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Contents

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Man, Matador and Meteorology[1]

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ABSTRACT

The International Biological Programme was inaugurated in 1964 as a result of increasing world-wide concern about man's relations with the natural environment. Canada's participation in the Programme includes a study of the productivity of prairie grassland in an area of southwestern Saskatchewan. This study, the Matador Project, is described with particular emphasis on its meteorological aspects.

1 Introduction

Although man has inhabited the earth for a million years, his impact on it was small and localized until the time of the Industrial Revolution. Since then, both the human population and the per capita impact have increased dramatically. During this period of rapid change man tended to look on the earth's resources as unlimited and their exploitation as a challenge to his ingenuity.

Only in very recent years has it become generally realized that the earth's resources are finite and that, if present trends continue, many of the non-renewable resources will be used up within a few generations. Even the renewable resources are being taxed severely. More natural lands are being converted to agricultural use; more fertilizers and pesticides are being used; more dams and irrigation canals are being built. The building of roads, airfields, and new urban areas also take their toll of the natural lands still remaining on the earth. The concern of many people is that our actions are not only driving many animals into extinction, and causing pollution which is offensive to all of our senses as well as our health, but may ultimately lead to the destruction of life on this planet.

Since almost every action of man has some harmful effect on the natural environment we must, if we are to preserve it, try to minimize this environmental damage. This will require a far better understanding of the interrelationships between all forms of life and their environments. To achieve this end future research in the fields of agriculture, forestry, wildlife management, resource development, etc. will need to take a more holistic, integrated approach than in the past.

2 The International Biological Programme (IBP)

These rapid world-wide changes in natural environments and the increasing world population led to the initiation, by the International Council of Scien-

[1]Issued as Canadian IBP Contribution No. 124.

tific Unions, of the International Biological Programme. The theme was to be *The Biological Basis of Productivity and Human Welfare*. The First General Assembly of the IBP was held in Paris in 1964 and the following timetable was adopted: Phase I – Planning and Preparation (1964–1967); Phase II – Operations (1967–1972). Subsequently, there was the creation of a Phase III – Synthesis and Transfer (1972–1974). The IBP was organized into seven general sections: Productivity Terrestrial (PT), Production Processes (PP), Conservation Terrestrial (CT), Productivity Freshwater (PF), Productivity Marine (PM), Human Adaptability (HA), and Use and Management (UM).

Throughout the world over 2000 research projects were in operation under the seven sections of the IBP. In Canada, the major IBP projects include a grassland ecosystem study in southwestern Saskatchewan – Matador Project (PT, PP), a high arctic tundra study – Devon Island Project (PT), and a freshwater lake study in southwestern British Columbia – Marion Lake Project (PF).

3 The Matador Project

The Matador Project was initiated in 1967 by a group of University of Saskatchewan scientists with the aim of studying all pertinent aspects of the mixed-grass prairie ecosystem as found in the Matador area (Fig. 1). This area is one of the last extensive (15–20 mi^2) uncultivated areas of arable clay soil in the Canadian Prairies. It was formerly part of the Matador Ranch and in recent years has been used as a community cattle pasture. The vegetation and soil are uniform over most of the study area (three sections in the south-central part of the block), and the terrain is relatively level (Fig. 1).

Some of the reasons for choosing a natural ecosystem for this study were:

1. The ecosystem is presumably in a "steady-state" condition;
2. The natural area is a logical reference with which to compare adjacent agricultural areas;
3. It may be used as a "bench-mark" area to assess environmental change.

Initially, it was hoped that parallel studies of the native grass and adjacent wheat and seeded pasture could be carried out. Resources proved to be inadequate for this, however, and work was confined mainly to the native prairie with some comparison studies being carried out in nearby wheat fields.

The Matador Project involves integrated research carried on by close to one hundred persons under the direction of about two dozen scientists. The fields of research may be loosely divided into Producers (green plants), Consumers (invertebrates, small mammals, birds), Decomposers (microorganisms), and Abiotic Factors (meteorology, soil physics, nutrient cycling).

Studies include: regular (approximately every two weeks during the summer, less frequently during other seasons) biomass determinations for each of the major plant and animal species on the site; continuous monitoring of the atmospheric and soil environment; field and laboratory experiments to determine the ecosystem interactions and environmental responses; and development of a computer model to integrate all of the information obtained into a usable form.

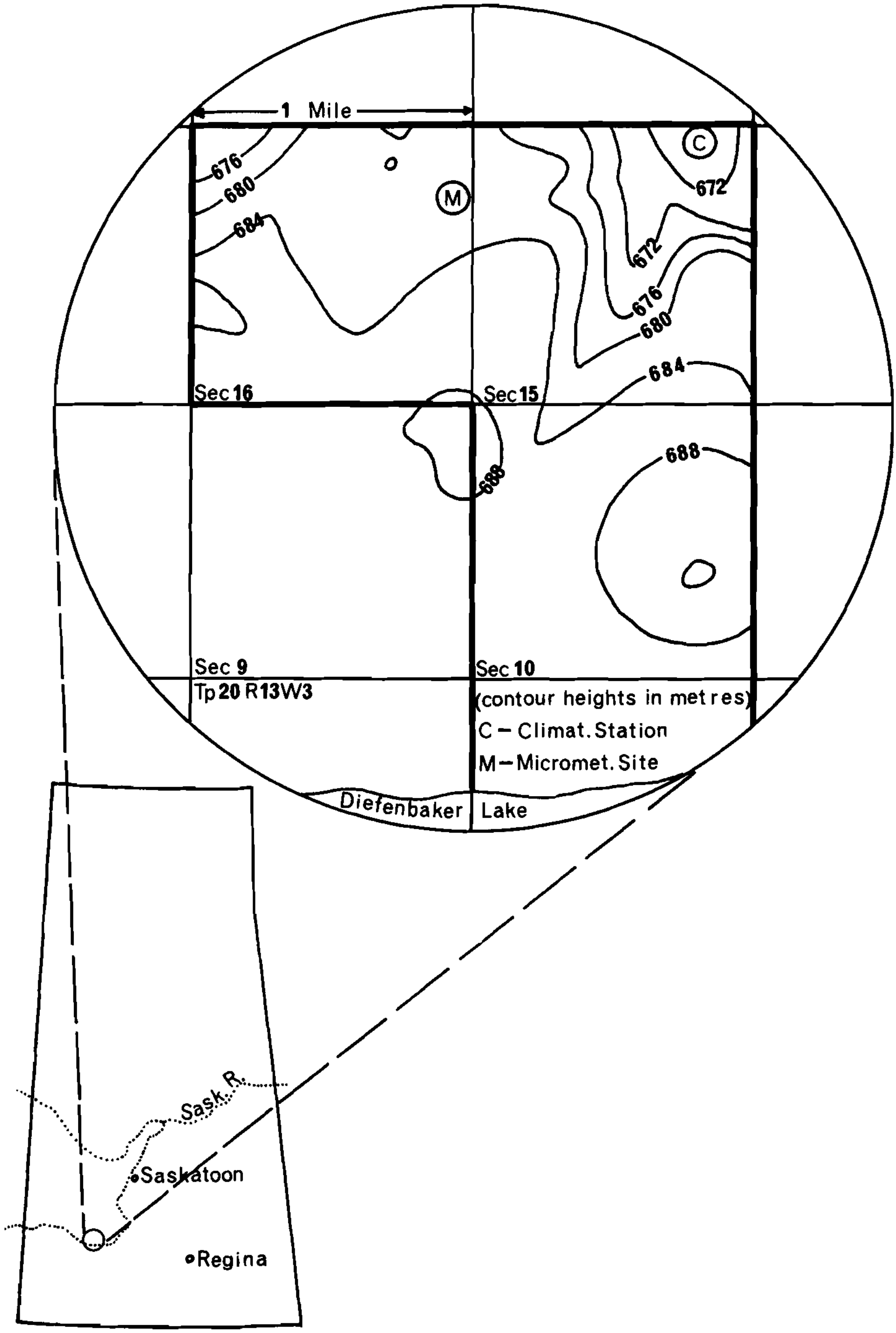

Fig. 1 Saskatchewan, showing the location of the Matador study area, its topography, and the location of the climatological and micrometeorological measurement sites.

4 Meteorological studies

a *General*

An organism responds to its immediate spatial environment and not to that at some remote location (e.g., in a Stevenson Screen). Therefore, it is necessary, in an ecosystem study, to determine the meteorological conditions throughout the biosphere as functions of time and space and to apply to each organism the microclimate determined by its location.

The approach to environmental specifications in this study was to:

(1) Record the actual macroclimate for the duration of the Project,

(2) Relate the macroclimate in the Matador area to that at adjacent long-term stations,

(3) Determine topoclimatic variations over the study area,

(4) Relate the atmospheric and edaphic microclimates in the biosphere to the macroclimate and vegetation and soil properties.

To meet these ends (and others to be detailed later) two separate meteorological measurement facilities were established at Matador: a permanent year-round "climatological station"; and a trailer-based micrometeorological station.

The climatological station was established at Matador (Fig. 1) in the spring of 1968 and has been in year-round operation since then. The location (about 200 m north of the laboratory and administration buildings) was chosen because of accessibility (particularly during the winter) for the taking of manual observations and the repair and maintenance of automatic instrumentation. The climatological station was enclosed by a barbed-wire fence for the protection of the sensors.

A network of twenty (non-recording) rain gauges and minimum thermometers was set up with the aim of investigating differences in temperature and rainfall over the Matador study area. These instruments were read daily during the summer season.

Certain manual measurements are taken once daily (near sunset). These include reading of the maximum and minimum thermometers, cup-counter anemometers, and precipitation gauges, changing the sunshine card, and servicing the evaporation pan.

Automatically logged measurements include incoming and reflected short-wave radiation and net all-wave radiation at a height of 2 m above the ground; rainfall; wind speed and direction (10-m height); screen dry-bulb, wet-bulb, and dew-point (Dewcel) temperatures; soil temperatures (at depths of 5, 10, 20, 50, 100, and 200 cm); and air temperatures at heights of 2, 5, 7.5, 10, 15, 25, and 50 cm above the ground. All temperature sensors were constructed of copper-constantan thermocouples. The above-ground sensors were aspirated and were lagged to increase their time-constants to 1–2 min.

In addition to the regular radiation sensors two photocells were mounted on small posts in the vegetation at heights of 10 and 20 cm above the ground, with a reference photocell at 2 m. These measure the light levels under the snow.

This is of interest particularly in the spring and autumn when some vegetation growth may take place when the ground is covered with snow.

A 24-point chart recorder is used for all temperature measurements (scale −50 to +50°C) and for radiation and light measurements (−5 to +20 mV). This recorder is fitted with a shaft encoder and outputs onto a teletype machine (punched tape and print-out) as well as providing the regular chart record.

Because the sampling rate of the recorder (1 cycle in 5 min) is too slow for the short time-constant radiation sensors (about 30 s), electronic integrators are used to continuously sum the outputs of the radiation sensors. The digital outputs of the integrators are connected to a counter system having an hourly printout.

Wind speed and direction are recorded continuously on a separate chart recorder.

b *Radiation and Sunshine*

The ultimate source of almost all of the energy used in biological processes is, of course, the sun. Although only a few per cent of the incident solar energy is used directly (as in photosynthesis) the remainder is converted to heat to provide suitable temperatures for organisms and to power such processes as atmospheric diffusion, convection, evaporation, etc. Although the solar energy at the limit of the earth's atmosphere is a well known function of astronomical geometry, the fraction of it that reaches the surface varies considerably because of absorption, reflection, and scattering by the atmospheric gases, particulate matter, and clouds. As mentioned above, continuous measurements are made at Matador of incoming short-wave (global) radiation, reflected short-wave radiation, and net all-wave radiation. The net radiation is the main input for the surface energy balance. Photosynthesis is a function of the visible light intensity (about one-half of the global radiation). Some useful quantities which may be derived from the above radiation measurements are the reflection coefficient (or albedo) of the surface (equal to the ratio of reflected to global radiation), and the net long-wave exchange (equal to net all-wave minus net short-wave).

An analysis of mean monthly albedo for Matador for the period July, 1969, to March, 1970, shows a near-constant pattern for the summer months with a value of 0.15 at midday increasing to 0.20 at sunrise and sunset. The presence of snow cover produces a dramatic increase in albedo. The months, January to March, 1970, during which the snow cover was continuous, showed a midday albedo of about 0.78 dropping to about 0.70 at sunrise and sunset. The apparent decrease in albedo of the snow cover at low solar angles is, as yet, unexplained. It is hoped that further observations will show whether this is a real phenomenon or the result of instrument errors (frost formation or temperature effects).

The importance of the solar radiation reaching the earth's surface and the scarcity of direct measurements has encouraged the search for correlations be-

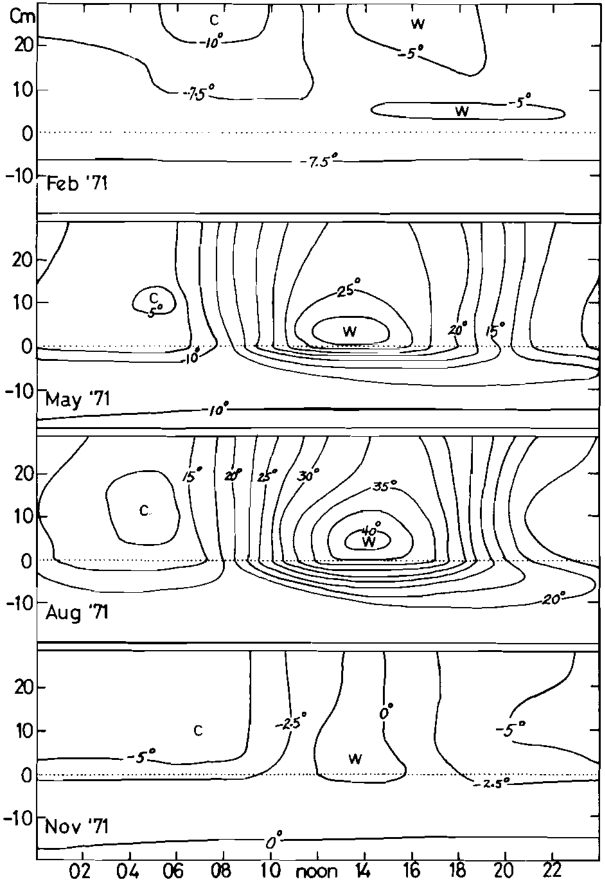

Fig. 2 Diurnal variation (CST) of mean monthly canopy and soil temperatures for February, May, August and November, 1971, at Matador.

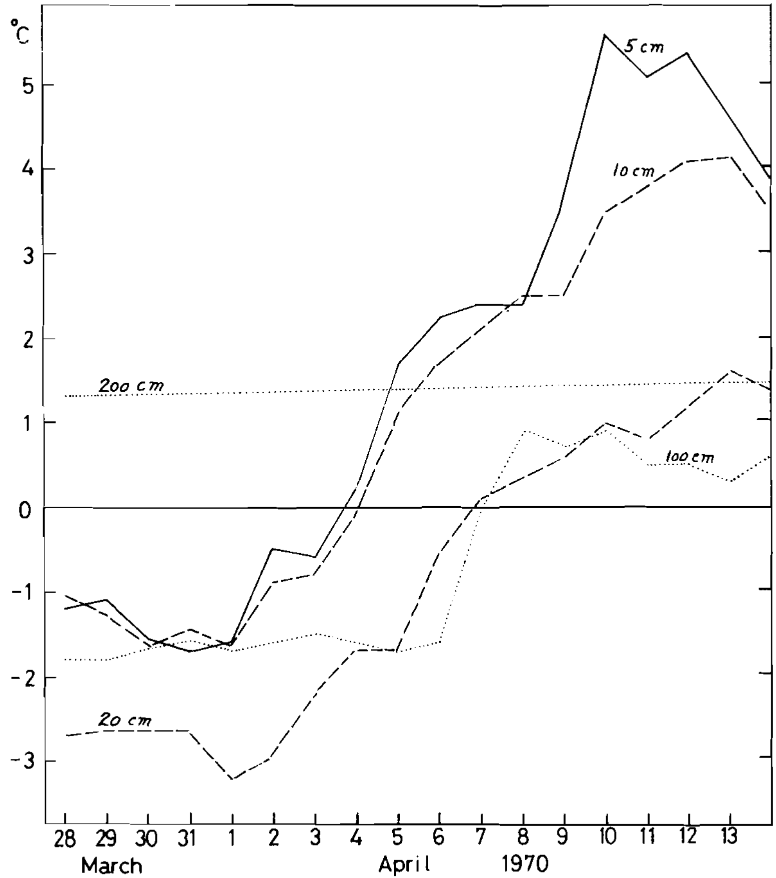

Fig. 3 Variation of mean daily soil temperatures at Matador during late March and early April, 1970.

tween global radiation and other possibly related available data (such as hours of sunshine). A preliminary analysis of the Matador radiation and sunshine data has produced the following Ångström-type relation:

$$G/G_0 = 0.22 + 0.55\, n/N \qquad \text{(correlation coefficient } r = 0.91\text{)}$$

where G/G_0 is the fraction of the extraterrestrial solar radiation that reaches the surface of the earth, and n/N is the fraction of the total possible hours of bright sunshine. Both G_0 and N are functions of date and latitude and may be found, for example, in List (1966).

The values of the coefficients shown above compare fairly well with the values of 0.25 (intercept) and 0.62 (slope) determined by Baier and Robertson (1965), and even better with the values of 0.23 and 0.57 estimated by Selirio *et al.* (1971). The above Matador regression was based on less than 2 years' data. As more data are collected they will be subjected to further, more detailed analysis.

c *Canopy Temperatures*

Because most of the radiant energy exchange takes place at or near the surface this is the region of greatest diurnal temperature variation. The diurnal wave diminishes in amplitude and lags in phase away from the surface both in the atmosphere and in the soil. A summary of the diurnal variation of mean monthly temperatures at numerous levels in the soil and atmosphere is presented in Fig. 2 for the months of February, May, August and November, 1971. The vegetation has an effective height of about 20 cm and varies only slightly from season to season. During February the snow depth was about 20 cm all month and temperatures were close to −7.5 °C both in the snow and in the top layers of soil. The diurnal temperature range (5 to 10 deg. C) was greatest at the surface of the snow. A warm spot about 5 cm above the ground during the afternoon and evening was likely due to penetration of solar radiation through the snow. The snow cover disappeared in early April and by mid-May the soil had warmed to +10°C at 15 cm. The warmest level in May was close to 5 cm above the surface at about 1300 CST (approximately solar noon) while the coolest level was about 10 cm above the surface. The difference is undoubtedly due to the geometry of the radiation exchange coupled with night-time reduction of turbulence and radiative flux divergence effects. The maximum diurnal range in May is about 25 deg. C. This range increased to 30 deg. in August when the mean canopy temperature at 5 cm exceeded 40°C. The penetration of the diurnal wave into the soil and its time lag is particularly noticeable on the August chart. By November, the low solar angle had reduced the diurnal variation to about 10 deg. C. With only a trace of snow on the ground most of the month the coldest and warmest levels were much the same as they were during the summer.

d *Soil Temperatures*

In the Prairies, spring snow melt is a very important source of water for the

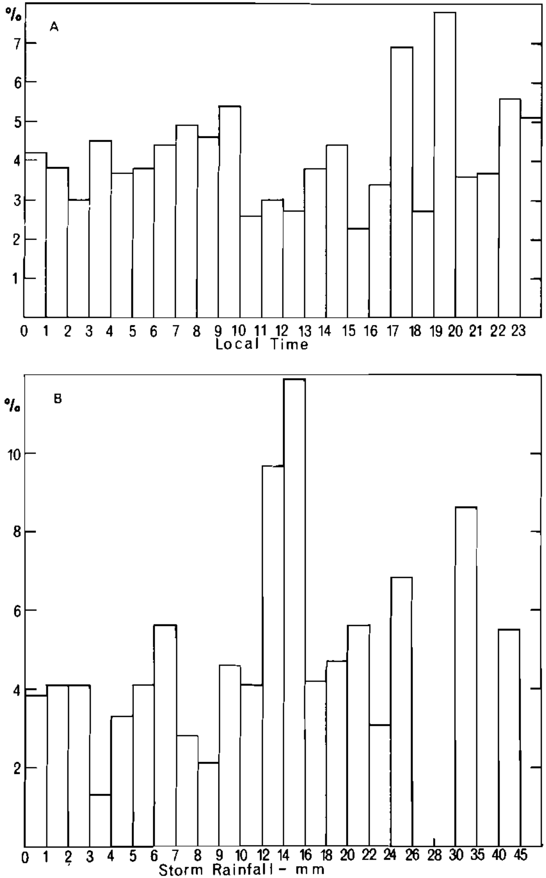

Fig. 4 Percentage distribution of summer rainfall at Matador – 1969–71: (a) diurnal variation; (b) distribution of total storm rainfall amount.

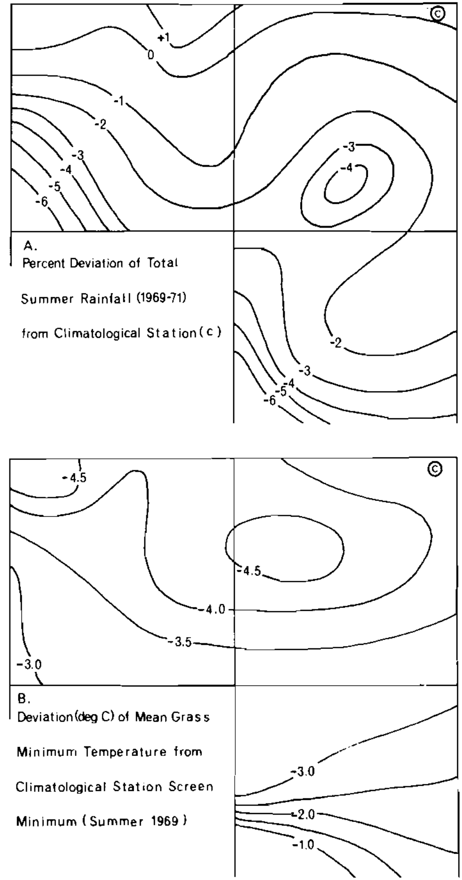

Fig. 5 Spatial variation over the Matador study area of: (a) total summer rainfall; (b) mean grass minimum temperature.

growth of vegetation. The soil is recharged with water at the time of the spring thaw, and combined with the heavier rainfall during June and July, this provides sufficient moisture for early summer growth. From August onwards the soil dries out and is usually quite dry at the time of freeze-up. Because of this, the next year's snow melt is able to infiltrate rapidly into the soil, thus completing the cycle. At Matador, spring infiltration is further assisted by the many cracks which develop in the clay soil as it dries out in the late summer. A plot of the variation in mean daily soil temperatures at a number of depths during the 1970 spring thaw at Matador is presented in Fig. 3. The warm-up covered a period of about 10 days near the surface with only a few hours lag between the 5- and 10-cm levels. The 20-cm level lagged by about three days with the 100-cm change close behind. The rapid change at the lower levels indicates that the warming was likely a result of rapid infiltration of liquid water, probably down cracks. The 100-cm temperature rose from −2°C to +1°C in two days.

e *Wind*

The vegetation microclimate is influenced to a considerable extent by the wind field near the surface. On windy days the spatial and temporal contrasts are much less than on correspondingly calmer days. The mean wind speed (at 10-m height) of 4.4 m/s at Matador does not vary a great deal with season but there is a considerable diurnal variation, mainly during the summer, due to convection. The mean April to November diurnal range has a low of 3.7 m/s about dawn and a high of 6.2 m/s in the early afternoon. The mean wind speed is higher than 10 m/s about 5 percent of the time but only rarely exceeds 20 m/s.

f *Precipitation*

The diurnal variation of summer rainfall for the period 1969–71 is shown in Fig. 4 (a). The distribution is fairly uniform over the day except for a slight drop about midday and some evening peaks due to convective storms. Fig. 4 (b) shows the distribution of individual rainstorms into total amount classes. Since a near constant amount of each rainstorm is intercepted by the vegetation and top layer of litter and soil and re-evaporated without ever being available for use by the vegetation, the effective rainfall is highly dependent on rainstorm amount. On the one hand very light rainfalls never reach the plant roots because of return to the atmosphere by evaporation, while on the other, heavy rainfalls result in water loss by runoff. The time of occurrence is also important as regards loss because of the diurnal variation of evaporative demand. With reference to Fig. 4(b) about one-third of Matador's rainfall occurs in storms of less than 10 mm; another third in the range of 10–20 mm; and the remainder in storms of greater than 20 mm total.

The importance of the contribution of snow melt to the replenishment of soil water reserves in the Prairies has been mentioned earlier. The amount of recharge depends on the water equivalent of the snow pack at the time of melt, the infiltration characteristics of the soil, topography, and the rapidity of the thaw. Although no hydrological studies have been carried on at Matador some of these factors have been measured and estimates can be made of the others.

While winter snow depth appears to be relatively stable in the 20–30 cm range snow density increases through the winter. In 1970, for example, the density was 0.18 on 14 January, 0.22 on 10 February, and 0.32 on 26 March. At the time of the thaw that year (first week in April) the water equivalent of the snow pack was 98 mm which is approximately one-quarter of the total annual precipitation.

In 1971 the water equivalent just before the thaw was 86 mm. Soil moisture measurements (by the neutron scattering method) before and after the thaw show an overall increase of about 100 mm in the profile. The two measurements were taken in different areas and the discrepancy could be due to variation in snow pack depth or density or to surface flow of the melt water.

g *Network Measurements*

Snow depths were sampled in a uniform grid of 100 points on Section 16 (Fig. 1) in late March 1969. The mean snow depth was found to be 39.2 cm with a standard deviation of 5.3 cm. The spatial variation was quite complex with individual depths ranging from 27 to 47 cm. However, no correlation could be found with topography.

The mean of the three summers' rainfall at the network stations is displayed in a map in Fig. 5(a). The climatological station, shown in the upper right-hand corner, was used as a reference and rainfall at the other locations recorded as percent deviations from that at this station. Considerable variation was found in the rainfall pattern from month-to-month and year-to-year. The only permanent feature was the decrease towards the river breaks. There is a sharp drop of about 500 feet towards the south with coulees extending northwards at several points. Most of the experimental work was carried on away from the river breaks and the annual precipitation varied less than a few percent within this area.

The deviation of grass minimum temperatures over the study area from the screen minimum temperature is shown in Fig. 5(b). At the climatological station the grass minimum (5 cm above the ground) averaged about 3.5 deg. C cooler than the screen minimum. Other parts of the study area were as much as 5 deg. cooler. Again, the river breaks had a large effect with warmer night-time temperatures than elsewhere (by several degrees C). This was presumably due to the greater mixing in these areas caused by orographic circulations.

5 Micrometeorology

The micrometeorological studies at Matador have two major aims: (1) to take detailed measurements of the canopy and soil microclimate and to relate these to the macroclimate and canopy properties; (2) to determine the fluxes of momentum, heat, water vapour, and carbon dioxide in the surface boundary layer and to relate these to macrometeorological factors, plant microclimate, soil and plant water status, etc.

Whereas the climatological station was designed to operate on a year-round basis, the micrometeorological studies were carried out only during the growing season and had numerous gaps due to severe weather, calibration, instrument repair, etc.

The field layout for the micrometeorological studies carried out in the summer of 1971 is shown in Fig. 6. The data-acquisition system was housed in a 30-ft trailer located at point H in Fig. 6 with the general location shown as point M in Fig. 1. Sensors were located so as to minimize the effects of the trailer with regard to prevailing wind direction. The micrometeorological site

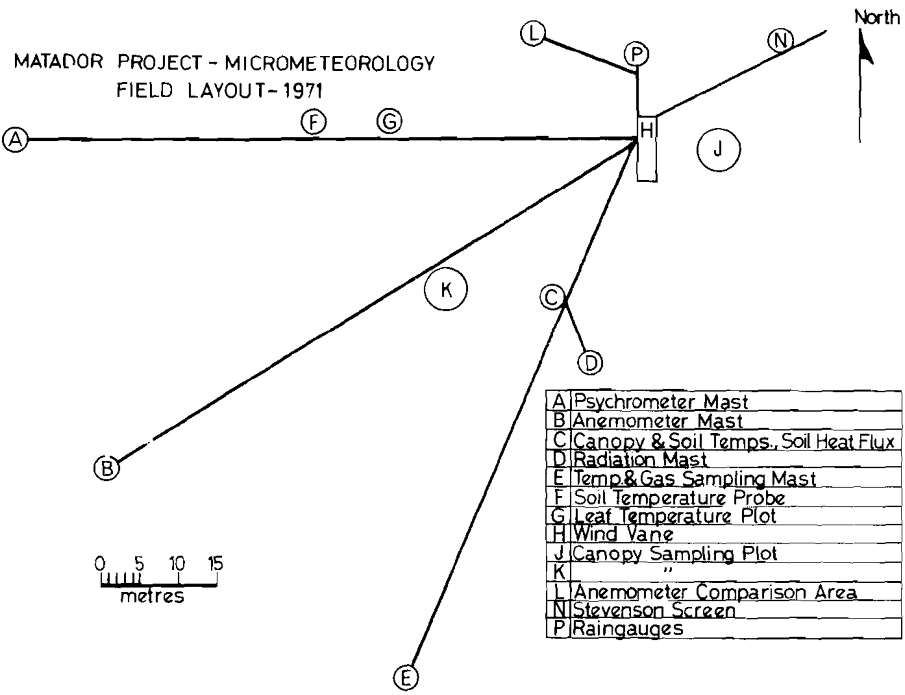

Fig. 6 Matador micrometeorological field layout – summer, 1971.

was chosen so as to have a satisfactory fetch of at least 2 km in all directions.

The psychrometer mast (Location A, Fig. 6) has five aspirated resistance thermometer psychrometers arranged at logarithmic height intervals up to 160 cm above the estimated zero-plane. It was designed to permit manual rotation about a vertical axis so it could be faced into the wind, and it also rotated automatically about a horizontal axis several times a day to bring all psychrometers to the same level for comparison.

The canopy temperature was measured at heights of 2, 5, 7.5, 10, 15, 20, 35, and 50 cm above the ground. The gas sampling and dry-bulb temperature mast is shown in Fig. 7. Half-inch copper tubing was used to carry the air from the six heights (30, 50, 90, 170, 330, and 650 cm) back to the instrumentation trailer for carbon dioxide and water vapour analysis. The copper tubes were heated to prevent condensation. Other instrumentation included soil heat-flux

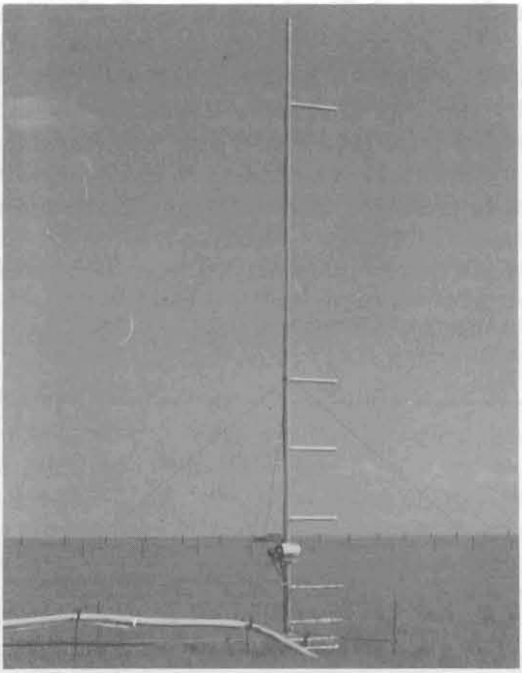

Fig. 7 Matador micrometeorological study area – gas sampling and dry-bulb temperature mast. Note the flat terrain.

plates and temperature probes, anemometer mast, leaf thermocouples, windvane, rain gauges, and Stevenson Screen.

All sensors were ultimately fed into a 200-channel (in a three-wire configuration) digital data acquisition system. The system was programmed to scan the sensors once every three minutes and to record the readings on magnetic tape. The carbon dioxide and water vapour profiles were also monitored on a strip-chart recorder.

The field data are processed on the University's IBM 360 computer. The raw data tape (7-track, low density) is checked and re-recorded by the computer on a 9-track, high-density tape. There it is converted to proper units and summarized for half-hour periods by special programs *Summary I* and *Summary II*. Then a *Plot* program is used to plot profiles of wind speed, temperature, and humidity for examination. Decisions are then made as to the best periods for further analysis and these are then run through program *Fluxes* which computes the desired fluxes by energy-balance and aerodynamic theoretical techniques.

An actual Calcomp plotter output is shown in Fig. 8. This is for the 4 August 1970 and shows the wind speed and direction at the top of the figure with global and net radiation, soil heat, sensible and latent atmospheric heat fluxes beneath. The first 3 fluxes are positive downwards and the other two positive upwards. No carbon dioxide measurements were taken during 1970. It is interesting to

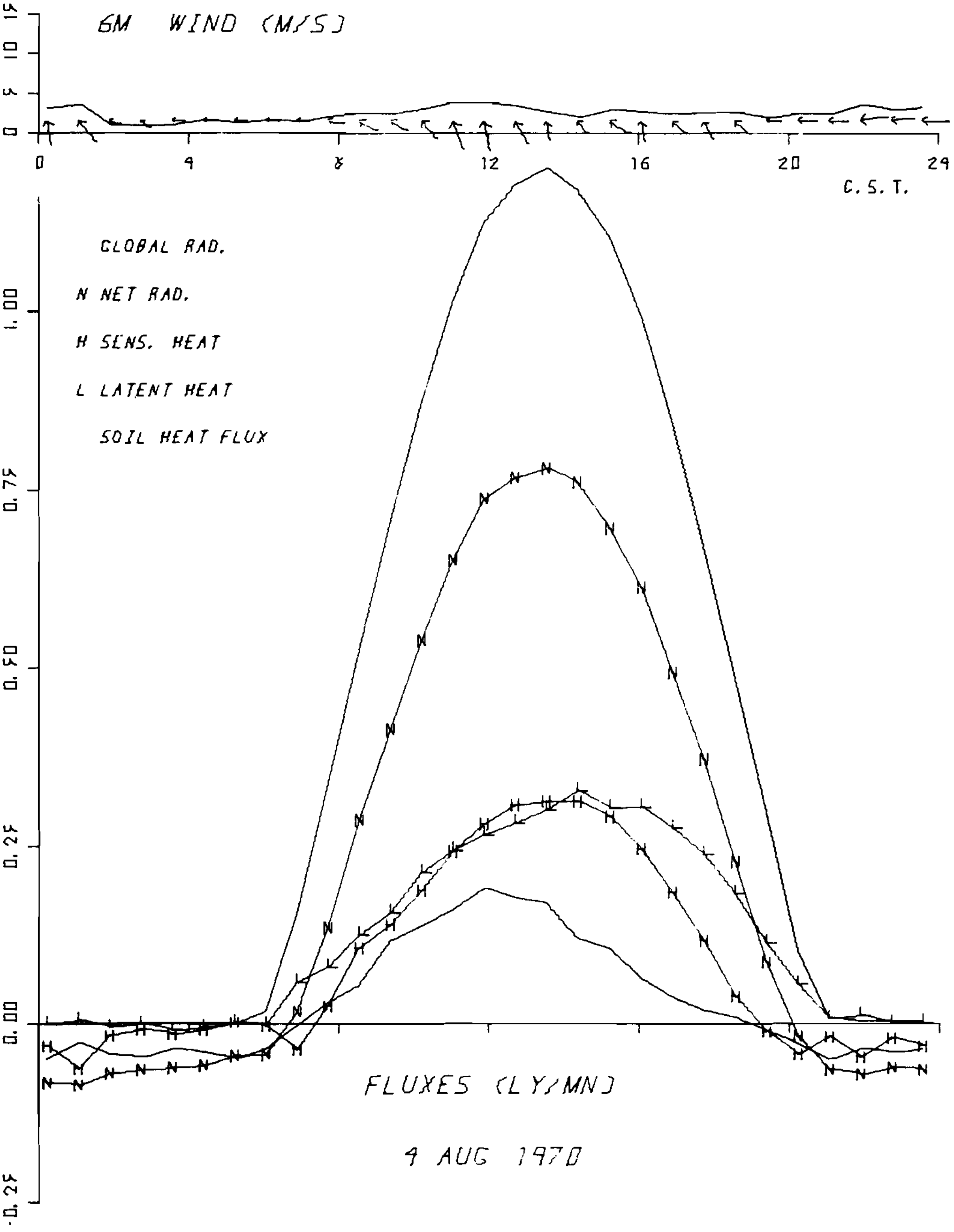

Fig. 8 Computer plot of fluxes over the native grassland at Matador on 4 August, 1970. Global solar and net (all-wave) radiation and soil heat flux were measured directly, while the sensible and latent heat fluxes were calculated from temperature and humidity profiles using the energy-balance approach.

note the near equality of the sensible and latent heat fluxes (H and L) in Fig. 8 except during the evening when the sensible heat flux drops off much more rapidly than the latent heat flux. At this time of year the vegetation was likely just beginning to feel some moisture stress after well above normal early summer precipitation. There is what appears to be a slight "mid-day depression" in the latent heat flux. The soil heat-flux curve shows a peak about noon at which time its value was about one-quarter that of the net radiation.

Through analysis of plots of the fluxes, as in Fig. 8, over the growing season it will be possible to learn a great deal about the response of the vegetation to the environmental variables (such as radiation, temperature, soil moisture and wind).

6 Synthesis and modelling

A considerable amount of work remains to be done in regard to explaining the behaviour of the biological components of the ecosystem in terms of each other and the environmental variables. Sufficient data are now available to permit most of these studies to be carried out. Some supplementary information will have to be provided by laboratory studies.

The main effort of the Project is now being directed towards the development of a computer model of the ecosystem. This will incorporate all of the interactions revealed by the experimental work and will be verified using both the field and laboratory data.

A program for a weather simulation submodel has been written. It is based on air mass trajectories and persistence, and will be used to provide the driving variables for the ecosystem model. With the weather simulator, realistic daily weather can be generated for any period of time. By adjustment of parameters extreme conditions can be simulated (such as climatic change, which might be induced by atmospheric pollution).

Development of a computer model of something as complex as a natural ecosystem will have to be done over a period of years. There are severe limitations because of our inadequate knowledge of many component interactions; because of the great difficulties in measuring even the biomass of many organisms; and because present-day computer hardware and software are inadequate to deal with any but the most simplistic ecosystem models. It is expected that the simple model produced at this stage will be only a beginning and that it will be improved and extended as more information and more powerful computers and computational methods become available.

The use of even a simple ecosystem model will permit assessment of the effects of both natural variations and, in particular, of man-induced perturbations on all of the components of the ecosystem. Instead of looking at only one or two items we will be able to examine every pertinent aspect. Instead of only short-term responses we will be able to study effects after decades or longer. The total-ecosystem computer model holds the promise of providing an effective tool with which man can assess the impact of his actions on natural environments. It is hoped that this additional information will lead toward a wiser utilization of our natural resources and a more harmonious relationship between man and nature.

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ANNOUNCEMENT

Current Awareness Service – World Meetings Information Center

World Meetings Information Center announces a new current awareness service based upon the programs of scientific and technical meetings. The service, to be called *Current Programs,* will be essentially a "contents" type of publication. However, being based upon meeting programs, it will give the scientific community an average of more than a year's advantage over publications based on the journals.

Studies by the Center for Research in Scientific Communications at the Johns Hopkins University have shown that almost half of the papers published in selected core journals are made public *at meetings* as much as thirty-six months earlier. Equally important, almost one-third of the papers presented at meetings never see journal publication. As a result, much valuable information has, in the past, been lost. The need for the new current awareness service is clearly implicit in the results of these studies.

Current Programs is expected to publish the scientific programs of about 1,200 international, national, and regional meetings each year. These meetings will include about 120,000 papers covering the life sciences and medicine, chemistry and the physical sciences, and engineering.

The monthly publication will give the titles of the papers and the names and addresses of the first authors as listed in the program. In addition, full information will be given on all preprints, reprints, proceedings, or abstract publications expected to issue from each meeting. *Current Programs* will be priced at well under $100 per year, putting it within the budget of the individual scientist and engineer.

Detailed subject, author, and meeting indexes will be available on a quarterly and on an annual basis to permit retrospective search of *Current Programs.*

The detailed format of *Current Programs* will be based largely upon the results of information recently solicited from more than 500 key members of the scientific and technical communities.

Literature describing *Current Programs* and giving full information on pricing is available and may be requested from World Meetings Information Center, 824 Boylston Street, Chestnut Hill, Massachusetts 02167, U.S.A.

On the Propagation of Local Errors in a Primitive Equations Model[1]

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ABSTRACT

Numerical experiments have been performed to determine the way in which initial errors of relatively small horizontal extent propagate in a barotropic primitive equations model. Six-day forecasts are made with the model, starting from initial conditions which are assumed to be free from errors. The forecasts are then repeated using the same initial data, except for a small area near the Gulf of Alaska where an error in the form of a low pressure system is added. The difference between the two forecasts, or error, is then examined as a function of time. The results obtained from sixteen cases run with winter data indicate that on the average the largest value in the error pattern travels, in six days, from the Gulf of Alaska to the western tip of the Great Lakes and decreases in amplitude by a factor slightly greater than 2 for an initial amplitude of 8.4 dam at 500 mb. The root mean square error computed over the entire forecast area, on the other hand, is found to remain nearly constant for the first 24 hours and to increase systematically thereafter, with a doubling time of 5 days.

1 Introduction

It is generally recognized that one of the important sources of errors in weather forecasts made in many parts of the world is the lack of proper observations over relatively large areas of the globe. While it seems clear now that this problem will soon be alleviated to a large extent by the advent of modern observational techniques such as the meteorological satellite, it also seems likely that our data network will continue to suffer from observational gaps for some time to come. At the very least we can expect that the quality of the data used as initial conditions to produce forecasts will not be uniform in space so that the quality of the forecasts will also be a function of space.

The purpose of the present study is to examine how an error pattern of relatively small horizontal extent which is present in the initial data propagates in forecasts made with a numerical model. The procedure is as follows. A numeri-

[1]Paper presented at the Sixth Annual Congress of the Canadian Meteorological Society, Edmonton, May 31–June 2, 1972.
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cal model is used to produce one forecast from each of two sets of initial stream function data which differ from each other by a prescribed amount over a certain area and which are identical everywhere else. The difference between the two initial states, or between the corresponding forecasts, will be called the error. It is of interest, in particular, to determine the rates at which the area affected by the error as well as the magnitude of the error change as functions of time. Studies of this nature have been made recently by Irvine and Houghton (1971) and Houghton (1972). In both instances some emphasis was placed on studying the way in which the propagation of the error pattern is influenced by its original location. In all the computations performed for the present study the error pattern is introduced in the same location initially but the synoptic situation is allowed to change from one set of computations, or experiment, to the next. The results of a number of experiments are then averaged in order to obtain reasonably representative results and the attention is focussed on the mean behaviour of the error pattern rather than on the differences between individual cases.

The forecast model which was used in this study will be presented briefly in Section 2 while the position, shape and amplitude of the error which was assumed to be present in the initial data will be described in Section 3, followed by a discussion of the results in Section 4.

2 The model

The forecasts necessary for this study were made using the semi-implicit primitive equations barotropic model described by Kwizak and Robert (1971), except that in the present version the effects of the earth's topography have been included and the mean depth of the fluid was assumed to be one quarter of the mean 500-mb height in order to prevent an excessive retrogression of the ultra long waves. The model was integrated over an area of 51 × 55 grid points covering most of the Northern Hemisphere, with a grid spacing of 381 km at 60°N, using one-hour time steps. The initialization method used in this model assumes that the stream function is available; the corresponding geopotential is then obtained by solving the model's "reverse balance" equation. Thus all forecasts (i.e., with or without the error perturbation in the stream function) are started from balanced initial states. The same model, without the effects of the earth's topography, was integrated over a period of 25 days by Kwizak (1970) who found that the total energy of the model varied by less than 1% over this period.

3 The data

The data used as initial conditions for the forecasts "without error" were the 500-mb stream function fields made available by the Canadian Meteorological Centre (AES, Montreal), for the period February 4, 1971, 12Z through March 8, 1971, 12Z, at 2-day intervals, except for February 24 where the data could not be used. Sixteen different synoptic situations covering a period slightly greater than 1 month were therefore used in the investigation. For each case a

6-day forecast was made using the unmodified stream function as initial data, after which another forecast was made using a perturbed stream function, the perturbation being given by

$$\psi_E = \frac{Aga(n^2 - r^2)}{f_0 n^2(a + br^2)}, \qquad r \leq n$$

$$\psi_E = 0, \qquad r \geq n$$

where g is the acceleration of gravity, f_0 is the value of the Coriolis parameter at 45°N, $A = -10$ dam, $a = 1.1162$, $b = 0.5229$, $n = 5$, and r is the distance between a given grid point and the centre of the perturbation, measured in units of grid intervals. Clearly ψ_E is a radially symmetric function on the polar stereographic map with a value of -10 dam at the centre, decreasing monotonically to zero at a distance of five grid points from the centre. A similar formula is used as the weighting function in the objective analysis of height fields at the Canadian Meteorological Centre except that n is set equal to 4 (Kruger, 1969a, 1969b). In all the experiments the error in the stream function was centered on the cross mark shown in Fig. 1(a).

4 The results

The average error in the 500-mb height field for the 16 cases is shown in Fig. 1 for time $t = 0$, 2, 4 and 6 days. Intermediate results for $t = 12$ and 24 h (not shown here) indicate that for the first 12 hours the average error pattern moves downstream with relatively little change in the shape of the pattern. After about 24 hours there is a tendency for a high pressure pattern to form on the southeast side of the main low pressure system and to persist for several days, as seen in Fig. 1. A similar result was obtained by Irvine and Houghton (1971). After six days, in particular, there is a tendency for the error pattern, as revealed by the average of the 16 cases, to have negative values along the west coast of North America, positive values along the east coast and negative values again over the central Atlantic. By this time the average value of the error is quite small everywhere, however, reflecting in part the fact that there was a tendency for the 16 error patterns to cancel each other out in the mean, some cases yielding error patterns of one sign in a given area where others gave error patterns of the opposite sign. Fig. 1 clearly cannot be interpreted as giving the average magnitude of the error at any one time but it does, on the other hand, provide some information on the preferred sign and value of the error.

Fig. 2 shows the root mean square error for the 16 cases for times $t = 0$, 2, 4 and 6 days as in Fig. 1. The region of influence of the error, defined arbitrarily as the area within the 1-dam contour, is seen to extend slowly westward with time but by far the most rapid propagation takes place in an eastward direction, the eastern tip of the 1-dam contour moving at an average speed of about 20° longitude per day (or 18 m s^{-1} at 45°N). The centre of maximum error, on the other hand, moves at the slower average speed of 10° longitude per day (or 9 m s^{-1}) and is located at the western tip of the Great Lakes on the sixth day.

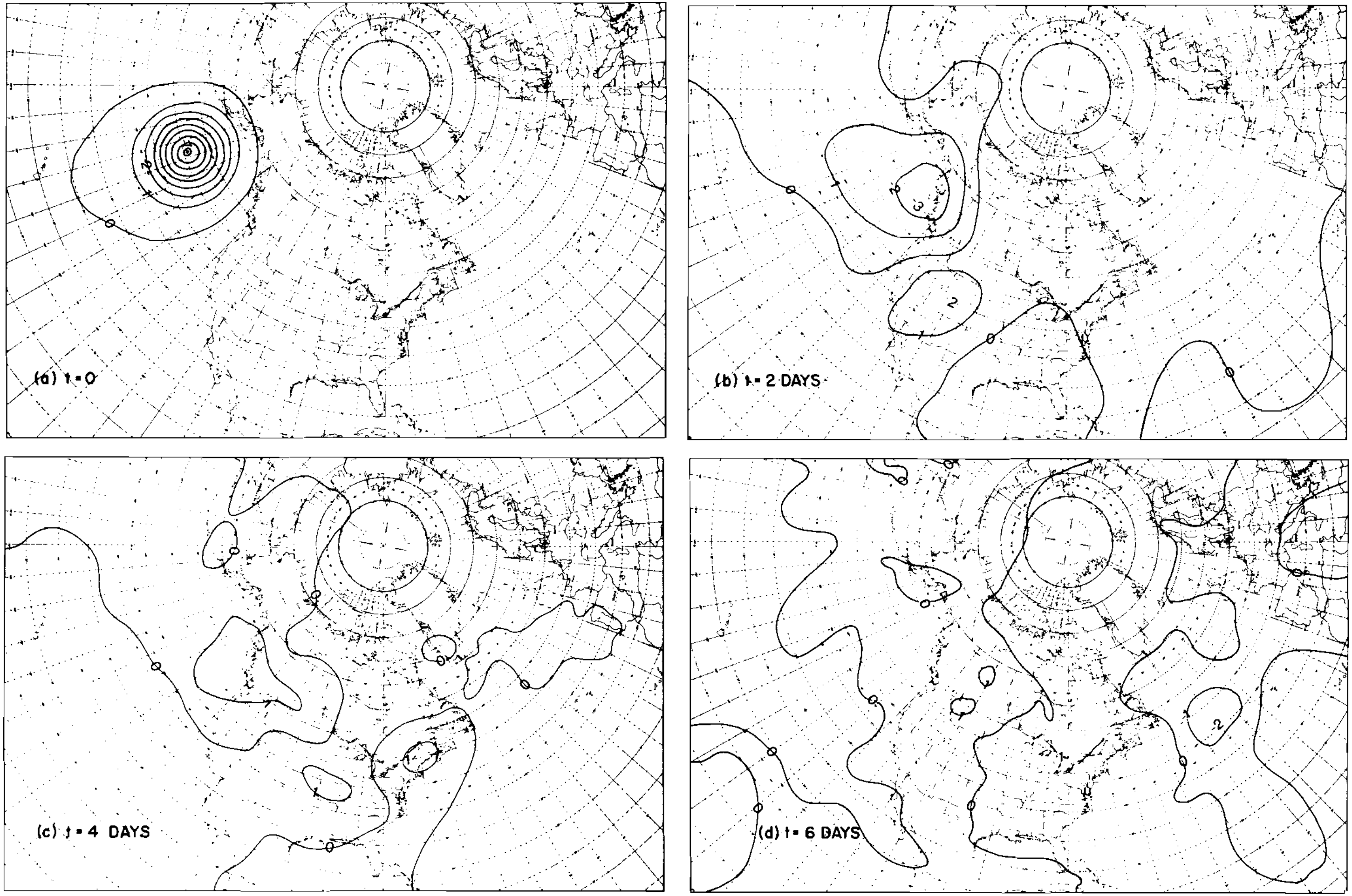

Fig. 1 The average error in the 500-mb height field, in dam: (a) $t = 0$, (b) $t = 2$ days, (c) $t = 4$ days and (d) $t = 6$ days.

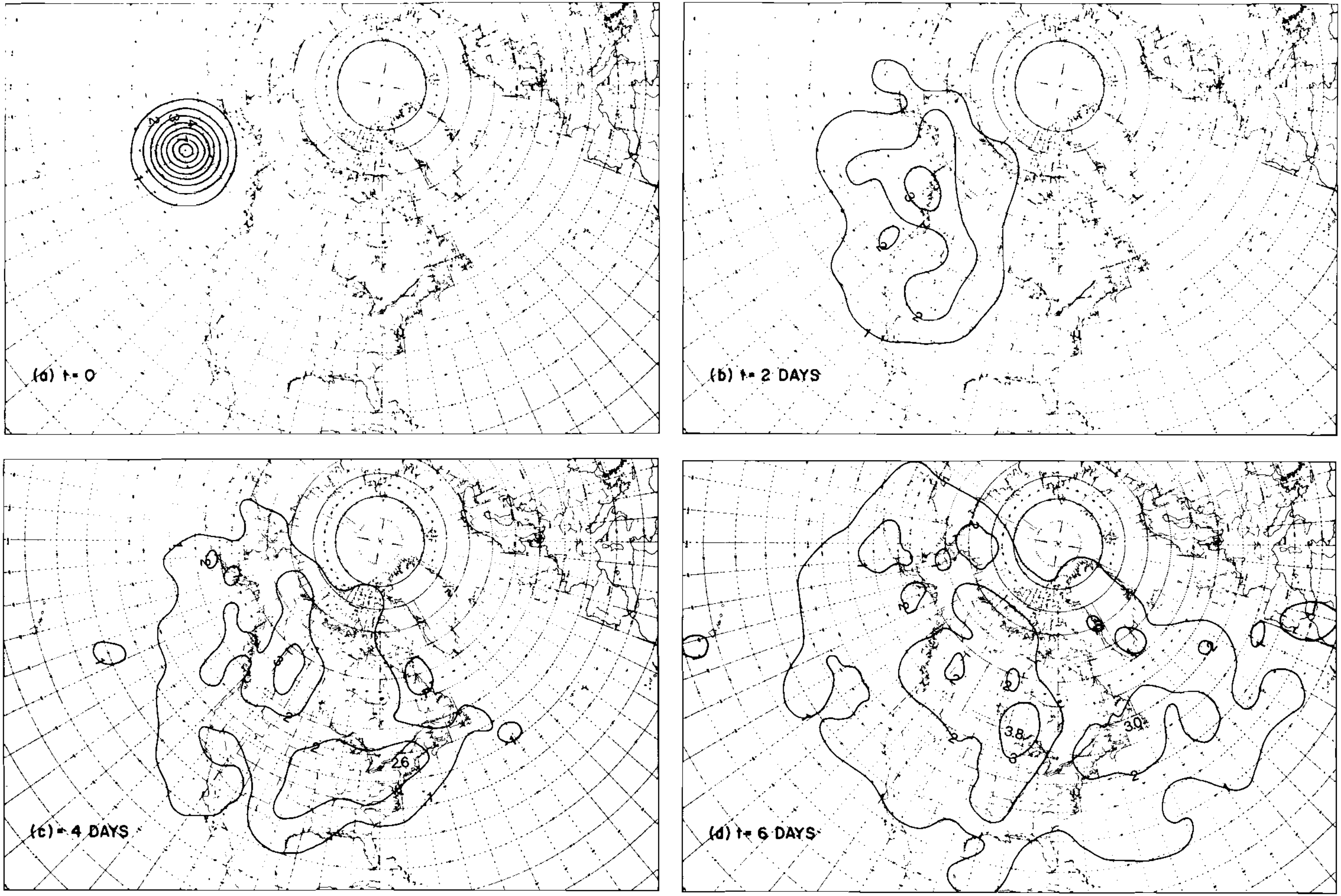

Fig. 2 The root mean square error in the 500-mb height field, in dam, for the same times as in Fig. 1.

To obtain some comparison between the propagation velocity of the error patterns and the mean flow pattern during the period under consideration, the 16 stream functions used as initial conditions for the unperturbed states were averaged and the wind speed associated with this stream function was computed. The results are shown in Fig. 3 for the mean stream function and in Fig. 4 for the wind speed. Fig. 3 also contains the position of the main error pattern, in an RMS sense, as a function of time, using information at 24-h intervals. It should be kept in mind that some of the raggedness in the tracks of the system is undoubtedly due to the fact that the centre of a system was always assumed to coincide with a grid point. In the case of the secondary error maxima the tracks could not be clearly determined after the fourth or fifth day using data at 4-h intervals and so they have been omitted.

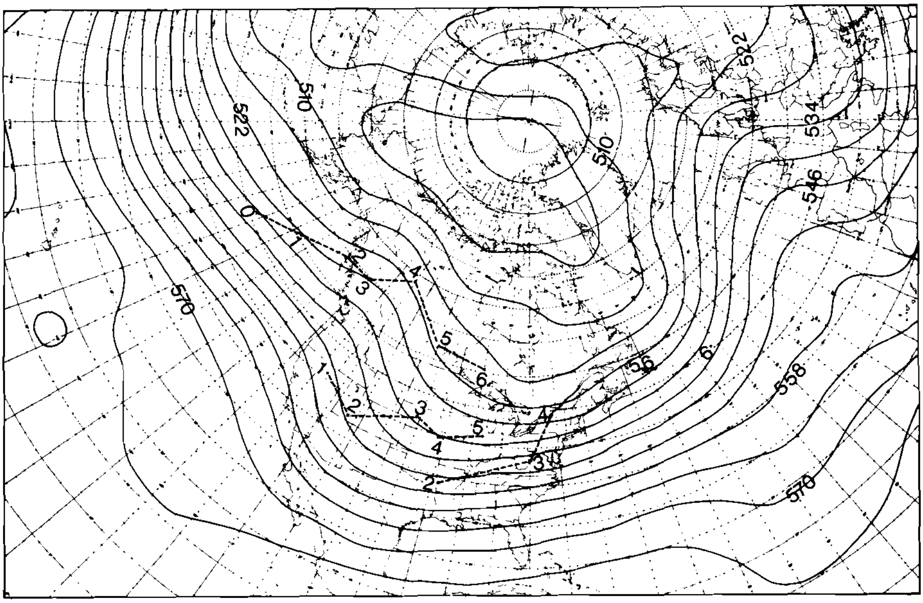

Fig. 3 The average of the 16 undisturbed stream functions at $t = 0$, in dam, together with the positions of the main error maxima at various times (in days).

It is apparent that the centres of the error patterns tend to move toward lower values of the stream function at speeds which are smaller than those shown in Fig. 4. The speed of 20° longitude per day (18 m s^{-1} at 45°N) mentioned earlier for the speed of the 1-dam contour, on the other hand, is comparable with the mean zonal velocities which can be deduced from Fig. 3.

The number of computational grid points contained within the 1-dam contour in Fig. 2 can be taken as an approximate measure of the area where the error is 1 dam or more, that is, the region of influence of the error. This number is shown as a function of time in Fig. 5. After 6 days the region of influence of the error is seen to have increased by a factor of nearly 13.

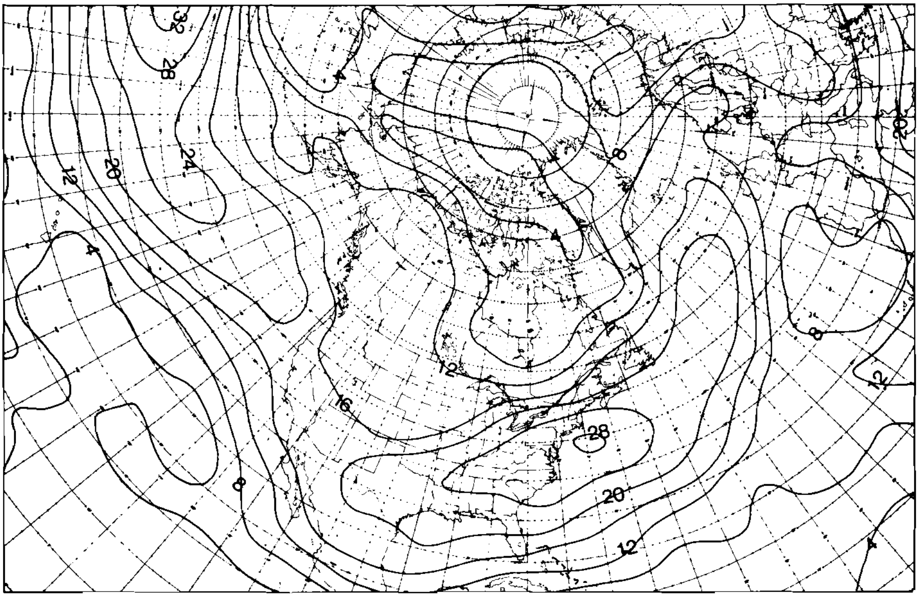

Fig. 4 The wind speed computed from the stream function in Fig. 3, in m s^{-1}.

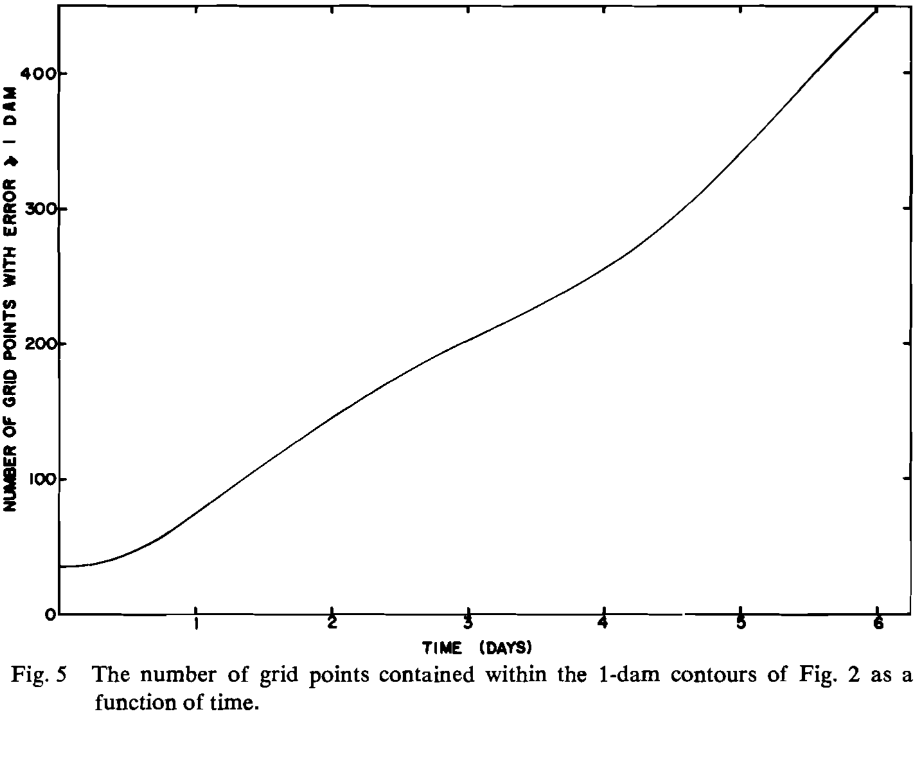

Fig. 5 The number of grid points contained within the 1-dam contours of Fig. 2 as a function of time.

If we look for the maximum value in the RMS error field we find that it is normally ($t = 3$ days is an exception) associated with the error pattern which moves from the Gulf of Alaska at initial time to the northwestern tip of the Great Lakes on the sixth day of the forecasts. This maximum value is plotted as a function of time on Fig. 6. It is important to observe also that the secondary systems which develop during the course of the forecasts are not by any means negligible. Fig. 2(d), for example, shows that the RMS error over Newfoundland has a value of 3.0 dam, only 0.8 dam less than the primary maximum over the continent.

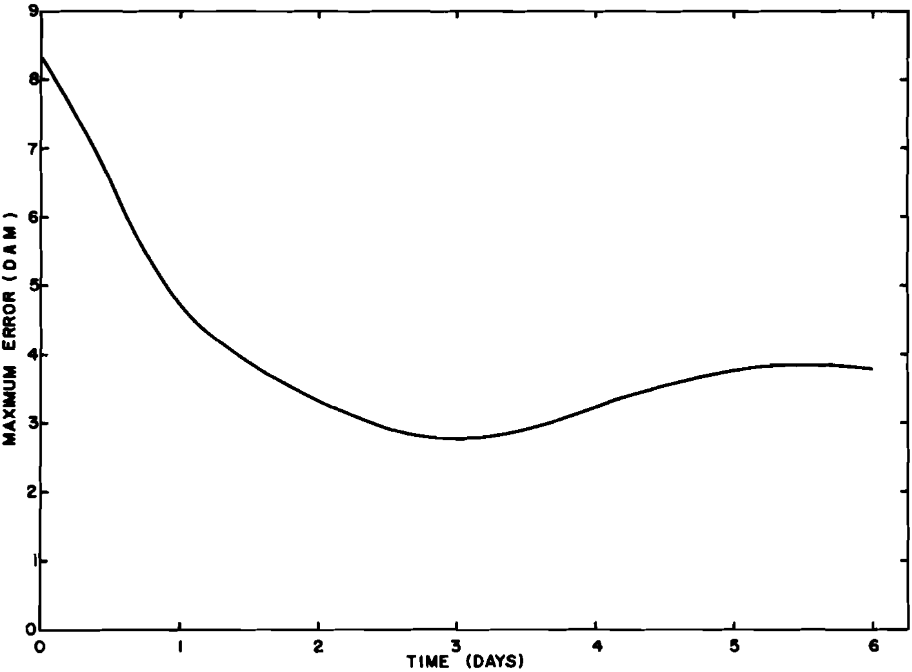

Fig. 6 The time variation of the central value of the RMS error pattern which appears at the northwestern tip of the Great Lakes on the sixth day (see Fig. 2).

So far we have looked at the RMS error where the averaging was done over the 16 numerical experiments which were performed. A hemispheric RMS error E_k was also computed as

$$E_k = \left[\frac{1}{M} \sum_{m=1}^{M} E_{k,m}^2 \right]^{\frac{1}{2}}$$

where $E_{k,m}$ is the error computed at grid point m for experiment k and $M = 2805$, the number of grid points. Finally an overall average error was computed from

$$E = \left[\frac{1}{KM} \sum_{k=1}^{K} \sum_{m=1}^{M} E_{k,m}^2 \right]^{\frac{1}{2}} = \left[\frac{1}{K} \sum_{k=1}^{K} E_k^2 \right]^{\frac{1}{2}}$$

We shall call E the overall hemispheric RMS error. The results obtained for E as a function of time are shown as the solid curve in Fig. 7. The vertical barbs give the extreme values obtained for E_k. We find that for the first 24 hours the hemispheric RMS error remains nearly constant but that after about 2 days it grows with a doubling time of about 5 days. For comparison, the average of the

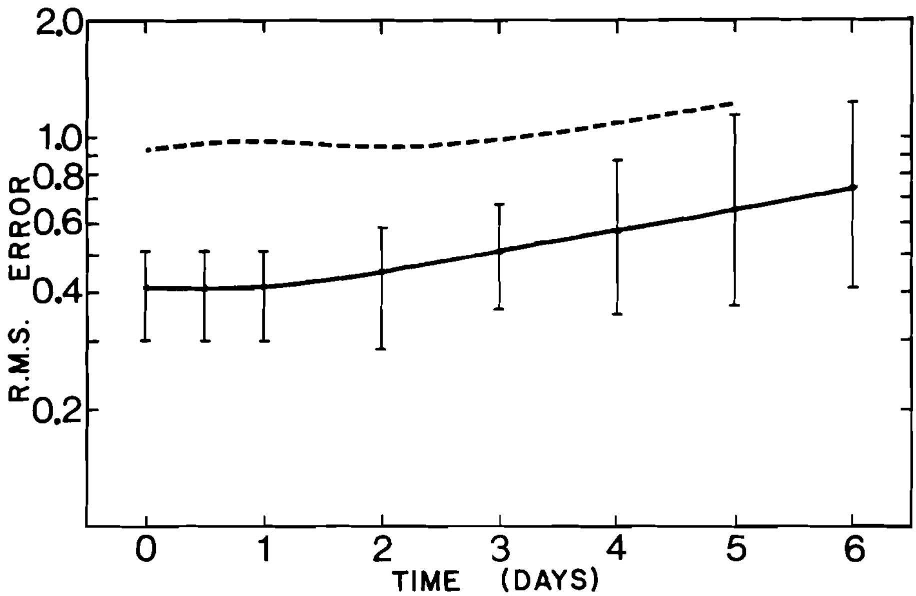

Fig. 7 The overall RMS error as a function of time. The solid curve applies to the average height error, in dam, obtained in the 16 experiments performed in this study while the dashed curve applies to the normalized error in the pressure field obtained by Houghton (1972) (see text). The vertical barbs give the range of values obtained in these 16 experiments. Note that the solid and dashed curves are not expressed in the same units so that only their slopes can be compared.

results obtained by Houghton (1972) for his experiments A and B are shown by the dashed line. His results apply to the error in the pressure field as computed by the NCAR six-layer 5°-mesh general circulation model, the error patterns being injected in the initial data either at 50°N (experiment A) or 30°N (experiment B) and the perturbed integrations being started from geostrophically balanced wind and pressure fields. It is most interesting to note that after the first few days the error growth in the two models is quite similar. This lends support to Lorenz's (1972) contention that *barotropic* instability may well play a leading role in the growth of errors in the atmosphere.

5 Summary and conclusion

Numerical experiments have been performed to determine the way in which an error in the stream function which is confined to a relatively small area at a given time will propagate in the course of a forecast performed with a barotropic primitive equations model. It has been found that while some identifiable features in the height error field, such as local maxima, propagate eastward at speeds which are somewhat smaller than the mean wind speed, the leading edge of the height error pattern travels eastward at a speed roughly comparable with that of the mean zonal flow. The area significantly affected by the error has been found to increase by a factor of 13 in six days, in such a way that an error which is confined to the Gulf of Alaska at initial time, will affect the entire North American continent and most of the Atlantic region in a six-day forecast for typical winter synoptic conditions. The magnitude of the error, as measured by the RMS height error for the Northern Hemisphere, has been found to remain nearly constant during the first 24 hours of the forecast and to increase with a doubling time of 5 days thereafter. The growth rate of the error computed with the barotropic model was found to be quite comparable with that obtained by Houghton (1972) with the NCAR six-layer model, indicating that the growth of the error may be a manifestation of barotropic rather than baroclinic processes.

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Snow Rollers – Lakeburn, N.B.
April 5, 1972

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[Manuscript received 23 June 1972]

Weatherwise (1971) featured a cover story on the occurrences of snow rollers in Minnesota. The article stated, "snow rollers, unfortunately, are witnessed by only a very few and seldom is a camera at hand to record these wonders of nature for others".

Mrs. Norman LeBlanc of Lakeburn, N.B., happens to be one of those "very few" who witnessed such an occurrence and she had a camera at hand to record the proof.

Shortly after midnight on April 6, 1972, the technician on duty at the Moncton Weather Office received a call from a lady who stated that, while skidooing in a field near her home, she was suddenly confronted with "large balls of snow falling from the sky". The technician, remembering the *Weatherwise* article, suspected that the lady had witnessed an occurrence of snow rollers. The fact that they appeared to be "falling from the sky" was readily explained—the speed of the rollers and the darkness of the night would not permit one to discern their movement along the snow surface and all one would actually notice was the roller as it came to rest.

Unfortunately, the technician could not leave his post at the time to check out his suspicions. However, approximately seven hours later, he and the Officer-in-Charge of the Weather Office visited the site and the snow rollers were positively identified. An inspector from the Regional Office staff was called in with a camera and photographs were taken. Later, the lady caller was

H.A. Kinden, OIC, Moncton Weather Office.

identified as Mrs. LeBlanc, who kindly provided prints of the pictures she had taken at night with a flash polaroid. While weather conditions were not conducive to good photography and the paths of the rollers had been obliterated by drifting snow after their formation, the pictures leave no doubt as to the identity of the rollers.

The rollers were observed at frequent intervals between the hours of 7:00 and 10:00 p.m. AST on April 5, 1972 in a large open field approximately one mile east of Moncton Airport. The field is located on the south side of highway 32A which connects the Airport (in the town of Dieppe) with the Trans-Canada Highway, has a north to south slope of approximately 40° from the highway and is about one-half mile wide.

A low pressure system with a trough line extending northward from a low centre near Cape Breton Island, N.S., was passing eastward over the area at the time. Until 6:00 p.m. AST the Moncton area had been experiencing light snow, light southeasterly winds and temperatures at or near the freezing point. At 6:00 p.m. AST the wind shifted to west-north-west increasing to 18 mph with gusts to 32 mph, and the temperature dropped from 34°F to the freezing point —conditions not unlike those described in the *Weatherwise* article. However, according to the eye-witness report, the rollers continued to occur even after the temperature at the Airport had dropped to 27°F and the wind to 10 mph. It is likely that the rollers began forming with the passage of the trough line at approximately 6:00 p.m. AST, even though they were first observed an hour later.

The largest roller measured 23″ × 15″ and there were many measuring in the vicinity of 16″ × 10″. Most had soft, fluffy cores which could be removed by a gentle pressure and some were completely clear through the centre, resembling the old-fashioned fur muffs once used by ladies to keep their hands warm in cold weather.

One of the larger rollers was found near the side of the highway on the uppermost part of the slope. Since it is unlikely that it had crossed the highway from the field on the opposite side, it could have attained its size only by moving in a circular path and coming to rest near its original starting point. Of course, it is possible that the rollers increase somewhat in size *after* they have come to rest. The cyclonic features of the roller itself and that of the snow crater in which it rests would suggest some cyclonic activity around the roller for some time after it has come to rest.

Since weather conditions existing at the time are not uncommon in this area, snow rollers may not be as rare as their infrequent sightings would indicate. In fact, unconfirmed reports of similar occurrences were received from Amherst, N.S., 40 miles south of Moncton some time after the Lakeburn sightings were publicized. Future observations in appropriate areas under similar weather conditions might prove interesting.

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Canadian Participation in the Commission for Agricultural Meteorology – World Meteorological Organization

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1 Introduction

Canadians have taken an active part in the work of the Commission for Agricultural Meteorology (CAgM) of the World Meteorological Organization through delegations to sessions, memberships in working groups and as rapporteurs. In fact, Canada was one of the 20 WMO Members that sent delegates to the First Session of this Commission at Paris in 1953. Delegations were also sent to each of the subsequent Sessions held at Warsaw (1958), Toronto (1962), Manila (1967), and Geneva (1971). National reports on the activities in agricultural meteorology in Canada were prepared for each Session and submitted through the Permanent Representative of Canada with WMO.

Recently, Dr. W. Baier of the Canada Department of Agriculture, was elected President of CAgM for the present 1971–74 term. This brief review of past achievements and current activities should be of interest to readers of *Atmosphere* and hopefully will encourage them to participate according to their interest in the program of this Commission.

2 Review of past achievements

The duties of the Commission include the advancement of agrometeorology both in pure and applied research, the publication of such research work and the training and education of agrometeorological personnel at all levels. WMO and other UN agencies have attached great importance to these activities since agrometeorologists are contributing towards solutions to two major world problems: the efficient production of extra food and the preservation of our environmental resources.

The performance of these duties was accomplished through the activities of working groups and rapporteurs. The results have been published in the *Technical Note* series and other WMO reports covering a variety of subjects dealing with the influence of the atmospheric environment on soils, crops, animals, pests and diseases. Canadians contributed to these accomplishments especially in the fields of evaporation measurements (G.W. Robertson), wind breaks and shelter belts (G.W. Robertson), air pollutants and plant injury (E.I. Mukammal), practical soil moisture problems (R.M. Holmes and W. Baier), agrotopoclimatology (L.B. MacHattie) and in the preparation of syllabi for instruction in agricultural meteorology (K.M. King). Some 23 out of the 121 published

Technical Notes dealt with agrometeorological subjects. These publications are of an outstanding standard of quality and provide resource material which is largely lacking in textbooks for research, education and teaching purposes.

Training and formal instruction in agricultural meterology were provided by a series of seminars held at Maracay (Venezuela), Cairo (Republic of Egypt), Melbourne (Australia), Wageningen (Netherlands) and Barbados (West Indies).

3 Current activities

The current activities were planned during the Fifth Session of the Commission held at the WMO Headquarters Building in Geneva from 18 to 30 October, 1971.

The Session was attended by 87 participants and comprised representatives from 47 countries, 8 international organizations and the Holy See. Dr. R.A. Treidl of the Atmospheric Environment Service, was the principal delegate for Canada and Dr. W. Baier of the Canada Department of Agriculture was a delegate.

The Commission held five plenary meetings under the chairmanship of Mr. L.P. Smith who was President of the Commission for the past nine years. Two Working Committees were established: Committee A to deal with questions of an administrative or organizational character, chaired by Dr. J. van Eimern (Federal Republic of Germany); and Committee B to deal with questions of a theoretical or scientific character, chaired by Dr. W. Baier (Canada).

In developing plans for its activities during the current 3-year term, the Commission paid special attention to those problems that require interdisciplinary approaches at the international level for their possible solution.

The Commission proposed 9 Working Groups and 17 Rapporteurs in the following areas:

(i) *Methodology:* International experiments for the acquisition of crop-weather data; Crop yields and forecasting of yields; Methods in agroclimatology; Aerobiology; Agroclimatic maps; Use of shade in agriculture; Measurement of minimum temperature near the surface; Techniques for frost prediction; Frost protection methods;

(ii) *Meteorological Factors Affecting Soils and Crops:* Soil deterioration and erosion; Adaption and production of cocksfoot and red clover; Commercial production of cotton; Commercial production of soyabean; Soil cover; Production of lucerne; Rice production;

(iii) *Meteorological Factors Affecting Plant Injury, Pests and Diseases:* Coffee leaf rust disease; Non-radioactive pollutants of the biosphere; Oriental fruit moth and codling moth; Rice blast;

(iv) *Meteorological Factors Affecting Animal Production and Diseases:* Weather and animal diseases; Livestock meteorology; Controlled climates; Economic value of agrometeorological information; Training requirements in agricultural meteorology.

The Advisory Working Group of the Commission was re-established which will, in addition to its normal duties of assisting the President and planning the next Session of CAgM, also supervise and participate in the rewriting of the *Guide to Agricultural Meteorological Practices*. Canadians are actively participating in this program as President of the Commission and Chairman of the Advisory Working Group (W. Baier), as a Member of the Working Group on International Experiments (G.W. Robertson), as Rapporteurs on Non-radioactive Pollutants (E.I. Mukammal), and on Rice Production (G.W. Robertson).

Postgraduate seminars and international symposia have been planned at such a level that maximum benefit can be derived by participants having either a physical (meteorological) or an agricultural (biological) background. One WMO/UNESCO Symposium will deal with the agrometeorology of a single crop in tropical agriculture, probably rice, at the International Rice Research Institute in the Philippines, and one, with the planning and analysis of agrometeorological field experiments, incorporating both meteorological and biological observations, probably at the "Agrarmeteorologische Forschungsstelle", Braunschweig-Volkenrode in Germany. One follow-up seminar to the agroclimatology survey of the East African highlands has been planned, probably to be held at Nairobi in Kenya.

The Commission recognized the urgent need for an adequate handbook dealing with the principles and practices in the application of meteorology to agriculture. Five participants attending the session are planning the preparation of such a handbook for postgraduate training of personnel or for self-study.

4 Collaboration with other international agencies

Close contacts are maintained by the Commission with other UN agencies especially FAO, UNESCO, and UNDP, through the WMO Secretariat and the Inter-agency Group on Agricultural Meteorology. There is active collaboration in interdisciplinary, international programs. For example, interagency projects on agroclimatological surveys have been completed for the Semi-arid and Arid Zones of the Near East (*WMO Technical Note* No. 56), the Semi-arid Area in Africa South of the Sahara (*WMO Technical Note* No. 86), the South-East Asia Archipelago (unpublished report by G.W. Robertson) and the East African Highlands (*FAO Tech. Rept.*, 1969).

A Global Research Project in Agricultural Biometeorology is being planned with the overall objective to improve cereal production and to forecast yields in five selected developing countries (Ethiopia, Morocco, Nigeria, Senegal, Tunisia).

Other international organizations such as ISB, IGU, ISSS, IUGG and IUCN have also expressed their interest and willingness to assist CAgM by giving advice, and to cooperate in working groups of the Commission.

5 Outlook

Besides the activities previously mentioned, and in addition to the important function of assembling and disseminating relevant information, the Commission's work has been extended to include the acquisition and exchange of agrometeorological data for research purposes through an international crop-weather project. Instructions for such experiments were recently prepared during a meeting of the CAgM Working Group on International Experiments for the Acquisition of Crop Weather Data.

The Secretary-General of WMO has accepted an offer by the Government of the United States of America to hold the Sixth Session of the Commission for Agricultural Meteorology at Washington, D.C., in the fall of 1974.

BOOK REVIEWS

A CITIZEN'S GUIDE TO AIR POLLUTION. By D.V. Bates. McGill-Queens University Press, Montreal and London, 1972, 140 pp., $2.95.

The Canadian Society of Zoologists is sponsoring a series of popular monographs on environmental issues. Vol. 1 was by Prof. M.J. Dunbar, *Environment and Good Sense*. Other manuscripts in preparation include *Lakes and Streams of Canada* by Peter Larkin, *Ecologic and Sociologic Viewpoints*, by Milton Freeman, *The Canadian Marine Environment* by Michael Waldichuk, *Pesticides* by Tony Keith, and *The Arctic* by Charles Jonkel.

Dr. Bates is a professor of experimental medicine who has recently left McGill to become Dean of Medicine at the University of British Columbia. One might have expected, therefore, that his discussion of the health aspects of air pollution would dominate the book and would be rather more convincing than his treatment of other topics. In fact, Dr. Bates has produced a well-balanced monograph that can be recommended.

In contrast with the philosophy of Professors Brinkhurst and Chant, whose paperback I reviewed recently (*Atmosphere*, **9**, 59–60), Dr. Bates states in the preface that he does not "share the opinion, expressed by some scientists concerned about environmental pollution, that it is necessary deliberately to exaggerate if any impact on the public or the politicians is to be achieved". Later (page 43), Dr. Bates cautions the reader concerning the difficulty in drawing conclusions regarding health effects, suggesting that oversimplified statements "may do something to illuminate the issues, but they do little to illustrate the truth".

The author is widely read, quoting from numerous medical journals, the *Journal of the Air Pollution Control Association* and *Science*. He comments that "keeping track of the papers relating air pollution to respiratory disease alone can easily become a full-time job". This publication explosion has evidently prevented him from reading *Atmospheric Environment* and *Nature*, two British journals that might have helped illuminate some specific points he wished to make.

Meteorological discussions are included, where relevant. In contrast again with Brinkhurst and Chant's paperback, the paragraphs generally read as if they had been written by a specialist. The only clue to the contrary is Dr. Bates' description of a Montreal inversion (page 8), in which he fails to recognize that there is a surface urban mixed layer, capped by an inversion.

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INTRODUCTION TO THE SCIENTIFIC STUDY OF ATMOSPHERIC POLLUTION. B.M. McCormac (Ed.). D. Reidel Publishing Company, Dordrecht, Holland, 1971, 169 pp., $11.55 (U.S.); paperbound $7.50 (U.S.).

According to the editor, B.M. McCormac, this book was prepared to meet the need for an introductory text for students and researchers, and to serve as a readable source book for interested laymen and for officials with governmental or advisory responsibilities concerning air pollution. The book comprises four main parts that can be classified under the headings: atmospheric pollutants, air pollution meteorology, effects of air pollution on human health and vegetation, and air quality surveillance. The four parts were written by eight authors who are specialists in one or more of the many disciplines involved in air pollution studies.

The book tries to serve a wide range of needs and, judged on that basis, has both strong points and weaknesses. It fills in part a real need for a multidisciplinary summary somewhere between the numerous elementary and often shallow treatises on air pollution, and the lengthy and detailed handbooks that are available. With some unevenness in scope and depth it provides objective technical summaries for the four topics listed above, that are difficult if not impossible to find in the burgeoning popular and technical literature on air pollution. The technical content is up-to-date and approximately 300 references are cited in partial compensation for the brevity of the articles. In general, diagrams are clear and used to good advantage, and the printing is of good quality, remarkably free of errors.

The book opens with a brief introduction (by B.M. McCormac and R. Varney) that attempts to define air pollution, and discusses the importance and complexities of air pollution problems. Historical notes include an interesting account of a black day in Detroit (October, 1962). The introduction contains some speculations and some categorical statements that seem out of place in the book. For example, on page 3 we find the statement "Two things have happened to change man's outlook on pollution". This is elaborated further in subsequent sentences, but no mention is made of increased emissions and increased concentrations as factors in this change. Again on page 3, we find "In general, with a little effort, one can detect most substances at concentrations far below their potential harmful level", yet later in the book (p. 99), we are told that "we may indeed be required to substantially revise our estimates of possible effects of air pollution on humans and animals and other life forms" and that "we will discover effects which today are completely unknown." The following remarkable statements are found in page 8 in the section "Atmospheric Pollutants" by R. Varney and B.M. McCormac: "In many urban areas, improvements in air quality have been documented for 10 to 20 yr. ... Except in newly developing areas, for the most part atmospheric pollution is decreasing ... The serious effects are limited to about 50 km distance or much less." The first two statements seem to be contradicted in part on page 6 where we find (by the same authors): "Data on monitoring the various pollutants are very sparse. It is very difficult to compare current observations with measurements taken only 5–10 years ago because of changes in techniques."

The chapter "Atmospheric Pollutants" by R. Varney and B.M. McCormac begins with a general discussion of types and effects of air pollutants, describes the composition of natural air, and lists some of the known photochemical reactions. Readers may wonder why log-log scales are used in this context to portray the vertical thermal structure of the atmosphere (Fig. 2). The bulk of the text is given to descriptions of individual elements, compounds, and particles recognized to be serious pollutants or potential pollutants. Sulfur compounds, heavy metals, hydrocarbons, allergens, and several others are included along with relevant basic chemistry. The chapter provides a concise source of information on the atmospheric chemistry of pollution with many references to more detailed works.

"Air Pollution Meteorology" by R.W. Shaw and R.E. Munn is a highly concentrated source of information both on historical development and current knowledge. An extensive set of references is included. The authors have made no concessions regarding the mathematical preparation of readers. Second-order partial differential equations and Lagrangian correlation coefficients are but two of the tools used freely and, perhaps, necessarily, to emphasize the quantitative nature of air pollution modelling. One or two examples of how well the formulas work in solving typical pollution problems would have been useful.

In the opinion of this reviewer the book is worth its price for the chapter "Air Pollution – Human Health Effects" by R.L. Masters. This is a well-written, well-edited, and thoroughly organized summary (in 33 pages) of a difficult subject that has few firm answers. Dr. Masters attacks his subject directly, identifying essentials, yet leaving the reader with respect for, and appreciation of, the complexities of the problem. Examples of health risks are included, not exhaustively, but in such a way that they can be related readily to other chapters.

"Effects of Air Pollutants on Vegetation" by S.N. Linzon is more formally, but somewhat less effectively, organized than the preceding chapter. Here, as in the early chapter on pollutants, the text is organized according to the principal known pollutant elements and compounds. Some elaboration on basic plant physiology and the methodology of effects investigations would have been helpful. In discussing specific effects the author takes pains to specify dosages rather than concentrations wherever possible. A list of 98 references is included.

The final chapter "Air Quality Surveillance" by G.B. Morgan and G. Ozolins provides clues to the problems faced by control officers in selecting samplers and analysis techniques, and in designing monitoring networks. The chapter is brief and no references are included. A summary of procedures and approaches to surveillance problems in countries outside of North America would add much to the value of this chapter.

In summary "Introduction to the Scientific Study of Atmospheric Pollution" is a valuable book that goes a good part of the way towards meeting the stated objectives. In large measure it does "combine the multidisciplinary aspects of atmospheric pollution." An expanded introduction or summary is needed to add unity to the book and to identify and clarify important interdisciplinary questions that are raised in the mind of the reader but not dealt with by the text in its present form.

K.D. Hage
The University of Alberta
Edmonton

FORECAST FOR OVERLORD – JUNE 6, 1944. By J.M. Stagg. Ian Allan, London, 1971, 128 pp., £2.60.

Where were you on the morning of D-Day June 6, 1944? Many a veteran meteorologist probably has vivid memories of what he was doing that day and perhaps has always wondered about the contribution of meteorology to the invasion and who was responsible for forecasts. If you are one of those, you are in luck since Dr. Stagg has written a detailed description of meteorological events leading up to June 6, 1944, the problems of coordinating meteorological analysis and of giving meteorological advice to the military. Younger meteorologists will be interested also in reading of the agonizing decisions that had to be made without the benefit of computers or facsimile, and with only very little upper air data.

Late in November 1943, Dr. J.M. Stagg was appointed to the invasion planning staff and was directly responsible to General Eisenhower for meteorological advice pertaining to the planning of the invasion and for forecasting at the time of the attack. Dr. Stagg, who was given the rank of Group Captain but remained in civilian clothes until mobilized in April 1944, was given an American deputy (Col. Tieman who was succeeded by Col. Yates), but no staff. In planning for the invasion it was Stagg's responsibility to interpret all the climatological statistics and weather assessments made independently and in secret by various British and American groups, along with the criteria laid down by the different sectors of the invasion group for "good invasion weather". Low tides at time of new or full moon turned out to be the most important factor in setting the date, and every service wanted a "period of quiet weather" before, during and after the initial landings. On Stagg's forecasts and advice the actual landings were delayed one day and the story of how this advice was decided is the gripping story of the book.

Early in 1944 Stagg began preparing experimental five-day forecasts. He regularly consulted with the meteorologists in charge of the Forecasting Centres at Dunstable (Meteorological Office), Teddington-Widewing (U.S. Army Air Forces) and London (British Admiralty), to attempt a consensus of the analysis and the 5-day forecast. In addition, Staff Weather Officers to the Naval and Air Commanders-in-Chief often participated and readers will be interested in learning that such famous meteorologists as Col. Holzman, Col. Krick, Mr. Douglas, Dr. Petterssen and Dr. Sutcliffe played leading roles in these telephone conferences which, during the days immediately preceding D-Day, frequently lasted as long as two hours, and were repeated twice a day. Stagg's role was not an easy one – Dunstable and Widewing were more often as not at odds over not only the forecast, but even the current analysis! These consultations were scheduled immediately before Stagg briefed the Supreme Commander and about a dozen of his top-ranking officers such as Air Chief Marshal Tedder, Admiral Ramsay, Gen. Montgomery, Air Chief Marshal Leigh Mallory, Gen. Bedell Smith, etc.

The drama of Stagg and his associates producing detailed five-day forecasts in late May and early June 1944 without the aid of those data and techniques we now consider essential, makes most interesting reading. The occurrence, a few days prior to June 6th, of two very intense low pressure areas over the North Atlantic, each a mid-winter phenomenon, add to a drama which will make it impossible for you to put down the book once you start Stagg's short but intensive story. There is a copy of the book in the AES Headquarters' Library, but I urge you to order your own copy from a bookseller. It is not every day that a meteorologist publishes a book on the meteorological circumstances which surrounded the start of probably the greatest sea and air-borne invasion that has ever been executed!

M.K. Thomas
Atmospheric Environment Service
Toronto

CORRESPONDENCE

To the Editor:

With reference to Dr. Christie's reply (*Turning off the Stars*) * to Dr. von Braun's crystal ball gazing (*Turning on the Sun*), please allow me to add a few comments of my own (Turning up the Facts). Although I respect Dr. Christie's ability as a scientist (as I do that of Dr. von Braun), I find they are both guilty in differing degrees of making the same mistake; namely, using the prestige of their expertise in a particular field to enable them to make pronouncements about a field in which they are not so well-informed. This is a natural tendency of human nature, and can be forgiven provided one's statements are well-researched and based on the facts as they are currently known and understood. However, in at least one area, the facts of Dr. Christie's article do not correspond with current knowledge. He says, "Control of local events by seeding currently *attempts* intervention in the droplet growth phase of the cloud physics sequence, and in the case of hail suppression by selectively controlling the site of latent heat release by hail stone melt producing a local change in the convective stability ..."

Although there is still some uncertainty as to the precise mechanisms by which seeding may suppress hailstone growth, current *attempts* are based on the concept of growth competition, as described by Mason in the second edition of his book *The Physics of Clouds* (p. 392): "The working principle behind most of the trials is that, if a growing supercooled cloud is seeded with a massive dose of ice nuclei, the competition for the available water between the high concentration of ice particles will prevent any of them growing into large hailstones." I hope this sets the facts straight.

Let me conclude by making a recommendation. Since the Society should not be the source of misinformation (especially when it is trying to correct the misguided ideas of others), may I suggest that the Public Information Committee be more careful in choosing its "experts", possibly drawing on the talents of several individuals rather than merely one. Even if this is not possible, the work of one individual should at least be critically scrutinized by a referee before being given the imprimatur of the Society's president and then published.

E.P. Lozowski
The University of Alberta
Edmonton

Atmosphere*, **10, 62–65.

NOTES FROM COUNCIL

The following were accepted as members by Council:
October 12, 1972

Member	Ford Bergwall J.T. Kotylak	Robert H. Swansburg*
Student Member	Peter Richard Kry	Ronald Earl Stewart

November 20, 1972

Member	Norman Paul Barber*
Student Member	Goolam Mahomed Oodally

*1973 membership

The Youth Science Foundation

The C.M.S. makes one charitable donation a year. This donation is a $50 cheque to help support the Youth Science Foundation.

The Y.S.F. is an incorporated non-profit organization set up by 25 national professional Societies – scientific, technical, and educational – to promote "extra-curricular science activities" for students at the high-school level. The campaign to interest these students takes two basic forms: programs or services, and publications.

In the first category is the Career Information Service which provides brochures and pamphlets, supplied by the 25 constituent members, explaining the career possibilities in science. This is available to all the high-school students involved. The Summer Science Program, a six-week long period of lectures, labs and field trips, is also organized and run by the Y.S.F., but the number of students handled per summer is only about 60. The third and major program is the annual Canada-Wide Science Fair. Before and through this Fair, the Y.S.F. actively encourages the founding and development of school, local, and regional science fairs where presently some 12,000 high-school students vie for the 90 positions at the annual Fair. (The C.M.S. awards a prize at this annual Fair. Unfortunately, sometimes the exhibit and/or the prize bears little relation to meteorology.)

Publications play a major part in the promotional campaign of the Y.S.F. The first and major effort is *Science Affairs*, a quarterly with a circulation of 22,000 per issue. It is "distributed to all Canadian secondary schools and to other interested persons throughout Canada." It was "designed to provide young Canadians with a source of sound scientific material of basically Canadian origin and to be a bridge between the 'popular' science magazine and the somewhat too esoteric scientific journals". (Unfortunately, very little meteorology has been in it – perhaps as a result of a scarcity of meteorologists willing to contribute??) Advertising helps to defray the costs of this journal. A second publication of the Y.S.F. stems from its formation of SECCAN – National Federation of Science and Engineering Clubs of Canada – to help co-ordinate and encourage programs of the Clubs in the high schools of Canada. A monthly Newsletter, with an excellent format, *SECCAN NEWS*, serves as an up-to-date vehicle for communication between the Clubs and also for news of professional Associations and meetings of interest. (The C.M.S. could well imitate such a newsletter* and also could use this medium for announcements of annual congresses, etc.)

As a final note of interest, the 25 Societies (one of which is the C.M.S.) contribute $50 or $100 apiece to the annual budget of the Y.S.F. which is $100,000, most of it coming from N.R.C. grants and other donations.

J.D. McTaggart-Cowan
University of Toronto

*Newsletter No. 1, dated 20 November, 1972, has been issued for distribution to local Centres (Ed.).

Annual Canada-Wide Science Fair

The *Youth Science Foundation* will sponsor the 12th Annual Canada-Wide Science Fair at Thunder Bay, 15–19 May, 1973. As in past years the CMS will present an award for the best meteorological exhibit.

At the 11th Fair (Sarnia, Ontario), there were 96 excellent and interesting displays. Six of these were judged by D.M. Scott (OIC of the London, Ont. Weather Office) to be serious contenders for the CMS Award which was won by Jeffrey Newfeld, a grade 8 student from *Homelands* Senior Public School in Mississauga, Ontario. For his display on "Weather and Air Pollution" Jeffrey measured a "coefficient of haze" and related it to 6 meteorological parameters.

Two other meteorological exhibits of mention dealt with tornadoes and a meteorological station.

REPORT

SOMAS Meeting 26 October 1972

The Sub-Committee on Meteorology and Atmospheric Science held its 25th meeting in Ottawa on October 26, 1972. To permit the scientific functions of SOMAS to be phased out over the next year, two motions were approved which had great significance for the future growth and evolution of the CMS.

SOMAS moved that: any national or international role in meteorology and atmospheric physics be assigned to CMS; SOMAS suggest to CMS that it is prepared to act as the scientific committee of CMS during the transitional period.

(Dr. B.W. Boville is presently chairman of SOMAS as well as chairman of the CMS Standing Committee on Scientific and Professional Matters.)

Because of the need to support Canadian research on the environmental impact of SST operations, SOMAS passed a resolution recommending to NRC and AES that:

a) provision be made for additional manpower and facilities to be assigned to stratospheric pollution studies as a matter of urgency,

b) relative priorities for assignment of existing resources be readjusted in acknowledgment of the importance to Canada of these studies.

MEMBERSHIP APPLICATION FORM

(Please write in Block Letters)

General or Student Member

SURNAME ....

GIVEN NAMES ....

PERMANENT ADDRESS ....

....

TITLE, RANK, DECORATIONS, DEGREES OR PROFESSIONAL QUALIFICATIONS ....

....

OCCUPATION ....
(for record purposes only; if student, indicate university and year studies will be completed)

Sustaining Member

NAME OR AGENCY ....

BUSINESS ADDRESS ....

....

Membership Status Required

Please enroll me as a .... member of the Canadian Meteorological Society effective January 1, 19........, to receive all publications issued by the Society from that date. I attach a cheque for $.......... payable to the *Canadian Meteorological Society*.

Signature of Applicant

Mail completed application forms to:

Corresponding Secretary
Canadian Meteorological Society
P.O. Box 41, Willowdale, Ontario
M2N 5S7.

CMS dues for 1973:

General Member	$15.00
Student Member	$ 5.00
Sustaining Member	$50.00 (min.)

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Section A: Index of Contributions by Author

Section B: CMS Subject Index

Section C: General Subject Index

CALL FOR PAPERS – SEVENTH ANNUAL CONGRESS

The Seventh Annual Congress and Annual General Meeting of the Canadian Meteorological Society will be held at Dalhousie University, Halifax, N.S. 30 May – 1 June, 1973.

The theme of the Congress is *The Atmosphere and the Oceans* and the 30th May sessions will be devoted to invited and contributed papers on this topic. On subsequent days, contributed scientific papers on other aspects of meteorological research will be presented.

Members and others wishing to present papers at these meetings should send titles and definitive abstracts (preferably less than 300 words) to the Program Chairman, R. A. Hornstein, 2925 Dutch Village Road, Halifax, N.S., no later than **19 February 1973.**

Authors whose papers have been accepted for presentation at the meetings will be notified by 6 April 1973.

Information on registration, accommodation, etc., will be provided in due course. Miss Nancy Waller of Maritime Command Headquarters, FMO Halifax, N.S., is Arrangements Chairman for the Congress. (Phone: 902–454–7771, Ext. 2210.)

CALL FOR NOMINATIONS – 1972 AWARDS

Nominations are requested from members and Centres for the 1972 Society Awards to be presented at the 1973 Annual Meeting. Four awards are open for competition: 1) the President's Prize for an outstanding contribution in the field of meteorology by a member of the Society; 2) the Prize in Applied Meteorology for an outstanding contribution in the field of applied meteorology by a member; 3) the Graduate Student Prize for a contribution of special merit by a graduate student; and 4) the Dr. Andrew Thomson Undergraduate Student Prize for a contribution of special merit by an undergraduate student. The awards will be made on the basis of contributions during the 1972 calendar year. Nominations should reach the Corresponding Secretary not later than March 1, 1973.

NEW POSTAL CODE FOR C.M.S.

The C.M.S. address has been amended to include the new postal code as follows:

Canadian Meteorological Society
P.O. Box 41
Willowdale, Ontario
M2N 5S7

The Canadian Meteorological Society
La Société Météorologique du Canada

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

Correspondence regarding Society affairs should be directed to the Corresponding Secretary, Canadian Meteorological Society, P.O. Box 41, Willowdale, Ontario, M2N 5S7.

There are three types of membership – Member, Student Member and Sustaining Member. For 1973, the dues are $15.00, $5.00 and $50.00, respectively. Libraries and Institutions can subscribe to *Atmosphere* at the annual subscription rate of $10.00.

Correspondence relating to CMS membership or to library or institutional subscriptions should be directed to the University of Toronto Press, who have been engaged by the Society to collect membership and subscription fees, to maintain all mailing lists, as well as to print and distribute *Atmosphere*. Cheques should be made payable to the University of Toronto Press and sent to the University of Toronto Press, Journals Department, Front Campus, Toronto, Ontario, Canada M5S 1A6.