1951-59), Dr. Senn (1959-60), Dr. Ludwig (1960-65) and Dr. Chan (1965-69) of CDA (Ottawa) and Mr. C.C. Boughner and Mr. M.K. Thomas (1951-68) of the Climatological Division, CMS (Toronto).

Robertson's duties were primarily in the field of research although his responsibilities included the task of serving as the liaison meteorologist between the CDA and the CMS, including meteorological advisor to the Department of Agriculture (see Part 3).

Counterpart Recruited by Agriculture - 1952, 1955

The first recruit as an agricultural counterpart was Dr. J.L. Dionne, a recent graduate in soil chemistry. He worked for about two years during which time he prepared a bibliography of agrometeorology and related topics. His leaning was towards soil chemistry however, and he left Ottawa and agrometeorology to continue his career as a soils chemist at the Experimental Farm, Lennoxville, Quebec.

Dr. R.M. Holmes was recruited in 1955 to replace Dr. Dionne. Holmes graduated from Brigham Young University, Provo, Utah, with a B.S. in Agronomy and Chemistry in 1952, and completed his Ph.D. in Soil Physics and Plant Physiology from Rutgers University, New Brunswick, N.J., in 1955. The Department sent him to the University of Michigan for a short time in 1961-62 to undertake post-doctoral studies in micrometeorological instrumentation. He worked with Robertson for eight years. During this time many advances were made in agrometeorology, both in Canada and elsewhere.

National Groups Provide Support

It soon became apparent that there were innumerable weather-sensitive problems in agriculture across Canada (Robertson, 1957). Agricultural scientists were tackling many of these problems, some of which required the expertise of agrometeorologists. To bring these people together to exchange ideas, Robertson organized, with the assistance of the Scientific Societies of the Agricultural Institute of Canada, half-day sessions on agrometeorology at three consecutive conferences of the AIC (1956-58) (see section "Assistance from the AIC", below).

These sessions appeared to bear fruit, as both the AIC and the National Advisory Committee on Agricultural Services (NACAS, later CASCC) set up subcommittees to look into meteorological services for agriculture in 1956. The NACAS subcommittee continued for three years and eventually developed into the National Committee on Agrometeorology (NCAM) in 1959 (see Chapter 5).

CDA Reorganization - 1959

Prior to 1959 there were two services in the CDA that were engaged in research. Both had a chain of research establishments across the country; often at the same centres. Through the efforts of Dr. K.W. Neatby, Director of the Science Service and Dr. C.H. Goulden, Director of the Experimental Farms Service, these two services were amalgamated into the Research Branch on April 1, 1959. Several other organizational changes also took place. The Agrometeorological Section, which had been under the direction of Ripley, was moved to the new Plant Research Institute, one of eight institutes of the new Research Branch. Robertson was confirmed as Chief of the Section.

A Central Corps of Agrometeorologists - 1960

One topic discussed at the first meeting of the NCAM in 1960 was the development of centres where teams (meteorologists and agriculturists) could work together on weather-sensitive agricultural problems. One centre suggested for increased support was the Agrometeorological Section of the PRI.

To this end the staff of the Agrometeorological Section was substantially increased. Dr. K.H. MacKay was recruited in 1960 to fill the role of statistician in crop-weather studies. He graduated from Macdonald College with a B.Sc., from the University of New Hampshire with an M.Sc., and from the University of Wisconsin with a Ph.D. in plant breeding and in statistics and computer programming. He was with the Section for about 3 years.

Mr. G.D.V. Williams was seconded to the Agrometeorological Section at this time, primarily to do agroclimatic analysis using climatic data and research results developed on crop-weather relationships by the Section.

Before attending university Williams worked for a year on Forest Inventory in Ontario. He graduated from the Ontario Agricultural College, Guelph, in 1954 with a Bachelor of Science degree in Agriculture (BSA), specializing in agricultural engineering. After graduating he assisted with Farm Structures Research at OAC for a year. He was recruited by the CMS in 1955, and took its Meteorological Officers Training Course. Afterwords he worked as a forecaster, mainly in the Aviation Forecasting Office at Bagotville for five years. Over the next 19 years he worked on such regional and national problems as weather-based crop monitoring, agroclimatic resource mapping and evaluation, agroclimatic impact analysis, and international applications of these. He found time to complete studies at Carleton University for an M.A. degree in Geography in 1971. He specialized in land resource use. The title of his thesis was "The physical resources for barley production on the Canadian Great Plains".

About this time Mr. W.E. Cordukes, an agronomist with the PRI was transferred to the Section to undertake field crop ecology studies. After two years he left to take charge of turf research in the Ornamental Plants Section of the PRI.

The Section Reaches Maturity - 1961

By the end of 1961 the Agrometeorological Section of PRI had become the largest group in Canada to be involved in Agrometeorological research. The staff consisted of:

- Robertson, meteorologist, seconded from the CMS; Section Head,
- Holmes, micrometeorologist,
- MacKay, statistician,
- Cordukes, agronomist and crop ecologist,
- Williams, agroclimatologist, seconded from the CMS.

It would be remiss not to mention the support staff who were recruited early in the life of the Section and played an important role in its development. Mr. W.F. Baker was the weather observer when Robertson joined the EFS. He not only took the daily weather observations at the CEF but also kept files of monthly data sent in from other Experimental Farms for use by agricultural scientists at the CEF. He continued with this work until his retirement.

Mr. D.A. Russelo was the first technician to be recruited for the Section and soon mastered computer programming. He was senior computer-systems analyst in the Section until his untimely death in 1971. Mr. D.Z. Chaput and Mr. L. Martell were recruited from CMS as technicians. Chaput also became a programmer and, eventually, senior computer-systems analyst, but Martell's career was cut short by a tragic swimming accident. Mr. R.W. Sharp was a greenhouse technician in the PRI. He was transferred to the Section and also became a computer-systems analyst. Mr. H.C. Carson was recruited from the CMS as an electronic technician to work with Holmes on micrometeorological equipment. Mr. P. Graham was the first problem-oriented plot-man for the Section. He not only looked after plots and helped with growth and development observations, but also became an expert weather observer and calculator operator. He moved on to administration after a few years with the Section.

The work of this group of support staff was far from routine, being varied and challenging and probably frustrating at times. However, they rose to the occasion to help solve a variety of problems and to keep abreast of rapidly developing technology. In their individual ways they all helped the early development and growth of the Section during the late 1950's and into the 1960's.

The Section was committed to a three-fold responsibility as follows.

- To undertake research on the physical aspects of crop environment and to cooperate with physiologists, ecologists, agronomists, etc., at an Institute and a Branch level, in a program of research on the effects of the environment on plant growth, development, yield and quality.

- To provide leadership and technical advice and guidance where required in the field of agrometeorology and agroclimatology at the national level.

- To provide liaison between Canada's National Weather Service (CMS) and the Canada Department of Agriculture.

To carry out these responsibilities the five research scientists were engaged in several areas of activity, some independently, others in cooperation with research scientists of other establishments. These activities provided the background information necessary to carry out the functions of the Section as listed above.

Staff Changes

MacKay resigned in July 1962 to accept a position with the Data-Processing Section of the Administration Branch, CDA. Cordukes was transferred a short time later to the Ornamental Plants Section, PRI, to do research on turf.

Mr. C.E. Ouellet was transferred from the Research Station at L'Assomption to the Section in January 1963 to fill the position of field-crop ecologist (ecoclimatologist) vacated by Cordukes. He received his university education at Laval (B.A. and B.S.A.) and at Montreal (M.Sc.). He joined the CDA in 1945 and worked at the Experimental Farm at Normandin for five years before being transferred to L'Assomption. He was a horticulturist by training but was keenly interested in the role of weather on plant growth. He was responsible for the agrometeorological observing program at L'Assomption and had started some plant-weather studies there.

Ouellet was hampered by lack of data, data processing facilities, and assistance from experts in agrometeorology. It was felt that he could accomplish more in his field of interest by working with the group in the Agrometeorological Section in PRI. He retired in December 1980 after a very productive career.

In 1963 Holmes resigned to take up a career in music and radio broadcasting. In May, 1964, Dr. W. Baier joined the Agrometeorological Section as a Research Scientist to replace him.

Baier was the first member of the Section who had formal training in agrometeorology. He studied at the University of Stuttgart-Hohenheim (Federal Republic of Germany) during the period 1946-52, and earned two degrees: a "Diplomlandwirt" in 1949, for which his thesis was "The Importance of Phenology in Plant Pathology"; and a "Dr. Agric." in 1952 for which his thesis was "Methods and Results of Soil Moisture Studies at Stuttgart-Hohenheim". In 1949 he joined the German Weather Service at Stuttgart-Hohenheim, where he was Officer-in-Charge of the Agrometeorological Research Station. In 1955 he left this post and moved to South Africa where he was Chief of the Agrometeorological Section, College of Agriculture and Research Institute, Potchefstroom. While there he earned an M.Sc. (Agric.), for which his thesis was "Studies of Macroclimates and Microclimates and Their Influence on Crops." In Canada he immediately undertook research on soil water where Holmes had left off.

R.L. Desjardins joined the Agrometeorology Section in 1965 as a micrometeorologist to continue the work that Holmes had started earlier in that area. He had worked as a CMS summer student in the Section from 1960 to 1963. CMS had a policy of hiring students with a potential for becoming meteorologists, and of placing them at various meteorological centres and with seconded meteorologists. Desjardins was assigned as an assistant to Robertson. He graduated from the University of Ottawa in 1963 with a B.Sc. in Physics and went on to earn his M.A. degree in Meteorology at the University of

Toronto in 1965. His thesis was on ozone fluxes in the lower atmosphere. For this study he developed miniaturized sensors. This work became the basis for much of his later research on the fluxes of gases above field crops.

After working in the Section for five years, the Department sent him on educational leave to Cornell University where he earned his Ph.D. in micrometeorology in 1972. His thesis involved work on CO_2 fluxes above crops. Later the Department sent him to work in the Bioclimatology Laboratory of INRA in France for a year in 1985.

Although the Section appeared to be well staffed, there were some housekeeping tasks that could not be taken care of without jeopardizing the research role of individuals. Tasks such as managing the agroclimatic observing program at research establishments, organizing and managing the agroclimatic archives, compiling reports for the NCAM, organizing the Section's growing library, and preparing technical notes and bulletins were tasks that needed special attention. The CMS was convinced to second a third meteorologist to the Section as an assistant to Robertson. The incumbent was Mr. S.N. Edey who joined the Section in 1966. He continued to contribute to its progress and that of national and international agrometeorology for the next 23 years, until his retirement in May 1988.

Edey graduated from McGill (Macdonald College) in 1956 with a B.Sc. (Agric.) degree. He immediately joined the CMS at Canadian Forces Base, Greenwood, NS, where he was a forecaster and lecturer in meteorology for the next 10 years before joining PRI.

Enter ARDA and the CLI - 1962

Projects under the Agriculture Rehabilitation and Development Act (ARDA) began in 1962. Within a year ARDA had let four contracts for agroclimatic studies concerning the Canada Land Inventory (CLI): the development of a preliminary atlas of agroclimatic zones in Canada; a study in British Columbia of climate in mountainous areas; a study of the soil-temperature climate in Canada undertaken at the University of Calgary; and an analysis of climatic data at some 40 CDA stations across Canada for irrigation and agricultural planning purposes. These studies were based on earlier research undertaken or encouraged by members of the Agrometeorological Section. It was only natural, then, that the Section should be involved in the technical coordination of their application. Also, Robertson was called on to serve on the ARDA Agroclimatic Steering Committee for these projects. Moreover, the studies involved practical applications of research results, and did not meet the original research responsibilities of members of the Section as spelled out by Research Branch policy.

Mr. W.K. Sly was recruited in 1967 to undertake the coordination of the climatological requirements and projects of ARDA and the CLI.

Sly graduated from the University of Saskatchewan in 1938 with a B.A. (Honours) in Mathematics and Physics. He taught high school for a short time before joining the CMS in 1941. After taking the Short Course in Meteorology at Toronto he worked as a forecaster/lecturer with the British Commonwealth Air Training Plan at Hagersville, Moosejaw and Prince Albert. In 1946 he attended the Advanced Course for Forecasters. Afterwards he worked at the Edmonton Weather Office as an aviation and public weather forecaster from 1946 until he joined CDA in March 1967 to work with the Agrometeorology Section. He retired in December 1976.

His terms of reference were to coordinate the ARDA field projects in climatology and to apply research results to practical applications (i.e. technology transfer). He undertook much of the agroclimatic analysis in cooperation with other members of the Agrometeorological Section, which now had a good archive of climatic data, access to computers, and problem-oriented computer-systems analysts and other support staff.

Mr. M.C. Coligado was awarded a contract in 1967 to assist Sly with the agroclimatic analyses. He graduated from the Agriculture College at Los Ban os, the Philippines, with a B.Sc. in 1962 and from Texas A. and M. with an M.Sc. in 1966. Upon completion of the contract in 1969 he registered for post-graduate work in agrometeorology at the University of Guelph where he received a Ph.D. in 1974.

Section Program Reviewed - 1966

In 1966 the Agrometeorological Section reviewed its research programs (Robertson, 1966). The practical importance of fundamental research in crop-weather relationship studies was emphasized by the number of studies that were under way or being planned by ARDA, by the Atlantic Development Board, by the Economic Council of Canada, and by the Economic Branch of Canada Agriculture These initiatives focussed on the future impact on agriculture of alternate land use, changing economic patterns, a highly developed technology, and a rapidly increasing world-wide need for more food. They demanded an understanding and interpretation of the role of continually changing weather and climatic conditions on crop production. As there was considerable climatic data available, it was anticipated that the research scientists of the Agrometeorological Section could develop worthwhile crop-weather relationships that were expected to have national and possibly international applications.

It was decided that the staff of the Agrometeorological Section should continue, cooperatively, to study plant-weather relationships. Such a study was too complex for a single individual to undertake and required strong coordination, close cooperation among the research scientists, and a common pool of climatic data and expertise for data processing.

Working as a team, the following areas of the Section objective were assigned to individual scientists:

Crop Development and Weather (Robertson). Objective: to develop quantitative techniques for calculating the influence of day-to-day weather variations on the rate of development of certain economic crops.

Crop Production and Weather (Baier). Objective: to develop techniques for estimating from standard climatological data useful agroclimatic factors, such as soil water, and to establish relationships between these factors and crop-production components using physically sound crop-weather models.

Plant Survival and Weather (Ouellet). Objective: to develop techniques for relating survival of plants to weather and climate for zonation and other purposes.

Agroclimatic Analysis (Williams). Objective: to develop and demonstrate techniques for applying existing knowledge of crop/weather relationships to the solution of agroclimatic problems.

Micrometeorology of Crops and Plants (Desjardins). Objective: To determine microclimatic patterns of plant communities and to relate elements of the microclimate to macroclimate data.

The End of Secondment Policy by CMS - 1969

According to a new policy of the CMS, all secondments were to terminate by April 1, 1969.

In anticipation of changes to come, Robertson transferred from the CMS seconded position he had held for the past 17 years to the staff of the Research Branch, CDA early in 1968. Other than cessation of official liaison duties, no other change in responsibilities was involved.

Both Edey and Williams were transferred from CMS to the Research Branch, CDA, early in 1969.

By mid-1968 Robertson appraised his position with CDA and concluded he had contributed all that he could both scientifically and administratively. CDA did not consider that a coordinator for

agrometeorology was necessary even though much of Robertson's work was devoted to coordination and liaison, in spite of the work of the NCAM and other members of the Agrometeorological Section. Furthermore, his productivity was measured by his scientific output, which was hampered both by duties as Chief of the Section and as coordinator and liaison agrometeorologist within CDA and regarding certain national and international matters. Consequently, he looked for an opportunity for a short change in his work venue.

In the autumn of 1968, WMO had an opening in the Philippines for an agrometeorologist to develop an agrometeorological program in the Philippine Weather Bureau, and to lecture in agrometeorology and climatology at the University of the Philippines. The financial arrangements were such that Robertson could not refuse. He was granted two years' leave of absence by CDA, but had to relinquish the position of Chief of the Agrometeorological Section. He left to undertake this assignment in March 1969. On his return to Canada he accepted a position with CDA at Swift Current as Head of the Crop Environment Section at the Research Station.

Baier Appointed Chief of the Agrometeorology Section

Baier replace Robertson as Chief of the Section and later was appointed secretary of the CCAM (NCAM) (Chapter 6).

Work in the Section continued as in the past. The usefulness of environmental elements, derived factors such as soil water, actual evapotranspiration and crop-weather indices continued to be demonstrated in various applications. These included the interpretation of climate in relation to soil classification, land use capability, prairie wheat yield estimation and crop zonation. The Section continued its liaison work, including the provision of information and reports to CMS, WMO, and FAO.

In 1972 Dr. H.N. Hayhoe joined the Section. He received a B.Sc. (Honours) in mathematics at Carleton University in 1968, an M.Sc. in mathematics at the University of Illinois at Urbana in 1967, and a Ph.D. in Biomathematics from the same university in 1971. As an undergraduate he won the Maxwell MacOdrum Scholarship in 1963 and the Carleton University Alumni Association Scholarship in 1964. He worked at Carleton on a Post-Doctoral Fellowship in 1971, prior to joining the Agrometeorology Section in 1972.

His general responsibility in the Section was to apply mathematical and statistical knowledge to practical agrometeorological problems.

Administrative Reorganization - 1973

The PRI was disbanded in 1973 and the Section was transferred to the new Chemistry and Biology Research Institute (CBRI) under the direction of Dr. G. Fleischmann. It became known as the Agrometeorology Research and Service Section. This is the first time that the "service" nature of some work of the Section was recognized by its name, although placement in the CBRI was somewhat of a puzzle. Baier continued as Section Head.

During 1976 the Research Branch, CDA, reorganized its research activities, introducing a system of objectives and goals. In general the Section continued to participate in agrometeorological activities designed to promote, plan, and conduct agrometeorological research and services at the national and international levels.

Baier presented a summary of the objectives and goals of the Agrometeorological Section to the Eighteenth Annual Meeting (1977) of the ECA. The following is taken almost verbatim from his report.

The main goal of the Agrometeorological Section was, by 1980, to have derived selected meteorological and climatic indices that would contribute to improved decisions in weather-sensitive agricultural

operations; to provide improved methods of assessing the productivity of climatic resources; and to contribute to the interpretation of climate data for selected research programs.

To achieve the Section Goal, sub-goals were specified:

AgMet Sub-Goal re Crop-Environment Modelling. By 1980, to have developed and applied conceptual models suitable for analysing plant-weather relationships and for assessing climatic resources in relation to crop production, land evaluation and cultural practices.

AgMet Sub-Goal re Operational Systems. By 1980, to have developed and applied methodology for interpreting meteorological data in terms useful for improved agricultural planning, management decision making, and day-to-day farming operations.

AgMet Sub-Goal re Agrometeorological Research Services. In a continuing program, to coordinate the acquisition and distribution of agrometeorological data and information; to provide data processing support in compiling and analyzing agrometeorological data; to develop computer programs for agrometeorological research and application; and to assist users in the interpretation of research results.

Staff Changes, 1976

Mr. J.A. Dyer joined the Staff of the Agrometeorology Section in November 1976. His immediate responsibilities were in the field of systems analysis and development, particularly in relation to field-workdays and hay-drying weather. The Section had been working on this topic for several years, and it now was ready for the operational stage.

Dyer received a B.Sc. (Agric.) in Soil Science from Macdonald College in 1972 and an M.Sc. in Agrometeorology from Guelph University in 1974. His thesis topic was "Simulation Surface Temperatures". During 1975 he worked at Guelph University where he developed a computer simulation model for hay-drying risk analysis from climate records (Dyer and Brown, 1977).

A review of activities of the Section in 1976 revealed programs on:

- Development of several crop-environment models;
- Increased agrometeorological input to Research Branch and other establishment programs;
- Continued applications of earlier developed agrometeorological techniques to research and services in Canada and elsewhere;
- Increased participation in national (CCA) and international (WMO) agrometeorological activities.

Sly retired at the end of 1976, after completing a substantial project on the Agroclimatic Atlas of Canada.

Dr. D.W. Stewart joined the Section in 1977. He was formerly a research scientist at the Swift Current Research Station, where he worked for five years, in turn, with Pelton and Robertson. He resigned that position in 1974, and was self-employed as a consultant in computer simulation and farming until joining the Section as a Research Scientist. In general, his work in the Section was in the area of soil-plant-atmosphere modelling.

Transfer to Land Resource Research Institute - 1978

In 1978 the Section was included in the new Research Branch Institute, the Land Resources Research Institute (LRRI), formerly known as the Soil Research Institute (SRI). Dr. J.S. Clark became the Director. Dr. A.R. Mack was transferred to the Section from the Soil Research Inventory Section of the former SRI, with responsibilities for the remote sensing program he had been working on for the past eight years.

Mack received a B.Sc. in agriculture from the University of Manitoba in 1949, a M.S. in soil fertility from Iowa State University in 1952, and a Ph.D. in environmental effects on soil fertility from Purdue University in 1958. He worked at the Melfort Experimental Farm from 1949 to 1955 and then with the Illustration Station Division (ISD) of the EFS in Ottawa from 1956 to 1959. While with the ISD he spent considerable time, with the cooperation of Robertson, in upgrading the quality of the observational program at Illustration Stations across the country. When the Department reorganized in 1959 he was transferred to the Soil Research Institute. There he undertook extensive field experiments on the effect of soil temperature and soil water on nutrient uptake and crop growth. Much of this work was in close cooperation with the Agrometeorology Section (Mack, 1963: Mack and Evans, 1965; Mack, 1965; Mack, 1973; Mack and Wallen, 1974).

Mack had become involved in remote sensing eight years before joining the Section, and some two years before the launch of the first Earth Resource Technology Satellite in 1972.

Because of this new involvement of the Agrometeorology Section it became known as the Agrometeorology and Crop Identification Section. There was much interest in remote sensing at this time. This new affiliation of the Section with LRRI resulted in a more positive alignment of its productivity and was expected to prove most complementary to current and future research and service commitments.

A significant change in leadership also occurred at this time. Although Baier continued as Head of the Section, he was appointed to serve also as Assistant Director of the LRRI.

The goal of the Section was reworded as follows to fit its new position in the LRRI: "By 1983, to have developed methodology for the assessment of agroclimatic resources and for analyzing and monitoring crop response to weather, soil and land management, to provide agrometeorological information as required for agricultural research and service and as input to planning, marketing, and farm management decision-making."

Dr. R.B. Stewart joined the Section in February 1978 to undertake research regarding agroclimatic resource assessment. Stewart earned a B.A. with honours in geography from the University of Windsor in 1971; an M.Sc. in micrometeorology in 1972 and a Ph.D., also in micrometeorology, in 1975, both from McMaster University. He held the Ontario Graduate Fellowship from 1971 to 1975 while at McMaster and an NRC Post-Doctorate Fellowship with the CMS in Downsview from 1975 to 1978.

Another addition to the staff was Dr. L.M. Dwyer who joined the staff in September 1978 as a National Research Council post-doctoral research fellow in agrometeorology, a position she held for two years. She was taken on as a research scientist in the Section in December 1980 as Bio-environmentalist and Crop Physiologist. She received her academic education at Carleton University: B.Sc. in 1971, M.Sc. in 1973, and Ph.D. in 1978 in Biology. After graduation she worked for a short time as a physical scientist with the Water Quality Branch, Environment Management Service, Environment Canada.

By the end of the decade (1979) the Agrometeorology Section was firmly integrated with the LRRI. The Crop Information System Program (CISP) became a focal point for ongoing activities in remote sensing, weather-based crop-yield predictions, and land-resource research. Likewise, the Land Evaluation Program (LEP) was strengthened through increased agrometeorological research input, especially crop yield modelling, agroclimatic resource analysis and climate-soil evaluations. This reorientation of agrometeorological activities and the increasing involvement in contract research required close coordination of effort.

Meeting the Challenge of Technological Transfer

It appeared that the science of agrometeorology had now developed to such a stage that research results could readily be applied to practical problems encountered by most weather-sensitive programs such as CISP, LEP, and others.

To meet the challenge of technology transfer, the organization of the Section was further realigned. Rather than individual research projects, four group projects were identified similar to previously specified Section goals. It was anticipated that the group-project approach would more fully use the cross-discipline approach to problem-solving. This was in complete antithesis to earlier approaches to research and development, which expected every scientist to do original, independent research and produce publishable scientific papers. The four group projects had the folloing objectives, to be met by 1983.

Crop-Weather Analysis: To develop a crop-environmental data acquisition and analytical processing system for analysing selected biophysical plant-weather relationships required for assessment of growing conditions, agroclimatic resources, and other interpretive agrometeorological aspects. Coordinator: Desjardins.

Crop Information (marketing requirements): To develop a system for evaluating the spatial distribution of crops, crop conditions, and yield prospects from remote-sensing and weather data for improved marketing and supply information derived from biophysical and statistical analytical research. Coordinator: Mack.

Climatic Resources: To develop methodology for assessment of agroclimatic resources based on biophysical and statistical relationships, and to provide agroclimatic information required for efficient management of natural resources used for production of food and fibre. Coordinator: R.B. Stewart.

Agrometeorological Applications: To develop agrometeorological techniques for interpretative applications at a farm-management level and to maintain operational agroclimatic data systems in support of research and service.

Most of the projects under these four groups had been started earlier and work continued on them. One new project was the FAO Agro-Ecological Zones Project in which climate, soils, and yield data were integrated to achieve a classification of soils productivity. The yield component had to be modified to meet Canadian conditions.

Serious Staff Losses, 1979

In 1979 there were two important staff losses. Baier, who had been Head of the Section for the past 10 years, and served a dual role as Section Head and as Assistant Director of LRRI for the past two years, was officially appointed as A/Director of the CBRI. His involvement in the Agrometeorology Section decreased, leaving it with no definitive leadership. Mack was appointed as Acting Head but his duties in this position were never firmly spelled out.

Another long-time member of the Section was lost in June 1979. Williams, who was originally seconded to the Section from the CMS, resigned to accept a post with that organization, now the AES. He had been a member of the Section for 19 years.

During 1980 the Section continued to be integrated into the organization and programs of the LRRI. In spite of this, or because of it, the Section suffered a severe setback in the loss of more members in 1980. A decision was made by the CDA to form a second agrometeorological group in the Regional Development and International Affairs Branch (RDIA). Later, this group became the Soil and Climate

Section in the Agricultural Development Branch. R.B. Stewart and Dyer resigned, after only a few years, to join this new Section. Ouellet retired at the end of the year, after serving for 18 years.

Staff losses over the past two years left the Section with vacancies for four agrometeorologists plus two data processing technicians. By the end of 1980 the staff of the Section consisted of Mack (Acting Head), Desjardins, Dwyer, Edey, Hayhoe and D.W. Stewart.

Agric-Food Strategy for Canada: Meeting the Challenge - 1981

In March, 1981 Dr. W.G. Bailey joined the Section as agroclimatologist but remained with it for less than a year. He had been working at the Research Station at Beaverlodge as a micrometeorologist.

Realignment of research and service within the Section in 1981 continued to reflect the new change of priorities resulting from recent policy decisions of the Department. Major staff changes were made to involve both professional and support positions. The Department's discussion paper entitled "Challenge for Growth: an Agri-Food Strategy for Canada" was of immediate importance. This report was a framework document outlining the requirements and direction to be taken during the 1980's whereby the food and agricultural sector of Canada's economy would maximize its contribution during the decade.

Of equal importance was the Research Branch's role in fulfilling its obligations relating to research and development in support of the Departmental strategy. Agrometeorology was prominent in relation to several key Branch programs, included the following areas of priority:

Food safety
-to reduce the dependence of the agri-food system on pesticides.

Natural Resources
strengthen programs to collate basic soil and climate data by:
- acceleration of climatic resource modelling and land evaluation methodologies wherein the climatic component should be pertinent to the Canadian Climate Program,
- monitoring the effect of all forms of atmospheric pollution on growing crops,
- determining the impact of CO2 on agricultural production directly or through predicted climatic change,
- determining crop production potential through increased irrigation
- anticipating potential water diversion schemes to the USA and articulating costs and benefits to affected areas within Canada.

To meet anticipated requirements regarding the strategy, the Section Work Plan was altered from that stated in 1979. The goal of "Crop-Weather Analysis" coordinated by Desjardins was replace by a new goal, "Operations Management" with Hayhoe as coordinator. Under this goal, Farm Weather Services were given high priority. The goal of "Climatic Resources" coordinated by R.B. Stewart was altered to "Agroclimatic Resource Assessment" with Bailey as coordinator.

In 1982 Mr. A. Bootsma, formerly with the Prince Edward Island Department of Agriculture and Forestry, was recruited to fill a position as an Agrometeorological Resource Specialist in the Section. He was a graduate from the University of Guelph with a B.Sc. (Physics and Math.) in 1969 and an M.Sc. (Meteorology) in 1972. He worked in PEI from 1971 to 1982 as an agricultural climatology specialist.

Work continued in the four main areas of activity of the Section. Progress appeared very good as some 24 achievements were listed in the Annual Report of the ECA. There appeared to be an increasing emphasis on supplying information and data in aid of practical operational projects by other CDA agencies and provincial groups. That same year Ms. J. Boisvert joined the Section as a specialist in farm-weather services.

Agrometeorological Leadership Uncertain - 1983

The Section had been without a dedicated, discipline-oriented leader since Baier left the Section in 1979. Mack served as Acting Head of the Section from 1980 to 1983. Dr. J. van Schaik, a soils scientist and Deputy Director of the LRRI, was then appointed to serve, also, as Head of the Section.

The activities of the Section were redefined in 1984 and directed through three projects:

Crop Environment Assessment. Activities in this area included the continuation of work on soil-water estimates in Saskatchewan; crop-yield and wheat-protein estimates for the Prairies using both current weather data and satellite information; and studies of CO_2 fluxes and the estimation of instantaneous growth rates of crops.

Agroclimatic Resources Assessment. Work continued on the agroclimatic zonation of forage crops and wheat in the Atlantic Region; the effect of climatic change on dry-matter production; mapping of freezing-temperature risks in PEI; field and growth-room observations of leaf-area index, phenology, growth and water potential of several crops and their use for model developed; a soil-water budget for soybeans under southern-Ontario conditions.

Operations Management. Data on soil-water continued to be supplied for Grassroots' files. Work also continued on the Research-Branch Agrometeorological Network and the selecting, designing and testing of sensors for leaf-wetness duration, depth of snow on the ground, and a telephone data retrieval system for automating the observational procedures. Studies of the effects of weather on irrigation, soil-water movement, soil freeze-thaw processes and grasshopper populations continued.

The fourth project dealing with the provision of improved agrometeorological information services appears to have been dropped for the Section's list of activities although the service appears to have continued, mainly by the support staff who maintained the data files and the operational computer programs.

The Section Loses Its Identity - 1987

The LRRI became known as the Land Resource Research Centre (LRRC) in 1987 with Mr. J.L. Nowland as acting Director. The retirement of Van Schaik in July left the Agrometeorological Section without a leader.

Following organizational restructuring within the LRRC, research and development on a discipline basis was replaced by a commodity-based structure. This spelt the death-knell of the Agrometeorology Section after some 35 years of continued dedication and contribution to agrometeorology in Canada. Members of the ECA noted with concern the proposed disappearance of the Agrometeorology Section from within the LRRC. They expressed concern that there would be a lack of recognition, by the Research Branch and CDA, that agrometeorology was an essential discipline to accompany Canadian agricultural development. Such a situation was considered retrograde and was predicted to hurt this area of applied research. The members drafted an expression of concern for submission to CASCC at the time of their annual meeting in May 1987.

Staff of the former Section were moved into a new Research Section under the Head of Dr. S.U. Khan, and split into two groups: Climatic Assessment and Information under the leadership of Bootsma and Weather and Soil-in-Crop Production under the leadership of Stewart, The former group's work included research on farm weather services (Boisvert), applications (Edey), biomathematics (Hayhoe), and remote sensing (Mack). Work of the latter included micrometeorology (Desjardins) and environmental meteorology (Dwyer).

For the first time in the history of the ECA there were no representatives from either of the agrometeorology groups in the LRRC at the 1988 Annual Meeting. Edey, who had served as Secretary for 22 years retired in May. Bootsma prepared an annual report but this was presented by Blackburn (Soil and Climate Program in the Agriculture Development Branch of CDA). The 1989 Annual Meeting of the ECA was held in Downsview at AES Headquarters. Again, no member of the former Agrometeorological Section was present at the Meeting, a very sad state of affairs.

Staff Summary - Research Scientists - 1951-1989

Robertson, G.W.	1951-71 (Section Head 1959-69)
Dionne, J.L.	1952-54
Holmes, R.M.	1955-63
MacKay, K.H.	1960-62
William, G.D.V.	1960-79
Cordukes, W.E.	1961-62
Ouellet, C.E.	1963-80
Baier. W	1964-79 (Section head 1969-79)
Edey, S.N.	1965-88
Desjardins, R.L.	1965-
Sly, W.K.	1967-76
Coligado, M.C.	1967-74
Hayhoe, H.N.	1972-
Dyer, J.A.	1976-80
Stewart, D.W.	1977-
Dwyer, L.M.	1978-
Stewart, R.B.	1978-80
Mack, A.R.	1978- (Acting Section Head 1980-83)
Bailey, W.G.	1981-82
Bootsma, A.	1982-
Boissvert, J.B.	1982-
Van Schaik, J.C.	1984-87 (Section Head)

PART 3 - LIAISON, CONSULTATION AND COMMITTEES

Agroclimatic Observing Program

The main purpose for establishing experimental farms under the Experimental Farms Act of 1886 was to study the problem of raising crops under the diversified soils and climatic conditions existing in the various agricultural areas of Canada. Dr. W. Saunders, the first Director of the Experimental Farms Services contacted the Director of the CMS, Mr. C. Carpmael, in Toronto for assistance in taking weather observations at the experimental farms.

The CMS saw the potential for securing excellent sites for permanent climatic stations at experimental farms. It agreed to provide the basic instruments in return for a monthly copy of the daily observations. Instruments consisted of a simple rain-gauge, maximum and minimum temperatures in a standard shelter and, in some cases, recorders for measuring the duration of bright sunshine. One of the first experimental projects set up at newly established experimental farms was the measurement and identification of local and regional climatic conditions. The first stations to be so equipped were the five original experimental farms: Nappan, Nova Scotia; Ottawa, Ontario; Brandon, Manitoba; Indian Head, Saskatchewan (then N.W.T.); and Agassiz, British Columbia.

Robertson's first task as liaison and advisor to CDA was to upgrade the meteorological observing program at the Experimental Farms. This involved visiting all Experimental Farms and some Science Service Laboratories across the country. There were some 30 of these establishments at which weather observations were taken and reported to the CMS in Toronto and to the Central Experimental Farm at Ottawa.

Some sites, such as that at the Central Experimental Farm, had to be relocated to improved exposure to wind and sunshine. Arrangements were made with the CMS to provide Nipher shielded snow gauges to most sites. Equipment for measuring soil temperature at various depths at a few selected stations (Ripley 1959; Potter, 1962) was also provided by CMS. The National Research Council's Snow and Ice Subcommittee of which Robertson was a member, also had an interest in these measurements and provided support for the observing program.

In addition, there were many Illustration Stations across the country that observed rainfall only. Some were not equipped with official CMS equipment. The rainfall observation program at these stations had to be reviewed, upgraded, and, in some cases, temperature observations added.

When Williams joined the Section in 1960 he assumed responsibility for the network of agroclimatic stations that the Research Branch had at some 35 agricultural research stations and about 100 rainfall stations at Agricultural Project Farms (Illustration Stations). This work involved liaison with the CMS in Toronto.

Early in 1963 the Director of CMS announced that it was considering the revision of wind observations, instrumentation, and reporting procedures. They were seeking comments on the requirements for wind information. Since agriculture was a large user of such information it was considered that the NCAM would be a good medium for the collection of agriculture users' requirements. Robertson along with four other members (Pelton, King, Leefe, and Villeneuve) of NCAM were named to a subcommittee to look into these requirements. The subcommittee brought forth its recommendations to the NCAM in 1965 (See Chapter 5).

Eventually the observing program at most Experimental Farms was upgraded to include observations of wind speed, humidity, rainfall intensity, and improved evaporation measurements. Dew duration was also measured at a few stations, particularly where research on fungus-type diseases was conducted. Because of the interest of CMS in the equipment and observations at CDA stations, arrangements were made for CMS staff to periodically inspect the stations and review observing programs and procedures with those responsible for the project.

When Edey join the Agrometeorological Section in 1965 one of his responsibilities was to supervise the weather-observing program of the Research Branch. To improve the calibre of observations, Edey took over the preparation of a series of information and instruction letters to weather observers. This publication, entitled "Agroclimatological Observations Bulletin", was started by Robertson in 1960 and was issued intermittently for several years. It helped to keep observers at research stations informed regarding proper observing and reporting techniques. Some bulletins explained the important use made of the observations. Through these efforts an improvement in the quality of the observations was achieved.

CMS was eventually convinced to undertake the publication of agrometeorological data and a new CMS monthly publication "Daily Agrometeorological Data" was started in 1965. The purpose was to make daily weather data from Research Stations and other agricultural research and educational establishments more readily available to agricultural research scientist. The publication contained, in addition to regular weather data, such elements as wind run at two metres, dew-point temperatures, soil temperatures, snow water content, and potential evapotranspiration that were not published elsewhere. The publication contained information for some 40 agricultural research establishments across Canada. Some 16 daily weather factors were listed for each of 40 stations. Data quality was carefully controlled before

publication. The publication continued for 9 years but was discontinued in 1973 when other CMS publications containing essentially the same information replaced it.

A soil-water measuring program for the Canadian Prairies was started in 1966 by the Agrometeorological Section at the request of the NCAM. It was suggested that all federal and provincial research and service establishments should take gravimetric samples early in the spring and late in the autumn, and report these to the Section. Baier, Robertson and Edey prepared instructions and reporting forms. Data were entered on punch cards for ease of processing and publication (see Agrometeorological Instruction Bulletin No. 23 - Soil-Moisture Reporting Network). Eventually Edey became responsible for the program and the number of contributors increased.

By 1974 Edey was supervising the collection of soil water from 43 prairie sites in the spring and fall. Data were used for the preparation of semi-annual reports on crop conditions and yield prospects. By 1976 the program became known as the Soil Moisture Evaluation Project (SMEP). Reports were now issued weekly and turn around time for data preparation, printing and mailing was less than 24 hours thanks to a well-managed program, the cooperation of observers and readily available computer services. Edey was also responsible for upgrading the 40 agrometeorological stations at agricultural establishments throughout Canada by the end of 1969. Data were carefully quality controlled for publication in the CMS bulletin "Daily Agrometeorological Data".

Preliminary work was undertaken in 1969 to establish a mesoscale soil-temperature data collection program ("Instruction Bulletin No. 24 - Soil Temperature Data Program, CDA"). Soil-temperature observations had been taken regularly at several research stations since the soil-temperature program started in 1960. To properly interpret these observations it was necessary to know certain physical characteristics of the soil at the measuring site. CDA gave Carleton University a contract to determine these characteristics. A geography student undertook the work as a thesis project, supervised by Edey (Edey and Joint, 1975).

To meet changing financial conditions within the Research Branch the manual observing of weather factors was questioned during the early 1970's. Emphasis was placed on techniques and procedures for making the most efficient use of labour and time. Semi-automatic observational procedures were becoming available and there was a possibility of eventually converting the manual observing program to a fully automated system. Considerable research was still required, however. In 1973 Edey began a long program of research and development with the objective of automating all agroclimatic stations. By 1975 sufficient progress was made to recommend equipment and procedures for taking weekend observations where manual observations were no longer practical and economical.

Equipment was not fail-safe and development and testing continued for some time. Field evaluations of the MATER System (Magnetic Tape Event Recorder) developed by CMS were undertaken in 1976. Results were most promising and operational use of the system was expected in a year or so. Further tests indicated that sensors and data acquisition systems were still not acceptable for routine observations by 1977. The development of reliable equipment for automatic weather stations was slow. By 1983 Edey was investigating the design of suitable sensors and techniques for measuring leaf wetness, depth of snow on the ground, and frost depth (Hayhoe et al., 1983). A microprocessor-based data logger for automatically recording and transmitting the information on critical environmental factors via telephone lines to a central computer was also being tested (Edey, 1985; Edey et al., 1986). The system had the potential to reduce manpower and increase availability of current weather data.

Liaison and Consultation

Robertson's responsibilities as Chief of the Agrometeorology Section increased substantially by 1963. Liaison between agriculture and meteorology required almost monthly trips to the Meteorological Headquarters in Toronto. Advisory and consultant services were encouraged by both CDA and CMS.

Being closely associated with the research wing of CDA, he was expected to do independent research, a role he found increasingly difficult to undertake as the load of liaison and advisor work increased.

His services were sought regarding many weather-sensitive problems in agriculture. He assisted several entomologists with specific insect problems, (aphids, diamond-back cabbage moths, grasshoppers, six-spotted leaf hoppers) mainly by recommending suitable instruments for taking microclimatic measurements in the insect's habitat. Regarding the six-spotted leaf hopper, which carries aster yellows virus, he demonstrated that the insect could be carried from its wintering grounds in the southern central States northward into Manitoba by strong southerly winds under certain synoptic weather conditions in the spring, thus explaining its sudden appearance in that province in the springtime even though it could not overwinter there in the severe cold.

Assistance from the Agricultural Institute of Canada

To increase the awareness of agriculturists to the potential use of meteorology and the services of the CMS in their research, planning and operational work, Robertson conceived the idea of holding a short session on agrometeorology at the annual convention of the Agricultural Institute of Canada (AIC). The idea was accepted by the Canadian Society of Agronomy and the Horticulture Section, and he was asked to arrange a program for a half-day session, which was held at the 36th Annual Meeting and Convention of the AIC at the University of Toronto in June, 1956.

This historic joint session was chaired by Dr. P.O. Ripley, Director of the Division of Field Husbandry, Soils and Agricultural Engineering of CDA, who opened the session with a topic entitled "Agricultural meteorology is everybody's business". This was followed by six other speakers dealing with the application of meteorology to some specific facet of agriculture: K.T. McLeod, Superintendent of Public Weather Services, CMS, discussed "Weather services for agriculture"; W.L. Godson of the Atmospheric Research Section, CMS spoke about "Induced precipitation"; G.R. Kendall and M.K. Thomas of the Climatological Section, CMS, told about "Variability and trends of precipitation in the Prairie Provinces"; Robertson delivered a paper on "The use of climatic data in irrigation planning"; R.J. Mercier, Ontario Department of Agriculture, Vineland and L.J. Chapman, Ontario Research Foundation, Toronto delivered a paper on "Peach climates in Ontario"; and J.W. Wilcox, Experimental Farm, CDA, Summerland, BC, talked about "Weather and the establishment of irrigation requirements".

The joint session was such a success that it was agreed to hold a similar one the following year in Western Canada at the 37th Annual Meeting and Convention of the AIC, held at the University of British Columbia in Vancouver in June 1957. Robertson was organizer and Chairman of the half-day joint session sponsored by the Canadian Society of Agronomy and the Canadian Society of Soil Science. A completely new and diverse program was arranged:

"Agricultural meteorology in the United States, a progress report" by J.M. Beall, Chief, Public and Agricultural Forecast Section, United States Weather Bureau, Washington.

"Predicting deciduous fruit blossoming dates from temperature data" by T.H. Anstey, Experimental Farm, CDA, Summerland, BC.

"Frost protection in the Okanagan Valley" by D.N. McMullen, Vancouver Weather Office, CMS, Vancouver.

"Meteorological services available to agriculture" by Andrew Thomson, Director, CMS, Toronto.

"Evaporimeters for determination of consumptive use" by W.L. Wilcox, Experimental Farm, CDA, Summerland.

"Hailstorm research in Alberta" by N.H. Grace, Director, Research Council of Alberta, Edmonton.

"Winter injury studies using a field growth chamber" by R.M. Holmes, CDA, Ottawa and G.W. Robertson, CMS, seconded to CDA, Ottawa."

The third and last half-day session on agrometeorology was held the following year at the 38th Annual Meeting and Convention of the AIC held at Acadia University in Wolfville, NS, June 1958. Robertson again arranged the program that was jointly sponsored by the Agricultural Engineering Section, The Canadian Society of Agronomy, and the Canadian Society for Horticultural Science. The chairman was Dr. H.A. Steppler, Chairman of the Department of Agronomy at Macdonald College. Following his opening remarks, five papers were presented:

"Crop growth and day-degrees" by Holmes and Robertson.

"Climatic zones for crops in Ontario" by L.J. Chapman, Ontario Research Foundation, Toronto.

"The influence of climate on the colour and size of Nova Scotia apples" by C.J. Bishop, Experimental Farm, CDA, Kentville, NS

"Characteristics of artificial light" by W. Kalbfleisch, CDA, Ottawa.

"The influence of meteorological conditions on crop drying practices with unheated air" by C.P. Hedlin, Ontario Agricultural College, Guelph."

Sessions on agrometeorology had now been held in Central, Western and Eastern Canada, exposing many administrators and research scientists to the potential application of agrometeorology and meteorological services to weather-sensitive agricultural problems. This exposure was considered sufficient for the time being. It was to be nearly 30 years before another session on agrometeorology was to be held during an AIC Convention (Saskatoon, Saskatchewan in 1986).

Following the 1956 Session on Agrometeorology the National Council of the AIC formed an ad hoc Committee on Agrometeorology with Dr. D.G. Hamilton (then Honorary Secretary of AIC) as chairman and Robertson as secretary. Assisted by subcommittees of local AIC Branches, a survey was made of current activities in agrometeorology and of the recognized meteorological problems facing agriculture at the time. The committee discovered that there were some 80 weather and climate related studies being conducted at some 39 CDA establishments across Canada. Most of these needed the assistance of a professional meteorologist or agrometeorologist, particularly regarding environmental measurements, data analyses, and data interpretation.

Committee Involvement

By the end of the 1950's Holmes and Robertson were involved in several committees, with liaison work, and as consultants. Since Robertson was recognized as the liaison meteorologist with CMS and the advisor to CDA on meteorological matters, most of these responsibilities fell on his shoulders. The following list illustrates the extent of this work:

Evapotranspiration and heat and water-vapour fluxes - Pelton, Experimental Farm, Swift Current (Holmes).

Prairie grassland ecology - Dr. Coupland, University of Saskatchewan - EMR Grant (Robertson).

Microclimate of plastic tents - Experimental Farm, Whitehorse (Robertson).

Response of wheat to fertilizers and soil moisture at Experimental Project Farms - Mack, Soil Research Institute (Holmes and Robertson).

Cooperative crop-weather relationship study at Experimental Farms and Research Stations - Harrow, Ottawa, Normandin, Swift Current, Lacombe, Beaverlodge, Ft. Vermilion, and Ft. Simpson. (Robertson).

Grasshopper epidemiology and weather - Dr. Edwards, Research Station, Saskatoon (Robertson).

Soil erosion and wind speed frequencies - Anderson, Research Station, Lethbridge (Robertson).

Working Group on Wind Breaks and Shelter Belts - WMO/CAgM (Robertson).

Subcommittee on Watershed Research for the Eastern Rockies - Forest Conservation Board (Robertson).

Subcommittee on Hydrology of the Associate Committee on Geodesy and Geophysics of the National Research Council (Robertson).

AIC Committee on Agrometeorology (Robertson was secretary).

NACAS Special Subcommittee on the Needs of Agriculture for meteorological services (Robertson was secretary).

One committee of which Robertson was a member for several years was the Agricultural Meteorology Committee of the American Meteorological Society. He was Chairman from 1964 to 1967. During this period he arranged for CDA to invite the group to Ottawa for their eighth regular scientific meeting, held once every 18 months. CDA hosted the meeting in May 1967, which was held at Carleton University. Some 180 participants attended.

Baier was active in the affairs of the Commission for Agricultural Meteorology (CAgM) of the World Meteorological Organization (WMO) and was elected President for two terms, 1971-79, during which time he attended several international meetings and arranged international symposia, seminars and workshops (see Chapter 10).

By 1976 Section members were active in the CAgM/WMO, CCA, the AES Committee on Climatic Fluctuations and Man, and Provincial Agrometeorology Committees. Liaison work by staff members increased in 1978, primarily due to the remote sensing commitments of staff members .

After about 1980 funds for committee work appeared to slowly disappear, possible due to government restrictions on available funds for such purposes, but there is a suggestion that conflict of interest by leaders played a role in this matter.

The National Committee on Agrometeorology (NCAM, CCAM, CCA, ECA)

Due largely to the activities of the members of the Agrometeorological Section and the publicity given to agrometeorology at the three AIC sessions, agriculturists had been made aware of the potential of agrometeorology, and the need for organized meteorological services for agriculture. This need was brought to the attention of the National Advisory Committee on Agricultural Services in 1956, and a special subcommittee on meteorological services for agriculture was formed to look into the matter. The committee held three meetings. Robertson was secretary for the first two during which time he prepared a comprehensive report on the matter (Chapter 6). He chaired the third meeting in 1959 when the concept of a National Committee on Agrometeorology (NCAM) was conceived. Robertson served as secretary of the NCAM from its inception until he took leave of absence in 1969. Edey was its secretary from 1966 to 1988. Baier was secretary from 1970 to 1977 and chairman from 1978 to 1982.

It was considered that this proposed national committee would serve as a means to accomplish much of the liaison, consulting, and coordinating work undertaken in the Section. It was felt that members of the committee, drawn from agricultural establishments, universities, and the CMS across Canada would become a forum for the exchange of information, for discussion, and for proposing solutions to major problems in the development of agrometeorological research and services in Canada.

Holmes worked with Ripley in 1962-63 on the preparation of comments on soil water measurements and standardization that were later presented to the NCAM. Two major problems relating to soil water were recognized: how to measure this entity in situ and the lack of information on the water-holding capacity of various soils in terms of depth of soil water per unit depth of soil. In 1961 the NCAM established a sub-committee to study climatic data needed by agriculture. This subcommittee, essentially, was continuing the work which Robertson had started earlier to upgrade the climatological observing program at agricultural research establishments, consequently he was named one of its four members. In 1962 the subcommittee reported on the lack of a suitable publication and distribution of special daily agroclimatological data gathered at research establishments. It was recommended that such data should be published in a separate monthly bulletin. The subcommittee continued its study of agroclimatic data and their publication. It was partly responsible for expanding programs for measuring wind at two metres, soil temperature, and the water content of snow. The early publication of monthly summaries by the CMS was a perennial consideration and, finally in 1966, CMS was convinced to launch a new monthly publication entitled "Daily Agrometeorological Data" on a regular basis.

Williams became involved in a NCAM subcommittee to study the format of tables, definitions of agroclimatic factors used in agroclimatic publications, and the limits of ranges of these factors. The subcommittee presented a detailed report to the 1967 NCAM Annual Meeting (Brown et al., 1967).

Manpower availability for agrometeorological research and services was the topic of another NCAM sub-committee. Robertson was named one of three members on this subcommittee that was established in 1966.

Baier attended the 1969 NCAM Annual Meeting as an invited participant to take part in the discussion of a position paper on weather modification. He presented a paper on the "Potential Role of Weather Modification to Agriculture" and also one prepared by Williams entitled "Possible Effects of Weather Modification on Wheat Production". Baier became a regular member in 1970 and over the next decade presented several working documents to the Committee: "Crop-yield predictions" in 1973; "Role of agricultural meteorology in the new world-food situation as related to weather/climate variability" in 1975; and the keynote paper entitled "Meteorology in aid of food/fibre production" in 1976. The latter contained a proposal for the theme of the 1977 Annual Meeting, viz. "Climatic Variability in relation to agricultural productivity and practices".

Members of the Section contributed to a report on this theme:

- Dyer and Baier: "The use of workday information in some Canadian farm planning computer models"
- Edey: "Climatic variability and Canadian agriculture freeze probabilities"
- Ouellet: "Climatic variability versus plant winter survival"
- Williams: "Barley productivity in Canada under varying climatic conditions"

- Desjardins and Ouellet: "Influence of climate on wheat yield components during development stages"
- St-Pierre and Baier: "Timothy-weather analysis model - a summary"
- Baier: "Analysis of present knowledge of climatic variability as related to Canadian agriculture"

The CCA held two annual meetings in 1978, one in January and the other in December. Baier served as acting chairman of the first meeting, replacing Ferguson who had passed away suddenly, and was appointed chairman of the December annual meeting.

CASCC approved the formation of a Task Force to Study a National Farm-Weather Service for Canada and members of the Section were expected to be involved in this activity. Following a recommendation of this task force, CASCC, in 1980, authorized the formation of a permanent Farm-Weather Services Coordinating Group of which Baier was chairman and Edey the secretary. Edey also served on the ECA Soil-Water Committee for several years.

Edey missed attending the 1985 ECA Annual Meeting as he was in Ethiopia at the time. This was the first time he missed a meeting since joining the Agrometeorological Section in 1965. Furthermore, the Agrometeorological Section was not represented on the ECA in 1985. This was the first time in 25 years that this happened.

On Edey's retirement in 1988 The annual meeting of the ECA paid a tribute to him by expressing "its desire to recognize formally, the contributions that S.N. Edey has made to the ECA over the past 22 years. Blackburn (the new secretary) will organize the preparation of the plaque to reward these efforts" (ECA minutes, 1988).

Wet-Weather Leaf Fleck of Tobacco

In 1958 Robertson was asked to review a report prepared by a research group working on the problem of wet-weather leaf fleck of tobacco. He recommended that the CMS become involved in this project (Chapter 3). He served on the Advisory Committee on Tobacco-Leaf Fleck for a few years afterwards.

Expo 67 and the Shad Fly

Another interesting bit of liaison work was undertaken in 1963. At that time plans were being made for Expo 67 at Montreal. Although the site on Ste Hélène Island had been selected, it was badly plagued by the shad fly that bred in the waters of the St. Lawrence River. The fly was attracted in countless numbers by lights, and was expected to be a severe nuisance unless control measures could be found.

Dr. P.S. Corbet, an entomologist, from the Research Branch, had been assigned to study the life habits of the insect and develop a control program. He came to Robertson for advice; this time on instrumentation for measuring wind. Following a discussion it was ascertained that, instead of a single anemometer, a mesoclimatic study of the Island would be desirable to obtain a complete picture of the shad-fly environment around the Island and of the air currents that transport the fly to the Island. Robertson approached the Director of the CMS about the matter. He authorized a project involving two summer students for 1963 and 1964 and instruments for four weather sites, one at each end of the Island and one on each side. Williams of the Section coordinated the observing program and Robertson served on the steering committee.

Agrometeorological Workshops and Work-Planning Meetings

By 1965 the Section was well-staffed, and had a good deal of experience in various facets of agrometeorology such as crop-weather modelling, agroclimatic analysis, the use of evaporation data in soil-water budgets for irrigation purposes and the management of the Research Branch network of climatological stations. There were several research scientists at research stations who had serious weather-sensitive problems in their work. It was felt that exposure of these individuals to experienced agrometeorologists in the PRI and the University of Guelph, as well as to meteorologists in the CMS, would be to their benefit. The Research Branch authorized a two-week Workshop on Agrometeorology that was held in the fall of 1966, under the direction of Robertson. Baier and Williams took part in the workshop as lecturers.

In the following years a number of workshops and work-planning meetings were held in which members of the Section took an active part. A few of the most noteworthy ones include:

A Work-Planning Meeting on Agrometeorology, sponsored by the Research Branch, CDA was organized and chaired by Dr. W.S. Ferguson, Research Coordinator for Soil Fertility (including Agrometeorology), and held in Ottawa, 24-25 November 1971. Baier took part in this meeting and presented a paper on "Derived climatological indices currently used in Canada". Other members of the Section (including former and future members) who took part in working groups were: Desjardins, Mack, Ouellet, Robertson, Sly, and D.W. Stewart.

A Farm-Weather Services Workshop was sponsored by the Canadian Federation of Agriculture and held in Ottawa, 22-23 March 1979. A number of members (including former and future members) of the Section took part in this meeting: Baier, Bootsma, Edey and Robertson).

An Agricultural Sector Workshop was organized by the Canadian Climate Program of CMS and sponsored jointly by CDA and CMS. It was held in Ottawa, 22-23 November 1979. Members of the Section took part in this. Baier presented a paper "National Perspective - climate and agriculture". Others served on working groups: Desjardins, Dyer, Ouellet, Sharp, Sly, R.B. Stewart, D.W. Stewart, and Williams.

PART 4 - RESEARCH

One of the first problems that faced Robertson and Holmes was a lack of techniques for interpreting meterological data in terms of agricultural usage. There was, furthermore, a dearth of readily available biological data suitable for developing rational and objective relationships involving the influence of weather on agricultural planning, operations, and production. Consequently, much of the effort in agrometeorology during this period was devoted to establishing experimental techniques for gathering suitable biological data, accompanied by coexisting environmental data.

After reorganization of CDA in 1959 and the formation of the Research Branch, research, of course, was recognized as its prime function and the productivity of the Agrometeorological Section was measured by the research undertaken and published as scientific papers.

National Crop-Weather Studies

To this end, preliminary field experiments were undertaken at Ottawa in 1952 preparatory to establishing, in 1953, a national program for gathering growth and phenological information, and other environmental data. The project included a number of common field crops (including spring wheat and barley) (Robertson, 1953, 1955) at Experimental Farms throughout eastern Canada and the Great Plains region. Cooperative stations included: Normandin in Que bec; Harrow, Ottawa, and Kapuskasing in Ontario; Swift Current, Saskatchewan; Lacombe, Beaverlodge, and Fort Vermilion in Alberta; and Fort Simpson in the N.W.T. (Ripley, 1959). Later, with the cooperation of Prof. A.J. Pascale of the Facultad de Agronomie y Veterinaria, valuable data were gathered for spring wheat grown at Buenos Aires, Argentina. The national project continued for 10 years in Canada although Prof. Pascale continued to gather information for the project until 1965.

Preliminary to analysing the data from this project, a number of studies were undertaken. One that received considerable attention at the time was a review of crop heat units that resulted in the preparation of a CDA technical bulletin (Holmes et al., 1959). MacKay was taken on staff in 1960 to serve as a statistician in the Section. He immediately started research on mathematical models relating plant development and growth to the meteorological environment, particularly regarding the problem of tree survival in the arboretum (Bassett et al., 1961) but resigned a short time later.

Using data from the National Crop-Weather Project (Robertson, 1955), a study of the rate of development of wheat as influenced by day and night temperatures and photoperiod was completed. This model was based, partly, on the earlier statistical work of MacKay (Bassett et al., 1961). It indicated that wheat development was dependent on a biometeorological timescale (BMTS): an interaction of temperature and photo-period, rather than on calendar time (1968).

Several other studies followed using data from the National Crop-Weather Project and the results of the BMTS study. (Baier and Robertson, 1967; Baier, 1968, 1973; Williams, 1971, 1974).

The model was used for mapping the area in Canada in which wheat and barley could be successfully matured. The technique was particularly useful for determining the agricultural potential of the underdeveloped fringe areas in Canada (Williams, 1969, 1974).

Evapotranspiration Studies

It was recognised that the measurement of evaporation would be of great importance in crop-weather modelling, in irrigation and to soil scientists who were interested in the water balance in the semiarid prairies. Research in this area was undertaken soon after Robertson joined the CDA. Penman and Thornthwaite had just introduced (1948) their concepts of modelling the estimation of potential evapotranspiration, and many scientists in agriculture wanted confirmation of these techniques. Several atmometers and pans of different sizes, as well mathematical models for estimating evapotranspiration, were tested in an attempt to bring some order to the chaos that existed. It was concluded that the black Bellani plate atmometer was superior to other measuring techniques that included a three foot buried pan, a piché atmometer, a larger white colored atmometer and a small pan above ground (Robertson, 1954, 1955; Holmes and Robertson, 1958; Robertson and Holmes, 1958). The USWB Class A pan was not yet well known.

The black Bellani plate had three mechanical weaknesses: it absorbed rainwater; it was very susceptible to the slightest degree of freezing; and it was fragile. Holmes solved the problem of rainwater absorption by developing a plastic rain shield. After many experiments with various porous materials, Robertson finally solved the problems of the black Bellani atmometer by using a black carborundum disc as the evaporation surface and a gravity water feed that solved the rainwater absorption problem (Robertson, 1961).

Baier and Robertson (1965) developed a model for estimating evaporation from the black porous-disc atmometer (BPDA) using daily weather data. This model was used extensively for estimating potential evapotranspiration for many future studies and projects of the Section. The BPDA was tested at several CDA Research Stations starting in 1962 and several reports of its use were published (Robertson, 1964). By 1965 the black porous-disc atmometer was in general use at all Research Branch agroclimatic sites. A bulletin dealing with its operation was prepared (Anonymous, 1965)

The instrument was used for over 20 years for measuring potential evapotranspiration, but was finally abandoned in favour of the US Weather Bureau Class A evaporation pan that became recognized as an international standard for evaporation measurements.

Soil-Water Budgeting

Soon after joining the CEF, it became obvious to Robertson that the main concern in agriculture was soil-water and that rainfall and evaporation observations were only a means towards an end: the determination of soil water. The measurement of soil water was a major problem in agrometeorology. Robertson (1954) tackled the problem almost immediately. Many attempts were made to calibrate soil-water measuring equipment and to obtain a reliable measurement for crop modelling purposes. It became obvious that a better approach was needed, so he turned to soil water budgeting, a technique used by both Penman and Thornthwaite.

When Holmes arrived on the scene the problem was researched in greater depth. The result was a multiple-layer soil-water budget (Holmes and Robertson, 1959) involving allowance for the root density at various depths and for the effect of soil-water depletion on the transpiration rate of the crop. Work continued on soil-water problems, particularly regarding their application to crop-weather relationships. After Holmes resigned and was replaced by Baier, the research in this area was renewed.

By the autumn of 1965 Baier and Robertson had completed work on a revision of the Modulated Soil-Moisture Budget. Essentially this consisted of a systematic means of simultaneously removing water from several layers of soil based on the soil-water content and the root distribution with depth. This new budget or model was call the Versatile Soil-Moisture Budget. (Baier and Robertson, 1966). This paper earned for Robertson the President's Prize for the most outstanding scientific paper in applied meteorology published by a member of the Canadian Meteorological Society in 1966.

Baier and Robertson (1967) completed two phases of a study of the effect of estimated soil moisture (the VSMB) on wheat-yield components and on total wheat yield (Baier, 1968). Baier continued with the development of techniques for analyzing daily weather data for irrigation-planning purposes (Baier and Russelo, 1970) including improvements to the VSMB. He eventually completed a computer program and documentation for the VSMB (Baier et al., 1972). This was revised in 1979 (Baier et al.) and again in 1984 (Dyer and Mack).

About this time Baier began work on the application of the VSMB to determine criteria for characterizing drought regimes on the Prairies. This project lead to a study of the water efficiency of summer fallow (Baier, 1972).

As increasing experience was gained with the use of the VSMB, minor improvements were made. In 1974 an algorithm was added to the computer program to account for the downward movement of water in various soil types. An algorithm was also added to allow the calculation of water in various profile depths for comparison of estimated water with actual soil-water measurements. The third revision to the program and its documentation was made in 1984 by Dyer and Mack.

The originators of the VSMB used the model in many studies involving soil-water and crop yields. Baier eventually wrote more than 20 scientific papers and reviews dealing with, or using, the model. Robertson used it in several projects in developing countries (Robertson, 1985). Several other agrometeorologists also used the model extensively and published research results based on its application to specific problems (Dyer and Baier, 1979, 1980; De Jong, 1981; Stewart, 1981; Dyer and Mack, 1984).

Shortly after joining the Section in 1986, Boisvert took up research on the VSMB with the objective of adapting it for use under Quebec climatic conditions, particularly regarding use of water from the water table (Boisvert and Dyer, 1987), and in the application of budgets to the problem of supplemental irrigation (Boisvert and Dwyer, 1987).

Hayhoe also became involved in soil-water budgeting in the early 1980's and, with the cooperation of Dr. R. De Jong of the Prairie Regional Land Evaluation Unit, made improvements in soil-water budgeting techniques (Hayhoe and De Jong, 1987; De Jong and Bootsma, 1988). The Hayhoe-De Jong soil-water budget was adapted for use with soybeans in Ontario by introducing a salt movement and leaching term (Hayhoe and De Jong, 1987).

Crop-Weather Production Modelling

Crop-weather modelling in the Section started in 1952 when a National Crop-Weather Observing Project was initiated (Ripley, 1959; Robertson, 1953). In the project outline prepared for this study Robertson foreshadowed the possibility of relating crop development, growth, and yield to environmental factors using mathematical relationships. Several preliminary studies were undertaken while the data-gathering phase of the project was in progress.

Further progress had to wait for the development of improved practical methods for determining evapotranspiration and soil water under the crop, as well as and an incentive. The incentive came in 1962. A severe drought on the Canadian Prairies in 1961 dangerously depleted the stocks of Canadian wheat for export. Fearing a continuation of the drought in 1962, the Minister of Agriculture requested the Agrometeorological Section to prepare weekly prairie rainfall reports so that the state of the prairie wheat crop could be appraised. Not satisfied with the rainfall reports, he asked that these be interpreted in terms of expected wheat production.

A system was quickly developed, based on experience and knowledge gained through years of research. (Williams and Robertson, 1965). Daily rainfall data were obtained for some thirty prairie stations from the CMS teletype circuit at Ottawa. These were supplemented by weekly precipitation reports for some 65 climatological stations obtained by long-distance telephone each Monday morning from the CMS Grain Exchange Weather Office in Winnipeg. Weekly reports on crop conditions and progress were received from eighteen research establishments, weather stations, and provincial government agencies throughout the Prairie Provinces. From the analysis of these reports a brief one-page soil-moisture and crop-condition statement was issued weekly on Tuesday.

Soil moisture was calculated from precipitation data using relationships determined earlier by the Experimental Farm at Swift Current for moisture conservation on summer fallow (Staple and Lehane, 1952). The effect of soil moisture on yield was determined by using relationships also developed earlier at the Swift Current Farm and adapted by members of the Agrometeorological Section. Consideration was given to the distribution of wheat acreage by crop districts relative to the location of the precipitation stations, and to the normal productivity of each crop district. By the end of the summer a system was worked out to handle all data on a high-speed electronic computer.

The estimates proved to be quite useful for planning purposes and were well accepted by members of the Department of Agriculture who received the reports on a confidential basis. This exercise was most beneficial to the Agrometeorological Section in that it demonstrated the practical use for much of the basic research in this field that had been on-going for several years. It indicated, furthermore, where weaknesses existed in the system and pointed up problems in crop-weather relationship studies that needed further research. These included a need for soil-water measurements, for research on soil-water and snow conservation, for a more realistic crop-weather model involving a biometeorological time-scale (Robertson, 1968) and estimated soil water (Holmes and Robertson, 1959), and for a method to express predictions in terms of probabilities.

Another boost for crop-weather model development resulted from activities in the Ungava Bay area of Quebec, where there was an interest in providing agricultural training and assistance to the local natives. One problem was to determine hay productivity under the climatic conditions of the region. Hay-yield and climatic data for several years from experimental plots across Canada were used to develop a climate-yield model with which to estimate the potential productivity of hay at Ft. Chimo (Robertson, 1963). The results agreed well with observed yield from wild grass clumps and patches found at old camp sites in the area.

Members of the Section were encouraged to continue research work in this area of crop-weather modelling, although interest waned as wheat reserves increased towards the end of the 1960's. Baier undertook a number of yield-weather studies after he joined the Section in 1965 primarily to learn more about crop-weather relationships for establishing meaningful techniques and procedures (Baier and Robertson, 1967; Baier, 1968, 1973).

A world food crisis in the early 1970's created a renewed interest in crop-weather modelling and a demand for practical production estimates. In 1973 the Section renewed its efforts of a decade earlier, embarking on a program of weekly estimates using undated models. Models were readily adapted to barley and oats as well as wheat. Predictions were made during July and August under the coordination of Williams. The information was made available, on a restricted basis, to CDA officials, to the Canadian

Wheat Board, Statistics Canada, and Industry, Trade and Commerce (Baier and Williams, 1974). These predictions continued for several years with improvements being made as experience was gained. The Canadian Wheat Board provided a staff member to help with the development and operation of the prediction system. It was eventually transferred to the Board to permit them to make their own yield predictions and extend the system for global operations.

Work on improving crop-weather models continued, particularly regarding practical applications. By 1973 Baier completed the development of a crop-weather model that evaluated the daily contribution of any three meteorological variables to the final yield of wheat as a function of biometeorological time, using the multiple-factorial regression technique developed by Robertson (1968) for solving non-linear regression equations involving multiple variables (Baier, 1973). Williams eventually made two major improvements to the model by introducing potential evapotranspiration (essentially a temperature factor) (Williams, 1973) and a factor depending of regional soil characteristics (Baier and Williams, 1974; Sheppard and Williams, 1976). By 1976 the development phase of a Timothy-Weather Analysis Model was completed and its potential use in operational applications was investigated (Baier et al., 1976). Baier's interest and work on crop-weather models continued until after he left the Section in 1979 (Baier, 1977; Baier et al., 1980; Baier, 1983).

Modelling Environmental Crop Physiology

D.W. Stewart and Dwyer joined the Section in the late 1970's. Together with Dyer (who left the Section in 1980), they worked under a general project that eventually became known as "Agroclimatic Resources Assessment". Their research involved considerable work on environmental physiology such as water potential in plants as determined by the soil-root interface, and the development of a growth simulation model based on this research (Dyer and Dwyer, 1982; Stewart and Dwyer, 1983; Dwyer and Stewart, 1984).

They completed four years of data collection in 1984 on leaf-area index, phenology, growth and water potential of corn, soybeans, and barley. By the mid-1980's several studies were completed, such as: plant water deficits in corn (Dwyer and Stewart, 1985); a model for crop transpiration (Stewart et al., 1985); a leaf-area model for maize (Dwyer and Stewart, 1986); a growth model for maize (Stewart and Dwyer, 1986); a resistance model for water balance calculations in spring wheat (Stewart and Dwyer, 1985); environmental effects on the developemnt and growth of barley (Dwyer and Stewart, 1987); and rooting characteristics of crops (Dwyer et al., 1988).

By 1985 Stewart and Dwyer were applying earlier research results to the practical problem of estimating grain yield and protein content of wheat on the Canadian prairies. Eventually models for soil-nitrogen transformations and uptake by plants had to be developed in connection with protein models (Stewart and Dwyer, 1986, 1990, 1990). During the latter part of the 1980's they continued research to improve their models, paying particular attention to the rooting characteristics of crops (Dwyer et al., 1987).

These models were also used for the Production and Marketing Branch's analyses of production trends on the Prairies (Stewart et al., 1986; Stewart, 1988).

Micrometeorology

During the late 1950's there was a growing concern about the physical nature of the movement of water vapour and carbon dioxide to and from field crops. Considerable research was underway in the USA, with some in Canada at Guelph (King) and Swift Current (Pelton). The study of this problem was relatively new and the development of techniques, sensors and recording equipment was in its infancy. Holmes had some training in micrometeorology at Rutgers University, but none in micrometeorological instrumentation. During the winter of 1960-61 the Department sent him to the University of Michigan to work with Dr. G. Gill on micrometeorological instruments (Holmes et al., 1964). Upon returning to the

Section he immediately set out to design a system for measuring CO_2 and for recording it on a 100-point data logger using punched paper tape (Holmes and Carson, 1964).

Desjardins was hired in 1965 to continue work in the field of micrometeorology after Holmes resigned in 1963. Using the data logger designed by Holmes, he undertook studies of the microclimate of plant environments (Desjardins et al.,1967, 1968, 1968) including a study of the effect of wind on the BPDA (Desjardins and Hansen, 1967). Starting about 1969 Desjardins began development and construction of instruments for measuring the effects of various meteorological elements on the energy balance of crops, including a gas-exchange metre for measuring water vapour and CO_2 fluxes in corn and barley crops. In 1970 he began educational leave to study micrometeorology at Cornell.

After returning from postgraduate studies in 1972 be began a long series of original studies of the fluxes of various gases above crops. By this time many advances had been made in technology, sensors and data logging, and Desjardins undertook the development and adaption of these to his studies. (Desjardins, 1977; Desjardins et al., 1978, 1981).

Low-flying aircraft were used by Desjardins, starting in 1980, to supplement the ground observations that had been used up to this time for studying CO_2 fluxes above crops. He soon began developing techniques for undertaking such studies on a large-area basis. He enlisted the close cooperation of staff in other CDA Research Institutes, the Flight Research Laboratory of NRC, McGill University, Laval University, the Canada Centre for Remote Sensing, and the CMS in connection with this work. (Desjardins et al., 1982 and 1984).

The potential for measuring crop growth and water use was demonstrated by using a specially designed airborne analysis system. This was developed in cooperation with the Engineering and Statistical Research Institute and the National Aeronautical Establishment of the NRC. Test crops included canola, flax, wheat and corn (Desjardins et al., 1984). Desjardins continued his research in France for a year in 1985 where he had the opportunity to exchange ideas and solutions (Desjardins, 1986).

When he returned to Canada in 1986 he continued with refinements and practical applications of the technique. These included the measurement of the rate of biomass production (Austin et al., 1987), evapotranspiration estimates and water use efficiency (Schuepp et al., 1989).

An international test was conducted in Manitoba in the summer of 1986 to evaluate systems developed in Canada to measure the flux of CO_2 AND H_2O. Six Canadian scientists including Desjardins from the Section and others from Japan and the USA took part in the tests. Both surface measurements and measurement from aircraft flying at 25 and 50 m were made. Results were reproducible with a high degree of accuracy.

Further developments included the application of airborne measurements of the fluxes of environment-polluting gases such as methane, and oxides of nitrogen and sulphur (Desjardins et al., 1989).

By the end of the 1980's photosynthetic rates over large areas as determined from flux measurements of CO_2 by low-flying aircraft compared favourably with determinations of vegetative indices estimated from data provided by Landsat multi-spectral scanners (Desjardins et al., 1987).

Progress in monitoring crop growth and transpiration using airborne sensors received international attention in 1986. The participants, viz. CDA, NRC and McGill University, were funded by NASA and invited to participate in the First International Satellite Land Surface Climatology Project field experiment in Kansas in 1987. This project greatly aided in demonstrating the usefulness of both aircraft sensing and of satellites (NOAA, GOES, SPOT and LANDSAT) for monitoring surface temperatures, albedo, vegetation, soil-water conditions, and CO_2 and H_2O fluxes.

Spectral Quality of Light

One of many problems facing plant physiologists in the 1950's was how to measure the intensity of light available for photochemical reactions in plants. Growth rooms or chambers were in use and more were being constructed, but there was no satisfactory means of comparing the photosynthetic efficiency of various forms of artificial illumination with natural light. It had been demonstrated that plants responded differently to different sources. The common instrument, probably because it was readily available, was the ordinary illumination light metre calibrated in foot-candles. In fact, the Agrometeorological Section measured, on a continuous basis, the intensity of daylight with a recording illuminometer for use by plant physiologists and other plant scientists.

In the early 1960's work was undertaken to develop a special spectral light metre for measuring light intensity for plant photochemical purposes. With encouragement from Mr. V.A. Helson of the Plant Physiology Section of the PRI, a suitable instrument was designed by Robertson and Holmes and constructed by Mr. W. Evans of the Ottawa Service of the Research Branch (Robertson and Holmes, 1963). The instrument measured the energy in five spectral bands, corresponding to the main bands that influenced various photochemical reactions in plants.

The metre was later used to study the quality of daylight in different geographical locations at different times of the day, and of artificial light under different combinations of fluorescent and incandescent sources in growth rooms. It was also used to measure the quality of light transmitted by a crop canopy in the field (Robertson, 1964, 1966). The instrument was used extensively in the plant-growth rooms at the Central Experimental Farm for quantifying the spectral composition of artificial light used for experimental purposes (Helson, 1965). Several reproductions were manufactured by a private engineering firm.

Soil Temperature, Frost Penetration, and Winter Injury

The winter survival of alfalfa in eastern Canada had been recognized for some time as a major climatic problem. Shortly after joining the Section in 1955 Holmes became interested in this. A portable growth chamber was designed for reviving alfalfa plants at various times throughout the winter to determine when injury took place. Soil heaving was also studied by using vertical wooden dowelling buried at different depths in the soil. Soil temperatures were also recorded at different depths (Holmes and Robertson, 1958, 1960).

Holmes retired in 1963 and research on winter injury was discontinued by agrometeorologists at the CEF until Ouellet took up the problem in 1969.

Having had great success with the study of ornamental plants, Ouellet started a study of the winter survival of alfalfa. It was soon discovered that information on soil temperature was lacking at many sites. Considerable time was spent developing a regression model for estimating monthly soil temperatures at six different depths using climatological data (Ouellet, 1970, 1972). This model was used to estimate the soil temperature profile down to 150 cm at some 600 climatological stations across Canada (Ouellet, 1973; Ouellet et al., 1975). Several related reports resulted from this study (Ouellet, 1973, 1975; Ouellet and Desjardins, 1975).

These studies along with forage crop information gathered from across Canada, provided the basis for a study of the regional adaptability of forage crops in Canada as a function of their winter survival (Ouellet, 1976). A statistical technique was developed, with the assistance of the Statistical Research Service, to determine the long-term climatic contribution of each month to the winter injury of alfalfa during the whole annual growth cycle (Ouellet, 1977). The technique was also used to evaluate statistically the relative importance of selected agrometeorological variables at critical development stages of a wheat crop. Before retiring in 1980, Ouellet completed two more phases of this research on the winter survival of alfalfa (Ouellet, 1978; Ouellet and Desjardins, 1981).

Hayhoe, Dwyer and others undertook to continue the work started earlier by Ouellet on soil-temperature estimation and the effect of environmental conditions on alfalfa and other overwintering crops. Bootsma and Suzuki (1985) studied the effect of weather on the optimum autumn harvest period of alfalfa. Winter wheat was also a candidate for study because of problems with winter kill (Bootsma and Suzuki, 1985). An electronic frost probe for soil was developed and tested (Hayhoe et al., 1986). Hayhoe and Bailey (1985) looked at the water and ice content of frozen soils. Zonation maps for seeding dates of winter wheat, optimum maturity dates for first cuts of forages and the critical autumn-rest period for alfalfa were studied. These efforts lead to improved crop-management practices.

Winter soil-temperature data for 21 years at the CEF, Ottawa, (see the Agricultural Observing Program section of Part 3) were used to develop an empirical model for improving winter soil-temperature estimates. Daily depth of snow on the ground was considered in these models. A cooperative test for frost penetration into the ground was established between researchers at Ottawa and at Saskatoon. (Dwyer and Hayhoe, 1985; Hayhoe and Mukerji, 1987; Hayhoe et al., 1987, 1990).

Hayhoe also successfully tested new electrical capacitance, time-domain reflectometry, and neutron moderation techniques for measuring frost penetration into the soil (Hayhoe and Bailey, 1985; Hayhoe and Balchin, 1988). These relationships were later applied to the problem of soil heaving (Hayhoe and Balchin, 1989).

Crop Observations from Satellites

Studies on the use of data from Landsat for analysing crop conditions were started in 1972 in CDA by Mack of the Soil Research Institute. Research results involving imagery acquired over test areas of spring- and fall-seeded crops in Canada and the USA were used successfully for determining the area and conditions of cereal, oil-seed, and several other specialty crops (Large Area Crop Inventory Experiment - LACIE). After Mack was transferred to the Agrometeorology Section in 1979 he began using meteorological data and crop-weather models to supplement remotely sensed crop conditions. Software programs were developed for overlaying soil, climatic and legal survey information on satellite imagery, and were used for locating selected agricultural areas, land, features, and crop districts on successive years of imagery (Mack et al., 1978, 1980).

By 1980 yield estimates were being prepared weekly, based on meteorological data and remotely sensed crop areas for the crop-reporting districts of the prairie region, and the three major cereal crops. SMEP data were used to complement the yield estimates and provided information on the amount of moisture available to carry the estimated crop to maturity in case of limited rainfall. Much of the research in this regard was undertaken in cooperation with other members of the Section, with the Engineering and Statistical Research Institute, and with the Canadian Centre for Remote Sensing. (Mack et al., 1977, 1979, 1983; Desjardins et al., 1987).

Section Publications

Although much of the research and development undertaken in the Section was published in scientific journals and CDA publications, there was much work that had no publication outlet, yet was of interest to others working in the area of agrometeorology. This included descriptions of analytical procedures, extensive tables of derived data, and documentation of computer programs. This type of information was not acceptable to scientific journals, and was not of sufficient general interest for a Departmental publication. Robertson conceived the idea of a Section publication to be called the "Ag. Met. Tech. Bull". using the offset printing technique. The first two issues were merely mimeograph copies. Ag. Met. Tech. Bull. No. 1 was issued in 1962 by the Staff of the Section and was entitled "Selected Canadian Contributions to Agrometeorology and Allied Fields". Issue No. 3 "A summary of literature pertaining to latent evaporation and its application to soil moisture estimation and irrigation scheduling" was printed by the offset method in 1964. Tech Bull. No. 92 dated 1980 was the last issue of the series.

Another successful publication prepared by the Section under the supervision of Edey was "Selected Canadian agrometeorological publications" (SCAP). This was an announcement of agrometeorological publications prepared by members of the Section and by other Canadian authors. Another purpose served by SCAP was to provide information for an inventory requested by CMS and WMO every four years for the meeting of CAgM. The mailing list for SCAP included over 100 agrometeorologists and interested scientists in Canada, the USA, and many foreign countries, who otherwise would not be aware of Canadian publications. Between 1966 and 1981 Edey prepared 91 issues of SCAP.

PART 5 - AGROCLIMATIC ANALYSIS

Agroclimatic Normals

Research scientists in agriculture as well as agrometeorologists made frequent use of climatological normals, i.e. long-term averages, normally over 30 years. Normal values of temperature and rainfall were usually taken from values provided by the CMS. The CMS normals are for discrete points and often it is necessary to interpolate to determine values for intermediate points. Hopkins (1938) developed a technique for doing this using only latitude, longitude, and elevation of the point in question. Williams undertook to update the technique and apply it to derived variables required in agrometeorological studies (Williams and Sharp, 1967; Williams, 1968). He used these relationships and the BMTS (ee section "Research", above) to prepare a zonation map for wheat on the Canadian prairies (Williams 1969, 1971).

Agroclimatic Variability

When Robertson and Holmes started work in agroclimatology they found that the usual method of presenting climatic normals for rainfall and temperature fell short of meeting the requirements of agriculture. Methods were developed for analysing long-term daily weather data in terms of probabilities of such entities as various degrees of freezing temperatures, deficits of crop water for irrigation planning, and crop heat units for growth and development. These studies led to a series of agroclimatic bulletins designed for practical agricultural usage (Robertson and Holmes, 1956, 1959; Holmes and Robertson, 1959).

In anticipation of the requirements of the ARDA CLI program for information on freezing temperature probabilities, Robertson and Russelo (1968) documented a computer system developed a few years earlier for preparing probability tables of first and last freezing-temperature dates from daily data. In place of the average dates of the last spring frost and the first fall frost, this technique analysed daily minimum temperature data to show the dates of the last spring freezes and first fall freezes for several threshold temperatures at different probability levels. This information was later used to develop a technique for estimating freeze risks from monthly normals (Sly et al., 1971).

These systems were used by Edey et al., (1968) to prepare freezing temperature probability tables for Ottawa and by Coligado et al. (1968) and Sly et al. (1974) to prepare tables of freezing temperature probabilities for the ARDA CLI program (see next section).

The CCAM discussed climatic variability at the 16th and 17th Annual meetings. At the 18th Annual Meeting at Winnipeg, 11-12 January, 1977 the theme was "Climatic Variability in Relation to Agricultural Productivity and Practices". Several members of the Section presented papers at this meeting (see the section on The NCAM, above).

Hayhoe later introduced the concept of Markov chain models for estimating probabilities of sequences of events, and applied this to the analysis of weather information in terms of field-work days (see Field Work-Day Probabilities, below).

ARDA CLI Agroclimatic Analyses

The Canada Land Inventory (CLI), part of the ARDA program, was approved in 1963. A part of this initiative was the preparation of a detailed classification of Canada's agroclimates. Robertson was named a member of a steering committee for this project (Robertson, 1964). He was largely responsible for negotiating arrangements with the CMS to have daily climatic data entered on punch cards, for establishing a climate data bank within the Section (Baier and Russelo, 1974), and for recruiting a meteorologist (Sly) and an assistant (Coligado) to undertake agroclimatic studies within the Agrometeorological Section for the CLI. By 1970 agroclimatic data analyses for the CLI (ARDA) were completed for 57 stations, and individual reports issued for each (for example: Coligado et al., 1968). The derived data in these reports were used to prepare maps of freezing temperature information, and water deficiency for the Agroclimatic Maps of Canada.

The data in these reports were also used to derive an agroclimatic index which showed the approximate percentage of time that the growing season precipitation contributed to the total amount of water required by a crop (Sly and Baier, 1971). This Climatic Moisture Index was successfully used for representing the moisture regimes in the Soil-Climate Map of Canada. The moisture classes were shown to be related to those in the Soil-Climate Map of North America, prepared for FAO by the USDA.

About 700 stations in Canada, for which normals were available, provided basic data for the preparation of water deficiencies, and dates of critical temperatures near freezing to be included in the Canada Land Inventory data bank. The information was eventually presented in atlas form. The atlas project was under the general direction of Baier and supervised by Sly (Baier et al., 1973; Sly, 1973, 1977; Sly and Coligado, 1974). The first set of 17 maps in the atlas was completed and published in 1977.

Sly continued to work, on a contract basis, on the atlas and eventually completed 18 additional maps that were published as inserts to the original in 1983. These dealt with water reserves and deficits for spring wheat on four different soil textures (Sly, 1977, 1982; Mack and Bootsma, 1984). Considerable research had to be undertaken to verify derived data (De Jong and Sly 1985).

Ornamental Plant Zonation Map

In 1967 Ouellet, together with Mr. L. Sherk of the Ornamental Section of PRI, completed a map for the hardiness zones for woody ornamentals in Canada. Several scientific papers and popular articles describing the map were published (Ouellet and Sherk, 1967a,b). This map received several very complimentary reviews and comments from horticulturists and others, including Dr. H.T. Skinner, Director of the United States National Arboretum in Washington, D.C. and author of the "Plant Hardiness Zonation Map" covering the USA and southern Canada. This map is still to be found in nursery seed catalogues and books on ornamental plants in Canada.

Field Work-Day Probabilities

Field-work days depend on a number of factors according to the operations to be undertaken and the type of machinery used. Haying and harvesting require a period of drying weather before operations can begin. Land tillage and seeding depend on the state of the soil.

Shortly after joining the Section in 1972 Hayhoe undertook to analyse climatological data in a manner that would provide estimates of field-work days. Special models were developed for relating hay drying to weather conditions, while the Versatile Soil-Moisture Budget was used to calculate soil moisture conditions. The completion of a certain field operation usually requires a series of consecutively favourable days. The Markov chain model was used for determining the probabilities of successful field-work periods (Hayhoe, 1973; Hayhoe and Baier, 1974; Hayhoe and Jackson, 1974). Staff of the Section used the methods of Hayhoe to prepare a bulletin of field workday probabilities for several sites across

Canada (Dyer et al., 1977; 1978). The concept of field-work days and the associated analytical techniques were extended to estimate tractor size for various field operations (Dyer and Baier, 1978).

Climate as a Resource

While doing postgraduate work at Carleton during the early 1970's, Williams conceived the idea of climate as a "resource". This concept was carried through into much of the agroclimatic analysis undertaken by the Section in future years. In 1972 Williams embarked on a new line of studies involving agricultural land and agroclimatic resources. Emphasis was placed on the loss of agroclimatically favourable agricultural land to urbanization (Williams, 1973, Williams and Oakes, 1978).

A cooperative agrometeorological study with the Beaverlodge Research Station was started in 1976. Its objective was the preparation and analyses of meteorological and crop data for the northern parts of Alberta, British Columbia, the Yukon, and parts of the Northwest Territories, to evaluate the agroclimatic resources and the response of selected crops to the total environment of the north. Staff members of the Section and the Beaverlodge Research Station participated in this cooperative study (Bailey, 1981).

Bootsma joined the Section in 1982, but continued some of the work he had started in the Maritimes. This was undertaken at the request of the Atlantic Advisory Committee on Forage Crops and included an assessment of agroclimatic resources in the Atlantic Region for the purpose of improving production and management of forage crops. Part of this undertaking involved the preparation of some 74 detailed maps of the risk of freezing temperatures in PEI (Bootsma, 1984; Bootsma and Dwyer, 1989).

A study of the possible impact of climatic change on potential dry-matter yields of crop was started in 1983. This was undertaken in cooperation with the Crop Production Division of the Regional Development Directorate and the Land Use and Evaluation Section of the LRRI. Estimates were prepared of potential yields for 22 different climatic-change scenarios, and 755 soil map units covering all land areas in Canada were completed. Crop-growth models developed by the Section for real-time estimates of crop yield potential were used (Bootsma et al., 1984).

The LRRC began a Prairie Regional Land Evaluation Program in 1986. Work in this area had a large agrometeorological component. Activities were mainly concentrated in the Prairie Region, although it was expected that similar work would be carried out for other areas of the country in a later phase. The objectives were to prepare integrated environmental maps involving data on agroclimate resources, land use, crop yield, and soil degradation. Models for soil water and crop yield would be used along with these maps to undertake land-evaluation studies of the Prairie Region (Stewart et al., 1986; Stewart, 1988; De Jong and Bootsma, 1988).

Soil-Water Climatology: Irrigation

Supplemental irrigation experiments were being conducted at the Experimental Farm by field husbandry staff for the first time in the early 1950's. Alfalfa was the crop and treatments consisted of one, two and three inches of water per week. Needless to say, the three-inch treatment was like a marsh and the two-inch treatment not much better. Robertson was asked for his opinion on the matter and thus started a long series of studies of the application of soil-water budgeting to irrigation and, eventually, other agricultural problems.

Some early experiments relating soil water to rainfall and evaporation were undertaken by using a simple budgeting model (Robertson, 1954). This eventually lead to the development of a system for estimating irrigation requirements and the analysis of estimated soil water on a probability basis (Robertson, 1956, revised in 1959).

Following this, various soil-water budgeting models were developed and improved upon, first by Holmes and Robertson (1959), then by Baier and Robertson (1965) and Baier et al., (1969). These models or variations of them have been used from time to time to express agroclimatic data in terms of irrigation requirements, usually expressed in terms of probabilities (Baier and Robertson, 1967; Baier and Russelo, 1968; Baier et al., 1969).

Sly and Wilcox of the Summerland Research Station worked on the problem from a practical point of view in the early 1970's. They developed improved budgeting techniques that could be used at the farm level (Wilcox and Sly, 1974; Sly and Wilcox, 1974).

Sly undertook a study of the irrigation requirements in the Roseau River Valley in Manitoba using data from 11 climatic stations for a period of eight years (1965-72). Several maps were prepared for the Lands Directorate of the Department of the Environment. It was shown that average water deficits ranged from 6 inches on heavy-clay soils to 14 inches on sandy soils within the same climatic regime. This study conclusively demonstrated the necessity for having a reasonable approximation of the water-holding capacity of soils in the rooting zone of crops if reliable assessments of soil-aridity conditions were to be made in connection with soil-capability studies.

A study of prairie soil-water reserves was started in 1974 following a successful study of estimated soil water and the economics of fallow-seeded and continuous wheat (Baier, 1972). Data on climate, soils, crops, and cropping procedures were used to estimate soil-water reserves under dryland conditions and fallow-wheat rotation at 12 locations in the prairie provinces for each year in the 1941-1970 period. Estimates were made for the various stages of crop development for two water-holding capacities of the soil and two dates of planting (Baier, 1974). Studies continued into the 1980's (De Jong and Sly, 1985; De Jong and Bootsma, 1988).

A new numerical technique for modelling soil-water transfer was developed by Hayhoe in cooperation with de Jong of the Prairie Regional Land Evaluation unit of the LRRC. A computer program was written in the BASIC language (Hayhoe, 1978: De Jong and Hayhoe, 1984).

Boisvert initiated a project in 1983 to select and test a numerical soil-water model suitable for application in an irrigation-water evaluation project for Quebec and other locations in Eastern Canada. A problem was to introduce a term in the model to account for uptake of water by a crop from the watertable. In 1985 irrigation studies were extended to strawberry crops in the Ottawa area. (Boisvert and Dwyer, 1987). Later research was conducted on soil characteristics in soil-water models (Boisvert and Dyer, 1987).

Eventually a user-friendly computer program and manual were developed for estimating soil-moisture content and scheduling irrigation at the farm level using a microcomputer. The program was successfully used in Quebec, the Atlantic Provinces and Ethiopia.

PART 6 - FARM-WEATHER SERVICES

In the fall of 1964 the CMS established a working group to devise improved methods for determining the broad needs of agriculture for meteorological information. Robertson was named a member of this group. It made a survey of agricultural's requirements for meteorological services in Alberta. A report was presented to the NCAM at its 1965 Annual Meeting (See Chapter 6).

A seminar on "Agricultural Weather Forecasting and Advisory Services" was held in Ottawa, 5 May 1977. This was sponsored jointly by the CFM and the Agrometeorological Research and Service Section, and chaired by Baier.

A new project started by Edey in 1980 was the development of the meteorological component of Telfarm (Telidon tells the farmer), an interactive video communication system dedicated to the provision of an integrated agricultural advisory service. Weather advisories made up 25 percent of the service. Under the SMEP program 20 soil-moisture evaluation reports were produced by Edey in 1983, along with over 400 manuscript maps for adaption to the Telidon technology for the Grassroots videotex service. This service was still in use in the late 1980's.

Farm-weather services were highlighted by the Agrometeorological Section at the 1983 International Plowing Match at Richmond, Ontario. Edey, Boisvert and Sharp present a display "Agrometeorology in the Farm Home" featuring the communications aspects of Weatheradio, Agriphone systems, and Telfarm.

PART 7 - DATA PROCESSING SERVICES

Computer Facilities

The Department acquired its first electronic data processing (EDP) equipment in the mid-1950's. The equipment used IBM punch cards and programming was accomplished by wiring plug-in boards. A big step forward was the acquisiton of an IBM 650 with a central processing unit (CPU) or memory that could be programmed by punch cards, thus giving the operator better and speedier control over the manner in which data were manipulated. Next came the IBM 1620 with more memory.

Originally, data and programs had to be sent to the computer centre for keying-in and processing, an operation that at best took 24 hours turn-around time. Eventually the Section acquired a key punch that speeded the preparation of data and programs, but slow turn-around time was still an annoying problem, particularly for program development and debugging.

The next significant step came in the mid-1960's with the installation of a UNIVAC 1108 system with magnetic tape drives and a larger CPU. Both data and programs could be saved to magnetic tape, making for an enormous increase in the speed of handling and processing data. Up to this time computer services were under the control of the Administration Branch and located one or more kilometres from the Agrometeorology Section.

A major advance was made with the installation in the Section headquarters in 1969 of a send-receive (ASR) Model 33 Teletypewriter terminal which was connected to a Nova 800 mini-computer, forming part of the Eastern Time Sharing System of the CDA. The change-over by the CDA Data Processing Division in 1976 from the Univac 1108 to the IBM 370/168 was another improvement in computer services. Finally came the VAX system which had both tape drives and hard disks and extensive memory for multitasking and terminal support. By the late 1970's the Section had its own complete terminal including printer on the CDA central computer network (AgriNet). The first microcomputer was acquired in the early 1980's.

Before the advent of computers, technicians and clerical staff in the Section were expected to learn to operate hand calculators and eventually electric calculators for processing and analysing data. As soon as it was learned that the Department had EDP equipment that was available on a time-share basis for research purposes, all staff members were encouraged to become acquainted with EDP procedures and programming. Eventually most of the clerks and technicians in the Section were reclassified as computer programmers (administrators).

Climatic Archives

The climatological daily data archive within the Section was started in 1962 when the Section became involved with the ARDA CLI (See above, Section "Program Review, 1966"). To meet growing demands for more extensive climatic data, the archives were steadily increased and upgraded. The original archive data were on punch cards (Russelo, 1967) obtained from the CMS, but these were transferred to magnetic tape starting in 1974 (Baier and Russelo, 1974). At the same time assistance was given to research stations at Beaverlodge, Lethbridge, and Swift Current in establishing their own data archives.

The conversion of all historical files in the Section archives to the new IBM system was completed in 1976. These data files, including long-term daily climatic records for some 90 stations, were directly accessible at any research station that had access to a terminal of the Data Crown system.

The daily data archives for the Atlantic Region were expanded, in 1983, by the addition of data for 116 climate stations supplied by CMS. This was for a project on freezing temperature, and other agroclimatic analyses.

Daily data for snow depth on the ground for some 160 climate stations in agricultural areas were upgraded in the Section's archives in 1985 in cooperation with CMS. Daily soil-temperature data were also acquired from CMS for the archives. This information was needed for soil-temperature modelling that was being undertaken by the Section.

Near-Real-Time Data Archives

Early in the 1980's a new section in the archives was opened. This was for current weather data for Ontario and the Prairie Provinces. These files were updated weekly for use by regional agricultural researchers for near-real-time estimates of insect populations, disease development and crop maturity.

Starting in 1985, current weather files for Ontario and the Prairie Provinces were placed under the project "Operations Management". These files continued to be updated on a weekly basis for use by researchers in the Agrometeorological Section, by integrated pest-management programs across Canada, and by others.

Programming and Data-Processing Support

From the time that computers became available for research in CDA, members of the Section documented their programs for the use of other scientist (Williams and Sharp, 1967, 1972; Robertson and Russelo, 1968a,b; Baier and Russelo, 1968, 1974; Baier et al., 1972, 1973). Subsequently, programs developed by members of the Section were made available online to other research scientists.

Data processing support provided to other CDA establishments and user agencies increased significantly during 1974 due largely to the reorganization. Service analyses have been undertaken for CANFARM, the Economics Branch of CDA, Provincial Departments, and other user agencies. Program packages for day-length estimation, soil-water estimation, crop-development rates, and evapotranspiration estimation were distributed on request to universities, government agencies, and private research establishments.

PART 8 - WORLD-FOOD AND CROP-WEATHER MONITORING

In 1974 Baier prepared a paper on crop-yield predictions for presentation to the 1975 Annual Meeting of the CCA. In this he discussed the world food crisis that developed during the years 1972-74 due to droughts in Australia, the USSR and parts of Europe. The shortage of food reserves had prompted the large grain growing countries of the world to demand more timely and more detailed quantitative

assessments of crop-yield prospects other than the information then available from the established survey-type crop production estimates. This demand together with the ready availability of world-wide weather data on a near-real-time basis and the development of potentially suitable models for analysing the data lead to a marked increase in the demand for better and faster crop and weather monitoring systems. This, in turn, gave research in crop-weather modelling a much needed impetus.

In November 1974 the Assistant Deputy Minister (Research) of CDA called a special meeting to discuss a proposal to optimize the use of resource-satellite and weather data in a crop inventory program. This information was to be used to meet Canadian needs for information on crop conditions and yield prospects in Canada and other countries involved in world food trade. The participating agencies included the Remote Sensing, Pedology, and Agrometeorology Groups of CDA, the CMS, the Canada Centre for Remote Sensing, Statistics Canada, and the Canadian Wheat Board.

A Large Area Crop Inventory Experiment (LACIE) was set up as a cooperative experiment by several interested government agencies in the USA. This experiment was to develop and test methods of gathering and using all available data from earth resources satellites, meteorological satellites, and surface weather observations for monitoring crops and estimating their potential production. Canada was invited to participate in the program and thus the Agrometeorological Section became involved in an increased tempo of gathering ground-truth data, and of model development and testing.

By 1974 there was a suspicion of a climatic change brought on by human intervention in atmospheric processes (pollution of numerous types from various sources). Williams investigated the possible impact of climatic change on cereal production in Western Canada, and presented a paper on the matter at the Sterling Forest, N.Y. Conference in December, 1974 on World Food Supply in a Changing Climate (Williams, 1975). In January 1975 Williams spent a couple of weeks at the Canadian Wheat Board in Winnipeg. During this period of time he helped their agrometeorologist to make operational the crop-weather model which he had developed over the past several years (Williams, 1965, 1973, 1975).

Deloitte, Haskins & Sells Associates were retained in 1976 to undertake development research regarding the use of WMO Synoptic Weather Data in connection with the Branch's crop information system (Mack, et al., 1977).

PART 9 - RESEARCH CONTRACTING

By 1976, due to insufficient staff and new government policy, a great deal of the Agrometeorological Service work of the Section had to be contracted out. Five subcontracts were active during 1976 in connection with the Research Branch Land Evaluation Program:

- Macroscale Analysis of Climatic Resources for Field Crops (University of Waterloo)
- Estimates of Precipitation and Temperature Spatial Statistics for a Pilot Study Area (Shawinigan Engineering Company)
- Development of a Corn Production Simulation Model for Land Evaluation Purposes (University of Guelph)
- Review of Corn Requirements (soil/climate) in regard to agricultural productivity (Laval University)
- Estimates of Precipitation and Temperature Spatial Statistics for an Area Including Nine Map Sheets on the Prairies (Shawinigan engineering Company).

Sly was retained on contract from 1976 to 1984 to prepare additional maps for the Agroclimatic Atlas. Robertson prepared information for the Task Force on Farm-Weather Services on contract in 1979. In addition, professionals in the Agrometeorological Section participated in research activities and provided services in support of the other contract components of the Research Branch Land Evaluation Program.

PART 10 - INTERNATIONAL ACTIVITIES

Members of the Section took an increasing interest and activity in international agrometeorological affairs almost from the time CDA became interested in the science. Members of the Section involved in international work were: Baier, Desjardins, Edey, Mack, Robertson and Williams. These activities are discussed in Chapter 10.

PART 11 - PUBLICATION HIGHLIGHTS

1953 ROBERTSON, G.W. Some agrometeorological problems in Canada. Royal Meteorological Society, Canadian Branch, Toronto, 4(2):1-21.

ROBERTSON, G.W. Agrometeorology. Cereal News, Cereal Division. Experimental Farms Service, CDA, Ottawa. 1(9):8-12.

1954 ROBERTSON, G.W. Latent evaporation: its concept, measurement, and application. Seminar Paper. Field Husbandry, Soils, and Agricultural Engineering Division, Experimental Farms service, Ottawa. 14 pp + VII figs.

1955 ROBERTSON, G.W. The standardization of the measurement of evaporation as a climatic factor. WMO-42, Tech. Note No. 11. WMO, Geneva. 10 pp.

ROBERTSON, G.W. Data Summary for Project F.1.8.2: "An Investigation of the Growth and Development of Crops in Relation to their Meteorological Environments" - Third Report. Division of Field Husbandry, Soils and Agricultural Engineering, Experimental Farms Service, Department of Agriculture. Ottawa. 90 pp.

ROBERTSON, G.W. A guide to field and observational work in connection with Project F.1.8.2: "An Investigation of the Growth and Development of Crops in Relationship to Meteorological Environment". Division of Field Husbandry, Soils and Agricultural Engineering, Experimental Farm Service, Department of Agriculture, Ottawa. 11 pp.

1956 ROBERTSON, G.W. and HOLMES, R.M. Estimating irrigation water requirements from meteorological data. Experimental Farms Service, CDA, Ottawa. Pub. No. 1054 (Revised 1959). 19 pp.

1957 ROBERTSON, G.W. Weather and farm planning. Paper presented to the Ontario Soil and Crop Improvement Association. January 31, 1957. 6 pp.

1958 ROBERTSON, G.W. and HOLMES, R.M. A new concept for the measurement of evaporation for climatic purposes. International Association for Scientific Hydrology; I.U.G.G. Assemblé e Gé né rale de Toronto, 1957 (Genthrugge 1958). Tome III. p. 399-406.

HOLMES, R.M. and ROBERTSON, G.W. Note on a portable field growth chamber for winter injury studies. Can. J. of Plant Sci. 38:377-379.

HOLMES, R.M. and ROBERTSON, G.W. Conversion of latent evaporation to potential evapotranspiration. Can. J. of Plant Sci. 38(2):164-172.

1959 HOLMES, R.M. and ROBERTSON, G.W. Heat units and crop growth. CDA, Ottawa, Publ. No. 1042. 32 pp.

HOLMES, R.M. and ROBERTSON, G.W. A modulated soil moisture budget. Monthly Weather Review, 87(3):1-7.

RIPLEY, P.O. Progress Report 1954-1958. Field Husbandry, Soils and Agricultural Engineering Division. Experimental Farms Service, CDA, Ottawa. 41 pp.

ROBERTSON, G.W. and HOLMES, R.M. Freezing temperature probabilities at Ottawa. Experimental Farms Service, Canada Dept. of Agriculture, Ottawa. Publ. No. 1047. 4 pp.

1960 HOLMES, R.M. and ROBERTSON, G.W. Soil heaving in alfalfa plots in relation to soil and air temperature. Can. J. Soil Sci. 40:212-218.

1961 BASSETT, I.J., HOLMES, R.M. and MacKAY, K.H. Phenology of several plant species at Ottawa, Ontario, and an examination of the influence of air temperature. Can. J. Plant Sci. 41:643-652.

ROBERTSON, G.W. Discussion on evaporation measurements. Proc. of the Hydrology Symposium No. 2, Evaporation. Toronto, 1-2 March 1961. Dept. of Northern Affairs and National Resources, Water Resources Branch, Ottawa. pp 104-105.

1962 POTTER, J.G. Soil temperature records at eight localities in Canada 1959-1960. PRI, CDA. 31 pp.

1963 CORDUKES, W.E. and ROBERTSON, G.W. Note on the temperature distribution within an oat crop. Can. J. Plant Sci. 43:235-239

1963 MACK, A.R. Biological activity and mineralization of nitrogen in three soils as induced by freezing and drying. Can. J. Soil Sci. 43:316-324.

ROBERTSON, G.W. Estimating hay yield from climatic data. Soil Horizons. 4(1):23-27.

ROBERTSON, G.W. and HOLMES, R.M. A spectral light metre: its construction, calibration and use. Ecology, 44:419-423.

1964 HOLMES, R.M. and CARSON, H.W. Carbon dioxide flux in nature. Agrometeorology Section, PRI, CDA, Ottawa. Tech. Bull. No. 2. 28 pp.

HOLMES, R.M., GILL, G.C., and CARSON, H.W. A propeller-type vertical anemometer. J. Appl. Meteorol. 3:802-804.

HOLMES, R.M. and ROBERTSON, G.W. The calculation of the soil moisture profile under various conditions using the modulated soil-moisture budget. In: Land Erosion, Precipitation, Hydrology, Soil Moisture. IUGG, IASH, Publ. No. 65, pp.454-461.

ROBERTSON, G.W. A summary of literature pertaining to latent evaporation and its application to soil moisture estimation and irrigation scheduling. First Irrigation Research Workshop 5-6 August 1964, Summerland, BC Agrometeorology Section, CDA, Ottawa, Tech. Bull. 3. 11 pp.

ROBERTSON, G.W. The measurement of light energy for photochemical processes in plants. Agrometeorol. Sect., PRI, CDA, Ottawa. Tech. Bull. 4. 17 pp.

ROBERTSON, G.W. Agroclimatic parameters for soil capability classification. Land Inventory Seminar Background Papers, Winnipeg. 1(C7):1-14.

1965 ANONYMOUS. The black porous-disk atmometer for measuring latent evaporation. (Rev. of Bull. No. 9; 1962). Agroclimatological Observations, Agrometeorology Section, PRI, CDA, Ottawa, Bull. No. 16. 4 pp. + 2 figs.

BAIER, W. and ROBERTSON, G.W. Estimation of latent evaporation from simple weather observations. Can. J. Plant Sci. 45:276-284.

1965 HELSON, V.A. Comparison of Gro-Lux and cool-white fluorescent lamps with and without incandescent as light sources used in plant growth rooms for growth and development of tomato plants. Can. J. Plant Sci. 45:461-466.

MACK, A.R. Effect of soil temperature and moisture on yield and nutrient uptake by barley. Can. J. Soil Sci. 45:337-346.

MACK. A.R. and EVANS, W.A. Soil temperature control system for field plots. Can. J. Soil Sci. 45:105-107.

WILLIAMS, G.D.V. and ROBERTSON G.W, Estimating most probable prairie wheat production from precipitation data. Can. J. Plant Sci. 45:34-47.

1966 BAIER, W. and ROBERTSON, G.W. A new versatile soil-moisture budget. Can. J. Plant Sci. 46:299-315.

ROBERTSON, G.W. Soil temperatures measured during the International Forest-Soil Survey Trip in August 1965 - Note from the Plant Research Institute. Soil Horizons. 7(1):30-32.

ROBERTSON, G.W. Organization, function and 1963-66 progress report of the Agrometeorology Section. Agrometeorol. Sect. PRI, CDA. Agric. Meteorol. Tech. Bull. 8. 12 pp.

ROBERTSON, G.W. The light composition of solar and sky spectra available to plants. Ecology, 47:640-643.

1967 BAIER, W. and ROBERTSON, G.W. Estimating supplemental irrigation water requirements from climatological data. Can. Agric. Eng. 9:46-50.

BAIER, W. and ROBERTSON, G.W. Estimating yield components of wheat from calculated soil moisture. Can. J. Plant Sci. 47:617-630

BROWN, D.M., MCKAY, G.A., and WILLIAMS, G.D.V. Some recommendations on standard limits and formats for presentation of agroclimatic analyses. Agrometeorol. Sect., PRI, CDA, Ottawa. Tech. Bull. 16. 6 pp.

DESJARDINS, R.L. and HANSEN, R.O. Wind response of black porous disc and Bellani plate atmometers. Can. J. Plant Sci. 47:493-498.

DESJARDINS, R.L. and HANSEN, R.O. A topoclimatic study in the arboretum. PRI, CDA, Ottawa, Greenhouse-Garden-Grass, 6(2):1-5.

1967 OUELLET, C.E. and SHERK, L.C. New Canadian plant hardiness zone map. Greenhouse-Garden-Grass, PRI, CDA, Ottawa, 6(4):1-5.

OUELLET, C.E. and SHERK, L.C. Woody ornamental plant zonation. III. Suitability map for the probable winter survival of ornamental trees and shrubs. Can. J. Plant. Sci. 47:351-358.

ROBERTSON, G.W. Where does the sunshine go? Greenhouse-Garden-Grass, PRI, CDA, Ottawa, 6(3):6-8.

RUSSELO, D.A. Problems to be anticipated when processing Meteorological Branch type 4 format. Agromet. Sect., PRI, CDA, Ottawa. Tech. Bull. 13. 6 pp.

WILLIAMS, G.D.V. and SHARP, W.R. A program to estimate normals of temperature and related agroclimatic elements for locations on the Canadian Great Plains. Agrometeorol. Sect., Res. Br., CDA. Tech. Bull. 11. 27 pp.

1968 BAIER, W. The performance of soil moisture estimates as compared with direct use of climatological data for estimating crop yields. Agric. Meteorol. 5:17-31.

BAIER, W. and RUSSELO, D.A. A computer program system for estimating risks of weekly irrigation requirements from climatic data. Agrometeorology Section, PRI, CDA. Tech. Bull. 59. 60 pp.

COLIGADO, M.C., BAIER, W. and SLY, W.K. Risk analysis of weekly climatic data for agricultural and irrigation planning for Swift Current, Saskatchewan. Agrometeorology Section, PRI, CDA, Ottawa. Tech. Bull. 43. 8 pp. + 26 tables.

DESJARDINS, R.L. and SIMINOVITCH, D. Microclimatic study of the effectiveness of foam as protection against frost. Agric. Meteorol. 5:291-296.

DESJARDINS, R.L. and ROBERTSON, G.W. Variations of meteorological factors in a greenhouse. Can. Agric. Eng. 10:85-89.

EDEY, S.N., WILLIAMS, G.D.V. and ROBERTSON, G.W. Climatic normals and deviations and freezing probabilities at the Central Experimental Farm, Ottawa. Agrometeorology Section, PRI, CDA, Ottawa. Tech. Bull. 15. 50 pp.

ROBERTSON, G.W. A biometeorological time scale for a cereal crop involving day and night temperatures and photoperiod. Int. J. Biometeorol. 12:191-223.

ROBERTSON, G.W. and RUSSELO, D.A. Astrometeorological Estimator. Agrometeorology Section, PRI, CDA, Ottawa. Tech. Bull. 14. 21 pp.

ROBERTSON, G.W. and RUSSELO, D.A. Freezing temperature risk calculations: systems analysis and computer program. Agrometeorology Section, PRI, CDA, Ottawa. Tech. Bull. 60. 31 pp.

WILLIAMS, G.D.V. Using a computer to estimate normals of temperature and derived variables for any point on the Great Plains. Atmosphere, 6:81-86, 116-120.

1969 BAIER, W., ROBERTSON, G.W. and CLARKE, M.F. A climatological analysis of irrigation requirements in the Lower Fraser Valley, BC. CDA, Publ. 179 pp.

WILLIAMS, G.D.V. Applying estimated temperature normals to the zonation of the Canadian Great Plains for wheat. Can. J. Soil Sci. 49:263-276.

1970 BAIER, W. and RUSSELO, D.A. Soil temperature and soil moisture regimes in Canada. pp. 35-65. In: Proceedings of the Eighth Meeting of the Canada Soil Survey Committee, Ottawa.

SLY, W.K. The effect of growing-season lengths on values of the climatic moisture index. In: Proceedings of the Eighth Meeting of the Canada Soil Survey Committee, Ottawa. pp. 66-73.

SLY, W.K., ROBERTSON, G.W. and COLIGADO, M.C. Estimation of probable dates of temperatures near freezing from monthly temperature normals, station elevation, and astronomical data. Agrometeorol. Sect., PRI, CDA, Ottawa. Tech. Bull. No. 79. 22 pp.

WILLIAMS, G.D.V. Remarks on recent progress in agroclimatic research and mapping methods to aid land capability evaluation. p. 74-76. In: Proceedings of the Eighth Meeting of the Canada Soil Survey Committee, Ottawa.

1971 SLY, W.K. and BAIER, W. Growing seasons and the climatic moisture index. Can. J. Soil Sci. 51:329-337.

WILLIAMS, G.D.V. Wheat phenology in relation to latitude, longitude, and altitude on the Canadian Great Plains. Can. J. Plant Sci. 51:1-12.

1972 BAIER, W. An agrometeorological probability study of the economics of fallow-seed and continuous spring wheat in southern Saskatchewan. Agric. Meteorol. 9:305-321.

BAIER. W., CHAPUT,, D.Z; RUSSELO, D.A. and SHARP, W.R. Soil-moisture estimator program system. Agrometeorol. Sect., PRI, CDA, Ottawa. Tech. Bull. 78. 55 pp.

CORBET, P.S. The microclimate of Arctic plants and animals, on land and in fresh water. Acta Arctica. Arktisk Institut, Kϕbenhavn, Munksgaard. Fasc. XVIII. 43 pp.

OUELLET, C.E. Analyses of the annual cycles of soil and air temperature. Natur. Can. 99:621-634.

WILLIAMS, G.D.V. and SHARP, W.R. Computer mapping in agrometeorology. Agrometeorol. Sect., Res. Br., CDA. Tech. Bull. 80. 40 pp.

1973 BAIER, W. Crop-weather analysis model: review and model development. J. Appl. Meteorol. 12:637-647.

BAIER, W., SHARP, W.R. and ROBERTS, J.G. Recent developments in preparing coloured agroclimatic maps by computer. Can. J. Soil Sci. 53:133-134.

HAYHOE, H.N. Weather effects on field drying of forages: a review. Naturaliste Can. 100:395-405.

MACK, A.R. Influence of soil temperature and moisture conditions on growth and protein production of Manitou and two semi-dwarf Mexican spring wheats. Can. J. Soil Sci. 73:721-735.

OUELLET, C.E. Freezing temperatures in the top soil layer. Soil Horizons. 14(1):1-2.

OUELLET, C.E. Estimation of monthly soil temperatures. Agrometeorology Section, PRI, CDA, Ottawa. Tech. Bull. 82. 9 pp. + 13 tables.

OUELLET, C.E. Macroclimate model for estimating soil temperatures under short-grass cover in Canada. Can. J. Soil Sci. 53:263-274.

ROBERTSON, G.W. Development of simplified agroclimatic procedures for assessing temperature effects on crop development. In: Proc. Unesco Uppsala Sym. on Plant Response to Climatic Factors, 1970, Unesco, Paris. Ecology and Conservation. 5:327-342.

SLY, W.K. Maps for derived climatic data for agriculture. Can. Agric. 18(3):36-39.

WILLIAMS, G.D.V. Urban expansion and the Canadian agroclimatic resource problem. Greenhouse-Garden-Grass, PRI, CDA. 12(1):15-26.

WILLIAMS, G.D.V. Estimates of prairie provincial wheat yields based on precipitation and potential evapotranspiration. Can. J. Plant Sci. 53:17-30.

1974 BAIER, W. Crop water balance for Canada. Appendix III, Chapter II. The Climate of Canada and Alaska by F.K. Hare and J.E. Hay. In: World Survey of Climatology Vol II. Climate of North America, edited by R.A. Bryson and F.K. Hare. Elsevier Scientific Publishing Co. pp. 178-187.

BAIER, W. and RUSSELO, D.A. Agrometeorological data bank. Can. Agric. 19(1):3-5.

BAIER, W. and WILLIAMS, G.D.V. Regional wheat-yield predictions from weather data in Canada. pp. 265-283. In: Agrometeorology of the Wheat Crop, Proc. of the WMO Symposium, Braunschweig, Federal Republic of Germany, Oct. 1973. WMO No. 396.

HAYHOE, H.N. and BAIER, W. Markov chain model for sequences of field workdays. Can. J. Soil Sci. 54:137-148.

HAYHOE, H.N. and JACKSON, L.P. Weather effects on hay-drying rates. Can. J. Plant Sci. 54:479-484.

MACK, A.R. and WALLEN, V.R. Effects of various field levels of soil temperature and soil moisture on the growth of beans infected with bacterial blight. Can. J. Soil Sci. 54:149-158.

SLY, W.K. and COLIGADO, M.C. Agroclimatic maps for Canada derived data: moisture and critical temperatures near freezing. Agrometeorol. Sect., PRI, CDA, Ottawa. Tech. Bull. 81. 31 pp + 5 maps.

SLY, W.K. and WILCOX, J.C. Effects of time taken to apply an irrigation on seasonal irrigation requirements. Can. Agric. Eng. 16:82-85.

WILCOX, J.C. and SLY, W.K. A weather-based irrigation scheduling procedure. Agrometeorol. Sect., PRI, CDA, Ottawa. Tech. Bull. 83. 23 pp.

WILLIAMS, G.D.V. Physical frontiers of crops: the example for growing barley to maturity in Canada. In: R.G. Ironside, V.B. Proudfoot, E.N. Shannon, and C.J. Tracie (Eds.), Frontier Settlement, University of Alberta Studies in Geography Monograph 1. pp. 79-92.

WILLIAMS, G.D.V. Deriving a biophotothermal time scale for barley. Int. J. Biometeorol. 18:57-69.

1975 EDEY, S.N. and JOINT, M.J. Mechanical and thermal characteristics of the soil at selected agrometeorological stations. Agrometeorol. Sect., CBRI, CDA, Ottawa. Tech. Bull. 84. 40 pp.

OUELLET, C.E. Soil and air temperatures at Ottawa. CDA, Ottawa. Publ. 1541. 29 pp.

OUELLET, C.E. and DESJARDINS, R.L. Annual variability of minimum soil temperature. Can. J. Soil Sci. 55:167-176.

OUELLET, C.E., SHARP, W.R. and CHAPUT, D.Z. Estimated monthly normals of soil temperatures in Canada. Agrometeorological Research and Servive, CBRI, Research Br., CDA. Tech. Bull. 85. 148 pp.

WILLIAMS, G.D.V. An Assessment of the Impact of some Hypothetical Climatic Changes on Cereal Production in Western Canada. In: World Food Supply in a Changing Climate. Proceedings of the Sterling Forest, N.Y., Conference, December 1974. p. 88-102

1976 DESJARDINS, R.L. Continuous recording black porous disc atmometer - capacitance method. Agric. Eng. Res.

OUELLET, C.E. Survey report of forage crop survival in Canada. Agrometeorology Research and Service, CBRI, Research Br., CDA, Misc. Bull. 5. 30 pp.

SHEPPARD, M.I. and WILLIAMS, G.D.V. Quantifying the effects of great soil groups on cereal yields in the prairie provinces. Can. J. Soil Sci. 56:511-516.

1977 BAIER, W. Crop-Weather Models and Their Use in Yield Assessments. WMO-No.458. WMO, Geneva. Tech. Note. 151. 48 pp.

CCA. Climatic variability in relation to agricultural productivity and practices. Theme papers prepared for the 1977 CCA Meeting, Winnipeg, Man. 11-12 January 1977. Canada Committee on Agrometeorology. Research Branch, CDA, Ottawa. 214 pp.

DESJARDINS, R.L. Description and evaluation of a sensible heat flux detector. Boundary-Layer Meteorol.11:147-154.

DYER, J.A. and BROWN, D.M. A climatic simulator for field-drying hay. Agric. Meteorol. 18:37-48.

MACK, A.R., SCHUBERT, J., GOODFELLOW, C., CHOGARLAMUDI, P. and MOORE, H. Global agricultural productivity estimation from Landsat data. Proc. 4th Can. Symp. on Remote Sensing, Quebec City. May 1977. pp. 8-18.

OUELLET, C.E. Monthly climatic contribution to the winter injury of alfalfa. Can. J. Plant Sci. 57:419-426.

SLY, W.K. Agroclimatic Atlas for Canada: Derived Data. Agrometeorology Res. and Ser., CBRI, CDA, Ottawa. 17 maps (+ 18 maps added in 1983).

1978 DESJARDINS, R.L., ALLEN, H.A., Jr., and LEMON, E.R. Variations of carbon dioxide, air temperature, and horizontal wind within and above a maize crop. Boundary-Layer Meteorol. 14:369-380.

DYER, J.A. and BAIER, W. Weather-based selection of tractor sizes. Agric. Can. pp. 22-23.

DYER, J.A., BAIER, W., HAYHOE, H.N. and FISHER, G. Spring field workday probabilities for selected sites across Canada. Agric. Can. Tech. Bull. 86. 96 pp.

HAYHOE, H.N. Study of the relative efficiency of finite difference and Galerkin techniques for modelling soil-water transfer. Water Resour. Res. 14:97-102.

MACK, A.R., BRACH, E.J., and RAO, V.R. Investigation of crop spectra and selection of optimal spectral channels. Can. J. Spectrosc. 23:42-51.

OUELLET, C.E. Survey report on the winter survival of alfalfa. Agrometeorology (Res. and Serv.) Sect., CBRI, Research Br., CDA. Bull. 8. 17 pp.

WILLIAMS, G.D.V. and OAKES, W.T. Climatic resources for maturing barley and wheat in Canada. In: K.D. Hage and E.R. Reineilt (eds.), Essays on Meteorology and Climatology in Honour of Richmond W. Longley. Department of Geography, University of Alberta, Edmonton. pp. 367-385.

1979 BAIER, W.; DYER, J.A.; and SHARP, W.R. The versatile soil moisture budget. Agrometeorol. Sect., LRRI, CDA, Ottawa. Tech. Bull. 87. 52 pp.

DYER, J.A. and BAIER, W. Weather-based estimation of field workdays in fall. Can. Agric. Eng. 21:119-122.

MACK, A.R. and KING, G.J. Improving Canadian information on world crop statistics. The crop information system based on remotely sensed and weather data. A summary of presentations made at a seminar on the Crop Information System - a review. Ed: A.J. Kin. Commodity Market Analysis Division, Policy, Planning and Economics Br. CDA. 144 pp.

1980 BAIER, W., St.-PIERRE, J.C. and LOVERING, J.H. Analysis of environmental factors affecting timothy yields. Agric. Meteorol. 22:319-339.

DYER, J.A. and BAIER, W. The influence of zones in budgeting plant-available soil moisture. Can. Agric. Eng. 22:65-70.

HAYHOE, H.N. Calculation of workday probabilities by accumulation over sub-periods. Can. Agric. Eng. 22:71-75.

MACK, A.R., BRACH, E.J. and RAO, V.R. Changes in the spectral characteristics of cereal crops with physiological development. Can. J. Plant Sci. 60:411-417.

1981 BAILEY, W.G. The climatic resources for agriculture in northwestern. Canada. Agric. For. Bull. 4:11-17.

BRACH, E., DESJARDINS, R.L. and St-AMOUR, G. Open-path CO_2 analyzer. J. Physics, E. Scientific Instruments. 14:1415-1419.

DE JONG, R.. Soil-water models: a review. LLRI, Research Branch, CDA. Contribution No. 123. 39 pp.

OUELLET, C.E. and DESJARDINS, R.L. Interprétation des relations entre le climat et la survie à l'hiver de la luzerne par l'analyze des correlations. Can. J. Plant Sci. 61:945-954.

STEWART, R.B. Modeling methodology for assessing crop production potentials in Canada. Agrometeorol. Sect., LRRI, CDA, Ottawa. Tech. Bull. No. 96. 29 pp.

1982 DESJARDINS, R.L., BRACH, E.J. ALVO, P. and SCHUEPP, P.H. Aircraft monitoring of surface carbon-dioxide exchange. Science., 14:733-735.

DYER, J.A. and DWYER, L.M. Root extraction coefficients for soil moisture budgeting derived from measured root densities. Can. Agric. Eng. 24:81-86.

SLY, W.K. Agroclimatic maps for Canada - derived data: soil water and thermal limitations for spring wheat and barley in selected regions. Agrometeorology Res. and Ser., CBRI, CDA, Ottawa. Tech. Bull. 88. 25 pp.

1983 BAIER, W. Agroclimatic Modelling: An Overview. In: Agroclimate Information for Development: Reviving for Green Revolution. (Ed. D.F. Cusack.) Westview Press Inc., Boulder, Colorado. pp. 57-81.

HAYHOE, H.N., TOPP, G.C. and EDEY, S.N. Analysis of measurement and numerical schemes to estimate frost and thaw penetration of a soil. Can. J. Soil Sci. 63:67-77.

MACK, A.R., BRACK, E.J. and RAO, V.R. Appraisal of multi-spectral analyses of high resolution crop spectra. Int. J. Remote Sens. 5:279-288.

STEWART, D.W. and DWYER, L.M. Stomatal response to plant water deficits. J. Theor. Biol. 104:655-666.

1984 BOOTSMA, A. Climatic zonation for forage crops in the Atlantic Region. Agric. Can. Res. Br. Tech. Bull. LRRI No. 83-01. 1983-27E. 44 pp.

1984 BOOTSMA, A. Forage crop maturity zonation in the Atlantic Region using growing degree-days. Can. J. Plant Sci. 64:329-338.

BOOTSMA, A., BLACKBURN, W.J., STEWART, R.B., MUMA, R.W. and DUMANSKI, J. Possible effects of climatic change on estimated crop yields in Canada. Agric. Can. Res. Br. Tech. Bull. LRRI No. 83-64. 1984-9E. 26 pp.

DE JONG R. and HAYHOE, H.N. Diffusion-based soil-water simulation for native grassland. Agric. Water Manage. 9:47-60.

DESJARDINS, R.L., BUCKLEY, D. and St-AMOUR, G. Eddy flux measurements of CO_2 using a microcomputer system. Int. J. Agric. Meteorol. 32:257-265.

DESJARDINS, R.L., MacPHERSON, I., ALVO, P. and SCHUEPP, P.H. Measurements of turbulent heat and CO_2 exchanges over forest from aircraft. In: B.A. Hutchinson, Ed., Forest Environmental Measurements. D. Reidel Publishing Company. pp. 645-658.

DWYER, L.M. and STEWART, D.W. Indicators of water stress in corn Zea mays L.). Can. J. Plant Sci. 64:537-546.

DYER, J.A. and MACK, A.R. The versatile soil-moisture budget version three. LRRI Contribution No. 82-33. Research Branch Tech. Bull. 1984-E. 59 pp.

MACK, A.R. and BOOTSMA, A. Agroclimatic resource maps for agriculture in Canada. Can. Agric. 30:16-20.

1985 BOOTSMA, A. and SUZUKI, M. Critical autumn harvest period for alfalfa in the Atlantic region based on growing degree-days. Can. J. Plant Sci. 65:573-580.

BOOTSMA, A. and SUZUKI, M. Optimum seeding period for winter wheat in the Atlantic Region. Agric. Can. Canadex. 112.22. May. 2 pp.

DE JONG, R. and SLY, W.K. Comparison of modelled soil water reserves on Canadian prairie soils with water-holding capacities of 280 and 250 mm. Can. J. Soil Sci. 65:219-223.

DWYER, L.M. and STEWART, D.W. Water extraction patterns and development of plant-water deficits in corn. Can. J. Plant Sci. 65:921-933.

DWYER, L.M. and HAYHOE, H.N. Comparison of observations and macroclimatic model estimates of monthly winter soil temperatures at Ottawa. Can. J. Soil Sci. 65:109-122.

EDEY, S.N. The role of the micro-logger in the taking of standard agroclimatic observations at Agricultural Research Stations. Research Branch Internal Report. 31 pp.

HAYHOE, H.N. and BAILEY, W.G. 1985. Monitoring changes in total and unfrozen water content in seasonally frozen soil using time domain reflectometry and neutron moderation techniques. Water Resour. Res. 21:1077-1084.

ROBERTSON, G.W. Multiple-crop multiple-layer soil-water budget - a computer program documentation. Contract DSS/RN:04GR.01A09-3-1722; FC: 9644-968-4001; FC: 9641-968-1001-0000; Ser. No. 0GR83-00644. Supply and Services Canada, Ottawa. 42 pp.

STEWART, D.W. and DWYER, L.M. A resistance model for water balance calculations and spring-wheat yield estimates. In: ASAE National Symposium on Advances in Evapotranspiration. Dec. 16-17, 1985. Chicago. pp. 16-17.

STEWART, D.W., DWYER, L.M. and DESJARDINS, R.L. A mathematical model of transpiration using a nonlinear least squares analysis. Can. Agric. Eng. 27:1-6.

1986 DESJARDINS, R.L. Présentation d'une expérience canadienne dans le domaine de la télédétection et de recherche atmosphérique. Technical Report of INRA.

DWYER, L.M. and STEWART, D.W. Leaf area development in field-grown maize. Agron. J. 78:334-343.

EDEY, S.N., BUCKLEY, D.J., LaLONDE, M.J.L. and NICHOLLS, C.F. Automatic retrieval of agrometeorological data using a microcomputer and radio telemetry. Computers and Electronics in Agriculture.

EDEY, S.N., BUCKLEY, D.J., LaLONDE, M.J.L. and NICHOLLS, C.F. Automated monitoring of depth of snow on ground. Agric. Forestry Meteorol.

HAYHOE, H.N., MACK, A.R., BRACH, E.J. and BALCHIN, D. Evaluation of the electrical frost probe. J. Agric. Eng. Res. 33:281-287.

STEWART, D.W., DWYER, L.M. and BOOTSMA, A. Impact of drought on Canadian spring wheat yields. In: Drought: The Impending Crises. Proc. of the Can. Hydrology Symposium No. 16, June 3-6, 1986, Regina, Sask. pp. 475-484.

STEWART, D.W. and DWYER, L.M. Development of a growth model for maize. Can. J. Plant Sci. 66:267-280.

1987 AUSTIN, L.B., SCHUEPP, P.H., and DESJARDINS, J.L. The feasibility of using airborne CO_2 flux measurements for the imaging of the rate of biomass production. Agric. Forest Meteorol. 39:13-23.

BOISVERT, J.B. and DWYER, L.M. L'informatique au service de l'irrigation. Conférence présentée le 13 novembre 1987 dans le cadre de la journée d'information sur la pomme de terre. Conseil de productions végétales du Québec. Agdex 161, pp. 77-87.

BOISVERT, J.B. and DYER, J. Coefficients de sol dans les modèles empiriques de bilan hydrique. Can. Agric. Eng. 29:7-14.

DESJARDINS, R.L.; MACK, A.R.; MacPHERSON, J.I.; and SCHUEPP. P.H. Characterizing crop conditions using airborne CO_2 flux measurements and Landsat-D MSS Data. pp. 97-100. In: Proceedings of the 18th Conf. on Agric. and Forest Meteorol. West Lafayette, Ind. LRRC Contribution No. 87-56.

DWYER, L.M. and STEWART, D.W. Influence of photoperiod and water stress on growth, yield and development rate of barley measured in heat units. Can. J. Plant Sci. 67:21-34.

HAYHOE, H.N. and MUKERJI, M.K. Influence of snow cover on soil temperature in the biologically active zone. In: Proc. 11th International Congress of Biometeorology, 13-18 September 1987, West Lafayette, Ind., AMS, Boston, Mass. pp. 45-48.

HAYHOE, H.N. and DE JONG, R. Comparison of two soil-water models for soybeans. Can. Agric. Eng. 30:5-11.

HAYHOE, H.N., BOOTSMA, A. and DWYER, L.M. Monitoring and analysis of soil temperature regimes for soil climate classification. Can. J. Soil Sci. 67:667-678.

1988 DE JONG, R. and BOOTSMA, A. Estimated long-term soil moisture variability on the Canadian prairies. Can. J. Soil Sci. 68:307-321.

DWYER, L.M., STEWART, D.W. and BALCHIN, D. Rooting characteristics of corn, soybeans and barley as a function of available water and soil physical characteristics. Can. J. Soil Sci. 68:121-132.

HAYHOE, H.N. and BALCHIN, D. Combined time-domain reflectometry and electrical conductance measurements for analysis of seasonal soil frost. Cold Regions Science and Technology. 15:195-200.

STEWART, D.W. Risk analysis of cereal yields in the Canadian prairies. pp. 89-112. In: J. Dumanski and V. Kirkwood, eds: Crop production risks in the Canadian prairies region in relation to climate and land resources. Agric. Can. Tech. Bull. 1988-5E:89-112.

1989 BOOTSMA, A. and DWYER, L.M. Soil-climate classification and winter risk assessment for the Atlantic Region based on estimated soil temperatures. LRRC, CDA, Ottawa. Tech Bull.

DESJARDINS, R.L., MacPHERSON, I., SCHUEPP, P.H. and KARANJA, F. An evaluation of airborne eddy flux measurements of CO_2, water vapour, and sensible heat. Boundary-Layer Meteorol. 47:55-70

SCHUEPP, P.H., DESJARDINS, R.L., MacPHERSON, J.I., BOISVERT, J., and AUSTIN, L.B. Airborne determination of regional water use efficiency and evapotranspiration: present capabilities and initial field tests. Agric. Forest Meteorol. 41:1-9.

1990 HAYHOE, H.N., TASNOCAI, C. and DWYER, L.M. Soil management and vegetation effects on measured and estimated soil thermal regimes in Canada. Can. J. Soil Sci. 70:61-71.

a STEWART, D.W. and DWYER, L.M. A model of spring wheat (Triticum aestivum L.) for large area yield estimations on the Canadian Prairies. Can. J. Plant Sci. 70:19-32.

b STEWART, D.W. and DWYER, L.M. Yield and protein trends of spring wheat (Triticum aestivum L.) on the Canadian Prairies. Can. J. Plant Sci. 70:33-34.

CHAPTER 5
THE ROLE OF THE NCAM

PART 1 - FORMATION OF THE NCAM

The National Committee on Agricultural Meteorology (NCAM, CCAM, CCA, ECA) can trace its origin to the annual meeting of the National Advisory Committee on Agricultural Services (NACAS) held in Ottawa, 6 December 1956.

The NACAS

The NACAS was a powerful national group in agriculture, consisting of the Deputy Minister of Agriculture for Canada and the deputy ministers of provincial departments of agriculture, which together formed the executive. Regular designated members included the Assistant Deputy Minster of Agriculture for Canada, the directors of various services of CDA, the deans of the faculties of agriculture, the principals or presidents of agricultural colleges, the Director of the Division of Applied Biology of the National Research Council, the Executive Secretary of the Agricultural Institute of Canada, the Director of the Department of Colonization and Agriculture of Canadian National Railways, the Director of the Agricultural Division of the Dominion Bureau of Statistics, the Director of the Ontario Research Foundation, and the General Agricultural Agent of Canadian Pacific Railway.

The following is from the minutes of the meeting of the NACAS held in Ottawa on 6 December 1956.

> "Mr. Putnam, Deputy Minister of Agriculture for Alberta and Dr. McCalla, Dean of the Faculty of Agriculture at the University of Alberta raised the question as to whether the Meteorological Division of the Department of Transport could not serve the needs of agriculture more fully. Mr. Putnam referred to the possibility of compiling useful data from records already existing and Dr. McCalla stressed the value of short-term regional forecasts for agriculture. The suggestion was made that if the need was recognized and positions established the existing shortage of meteorologists might in time be overcome. It was agreed that the whole question warranted further study. The Chairman asked Dr. Neatby, Director of Science Service (SS) and Dr. Goulden, Director of the Experimental Farms Service (EFS), to get a small group together from the Experimental Farms' Service and Science Service for the purpose of preparing a report on the new or expanded meteorological services needed by agriculture."

There is little doubt that the thinking and considerations regarding this matter by the proponents and the members were influenced by the Session on Agrometeorology held by the AIC in Toronto some six months earlier.

A Proposed Subcommittee on Agrometeorology

A special subcommittee of the NACAS to consider the needs of agriculture with respect to meteorological services was called together by Dr. Neatby consisting of:

Dr. K.W. Neatby, Director, CDA Science Service (Chairman)
Mr. G. W. Robertson, Meteorological Unit, Division of Field Husbandry, EFS (Secretary)
Dr. A.P. Arnasson, Field Crop Insect Unit, Entomology Division, SS
Dr. D.G. Hamilton, Chief, Cereal Division, EFS
Dr. H. Hill, Chief, Horticulture Division, EFS
Dr. D.S. MacLachlan, Plant Pathology, Botany and Plant Pathology Division, SS.

The subcommittee held two meetings. At the first meeting the group dealt with the subject in a general manner, recognizing many of the meteorological problems of agriculture but failing to make any real, concrete suggestions. Most of the problems recognized by the group pertained to weather forecasting, especially long-range forecasts such as 2-week and 30-day forecasts with special emphasis on factors that affect agriculture such as duration of wet spells, wind speed and air turbulence for spraying purposes, and duration of dry spells with low humidity and high temperature for harvesting operations. It was suggested that the 24- to 36-hour forecast could be tailored to the specific needs of the farmer for special operational purposes such as pest control, irrigation, planting, and harvesting. The inadequacy of the current network of climatological stations was highlighted. In this regard the meeting suggested that all agricultural research units staffed the year around should be encouraged to participate in an agrometeorological observing program. The need for an agroclimatic atlas was recognized but many details concerning contents, presentation and costs were needed.

A report of this first meeting was considered by the Deputy Minister of Agriculture for Canada and by the Director of the Meteorological Branch. Both felt that it contained a good discussion of many meteorological problems that agriculture faces, but that no practical and specific recommendations were proposed. It was suggested that Robertson, in his capacity as liaison meteorologist, look into this whole matter during his summer trip to western Canada (1957).

During his trip Robertson discussed the matter of meteorological services for agriculture with personnel of experimental farms, science service laboratories, universities, and provincial departments of agriculture. It was found that there were many problems with the emphasis varying from province to province and even from region to region. These problems could be classified under five main headings:

1. Forecasting
2. Climatic analysis
3. Research
4. Observations
5. Extension and liaison

In his report Mr. Robertson stated that the major problem in the application of meteorology to agriculture was the lack of a corps of experts to attend to the many regional or provincial problems that fall into these five categories. The suggested solution is for the Meteorological Branch to second at least one meteorologist to each province that requires assistance. These meteorologists, as a group, would provided an agrometeorological service which would aid in bridging the gap between the national weather service and agriculture.

His report was considered by the Special Subcommittee on Meteorological Services for Agriculture at a meeting held in Ottawa, 1 October 1957. The second meeting of the Subcommittee fully endorsed the principles outlined in the report. A third meeting of the Special Subcommittee was held in Ottawa 11 March 1959 under the chairmanship of Robertson. Five new members were added to the subcommittee:

Mr. Wm. Kalbfleisch, Head, Agricultural Engineering Section, Field Husbandry Division, EFS
Dr. M.L. Prebble, Chief, Forest Biology Division, SS
Dr. P.O. Ripley, Chief, Field Husbandry Division, EFS
Dr. H.A. Senn, Head, Plant Physiology and Botany Unit, SS
Dr. R.M. Holmes, Agrometeorological Unit, Field Husbandry Division, EFS. (Secretary).

Dr. Neatby died on 27 October 1958. His guidance in connection with the activities of the subcommittee was sorely missed.

The terms of reference of the subcommittee when it was first appointed in 1956 were: "To consider and define as clearly as possible the needs of agriculture with respect to meteorological services".

These were further extended at the November 1958 meeting of the NACAS to include: "To coordinate the carrying out of the recommendations of the subcommittee in connection with the secondment of meteorologists from the Department of Transport to the Provincial Departments of Agriculture".

An earlier proposal of the Subcommittee concerning the secondment of meteorologists to Provincial Governments was not working out too well. The report of the Subcommittee contained comments on this matter:

> "The Meteorological Branch of the Department of Transport received formal requests for secondment of meteorologists from the Saskatchewan and Alberta Departments of Agriculture. The Meteorological Branch is most desirous of assisting with the development of agricultural meteorology within the provinces but, unfortunately, staff shortages render it impossible to make any assignments before the fiscal year 1960-1961.
>
> "Because of keen competition for weather services from all sections of the Canadian economy as well as from National Defence and because Treasury Board must be convinced of the necessity of establishing new positions, it is of utmost importance that requests for meteorological services be adequately supported."

The questions of "adequate" support was discussed by the Subcommittee. From this discussion it became obvious that further consideration should be given to determining specific reasons for establishing meteorological services for agriculture at provincial levels. It was suggested that a special ad-hoc committee with provincial representation familiar with the local needs of agriculture for meteorological services should study the problem. At this point Chairman Robertson suggested forming a National Committee on Agrometeorology with authority to appoint technical or "special problem" subcommittees to deal with such matters.

Proposal for a National Committee on Agrometeorology

He presented a proposal for this committee that included the following.

> Weather and climate profoundly affect agriculture. That weather has a major control over nearly all facets of agriculture has been known ever since man evolved from the hunter to the farmer. The farmer knows that his crop production is a gamble on rains, frost, wind and hail. He has ever watched the skies anxiously for symptoms of coming weather so that he can plan and undertake his farming operations in harmony with the expected weather.
>
> Agricultural meteorology deals with the various problems of crop growth and production in relation to the environmental factors, i.e. the weather factors and their time sequence during the growing season (as well as prior to it in the case of perennial crops). These same environmental factors also affect the many crop diseases and insect pests and thus bring about further indirect control of plant growth and yield.
>
> Man has as yet only very limited control over weather and climate. Nevertheless, a thorough understanding of meteorological processes and their influence on crop growth and development, on animal behaviour, and on the increase and dispersion of insects and diseases is necessary to enable the farmer to live with the weather and make the best of the existing climate.
>
> Many agricultural groups make use of meteorological data and knowledge that either directly or indirectly benefit the farmer:
>
> 1. The farmer who can take preventative action or govern his operations accordingly can use the daily weather forecast to economic advantage. Examples are the fruit growers in the Okanagan Valley of BC who use orchard heaters when frost is predicted and the potato farmers of the

Maritimes who apply preventative sprays when weather suitable for late blight is predicted. A knowledge of the influence of terrain on local climate is of assistance to the farmer in selecting areas of his farm for special crops. An example would be to avoid planting tender crops in low, sheltered areas where untimely frosts might occur.

2. Municipal governments use climatic data for land appraisal. Low areas which may be frost pockets have shorter growing seasons and therefore may be less productive than higher land. Some areas may be more susceptible to damage by hail than others. Rainfall, evaporation and soil type considered together determine the droughtiness of an area.

3. Crop zonation committees use climatic data (rainfall, evaporation, frost-free season and growing-season temperature) for making recommendations regarding the most suitable crop species and varieties to be grown in a given area.

4. Engineers use climatological data for designing farm buildings, greenhouses, air-conditioning systems, drainage ditches, and irrigation reservoirs and canals. For these reasons they may require data on rainfall, evaporation, temperature and humidity frequencies, snow loads, and maximum wind speeds.

5. The research scientist may be interested in studying the influence of certain meteorological factors on certain biological responses. Such studies cover an extremely broad field both meteorologically and biologically. For some purposes it might be sufficient to use regular meteorological observations. For others it might be necessary to use special observations of the environment in the immediate vicinity of the plant or animal being studied.

6. Weather modification is in its infancy. On a large scale little can be done as yet although the prospects are encouraging. Fundamental work in this field is being done at McGill University, in an area immediately north and west of Ottawa, and in Alberta. Microclimate, on the other hand, can be modified to a large degree. Shelter-belts are used on the Prairies to lower wind speed to retard soil erosion, and to catch snow. Fibrous mulches have long been used to control soil moisture and temperature. More recently, sheets of thin plastic have been used more effectively on the soil surface for the same purpose. Plastic tents have also been used successfully for increasing the length of the growing season as well as the temperature during the growing season. With such devices corn and tomatoes have been ripened at Whitehorse without the use of artificial heat.

As an illustration of the interest in Canada in agrometeorology and the related fields of bioclimatology, phenology, and ecology, a recent survey indicated that some 80 studies were being made in this field by 39 units of the Research Branch of the Canada Department of Agriculture. Most of this work is secondary to biological or agricultural investigations. Undoubtedly there is an equal interest by colleges, universities, provincial research councils and foundations, and provincial experimental stations across the country. There are a dozen or more meteorologists, soil scientists, agronomists, and entomologists at both federal and provincial levels and at colleges and universities who are working full time or nearly so on agrometeorological, bioclimatological, and related subjects. In addition there are 30 or more scientists in the field of agriculture who are vitally interested in the application of meteorology and climatology to their problems. There is a need to promote coordination and mutual assistance in connection with some of the problems of common interest (measurement of evaporation, micrometeorological studies, extension of the climate observing program, instrumentation, data analysis, etc.) to these individuals.

The Meteorological Branch of the Department of Transport is charged with the responsibility of issuing weather forecasts, the collection and publication of climatic data, the conducting of fundamental meteorological research, and liaison with the World Meteorological Organization on all phases of meteorology and climatology in Canada. An Interdepartmental Committee on Meteorology used to exist through which federal government requirements for meteorological services were made known to the

Director of the Meteorological Branch of the Department of Transport. The work of this Committee is now being accomplished by liaison meteorologists seconded by the Meteorological Branch to various federal and provincial departments. A representative of the Meteorological Branch has suggested that, if agriculture could define its needs for meteorological services in reasonably concrete terms, the necessary cooperation of that Branch could probably be secured. It is felt that a National Committee on Agrometeorology would provide a means for defining such needs and also provide information useful for liaison purposes.

It is suggested that a National Committee consider the many facets of agrometeorology is required in Canada. Such a Committee, with responsibility to the chairman of the NACAS, would assist with the orderly progress and development of the science of agrometeorology in Canada:

1. It would be a coordinating body promoting mutual assistance amongst these agricultural scientist (plant physiologists, entomologists, pedologists, agronomists, agrometeorologists and others) both federal and provincial who may have requirements for meteorological data, techniques, or knowledge in connection with their work.

2. The Deputy Minister of the Canada Department of Agriculture, being chairman of the NACAS, would be kept informed of trends and developments in agrometeorology.

3. It is suggested that the chairman of the proposed National Committee be a member of the Program Directorate of the Research Branch of the Canada Department of Agriculture. Through this channel the Program Directorate would also be informed of trends and developments in agrometeorology.

4. Likewise, members of the proposed National Committee from provincial departments of agriculture, provincial research councils or foundations, colleges and universities would be similarly informed.

5. It is suggested that the secretary of the Committee be the liaison meteorologist seconded by the Meteorological Branch of the Department of Transport to the Research Branch of the Canada Department of Agriculture. Through this channel the Meteorological Branch would be informed of the requirements of agriculture for meteorological services.

Recommendations:

1. It is recommended that a National Committee on Agrometeorology (NCAM) be established by the NACAS. The purpose of the committee is: to promote the coordination of meteorological research and services necessary to meet the needs of Canadian agriculture.

2. It is recommended that the NCAM be authorized to appoint technical subcommittees to consider specific problems. Problems requiring immediate consideration by the technical subcommittees are discussed at the end of this proposal. The membership of the subcommittees should be chosen from the members of the NCAM and consist of a chairman and 4 to 6 members.

   Proposed Committee: Members of the NCAM should be appointed by the Deputy Minister of CDA. It is suggested that initial appoints be as follows:

   - Chairman: To be appointed from the Program Directorate by the Executive Committee of the Research Branch.
   - Secretary: G.W. Robertson. meteorologist seconded from the Meteorological Branch, Department of Transport, to the research Branch, Department of Agriculture.

One-year term:
- Mr. W.M. Berry, Chief, Hydrology Division, P.F.R.A., Regina.
- Dr. D.N. Huntley, Head, Department of Field Husbandry, Ontario Agricultural College, Guelph.
- Dr. H.A. Steppler, Chairman, Department of Agronomy, Macdonald College.

Two-year term:
- Mr. L.J. Chapman, Senior Research Fellow, Ontario Research Foundation.
- Dr. B.W. Currie, Head, Physics department, University of Saskatchewan, Saskatoon.
- Dr. J.A. Toogood, Associate Professor of Soil Science, University of Alberta, Edmonton, Alberta.

Three-year term:
- Representative from Regional Laboratories and Experimental Farms (to be appointed by the Executive of Research Branch).
- Mr. E.A. Barks, Regional Meteorologist, Department of Transport, Moncton.
- Dr. F.K. Hare, Chairman, Geography Department, McGill University.

Initially three members should be appointed for one year, three for two years, and three for three years. Subsequent appointments should be made by the Deputy Minister on recommendation of the Committee and should be for a period of three years except when filling unexpired terms. Retiring members will be eligible for re-appointment.

Members should be nominated because of their interest in agrometeorology, their affiliation with organizations conducting agrometeorological research, their knowledge of the subject, and their affiliation with groups making use of climatological data and meteorological services.

Problems requiring consideration by technical subcommittees.

There are four problems which should be considered immediately by the proposed NCAM, and that may require detailed study by technical subcommittees:

1. A further study of the meteorological services required by provincial departments of agriculture. A study was completed by a special ad-hoc committee and a report made to the NACAS when it met on 14 November 1958. It was recommended that those provincial departments of agriculture that had a real need for meteorological services should apply to the Meteorological Branch, Department of Transport, for the loan (secondment) of a meteorologist to do service work within the province. Two provinces, Saskatchewan and Alberta, have made formal requests for such service. Unfortunately, there is an acute shortage of meteorologists at the present time. Because of the competition for their services, very strong cases must be presented to Treasury Board to justify requests. It is felt that a technical subcommittee composed chiefly of members from within the province requiring assistance could advantageously review the requirements and possibly strengthen the request for assistance.

2. The requirement of agriculture for standard measurements of evaporation on a climatic basis. Many agricultural scientist are of the opinion that evaporation should be measured on a climatic basis much the same as maximum and minimum temperatures and precipitation are currently measured. The Meteorological Branch is considering such a program but many obstacles have been encountered. The chief ones are the lack of a standard instrument or technique at the international level and inconsistencies between different instruments and techniques. Since agricultural scientists collectively have as great a requirement for evaporation data as any other group it is important that their requirements be fully expressed and understood.

3. A review and possible revision of other climatological observations required by agriculture. At present agricultural research stations across the country are taking standardized observations of precipitation, temperature and sunshine. A few are measuring solar energy and soil temperature. Is there a need to observe and report, using standard techniques and equipment, other meteorological factors (dew duration and amount, water content of snow, wind speed and direction, or dew point temperature)? If so, should data be published regularly and in what form? The Meteorological Branch requires guidance in these matters.

4. The development of a micrometeorological program in Canada. Several of the special-duties meteorologists seconded from the Meteorological Branch to other federal and provincial departments (including the one seconded to the Research Branch, CDA) have recognized the need for equipment and technical advice in connection with certain applied micrometeorological studies. The Meteorological Branch has recognized this requirement and has plans for developing such a program. Some guidance is required to fully develop the program in accordance with the combined needs of agriculture, forestry, hydrology, and air pollution."

Discussion by NACAS

A full and animated discussion by NACAS members followed the presentation of the report, reflecting the importance of meteorology to agriculture. Finally, these recommendation were given unanimous approval. Dr. Hamilton, of the Program Directorate was named Chairman of the new NCAM and Dr. T.H. Anstey, Director of the Research Station at Lethbridge, was appointed by the Executive Committee of the Research Branch to represent Regional Laboratories and Experimental Farms. It was suggested that Dr. J.W. Hopkins of the Division of Applied Biology in the National Research Council should be informed of the activities of the new Committee.

The shortage of meteorologists and the possibility of offering specialized training in agrometeorology at Canadian universities was discussed. The deans of agriculture discussed this matter at a meeting held later in St. Anne de la Pocatiere, P.Q.

PART 2 - FIRST MEETING OF THE NCAM

The first NCAM meeting was held in Ottawa 14-15 January 1960. Dr. Hamilton was chairman and all members but one attended. Dr. Currie had an engagement made previously and because of other heavy commitments he recommended that he be replaced by Dr. T.P. Pepper of the Saskatchewan Research Council at this and future meetings.

The Chairman's introductory remarks are worthy of note as they summarized the status of agrometeorology in Canada at the time and set the framework for future activities of the Committee for some time:

Chairman's Introductory Remarks

"This Committee is one of the few specially designated committees set up by the National Advisory Committee on Agricultural Services (NACAS) to help determine research needs and how to meet them. The chairman of the NACAS is the Deputy Minister of the Canada Department of Agriculture and his executive consists of the deputy ministers of the provincial departments. There are twenty designated members, namely, the deans of agriculture, representatives from the Canada Department of Agriculture, representatives from the National Research Council and a few other representatives from such bodies as the Board of Grain Commissioners."

The chairman appointed a special subcommittee on Meteorological Services for Agriculture in December, 1956. Its terms of reference were to consider and define as clearly as possible the needs of agriculture with respects to weather services. I presume we could all agree on a definition of agrometeorology and say that it deals with problems of agriculture in relation to weather factors. Agriculture has always wanted to know how to take advantage of weather information. I suppose that we have always realized that before we can go very far towards this goal, we must record climatic factors and eventually we must try to understand the relationships between these factors and certain responses pertaining to agricultural production.

The subcommittee was to shed some light on these matters, particularly to point the way and say what should be done. We have all read the subcommittee reports and have read articles in reports from numerous services. I think that from the information available, one would have to record the following impressions:

1. That agriculturists as a group have never made known what their actual requirements are. The reason why so much effort goes into providing forecast data for aviation is because the Air Force knows what it wants.

2. Everyone realizes that weather and climate are all-important to the agricultural industry, and from this it follows that the collection of data and interpretation of the data in terms of plant and animal needs are foremost in importance. But we do not know what data to collect for certain and if we did we do not know how to relate the data to specific agricultural needs. At this point the picture becomes hazy. A lot of discussion is aroused but the air is still hazy. One can find many general statements which are not very helpful. There are a few bright spots, but I know only of a few. For example, we are learning about plant responses under controlled conditions. We do have information showing the relationships for heat units and growth. We do know, through a study of agricultural environments, where some species of plants might be grown. We know that early maturing varieties are the efficient ones for utilizing the low amount of heat obtained in the North. We have seen that seed production of most of the common field crops is associated with much less vegetative growth in Northern Canada than farther south. A study of aridity of the prairies is being done now by the Meteorological Branch and the Tabulation Unit of the Canada Department of Agriculture. I believe that without too much effort we could put out publications on such things as The Climatological Adaptation of the Strawberry Plant in Canada. So we are making some progress and, at the same time, we are trying to get a better understanding of the relationship between climate and crop.

3. The subcommittee was told that agriculture needed a greater range of types of forecasts; that climatic analysis tables were needed; that more and more pertinent data must be obtained; and that provincial extension services needed seconded meteorologists to help harness the information on the effects of the agricultural environment and thus bridge the gap between the Meteorological Branch of the Department of Transport, and Agriculture.

4. The provinces were asked to state their needs for seconded meteorologists and only two asked for assistance. The real need for services was not clear.

5. On top of these different opinions is the fact that there is a great shortage of trained meteorologists.

6. It became evident that we must have clear and sound reasons for establishing meteorological services for agriculture at provincial levels. This would not be an easy task. Someone began to conceive the idea of a national committee to do the job. Also, the task of evaluating our requirements was getting more complex instead of simpler. The matter of weather modification came to the fore. There was one area in which requirements became quite clear and that was simply the fact that we needed to team up with meteorology to find and understand the cause for

occurrences in agriculture. One good example of the cooperative approach is the effort to find out the cause for the serious weather fleck trouble in tobacco in Ontario.

7. We do not know what we want in agriculture and it will not be easy to find out. However, forecasts are being used in the fruit areas to take preventative action against frost; late blight outbreaks on potatoes can be predicted by studying weather data; crop recommendations are based, to quite an extent, on certain types of varieties being suited to certain climatic areas; climatological data are used in connection with agricultural engineering; and alterations to the microclimate are important for crop production in certain areas. Also, a great many studies are going on in various institutions in Canada where various meteorological measurements and agricultural crop responses are being studied together.

8. It was once suggested by a representative of the Meteorological Branch that if agriculture could define its needs for meteorological services in reasonably concrete terms, then the Meteorological Branch would know where it stood with respect to planning to work with agriculture.

The National Committee on Agrometeorology was appointed in April 1959. This is its first meeting. We have been referred to as a coordinating body for tying together all the interests in programs which exist or may exist some day in various institutions in Canada. This means the coordination of meteorological research and services necessary to meet the needs of Canadian agriculture.

We must define the requirements of agriculture for meteorological services. We should also assist in helping to bring about orderly progress and development of the science of agrometeorology in Canada.

Every agriculturist knows that the weather has a tremendous influence on agricultural production, yet he tends to avoid getting too closely tied up with meteorology because he knows so little about it. On the other hand, meteorologists know very little about biology and tend to work in areas where things are easier to fit together and where real demands are made upon them. Therefore, it has been very difficult for anyone to prepare to write an appreciation of the whole situation and state agriculture's needs in clear terms.

I think it is fair to say that agrometeorology in largely undeveloped. We must not back away from it because it looks complex. Soil is also complex and variable but we are doing an awful lot to understand it. We must get busy and try to understand more about the plants' environment just above the soil. We even try to pattern the soil variability but we never think of looking into the pattern of weather variation. Actually, we would not know what variables to pattern because we are not sure which ones are significant agriculturally.

No one needs to stress the importance of agrometeorology because we are really talking about the environment in which agriculture is being carried on. One can detect in many of the reports and articles a pleading to rally around an organized plan of approach. I believe that this is exactly the position in which we find ourselves. We have got to sort out what we want to do before we can have much of a program to talk about in agrometeorology. That is why this committee was formed so that someone will attempt to describe agriculture's needs in fairly specific and concrete terms. This has not been done before. What do we mean by concrete terms? Would the following be an example of a concrete statement if it were true? The greatest advances in agrometeorology will be made in application and interpretation of weather forecasts and climatic data at the farmer level.

The members of the committee who are located in Ottawa, that is, Mr. Robertson and myself, felt that this meeting had to take some organized form and we brought forward ten questions for discussion.

I shall end this introduction by bringing forth a statement on what agrometeorology comprises. The ideas for this statement came from the 1953 report of the Commission for Agricultural Meteorology of WMO.

To measure, evaluate and suitably present single and complex factors of weather and climate as they affect soils, plants, animals and their enemies. Along with it is the responsibility for advising on the most practical utilization of weather and climate (natural and artificial) for agricultural purposes including production aspects, forecasting, combatting influences of unfavourable weather, pests and diseases."

A Ten-Point Agenda

Ten items were on the agenda for this first meeting of the NCAM. Each member was asked to be prepared to speak on certain items:

- General Observations, T.H. Anstey.
- Publication of Data, L.J. Chapman.
- Station Density, E.F. Durrant.
- Micrometeorology at Universities, H.A. Steppler.
- Weather Modification, T.P. Pepper.
- Meteorological Training for Agriculturalists, J.A. Toogood.
- Weather Forecasts for Agriculture, E.A. Barks.
- Central Corps of Agrometeorologists, F.K. Hare.
- Seconding Meteorologists to Provinces, D.N. Huntley.
- Agrometeorology in Proper Perspective, D.G. Hamilton.

In general the ten agenda items served as guidelines for preliminary discussion and only a few general recommendations were proposed. The main recommendation was that members responsible for the fourth to ninth agenda items should consider these topics during the forthcoming year and report back to the Committee at its next annual meeting. The first to third agenda items all related to one general topic, viz. agroclimatology, and it was suggested that a subcommittee consisting of Anstey, Chapman, Durrant and Robertson be established to look into this matter and report back at the next annual meeting.

Recommendation re Education and a Central Corps

Discussions of the fourth, sixth, eighth and ninth agenda items indicated that there was a real shortage of individuals trained in the dual field of agriculture and meteorology and that this shortage would limit progress in agrometeorology for some time to come. The Committee recommended that universities, particularly those already involved in meteorological training (Toronto and McGill) be encouraged to establish training or research institutes in bioclimatology. Since agrometeorology requires the cooperation of meteorologists and agriculturists, the committee recommended that central corps of expertise be established where such cooperation could most effectively be enacted, particularly at the Central Experimental Farm, at Macdonald College in conjunction with McGill's Meteorological program and at the University of Toronto as an outgrowth of the training program for meteorologists in cooperation with the Meteorological Branch.

Other recommendations were concerned with the limitation of secondment of meteorologists to provincial governments, the preparation of 3-5 day forecasts by the Meteorological Branch, the tailoring of forecasts to the specific seasonal requirements of the farmer, the support of further study of rainfall enhancement and hail suppression, and an invitation to the Director of the Meteorological Branch to attend the next meeting of the NACAS in April when the Report of the NCAM would be discussed.

PART 3 - COMMITTEE MEMBERSHIP AND POLICY

Officers

It was the policy of the Research Branch of CDA for chairmen of all national committees to be members of the administration staff. Hamilton continued as chairman for six years. Following reorganization and staff changes in the Branch in 1965 Dr. R.A. Ludwig, Director of the PRI, was appointed chairman. He was unable to assume his full role as chairman until 1967. Ripley acted as chairman in 1965 and Nowosad in 1966. Ludwig them served as chairman until 1972 when he stepped down to be replaced by Dr. W.A. Ferguson, the newly appointed Research Coordinator (Soil Fertility), RB/CDA. He chaired the 13th Annual Meeting but missed the next two. Baier served as acting chairman at the 14th and 15th Meetings. Ferguson then served until his untimely death in 1978.

Baier, again, was acting chairman at the 19th Meeting at which time he was elected chairman. He was now Assistant Director of the LRRI as well as Head of the Agrometeorology Section. He served as chairman until 1982 when he was appointed Acting Director General of the new Pacific Region of the Research Branch and was no longer available.

He was replaced by Dr. R.H. Douglas of Macdonald College who served until his retirement a couple of years later. The choice of Douglas as chairman was a departure from tradition. King served as acting chairman at the 1984 Annual Meeting when Douglas was unable to attend. Dr. P. Dubé of Laval University was elected chairman at the 1984 meeting and continued at least to the time of this writing.

Robertson was named permanent secretary at the inception of the Committee. Edey, a meteorologist seconded from CMS to the Agrometeorological Section, CDA in 1965, was appointed as a permanent member and recording secretary. When Robertson took leave-of-absence in 1969 Baier took over as permanent secretary. When he was appointed chairman in 1978, Edey became secretary, a position he held until his retirement in 1988. He missed only one meeting: in 1985 when he was in Ethiopia. Blackburn served as secretary in his absence. The 30th meeting formally recognized Edey's contributions to the Committee over the past 22 years and it was proposed that an appropriate plaque be prepared in recognition of these efforts.

After Edey's retirement Blackburn became secretary for two years, in 1987 and 1988 followed by Ms. J.M. Masterton of CMS in 1989.

When the NCAM was first formed, three permanent members of the Research Branch made up the executive of the NCAM: the chairman, an assistant to the chairman and the secretary. Dr. K.H. Hill of the Program Directorate served as assistant from 1961 until he resigned in 1963 when he was replaced by Dr. P.O. Ripley who served for a couple of years. When Edey joined the Section in 1965 the executive was comprised the chairman, the secretary and the recording secretary, all located in Ottawa.

Membership

Originally, the policy was to have a three-member executive located in Ottawa and nine appointed members from the field. The nine members were divided into three groups, each serving for three years. Appointments were made by CASCC with recommendations from the Committee. It was the aim of the executive to have a broad representation on the Committee from all groups having weather-sensitive agricultural problems. Three new members appointed each year assured that representation was obtained from all interested groups. The three-year term of office also ensured that members had a chance to learn how the Committee functioned, to contribute to the work of the Committee, and to profit from association with it. Members did not have to be experts in the field of agrometeorology. Unfortunately it was not possible to follow this plan strictly because of lack of representatives in some

areas and a deep and continuing concern by certain individuals in other areas. The proposed system provided guidelines, however, for many years.

The name of the Committee was changed twice. In 1969 at the 10th Annual Meeting the Committee became the "Canada Committee on Agrometeorology" (CCAM) according to a new policy of the parent organization, CASCC. At this meeting it was also decided to increase the permanent membership of the committee by two members: one from the CMS in view of the fact that the policy of secondment by CMS was being terminated and Robertson would no longer be the official liaison between CMS and CDA. Representatives were alternated depending on the main topic of the Annual Meetings (see "Membership List", below). It was felt that Macdonald College should have permanent representation in recognition of its increasing significance in the field of education and research at the university level. Douglas served in this position until his retirement in 1985.

Special-interest groups with agrometeorological and related problems were asked to join the Committee starting in 1975. Forestry was invited to send a representative to the 16th Annual Meeting (1975) and Dr. R.H. Silversides attended as the first representative. The Department of Indian and Northern Affairs (DINA) was also invited to send a representative and Mr. J.I. Sneddon attended the 18th Annual Meeting as their first representative. Although Forestry continued to send a representative, one from DINA attended only five meetings.

The Canadian Federation of Agriculture was invited to send a representative in 1980 and Dr. M. Bursa attended, bringing the total membership to fourteen. This was the first time that the farming community was represented on the Expert Committee on Agrometeorology, as the CCAM had now become.

From time to time members found it difficult to attend meetings due to a shortage of travel funds. This became a serious matter in the early 1980's. In 1982 and 1983 one-quarter of the members were absent because of the cost-constraint situation in CASCC. Chairman Douglas led a discussion of concern regarding this matter at the 25th Annual Meeting (1983). The Committee unanimously agreed to send to CASCC the following "expression of concern", pointing out the attendance problem. "At the last few meetings of the Expert Committee on Agriculure, one or more committee members (representing provincial agencies) have been unable to attend, due to financial restraint. While the need for restraint is appreciated, the ECA is greatly concerned that such absences jeopardize the vital and highly desirable "mix" of government-university representation which is an important feature of the CASCC committee system. The appropriate agencies are urged to do all in their power to assure their representation in the ECA."

Chairman Dubé briefed the 31st Annual Meeting on the results of the most recent meeting of the CASCC Committee on Land Resource Services. It was emphasized that CASCC financial support applied only to universities as it had for several years, not to provincial representatives.

In 1986 the 28th Meeting of the Committee endorsed an additional member to represent the Canadian Climate Centre of AES.

Membership List

The following list shows terms of office and the status of those that attended the 31 meetings since the Committee held its first meeting in 1960. Names are shown in the order in which they were first appointed. The status of individuals at the meeting is shown by:

C	chairmanVCvice-chairman
AC	acting chairmanSsecretary
R	recording secretary Mappointed member
a	alternativelinvited for one meeting only
P	permanent representative

	Name	Affiliation	Status and Term
D.G.	Hamilton,	Research Branch, Ottawa,	C/1960-64.
G.W.	Robertson,	Agrometeorol. Sect. CDA, Ottawa.	S/1960-69, I/1978.
T.A.	Anstey,	Research Branch, Summerland.	M/1960-64.
L.J.	Chapman,	Ont. Res. Foundation, Toronto.	M/1960-64, I/1970.
E.F.	Durrant,	PFRA, Regina.	M/1960-64
J.A.	Toogood,	Univ. of Alberta, Edmonton.	M/1960-64.
H.A.	Steppler,	Macdonald College.	M/1960-64.
T.P.	Pepper,	Sask. Res. Council, Saskatoon.	M/1960-63.
E.A.	Barks,	CMS, Moncton.	M/1960-63.
F.K.	Hare,	McGill University, Montreal.	M/1960-63.
D.N.	Huntley,	Ontario Agric. College, Guelph.	M/1960-63.
K.H.	Hill,	Research Branch, Ottawa.	VC/1961-62.
K.M.	King,	University of Guelph, Guelph.	M/1963-64, 1965-68, I/1972. AC/1984, M/1985- .
W.G.	Malaher,	Searle Grain Co. Ltd. Winnipeg.	M/1963-66.
J.S.	Leefe,	Research Branch, Kentville, NS	M/1964, 1966.
G.O.	Villeneueve,	Que. Dept. Nat. Resour., Que.	M/1964-66.
W.L.	Pelton,	Research Branch, Swift Current.	M/1964-66.
A.C.	Carter,	BC Dept. of Agric., Victoria.	M/1964-65, 1969-71.
P.O.	Ripley,	Research Branch, Ottawa.	VC/1964-65.
R.A.	Ludwig,	Plant Res. Institute, Ottawa.	C/1965-71.
R.W.	Longley,	Univ. of Alberta, Edmonton.	M/1965-67, I/1968.
D.M.	Brown,	University of Guelph.	M/1965-67, 1969-71, 1978-80, 1983.
D.	Elrick,	University of Guelph.	a/1965.
D.S.	Stevenson,	Res. Branch, CDA, Summerland	a/1965, M/1966-70.
A.G.	MacVicar,	CMS, Toronto.	a/1965.
F.S.	Nowosad,	Research Branch, CDA, Ottawa.	VC/1966, I/1968.
S.N.	Edey,	Agrometeorol. Sect. CDA, Ottawa.	R/1966-77, S/1978-84, S/1986-87.
V.C.	Brink,	Univ. of BC, Vancouver.	M/1966-68.
R.A.	Hedlin,	Univ. of Manitoba, Winnipeg.	M/1967-68.
J.	Maybank,	SRC, Saskatoon.	M/1967-69, I/1971.
L.J.	O'Grady,	University of Laval, Ste-Foy.	M/1967-72.
I.D.	Steeves,	NB Dept. Agric., Fredericton.	M/1967-69.
M.K.	Thomas,	CMS, Toronto.	I/1967-68.
W.	Fox,	Ont. Dept. of Agric., Guelph.	M/1968-70.
W.O.	Haufe,	Res. Branch, CDA, Lethbridge.	M/1968-70, a/1973, M/1974-79.
R.H.	Douglas,	Macdonald College.	I/1968-69, P/1970-82, C/1983.
W.	Baier,	Agrometeorol. Sect. CDA, Ottawa.	I/1968-69, S/1970-72, AC/1973-74, S/1975-77, C/1978-82.
W.K.	Sly,	Agrometeorol. Sect. CDA, Ottawa.	I/1968.
K.	Shaykewich,	Univ. of Manitoba, Winnipeg.	M/1969-71.
F.W.	Hitschfeld,	McGill Univ., Montreal.	I/1969.
J.D.	Holland,	CMS, Toronto.	I/1969, P/1970.
P.W.	Summers,	Alberta Res. Couns., Edmonton.	I/1969.
G.	Vali,	Macdonald College.	I/1969.
R.B.B.	Dickison,	Univ. of NB, Fredericton.	M/1970-71.
J.L.	Bergsteinsson,	SRC, Saskatoon.	M/1970-72, 1978-79, 1981-82.
B.J.	Findlay,	CMS, Toronto.	I/1970.

J.	Wingfield,	CMS, Hamilton.	I/1970.
K.R.	Stevenson,	University of Guelph.	I/1970.
D.A.	Pallett,	OMAF, Brampton.	I/1970, M/1971-72.
D.C.	MacKay,	Res. Branch, Lethbridge.	M/1971-72.
G.A.	McKay,	CMS/AES, Toronto/Downsview.	P/1971, 1973, I/1976.
K.	Hage,	University of Alberta, Edmonton.	I/1971.
J.	Hay,	Research Branch, CDA, Ottawa.	I/1971.
J.	McCullum,	Defence Res. Board, Ottawa.	I/1971.
F.	Mahaffy,	CMS, Toronto.	I/1971, P/1972.
H.	Morley,	Research Branch, CDA, Ottawa.	I/1971.
R.A.	Treidl,	AES, Downsview.	I/1971, a/1973, P/1974-78.
K.	Clark,	Univ. of Manitoba, Winnipeg.	M/1972-74.
W.S.	Ferguson,	Research Branch, CDA, Ottawa.	C/1972, 1975-77.
T.	Gillespie,	University of Guelph.	M/1972-77, 1981-82.
A.	Black,	University of BC, Vancouver.	M/1972-74, 1976-78.
R.L.	Desjardins,	Agrometeorol. Sect., Ottawa.	I/1972, I/1984.
W.R.	Watts,	University of Guelph.	I/1972.
R.	Shaw,	University of Guelph.	I/1972.
H.	Neumann,	University of Guelph.	I/1972.
W.R.	Wilde,	University of Guelph.	I/1972.
R.A.	Willoughby,	University of Guelph.	I/1972.
D.	Thawley,	University of Guelph.	I/1972.
J.	Mayhew,	University of Guelph.	I/1972.
A.	Bootsma,	PEI Dept. Agric., Charlottetown.	M/1973-78, a/1982, I/1984.
P.	Lavigne,	Inst. Agric. Tech., St. Hyacinthe	M/1973.
R.E.	Harris,	Res. Branch, CDA, Beaverlodge.	M/1974-76.
P.A.	Dubé,	Université Laval, Ste-Foy	M/1974-84, C/1985- .
A.L.D.	Martin,	Man. Dept. Agric., Winnipeg.	M/1975-81.
R.H.	Silversides,	CFS, Victoria.	P/1975-78, I/1981.
D.	Scott,	AES, Downsview.	I/1975, M/1977-78, P/1982.
P.	Aber,	AES, Downsview.	I/1976.
R.	Halstead,	Research Branch, Ottawa.	I/1976.
J.I.	Sneddon,	DINA, Ottawa.	I/1977-80.
J.M.	Powell,	NFRC, CFS, Edmonton.	I/1977, a/1980, P/1981-86.
R.D.	Major,	Research Branch, CDA, Lethbridge	I/1977.
R.	Trottier,	Res. Branch, CDA, Ottawa.	I/1978.
M.F.	Ronayne,	Res. Branch, CDA, Ottawa.	I/1978.
P.	Smith,	NB Dept. Agric. Fredericton.	M/1978-80.
R.G.	Wilson,	BCME, Victoria.	M/1978-79.
R.	Dodds,	AES, Downsview.	I/1978, P/1980-81.
M.O.	Berry,	AES, Downsview.	I/1978, P/1980-81, M/1982-84.
G.D.V.	Williams,	AES, Downsview.	a/1979.
R.L.	Davis,	BCME, Victoria.	M/1980-81.
M.	Bursa,	CFA, Ottawa.	P/1980-85, 1987.
D.	Chanasyk,	Univ. of Alberta, Edmonton.	M/1981-82.
P.	Dzikowski,	NS Dept. of Agric., Truro.	M/1981, 1983, I/1985, M/1987- .
R.	Williams,	BCME, Victoria.	I/1981.
M.C.	Coligado,	BCME, Victoria.	I/1981.
R.A.	Sharp,	Agrometeorol. Sect. CDA, Ottawa.	I/1982.
W.	Blackburn,	Reg. Devel., CDA, Ottawa.	I/1982, M/1983-84, S/1985, M/1986-87, S/1988.
C.F.	Shaykewich,	Univ. Manitoba, Winnipeg.	a/1982, M/1984- .
R.B.	Saunders,	AES, Downsview.	P/1982-84, a/1986.
R.	Street,	AES, Downsview.	I/1983, M/1987.

E.I.	Mukammal,	AES, Downsview.	I/1983, M/1984.
J.	McBride,	AES, Downsview.	I/1983, a/1986, M/1989-.
R.T.	Heywood,	Alberta Agric., Lethbridge.	M/1984-86.
G.	Read,	NB Dept. of Agric., Fredericton	M/1984-86, 1988.
B.	Schneller,	OMAF, Guelph.	M/1984-8.
J.	Boisvert,	Agrometeorol. Sect., Ottawa.	I/1984.
S.	Shewchuk,	SRC, Saskatoon.	a/1985.
W.	Richards,	AES, Bedford.	a/1985.
B.	Taylor,	AES, Bedford.	a/1985.
E.E.	Wheaton,	SRC, Saskatoon.	M/1985- .
M.	Letendre,	Ministère de l'Agric. Ste-Foy.	M/1985-88.
P.	Ducharme,	AES, Quebec City.	I/1986.
M.A.	MacLeod,	AES, Downsview.	P/1987-88.
J.	Harrington,	PNFI, CFS, Chalk River.	P/1987- .
W.G.	Bailey,	Simon Fraser Univ., Burnaby.	M/1987- .
J.	Masterton,	AES, Downsview.	M/1987- .
A.	Dolberg,	CFA, Ottawa.	P/1988- .
R.	Gordon,	Atlantic Region.	M/1989- .

Terms of Reference

At the request of the National Coordinating Committee on Agricultural Services (NCCAS), formerly the NACAS, the NCAM (2nd Meeting, 1961) reviewed its terms of reference and agreed on the following:

1. To consider and define the needs of Canada's agriculture for meteorological services.

2. To maintain an informed opinion on agrometeorology and to assist in the orderly development of this science.

3. To act as a coordinating body for research and development in agrometeorology.

These terms of reference provided guidance for the NCAM for the next 17 years.

From time to time the Chairmen lead discussions of the activities and role of the Committee. At the 1971 Meeting Ludwig pointed out that the CCAM (NCAM) was originally established by CASSC to promote the orderly development of agrometeorology in Canada through coordinated meteorological research and services necessary to meet the needs of Canadian agriculture. Furthermore, he emphasized that the Committee's role was strictly advisory with the aim of bringing to the attention of the parent group pertinent questions and problems that might be aired and discussed for possible solutions by the parent action group.

In keeping with CASCC reorganization in 1978, Chairman Douglas suggested that the terms of reference for the Expert Committee on Agrometeorology (as the CCAM had been renamed) should be reviewed by the 20th Annual Meeting. A subcommittee consisting of Brown (Chairman), Smith, and Robertson was named to look into this matter. The terms of reference, proposed in 1961, were found adequate and no revisions were proposed by the subcommittee.

Douglas also pointed out that in 1978 CASCC had reorganized its Canada Committee structure and developed the present system of having both Expert and Canada Committees. The ECA reported to CASCC through the parent Canada Committee on Land Resource Services (CCLRS).

The terms of reference were again reviewed at the 25th Annual Meeting in 1983 and revised as follows:

1. To serve as an advisory committee in national problems in agrometeorology;
2. To advise the appropriate authorities about them;
3. To make recommendations on which a sound national policy (on agrometeorology) can be based.

Two serious items of policy changes were discussed at the 29th Annual Meeting in 1987:

1. The Memorandum of Understanding (MOU) between CMS and Agriculture Canada.
2. Restructuring of CASCC and the Future of ECA.

Both of these items affected the future of ECA.

Blackburn, a principal in drafting the new MOU, briefed the Members of the 29th Meeting on events to date and emphasized the portion relative to the ECA. A preliminary meeting was held on 27 April 1987 with officials of CMS (Policy and Planning Division, Weather Services Directorate) and Agriculture Canada (Research Branch, Policy Branch, and PFRA) to review the existing MOU, dated 1980. Since that time a number of meetings were held involving Agriculture Canada and various units of AES. (See Ch. 4.).

A detailed draft of the restructuring of the CASCC System was presented to the 29th Meeting (1987) for review, particularly as it affected the ECA.. Edey (Committee Secretary) reviewed the current structure of CASCC based on a three-tier system:

1. CASCC as parent body
2. Canada Committees reporting to CASCC
3. Expert Committees reporting to the Canada Committees.

The mandate of the Canada Committees was, primarily, to be a source of information and to assist with priority setting on current and potential issues in Canadian agriculture as related to the services that federal and provincial governments and universities were providing to the industry. Canada Committees, on their own initiative, were expected to attempt to alleviate or prevent the development of such service-oriented problems, bringing to the attention of CASCC only those problems that were beyond their ability to resolve. The services were many and varied, ranging from regulation to research and development, and to information or technology transfer.

As background information, it was pointed out that CASCC was the national focus for the coordination of governmental and institutional agricultural services. CASCC's role centred on communication and included the prioritizing of recommendations to the various agencies involved, discussion of current and anticipated policy issues and the review and/or approval of various studies carried out on its behalf. It was not a decision-making body inasmuch as decisions rest with funding agencies.

Restructuring included a recommendation that the parent body, CASCC, be incorporated. This would give it the profile and flexibility necessary to better coordinate the total national effort toward the economic and social development of the agricultural industry, and the promotion of the optimum utilization of manpower and financial resources within and between the various operational agencies.

After considerable discussion of the new mandate and recommendations for the CASCC System, the following resulted.

1. Membership recommendations contained two requirements which were of concern to the ECA. One was that Expert Committees should consist of "experts", with the number ranging from 8 to 12 if possible. All sectors of agriculture (federal, provincial, university and private sector) should be represented on the committees. It was not intended that each province have a member on each committee.

2. A requirement that 50 percent of the membership should be from industry generated some discussion. As far as the ECA was concerned, these two requirements were in conflict: there were not enough "experts" in industry to meet the 50 percent requirement. Further, the Committee felt that if industry were given a 50 percent representation then the Committee would no longer be an "expert" Committee. It was felt that industry's interests were conveyed to the ECA through the provincial representatives and, where necessary, special subcommittees could be setup to deal with industry's specific problems.

3. Funding was another problem of concern to the Committee. The new recommendations stated that all members be funded by the organization which they represented. In the past, ECA members from provinces and industry had been unable to attend because local funds were not available. Furthermore, universities objected to providing their own funds. Therefore, it was considered that attendance at meetings would deteriorate further if all members had to provide their own funds.

4. ECA agreed that, in general, only national issues should be passed onto CASCC while others such as regional issues would be passed on to the appropriate Canada Committee or agency concerned. In some cases regional issues with a potential national interest might be referred to CASCC. Self-serving or scientist-driven resolutions were to be avoided.

5. The Chairman, Dubé, pointed out that the ECA seemed to be unique in its structure. The fact that agricultural structure varies across the country due to climatic differences, results in regional agroclimatic situations and problems needing regional solutions. Regional representation allows a recognition of this fact, which then separates out issues of national scope that may require action that is adapted regionally. It was felt that any changes leading to modification of the structure of the ECA might seriously affect its equilibrium, create a misrepresentation from regions and universities and completely change its role. If any modification were to make the Committee no longer an Expert Committee then it should be disbanded.

Chairman Dubé informed the 31st Annual Meeting (1989) that a new MOU between CDA and CMS was recently signed. A working group was established in support of the MOU. This working group coordinated activities such as subjects of mutual interest between CDA and AES.

Annual-Meeting Venue

The first twelve Annual Meetings of NCAM were held in the Neatby Building at the Central Experimental Farm in Ottawa. After several years of discussion, the venue of the Annual Meeting was, for the first time, held away from Ottawa in 1972. The University of Guelph was chosen because of the concentration there of interest in agricultural micrometeorology and agroclimatology, and because several invitations had been received from the Agrometeorological Group there.

Following the success of this meeting, others were held at other centres from time to time as shown in the following.

1972 - University of Guelph, Guelph.
1974 - AES, Toronto.
1977 - Manitoba Dept. of Agriculture, Winnipeg.
1978 - University of Laval, Ste-Foy

1981 - BC Ministry of Environment, Victoria.
1983 - AES, Toronto
1985 - AES, Bedford.
1986 - University of Laval, Ste-Foy
1987 - Saskatchewan Research Council, Saskatoon.
1988 - Simon Fraser University, Burnaby, BC.
1989 - AES, Toronto.

Problems, Activities and Accomplishments

The Chairman (Hamilton), at the 4th Annual Meeting, summarized the activities of the NCAM during the past four years 1959-63, and during the three years leading up to the formation of the NCAM. He pointed out that, although much had been accomplished, there was still a great deal to be done. Encouragement needed to be given to certain provincial governments to utilize weather information and to the CMS to give greater attention to the development of 3- to 5-day forecasts. Research in agrometeorology with particular reference to predicting crop production from meteorological data needed to be encouraged. Climatological networks needed improvement and consideration should be given to the use of climatological data gathered by agencies other than CMS. The NCAM should continue to be the coordinating body which stands behind meteorological research and services geared to meet the needs of Canada's agriculture, and in these matters continue to be the one informed body to whom anyone in Canada may turn for guidance.

Members added to the Chairman's list of problems as follows.

1. Better farm-weather services.
2. The areal distribution of rainfall over the prairies and the representativeness of a limited number of stations should be studied.
3. A network of soil moisture observations on the prairies was needed.
4. The inspection of climatological stations by CMS should be increased.
5. Extend the Swift Current research relative to soil moisture to other parts of the prairies.
6. There is a growing need for a conference or symposium on agrometeorology in Canada for researchers in this field to get together for presenting research results and discussing research progress and problems.
7. The Committee should keep a watchful eye on cloud physics and weather modification research as well as on commercial operations.
8. Air pollution problem should be watched closely and encouragement given to research on the tolerance of plants to air pollution.
9. Crop-weather relationship research should be continued in order to improve the understanding of the role of weather in crop production.
10. Standardization and simplification of equipment for measuring evaporation and potential evapotranspiration should receive more attention.
11. Installation of automatic data recorders should be encouraged.

In his introduction at the 6th Annual Meeting the Chairman (Ripley) reviewed some of the recent recommendations of the Committee. Several of these led to firm action: in particular the development of farm-weather forecasts in Alberta and Saskatchewan; and the earlier publication of climatic data, along with the publication of special agroclimatic data by the Meteorological Branch. Discussions indirectly assisted in the development of a central corps of agrometeorologists at Ottawa; the development of a graduate program in agrometeorology at the University of Guelph; and the recognition of the need for a climatological network in the South Saskatchewan River Development Area. The Committee developed and maintained an informed opinion on such topics as weather modification, hail suppression and rain making, the need for and use of long-range and extended forecasts; air pollution problems as they affect agricultural plants, and the need for various phases of agrometeorological research in Canada. Because of the Committee's policy to replace one third of its members each year and to keep former members on the mailing list for information purposes, there has developed a relatively large body of individuals with an informed opinion regarding agrometeorological matters. In this respect it was felt that the Committee was serving a very useful educational purpose.

With regard to the future of the NCAM, it was judged that it was serving a very useful purpose as a coordinating, educational and problem-recognition group. Considering the number (11 in total) of recommendations arising from discussions, it was thought that there would be enough follow-up work for the Committee in the future, even if no new problems arose. Since the interests of the Committee covered, not only research problems, but also service and educational problems involving the interests of the CMS and the provinces, it was deemed logical that the Committee should continue to be directly responsible to CASCC.

The several recommendations made at the 6th Annual Meeting (1966) were discussed in some detail at the 7th Meeting. It was disconcerting to note that, of the 11 recommendations made by the NCAM in 1965, only three were acted upon fully; five received some attention or action; and three received no attention at all. The Committee felt it might have erred in addressing some of the recommendations to the wrong groups. In other cases, there was insufficient follow-up. The Acting Chairman, Nowosad, stressed the need for increased "toughness" in regard to suggestions and recommendations,. He suggested that a more vigorous follow-through attitude was an increasing committee responsibility. The need for a continued annual meeting was essential in order to keep members current and to provide policy cohesion and correlation of Committee functions.

The 8th Annual Meeting (1967) of the NCAM was chaired by Ludwig, the first meeting to which he was able to devote full time. In his opening remarks he made the suggestion that the NCAM should become a Research Branch Committee, "thus allowing the Committee to report to the Director-General of the RB/CDA". This was thought, by some, to be a retrograde step. The Research Branch was primarily concerned with research and had no mandate to undertake service work. Thus, it was thought that problems relative to such services as farm-weather forecasts, agroclimatic networks, observations and data management and other service work would suffer under such an arrangement. Furthermore, the contact which the NCAM enjoyed with provincial authorities, educational institutions and other agricultural groups through CASCC would be lost. However, the majority of the Committee felt that a more solid influence and diversified character, resulting from association with the Research Branch, would prove of benefit to the NCAM. The Committee agreed that Ludwig should discuss such a change-over with the Director-General and, if agreeable, make such a recommendation to CASCC. Membership should continue to be diversified and include representatives from other disciplines. The suggestion was not supported by either the Branch or CASCC.

At the 9th Annual Meeting (1968) the subject of agroclimatic analysis was singled out for special discussion. Because of its special nature, the membership of the meeting departed somewhat from tradition. A number of non-members with an interest in the subject were invited to attend the meeting and participate in the discussions (see Membership List, above).

This topic and the procedure for handling it prompted some comments on the overall policy and goals of the NCAM. The idea appeared to have a number of good points and it was decided that a series of topics involving practical farm-weather problems should be the focal point for the next few years with one topic being highlighted at each annual meeting. It was suggested that by such action the NCAM could present material and recommendations in support of singular topics that could be used by various agencies (CMS, RB/CDA, universities, and so forth) for formulating both short- and long-term operating goals and plans. This idea was not a new policy or goal, only a more effective way of achieving one of the original terms of reference of the NCAM, viz. "To consider and define the needs of Canada's agriculture for meteorological services".

During the next four meetings a series of position papers or themes were discussed:

1969 - Weather Modification.
1970 - Freezing Temperatures, Farm-Weather Services.
1971 - Pollution, Communication.
1972 - Micrometeorology.

When Ludwig stepped down as chairman following the 1971 meeting he had completed seven years of fruitful work. Ferguson, chairman of the 1972 meeting, commended him for his interest and ability in providing an input from the areas of both research and extension to past CCAM meetings. His introduction of special topics in 1968 within the framework of the NCAM/CCAM that led to the preparation of position papers and their subsequent publication was given special note. These papers provided substantial material for discussions and resulted in positive and concrete conclusions and recommendations by the meetings.

Following a discussion at the 1972 meeting of the future role of the CCAM, it was concluded that regional problems should be emphasized at future meetings. Such regional problems should be the basis for national problems, and consideration and recommendations by the Committee would add credence to the recommendations, and strengthen requests for support at both the regional and national levels.

In his opening remarks at the 14th Annual Meeting (1973), Baier stressed the need and importance of a strong provincial-federal relationship that was vital and necessary for the proper functioning of the National Committee. It was proposed that the objective of the next three meetings should be Regional Problems and Priorities, covering the following topics:

1. Crop-Yield Prediction.
2. Pest and Disease Control.
3. Harvest Operations.
4. Soil-Water Management.
5. Ecosystem Assessment.
6. Special Weather Forecasts.

In reviewing the past activities of the CCA (formerly CCAM, NCAM) in 1974, he pointed out that past activities could be separated into three fairly distinct phases. During the first phase, covering a span of several years, the Committee zeroed in on problems relating to climatic networks, education, the supply of trained agrometeorologists, the development of a central corp of agrometeorologists, the provision of farm-weather services, and the encouragement of cooperation between provincial and federal groups or agencies. The second phase, again covering several years, related to technical studies of individual problems associated with Canadian agriculture. These studies resulted in several position papers, e.g. weather modification, pesticide pollution, etc., which were published and which were well received in research circles for their value as review papers. In the third phase, that included up to the 15th Meeting, attention was focussed on applications or operational aspects of user groups including, not only farm operators, but also extension or agricultural representative groups. This third phase involved the recognition and isolation of regional priorities and the development of a national program in

agrometeorology. To this end, the theme of the 15th Annual Meeting was the formulation of a "Strategy for Effective Agrometeorological Activity in Canada".

Some discussion continued on this theme in 1975 and three new topics were added:

1. Forest Meteorology.
2. Weather/Climate and the World Food Situation.
3. Land Use Evaluation.

Ferguson chaired the 16th Annual Meeting (1975) of CCA, which was held in Ottawa. Dr. B. Migicovsky, Director-General, RB/CDA gave the opening remarks and formally welcomed the members and invited participants. This was the first time in the history of the CCA (or NCAM) that a Director-General from Agriculture had addressed the Annual Meeting.

Migicovsky briefly outlined the role of CASCC and the advisory functions of the 16 Canada Committees of which CCA was one. In addition CASCC received advisory input from the Canadian Agricultural Research Council, composed of representatives from federal and provincial departments of agriculture, other government departments, deans of the faculties of agriculture, and representatives from the agro-business community. The secretariat is provided by CDA. He also explained the new "make or buy" policy of the government and noted the extension of the program to include universities and industry. This allowed for total funding of approved studies or projects to universities, which was in contrast to the past operational-grant system whereby only partial funding was available.

Climatic Variability in Relation to Agricultural Productivity and Practices, a very timely and important topic, was the main theme at the 18th Annual Meeting (1977) of CCA, held in Winnipeg with Ferguson in the chair.

Several changes in the policy and membership took place at the 19th Annual CCA Meeting in 1978. The Chairman, Ferguson, passed away suddenly and Baier served as Acting Chairman. Baier reflected on Ferguson's past work, both as a researcher and an administrator, his dedication to the research community and particularly, his guidance as Chairman of the CCA. The Chairman noted that CASCC no longer recommended on committee appointees, preferring to leave the decision to the provincial authorities involved.

Baier outlined the recent administrative changes within the Research Branch. As of 1 April 1978, the Branch would operate under a three-region (East, West and Central) system with an Associate Director-General (ADG) responsible for each region. This would be the first time that CDA ADG's were positioned outside Ottawa. This regional approach would provide much greater flexibility for resolving local problems. All financial, research and operational functions would be exclusively controlled by the region in question.

Dr. Fleishmann, the ADM of the new Policy and Planning Branch, and the acting ADM of the Research Branch addressed the meeting. He explained the new regionalisation by the Research Branch administration and how this was expected to enhance Branch performance relative to staff, physical resources and problem-solving ability.

Coinciding with the changes in the branch structure, a reorganization of the role and operation of the Canada Committees system was made. In the future, seven Canada Committees supported by a number of Expert Committees, would report directly to the parent group, CASCC. The reorganization was to take place over the next two years. The new system was designed to improve and maximize the advisory aspects now supplied by the CASCC to Canadian agriculture. The Expert Committee on Agrometeorology (effective September1978) would assist those other Expert Committees with input into the Canada Committee on Crop Production Service.

Baier was named chairman at the 20th Annual Meeting of the Committee, which was now called the Expert Committee on Agrometeorology (ECA). He was still head of the Agrometeorology Section of the Land Resource Research Institute and also Assistant Director of the Institute. This was the first time since the establishment of the Committee that someone below the office of Director had been permanent Chairman of the Committee. Edey was named secretary to replace Baier, and the position of recording secretary was abolished.

Due to the reshaping of the Canada Committee system, it was necessary to schedule a second meeting in late 1978 instead of early 1979. This meeting was held 13-14 December 1978 at University of Laval. Physical arrangements were made by Dubé.

A priority list of agrometeorology problems was considered at the 20th Meeting held in 1978. This item was first discussed at the 13th Annual Meeting (1972) and at several meetings since then. After considerable discussion the following list of six items was prepared, all of which had the same priority.

1. Meteorological soil-water budgeting.
2. Weather-based crop yield predictions.
3. Determination of precipitation patterns from remote sensing.
4. Long-range atmospheric transport of pollutants, spores, and insects.
5. Impact of climate variability on agriculture and forestry.
6. Weather scheduling of pest control.

Baier chaired the 22nd Annual Meeting (1980) while on temporary assignment to Research Coordination. For the first time in the history of the Committee a representative attended from The Canadian Federation of Agriculture (CFA). Baier reviewed some changes in the operation of CASCC. A General Services Section (GSS) of CASCC was set up to make a pre-meeting screening of recommendations by committees before these were presented to CASCC, but the latter was under no obligation to the former.

With the introduction of the new Agri-Food Strategy for Canada, the 23rd Annual meeting (1981) was told that agrometeorology was expected to make a significant contribution to many programs both national and international. However, there was a serious lack of emphasis on the climate and weather component relative to the Strategy. The meeting considered that lack must be remedied through more research and technology transfer by pertinent agencies, particularly Agriculture Canada itself. Bursa, CFA, expressed concern over the lack of agrometeorological input in the Agri-Food Strategy considering the very significant increase in production goals specified in the document. It was agreed to indicate to CASCC this very obvious shortcoming in the Strategy.

Several members commented on the status of professional positions in their respective provinces. It was encouraging to note that BC, Alberta, and Saskatchewan were attempting to fill existing positions. All concurred that staff must exist prior to any demonstration of agrometeorological potential in problem-solving situations in connection with the Agri-Food Strategy.

Regarding the staffing situation, Baier pointed out the critical situation relative to agrometeorology in Canada. This situation was dramatized through the loss of two agrometeorologists in the Atlantic Region. Such positions were established only through many years of effort on the part of ECA, and their loss should not be taken lightly..

The 25th Annual Meeting (1983) was unique in several respects. It was held at CMS headquarters in Toronto, the second time for this venue. For the first time in the history of the Committee the chairman, Douglas, was a non-staff member of the Research Branch, CDA. Also, for the first time in the history of the Committee, there was no representation at the meeting from the four western provinces due to financial restraints.

Regarding appointment of new members it was noted that seven members now had served three or more years. New appointments were needed as the Committee needed fresh blood and new ideas.

In his opening remarks, Douglas reflected on the past 25-year history of the ECA (a.k.a. NCAM, CCAM, CCA). In particular he reflected on the role and significance of position papers produced by the Committee in the past (see the section Major Documents Arising from Theme Papers, below).

Members of the 30th Annual Meeting expressed concern over the difficulty in creating visibility for agrometeorology in both the provincial and national committee systems. Concern was also expressed that no ECA member attended the Toronto conference "The Changing Atmosphere: Implications for Global Security" held June 27-30, 1988. This lack of attendance was considered significant given that the ECA's national role was most certainly related to issues raised at the conference.

Dr. Olson, Manager of CASCC, chaired a special meeting, in 1988 to review improvements in the CASCC System. Canada and Expert Committees were asked to respond to these proposals.

Some of the issues considered by ECA were as follows.

1. It was proposed to change the name of "Expert Committee" to "Advisory Committee". The Committee felt that "Advisory Committees" were designed to provide general guidance and, by definition, are not necessarily experts in the discipline. It was agreed that the name "Expert Committee on Agrometeorology" be maintained.

2. It was proposed that the membership of committees be increased to not less than 25 percent from industry. ECA favoured representation from industry but noted the difficulty in identifying individuals in the private sector that are experts in agrometeorology. Further, the ECA suggested that the federal Deputy Minister could identify potential appointees from the private sector such as in the areas of livestock, grains, and fruit/vegetables. It was agreed the ECA would support representation of industry up to 25 percent, but not at the expense of replacing existing representatives.

3. ECA members from universities again reiterated the need for CASCC to cover travel expenses incurred for participation in ECA meetings.

The 31st Annual meeting of the ECA was held at the Atmospheric Environment Service, Toronto, Ontario on October, 1989. Mr. Brian O'Donnell, Regional Director-General for AES Western Region welcomed the Committee. Dubé was Chairman and Masterton, Secretary.

The Chairman briefed the meeting on the results of the most recent meeting of the CASCC Committee on Land Resource Services. Membership issues were clarified by the Chairman. Industry participation to the extent of 25 percent applied only to CASCC membership, not to the Expert Committees. CASCC financial support applies to universities only, not to provincial representatives. The name of the Committee would remain the same, i.e. ECA.

Major Documents Arising From Theme Papers

1968 - Climatological Services for Resource Development Planning in Agriculture.
1969 - Freezing Temperatures in Canada.
1970 - Weather Modification: A Survey of the Present Status with Respect to Agriculture.
1971 - Meteorological Aspects of Pollution in Relation to Agricultural Pesticides.
1977 - Climatological Variability in Relation to Agricultural Productivity and Practices.
1981 - Requirements and Availability of Agrometeorological Data in support of Agriculture.

Several of these reports were very well received both nationally and internationally.

PART 4 - AGROCLIMATIC DATA

This Section deals with the activities of the NCAM in the betterment of the existing CMS climatic networks, the additions to this network of special observations of immediate concern to agriculturists and the improvement of the content and availability of data in the climatic archives, particularly for electronic data processing (EDP).

The CMS Climatic Network

The Subcommittee on Agroclimatology, appointed at the 1st Meeting, presented a report at the Second Meeting (1961). It was recognized that there was a need for CMS to improve the availability of climatic data across the country, including increased station density, improved quality of reports and earlier publication of data. The use of unofficial reports (such as those of the Searle Grain Company) was also discussed (see "Unofficial Observations", below).

It was suggested that bench-mark stations be established to offset the effects of urbanization and station relocation on long-term climatological data. These stations should be selected both for their permanency of location with ideal exposure and their continuity of record. They would form the basis for a continuing climatological network.

Station Inspection

The 1962 Annual Meeting also considered the problem of inspection of climatological stations. It was noted that in some cases, stations had not been inspected for four or more years. Equipment and exposure were deteriorating and observers were becoming disinterested and incompetent. It was suggested that climatological stations should be inspected at least once a year by the CMS. To help with station inspection matters, the use of climatological data, and the need for more stations, it was suggested by the Committee that local or regional committees be set up to keep a closer watch on the regional climatological networks.

Unofficial Observations

The Subcommittee on Agroclimatic Observations, appointed at the First Meeting, reported to the Second Meeting (1961) that there were numerous seasonal observations, particularly of rainfall, that would be useful to agriculture, but were not recognized by the CMS, and were not readily available. These are taken by forestry stations, grain companies, power corporations, and so forth. Their number was reported to exceed the number of official stations operated by the CMS. It was agreed that discussions should continue with the CMS on how to make use of these secondary stations, and make the information more readily available.

Malaher reported to the 4th Annual Meeting (1963) that detailed geographical observations of rainfall were most important in following the production and marketing of wheat and that historical records were useful for certain economic and probability analyses including crop insurance. He reported that some 500 Searle Elevator Agents throughout the prairie grain growing area took daily rainfall observations during the period April 1 to October 31, and sent these to their head office in Winnipeg.

Barks reported that composite rainfall maps were being prepared for the Maritimes making use of official Meteorological Branch data plus observations from other agencies such as forestry and hydrology. In this connection the NCAM (1963) established a special Subcommittee on Unofficial Observations consisting of Toogood (Chairman), Hill, and Anstey. A lengthy report was prepared by Toogood and Anstey on the matter and presented at the 5th Annual Meeting (1964). The reports were informative but no definite recommendations were forthcoming. Apparently CMS and the Searle Grain Company were discussing the matter.

Malaher reported to the 6th Annual Meeting that a third precipitation report would have to be prepared by agents to send to the CMS. This would be too much for many agents who already prepared one report for the Searle Company in Winnipeg and another for local newspapers, consequently any hope that CMS would collect and publish the data died.

Work undertaken for ARDA and the CLI had made extensive use of existing climatic data and in many cases special climatic networks had to be established for certain studies. A good example was the work by the BC ARDA group in mountainous areas.

The 8th Annual Meeting (1967) considered a report on "The Climate Network and Natural Resources Management" prepared by J.R. Marshall of the BC ARDA Agroclimatic Group. This group had made extensive use of climatic data in British Columbia and had established some 400 climate stations to supplement the CMS network. This had provided an opportunity to take a critical look at the data available from existing records of the CMS. The group prepared five recommendations that can be summarized as follows.

1. Evaluation of the representativeness, homogeneity and quality of long-term records.

2. Stations with acceptable records should be established as benchmark stations. Others should be relocated.

3. All climate data ever collected in BC should be entered on punch cards or magnetic tape and lodged at an convenient location in the province for local use.

4. A provincial inter-agency committee should be formed to function as a Climate Data and Network Control Board.

5. The feasibility of a technician-operated automatic network should be investigated (see "Automatic Weather Stations", below).

As the project was now winding down there was concern for the future of the 400 stations established by the ARDA Project. These were not a continuing responsibility of ARDA. The feeling of the NCAM was that the more important stations should be continued and that the network should be broadened to cover the major areas of resource potential in BC.

McLeod reported on the CMS position regarding the ARDA climatological networks in British Columbia at the 10th Annual Meeting. The Pacific Regional Office of CMS was reviewing the network with the intent of making use of the expertise gained by personnel in the operation of autographic stations in remote mountainous areas.

Publication of Climatic Data

During the war years the publication of daily climatological data on a monthly basis in the "Monthly Record of Meteorological Observations" had fallen severely behind schedule and updating the information was progressing painfully slowly. The Subcommittee on Agroclimatic Observations reported on the matter at the 2nd Meeting (1961). They noted that a number of agricultural research establishments now took a fairly complete set of observations of interest to agriculturists but that these were not published soon enough for practical use. It was suggested that the CMS consider publication of these data within six to eight weeks following the end of the month in which they were taken.

The Subcommittee also noted that the CMS had equipped several agricultural research establishments and other climatic stations for taking soil temperature, water content of snow, and precipitation intensity.

The NCAM commended CMS for its efforts in this regard and suggested that they continue to consider the publication of the information so that it would be readily available to those requiring it.

The 3rd (1962) Annual Meeting of NCAM was gratified to learn that the CMS had made several changes in data publication. Plans were completed for a new publication "The Canadian Weather Review" to replace "The Monthly Weather Map". The "Monthly Record of Meteorological Observations", that contained daily data, was being published earlier. Bilingual titles and text were added to all publications.

The monthly publication of the special daily agroclimatic data taken at CDA establishments was still under consideration. The need for such a publication was again discussed at the Third Meeting and it was suggested that a separate publication, to be available six to eight weeks after the end of each month, was desirable. Data from a few provincial agricultural stations and agricultural colleges should also be included. It was pointed out by CMS that such a separate publication would be costly, but they opposed the inclusion of such information in their regular publications.

In November 1962, Hamilton and Robertson met with officials of the Meteorological Branch (McTaggart-Cowan, Boughner and Thomas) to discuss the publication of observations taken at agricultural research establishments. As a result of these discussions the Branch agreed to include monthly data from these stations in their "Monthly Weather Review" which would be released two to three weeks after the end of each month. Daily observation from these establishments would appear in the Monthly Record which would eventually be published with a lag of six months. Data to appear would include the following.

1. Grass minimum temperature.
2. Depth of snow on the ground.
3. Dew-point temperature.
4. Total daily wind mileage.
5. Maximum hourly wind with direction.
6. Latent evaporation (Bellani plate).

Considerable expense was involved in taking these observations and it was agreed that they should be made readily available to all who might have a use for them. Good progress was made over the next two years, and it was announced at the 5th Annual Meeting (1964) that the publication of the monthly records was up-to-date as planned. However, no progress was made in undertaking the publication of observations taken at agricultural research establishments as recommended by the NCAM.

Finally in 1967 after six years of negotiations, the Eighth Meeting noted with gratification that the CMS had launched a new publication entitled "Daily Agrometeorological Data" (DAD). Robertson outlined the physical attributes of the publication that involved 16 factors at 40 research establishments across Canada. The first number was issued for observations taken in January 1965.

This publication continued for 8 years when the 15th Annual Meeting (1974) was informed that, for financial reasons, CMS decided to discontinue the publication of "Daily Agrometeorological Data". The final issue was for September 1973.

Edey presented two papers to the 15th Annual Meeting concerning daily agrometeorological observations, viz. "Daily Agrometeorological Data" and "Discontinuation of the Observational Form 63-2310." This form had been designed for the purpose of reporting observations in a format suitable for transfer to magnetic tape and eventually for publication.

Much of the data reported on CMS Form 63-2310 and published in DAD would be collected and published by CMS by other means. However, records of three elements: grass minimum temperature, wetting duration and total wind run were in danger of being lost. All three elements were consider vital by CCA, and the recommendation was made that the Chairman make representation to CMS for an alternative means of maintaining a permanent record of these three environmental factors.

Special Agrometeorological Observations

At the Fifth Annual Meeting (1964) the Meteorological Branch asked agriculture to put its requirements for observations of certain climatological factors on paper. In particular there was concern about requirements for wind information near the surface, for extension of the present soil temperature network, and for publication of agroclimatic data in the official record. It was pointed out that 16 stations in Canada were now equipped to take soil temperature observations. The Meteorological Branch was prepared to equip 6 more and wanted recommendations. The monthly publication of daily information from agricultural establishments was not yet settled. The NCAM decided to appoint a subcommittee to look into these matters. Members were W.L. Pelton (Chairman), K.M. King, J.S. Leefe, G.W. Robertson, and G.-O. Villeneuve. The report of the subcommittee was presented to the 6th Annual Meeting (1965) and, along with MacVicar's Report, formed the basis for a lively and lengthy discussion of requirements for agrometeorological observations. Topics covered included the inadequacy of climatological data, including precipitation and temperature networks, sparsity of stations in certain areas such as northern Alberta, observations of special factors such as soil moisture, soil temperature and evaporation, the inadequacy of data on punch cards, and the lack of analysed information in tabular and map form.

However, it was also pointed out that possibly better use of existing data could overcome some of these problems. For example, soil moisture might be estimated from precipitation and evaporation data, and soil and crop characteristics, rather than by establishing a more expensive and time-consuming network of soil-moisture observing stations. Similarly, for soil temperature measurements it might be possible to use simple climatological measurements together with soil physical properties to develop techniques for estimating soil temperature with suitable accuracy for many agroclimatological purposes. Such research, of course, would required adequately trained agrometeorologists.

The observation of weather elements other than rainfall and temperature were discussed from time to time. Research people had experienced difficulties with data, or lack thereof, for wind speed, snowfall, dew duration, soil water, and soil temperature (see the following Section). The Subcommittee on Agroclimatic Observations (appointed in 1961) reported on some of these matters. Wind speed was particularly troublesome because, although the standard height for anemometer exposure was 10 metres, CMS instruments were exposed at a height of convenience. For agricultural purposes it was desirable to have measurements at 2 metres, nearer crop level.

In connection with wind observations, there are so many characteristics to be measured and so many uses for them that it was decided that only a minimum requirement would be sufficient to characterize the wind for a day for agroclimatic purposes. In this regard it was recommended that wind be measured at two metres and only three characteristics be observed for agroclimatic and publication purposes: the total run for the day and during daylight hours, and the hourly maximum wind speed with direction.

CMS was encouraged to pursue studies of instrumentation for the measurement of soil water and near-ground (2-metre) winds. Finally, CMS reported to the Seventh Meeting that equipment would not be provided for wind observations near the ground for agrometeorological purposes. They would publish, however, data from stations that supplied their own equipment.

Snow measurement was another problem brought to the attention of the Eighth Meeting (by Steeves). Since this was of primary concern to agriculture, Robertson was of the opinion that CMS would not do anything about the matter until agriculture had stated its exact requirements. A small subcommittee consisting of O'Grady (chairman) and Steeves was established to study the matter. A report was presented at the Ninth Annual Meeting. This was based on a somewhat limited survey of the problem. It appeared that snowfall measurements were considered useful for certain agricultural purposes but that their use was dubious. It was suggested that studies of the effects of ice-sheets on plant survival and the penetration of snow-melt into the soil might illustrate whether or not snowfall measurements have a practical meaning. It was pointed out by Robertson that there were several methods for measuring depth of snowfall, for determining its water content, and for measuring the depth of snow lying on the ground.

These had not been investigated by the committee. After some discussion it was agreed that measurements should not be discontinued and that serious study should be made concerning use of snow-depth data and the improvement of measuring techniques.

Soil Temperature

The CMS soil-temperature network was started in 1959 through the initiatives of Robertson and the NRC Associate Committee on Snow and Ice to meet the interests of agriculture and others. Originally eight stations were supplied with special equipment (Potter, 1962).

Although soil-temperature observations had been discussed at earlier Meetings, the 5th Annual Meeting (1964) established a subcommittee to look into this matter as well as other observations of interest to agriculture. CMS had asked for recommendations regarding the placement of 8 additional sets of soil-temperature measuring equipment. After discussing the subcommittee's report on the matter the NCAM recommended that an additional observation be taken at 300 cm, and proposed additional sites at Saanichton, Agassiz, Lethbridge, Lacombe, Regina, Brandon, Vineland, Lennoxville, Leamington, and St. Augustine.

At the 7th Annual Meeting (1966) it was learned that the CMS now had 36 soil temperature observing sites across Canada, and expected to increase these by about 5 sites a year. They were acting on the committee's recommendation and adding a 300-cm level to all new equipment.

Seventeen years later the 25th Annual Meeting (1983) was asked to review the requirements for soil temperature measurements with the objective of reducing the expense of the operation. At this time there were 69 stations in the network according to a 1982 census. Many of these were at CDA research stations. Measurements were being made at 7 depths ranging from 5 to 300 cm. Installation, maintenance and data control constituted a costly operation. Mukammal of CMS pointed out the need for detailed soil-temperature measurements, and noted that WMO recommended measurements at a minimum of 6 depths, viz. 10, 20, 50, 100, 150 and 300 cm.

The secretary made a survey of interested agricultural agencies as well as members of ECA, and of the Expert Committees on Soil and Water Management and on Soil Survey as to their requirements for soil temperature data and the adequacy of the network. The Quebec Group through Dubé was the only agency to comment on the program at the next Meeting in 1984. Rather than shelve this important matter the members felt that the topic should be brought forth for discussion again at the next meeting. The Secretary made another request for comments and Heywood (Alberta) presented the only new viewpoint at the 1985 meeting, expressing the opinion that it was desirable to maintain the present measurement depths although some consideration to reduce the frequency of measurement at certain depths might be given. The ECA generally supported the existing soil-temperature measurement network.

Availability of Climatological Data in Digital Format

The availability of climatological data on punch cards was discussed at the 8th Annual Meeting (1967). Thomas explained that the CMS now had 60 million cards in its card library and that these were increasing at the rate of 600,000 cards per month. Space was becoming a problem. The provision of cards to outside users was also a problem. Requests currently surpassed the rate of duplication of 25,000 per month. The current "free" system of providing cards to users had fallen prey to irresponsible requests, consequently a system where the user pays a service fee was warranted. Such a program would eliminate irresponsible requests and place priority determination where it belongs, with the user. It was suggested that a central service bureau might be established for the sole purpose of providing a card library service. This might be accomplished on a regional basis.

The accessibility of on-line data was referred to during the presentation of a report by Haufe on Ecosystem Assessment at the 18th Annual Meeting (1977). The feasibility of using hourly observations from first-order stations of the CMS was discussed. Although all such data were transmitted by computer networks, accessing the data would be costly. Furthermore, the observing-station network was not considered sufficiently dense in the required areas for such purposes as integrated pest-management and crop-weather condition monitoring.

Complementary Data Networks

McKay presented a report on climatic data and their suitability for agricultural purposes at the 1971 meeting. The purpose of the national climatological network was to measure the broad-scale features of the climate of Canada. For many research purposes there was a need for complementary networks that measure crop-scale factors. It was pointed out, furthermore, that the analyses of climatological data must carefully consider certain topographical features such as frost pockets, otherwise gross errors may be made in data interpretation. After some discussion it was agreed that McKay and Edey should prepare a discussion paper on complementary crop-scale meteorological networks and data, and indicate relationships to macroscale information.

Complementary networks was the major topic for discussion at the 13th Annual Meeting (1972). Ten speakers contributed material in preparation for discussion of the topic. McKay, Treidl, and Mahaffy elaborated on the distinguishing features of the national climatological network, mesoclimatic networks, and microclimatic networks. Edey described the special features of the agroclimatic network of CDA. Watts discussed the microclimate and biological programs being undertaken by the Agrometeorological Group at Guelph, and distinguished between the objectives of physicists and meteorologists who study the influence of plants and crops on the microclimate, and of plant physiologists who study the effect of the microclimate on plant-growth processes. Wilde pointed to the specific requirements for studying the influence of weather on plant pests and pest control. Willoughby, Thawley and Mayhew identified the special problems encountered when relating microclimates to animal diseases. Gillespie related the specific requirements needed to study the effect of leaf wetness on plant-disease forecasting. The minutes of the meeting indicate neither the results of discussions nor that any recommendations were made.

Availability of Agrometeorological Data for Research

Six years later, at the 20th Annual Meeting (1978) Bergsteinsson suggested that the topic "Requirements and Availability of Agrometeorological Data in Support of Agriculture and Forestry Programs" be the theme for the next meeting. At the 21st Annual Meeting he introduced the topic by pointing out that, rather than discussing only climatological input, consideration should be given to phenological information and related biological matters, in addition to basic landscape factors such as physiography, drainage, elevation, and soils. Before the 21st Meeting the chairman of ECA, Baier, wrote to members for a statement on their thoughts on the matter. He had provided guidelines and a sample format to follow. Several replies were received for discussion at the 21st Meeting. It was proposed that a position paper be prepared on the topic.

Berry discussed the proposed position paper at the 21st Annual Meeting in 1979. He was well acquainted with the topic as he was a member of CAgM/WMO working group on the same subject. The working document for this working group had been prepared for WMO by Robertson a few months earlier.

Berry took exception to the suggestion that crop surveillance by satellites and resource information systems based on remote sensing should be of direct concern to agrometeorology. Instead, such activities should be considered only as complementary to agrometeorology, when used as a tool for measuring soil water, soil temperature, crop phenology assessments, and so forth for real-time applications in crop-weather models.

He agreed that a "data-bank for the future" might require extensive information. However, it should be kept in mind that there must often be compromise between apparent data needs and availability. Trying to meet the precise data needs as specified by the user may turn out to be quite costly or impractical. Perhaps somewhat different data that are readily available could meet the needs almost as well, or the user might have to tailor his procedures to make use of whatever data are available. In particular, cost and other considerations often place constraints on the extent to which needs for additional data can be met by expanding weather observing networks. Remotely sensed data and methodology for interpolating from current observation sites must be considered carefully as alternatives. Considerable development work would be needed to realize the potential of these methods. (Note that this same topic had been discussed earlier in 1964-65, see "Special Agrometeorolgical Observations", above.)

The suggestion of ECA that mathematical modelling of biophysical processes was considered good, but it would initially require short-period measurements of intricate and complex meteorological factors that are at present unavailable, and could not be estimated from simple climatological data. It was suggested that such sub-models incorporated into larger yield-production models might be derived from simple observations.

He pointed out that several agencies, including CMS and CDA, were considered likely to be involved in data collection and interpretation. CMS could provide the climatological data and could also be involved in climatic impact studies. CDA would be involved in the agricultural interpretation of the data. Macroscale users of data would include the Science Council of Canada, departmental task forces, and federal and provincial government committees dealing with policy and long-range planning. Agencies interested in mesoscale analyses would included provincial and regional land-use planners and zoning authorities. Users at the local-scale would include the provincial agricultural extension personnel who provide advice to farmers.

The position paper was presented and discussed at the 22nd Annual Meeting (1980). After some discussion it was agreed that Provincial Committees (PAMC) should be approached for their views on what should be developed in their own areas of interest. It was further agreed that Drs. Macdonald and Dumanski of the Land Resource Research Institute, CDA, should be approached to prepare reviews of landscape and biological data. Their reports were presented at the 23rd Annual Meeting in 1981. Five provinces provided material in response to the Chairman's request. After considerable discussion it was decided that the Secretary, Edey, should edit the report and circulate it. After being evaluated by the Climate Advisory Committee, The Climate-Data Committee, The Farm-Weather Services Committee of CFA, and the chairmen of the regional or provincial agrometeorological committees, the report was finally published in 1982.

Automatic Weather Stations

The problem of automatic weather stations appears to have been first raised in the Committee by the BC ARDA Agroclimate Project report to the Committee in 1967 (see "Unofficial Observations", above).

The 8th Annual Meeting considered this new problem of automatic weather stations. The BC ARDA/CLI program needed equipment in remote mountainous regions to supplement some 400 observing sites that had been established in the less remote areas. Suitable automatic climatic observing stations were not available at the time, and it was suggested that the CMS consider the development of suitable equipment. An ad-hoc committee (Brink and Maybank) studied the problem and made the following suggestions for CMS consideration:

1. To examine the philosophy behind the climatological station network with the view to improving its density and the methods of obtaining, storing and analysing data.

2. To develop suitable recording equipment for remote stations. The equipment adopted should be reasonably accurate, however reliability under all weather conditions should take precedence. It

should be capable of operating for periods of at least a week and operate on a multi-power source basis. The data readout should be flexible but relatively cheap, and include daily maximum and minimum temperatures and precipitation.

3. Examine the need for appointing technicians to service and maintain such equipment and any revisions to it.

Automatic weather stations were again discussed a the 27th Annual Meeting (1985), particularly in reference to the collection of routine agroclimatic data at Research Branch Stations. Manual observations were labour intensive and, because of financial constraints, it was feared that climatological observations might be discontinued at certain locations or, alternatively, that they might be replaced by inadequate automated weather stations. ECA expressed concern that this conversion might create a risk of discontinuity in the data record as compiled by CMS, due to the lack of adequate guidelines for installation, and suitable sensors. Consequently, the ECA encouraged either the adoption of alternative, acceptable sensors, or the acceleration of development of suitable sensors subject to the standardization established by AES.

After considerable deliberation of these matters, the committee chairman established a sub-committee on automated data acquisition with the mandate to draft a report on data standardization and automated data acquisition for real-time networks, and to develop guidelines regarding equipment type and accuracy for data acquisition in automated systems. Membership: King (chairman), Shewchuk and others to be appointed by the chairman.

The 1986 Meeting considered a report from King on this matter. It was noted that CMS began cooperative tests of autostations in September 1986. Data loggers currently in use meet CMS standards. The one remaining problem is the lack of satisfactory sensors for monitoring such agroclimatic events as hours of bright sunshine, daily snowfall, and depth of snow on the ground. The subcommittee noted encouraging progress by the CMS over the past year in the formulation of the requirements of climate data logging systems and in developing policies, procedures and systems for data processing, archiving and accessing the data obtained from autostations. Further progress was expected during the coming year.

The report noted that, although data loggers are now sufficiently reliable for autostations, sensors are not. Progress in development and certification of appropriate sensors for autostations over the next several months was expected, and significant progress was expected over the next year towards the establishment of a national code for ensuring the requisition and handling of climatic data of high quality from automated stations.

The Committee expressed concern about the rapid introduction of autostations and the resulting effects on data continuity and the inability to access, on a real-time basis, the standard climatological data (maximum and minimum temperatures, precipitation, etc.) required for special agroclimatic programs. A letter of concern was sent to CMS asking them to carry out tests on commercially available sensors.

King tabled a final report on this topic at the 30th Meeting (1988). This report addressed proposed reporting requirements for standards for air temperature, soil temperature, precipitation, snow on the ground, incoming solar radiation, hours of bright sunshine, wind run and maximum wind speed and direction. The Committee agreed to publish the report, after some revisions, as an ECA Technical Paper.

PART 5 - FARM-WEATHER SERVICES

Experimental Farm-Weather Forecasts

Experimental farm-weather forecasts were discussed at the First Annual meeting of NCAM, It was suggested that such forecasts be prepared and issued cooperatively by the CMS and agriculturists from the provincial departments of agriculture. The Alberta Department of Agriculture, the Saskatchewan Research Council, Macdonald College, and the Moncton Aviation Meteorological Office conducted the first experimental agricultural weather forecasts.

At the 2nd Meeting (1961) it was noted that the experience gained from experimental farm-weather forecast established that existing weather-service facilities were capable of supporting substantially improved forecast services for agriculture through the participation of dedicated agriculturists receiving only brief on-the-job training. Macdonald College discontinued its one-season experimental project. This demonstration project was well received but the province was not ready to continue with the service.

The Committee repeated its recommendation for these experimental forecasts and encouraged the CMS to develop a three- to five-day forecast service for agricultural areas in Canada.

The 1962 Annual Meeting learned from Toogood that Alberta was the only province providing provincial support for the farm-weather forecasts. It appears that other provinces were not interested because of financial restraints and the fact that the CMS provided a public weather service that was becoming more and more geared to farmers' requirements, particularly during the growing season, and in rural areas.

The Fredricton City Weather Office was a case in point where farm-weather forecasts were issued solely by the meteorologist (Dickison). From the reports of the activities in Alberta and New Brunswick, the NCAM drew up a list of five recommendations regarding farm-weather services. In summary these dealt with the following.

1. Cooperation between the local meteorologist and agriculturalist, the latter being responsible for preparing the report.

2. Service should be provided seven days a week since weather does not take a holiday on weekends.

3. Seasonal forecasts for farmers must start early in the spring and continue well into the fall until all farm operations cease.

4. The service should be given publicity and should be made readily available to all local newspapers as well as TV and radio stations.

5. Full-time (annual) farm-weather forecast officers might undertake research, extension and educational work, relative to their summertime farm-weather service, during the slacker winter months.

The Fredericton City Weather Office continued with its program of farm-weather forecasts including special potato late-blight forecasts and an extensive program of supporting services.

The 5th Annual Meeting (1964) heard that the Alberta Government was planning its 4th year of cooperative farm-weather forecasts. The Edmonton Weather Office issued experimental 3-day weather outlooks and, occasionally, issued an outlook for the 4th day. The Saskatchewan Research Council worked closely with the Provincial Department of Agriculture and the Saskatoon City Weather Office in 1964-65 to issue farm-weather forecasts similar to those issued by Alberta. By this time several City

Weather Offices and Public Weather Offices prepared and issued special farm-weather forecasts on a limited basis. These included centres at Halifax, Fredericton, Hamilton, London, Saskatoon, Regina, Edmonton, Calgary, Penticton, Vancouver, and possibly others. The forecasters at these centres collaborated with agriculturists to varying degrees in preparing the forecasts.

The Committee followed these advances closely and after much discussion recommended to CMS that a workshop be conducted for individuals directly responsible for the preparation of special farm-weather forecasts. No action was taken on this matter, however, possibly because the CMS was short staffed in the area of public forecasting, and was not in a position to undertake a firm commitment regarding farm-weather services that, up to this time, were provided on an ad-hoc basis.

Interest in farm-weather forecast increased and Alberta, in particular, continued with experimental services for several years. Brown informed the 8th Meeting (1967) that Dr. Wilde, an entomologist at the University of Guelph, had indicated that improved farm-weather forecasts, especially for the fruit and vegetable growing areas of Ontario, might reduce pesticide usage by 30 percent. Such forecasts required indications of duration of leave wetness, supplemented by data from networks of dew-duration gauges. Also needed in the forecasts was a statement on the depth of the inversion layers with wind speeds above the layer to indicate the danger of transport of fine spray material downwind to pollute other crops.

Haufe discussed the use of medium-range weather forecasts in connection with the control of biting flies in Northern Alberta in 1968. Such forecasts were needed for evaluating the development, behaviour and extent of pest outbreaks.

By the end of the decade farm-weather forecasts, prepared in cooperation with provincial departments of agriculture, were becoming fairly routine, particularly in New Brunswick, Alberta and Ontario where continuing success was reported.

Recommendations arising from the first year's operation of a pilot project in Ontario, reported by Fox, and supported by the committee are worthy of note:

1. Introductory meteorological and climatological training should be given to all Department of Agriculture and Food personnel involved in this program.

2. More phenological observations are required.

3. A complete network of agrometeorological observing stations was required.

4. A closer liaison was needed between research and the agrometeorological forecasting program.

5. A more accurate and economical method of data collection and dissemination was required.

6. A complete seven-day program should be provided.

McLeod observed that the gap between the Weather Office (the forecaster, the climatologist, and the general advisor) and the farmer had not been bridged in spite of several years of efforts by the NCAM.

He pointed out at some length that there was a real need for a knowledgeable person to inform the Weather Office of the farmers' day-to-day weather problems and requirements in the same way an airline dispatcher makes his airline's needs known. The trend, therefore, has been for provinces to arrange to have someone act as the agricultural dispatcher who works closely with the Weather Office staff in preparing advice for the farmer.

McLeod went on to note that, as a result of a resolution at the annual meeting of the Canadian

Federation of Agriculture, the CMS was holding a series of meetings with the various Provincial Federation Executives in an attempt to organize forecast services for agriculture that will be more adapted to their current and local requirements. The Committee named Fox as a chairman of a panel along with Bergsteinsson, Pallett and McLeod to consider problems with farm-weather forecast services.

The discussion that followed the presentation of the chairman's report in 1971 revealed that:

1. Agrologists are inadequately trained in meteorology and do not communicate effectively with meteorologists.
2. Meteorologists are generally unaware of crop progress and real-time farm operations.
3. Mass-media communications do not give high priority to farm forecasts.
4. Meteorological networks are not sufficiently dense and agronomic data were almost non-existent.
5. Specialized forecast systems are not readily available for the routine preparation of farm-weather forecasts.
6. Evaluation of farm forecasts, in terms of both scientific skill and cost-benefit ratio, have not been adequately made.
7. Considerable extension work is required to make forecasts most effective for farm use.

Based on the discussions of these problems the Committee recommended the following.

1. That provinces arrange discussions with Regional Meteorological Officials with the view to establishing a cooperative and coordinated program, including provision of crop conditions and farm operations, communications systems and program evaluation.
2. That information on the influence of the environment on specific farming activities be obtainable on request.
3. That appropriate meteorological courses oriented to agriculture be introduced in degree and non-degree courses in appropriate universities and colleges.
4. That informative literature be developed for use by farmers and agriculturists.
5. That CMS be encouraged to adopt the principle of giving the probability of precipitation in all forecasts.

It was recognized that probably the weakest link in the farm-weather services system at this time was poor communications with the farmer.

Communications in the Farm-Weather Services System

Communication problems were first raised as an issue in farm-weather services at the NCAM in 1968 by Fox of the Ontario Provincial Department of Agriculture and Food. A new agricultural forecast, issued from the Malton Weather Office, for the Toronto agricultural area was initiated in 1968 and was expanded the following year to cover 14 counties around Toronto. Although the forecasts were well aired by some 10 rural radio stations, the biggest unresolved problem was a matter of communication, i.e getting the forecast to the user on time.

This problem was the second major topic for discussion at the 12th Annual Meeting (1971). Pallett was coordinator of the panel, supported by Mahaffy. Three supporting papers were presented: "Communications in Farm-Weather Service", "Marketing Methods and Research with Special Reference to the Ontario Farm-Weather Service"; and :Communication Channels or Networks".

The discussions that followed the presentation of these papers indicated that CCAM recognized the great importance of weather in agricultural decision-making and the many problems in getting timely information to the user. However, no firm recommendations were forthcoming.

The problem was not considered again until four years later. Following discussions in 1975 the meeting recommended that CASCC consider the desirability of discussing the matter with the Canadian Radio and Television Commission. It was suggested that the CRTC might be able to influence the local broadcasting stations to carry specialized agricultural-weather forecasts, and also recommend appropriate lines of communication to achieve improved public services. The Committee also recommended that CASCC support the development of an improved communication network to render operational the weather-based recommendations on a number of farm operations including pest control and harvest indices. It was proposed that such a network would included the services of a field biologist, personnel from CMS, a broadcasting network, and a grower.

Although CASCC agreed in principle with these recommendations, no satisfactory conclusion was reached. A preliminary investigation by the Information Service, CDA, revealed a pessimistic assessment of the existing situation regarding communication in respect to farm-weather forecasts across Canada.

Aber of CMS offered an explanation for the seemingly chaotic situation across Canada regarding farm-weather forecasts and their dissemination. He explained that regional differences in services reflected the autonomous nature of the CMS regions and the varying industrial demands and priorities in the various region. Cost-sharing programs were implemented when and where local needs were known and properly documented. The 5-day forecasts were rapidly assuming a common format but it was expected that this would continue to change as demand dictated.

Communication to user groups slowly improved by the introduction of direct-dial telephones, recorded information, use of dedicated VHF radio, and other mass-media methods. It was noted that the wire services between the radio stations and CMS were at fault in many cases, and that the situation would be self correcting if demand and priority were established by the radio station, with the backing of the farm community.

A Fresh Approach to an Old Problem

Commenting on the theme, Farm-Weather Service, for the 19th Annual Meeting (1978), Baier reviewed the somewhat perennial nature of the problem, delving back to as early as 1959 at which time a NCAM technical subcommittee was formed to examine and recommend a solution. In subsequent years, namely 1968 and 1970, the CCA again attempted to resolve the situation. It was hoped that the 19th Annual Meeting of the CCA would find a more specific approach and emphasize a restructuring of existing facilities in order to provide an improved farm-weather service to the agricultural community. The Committee agreed that such a service should be all-inclusive, embodying, besides the synoptic aspects, such services as climatological statistics, descriptions of cause and effect, and, most importantly, the problem of communication for the timely dissemination of information.

Four papers were submitted in support of the theme. The first was a joint report prepared by the Canadian Federation of Agriculture (CFA) and the Agrometeorological Research and Service Section (AMRSS), CDA. It was based, largely, on a Seminar on Agricultural-Weather Forecasting Requirements held in May 1977 in Ottawa and chaired by Baier. Initiatives that led to the holding of the seminar had been taken by both the CFA and the AMRSS. The seminar was also prompted by the Winnipeg

Conference of January 1977 on Living with Climatic Change, sponsored by the NRC and the Canadian Meteorological Society; and by Dr. Prem Shankar, Agrometeorologist, on leave from his university in Australia, and in Canada as a consultant to the AMRSS on farm-weather forecasting.

The Seminar was attended by 44 persons representing farmers, CFA, AES, CDA (AMRSS), the Universities of Guelph and New Brunswick, The Saskatchewan Research Council, The Canada Centre for Remote Sensing, and visiting meteorologists from Australia, Kenya and Japan.

The purpose of the Seminar was to conduct a one-day seminar and workshop with farmers and weather forecasters on farm weather forecasting requirements, to derive a more exact understanding of farmers' weather forecast needs, in a form that weather forecasters could utilize to improve the content and dissemination of agricultural weather forecasts for farmers; and to forward the findings to CCA and CFA.

After listening to comments from the CMS (Scott), University of Guelph (Gillespie), and from Shankar regarding his research program in Canada, the participants were divided into groups for workshop discussions. Excellent interaction between farmers and forecasters was achieved. Major overall farm needs were defined:

1. Farm-weather services should be improved at both the national and regional levels (by enterprise) Exploratory meetings such as this seminar should be held at local levels across the country.

2. Two-way communication between farmers and meteorologists should be undertaken to bring about agreement on technical terms, essential weather elements and derived data.

3. Farm-weather service requirements should be identified by enterprise at the regional or provincial level.

4. Identification of jurisdictional and fiscal responsibilities for a farm-weather service. Also, coordination should be strengthened between the CMS and CDA regarding responsibility for forecast information and derived data.

5. Extension of the 3-day weather forecast to the fourth and fifth days and beyond to the sixth and seventh days with advanced warnings of violent changes.

6. Confidence ratings should be given for all forecasts and when there is a near-even chance of two or more weather events occurring, the alternative event should be mentioned.

7. Forecasts for farmers should be localized, ideally for each individual farm.

8. Research toward longer-range seasonal forecasts should be strengthened.

9. Special advisory services should be provided through close cooperation of meteorologists and provincial agrologists with input from the farmer on specific existing conditions relative to his operations.

10. Climatological analyses and probabilities derived from historical data would be of great use to farmers.

11. Two categories of problems requiring research were recognized: meteorological research on long-range forecasting and improved utilization of established technical capabilities in order to provide an improved farm-weather service.

It was realized that both these problems would be costly but, unfortunately, no cost-benefit studies of this nature had been undertaken in Canada. Such studies in Great Britain, Australia and the United States had indicated benefits many times greater than cost.

A second position paper on Farm-Weather Forecasting and Climatic Advice in Canada was presented by Shankar. In this he discussed nine pertinent questions about farm-weather services.

In summary his conclusions were that, in Canada increasing use was being made of weather forecasts and climatic advice in construction, manufacturing, all types of business, and transportation. Producers and users of agricultural-weather information are conscious of the potentialities of weather forecasts and climatic advice. Sporadic and isolated attempts had been made to provide farm-weather services in New Brunswick, Quebec, Ontario, Saskatchewan, Alberta, and British Columbia. However, as the nation entered the last quarter of the 20th Century, it was evident that agriculture on the whole was a forgotten user of weather services.

CDA and CMS had well-established organizations at provincial and national levels. In all regions adequate, if not ideal, agrometeorological and climatological observation networks were in operation. Never the less, farm-weather forecasts and climatic advice were not yet available on a large scale to farmers.

The third position paper was by Trottier on a Warning System for Pest Management in Apple Orchards. In this paper he described the development and use of bioclimatic indices and improved monitoring methods necessary for the implementation of pest management programs in Ontario apple orchards.

The fourth position paper was by Mukammal entitled "Meteorology in Support of Agriculture (A Personal Viewpoint)". He elaborated on many aspects of agrometeorological research, development, and applications to operational agriculture. His view was that advisory services relevant to agrometeorological problems would be of benefit to the agricultural industry only under the following circumstances.

1. The weather-induced problem was clearly identified.
2. The weather element or elements responsible are identified and the timing and interaction are understood.
3. Crop response or other responses to the weather element or elements can be determined.
4. Cultural practices or other action can be identified that would eliminate or minimize the weather-induced problems.
5. The grower or agriculturalist clearly understood the strategic actions that he should take to realize maximum benefits after he has received the weather advice.
6. Communications were available to deliver the advice to the agriculturalist or farmer.

The fifth and last paper was a proposal by Edey for An Operational Agricultural-Weather Service. He noted that the regular meteorological forecast, whether it was short-, medium- or long-range, was not expected to improve significantly over the next 5 to 10 years. Working on the premise that the necessary technology, expertise, and institutional resources existed, he proposeda service with: existing meteorological forecasts;. the real-time monitoring of present and immediate past weather; the preparation of forecasts of agricultural events (indices, yields, and so forth); the regionalization of the service to provide local information by crops and areas; the acquisition of real-time biological or agronomic information; the latest technology to communicate the timely information to the farmer and user groups.

After discussion by the Committee it was recommended that CDA establish a Task Force to study and implement the proposal for an Agricultural Weather Service as outlined by Edey. Such a group should include representatives from CDA, CMS, appropriate provincial departments and the CFA.

The 23rd Annual Meeting (1981) noted that only three provinces currently had agrometeorological extension specialists on staff. Without the services of such specialists the success of various programs to increase farm production was in jeopardy. Such programs included the Agri-Food Strategy for Canada, the CMS Regional Farm-Weather Services, and the CMS Canadian Climate Program. It was strongly recommended that CASCC urge all provinces to fill existing vacant agrometeorological extension positions in support of federal-provincial climate-related programs, and to enhance weather services to farmers.

CFA and the Farm-Weather Services Committee

Several activities at the close of the decade lead to the formation of a Task Force to Study a National Farm-Weather Service for Canada. These included: a seminar on "Agricultural Weather Forecasting and Advisory Services" sponsored jointly by the CFA, AES, and CDA and held in Ottawa, May 5, 1977; the 1978 position paper of CCA on Agricultural-Weather Services; the presentation by Edey to the 19th Meeting of a "Proposal for an Agricultural-Weather Service; the position paper by Dr. P. Shankar, consultant, on "Farm-Weather Forecasting and Climatic Advice in Canada" presented to the 19th Meeting in 1978.

The Task Force was recommended by the 20th Annual Meeting. Both CASCC and CARC concurred (in 1978) that CDA should establish a Task Force to study and implement the CCA proposals (by Edey) for an Agricultural-Weather Service. Subsequently, the Task Force was established under the chairmanship of Baier. Campbell of the CMS was named vice-president and Edey, secretary. Robertson was selected as a consultant to be responsible for documentation relative to the final proposal of the Task Force. His survey and report on "Agricultural Weather Services in Canada with Special Reference to Operational Farm-Weather Services" was completed in April 1979.

After discussion by the 21st Annual Meeting (1978), steps were proposed for setting up pilot projects. Eventually two projects were established, one in Saskatchewan near Weyburn and the other in Ontario for the Niagara Peninsula. These pilot projects included "now-casts" (1-6 hours), forecasts (1-2 days), and outlooks (3-5 days). Services were distributed to the farmer via Weatheradio. CMS provided the forecasting service; the provincial government provided expert extension staff; and the Agrometeorological Section, CDA, was responsible for research input and updating of methodology, including the availability of agrometeorologists on an advisory basis. Ultimately, it was proposed to add to the program more detailed services tailored to the local weather-sensitive problems on a mesoscale basis. It was announced at the 22nd Annual Meeting that New Brunswick, Quebec, Alberta, and British Columbia were developing comprehensive programs to satisfy local requirements.

CASCC, at its 1980 annual meeting, accepted the report of the Task Force on Agricultural-Weather Services and noted its progress in developing farm-weather services. They requested that the Chairman of the Task Force (Baier) establish a permanent coordinating committee. Consequently, a Farm-Weather Service Coordinating Group (FWSCG) was established in June, 1980, consisting of Baier of CDA (Chairman); McCulloch, AES; Bursa, CFA; and Edey, CDA. The Group's responsibilities were to keep the whole farm-weather service problem under review and to promote, at a national level, the needs of farmers as expressed by them in their provincial farm-weather service committees. The Group was to liaise closely with work done on farm-weather services in the provinces, and was to be available and willing to assist at the national level. Encouragement was given to the establishment of Farm-Weather Service Committees at the provincial level with the responsibility to improve farm-weather services.

The 24th Annual Meeting noted that progress towards the improvement of farm-weather services was slow, partly because of inadequate involvement of farmers. Members of the FWSCG recognized this

shortcoming and agreed on a different course of action. At the meeting of the Board of Directors of the Canadian Federation of Agriculture in Winnipeg in July 1982, three members of the FWSCG made a joint presentation on the status of farm-weather service in Canada.

Following this presentation and discussion the Board passed a resolution to establish a CFA Farm-Weather Services Committee (FWSC). This Committee was to consist of farmers' representatives and liaison membership with the CMS and the Research Branch of CDA. It took over the work of the FWSCG, which became defunct. This was an encouraging trend since farmers, became directly involved in developing improved farm-weather services, particularly at the provincial level.

In a survey of activity in the various provinces it was found that the resolution was strongly accepted by all. However, positive action varied from province to province. British Columbia, Ontario, New Brunswick and Newfoundland were actively engaged in farm-weather services on a limited scale. Alberta and Saskatchewan strongly supported the program and planned action in the near future. Prince Edward Island did have a program but had to curtail it due to staff cutbacks.

Bursa reported to the 24th Meeting (1982) that four directors had been named to the FWSC, with an additional director from the Ontario Federation of Agriculture. It was anticipated that the new group would continue in a coordination role at the national level much like its predecessor. A more political role was anticipated in order to motivate contributing agencies.

Chairman Douglas pointed out to the 25th Annual Meeting (1983) the inadequacies of the provincial extension services for providing a farm-weather service by bridging the gap between the professional agrometeorologist and the farmer as recommended by the 24th annual Meeting. The situation was deteriorating since the number of extension specialists had decreased during the past year. With advancing technology in the field of communication such as Weatheradio, Telidon videotex, microcomputers, etc., there was an increasing need for specialists with the ability to handle the interpretative and extension processes required by modern agriculture. These matters had been discussed with the parent organization (CCLRS) and CASCC, but there was no feedback from either.

Bursa reported at the 25th Annual Meeting that the FWSC was responsible only to the CFA Board of Directors. She considered it a matter of courtesy that copies of the FWSC semi-annual meeting were made available to the ECA.. FWSC also had close contacts with CDA through van Schaik, Deputy Director of the LRRI and Head of the Agrometeorological Section, as well as with CMS through Smith, Director-General of the Field Services Directorate. The FWSC had nine farmers as members, all of whom were directors of CFA. The present activities of the Committee were directed towards getting undistorted weather information to the farmer and Weatheradio was the preferred means.

She also pointed out that there was a positive trend towards greater farmer representation and participation in the membership of the provincial Farm-Weather Services Committees. There was a move towards electing farmers to the executive positions in these committees, which augured well for their long-term interests.

Commenting on the activities of the FWSC at the 26th Annual Meeting (1984) Bursa noted that it had met twice: once at Edmonton in February and again in Regina in July. Both meetings were held during the annual and semi-annual meetings of the CFA.

The FWSC continued to put strong emphasis on farm-weather services. Weatheradio was a great boon to the farmer and indicated that CMS was getting the message. Never the less CMS had indicated that they needed more specific information regarding farmers' requirements. To this end CFA drafted an updated CFA Policy which was passed unanimously by the CFA FWSC, and accepted as a resolution by the CFA Board of Directors. Essentially the policy stated that there should be more provincial effort put into the provision of farm-weather services. Much of the input to this policy was based on the ECA's publication "Requirements and Availability of Agrometeorological Data in Support of Agriculture". This

report was considered an important publication for farm-weather services. It was claimed to bridge the gap between the articulation of farmers' operations and meteorologists' understanding of the data requirements for servicing these farm operations.

Computer-Based Farm-Weather Information

The next step in developing a farm-weather service was to make use of the private proliferation of desk-top computers which occurred in the 1980's.

Edey presented a review of computer-based farm-weather information packages available in Canada and the USA at the 26th Annual Meeting (1984). Canada launched North America's first "Videotex" farm and market information system four years earlier in 1980. Known as Grassroots, the service included a good menu of weather and weather-related topics, such as the availability of soil water in Western Canada. The latter information was provided by the Agrometeorological Section in Ottawa.

Grassroots, a commercial venture of Infomart Canada, was based in Winnipeg. Originally the service was directed towards the farm community in Manitoba. By 1984 it had expanded into Saskatchewan, under the name Agritex; into southwestern Ontario (via the University of Guelph) under Universitel; and into California under Gateway. Future expansion was scheduled for Alberta, and several states in eastern U.S.A. Edey pointed out that a wide spectrum of farm-weather services were available in the USA. Some were detailed weather forecasts, while others were a combination of weather, agrometeorological indices, and crop and pest advisories. Some were very successful, while others were not.

The most comprehensive programs were to be found in Michigan, Iowa, and California. All programs were cooperative efforts in that several agencies provided basic input information and data. The agencies include the National Weather Service, State Agrometeorological Services, NOAA Weatheradio, university and state extension groups, and departments of food and agriculture.

Also considered was the use of historical and real-time data sets, the latter becoming increasingly important in day-to-day operational decisions. The ready availability of such data on a demand basis from the data source was a major consideration. Data acquisition was considered the first, vital step in the long chain of events leading to improved farm-weather service. It was agreed that Agriculture Canada (The Agrometeorological Section) would initiate discussions with AES, provincial departments, agribusiness, and farmer organizations on how proposals for a computer information systems network (AgWxEast and AgWxWest) could best be implemented.

The second problem, interpretation and dissemination, was essentially another exercise in logistics wherein computer technology provided the communication linkage. Small microcomputers were rapidly being introduced at the farm level. Larger minicomputers were being used extensively by agribusiness. Large main-frame computers had been in use by governments, universities and large businesses for many years. Thus it was considered that the agricultural sector should determine which links in the chain required upgrading, and what form or role a given link should take. Regardless of the choice of chain, the entire process was considered one of cooperation by various agencies in which no one link should be expected to be self-contained..

The Committee recommended that Agriculture Canada approach principal agencies such as AES, provincial departments of agriculture, and major farm organizations to determine the appropriate means of implementation of provincial or regional "real-time" agroclimatic networks dedicated to the day-to-day operational aspects of integrated pest management procedures, yield predictions, nowcasting,and other associated information requirements.

A New AES Policy on Meteorological Services for Agriculture

The 28th Annual Meeting (1986) heard a report from Mr. J. McBride of Policy and Planning, Weather Services Directorate, AES concerning the new policy of CMS in regard to weather services for agriculture. In essence, the policy was as follows.

"Provinces have historically borne the responsibility for the effective management of their agricultural interests. Recognizing that agricultural products contribute significantly to Canada's food supply and overall economic well-being, the federal government also supports the provinces through a variety of programs. One such program is that of AES, which provides services to the agricultural community, by means of an information base, to assist them in making decisions. In fact, for over 35 years, some form of meteorological support has been provided to farmers in Canada.

"AES weather offices (and weather offices at some military establishments) began responding to farmers' requests for agrometeorological services on an ad-hoc basis. Over the last decade, provincial farm-weather service committees have been formed in most provinces to deal with the needs of the agricultural community for farm-weather services. The purpose of this policy is to state what would be an equitable level of service to the agricultural community based on our historical relations with them, and on recent government initiatives to identify what is a reasonable level of service to expect from the federal tax base."

A number of specific points were raised regarding the policy but there appeared to be consensus on one major point, viz. the time of implementation. The Committee felt that more dialogue was needed prior to implementation since so much time and effort on the part of the provincial agencies had already gone into establishing the current level of service to the farm community. The Committee noted that, during the past 45 years, and more especially during the last 25 years, the development of agrometeorology had been characterized by basic and applied research in order to implement a farm-weather service tailored to regional needs. In most regions, this service was developed by agricultural agencies in cooperation with the AES; this service being offered as an extension of the weather forecast. A recent survey of the economic value of weather information in Canada indicated that it was worth an estimated $685 to $785 millions annually to agriculture alone.

According to the newly proposed AES policy on meteorological services for agriculture (October 10, 1986), the specialized agricultural services and special studies would fall in the cost-recovery section, although some room was left for negotiation with AES regional directors. Foreseen changes resulting from this policy needed discussion with agricultural agencies (farmers, producer's associations, provincial departments of agriculture, universities, etc.) and more time was required to give these agencies an opportunity to assess the full significance of the proposal and to negotiate the level of service from AES regional offices and to prepare adequate budgeting. Too early implementation of the policy might result in discontinuation of certain specialized services now available to farmers and of special studies now under way.

It was, therefore, resolved that the AES should consider phasing in its "Policy on Meteorological Services for Agriculture to ensure that provincial agencies had adequate time for consultation or negotiation, and to assess the full impact of this policy, thus insuring an equitable arrangement."

PART 6 - WEATHER MODIFICATION

Early Considerations by the NCAM

The Committee heard reports and reviewed projects on weather modification at all meetings up to the 10th (1969). Since these projects appeared to be well in hand and progressing well, the Committee made no specific recommendations in regard to them except to keep abreast of developments and encourage further basic research on the topic.

At the 5th Annual Meeting (1964) the Committee received a 12-page report on weather modification outlining projects in Canada and world wide prepared by Malaher. This information was requested by the Committee in keeping with its terms of reference "to maintain an informed opinion on agrometeorology ....".

Searle Grain Company Report

The 6th Meeting held a thorough discussion of all aspects of weather modification including commercial cloud seeding. The general indications were that some farmers and scientists were becoming disillusioned about weather modification and the costs of research programs, some of which were running into their tenth year. There was still a strong interest in the subject as indicated by the Malaher Report. Ten thousand copies of this report were released as a bulletin by the Searle Grain Company. It was now out of print.

The Committee made two suggestions regarding the matter. The first was that the Searle Grain Company should consider updating and republishing their Bulletin. The second was that the Stormy Weather Research Group at McGill University prepare a simplified progress report on the practical results of the Alberta Hail Research Project. This should be in layman's language so that material from it could be used in the updated the Searle Bulletin.

Commercial Cloud Seeding

At the 8th Annual Meeting the Committee learned that there was increased interest in hail suppression in Alberta because of claims being made by a commercial cloud seeding companies (Irving P. Krick Associates). The Hail Advisory Committee, under the auspices of the Alberta Research Council and with members from McGill University, University of Alberta and the CMS was continuing its study of hail and hail suppression.

In consideration of this renewed interest in hail research it was suggested that Maybank monitor future activities in this field for the NCAM.

Maybank Report

Maybank presented a report on "Weather Modification" at the 9th Annual Meeting. This report together with one prepared by Baier on "Weather Modification Through Cloud Seeding" prompted the Committee to suggest that the entire matter of weather modification should be highlighted at the 10th Annual meeting in accordance with the new program policy of the NCAM to focus attention on a single topic at each meeting.

Maybank chaired the session on "Weather Modification (Restricted to Cloud Seeding)" at the 10th Annual Meeting (1969). Topics and contributors were as follows.

- History of Weather Modification, Maybank, Saskatchewan Research Council.
- Modern Theories .

- Status of Present Research, Douglas, Macdonald College.
- Status of Rainmaking in Holland, CMS.
- Status of Hail Suppression, Summers, Research Council of Alberta.
- Knowledge of Cloud Type and Parameters, Crozier, CMS.
- Storm Models & Dynamics, T. Takeda, Nagoya University, with postscript on cellular storms in Japan (presented by Hitschfield of McGill University).
- Ice Nucleation, Vali, Macdonald College.
- Experimental Design & Analysis, Longley, University of Alberta.
- Legal Aspects of Weather Modification, J.P.S. McLaren (presented by Maybank).
- Potential Role to Agriculture, Baier, RB/CDA.
- Possible Effects on Wheat Production, Williams, RB/CDA (presented by Baier).

The discussions following the presentations lead to a number of conclusions and recommendations which are worthy of note:

1. Various weather control measures, including modification of precipitation by cloud seeding, could have a great potential to Canada's agriculture. However, any modification of precipitation is warranted only in certain parts of Canada, and only when precise control of this modification with respect to time and area is ensured.

2. The basic and applied hail research programs being conducted in Alberta and at McGill University by CMS, the National Research Council, and the Research Council of Alberta should be continued and strengthened. The suppression of hail may be accompanied or followed by other less desirable effects. It is, therefore, recommended that "side-effects" and their impact on all sectors of the economy be investigated.

3. CMS should continue and expand, where possible, its basic and applied research program concerning the influence of cloud seeding on rainfall. A review of the collection program for climatological data concerning clouds would be most desirable, so as to ensure that the necessary data will be on hand for determining seedability and weather modification potential for cloud types and areas when required. Since forecasts for 3- to 10-day periods would be invaluable in the determination of seeding schedules for future operations, further support for medium-range weather forecasting is urged.

4. Conflicts of interest could arise from weather modification. These conflicts might involve other than agricultural interests. Investigations into economic potential of rainfall modification and the total effects in fields such as agriculture, forestry, recreation, and hydroelectric power generation were encouraged.

5. The minimum legislative requirements in the weather modification field was considered to be enactment of laws to ensure registration and reporting of all weather modification activities in Canada. This would not conflict with any possible provincial legislation that might further regulate or restrict weather modification operations.

6. Research into the relationships between weather on the one hand and crops, animals, pests and diseases on the other, was considered necessary before the beneficial and detrimental effects of rainfall modification on agricultural production could be assessed. Research projects and experimental work on the relations between water use and crop production should be conducted in each major climatic region of Canada.

7. In view of the present uncertainties in techniques, results and benefits, more research is required. This includes modification theories, cloud seeding techniques, and statistical techniques for the evaluation of the beneficial and detrimental effects of weather modification on specific agricultural

production phases. Solutions to these problems should be obtained before large-scale operational weather modifications are attempted.

Before the start of the session Chairman Ludwig outlined the reasons and purpose of the study, stressing that a combined effort must be made in order to maximize the response and follow-up to a position paper. Such an effort might be realized by a more formal handling and publication of the submitted material. Furthermore, a much wider distribution of the finished document should be attempted. Maybank and Baier were asked to edit the 12 papers and coordinate their printing and publishing in a 133-page report.

Weather modification appears to have been put to rest by NCAM following publication of the report. No further discussions of the topic by the Committee were undertaken following the 10th Meeting.

PART 7 - AIR POLLUTION

A New Topic

A totally new, and very important topic, air pollution, was introduced at the 2nd Annual Meeting (1961). Agricultural research agencies had established that industrial air pollution had toxic effects on crops (e.g. leaf fleck of tobacco in Southern Ontario near Port Burwell). It was apparent that the quantity and complexity of these pollutants would increase. Further, it was noted that since it was likely impractical to completely eliminate them from the environment, agricultural scientists would ultimately need to know the threshold levels of toxicity for crops and livestock to various substances. A strong meteorological component was involved in this problem.

The Committee decided to collect and summarize available data on atmospheric pollutants and on water polluting materials so that they would be available to interested personnel. It was emphasized that the problem of industrial air pollution could be more effectively and efficiently dealt with if the constituents and concentrations of pollutants were known and if an inventory of these could be obtained from the sources of pollution.

Dr. M. Katz, Director of the Environmental Assessment Unit and Consultant on Atmospheric Pollution, Occupational Health Division, National Health and Welfare Department, spoke to the 3rd Annual Meeting (1962). He was one of the members of a cooperative team that was working on the tobacco leaf fleck problem at Port Burwell.

He pointed out that a national program had been set up for studying air pollution on a cooperative basis with certain municipalities. Both pollution and related micrometeorological observations were taken on a routine, standardized basis. The program was operative only in areas where serious problems existed. He also indicated that there was no complete inventory of pollutants entering the air in Canada although there was considerable information on file in various places concerning the amount and type of pollution arising from various industrial sources. Such information was of limited use since downwind concentration and photochemical reactions in the polluted air determined, to a large extent, the amount of damage they could cause. There was a need for sampling in the country at sites far removed from pollution sources in order to establish background levels of pollution. He indicated an interest in cooperating with a limited program of this nature. He pointed out that there was no area in Canada where pollution emission was controlled according to local and current meteorological conditions.

After discussing Katz's comments the NCAM made the following recommendations:

1. The determination of thresholds of susceptibility of plants to various pollutants was the responsibility of agriculture. Such information was required as a prerequisite to determining the potential amount and extent of damage to plants by existing and future air pollution.

2. There should be some organization or body in each province responsible for information on air pollution from an agricultural point of view. It would be responsible for consolidating information on sources of pollution and damage to agricultural plants and animals. This would facilitate the exchange of information between provinces. In Ontario, for example, there is no one body from which one can obtain information concerning air pollution and its agricultural implications.

3. An interdepartmental National Committee on Air Pollution to coordinate activities in this field was desirable.

The 4th Annual Meeting of the NCAM noted that there was little to add to developments in the field of air pollution. The tobacco leaf fleck study at Port Burwell was nearing completion. The field work was discontinued, and collaborators were busily writing papers and reports.

The Committee learned that two provinces were very concerned about air pollution and were taking steps to study the matter. The Ontario Agricultural Research Institute, the Ontario Agricultural college, The Air Pollution Branch of the Ontario Department of Health, and the Ontario Department of Mines were involved in a cooperative study of the effects of certain air pollutants from refinery smokestacks on oat crops in Humbertstone Township and at Guelph. The Alberta Air Pollution Commission was faced with a serious pollution problem in Southern Alberta. Large quantities of sulphur dioxide and hydrogen sulphide gases were released from natural gas separators into the atmosphere causing serious crop damage.

The NCAM again reiterated their position that the first responsibility of agriculture in connection with air pollution research was to investigate thresholds of responsiveness of plants to various air-borne pollutants

Atmospheric Pollution by Pesticides

It was not until the 8th Annual Meeting (1967) that the Committee again considered the air-pollution problem, this time from agricultural pesticides. Several members reported on provincial problems. Maybank announced that CDA and SRC had embarked on a joint study of pesticide dispersal in the ground layer of air. Brink indicated that there was official concern regarding the heavy use of chemicals for weed and pest control in the Okanagan Valley. Steeves commented on similar concerns regarding stream pollution by pesticides in New Brunswick, and the possible adverse effect on the salmon industry. A two-man panel, Stevenson and Steeves, was appointed to review these problems.

At the next meeting, in light of their report and the growing concern in Alberta regarding industrial pollution, the Committee decided that the panel should continue its investigations and determine what and how federal and provincial agencies should be involved. Of prime consideration would be the meteorological aspects of the problem, and the manner in which an active role by CASCC might be initiated through CCAM. Steeves (chairman) and Haufe were named as panel members.

Haufe reported to the 10th Annual Meeting that the panel had sent out a questionnaire to determine what various groups were doing. This appeared to create more interest in the problem than action. Preliminary indications were that very little, if any, planning by government bodies was concerned with atmospheric pollution of any kind.

The panel continued its work for another year with Dickison replacing Steeves. Their report to the 11th Annual Meeting revealed that there was a serious lack of information concerning the meteorological influences on the conventional methods of applying chemicals, and their contribution to environmental pollution. It was apparent that assessments and recommendations pertaining to the contribution of

agricultural chemicals and pesticides to environmental pollution may have to be revised on scientific grounds, recognizing the role of meteorological factors.

The Panel presented a comprehensive report at the 12th Meeting (1971) at which time the topic received a prominent role for discussion. Bergsteinsson replaced Haufe on the panel. Six speakers contributed to different aspects of the problem as follows:

- sources of airborne pesticides (Bergsteinsson);
- pesticide-spray dissemination (Maybank);
- microscale and mesoscale transport (Hage);
- synoptic-scale transport (Mukammal);
- analysis of pesticides (Morley);
- biological significance of deposited pesticides (Hay);
- monitoring of airborne pesticides (Bergsteinsson).

Significant conclusions and comments of the panel indicated that commercial pesticides have been in use for over 25 years, yet their was no comprehensive body of statistical data on the types, amount and places of their release. Furthermore, there were no standard techniques and procedures for the evaluation of spray equipment, nor for analysing airborne pesticides. Knowledge was lacking concerning the rate at which pesticides enter and leave the atmosphere; the relationship of droplet size to toxicity; and the chemical species and toxicity of pesticide reaction products formed while the pesticides were in the atmosphere.

The Committee offered several points for consideration by CASCC, many of which were beyond the competence of agrometeorology. Some of the more important agrometeorological considerations can be summarized as follows:

1. There was a growing need for monitoring pesticides that enter the environment,

2. Spray equipment should be designed to minimize the amount of chemical drift,

3. Research on models for estimating spray drift by wind currents and turbulence should be undertaken,

4. Research should be undertaken on the reentry of pesticides into the atmosphere after retention in various sinks following original application,

5. Research should be undertaken on the synoptic-scale transport of pesticides,

6. Although the Committee didn't identify the immediate need for an airborne pesticide monitoring network, it did recommend the establishment of one prototype hardware system as a research tool for developing techniques and procedures in readiness for the day when network monitoring became a necessity.

The report of the panel was lengthy and was published as a separate document by the Information Service, CDA.

The Committee devoted no further time to discussions of air pollution following the 12th Meeting in 1971.

PART 8 - SOIL WATER

The study of soil water and the application of research results and data, although undertaken by individuals at several institutions, had many national and even international ramifications that eventually became the concern of the NCAM. It was not until the 4th Annual Meeting, however, that the topic of soil water received serious discussion. Afterwards the subject became a topic for discussion at several Annual Meetings.

A Perennial Problem

Soil water was a problem for consideration at nearly every meeting of the NCAM since its inception. Although no direct mention of the matter was made at the first two meetings, there were implications of its requirements during discussions of agrometeorological networks at the 1st Meeting, and of the need for agrometeorological observations in connection with the South Saskatchewan River irrigation project discussed at the 2nd Meeting. Soil water was discussed implicitly at the 3rd Meeting, but it was agreed there were so many unsolved problems in connection with instrumentation and techniques that no definite recommendations could be made except to encourage research on the problem.

Incidentally, the 3rd Session of the CAgM was held in Toronto 9-26 July 1962. At that meeting, Holmes was appointed to the Working Group on Practical Soil Moisture Problems in Agriculture.

Soil-moisture measurement received a great deal of attention at the 4th Annual Meeting (1963), primarily because of the emphasis placed on it during the 1961 drought episode, and the subsequent actions taken by the Agrometeorological Section of PRI to evaluate the effect of weather on prairie-wheat production. The Committee recommended that the Program Directorate (Soils) set up a small subcommittee to look into the matter of the standardization of agrometeorological measurements, particularly soil-moisture observations. It was noted that the CAgM was working on this matter, but their report would not be available until their next meeting, five years hence. it was also recommended that a standard technique for measuring and reporting soil moisture was urgently required, and that a network of soil-moisture stations throughout the prairies should be established.

A detailed report on the matter was presented to the 5th Annual Meeting (1964) by Ripley of the Program Directorate (Soils). He discussed the current status of soil-moisture measurement in Canada including gravimetric, neutron probe, Bouyoucos' blocks, Coleman's fibre glass blocks, and tensiometers. He also mentioned soil-water calculations, and methods of reporting soil water. He pointed out that there was a lack of information on the water-holding capacity of soils, their wilting point, field capacity, and bulk density. Such information was required for interpreting precipitation in terms of soil moisture and ultimately in terms of plant growth and yield.

It was suggested that Ripley make this report and his recommendations known to soil specialists in Canada, and to the National Soil Survey Committee.

The NCAM was briefed on the activities of the IHD. One of the many items to be investigated by the IHD program was the "Physics of Soil Moisture". The NCAM suggested that agriculture's part in IHD might be, through ongoing programs, to contribute to knowledge concerning the balance, conservation and chemical constituents of soil moisture and to encourage additional research along these lines at universities and colleges.

The problem of soil moisture observations was again discussed the following year in light of MacVicar's Report (see Chapter 3,"Working Group on Agrometeorological Services in Alberta") and that of the special subcommittee appointed at the last NCAM meeting. The problems of instrumentation, standardization of procedures and reporting format, publication, usage, and other factors had not yet been settled.

Small soil-moisture networks were being established for research purposes in southern Ontario by King, and in western Canada. Holmes, formerly of the PRI Agrometeorological Section, had prepared a report on the topic for WMO in 1964, and W. Baier of that Section was currently working on the use of soil-moisture budgets.

The First Committee on Soil Water

It was decided that the problems needed further study, and a small ad-hoc committee was established to look into the matter of soil-moisture recordings and publication of data for the Prairie Provinces, keeping in mind the requirements for broad scale (agroclimatic) purposes, rather than specific research purposes. Members of the committee were Pelton (chairman), A.M.F. Hennig of Beaverlodge Research Station, and King. The terms of reference were as folows.

1. Possible standardization of previous soil moisture records from various sources in the Prairie Provinces.

2. Gathering of records in 1. above and publishing same in a readily available form.

3. Standardization of soil-moisture measurements to be gathered in the future at all CDA stations and universities in Western Canada, i.e. sampling technique; depths and increments of sampling; dates samples to be taken: number of locations of samples on stubble; summer fallow and sod using Ripley's and Holmes' surveys as guidelines.

4. Annual publication of current data.

5. Possibility of some information being useful in Eastern Canada.

It was also recommended that the Director, CMS, should encourage his post-graduate students in meteorology to undertake research work on agrometeorological problems, including the measurement and estimation of soil water and the use of the data.

The ad-hoc committee reported to the 7th Annual Meeting that some progress had been made on this difficult problem. Many historical data were collectedm and it was recommended that they be put in a suitable form for publication. Because of the many problems associated with the standardization of the measurement of soil moisture on a routine basis, the ad-hoc committee was asked to give this matter further study. Since Pelton's term on the NCAM had expired, the Committee appointed Maybank to serve along with King and Hennig on the ad-hoc committee. Pelton agreed to be available on an advisory basis.

At the 8th Meeting (1967) the ad-hoc committee reported disapproval by all groups contacted regarding any expanded soil-water observational program. There was, however, a positive attitude for a twice-yearly sampling (April and fall). Maybank indicated that the SRC planned to call a meeting of concerned groups in Saskatoon including CDA and the University. King pointed out the need for soil-moisture observations for substantiating mathematical techniques (e.g. Baier and Robertson, 1966) now available for estimating soil water. He also expressed a preference for measurements taken with a neutron probe. The ad-hoc committee (now Stevenson, Hedlin and King) tabled the following recommendations for a soil-moisture observing program for the Prairies.

1. Proceed with the establishment of a twice-a-year program, i.e. spring and fall, at as many locations as possible.

2. Discard the previous proposal of collecting wheat yield data because of the lack of information correlating yield with soil moisture.

3. There appears to be a need for research on soil-moisture variability and on what constitutes a network. Encourage research agencies to investigate the requirements for an adequate evaluation of soil-moisture status and the requirements for a soil-moisture observation program.

4. Arrangements be made for prompt publication of data.

The ad-hoc committee was instructed to continue its efforts on the development of a comprehensive program, and to prepare a summary of results up to the present time. Ludwig was named to liaise with the CMS on the publication of this summary, possibly through the publication "Daily Agrometeorological Data".

Maybank (acting for Stevenson, the chairman) presented the report of the ad-hoc committee at the 9th Annual Meeting. Methods for measuring soil moisture were reviewed and detailed instructions for taking soil moisture measurements were presented along with methods for determining certain moisture physical characteristics of the soil. The following recommendations summarized the findings of the committee;

1. Some means of placing springtime soil-moisture data before the public in simple or popular form prior to mid-June should be devised.

2. A need was recognized for establishing advisory support to the cooperating stations.

3. Efforts should be made to expand the program.

4. The program should be critically reviewed at least once every five years.

The ad-hoc committee continued its work and Stevenson reported back to the 10th Meeting that it had deteriorated from the original three-man group to a single individual. He expressed concern about the publication, use and archiving of the data but did not get much guidance from the NCAM. Chairman Ludwig proposed that Stevenson write to him with a proposal for publishing the data and that he would take the matter up with various authorities. The NCAM felt the entire matter should be kept active and it was suggested that Stevenson continue in a consultatory position to ensure the continuing development of the soil-moisture network.

Soil-Water Observations Become Routine

Stevenson gave a brief report at the 11th Meeting (1970). Since the Agrometeorological Section of the PRI (Baier and Edey) had taken over responsibility for the soil-moisture program in Canada, it was felt that the subcommittee could be disbanded.

Soil water was not discussed again by the Committee until the 18th Annual Meeting in 1977, at which time the theme was Climatic Variability in Relation to Agricultural Productivity and Practices. Soil water was discussed under the heading Analyzing Climatic Variability for Agriculture and included two papers:

1. Soil moisture regimes (Bootsma).
2. Long-term variations in moisture stress index (Mack).

Two recommendations concerning soil water emerged from the discussions:

1. Greater efforts are required in classifying soil-moisture regimes at a more detailed level.
2. The extension of coordinated soil-moisture measurements throughout the season under selected field crops should be encouraged.

During Berry's comments, made at the 21st Annual Meeting, regarding the position paper for the 22nd (1980) Annual Meeting, he observed that remote sensing, when used as a tool for measuring soil water, soil temperature, crop phenology assessments, and so forth in real-time applications of crop-weather models, could conceivably become an integral part of agrometeorological work in the future.

A New Soil-Water Subcommittee

At the request of the Climate Advisory Committee (CAC) of CMS, the ECA established a Soil-Moisture Subcommittee with Dr. David Chanasyk as chairman. Members were to be drawn from the Prairie Provinces, AES, PFRA, and CDA. The main responsibility of the Sub-Committee was to advise CAC on matters pertaining to the measurement and estimation of soil moisture.

Chanasyk presented a brief progress report at the 1982 Annual Meeting and a more complete report the following year. Questionnaires were sent to various government departments, universities, and private consulting firms within Alberta. Seventeen contacts were made. He developed a standard format for reporting information. He also volunteered to contact interested parties in Saskatchewan and Manitoba, and to serve as a clearing house for the data collected. The ECA accepted Chanasyk's suggestions and his recommendation that the formal subcommittee be discontinued.

The 29th Annual Meeting (1987) heard a report that there was an escalating problem of duplication relative to soil-water monitoring and reporting. A number of agencies including CDA, PFRA, CMS, and several provincial groups were involved in essentially the same activity. Edey (chairman) and Wheaton were asked to form a subcommittee to investigate the matter. As Edey retired the following year no further reports on the matter were presented.

PART 9 - EDUCATION AND HUMAN RESOURCES

A Shortage of Agrometeorologists Limits Progress

Training and research in agrometeorology was discussed in some detail at the 1st Meeting of NCAM (1960). The Committee recognized that there was a real shortage of agrometeorologists and that this shortage would immediately and for some time limit the progress that could be made in the science. The Committee, therefore, endorsed the view that a research and teaching institute in bioclimatology (or agrometeorology) be organized at a university as soon as possible.

The 2nd Annual Meeting (1961) reaffirmed its encouragement for establishing a research and training centre in bioclimatology at a university. It noted that a new Department of Meteorology had been established at McGill University under the direction of Professor S. Marshall.

The 3rd Annual Meeting was told that research projects in agrometeorology and micrometeorology were underway by King at the Ontario Agricultural College. The NCAM continued to recognize the need for trained professional agrometeorologists and pushed for the establishment of postgraduate training in agrometeorology.

The Committee learned at the 4th Annual Meeting that OAC planned to offer a Master of Science degree program in agrometeorology under the direction of King. It was noted that King had been appointed to a CAgM Working Group on Syllabi for Instruction in Agricultural Meteorology. A year later (1964) King announced that there were two students registered in the Graduate Program in Agrometeorology.

In spite of the apparent need for several professionals in the field of agrometeorology, the Committee noted in 1965 that there was not a single authorized position in the country to be filled. This provided little incentive to students to enter this field as a career. In spite of this lack of vacancies for

agrometeorologists, the 6th Annual Meeting (1965) noted the developments at the University of Guelph leading to the current graduate program in agrometeorology. However, it felt that this one program fell far short of meeting all the requirements for training in Canada, and it was suggested that it should be duplicated in at least one university in western Canada.

It was also noted that professional agriculturalists rarely get a course in meteorology during their academic career and subsequently, no in-service training in meteorology. Farmers also need training in agrometeorology, particularly in regard to the use of farm-weather forecasts and agroclimatic information. From the long discussion of this matter four recommendations resulted, as summarized below.

1. Elective courses in meteorology and climatology should be made available to agricultural students.

2. CMS should encourage M.A. students in meteorology to do their thesis work on problems of concern to agriculture, such as the turbulent fluxes of various entities; the radiant energy balance under different agronomic practices; the transport of air-borne particles on a synoptic scale; and water-balance in the soil. Also, students showing an interest in agricultural problems should be encouraged to seek a career in agrometeorology. (Desjardins was one student-employee of CMS who followed this line of training. See Chapter 3).

3. The CDA Research Branch should conduct at least one in-service training course for staff members who encounter weather-sensitive problems requiring agrometeorological considerations in their research.

4. Provincial departments of agriculture should encourage the discussion of agrometeorological and agroclimatological topics at farmers' meetings, at farm short courses, in 4-H club activities, and in the curricula of agricultural schools (diploma courses). The farm press should be encouraged to include articles of an educational nature on agrometeorology.

In response to the second recommendation, the CMS informed the meeting that, while realizing the importance of research in agrometeorology at the postgraduate level, very few of the small number of postgraduate students in meteorology could be expected to specialize in agrometeorology. There are many other special fields where meteorology can be applied, and the competition is very keen.

First Workshop in Agrometeorology

In accordance with the third recommendation, above, a two-week Workshop on Agrometeorology for research officers of the Research Branch was held in Toronto 5-17 September 1966. This was sponsored by the RB/CDA and directed by Robertson, Chief of the Agrometeorological Section, PRI. The seminar participants were Research Branch personnel representing most areas of the country,

Lectures were given by various specialists from CMS, ORF, the University of Guelph, the Agrometeorological Section of CDA, and the Data Processing Centre of CDA. Participants had the opportunity to listen to and converse with some 45 experts in the fields of administration, climatology, hydrology, ecology, instrumentation, micrometeorology, agrometeorology and computer science.

The Workshop appears to have made some contribution to removing the communications barrier that distances impose on scientists in Canada. This was noted in the following unsolicited statement in a letter, dated 30 September 1966, to Robertson from Dr. Gloyne, agrometeorologist with the United Kingdom Meteorological Office at Edinburgh following a tour of agrometeorological and related programs across Canada:

"I was greatly impressed and envious of the lavish facilities now being made available to the universities. The sky seems the limit in this, the biggest 'growth industry' in Canada!

"I wonder if it would be a fair comment to say that everyone is so busy developing and expanding their own departments and carrying out their own programs that there is insufficient time for communication, for assimilating other people's findings and for putting results to practical use. I appreciate the enormous distances you have, but even so it was strange for me to find that, in the course of a series of short visits, I often apparently knew more about what was going on at any one centre than did the workers in allied fields at other centres."

Unanimous in approval, The NCAM expressed the desirability of continuing the workshop program. It was proposed that CASCC should be approached on having similar courses on a continuing basis at the University of Guelph. Ludwig felt that administrative arrangements through grants or registration fees could defer much of the cost.

There appears to have been no follow-up regarding this matter, as no further workshops on general agrometeorology were held. However, a number of workshops and seminars on special topics were held from time to time over the next 25 years, many of these following recommendations by the NCAM (CCAM, CCA, ECA).

Increased Activity at the University of Guelph

In the field of academic education the University of Guelph made progressive strides in the establishment of both graduate and undergraduate courses in agrometeorology. Undergraduates majoring in soils were required to take specific agrometeorological courses. The first student, T.J. Gillespie, to register for a Ph.D. degree in agrometeorology, began his work in 1965. NCAM noted with interest that he was a meteorologist on leave from CMS. He became the third staff member on the faculty in 1968.

NCAM continued to monitor agrometeorological education in Canada, and noted that the Graduate School at Guelph continued to grow slowly but steadily, with three Ph.D. and one M.Sc. candidates enrolled by 1967. A 70-acre site was acquired for agrometeorological research at Elora. King was named the Canadian member of the CAgM/WMO Working group on Agricultural Meteorology Training and Syllabi.

By 1968 the program at Guelph was being supported by IBP grants, the training program was enlarged, and graduate-student enrolment showed accelerated growth. The faculty grew by three new members: a meteorologist, an agricultural physicist, and a crop physiologist, as well as a postdoctoral fellow. Total enrolment in agrometeorology included two M.Sc. and seven Ph.D. students. A new Crop Science Building, with about 10,000 square feet of growth-chamber facilities, was opened on campus early in 1968, primarily for the use of crop physiologists.

Brown also informed the 10th Annual Meeting about the cross-Canada tour undertaken by King. The tour, sponsored by the CMS, was to promote a better understanding of the "Application of Micrometeorology and Microclimatology in Agriculture". His talks were aimed at regional meteorologist groups, universities, and local meteorological societies.

Nucleus Formed at Macdonald College

Following a recommendation by the NCAM, Macdonald College appointed a Chairman of their new Agricultural Physics Department in 1965. The appointee, Dr. R.H. Douglas, was a former CMS meteorologist and staff member of the McGill Department of Meteorology. This interesting development was heralded by the Committee as the beginning of an agrometeorological education program at the college.

In recognition of the increasing significance of university participation and importance in the field of agrometeorology, Ludwig, Chairman of the Committee, recommended that Douglas be appointed as permanent representative on the Committee for Macdonald College, a position he held until his retirement in 1984.

Douglas reported to the 9th Meeting (1968) that a decision was made at Macdonald College to provide courses and training only at the Doctorate level. A study indicated that there was little need for training leading to Bachelor and Master degrees. A syllabus to this end was prepared. At the time no agrometeorological projects had been approved although several interesting ones were being seriously considered for graduate study.

Agrometeorology at Other Universities

Now that two research and training centres had been established, the Committee became less concerned with postgraduate training. However, it continued to monitor progress and developments in this field and included in its membership, over the years, a number of people from universities. Over the next 20 years or so the Committee noted activities in agrometeorology at universities such as Alberta, Saskatchewan, Fredericton, British Columbia, Laval, Waterloo, Manitoba, and Simon Fraser.

Manpower Situation

The 7th Annual Meeting (1966) considered a new topic that had been touched on lightly at some past meetings. This concerned the manpower situation for agrometeorologists in Canada. At the 6th Meeting it was reported that there was possibly only one firm position available for an agrometeorologist in Canada. A year later there appeared to be eight such positions available but no one to fill them.

A small subcommittee (Robertson and King) looked into this man-power situation. Their report was discussed at the 8th Annual Meeting. It was felt that the shortage of manpower could be traced to two factors: the secondment policy of CMS, which could not keep up with the demand for qualified agrometeorologists; the qualifications for meteorologists which demanded an undergraduate degree in mathematics and physics, or similar training. It was felt that the undergraduate requirements for agrometeorologists should be broadened to permit those in the biological and related sciences to do graduate work in agrometeorology taking, if necessary, the mathematics and physics as required.

Except for a note by O'Grady at the 9th Annual Meeting that progress in agrometeorology in Quebec was limited by the manpower shortage, no further discussions appear to have taken place until the 12th Annual Meeting. It was pointed out that there was a problem concerning the employment of graduate students in agrometeorology. Not too many years before, this Committee lamented the lack of qualified personnel in this field. In 1971 there appeared to be a serious reversal of the situation in that jobs or vacant positions were non-existent. Brown was asked to look into this situation and report back the Committee as to the status of graduate students. A survey taken of members at the Meeting revealed that within the next three years (1971-73) there would be four M.Sc. graduates and five Ph.D. graduates, plus a potential of three or more new students in 1972.

No further significant comments were made by the Committee until the 23rd Annual Meeting when it was noted that the need to increase food production as proposed in the Agri-Food Strategy outline was dependent on the interaction of weather and modern agricultural technology. It was agreed that ECA recommend to CASCC that CDA fulfill its responsibility in the area of agrometeorology by providing sufficient staff to carry out research, and to ensure adequate technology transfer in various regions of Canada in order to discharge its responsibility as outlined in the Agri-Food Strategy for Canada.

It was also noted that the current demand for trained agrometeorologists in Canada exceeded the supply and that the implementation of certain sectors of the Agri-Food Strategy would further increase the demand for properly trained agrometeorologists. It was therefore recommended that post-secondary

training institutions offering degree or diploma programs in agriculture should ensure that their curricula contain an exposure to the techniques and benefits of utilizing agrometeorological information in farm management, and that schools of graduate studies and research-funding organizations should give priority to programs leading to an M.Sc. or Ph.D. degree in agrometeorology.

Agrometeorological Operational Centres were proposed at the 27th Annual Meeting (1985). After considerable deliberation of this matter, the Committee chairman proposed a subcommittee to address the problem of staff shortages and education in agrometeorology. Members of the subcommittee were Schneller (Chairman), Read, and Powell. In a report at the 29th Annual Meeting (1987) the subcommittee expressed concern that the level of education in agrometeorology received by graduates in agriculture was inadequate. If taught, the relevant material was often limited to incorporation as a portion of courses in field crop or horticultural production (Author's note: This was the case some 42 years earlier when I took a course in Field Crop Management from McCalla at the University of Alberta). Agriculture today faces demands for more efficient production and marketing as well as conservation and environmental protection. Climatic information also has a strong influence both on the economy and on political decisions related to agriculture and along with prices, is the cause of most natural and economic uncertainties. Furthermore, weather and climate are the main components of crop production and the newly emerging insect- and disease-control models, all of which constitute useful tools in production and marketing decision-making.

He suggested a resolution "that deans of agriculture and principals of colleges be encouraged to review course content at their institutions to ensure that graduating students receive a satisfactory level of training in weather and climate subjects." After some discussion, this draft resolution was placed in abeyance for the time being. Schneller asked to be relieved of his duties as chairman of the subcommittee.

Inventory of Canadian Capability in Agrometeorology

Secretary Edey made available to members of the 1986 Annual Meeting a copy of a report entitled "Meteorology and Hydrometeorology in Support of Agriculture and Forestry: an Inventory of Capability", prepared by Robertson for CIDA. As only a limited number of copies of the report were available the ECA recommended that additional copies be produced and distributed more widely. ECA further recommended that the report be updated in 2 or 3 years. The report was again discussed by the Committee in 1988. The material in the report was now more than 3 years old, and the Committee felt it should be revised and updated and agreed that CIDA should be advised accordingly.

CHAPTER 6
CANADIAN FORESTRY SERVICE

PART 1 - INTRODUCTION

Forestry in Canada

In a special report to the CCAM at its 16th (1975) Annual Meeting, Dr. R. Silversides presented a special report on forest meteorology. The following is taken from the introduction to that report.

> "Canada's forests contribute significantly to the economic and social well-being of all Canadians. About five percent of the GNP is derived from forest-based industries, directly employing over a quarter of a million workers. Forest products contribute a $4.1 billion surplus to the export market, which is over one fifth of the total export surplus.
>
> "It has been estimated that the potential value of standing merchantable timber after manufacturing is $674 trillion. A direct dollar estimate cannot be placed on the recreational value of forests, but there is no doubt that they have helped to mould the national character. Increased population, greater mobility, and more leisure time have resulted in Canadians making much greater use of the forests for recreational purposes.
>
> "The role of forest meteorology will be to provided low-profile research and applications of a continuing nature, but on occasion it will be necessary to respond to the urgent demands of special projects. This is a challenging role and a difficult one; and since no individual can be an expert in all things, it is the agricultural meteorological community as a whole which must be prepared to accept responsibility."

Early Meteorological Problems

Forest meteorology is concerned with the application of meteorology to forestry problems, and in this respect follows the principles given in the WMO Guide to Agricultural Meteorological Practices (WMO, 1963, 1981).

In general the basic or fundamental problems in forestry meteorology are the same as in agricultural meteorology. On a practical basis, the problems in forestry are different in many respects. The remaining commercial forests in Canada occupy soil-climate zones that are generally unfavorable for agriculture. For this reason forests are found in areas where climate is a major stress, particularly temperature and length of the growing season. Precipitation is usually adequate for growth, more so than in many agricultural areas, but at times runoff and erosion may be problems. Summer drought, particularly in the litter layer on the forest floor may result in fire hazard.

Major meteorological influences involved in forestry concern such problems as fire control (Wright, 1932), insect and disease control, forest regeneration, forest productivity, forest environment control, and more recently, the effects of atmospheric pollution on forests. Generally, research in the field of forest meteorology has been carried on by the Federal Government through the Canadian Forestry Service (CFS) and at some universities. Fire, insect, and disease control usually is the responsibility of the provincial governments. The CMS has played an active role, particularly in providing special forecasting services for fire and pest control, as well as support for special forest-meteorology research and services.

PART 2 - EARLY ACTIVITIES

Fire-Hazard Research

Probably one of the earliest research activities involving meteorology was undertaken at the Petawawa Forest Experiment Station concerning forest-fire hazards. The result of this research was an index based primarily on the current and recent-past weather events. This was used to assess the likelihood of forest fires and to warn of their impending danger (Wright, 1932).

The Bioclimatology Section of Forest Biology

Dr. W.G. Wellington, an entomologist with some meteorological training, joined the Forest Biology Division of the Canada Department of Agriculture in Sault St. Marie in 1945. He undertook research on insect biometeorology and soon became well known for his work in this area. Instead of using climatological data for explaining insect behaviour as many earlier researchers had done, he studied the microclimate of the insect habitat to explain behaviour, and used synoptic meteorology to study the movement and behaviour of flying insects, particularly the spruce budworm. Wellington soon became Head of the Bioclimatology Section of what eventually became. the Great Lakes Forest Research Centre, and later the Forest Pest Management Institute.

Dr. G.W. Green joined him in 1951 to work on the effects of weather and climate on insect behaviour, activity, development, and success. From 1955 to 1965 he worked as a member of a team to investigate the European pine-shot moth.

Academically, Green was trained as an entomologist, having received a B.A. degree with Honours in Biology from the University of Toronto in 1951; an M.A. in Forest Entomology in 1953 from the same institution; and a Ph.D. degree in Sensory Physiology (Entomology) from the University of Pennsylvania in 1963. He continued to work with Wellington until 1968 when he abandoned active research to become increasingly involved with various levels of research management.

Seconded Meteorologists

The Forestry Branch was concerned with a number of weather-sensitive problems, the most important of which was fire control. They had made use of the services of the CMS by consultation and correspondence. This proved not too satisfactory and in 1949 G.T. Allison was hired on contract to study fire control and related problems on the east slopes of the Rocky Mountains.

Realizing the importance of meteorology in fire control as well as forest production and management, the Forestry Branch took advantage of the secondment policy of the CMS (see Chapter. 3, "A Period of Secondment"). H.C. Cameron, a meteorologist with experience at the Winnipeg Weather Office and the Central Analysis Office in Ottawa, was seconded to the Branch in 1951. A few years later he moved on to another assignment with CMS, and was replaced in 1954 by L.B. MacHattie, another meteorologist who had been a practising forecaster in the Atlantic Region, and in Ireland.

Later M.S. Webb was seconded by CMS to the Forest Fire Research Institute of the new CFS in 1964. He reverted back to CMS at the termination of secondment in 1968. MacHattie and Webb undertook research on topoclimatology in the Rocky Mountains near Kananaskis in southern Alberta. Although stationed in Ottawa they spent several summers doing research in the mountains.

PART 3 - DEVELOPMENTS AT FORESTRY CENTRES

Northern Forest Research Centre

J.M. Powell joined the Forest Biology Laboratory, Forest Biology Division of CDA in Calgary in 1959, where he worked as a biometeorologist and biologist until 1970. He then transferred to the Northern Forest Research Centre of CFS in Edmonton where he became Program Director of Forestry Environment and Planning in 1984.

Powell graduated from the University of London (U.K.) with a B.Sc. (1956) in Plant Geography; from McGill University with a M.Sc. (1959) in Biogeography and Climatology under Dr. F.K. Hare; and from the University of British Columbia with a Ph.D. (1969) in Forest Pathology. He is the author of many papers dealing with topics in forest meteorology, a small sample of which is listed below.

By the end of the 1980's a number of projects were under way by the Canadian Forest Service in Alberta. These included a study of snow evaporation in an artificial juvenile lodgepole stand, estimation of snow evaporation in an open field, and a study of air and soil climate in peat bogs before and following drainage. Research into and monitoring of forest fires was an ongoing activity. Automatic-weather stations, hooked into a radio-telemetry system were used for the remote retrieval of data. An Alberta Fire-History Atlas for the period 1930-83 was completed. A report on "An Exploration and Assessment of the Implications of Climatic Change for the Boreal Forest and Forest Economics of the Prairie Provinces and the Northwest Territories" was near completion.

The Pacific Forest Research Centre

Dr. J.A. Turner joined the Pacific Forestry Research Centre in 1967. Formerly he was a CMS meteorologist seconded to the British Columbia Forest Service in 1950. He transferred to the CFS in 1967 on a seconded basis, and at the termination of the secondment policy by CMS, he joined the CFS in Victoria as a research scientist in forest meteorology.

Dr. R.H. Silversides transferred from Sault Ste. Marie to the Pacific Forest Research Centre (PFRC) of the CFS in Victoria in 1975 to fill the vacancy left by the resignation of Turner in 1974. Silversides was hired by the CFS at Sault Ste. Marie in 1973. He had an M.A. in meteorology from the University of Toronto (1961) and a Ph.D. in agrometeorology from Guelph (1972). He worked as a CMS forecaster in the Atlantic Region from 1961 to 1968.

The Petawawa Northern Forest Institute

Dr. J. Harrington joined the Forest Fire Research Institute in 1975, and in 1979 moved to the Petawawa Northern Forest Institute (PNFI) of the CFS. He received a B.Sc. degree from the University of Saskatchewan in 1947, an M.Sc. in Meteorology from the University of Toronto in 1956, and a Ph.D in Meteorology from the Dept. of Atmospheric Science, Michigan State University in 1965. He worked at Michigan State from 1965 to 1974 in the College of Agriculture and in Agricultural Engineering, where he taught agrometeorology to both agricultural and forestry students.

Work at Other Research Centres

Forestry scientists soon learned through experience and association with forestry meteorologists that training in meteorology was essential in many phases of their work. Consequently many foresters studied meteorology, attended forest meteorology workshops, and some even majored in meteorology during postgraduate training.

During the 1970's forest research showed an increased interest in climate and meteorology at a number of other centres. This increase in activity was stimulated by:

1. The activities of the IBP were at their peek during the early 1970's and results were being discussed. Mukammal of CMS worked in collaboration with the CFS at Petawawa, where research was underway on ecosystem productivity and boundary-layer micrometeorology in forest stands.

2. Increased cooperation with the CMS through their Regional Offices;

3. Increased interest in forest meteorology on the part of universities;

4. In 1975 the CCAM appointed a representative from forestry to attend their Annual Meetings.

Activities and interest continued to grow in the 1980's, spurred on by several new events:

1. The holding of a WMO Symposium on Forestry Meteorology at Ottawa in 1978. Local coordinators were Harrington of CFS, Baier of CDA, and Thomas of CMS. Some 75 people attended the conference from universities, CDA, CMS, provincial establishments, as well as from CFS.

2. Forestry held a 2-day Climate Workshop in connection with the Canadian Climate Program (CCP) and forestry appointed the ADM, Mr. F.L. Reed, as representative on the Climate Planning Board of the Canadian Climate Program.

3. A second meeting of the Forestry Sector Working Group of CCP was held in Regina in 1981.

4. The Canadian Meteorology and Oceanography Society formed a Special Interest Group in Agriculture and Forest Meteorology that helped bring together scientists in these sister areas.

Although meterological and climatological knowledge and data were used in a wide variety of projects and studies in all of CFS's nine Forest Centres, there appeared to be little policy recognition of forest meteorology as a distinct science. A great deal of the forest meteorology carried on at the Research Centres was performed by individuals in connection with their research and service involving local or regional forest problems having weather sensitivity.

Membership in NCAM

The NCAM was originally established in 1959 by the CDA as an internal organ for agriculture. It was not until 1975 that CFS was invited to send a representative to the meetings. Silversides was the first permanent representative, serving from 1975 to 1978. He was replaced by Dr. J.M. Powell of the Northern Forest Research Centre, CFS Edmonton from 1981 to 1986. Dr. J. Harrington of Petawawa Forest Research Centre, Ontario, replaced Powell in 1987 (see Chapter 5, Sections on "Membership" and on "Membership List".)

PART 4 - RECENT RESEARCH PROBLEMS

Near the close of the 1980's the problems being investigated at Forest Centres had expanded to include (as reported by Powell to ECA, 1987).

Newfoundland Forest Centre:
- energy-balance studies,
- microclimatic effects on biomass,
- impact of wind on a balsam fir wave forest,
- use of trees as biological indicators.

Maritimes Forest Centre:
-delineation of climatic regions using multivariate statistical methods.

Laurentian Forest Centre:
- effects of air pollution and acid rain,
- climatological data acquisition,
- characterization of tree sites.

Great Lakes Forest Centre:
- evaluation and calibration of the Ontario Forest Fire Danger Rating System,
- regeneration silviculture research,
- insect control operations,
- modelling of forest insect population,
- impact of long-range transport of air pollutants.

Alberta Forest Centre:
- data collection on the Marmot Creek watershed,
- snow evaporation in lodgepole stands,
- microclimatic effects of opening size,
- air and soil climate studies,
- forest vegetation management,
- effects of increased CO_2 concentration on tree growth,
- effects of climate change and variability on forest vegetation,
- experimental burns in controlled conditions.

Pacific Forest Centre:
- networking of autostations by UHF,
- decomposition of organic layers,
- site disturbance,
- black-army cutworms and budworm studies,
- pathogens for controlling mountain pine beetle.

Forest Pest Management Institute:
- research in spray-cloud dispersal,
- environmental impact studies.

Petawawa National Forestry Institute:
- artificial intelligence as applied to fire-control operations,
- techniques for forest inventory using airborne and satellite imagery,
- use of satellite imagery in locating and measuring forest fires,
- effects of climate, climatic change and air pollution on forests,
- drying of forest fuel,
- modelling of broad-scale forest yield,
- tree-seedling growth as related to edaphic and atmospheric conditions,
- seed production and pollen transport,
- flower induction trials in jack pine.

Many of these studies are more in the nature of plant physiology than forest meteorology, requiring only proxy climatic data or the simplest environmental measurements.

Examples of research undertaken and completed are shown in the following list of published papers (in chronological order):

1932 WRIGHT, J.G. Forest-fire hazard research as developed and conducted at the Petawawa Forest Experimental Station, Dept. of Mines and Resources, Ottawa. Forest-fire hazard paper No. 2.

1951 WELLINGTON, W.G., SULLIVAN, C.R. and GREEN, G.W. Polarized light and body temperature level as orientation factors in the light reactions of some hymenopterous and lepidopterous larvae. Can. J. Zool. 29:339-351.

1954 GREEN, G.W. Humidity reactions and water balance of larvae of Neodiprion americanus banksianae Roh. and N. lecontei (Fitch) (Hymenoptera: Diprionidea). Can. Ent. 86:261-274.

WELLINGTON, W.G. Weather and climate in forest entomology. Meteorol. Monogr. 2(8):11-18.

1955 GREEN, G.W. Temperature relations of ant-lion larvae (Neuroptera Myrineleontidae). Can. Ent. 87:441-459.

1958 MacHATTIE, L.B. The accuracy of the hair hygrograph. Meteorol. Br. Tech. Cir. 265. 9 pp + figs.

1962 POWELL, J.M. Climate in relation to the mountain pine beetle. p. 113. In: Annual Report Forest Entomology and Pathology Branch Year Ended March 31, 1962. Can. Dept. Forestry, Ottawa.

1963 MacHATTIE, L.B. Winter injury of lodgepole pine foliage. Weather, 18:301-307.

1964 SULLIVAN, C.R. and GREEN, G.W. Freezing point determination in immature stages of insects. Can. Ent. 96:158.

1965 POWELL, J.M. Changes in amounts of sunshine in British Columbia, 1901-1960. Quart. J. Roy. Met. Soc. 91:95-98.

1966 MacHATTIE, L.B. Relative humidity in Rocky Mountain forests of southern Alberta in summer. Can. Dept. of Forestry, Forest Res. Inst., Ottawa. Information Rep. FF-X-1. 54 pp.

WEBB, M.S. An approach to forecasting low surface humidities at night in the Rocky Mountains. Meteorol. Br. Tech. Cir. 598. 9 pp.

WELLINGTON, W.G., SULLIVAN, C.R. and GREEN, G.W. Biometeorological research in Canadian forest entomology: a review. Int. J. Biometeorol. 10:3-15.

1967 POWELL, J.M. A study of habitat temperature of the bark beetle Dendroctonus ponderosae Hopkins in lodgepole pine. Agric. Meteorol. 4:189-201.

1968 GREEN, G.W. Weather and insects. Proc. 28th Ann. Biol. Colloquium, Oregon State University, (1967) pp. 81-112.

WRIGHT, J.G. and BEAL, H.W. The application of meteorology to forest fire protection. Forest Fire Research Institute, Ottawa, Ontario, Information Report, FF-X-11.

1969 POWELL, J.M. Historical study of the relation of major mountain pine beetle outbreaks in western Canada to seasonal weather. Can. Dept. of Fisheries and Forestry, For. Res. Lab., Calgary. Inform. Rep. A-X-23. 11 pp.

WEBB, M.S. Variability of summer rainfall and its effect upon the areal representativeness of a point observation. Forestry Branch Publ. No. 1251. pp. 1-14.

1970 POWELL, J.M. A forest climate classification for Canada - discussion. pp. 227-228. In: Powell, J.M. and C.F. Nolasco (eds). Proc. Third Forest Microclimate Symposium, September, 1969. Can. For. Serv., Alberta/ Territories Region, Calgary, Alberta, March.

1971 MUKAMMAL, E.I. Some aspects of radiant energy in a pine forest. Arch. Meteorol. Geoph. Biokl. Ser. B, 19:29-52.

1974 POWELL, J.M. Environmental factors affecting germination of Cronartium comandrae aeciospores. Can. J. Bot. 52:659-557.

1977 POWELL, J.M. and MacIVER, D.C. A summer climate classification for the forested area of the prairie provinces using factor analysis. Fish. and Environ. Can., Can. For. Serv., North. For. Res. Centre, Edmonton, Alberta. Inf. Rept. NOR-X-177. 51 pp.

1978 POWELL, J.M. Climatic networks for forestry purposes. pp. 20-32. In: Powell, J.M. (Compiler). Climatic Networks: Proc. of the Workshop and Annual Meeting of the Alberta Climatological Association, April 1978. Fish. and Environ. Can., North. For. Res. Cent., Edmonton, Alberta. Inf. Rept. NOR-X-209. 101 pp.

1979 MacHATTIE, L.B. Meteorology and forest insect control in Canada. pp. 139-148. In Proc. of the WMO Symposium on Forestry Meteorology, August 21-25, 1978. Published by the Can. For. Serv. on behalf of WMO. WMO-527. 234 pp.

1981 POWELL, J.M. Impact of Climatic Variation on Boreal Forest Biomass Production. pp. 189-194. In: Harrington, C.R. (Ed.) Climatic Change in Canada 2. Nat. Museums of Can., National Museum of Natural Sciences, Ottawa, Syllogeus. No. 33. 220 pp.

1987 JOZSA, L.A. and POWELL, J.M. Some climatic aspects of biomass productivity of white spruce stem wood. Can. J. For. Res. 17:1075-1079.

CHAPTER 7
OTHER FEDERAL GOVERNMENT AGENCIES

PART 1 - SWIFT CURRENT RESEARCH STATION

Early Problems

Much of the following is taken verbatim from the publication "The Swift Current Research Station, 1920-1970 (Campbell, 1971).

In 1920, the Saskatchewan Legislature appointed a royal commission to inquire into the conditions of the farming industry in the western and southwestern parts of the province. One of the recommendations of the commission was that agricultural experimentation be done in the area so that farmers could obtain a complete and thorough knowledge of crops, soils and farming methods to make their farming productive, profitable and permanent. In the summer of 1920, the federal government obtained land near Swift Current to establish an experimental station. Work on soil physics and related agrometeorological problems were under the direction of S. Barnes.

Barnes reported directly to the Field Husbandry, Soils, and Agricultural Engineering Division of the Experimental Farms Service in Ottawa. He was responsible for some of the earliest practical research work in soil physics and agrometeorologically related topics such as soil-water conservation and control of soil erosion by wind. Barnes died in 1935, just at the peak of the serious drought which plagued the prairies during the 1930's.

Soil Research Laboratory

In 1936 the Prairie Farm Rehabilitation Administration (PFRA) provided funds for a Soil Research Laboratory (SRL) at Swift Current to continue the work of Barnes. J.L. Doughty was appointed Director and continued in this position until his retirement in 1957. Doughty brought to the SRL a broad knowledge of soil research from his studies in the U.S.A., from his teaching experience at the University of Alberta and from his direction of soil surveys as soil specialist with the PFRA.

W. Chepil was transferred from the Regina Experimental Farm to continue his work on soil erosion. He remained on staff until he resigned to join the faculty of State College, Manhattan, Kansas in 1950. W.J. Staple and J.J. Lehane joined the SRL in 1937 and undertook work in soil physics, particularly soil-water conservation, which also involved some shelter-belt research. F. Bisal joined the group later and worked on soil erosion problems and control. Staple became acting director of the SRL after Doughty retired.

Soil Section of the Experimental Station

Shortly afterwards, the SRL was transferred to the Swift Current Experimental Station where it became the Soil Section. Staple was transferred to the Central Experimental Farm in Ottawa to continue work on soil physics, particularly the movement of water through soil. K.F. Nielsen was transferred from the Central Experimental Farm to become head of a section then called the Soil Science Section. Nielsen resigned in 1966 and W.S. Ferguson was transferred from the Brandon Experimental Farm, where he had been doing soil studies. He was moved to the Program Directorate in 1970, and Robertson was appointed head of the Section in 1971, when he returned from a leave of absence in the Philippines. By then the Section was known as the Environment Section and included soil chemistry, soil bacteriology, soil physics, as well as agrometeorology and micrometeorology. Robertson retired in 1973 after 35 years of work with the CMS and CDA.

Although the main thrust of the Section was in the area of soil physics, several research problems involved areas related to agrometeorology, such as wind and rainfall effects on soil erosion, the conservation of precipitation (both rain and snow), the movement of wind through wind breaks, evaporation and the use of soil water by crops, soil-water measurements, crop yield estimation, and other studies related to soil erosion and water conservation. By 1958 the involvement in agrometeorological topics was such that an agrometeorologist was needed.

W.L. Pelton became the first agrometeorologist to work in the Section. He received his Ph.D. degree in soil physics (micrometeorology) from the University of Wisconsin in Madison. He worked on such problems as the measurement of the fluxes of water vapour and energy above different soil-surface covers, the measurement of evapotranspiration with floating lysimeters, various methods for measuring soil water, agroclimatic analyses and so forth. He took leave of absence in 1970 to accept an appointment in international work sponsored by CIDA.

D.W. Stewart joined the Section in 1969. He graduated from the University of Guelph (OAC) with a B.Sc. in 1964 and an M.Sc in 1965. His M.Sc. thesis title was "Water Relationships in the Soil-Plant-Atmosphere System." He received a Ph.D. in Meteorology from Cornell University in 1969. His thesis title was "A Simulation of Net Photosynthesis of Field Corn." He undertook research on micrometeorology and crop-weather modelling and continued some of the work started earlier by Pelton. Stewart resigned in 1974 to pursue a career as a private consultant in the field of computer simulation.

Pelton returned from his leave of absence in 1973 and replaced Robertson as Head of the Section now called the Soils and Environment Section. He continued as Head until he was transferred to Lethbridge in 1975. C.A. Campbell, a soils chemist and long-time member of the Section, replaced Pelton as Section Head. He still occupies this position at the time of writing.

H.R. Davidson was recruited in 1975 as an agrometeorologist to replace Stewart. He stayed with the Section for about eight years. He was transferred to the Pacific Region in 1983. H.W. Cutforth was appointed as agrometeorologist and soil physicist in 1985 to continue the work of Davidson, R. De Jong, a soil physicist, spent three years (1977-79) in the Section working on soil physics and agrometeorological problems. He eventually transferred to the LRRI in Ottawa to continue work on soil physics.

Research Activities

The Experimental Farm and Soil Research Laboratory were established in the early 1920's during a serious drought period which started about 1916. There were serious problems with soil erosion and crop failures. The old system of heavily cultivating soils to control weeds left a fine dust mulch that was subject to severe erosion. Farmers tried various alternatives such as leaving fields covered with clods and practising strip farming (alternating 16-rod strips of crop with an equal width of summer fallow running at right angles to the prevailing wind). Grasshoppers were also a serious problem, and wheat rusts and frosts took their toll. Many farms, particularly those on the lighter soils, were abandoned. There was no dearth of practical research problems when the Experimental Farm and Laboratory opened.

When the Experimental Farm was established one of the first projects was to start taking weather observations in order to monitor the weather and evaluate the climate of the area. The first annual report (1922) of the Experimental Station contained one page of discussion on the weather during the growing season. Rainfall, of course, was the main concern.

In the early 1920's much of the research was related to the conservation of soil water and the questionable role of mulches and standing stubble. By 1923 experiments were being undertaken to determine water use by crops with "absolute accuracy". Tanks filled with soil and weighed periodically were used for the purpose.

By 1927 attempts were being made to forecast crop yields based on preseason precipitation plus that for the growing season up to the end of July. Rainfall after July was found not to influence the yield of wheat for that season.

In the Progress Report of the Division of Field Husbandry (Ottawa) for 1931-35 for the Prairie Provinces, seven pages were devoted to a discussion of current-season weather compared with long-term averages. Most of this came from the Soils Laboratory in Swift Current, as it reported directly to Ottawa. Also the 1931-36 Annual Report of the Swift Current Experimental Farm contained a six-page discussion on the climate and seasonal weather of the area. The past seasons weather was described, climatological comparisons involving precipitation, sunshine and frost-free seasons were made and comments on soil-moisture measurements and the use of soil water by crops were included. By the end of the 1930's, investigations included the conservation of snowfall.

In the 1948-54 report there was a section on crop forecasting experiments. The procedure was based on measurements of the depth of moist soil at seeding time and the May-June-July total rainfall.

Research Chronology

Nearly 50 years of research programs and progress at Swift Current can best be summarized by the following scientific publications:

1938 BARNES, S. Soil moisture and crop production under dry land conditions in western Canada. Can. Dept. of Agric. Publ. 595.

1939 CHEPIL, W.S. and MILNE, R.A. Comparative study of soil drifting in the field and in a wind tunnel. Sci. Agric. 19:249-257.

1940 STAPLE, W.J. and LEHANE, J.J. Response of the Livingston atmometer to single meteorological factors. Sci. Agric. 20:308-310.

1944 STAPLE, W.J. and LEHANE, J.J. Estimation of soil moisture conservation from meteorological data. Soil Sci. 58:177-193

1945 CHEPIL, W.S. Dynamics of wind erosion: I. Nature of movement of soil by wind. Soil Sci. 60:305-320.

1952 STAPLE, W.J. and LEHANE, J.J. The conservation of soil moisture in southern Saskatchewan. Soil Sci. 32:36-47.

1955 STAPLE, W.J. and LEHANE, J.J. The influence of field shelterbelts on wind velocity, evaporation, soil moisture, and crop yield. Can. J. Agric. Sci. 35:440-453.

1960 BISAL, F. The effect of raindrop size and impact velocity on sand splash. Can. J. Soil Sci. 40:242-245.

1965 LEHANE, J.J. and STAPLE, W.J. Influence of soil texture, depth of soil moisture storage and rainfall distribution on wheat yields in southwestern Saskatchewan. Can. J. Soil Sci. 45:207-219.

1968 BISAL, F. The Influence of plant residue on sand flow in a wind tunnel. Can. J. Soil Sci. 48:49-52.

1969 PELTON, W.L. and KORVEN, H. Evapotranspiration estimates from atmometers and pans. Can. J. Plant Sci. 49:615-621.

CAMPBELL, C.A., PELTON, W.L. and NIELSEN, K.F. Influence of solar radiation and soil moisture on growth and yield of Chinook wheat. Can. J. Plant Sci. 49:685-699.

1973 ROBERTSON, G.W. Weather and World Food Production. Weekly Letter, Agriculture Canada, Swift Current, Saskatchewan, March 2, 1973. 2 pp.

STEWART, D.W. Simulation modelling of plant processes and microclimate in relation to net assimilation. Grassland Species. In: Measurement and modelling of photosynthesis in relation to productivity, Intl. Biol. Programme, Proc. Guelph Workshop. pp. 215-230.

1974 ROBERTSON, G.W. Wheat yields for 50 years at Swift Current, Saskatchewan, in relation to weather. Can. J. Plant Sci. 54:625-650.

1979 DE JONG, R. and CAMERON, D.R. Computer simulation model for predicting soil-water content profiles. Soil Sci. 128:41-48.

1980 DAVIDSON, H.R. Solar energy applications in agriculture. Proc. Saskatchewan Energy Show, Saskatoon, Sask. (July).

1983 DAVIDSON, H.R. and CAMPBELL, C.A. The effect of temperature, moisture and nitrogen on the rate of development of spring wheat as measured by degree days. Can. J. Plant Sci. 63:833-846.

1984 DAVIDSON, H.R. and CAMPBELL, C.A. Growth rates, harvest index and moisture use of Manitou spring wheat as influenced by nitrogen, temperature, and moisture. Can. J. Plant Sci. 64:825-839.

1986 CUTFORTH, H.W., SHAYKEWICH, C.F. and CHO, C.M. Effect of soil water and temperature on corn (Zea mays L.) root growth during emergence. Can. J. Soil Sci. 66:51-58.

PART 2 - BEAVERLODGE AND OTHER RESEARCH STATIONS

The Beaverlodge Experimental Sub-Station

The Sub-Station was opened in 1916 with W.D. Albright as Experimentalist-in-Charge. Its purpose was to sstudy agricultural production under the particular climatic conditions in the Peace River area: a short growing season, cool air and soil temperatures, frost, long days and to some degree, drought, although drought was not as much of a problem as in the southern prairies. Albright took a keen, personal interest in the climate of the area and its effects on crop growth and production.

The First Agrometeorologist

Albright was reclassified as Superintendent of the Sub-Station in 1923. He retired in 1945 and E.C. Stacey became Superintendent in 1947 while at the same time the Sub-Station was raised to the status of an Experimental Station.

It was realized that the study of climate and agrometeorology in the Peace River area was more than an agronomist and superintendent could manage, so A.C. Carder, an agronomist at the Sub-Station was encouraged to become an agrometeorologist.

Carder was a 1935 graduate of the University of British Columbia with a B.A. and B.Sc. in botany and agronomy. He worked at the Experimental Sub-Station after graduation until he was granted leave of

absence to attend Macdonald College (McGill). War intervened and he joined the Light Anti-Aircraft Division, Canadian Army in 1941. While serving overseas he took the opportunity, when on leave, to visit Rothamstead and other research establishments in England and elsewhere in Europe. Upon returning to Canada in 1946 he rejoined the Experimental Sub-Station at Beaverlodge, but was again granted leave of absence to attend Macdonald College. He was granted an M.Sc. degree in Agronomy in 1948. At Beaverlodge he became interested in the agrometeorological problems of the area so again took leave of absence to study agrometeorology at the University of Madison in Wisconsin where he earned a Ph.D. (1954) in Agricultural Climatology. He thesis topic was "Comparison of Growth Responses of Crops at Two sites (Beaverlodge and Madison).".

Unfortunately Carder spent only about half his time on agrometeorological research. The balance was on agronomic problems such as weed and insect control. Carder was appointed Head of the Weed Control and Agrometeorological Section in 1969, but retired in 1970. R.E. Harris was then appointed Head of the Environment and Special Crops Section. It was eight years before another agrometeorologist was hired. W.G. Bailey joined the Section in 1978 as micrometeorologist, but left in a couple of years later, and was replaced by P.F. Mills in 1981.

Research Problems

The recording of weather observations was started when the station opened. By 1921 the Annual Report of the Sub-Station Contained 3 pages devoted to a discussion of the seasonal weather and comparing it with the 6-year averages since the station opened in 1916. In 1922 seven pages were devoted to a discussion of weather. Soil-temperature measurements (at 3 inches) were started in 1922, particularly to relate to soil nitrification action that takes place above 41° F. Comparisons were made with similar soil-temperature measurements made at Swift Current. It was assumed that soil-temperature measurements would be a better indication of crop growth than air temperature since the former might suggest the amount of natural soil nitrate available to the crop.

Albright had noted differences in minimum temperatures at different elevations nearby. He set up a series of instruments in 1925 to measure minimum temperatures along a slope from a knoll to a slough (Albright and Stoker, 1944). Differences as great as 20° F. were found. Albright noted the practical significance of this. "Apart from its scientific interest and its value in establishing safeguards for further investigations, the outstanding practical significance of these tests is an emphasis of the fact that at northern latitudes the elevated slopes and water-protected areas should be chosen for frost-susceptible crops such as wheat, flax, barley, and potatoes, while the lower levels are reserved, during the early days at least, for production of hay, pasture, and 'green feed'. The value to new settlers of having such information available in concrete form is considerable."

"Another point suggested by the data is that weather records should be published with cognizance of the local conditions under which they are obtained. If one observing station has its instruments on a hill and another, 100 or 200 miles farther south, has its instruments in a hallow, it is easily possible for the latter to record the more extreme temperature. Isothermal lines drawn accordingly may be very erratic.

"Agronomists are warned, too, that temperature figures obtained in the caged instruments at 3 1/2 ft off the ground are a very untrustworthy index of the temperature to which plants may be actually subjected. It is not uncommon to find crops covered with frost when the caged thermometer is several degrees above the freezing point."

Weather Site Change

When Carder returned from Madison he investigated the suitability of the exposure of the weather site that had been used for the past 37 years. Although the site was well exposed when originally selected, Carder recognized that buildings and ornamental shrubbery had grown up around it and reduced its exposure. When Robertson visited the Station in 1952 a new, well-exposed site was selected and a

duplicate set of instruments obtained from the CMS. Both sites were operated for a number of years to determine the difference in observed values between them (Carder, 1961).

Research After 1955

Agrometeorological problems and research at Beaverlodge is illustrated by the following chronological list of publications:

1957 CARDER, A.C. Growth and development of some field crops, as influenced by climatic phenomena at two diverse latitudes. Can. J. Plant Sci. 37:392-406.

1960 CARDER, A.C. Atmometer assemblies: a comparison. Can. J. Plant Sci. 40:700-706.

1961 CARDER, A.C. Rate of evaporation from a free-water surface as influenced by exposure. Can. J. Plant Sci. 41:199-203.

CARDER, A.C. Climate of the Beaverlodge area. In: Soil survey of the Beaverlodge and Blueberry Mountain sheets. Alberta Soil Survey Report, 20:104-109.

1962 CARDER, A.C. Climatic trends in the Beaverlodge area. Can. J. Plant Sci. 42:698-706.

1965 CARDER, A.C. Climate of the upper Peace River region. Can. Dept. Agric. Pub. 1224.

1966 CARDER, A.C. and HENNIG, A.M.F. Soil moisture regimes under fallow, wheat and red fescue in the upper Peace River region. Agric. Meteorol. 3:311-331.

1968 CARDER, A.C. The black Bellani-type atmometer as an instrument to estimate the evapotranspiration of crop plants. Int. J. Biometeorol. 12:11-14.

1970 CARDER, A.C. Climate and rangelands of Canada. Can. J. Range Management. 23:263-267.

1971 CARDER, A.C. Climate of the lower Peace River region. Can. Dept. Agric. Publ. 1408. 89 pp.

1974 HARRIS, R.E. and CARDER, A.C. Rain and snow gauge comparisons. Can. J. Earth Sci. 11:557-564.

1975 HARRIS, R.E. Plant responses to northern environments. Can. Agric. 20:7-9.

1982 BAILEY, W.G., LERER, H., and MILLS. P.F. Humidity influence on the pollination activity of Megachile rotundata. Environ. Entomol. 11:1063-1066.

1984 MILLS, P.F. Fort Vermilion Experimental Farm. Weather observations for 1983 plus summaries and averages for 49 years of continuous recording. North Res. Group Publ. 84-9.

1987 MILLS, P.F. Beaverlodge meteorological station 1986 weather observations with 71 years long-term averages. North Res. Group Publ. 87-03. 10 pp.

Other Research Stations

Staff at several other research stations carried on work related to agrometeorology in connection with their specific field of expertise. An excellent example of this is the work of Haufe at the Lethbridge Research Station in connection with the development of a program concerning insect biometeorology (Haufe, 1957, 1963, 1976). Other examples are: research on the effect of weather elements on grasshopper populations by R.L. Edwards at Saskatoon in the early 1960's; work on topography and frost

pockets in the Okanagan Valley (Anstey et al., 1959); orchard irrigation research developed over several years at Summerland (Wilcox, 1963, 1967; Sly and Wilcox, 1974); field crop irrigation at Lethbridge (Hobbs, et al., 1963, Hobbs and Krogman, 1968); and horticultural crop irrigation at Smithfield (Heeney et al., 1961).

Agrometeorology was slow in gaining recognition at many research stations, but could not be avoided. Interested and affected research sciences often had to deal with their weather sensitive problems themselves. However, as time went by an increasing number of stations hired research scientists professionally trained in agrometeorology. By the end of the 1980's, besides Swift Current and Beaverlodge, agrometeorologists were on staff at four other research stations: Ste.-Foy (Y. Castonguay), Harrow (C.S. Tan), Vineland (R.J.M. Trimble), and Lethbridge (B.W. Grace and S.M. McGinn).

PART 3 - PRAIRIE FARM REHABILITATION ADMINISTRATION

Enactment of PFRA

The Prairie Farm Rehabilitation Act was passed by the Parliament of Canada in April 1935. The main reason for it was the severe drought that started in the early thirties and caused crop failures, soil erosion, land abandonment, and general hardship to the prairie farm community. In many areas of the prairies pioneer farmers had been urged to settle on land with no knowledge of the effect of climatic variability and soil characteristics on potential crop productivity. Virgin soil and a few good years with above-average precipitation during the previous 20 to 30 years had encouraged mass settlement.

The purpose of the Act was to encourage farmers to solve their own problems along three lines of action, viz: develop better cultural practices to cope with a wide range of fluctuating physical and economic hazards, diverting of poor land from crop production to pasture, and conserving and making better use of limited water resources.

Activities

Early work of the PFRA was under the leadership of an Advisory Board. Information, data, recommendations and advisory services were based on experimental results from the Experimental Farms which had been established in the prairie region at the beginning of land settlement, viz: Brandon, Morden, Indian Head, Swift Current, Rosthern, Scott, Lacombe, Lethbridge and Manyberries.

Two groups were established in 1936 to undertake special technical work required in connection with the terms of the Act. One was the Soil Research Laboratory at Swift Current (see above) and the other was a separate administration (PFRA) in Regina. The group in Regina was to direct the policy regarding water development. This involved the building of small dugouts, reservoirs, irrigation dams and canals and irrigation projects as well as establishing shelter belts and community pastures.

Up until 1959 most of the requirements for climatological and related information was provided by the Soil Research Laboratory at Swift Current, by the experimental farms in the area, by the Central Experimental Farm in Ottawa and by CMS. In addition, the Regina office of PFRA had their own engineers who undertook many of the hydrometeorological studies necessary for their water development projects. One of these engineers, E.F. Durrant, was one of the original members of the NCAM when it held its first meeting in 1960 and served on a subcommittee to consider improvements in the climatological network as required by agriculture. He also presented a report to the 1st Annual Meeting of NCAM on climatological station density, particularly throughout the prairie region where his interests lay (see Chapter 5, "A Ten-Point Agenda").

Secondment of Meteorologists

By 1959 the activities of the Regina group were becoming more complex and climate sensitive, demanding more sophistication in climatic analysis. It was felt that a dedicated staff meteorologist was required and advantage was taken of the secondment policy of CMS to acquire one. G.A. McKay was seconded to PFRA in Regina in 1959 as a hydrometeorologist. He was with PFRA for seven years, then moved to CMS Headquarters in Toronto (Chapter 3, A Period of Secondment). It appears that the hydrology engineers continued with the necessary hydrometeorological studies following McKay's departure.

During his tenure with PFRA, McKay completed several hydrometeorological studies relative to his work for the farming community. Following is a brief sample.

1961 McKAY, G.A. A detailed map of Prairie annual precipitation. Can. Dept. Transport, Meteorol. Br. Cir-3159, Tec-365. 8 pp.

1963 McKAY, G.A. The analysis of storm rainfall information. Can. Dept. Agric. PFRA Met. Report No. 10. 31 pp.

1964 McKAY, G.A. Statistical estimates of probable maximum rainfall ion the Prairie Provinces. Can. Dept. Agric. PFRA, Eng. Br. Met. Report No. 7, (revised). 16 pp.

McKAY, G.A. Meteorological measurements for watershed research. Proc. NRC Hydrol. Sym. No. 4, Research Watersheds. pp. 185-209.

1965 McKAY, G.A. Climatic maps of the Prairie Provinces for Agriculture. Can. Dept. Transport, Meteorol. Br. Climatological Studies No. 1, Toronto. 18 pp.

1967 McKAY, G.A., MAYBANK, J., MOONEY, O.R. and PELTON, W. The agricultural climate of Saskatchewan. Can. Dept. Transport, Meteorol. Br. Climatological Studies No. 10. 110 pp.

1968 McKAY, G.A. Meteorological conditions leading to the project design and probable maximum flood on the Paddle River, Alberta. Trans. Am. Soc. Agric. Eng. 11:821-823.

PART 4 - CANADIAN WHEAT BOARD WEATHER AND CROP SURVEILLANCE SECTION

by

E.R. Garnett and G.K. Walker

Pre-1975

In the early 1970's there were forces at play which prompted a need for better early warning intelligence related to food. The first was the situation in 1972 where the USA. sold wheat to the USSR.at low prices, mainly because America's free-enterprise system allowed the Soviets to secretly buy grain from different multinational companies. Nobody in the USA. seemed to have the big picture, i.e. the USSR. had severe winter kill in the winter months of 1971-72 which was followed by drought later in the year, and that the Soviets were astute buyers. This event, plus the sharp decline in world food reserves in the early 1970's, increased the need for improved early-warning capability.

Coincidentally, in July of 1972 the first of a series of U.S. Earth Resources Technology Satellites (ERTS-1) was launched. These satellites (also known as LANDSAT) were expected to revolutionize crop forecasting, and bold predictions of their usefulness were made. Encouraged by such predictions, the U.S. government supported two large research programs aimed at exploiting satellite data, in combination with weather data for crop production assessments. The two programs, LACIE (Large Area Crop Inventory Experiment) and its successor, AGRISTARS (Joint Program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing) lasted about a decade, but actually contributed little to the crop monitoring programmes that are in place today in the US Department of Agriculture, and in the Canadian Wheat Board. Their contribution was more in helping to define data requirements for crop monitoring work, and in showing the limitations of a number of possible surveillance approaches.

Another contributing factor to the Board's decision, in all likelihood, was a timely press release from the Swift Current Research Station concerning drought and the current world food situation, and how this might be monitored on a real-time basis by using WMO/WWW information (Robertson, March, 1973). The CWB became seriously interested in weather and crop-condition monitoring early in 1973 and began activity leading up to the development of a system for this purpose. A noteworthy event was a trip taken by Drs. Larry Kristjanson and Jim Leibfried (a Wheat-Board delegation) and George Robertson (agrometeorologist at the Swift Current Research Station) to the University of Wisconsin in May, 1973. They visited Reid Bryson who was developing a system for US interests. The purpose was to see if and how weather information and forecasts could be used for the purpose, and whether or not his system could be used by CWB. Bryson's colourful manner and unconventional approach on that occasion are still remembered and, if anything, the visit served to pique the interest of the visitors.

The Wheat Board continued interest in the subject, and in the summer of 1973 seconded Robert Niemi to Ottawa to work alongside Dan Williams of the Canada Department of Agriculture, who had developed a wheat yield prediction model for the Canadian prairies (Williams and Robertson, 1965). That summer, with Robert Niemi's assistance, Williams generated weekly wheat yield estimates for the Canadian prairies, and one can safely state that the Canadian Wheat Board has been modelling prairie climate and wheat yields in one fashion or other ever since.

Also in the summer of 1973 Ray Garnett was seconded to the University of Saskatchewan with Lorne Crosson to investigate the potential value of remote sensing to the Canadian Wheat Board. It was following these two secondments in 1973 that the Board approached George Robertson (then retired) to do an in-depth study of agrometeorology and potential applications within a Wheat Board setting. In late 1973 Robertson and Garnett drafted a Proposal for a Weather and Crop-Condition Surveillance Program, which recommended in-house expertise in agrometeorology (Robertson and Garnett, 1973). In early 1974 the Board agreed in principle that such a program be established and that resources be devoted to it. It was at this time that Adrian Measner was hired to bolster the Board's efforts in this regard. Measner and Garnett made up the climatology unit until March 1975, when Terry Martin was appointed Director of Weather and Crop Surveillance.

The 1975-77 Period

Nineteen seventy-five was the Section's first year of operation, and came at a time when the USSR was to experience one of the worst overall droughts in decades. This drought was depicted in a crude fashion, using hand-drawn maps, and marked the beginnings of routine application of WMO/WWW data within the Wheat Board. That summer the Section began giving weekly weather and crop presentations to the Board and to interested departments.

In 1976 the following write-up appeared in the 1975-76 Canadian Wheat Board Annual Report.

> "With the sharp decline in world food reserves which occurred in the early 1970's, the impact weather patterns can have on market conditions became very apparent. Accurate and timely crop

estimates, not only for Canada but for other important agricultural areas of the world, are extremely important to the Board in carrying out its marketing functions.

"In March of 1975 the Weather and Crop Surveillance Section became an operational unit of the Board. This Section assimilates and analyses meteorological data which are available for all important agricultural areas throughout the world. These data are provided to the CWB by AES from the WMO/WWW network on an instantaneous basis via a direct computer hook-up. Computer yield-projecting models which have been developed by agrometeorologists in Canada and the USA. also use these data as input. These models measure the effects of weather on a crop during a growing season and yields are projected based on these data. This type of analytical work greatly assists in determining the requirements of importing countries and the availabilities of exporting countries.

"In addition, this Section keeps close watch on developments in the area of satellite imagery. As soon as expertise is gained in the interpretation of these data, consideration will be given to incorporating them into the Board's overall crop surveillance program. "

During the 1975-77 period several major strides were undertaken. Initially WMO/WWW weather data were sent to the Wheat Board on magnetic tape weekly, but for just the northern hemisphere. Action was subsequently taken to receive global data daily via a dedicated telecommunication line from AES. With the in-house development of a comprehensive weather database, this latter enabled fingertip access to the data through computer terminals. Another major initiative was the computer contour-mapping of the weather data. Base maps were developed, largely with summer-student help over several summers. Other than the more flexible production of base maps, the Section's unique yet basic method of mapping World Meteorological data has gone unchanged since the late 1970's. It was also during this period, about the time of the World Food Conference in 1974, that the USA. embarked on the Large Area Crop Inventory Experiment (LACIE). The Section endeavoured to make full use of models generated by the LACIE program, particularly the wheat yield models produced by the Centre of Climatic and Environmental Assessment in Columbia, Missouri.

The 1977-85 Period

In October 1977, John Benci was hired by the Board to direct the Weather and Crop Surveillance Section while Terry Martin took on other duties as Special Assistant to the Board. Benci, as the first formally trained agrometeorologist, raised the profile of the Section and pursued crop-weather modelling where possible. For example, Benci's corn model was used to help monitor the US corn-crop situation. One of the keynotes of this period was the high degree of cooperation between organizations and within the Wheat Board. Joint projects were initiated with the Canada Centre for Remote Sensing, CDA, Statistics Canada, and AES to further automate and refine the Wheat Board's early warning crop information system, and to generally bring the science of agrometeorology into play in the business world. There was also considerable liaison with universities and research scientists with respect to guiding research support. Within the organization, cooperation was forthcoming from many sources: Canadian Wheat Board Commissioners, Management Information Services Division, Market Analysis, Sales Department, and the Library.

Collecting all the necessary data was a major undertaking in itself. In making crop estimates, a variety of sources are often drawn upon, such as shortwave radio reports, embassy telexes, Reuters news releases, model results. A major effort was made to pull all such factors together for meaningful estimates. The collection of complete and accurate World Meteorological Organization data requires constant vigilance. Also, during this period there were efforts aimed at bringing polar orbiting and geostationary satellite data into the system.

In July 1983 Benci was appointed General Director of Management Information Services Division, and Harvey Glick was made Acting Director of the Section. Glick directed the Section until he left the Board

in the fall of 1984. His successor was Graham Walker, who joined the Canadian Wheat Board in the spring of 1985.

From 1985 to 1989

Since March 1985, Walker considerably advanced the level of satellite image analysis and crop weather modelling. Strides were also made in improving the quality control of weather data and in increasing the real-time aspect of operations. A centralized crop-data base was established and a major effort was made in quantifying the effects of the weather on a worldwide basis, and presenting this information in such a fashion that global impacts could be quickly grasped by users. This involved, for example, a weekly tabulated review of crop development and yield and quality prospects for 60 or more countries, with usually several crops in each. Since the mid-1970's the Canadian Wheat Board's Weather and Crop Surveillance activities had greatly increased in scope. In the early days, our weather maps were contoured and coloured by hand, whereas now up-to-date global weather data are computer processed, mapped, and displayed for perusal first thing each morning.

Advances in satellite and computer technology enabled the Section to observe weather in North America and Europe almost instantaneously. Radar and weather satellite imagery were some of the new tools used by the Section. Increased automation and real-time operation permitted the Section to respond more effectively to requests from the Sales Department and the Board. Moreover, in the late 1980's crop forecast models developed in-house for the Canadian situation had proven accurate and robust, meaning primary customers could be advised and assured, at an early pre-harvest date, of the potential size and quality of the Canadian crop (Walker, 1989). Also, in 1989 the Section was able to perform near-real-time analyses of drought problems using satellite imagery, to support and strengthen weather-based analyses.

In the spring of 1986 Ray Garnett spent six weeks with Professor James Newman at Purdue University to pursue interest in longer-range forecasting. The Section continues to follow developments in this area, but did not engage in long-range forecasting because of the overall lack of skill in such endeavours. An exception was the El Niño phenomenon, which could be used in certain parts of the world for long-range crop forecasting. Interest in longer-range forecasting dates back to the inception of the Section, and will probably continue, given the role it plays in the uncertainties of grain marketing.

On-the-spot observations or crop touring had also been a vital part of the information gathering process. The Section had been associated with many field trips, including one to India in 1980, one to Argentina and Brazil in 1982, and many others throughout North America.

There have been a number of cases where the Section's weather intelligence has given the Wheat Board a marketing edge. In general, we are referring to the strategic wheeling and dealing and high stakes poker-game style of international grain trading. As to who comes out best in the cat-and-mouse manoeuvres of negotiations, superior knowledge and information can often make the difference of a dollar or two on the sale of a tonne of grain. When dealing in millions of tonnes of grain, the dollar value of that knowledge becomes substantial. In any case, the negotiating team with the truest picture has the edge, and providing this clear picture has always been one of the Sections's prime objectives.

Over the years, the number of people working in the Section at any one time has remained small, fostering a global perspective and generalised approach to problems. The Section was largest in size during the 1981-83 time frame, when there was a Director and three analysts. It is expected to reach that size again early in 1990, when an analyst with responsibility for remote sensing will be added to the team. Much credit belongs to George Robertson, who established the original conceptual framework and recommended some of the early personnel. The Section has not strayed far from Robertson's initial vision of it, and it remains in good stead.

PART 5 - AGRICULTURAL DEVELOPMENT BRANCH, CDA

Organization of the Soil and Climate Section

A new group concerned with agrometeorology was established in the fall of 1980. This was the Resources and Environment Section of the Crop Production Division, Regional Development Branch, CDA. During reorganization of the Department in 1986 the group became the Soil and Climate Section of the Crop Development Division of the Agriculture Development Branch.

The role of the Crop Production Division concerns primary crop production. This role was to be achieved by working in concert with other groups within the Branch and the Department, and with provincial governments, universities, producer and industry organizations and other federal groups. The role of the Resources and Environment Section was to provide practical information and support for the projects and new developments undertaken by the Division.

Staff

Originally the Section was staffed by two agrometeorologists recruited from the Agrometeorology Research and Service Section of the LRRI, R.B. Stewart, Chief of the Section, and J.A. Dyer. They were later joined by W.J. Blackburn, who was with the Section for six years from 1982 to 1988.

Objectives and Achievements

The Section has been involved in the agrometeorological aspects of:

- production potential assessment in Canada,
- integrated pest management,
- climatic change and production potentials,
- crop insurance,
- soil degradation,
- an assessment of the potential consequences of nuclear war on cereal production in Canada,
- a work transfer with the University of the Orange Free State in South Africa which focused on drought analysis techniques,
- an operational forage drought early warning system for western Canada,
- cooperative with CIDA and the Agrometeorology Research and Service Section of LRRI on an early warning system for drought in Africa was developed and demonstrated,
- managing and upgrading data in the national data base containing climatic data and information of land-resource potential for various crops.

The following reports and papers are examples of some of these topics:

1981 DYER, J.A., STEWART, R.B. and WARNER, D.G. Environmental resources in crop production. Can. Farm Economics. 16:27-30.

1982 DYER, J.A. and DWYER, L.M. Root extraction coefficients for soil moisture budgeting derived from measured root densities. Can. J. Agric. Eng. 24:81-86.

DYER, J.A., STEWART, R.B. and MUMA, R.W. A weather-based drought monitoring scheme for spring forage in Western Canada. Can. Farm Economics, 17:9-16.

1983 BLACKBURN, W.J., STEWART, R.B. and NEISH, G.A. Weather factors and Fussarium head blight in wheat. Can. Agric. 29:20-22.

1984 DYER, J.A. and MACK, A.R. The versatile soil-moisture budget version three. LRRI Contribution No. 82-33. Research Branch Tech. Bull. 1984-E. 59 pp.

STEWART, R.B., DUMANSKI, J. and ACTON, D.F. Production potential for spring wheat in the Canadian Prairie Provinces - an estimate. Agric., Ecosystems and Environment., 11:1-14.

1985 DYER, J.A. and BOISVERT, J. Potential future developments in soil moisture budget model for humid regions in Canada. Can. Water Resources J. 10:1-13.

1986 DYER, J.A. and DEJAGER, J.M. The predictability of summer droughts in South African grassland. Water International. 11:78-87.

DYER, J.A. and MACK, A.R. A drought early warning system for Africa. Prepared for CIDA under terms of an Interdepartmental Letter of Agreement, R & E Report, 86-3. Resource and Environment Section, Agriculture Development Branch, CDA, Ottawa. 34 pp.

STEWART, R.B. Climate change implications for the Prairies. In: Effects of Changes in Stratospheric Ozone and Global Climate. Volume 3: Climate Change. Edited by J.G. Titus, US Environmental Protection Agency, Washington. D.C. October 1986. pp. 103-136. Also In: Trans. Royal Soc. of Canada. Series V(I): 67-96.

1989 DYER, J.A. PROXDAYS - An algorithm for generating realistic normal sequences of daily rainfall from monthly climatic normals. Climatological Bull. 23:119-131.

CHAPTER 8
UNIVERSITIES

PART 1 - LAVAL AND THE UNIVERSITY OF NEW BRUNSWICK

University of New Brunswick

Serious training and research in forest meteorology was first introduced to the University of New Brunswick when R.B.B. Dickison joined the Faculty of Forestry in 1969.

Dickison was a former employee of CMS, having served as Officer-in-Charge of the Fredericton Weather Office during the period 1960-69 and as aviation forecaster in support of military aviation in Canada and Europe from 1949 to 1960. He graduated from Acadia University in Chemistry and Mathematics (B.Sc., 1949) and in Forest Climatology from Duke University (M.A., 1970).

He developed undergraduate courses in forest meteorology and climatology, forest hydrology, hydrometeorology, engineering hydrology and selected environmental impact studies. At the graduate level he developed courses in forest meteorology and forest hydrology.

Shortly after joining the university staff, Dickison became involved in several research projects, and was a principal initiator of the Nashwaak Experimental Watershed Project. This was a joint university, government and private industry cooperative project to study the effects of forest management practices on the water resource.

Research in the area of forest meteorology at the university is reflected in the following publications:

1977 DICKISON, R.B.B. and DAUGHARTY, D.A. Effects of forest cover and topography on snow cover in the Nashwaak Experimental Watershed Project. pp. 245-250. In: Preprints, Second Conf. on Hydrometeorol., Amer. Meteorol. Soc., Oct. 25-27, 1977, Toronto, Ont.

1980 DICKISON, R.B.B. and DAUGHARTY, D.A. Effects of forest cover and topography on snow cover in central New Brunswick, Canada. pp. 329-335. In: Proc. IAHS Sym. on The Influence of Man on the Hydrologic Regime with Special Reference to Representative and Experimental Basins. Helsinki, June 1980. IAHS-AISH, Publ. No. 130.

1981 DICKISON, R.B.B., DAUGHARTY, D.A. and RANDALL, D.K. Some preliminary results of the hydrologic effects of clear cutting a small watershed in central New Brunswick. pp. 59-74. In: Proc. 5th Can. Hydrotech. Conf. Can. Soc. Civ. Eng., Fredericton, NB, 26-27 May 1981.

1983 DICKISON, R.B.B., HAGGIS, M.J., RAINEY, R.C. and BURNS, L.M.D. Spruce budworm moth flight and storms: case study of a cold front system. J. Clim. Appl. Meteorol. 22:278-286.

1984 DICKISON, R.B.B. and DAUGHARTY, D.A. Influence of forest cover and forest removal on accumulation and melting of snow in an eastern Canada catchment study. pp. 419-447. In: Proc. DVWK/IUFRO Workshop on Snow Hydrologic Research in Central Europe. Hann.-Munden, W. Germany, 12-15 March 1984. Bonn.

1988 DICKISON, R.B.B. and STEEVES, B.G. The measurement of site-specific weather for aerial pesticide applications. pp. 209-214. In: Proc. Sym. on The Aerial Application of Pesticides in Forestry, 20-22 Oct. 1987, Ottawa. (G.W. Green, ed.) Nat. Res. Coun. Assoc. Comm. Agric. For. Aviation. Rept. AFA-TN-18 (NRC No. 29197). ix + 387 pp.

DICKISON, R.B.B. and STEEVES, B.G. Meteorological operations in support of pheromone spray trials, 7 July 1988. AWEC. Rept. Produced for Dept. Biol., Univ. N.B., Fredericton. 18 pp.

Laval University

Laval University did not become seriously involved in training and research in agrometeorology until about 1970. Prior to this the only training offered was an extension course in meteorological observing and basic instrumentation. Soil scientists, field husbandry staff and ecologists were interested but little action was taken. The Forestry Department conducted some experiments at Montmorency Forest regarding the effect of sunshine on the germination of coniferous seedlings and some hydrology studies were under way by the engineers.

L.J. O'Grady, of the Soils Department, Faculty of Agriculture and Food Science, was interested in climate effects on crops and was invited to attended the NCAM Annual Meeting in 1967. He continued as a member for five years (1967-72). He was replaced in 1973 by P. Lavigne who was the chairman of the Committee for Agrometeorology for Quebec. The following year P-A. Dubé of the Department of Plant Science was named a member of CCAM, and continued as a member to the time of writing. He has been chairman of the Committee since 1985.

Training and research in agrometeorological were expanded significantly during the early 1970's. Two scientists from France helped to launch an agrometeorological program in the Soil Science Department. Professor Remy Durand of the Central Station of Agricultural Bioclimatology, Versailles, organized a one-semester course in agriculture bioclimatology. Mr. Bruno Massin, agrometeorologist from the French Meteorological Service organized agroclimatological studies of Quebec, and introduce a version of Grebet's evaporimeter for irrigation control purposes.

Dubé, with the cooperation of others, established the Quebec Committee on Agrometeorology in 1968, following recommendations of the NCAM. The objectives were: to establish and operate a network of meteorological and phenological sites; to draw phenological and agrometeorological maps; to apply agrometeorological practices; and to encourage agrometeorological research. Dubé was the first chairman of the committee and continued as such for several years.

With the cooperation of other agencies, including the CMS Regional Office in Dorval, several new agrometeorological stations were established and research programs initiated. Phenological observations were undertaken at a number of sites under the direction of J. Chevrette. Also a study of water use by crops was undertaken by A. Bentz.

By 1977 cooperative agroclimatic research was under way in several departments dealing with land-use planning, irrigation, late blight of potatoes and other diseases. Dubé took the lead in analysing phenological data which had accumulated for several years. He applied theories of accumulations of temperature, solar radiation and other methods for explaining the phenological development of plants in response to weather. During the late 1970's progress was made in the study of the relationship of the production of forages, cereals and vegetables to various weather and soil factors.

During the 1980's there were several graduate students in the Faculty working at both the Master and Doctoral level. Thesis topics included such research items as remote sensing, phenology, integrated pest management, soil-water budgets in relation to irrigation (strawberries and potatoes) and land drainage, the winter survival of plants, artificial light in green houses, the effect of ozone and other atmospheric pollution on plants (maple trees), agrometeorological aspects of wind breaks, and the economic value of agrometeorological forecasts. Some of these projects were undertaken in cooperation with the Quebec University at Chicoutimi (D. Lord) and the University of Sherbrooke (F. Bonn).

PART 2 - MACDONALD COLLEGE

Influence of the NCAM

Two faculty members from McGill and Macdonald were invited to attend the first meeting of the NCAM in 1960. F.K. Hare, Chairman of the Geography Department at McGill, was a member for three years (1960-63), and H.A. Steppler, Chairman of the Department of Agronomy at Macdonald College, was a member for four years (1960-64). The development of an agrometeorological program at Macdonald can be partially credited to the activities of the NCAM in encouraging postgraduate training at Universities.

An Early Experimental Farm-Weather Forecast Service

Macdonald College established, in accordance with suggestions made at the 1st Annual Meeting of the NCAM, an experimental agricultural forecast service in 1960. This was developed in conjunction with the Dorval Weather Office. Material was distributed through the local CBC outlets and at times was read by the agronomist assigned to the task. He was given training for one month at the Dorval Weather Office and, after a few months of on-the-job training, both the agronomist and the meteorologists operated efficiently as a result of improved understanding, even though the agronomist had to work with several meteorologists as a result of the shift roster. Long-distance telephone was used to gather information on current crop conditions.

The experiment, which was undertaken by Macdonald College for one year, was quite successful. However, no group in Quebec was in a position to continue the service and so it was discontinued.

The New Department of Agricultural Physics

Agrometeorology as a postgraduate subject evolved slower and in a different manner than at Guelph. About 1965 the chairman of the Department of Agricultural Physics retired and the opportunity arose to rebuild the Department. R.H. Douglas joined the Department in 1965 as its new chairman and proceeded to introduce environmental physics in the Department's program.

Douglas was invited to attend the 1968 and 1969 Annual Meetings of the Committee, and in 1970 was named a permanent representative for Macdonald College. He continued as permanent representative until his retirement in September 1985. He served as Chairman of the Committee at the 1984 Annual Meeting. G. Vali was an invited representative to the 1969 Annual Meeting. Undoubtedly these associations with the Committee had an influence on the development of courses and research programs in agrometeorology at the College.

Douglas was a graduate of the University of Alberta with a B.Sc. (1941) in Mathematics and Physics. After obtaining an M.A. in Meteorology from the University of Toronto he joined the CMS. He worked for a while as a trans-Atlantic aviation forecaster at Gander and, from 1947 to 1951, as an aviation and public weather forecaster at the Dorval Meteorological Office. From 1952 to 1954 he was assigned to the Low-Temperature Laboratory of the Aeronautical Research Division of the NRC in Ottawa. There he participated in airborne cloud-seeding experiments and evaluated commercial cloud seeding in the Lac St.-Jean Region.

In 1954 he was seconded by CMS to the Stormy Weather Group of the Physics Department at McGill University, where he undertook studies of cloud and precipitation physics. He worked on his Ph.D. during this period and received it in 1957. The Department of Meteorology at McGill was formed in 1960 and Douglas became a "charter member". He taught undergraduate and graduate courses in physical meteorology and directed field operations each summer in Alberta on a hailstorm research project that he had initiated in 1957.

Prior to 1965 the Department of Physics at Macdonald offered an elementary course in weather (observations, simple climatology, and so forth) and the Department of Soil Science offered an elementary course in micrometeorology.

Douglas took the opportunity to rebuild the Department by seeking staff with an interest in environmental physics and introducing lectures on related subjects. Vali, who had recently completed his doctoral studies into problems of ice nucleation from McGill, was recruited to assist Douglas. Together they modified the micrometeorological course to include more atmospheric physics, especially in the biosphere. In addition, an elective in basic meteorology was introduced into the Diploma of Agriculture program. However, the research program of the Department was mainly in precipitation physics, especially the hail problem. Several graduate students in meteorology completed their work at Macdonald College under the direction of Douglas.

N.N. Barthakur joined the Department in 1966. He received a Ph.D. Degree from the University of Saskatchewan in 1965. His thesis was on the "Growth of ice crystals on organic substances and some related phenomena."

P.H. Schuepp joined the Department in 1969. He received undergraduate training in atmospheric physics at the Swiss Federal Institute of Technology in Zurich and later received a Ph.D. Degree in Cloud Physics from the University of Toronto, where he worked with Dr. List. Following this he did two years of postdoctoral research on the heat and mass exchange of hailstones at the University of Toronto.

A benchmark climatological station was established in 1969, on the premises of the Emile A. Lodsm Agronomy Research Centre of the faculty of Agriculture by the staff of the Department in cooperation with the CMS. This replaced an earlier station operated by the Agricultural Engineering Department that was being crowded out by campus expansion.

Further Reorganization

Agrometeorological training and research at Macdonald was not clearly defined and was subject to the whims of the departments in which staff were located. During the early 1970's the Faculty of Agriculture undertook a major revision of its program, and the opportunity was taken to revise and expand the meteorological and climatological offerings by the Department of Agricultural Physics. Courses in Introductory Meteorology, Biometeorology, Mathematical Modelling Techniques, and Boundary-Layer Processes were introduced. Eventually a course in Agricultural Weather and Climate became mandatory for agricultural students, but this was dropped later in the 1980's. In 1976 the Department joined the Department of Agricultural Chemistry to form the Department of Agricultural Chemistry and Physics. Douglas continued as Chairman of this new department until 1980 when Schuepp took over for the next six years. The chemistry component of the Department was heavily oriented towards food sciences so, in 1986, the physics component was transferred to the Department of Renewable Resources.

Postgraduate Training

Postgraduate training in agrometeorology was offered at both the Master and the Doctoral levels. Several students have completed their postgraduate work in agrometeorology at Macdonald College since 1965. Thesis topics were based on the research program as noted below. No undergraduate program in agrometeorology was offered. Some undergraduate courses were offered to agricultural students in other departments but these did not appear to be well received.

Research Projects

Early interests of the staff centred on cloud and precipitation physics, particularly the physics of hailstone formation. In due course, however, research became more oriented towards agrometeorological topics

and it is noted that staff at the College cooperated with staff in the Meterological Section of the CDA Research Branch in Ottawa, and of the CMS in Toronto.

The following list of publications indicates the trend in research interests:

1969 BOSISIO, R.G. and BARTHAKUR, N.N. Microwave protection of plants from cold. J. Microwave Power, 4:190-193.

1971 SCHUEPP, P.H. Experiments of the local convective mass transfer of smooth and rough hailstones models. J. Appl. Meteorol. 10:1018-1025.

1975 SCHUEPP, P.H. and WHITE, K.D. Transfer processes in vegetation by electrochemical analog. Boundary-Layer Meteorol. 8:335-358.

1978 DOUGLAS, R.H. Development and modification of the thermal environment in corn. In: Essays on Meteorology and Climatology, (K.D. Hage and E.R. Reinelt, eds.). University of Alberta (Department of Geography). Mono. 3.

1980 SCHUEPP. P.H. Heat and moisture transfer from flat surfaces in intermittent flow: a laboratory study. Agric. Meteorol. 22:351-366.

1983 BARTHAKUR, N.N. The beta-ray gauge as a leaf-surface wetness detector. Int. J. Appl. Radiation and Isotopes. 34:1549-1552.

1984 SCHUEPP, P.H. Observations on the use of analytical and numerical models for the description of transfer to porous surface vegetation such as lichen. Boundary-Layer Meteorol. 29:59-73.

1988 BARTHAKUR, N.N. A non-equilibrium thermodynamics approach to surface evaporation of water drops. Agric. and Forest Meteorol. 42:287-294.

GORDON, R., LECLERC, M.Y., SCHUEPP, P.H. and BRUNKE, R.R. Field estimates of ammonia volatilization from swine manure by a simple micrometeorological technique. Can. J. Soil Sci. 68:369-380.

1989 SCHUEPP, P.H., DESJARDINS. R.L., MacPHERSON, J.I., BOISVERT, J. and Austin, L.B. Airborne determination of regional water-use efficiency and evapotranspiration: Present capabilities and initial field tests. Agric. and Forest Meteorol. 41:1-19.

BARTHAKUR, N.N. and ARNOLD, N.P. Thermal response characteristics of tobacco leaves exposed to microwave radiation. Beitrage zur Tabakforschung International. 14:171-176.

PART 3 - THE UNIVERSITY OF GUELPH

Because of the diversity of agriculture in Ontario, the many meteorological constraints to agriculture in the province, the lead taken by the ORF in undertaking climatic studies in relation to agriculture, the proximity to the Agrometeorological Section of the Research Branch, CDA, and the CMS in Toronto, formal education and research in agrometeorology was destined to develop in Guelph at the Ontario Agricultural College (OAC), formerly affiliated with the University of Toronto and now a College of the University of Guelph.

Early Activities

Prior to 1956 there was only passing interest in agrometeorology. Climatic observations began at OAC in 1886 in cooperation with the CMS (see Chapter 2). J.S. Smith from Guelph attended the Eighth Session of CAgM/IMO in Toronto in 1947. Also Professor MacNaughton of the Physics Department at the College was interested in climatological observations. In the early 1950's he started solar radiation observations. Brief references to climatology were made in his physics lectures prior to 1956.

The Beginning of a Graduate Program

Postgraduate training in agrometeorology had its beginning in Canada in 1956 when the first agrometeorologist, K.M. King, was appointed at OAC. King graduated from OAC in 1951 with a B.S.A. in Agricultural Chemistry and from the University of Wisconsin at Madison in 1952 with an M.Sc. in Soils. Following a year as a Soil Conservation Farm Planner (1952-53) at OAC he returned to Madison where he earned his Ph.D. (1956) in Soil Physics and Meteorology. He was then appointed Assistant Professor of Soil Science (Agrometeorology) in the Soils Department at OAC. Two years later, in 1958, the first M.S.A. Degree in Soils with specialization in Agrometeorology was granted to M.B. Harrison.

NCAM was established about this time. D.N. Huntley, Head of the Department of Field Husbandry at OAC was one of the original members at the first meeting held early in 1960. During the early meetings of this Committee the problem of the shortage of agrometeorologists in Canada was discussed and educational institutions were encouraged to undertake the training of professionals in this field. It was highly probable that these discussions and recommendations encouraged the development of an agrometeorological training program at OAC.

In 1962 MacNaughton of the Physics Department and King, in cooperation with the CMS, established a benchmark climate station at a well-exposed site in a research field near the campus.

Early research in agrometeorology at OAC involved studies of heat fluxes in connection with evapotranspiration from corn; studies of soil temperature variations under corn, hay, oats, and bare soil; in cooperation with the Agricultural Engineering Department a study of evaporation from snow surface was undertaken; in cooperation with the Field Husbandry Department and the Ontario Research Foundation microclimatological measurements were taken in forage stands for the purpose of relating growth and development of different species and varieties to soil and aerial environment; and in cooperation with the Dept. of Entomology and Zoology a study was undertaken to relate differences in microclimate under variations in tree cover and topography to the behaviour of rabbits, moose, and other animals.

A separate Master's-Degree Program in agrometeorology became available in 1963 and two students registered. About this time King was named a member of a WMO-CAgM Working Group on Syllabi for Instruction in Agrometeorology (see Chapter 6). His work and contacts on this Working Group together with guidance from the NCAM of which he was a member from 1963 to 1968 contributed greatly to the development of agrometeorological training programs at Guelph, both undergraduate and graduate.

The year 1964 was a banner year for agrometeorology at Guelph. The University of Guelph was formed and agrometeorology, now recognized, was organized under the new Department of Soil Science. King spent the winter of 1964-65 on educational leave in Australia where he was Visiting Scientist at the Division of Meteorological Physics, CSIRO, Aspendale. Upon returning to the university he organized electives in meteorology and climatology at the undergraduate level, including additional courses at the graduate level.

Ph.D. Program Introduced

Shortly after returning from Australia King organized a postgraduate program leading to a Ph.D. He was named chairman of an Interdepartmental Committee on Agrometeorology that directed the graduate training program in agrometeorology at the University of Guelph. T.J. Gillespie was the first to graduate with this degree, granted in 1968.

During these formative years for education in agrometeorology there was not a single authorized position in the country to be filled. This provided little incentive to students to enter this field as a career, even though it was recognized (by the NCAM) that several positions were needed, particularly at the provincial level. The situation changed by the end of 1965, when it was reported (to the NCAM) that some eight positions had then been established across Canada and were still vacant.

Staff Increases

D.M. Brown left the ORF in 1965 and joined King in the Dept. of Soil Science to work in the area of agrometeorology. He brought to the department several agrometeorological projects started at ORF. Although teaching and research in agrometeorology was officially centred in the Dept. of Soil Science with recognized agrometeorologists, several other departments were involved in related areas: the School of Agricultural Engineering was doing research on hydrology; the Dept. of Crop Science was doing work in field crop physiology; the Dept. of Horticulture was investigating environmental effects on horticultural crops; the Dept. of Zoology was engaged in work on wild-life ecology and microclimates; and the Dept. of Botany was studying plant ecology.

By the beginning of 1966 there were 38 students from Soil Science, Resource Management, Animal Science and Plant Science programs enrolled in a one-semester undergraduate course in Agrometeorology. In the fall of that year a second one-semester course, "Meteorology and Climatology" was made available to students on an elective basis. Four courses were now available at the graduate level, two being given each year, to students in Agrometeorology and to those working in associated areas in Soil Science, Engineering, and Plant Science or Biology. A new 70-acre site for agrometeorological studies was located at the new research farm purchased by OMAF for agricultural research near Elora. By the end of 1966 there were three Ph.D. candidates and one M.Sc. candidate enrolled in agrometeorology.

A Boost from IBP

Two years later a substantial 5-year grant was received from CMS in connection with the IBP, making it possible to recruit three more scientists: T.A. Gillespie, G.W. Thurtell, and G.E. Kidd. Research work was extended to include studies of CO_2 fluxes in crops and leaf wetness in connection with plant diseases.

Gillespie was a B.Sc. graduate from the University of British Columbia in 1962 with specialization in Mathematics and Physics. He received an M.A. in Meteorology from the University of Toronto in 1963. He was recruited as a meteorologist by the CMS, and worked with them as a forecaster and weather analyst in Toronto, Goose Bay and Montreal from 1962 to 1965. He then continued his education at the University of Guelph and became the first student to graduate from the new Ph.D. program in agrometeorology.

Thurtell moved from the University of Wisconsin to the Agrometeorology Program at Guelph, also in 1968. He had received two degrees from OAC: a B.Sc. in 1957 and an M.Sc. in 1960,as well as a Ph.D. from the University of Wisconsin in 1965. Thurtell's areas of research specialization were diffusion processes in the surface layer, flux measurements, instrument development, and plant-water relationships.

Kidd joined the Agrometeorology Program in 1969. He had a M.A.Sc. from the University of Waterloo. His background in electronic engineering had a major influence on both the research and the graduate training programs that developed at Guelph.

The year 1968 was another banner year for the Agrometeorological Group. King undertook a speaking tour across Canada, sponsored by the CMS. Its purpose was to promote a better understanding of agrometeorology as it existed at the time in Canada. Emphasis was placed on the applied aspects of micrometeorology to agriculture, and included such areas as improved agricultural weather forecasts, improved farm management practices and disease prevention.

A new Crop Science building, with about 10,000 sq ft of controlled-climate growth-chamber facilities was opened on the campus in the early part of the year. At this time there were nine graduate students registered: seven for the M.Sc. program and two for the Ph.D. program. One postdoctorate fellow was also on staff.

The 1969-70 program of instruction offered by the Agrometeorological Group included five graduate courses (Agricultural Climatology, Environmental Measurements, Micrometeorology, Micrometeorology Applied to Agriculture, and Micrometeorological Instrumentation) and five undergraduate courses (Meteorology and Climatology, Agrometeorology, Micrometeorology, Physical Meteorology, and Dynamic and Synoptic Meteorology).

Research work at the Elora Research Station included work on photosynthesis, evapotranspiration and other micrometeorological investigations. Three floating lysimeters were installed and a trailer was used to house recording and digitizing systems for measurement of net radiation, and profiles of CO_2, humidity, temperature, and wind. This site and others in the area, that provided opportunities for topoclimatology studies, were used by students for their thesis projects.

The Research Program Expands

By 1972 the Agrometeorology Group had five years of research measurements both of the effect of crops on the environment and for the effects of the environment on crops. The Group was now beginning a new phase in their work to bring all this information together in the form of a model in an attempt to simulate the functioning of a crop (corn) ecosystem and to ultimately predict how the crop would grow under varying environmental conditions.

Since joining the Agrometeorological Group in 1968 Gillespie had been studying the use of meteorological data in pest and disease control, with the objective of developing more efficient spraying techniques leading to better environmental protection. By 1973 the state of knowledge concerning several disease (e.g. late blight of potatos and apple scab) was sufficient to warrant development of forecasting schemes for control of pesticide spray programs. Although knowledge concerning the use of meteorological data for forecasting spray programs for the control of crop pests was not as well advanced, good progress was being made in studies of the coddling moth, European corn borer, apple maggot, red banded leaf roller, and the oriental fruit moth. With continued financial support control programs for many of these pests were expected to be operational within two to five years.

In 1970 the Ontario Agrometeorology Research Committee (OAmRC) was formed. Staff from the Agrometeorological Group played a prominent role in the operation of this committee. King was first chairman from 1970 to 1974, and again from 1984 to 1989, and Brown from 1978 to 1984. Following its organization several workshops were held to bring together AES meteorologists with OMAF specialists. These were held every two or three years.

Research and Training Peaks

Education in agrometeorology at Guelph peaked during the period 1979-80. During this two-year period six M.Sc. and five Ph.D. degrees were awarded. The research program continued to evolve over the years as problems warranted. In 1981 research was being conducted in four areas, either alone at Land Resource Science or in cooperation with other groups.

1. Crop-Water Use and Management:
   - plant-water relationships
   - feasibility of field crop irrigation
   - characteristics of droughts and their effects on field crop yields
   - maximum possible productivity

2. Environmental Effects on Crops:
   - air quality and crops
   - ozone
   - diffusion in and over canopies

3. Pest Control:
   - instrumentation for pest monitoring
   - weather effects on downy mildew epidemics and insects in onions
   - environmental influences on apple scab ascospore release in spring

4. Land Productivity:
   - refinement and testing of crop-yield models for estimating land productivity

The education course also developed and by 1981 included the following.

Undergraduate Courses:
- Meteorology and Climatology
- Microclimatology
- Microclimatic Measurements
- Agrometeorology
- Micrometeorology
- Intermediate Meteorology

Graduate Courses:
- Agricultural Climatology
- Micrometeorology
- Agrometeorological Instrumentation
- Seminar
- Special Topics

Enrolment was down from the high enjoyed during the previous two years, and it was reported to the ECA that a shortage of trained personnel existed in Canada.

The year 1983 was a fairly active one. King, who had been absent from the Group for seven years (when he served as Chairman of the Department of Land Resource Science) returned to full time teaching and research. In 1983 a Workshop on Agrometeorology, sponsored by the OAmRC, was held at the University of Guelph, with King serving as moderator. A total of 9 papers were presented and published in a proceedings.

J.D. Wilson joined the staff in 1983 as a NSERC University Research Fellow, a position he held for two years. He graduated from the University of Canterbury, N.Z. with a B.Sc. in Physics in 1974, from the

University of Alberta with an M.Sc. in Meteorology in 1978, and from the University of Guelph with a Ph.D. in Micrometeorology in 1980.

An Exchange Program with China, known as the "University of Guelph/Agricultural University of Beijing, China Exchange", was initiated. The Land Evaluation Model (LEM) project for Ontario was completed and a new project "Land Evaluation for Canada", also supported by Agriculture Canada, was initiated.

By 1984 the agrometeorological research program had expanded under each staff member as follows:

Brown:
- crop response to irrigation during dry spells
- computer simulation modelling of corn yield
- land evaluation studies

Gillespie:
- drying of water drops on leaves in regard to leaf wetness and disease development
- modelling crop microclimates from weather-station data
- final yield test for onion-spray scheduling using temperature and leaf wetness

King:
- methods to measure ET and CO_2 flux in the field
- effects of elevated CO_2 and VPD in controlled environments on growth and transpiration ratios
- implementation of weather station automation

Thurtell:
- modelling diffusive transport in and above crop canopies
- environmental limitation to maximum yield of corn
- development of open-path sensors for water vapour and CO_2 measurement

Wilson:
- air flow through a windbreak
- low wind-speed canopy transport

Wilson resigned his Fellowship in 1985 to take a position at the University of Alberta.

In 1986 the aims and goals of the Agrometeorological Program were spelt out as follows:

1. To gain a better understanding of Ontario's climatic resources and the fundamental physical and biological processes linking the atmospheric environment with plants, soils, animals and crop pathogens.

2. To assure, in cooperation with other scientists, that information for Ontario's farmers is available on agrometeorological aspects of the following: integrated pest management, cultivar selection, field microclimates and their modification, irrigation needs, climatic hazards and their control, implication of future climatic change; and other topics of concern.

Five objectives were proposed to carry out this work:

1. To increase our understanding of the fundamental processes controlling the transfer of material and energy in the lower atmosphere.

2. To determine the soil and atmospheric factors in the physical environment of Ontario crops that limit yield.

3. To provide meteorological support for plant disease and insect-control programs.

4. To assess the effect of water shortages on alternative crop production practices, through use of computer models that simulate crop response to climate and soil conditions.

5. To acquire and compile agroclimatic data.

The Agrometeorological Group continued its strong lead in Canada in the fields of both education and research. New activities undertaken by the Group included research on the use of laser techniques for measuring environmentally important gases, the rainfall distribution from thunderstorms following dry spells, and the effect of leaf-surface wetness on the sink strength of vegetation for SO_2 and O_3. Members of the Group achieved, as well as a national status in agrometeorology, international recognition as indicated by their involvement in international agrometeorological activities (see Chapter 10).

Membership in the NCAM (CCAM, CCA, ECA)

From the inception of the NCAM in 1960 Ontario Agricultural College and later the University of Guelph had a representative on that Committee. King was the first member from the Agrometeorology Group. He served three terms and was acting chairman in 1984. Brown and Gillespie also served several terms each (see Chapter 5, "Membership List").

Members of the Group also served on several provincial committees as well as international committees (see Chapter 10).

Scientific Research and Literature

Members of the group carried on a continuing program of research in various aspects of agrometeorology. The results of this work have been published in numerous scientific journals. A brief cross-section of this work is indicated by the following:

1966 MUKAMMAL, E.I., KING, K.M. and CORK, H.F. The use of aerodynamic techniques in estimating evapotranspiration from a cornfield and the difficulties encountered. Arch. Met. Geophys. Bioklimatol. Series B, 14:384-395.

1967 DYER, A.J., HICKS, B.B. and KING, K.M. The fluxatron: a revised approach to the measurement of eddy fluxes in the lower atmosphere. J. Appl. Meteorology, 6:408-413.

1969 BROWN, D.M. Heat units for corn in southern Ontario. Ont. Dept. of Agric. and Food. Information Leaflet. Agdex. No.111/31. 4 pp. (Revised 1970 as Factsheet, Agdex. No. 111/31. 4 pp. Revised 1972. Reprinted 1973. Revised 1975. Reprinted 1976. Revised 1978.)

1970 THURTELL, G.W., TANNER, C.B. and WESELY, M. Three-dimensional pressure sphere anemometer system. J. Appl. Meteorol. 9:379-385.

1971 GILLESPIE, T.J. and KING, K.M. Night-time sink strengths and apparent diffusivities within a corn canopy. Agric. Meteorol. 8:59-67.

SELIRIO, I.S., BROWN, D.M. and KING, K.M. Estimation of net and solar radiation, Can. J. Plant Sci. 51:35-39.

1974 SHAW, R.H., SILVERSIDES, R.H. and THURTELL, G.W. Some observations of turbulence and turbulent transport within and above plant canopies. Boundary-Layer Meteorol. 5:429-449.

1975 COLIGADO, M.C. and BROWN, D.M. A biophoto-thermal model to predict tassel initiation time in corn (Zea mays L.). Agric. Meteorol. 15:11-31.

1978 KING, K.M. Modeling evapotranspiration. In: Proceedings of the International Workshop on the Agrometeorological Research Needs of the Semi-Arid Tropics. ICRISAT, Hyderabad.

DENMEAD, O.T., NULSEN, R. and THURTELL, G.W. Ammonia exchange over a corn crop. Soil Sci. Soc. Am. J. 42:840-842.

1979 GILLESPIE, T.J. and Sutton, J.C. A predictive scheme for timing fungicide applications to control Alternaria leaf blight in carrots. Can. J. Plant Path. 1:95-99.

SELIRIO, I.S. and BROWN, D.M. Soil moisture-based simulation of forage yield. Agric. Meteorol. 20:99-114.

1982 PEDRO, M.J. and GILLESPIE, T.J. Estimating dew duration II. Utilizing standard weather-station data. Agric. Meteorol. 25:297-310.

WILSON, J.D., WARD, D.P., THURTELL, G.W. and KIDD, G.E. Statistics of atmospheric turbulence within and above a corn canopy. Boundary-Layer Meteorol. 24:495-519.

1983 WILSON, J.D., CATCHPOOLE, V.R., DENMEAD, O.T. and THURTELL, G.W. Verification of a simple micrometeorological method for estimating the rate of gaseous transfer from the ground to the atmosphere. Agric. Meteorol. 29:183-189.

1984 AMIRO, B.D., GILLESPIE, T.J. and THURTELL, G.W. Injury response of phaseolus vulgaris to ozone flux density. Atmos. Environ. 18:1207-1215.

1985 AMIRO, R.D. and GILLESPIE, T.J. Leaf-conductance response of Phaseolus vulgaris to ozone flux density. Atmos. Environ. 19:807-810.

WILSON, J.D. Numerical studies of flow through a windbreak. J. Wind Eng. Indust. Aero. 21:119-154.

1986 BROWN, D.M. Corn yield response to irrigation, plant population and nitrogen in a cool, humid climate. Can. J. Plant Sci. 66:453-464.

KING, K.M. and GREER, D.H. Effects of CO_2 enrichment and soil water on maize. Agron. J. 78:515-521.

KING, K.M. and THURTELL, G.W. Measurement and prediction of evapotranspiration for agriculture. In: D.G. MacIver and R.B. Street (eds.) Proceedings of the Workshop on Evapotranspiration, Irrigation and Plant Moisture Stress in Agriculture and Forestry. AES, Downsview. pp. 21-35.

1987 GILLESPIE, T.J. and DUAN, R-X. A comparison of cylindrical and flat plate sensors for surface wetness duration. Agric. and Forest Meteorol. 40:61-70.

1988 HEIKINHEIMO, M., THURTELL, G.W. and KIDD, G.E. An open path IR gas analyzer for simultaneous eddy-correlation measurements of carbon dioxide and water vapour. J. Atmos. Oceanic Technol. 6:624-636.

1989 BROWN, D.M. and PLACE, R.E. Rating climate in southwestern Ontario for horticultural crops. Can. J. Plant Sci. 69:325-336.

The Canadian Society of Agrometeorology

Through the efforts of Brown and some of his former students, a special half-day session on agrometeorology was held at the 1986 Annual Convention of the Agricultural Institute of Canada in Saskatoon. This technical session was encouraging enough for participants to form an executive to make plans for an agrometeorological society, and to hold a second session at the AIC Convention to be held in London, Ontario, in 1987. Brown was elected chairman, Selirio vice-chairman, and Schneller secretary-treasurer. The second technical session in London was a success. The executive presented a Constitution for the new society to be called the Canadian Society of Agrometeorology. Provision was made in the Constitution for the election of fellows and three were honored at the London meeting: G.W. Robertson, M.K. Thomas, and L.J. Chapman.

Since then the Society has held successful annual meetings at the AIC Conventions and has become affiliated with that Institute. Two more members have been honored by being elected Fellows of the Society: K.D. Hage (1988) and R.H. Douglas (1989).

Graduates in Agrometeorology from Guelph

YEAR	NAME	DEGREE	THESIS TITLE & SUPERVISOR
1958	Harrison, M.B.	M.S.A.	Effects of some soil and microclimate variables on corn and pasture. (King).
1959	Graham, W.G.	M.S.A.	Changes in the heat budget of a corn crop with plant development. (King).
1960	Patil, A.S.	M.S.A.	Self-diffusion coefficient of rubidium as influenced by soil water tension. (King).
1965	Pech, G.	M.S.A.	Characterization of visible radiation in plant communities. (King).
1965	Stewart, D.W.	M.S.A.	Water relationships in the soil-plant-atmosphere system. (King).
1968	Gillespie, T.J.	Ph.D.	Dew and night-time transfer of heat and water vapour in a corn field. (King).
1969	Muzik, I.	M.Sc.	Determination of evaporation and drainage components of the soil-moisture balance method. (King).
1969	Rahn, J.J.	Ph.D.	Air and plant temperatures in a corn canopy. (Brown).
1969	Selirio, I.S.	M.Sc.	Climatological estimation of planting days. (Brown).
1971	Smith, P.J.	M.Sc.	Studies of night-time CO2 diffusion using environmental variables to predict crop and soil respiration rates. (Gillespie).
1972	Bootsma, A.	M.Sc.	Environmental factors affecting the development of yellow leaf blight (Phyllosticta maydis) in corn. (Gillespie).
1972	Shaw, R.H.	Ph.D.	An experimental study of turbulent transport within plant canopies using a split-film heat transfer anemometer. (Thurtell).
1973	den Hartog, G.	Ph.D.	A field study of the turbulent transport of momentum between the atmosphere and a vegetative canopy. (King).
1973	Jenkinson, R.C.	M.Sc.	The effect of simulated early fall frost on the yield and drying rate of corn (Zea mays L.). (Brown).
1973	Neumann, H.H.	Ph.D.	Water-potential relationships in plant tissues measured by a new dew-point hygrometer technique. (Thurtell).
1973	Silversides, R.H	Ph.D.	The structure of thermal turbulence above and within canopies of Zea mays L. and Pinus resinosa ait. (Thurtell).
1974	Coligado, M.C.	Ph.D.	Tassel initiation studies on corn (Zea mays L.): Temperature and photoperiod effects and a bio-photo-thermal model. (Brown).
1974	Dyer, J.A.	M.Sc.	Simulation of the day-time bare-soil surface temperature. (Gillespie).

1974	Labine, C.L.	M.Sc.	Measurement and computer simulation of microclimatic differences between a polar desert plateau and a nearby coastal lowland. (Gillespie).
1974	Langenberg, W.	M.Sc.	Carrot-leaf blight (Alternaria dauci) development in relation to environmental factors and fungicide application. (Gillespie).
1974	Nulsen, R.A.	M.Sc.	Hydraulic continuity and leaf-water potential recovery of mildly and severely stressed corn (Zea mays L.). (Thurtell).
1975	Ike, I.F.	M.Sc.	Studies of plant-water relationships in cassava (Manihot species). (Thurtell).
1975	Selirio, I.S.	Ph.D.	Study of variation of apparent Bowen ratio with height above a corn field. (King).
1977	McKay, D.C.	Ph.D.	Measurement of the structure of atmospheric turbulence and energy fluxes involved in the energy budget of a snow cover. (Thurtell).
1977	Nulsen, R.A.	Ph.D.	Water flow through the roots of well-watered and water-stressed corn plants. (Thurtell).
1978	Ike, I.F.	Ph.D.	Water relations of indoor-grown Cassava (Manihot species). (Thurtell).
1978	Mintah, C.N.	M.Sc.	A numerical model to estimate leaf wetness duration. (Gillespie).
1978	Skretkowicz, A.K.	M.Sc.	Comparative water-stress studies on drought resistant and susceptible corn grown in chamber and field environments. (Thurtell).
1978	Swanton, C.J.	M.Sc.	Influence of environmental factors on development and control of Botrytis leaf blight of onions. (Gillespie).
1978	Thomas, L.J.	M.Sc.	Agrotopoclimatological studies in the Sparta and Blenheim study areas with respect to freeze incidence. (King).
1978	Ward, D.P.	M.Sc.	Some observations of atmospheric turbulence within and above a corn canopy using a modified split film heat transfer anemometer. (Thurtell).
1979	Abdul-Ghani, M.M.	M.Sc.	Estimation of daily soil-heat flux during the spring season in a perennial forage crop from climatological data. (Brown).
1979	Brunini, O.	Ph.D.	New devices for *in situ* measurements of soil- and root-water potentials and transport of water in the soil-plant system. (Thurtell).
1979	Crawford, B.E.	M.Sc.	Estimation of seed-depth soil temperature using air temperature data. (Brown).
1979	Walton, V.J.	M.Sc.	The response of corn (Zea mays L.) to temperature changes on a 3-day cycle during emergence to tassel-initiation period. (Brown).
1980	Dzikowski, P.A.	M.Sc.	The use of weather information to timed fungicide application for control of Botrytis onion-leaf blight. (Gillespie).
1980	Foong, S.F.	M.Sc.	Weather-based model for estimating soil palm fruit yield. (Brown and Robertson).
1980	Grace, B.	Ph.D.	A study of threshold sulphur dioxide concentrations for the lichen Cladina rangiferina (L.) harm. (Gillespie).
1980	Walker, J.	Ph.D.	Ozone uptake by corn (Zea mays L.). (Thurtell).
1980	Wilson, J.D.	Ph.D.	Turbulence measurements in a corn canopy and numerical simulation of particle trajectories in inhomogeneous turbulence. (Thurtell).
1981	Day, D.	M.Sc.	Leaf-osmotic potential measurements in corn (Zea mays L.) and use of wind machines for frost protection in Ontario. (King).
1981	Livingston, N.	M.Sc.	Development and field use of a steady-state diffusion porometer. (Thurtell).

1981	Pedro, M.	Ph.D.	Relation of leaf-surface wetness duration to meteorological parameters. (Gillespie).
1982	Chan, A.K.	M.Sc.	Moisture reduction in corn grain. (Brown).
1982	Leclerc, M.	M.Sc.	Development and testing of two mathematical models to predict evaporation to surface wetness. (Thurtell).
1982	Pierce, W.G.	Ph.D.	Osmotic adjustment to water stress in the leaves of spring wheat. (Thurtell).
1983	Amiro, B.	Ph.D.	Studies of ozone flux and leaf temperature in Phaseolus vulgaris. (Gillespie).
1984	Okoye, C.A.	M.Sc.	Response of irrigated field corn to rate and time of nitrogen application on a sandy soil. (Brown).
1984	Place, R.A.	M.Sc.	Development of a method for estimating the yield response of field corn to irrigation. (Brown).
1985	Barr, A.G.	M.Sc.	The influence of CO_2 enrichment on transpiration and photosynthesis in maize during short-term changes in the vapour pressure gradient. (King).
1985	Brown, R.D.	Ph.D.	Estimation of remote microclimates from weather-station data with applications to landscape architecture. (Gillespie).
1986	Graham, M.E.	Ph.D.	The effect of increased transpiration on photosynthesis in maize. (Thurtell).
1986	Heikinheimo, M.	Ph.D.	Techniques for detecting carbon dioxide and water vapour transport above a vegetated surface using the eddy-correlation method. (Thurtell).
1987	Fuentes, Josè	M.Sc.	Leaf photosynthesis, leaf conductance and intercellular CO_2 concentration of maize grown hydroponically and in soil. (King).
1987	Hopps, P.	Ph.D.	(Awarded posthumously). (Thurtell).
1987	Kalliomaki, M.	M.Sc.	The water-retention characteristics, and resistances to water loss and water uptake, of dead winter-wheat tissue. (Gillespie).
1987	Leclerc, M.	Ph.D.	Turbulence and turbulent diffusion inside and above vegetation. (Thurtell).
1987	Shi. G.	M.Sc.	Studies of atmospheric turbulence within and above a deciduous forest. (Thurtell).
1988	Berard, R.	Ph.D.	Whole-plant enclosure studies on the effects of increased evaporative demand and soil-water content on photosynthesis in maize. (Thurtell).
1988	McGinn	Ph.D.	Heat, water vapour and CO_2 exchange above alfalfa and maize. (King).
1989	Lin, Ping	M.Sc.	The feasibility of a time-lag anemometer by a thermometer array. (Thurtell).
1989	Singh, Gurmeet	M.Sc.	Modelling soil-water status for irrigation scheduling in potatoes. (Brown).
1989	Sribimawati, T.	M.Sc.	Comparison of rainfall distribution during dry spells using radar images and gauge networks in southwestern Ontario. (Brown).
1989	Zhang, Yun	M.Sc.	A model to estimate leaf-surface wetness duration using standard weather station data. (Gillespie).

PART 4 - WESTERN CANADIAN UNIVERSITIES

University of Manitoba

Research and training in agrometeorology had a slow start at the University of Manitoba. The Department of Soil Science was, originally, mainly concerned with soil physics, soil surveys, and other problems and characteristics of prairie soils. It was not until the late 1960's that interest in climate and its effects on soil-water content, soil temperature and plant growth began to develop. From that time onwards C.F. Shaykewich, soils physicist, became increasingly interested in agrometeorological problems in relation to soils and crop growth.

Shaykewich was a graduate of the University of Manitoba with a B.Sc. (1963) and an M.Sc. (1965) in Agriculture. He took postgraduate work at Macdonald College (McGill) and earned a Ph.D in 1968. He joined the Dept. of Soil Science at the University of Manitoba in 1967 as an Assistant Professor, became an Associate Professor in 1973 and Professor in 1979.

During the early 1970's course work began to include an increasing amount of material relative to agrometeorology, and graduate students were encouraged to undertake theses dealing with problems related to agrometeorology. The following list of theses supervised by Shaykewich indicates this development:

1971	Pawloski, M.C.	M.Sc.	The effect of water stress on the photosynthesis of the potato.
1971	Partridge, J.R.D.	M.Sc.	Effects of nitrogen, temperature and moisture regime on the yield and protein content of Neepawa wheat.
1974	Tataryn, J.H.	M.Sc.	Evaluation of the corn heat unit for southwestern Manitoba.
1975	Keatinge, J.D.H.	M.Sc.	The influence of the physical environmental factors on the productivity potential of fababeans.
1978	De Jong, R.P.	Ph.D.	Energy exchange of the soil surface and the soil temperature regime.
1978	Reimer, A.	M.Sc.	Soil temperature estimation from meteorological measurements.
1980	Cutforth, H.	M.Sc.	Evaluation of a crop-simulation model.
1980	Gauer, E.	M.Sc.	Soil temperature and moisture of conventional and zero-tilled soils in Manitoba.
1981	Dunlop, S.	M.A.	An agrometeorology of southern Manitoba.
1981	Falk, G.	M.Sc.	Environmental factors affecting soybean growth in Manitoba.
1982	Krpan, J.R.B.	M.A.	The characterization and estimation of soil temperature in Manitoba.
1984	Zinyk, J.	M.Sc.	Using infrared radiation for assessing crop-water status.
1984	Burnett, R.B.	M.Sc.	Determination of climatically suitable areas for soybean production in Manitoba.
1985	Ives, R.	M.Sc.	Effect of simulated soil erosion on wheat yields.
1985	Basnayake, A.K.	M.Sc.	Soil erosion in the tea land of Sri Lanka.
1985	Cutforth, H.W.	Ph.D.	Dependence of corn development from germination to silking on the physical environment.
1986	Onofrei, C.	Ph.D.	A model for land evaluation using crop simulation techniques.
1987	Pauls, W.J.	M.Sc.	The applicability of the Universal Soil Loss Equation in Manitoba.
1987	Kenyon, B.E.	M.Sc.	Effect of simulated erosion on canola productivity.
1989	Wahome, E.K.	M.Sc.	Soil erosion measurements under natural rainfall for evaluating the Universal Soil-Loss Equation.

Although research activities in the Department of Soil Science leaned heavily towards soil physics, there was a trend to include an increasing amount of agrometeorological and other related environmental

studies in the research program. A number of these studies centred around the study of the agroclimate of Manitoba, soil water problems in connection with soil conservation and irrigation, and later with crop-weather models for potential new crops for Manitoba.

In 1974 Shaykewich published a comprehensive review of the "Climate of Southern Manitoba as it Relates to Agriculture." Besides the usual climatic information this report included information such as frost-free periods, corn heat units, and other factors relative to crop production.

The following sample of published papers further illustrates the increasing interest in agrometeorology:

1968 SHAYKEWICH, C.F. and ZWARICH, M.A. Relationships between soil physical constants and soil components of some Manitoba soils. Can. J. Soil Sci. 48:199-204.

1972 PARTRIDGE, J.R.D. and SHAYKEWICH, D.F. The effects of nitrogen, temperature and moisture regime on the yield and protein content of Neepawa wheat. Can. J. Plant Sci. 52:179-185.

1975 BARON, V., SHAYKEWICH, C.F. and HAMILTON, R.I. Relation of corn maturity to climatic parameters. Can. J. Soil Sci. 55:343-347.

1977 SHAYKEWICH, C.F. and STROOSNIJDER, L. The concept of matric-flux potential applied to simulation of evaporation from soil. Neth. J. Agric. Sci. 25:663-82.

1980 REIMER, A. and SHAYKEWICH, C.F. Estimation of Manitoba soil temperature from atmospheric meteorological measurements. Can. J. soil Sci. 60:299-309

DE JONG, R., SHAYKEWICH, C.F. and REIMER, A. The calculation of net radiation flux. Arch. Met. Geoph. Biolkl. B, 28:353-363.

1982 GAUER, E.L., SHAYKEWICH, C.F. and STOBBE, E.H. Soil temperature and soil water under zero tillage in Manitoba. Can. J. Soil Sci. 62:311-332.

1985 BURNETT, R.B., FALK, G.W. and SHAYKEWICH, C.F. Determination of climatically suitable areas for soybean (Glycine max L. Merr.) production in Manitoba, Can. J. Plant Sci. 65:511-522.

1987 CUTFORTH, H.W., SHAYKEWICH, C.F. and CHO, C.M. A model to estimate the time to emergence for corn under field conditions. Can. J. Soil Sci. 67:659-665.

1990 CUTFORTH, H.W. and SHAYKEWICH, C.F. A temperature response function for corn development. J. Agric. and For. Meteorol. 50:159-171.

R.A. Hedlin of the Faculty of Agriculture was the Manitoba representative on the NCAM for two meetings, 1967 and 1968. He was succeeded by K. Shaykewich for the three Annual Meetings, 1969-71, by K. Clark for those in 1972-74 and by D.F. Shaykewich for those from 1984 to the present. During the period 1975 to 1983 Manitoba had no representation on the Committee.

University of Saskatchewan

B.W. Currie, Professor of Physics, probably introduced meteorology at the University of Saskatchewan in the early 1940's, and appeared to be interested in weather and agriculture as he made a study of frost-free seasons in the late 1940'ss (Currie, 1948).

Sometime later the Saskatchewan Research Council became interested in agrometeorology, probably a result of T.P. Pepper's association with the NCAM and its early stand regarding education and research

in the field of agrometeorology (Chapter 5). In the early 1960's two meteorologists were recruited, J. Maybank and J.L. Bergsteinsson who, among other things, undertook research and service work relative to agrometeorology. Undoubtedly, they took part in research programs at the University and offered services as part-time lectures.

It was not until R.T. Coupland became interested in the International Biological Project (IBP) in the late 1960's that agrometeorology really got started at the University. E.A. Ripley was hired in 1968 to undertake research on the fluxes of latent and sensible heat and carbon dioxide over native prairie grass at the IBP site at Matador, under the direction of Coupland.

Ripley was a graduate in Physics from Dalhousie, (B.Sc. 1953) and in Meteorology from Toronto (M.A. 1956). He worked with at the CMS Weather Office in Halifax until he was offered a job with the Nigerian Meteorological Service as a forecaster in 1960. Two years later he went to Kenya as a Munitalp Fellow to work with the East African Agriculture and Forestry Research Organization. This was his first contact with agrometeorology. In 1965 he accepted a CIDA assignment in Kenya, Uganda, and Tanganyika where he worked on microclimate and micrometeorology problems in coffee and tea plantations until he returned to Canada to do IBP research in Saskatchewan.

After completing the IBP work in 1973 he became an Associate Professor in the Department of Ecology of the College of Agriculture. He introduced courses in agrometeorology and biometeorology at both the diploma and degree levels. He supervised several theses.

1974	D.L. Spittlehouse	M.Sc.	Relationships between the structure and microclimate of mixed prairie in Saskatchewan, Canada.
1982	B.J. O'Connor	M.Sc.	A planting-to-emergence model for wheat and barley.
1982	S.M. McGinn	M.Sc.	SIMCER - A simulation model for cereal growth and development.
1983	G.K. Gibney	M.Sc.	Wind barrier effects on microclimate and evapotranspiration.

From 1974 to 1989 Ripley was the Secretary of the Saskatchewan Intercouncil Committee on Agricultural Meteorology and, from 1982 to 1989, Secretary of the CMOS Special-Interest Group on Agricultural Meteorology. In 1986 he was a consultant to the Ontario Council on Graduate Studies to carry out a review of the M.Sc. and Ph.D. programs in agrometeorology at the University of Guelph. He has also served on international agrometeorological committees (See Chapter 10). He also has several papers and reports which are listed in Appendix 1.

University of Alberta

The earliest activities in meteorology at the University of Alberta were probably by Prof. L.H. Nicholls and Dr. E.H. Gowan of the Physics Department. During the mid-1930's Nicholls became interested in low-level inversions during the winter, and made several airplane flights over the Edmonton area. He discovered that, when a chinook occurred in Calgary, the temperature a few hundred feet above Edmonton was frequently several degrees above zero Celsius even though the surface temperature was several degrees below zero. He referred to these measurements during his lectures in physics and, along with other references to weather events and weather instruments, caught the imagination of several of his students, among them Douglas and Robertson who later became meteorologists and applied their knowledge to agriculture. Gowan was doing research on the intensity of natural ultraviolet light and had many interesting recordings of the hourly and daily fluctuations of this entity.

Eventualy Nicholls introduced a course in elementary meteorology and Robertson, while working at the Edmonton Weather Office of CMS, assisted him with the laboratory part of this course for five years (1945-50). This part of the course dealt with the interpretation of daily synoptic weather maps.

In the Faculty of Agriculture A.G. McCalla gave a course in Field Crops Management which had a substantial agrometeorological content.

During the late 1950's Prof. A.H. Laycock of the Geography Department began a research program on the climate of Alberta, and developed and offered courses in meteorology and climatology. Prof. R.W. Longley joined the Department about 1965 and also contributed to the study of the climatology of Alberta. He also assisted J.A. Toogood of the Faculty of Agriculture with the establishment of a Benchmark Climatology Station on the University Farm near Ellersley, where special agrometeorological observations were taken. A number of studies were undertaken in cooperation with the Faculty of Agriculture, including studies of the effect of topography on temperature using mobile thermometers.

K.T. Hage joined the Geography Department as a micrometeorologist in 1967. He received his Doctorate in Meteorology at the University of Chicago in 1957. Both he and Longley were former meteorologists with the CMS and had worked with the Defence Research Board at the Suffield Forces base in southeastern Alberta. Hage undertook several micrometeorological studies at the University Farm.

Courses for undergraduate and graduate students at both the Master and Doctoral levels were offered from the time Laycock joined the Department. Although designed primarily to train meteorologists, some of the courses dealt with agrometeorological topics such as climatology, micrometeorology, hydrometeorology, biometeorology, and instrumentation.

Until about 1977 most of the graduate students taking meteorology were financed by AES. However, there were an increasing number of students wanting to do graduate work in meteorology and seek employment outside AES. There was a problem regarding the financing of graduate programs for such students, as outside funds were not readily available. The Alberta Agrometeorology Advisory Committee appointed a sub-committee consisting of Hage (Chairman), R.J. Christopherson, D. Chanasyk, and W.G. Bailey to look into this matter, as well as curriculum improvement in secondary and post-secondary institutions.

In 1985 J.D. Wilson joined the Department as a micrometeorologist. He came from the University of Guelph where he had been a NSERC University Research Fellow.

Toogood of the Faculty of Agriculture was one of the original members of the NCAM and served from 1960 to 1964. Longley replaced in him in 1965 and served for two years. He was invited as an expert in 1968 and Hage was an invited expert in 1971. D. Chanasyk of the Faculty of Agriculture and Forestry was a member from 1981 and 1982.

Research by staff and students dealing with agrometeorology and related topics is illustrated by the following published papers:

1960 LAYCOCK, A.H. Drought patterns in the Canadian prairies. Int. Assoc. Sci. Hydrol. Publ. No.51. pp. 34-47.

1965 LONGLEY, R.W. and THOMPSON, C.E. A study into the causes of hail. J. Appl. Meteorol. 4:69-82.

1967 LAYCOCK, A.H. Water deficiency and surplus patterns in the Prairie Provinces. Prairie Provinces Water Board. Regina. Rep. No. 13. 185 pp.

LONGLEY, R.W. Temperature increases under snow during a mild spell. Soil Sci. 104:379-382.

LONGLEY, R.W. The frost-free period in Alberta. Can. J. Plant Sci. 47:239-249.

1970 LONGLEY, R.W. Climate classification for Alberta forestry. Proc. 3rd Forest Microclimate Symp., Kananaskis, Alberta, Sept. 1969. Can. Forestry Serv., Calgary. pp. 147-153.

1971 HAGE, K.D. Microscale and mesoscale transport. In: Meteorological Aspects of Pollution in Relation to Agricultural Pesticides. Canada Committee on Agricultural Meteorology, CDA. 25-32.

1975 HAGE, K.D. Averaging errors in monthly evaporation estimates. Water Resources Research. 11:359-361.

1978 CAIAZZA, R., HAGE, K.D. and GALLUP, D. Wet and dry deposition of nutrients in central Alberta. Water, Air and Soil Pollution. 9:309-314.

1985 HAGE, K.D. Weather extremes in Alberta: 1880 to 1960. Climatological Bulletin. 19:3-15.

1988 WILSON, J.D. Turbulent transport within the plant canopy. In: Estimation of areal evapotranspiration. Intl. Assoc. Hydrol. Sci. Publ. No. 177. pp. 43-80.

University of Calgary

In the 1960's there was some activity in topics of interest to agrometeorology. In 1965 Dr. I.Y. Ashwell of the Geography Department undertook some research on the economical implications of the Chinook to farmers in southern Alberta. A graduate student, J.S. Marsh, worked on the problem for his M.Sc. thesis, "Chinook and its geographical effects in southern Alberta." Prof. R.E. Chambers of the Department of Geography undertook a study of soil temperature as an ARDA contract in 1966.

University of British Columbia

Geographers, agriculturists and foresters had undertaken or encouraged climatic studies prior to 1965. One activity of note was the preparation of a climatic analysis of the province by V.C. Brink, Chairman of the Division of Plant Science, Faculty of Agriculture. He was also involved in a study of the effect of frozen soil on the mortality of forage crops.

Active interest in agrometeorology at the University was created by ARDA and its CLI program in the latter half of the 1960's. The meteorological component of the British Columbia ARDA CLI program was the largest provincial program in Canada. The University became indirectly involved in training and basic research about the same time as the BC ARDA program began to take shape. A bibliography of agroclimatic references was prepared by A.L. Farley and C.C.E. Denike of the Geography Department. Farley, with the assistance of Rheumer, both of the Geography Department, undertook the mapping of climatic variables in BC. Started in 1965, this was completed and published in 1971.

After T.A. Black joined the Department of Soil Science in the late 1960's, it gave more attention to agrometeorology. Early work involved a study of evapotranspiration processes and water use by specialty crops grown locally in BC, integrated pest control, and pollution studies.

The Department of Soil Science began studies of the difficult problem of measuring evapotranspiration from stands of forest trees in 1970. Special equipment was designed to provide data for the Bowen ratio approach to the problem. Studies continued through the early 1970's.

In 1972 the Department designed and built a mobile micrometeorological station for studying the energy balance of various agricultural crops. The system was used in the interior valleys in connection with the consumptive use of water. This same apparatus was also used in the BC Land Inventory program for some of their studies.

The AES funded a project to study surface temperature of a forest floor. The project started in 1972 and was conducted by the Department of Soil Science. The information was important in connection with regeneration of clear-cut forests.

Training in Agrometeorology

Courses in micrometeorology were taught in the Departments of Soil Science and Geography as well as in the Institute of Oceanography. Agrometeorology and forest meteorology were developed in the Department of Soil Science, and students were encouraged to do graduate work in agrometeorology. By 1974 the first graduate student with specialization in agrometeorology was granted a Ph.D. Within the next few years several graduates specialized in agrometeorology and were hired by various agencies working on forest-meteorological and agrometeorological problems in BC. By 1980 several courses were being given by the Department of Soil Science, including forest meteorology and agrometeorology, biometeorology, soil physics, instrumentation in biometeorology, and biological responses to weather. Courses relative to agrometeorology were also being given in the Departments of Geography and Physics, and in the Institute of Oceanography.

M.D. Novak, a U.B.C graduate in agrometeorology. joined the Department of Soil Science in 1981. He began research on soil and water conservation. Other new programs in the Department include work on soil thermal characteristics, and the effects of mulches, pasture-production models, and tree seedling microclimates.

By 1987 activities in agrometeorology and forest meteorology began to slow down due to restricted funding by both the Provincial and Federal Governments.

Brink was an early member (1966-68) of the NCAM when it was still encouraging universities to become involved in training and research in agrometeorology. Later, Black served on the Committee for two terms, 1972-74 and 1976-78, as a representative for BC.

Simon Fraser University

Participation in agrometeorology started late at Simon Fraser University when W.G. Bailey was hired in 1982 to conduct research and training in agrometeorology. He had previously worked with the Research Branch, CDA at the Beaverlodge research station and in the Agrometeorology Research and Service Section of the LRRI. He started research on the environmental physics of ginseng and later undertook investigations of heat and mass transfer in mountain environments. (Bailey et al, 1988; Bailey et al, 1989). Work in agrometeorology appeared to decline after 1987. Bailey served on the ECA from 1987 to 1990 as the representative for BC.

PART 5 - OTHER UNIVERSITIES

There are probably some dozen other universities and colleges across Canada wherein agrometeorology or related subjects are taught and researched. This activity at most of these institutions takes place on an ad-hoc basis, usually within departments and faculties other than agriculture. In many cases there are activities involving weather-sensitive areas such as the environment, environmental protection, pure meteorology, wild life, recreation and geographical climatology. Although they are frequently not directed specifically at agriculture, they may have practical applications in that area. In some faculties and colleges of agriculture, agrometeorology and related topics may be taught at an elementary or introductory level. These topics have inspired some students to seek further education and a career in agrometeorology. The development of involvement and progress in these areas are too nebulous and diverse for inclusion here.

CHAPTER 9
PROVINCIAL ACTIVITIES

PART 1 - THE ATLANTIC PROVINCES

Early Activities

First concerns about the effect of weather on agriculture and crop production were indicated by the undertaking of climatic observations at CDA Experimental Farms in cooperation with CMS when Experimental Farms were first established at Nappan in 1887, Charlottetown in 1909, and Fredericton in 1911. The Experimental Farms provided sites, provided staff to take the observations, and sent reports to CMS who provided instruments and instruction.

It was not until 1947 that meteorological data were used in a practical manner for assisting with farm operations. A weekly potato bulletin was prepared by L.C. Callbeck of the CDA Research Station at Charlottetown based on weather recorded at the Research Station. It was mainly concerned with late blight of potato. This bulletin was prepared for many years.

Other than this, there appears to have been very little activity in the field of agrometeorology in the Atlantic Provinces prior to the formation of the NCAM in 1960. What little activity there was appears to have been confined to a few public weather forecasters who attempted to direct a part of the public weather forecast at farmers' weather-sensitive operational problems such as the prediction of untimely frost and of dry spells for haymaking.

CMS Opens Fredericton City Weather Office

E.A. Barks, Regional Meteorologist of the CMS in Moncton, was appointed in 1960 to represent interests in the Atlantic Provinces on the NCAM. During his 4-year term he prepared several reports on weather forecasts for farmers and reported on agrometeorological activities in the Atlantic Provinces. Through this association with the Committee and his position as Regional Director he became aware of farm-weather problems and was able to initiate farm-weather services within his staff and financial means.

In April 1960 the CMS opened a City Weather Office in Fredericton, NB, with R.B.B. Dickison as Officer-in-Charge. This office was primarily for service to agriculture in the Province.

Dickison had a B.Sc. in Chemistry and Mathematic from Acadia University (1949), and later obtained an M.A. in Forest Climatology from Duke University (1970). He joined the CMS as an aviation forecaster in 1949 and served in Europe as a military aviation forecaster (1953-55). He served as Officer-in-Charge of the Fredericton Weather Office from 1960 to 1969, then moved on to teach forest meteorology at the University of New Brunswick.

CMS Farm-Weather Forecasts

By the beginning of the growing season of 1960, Barks and Dickison had initiated the release of general forecasts from the Fredericton Weather Office, prepared by the Halifax Weather Office. These forecasts were tailored for farmers, primarily in the Saint John River Valley, and included elements such as expected heavy rain, high humidity, frost and strong winds. Late blight of potato and its control by chemical sprays are both weather sensitive and, although the weather office did not attempt to predict late blight, an attempt was made to relate its development to current weather conditions. Use was made of the USWB 5-day weather forecasts, and late blight forecasts prepared by the USDA for Maine.

Forecasts were released through both the daily press and by several local radio stations. Dickison also initiated the preparation of special weekly and monthly weather reports which were distributed to agricultural interests.

The 1960 forecasting program continued into 1961 with more emphasis on predicting late blight. A Potato Blight Conference was held at the CDA Research Station with personnel from CMS, CDA, and USDA offices in Maine.

Encouraged by the NCAM and Barks, an experiment was set up in 1961 to demonstrate the value of controlled spraying making use of weather-based predictions of late blight. Barks and Dickison were able to demonstrate that spraying operations based on weather data were less frequent, used less spray material and gave control equal to or better than conventional routine spraying.

Over the next few years the program continued to develop and improve. Field-operations reports from agricultural extension workers were collected for use as guidance material for preparing special farm-weather forecasts.

Dickison conducted a number of successful seminars and workshops for various agricultural groups, thus increasing their interest in farm-weather forecasts. He was also instrumental in inviting Mukammal of the CMS in Toronto to speak on micrometeorology at a seminar of the local branch of the AIC in 1962.

By 1967 farm-weather forecasts were issued regularly; a potato-blight index, developed by Dickison, was issued cooperatively by the NB Dept. of Agriculture and the Fredericton Weather Office, and a similar forecast of apple scab was being developed for the Annapolis Valley in cooperation with the CDA Research Station at Kentville. Three years later farm-weather forecasts and other services had extended to all three maritime provinces. Three CMS centres (Moncton, Halifax and Gander) were providing meteorological services, including farm-weather services to the Atlantic Provinces. With the reorganization of the CMS under Environment Canada a new position, Regional Supervisor of Scientific Services, was created in the Regional Office at Moncton, and filled by C.H. Sutherland, former Officer-in-Charge of the Newfoundland Weather Office. This position provided assistance to agricultural scientists and farmers.

Experimental three-day weather forecasts were begun by the Maritimes Weather Office and distributed by radio and press. These were discontinued in 1972 but reinstated in 1973 due to heavy demand by farmers who used them for operational decisions.

The NB Plant Industry Branch developed a Potato Anti-Bruise Index Service to help producers avoid mechanical bruising during harvest. The index was based partly on soil and air temperatures. Assistance in monitoring and forecasting these values was provided by the Fredericton and the Maritimes Weather Offices.

Services had expanded to included hay-drying forecasts, a study of the economics of irrigating strawberries and apples, the effect of weather on the growth of low bush blueberries, overwintering of anthropods, and the occurrence of extreme low temperatures.

A code-a-phone system was introduced in Nova Scotial for distributing the farm-weather forecasts and related information to farmers. A total of 12,000 calls were recorded during the first 103 days of operation in 1977. So popular was the program that two code-a-phones were installed at the CMS office in Bedford for the 1978 growing season. Information was provided in cooperation with the NS Dept. of Agriculture and Marketing.

AES developed a dedicated Weatheradio System, broadcasting on VHF (162.55 MHz), with the first established in NS in 1978 to serve agriculture and marine interests. The system was extended to cover all of NS and part of PEI in 1979 and into Newfoundland and NB in 1980. By 1982 the system had been

expanded to 34 broadcasting sites which covered most of the agricultural areas in the Atlantic Provinces. Farm-weather forecasting services were extended to Newfoundland in 1980 for the first time. These were similar to those provided by CMS to the other three Atlantic Provinces.

Regional farm-weather forecast services by CMS were well established by 1984. The Canadian Climate Program was active in all four provinces, each having a Provincial Climate Advisory Committee. Probably the greatest advance in farm-weather forecast services was the introduction, in 1989, of a new weather channel on cable TV called "Weather Now", provided by industry, with near-real-time data and information provided by AES and local provincial governments.

The Atlantic Committee on Agrometeorology

An ad hoc climate committee was formed in the late 1960's, primarily to direct the preparation of a climatic atlas for agriculture in the Atlantic Provinces. The first report by this committee was released in 1970, entitled "The Climate of Prince Edward Island, Tignich Area".

Through the continuing efforts of Bootsma, the ad-hoc climate committee became the Atlantic Committee on Agrometeorology (ACA) in 1975, and its activity increased. Its principal function was to promote and give direction to agrometeorological research and extension in the Atlantic Provinces through appropriate recommendations to its parent body: the Atlantic Provinces Agricultural Service Coordinating Committee (APASCC). At its first meeting in December 1975 and under the chairmanship of Bootsma, the ACA decided that the immediate priority would be to document agrometeorological progress and problems in the Atlantic Region.

During the next five years the committee worked on such problems as the use of weather data for interpreting data from agricultural field trials; the development of a workable corn-heat unit system for the Atlantic provinces; and support to the publication of work-day probabilities for the Atlantic Provinces (Baier et al., 1978; Bootsma, 1980). A map of corn-heat units was eventually completed for NB and PEI, and with the help of AES, for NS (Bootsma et al, 1979).

In 1981 The ACA recognized the potential impact of acid rain and climatic variability on agriculture and expressed concern about these matters. It also held meetings with AES which resolved the issue of farm-weather forecast content on Weatheradio. Smith's resignation in 1981 left a vacancy in the ACA. The ACA presented a brief report in 1982 to the CFA in support of their efforts to promote a national policy on farm-weather services.

Interest in agrometeorology continued high in 1983, due largely to the activities of the ACA. As an indication of their interests and activity and the problems in the region, the following items were discussed at the 1983 meeting:

- new forage zonation map.
- a rewrite of "Public and Farm-Weather Forecasting Terminology".
- a new atlas entitled "Climate for Agriculture in Atlantic Canada".
- the reduction to a 5-day observing week at Charlottetown CDA.
- a course in agrometeorology at NS Agriculture College.
- forecasting of dew duration by AES.
- the use of Weatheradio was promoted as the most promising means of dissemination of weather information to the farm community.
- the introduction of probability of precipitation (POP) was considered a major improvement in the farm-weather forecast issued by CMS.

In 1981 the ACA received a review from the Task Force on the Canadian Weather Forecast System prepared by Dzikowski, chairman of the committee. This was essentially a review of weather-services for agriculture and the latest on-going research and development projects including agroclimatic studies.

Agrometeorology in the Atlantic Provinces appeared to be at its pinnacle in 1985. The ACA had completed a number of projects:

- a regional atlas entitled "The Climate for Agriculture in Atlantic Canada";
- a fact sheet re forecast coverage in Newfoundland;
- a publication entitled "Climatic Zonation for Forage Crops in the Atlantic Region;"
- a report on the climate impact of the Fundy Tidal Power project;
- an introductory section on climate in the "Field Crop Guide";
- the climate section in "The Atlantic Field Crop Guide".

The committee had been responsible for a number of changes in the Farm-Weather Services Program.

- Drying-index categories were altered during August and September to make them relative to the time of the year.
- A hay-drying index was included for the first time in the Newfoundland forecast for one region on an experimental basis.
- The format of the public weather forecast was changed to provide separate bulletins for NB, NS and PEI. PEI was divided into three forecast areas: Prince, Queens and Kings Counties.
- Special forecasts services were provided to a part of NB by the Fredericton Weather Office. Three farm-weather forecasts per day, tailored to the Gagetown-Woodstock area, were prepared and distributed via code-a-phone.
- Services as provided by the various provincial agencies were both extensive and varied and included weather and climate summaries, crop advisories via press and radio, specialized data collection and various reports including an atlas.

Two agroclimatologists were on staff in the region: Dzikowski in NS and Read in NB

Another agroclimatic study "The Climate for Agriculture in Atlantic Canada" was completed in 1985. This was modelled after the Nova Scotia Agroclimatic Atlas. Its preparation was spearheaded by the ACA and the text and maps were prepared by G. Read, Climatologist with the NB Dept. of Agriculture, W. Richards of AES in Nova Scotia, G. Kerby of Newfoundland and Dzikowski.

The ACA continued active, setting up three sub-committees to deal with:

- Use of modelling for overwintering of strawberries,
- Drying-index climatology,
- Soil moisture modelling using microcomputers.

By 1987 the main concern of the ACA was the use of automated data acquisition systems to replace manual observations, particularly at CDA Research Stations which had long records of manual observations. The committee inspected the system which Lein Chow had installed at the Fredericton Research Station. Sensor development for some weather elements was still required. The committee followed closely and with great interest the activities of the ECA in regard to this matter.

Another area of concern to the ACA was the calculation of soil water. Droughts during the past few years and the introduction of supplemental and drip irrigation systems had prompted the study of soil-water budgeting. A successful soil-moisture workshop was held in October in Fredericton. This was attended by over 45 professionals from both research and extension units of federal and provincial institutions.

Cooperative Research Projects

During the latter half of the1960's the CMS Office in Moncton became involved with providing assistance to the CDA Research Stations in Charlottetown and in Fredericton in regard to topoclimatic surveys to locate favourable tobacco-growing areas. Similar assistance was given to the CDA Research Station at

Kentville regarding topoclimatic studies along the Annapolis Valley, and to help define the influence of open water in the Annapolis Basin in controlling winter minimum temperatures, which affect the survival of certain species of fruit trees.

Dickison also become involved in several research projects concerning the effect of weather on late blight of potato, overwintering of bees, and the potato yield. Local studies of temperature and rain differences due to slope and site in valleys were undertaken.

Activities continued at about the same level for the next few years. Barks was replaced on the NCAM in 1964 by J.S. Leefe of the CDA Research Station in Kentville. He served three years on the Committee and was replaced by I.D. Steeves of the Field Crops Branch, NB Dept. of Agriculture. Steeves served on sub-committees dealing with snow-fall measurements and atmospheric pollution by pesticides. Dickison replaced Steeves in 1970 and served for two years.

Several other activities were initiated in 1971. A project was started by Nappan CDA Research Station to secure ground-truth data for Persian Lilac phenology for a regional atmosphere-ecosystem study. Several studies by the Fredericton CDA Research Station included the relationship between forage and cereal-crop production and harvesting in relation to weather, the influence of photoperiod and degree-day temperature accumulations on the development and activity of potato-infesting aphids, and the influence of weather on the results of experimental applications of insecticides and herbicides. The Research Station at Charlottetown started work on projects involving the effect of weather on forage production and harvesting and chemical weed control.

Agrometeorology in Prince Edward Island

During the summer of 1969 a new agrometeorological project was begun in PEI. This project, involving climatological data collection at 172 sites, had the objective of identifying production probabilities for such weather-sensitive crops as tobacco and strawberries.

In 1971 the PEI Department of Agriculture and Forestry appointed an agroclimatologist, A. Bootsma. He was expected to provide, among other things, a communications link between meteorology and practical agriculture. Lack of this link had been frequently pointed out by CCAM as a weakness in the application of agrometeorology at the provincial level. Bootsma received a B.Sc. in Physics and Mathematics in 1969 and an M.Sc. in Agrometeorology in 1972, both from the University of Guelph.

He immediately undertook several tasks. A program in cooperation with the AES for upgrading the basic climatological network in PEI was initiated. The publication of climatological data for certain major stations was begun and regularly released to district agricultural offices and others. The summaries included references on the relevance of weather conditions to current farm operations. Radio tapes and monthly news releases were prepared to convey information to the public. Involvement in educational short courses was also used as a means of conveying specialized information to the farming community. Several specialized reports on specific climatic information useful in planning certain agricultural operations were prepared. Bootsma also was involved in land-use and crop-zonation studies and undertook research to adapt the corn-heat-unit system (Brown, 1963) to conditions in the Atlantic Provinces. This was completed about seven years later (Bootsma et al., 1979).

Bootsma was appointed to the CCAM in 1973 as the representative of the Atlantic Provinces. He held this office for six years during which time he reported on activities in the Atlantic Provinces, contributed towards setting research priorities, and helped prepare position papers on timely topics (Bootsma, 1977).

Under his leadership the PEI Department of Agriculture and Forestry began an extensive study of land use, particularly in regard to tobacco and corn. Freezing temperatures were the deterrent to tobacco growing. Extensive studies of the distribution of these temperatures and frost pockets over all of PEI were begun in 1973. These involved the establishment of a complementary climatological network in

cooperation with the AES, which provided technician training and quality control of the observations; the establishment of a number of minimum temperature sites at tobacco farms; and a survey of frost pockets by means of mobile temperature measuring equipment. He also was involved in studies on the probability of work days for various field operations for input into a project to determine the optimum machinery size for farms; in a study of the relationship of weather factors and winter kill in forage crops; and in the development of an improved hay-drying index involving estimates of latent evaporation (Baier and Robertson, 1965).

During the next five years activities included:

- extension of the lilac and honeysuckle phenological study to include all five CDA Research Stations and the Thrower Agricultural College
- preparation of a Climatic Atlas for the Maritime Provinces by the Maritime Weather Office
- studies of soil erosion and nutrient, pesticide and sediment discharge from watersheds in collaboration with the CDA Research Station at Fredericton, the AES, the Water Survey of Canada, and the PEI Dept. of Environment and Tourism
- a study of the effects of local conditions such as air drainage, topography, distance from sea coast, cloudiness and wind on the departure of local farm minimum temperatures from that forecast at reference stations. This study was to provide the farmers with a means for estimating on-farm temperatures from the official forecasts for reference stations
- the preparation of instructional material for agricultural training courses

A potato late-blight forecasting and spray scheduling service, developed by Bootsma, was begun in PEI on a province-wide basis for the first time in 1978. This trial service was carried out in cooperation with the Charlottetown Weather Office, the Fredericton Research Station, and the Plant Quarantine Division of Agriculture Canada at Charlottetown (Bootsma, 1979).

New research projects started in 1978 included a study of the effect of weather on growth and yield of potatoes; the determination of the irrigation needs of potatoes; a study of the variability of leaf-wetness duration and humidity; and a study of the effect of diurnal temperature variations on orchard insect activity. These were in addition to some 11 on-going projects.

Bootsma also became involved in the PEI Committee on Farm-Weather Services which was formed in 1979 under the umbrella of the PEI Federation of Agriculture, and was responsible for identification of agrometeorological service requirements of practical agriculture. The committee held two meetings in the spring of 1981 to discuss improvements in farm-weather forecast services and made several recommendations: an expansion in the operating hours of the Charlottetown Weather Office; complete coverage of the province by Weatheradio; and a second telephone line to improve access to taped weather forecasts at Canada Forces Base, Summerside. It was also recommended that the Weatheradio broadcasts include information on local frost warnings, hay-drying indices, and potato blight/weather information. These resolutions were presented to Members of Parliament representing PEI by the Board of Directors of the PEI Federation of Agriculture.

New projects started in 1980 included the effect of weather on the economics of grain drying, and a project to study temperature inversions in a tobacco field to determine the feasibility of using helicopters for frost protection.

The climatological program in PEI terminated as a result of reduced funding available to the province from the Federal Government under the Comprehensive Development Plan Agreement. As a consequence Bootsma transferred to the Agrometeorology Research and Service Section of LRRI, Research Branch, CDA, in 1982.

A program for a microcomputer, based on the versatile soil-water budget of Baier and Robertson, had been developed by J. Boisvert in the Agrometeorology Section of the LRRC. This was demonstrated to

the ACA in 1987 by Bootsma, and in 1988 was being evaluated in PEI for scheduling the irrigation of potatoes.

Later Work in New Brunswick

The New Brunswick Dept. of Agriculture and Rural Development recruited an agrometeorologist, P. Smith, who continued with much of the work started earlier by Dickison, who had left AES to join the University of New Brunswick in 1969. Smith undertook some new projects including the study of such problems as environmental stress, ice-sheet injury to plants, soil moisture, soil temperature, field-work days, phenology, and frost zonation.

In 1978 Smith replaced Bootsma as representative of the Atlantic Provinces on the ECA (former CCA or NCAM) and continued to represent the Atlantic Provinces until 1981 when he was succeeded by Dzikowski.

A project to study topoclimatology in NB was initiated in 1977 and completed in 1981. Also a study of the "The Climate for Agriculture in New Brunswick" was completed and published.

Smith resigned in 1981 to accept the position of General Manager of the NB Crop Insurance Commission, and was not expected to be active in agrometeorology except in a consultative capacity. G. Read replaced Smith in 1982. He undertook studies of frost penetration in peat soils; the evaluation of soil-darkening methods to increase soil temperature and thus increase the length of the growing season for corn and soybean production; and the evaluation and demonstration of artificial windbreaks for several horticultural crops.

Nova Scotia Recruits an Agrometeorologist

In 1979 additional research projects were started at the Kentville CDA Research Station including: a study of cold injury to apple and raspberry cultivars in relation to the degree of winter hardiness; research on the effect of diurnal temperature on the flight and trapping of apple pests; a study of trickle irrigation on fertilizer requirements, performance and yield of tomatoes and raspberries; and an investigation of the effect of the water table on the yield of apples.

In 1980 P. Dzikowski was hired as an agrometeorologist by the Soils and Crop Branch of the NS Dept. of Agriculture and Marketing in Truro, thus bringing to three the number of provincial agrometeorologists in the Atlantic Provinces (Bootsma in PEI, Smith in NB and Dzikowski in NS). Dzikowski held this position for six years.

Dzikowski graduated from McMaster University, Hamilton in 1974 with a B.Sc. in Botany and Plant Ecology. Later, he graduated from the University of Guelph with an M.Sc. in Agrometeorology. He had province-wide responsibilities and the first project he initiated was the "Nova Scotia Weekly Weather Summary." Dzikowski was active in committee work in NS He was secretary of the ACA for two years (1981-83) and chairman for three years (1983-85). He was the representative for the Atlantic Provinces on the ECA for three years (1981-83) and was an inaugural member of the NS Climate Advisory Committee in 1982, and continued as a member until 1986.

A number of new projects were initiated in NS under the leadership of Dzikowski during the next few years:

- the use a low-altitude, infra-red air-photo survey of winter crops and soil-drainage systems was designed to assess winter damage and related farm problems;
- study the effect of plastic mulches on the growth and yield of tomatoes and cucumbers;
- study of the effect of weather on storability and ventilated storage of vegetables;

- research on the effect of weather on disease and yield of low-bush blueberries and the production of maple syrup;
- a project dealing with the measurement of soil-thermal properties in connection with the use of soil for heating greenhouses;
- the use of solar-heat collectors for agricultural purposes;
- the forecasting of migratory pest outbreaks using synoptic weather data and upper-level circulation charts;
- lectures for an agrometeorological course at the NS Agriculture College in Truro;
- consultative services to prospective grape growers on microclimate characteristics for evaluating sites for vineyard establishment.
- the second edition of the Nova Scotia Agroclimatic Atlas was completed in 1985.
- installation of a tower in the Annapolis Valley to provide temperature inversion data in connection with the operation of wind machines for frost protection by commercial strawberry growers.
- modelling for the control of insects in corn.

In addition, Dzikowski secured funds from the Federal-Provincial Agri-Food Development Agreement in 1983 to determine the "Mesoscale Climate of Major Agricultural Areas of NS". The study was undertaken by a private engineering firm in Halifax. Fifty automatic weather stations were used in the 3-year study. The short-term data set was adjusted to 1951-80 normals by comparison with existing CMS climate stations within the study area. Satellite thermal imagery of the Annapolis Valley was also acquired to help delineate significant frost-prone areas.

Nova Scotia Agrometeorological Committees

The Nova Scotia Farm Weather Services Committee was formed and held its first meeting in the fall of 1981. This was a committee of the NS Federation of Agriculture with representatives from the NS Fruit Growers Association, the NSDAM, the AES and Agriculture Canada. Members welcomed this as a means of passing on their concerns about weather-related farm problems, and now felt that there was someone listening to some of their problems.

Newfoundland

Agrometeorological research in Newfoundland was carried out primarily by scientists at the CDA Research Station in St. John's. Studies of the effect of weather on blueberries, early in the 1970's led the Newfoundland government to use heat-unit accumulation as an aid in setting the legislated date for commencing blueberry harvest. Investigations were carried out on the influence of soil temperature on the emergence of adult cabbage root maggots and the development and activity of the golden nematode.

CMS approved funds for five new climatic stations in agricultural areas of Newfoundland and these were established in 1981. Also, a topoclimatic study was begun in an agricultural area near St. John's. AES cooperated by providing instruments.

PART 2 - QUEBEC

Reorganization of Meteorology in Quebec

Before 1962 there were several agencies which had become involved in taking weather observations for local or special use. The Hydraulic Service was interested in river flow; the Department of Lands and Forests was interested in meteorological data from the standpoint of forecast forest-fire control; various societies for the protection of forests had their own networks; several other provincial departments had their own networks for special purposes; and the agricultural experimental stations took observations.

In April 1962 the Provincial Government united all meteorological activities in the province under one agency, the Meteorological Service, within the National Resources Department. The aim of the new Service was to satisfy the requirements of all provincial departments, to establish and maintain a close cooperation with the CMS, and to prepare a program of studies and work in order to help scientists in all fields. The new Service reviewed all climatological networks within the provinces, inspected stations, prepared standard instructions and brought instrumentation up to WMO and CMS Standards.

The new Meteorological Service took over the monthly publication of the daily weather data, which had been done by the Department of Trade and Commerce since 1932. These publications involved data from 300 permanent stations and 150 part-time or seasonal stations. Another important undertaking was the preparation of an inventory of all climatological data gathered in Quebec in the past. This was expected to be an expensive operation but of great value to the many provincial and federal agencies in Quebec dealing with weather-sensitive agricultural problems.

G.O. Villeneuve was appointed acting chief of the new Quebec Meteorological Service. He had been a meteorologist with the Quebec Department of Lands and Forests since the early 1940's. During the next 10 years he was responsible for the publication of some 85 data summaries, analyses, and studies, mainly of a climatological nature for various locations throughout Quebec.

Membership in the NCAM (ECA)

Quebec had representatives on the NCAM from the 1st Annual Meeting in 1960. This meeting was attended by two representatives from Quebec: Hare (1960-63) from McGill and Steppler (1960-64) from Macdonald College.

Villeneuve from the Quebec Meteorological Service replaced Steppler in 1964 and continued for a full term of three years. O'Grady of Laval University was a member from 1967 to 1972. He was followed by Lavigne of the Institute of Agricultural Technology, St-Hyacinthe, in 1973 then by Dubé of Laval University, who was representative from 1974 to 1989 and Chairman of the Committee from 1985 to 1989. Douglas of Macdonald College was an invited observer in 1968 and 1969, and was appointed permanent representative from Macdonald College from 1970 until his retirement in 1984. He was Chairman of the Committee in 1983.

The Quebec Committee on Agrometeorology

The development of agrometeorology in Quebec progressed slowly. In 1965 Villeneuve started a Climatic Atlas for Quebec, which was revised in 1967 to include the northern part of the province.

The Quebec Centre of the Canadian Meteorological Society was formed in 1968, mostly due to the effort of Villeneuve. That same year the Quebec Committee on Agrometeorology was formed following recommendations of the NCAM. Its objectives were:

- to establish and operate a network of meteorological and phenological sites,
- to draw phenological and agrometeorological maps,
- to apply agrometeorological practices,
- to encourage agrometeorological research.

Through the activities of the Committee a phenological network was established at several sites. Cooperative research was encouraged at universities (Laval, Chicoutimi, and Sherbrooke), in the Quebec Meteorological Service, with the AES Quebec Weather Centre, with CDA research stations, and with provincial agricultural research stations. By 1970 activities in agrometeorology had increased at the universities, more weather stations were established and farmers were beginning to demand forecasting and advisory services.

Over the next five years activities and interest in agrometeorology increased. The membership of the Committee in 1974 indicates the extent of the operations of the Committee:

Bouchard, C., Quebec Department of Agriculture, Ste-Foy. (Secretary).
Chevrette, J.E., Faculty of Agriculture and Food Sciences, University of Laval, St-Foy.
Deschenes, J-M., Canada Department of Agriculture, Ste-Foy.
Doyon, D., Quebec Department of Agriculture, Ste-Foy.
Dubé, P-A., Faculty of Agriculture and Food Sciences, University of Laval, St-Foy. (Chairman).
Lavigne, P., Quebec Department of Agriculture, St-Hyacinthe.
O'Grady, L.J., Faculty of Agriculture and Food Sciences, University of Laval, St-Foy.
Ouellet, C.E., Agrometeorology Service and Research Section, CBRI, CDA, Ottawa.
Paquin, R., CDA, Ste-Foy.
Pichette, R., Crop Insurance Commission of Quebec, Ste-Foy.
Richard, M-A., Quebec Department of Agriculture, Ste-Foy.
Villeneuve, G.O., Department of Natural Resources, Quebec City.

The Committee held regular meetings two or three times each year until the 1980's, when the amount of business sometimes required four per year.

One of the main functions of the Committee was to study the requirements of farmers and the farming industry for meterological information and services. In 1977 the Committee proposed that the Farm-Weather Centre of AES provide information on soil water and potential evapotranspiration in the farm-weather forecasts. Côté was named chairman of an ad hoc committee to look into this matter and to compare different methods for calculating potential evapotranspiration and soil water.

The first phase of the phenology program was completed in 1977. Several years of data from some 300 stations had been gathered. The information was analyzed and a number of indices developed which were mapped to show the bioclimate zones of Quebec. Studies were also made to relate phenological indices with climatic information, particularly growing degree-days and solar-thermal indices.

Two important undertakings of the Agrometeorological Committee in 1979 were the preparation of a Guide to Agrometeorology, and cooperation with the Canadian Federation of Agriculture regarding the requirements of farmers for weather services.

During the 1980's the Quebec Agrometeorological Committee continued its activities. It held meetings three or four time per year. Discussions ranged over a wide variety of topics and several projects were completed, for example.

- the preparation of a crop calendar for potatoes and strawberries.
- air pollution and air-quality problems.
- a Symposium on Water was held in 1985 attended by some 200 scientists including 65 agronomists.
- meetings with a group in the northeast USA regarding joint research in agroclimatology.
- meetings of the CFA Committee for Meteorological Services to Farmers.
- development of an Integrated Pest-Control Program.
- the use of automatic weather stations for certain climatic purposes.
- preparation of numerous bulletins and reports to provide farmers with farm-weather information, and to acquaint them with its use.

The latest executive of the Committee (1989) was M. Letendre (Chairman), J. Côté (Vice-Chairman), and R. Poiré (Secretary).

The Quebec Meteorological Service

With an increase of staff in the Quebec Meteorological Service, research activies slowly increased in many areas. Of particular interest to agrometeorology and forest meteorology were studies of evapotranspiration and lysimetric techniques in forest soils started in 1969. During the early 1970's several publications of interest to agriculture were prepared. In 1979 the farm-weather bulletin was improved by the addition of information on degree-days above 5°C and cumulative degree-days above 5°C for periods of 10 days and one month, compared with values during the previous year and with normal values.

A daily soil-temperature data acquisition network was implemented by AES in cooperation with the Quebec Meteorological Service at nine additional stations in 1979.

By 1981 a number of cooperative projects were underway.

- With Laval University regarding phenology in relation to climatic factors and the production of corn and cereals.
- With the Department of Phytology at Laval University dealing with the revaluation of degree-days and biological indices for apple trees and insects in connection with control measures.
- With the Quebec Farm-Weather Service of AES and the Department of Phytology was under way to revise the zones of degree-days in Quebec.
- With the University of Chicoutimi for the preparation of a climatic atlas for the middle northern regions of Quebec.
- With the Soil Service and the Environmental Protection Service of Quebec regarding the impact of soil water, temperature and structure on the production of corn.
- With the Crop Protection Service to develop models based on climatic and soil data for the control of diseases and insect pests.

Quebec Farm-Weather Services Program of AES

Reacting to pressure from farmers and farm organization and suggestions from the Quebec Agrometeorological Committee, the Regional Office of AES established the Quebec Farm-Weather Service Program in 1973. J. Côté, a supervisor in the Quebec Weather Centre, was assigned as superintendent of the new Farm-Weather Service Program.

Côté had been a forecaster with the CMS since 1958. He worked at Armed Forces Units in Saskatchewan, Manitoba, and Ontario (North Bay, Trenton, and Ottawa). He move to the Quebec Weather Centre in Montreal in 1970. Under his leadership Quebec Farm-Weather Services within AES developed rapidly over the next few years.

The first regions to receive special farm-weather forecasts in 1973 were those south and east of Montreal. This service was provided in cooperation with officers of the Quebec Department of Agriculture at Châteauguay, St-Hyacinthe and l'Assomption who provided information on farm operations and crops. In 1975 the services were extended to the region between Montreal and Quebec City.

L. Tartier of the Crop Protection Division of the Quebec Department of Agriculture at St-Hyacinthe had been studying the effect of weather on fungus diseases of potatoes for 8 years. By 1972, using data from 25 climatic stations in the area, he developed a system for warning farmers to apply sprays when the risk of infection was high. The system continued over the next few years with the addition of other crops and diseases. The system was gradually integrated into the Farm-Weather Services Program, and became an integral part of it by 1977. Following this there was a marked increase in interest by members of the Crop Protection Division of the Quebec Department of Agriculture regarding the use of weather data in connection with combatting agriculture diseases and pests. During the next two years, under the continued guidance of Côté, and in collaboration with the Meteorological Service of Quebec, good

progress was made in providing an improved farm-weather service, including forecasts and information required by farmers and groups such as the Division of Crop Protection.

By 1981 the distribution of agrometeorological information provided by the Quebec Farm-Weather Service of AES was made from April 1 to November 1 for all regions of Quebec excepting the Gaspé. The service was provided in cooperation with the Quebec Department of Agriculture, the Quebec Meteorological Service, and the Division of Crop Protection. In 1983 a special Farm-Weather Forecast Program began for southwestern Quebec and the Ottawa Valley. The program offered a variety of services included farm-weather forecasts, climatic data, consultation, and indices, all of which were aimed at helping farmers and producers maximize both quality and yield of crops, as well as minimizing losses and costs due to weather hazards, pests, and diseases. Studies to improve indices, development of models and special projects are also undertaken.

About this same time (early 1980's) AES introduced Weatheradio as a means of distributing information to the user. Transmitters at three sites, Montreal, Ottawa, and Quebec City established primarily for urban listeners also served some of the nearby rural areas. It was not until 1989 that Weatheradio transmitters were established at 5 sites in generally rural areas to meet farmer's requirements.

This program required some research on technologies. In 1984 the Farm-Weather Service Office, in cooperation with CDA (Boisvert), Laval University (Dubé), and the Quebec Department of Agriculture, embarked on a task of developing a soil-water budget to provide a soil-moisture index for agrometeorological forecasting. This project began in St-Hyacinthe and was expected to take three years. The same group began work on a crop calendar, showing the crucial weather information required for potatoes, corn and strawberries. Another cooperative project was started in the Huntington area to improve corn production. AES provided instruments for three weather sites for maximum and minimum temperatures, precipitation, and soil temperature at 10 cm.

The Farm-Weather Service Program continued into the late 1980's unabated. Farm-Weather Services were increased by adding the Abitibi-Temiscaming Region. AES and the University of Laval undertook research on improving the hay-drying index for Quebec. Other activities included the preparation of reports and guidance material, the provision of consultative services, and attendance at committees, workshops and conferences.

PART 3 - ONTARIO RESEARCH FOUNDATION

Much of the early work in agrometeorology at the provincial level in Ontario was done by the staff of the Ontario Research Foundation (ORF).

The ORF was founded in 1927 primarily for the purpose of serving small industries who could not afford research departments. It was established by the industries themselves with dollar-for-dollar support from the Ontario Government. Its several departments specialized in such things as metallurgy, textiles, chemicals, engineering, plastics, and ceramics. It charged, at cost, for work done. The Foundation had its own Board of Governors, and being a separate institution, it reported directly to the Premier.

The Department of Physiography

There was a clause in the ORF Act that said it must do some work on the natural resources of the province. Thus the Department of Physiography ultimately came into existence and became involved in research on soils and climate. T.D. Jarvis was hired as a botanist, and it was inevitable that his work involved climate. By 1931 he had written a paper on soil, climate and location (Jarvis, 1931). L.J. Chapman was hired by Jarvis in 1932 to assist in his study of crop adaptations in Ontario. He was to define the soil and climatic conditions under which farmers operated in Ontario. Chapman was raised on

a farm near Toronto. He graduated from the Ontario Agricultural College, Guelph, in 1930 and obtained his M.Sc. in Soil Science at Michigan State College in 1938.

D.F. Putnam joined the staff of ORF in 1934 to work with Chapman to produce an account of the background of glacial geology and its role in the formation of the soils of Southern Ontario; they called it Physiography. By 1938 they produced a report on the climate of Southern Ontario (Putnam and Chapman, 1938). This description was not updated until 30 years later (Brown, et al., 1968).

In their studies of climate, Chapman and Putnam became concerned about the rainfall efficiency for crop growth. Was there too much, too little or just the right amount? Prior to 1948 the balance between rainfall and evaporation had not been thoroughly rationalized. Marie Sanderson was recruited in 1947 to look into this matter.

Potential Evapotranspiration Studies

Sanderson graduated in geography from the University of Toronto in 1945. She received a scholarship to do graduate work in geography at the University of Maryland. One of her professors there was C.W. Thornthwaite, who was working at the Soil Conservation Service in Washington, and gave lectures in climatology in the evening. He became the supervisor of her thesis entitled "Drought in the Canadian Northwest Territories of Canada." The research made use of Thornthwaite's newly developed climatic indices, and involved the computation of potential evapotranspiration (Sanderson, 1948a).

Her first field research effort with the ORF was to make field measurements of potential evapotranspiration (PE) in Mount Pleasant Cemetery in Toronto. Excellent agreement was found between measured PE and computed PE using the Thornthwaite method (Sanderson, 1950a)

Meanwhile, desk research involving the Thornthwaite water balance method applied to Canadian climatic data resulted in two papers (Sanderson, 1948b; 1950b).

With encouragement from Thornthwaite, she installed evapotranspirometers at Norman Wells (lat. 64° N.) in the Northwest Territories in 1948. Again, agreement between measured PE and computed PE was excellent (Sanderson, 1950c).

Sanderson left the ORF in 1950 to join the staff of the University of Windsor where she continued her measurements of PE (Sanderson 1954).

During the period 1960-65 she worked on her Doctorate at the University of Michigan and in 1965 was hired by the University of Windsor where she remained until 1988. During this period she produced two papers relative to agriculture, one dealing with precipitation probabilities and the other with precipitation quality (Sanderson, 1976, 1978).

Climate and Land Use

Chapman continued his studies of the climate of Ontario, and in 1953 produced a report on the climate of Northern Ontario (Chapman, 1953).

Prime peach land was beginning to disappear about this time due to urban and industrial development. Searching for other areas with suitable land and climate, Chapman cooperated with R.G. Mercier of the Vineland Horticultural Experiment Station and Products Laboratory in a study of the soils and climate favourable for peach production in Ontario (Chapman and Mercier, 1956).

About this same time (1953) D.M. Brown was recruited to undertake studies of crop adaptation in Ontario. (Jarvis had retired a short time earlier.) He earned a B.S.A. in 1951 in Agricultural Chemistry from OAC/University of Toronto and an M.S.A. from the same institution in 1953 in Field Crops.

During the period 1951-53 he worked as research assistant on potato investigations for the Department of Field Husbandry at OAC. Later he attended Iowa State University, Ames, Iowa where he earned his Ph.D. degree (1958) in Agricultural Climatology and Crop Production. His thesis subject was "A Phenological Study of Soybeans in Iowa and Ontario" (Brown, 1960).

Crop-Development Research and "Heat Units"

At the ORF Brown and Chapman continued experiments, in both the field and growth chambers, on the effect of weather on soybean development and growth. This work resulted in a series of papers in 1960 and 1961 (e.g. Brown and Chapman, 1961).

Another concern in Ontario at this time was the zonation of hybrid-corn varieties. Brown applied his knowledge and experience with soybean development to the problem of hybrid-corn development and eventually developed the idea of "corn-heat units" (Brown, 1963), a concept that has won international recognition for hybrid-corn zonation.

Chapman continued the work started by Sanderson on evapotranspiration by extending lysimeter observations to Northern Ontario in cooperation with P. Dermine of the CDA Experimental Station at Kapaskasing (Chapman and Dermine, 1961).

Membership in the NCAM

When members for the NCAM were recruited in 1959, it was considered that the ORF should be represented, and it was only natural that Chapman was chosen. He was a member of the Committee for the next 5 years. Having used climatic data in many of his studies, he was thoroughly familiar with climatic stations in Ontario, including their representativeness and any gaps in the network. Subsequently he was made chairman of a subcommittee to look into network weaknesses, station inspection and location, and timely publication of data (see Chapter 5).

In 1965 Brown replaced Chapman as the representative from ORF on the NCAM.

Climate Studies for ARDA

ARDA was enacted in 1962, and under this umbrella the Canada Land Inventory was begun in 1963. The ORF was given the task of preparing a preliminary study of the Climate of Canada for Agriculture. Chapman and Brown worked together on this projects in cooperation with the CMS which provided the climatic data and a steering committee consisting of R.C. Hodges, chairman (ARDA), G.W. Robertson, (CDA - PRI), P.O. Ripley (CDA - RB), and M.K. Thomas (CMS). The project required that Chapman tour all of Canada west of Toronto, and Brown that part east of Toronto to assess the quality of climatic data and to study the effect of soils and topography on local climates. The first draft of the report was ready by 1963 and the final report was published three years later (Chapman and Brown, 1966).

ORF Crop-Weather Research Transferred to OAC

By 1965 the ORF, under the leadership of Brown, had established a number of crop-weather research projects. An extensive phenological study of grain corn was conducted in cooperation with L.S. Donovan of the Research Station, CDA, Ottawa, and agronomists at universities and CDA research stations across Canada, and at two locations in the USA.. A project to determine the frequency of seasonal soil-water deficiencies and surpluses based on soil-water budget methods on a day-to-day basis was established in cooperation with Baier and Robertson of the Agrometeorological Section, PRI, CDA, Ottawa, and the OAC at Guelph. Microclimatological measurements were recorded in connection with an alfalfa experiment conducted by the Crop Science Department at OAC at three locations in Southern Ontario. The purpose of the measurements was to help explain differences in carbohydrate reserves in alfalfa roots in the fall and spring caused by different management practices.

In 1965 Brown left the ORF to work with King in the Soil Science Department of the University of Guelph. He took with him most of the agrometeorological projects he started at ORF.

In 1967 Chapman was instrumental in persuading the CMS to undertake a topoclimatological study of temperature differences between the slopes and bottom land in the Beaver Valley. These differences were modified by the proximity to the waters of Georgian Bay and by ridges that traverse the valley. The information was required by farmers in connection with the establishment of apple orchards in the area. CMS established a number of temporary climatological stations in the valley and supplemented these observations by measurements with a mobile station.

In 1968 a revision of "The Climate of Southern Ontario" was released (Brown, et al., 1968) as well as a new report on the climate of Northern Ontario (Chapman and Thomas, 1968).

In 1970 Chapman was invited to attend the 11th Annual Meeting of the CCAM to participate in a discussion of freezing temperatures in Canada. He presented a paper on the "Occurrence and distribution of freezing temperatures in the agricultural areas of Canada."

It appears that no further agrometeorological work was undertaken by ORF, their responsibilities in this area being adequately covered by the agrometeorological group at the University of Guelph, the CMS, and the Ontario Dept. of Agriculture.

Chapman retired from ORF in 1973. Fourteen years later he was elected a Fellow of the Canadian Society of Agrometeorology, a fitting tribute in recognition of his many contributions to agrometeorology over an extended period of some 41 years with the ORF. He also received an Honorary D.Sc. degree from the University of Waterloo in 1985 in recognition of his long scientific career and his many contributions to a better understanding of the soils and climate of Ontario.

A Chronology of Research Results

1931 JARVIS, T.D. The "coincidence" as a major factor in agriculture. Sci. Agric. 11:760-774.

1938 PUTNAM, D.F. and CHAPMAN, L.J. The climate of southern Ontario. Sci. Agric. 18:401-446.

1948 SANDERSON, M. Drought in the Canadian northwest. Geographic Rev. 38:289-299.

SANDERSON, M. The climates of Canada according to the new Thornthwaite classification. Sci. Agric. 28:501-517.

1950 SANDERSON, M. Three years of evapotranspiration in Toronto. Can. J. Research, C. 28:482-492.

SANDERSON, M. Moisture relationships in southern Ontario. Sci. Agric. 30:235-255.

SANDERSON, M. Measuring potential evapotranspiration at Norman Wells. Geographical Rev. 40:636-645.

1953 CHAPMAN, L.J. The climate of northern Ontario. Can. J. Agric. Sci. 33:41-73.

1954 SANDERSON, M. Observations of potential evapotranspiration at Windsor, Ontario. Johns Hopkins University Lab. of Climatology. Publications in Climatology. 7:91-93.

1956 CHAPMAN, L.J. and MERCIER, R.G. Peach climate in Ontario. In: 1955-56 Report of the Horticultural Experiment Station and Products Laboratory, Vineland, Ontario. pp. 6-21.

1960 BROWN, D.M. Soybean Ecology I. Development-temperature relationships from controlled environment studies. Agron. J. 52:493-496.

1961 BROWN, D.M. and CHAPMAN, L.J. Soybean ecology III: Soybean development units for zones and varieties in the Great Lakes region. Agron. J. 53:306-308.

CHAPMAN, L.J. and DERMINE, P. Evapotranspiration at Kapuskasing, Ontario. Can. J. Plant Sci. 411:563-567.

1963 BROWN, D.M. A heat-unit system for corn hybrid - recommendations. In: Proc. of the 5th Conf. Agric. Meteorol., Lakeland Florida.

1966 CHAPMAN, L.J. and BROWN, D.M. The climates of Canada for agriculture. The Canadian Land Inventory Report No. 3. ARDA, Canada Department of Forestry and Rural Development. 24 pp. + 19 maps.

1968 BROWN, D.M., McKAY, G.A. and CHAPMAN, L.J. The climate of southern Ontario. Dept. of Transport, Meteorological Branch, Toronto. Climatological Studies No. 5. 50 pp.

CHAPMAN, L.J. and THOMAS, M.K. The climate of northern Ontario. Canada Dept. of Transport, Meteorol. Br. Climatological Studies No. 6.

1969 BROWN, D.M. 1969. Heat units for corn in southern Ontario. Ont. Dept. of Agric. and Food. Information Leaflet. Agdex. No.111/31. 4 pp. (Revised 1970 as Factsheet, Agdex. No. 111/31. 4 pp. Revised 1972. Reprinted 1973. Revised 1975. Reprinted 1976. Revised 1978.)

1976 SANDERSON, M. Monthly precipitation probability maps for the growing season in southern Ontario. Can. J. Plant Sci. 56:639-645.

1978 SANDERSON, M. Precipitation quantity and quality. Agricultural watershed Studies, Great Lakes Drainage Basin. Task Group C. PLUARG. International Joint Commission. 137 pp.

PART 4 - ONTARIO FARM-WEATHER SERVICES

Cooperative Efforts

Farm-Weather Services in Ontario developed as a cooperative effort involving CMS, the Ontario Department of Agriculture and Food, Canada Agriculture, and the University of Guelph (OAC). In general the CMS provided weather-forecasting services while the Ontario Government provided agricultural information and aid in the dissemination of the information. The University of Guelph and Canada Agriculture provided the backup research and aided in technological transfer. This arrangement, and services to farmers, developed slowly over a period of time, encouraged by various committees and farmer organizations. Furthermore the location of the headquarters of the CMS in Toronto, the location of the leading centre for agrometeorological training and research at the University of Guelph, and the diversity of weather-sensitive crops and agricultural activities in Ontario, materially aided in the development.

CMS Public Weather Offices

Public weather forecasts were issued by CMS from their Bloor Street Headquarters as early as 1876, and undoubtedly farmers made as much use of these as possible, considering the problems of communication. A more timely release of the forecast was made possible with the advent of radio

broadcasting in the late twenties. However, these forecasts were of a general nature, both in space and time, and did not meet the specific needs of individual farmers.

A great improvement was made in the forecasting service when the CMS opened an aviation meteorological office at the Malton Airport in the late 1930's, but it was not until the late 1940's that public weather forecasts were issued on a routine basis four times a day. Special farm-weather forecasts were not issued until about 1954 when special frost warnings were issued for the fruit growers of the Niagara Peninsula and the Tobacco Growers of Norfolk and surrounding counties.

At the first meeting of the NCAM in 1960, the requirements of farmers for timely, specialized weather forecasts and other services were discussed. Huntley and Chapman were original members of that Committee for several years and both were knowledgeable regarding practical farming problems and the necessity for timely specialized farm-weather forecasts. They contributed greatly to the discussions and recommendations in this regard. The NCAM recognized, at its first meeting that the provinces, through their respective departments of agriculture, had a responsibility to provide a farm-weather advisory service. This would require cooperation with the CMS, the provision of specially trained agriculturalists, the acquisition (through secondment or otherwise) of agrometeorologists by the provincial departments of agriculture, the development of a real-time crop-reporting system, and improvements in communications with the farmer. These and related problems were discussed at nearly every NCAM meeting since the first one in 1960.

City Weather Offices Open

In 1964 the CMS opened City Weather Offices at Hamilton and London. These provided a more localized forecast to the public and included some specialization in farm-weather forecasts and other services. Furthermore, the staff at these City Weather Offices were in a good position to become acquainted with the local requirements of agriculture for weather services.

By 1965 several establishments (CMS, ORF, MacMaster University, Vineland Experiment Station, and OAC) were engaged in the study of microclimate and topoclimate, primarily in connection with the spatial and temporal occurrence of freezing temperatures and the occurrence and distribution of high humidity and leaf wetness in connection with disease epidemics. This research led eventually to better farm-weather forecast services in regard to frost and disease occurrence and protection.

Also in 1965 a special committee consisting of personnel from both the CMS and the ODAF was formed to study the requirements of farmers for meteorological services. The results of a questionnaire circulated to 100 agricultural representatives and second-year Diploma Students indicated a definite need for a specialized farm-weather forecast.

Special Farm-Weather Forecasts

In 1967, as a result of the committee's findings, the CMS Forecast Office at Malton introduced a more comprehensive farm-weather service for the Toronto agricultural area. CMS also established a pilot project for the 1967 growing season in 14 counties: Grey, Bruce, Wellington, Waterloo, Dufferin, North and South Simcoe, Halton, Peel, York, Ontario, Durham, Victoria and Peterborough. An agricultural weather bulletin was issued daily at 6:30 a.m. Monday to Friday, and disseminated to those radio stations subscribing to the Metro Toronto Weather Teletype Circuits. Based on experience gained in 1967, the program was modified for the next season.

Agricultural Information from ODAF

The problem of gathering pertinent agricultural information from the weather-sensitive cropping areas was remedied by ODAF, which installed a telephone at the Toronto Weather Office. This was used by the agrometeorologist on duty to gather information from agricultural representatives in the various

counties. The CMS forecasters experimented with the preparation of probabilities of precipitation, and in certain cases, extended the range of the forecast period to the third and fourth days. The preparation of the agricultural weather bulletins was increased to twice-daily (6:00 and 11:00 a.m.), and distribution over their teletype circuits was increased to City Weather Offices at Toronto, Hamilton, Simcoe, London, Sarnia, Windsor, Wiarton, Mount Forest, and Camp Borden. These City Weather Offices made the information available for broadcasting several times each day by the local radio stations. This local distribution partially solved the problem of communication to the farmer.

The Canadian Federation of Agriculture had, for many years, recognized the need for improved farm-weather services. In 1968, as a result of a resolution passed at the annual meeting of the CFA, CMS held a series of meetings with the Ontario Federation of Agriculture to discuss this matter.

That same year W. Fox, Associate Director, Information Branch of ODMF became the first representative from that Department to become a member of the NCAM. He served a three-year term from 1968 to 1970.

At the 1969 Annual Meeting of the NCAM Fox was named chairman of a subcommittee to prepare a position paper on farm-weather forecasts. In view of the lead taken by the CMS and the ODAF in providing farmers with a forecast service, Fox and his committee (D.A. Pellett of ODAF, McLeod, and Bergsteinsson) were in a splendid position to prepare a useful paper. This was presented to the 1970 Annual Meeting, pointing out the strengths and weaknesses of the Ontario program.

Pallett replaced Fox in 1971 as the representative from ODAF on the CCAM. He was a member for two years (1971-72). At the 1971 Meeting he presented two reports, one on "Communication in Farm-Weather Services" and the other on "Education".

By 1971 the Farm-Weather Bulletins were updated and issued three times per day, seven days per week. The information was provided to farmers over an In-Watt telephone line along with market information for slaughter cattle, hogs, fruits, and vegetables.

On January 17, 1972, the first joint symposium with the AES and representatives of the research and extension wings of ODAF was held at the AES Headquarters in Downsview, Ontario. Although the main purpose of this meeting was to familiarize both groups with the operations and research projects presently underway, a resolution was passed, forming the Ontario Agrometeorological Research Committee (OAmRC).

In connection with the preparation of frost forecasts and land selection for sensitive fruit crops, frost research in 1971 was intensified cooperatively by ODAF and Treidl of AES. This research was originally conducted on a single fruit farm near London but, over the next five years, was expanded to cover critical areas bordering on lakes Ontario, Erie, and Huron. The University of Guelph also became involved in this study.

Integrated Pest-Management Program

About this time there was an increasing concern about the amount of chemical spray material used by farmers and the effect on the environment. The 1971 Annual Meeting of the CCAM tabled a special position paper on Pollution in Relation to Agricultural Pesticides.

Realizing that something must be done about the problem, a year later staff at the CDA Research Station in Vineland, in cooperation with the ODAF Extension Specialists, began an intensive study of the effect of weather on insects and diseases of apples in nine orchards of the Georgian Bay apple-growing region. The purpose of this project was to improve the timing of spray applications by farmers to increase the effectiveness of chemical applications, and to reduce the number of unnecessary applications.

Information gathered was used later for developing an Integrated Pest Management (IPM) Program for apple orchards.

By 1975 research on the IPM Project reached a stage where it could be made operational. The OMAF, in cooperation with CDA, ran an extensive pest-monitoring and spray-guidance program in the Meaford-Thornbury-Collingwood apple-growing area of Georgian Bay. Eight special weather stations were set up and operated by an off-semester agricultural student who also took observations of insects and disease. The information was interpreted in terms of the necessity for spraying of insecticides and fungicides and made available on a timely basis to growers via code-a-phones. Growers using the information maintained good disease and insect control with reduced amounts of chemicals, and were very pleased with the program.

In an attempt to evaluate this IPM Program, Gillespie prepared a report for the 1977 Annual Meeting of the CCAM. He estimated that the cost of spray materials alone in the area was 37 percent below the provincial average, even though the degree of infestation was roughly equivalent throughout all fruit growing regions of Ontario. Considering labour, fuel, and machinery depreciation the total savings over three years amounted to $75,500, more than enough to offset the $50,000 grant obtained for the development research.

A somewhat similar program was established on an experimental basis in 1975, cooperatively by OMAF and the University of Guelph (Gillespie), in the Bradford Marsh for the control of insects and diseases of a number of vegetable crops (carrots, onions, tomatoes and potatoes) with equal success. By 1976 this program moved from the experimental to the operational stage. Three years later the IPM Program had become so successful that seven other centres throughout Ontario provided a service for insect and disease control.

Introduction of Code-a-Phones

In 1973 OMAF improved communications with farmers by providing a number of code-a-phones whereby farmers could telephone for a pre-recorded weather bulletin at there leisure, and when the information was needed.

The following year the farm-weather forecast area was extended eastward from Toronto to cover all lake-shore counties between Toronto and Kingston. These services were provided from the Toronto Weather Office. Similar services were provided to all other counties east of Kingston by the CMS Montreal Weather Office. A year later the area covered by the Farm Weather Bulletin issued by the Toronto Weather Office was extended northward to cover the region north of Lake Ontario.

Drought Insurance

A new operational service was developed when the Ontario Government introduced drought insurance in the late 1970's. This required climatological and agrometeorological input which was provided by the University of Guelph (Selirio and Brown, 1979) in cooperation with OMAF.

The Ontario Agrometeorological Services Committee (OAmSC)

An ad hoc committee of the OAmRC, established as a result of recent interest by the CFA and the ECA, met early in 1979 and discussed the preparation of a proposal for an Agricultural Weather Service outlet in Southwestern Ontario. This proposal was assembled by R.G. Lawford, AES Toronto Regional Office assisted by Brown, Gillespie and Proctor of the University of Guelph; P. Pender and W. J. Wyllie of AES Toronto Regional Office; and D. Dittner of the OMAF. To deal with this report, the ad hoc committee was expanded to included representatives from the Ontario Federation of Agriculture, Ontario Soil and Crop Improvement Association, Ontario Fruit and Vegetable Growers Association, Processing Vegetable Growers Marketing Board, and the Soils and Crops Branch of OMAF.

In 1980 this ad hoc committee become the Ontario Agrometeorological Services Committee (OAmSC) with additional representation from the Agrometeorology Section of the LRRI/CDA. H. Pattinson of the Ontario Federation of Agriculture was elected chairman and W.D. Wyllie of the University of Guelph was secretary.

The ad hoc committee had recognized certain problems, particularly with regard to communication, in connection with the Farm Weather Service for Southwestern Ontario. The OAmSC, following the proposals of the ad hoc committee, organized, on a trial basis, a Special Farm-Weather Forecast for the Niagara Area in 1981. This forecast was in addition to the regular Farm-Weather Bulletin issued by AES in cooperation with the OMAF. It was issued at 4:00 a.m. and again at 11:00 a.m. and consisted of the following:

- a weather synopsis,
- days with temperature inversions below 100 feet,
- general sky and weather forecast for today and tomorrow,
- probability of the occurrence of precipitation,
- estimation of precipitation amount in three ranges,
- surface wind direction and speed with times of significant changes,
- maximum and minimum temperatures,
- confidence levels of temperatures and wind forecasts,
- an outlook giving sky, weather, wind, drying conditions, and temperatures.

The 11:00 a.m. issue gave additional information on growing degree-days, corn-heat units, 24-hour rainfall and accumulated rainfall collected by selected growers in the area. The communication problem was solved by the use of a Weatheradio on the CN Tower in Toronto. The cost of dissemination was shared by AES and OMAF.

Manager for the OMAF Agroclimatic Program

OMAF created a position of Manager of the Agroclimatology Program for the Plant Industry Branch in 1982. This position had been recommended by the OAmRC for the past four years. The position was filled the following year by B. Schneller, who was given office space in the Department of Land Resource Science at the University of Guelph. A year later, Schneller was named OMAF representative on the ECA for the next three years (1984-86). OMAF had been without direct representation on the Committee since Pallett's term of office expired in 1972 although much of the work for Ontario was undertaken by representatives from the University of Guelph.

In October 1983 the OAmRC and the Ontario Region of AES cosponsored a workshop, and published the Proceedings, "The Role of Long-Range Transport and Weather in Agriculture". This was held in Guelph. King served as moderator for the discussion period.

Services for farmers in Northern Ontario were initiated by the AES in 1984 by including frost warnings in the public-weather forecasts for Algoma, Cochrane, Haliburton, Northern Georgian Bay, and Timagami Regions. The code-a-phone service which was installed in the AES Niagara Weather Office at St. Catharines in 1983, was expanded to three lines in 1984, funded by OMAF. These were necessary to fill the gap in communications which existed just beyond the range of the CN Tower Weatheradio Station. Due to increased volume of calls on the code-a-phone the OMAF maintained in the Waterloo-Wellington Weather Office, new digital-voice answering equipment was installed.

For the second year a seminar for AES forecasters was organized by OMAF in Guelph. This was to provide staff of the Ontario Weather Centre and of the Ontario City Weather Offices with a better knowledge and understanding of some current agricultural practices and the impact that weather and climate have on farm activities and decision-making by farmers. Also, the Weekly Field-Crop and

Horticultural Reports, as well as factsheets, were sent to all forecasters and presenters to keep then informed of current agricultural activities.

Schneller was appointed to service another 3-year term (1987-1989) on the ECA as the representative from OMAF.

Farmers Become More Involved

Advances in farm-weather services cooperation continued during the remainder of the 1980's. OMAF started a program of on-farm weather observations. Small rain gauges and inexpensive thermometers and shelters were provided at cost for this purpose. By 1986 some 500 cooperators were involved in this program. The University of Guelph was responsible for computer archiving and data analysis and report preparation and circulation.

In 1986 the OMAF (Schneller) set up a permanent network of nine automatic weather stations at provincial agricultural colleges and research stations. In addition, four temporary sites were established on private farms, including one site at the University of Guelph Arboretum. Tests were conducted by AES and OMAF regarding the relaying of Weatheradio information via satellite (Anik C). The results were both satisfactory and economical.

The Ontario Agricultural Weather Service Committee (OAWSC) continued to be active into 1988. In 1984 the chairman of the committee was a farmer and by agreement the chairman, in the future, was to be selected from members of farm organizations. By 1987 there were more members from farm organizations on the committee than from government agencies. The committee continued to be a vital link with the AES, reflecting the ongoing needs of farmers for improvements in the content and the delivery of farm-weather forecasts. The main concern of the committee was the lack of coverage of the agricultural areas of Ontario by Weatheradio. Three more stations (besides Toronto and Ottawa) were proposed.

PART 5 - MANITOBA

Membership on the NCAM (ECA)

Because of their interest in climate, it was only natural that PFRA should provide the first representative for Manitoba to the 1st NCAM Meeting held in 1960. E.F Durrant was an hydrology engineer who served for three years. He was followed by W.G. Malaher, Searle Grain Company (1963-66), R.A. Hedlin, University of Manitoba (1967-68), A.L.D. Martin, Manitoba Dept. of Agriculture (1975-81), and finally, C.F. Shaykewich, University of Manitoba (1982, since 1984).

In connection with the hydrology activities of PFRA, Durrant made considerable use of climatic data provided by the CMS. He was active in the NCAM in attempting to improve the climatological networks on the prairies.

There was no organized or coordinated activity in agrometeorology until about the mid-1970's, even though there was been considerable activity in the area of water resources and irrigation.

Farm-Weather Services

In 1974 farmers in Manitoba became concerned about the inadequacy for agricultural operations of the public weather forecast issued by the AES Office at Winnipeg. To meet their demands, a pilot farm-weather service was established. A.L.D. Martin, Chief of the Crops Section, Manitoba Department of Agriculture, in collaboration with H. Fraser, Superintendent of Scientific Services, AES, Winnipeg,

arranged for a pilot farm-weather forecast for the area around Altona in southern Manitoba. The pilot project was successful and farm-weather forecasts were extended to other areas of Manitoba.

The first Weatheradio in Manitoba was established by AES for the Winnipeg area in 1980. Response to this means of disseminating farm-weather forecasts was not too satisfactory. The main complaint was that farmers would not buy the special receivers required. The Manitoba Agrometeorological Committee recommended that Weatheradio frequencies be shifted to the commercial FM band so that broadcasts could be picked up on ordinary FM receivers.

Following persistent action by the Manitoba Farm Bureau, and as a partial solution to the communication problem, a code-a-phone farm-weather information system was established in the Red River Valley in 1983. This was a cooperative project involving the AES and the Province of Manitoba. The Red River Valley was selected because of the dense farm population in the area and the great diversity of specialty crops grown there. The project proved to be successful and of great value to local farms.

The code-a-phone system was extended to Brandon and Dauphin in 1984. The system was not toll free and users outside the local calling areas had to pay long-distance toll charges. The system proved quite popular with farmers.

In 1985 special farm-weather forecasts were replaced by a more detailed urban-rural format for the public forecasts. A pilot project was initiated in 1985 to provide an agrometeorological advisory, particularly in connection with weather-based pest-management forecasts. The project was a cooperative effort involving AES, Manitoba Agriculture, the University of Manitoba and CDA.

During the latter half of the 1980's Manitoba Agriculture and AES joined forces to develop an agrometeorological advisory service. Trial bulletins were issued in 1986 and, starting in 1987, five bulletins were issued weekly. These covered: cereals, oil seed crops, row crops, forage crops, and insect phenology and fallow. Each bulletin included relative crop information on weather, the stage of physiological development, soil water status, disease and insect hazards, critical field operations.

Manitoba Agrometeorological Subcommittee

In 1977 Manitoba formed an Agrometeorology Sub-Committee of the Soil Science Lead Committee of the Manitoba Agricultural Services Coordinating Committee. One of their first actions was to make a strong plea that AES initiate 5- to 6-day farm-weather forecasts to be made available on Sunday so that farmers could plan their week's work.

The membership of the Agrometeorology Subcommittee was increased to include a member from the Manitoba Farm Bureau and a farmer in 1978. The Committee cooperated closely with the Canadian Federation of Agriculture in an attempt to obtain an improvement in farm-weather services for Manitoba.

Other Activities

Martin attended the organizational meeting of a North American Interstate Weather Modification Council in Denver in 1975. Other Canadian representatives included Maybank from Saskatchewan and G. Sterling from Alberta. Sterling was made vice-president. Manitoba's position was undecided and, although drought was a problem on the Manitoba prairies, the Manitoba Government did not become deeply involved in this type of operation..

In 1985 long-term climatic records were used to simulate wheat yields in an attempt to evaluate land capability in Manitoba.

During the late 1980's the publication "Southern Manitoba's Climate and Agriculture" was updated with information on the potential for agriculture in Manitoba through the use of maps for frost-free periods,

heat units of various kinds, estimates of soil-water stress, workday probabilities, hay drying, and phenological units for insect development. The latest available climatic data were used.

The Whiteshell Nuclear Research Establishment at Pinawa, Manitoba, started research on some micrometeorological factors of interest to agriculture and forestry, including evapotranspiration for forested catchment areas and turbulence measurements within forest canopies.

PART 6 - SASKATCHEWAN

Membership in the NCAM

T.P. Pepper, Head of the Chemistry Division of the Saskatchewan Research Council (SRC), was the Saskatchewan representative at the 1st Meeting of NCAM in 1960. He had an interest in agrometeorology because the Council was attempting to recruit a meteorologist to undertake, among other things, some research in micrometeorology and agrometeorology. W.L. Pelton, from the Swift Current Research Station, replaced Pepper in 1964, followed by J. Maybank, SRC, in 1967. J.L. Bergsteinsson, SRC, later served 3 terms: 1970-72, 1978-79 and 1981-82 followed by E.E. Wheaton, SRC, in 1985 to the present. Maybank was an invited participant in 1971, as was S. Shewchuk, SRC, in 1985.

South Saskatchewan River Irrigation Project

Following a suggestion by the NCAM, an Agrometeorological Committee of the South Saskatchewan River Irrigation Project was formed and met in December 1961 to consider the requirements of the South Saskatchewan River Irrigation Project for climatological data, not only for irrigation purposes but also for crop zonation.

Members were:

J.E. Dehm, Project Director (Chairman)
E.F. Durrant, Chief, Hydrology Division, PFRA
G.A. McKay, Hydrometeorologist, PFRA.
T.P. Pepper, Head, Physics Division, SRC
J.L. Bolton, Forage Crops, Research Station, CDA, Saskatoon
J. Maybank, Atmospheric Scientist, SRC
D.M. Robertson, Regional Meteorologist, CMS, Winnipeg
H.J. Wolbeer, SRC.

A Bench-Mark Climatological Station was eventually established at the Pre-Development Farm of PFRA at Outlook in 1963. PFRA provided land, a building and staff, while the CMS provided standard instruments for an agrometeorological station.

The Environment Division, SRC

J. Maybank was hired in 1963 by the SRC as a meteorologist to undertake research and training in cooperation with the Department of Physics at the University of Saskatchewan. J. Bergsteinsson was hired during the early 1970's, S.R. Shewchuk and E. Wheaton in 1980. Wheaton was a graduate of the University of Saskatchewan with a B.Sc. in Geography in 1973 and an M.Sc. in Climatology in 1979.

Agrometeorological Activities at the SRC

Maybank was instrumental in establishing a BenchMark or Climatological Reference Station at Saskatoon in cooperation with the University of Saskatchewan and the CMS. This replaced a weather site on campus, the exposure of which had been slowly deteriorating due to the building program on the campus. The new site was established a couple of years before the old one was abandoned in order to provide a comparison.

The Environmental Division undertook a number of research projects related to agrometeorology.

- In collaboration with the Saskatchewan Department of Agriculture, and the CMS office in Saskatoon, a pilot farm-weather forecast was undertaken in 1964 for a small area around Saskatoon. This continued for a couple of years and demonstrated the feasibility of such a venture on a larger scale.
- A joint study was begun in 1967 with the CDA Research Station in Saskatoon regarding the dispersal of pesticides and the influence of wind flow. This study continued for several years and looked at many aspects of farm pollution of the environment and control measures. The Regina Research Station of CDA was eventually (1974) brought in as a collaborator.
- In cooperation with the Crop Science Department of the University of Saskatchewan, regression wheat yield models were investigated, using plot data for Marquis and Thatcher wheats.
- Agroclimatic maps were completed for Saskatchewan showing a number of parameters, based on the 1941-70 standard period.
- SRC coordinated grasshopper surveys and forecasts of outbreaks. Research was also underway to determine the causal mechanisms involved in insect population changes and modelling.
- SRC also carried out a number of projects on air pollution meteorology, applied climatology, climatic change, and the impact of climate warming.
- Investigation of the possibility of automating the Climatic Reference Station.

The Saskatchewan Committee on Agricultural Meteorology

The Saskatchewan Committee on Agricultural Meteorology was established in 1974 under the aegis of the Saskatchewan Agricultural Service Coordination Committee. Maybank was Chairman, Ripley Secretary and Bergsteinsson CCA representative. Organizations represented included: the University of Saskatchewan, University of Regina, CDA, Saskatchewan Department of Agriculture, SRC, AES, Saskatchewan Crop Insurance Board, and the Saskatchewan Wheat Pool. The first business of the Committee was in connection with farm-weather services and extended forecasts.

Farm-Weather Services

Experimental farm-weather forecasts were initiated by AES in the Kindersley-Rosetown area in 1974. In 1977 the service was expanded to cover the area south and west of Kindersley. The rest of the province appeared to be adequately covered by general public weather forecasts. Five-day forecasts became routine issue from all forecasting offices in 1975.

In 1982 the Saskatchewan Federation of Agriculture and a District Wheat Pool Committee indicated a need for a better farm-weather service. In 1983 AES installed Weatheradio at Regina and Saskatoon, which carried detailed farm-weather forecasts. In 1985 AES began a urban-rural forecast service to replace a number of special farm-weather forecasts. This service added to the public weather forecast a number of items of interest to agricultural including the five-day outlook.

Other Items of Interest

During the last half of the 1980's numerous activities were under way in Saskatchewan. Many of these were inspired by the drought situation which peaked in 1988. Other activities of interest included the following.

- The Forest Fire Branch of Saskatchewan Parks, Recreation and Culture operated 28 automatic weather stations, one manned weather station, and a lightning detection system for fire-hazard research and control.
- The Saskatchewan Climate Advisory Committee continued to investigate the feasibility of a Climate Service Centre for Saskatchewan.

PART 7 - ALBERTA

Early Post-War Activities

Soil surveyors on the prairies had noted that the soil zones in the three prairie provinces followed closely, the isohyets for normal total annual rainfall. However, there were some discrepancies in central and southern Alberta, and temperature was the suspected cause.

In the latter part of the 1940's, the Soil Survey Group in Alberta formed a Subcommittee on Soil and Climate Analysis. The members of this subcommittee were W.E. Bowser of CDA, A.G. McCalla, Dean of the Agricultural Faculty, University of Alberta (U. of A..) and Robertson of the Edmonton Weather Office of CMS. Robertson prepared a report on the potential productivity of wheat that the climate of Alberta would support. This was based on historical records of rainfall and temperature, making use of J.W. Hopkins statistical relationships between wheat yield and weather data (Hopkins, 1935). The resulting map of isolines of weather-based estimates of wheat yield gave a better fit to soil-climate capability than did rainfall maps alone. This was probably the first application of crop-weather models to soil-climate zonation problems in Canada.

Some 20 years later the Alberta Soil Survey Group again became interested in soil-climate capability. They undertook a classification of Alberta land regarding its capability for agriculture, forestry, and wildlife. Climatic data and Hopkins earlier work (Hopkins, 1935) along with soil information were used for this purpose.

Membership on the NCAM

Alberta was well represented on the NCAM. The 1st Annual Meeting in 1960 was attended by J.A. Toogood of the Soils Department of the U. of A., who held a three-year term. Longley became representative in 1965 for three years. Others were: W.O. Haufe of the Lethbridge Research Station, 1968-70 and 1973-79; D.C. MacKay, Research Station, Lethbridge, 1971-72; R.E. Harris, Beaverlodge Research Station 1974-76; D. Chanasyk, U. of A., 1981-82; R.T. Heywood, Alberta Agriculture, Lethbridge, 1984-86; P. Dzikowski, Alberta Agriculture, 1987 to the present. Invited participants included: R.W. Longley, 1968; P.W. Summers of the Alberta Research Council, 1969; K.T. Hage U. of A. in 1971; J.M. Powell, Canadian Forestry Service, Edmonton, 1977; R.D. Major, Lethbridge Research Station, 1977; Powell was representative for the Canadian Forestry Service, 1980-86.

Farm-Weather Services

In the late 1940's the public weather forecasters at Edmonton occasionally provided special consultative service to agriculture. One such service, which involved an extended forecast before they were officially authorized, was to the flour-milling companies in Edmonton. The mills had to be debugged periodically

and the most economical way to do this was to open the mill in the winter and turn off all heat to freeze the insects. This operation required about five days to complete: two days to stop operations and turn off and drain all steam and water pipes and three days of progressively colder temperatures ending with the nighttime temperature below -30°C. Such periods of arctic air outbreaks were rare but not too difficult to foresee, and the success rate was fairly good.

Farm-weather services was an important topic at the first meeting of the NCAM. The Committee recommended that provinces should take the initiative in this operation by providing agronomists who could work closely with the public weather forecasters to produce a farm-weather advisory service. In 1961 the Alberta Department of Agriculture offered to assign an agriculturist, B.J. Godwin of the Provincial School of Agriculture at Vermilion, to the office of the CMS in Edmonton to assist with an experimental farm-weather forecast service during 1962. Forecasts were issued five days a week for the next two days and with an outlook for the third day. Distribution was over the existing teletype link to the offices of Broadcast News. Godwin was given a three-week training course by the staff of the forecast office, similar to that given to university student summer assistants. The meteorologists in the CMS office mainly responsible for the meterological aspects of the program were C.E. Thompson and J.J. Kinisky.

The farm-weather forecasts were again issued in 1963 with the addition of a fourth-day outlook. Godwin continued to work during the summer in the Edmonton Public Weather Office, assisting with the preparation of a special farm-weather forecast geared to the immediate needs of the farmer.

These forecast continued until 1970 when the service was discontinued temporarily. For the next seven years no special farm-weather forecasts were issued. The public weather forecast, which was now more detailed, was felt by AES to adequately cover farmer's requirements.

Special advisory services were undertaken in certain areas. For example, in 1977 AES started a special forecast for the sugar-beet industry around Lethbridge. A new project, the Spring-Start Moisture Project, was initiated in 1983. It was intended to help farmers estimate fertilizer, herbicide, and pesticide requirements.

Weatheradio became operational in the Edmonton area in April 1981. This was a joint effort on the parts of the Alberta Department of Agriculture and the AES. This program was not fully accepted by farmers, as there were several short coming. The Alberta Agrometeorology Advisory Committee was concerned both with the content of the broadcasts, and the acceptance by farmers. Also, the Farm-Weather Services Committee, at their 1983 meeting, gave the matter a great deal of consideration. The system's coverage was considered inadequate, the information not satisfactory for farm operations, and the radio frequency inconvenient. Nevertheless, a Weatheradio facility was established to cover Calgary and the surrounding area in 1983.

That same year AES made experimental agricultural forecasts of general weather information including relative humidity, and drying indices. These were broadcast from their Weatheradio in Edmonton. This was in preparation for a full Farm-Weather Service that was inaugurated for the first time in 1984, covering the Peace, Parklands, and Prairie regions. Information was carried on local rural radio stations and on Weatheradio for the Edmonton and Calgary areas.

Through the efforts of the Alberta Agrometeorology Advisory Committee and the Subcommittee on Farm-Weather Services, a code-a-phone system was established in four locations in Alberta. This was a cooperative project involving Alberta Agriculture and AES.

Hail Suppression and Rain Making

Schaefer and Langmuir in the USA in 1956 demonstrated that dry ice could be used as the nucleus for the formation of ice crystals in an atmosphere containing supercooled water droplets. Following that

discovery a number of research projects and trials were undertaken in an attempt to adapt the discovery to the problem of artificial inducement of precipitation. Other nucleating agencies were tested and silver iodide was found to be a promising one. Eventually research indicated that by over-seeding potential hail-bearing clouds before hail had formed would release the cloud moisture as rain and snow instead of hail. The potential for farm relief from damaging hail storms appeared phenomenal, if it could be accomplished.

A cloud physics program was started in 1956 near Red Deer to study cloud physics problems with emphasis on hail suppression. This was a cooperative project undertaken by the Alberta Research Council, CMS, the Stormy Weather Group of McGill University, and NRC.

About this same time a private company organized farmers in a hail suppression scheme in which farmers paid a small fee to have potential hailstorms suppressed before damage was done. It was felt by many that this commercial operation was untimely, since little was known about the success of the venture. Nevertheless commercial hail suppression and late rainmaking projects continued for several years.

A commercial cloud seeding operation to suppress hail claimed to have increased rainfall in the hail suppression area and so had the support of farmers who wanted the government to underwrite a rain making program in 1962. A.H. Laycock, Associate Professor in Geography at the University of Alberta, prepared a special report on weather modification which was brought to the attention of the NCAM. He wrote:

> "It should not be suggested that there is no point in making further rain-making and hail-suppression studies. There are still many possibilities that might be developed. It should be recognized, however, that these studies would still be experimental, and that the chances for more than very limited success are small. There is little point in reusing those techniques that have not been proven effective in plains areas, and paying heavily for the associated showmanship, salesmanship, and statistical distortion."

Commercial cloud seeding slowly disappeared from the scene as pressure from scientific groups continued to grow because of doubt about the validity of claims for success. Research by the cooperative group continued, however, until 1980. At that time all cloud seeding operations were brought under the control of the Alberta Weather Modification Board. By this time there was research underway regarding cloud seeding to increase winter snow pack in the mountains, which appeared to offer more hope of success that either hail suppression or precipitation enhancement on the prairies.

Cloud seeding field activities ground to a halt during the late 1980's. Funding was substantially reduced, and activities were directed towards a review and analyses of past work.

The Alberta Agrometeorological Advisory Committee

An Agrometeorological Subcommittee was formed by the Soils Advisory Committee in 1971. Recommendations by this Subcommittee and the Committee resulted in the formation of the Alberta Agrometeorological Advisory Committee (AAAC) in 1973 and the establishment of an agrometeorological position in the Alberta Department of Agriculture (ADA). Subsequently C.W. Gietz was hired to fill this position..

The first annual meeting of the AAAC was held in Edmonton in October 1975. Special terms of reference for the AAAC were to provide a forum for discussing agrometeorological problems that are common to the various disciplines represented by the other Advisory Committees, and to provide direct input into the deliberations and actions of the Canada Committee on Agrometeorology through the Alberta representative on the National Committee.

Farm-Weather Services Subcommittee

The Farm-Weather Services Subcommittee (FWSS) was formed by the AAAC, and held its first meeting in 1981. Its simple terms of reference were "to identify agricultural weather services issues and requirements and to make recommendations to the AAAC". Membership included, besides agrometeorology experts, representatives from Alberta Agriculture and from farm organizations. Their immediate main concern was a farm-weather advisory service and improvement in the Weatheradio system from the farmer's standpoint.

Agrometeorology in the Alberta Hail and Crop Insurance Board

In 1978 I.S. Selirio, a recent graduate in agrometeorology from Guelph, was hired by the Alberta Hail and Crop Insurance Corporation to develop a meteorological-based system for appraising weather-based crop insurance claims.

Agrometeorology a Concern of Several Agencies

During the first half of the 1980's a number of agencies in Alberta were involved in agrometeorology or related activities.

- AES did not provide special farm-weather forecasting service in Alberta. Instead, the public weather forecast had been upgraded to meet all public requirements, including those of agriculture, in the province. Information on hay drying and relative humidity were broadcast over the Weatheradio at Edmonton.
- The Alberta Research Council continued cloud seeding and hail suppression experiments, as well as studies of air flow and sulphur dioxide pollution.
- Alberta Energy and Natural Resources (S. Dupuis) developed a system for normalizing short-term meso-scale observations and undertook studies of agroclimatic capability of new land areas.
- Alberta Agriculture (Gietz) had a number of ongoing projects: computerized irrigation scheduling, climate and water-use relationships, development of solar-radiation instruments, preparation of estimated spring soil-water reserves, maps of potential areas subject to wind erosion, assessment of the likely impact of climatic change on Alberta agriculture.
- Alberta Hail and Crop Insurance Corporation continued work on a weather-based model for estimating hay and pasture productivity (Selirio).

The last half of the 1980's found a great deal of agrometeorological activity in Alberta. Several agencies were involved.

- The Alberta Agrometeorology Advisory Committee completed a report on "Alberta Climate Rated for Arable Agriculture". This was a cooperative activity with Alberta Forests, Lands and Wildlife.
- Alberta Department of Agriculture's Dzikowski was appointed Weather Resource Specialist in 1986 in support of weather interpretation programs and activities. Alberta Farm-Weather Service installed code-a-phones (in cooperation with AES). Fall and spring stubble and soil-moisture map, weekly weather summaries and selected agroclimatic maps were published. Research involved soil temperature, irrigation and drainage assessment, snow management, evaporation and soil-water, moisture supply for crops, irrigation scheduling, and irrigation risk analysis.
- Activities at Alberta Forests, Lands, and Wildlife included reports on the climatic inventories produced from five mesoclimatic networks in sparsely populated areas relative to possible agricultural development, and a special climate network in southern Alberta in support of rangeland-grazing lease management.
- The Alberta Hail and Crop Insurance Corporation continued work on the development and verification of a forage- and hay-production model. Yield measurements were taken at some 2000 sampling sites (about one per township) for both verification and insurance purposes.

- The Alberta Climate Advisory Committee was formed under the Canadian Climate Program of AES. One objective was a feasibility study of an Alberta Climate Centre financed by the Alberta Government. Work included a study of the climate of the prairie provinces, an atlas based on 1961-1990 normals and climatic-change impact assessment.
- Work at the Alberta Research Council on hail suppression and precipitation enhancement ground to a halt. Efforts were concentrated on the analysis of past results. A study was completed regarding the feasibility of using weather radar to measure rainfall. In cooperation with AES a project was started to assess the feasibility of using radar for quantitative precipitation forecasts.

PART 8 - BRITISH COLUMBIA

Early Post-War Activities

The mountainous nature of British Columbia and the resulting wide range in climatic conditions had created a keen interest and concern about climate and weather amongst agriculturists and foresters in that province. Also, because of the great variety of crops grown, it is not surprising that there had been a prolific development of agrometeorology there. Although studies of agrometeorology did not seriously begin until in the late 1960's, early concern was felt by members of university faculties of agriculture and geography, and by others.

Probably the first real meterological activity for the benefit of farmers was the Okanagan Valley frost forecast service which started out of the Victoria Weather Office in 1935. This was for the valuable fruit grown in the area. The Victoria Office sent a forecaster to the Valley every spring to make on-the-spot adjustments to the forecasts issued from Victoria, and later from the Vancouver Weather Office, when it took over all forecasting responsibilities for the province.

NS Wright had developed a method of forecasting late blight on potatoes in the Lower Fraser Valley in the early 1950's using only rainfall data.

NCAM Membership

T.A. Anstey, CDA Research Station, Summerland, was the first representative from BC to serve on the NCAM. He was a member from 1960 to 1964, followed by A.C. Carter of the Department of Agriculture, Victoria, 1964-65 and 1969-71; D.S. Stevenson, summerland Research Station, 1965-70; V,C, Brink, UBC., Vancouver, 1966-68; A. Black, UBC, Vancouver, 1972-74 and 1976-78; R.G. Wilson, BC Ministry of the Environment, Victoria, 1978-79; R.L. Davis, BC Ministry of the Environment, Victoria, 1980-81; W.G. Bailey, Simon Fraser University, Burnaby, 1987 to the present . R.H. Silversides was the representative from the Canadian Forestry Service, Victoria, 1975-78; Invited participants included: R.H. Silversides, 1981; M.C. Coligado and R. Williams, both from the BC Ministry of the Environment, Victoria, 1981.

Farm-Weather and Advisory Service

Apart from frost-warning services, the Vancouver Weather Office made no attempt to provide special farm-weather forecasts during the 1960's. However, they provided consultative services when requested to do so.

Frost-warning services were provided for the Okanagan Valley every spring. J. Henderson of the Vancouver Office went to Penticton where he prepared frost warnings and wind forecast for orchard growers starting in mid-March. Information was release through local radio stations, and general information sessions were broadcast from time to time by Henderson himself over local stations. This responsibility was taken over by the newly opened Penticton Weather Office in the spring of 1974. Two

years later a Weather Office was established in Kelowna, and a presentation officer there also released frost and wind forecasts for the area. Other advisory and consultative services were also provided.

A special Farm-Weather Forecast Program for the Fraser Valley was started in the late 1960's. This service was increased in 1976 with the addition of more forecasts and the inclusion of a special hay-drying forecast.

Good rapport appeared to exist between AES personnel in Vancouver and farm groups. Several meetings and consultations between F. Williams and D.A. Faulkner of the Vancouver Weather Office and the BC Federation of Agriculture took place in the mid-1970's, regarding the improvement of farm-weather services. R. Janes, Officer-in-Charge of the Kelowna Weather Office, represented the AES at the BC Federation of Agriculture Convention in Kelowna in 1977, where farm-weather services were discussed

A survey was conducted by AES in 1980 to determine the economic value of weather forecasts to tree fruit, grape and vegetable growers in the Okanagan Valley. The survey identified the following priorities for weather services:

- Firm times for radio broadcasts of weather forecasts should be scheduled
- A toll-free, dedicated 24-hour telephone service should be established
- Greater spatial forecast detail is required
- Wind and precipitation outlook forecasts should continue through the growing season
- A program for "monitoring and disseminating heat-unit information" should be established
- Greater lead time and accuracy is required.

As a result of the Survey, AES took the following action.

- "Noon Outlook" broadcasts of temperature, precipitation and wind were scheduled.
- Broadcast of "Five-Day Haying Outlooks". A new hay-drying index was being developed by the Pacific Weather Centre.
- The spraying forecast was extended to continue throughout the summer.
- Bulletins of growing degree-days were issued weekly for representative stations in the Okanagan Valley.

Lower Fraser Valley farmers were surveyed in 1983 to determine the farm-weather service requirements. As a result AES initiated, in 1984, a special, improved farm-weather service for the area. This was disseminated over local radio stations in the Valley, from code-a-phones in the Vancouver Weather Office, and from the Weatheradio in Victoria.

In 1975 D. Faulkner and R. MacKenzie of Scientific Services, AES prepared the introductory chapter on the climatic resources of BC and the importance of forestry and agriculture to the general economy of the province for the "Forestry and Agriculture Handbook". The first section, dealing with general information, was published in 1985 for the benefit of farmers and foresters.

Fire-Weather Forecasts

Fire-weather forecasts were started in the late 1940's, and were issued from the Vancouver Weather Office for use by the BC Forestry Service in Victoria. J.A. Turner was seconded by the CMS to the BC Forest Service to assist with their fire-weather program.

In preparation for an expanded fire-weather forecast service, AES organized a two-week basic meteorological course for BC Forest Service personnel in 1975. This was funded by the Forest Service. With the expansion of the CMS weather services and the BC Forest Service, fire-weather services became less centralized. In 1975. AES presentation officers at Nelson, Kamloops, Williams Lake, and

Prince Rupert provide daily briefings and consultation on fire weather and hazardous conditions. In 1976 Prince George was added to this list of stations. AES Headquarters in Toronto developed a reading course in Forest Meteorology. This proved of great interest to foresters, presentation officers, and meteorologists alike.

Lightning-strike probability estimates were a new factor included in fire-weather forecast for the Okanagan District starting in 1977.

Under the leadership of F. Williams and D.A. Faulkner of AES Weather Services, Vancouver, close cooperation continued with the BC Forest Service throughout the late 1970's and into the 1980's.

The BC Land Inventory Project

ARDA and its Canada Land Inventory program provided a great impetus for the study of agrometeorology in BC This program was started in 1965 with five projects under way.

- A bibliography of agroclimatic references was prepared by C.C.E. Denike of the Geography Department.
- Wilcox extended his network of evaporimeters, which had covered the interior valleys, to include 32 new sites in the Peace River area. This network was expanded to 100 sites in 1966
- The BC Forest Service, under the leadership of R. Schmidt and J. Marshall, started a program of standard climatic observations of precipitation and temperature in mountainous areas along slopes and on plateaus where observations had not been taken before. Included in the studies were areas around Prince George and in the south Rocky Mountain Trench. In all 150 short-term climatological stations were established and botanical sampling was taken from 220 vegetation plots.
- The mapping of climatic variables in BC was undertaken by Farley of the Geography Department, UBC.
- Turner and Schmidt of the BC Forest Service started work on automated instrumentation for recording temperature and precipitation in remote areas. The importance of automated stations became more apparent as the project progressed and difficulty was experienced in obtaining data from remote or inaccessible areas.

The activity of the Climatology Sector of the BC ARDA program continued to grow. By 1971 there were a total of 650 active climatology stations in the Province. The projects, which started as support for agriculture, were extended for use in classifying land for forestry, recreation and wild life. By 1975 most of the data gathering work of the BC Land Inventory Program was completed and the first phase of the project terminated. The second phase. consisting primarily of data analysis, involved several agencies and committees each working on separate analytical and interpretive problems.

BC Forestry

During the late 1960's and early 1970's forestry in BC received a great deal of assistance from the BC ARDA program, particularly regarding topoclimatological studies in mountainous areas. AES. Also expanded its capabilities for providing assistance in the form of fire-weather forecasts, forecasts of fire danger, and consultative services (See the above section, Fire-Weather Forecasts").

By 1975 the BC Environment and Land Use Committee Secretariat, besides agrometeorology, was also engaged in forest meteorology, as follows.

1. Data collection for forest productivity programs on Vancouver Island were under way.
2. Evaluation of wind damage to forested areas in the MacMillan Park area of the Cameron River was completed.
3. Evaluation of climatic constraints to logging in the Terrace-Hazelton Forest Resources Management Area was completed.

BC Climate Coordinating Committee

The BC Climate Coordinating Committee (BCCCC) was formed in 1972 to coordinate all climatological programs in BC; to identify user requirements; and to encourage communication between the user and provider of data and information. Members of the committee represented AES, the BC Land Inventory, BC Department of Agriculture, CDA, Simon Fraser University, UBC, University of Victoria, BC Forest Service, Water Survey of Canada, the Pollution Control Branch, and the Department of Recreation and Conservation.

The New BC Agricultural Land Reserve Program (ALRP) made heavy demands on the BCCCC for agroclimatic and soils data in 1973 and following years.

Agricultural Climate Classification Committee

An Agricultural Climate Classification Committee was established in 1973 to develop a land classification scheme for the West Coast. Such a scheme was required in connection with the ALRP. This Committee's activities included the following.

- Maps of climatic capability for the Prince George and Kamloops areas were completed. (BCLI).
- A mobile micrometeorology station was used in the Kamloops and Okanagan areas for a study of range-land moisture deficits in connection with range-land management. (BCLI).
- A project was begun to evaluate the effectiveness of wind machines as a frost management tool in the Okanagan Valley, where several research machines were installed. The effectiveness of the down-wind plum was evaluated in relation to land form, microclimate, and synoptic weather map units. (BCLI).
- Detailed mapping of tree fruit microclimates as part of the Crop Insurance Program for the Okanagan and Similkameen Valleys was completed in 1975. BCLI).

BC Environment and Land Use Committee

The BC Environment and Land Use Committee Secretariat was engaged in several agrometeorological projects in 1975.

- Development of an agricultural climate capability classification for the coastal areas of BC.
- Climate capability for agriculture mapping for Omineca, Salmon and Lower Fraser Valleys.
- Data collection for agroclimatic capability completed for the Fraser Valley between Prince George and Valemount, Vancouver Island, and the Lower Mainland.
- Extensive topoclimatic mapping of frost risk for tree fruits in the Okanagan and Similkameen Valleys.
- Evaluation of infrared photographic techniques for topoclimatic mapping.
- Evaluation of wind machines for frost protection in the Okanagan Valley.
- Preliminary development of an agricultural productivity model for grasses and vegetable.
- Water-use efficiency of fertilized and unfertilized seeded range land being studied with a mobile energy-balance system.
- Effect of summer precipitation on range-land weed toxicity in the Kamloops area.

Soil Science Workshop

"Energy, Water and the Physical Environment of the Soil" was the topic of the Sixth Soil Science Workshop held in April 1977. There were 24 speakers and 107 scientists in attendance. It brought together agriculturists and foresters from both southern and northern BC as well as agrometeorologists, micrometeorologists, climatologists, hydrologists and soil scientists. The Workshop accomplished three objectives of the organizers: to bring together people from several disciplines, to expose them to the

problems in different areas and how they are being tackled, and to encourage further communications amongst members of the various disciplines represented.

Resource Analysis Unit (RAU) of the Ministry of the Environment

In 1976 a Resource Analysis Unit (RAU) of the BC Environmental and Land Use Committee Secretariat, which was formerly under the BC Department of Lands, was brought under the administration of the Ministry of the Environment. There were climatologists working in two groups in RAU: the Resource Inventory Division and the Analysis Impact Division.

Several projects are underway.

- Continuation of agricultural-land capability classification for coastal areas of BC (M. Coligado).
- Extensive topographic mapping of frost risk for tree fruits in the Okanagan and Similkameen Valleys (R. Davis).
- Prediction of minimum temperatures in the Saanich area of Vancouver Island (R. Chilton). This was being done in cooperation with Professor Tuller, Department of Geography, University of Victoria.
- Evaluation of infrared photographic techniques for topographic mapping (R. Bennet).
- Evaluation of wind machines for frost protection in the Okanagan Valley (R. Davis).
- A study of the effect of weather on dry-land forage crop growth and productivity with the object of developing a model of the process (D. Marsh).

Short-term topoclimatological networks continued to be operated in various parts of the province by the Resource Inventory Division. In 1977 there were 145 combination daily temperature and precipitation stations, 255 combined daily temperature and monthly precipitation stations; 427 monthly precipitation stations; 26 recording wind-direction and speed stations; two solar-radiation stations; and one electronic data-logging unit used for temperature profile studies.

As these short-term data-gathering projects were completed, the information was subjected to a standard mapping program. Maps on the scale of 1:100,000 were prepared for some dozen factors, both observed and derived, of usefulness for determining land capability for agriculture, forestry, recreation, wildlife, and urban development.

A Mobile Energy Balance System was used in the Peace River District as part of the Land Evaluation Program in 1977. Two units were in use in the summer of 1978. Mobile temperature units were used for temperature transects in the Peace River and Telegraph Creek areas in 1978 to provide ground-truth information for thermal infrared flights.

R.J. Williams, an agricultural climatologist with the Resource Inventory Division was stationed at the CDA Research Station at Kamloops in 1976. He was involved in studies of the applicability of the corn heat-unit system (Brown, 1963, 1969) for determining maturity of corn grown in southern BC. Some problems were encountered with the system and modifications were proposed. He was also involved with a study of the effect of weather on the growth and development of range-land grasses. For this purpose he used a mobile micrometeorological station. The following year Williams, in cooperation with D.E. Waldern and L. Haupt of the Kamloops CDA Research Station, carried out evaluation trials of the modified corn-heat unit system at 11 sites in the Thompson and Okanagan Valleys, and the Quesnel and Creston areas. Williams also cooperated with A. van Ryswyk and K. Broersma of the Kamloops Research Station in the study of the effect of temperature and soil water on the growth and development of crested wheat grass.

In 1979 a start has been made on a Climatological Atlas for Grape Suitability in the Okanagan Valley by the Resource Analysis Unit, in conjunction with the BC Ministry of Agriculture.

The Climatology Unit of the Air Studies Branch was formed in part by the Climatology Division of the old Resource Analysis Unit.

This Unit was involved in various aspects of data collection and analysis related to agrometeorology, including climate-crop modelling, soil moisture measurement and modelling, evapotranspiration measurement and modelling, determination of irrigation requirements, testing of the sensitivity of the Climatic Moisture Index (Sly, 1970), and mapping of Climatic Variability for Agriculture.

An agrometeorological project, initiated in 1979, to study climate-soil correlation for growing grapes in the Okanagan and Similkameen Valleys started in 1981. This was a three-year project to produce maps showing grape growing-capability areas in the valleys. The project was completed in 1984. Williams was responsible for many of the maps and text in the 141-page report, which was published by CDA and the Association of British Columbia Grape Growers.

Cooperation with the Ministry of Food

During 1981 the Climatological Unit of the Air Studies Branch was involved in several studies in agrometeorology in cooperation with the BC Ministry of Agriculture and Food:

- West Chilcotin Climatic and Land Capability Study,
- Vancouver Island Irrigation Requirement and Soil Moisture Study,
- Nicola Valley Climate Network for Irrigation Water Allocation Study,
- Kamloops Sewage Effluent Irrigation Study Using Estimates of Irrigation Requirements (Sly, 1970; Sly and Baier, 1971).

In 1983, maps of the climatic capability for the Peace River Region were completed and published by the Ministry of the Environment.

The BC Subcommittee on Agrometeorology

Following a recommendation of the BC Agricultural Services Coordinating Committee in 1977, a BC Agrometeorological Committee was formed in 1978 as a subcommittee of the BC Soil Science Lead Committee. Membership of the Committee was drawn from interested people in AES, the Climatology Group of the Resource Analysis Branch, CDA Research Stations, the BC Ministry of Agriculture, and U. B.C. This Subcommittee was needed to determine the pressing agrometeorological problems in BC, and to determine research and service priorities. The BC Coordinating Committee did not have the power to speak specifically for agrometeorology in BC. In 1979 a member from the BC Federation of Agriculture, B. Peterson, was added to the Subcommittee.

The Subcommittee held two meetings in 1980. One was a special meeting to consider farm-weather services. This meeting disagreed with the proposal by the ECA that farm-weather services be standardized across Canada. The Sub-committee endorsed the recommendation of the Task Force on Agricultural Weather Services for Canada, i.e. that

> "The Agricultural Weather Service proposed by the Expert Committee on Agrometeorology is considered inappropriate since farmers have better identified their needs, and this situation calls for a new approach regionally and, through time, to locally different needs, different levels of participation, provincial preferences and evolving technology." (22nd Annual Report, ECA, 1980.)

A Complexity of Activities

By the 1980's there were no fewer than nine agencies actively involved in agrometeorology in BC.

- The BC Agrometeorology Subcommittee.
- The Atmospheric Environment Service.
- The BC Ministry of Environment Air Studies Branch.
- The University of BC Soil Science Department.
- Agriculture Canada.
- The BC Ministry of Agriculture and Food.
- The Pacific Forest Research Centre, CFS.
- The BC Forest Service
- Simon Fraser University

A shortage of funds for forest and agricultural meteorology training and research became apparent in 1986-87, and concern was felt for the future of the quality and continuity of such research and training in the Province. Could it have been that too many agencies in the province were involved in the science, and that funds were being spread too thinly?

CHAPTER 10
INTERNATIONAL ACTIVITIES

PART 1 - THE WORLD METEOROLOGICAL ORGANIZATION

Introduction

The WMO is a specialized agency of the United Nations of which 112 states and territories are members. Its terms of reference include the following:

- to facilitate international cooperation in the establishment of networks for making meteorological and geophysical observations,
- to promote the establishment and maintenance of information systems,
- to promote standardization of meteorological observations,
- to further application of meteorology to aviation, shipping, agriculture and other human activities,
- to encourage research and training in meteorology.

WMO has eight Commissions, composed of experts designated by member nations, which are responsible for the technical aspects, research and associated problems of a world-wide character. Each deals with a major branch of meteorology or its application. The Commission for Agricultural Meteorology (CAgM) is one of these Commissions.

Organization of CAgM

From the time of the organization of the first permanent Commission for Agricultural Meteorology by the International Meteorological Organization in 1913, Canadian meteorologists and agrometeorologists took an active interest in international activities in agrometeorology. Sir Frederic Stupart, Director of the CMS, 1894-1929, was present at the IMO meeting in Rome in 1913 when the formation of CAgM was discussed and ratified. Stupart was appointed a member of this first Commission. No meetings were held between 1914-18 because of the war.

A meeting of the Subcommittee for Agricultural Meteorology of IMO was held in London in 1921. There were no representatives from Canada, although two were nominated to the new International Commission for Agricultural Meteorology formed at that meeting. These were A.J. Connor, Climatologist of the Meteorological Service, Toronto and F.T. Shutt of the Royal Society, Ottawa. There is no record of the part played by Stupart, Connor and Shutt in the Commission.

The Last Meeting of CAgM-IMO

The last meeting of the CAgM-IMO was held at Toronto in August 1947. Several Canadians had the opportunity to attend this meeting. Boughner of CMS, Putnam of ORF, and Ripley of CDA were official members. Observers and guests included Chapman of ORF, J.L. Doughty, CDA, Swift Current, J.S. Smith from OAC, F.D. Thompson and A. Thomson of CMS, Toronto and W.G. Wellington, Toronto.

Canadians were more than mere observers at this meeting. Doughty collaborated with Prof. J.J. Burgos of Argentina on a proposal concerning soil moisture. Boughner collaborated with R. Feige of Palestine (Israel) and W.C. Jacobs of the USA on a resolution concerning soil formation, erosion and conservation. Chapman presented a report on an evapotranspirometer.

Officers and Delegates at CAgM-WMO

Boughner was the principal delegate for Canada at the First CAgM-WMO in Paris, November 1953. He presented reports on the agrometeorological activities in Canada as well as comments regarding agenda items dealing with several topics such as: agrometeorological stations and observations; artificial influences on weather and climate including artificial weather modification; biological observations for agrometeorological purposes; study of the meteorological requirements of plants; acclimatization of cultivated crops; and the application of agrometeorology to animal problems.

Boughner also was principal delegate for Canada at the Second Session held in Warsaw, September-October 1958. Besides presenting a report on agrometeorological activities in Canada since the last Session, he took part in discussions of agenda items of interest to Canada, as well as serving on the Nomination Committee.

The Third Session was held in Toronto, July 1962. Besides being principal delegate at this Session, Boughner was responsible for the overall organization of the physical facilities. A number of interested people were invited to attend as delegates including Hamilton and Hill from the Research Branch, CDA; Robertson, meteorologist seconded to CDA; King from the Ontario Agricultural College; and Thomas of the Climatological Division, CMS. Hill also represented the International Commission for Irrigation and Drainage and Robertson the International Society of Biometeorology. From the CFS there were: Powell as the official representative, Turner and MacHattie. Some 12 others, mainly from CMS, attended as counsellors.

Members of the Commission were welcomed by S.C. Barry, Deputy Minister of CDA, and by P.D. McTaggart-Cowan, Director of the Meteorological Branch, Canadian Department of Transport.

Several extra-agenda items were arranged by the Canadian Planning Committee. A display (Poster Session) of agrometeorological activities in the Agrometeorology Section of PRI, CDA, was prepared by the Section under the direction of Robertson. Tours were conducted to points of interest such as the Ontario Agricultural College, the Southern Research Station of the Ontario Department of Lands and Forests at Maple, the Field Station of CMS at Scarborough, the Vineland Research Station of the Ontario Department of Agriculture, the Forest Research Station at Petawawa, and the agrometeorological and plant research facilities at the Central Experimental Farm at Ottawa. The Canadian Branch of the Royal Meteorological Society along with CAgM cosponsored a scientific session at which papers were presented by four Canadians: Holmes, King, MacHattie, and Turner.

Boughner was again principal delegate at the Fourth Session held in Quezon City, Manila, November 1967. This time he was supported by two delegates: MacHattie and Robertson. The latter also acted as an observer for the International Society of Biometeorology. He also served as chairman of the Committee for Theoretical and Scientific Matters and was a member of the Committee for Nominating Rapporteurs and Members of Working Groups. Both MacHattie and Robertson took part in the Scientific Sessions, presenting papers on "Diurnal variations in valley winds" and "Research on crop-weather models in Canada", respectively.

Shortly after the Session Robertson was invited to fill the vacancy of vice-president created by the resignation of V.V. Sinelshikov of the USSR. However, he too had to resign when he accepted a two-year assignment with WMO as an Expert in Agrometeorology in the Philippines.

Treidl was principal delegate supported by Baier as delegate at the Fifth Session of CAgM held in Geneva in October 1971. Treidl also served as observer for the International Union of Geodesy and Geophysics. Baier served as chairman of the Committee for Theoretical and Scientific Matters and was a member of the Coordination Committee for the Session. He was elected President of the Commission for the next Inter-Sessional Period including the Sixth Session.

Treidl was again the principal delegate supported by Baier, MacHattie and Pelton as delegates at the Sixth Session held in Washington in October 1974. Baier was president of the Commission at the time

and was reelected president for a second term. Treidl also served as an observer for the International Union of Geodesy and Geophysics. Mukammal attended as an invited expert and presented a paper at the Scientific Sessions.

The Seventh Session was held in Sofia in September 1979. Berry was principal delegate supported by Baier and Brown as delegates and Robertson as observer. Thomas attended as observer, representing the Commission for Climatology and Applied Meteorology, of which he was President. Baier was president of the Commission.

Berry and Baier represented Canada as principal delegate and delegate, respectively, at the Eighth Session held in Geneva in March 1983. Robertson was invited by WMO to attend as an observer.

Berry again represented Canada as principal delegate at the Ninth Session held in Madrid in November 1986. He was supported by Baier and Robertson as delegates.

At the 1979, 1983 and 1986 Sessions, while the Canadian delegation provided strong support to CAgM initiatives which primarily benefited developing countries, it also worked hard to ensure that attention was paid to pressing issues which at the time were of more concern to developed countries, including Canada. It made a major contribution to initiating activities on subjects such as the impacts of climate change, forest meteorology and plant injury from air pollution.

The Role of the President

Baier was President of CAgM for two sessions, from 1971 to 1979. This was a period of exciting developments in agrometeorology, both in Canada and internationally. In the early part of the period severe droughts in many parts of the world led to a food crises and, in some cases, famine. FAO held the World Food Conference in Rome in 1974 at which time food production in relation to climatic change was discussed, and the use of real-time weather data in connection with global food strategies and early warning systems for predicting food shortages was proposed. CAgM, under the leadership of Baier, rose to the occasion and, following earlier recommendations by WMO that positive and realistic steps be taken to assist in increasing world food production, adapted this topic as its main theme. The outcome was the development of action programs to assist with the technological transfer of agrometeorological knowledge to developing countries to assist national meteorological services in the development of agrometeorology services. In turn these services would aid in increasing food production, the development of early warning systems for food shortages, and the development of national food strategies.

The office of president of the Commission carried with it many responsibilities concerning these programs. Besides being responsible for the Sessional meetings in 1974 and 1979, he was also chairman of the Advisory Working Group of the CAgM, which met at least once during the inter-sessional period to plan and organize the sessional meetings, and the inter-sessional activities of the Commission. The president also attended the meetings of the World Meteorological Congress to present reports on CAgM activities and take part in related discussions. He was a member of the Unesco-FAO-WMO Inter-agency Group on Agricultural Biometeorology, and represented CAgM at various working-group meetings.

The organization and direction of a number of agrometeorology-related international conferences, symposia and workshops were among the president's responsibilities. During Baier's presidency, two of these were held in Canada, viz: a WMO Expert on Crop-Weather Models held in October 1977, and a WMO International Symposium on Forest Meteorology held in October 1978. Baier also attended several meetings as an invited observer and speaker. During his tenure as president of the Commission he attended some 35 international gatherings of one form or another in different parts of the world, ranging from European centres such as Geneva and Rome to Nigeria, Australia, Colombia, the Philippines, and Bulgaria.

Working Groups and Rapporteurs

Much of the inter-sessional work of the Commission is accomplished by small working groups of 5 to 8 members and single rapporteurs dealing with specific matters. Canadians have taken an active role in many of the specific problems of the Commission. The following list indicates who worked at what and the resulting WMO publication, if any.

1958-62:

Robertson	- Member, WG on Wind Breaks and Shelter Belts. TN No. 59.
Turner	- Chairman, WG on Forecasts for Forest Fire Services. TN No. 42.

1962-67:

Baier	- Member, WG on Practical Soil Moisture Problems in Agriculture. TN No. 97.
Holmes	- Member, WG on Practical Soil Moisture Problems in Agriculture. TN No. 97.
King	- Member, WG on Syllabi for Instruction in Agricultural Meteorology.
MacHattie	- Member, WG on Agrometeorological Topoclimatology. TN No. 133.
Mukammal	- Chairman, WG on Plant Injury and Reduction of Yield by Non-Radioactive Air Pollutants. TN No.96.

1967-71:

MacHattie	- Rapporteur on Agrotopoclimatology.

1971-74:

Baier	- Chairman, Advisory WG of the CAgM.
Green, D.G.	- Member, WG on International Experiments for the Acquisition of Crop-Weather Data.
Mukammal	- Rapporteur on Non-radioactive Pollutants of the Biosphere and Their Injurious Effects on Plants, Animals and Yields. TN No. 147.
Robertson	- Member, WG on International Experiments for the Acquisition of Crop-Weather Data.
	- Rapporteur on Meteorological Factors Affecting the Production of Rice. TN No. 144.

1974-79:

Allsopp, M.A.	- Rapporteur on Climate Variability and Agricultural Productivity and Practices.
Baier	- Chairman, Advisory WG of the CAgM.
Edey	- Member, WG on International Experiments for the Acquisition of Wheat/Weather Data. CAgM Report No. 2.
Green, D.G.	- Member, WG on International Experiments for the Acquisition of Wheat/Weather Data.
Hyslop, N.	- Member, WG on Weather and Animal Diseases.
MacHattie	- Member, WG on the Applications of Meteorology to Forestry.
McElgunn, J.D.	- Member, WG on International Experiments for the Acquisition of Lucerne/Weather Data. TN No. 182.
Mukammal	- Rapporteur on Air Pollution and Plant Injury.
Treidl	- Member, WG on Weather and Climate as Related to World Food Production.
Williams	- Member, WG on Meteorological Aspects of Land-use and Agricultural Management Systems under Severe Climatic Conditions.

1979-83:

Baier	- Member, Advisory WG of CAgM.
Berry	- Member, WG on Data Requirements for Agriculture with Particular Reference to WCP.

Brown	- Member, WG on the Impact of Climatic Variability on Agriculture and of Agricultural Activities on Climate CAgM Report No. 17.
Davidson, H.R.	- Member, WG on Analysis of Wheat-Weather Data.
Edey	- Member, WG on Analysis of Wheat-Weather Data.
Harrington	- Member, WG on the Role of Forests in the Global Balances of Carbon Dioxide, Water and Energy.
Haufe	- Member, WG on Weather and Animal Health.
Mack	- Chairman (1979-82), Task Force on Crop Weather Models.
Neumann, H.H.	- Rapporteur on Air Pollution and Plant Injury. CAgM Report No. 9.
Robertson	- Member, Task Force on Crop Weather Models. Editor WCP-50.
	- Rapporteur on the Application of Models and Forecasting of Development and Ripening of Crops. CAgM Report No.15; TN No. 180.
	- Member, WG on Agrometeorological Services in Developing Countries. CAgM Report No. 22.
Shields, J.A.	- Rapporteur on Soil Water Studies.
Williams	- Rapporteur (joint) on Land-Use and Agricultural Management Systems Under Severe Climatic Conditions. TN No. 184.

1983-86:

Baier	- Member, Advisory WG of the CAgM.
Brown	- Chairman, WG on the Application of Knowledge of the Effect of Climatic Variability on Agriculture and of Agricultural Activities on Climate. Misc. Report No. 6.
Gillespie	- Member, WG on the Agrometeorological Aspects of Operational Crop Protection.
Mack	- Rapporteur (joint) on Satellite Applications to Agrometeorology. Misc. Report No. 11.
Neumann, H.H.	- Rapporteur on Air Pollution and Plant Injury.
Percy, K.E.	- Rapporteur on the Impact of Acid Rain on Forests.
Treidl	- Rapporteur (joint) on the Meteorological Aspects of Forage Provision and Animal Production.

1986-91:

Baier	- Member, Advisory WG of CAgM.
	- Coordinator, Task Force on Historical Perspective of CAgM.
King	- Rapporteur (joint) on Training and Education in Agrometeorology.
Riding, T.R.	- Rapporteur (joint) on Air Pollution and Plant Injury.
Street, R.	- Rapporteur (joint) on Operational Applications in Forestry.

The WMO-CAgM Working Group on International Experiments for the Acquisition of Crop-Weather Data is of special interest as it was one of the few working groups to become involved in original research. Robertson was a member of the group and attended the organizational meeting in 1972. Canada become one of several countries participating in the experiment. It was designed to observe the growth and development of wheat and to relate this to weather, similar to the Canadian experiment on crop-weather relationships established across Canada by Robertson in 1952. Canada had two sites: one at Swift Current Research Station supervised by Robertson and one at CEF, Ottawa supervised by Edey. Edey replaced Robertson on the working group when he retired in 1973. The project continued for 5 years during which time Edey attended two meetings of the Working Group at WMO Headquarters in Geneva.

Invited Studies and Papers

From time to time WMO invited individuals to prepare reports on specific topics of timely interest not covered by working groups or rapporteurs. A few Canadians were involved in such studies because of their expertise in these problems.

1955: Robertson - TN. No. 11. The standardization of the measurement of evaporation as a climatic factor. 10 pp.
1977: Baier - TN. 151. Crop-weather models and their use in yield assessments. 48 pp.
1977: Maybank - TN. No. 154. The scientific planning and organization of precipitation enhancement experiments, with particular attention to agricultural needs. 88 pp.
1980: Robertson - TN. No. 168. The role of agrometeorology in agricultural development and investment projects. 85 pp.
1983: Hare - WCP-44. Climate and desertification. 149 pp.

Consultants and Experts

WMO administers funds from various sources for conducting consultancies and expert missions. These include projects to transfer agrometeorological technology to developing countries. During the period 1969 to 1983 Robertson worked on four major WMO missions. The first, a two-year (1969-1971) training and research project, was in agrometeorology and climatology at the University of the Philippines and the Philippine Weather Bureau in Manila. The second was a feasibility study for the Unesco-FAO-WMO Inter-Agency Group for Agricultural Biometeorology concerning the preparation of an agroclimatic atlas for Southeast Asia. Following this he made a number of surveys and proposals regarding the development and strengthening of agrometeorological services within the national meteorological services in developing countries including the Philippines (1976), Bangladesh and Pakistan (1978), Tanzania (1980), Sudan and Ethiopia (1981), and Jamaica and Bahamas (1983). In 1981 he held a two-week roving seminar on "Rainfall and Soil-Water Analysis for Land-Use Planning" in each of Bangladesh, Burma (Myanmar), Pakistan, Sri Lanka, and Thailand. He undertook a second consultancy to Burma in 1984 to study the agroclimatic resources of the country and to assist with the preparation of an agroclimatic atlas that was completed in 1985.

Another major assignment for Robertson at the international level was a five-month consultancy at the WMO Secretariat in Geneva as assistant to the Chief of the Agrometeorological Division early in 1974.

Williams undertook a 6-week WMO consultancy in Ethiopia in 1985, regarding preparations for the mapping of agroclimatic resources. Gillespie conducted a one-week Agrometeorological Training Workshop in Pune, India, for WMO in 1985.

PART 2 - ACTIVITIES WITH OTHER INTERNATIONAL GROUPS

Committee on Agricultural and Forestry Meteorology of AMS

The development of agrometeorology in Canada parallelled that in the USA in many respects. As there was no scientific organization for agrometeorology in Canada for several years, it was only natural that Canadians turned to the American Meteorological Society's (AMS's) Committee on Agricultural Meteorology as their outlet for peer discussions of research activities and results. Holmes and Robertson attended the first Agricultural Meteorology Conference sponsored by AMS at the University of Madison in 1957. Shortly afterwards Robertson was invited to serve as a member of the Agricultural Meteorology Committee and ultimately served as vice-chairman and chairman until he resigned in 1967 due to pressure of other work.

During Robertson's term in office, the Committee held its regular 18-month (the Eighth) National Conference on Agricultural Meteorology in Ottawa in May, 1968. Robertson served as Conference Coordinator, Baier looked after physical arrangements, King was program chairman, and MacHattie arranged tours. Attendance at the conference was 180 agrometeorologists and others from both Canada

and the USA, as well as several from foreign countries. Some 38 scientific papers were presented during the week-long conference.

Since that time several other Canadians have served on the Committee included King, MacHattie, Brown, Schuepp (1983-86) and others. Many Canadians have also served as chairmen of sessions at the National Conferences of the AMS Committee on Agriculture and Forest Meteorology.

International Society of Biometeorology (ISB)

This society, founded in 1955, covers a broad spectrum of topics dealing with the effects of climate and meteorology on biological organisms and processes. It has sections dealing with weather effects on plants, animals, and agricultural insects and diseases. It is the only international scientific organization dealing with these agrometeorological topics. It is only natural that many agrometeorologists joined the society over the years.

Wellington served on the Advisory Board from 1957 to 1960 as Canadian representative. Robertson served on the Executive Board from 1960 to 1971. He was also a member of the Agricultural Meteorology Committee at the Second Congress in London (1960) and chairman of the Working Group on Agricultural Meteorology at the Fourth Congress at Rutgers University (1966).

Haufe was a member for some time and served on the Executive Board for several years as vice-president and later as president from 1970 to 1979.

Overseas Projects Secretariat, CDA

The Overseas Projects Secretariat (OPS) of CDA administers funds from the Canadian International Development Administration for assisting with development projects in Third World Countries. Many of these projects have had an agrometeorological component, and Canadian agrometeorologists have had the opportunity to demonstrate their ability to transfer agrometeorological technology to the problems of agricultural development in the Third World. In this connection Baier and Robertson have worked in India, Robertson in Pakistan, Edey in Ethiopia, Desjardins in Brazil, Dyer in South Africa, Zambia and Ethiopia, and Grace in Tanzania.

The Food and Agriculture Organization (FAO)

The Food and Agriculture Organization (FAO) of the United Nations is a sister organization of WMO. It has a small but active agrometeorological group in the Plant Production and Protection Division. Robertson undertook consultancies with FAO. He spent two and a half years in Malaysia (1974-77) researching the effect of weather factors on palm-oil production, and developing a system for monitoring weather and oil production. Six months were spent in India in 1976-67, developing analytical procedures for resource assessment in drought-prone and semi-arid areas. During this period he gave a series of lectures on agrometeorology at the Agriculture Meteorological Division of the Indian Meteorological Department in Pune.

Others undertook short-term assignments with FAO. Baier attended the FAO Expert Consultation on Crop-Soil-Weather Relations in Asia and the Far East in CSIRO, Canberra, Australia, in 1977. G.A. McKay and Robertson presented papers at the FAO-WMO Technical Conference on the Potential Economic Benefits of Agricultural Meteorology in Rome in 1978. Dyer represented Canada at two workshops on the FAO-WMO AGROHYMET Project: one in Niamey, Niger, in 1987 and one in Geneva in 1989.

U.S. National Academy of Sciences

In the spring of 1961 Robertson was invited by the U.S. National Academy of Science to participate in a ten-year planning program for atmospheric sciences. Two meetings were attended in Boston at the Headquarters of the American Meteorological Society, one on biometeorology in June and the other on agrometeorology in July. These meetings were attended largely by Americans, but experts from England, India, Ireland, Israel, and Switzerland, as well as Canada, were also invited. The task before the group was to develop a 10-year program for research with financial stability. They were to use imagination and originality in their ideas and plans.

The informal discussions that took place in various subgroups helped crystalize thinking concerning the aims and goals of the science of agrometeorology, and gave ample opportunity to reflect on the role that it could play in improving the living standards, particularly the nutritional level, of the human race as a whole.

Thus it was proposed that the aim of agrometeorologists and administrators responsible for agrometeorological programs should be as follows.

- To develop techniques for establishing relationships between weather on the one hand and plant, animal, and agricultural operations (including production, processing, and distribution) on the other. (Relationships developed today may be of no value tomorrow, but sound techniques for developing relationships will always be useful.)
- To develop techniques for climatic analyses based on probability, covariation, linear programming, bimodal distributions, and other recent developments in the field of mathematics.
- To develop techniques for more accurate extended, long-range, and seasonal weather forecasts.

To exploit this knowledge to the fullest, top-level planners would have to know how to apply these climatic analyses and forecasts to the problem of determining optimum or maximum food production. Geneticists would have to develop techniques for making use of climatic analyses for breeding desired varieties. Agricultural operators would have to know how to apply extended, long-range, and seasonal forecasts not only for day-to-day operations, but for seasonal planning.

The Working Group summarized that the goal of agrometeorology was deemed to be to learn how best to exploit weather in order to feed humanity.

Miscellaneous, 1960's and 1970's

A number of Canadians undertook other assignments of various types and durations in foreign countries and with international organizations. These experiences have undoubtedly had an influence on the direction of research, training and service in Canada, as well as providing valuable training, information and services to counterparts in recipient countries.

A chronology of these international activities follows

1960	In the autumn CDA sent Robertson to the ISB Congress in London, after which he visited several institutions in England and mainland Europe where agrometeorological and micrometeorological research and services were undertaken.
1962-65	E.A. Ripley held a post as a Munitalp Fellow in Agrometeorology at Muguga, Kenya, with the East African Agriculture and Forestry Research Organization.
1966-67	E.A. Ripley worked for the Canadian External Affairs Office (predecessor of CIDA) on the micrometeorology of coffee and tea crops in Kenya, Uganda and Tanganyika.

1964-65 King was a visiting scientist for five months at the Division of Meteorological Physics, Commonwealth Scientific and Industrial Research Organization, Aspendale, Australia, where he participated in a micrometeorological expedition to Hay, New South Wales and in the development of the fluxatron instrument for the measurement of sensible-heat flux.

1969-71 While in the Philippines during this period Robertson made many daily trips to IRRI and the College of Agriculture at Los Baños to assist staff with the measurement of solar radiant energy, evaporation and other factors, and their interpretation for agrometeorological purposes.

1974 King was a visiting professor for two months in the Department of Physiology and Environmental Studies, University of Nottingham School of Agriculture, Sutton Bonington, U.K. where he participated in crop micrometeorology research seminar discussions. During this time he also visited other agrometeorological research facilities in the UK, Belgium, Netherlands, and France. He also participated in a Seminar on Heat and Mass Transfer in the Environment of Vegetation held in Dubrovnik, Yugoslavia. Robertson spent several days at the Lyndon B. Johnson Space Center, Houston where he presented a paper at the Wheat-Yield Conference. Williams spent five weeks in Campinas, Brazil as a consultant relative to the mapping of the agroclimatic resources of Brazil.

1975 Brown visited Nairobi, Kenya, regarding a soil-moisture study for the International Atomic Energy Agency. Robertson presented an invitational paper at the Seminar on Remote Sensing Applications at the Indonesian National Institute of Aeronautics and Space.

1976 Dickison was visiting researcher at the U.K. Centre for Overseas Pest Control, London (sabbatical leave from UNB). Robertson visited IRRI in the Philippines to study the feasibility of, and lay the groundwork for, a cooperative WMO-IRRI Symposium on the Agrometeorology of the Rice Crop (later held in 1978).

1976-77 C.F. Shaykewich attended the Agricultural University at Wageningen, the Netherlands, on an International Agricultural Centre Research Fellowship.

1978 Marie Sanderson was involved in the International Joint Commission's Pollution from Land Use Reference Group Studies. Her contribution dealt with precipitation quantity and quality. King and Gillespie spent three weeks on a Canadian Executive Services Overseas assignment in Campina Grande, Brazil, advising on courses and curricula for developing a graduate program in agrometeorology at the University of Paraiba. Lectures were presented and he lead discussions on agrometeorological research topics. A paper on modeling evapotranspiration was presented by King at an International Workshop on the Agroclimatological Research Needs of the Semi-Arid Tropics held at ICRISAT, India.

1978-80 E.A. Ripley was a CIDA Consultant to Peru, where he was involved in a project to help with the local introduction of rapeseed and other crops in the high-altitude Andean environment.

1979 Brown visited Jalapa City, Mexico to teach a two-week course in agrometeorology with a professor from the University of Virginia sponsored by the Organization for Latin-American States.

1979-81 E.A. Ripley spent one month each year at the Instituto Venezolano de Investigaciones Cientificas in Caracas, Venezuela, teaching micrometeorology to graduate students.

Miscellaneous, 1980's

A chronology similar to that in the previous section, but for the 1980's, follows.

1981 Côté took part in a scientific tour of France in connection with the monitoring and warnings of plant disease and pest outbreaks.

1981-82 King worked for 10 months as a visiting scientist at the Plant Physiology Division, Department of Scientific and Industrial Research, Palmerston North, New Zealand, where he undertook research on the impact on maize of elevated atmospheric CO_2.

1982 Brown did a study of the Climate of Nepal for CIDA.

1982 Gillespie was a CIDA advisor for one month to the Brazilian Agrometeorological Service in Campinas.

1983-84 Dickison was visiting researcher at the Institute for Bioclimatology and Applied Meteorology, University of Munich (sabbatical leave from UNB).

1983-86 Williams was the leader of a five-member Canadian team for the IIASA-climate-change study in Canada. Other Canadians on the team included R.B. Stewart, Fautley, Jones, and Wheaton. (Williams et al, 1988).

1984 Gillespie and Thurtell presented a one-month training course in micrometeorology to university personnel at the Beijing Agricultural University, China. Dyer was awarded a grant as a visiting scientist to South Africa to assess soil moisture as a drought indicator in that climate. (Dyer and DeJager, 1986)

1984-86 R.B. Stewart undertook an investigation of nuclear winter implications for agriculture in Canada as part of a SCOPE project, and helped review the final report on this topic.

1985 Brown lectured on crop modeling and agrometeorology at the Beijing Agricultural University as part of a CIDA exchange program with the University of Guelph.

1985-86 R.B. Stewart supervised Section and cooperating scientists (Dyer and Mack) responsible for developing a drought monitoring system for continental Africa under contract to CIDA in support of their food aid early warning program. The system was later adapted for a microcomputer for use in Zambia (Dyer and Mack, 1986).

1985-89 E.A. Ripley served on the Board of Advisors of the International Centre for Tropical Ecology, Unesco, Caracas, Venezuela.

1986 Williams spent two months at IIASA's headquarters in Austria editing climatic-impact case studies for Brazil, Kenya and India. King worked for five weeks with CIDA in Beijing, China as part of the exchange program between the University of Guelph and the Beijing Agricultural University (BAU). Besides lecturing at BAU, he conducted discussions and seminars at eight other institutions in Beijing, Datum, Wugong, and Nanjing.

1986-88 R.B. Stewart undertook four activities with the US Environment Protection Agency (EPA). In 1986 he was invited to attend a Conference on Effects of Changes in Stratospheric Ozone and Global Climate, where he presented a paper concerning his work on climatic change implications for agricultural in Canada. In 1987 he attended, in Washington, the First North American Conference on Preparing for Climate Change, where he presented a paper on the implications of climatic change for agriculture on the Canadian Prairies. The third activity was in April, 1988 when he participated on a preliminary review team regarding the preparation of a report to Congress on the USA-EPA Program related to climatic change implications for the USA. In November he attended a further meeting of the team to review the final report. (Stewart, 1986)

1987 King spent a week in Jamaica working with the Organization of American States at the University of the West Indies in Kingston regarding the development of a reference evapotranspiration measuring technique for Jamaica.

1988 Robertson presented a keynote paper at the ICRISAT (India) Symposium on Drought Research Priorities for the Dryland Tropics. (Robertson, 1988)

CHAPTER 11
REFERENCES

AES, 1973. Canadian Normals: Precipitation 1941-1970. Atmospheric Environment Service. Vol. 2. 330 pp.

ALBRIGHT, W.D. and STOKER, J.G. 1944. Topography and minimum temperature. Sci. Agric. 25:146-155.

AMIRO, R.D. and GILLESPIE, T.J. 1985. Leaf-conductance response of phaseolus vulgaris to ozone flux density. Atmos. Environ. 19:807-810.

AMIRO, B.D., GILLESPIE, T.J. and THURTELL, G.W. 1984. Injury response of phaseolus vulgaris to ozone flux density. Atmos. Environ. 18:1207-1215.

ANSTEY, T.H. 1959. Variations of freezing temperatures over rough topography. Can. J. Plant Sci. 39:297-315.

AUSTIN, L.B., SCHUEPP, P.H. and DESJARDINS, J.L. 1987. The feasibility of using airborne CO_2 flux measurements for the imaging of the rate of biomass production. Agric. and Forest Meteorol. 39:13-23.

BAIER, W. 1968. The performance of soil moisture estimates as compared with direct use of climatological data for estimating crop yields. Agric. Meteorol. 5:17-31.

BAIER, W. 1972. An agrometeorological probability study of the economics of fallow-seed and continuous spring wheat in southern Saskatchewan. Agric. Meteorol. 9:305-321.

BAIER, W. 1973. Crop-weather analysis model: review and model development. J. Appl. Meteorol. 12:637-947.

BAIER, W. 1974. Crop water balance for Canada. Appendix III, Chapter II. The Climate of Canada and Alaska by F.K. Hare and J.E. Hay. In. World Survey of Climatology Vol II. Climate of North America, edited by R.A. Bryson and F.K. Hare. Elsevier Scientific Publishing Co. pp. 178-187.

BAIER, W. 1975. The role of agricultural meteorology in the new world food situation as related to weather and climate variability. Sixteenth Annual Report of the Canada Committee on Agrometeorology to the Canadian Agricultural Services Coordinating Committee. App. 13, 25 pp.

BAIER, W. 1977. Crop-Weather Models and Their Use in Yield Assessments. WMO-No.458. WMO, Geneva. Tech. Note 151. 48 pp.

BAIER, W. 1983. Agroclimatic Modelling: An Overview. In: Agroclimate Information for Development: Reviving the Green Revolution. (Ed. D.F. Cusack) Westview Press Inc., Boulder, Colorado. pp. 57-81.

BAIER, W. and ROBERTSON, G.W. 1965. Estimation of latent evaporation from simple weather observations. Can. J. Plant Sci. 45:276-284.

BAIER, W. and ROBERTSON, G.W. 1966. A new versatile soil-moisture budget. Can. J. Plant Sci. 46:299-315.

BAIER, W. and ROBERTSON, G.W. 1967a. Estimating supplemental irrigation water requirements from climatological data. Can. Agric. Eng. 9:46-50.

BAIER, W. and ROBERTSON, G.W. 1967b. Estimating yield components of wheat from calculated soil moisture. Can. J. Plant Sci. 47:617-630

BAIER, W. and RUSSELO, D.A. 1968. A computer program system for estimating risks of weekly irrigation requirements from climatic data. Agrometeorology Section, PRI, CDA. Tech. Bull. 59. 60 pp.

BAIER, W. and RUSSELO, D.A. 1970. Soil temperature and soil moisture regimes in Canada. p. 35-65. In: Proceedings of the Eighth Meeting of the Canada Soil Survey Committee, Ottawa.

BAIER, W. and RUSSELO, D.A. 1974. Agrometeorological data bank. Can. Agric.19(1):3-5.

BAIER, W. and WILLIAMS, G.D.V. 1974. Regional wheat-yield predictions from weather data in Canada. pp. 265-283. In: Agrometeorology of the Wheat Crop, Proc. of the WMO Symposium, Braunschweig, Federal Republic of Germany, Oct. 1973. WMO No. 396.

BAIER, W., CHAPUT, D.Z, RUSSELO, D.A. and SHARP, W.R. 1972. Soil-moisture estimator program system. Agrometeorol. Sect., PRI, CDA, Ottawa. Tech. Bull. 78. 55 pp.

BAIER, W., DYER, J., HAYHOE, H.N. and BOOTSMA, A. 1978. Spring field workdays in the Atlantic Provinces. Atlantic Committee on Agrometeorology. Publ. ACA-No. 1, Agdex 075. 43 pp.

BAIER, W., DYER, J.A. and SHARP, W.R. 1979. The versatile soil moisture budget. Agrometeorol. Sect., LRRI, CDA, Ottawa. Tech. Bull. 87. 52 pp.

BAIER, W., ROBERTSON, G.W. and CLARKE, M.F. 1969. A climatological analysis of irrigation requirements in the Lower Fraser Valley, BC. CDA, Publ. 1813, 179 pp.

BAIER, W., SHARP, W.R. and ROBERTS, J.G. 1973. Recent developments in preparing coloured agroclimatic maps by computer. Can. J. Soil Sci. 53:133-134.

BAIER, W., St.-PIERRE, J.C. and LOVERING, J.H. 1980. Analysis of environmental factors affecting timothy yields. Agric. Meteorol. 22:319-339.

BAILEY, W.G. 1981. The climatic resources for agriculture in northwestern Canada. Agric. For. Bull. 4:11-17.

BAILEY, W.G., LERER, H. and MILLS. P.F. 1982. Humidity influence on the pollination activity of Megachile rotundata. Environ. Entomol. 11:1063-1066.

BAILEY, W.G., STATHERS, R.J. and DOBUD, A.G. 1988, Seasonal soil temperature and moisture regimes in a ginseng garden. Korean J. Gingseng Sci. 12:53-62.

BAILEY, W.G., WEICK, E.J. and BOWERS, J.D. 1989. The radiation balance of alpine tundra, Plateau Mountain, Alberta, Canada. Artic and Alpine Res. 21:126-134.

BARNES, S. 1938. Soil moisture and crop production under dry land conditions in western Canada. Can. Dept. of Agric. Publ. 595.

BARON, V., SHAYKEWICH, C.F. and HAMILTON, R.I. 1975. Relation of corn maturity to climatic parameters. Can. J. Soil Sci. 55:343-347.

BARTHAKUR, N.N. 1983. The beta-ray gauge as a leaf surface wetness detector. Int. J. Appl. Radiation and Isotopes. 34:1549-1552.

BARTHAKUR, N.N. 1988. A non-equilibrium thermodynamics approach to surface evaporation of water drops. Agric. and Forest Meteorol. 40:287-294.

BARTHAKUR, N.N. and ARNOLD, N.P. 1989. Thermal response characteristics of tobacco leaves exposed to microwave radiation. Beitrage zur Tabakforschung International. 14:171-176.

BASSETT, I.J., HOLMES, R.M. and MacKAY, K.H. 1961. Phenology of several plant species at Ottawa, Ontario, and an examination of the influence of air temperature. Can. J. Plant Sci. 41:643-652.

BERRY, M.O. and WILLIAMS, G.D.V. 1985. Thirties drought on the prairies: How unique was it? In: C.R. Harington (Ed.), Climatic Change in Canada 5, Syllogues, 55:63-74. National Museum of Canada.

BHARTENDU, S. 1984. A climatology of corn-heat units in Ontario. Ontario Region, AES, SSD-84-1

BISAL, F. 1960. The effect of raindrop size and impact velocity on sand splash. Can. J. Soil Sci. 40:242-245.

BISAL, F. 1968. The Influence of plant residue on sand flow in a wind tunnel. Can. J. Soil Sci. 48:49-52.

BLACKBURN, W.J., STEWART, R.B. and NEISH, G.A. 1983. Weather factors and Fussarium head blight in wheat. Can. Agric. 29:20-22.

BOISVERT, J.B. and DWYER, L.M. 1987. L'informatique au service de l'irrigation. Conférence présentée le 13 novembre 1987 dans le cadre de la journée d'information sur la pomme de terre. Conseil de productions végétales du Quebec. Agdex 161, pp. 77-87.

BOISVERT, J.B. and DYER, J. 1987. Coefficients de sol dans les modèles empiriques de bilan hydrique. Can. Agric. Eng. 29:7-14.

BOOTSMA, A. 1977. Analyzing climatic variability for agriculture: soil-moisture regimes. In: Climate variability in relation to agricultural productivity and practices. Theme paper prepared for Canada Committee on Agrometeorology, Winnipeg, Manitoba, January 1977. 5 pp.

BOOTSMA, A. 1979. Potato late blight forecasting in Prince Edward Island in 1978. Can. Plant Disease Survey, 58(3):63-66.

BOOTSMA, A. 1980. Spring field workdays in Prince Edward Island. PEI Dept.of Agriculture and Forestry. Agri-Fact Sheet, Agdex 075. 3 pp.

BOOTSMA, A. 1984a. Forage crop maturity zonation in the Atlantic Region using growing degree-days. Can. J. Plant Sci. 64:329-338.

BOOTSMA, A. 1984b. Climatic zonation for forage crops in the Atlantic Region. Agric. Can. Res. Br. Tech. Bull. LRRI No. 83-01. 1983-27E. 44 pp.

BOOTSMA, A. and DWYER, L.M. 1989. Soil-climate classification and winter risk assessment for the Atlantic region based on estimated soil temperatures. LRRC, CDA, Ottawa. Tech Bull.

BOOTSMA, A. and SUZUKI, M. 1985a. Critical autumn harvest period for alfalfa in the Atlantic region based on growing degree-days. Can. J. Plant Sci. 65:573-580.

BOOTSMA, A. and SUZUKI, M. 1985b. Optimum seeding period for winter wheat in the Atlantic Region. Agric. Can. Canadex. 112.22. May. 2 pp.

BOOTSMA, A., BLACKBURN, W.J., STEWART, R.B., MUMA, R.W. and DUMANSKI, J. 1984. Possible effects of climatic change on estimated crop yields in Canada. Agric. Can. Res. Br. Tech. Bull. LRRI No. 83-64. 1984-9E. 26 pp.

BOOTSMA, A., GATES, A.D. and SMITH, P.J. 1979. Heat units for corn in the maritime provinces. Atlantic Committee on Agrometeorology. Publ. No. ACA 79-1, Agdex 111/31. 5 pp.

BOSISIO, R.G. and BARTHAKUR, N.N. 1969. Microwave protection of plants from cold. J. Microwave Power, 4:190-193.

BOUGHNER, C.C. 1964. The distribution of growing degree-days in Canada. Meteorol. Br., Canadian Meteorological Memoirs No. 17. 40 pp.

BOUGHNER, C.C. and THOMAS, M.K. 1959. The Climate of Canada. Meteorological Branch. In: Canada Year Book of the Dominion Bureau of Statistics, Ottawa. 74 pp.

BRACH, E., DESJARDINS, R.L. and St-AMOUR, G. 1981. Open-path CO_2 analyser. J. Physics, E. Scientific Instruments. 14:1415-1419.

BROWN, D.M. 1960. Soybean ecology I. Development-temperature relationships from controlled environment studies. Agron. J. 52:493-496.

BROWN, D.M. 1963. A heat-unit system for corn hybrid recommendations. In: Proc. of the 5th Conf. Agric. Meteorol., Lakeland, Florida.

BROWN, D.M. 1969. Heat units for corn in southern Ontario. Ont. Dept. of Agric. and Food. Information Leaflet. Agdex. No.111/31. 4 pp. (Revised 1970 as Fact sheet, Agdex. No. 111/31. 4 pp. Revised 1972. Reprinted 1973. Revised 1975. Reprinted 1976. Revised 1978.)

BROWN, D.M. 1986. Corn-yield response to irrigation, plant population and nitrogen in a cool, humid climate. Can. J. Plant Sci, 66:453-464.

BROWN, D.M. and CHAPMAN, L.J. 1961. Soybean ecology III: Soybean development units for zones and varieties in the Great Lakes region. Agron. J. 53:306-308.

BROWN, D.M. and PLACE, R.E. 1989. Rating climate in southwestern Ontario for horticultural crops. Can. J. Plant Sci. 69:325-336.

BROWN, D.M., McKAY, G.A. and CHAPMAN, L.J. 1968. The climate of Southern Ontario. Dept. of Transport, Meteorological Branch, Toronto. Climatological Studies No. 5. 50 pp.

BROWN, D.M.; McKAY, G.A. and WILLIAMS, G.D.V. 1967. Some recommendations on standard limits and formats for presentation of agroclimatic analyses. Agrometeorol. Sect., PRI, CDA, Ottawa. Tech. Bull. 16. 6 pp.

BURNETT, R.B., FALK, G.W. and SHAYKEWICH, C.F. 1985. Determination of climatically suitable areas for soybean (Glycine max L. Merr.) production in Manitoba, Can. J. Plant Sci. 65:511-522.

CAIAZZA, R., HAGE, K.D. and GALLUP, D. 1978. Wet and dry deposition of nutrients in central Alberta. Water, Air and Soil Pollution, 9:309-314.

CAMPBELL, C.A., PELTON, W.L. and NIELSON. 1969. Influence of solar radiation and soil moisture on growth and yield of Chinook wheat. Can. J. Plant Sci. 49:685-699.

CAMPBELL, J.B. 1971. The Swift Current Research Station, 1920-1970. Canada Department of Agriculture, Historical Series No. 6. 79 pp.

CANADIAN FORESTRY SERVICE. 1978. Proceedings of the Symposium on Forestry Meteorology, sponsored by the World Meteorological Organization and hosted by the Canadian Forestry Service and the Atmospheric Environment Services of the Departments of Fisheries and Environment at the University of Ottawa, Ottawa, Ontario, Canada, August 21-25, 1978. Published on behalf of WMO by the Canadian Forestry Service. WMO - No. 527. 234 pp.

CANNEGIETER, H.G. 1963. The history of the International Meteorological Organization 1872-1951. Annalen der Meteorologie, Neue Folge Nr. 1. Selbstverlag des Deutschen Wetterdienstes, Offenbach a. M. pp. 198-203

CARDER, A.C. 1957. Growth and development of some field crops, as influenced by climatic phenomena at two diverse latitudes. Can. J. Plant Sci. 37:392-406.

CARDER, A.C. 1960. Atmometer assemblies: a comparison. Can. J. Plant Sci.40:700-706.

CARDER, A.C. 1961a. Climate of the Beaverlodge area. In: Soil survey of the Beaverlodge and Blueberry Mountain sheets. Alberta Soil Survey Report, 20:104-109.

CARDER, A.C. 1961b. Rate of evaporation from a free-water surface as influenced by exposure. Can. J. Plant Sci. 41:199-203.

CARDER, A.C. 1962. Climatic trends in the Beaverlodge area. Can. J. Plant Sci. 42:698-706.
CARDER, A.C. 1965. Climate of the upper Peace River region. Can. Dept. Agric. Publ. 1224.
CARDER, A.C. 1968. The black Bellani-type atmometer as an instrument to estimate the evapotranspiration of crop plants. Int. J. Biometeorol. 12:11-14.
CARDER, A.C. 1970. Climate and rangelands of Canada. Can. J. Range Management. 23:263-267.
CARDER, A.C. 1971. Climate of the lower Peace River region. Can. Dept. Agric. Publ. 1408. 89 pp.
CARDER, A.C. and HENNIG, A.M.F. 1966. Soil moisture regimes under fallow, wheat and red fescue in the upper Peace River region. Agric. Meteorol. 3:311-331.
CCA. 1977. Climatic variability in relation to agricultural productivity and practices. Theme papers prepared for the 1977 CCA Meeting, Winnipeg, Man. 11-12 January 1977. Canada Committee on Agrometeorology. Research Branch, CDA, Ottawa. 222 pp.
CCP. 1979. Proceedings of the CCP Agriculture-Climate Workshop, November 22-23, 1979, Ottawa. Sponsored by: Agriculture Canada (Research Branch) and Environment Canada (Atmospheric Environment Service). 87 pp.
CHAPMAN, L.J. 1953. The climate of Northern Ontario. Can. J. Agric. Sci.33:41-73.
CHAPMAN, L.J. and BROWN, D.M. 1966. The climates of Canada for agriculture. Can. Dept. Forestry Rural Develop., Can. Land Inventory, Rep. No. 3. 24 pp. + 19 maps.
CHAPMAN, L.J. and DERMINE, P. 1961. Evapotranspiration at Kapuskasing, Ontario. Can. J. Plant Sci. 411:563-567.
CHAPMAN, L.J. and MERCIER, R.G. 1956. Peach climate in Ontario. In: 1955-56 Report of the Horticultural Experiment Station and Products Laboratory, Vineland, Ontario. pp. 6-21.
CHAPMAN, L.J. and THOMAS, M.K. 1968. The climate of Northern Ontario. Canada Dept. of Transport, Meteorol. Br. Climatological Studies No. 6.
CHEPIL, W.S. 1945. Dynamics of wind erosion: I. Nature of movement of soil by wind. Soil Sci. 60:305-320.
CHEPIL, W.S. and MILNE, R.A. 1939. Comparative study of soil drifting in the field and in a wind tunnel. Sci. Agric. 19:249-257.
COLIGADO, M.C. and BROWN, D.M. 1975. A biophoto-thermal model to predict tassel initiation time in corn (Zea mays L.). Agric. Meteorol. 15:11-31.
COLIGADO, M.C., BAIER, W. and SLY, W.K. 1968. Risk analysis of weekly climatic data for agricultural and irrigation planning for Swift Current, Saskatchewan. Agrometeorology Section, PRI, CDA, Ottawa. Tech. Bull. 43. 8 pp. + 26 tables.
CONNOR, A.J. 1918. Relation of the weather to the yield of wheat in Manitoba. Mon. Bull. Agric. Statist. April. 11 pp.
CONNOR, A.J. 1922. Modal atmospheric streaming in wet and dry seasons in the Canadian wheat region. Bull. Amer. Met. Soc. 3:35-36.
CONNOR, A.J. 1926. The distribution of precipitation in Canada. The Canada Year Book. pp. 42-46.
CONNOR, A.J. 1931. Agriculture, climate and population of the Prairie Provinces of Canada. Dominion Bureau of Statistics. pp. 9-21.
CONNOR, A.J. 1932. Droughts in Western Canada. The Canada Year Book. 128pp.
CONNOR, A.J. 1939. The Climate of Manitoba. Economic Survey Board, Winnipeg. Report No. 16. 163 pp. + tables + maps.
CONNOR, A.J. 1941. Snowfall maps of Canada. Proc. Cent. Snow Conf., Michigan State College, East Lansing. 1:153-159.
CORBET, P.S. 1972. The microclimate of arctic plants and animals, on land and in fresh water. Acta Arctica. Arktisk Institut, Kφbenhavn, Munksgaard. Fasc. XVIII. 43 pp.
CORDUKES, W.E. and ROBERTSON, G.W. 1963. Note on the temperature distribution within an oat crop. Can. J. Plant Sci. 43:235-239.
CUDBIRD, B.S.V. 1963. Means, standard deviations, tendencies, and extremes of pressure and temperature at selected Canadian Stations. Meteorol. Br. Tech. Cir. 448. 44 pp.
CURRIE, B.W. 1948. The vegetative and frost-free seasons of the Prairie Provinces and the Northwest Territories. Can. J. Research, 26C:1-14.
CUTFORTH, H.W. and SHAYKEWICH, C.F. 1990. A temperature response function for corn development. J. Agric. and For. Meteorol. 50:159-171.

CUTFORTH, H.W., SHAYKEWICH, C.F. and CHO, C.M. 1986. Effect of soil water and temperature on corn (Zea mays L.) root growth during emergence. Can. J. Soil Sci. 66:51-58.

CUTFORTH, H.W., SHAYKEWICH, C.F., and CHO, C.M. 1987. A model to estimate the time to emergence for corn under field conditions. Can. J. Soil Sci. 67:659-665.

DAVIDSON, H.R. 1980. Solar energy applications in agriculture. Proc. Saskatchewan Energy Show, Saskatoon, Sask. (July).

DAVIDSON, H.R. and CAMPBELL, C.A. 1983. The effect of temperature, moisture and nitrogen on the rate of development of spring wheat as measured by degree days. Can. J. Plant Sci. 63:833-846.

DAVIDSON, H.R. and CAMPBELL, C.A. 1984. Growth rates, harvest index and moisture use of Manitou spring wheat as influenced by nitrogen, temperature, and moisture. Can. J. Plant Sci. 64:825-839.

DE JONG, R. 1981. Soil-water models: a review. LLRI, Research Branch, CDA. Contribution No. 123. 39 pp.

DE JONG, R. and BOOTSMA, A. 1988. Estimated long-term soil moisture variability on the Canadian prairies. Can. J. Soil Sci. 68:307-321.

DE JONG, R. and CAMERON, D.R. 1979. Computer simulation model for predicting soil-water content profiles. Soil Sci. 128:41-48.

DE JONG, R. and HAYHOE, H.N. 1984. Diffusion-based soil-water simulation for native grassland. Agric. Water Manage. 9:47-60.

DE JONG, R. and SLY, W.K. 1985. Comparison of modelled soil water reserves on Canadian prairie soils with water-holding capacities of 280 and 250 mm. Can. J. Soil Sci. 65:219-223.

DE JONG, R., SHAYKEWICH, C.F. and REIMER, A. 1980. The calculation of net radiation flux. Arch. Met. Geoph. Biolkl. B, 28:353-363.

DENMEAD, O.T., NULSEN, R. and THURTELL, G.W. 1978. Ammonia exchange over a corn crop. Soil Sci. Soc. Am. J. 42:840-842.

DESJARDINS, R.L. 1977. Description and evaluation of a sensible heat flux detector. Boundary-Layer Meteorol. 11:147-154.

DESJARDINS, R.L. 1986. Présentation d'une expérience Canadienne dans le domaine de la télédétection et de recherche atmosphérique. Technical Report of INRA.

DESJARDINS, R.L., ALLEN, H.A. Jr. and LEMON, E.R. 1978. Variations of carbon dioxide, air temperature, and horizontal wind within and above a maize crop. Boundary-Layer Meteorol. J. 14:369-380.

DESJARDINS, R.L. and HANSEN, R.O. 1967a. A topoclimatic study in the arboretum. PRI, CDA, Ottawa, Greenhouse-Garden-Grass, 6(2):1-5.

DESJARDINS, R.L. and HANSEN, R.O. 1967b. Wind response of black porous disc and Bellani plate atmometers. Can. J. Plant Sci. 47:493-498.

DESJARDINS, R.L. and ROBERTSON, G.W. 1968. Variations of meteorological factors in a greenhouse. Can. Agric. Eng. 10:85-89.

DESJARDINS, R.L. and SIMINOVITCH, D. 1968. Microclimatic study of the effectiveness of foam as protection against frost. Agric. Meteorol. 5:291-296.

DESJARDINS, R.L., BRACH, E.J., ALVO, P. and SCHUEPP, P.H. 1982. Aircraft monitoring of surface carbon dioxide exchange. Science, 14:733-735.

DESJARDINS, R.L., BUCKLEY, D. and St-AMOUR, G. 1984. Eddy flux measurements of CO_2 using a microcomputer system. Int. J. of Agric. Meteorol. 32:257-265.

DESJARDINS, R.L., MacPHERSON, I., ALVO, P. and SCHUEPP, P.H. 1984. Measurements of turbulent heat and CO_2 exchanges over forest from aircraft. In: B.A. Hutchinson, Ed., Forest Environmental Measurements. D. Reidel Publishing Company. pp. 645-658.

DESJARDINS, R.L., MacPHERSON, I., SCHUEPP, P.H. and KARANJA, F. 1989. An evaluation of airborne eddy flux measurements of CO_2, water vapour, and sensible heat. Boundary-Layer Meteorol. 47:55-70.

DESJARDINS, R.L.; MACK, A.R.; MacPHERSON, J.I. and SCHUEPP. P.H. 1987.Characterizing crop conditions using airborne CO_2 flux measurements and Landsat-D MSS data. pp. 97-100. In: Proceedings of the 18th Conf. on Agric. and Forest Meteorol., West Lafayette, Ind. LRRC Contribution No. 87-56.

DICKISON, R.B.B. and DAUGHARTY, D.A. 1977. Effects of forest cover and topography on snow cover in the Nashwaak Experimental Watershed Project. pp. 245-250. In: Preprints, Second Conf. on Hydrometeorol., Amer. Meteorol. Soc., Oct. 25-27, 1977, Toronto, Ont.

DICKISON, R.B.B. and DAUGHARTY, D.A. 1980. Effects of forest cover and topography on snow cover in central New Brunswick, Canada. pp. 329-335. In: Proc. IHS Sym. on The influence of Man on the Hydrologic Regime with Special Reference to Representative and Experimental Basins. Helsinki, June 1980. IASH-AISH, Publ. No. 130.

DICKISON, R.B.B. and DAUGHARTY, D.A. 1984. Influence of forest cover and forest removal on accumulation and melting of snow in an eastern Canada catchment study. pp. 419-447. In: Proc. DVWK/IUFRO Workshop on Snow Hydrologic Research in Central Europe. Hann.-Munden, W. Germany, 12-15 March 1984. Bonn.

DICKISON, R.B.B. and STEEVES, B.G. 1988a. Meteorological operations in support of pheromone spray trials, 7 July 1988. AWEC. Rept. produced for Dept. Biol., Univ. N.B., Fredericton. 18 pp.

DICKISON, R.B.B. and STEEVES, B.G. 1988b. The measurement of site-specific weather for aerial pesticide applications. pp. 209-214. In: Proc. Sym. on The Aerial Application of Pesticides in Forestry, 20-22 Oct. 1987, Ottawa (G.W. Green, ed.). Nat. Res. Coun. Assoc. Comm. Agric. For. Aviation. Rept. AFA-TN-18 (NRC No. 29197). ix + 387 pp.

DICKISON, R.B.B., DAUGHARTY, D.A. and RANDALL, D.K. 1981. Some preliminary results of the hydrologic effects of clear cutting a small watershed in central New Brunswick. pp. 59-74. In: Proc. 5th Can. Hydrotech. Conf. Can. Soc. Civ. Eng., Fredericton, NB, 26-27 May 1981.

DICKISON, R.B.B., HAGGIS, M.J., RAINEY, R.C. and BURNS, L.M.D. 1983.Spruce budworm moth flight and storms: case study of a cold front system. J. Clim. Appl. Meteorol. 22:278-286.

DOUGLAS, R.H. 1978. Development and modification of the thermal environment in corn. In: Essays on Meteorology and Climatology, (K.D. Haig and E.R. Reinelt, eds.). University of Alberta (Department of Geography), Mono. 3.

DWYER, L.M. and HAYHOE, H.N. 1985. Comparison of observations and macroclimatic model estimates of monthly winter soil temperatures at Ottawa. Can. J. Soil Sci. 65:109-122.

DWYER, L.M. and STEWART, D.W. 1984. Indicators of water stress in corn (Zea mays L.). Can. J. Plant Sci. 64:537-546.

DWYER, L.M. and STEWART, D.W. 1985. Water extraction patterns and development of plant-water deficits in corn. Can. J. Plant Sci. 65:921-933.

DWYER, L.M. and STEWART, D.W. 1986. Leaf area development in field-grown maize. Agron. J. 78:334-343.

DWYER, L.M. and STEWART, D.W. 1987. Influence of photoperiod and water stress on growth, yield and development rate of barley measured in heat units. Can. J. Plant Sci. 67:21-34.

DWYER, L.M., STEWART, D.W. and BALCHIN, D. 1988. Rooting characteristics of corn, soybeans and barley as a function of available water and soil physical characteristics. Can. J. Soil Sci. 68:121-132.

DYER, J.A. 1989. Proxydays - an algorithm for generating realistic normal sequences of daily rainfall from monthly climatic normals. Climatological Bull. 23:119-131.

DYER, J.A. and BAIER, W. 1978. Weather-based selection of tractor sizes. Agric. Can. pp. 22-23.

DYER, J.A. and BAIER, W. 1979. Weather-based estimation of field workdays in fall. Can. Agric. Eng. 21:119-122.

DYER, J.A. and BAIER, W. 1980. The influence of zones in budgeting plant-available soil moisture. Can. Agric. Eng. 22:65-70.

DYER, J.A. and BOISVERT, J. 1985. Potential future developments in soil moisture budget models for humid regions in Canada. Can. Water Resources J. 10:1-13.

DYER, J.A. and BROWN, D.M. 1977. A climatic simulator for field-drying hay. Agric. Meteorol. 18:37-48.

DYER, J.A. and DeJAGER, J.M. 1986. The predictability of summer droughts in South African grassland. Water International. 11:78-87.

DYER, J.A. and DWYER, L.M. 1982. Root extraction coefficients for soil moisture budgeting derived from measured root densities. Can. J. Agric. Eng. 24:81-86.

DYER, J.A. and DWYER, L.M. 1982. Root extraction coefficients for soil moisture budgeting derived from measured root densities. Can. Agric. Eng. 24:81-86.

DYER, J.A. and MACK, A.R. 1984. The versatile soil-moisture budget version three. LRRI Contribution No. 82-33. Research Branch Tech. Bull. 1984-E. 59 pp.

DYER, J.A. and MACK, A.R. 1986. A drought early warning system for Africa. Prepared for CIDA under terms of an Interdepartmental Letter of Agreement, R. & E. Report, 86-3. Resource and Environment Section, Agriculture Development Branch, CDA, Ottawa. 34 pp.

DYER, J.A., BAIER, W., HAYHOE, H.N. and FISHER, G. 1978. Spring field workday probabilities for selected sites across Canada. Agric. Can. Tech. Bull. 86. 96 pp.

DYER, J.A., HICKS, B.B. and KING, K.M. 1967. The fluxatron: a revised approach to the measurement of eddy fluxes in the lower atmosphere. J. Appl. Meteorology, 6:408-413.

DYER, J.A., STEWART, R.B. and MUMA, R.W. 1982. A weather-based drought monitoring scheme for spring forage in Western Canada. Can. Farm Economics, 17:9-16.

DYER, J.A., STEWART, R.B. and WARNER, D.G. 1981. Environmental resources in crop production. Can. Farm Economics, 16:27-30.

EDEY, S.N. 1985. The role of the micro-logger in the taking of standard agroclimatic observations at Agricultural Research Stations. Research Branch Internal Report. 31 pp.

EDEY, S.N. and JOYNT, M.J. 1975. Mechanical and thermal characteristics of the soil at selected agrometeorological stations. Agrometeorol. Sect., CBRI, CDA, Ottawa. Tech. Bull. 84. 40 pp.

EDEY, S.N., BUCKLEY, D.J., LaLONDE, M.J.L. and NICHOLLS, C.F. 1986a.Automatic retrieval of agrometeorological data using a microcomputer and radio telemetry. Computers and Electronics in Agriculture.

EDEY, S.N., BUCKLEY, D.J., LaLONDE, M.J.L. and NICHOLLS, C.F. 1986b. Automated monitoring of depth of snow on ground. Agric. and Forestry Meteorol.

EDEY, S.N., WILLIAMS, G.D.V. and ROBERTSON, G.W. 1968. Climatic normals and deviations and freezing probabilities at the Central Experimental Farm, Ottawa. Agrometeorology Section, PRI, CDA, Ottawa. Tech. Bull. 15. 50 pp.

GAUER, E.L., SHAYKEWICH, C.F. and STOBBE, E.H. 1982. Soil temperature and soil water under zero tillage in Manitoba. Can. J. Soil Sci. 62:311-32.

GILLESPIE, T.J. and DUAN, R. X. 1987. A comparison of cylindrical and flat-plate sensors for surface wetness duration. Agric. and Forest Meteorol. 40:61-70.

GILLESPIE, T.J. and KING, K.M. 1971. Nighttime sink strengths and apparent diffusivities within a corn canopy. Agric. Meteorol. 8:59-67.

GILLESPIE, T.J. and Sutton, J.C. 1979. A predictive scheme for timing fungicide applications to control Alternaria leaf wilt in carrots. Can. J. Plant Path. 1:95-99.

GORDON, R., LECLERC, M.Y., SCHUEPP, P.H. and BRUNKE, R.R. 1988. Field estimates of ammonia volatilization from swine manure by a simple micrometeorological technique. Can. J. Soil Sci. 68:369-380.

GREEN, G.W. 1954. Humidity reactions and water balance of larvae of Neodiprion americanus banksianae Roh. and N. lecontei (Fitch) (Hymenoptera: Diprionidea). Can. Ent. 86:261-274.

GREEN, G.W. 1955. Temperature relations of ant-lion larvae (Neuroptera Myrineleontidae). Can. Ent. 87:441-459.

GREEN, G.W. 1968. Weather and insects. Proc. 28th Ann. Biol. Colloquiim, Oregan State University, (1967). pp.81-112.

HAGE, K.D. 1971. Microscale and mesoscale transport. In: Meteorological aspects of pollution in relation to agricultural pesticides. Canada Committee on Agricultural Meteorollogy, CDA. 25-32.

HAGE, K.D. 1975. Averaging errors in monthly evaporation estimates. Water Resources Research. 11:359-361.

HAGE, K.D. 1985. Weather extremes in Alberta: 1880 to 1960. Climatological Bulletin. 19:3-15.

HARRIS, R.E. 1975. Plant responses to northern environments. Can. Agric. 20:7-9.

HARRIS, R.E. and CARDER, A.C. 1974. Rain and snow gauge comparisons. Can. J. Earth Sci. 11:557-564.

HAUFE, W.O. 1957. Importance of air movement as a factor in mathematical expressions for biological response to environment. Intl. J. Biometeorol. 1B:1-2.

HAUFE, W.O. 1963. Entomological biometeorology. Intl. J. Biometeorolo. 7:129-136.

HAUFE, W.O. 1976. Development and application of biometeorology. Intl. J. Biometeorol. 20:92-96.

HAYHOE, H.N. 1973. Weather effects on field drying of forages a review. Naturaliste Can. 100:395-405.

HAYHOE, H.N. 1978. Study of the relative efficiency of finite difference and Galerkin techniques for modelling soil-water transfer. Water Resour. Res. 14:97-102.

HAYHOE, H.N. 1980. Calculation of workday probabilities by accumulation over sub-periods. Can. Agric. Eng. 22:71-75.

HAYHOE, H.N. and BAIER, W. 1974. Markov chain model for sequences of field workdays. Can. J. Soil Sci. 54:137-148.

HAYHOE, H.N. and BAILEY, W.G. 1985. Monitoring changes in total and unfrozen water content in seasonally frozen soil using time domain reflectometry and neutron moderation techniques. Water Resour. Res. 21:1077-1084.

HAYHOE, H.N. and BALCHIN, D. 1988. Combined time-domain reflectometry and electrical conductance measurements for analysis of seasonal soil frost. Cold Regions Science and Technology. 15:195-200.

HAYHOE, H.N. and DE JONG, R. 1987. Comparison of two soil-water models for soybeans. Can. Agric. Eng. 30:5-11.

HAYHOE, H.N. and JACKSON, L.P. 1974. Weather effects on hay-drying rates. Can. J. Plant Sci. 54:479-484.

HAYHOE, H.N. and MUKERJI, M.K. 1987. Influence of snow cover on soil temperature in the biologically active zone. In: Proc. 11th International Congress of Biometeorology, 13-18 September 1987, West Lafayette, Ind., AMS, Boston, Mass. pp. 45-48.

HAYHOE, H.N., BOOTSMA, A.. and DWYER, L.M. 1987. Monitoring and analysis of soil temperature regimes for soil climate classification. Can. J. Soil Sci. 67:667-678.

HAYHOE, H.N., MACK, A.R., BRACH, E.J. and BALCHIN, D. 1986. Evaluation of the electrical frost probe. J. Agric. Eng. Res. 33:281-287.

HAYHOE, H.N., TASNOCAI, C., and DWYER, L.M. 1990. Soil management and vegetation effects on measured and estimated soil thermal regimes in Canada. Can. J. Soil Sci. 70:61-71.

HAYHOE, H.N., TOPP, G.C. and EDEY, S.N. 1983. Analysis of measurement and numerical schemes to estimate frost and thaw penetration of a soil. Can. J. Soil Sci. 63:67-77.

HEENEY, H.B., MILLER, S.R. and RUTHERFORD, W.M. 1961. A meteorological method of calculating the irrigation requirements of the canning tomato crop. Can. J. Plant Sci. 41:31-41.

HEIKINHEIMO, M., THURTELL, G.W. and KIDD, G.E. 1988. An open path IR-gas analyser for simultaneous eddy-correlation measurements of carbon dioxide and water vapour. J. Atmos. Oceanic Technol. 6:624-636.

HELSON, V.A. 1965. Comparison of Gro-Lux and cool-white fluorescent lamps with and without incandescent as light sources used in plant growth rooms for growth and development of tomato plants. Can. J. Plant Sci. 45:461-466.

HEWSON, E.W. 1945. The meteorological control of atmospheric pollution by heavy industry. Quart. J. Roy. Met. Soc., 71:266-282.

HOBBS, E.H. and KROGMAN, K.K. 1968. Observed and estimated evapotranspiration in southern Alberta. Trans. Am. Soc. Agric. Eng. 11:502-503, 507.

HOBBS, E.H., KROGMAN, K.K. and SONMOR, L.G. 1963. Effects of levels of minimum available soil moisture on crop yields. Can. J. Plant Sci. 43:441-446.

HOLMES, R.M. and CARSON, H.W. 1964. Carbon dioxide flux in nature. Agrometeorology Section, PRI, CDA, Ottawa. Tech. Bull. No. 2. 28 pp.

HOLMES, R.M. and ROBERTSON, G.W. 1958a. Conversion of latent evaporation to potential evapotranspiration. Can. J. of Plant Sci. 38(2):164-172.

HOLMES, R.M. and ROBERTSON, G.W. 1958b. Note on a portable field growth chamber for winter injury studies. Can. J. of Plant Sci. 38:377-379.

HOLMES, R.M. and ROBERTSON, G.W. 1959a. A modulated soil moisture budget. Monthly Weather Review, 87(3):1-7.

HOLMES, R.M. and ROBERTSON, G.W. 1959b. Heat units and crop growth. CDA, Ottawa, Publ. No. 1042. 32 pp.

HOLMES, R.M. and ROBERTSON, G.W. 1960. Soil heaving in alfalfa plots in relation to soil and air temperature. Can. J. Soil Sci. 40:212-218.

HOLMES, R.M. and ROBERTSON, G.W. 1964. The calculation of the soil moisture profile under various conditions using the modulated soil-moisture budget. In: Land Erosion, Precipitation, Hydrology, Soil Moisture. IUGG, IASH, Publ. No. 65, pp. 454-461.

HOLMES, R.M., GILL, G.C. and CARSON, H.W. 1964. A propeller-type vertical anemometer. J. Appl. Meteorol. 3:802-804.

HOPKINS, J.W. 1935. Weather and wheat yields in western Canada, I. Influence of rainfall and temperature during the growing season on plot yields. Can. J. Res. 12:306-334.

HOPKINS, J.W. 1936. Agricultural meteorology: Some characteristics of precipitation in Alberta and Saskatchewan. Can. J. Res. C, 14:319-346.

HOPKINS, J.W. 1938a. Agricultural meteorology: Correlation of air temperatures in central and southern Alberta and Saskatchewan with latitude, longitude and altitude. Can. J. Res. C, 16:16-26.

HOPKINS, J.W. 1938b. Influence of air temperature and soil moisture subsequent to flowering on the nitrogen content of wheat. Can. J. Res. C, 16:135-144.

HOPKINS, J.W. 1939. Estimation of leaf area in wheat from linear dimensions. Can. J. Res. C, 17:300-304

HOPKINS, J.W. 1941. Agricultural Meteorology: Seasonal incidence of rainless and rainy periods at Winnipeg, Swift Current, and Edmonton. Can. J. Res. C, 19:267-277.

IMO. 1914. Report of the Tenth Meeting, Rome 1913. His Majesty's Printing Office, London. M.O. No. 216. 95 pp.

IMO. 1949. Commission for Agricultural Meteorology, 8th Session at Toronto, Canada from 11th to 23nd August, 1947 - Abridged Final Report. International Meteorological Organization, Publ. No. 63, Imprimerie la Concorde, Lausanne, Suisse. 32 pp.

JARVIS, T.D. 1931. The "coincidence" as a major factor in agriculture. Sci. Agric. 11:760-774.

JOZSA, L.A. and POWELL, J.M. 1987. Some climatic aspects of biomass productivity of white spruce stem wood. Can. J. For. Res. 17:1075-1079.

KENDALL, G.R. and PETRIE, A.G. 1962. The frequency of thunderstorm days in Canada. Meteorol. Br. Tech. Cir. 418. 21 pp.

KING, K.M. 1978. Modelling evapotranspiration. In: Proceedings of the International Workshop on the Agrometeorological Research Needs of the Semi-Arid Tropics. ICRISAT, Hyderabad.

KING, K.M. and GREER, D.H. 1986. Effects of CO_2 enrichment and soil water on maize. Agron. J. 78:515-521.

KING, K.M. and THURTELL, G.W. 1986. Measurement and prediction of evapotranspiration for agriculture. In: D.G. MacIver and R.B. Street (eds.) Proceedings of the Workshop on Evapotranspiration, Irrigation and Plant Moisture Stress in Agriculture and Forestry. AES, Downsview. pp. 21-35.

LAYCOCK, A.H. 1960. Drought patterns in the Canadian prairies. Int. Ass. Sci. Hydrol. Publ. No.51. pp. 34-47.

LAYCOCK, A.H. 1967. Water deficiency and surplus patterns in the Prairie Provinces. Prairie Provinces Water Board. Regina. Rep. No. 13. 185 pp.

LEHANE, J.J. and STAPLE, W.J. 1965. Influence of soil texture, depth of soil moisture storage and rainfall distribution on wheat yields in southwestern Saskatchewan. Can. J. Soil Sci. 45:207-219.

LOISELLE, M. 1984. An on-line drought index for forest-fire management purposes. Ontario Region, AES, SSD-84-2.

LONGLEY, R.W. 1967a. Temperature increases under snow during a mild spell. Soil Sci. 104:379-382.

LONGLEY, R.W. 1967b. The frost-free period in Alberta. Can. J. Plant Sci.47:239-249.

LONGLEY, R.W. 1970. Climate classification for Alberta forestry. Proc. 3rd Forest Microclimate Symp., Kananaskis, Alberta, Sept. 1969. Can. Forestry Serv., Calgary. pp. 147-153.

LONGLEY, R.W. and THOMPSON, C.E. 1965. A study into the causes of hail. J. Appl. Meteorol. 4:69-82

MacHATTIE, L.B. 1958. The accuracy of the hair hygrograph. Meteorol. Br. Tech. Cir. 265. 9 pp + figs.

MacHATTIE, L.B. 1963. Winter injury of lodgepole pine foliage. Weather. 18:301-307

MacHATTIE, L.B. 1966. Relative humidity in Rocky Mountain forests of southern Alberta in summer. Can. Dept. of Forestry, Forest Res. Inst., Ottawa. Information Rep. FF-X-1. 54 pp.

MacHATTIE, L.B. 1979. Meteorology and forest insect control in Canada, pp.139-148. In Proc. of the WMO Symposium on Forestry Meteorology, August 21-25, 1978. Published by the Can. For. Serv. on behalf of WMO. WMO-527. 234 pp.

MACK, A.R. 1963. Biological activity and mineralization of nitrogen in three soils as induced by freezing and drying. Can. J. Soil Sci. 43:316-324.

MACK, A.R. 1965. Effect of soil temperature and moisture on yield and nutrient uptake by barley. Can. J. Soil Sci. 45:337-346.

MACK, A.R. 1973. Influence of soil temperature and moisture conditions on growth and protein production of Manitou and two semi-dwarf Mexican spring wheats. Can. J. Soil Sci. 73:721-735.

MACK, A.R. and BOOTSMA, A. 1984. Agroclimatic resource maps for agriculture in Canada. Can. Agric. 30:16-20.

MACK, A.R. and EVANS, W.A. 1965. Soil temperature control system for field plots. Can. J. Soil Sci. 45:105-107.

MACK, A.R. and KING, G.J. 1979. Improving Canadian information on world crop statistics. The crop information system based on remotely sensed and weather data. A summary of presentations made at a seminar on the Crop Information System - a review. Ed.: A.J. Kin. Commodity Market Analysis Division, Policy, Planning and Economics Br. CDA. 144 pp.

MACK, A.R. and WALLEN, V.R. 1974. Effects of various field levels of soil temperature and soil moisture on the growth of beans infected with bacterial blight. Can. J. Soil Sci. 54:149-158.

MACK, A.R., BRACH, E.J. and RAO, V.R. 1980. Changes in the spectral characteristics of cereal crops with physiological development. Can. J. Plant Sci. 60:411-417.

MACK, A.R., BRACH, E.J. and RAO, V.R. 1978. Investigation of crop spectra and selection of optimal spectral channels. Can. J. Spectrosc. 23:42-51.

MACK, A.R., BRACK, E.J. and RAO, V.R. 1983. Appraisal of multi-spectral analyses of high-resolution crop spectra. Int. J. Remote Sens. 5:279-288.

MACK, A.R., SCHUBERT, J., GOODFELLOW, C., CHOGARLAMUDI, P. andMOORE, H. 1977. Global agricultural productivity estimation from Landsat data. Proc. 4th Can. Symp. on Remote Sensing, Quebec City. May 1977. pp. 8-18.

MAIN, T.C. 1935. Water conservation in the Prairie Provinces. Eng. J. Montreal.18:212-218/221-231.

McCALLA, A.G., WEIR, J.R. and NEATBY, K.W. 1939. Effects of temperature and sunlight on the rate of elongation of stems of maize and gladiolus. Can. J. Res. C, 17:388-409.

McDOUGAL. E.G. 1920. Influence of climate on the yield and quality of sugar beets in Canada. Mon. Bull. Agric. Statist. 13:295-301.

McKAY, G.A. and THOMPSON, H.A. 1968. Snow cover in the prairie provinces of Canada. Trans. Amer. Soc. Agr. Eng. 11:812-815.

McKAY, G.A. 1961. A detailed map of Prairie annual precipitation. Can. Dept. Transport, Meteorol. Br. Cir. 3159, Tec-365. 8 pp.

McKAY, G.A. 1963. The analysis of storm rainfall information. Can. Dept. Agric. PFRA Met. Report No. 10. 31 pp.

McKAY, G.A. 1964a. Meteorological measurements for watershed research. Proc. NRC Hydrol. Sym. No. 4, Research Watersheds. pp. 185-209.

McKAY, G.A. 1964b. Statistical estimates of probable maximum rainfall on the Prairie Provinces. Can. Dept. Agric. PFRA, Eng. Br. Met. Report No. 7, (revised). 16 pp.

McKAY, G.A. 1965. Climatic maps of the Prairie Provinces for Agriculture. Can. Dept. Transport, Meteorol. Br. Climatological Studies No. 1, Toronto. 18 pp.

McKAY, G.A. 1968. Meteorological conditions leading to the project design and probable maximum flood on the Paddle River, Alberta. Trans. Am. Soc. Agric. Eng. 11:821-823.

McKAY, G.A. 1979. Perceptions of the economic implications of climate variability. Environ. Can. Atmos. Environ. Serv., Can. Cli. Centre, Report No. 79-11E. 12 pp.

McKAY, G.A., MAYBANK, J., MOONEY, O.R. and PELTON, W. 1967. The agricultural climate of Saskatchewan. Can. Dept. Transport, Meteorol. Br. Climatological Studies No. 10. 110 pp.

McKIBBON, R.R. 1933. Climate and soil leaching variation in Quebec. Sci. Agric. 13:413-425.

MILLS, P.F. 1984. Fort Vermilion Experimental Farm. Weather observations for 1983 plus summaries and averages for 49 years of continuous recording. North Res. Group Publ. 84-9.

MILLS, P.F. 1987. Beaverlodge meteorological station 1986 weather observations with 71 years long-term averages. North Res. Group Publ. 87-03. 10 pp.

MUKAMMAL, E.I. 1965. Ozone as a cause of tobacco injury. Agr. Meteorol.,2:145-165.

MUKAMMAL, E.I. 1969. Air pollutants, meteorology, and plant injury. Tech. Note No. 96. WMO No. 234. 73 pp.

MUKAMMAL, E.I., MCKAY, G.A. and TURNER, V.R. 1971. Mechanical balance - electrical-read-out weighing lysimeter. Boundary-Layer Meteorology, 2:207-217.

MUKAMMAL, E.I. 1971. Some aspects of radiant energy in a pine forest. Arch. Meteorol. Geoph. Biokl. Ser. B, 19:29-52.

MUKAMMAL, E.I. 1976. Review of present knowledge of plant injury by air pollution. Tech. Note No. 147, WMO No. 431. 27 pp.

MUKAMMAL, E.I. 1981. Incidence of mesoscale convergence lines as input to spruce budworm control strategies. Inter. J. Biometeorol. 25:175-187.

MUKAMMAL, E.I. 1985. Some features of the ozone climatology of Ontario, Canada, and possible contributions of stratospheric ozone to surface concentrations. Arch. Met. Geoph. Biokl. Ser. A, 34:179-211.

MUKAMMAL, E.I. and NEUMANN, H.H. 1977. Application of the Priestley-Taylor evaporation model to the influence of soil moisture on the evaporation from a large weighing lysimeter and Class A pan. Boundary-Layer Meteorol. 12:243-256.

MUKAMMAL, E.I., KING, K.M. and CORK, H.F. 1966. The use of aerodynamic techniques in estimating evapotranspiration from a cornfield and the difficulties encountered. Arch. Met. Geophys. Bioklimatol. Series B, 14:384-395.

MUKAMMAL, E.I., NEUMANN, H.H. and GILLESPIE, T.J. 1982. Meteorological conditions associated with ozone in southwestern Ontario. Atmospheric Environment, 16:2095-2106.

MUNN, R.E. 1966. Descriptive meteorology. Advances in Geophysics, Supplement 1. Academic Press, New York. 245 pp.

NEUMANN, H.H. 1982. Recent developments in research on air pollution and plant injury. CAgM Report No. 9.

OUELLET, C.E. 1970. Climatic factors and plant winter survival. Can. Agric. 15(2):3-5.

OUELLET, C.E. 1972. Analyses of the annual cycles of soil and air temperature. Natur. Can. 99:621-634.

OUELLET, C.E. 1973a. Macroclimate model for estimating soil temperatures under short-grass cover in Canada. Can. J. Soil Sci. 53:263-274.

OUELLET, C.E. 1973b. Freezing temperatures in the top soil layer. Soil Horizons, 14(1):1-2.

OUELLET, C.E. 1973c. Estimation of monthly soil temperatures. Agrometeorology Section, PRI, CDA, Ottawa. Tech. Bull. 82. 9 pp. + 13 tables.

OUELLET, C.E. 1975. Soil and air temperatures at Ottawa. CDA, Ottawa. Publ. 1541. 29 pp.

OUELLET, C.E. 1976. Survey report of forage crop survival in Canada. Agrometeorology Research and Service, CBRI, Research Br., CDA, Misc. Bull. 5, 30 pp.

OUELLET, C.E. 1977. Monthly climatic contribution to the winter injury of alfalfa. Can. J. Plant Sci. 57:419-426.

OUELLET, C.E. 1978. Survey report on the winter survival of alfalfa. Agrometeorology (Res. and Serv.) Sect., CBRI, Research Br., CDA. Bull. 8, 17 pp.

OUELLET, C.E. and DESJARDINS, R.L. 1975. Annual variability of minimum soil temperature. Can. J. Soil Sci. 55:167-176.

OUELLET, C.E. and DESJARDINS, R.L. 1981. Interprétation des relations entre le climat et la survie à l'hiver de la luzerne par l'analyse des correlations. Can. J. Plant Sci. 61:945-954.

OUELLET, C.E. and SHERK, L.C. 1967a. New Canadian plant hardiness zone map. Greenhouse-Garden-Grass, PRI, CDA, Ottawa, 6(4):1-5.

OUELLET, C.E. and SHERK, L.C. 1967b. Woody ornamental plant zonation. III. Suitability map for the probable winter survival of ornamental trees and shrubs. Can. J. Plant. Sci. 47:351-358.

OUELLET, C.E., SHARP, W.R. and CHAPUT, D.Z. 1975. Estimated monthly normals of soil temperatures in Canada. Agrometeorology Research and Service, CBRI, Research Br., CDA. Tech. Bull. 85. 148 pp.

PARTRIDGE, J.R.D. and SHAYKEWICH, D.F. 1972. The effects of nitrogen, temperature and moisture regime on the yield and protein content of Neepawa wheat. Can. J. Plant Sci. 52:179-185.

PEDRO, M.J. and GILLESPIE, T.J. 1982. Estimating dew duration. II. Utilizing standard weather-station data. Agric. Meteorol. 25:297-310.

PELTON, W.L. and KORVEN. 1969. Evapotranspiration estimates from atmometers and pans. Can. J. Plant Sci. 49:615-621.

POTTER, J.G. 1962. Soil temperature records at eight localities in Canada 1959-1960. PRI, CDA. 31 pp.

POWELL, J.M. 1962. Climate in relation to the mountain pine beetle. p. 113. InAnnual Report Forest Entomology and Pathology Branch Year Ended March 31, 1962. Can. Dept. Forestry, Ottawa.

POWELL, J.M. 1965. Changes in amounts of sunshine in British Columbia, 1901-1960. Quart. J. Roy. Met. Soc. 91:95-98.

POWELL, J.M. 1967. A study of habitat temperature of the bark beetle Dendroctonus ponderosae Hopkins in lodgepole pine. Agric. Meteorol. 4:189-201.

POWELL, J.M. 1969. Historical study of the relation of major mountain pine-beetle outbreaks in western Canada to seasonal weather. Can. Dept. of Fisheries and Forestry, For. Res. Lab., Calgary. Inform. Rep. A-X-23. 11 pp.

POWELL, J.M. 1970. A forest climate classification for Canada - discussion. pp.227-228. In: Powelll, J.M. and C.F. Nolasco (eds). Proc. Third Forest Microclimate Symposium, September, 1969. Can. For. Serv., Albert-Territories Region, Calgary, Alberta, March.

POWELL, J.M. 1974. Environmental factors affecting germination of Cronartium comandrae aeciospores. Can. J. Bot. 52:659-557.

POWELL, J.M. 1978. Climatic networks for forestry purposes. pp. 20-32. In: Powell, J.M. (Compiler). Climatic Networks: Proc. of the Workshop and Annual Meeting of the Alberta Climatological Association, April 1978. Fish. and Environ. Can., North. For. Res. Cent., Edmonton, Alberta. Inf. Rept. NOR-X-209. 101 pp.

POWELL, J.M. 1981. Impact of Climatic Variation on Boreal Forest Biomass Production. pp. 189-194. In: Harington, C.R. (Ed.) Climatic Change in Canada 2. Nat. Museums of Can., National Museum of Natural Sciences, Ottawa, Syllogeus. No. 33. 220 pp.

POWELL, J.M. and MacIVER, D.C. 1977. A summer climate classification for the forested area of the prairie provinces using factor analysis. Fish. and Environ. Can., Can. For. Serv., North. For. Res. Centre, Edmonton, Alberta. Inf. Rept. NOR-X-177. 51 pp.

POWELL, L.B. 1932. Tree rings and wheat yields in southern Saskatchewan. Mon. Weath. Rev. 60:220-221.

PUTNAM, D.F. and CHAPMAN, L.J. 1938. The climate of Southern Ontario. Sci. Agric. 18:401-446.

REIMER, A. and SHAYKEWICH, C.F. 1980. Estimation of Manitoba soil temperature from atmospheric meteorological measurements. Can. J. Soil Sci. 60:299-309

RIPLEY, E.A. 1970. The climate of southern Saskatchewan and the Matador area. pp. 132-149. In: Grassland Ecosystems: reviews and research (R.T. Coupland and G.M. VanDyne - eds.). Fort Collins, Colo., Range Science Department, Colorado State University, Series No. 7.

RIPLEY, E.A. 1985. Prairie agriculture and society in the face of climatic change. pp. 3-8. In: Face of the Prairies - 2003 (F.A. Curtis, ed.). Community Planning Association of Canada, Regina.

RIPLEY, E.A. 1987. The climate, water use and productivity of savannas compared with other grasslands. pp. 78-106. In: La Capacidad Bioproductiva de Sabanas (J.J. San Jose and R. Montes, eds.). Instituto Venezolana de Investigaciones Cientificas, Caracas. 545 pp.

RIPLEY, E.A. 1989. The future of drought prediction on the Canadian prairies. pp. 60-83. In: Proc. of the 12th Annual General Meeting of the Alberta Climatological Association, March 1988. Environment Canada, Edmonton.

RIPLEY, E.A. and SAUGIER, B. 1972. Micrometeorological studies, 1970-71. pp.137-172. In: Measurement and Modelling of Photosynthesis in Relation to Productivity (K.M. King, ed.). Canada Committee for the International Biological Programme, Guelph Workshop December 8-10, 1972, Guelph, Ontario.

RIPLEY, E.A. and SAUGIER, B. 1974. Microclimate and production of a native grassland - a micrometeorological study. Oecol. Plant. 9:333-363.

RIPLEY, P.O. 1941. Observations on snow cover as affecting crops. Proc. Cent. Snow Conf., Michigan State College, East Lansing. 1:116-126.

RIPLEY, P.O. 1959. Progress Report 1954-1958. Field Husbandry, Soils and Agricultural Engineering Division. Experimental Farms Service, CDA, Ottawa. 41 pp.

ROBERTSON, G.W. 1953a. Some agrometeorological problems in Canada. Royal Meteorological Society, Canadian Branch, Toronto, 4(2):1-21.

ROBERTSON, G.W. 1953b. Agrometeorology. Cereal News, Cereal Division. Experimental Farms Service, CDA, Ottawa. 1(9):8-12.

ROBERTSON, G.W. 1954. Latent evaporation: its concept, measurement, and application. Seminar Paper. Field Husbandry, Soils, and Agricultural Engineering Division, Experimental Farms Service, Ottawa. 14 pp + VII figs.

ROBERTSON, G.W. 1955a. The standardization of the measurement of evaporation as a climatic factor. WMO-42, Tech. Note No. 11. WMO, Geneva. 10 pp.

ROBERTSON, G.W. 1955b. A guide to field and observational work in connection with Project F.1.8.2: "An Investigation of the Growth and Development of Crops in Relationship to Meteorological Environment". Division of Field Husbandry, Soils and Agricultural Engineering, Experimental Farm Service, Department of Agriculture, Ottawa. 11 pp.

ROBERTSON, G.W. 1955c. Data Summary for Project F.1.8.2: "An Investigation of the Growth and Development of Crops in Relation to their Meteorological Environments" - Third Report. Division of Field Husbandry, Soils and Agricultural Engineering, Experimental Farms Service, Department of Agriculture. Ottawa. 90 pp.

ROBERTSON, G.W. 1957. Weather and farm planning. Paper presented to the Ontario Soil and Crop Improvement Association. January 31, 1957. 6 pp.

ROBERTSON, G.W. 1961. Discussion on evaporation measurements. Proc. of the Hydrology Symposium No. 2, Evaporation. Toronto, 1-2 March 1961. Dept. of Northern Affairs and National Resources, Water Resources Branch, Ottawa. pp 104-105.

ROBERTSON, G.W. 1963. Estimating hay yield from climatic data. Soil Horizons. 4(1):23-27.

ROBERTSON, G.W. 1964a. A summary of literature pertaining to latent evaporation and its application to soil moisture estimation and irrigation scheduling. First Irrigation Research Workshop, 5-6 August 1964, Summerland, BC. Agrometeorology Section, CDA, Ottawa, Tech. Bull. 3. 11 pp.

ROBERTSON, G.W. 1964b. Agroclimatic parameters for soil capability classification. Land Inventory Seminar Background Papers, Winnipeg. 1(C7):1-14.

ROBERTSON, G.W. 1964c. The measurement of light energy for photochemical processes in plants. Agrometeorol. Sect., PRI, CDA, Ottawa, Tech. Bull. 4. 17 pp.

ROBERTSON, G.W. 1966a. The light composition of solar and sky spectra available to plants. Ecology, 47:640-643.

ROBERTSON, G.W. 1966b. Organization, function and 1963-66 progress report of the Agrometeorology Section. Agrometeorol. Sec. PRI, CDA. Ag. Met. Tech. Bull. 8. 12 pp.

ROBERTSON, G.W. 1966c. Soil temperatures measured during the International Forest-Soil Survey Trip in August 1965 - Note from the Plant Research Institute. Soil Horizons. 7(1):30-32.

ROBERTSON, G.W. 1967. Where does the sunshine go? Greenhouse-Garden-Grass, PRI, CDA, Ottawa, 6(3):6-8.

ROBERTSON, G.W. 1968a. A biometeorological time scale for a cereal crop involving day and night temperatures and photoperiod. Int. J. Biometeorol. 12:191-223.

ROBERTSON, G.W. 1968b. National summary of pertinent information from "Probability Analyses of Weekly Climatic Data for Irrigation and Agricultural Planning" prepared for the Annual Meeting of the National Soil Survey Committee, Edmonton, Alberta, 22-26 April 1968. Internal Report No. 10 of the Ag. Met Section, Research Branch CDA, Ottawa, 12 pp.

ROBERTSON, G.W. 1973a. Development of simplified agroclimatic procedures forassessing temperature effects on crop development. In: Proc. Unesco Uppsala Sym. on Plant Response to Climatic Factors, 1970, Unesco, Paris. Ecology and Conservation. 5:327-342.

ROBERTSON, G.W. 1973b. Weather and World Food Production. Weekly Letter, Agriculture Canada, Swift Current, Saskatchewan, March 2, 1973. 2 pp.

ROBERTSON, G.W. 1974a. Wheat yields for 50 years at Swift Current, Saskatchewan, in relation to weather. Can. J. Plant Sci. 54:625-650.

ROBERTSON, G.W. 1974b. World Weather Watch and wheat. WMO Bulletin, WMO Geneva. 23:149-154.

ROBERTSON, G.W. 1985. Multiple-crop multiple-layer soil-water budget - a computer program documentation. Contract DSS/RN:04GR.01A09-3-1722; FC: 9644-968-4001; FC: 9641-968-1001-0000; Ser. No. 0GR83-00644. Supply and Services Canada, Ottawa. 42 pp.

ROBERTSON, G.W. 1988. Possibilities and limitations of rainfall analysis for predicting crop-available water (uncertainties in the length of the rainy season), pp. 3-13. In: Drought Research Priorities for the Dryland Tropics. (F.R. Bidinger and C. Johansen, eds.). ICRISAT, Patancheru, Andhra Pradesh 502 324, India. 219 pp.

ROBERTSON, G.W. and GARNETT, E.R. 1973. Proposal for a Weather and Crop-Condition Surveillance Program for the Canadian Wheat Board. Canadian Wheat Board, Winnipeg. 131pp.

ROBERTSON, G.W. and HOLMES, R.M. 1956. Estimating irrigation water requirements from meteorological data. Experimental Farms Service, CDA, Ottawa. Pub. No. 1054 (Revised 1959). 19 pp.

ROBERTSON, G.W. and HOLMES, R.M. 1958. A new concept for the measurement of evaporation for climatic purposes. International Association for Scientific Hydrology; I.U.G.G. Assemblé e Gé né rale de Toronto, 1957 (Genthrugge 1958). Tome III, pp. 399-406.

ROBERTSON, G.W. and HOLMES, R.M. 1959. Freezing temperature probabilities at Ottawa. Experimental Farms Service, Canada Dept. of Agriculture, Ottawa. Publ. No. 1047. 4 pp.

ROBERTSON, G.W. and HOLMES, R.M. 1963. A spectral light meter: its construction, calibration and use. Ecology, 44:419-423.

ROBERTSON, G.W. and RUSSELO, D.A. 1968a. Astrometeorological Estimator. Agrometeorology Section, PRI, CDA, Ottawa. Tech. Bull. 14. 21 pp.

ROBERTSON, G.W. and RUSSELO, D.A. 1968b. Freezing temperature risk calculations: systems analysis and computer program. Agrometeorology Section, PRI, CDA, Ottawa. Tech. Bull. 60. 31 pp.

ROSE, J.K. 1937. Weather and wheat yield in Western Canada. Geogr. Rev. 27:140-142.

RUSSELO, D.A. 1967. Problems to be anticipated when processing Meteorological Branch Type 4 format. Agrometeorology Section, PRI, CDA, Ottawa. Tech. Bull. 13. 6 pp.

SANDERSON, M. 1948a. Drought in the Canadian Northwest. Geographic Rev. 38:289-299.

SANDERSON, M. 1948b. The climates of Canada according to the new Thornthwaite classification. Sci. Agric. 28:501-517.

SANDERSON, M. 1950a. Three years of evapotranspiration in Toronto. Can. J. Research, C. 28:482-492.

SANDERSON, M. 1950b. Moisture relationships in Southern Ontario. Sci. Agric.30:235-255.

SANDERSON, M. 1950c. Measuring potential evapotranspiration at Norman Wells. Geographical Rev. 40:636-645.

SANDERSON, M. 1954. Observations of potential evapotranspiration at Windsor, Ontario. Johns Hopkins University Lab. of Climatology. Publications in Climatology. 7:91-93.

SANDERSON, M. 1976. Monthly precipitation probability maps for the growing season in Southern Ontario. Can. J. Plant Sci. 56:639-645.

SANDERSON, M. 1978. Precipitation quantity and quality. Agricultural watershed studies, Great Lakes Drainage Basin. Task Group C. PLUARG. International Joint Commission. 137 pp.

SCHUEPP, P.H. 1971. Experiments of the local convective mass transfer of smooth and rough hailstones models. J. Appl. Meteorol. 10:1018-1025.

SCHUEPP, P.H. 1980. Heat and moisture transfer from flat surfaces in intermittent flow: a laboratory study. Agric. Meteorol. 22:351-366.

SCHUEPP, P.H. 1984. Observations on the use of analytical and numerical models for the description of transfer to porous surface vegetation such as lichen. Boundary-Layer Meteorol. 29:59-73.

SCHUEPP, P.H. and WHITE, K.D. 1975. Transfer processes in vegetation by electrochemical analog. Boundary-Layer Meteorol. 8:335-358.

SCHUEPP, P.H., DESJARDINS, R.L., MacPHERSON, J.I., BOISVERT, J. and AUSTIN, L.B. 1989. Airborne determination of regional water use efficiency and evapotranspiration: present capabilities and initial field tests. Agric. and Forest Meteorol. 41:1-9.

SELIRIO, I.S. and BROWN, D.M. 1979. Soil moisture-based simulation of forage yield. Agric. Meteorol. 20:99-114.

SELIRIO, I.S., BROWN, D.M. and KING, K.M. 1971. Estimation of net and solar radiation, Can. J. Plant Sci. 51:35-39.

SHAW, R.H., SILVERSIDES, R.H. and THURTELL, G.W. 1974. Some observations of turbulence and turbulent transport within and above plant canopies. Boundary-Layer Meteorol. 5:429-449.

SHAYKEWICH, C.F. and STROOSNIJDER, L. 1977. The concept of matric flux potential applied to simulation of evaporation from soil. Neth. J. Agric. Sci. 25:663-682.

SHAYKEWICH, C.F. and ZWARICH, M.A. 1968. Relationships between soil physical constants and soil components of some Manitoba soils. Can. J. Soil Sci. 48:199-204.

SHEPPARD, M.I. and WILLIAMS, G.D.V. 1976. Quantifying the effects of great soil groups on cereal yields in the prairie provinces. Can. J. Soil Sci. 56:511-516.

SHUTT, F.T. 1894. Observations on the quality of air at Ottawa. Trans. Roy.Soc. of Canada, Sect. III, p. 47-49 .

SHUTT, F.T. 1908. The fertilizing value of snow. Trans. Royal Soc. of Canada, Section III, pp. 181-185

SHUTT, F.T. 1909. The influence of environment on the composition of wheat. J. Soc. Chem. Ind. pp. 12-15

SHUTT, F.T. 1910. The nitrogen compounds of rain and snow. Roy. Soc. of Canada, Sect. III, pp. 55-59.

SHUTT, F.T. 1934. The quality of wheat as influenced by environment. Empire J. Exp. Agric. pp. 119-138.

SHUTT, F.T. and HOUSTON, G.N. 1915. Report of the climate and soil conditions in C.P.R. Company's Irrigation Project, Western Section, near Calgary, Alberta. Canadian Dept. of the Interior, Irrigation Branch Bulletin No. 3.

SIMINOVITCH, D. and SCARTH, G.W. 1938. A study of the mechanism of frost injury to plants. Can. J. Res. C, 16:467-481.

SLY, W.K. 1970. The effect of growing-season lengths on values of the climatic moisture index. In: Proceedings of the Eighth Meeting of the Canada Soil Survey Committee, Ottawa. p. 66-73.

SLY, W.K. 1973. Maps for derived climatic data for agriculture. Can. Agric.18(3):36-39.

SLY, W.K. 1977. Agroclimatic Atlas for Canada: Derived Data. Agrometeorology Res. and Ser., CBRI, CDA, Ottawa. 17 maps (+ 18 maps added in 1983).

SLY, W.K. 1982. Agroclimatic maps for Canada - derived data: soil-water and thermal limitations for spring wheat and barley in selected regions. Agrometeorology Res. and Ser. Sect., CBRI, CDA, Ottawa. Tech. Bull. 88. 25 pp.

SLY, W.K. and BAIER, W. 1971. Growing seasons and the climatic moisture index. Can. J. Soil Sci. 51:329-337.

SLY, W.K. and COLIGADO, M.C. 1974. Agroclimatic maps for Canada: derived data: moisture and critical temperatures near freezing. Agrometeorol. Sect., PRI, CDA, Ottawa. Tech. Bull. 81. 31 pp + 5 maps.

SLY, W.K. and WILCOX, J.C. 1974. Effects of time taken to apply an irrigation on seasonal irrigation requirements. Can. Agric. Eng. 16:82-85.

SLY, W.K., ROBERTSON, G.W. and COLIGADO, M.C. 1971. Estimation of probable dates of temperatures near freezing from monthly temperature normals, station elevation, and astronomical data. Agrometeorol. Sect., PRI, CDA, Ottawa. Tech. Bull. No. 79. 22 pp.

SPITTLEHOUSE, D.L. and RIPLEY, E.A. 1977. Carbon dioxide concentrations over a native grassland in Saskatchewan. Tellus, 29:54-65.

STAPLE, W.J. and LEHANE, J.J. 1940. Response of the Livingston atmometer to single meteorological factors. Sci. Agric. 20:308-310.

STAPLE, W.J. and LEHANE, J.J. 1944. Estimation of soil moisture conservation from meteorological data. Soil Sci. 58:177-193

STAPLE, W.J. and LEHANE, J.J. 1952. The conservation of soil moisture in southern Saskatchewan. Sci. Agric. 32:36-47.

STAPLE, W.J. and LEHANE, J.J. 1955. The influence of field shelterbelts on wind velocity, evaporation, soil moisture, and crop yield. Can. J. Agric. Sci. 35:440-453.

STEWART, D.W. 1973. Simulation modelling of plant processes and microclimate in relation to net assimilation. Grassland Species. In: Measurement and modelling of photosynthesis in relation to productivity, Int. Biol. Programme, Proc. Guelph Workshop. pp. 215-230.

STEWART, D.W. 1988. Risk analysis of cereal yields in the Canadian prairies. pp. 89-112. In: J. Dumanski and V. Kirkwood, eds: Crop production risks in the Canadian prairies region in relation to climate and land resources. Agric. Can. Tech. Bull. 1988-5E:89-112.

STEWART, D.W. and DWYER, L.M. 1983. Stomatal response to plant water deficits. J. Theor. Biol. 104:655-666.

STEWART, D.W. and DWYER, L.M. 1985. A resistance model for water balance calculations and spring-wheat yield estimates. In: ASAE National Symposium on Advances in Evapotranspiration. Dec. 16-17, 1985. Chicago. pp. 16-17.

STEWART, D.W. and DWYER, L.M. 1986. Development of a growth model for maize. Can. J. Plant Sci. 66:267-280.

STEWART, D.W. and DWYER, L.M. 1990a. A model of spring wheat (Triticum aestivum L.) for large area yield estimations on the Canadian Prairies. Can. J. Plant Sci. 70:19-32.

STEWART, D.W. and DWYER, L.M. 1990b. Yield and protein trends of spring wheat (Triticum aestivum L.) on the Canadian Prairies. Can. J. Plant Sci. 70:33-34.

STEWART, D.W., DWYER, L.M. and BOOTSMA, A. 1986. Impact of drought on Canadian spring wheat yields. In: Drought: The Impending Crises. Proc. of the Can. Hydrology Symposium No. 16, June 3-6, 1986, Regina, Sask. pp. 475-484.

STEWART, D.W., DWYER, L.M. and DESJARDINS, R.L. 1985. A mathematical model of transpiration using a nonlinear least squares analysis. Can. Agric. Eng. 27:1-6.

STEWART, R.B. 1981. Modelling methodology for assessing crop production potentials in Canada. Agrometeorol. Sect., LRRI, CDA, Ottawa. Tech. Bull. No. 96. 29 pp.

STEWART, R.B. 1986. Climate change - implications for the Prairies. In: Effects of Changes in Stratospheric Ozone and Global Climate. Volume 3: Climate Change. Edited by J.G. Titus, U.S. Environmental Protection Agency, Washington. D.C. October 1986. pp. 103-136. Also In: Trans. Royal Soc. of Canada. Series V(I): 67-96.

STEWART, R.B. and ROUSE. W.R. 1976. Simple models for calculating evaporation from dry and wet tundra surfaces. Arctic and Alpine Res. 8:236-274.

STEWART, R.B., DUMANSKI, J. and ACTON, D.F. 1984. Production potential for spring wheat in the Canadian Prairie Provinces - an estimate. Agric., Ecosystems and Environment, 11:1-14.

STEWART, R.B., WIEBE, J. and MUKAMMAL, E.I. 1977. Delineation of frost-prone areas in the Niagara fruit belt. Tech. Bull., Ont. Ministry of Food and Agriculture. pp. 29

STEWART, R.B., WIEBE, J. and MUKAMMAL, E.I. 1978. The use of thermal imagery in defining frost-prone areas in the Niagara fruit belt. J. Remote Sensing and Environ. 7:187-202.

STRANGE, H.G.L. 1954. A short history of prairie agriculture. Searle Grain Compnay, Limited, Winnipeg. 104 pp. + 9 tables.

SULLIVAN, C.R. and GREEN, G.W. 1964. Freezing point determination in immature stages of insects. Can. Ent. 96:158.

THOMAS, M.K. 1961. June 1961 - a record hot dry month on the Canadian prairies. Meteorol. Br., Tech. Cir. 372. 6 pp.

THOMAS, M.K. and ANDERSON, S.R. 1968. Guide to climatic maps of Canada. Meteorol. Br., Climatic Cir. Cli-1-67. 79 pp.

THOMSON, W.A. 1934. Soil temperatures at Winnipeg, Manitoba. Sci. Agric.15:209-217.

THURTELL, G.W., TANNER, C.B. and WESELY, M. 1970. Three dimensional pressure sphere anemometer system. J. Appl. Meteorol. 9:379-385.

TREIDL, R.A. 1978a. Climatic variability and wheat growing in the Prairies, pp.347-365 in: Essays on Meteorology and Climatology in Honour of Richmond W. Longley. Eds. K.D. Hage and E.R. Reinelt, Department of Geography, University of Alberta, Monograph 3.

TREIDL, R.A. 1978b. Handbook on Agricultural and Forest Meteorology - Part I. Atmospheric Environmental Service, Fisheries and Environment Canada; Supply and Services Canada No. En. 56-1/51. 75 pp. + 10 tables.

TREIDL, R.A. 1979. Handbook on Agricultural and Forest Meteorology - Part II. Atmospheric Environment Service, Fisheries and Environment Canada; Supply and Services Canada No. En. 56-1/52. 14 tables.

TREIDL, R.A. 1981. Handbook on Agricultural and Forest Meteorology - Part III. Atmospheric Environment Service, Environment Canada; Supply and Services Canada No. En. 56-1/53. 11 tables.

TREIDL, R.A., BIRCH, E.C. and SAJECKI, P. 1981. Blocking action in the Northern Hemisphere: A climatological study. Atmosphere-Ocean, 19:1-23.

WALKER, G.K. 1989. Model for operational forecasting of western Canada wheat yield. Agric. and Forest Meteorol. 44:339-351.

WEBB, M.S. 1966. An approach to forecasting low surface humidities at night in the Rocky Mountains. Meteorol. Br. Tech. Cir. 598. 9 pp.

WEBB, M.S. 1969. Variability of summer rainfall and its effect upon the areal representativeness of a point observation. Forestry Branch Publ. No. 1251. pp 1-14.

WELLINGTON, W.G. 1954. Weather and climate in forest entomology. Meteorol. Monogr. 2(8):11-18

WELLINGTON, W.G., SULLIVAN, C.R. and GREEN, G.W. 1951. Polarized light and body temperature level as orientation factors in the light reactions of some hymenopterous and lepidopterous larvae. Can. J. Zool. 29:339-351.

WELLINGTON, W.G., SULLIVAN, C.R. and GREEN, G.W. 1966. Biometeorological research in Canadian forest entomology: a review. Int. J. Biometeorol. 10:3-15.

WILCOX, J.C. 1963. Effects of weather on evaporation from Bellani plates and evapotranspiration from lysimeters. Can. J. Plant Sci. 43:1-11.

WILCOX, J.C. 1967. Effects of soil texture, net evapotranspiration and other factors on irrigation requirements of orchards as determined by a scheduling procedure. Can. J. Soil Sci. 47:149-156.

WILCOX, J.C. and SLY, W.K. 1974. A weather-based irrigation scheduling procedure. Agrometeorol. Sect., PRI, CDA, Ottawa. Tech. Bull. 83. 23 pp.

WILLIAMS, G.D.V. 1968. Using a computer to estimate normals of temperature and derived variables for any point on the Great Plains. Atmosphere, 6:81-86, 116-120.

WILLIAMS, G.D.V. 1969. Applying estimated temperatures normals to the zonation of the Canadian Great Plains for wheat. Can. J. Soil Sci. 49:263-276.

WILLIAMS, G.D.V. 1970. Remarks on recent progress in agroclimatic research and mapping methods to aid land capability evaluation. pp. 74-76. In: Proceedings of the Eighth Meeting of the Canada Soil Survey Committee, Ottawa.

WILLIAMS, G.D.V. 1971. Wheat phenology in relation to latitude, longitude, and altitude on the Canadian Great Plains. Can. J. Plant Sci. 51:1-12.

WILLIAMS, G.D.V. 1973a. Estimates of prairie provincial wheat yields based on precipitation and potential evapotranspiration. Can. J. Plant Sci. 53:17-30.

WILLIAMS, G.D.V. 1973b. Urban expansion and the Canadian agroclimatic resource problem. Greenhouse-Garden-Grass, PRI, CDA. 12(1):15-26.

WILLIAMS, G.D.V. 1974a. Deriving a biophotothermal time scale for barley. Int. J. Biometeorol. 18:57-69.

WILLIAMS, G.D.V. 1974b. Physical frontiers of crops: the example for growing barley to maturity in Canada. In: R.G. Ironside, V.B. Proudfoot, E.N. Shannon and C.J. Tracie (eds.), Frontier Settlement, University of Alberta Studies in Geography Monograph 1. pp. 79-92.

WILLIAMS, G.D.V. 1975. An Assessment of the Impact of some Hypothetical Climatic Changes on Cereal Production in Western Canada. In: World Food Supply in a Changing Climate. Proceedings of the Sterling Forest, N.Y., Conference, December 1974. pp. 88-102

WILLIAMS, G.D.V. 1985. Estimated bioresource sensitivity to climatic change in Alberta, Canada. Climatic Change, 7:55-69.

WILLIAMS, G.D.V. 1986. Land use and agro-system management in semi-arid conditions, pp. 70-90 and Land use and agro-system management in cold regions, pp. 138-161. In: Land Use and Agro-System Management Under Severe Climatic Conditions. Tech. Note 184, WMO No. 633. 161 pp.

WILLIAMS, G.D.V. and OAKES, W.T. 1978. Climatic resources for maturing barley and wheat in Canada. In: K.D. Hage and E.R. Reineilt (eds.), Essays on Meteorology and Climatology in Honour of Richmond W. Longley. Department of Geography, University of Alberta, Edmonton. pp. 367-385.

WILLIAMS, G.D.V. and ROBERTSON, G.W. 1965. Estimating most probable prairie wheat production from precipitation data. Can. J. Plant Sci. 45:34-47.

WILLIAMS, G.D.V. and SHARP, W.R. 1967. A program to estimate normals of temperature and related agroclimatic elements for locations on the Canadian Great Plains. Agrometeorol. Sect., Res. Br., CDA. Tech. Bull. 11. 27 pp.

WILLIAMS, G.D.V. and SHARP, W.R. 1972. Computer mapping in agrometeorology. Agrometeorol. Sect., Res. Br., CDA. Tech. Bull. 80. 40 pp.

WILLIAMS, G.D.V., FAUTLEY, R.A., JONES, K.H., STEWART, R.B. and WHEATON, E.E. 1988. Estimating effects of climatic change on agriculture in Saskatchewan, Canada. In: Perry, N.L., Carter, T.R. and Konijn, N.T. (eds.), The Impact of Climatic Variations on Agriculture, Vol. 1, Assessment in Cool Temperate and Cold Regions. Kluwer, Dordrecht, The Netherlands. pp. 219-379.

WILLIAMS, G.D.V. and MASTERTON, J.M. 1983. An application of principal component analysis and an agroclimatic resource index in ecological land classification for Alberta. Climatol. Bull. 17:3-28.

WILSON, J.D. 1985. Numerical studies of flow through a windbreak. J. Wind Eng. Indust. Aero. 21:119-154.

WILSON, J.D. 1988. Turbulent transport within the plant canopy. In: Estimation of areal evapotranspiration. Intl. Assoc. Hydrol. Sci. Publ. No. 177. pp. 43-80.

WILSON, J.D., CATCHPOOLE, V.R., DENMEAD, O.T. and THURTELL, G.W. 1983. Verification of a simple micrometeorological method for estimating the rate of gaseous transfer from the ground to the atmosphere. Agric. Meteorol. 29:183-189.

WILSON, J.D., WARD, D.P., THURTELL, G.W. and KIDD, G.E. 1982. Statistics of atmospheric turbulence within and above a corn canopy. Boundary-Layer Meteorol. 24:495-519.

WMO. 1981. Guide to Agricultural Meteorological Practices. (First edition in 1963.) WMO, Geneva. WMO No. 134.

WMO. 1987. Commission for Agricultural Meteorology, Abridged Final Report of the Ninth Session. WMO, Geneva. WMO No. 677. 46 pp.

WRIGHT, J.G. 1932. Forest-fire hazard research as developed and conducted at the Petawawa Forest Experimental Station, Dept. of Mines and Resources, Ottawa. Forest-fire hazard paper No. 2.

WRIGHT, J.G. and BEALL, H.W. 1968. The application of meteorology to forest-fire protection. Forest Fire Research Institute, Ottawa, Ontario, Information Report, FF-X-11.

ANNEX A
ABBREVIATIONS

APA - Alberta Agrometeorological Advisory Committee

ACA - Atlantic Committee on Agrometeorology

AES - Atmospheric Environment Service (see also MSC, CMS)

AFMS - Agriculture and Forest Meteorological Section of AES

ADG - Associate Director-General

ADM - Assistant Deputy Minister

AIC - Agricultural Institute of Canada

AMRSS - Agrometeorology Research and Service Section of LRRI

APASCC - Atlantic Provinces Agricultural Service Coordinating Committee

ARDA - Agricultural Rehabilitation and Development Administration

BC - British Columbia

BCME - BC Ministry of the Environment

CAC - Climate Advisory Committee of AES

CARC - Canadian Agricultural Research Council

CASCC - Canadian Agricultural Services Coordinating Committee (see also NCAS, NACAS)

CBRI - Chemistry and Biology Research Institute

CCA - Canada Committee on Agrometeorology (see also NCAM, CCAM, ECA)

CCAM - Canada Committee on Agrometeorology (see also NCAM, CCA, ECA)

CCC - Canadian Climate Centre

CCLRS - Canada Committee on Land Resource Services

CCP - Canadian Climate Program

CCRM - Monitoring and Prediction Division, CCC

CDA - Canada Department of Agriculture

CEF - Central Experimental Farm, Ottawa

CFA - Canadian Federation of Agriculture

CFS - Canadian Forestry Service

CLI - Canada Land Inventory

CMOS - Canadian Meteorological and Oceanographic Society

CMS - Canadian Meteorological Service (see also AES, MSC)

CWB - Canadian Wheat Board, Winnipeg

DINA - Department of Indian and Northern Affairs

DREE - Department of Regional Economic Expansion

DOT - Department of Transport (Canada)

ECA - Expert Committee on Agrometeorology (see also NCAM, CCAM, CCA)

EDP - Electronic Data Processing

EFS - Experimental Farms Service

FAO - Food and Agriculture Organization of the UN

FWSCG - Farm-Weather Services Coordination Group of CDA

FWSC - Farm-Weather Service Committee of CFA

GSS - General Services Section of CASCC

IASH - International Association of Scientific Hydrology

IBP - International Biological Program

IHD - International Hydrologic Decade

IIASA - International Institute for Applied Systems Analysis

IUGG - International Union of Geodesy and Geophysics

LRRC - Land Resource Research Centre, RB, CDA (see also LLRI)

LRRI - Land Resource Research Institute, RB, CDA (see also LLRC)

MB - Meteorological Branch of DOT

MOU - Memorandum of Understanding

MSC - Meteorological Service of Canada (see also AES, CMS)

NCAM - National Committee on Agrometeorology (see also CCAM, CCA, ECA)

NCAS - National Committee on Agricultural Services (see also NACAS and CASCC)

NACAS - National Advisory Committee on Agricultural Services (see also NCAS & CASCC)

NFRC - Northern Forest Research Centre

NOAA - National Oceanographic and Atmospheric Administration (USA)

NRC - National Research Council

NSERC - Natural Sciences and Engineering Research Council

OAC - Ontario Agricultural College

OAmRC - Ontario Agrometeorology Research Committee

OAmSC - Ontario Agrometeorology Service Committee

OAWSC - Ontario Agriculture Weather Services Committee

OMAF - Ontario Ministry of Agriculture and Food

ORF - Ontario Research Foundation

PAMC - Provincial Agrometeorology Committee

PFRA - Prairie Farm Rehabilitation Administration

PNFI - Petawawa National Forestry Institute

PRI - Plant Research Institute, RB, CDA, Ottawa

RB - Research Branch of CDA

SRL - Soil Research Laboratory, EFS, Swift Current, Saskatchewan

SRC - Saskatchewan Research Council

UBC - University of British Columbia

UN - United Nations

UNB - University of New Brunswick

Unesco - United Nations Educational, Scientific and Cultural Organization

USDA - United States Department of Agriculture

WMO - World Meteorological Organization of the UN

WWW - World Weather Watch, a program of WMO

ANNEX B
INDEX OF NAMES