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THE INTERNATIONAL GEOPHYSICAL YEAR

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FEATURING

THE INTERNATIONAL GEOPHYSICAL YEAR

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Titles and Authors	Page
1. "Astronomy and the International Geophysical Year" by Dr. Donald A. MacRae, Professor of Astronomy, University of Toronto.	1
2. "Glaciology and the International Geophysical Year" by Dr. J. A. Jacobs, Professor of Geophysics, University of Toronto.	4
3. "Canadian Meteorological Program for the International Geophysical Year" by Dr. W. L. Godson, Superintendent of Atmospheric Research, Meteorological Services of Canada.	8

ASTRONOMY AND THE INTERNATIONAL GEOPHYSICAL YEAR

by

Donald A. MacRae.'

The keynote of the International Geophysical Year is "concentration of effort". It is an international cooperative organization of scientific activity involving multiple disciplines on a world-wide scale. Tonight's addresses discuss the three sciences of astronomy, meteorology, and geophysics in relation to the I.G.Y. as if, perhaps, there are sharp dividing lines between them. Actually, of course, they overlap, and astronomy in particular spills over into the other sciences. Of the twelve disciplines listed by the Canadian National Committee for the I.G.Y. (1), astronomy is closely connected with nine: Geomagnetism, Aurora and airglow, Ionospheric Physics, Solar Activity, Cosmic rays, Longitude and Latitude, Seismology, Gravity and Meteor studies. Although it is not mentioned as a Canadian activity, the Earth-satellite program is of very great interest to astronomers.

The major participating groups in the Canadian Program are the Department of Transport, the Dominion Observatory of the Department of Mines and Technical Surveys, the National Research Council and Defence Research Board, and the Universities of Alberta, Saskatchewan, Toronto, Queen's and Western Ontario.

The greatest astronomical interest centres perhaps on solar activity. The period of the I.G.Y. was chosen so as to coincide with the maximum of the sun-spot cycle. Although it is somewhat erratic, the maximum will occur about this time; current observations suggest that the spottedness of the sun may not be as great as predicted and we may already be over the peak.

Sunspots are apparently secondary phenomena, one of a variety of symptoms of disturbed areas near the solar surface. Other phenomena associated with these disturbed areas are strong local magnetic fields, increased emission of light from areas in

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the lower corona (the low-density outer atmosphere of the Sun), and solar flares, or small areas of intense brightening of the solar surface. In addition, prominence activity is enhanced and corpuscular emission takes place occasionally.

Although the sun is on the whole steady and quiet at optical wave-lengths, at radio wave-lengths the situation is quite different. The intensity of emission of radio wave-length radiation (1 cm to 10 metres) is much more variable as the spot cycle waxes and wanes, and during disturbed periods (minutes to days in duration) great bursts of radiation and noise storms can be recorded by radio telescopes. Activity recorded at short radio wave-length is related to occurrences close to the solar surface, while that at the longer wave-lengths comes from disturbances in the outer corona. Such observations are valuable indices of general solar activity. They give warnings of associated terrestrial disturbances to follow, seconds to many hours later, such as auroral activity, geomagnetic disturbances, cosmic ray bursts, and disturbances of the ionosphere. The general circulation of the atmosphere may even be affected. The means by which the Sun exerts its influence on the Earth appears to be through increased emission of ultra-violet radiation at the time of flares and the emission of atomic particles or corpuscles in rapidly moving streams or sprays in the plane of the earth's orbit.

Solar radiation has been recorded continuously for over ten years by a group at the National Research Council in Ottawa at 10 cm wave-length. At the University of Toronto a new radio telescope will be in operation at a wave-length of one metre. (2) Other Canadian observations at 60 cm will be made by the D.R.B. These stations form part of a world-wide network which will keep a watch on the Sun for 24 hours a day. Based on their observations, "Alerts" and "Special World Intervals" will be declared by the World Warning Agency operated by the Bureau of Standards at Ft. Belvoir, Virginia. The Meteorological Telecommunication Networks distribute these warnings daily around noon. (3)

In addition to the radio observations, optical observations are also being made continuously on the Sun. The Dominion Observatory has equipment to photograph the Sun at a wavelength of 6563 A (H-alpha) in the search for solar flares.

The earth-satellite program is one of the high-points of the I.G.Y. Many details of the project will be found in the reference cited.(4) The latest word is that launching of the U.S. vehicle may be delayed until early 1958; the Russian satellite, which is generally expected to travel over the poles, may be launched at the same time or earlier; firings may be anticipated near the times of new moon. One of the many problems to be tackled by means of such space-borne equipment will be the measurement of the albedo of the earth. This will give meteorologists a measure of the fraction of solar energy absorbed by the terrestrial atmosphere, a basic meteorological quantity.

Meteorologists, especially those at remote stations, may be interested to know that simple visual observations are badly needed to fill gaps in the observations planned by some of the disciplines mentioned at the beginning of this article. In particular, observations of the aurora and of meteors are most valuable, and details of what kind of observations should be made can be obtained by correspondence.(5)

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GLACIOLOGY AND THE INTERNATIONAL GEOPHYSICAL YEAR

by

J. A. Jacobs'

About one tenth of all the land surface of the Earth (about 6 million square miles) is today permanently covered with ice. Glaciers are found on all continents, with the exception of Australia, and occur even in the tropics at high altitudes in S. America, Africa, and New Guinea. However, like Siberia, much of continental Canada, even though cold and relatively high, has only small glaciers, because of insufficient moisture. Glaciers are extremely sensitive to meteorological factors, and in turn, themselves exert an appreciable effect on the weather of this planet.

The I.G.Y. programmes in meteorology, oceanography, and glaciology will form a coordinated study of the heat and water budget of the Earth. Some of the main purposes of the glaciological programme are to investigate the dynamic properties and mass budgets of glaciers together with the exchange of mass and energy between glaciers and their environment. In particular, efforts will be made to determine the volume of polar ice locked in the great ice sheets of Antarctica and Greenland and the floating ice of the Arctic basin. If all the ice in Antarctica were to melt, sea level would rise by about 200 ft. which would have tremendous economic and political repercussions - ice locked ports in the far North would be opened, important coastal cities and low lying coastal lands would be flooded, and there would be a redistribution of the vast arid and verdant areas of the world. The area of the inland ice of Antarctica is more than 5 million square miles - the unknown is its thickness which will be measured by seismic methods. The bulk of the Antarctic ice probably lies under the East Antarctic dome - and it is anticipated that it may prove to be in excess of 15,000 ft. It is also estimated that the mean thickness for the entire ice sheet is more than 5,000 ft. A 647 mile traverse from Little America to Byrd Station was completed in January 1957 where

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the ice thickness was found to be 9850 ft. Since the station is only 4950 ft. above sea level, this means that the surface of the Earth's crust on which the ice rests in this area is more than 4,900 ft. below sea level. The Russians have also confirmed that the ice cap in several places is below sea level, and suggest that Antarctica may not be an ice capped continental land mass but a group of islands.

Melting of 25 to 35 ft. of ice from the entire surface of the Antarctic ice sheet would raise sea level by one foot, and this amount of melting currently occurs on glaciers in other parts of the world in a few years. Studies during the I.G.Y. of accumulation, wastage and other micro-meteorological factors will help to evaluate the possibility of such an occurrence in Antarctica. Wastage of Antarctic ice occurs by melting, evaporation, wind erosion, and calving in the form of ice-bergs, although melting and evaporation seem to be the only wastage processes likely to be much influenced by climatological changes. The Antarctic is so cold that a considerable warming could occur without notably increasing melting and evaporation. In fact it is more than possible that an increase of temperature in the Antarctic would produce an expansion of the ice owing to the increased snowfall resulting from the greater water vapour content in the atmosphere.

Other objectives in the I.G.Y. glaciological programme are a study of snow stratigraphy, ice movement, temperature and topography of the ice surface and the land beneath the ice. A detailed survey of the glaciers of the world will also be undertaken and an attempt will be made to determine the pattern of regional climatic trends and the historical pattern of climatic changes as revealed by present and past glacier activity. To obtain full benefit of such a programme, measurements should be repeated after an interval of some 10 to 20 years.

The Canadian I.G.Y. programme in glaciology is threefold -

1) Expeditions to the Salmon Glacier, B.C., 1956 and 1957.
2) Expeditions to Lake Hazen on Ellesmere Island, 1957 and 1958.
3) Extension of the present Canadian Snow Survey.

These projects were not entirely developed because of the I.G.Y.

The expeditions were carried out as part of an intensified development of Canadian science in Glaciology and it is hoped that the I.G.Y. will provide the impetus for a continuing programme in this field. The area chosen for the first expeditions was the Salmon and Leduc glaciers together with the surrounding snow fields which are situated near the coast of British Columbia opposite the southern tip of Alaska (approximately lat. 56° 10' N, long. 130° 15' W). This area lies between the glaciers from the Juneau ice field to the North which are retreating and those of the Washington Cascade and Olympic Mountains to the south which are advancing. Eleven men took part in the 1956 expedition which lasted from the middle of May until the end of August. It was sponsored by the National Research Council and was under the leadership of Professor J. A. Jacobs. The main part of the programme was given over to extensive seismic and gravity surveys. In all 354 seismic profiles were shot, the work being greatly facilitated by the Granduc Mining Company which provided air-borne support and the loan of a sno-cat tractor. Preliminary calculations indicate that the depth of ice is in general about one-half the width of the glacier - amounting to 2,000 - 2,400 ft. A very detailed gravity survey was carried out on the Salmon Glacier and the surrounding snow field. At first the survey was carried out in loops tied to a chained and levelled base line which extended over 20 miles with stations every 600 ft. As the firn line receded, severe crevassing made the work difficult and a survey was carried out using two transits located on adjacent mountains controlled by a system of visual signals. Absolute movement of the glacier surface was determined from the movement of stakes and was of the order of 8 inches a day. Samples of ice at various depths down to 80 ft. were collected for an analysis of their tritium content.

The 1957 expedition to the Salmon Glacier was under the joint leadership of Dr. R. R. Doell and Dr. G. Garland. The work this year was mainly meteorological including studies of the absolute movement of the glacier. This latter work was done by observing the movement of stakes and by detailed photogrammetric techniques which will also yield recent changes in the volume of the glacier. Further gravity work was carried out and the vertical component of the Earth's magnetic field was also measured. Other work included accumulation and ablation records from pit studies, stream gauging of the main rivers flowing from the glacier and geomorphological work in the surrounding ice-free areas.

An expedition to Lake Hazen on Ellesmere Island was made in 1957. This expedition was under the direct supervision of the Defence Research Board, and was led by Dr. Hattersley-Smith. Geophysical work included gravity and seismic traverses on the ice cap north of Lake Hazen. Meteorological observations were carried out in connection with glaciological studies and another party will spend the winter at the main base on the North shore of Lake Hazen so that a continuous record of the weather may be obtained for one year. Geologists accompanied the party and investigated the stratigraphy, petrology and structures of the region as well as glacial geology and limnology. These latter studies included erosion by the glaciers in the area , transportation and deposition of drift by ice, melt waters from the glaciers and wind. Physical and chemical processes of weathering under arctic conditions were also studied. It is hoped to run another larger expedition to this area in 1958, the party to include a biologist and an archeologist.

The snow cover survey sponsored by the National Research Council has been active in Canada since 1947 and observations at 7 additional stations will be made during the I.G.Y. There are three main objectives -

1) The determination of the relation of visibility with respect to blowing snow, wind velocity and snow surface characteristics.

2) The determination of the density of new snow and its relation to the meteorological variables measured.

3) The initiation of an investigation into ground temperatures near the surface and their dependence on the snow cover and measured meteorological variables.

CANADIAN METEOROLOGICAL PROGRAM

FOR THE

INTERNATIONAL GEOPHYSICAL YEAR

by

W. L. Godson '

World meteorologists have decided that International Geophysical Year investigations should be directed toward the large-scale physical, dynamic and thermodynamic processes of the general circulation of the atmosphere. It is certainly true that our knowledge and understanding of the general circulation are quite incomplete at present. However, it is quite probable that the behaviour of the atmosphere on a broad scale can be assessed adequately by an analysis of data from an expanded observational network.

With specific reference to the Canadian meteorological program, the expansion of observational networks will take many forms. The basic data concerning the general circulation are observations of wind and temperature fields. Our present networks cannot reasonably be extended in space or in time but can be extended in the vertical to permit the acquisition of data from relatively high levels. Near the standard meridian of 80°W, we will try to reach or exceed the 80,000 foot level, at least once a day, at a chain of seven stations. Even though only 2½ per cent. of the atmosphere lies above this level, it is now realized that phenomena at such levels are distinctive as well as interesting, and may well be significant as far as developments below are concerned.

Limited studies of meteorological charts at 100 mb (near 16 km) and 50 mb (near 20 km) have shown curious differences between these flow patterns and those at lower levels. Especially at 50 mb and above, there are found fairly extensive cyclones and anticyclones which move slowly and are poorly correlated with flow patterns at normal levels. In the winter Arctic stratosphere, the mean positions of the cyclones and anticyclones seem to vary

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from one year to the other. Cyclones are relatively cold, with temperatures of the order of -70 to -80°C. The coldest temperatures are found in the S-W quadrant of the cyclones and here no well-defined tropopause exists. Anticyclones, on the other hand, are relatively warm, with temperatures of the order of -40 to -50°C. Thus, in winter, the Arctic stratosphere is cold or warm according to whether the circulation is cyclonic or anticyclonic. The isotherm patterns seem to indicate that these temperature contrasts are chiefly maintained by vertical motions, but it is clearly necessary to invoke non-adiabatic processes to explain the development of these contrasts through the fall months and their decay through the late winter and spring months. The logical mechanism involves the differential radiative cooling and heating across the boundary of polar night as this boundary moves southward during the autumn months and northward during the winter months. The chief absorber of solar radiation at these high levels is ozone, whereas the chief agent promoting infrared radiative cooling is carbon dioxide. Since ozone is variable in the horizontal and vertical, as well as in time, ozone observations, especially in Arctic regions, will form a vital link in our IGY program.

In the Research Section of the Meteorological Service, we have been studying these phenomena in various ways. The time-smoothed temperature data at the 100 mb level have proved particularly revealing, and two winter sequences for four Arctic stations near the 80°W meridian are shown in Fig. 1. Here are shown 10-day running-mean 100 mb temperatures for Alert, on the northern tip of Ellesmere Island, Eureka, Resolute and Coral Harbour, on Southampton Island - for the winters of 1954-55 and 1955-56. The temperature scales extend from -40 to -75°C.

The most striking feature of this graph is the extreme dissimilarity of these two winters. During the 1954-55 winter, arctic stratosphere temperatures were generally relatively warm, typical of anticyclonic conditions. During the 1955-56 winter, arctic stratosphere temperatures were generally relatively cold, typical of cyclonic conditions. A detailed study of these curves reveals many other differences between the two winters. During late autumn 1954, there was no cooling, on the average, at Coral Harbour, and a cooling at Alert only until the end of the year. A moderate N-S temperature gradient developed, accompanied by periodic temperature fluctuations with a period of about 20 days. Shorter-period fluctuations are, of course, greatly damped by the use of 10-day running means. A pronounced change occurs in early January, with all stations warming to relatively high temperatures. N-S temperature gradients become insignificant and, simultaneously, large-amplitude temperature waves disappear. One has the impression of an instability phenomenon, generated by a maximum field of baroclinicity, followed by a thrust northward into the Arctic of warm stratospheric air from sub-Arctic or northerly temperate areas.

The following year displays a time sequence which is surprisingly different. During late autumn 1955, all stations cool quite rapidly until near the end of the year. During this period, only a weak N-S temperature gradient developed and no marked quasi-periodic temperature fluctuations were evident. The uniformly cold temperatures at the winter solstice represent a synoptic situation quite different from that a year previous. During the first two months of 1956, the central Arctic remains very cold at 100 mb, while further south there is a slow temperature recovery. As the N-S temperature gradient builds up, there develop quasi-periodic temperature fluctuations of increasing amplitude and a period of about 30 days. The maximum baroclinicity at the end of February was followed by an unstable wave behaviour in which cold air plunged southward from the central Arctic into the main Arctic and sub-Arctic areas. By mid-March, the normal winter N-S temperature gradient was temporarily reversed, but this situation only lasted for about 10 days. During the last two weeks in March temperatures warmed very rapidly at all stations and levelled off in April near -45°C. This warming had occurred over $2\frac{1}{2}$ months earlier in 1955, but in the previous winter had not been associated with a prior plunge southward of very cold air.

These quite different evolutions of the thermodynamic field of temperature were accompanied by markedly dissimilar dynamic developments. In particular, one can identify areas and times of strong temperature gradient as being associated with pronounced vertical wind shear. If wind velocities show a clearcut maximum in a three-dimensionally narrow current, we say that a jet stream is present. One would therefore expect the strongly baroclinic periods in the Arctic winter stratosphere to produce an intense high-level jet stream. Late December 1954 was one such period, and wind speeds as high as 140 knots were observed at that time. An excellent example of such a jet stream was observed in late February, 1956, and is to be found in the April, 1957, Journal of Meteorology (p. 131).

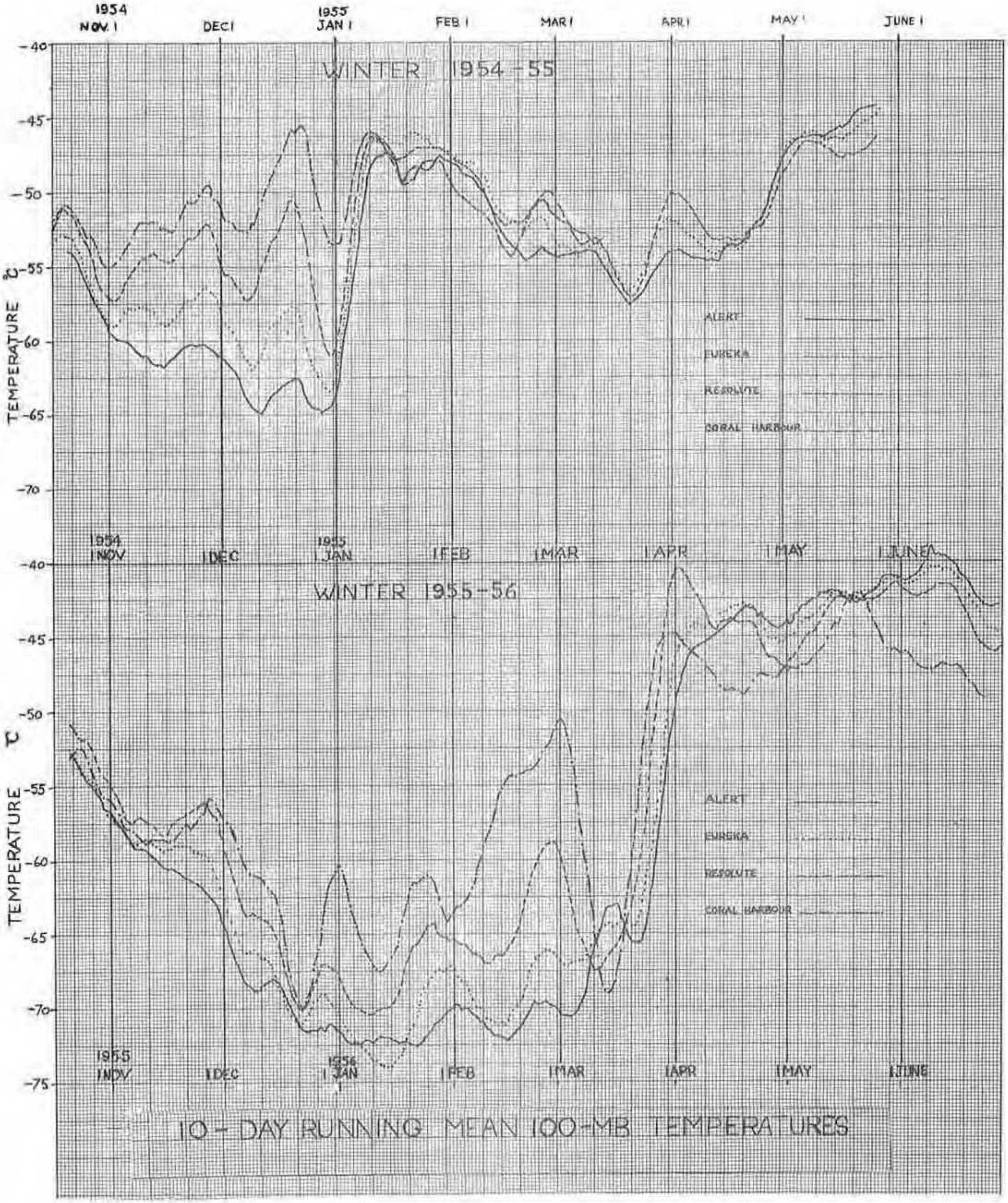
This vertical cross-section contains wind and temperature data for February 26, 1956, 1500 G.M.T., along a line from Alert, on the left, to Whitehorse, on the right. The strongest winds were NW to NNW, roughly at right angles to the section, the vector winds being represented symbolically on the plot. The solid lines are isopleths of wind speed in knots, the dashed lines are isotherms in degrees Celsius. The highest reported wind on this cross section is about 160 knots, near the 80,000 foot level at Eureka. The strong concentrated temperature gradient below the jet stream is clearly evident; the temperature increases from -70°C to -50°C in a distance of 700 nautical miles. Southwest of Resolute, the stratosphere is nearly isothermal both in the vertical and horizontal. It is also apparent from this cross-section that the wind structure below the tropopause, near 300 mb, is poorly correlated with that at high levels.

There seems to be good evidence that the Arctic area in winter exhibits a maximum independence of low-level and high-level circulations. The existence of the Arctic winter stratospheric jet stream offers excellent proof of this belief. It is probable that differential solar heating of the ozone layer, across the boundary of polar night, is the primary physical process initiating the jet stream in the fall, and intensifying it in the winter. The simultaneous development of strong baroclinicity and quasi-periodic large-amplitude temperature fluctuations is undoubtedly closely related to the intensification of the jet stream. The breakdown of all three was observed in both the winters so far studied and appears to be a form of baroclinic instability, associated with a circulation change to a marked cellular pattern - anticyclonic in early 1955 and cyclonic in 1956. The data collected to date are not, however, adequate to present a clear picture of the wind and temperature structure above the 100 mb level. The 25 mb, or 25 km, level is near the middle of the ozone layer and probably above the median level. It is here that the primary effects of differential solar heating should be sought, and correlated with ozone amounts and vertical distributions. Studies such as these will, it is hoped, be possible with the data to be gathered during the IGY, so that the mechanisms driving these high-level circulations may be elucidated.

It must not be thought that we will neglect studies of the dynamics and thermodynamics of the lower-level circulations.

Here, knowledge of the circulations themselves is relatively adequate, but this is not true of the driving forces involved. Of particular importance are studies of the budgets at the earth's surface of heat, water vapour and momentum. Equally important will be the assessment of the effects of topography and state of the ground on vertical fluxes of heat, water substance and momentum. Canadian studies such as these will be concentrated mainly on Arctic regions since the IGY offers a rare opportunity to carry out intensive and expensive programs in logistically-difficult areas.

It would be folly to try to estimate the long-range results of analyses of Canadian meteorological IGY data. It is our hope, however, that, when we have unravelled the mysteries of the physical motivations of the atmosphere's general circulation, we will be in a position to make a frontal attack on problems of extended-range and long-range forecasting. We are convinced that such forecasts are of great potential value to the nation's economy, and we are most anxious to overcome the scientific and manpower deficiencies which presently impede progress in this direction.


WINTER 1954-55
WINTER 1955-56
TEMPERATURE °C
ALERT
EUREKA
RESOLUTE
CORAL HARBOUR
1954 NOV. 1
DEC 1
1955 JAN 1
FEB 1
MAR 1
APR 1
MAY 1
JUNE 1
1955 1 NOV
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1956 1 JAN
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1 MAY
1 JUNE
10-DAY RUNNING MEAN 100-MB TEMPERATURES