# Atmosphere

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**Contents**



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# Acoustic Echo Soundings in Urban Toronto

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ABSTRACT

The construction of an acoustic echo sounding unit composed of a shielded parabolic reflector type of antenna and a suitable receiving system is described. Echo soundings obtained at the antenna site at the University of Toronto in downtown Toronto are presented indicating that sound scattered from temperature fluctuations in the atmosphere up to 350 m above the antenna site can be detected, even during the high background noise levels associated with rush hour traffic.

## 1 Introduction

Techniques have been developed in the past fours years for investigating the turbulence structure within the planetary boundary layer through the scattering of acoustic waves (McAllister *et al.*, 1969; Reynolds and Gething, 1970; Wescott, *et al.*, 1970). If the atmosphere is illuminated with acoustic pulses the resulting echoes produced by scattering from the small scale turbulence indicate the location and relative intensity of the turbulent regions.

Since acoustic waves are used to probe the atmosphere any acoustic noise from the environment will limit the range of the echo soundings by decreasing the signal to noise ratio. Therefore the work done up to now and cited above was carried out in rural areas relatively free from man made noise. The promise of this new technique prompted the investigation of the operation of an acoustic radar within a densely populated urban area in order to study problems related to urban atmospheric pollution. This paper gives the preliminary results of experiments with an acoustic radar developed at the University of Toronto. All data reported here were obtained with a unit located 58 m above ground level on the top of the McLennan Physical Laboratories (University of Toronto).

## 2 Theory

Acoustic waves propagating through a turbulent atmosphere are scattered by temperature fluctuations and by fluctuations in the motion of the air. Fluctuations of the absolute air temperature $T$ cause variations in the refractive index by inducing fluctuations in the speed of sound $c$ since $c \propto T^{1/2}$. The refractive index variations scatter a portion of the incident acoustic energy. A plane acoustic wave propagating in a turbulent atmosphere will be distorted by the turbulent motion along the wave front resulting in radiation of scattered waves from the region of the disturbance.

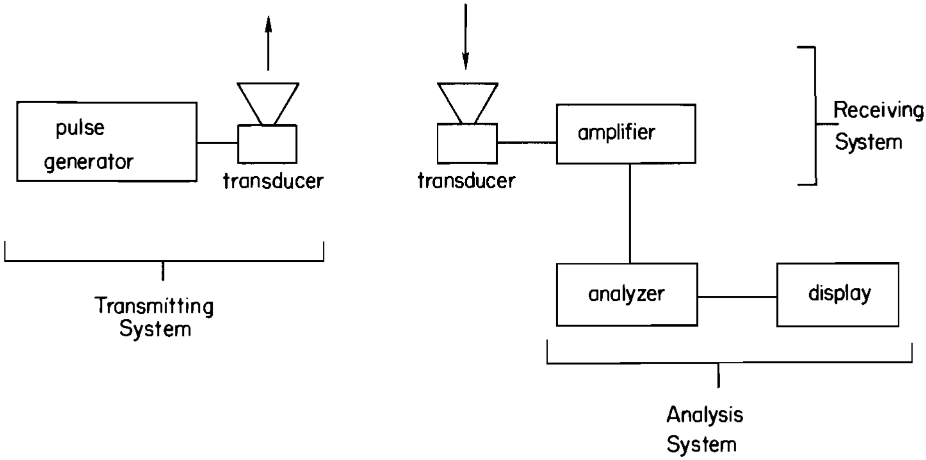


Fig. 1 The basic components of the three sections which comprise an acoustic radar.

A detailed analysis (McAllister *et al.*, 1969) indicates that the cross-section per unit volume per unit solid angle for backscattering is

$$\sigma_0 = \frac{\pi k^4 \phi_T(2k)}{2\,\overline{T}^2} \qquad [m^{-1}]$$

where $k = 2\pi/\lambda$ is the acoustic wave number, $\lambda$ is the acoustic wavelength, $\overline{T}$ is the mean temperature in the scattering volume and $\phi_T(2k)$ [deg$^2$ m$^3$] is the spectral density of the temperature fluctuations at a wave number for the turbulence corresponding to twice the acoustic wave number $k$. The received back-scattered power from a scattering volume at height $Z$ above the receiver of area $A$ is

$$P_r = \sigma_0 \frac{Pc\tau}{2} \frac{A}{Z^2} \beta$$

where $P$ is the power radiated by the transducer, $\tau$ is the pulse length, $c$ is the speed of sound in the scattering volume and $\beta$ is the attenuation due to atmospheric absorption and antenna-transducer efficiencies.

## 3 Apparatus

An acoustic radar consists of three basic systems (see Fig. 1): i) the transmitting system generates and transmits short, high power pulses of sound at a single frequency to illuminate the regions of the atmosphere to be investigated; ii) the receiving system detects and amplifies the small fraction of the incident pulse that is scattered by atmospheric turbulence; iii) the analyzing system records, processes and displays the received signal. For effective operation of an acoustic radar it is necessary that the scattered signal be greater than the portion of the environmental background noise reaching the receiving system since the variation in successive echo trains precludes use of wave-form averaging or the computing of correlation function-Fourier transform pairs to extract the signal from the noise.

The acoustic radar that was developed for this project operated in the monostatic mode with a single antenna and transducer serving the transmitting and receiving systems. The antenna was a modified microwave antenna consisting of a parabolic reflector whose surface area was approximately 1.45 $m^2$ fed by a square cross-section horn which was terminated at the focus with a 0.20-m exponential section. The antenna was mounted so that the beam axis was vertical and the horn axis was horizontal. Shielding, lined with sound absorbing material, was constructed around the antenna aperture to a height of approximately 1 m above it. The focus of the horn was also shielded. The transducer employed was a standard loudspeaker driver capable of handling 70 W of electrical power. As a receiver, the transducer sensitivity at 2.0 kHz was 1.0 $mV\,m^2\,N^{-1} \pm 10\%$.

During transmission of the output sound pulse and for approximately 100 ms after the pulse termination the receiving section of the system was disconnected from the transducer. The 100-ms delay in the turning on of the receiver was to allow for decay of ringing in the antenna. With the receiving section turned on, the echo signal detected by the transducer passed through a 100:1 step up transformer and was fed into a filtering and amplifying section. A 1-kHz high pass filter was located after the first stage of amplification to reduce the low frequency portion of the background noise. The signal then passed through a narrow (46 dB per octave) band filter centered at 2.0 kHz, another amplifying stage and finally, a very sharp band filter with a passband of 100 Hz centered at 2.0 kHz. The two amplification stages, the high pass filter and the first band filter were contained within a single frequency analyzer (Brüel and Kjaer, model 2107). A high speed level recorder (Brüel and Kjaer, model 2307) received the filtered signal and plotted the true rms value as a function of time. The amplitude of the echo train plotted by the level recorder was not corrected for the $1/R$ attenuation caused by the spherical divergence of the scattered signal.

## 4 Results

To ascertain the time dependence of the background noise at the antenna site, the noise passing through the high pass filter and the 46 dB per octave band filter at 2.0 kHz was measured for a period of four days (October 14–18, 1971) with a calibrated microphone (Brüel and Kjaer, model 4145) located at the antenna focus. The results of these measurements are contained in Fig. 2.

The variation of the noise level can be directly correlated with the automobile traffic. The quietest periods – 3:00 a.m. to 5:00 a.m. – corresponded to the period of least human activity. The sharp increases between 6:00 a.m. and 10:00 a.m. on Friday, October 15 and Monday, October 18 can be attributed to the morning rush hour. Saturday, October 16 and Sunday, October 17 were not as noisy during midday as weekdays. During weekdays the diurnal

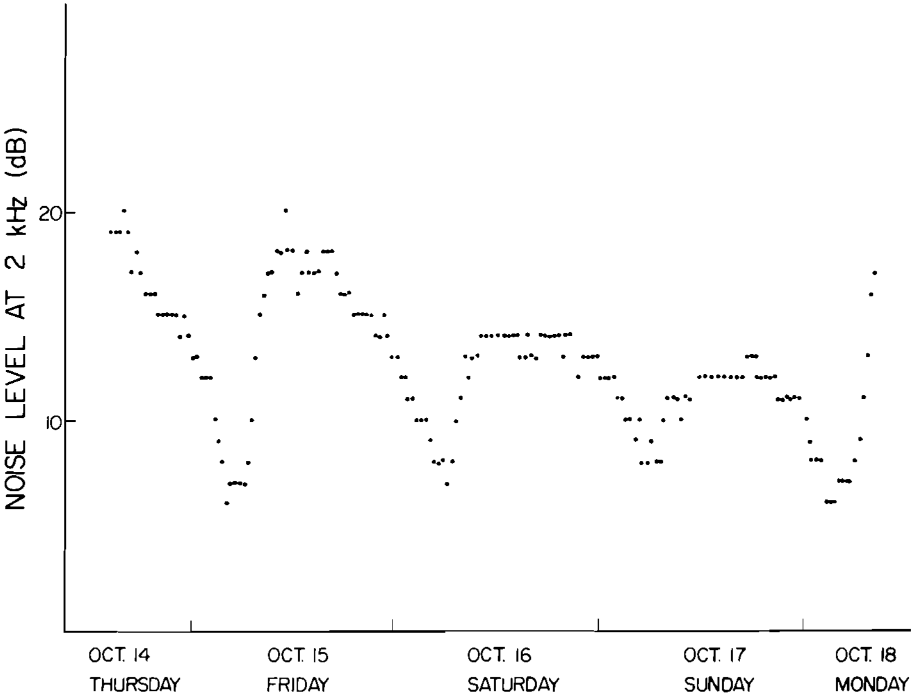


Fig. 2 Background noise at 2.0 kHz (in dB relative to $2 \times 10^{-5}$ $m^{-2}$ N) measured by a calibrated microphone at the focus of the antenna which was located on the top of the McLennan Physical Laboratories, University of Toronto. The measurements run from Thursday, October 14 to Monday, October 18, 1971.

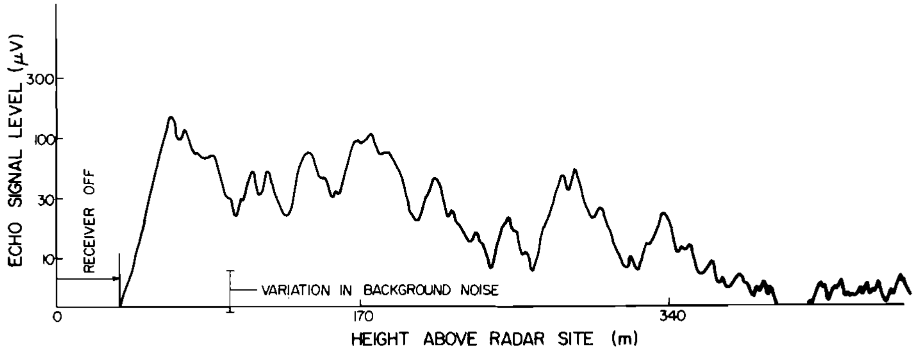


Fig. 3 Echo signal level received after illuminating the atmosphere with a 100-ms acoustic pulse of frequency 2.0 kHz at 7:50 p.m. January 10, 1972.

variation of the noise level at 2.0 kHz was approximately 15 dB. These results indicated that the maximum acoustic radar range would be obtained in the early morning hours during the period of minimum background noise.

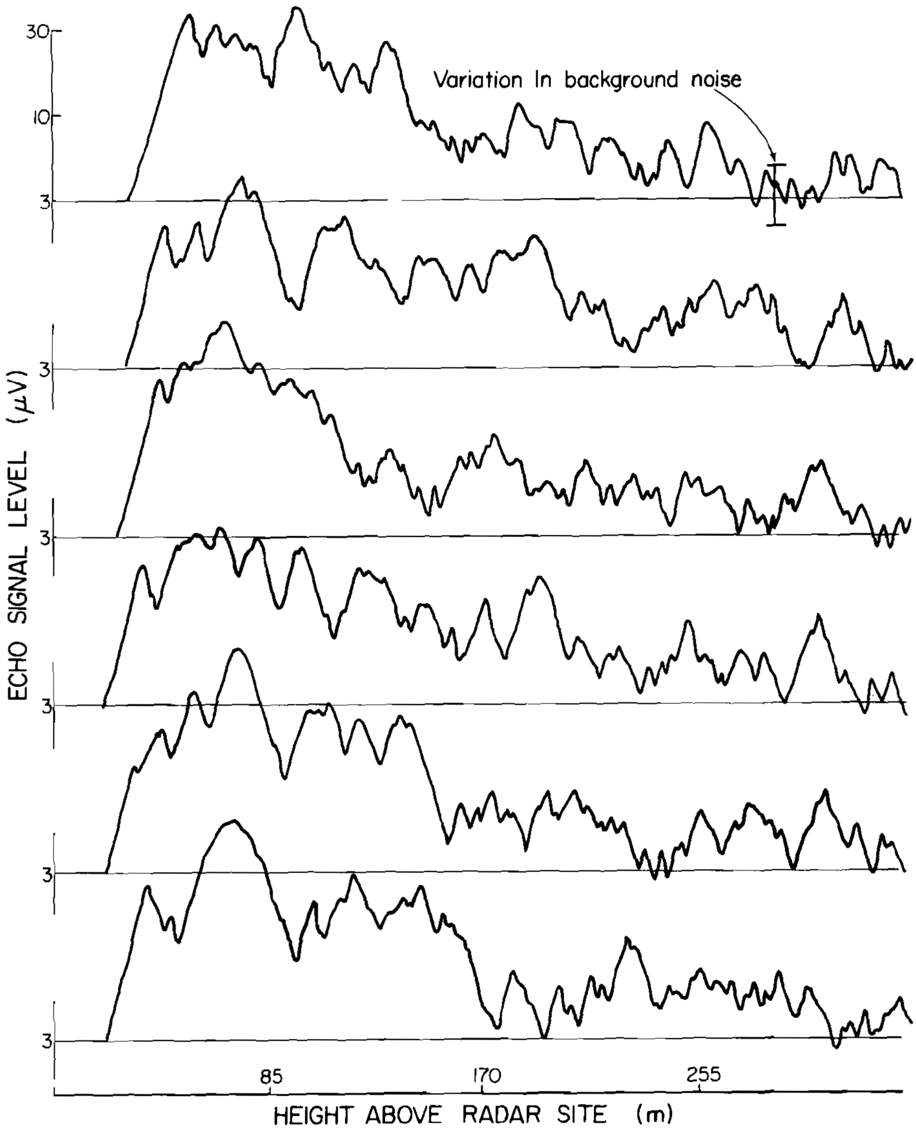


Fig. 4 Sequential acoustic radar echoes obtained at 5-sec intervals at 4:00 a.m. November 16, 1971. Time increases from top to bottom.

Using the equipment described above, measurements of echoes were made with the radar operated at a frequency of 2.0 kHz. The duration of the transmitted pulses varied from 50 to 100 ms with each pulse feeding 56 watts of electrical power to the driver.

A single echo train obtained at 7:50 p.m. January 10, 1972 is shown in Fig. 3. The signal levels refer to the voltage at the output side of the step up transformer. Despite the reduction in echo strength with height, echoes originating from at least 340 m above the radar site can easily be distinguished. This sounding was obtained while there was low level fog moving in over the city of Toronto from Lake Ontario. The antenna was situated above the fog bank and was illuminating a clear region of the atmosphere.

A sequence of echo trains that were produced by sending out pulses every 5 seconds at 4:00 a.m. Tuesday, November 16, 1971 is shown in Fig. 4. These échoes obtained during the quietest period of the day from a relatively calm (0–5 mi/hr winds at antenna level) clear atmosphere, illustrate the rapid variation of the turbulent scattering regions and the complexity of the turbulence distribution with height. A persistent echo originating from a height of approximately 300 m above the antenna site is evident.

## 5 Summary and comments

This paper has described an acoustic radar which filters the background noise sufficiently to allow operation within an urban environment. The amplitude of the echo trains was shown to be greater than the amplitude of the peak background noise for signals originating from scattering sources at heights up to 350 m above the radar site. The echoes indicate rapid variations in the distribution with respect to height of the turbulence at a wave number corresponding to the backscattering of 2.0 kHz acoustic waves.

The noise reduction was accomplished by both direct and indirect methods. The direct method entailed shielding the antenna with an acoustically insulated structure. The indirect method involved the use of a low cut filter to attenuate the dominant low frequency portion of the background noise and a pair of narrow bandpass filters in series to discriminate against all frequencies except $2000 \pm 50$ Hz.

Now that it has been shown that an acoustic radar can be operated successfully in an urban environment the techniques can be improved so that it can be used to study the urban atmospheric boundary layer. In particular it could be used to study the formation, vertical motion and break up of inversion layers. In its present location the University of Toronto unit could provide information on the behavior of the land-lake breezes associated with Toronto's proximity to Lake Ontario. Acoustic radar could also be used to monitor the low level turbulence created by large aircraft at airports.

Subsequent requirements to make the acoustic radar a working instrument include development of a timing network to automate the sounding operation, development of better display systems (such as the facsimile recorder techniques employed by McAllister *et al.*, 1969), and addition of instrumentation to allow digital data sampling and utilization of techniques based on doppler frequency shifting that occurs when the small scale turbulent eddies which scatter the sound are carried by larger scale turbulent systems or the mean wind. The vertical range of the instrument could also be increased by using a larger parabolic reflector to increase the antenna gain and better shielding to further decrease the background noise.

### Acknowledgements

The authors are grateful to Professors D.A. MacRae and E.R. Seaquist from the Astronomy Department of the University of Toronto for making the measuring platform and the microwave antenna available. One of the authors (R.C.B.) acknowledges receiving an NRC 1967 science scholarship. The study was supported through funds from the National Research Council of Canada.


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## BOOK REVIEWS

WEATHER RECORD BOOK. UNITED STATES AND CANADA. By D.M. Ludlum, Weatherwise Inc., 1971, 98 pages, $3.25.

David M. Ludlum has written extensively on the history of meteorological events in the United States and his series of books on this subject, published by the American Meteorological Society, as well as his numerous contributions to the magazine *Weatherwise*, of which he is editor, represent a major contribution to research in this field.

This little volume represents, in outline form, a summary of the most outstanding meteorological events during the period from ca. 1635 to 1971. The text is supplemented by a judicious selection of charts and photographs, and is followed, in the second half, by an extensive selection of statistical data giving the extreme values of various meteorological elements for about 250 cities in the United States and 50 locations in Canada. Many of these data tables have previously appeared in various issues of *Weatherwise* and are here assembled together for the first time.

The amount of Canadian material included is really far too little to serve as even an introduction to our climatological past, but so far we have not had a Canadian "Ludlum" to prepare such a review for us. Perhaps the appearance of this volume will stimulate someone to undertake this task.

Very few errors were noticed; however, on page 87 the snowiest calendar month at Toronto is not 2/1846 as given, but 3/1870 when the snowfall was 62.4 inches. The thought of such a monthly snowfall occurring again in the near future would certainly give nightmares to the city fathers!


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*Book Reviews continued on page 108*

# An Approach to the Mapping of the Statistical Properties of Gradient Winds (Over Canada)

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ABSTRACT

This paper describes the preparation of a preliminary set of maps of gradient-level wind climate over Canada and some neighbouring regions of the United States. The data for this study were drawn from twice-daily records of radiosonde ascents at a network of ten Canadian upper air stations. The period covered by the data was 1960–69, and this was supplemented by statistical information on upper level winds at fourteen points in the United States.

The analysis and subsequent mapping were carried out for 300 and 500 m above ground level and were based on a number of statistical models: the bivariate Gaussian distribution of wind velocities characterized by the vector mean and standard vector deviation, monthly Weibull distributions of wind speed and a new model of extreme annual wind occurrences developed from a consideration of wind as a stochastic process.

## 1 Introduction

Improved information on mean wind behaviour at or near ground level is needed in a growing number of important areas of application, including operational and environmental planning, aviation, and structural engineering. In the latter case, for example, the prediction of wind loading is often made more difficult by a lack of observational data representative of the wind climate at the site of a proposed structure and reflecting the interference of local topographical features.

Hitherto, it has been the general practice to derive the required statistical descriptions from surface observations at nearby points, such as airports and harbours. Unfortunately, the quality and consistency of these observations may be affected by the local and directional character of the terrain, the siting and possible relocation of the anemometer and the encroachment of urban development. Occasionally, adjustments can be made for terrain influences using wind tunnel tests on scale topographic models or anemometer/site correlations, but this cannot be done regularly. These difficulties in establishing wind climate at a particular location have been discussed more fully in earlier papers (Davenport, 1960, 1968).

An alternative approach is to describe wind climate in terms of winds at gradient height. These occur at the top of the atmospheric boundary layer and are relatively independent of terrain effects. Winds at lower levels can be deduced using theoretical and empirical wind profiles appropriate to the terrain conditions. Furthermore, the wind climate at gradient height is applicable to broad geographic regions and so can be determined from observations at points relatively remote from the site in question, or more usefully, from maps of gradient wind characteristics. The initial development of these maps is described in this paper.

## 2 Statistical descriptions of gradient wind climate

Several interrelated statistical models are employed in the description of the gradient wind climate presented here. These comprise:

a) The distribution of wind velocities having regard for direction; because of the cyclic seasonal variations, these are broken down into monthly periods.
b) The distribution of scalar wind speeds.
c) The distribution of the extreme annual wind speeds.

The theoretical background is summarized below.

### a *The Bivariate Normal Distribution of Wind Velocities*

Earlier work by Brooks *et al.* (1946) showed that the statistical distribution of upper level winds above the immediate frictional influence of the earth can be approximated by an isotropic, two-dimensional Gaussian distribution with equal standard deviations in the zonal (east-west) and meridional (north-south) directions and no correlation between the fluctuating components. This is written:

$$p(V_x, V_y) = \frac{1}{2\pi\sigma^2} \exp\left[ - \left( \frac{(V_x - \bar{V}_x)^2 + (V_y - \bar{V}_y)^2}{2\sigma^2} \right) \right] \quad (1)$$

where $V_x$ and $V_y$ are the zonal and meridional velocity components, $\bar{V}_x$ and $\bar{V}_y$ are their respective means, $\sigma$ is the *standard vector deviation* and the quantity $\bar{V} = (\bar{V}_x^2 + \bar{V}_y^2)^{1/2}$ denotes the *vector mean wind.* The form of this distribution is shown in Fig. 1.

The model implies that the mean flow at a point can be treated as a horizontally isotropic turbulent flow. Although more sophisticated models can be suggested in which the distribution is not assumed isotropic, the simpler model proposed appears more appropriate from the viewpoint of statistical confidence and the preliminary nature of the study.

Maps of $\sigma$ and $\bar{V}$ over Canada for isobaric surfaces above 850 mb (about 1300 m above *msl*) have already been obtained by Henry (1957); they are, however, above the altitudes of interest here.

### b *Distribution of Scalar Wind Speeds*

It is found straightforwardly that if the vector mean wind is zero ($\bar{V} = 0$), the probability density function of the scalar wind speed $V = (V_x^2 + V_y^2)^{1/2}$ is given by:

$$p(V) = (V/\sigma^2)e^{-V^2/2\sigma^2} \quad (2)$$

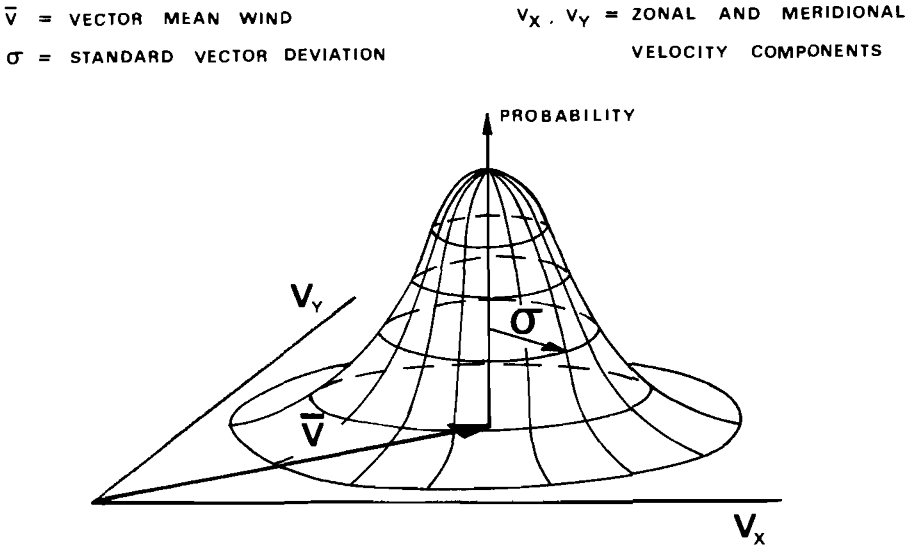



Fig. 1 Bivariate Gaussian distribution of wind velocity.

This is the Rayleigh distribution. It has the cumulative distribution:

$$P(> V) = e^{-V^2/2\sigma^2} \tag{3}$$

If $\bar{V}$ is non-zero the form of the distribution is more complicated and closed form solutions do not appear to exist. An alternative is to express the wind speed probability in terms of the Weibull distribution:

$$P(> V) = e^{-(V/c)^k} \tag{4}$$

in which $c$ and $k$ are constants. If $k = 2$, (4) reduces to the Rayleigh distribution. The additional flexibility of the variable exponent $k$ enables most wind speed data to be fitted successfully. As an example, Fig. 2 shows the Weibull distribution for January winds at 300 m over Churchill, Manitoba. Not unexpectedly, $k$ in this case, as in most others, is close to 2.

c *Distribution of Extreme Annual Wind Speeds*

Considering first a somewhat simplified approach, it can be shown that the extremes of a Weibull or Rayleigh distribution, which are of the exponential type, have an asymptotic distribution of the Fisher-Tippett Type I. This is written:

$$P(< V) = \exp\{- [e^{-a(V-U)}]\} \tag{5}$$

in which $U$ is the mode and $1/a$ is the dispersion. If we assume that the record of wind speeds consists of $N$ independent samples, it can be shown that:

$$U = c(\log_e N)^{1/k} \tag{6}$$

$$\frac{1}{a} = \frac{c}{k}(\log_e N)^{(1/k)-1} \tag{7}$$

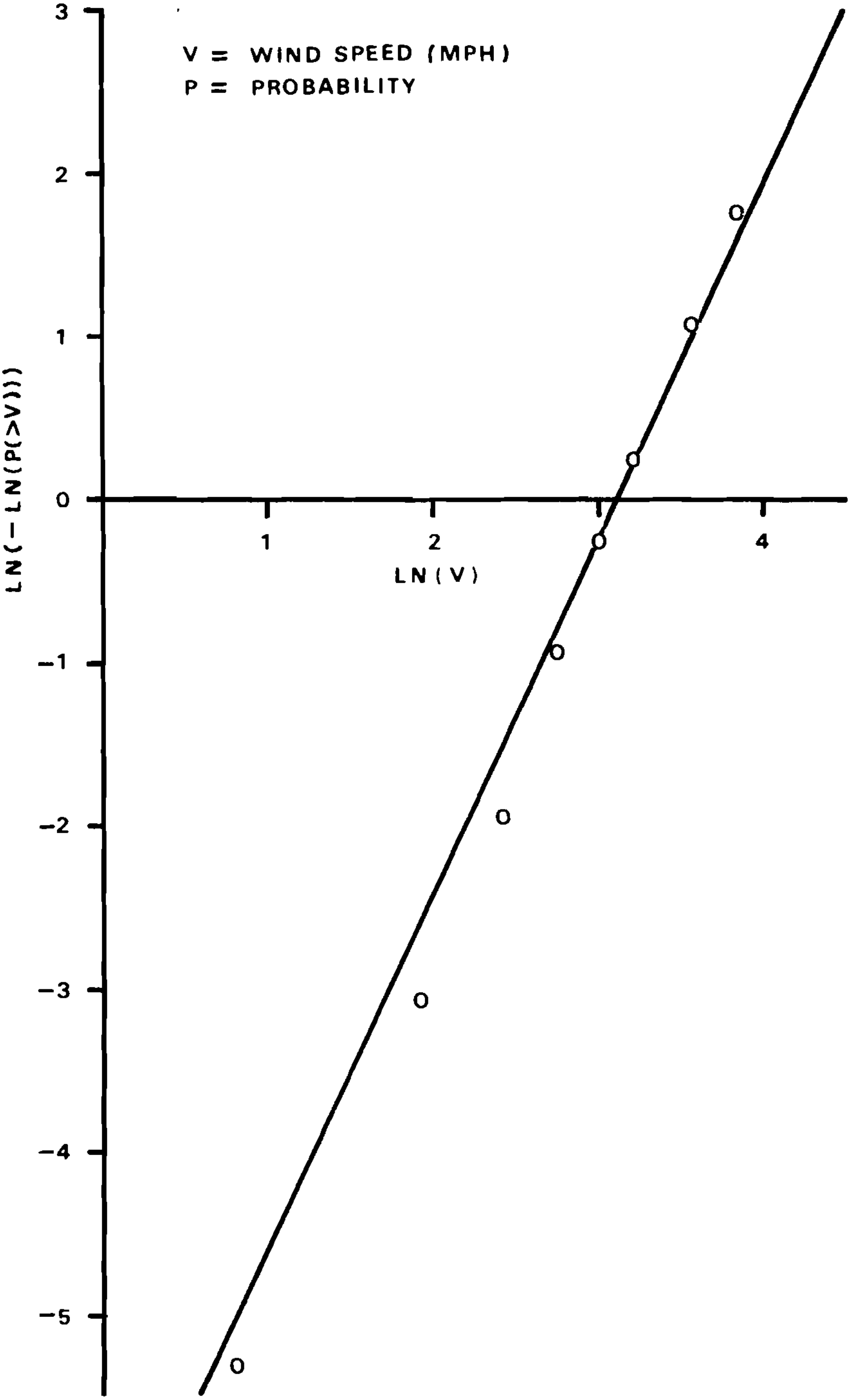



Fig. 2 Weibull distribution of wind speed (Churchill, Man., January, alt: 300 m).

Unfortunately, the requirement that the samples be independent makes this approach inappropriate where wind speeds over consecutive intervals are correlated. Crude estimates of the extremes can be made, however, if a reduced number of effective independent samples is substituted for $N$.

A more satisfactory approach considers the wind as a continuous process as follows. Let $N(V)T$ be the expected number of times the wind speed $V$ is crossed during the period $T$ under consideration. It can be shown that these crossings become independent rare events for the higher values of $V$ from which, it is expected, the extremes will be drawn. The distribution of the crossings can then be treated as Poisson and the probability of there being no crossings, i.e., no wind speed greater than $V$, is given by:

$$P(< V) = \exp(- N(V)T) \tag{8}$$

Owing to the seasonal character of the wind, the expected crossing rate $N(V)$ varies through the year. If the crossing rate during a specified period of the year is written $N_i(V)$, we can express the probability distribution for an entire year of $m$ periods as:

$$P(< V) = \exp\left(- \sum_{i=1}^{m} N_i(V)\, T\right) \tag{9}$$

$N(V)$ can be calculated from Rice's (1954) expression:

$$N(V) = \int_0^\infty \dot{V}\, p(V, \dot{V})\, d\dot{V} \tag{10}$$

where $p(V, \dot{V})$ is the joint probability density function of the wind speed $V$ and its derivative $\dot{V}$.

If it is assumed that the wind process is stationary, $V$ and $\dot{V}$ are uncorrelated and $p(V, \dot{V}) = p(V)\, p(\dot{V})$. Then,

$$N(V) = C\, p(V) \tag{11}$$

in which

$$C = \int_0^\infty \dot{V} p(\dot{V}) d\dot{V} \tag{12}$$

If the distribution of $V$ is assumed normal, it can be shown that;

$$C = \sqrt{2\pi}\, \sigma\, \nu \tag{13}$$

in which

$$\nu = \left[\frac{\int_0^\infty n^2 S_V(n)\, dn}{\int_0^\infty S_V(n)\, dn}\right]^{\frac{1}{2}} \tag{14}$$

is the average rate at which the mean value of $V$ is crossed. $S_V(n)$ is the spectral density of the process at frequency $n$ and $\sigma$ is the standard deviation of $V$.

Now, if the parent probability distribution is that of Weibull for each period $i$:

$$p_i(V) = \frac{k_i}{c_i}\left(\frac{V}{c_i}\right)^{k_i - 1} \exp\left[-\left(\frac{V}{c_i}\right)^{k_i}\right] \tag{15}$$

and

$$\sigma_i \sim 0.93 \frac{c_i}{k_i} \text{ for the range } (1.5 < k_i < 2.2) \tag{16}$$

Thus, from Equations (9), (11), and (13) the extreme value distribution becomes:

$$P(<V) = \exp\left\{-B \sum_{i=1}^{m} \left(\frac{V}{c_i}\right)^{k_i - 1} e^{-(V/c_i)^{k_i}}\right\} \tag{17}$$

in which

$$B = \sqrt{2\pi}\, \nu\, T \times 0.93 \tag{18}$$

If the summation in (17) refers to twelve monthly intervals, then $T \sim 720$ h. Examination of several long duration atmospheric spectra suggest that $\nu \simeq 0.1$ cycles/h. Typically, therefore, $B$ is taken as 170.

The distribution described in (17) can be approximated by a Fisher-Tippett Type I distribution fitted at its mode; this is illustrated in Fig. 3. In this case, the mode $U$ is given by the solution to:

$$\sum_{i=1}^{m} \left(\frac{V}{c_i}\right)^{k_i - 1} \exp\left[-\left(\frac{V}{c_i}\right)^{k_i}\right] = \frac{1}{B} \tag{19}$$

and the dispersion factor (denoting the left-hand side of (19) by $\sum$) is

$$a = \left.\frac{d(\log_e \sum)}{d V}\right|_{V=U} \tag{20}$$

Generally speaking, the Fisher-Tippett approximation obtained in this way is reasonably satisfactory, except near the tails of the distribution.

## 3 Data and treatment

Twenty-four upper air stations in Canada and the United States were selected to provide radiosonde data for this study (Map 1). The selection was intended to provide coverage of Canada south of 60°N and neighbouring regions of the United States, particularly the northeastern states. A greater density of points was chosen in the populous areas of Ontario and Quebec, so as to obtain more definitive results in this region.

The wind observations, taken twice daily at all stations (0000 and 1200 GMT), were analyzed at 300 and 500 m above ground level, corresponding roughly to the lower and upper limits of gradient height, that is, over very smooth and heavily built-up terrains respectively. In the case of the U.S. locations, statistical analyses were already available for these levels, generally for the period 1960–64. For Canada, however, histograms and statistical parameters had to be reduced from the punched card records of the individual balloon ascents during the decade 1960–1969. Simple linear interpolation was used to estimate conditions at

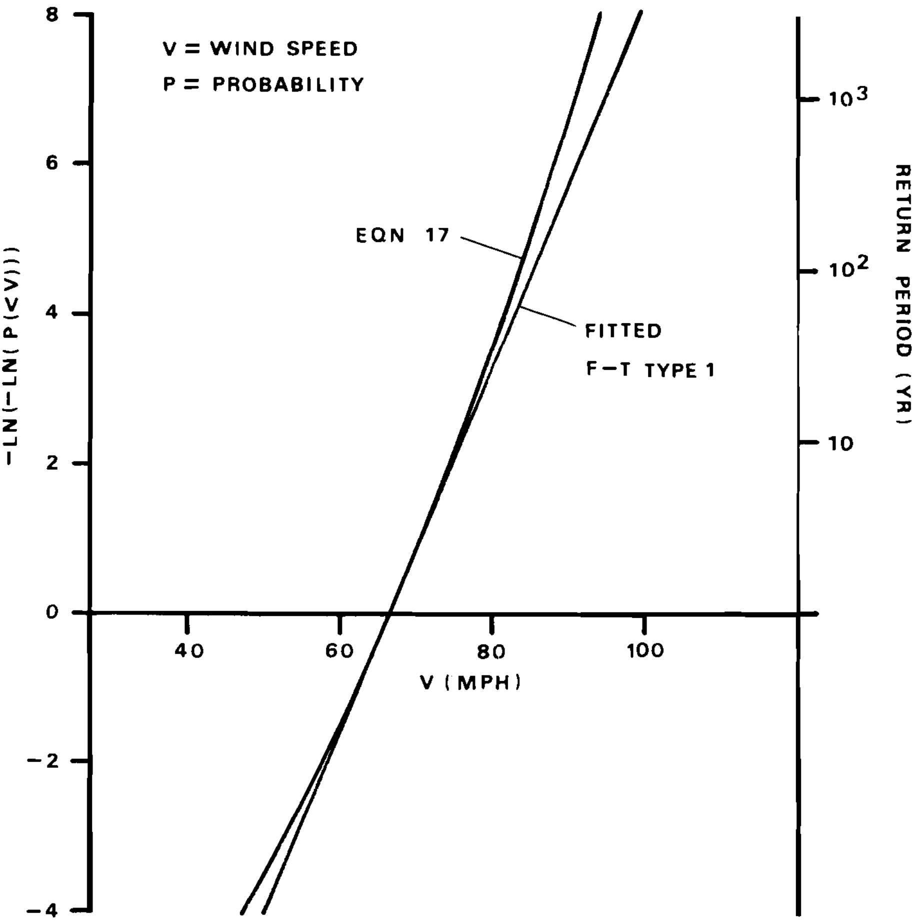
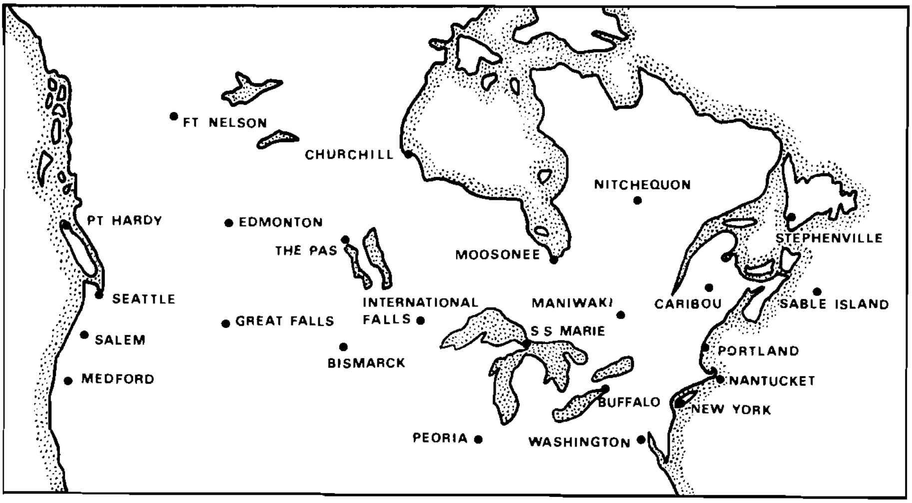



Fig. 3 Extreme annual wind distributions (Churchill, Man., January, alt: 300 m).

the desired levels from the observations at the standard isobaric surfaces (ground level and at 50-mb intervals above 1000 mb).

The monthly values of vector mean winds and standard vector deviations were computed for each station and a smoothing function applied to the annual cycle. Fig. 4 illustrates the smoothing process and the presence of clear seasonal trends in both $\sigma$ and $\bar{V}$. The examples shown are for the 300-m level at Churchill, Manitoba.

Maps of smoothed monthly values of $\sigma$ and $\bar{V}$ were then developed. The contours were drawn by a systematic procedure involving a digital computer and plotter and a standard mapping program (UWO, 1969). The results for the months of January, April, July, and October at 300 m are presented here (Maps 2–9). Directions of the mean vector winds are not shown. In general these were found to be within a few degrees of west except near the Rocky Mountains




Map 1: Radiosonde stations.

where southerly and northerly components also were found west and east of the mountains, respectively.

Weibull distributions were fitted to the observations of wind speed for each month by the method of maximum likelihood. The method consists of maximizing the likelihood function of the observations, $\Pi_{i=1}^{N}\ p(V_i, c, k)$, with respect to the Weibull parameters $c$ and $k$, where $V_i$ are the sample values of wind speed.

The distributions of extreme wind speeds were established from the monthly Weibull parameters at each station and level in the manner outlined above in Equation (17). The modes, $U$, and dispersions, $1/a$, of the corresponding fitted Fisher-Tippett Type I distributions were found from Equations (19) and (20) and mapped together with the 30-year return winds, that is, wind speeds which have a probability of being exceeded once in 30 years (Maps 10–15).

## 4 Discussion of results

### a *Vector Mean Winds and Standard Vector Deviations*

The general west to east circulation over Canada was confirmed for the 300- and 500-m levels considered in this study, although the prevailing winds exhibited strong southerly components on the Pacific seaboard throughout the annual cycle. The magnitudes of the vector mean winds are comparatively high to the southwest of the Great Lakes and extending northwest into southern Alberta and southeastern British Columbia, particularly in the winter and autumn months. Elsewhere, areas of high vector means are to be found along the Atlantic coast during most of the year and over Hudson Bay in winter.

Generally, the strongest circulation occurs in the winter. In the spring and summer, the pattern is more uniform but with a noticeable area of high vector means moving progressively northward along the east coast. There appears to be a year-round region of low means over southern Manitoba and Saskatchewan.

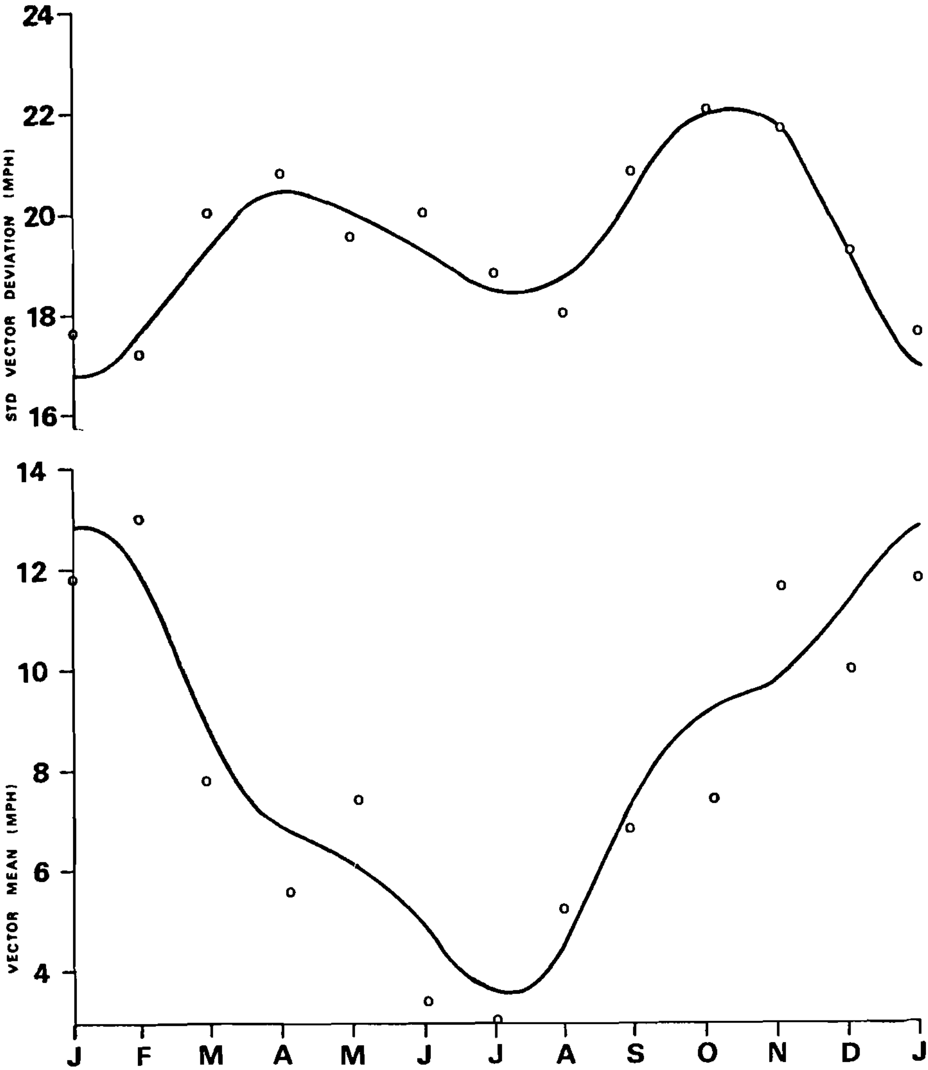
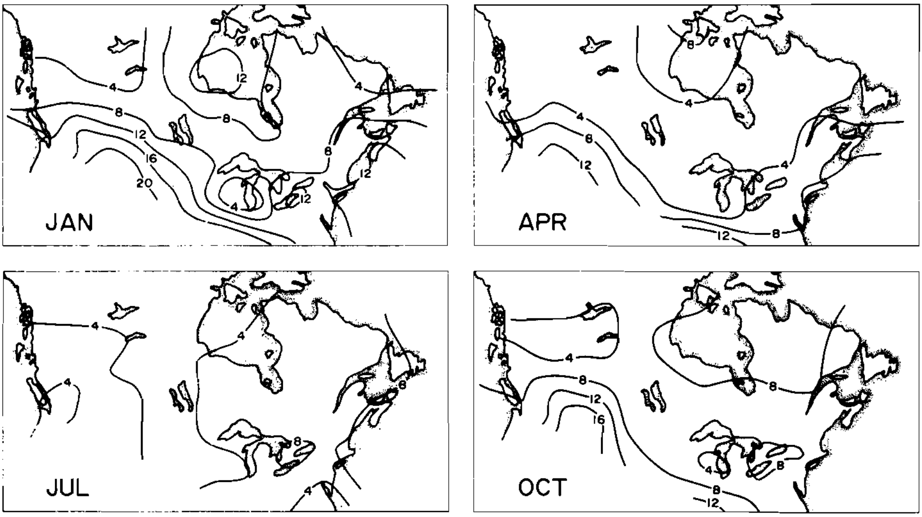


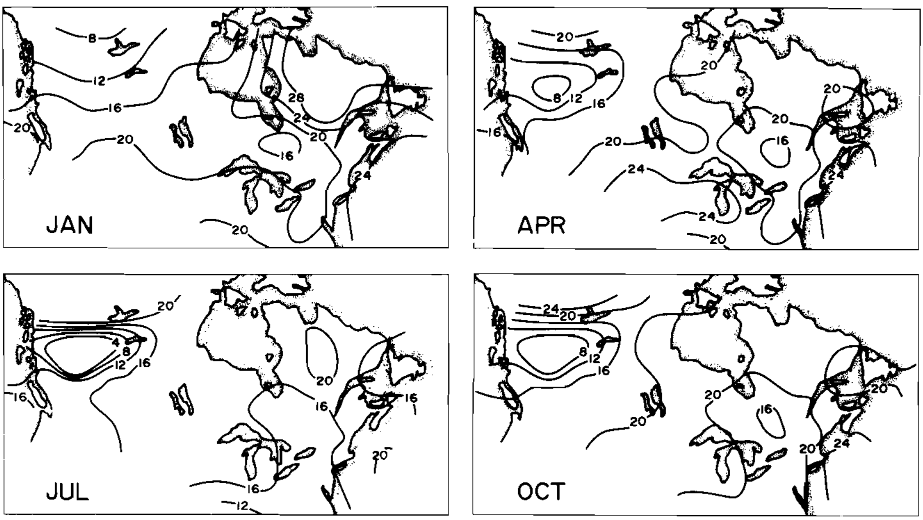

Fig. 4 Annual cycles of vector mean winds and standard vector deviations (Churchill. Man., alt: 300 m).

An area of low standard vector deviations is indicated over the mountainous region in the Canadian west, although this observation must be qualified on account of the relative scarcity of data for that region. Other notable features are the high deviations in the east during winter and spring, and to the west of the Great Lakes in the spring; in the summer the pattern is again more uniform.

The patterns of both vector mean winds and standard vector deviations are broadly similar to those found by Henry (1957) at the lowest level of his analysis, 850 mb (about 1300 m). However, where the distribution of the variate is fairly uniform, such as the standard vector deviation during the summer months, the



Maps 2-5: Smoothed vector mean winds (mph). Alt.: 300 m.

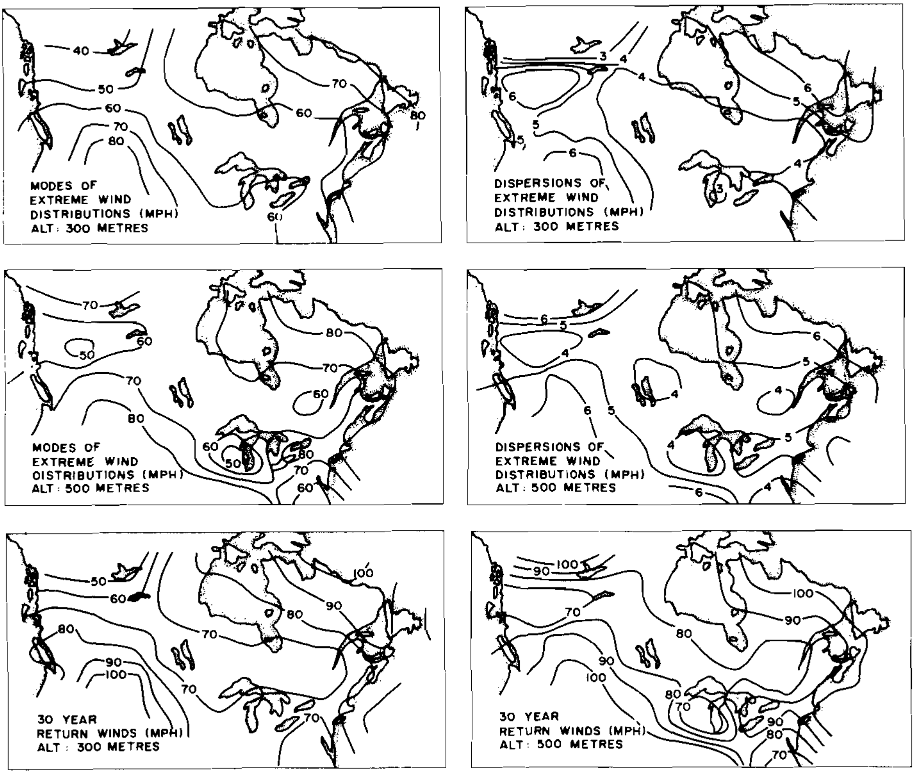


Maps 6-9: Smoothed standard vector deviations of winds (mph). Alt.: 300 m.

similarity may not be so marked. But, as Henry himself has pointed out, in these circumstances the contours are sensitive to small changes in the variate, such as might be obtained if a different period of record were used.

**b** *Extreme Wind Speeds*

The maps of the modes and dispersions ($U$ and $1/a$) of the fitted Fisher-Tippett Type I distributions may be used to estimate the maximum wind speed expected at a given location in a given period. Although these estimates will provide only a close approximation to those derived from the original distributions, it is seen




Maps 10-15: Extreme wind statistics.

from Fig. 3 that any errors will tend to be on the conservative side from the design point of view.

Areas of both high modal winds and dispersions will experience the greatest probabilities of high extreme winds, for example, along the Atlantic coast. In fact, in this region a check of $U$ and $1/a$ values may be made against Davenport's (1968) estimates for these parameters at gradient height, based on surface wind records and considerations of terrain roughness. There is close agreement for values of $U$ over the Canadian maritime provinces but a significant difference in values of $1/a$. Davenport estimated a mode of 79 mph and dispersion of 7.9 mph, averaged over twelve stations. The contours for 500 m suggest modes between 70 and 85 mph, but dispersions ranging from about 4.5 to 6.5 mph. Davenport's figures for points along the east coast of the United States are considerably higher for both $U$ and $1/a$, since they were based on observed "fastest miles of wind".

The 30-year return wind contours provide a comparison with the map of 30-year return winds at ground level prepared for the National Building Code of Canada (NRC, 1970) (Map 16). Although the contour patterns are quite similar, the Building Code predicts wind speeds approximately 20 mph lower over large areas of Canada, as might be expected with surface winds.


Map 16: Hourly wind mileage, annual probability 1/30 (from National Building Code of Canada (NRC, 1970)).

*c Limitations of This Study*

It should be emphasized that the results presented in this paper represent only a first attempt to define the climate of winds at gradient height over Canada. The validity of the maps is necessarily limited by the extent of the data, in particular the relatively short periods of wind records and the sparsity of radiosonde stations in the north and west. Moreover, the balloon observations at mountainous locations, such as Port Hardy, will have been influenced by local topography, even at 300 and 500 m above ground level. These influences would be reflected in the map contours for the surrounding region.

It is also necessary to point out some characteristics of the radiosonde measurements which should be considered when interpreting the maps:

i) wind velocities are essentially two-minute mean values and, therefore, do not reflect the occurrence of strong gusts,
ii) balloon ascents are twice daily at set times, hence introducing small biases into the results due to the diurnal cycle.

The utility of the preliminary maps will also depend on the estimates of gradient height at a chosen location and then appropriate interpolation between the 300 and 500-m contours.

**5 Concluding remarks**

A preliminary set of maps of wind climate at gradient height has been developed from radiosonde observations at some twenty-four Canadian and U.S. stations. Statistical analysis of the data was carried out to determine the parameters of the bivariate Gaussian distributions of wind velocities and the parameters of extreme wind speed distributions at 300 and 500 m above ground level. These parameters were systematically mapped for much of Canada and the northern United States.

Some confirmation of the results of the study are given by the following:

a) the patterns of vector mean winds and standard vector deviations are broadly similar to those given by Henry (1957) for the 850-mb level;
b) maps of the modes of the extreme wind speed distributions agree closely with estimates made previously by Davenport (1968) for the Canadian maritime provinces; there is, however, a significant difference in estimates of the dispersions;
c) the contours of 30-year return winds are of similar pattern but with values about 20 mph higher than those given for ground level in the National Building Code of Canada (NRC, 1970).

**Acknowledgement**

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Members of the Canadian Meteorological Society convened in the Henry Marshall Tory Auditorium at the University of Alberta for the Sixth Annual Congress, May 31 to June 2. Fair weather greeted the more than 180 who participated in the sessions and continued to favour them for the remainder of the week in accord with the invigorating atmosphere enveloping the papers which were presented.

Dr. Max Wyman, President, University of Alberta warmly welcomed the CMS members at their Congress and especially noted the topical theme *Meteorology of the North*. In his reply Mr. C.M. Penner, CMS President, remarked that the proposed Canadian expenditure of 30 billion dollars in the Arctic during the next several years surely justified an outlay of, say, 1% of this amount for Arctic environment research and development.

**Meteorology of the North**

The opening session was chaired by Mr. H.P. Wilson (Arctic Weather Central, AES) who introduced the theme speaker, Professor W.N. Fuller, Chairman of the Department of Biology at the University of Alberta. Dr. Fuller has participated in programs to preserve wildlife and natural resources including one at Fort Smith and Yellowknife to protect and conserve the whooping crane.

In asking the question: "Why do biologists look North?" he gave three main (and perhaps personal) reasons: First, to study adaptation of warm- and cold-blooded animal species to observed ecological parameters. It has been discovered that the Arctic fox with a special brown fatty tissue can produce heat (below about −40°C) without muscular or glandular activity. Other animals show that a critical body diameter exists so that no more insulating layers are required, only a less exposed surface area. Mosquitoes allow their eggs to freeze in open areas where the sun's rays may later produce rapid thawing. Very little is known about the properties of snow under which some animals (such as lemmings) breed. Light serves as a triggering mechanism for reproduction and as a migration regulator, but its penetration into the snow is significant but not known sufficiently well enough.

Secondly, biologists would like to understand the whole system. The northern environment is easier to study by computer modelling techniques since it is simpler to study: the food chains are much shorter and there are a manageable number of species to study, e.g., six on Devon Island.

Finally, the North is still wild and presents a fascinating frontier for scientists to explore. Prof. Fuller was not impressed with the bull-dozer attitude of developers who would spoil the North, e.g., by building the Mackenzie highway. Little do they know what they are doing.

Meteorology and biology share common areas of study dealing with energy resources and damage to the landscape. In response to the low conversion efficiency (10%) of solar energy, northern plants have restructured their food as useful as the concentrated fossil fuels which have resulted from the decay of animal corpses. Net radiation is positive only in summer when surface albedo is lowest, so that productivity of the land is much lower in the North. Thus the northern landscape heals very slowly after scarring, greatly exceeding the decade required in mid-latitudes. With this in mind, the first time that corporate boardroom decisions were not immediately accepted by government was in connection with the northern development proposals for the Trans-Alaska Pipeline system and the Yukon dam.

Biology can serve society by suggesting how energy might be harnessed; by classifying land-use; by assigning resource priorities. In regard to the first of these, Dr. Fuller asked whether more thought should be given to harnessing the diluted rather than the concentrated energy sources. For example, the Athabaska Tarsands, with 10 times the Arctic reserves, should be studied thoroughly to really decide which is more economically feasible to bring into production.

Land-use in the North should be investigated. Should energy fuels be exported? Should there be some reserves for Science? Some areas should be designated as wilderness before it is too late. The Federal Government has set aside land for parks but has not gone far enough.

Finally the speaker asked whether we are playing fair with the natives, since we have viewed the North under the following order of priorities: money, resources, environment, people; this order should have been reversed. One bad example of this was government response to the recent study of the effects of geological exploration on the livelihood of the natives of Banks Island: an attempt was made to discredit the author of this report rather than to understand the inadequacies of government policy in northern development. Responsible discussion with the natives is obligatory on moral and ethical grounds alone, before their land is devastated.

In concluding, Dr. Fuller stated that in the North we have something distinctly Canadian and something distinctly worth saving.

Research on the radiation climate of Meighen Island Ice Cap in the Queen Elizabeth Islands was discussed by the next speaker, Mrs. B. Barge of McGill University. The 80-km$^2$ ice cap is remarkable: it is topped at 260 m above msl, well below the snowline for mountains on islands to the east; even topographically similar islands to the west do not have glacier ice except for land rising to elevations above 1000 m. An explanation may be given based on an analysis of the observed radiation components (especially net long-wave) along with the frequency of fog-producing weather situations. The most common of these produces a cold thin Polar Ocean fog and low stratus which is advected from the north over the island, but which cannot be dissipated in the short distance between the shoreline and the ice cap. In this way the number of melting days are kept to a pronounced minimum by reducing the net long-wave radiation which is positive during the summer.

Additional ice cap studies in the High Arctic were reported by Dr. K.E. West (University of Calgary) in a joint paper with his academic colleague Dr. H.R.

cap northwest of Tanquary Fiord (Ellesmere Island) was analysed in terms of stratigraphy and density as well as isotopic ratio, $H_2O^{18}/H_2O^{16}$. Samples were taken from a 7-m deep snow pit and a core hole 22 m deeper. Discrepancies exist between the stratigraphic and isotopic layer analyses: the former indicates 21 years of accumulation at about 14.0 cm $H_2O$/yr; the latter, 15 years at 19.7 cm $H_2O$/yr. Spectral analysis of all isotopic data from pit and core supported a striking and consistent periodicity of variation with depth which may be correlated to seasonal temperature changes. Thus this technique seems to offer a more accurate picture of the annual layer structure, while stratigraphy provides insight into the variations within annual layers. A 4.3-year period in isotope variation (and hence also in climatic change) was found that agrees with that for temperature change at Edmonton. Dr. West therefore suggested that deeper pits and cores in the Arctic could help gain information about past Canadian climate. However, annual variations in isotope ratio could not be correlated with those measured by others in the north and south polar regions. Thus the technique may be more useful as an indicator of long-term trends and local variations in climate.

Professor A.H. Thompson (University of Alaska) presented a brief review of inversions: radiation, "trade", frontal and polar, in order to place the latter in proper context. Also mentioned were a number of climatological studies of the frequency and thickness of inversions in Canada. However, actual measurements of the changing temperature distribution in the surface layer must be made to understand the formation, maintenance and dissipation of the polar inversion. The author participated in a research study at Fairbanks, Alaska, which included cloud physics, micrometeorological, radiative, and macro/meso-scale processes. Temperature data for the surface, 500-m level and the top of the inversion were analysed. In January 1971, the general behaviour of the inversion layer was uniform in the Alaskan interior. In 1972 there was a gradual warming above the inversion to at least 400 mb, unlike the Wexler (1936) model for nocturnal inversions. Of particular interest is the rapid fall or rise in temperature as skies clear or cloud up, respectively, under conditions where little advection is evident. (Drops of 12-20C in 12 hr were observed.)

Professor R.W. Longley (University of Alberta) investigated January values (1966 and 1970) of mean relative humidity for 25 Canadian stations. Using radiosonde data (for the 950-mb level) and surface screen observations, he found that RH increased with increasing temperature, contrary to that expected. Lower RH values at cold temperatures may be explained by the fact that they are reported relative to a water surface and the 1970 values have been converted from mixing ratio data. However, a number of physical processes common in the winter Arctic atmosphere should tend to produce higher RH values at lower temperatures, including advection of moisture, subsidence, radiational exchange and turbulent mixing. Unfortunately very little quantitative estimates due to typical cases involving these effects were presented. According to Prof. Longley the apparent discrepancy may be explained by the and by the lag of the radiosonde humidity element.

A short contribution entitled "Mesoclimatic Amelioration in the Mackenzie River Delta During the Spring Flood", was given by Dr. D. Gill (University of Alberta) to answer the question: Why is it so warm in spring and summer in this valley? Other sections of N. America at the same latitude are not as warm. Past research has assumed that northward flowing warm river was significant. However, in the summer heat budget of the Delta one major factor is warm air drawn down the valley by weak lows which develop over the western Arctic. In addition, the flushing of sea ice towards the Polar Ocean helps to change the albedo markedly both in the lakes and channels and on the surrounding land surfaces which also become flooded. More solar energy is absorbed causing air and water temperatures to rise rapidly.

**Mountain Meteorology**

Professor E.R. Reinelt chaired the afternoon session in which, as expected, research groups from Alberta displayed their interest in the airflow over mountains. However, the first speaker was Dr. N. Cherry of McGill who was studying lee waves produced by a complex mountain chain, the Southern Alps of New Zealand, roughly 70 km wide, peaked from 1–2 km. Wave equations for 1-, 2-, 3- and n-level numerical models were developed for computer calculations which yielded waves with lengths in 5–25 km range. Comparison with actual observations was good: for one case (cf. 2 bell-shaped mountain solution) the actual and calculated wavelengths were both between 4–7 km; in another, several 2 bell-shaped mountain models were superimposed to approximate the Southern Alps, and produced wave amplitudes ($\simeq$ 400 m) in agreement with those observed. Cross-sections of temperature, wind and Scorer's parameter (computed over 1 km) were also presented. Calculations of the vertical transport of momentum and its effect on the horizontal energy transport have yet to be made.

H.P. Wilson, AES, Edmonton, discussed the association between lee-wave phenomena and weather anomalies in Alberta. Cross-sections of streamlines and stability were drawn based on Queney's extension of Scorer's work; these were related to real weather situations. Tropopause heights computed with the 2-mountain profile fit well with data for hail occurrence and cyclogenesis. For purposes of calculation the Rockies are slightly better modelled as a 2-mountain (Coastal Range and Continental Divide) than as a 1-mountain (a median position in central B.C.) system; however, the location of the lee trough also depends on wind speed. Unfortunately lee waves were not reported for the cases studied.

Y. Chung reported on his work with Dr. Reinelt at the University of Alberta to investigate cyclogenesis in the lee of the Canadian Rockies; 146 cases were identified and classified according to intensity and their tendency to persist over the mountains or move away. Data indicated that previous theory which suggested that winds should be stronger over the mountains did not apply to the development of a surface cyclone but not for its initiation (a point disputed by one member of the audience); initiation may rather depend on $\partial\omega/\partial p$ which is a maximum at the rock surface.

The next speaker Dr. M. Khandekar, also from the University of Alberta, presented the results from his one-layer atmospheric numerical model which he constructed to study the effect of orography on synoptic-scale motion. The model parameters included: different mountain profiles; 7½ sec time-step; and 250-km grid length. The model occupied 5 × 5 grid lengths over an area 10,000 × 5,000 km². A 2-layer model (also discussed in detail) has not been run as yet. For storms crossing mountain ranges either convex or concave to their tracks, the model suggests that the convex-shaped range may inhibit development. However, one member in the audience questioned whether such studies were realistic since actual atmospheric situations were non-steady.

Finally S. Fogarasi (DOE, Ottawa) showed a series of slides which emphasized how cold lows could contribute to flooding problems. The progression of flooding during one day (July 20, 1970) was depicted for a site on a river flowing from the Rockies into Alberta.

**Biometeorology**

In his opening remarks the Chairman, G.W. Robertson, stressed the value which biometeorological research, conducted at the universities and other institutions, had for agriculture.

The first speaker was Prof. P.H. Schuepp of McGill University. His topic was "Model Experiments on Free Convection Heat and Mass Transfer of Leaves and Plant Elements", a sequel to one given at Macdonald College in 1971 dealing with the same subject. This year attention was focussed on free convection, both laminar and turbulent. Dr. Schuepp's photographic technique is so advanced that the airflow around the leaves was made perfectly visible (against a dark background) and offered convincing proof of his findings. Measurements showed how heat and mass transfer depend on the leaf angle, whereby leaves are more effective (by about 20%) than vertical plates in organizing the transfer. Leaf roughness appears to be instrumental in maintaining laminar flow in their vicinity. Also there was evidence that the concerted action of heat and water transfer increases the efficiency of natural leaves (by almost 10%) over that of plates. Together these findings seem to explain the marked difference in transfer rates between plates and leaves.

Professor N. Barthakur co-authored a paper with A. Kumar (both of McGill) on "Leaf Temperatures as Affected by Controlled Environmental Factors". After reviewing this area of research, he described his method which employed a wind tunnel, a microwave transmitter as a source of heat energy, and thermocouples to measure temperature changes on exposed leaves. Using a balance equation technique, he was able to compute the convective and evaporative transfer rates. Leaf temperature changes followed exponential curves whenever the transmitter was turned on or off. Transpiration effects could be temperature was also studied in calm and controlled wind conditions; essentially linear relationships were found. Larger leaves suffer a greater temperature drop due to wind than smaller leaves; this could be increased by wetting the leaves; at higher temperatures the cooling may be reversed (advective heating). Forced convection led to more linear relationships than free convection. The effect of hair on leaves was also studied. In the discussion, the validity of the balance method was questioned in view of the metabolic heating, but the speaker replied that this was assumed to be less than 2 per cent. It was also revealed that the effect caused by increasing the level of turbulence had not been investigated.

The last speaker K.G. McNaughton reported on his work with Prof. T.A. Black at UBC, "Evapotranspiration From a Forest – A Micrometeorological Study". The balance equation was used to derive an expression for evapotranspiration in terms, principally of radiation and vapour pressure deficit. Mr. McNaughton claimed that the problem of estimating the runoff no longer existed. He discussed the annual and diurnal variation of terms in the equation. For the forest (near Haney, B.C.) as a whole, the second factor contributed only 40 mm/day (much smaller than the potential evapotranspiration rate) and near the forest floor becomes small while convection becomes dominant. Also discussed were the daily variation of wind velocity, aerodynamic resistance, surface resistance, and the free evaporation rate. The ground and eddy fluxes are often low in this type of forest which consists of Douglas fir trees 7–8 m high, 13 years old. A good correlation was found between evapotranspiration and net radiation; also good agreement, with results calculated by means of the Priestley-Taylor formula. One scientist remarked that he tried to correlate net radiation with evapotranspiration data for the network at Marmot Creek basin, but the points had a pronounced scatter. However, this difference could not be resolved.

**Hydrometeorology and Marine Meteorology**

On Thursday morning when consecutive sessions were chaired by D. Storr, the first paper dealt with Marmot Creek Basin, a 3-$mi^2$ area in the Kananaskis Valley. D.L. Golding of the Northern Forest Research Centre, Edmonton, is involved in a project to isolate those topographic and forest variables which govern snow accumulation. He found that 58% of the variance in snow water equivalent at 106 sampling points could be explained by considering various powers of forest density, slope aspect and elevation as well as certain basin parameters. Greater success would probably have been attained if weather types had been included in the analysis. Runoff was also examined and correlated highest and second highest with the March and maximum values of the snow course water equivalent, respectively. Poorest correlation occurred with mean sub-basin water equivalent which is surprising, since the mean represents an average of many observing stations (an estimate of actual accumulation, whereas the snow course data only produced an index). Future measurements will be carried out after controlled cutting in the basin has been made in order benefit basin hydrology by affecting snow accumulation and melt.

A preliminary study of the climate of Big Quill Lake, a 100-mi$^2$, shallow and saline lake in central Saskatchewan has been completed by Dr. J.M. Whiting, Saskatchewan Research Council. He tested the hypothesis that precipitation minus evaporation controls lake level and therefore drives the groundwater balance. All the hydrometeorological data collected since 1966 will eventually be used to define the total hydrologic balance of the lake's basin. Big Quill Lake differs significantly from most lakes: it is saline and experiences large seasonal fluctuations in lake level and consequently also in area and fetch. This is believed to have led to poor evaporation estimates using a modified mass transfer technique (after Lakshman); on the other hand, the use of upwind climatological data produced reasonable estimates using the energy budget technique of Penman. In 1971 an instrumented platform was installed on the lake which hopefully will provide for improved estimates of lake evaporation and ground-water flux.

Numerical computations of the movements of oil slicks was the subject of the paper by Dr. M. Khandekar of the University of Alberta (co-author, Dr. T.S. Murty, DOE, Ottawa). The ability to predict such movements and their spreading over the ocean surface would greatly assist in control operations (especially in coastal regions) since oil spills represent a serious environmental hazard. The slicks are essentially two-dimensional; a group existing in close proximity was modelled as a set of rectilinear vortices. Equations derived from hydrodynamical theory were used to account for the motion of an individual slick due to its mutual interaction with the others. However, this procedure is of more theoretical than practical interest, since it neglects the influence of winds, currents and waves as well as turbulent diffusion, all of which can significantly affect the dispersal of an oil spill.

Dr. E.R. Walker of the Frozen Sea Research Group, Victoria, B.C., spoke briefly on the Group's recent activities in the Canadian Arctic. At sites near Eureka and Cambridge Bay, meteorological observations are taken from a laboratory-raft anchored offshore. In addition, profiles of water temperature and salinity are observed so that changes in the sea stability can be assessed. This observational programme, which is continuing, is aimed at improving the understanding of the processes which lead to the formation and thickening of sea-ice. Later Dr. Walker showed a movie of their stations and facilities in the High Arctic.

**General Meteorology**

A variety of topics received consideration in the second morning session which opened with a paper presented by W.L. Clink (AES, Toronto), who with B.E. Sheppard carried out a meteorological calibration of a backscatter visibility meter. This videograph, tested at Toronto International Airport, yielded results which suggested that a common calibration might be acceptable for the many possible obscurants for visibility ranges beyond one mile; however, for lower visibilities, each parameter needs to be treated separately.

The next speaker, J.D. Reid (AES, Winnipeg) discussed the verification of terminal forecasts using the Ranked Probability Score. The parameters studied were the forecasts of ceiling and visibility made during a five-month period at Winnipeg International Airport. The forecasts showed significant skill over climatology for the first five hours; a persistence forecast showed skill for only three hours and is only slightly superior, in the first hour, to a subjective forecast. In all but one month the subjective forecast was somewhat better than both climatology and persistence when the 12 hours in the whole period were verified together.

Professor R.W. Longley of the University of Alberta talked about his study entitled "Precipitation over the Prairie Provinces". He computed the correlation between monthly precipitation amounts for various pairs of stations during the summer half-year (April-Oct.). The correlation isolines tended to be elliptically oriented in the direction of the prevailing winds. The correlations decreased more rapidly with distance for July than for the other months, as might be expected from the convective nature of the July rainfall.

The session concluded with two brief reports. Miss K. Swami (DOE Glaciology Division, Ottawa) described some anomalous features of the daily temperature cycle which appeared in the Mackenzie Valley only during the period when the mean temperature was below freezing.

Finally, E. Stashko (Alberta Forest Service, Edmonton) gave a polished presentation on the topic "Fire Weather Forecasting in Alberta". By utilizing basic AES forecast material, he issues a daily Forest Fire Index for Alberta to spotlight areas with great potential fire hazard; he also forecasts wind speed and direction, relative humidity and precipitation for those areas in which fires have already started. He alerts firefighting crews to possible occurrences of: strong winds, so that aircraft may be protected; heavy rainfalls, so that crews may be relocated to new sites before bush roads become impassable.

**Hail**

This Friday morning session, one of two concurrent, was chaired by Dr. P.W. Summers. Professor W.F. Hitschfeld of McGill started the proceedings with a review of world-wide research on hail and hail suppression. He touched on the achievements and exciting prospects of the National Hail Research Experiment underway in Colorado with its mission to test the Russian hail suppression concept by using airborne rockets for AgI delivery. He proved that hail is a real international plague in discussing the work accomplished in Africa both by governments and private citizens to reduce damage to the high cash yield tea and tobacco crops. Prof. Hitschfeld treated openly of the bitter disputes (involving claims of success and counter-claims) which exist, even in a field with such great potential benefits, between workers not only in S. Africa but in France as well. A special word was reserved for the Russian Work – extensive, but associated with theory that is now becoming hard to swallow – as without using consistent verification techniques. In summarizing, Prof. Hitschfeld warned of the pitfalls within this highly mission-oriented field of research and appealed to all to master hail suppression "with integrity and assurance".

Professor R. List (University of Toronto) in delivering a paper co-authored with T. Agnew, brought the session back to earth and into the Lab to look at ice. Artificially produced hailstones were analyzed in a series of experiments to relate their bubble structure to physical parameters important to their formation. The very encouraging results showed a high correlation between mean diameter and concentration of the air bubbles and the liquid water content and icing temperature. Prof. List considered that his faith had been restored in hailstone analysis – once again the future looks bright for unravelling the mysteries of hailstone growth through analysis of individual stones.

As a result of Mr. L. Wojtiw's (Research Council of Alberta) study in conjunction with Dr. Summers, he was able to put dollar values on the economic impact of hail damage in Alberta and showed maps of the geographic distribution and time variation of annual hailfall patterns. Annual direct crop losses were estimated at $20–25 million with an additional 50% loss caused by reduced business activity. The geographic distributions of hailfall impressed on the audience that the old adage "hailstorms follow rivers" still had some credence in Alberta along east-west river basins.

Next Dr. B.L. Barge (RCA) reported on progress made by staff at the Alberta Hail Studies Project toward distinguishing between radar returns from rain and hail. He presented data to illustrate that: radar Ze values in excess of 50 dBz are exclusively associated with hail; reflectivity values less than 30 dBz occur with "rain only"; for values between these limits, the circular depolarization ratio (CDR – obtained from ALHAS depolarization facility radar) allows rain and hail to be differentiated with reasonable reliability.

Results of another group study were described by Dr. N. Cherry who worked with Dr. R. Rogers (McGill University) to investigate the interaction between hailstorms and the environmental air using serial radiosonde ascent data measured at Penhold, Alberta. Although little effect was observed on the temperature field with approaching storms, there was an increase in moisture at all levels which reversed as the storm passed. Also, the static stability changed from neutral to stable with storm passage. Dr. Cherry indicated that "a radiosonde released 1½–2 hours in advance of a storm appears most representative of the air close to, but unmodified by the storm".

Dr. A.J. Chisholm (AES, Toronto), on behalf of himself and J. Renick (RCA), described their scheme of classifying major types of hailstorms which not only interact with their environment but have a characteristic mode which is a result of the atmospheric wind structure: first, the vertical stance single cell storm, which lives briefly in a non-sheared environment; secondly, the multicell, which lives in an environment with unidirectional shear, lasts longer than a single cell and propagates on its right flank by discrete cellular development; finally, the supercell, which thrives in an environment where the airflow and precipitation are organized by a vertical wind structure with veer (in low levels) and persists for up to several hours.

In bringing the morning session to a close, Dr. M. English of McGill focussed attention again on hail – but grown in the vast memory-core of a computer. She described the physical basis of her numerical hailgrowth model, developed in conjunction with Prof. Hitschfeld. Initial conditions were chosen to represent the two-dimensional structure of observed hailstorms. There was excellent agreement between the observed and computed maximum hailstone sizes. Dr. English concluded that the prerequisites for large hail are high values of updraft speed, water content, height of storm top along with a nearly vertical updraft. Embryos rise near the edge of the updraft region reaching radar detectibility in the overhang zone; while continuing to rise they grow most rapidly where the updraft speed and the water content are at a maximum.

**Weather Forecasting Research**

F.B. Muller chaired this session, the other of two occurring in parallel on Friday morning. A.L. Bealby (AES, Toronto) discussed the computerized use of hourly weather data. Reference was made to experience gained in setting up a complete system for computer reception and processing of hourly weather data on a minicomputer. Processing includes analysis and forecasting of MSL pressure. Planned improvements were summarized.

A paper describing numerical experiments on the propagation of local errors in a primitive equations model was presented by Dr. J.F. Derome (AES, Montreal). Six-day forecasts were made with a barotropic primitive equations model, starting from initial conditions assumed to be free from errors. Forecasts were then repeated using the same initial data, except for the addition of a small low pressure area near the Gulf of Alaska. Charts were projected to show how the error pattern propagated for selected cases. Sixteen cases tested were then summarized. On the average, the largest value in error travelled from the Gulf of Alaska to the western tip of the Great Lakes and decreased by a factor of 2. The area of the error grew by a factor of 13, giving a net increase of nearly 50 per cent in the *rms* error computed over the entire forecast area.

E.C. Jarvis (AES, Toronto) reported on a preliminary investigation into the depiction of weather using regression techniques. Three weather categories were studied and charts demonstrating an analysis of the three categories based on analyzed grid point data were shown. The agreement between the objectively analyzed fields and the observations was pointed out. The potential of this technique for depicting weather using the "perfect prog" approach was indicated.

The session closed with Mr. P. Hof describing the Satellite Receiving Station operated by the Institute of Earth and Planetary Physics, University of Alberta. Emphasis was placed on the Electronic Lobe Switching Antenna developed at the university. To track satellites the antenna system provides electronic switching of antennas rather than mechanical tracking. Current pictures from this facility were on display during the Congress.

Parallel sessions were held on the last afternoon of the Congress. Dr. P.W. Summers not only chaired the session on Hail and Cloud Physics but also contributed (as co-author) to the first two papers. J. Renick of the Research Council of Alberta described joint experiments with Dr. A.J. Chisholm (AES, Toronto) to seed super and multicell clouds. AgI flares were dropped by T-33 aircraft into feeder clouds and the rain samples were analysed by AgI tracers. The seeded cell was tracked by ground radar, by aircraft and by means of cloud photos. A time dependent radar technique was used to build up a vertical/time sequence. Cell tracks and profiles were then determined. For seeded cells the time from release to recovery of the AgI in rain or hail was measured. Location of seeding is very important: AgI must be injected into the hail-core centre. During the discussion several additional facts were revealed. For the ground-based seeding technique, the AgI may rise to the top of the updraft too quickly to form hailstones any larger than 1-mm size; seeding along the side of the updraft may allow more time for growth. The envelope for AgI in the recovery area was nearly identical to that in the seeding area, but displaced 10–30 min downstream. The efficiency of AgI to form embryos is difficult to measure even though far greater numbers of embryos may be required for seeding. It may not be possible to dissipate a storm completely by overseeding. A suggestion was offered that $CO_2$ or $N_2$ expansion could be employed in a homogenous seeding technique.

Dr. Summers then reviewed the progress made in "Project Hailstop", both the cloud seeding experiments and the development of theoretical models. Fallout patterns of AgI disclosed a primary zone 12–30 min ($\simeq$ 4–30 km) downstream from the release area; a secondary zone at 30–150 min ($\simeq$ 10–60 km); plus a fallout zone at a 3-hr ($\simeq$ 90 km) separation. Tracer trajectories of airflow through the cloud indicate that late seeding results in distant recovery of AgI in rainfall whereas early seeding gives rise to recovery in the heavy precipitation core within 30 min. For the summer of 1972, experimental plans include earlier seeding of the feeder clouds, and using radar chaff to trace the airflow through clouds more accurately. During the discussion period, it was mentioned that over-seeding may cause other problems, now that the number of nuclei are being increased by a factor of 1,000 over that for natural nuclei; for example, the total amount of precipitation may be decreased.

Professor E.P. Lozowski (Univ. of Alberta) described his theoretical research with Professor R. List (Univ. of Toronto) to develop an aerodynamic model for the tumbling of spheroidal hailstones about a horizontal major axis. This would help to explain why hailstone shell structure is sometimes symmetrical. Considerable success has been achieved in modelling realistic motions which depend on measured values of static drag, lift and torque as well as dynamic damping torque. However, values of the coefficient of damping must be obtained by experiment to determine the most likely motion of the spheroids: damped or amplified oscillations, the latter leading to tumbling for critical values of the damping coefficient.

analysis of atmospheric electrical potential gradient, conductivity and air-earth current density for several land stations. In addition to the well-known diurnal and semi-diurnal variations in the potential gradient a terdiurnal variation was found which was not always related to the corresponding variation in conductivity.

The electrification of a TNT explosion cloud was the subject of Prof. D.R. Lane-Smith's (Univ. of Western Ontario) talk. He used field mills in the ground to record the changing electric field as the cloud became charged and drifted over them. He outlined results arising from his numerical model to help explain the electric field changes produced by the explosion.

Finally the session concluded with a description by J.D. McTaggart-Cowan (University of Toronto) of a linear accelerator for water drops, which he constructed in association with Prof. R. List. The instrument was developed for water-drop collision experiments.

**Micrometeorology**

O. Johnson, the chairman, noted that over the past fifteen years the field of micrometeorology had greatly increased in importance internationally and serves many scientists other than meteorologists.

Professor R. Gilpin of the University of Alberta delivered a paper on his research into the absorption of solar radiation in ice and water. He devised a laboratory simulation of solar heating in ice, to help determine how the turbulent convection produced by the heating of water below the ice aids in melting. A power law of absorption fits the data better than an exponential: the index is $\simeq 0.8$ for solar radiation versus 1.3 for a tungsten lamp source. Ice absorbs much the same as water, except that absorption decreased with "bubbly ice". Turbulence generated by wind was more important than that generated by solar radiation.

The performance of a yaw-sphere/thermometer system was discussed by D. Yap who was part of a UBC research group including Profs. T.A. Black, J.R. Oke and Mr. R. Wilson. The system is required to measure vertical heat fluxes by the eddy-correlation technique, and comprises a 5-cm sphere (pressure measured at two ports, 45° apart) and a hot-wire thermometer. During calibration in a wind tunnel the constant b in the Tanner-Thurtell equation

$$p = p_s + (\rho/2)\, V^2 \,[1 - b\sin^2\psi]$$

was determined. The value 1.7 was good for the Reynolds number range, 6,000–20,000, in fair agreement with other reported values (1.6–1.7) but quite different from the theoretical value, 9/4. For turbulent flow 1.57 is appropriate. Tilt errors in moderately unstable flow amount to about 5%/deg; but in stable flow, 11%/deg. Fluxes can be measured up to 5–10 Hz, since temperature measurements are at 7 Hz with the same response as for pressure.

Dr. J.L. Honsaker described a data acquisition system which he developed with F. McDougall and D. Oracheski at the Univ. of Alberta for storage of eddy

Fluxatron array as well as from a remote sensor, in this case mounted on a model aircraft. Quality control checks can be imposed on the data while being received so that spurious frequencies can be eliminated.

An interesting study relating thermal structures in the air to surface heat sources was outlined by Dr. R.M. Holmes, Environment Resource Airborne Instruments Ltd., Calgary. He used an airborne infrared line scanner and other radiation equipment to measure surface temperature and the geometry of the thermal structures over the Cypress Hills, Lake Newell and the town of Brooks. Trees, barns and other buildings provide great temperature contrasts. Big blobs of air appear to stick to the surface, before a parcel suddenly breaks away; on slopes this may occur quickly, but on flat ground (as for irrigated areas) a parcel may remain on the ground for some time. The 8–14 $\mu$m range seemed best for making measurements, with very little effect caused by the short-wave region. In crops which were transpiring the emissivity values ranged from 0.93 to 0.97, causing errors in temperature (relative to black-body) of less than 2°C.

Prof. M.J. Curry presented the results of his work with Dr. R.C. Murty (Univ. of Western Ontario) to collect micro-scale pressure signatures caused by stormy weather systems. Three micro-barographs were installed about a half (pressure) wavelength apart. 59 events occurring in 1970 were matched: a wave must be recorded at all 3 sites for at least 2 cycles. Some events were checked for triple correlation (velocity $\simeq$ 10%; bearing $\simeq$ 5%). All cases but one were for waves within the 150–360° sector and were thought to be associated with approaching weather systems; the exception, with a thunderstorm. A question was raised whether pressure waves might not give wildlife warning of impending weather changes.

D.S. Davison of UBC gave a brief account of joint research with Dr. M. Miyake in July 1971 to study the structure and dynamics of plumes. Structures were compared using data recorded by two different systems: T-33 aircraft (10 hours of flight over 7 days) and a 100-m tower instrumented at 4, 48 and 92 m. Another array comprised 4 mini-towers, 4-m high with vertical Gill anemometers.

The session ended as it had begun, with a novel film, "The Ballad of the Ice-Worm Cocktail", by Prof. Gilpin. It illustrated what happens when water containing air is frozen: supercooling and freezing proceeds from the surface; cycling of surface temperature gives layers, with and without bubbles; melting causes the bubbles to migrate; and air collects at the centre part of an ice cube.

## ANNUAL GENERAL MEETING

Lively discussions and extended debates marked the deliberations of the Society's annual 1972 meeting at the University of Alberta. Vital policy matters concerning the operation of the CMS were thoroughly probed and discussed, particularly those involving the financial status and the editorial policy of *Atmosphere.*

The Minutes of the 5th Annual General Meeting held at Montreal on May 12, 1971 were approved. Highlights of the debate on the Executive Committee Reports (President, Nominating and Awards Committees, Treasurer, Editor) which were then presented are given below.

Society prizes were announced; only one recipient was present to receive his award, the President's Prize – Dr. M. Kwizak (AES, Toronto but formerly Montreal) for his work with Dr. A. Robert (co-winner, AES, Montreal) on improving computational techniques in atmospheric models of the primitive equations. Other awards are to be presented (wherever possible) at meetings of the Local Centres in the autumn: the Prize in Applied Meteorology to Professor J.S. Marshall of McGill for his original contributions in processing weather radar data; the Graduate Student Prize, to R.S. Schemenauer, who, together with Professor R. List at the University of Toronto, measured the drag coefficients and characteristic motions of snow crystal, graupel and small hail models; the Andrew Thomson Undergraduate Student Prize, to Tom Low (also U of T) for his B.SC. thesis study of the collisions between rain drops and metal chaff.

Financial affairs were of perennial interest to the members since previous budgetary estimates had forecast eventual deficit financing. However, the economic base of the Society's resources had been strengthened with the AES order for 200 subscriptions to *Atmosphere.* The extra funds (close to $2000) will permit the CMS to conduct its business without worrying about borderline operation. Furthermore, after accepting the Treasurer's Report and the 1973 Budget, members also approved a motion to increase fees to more realistic levels in accordance with the rising cost of living, and, in the case of Student Members, closer to the actual cost of publications received. The fees for 1973 were set as follows: General Members – $15.00; Student Members – $5.00; Sustaining Members – $50.00 (minimum).

The membership structure was simplified upon acceptance of an amendment to the By-Laws: newly defined class of Sustaining Membership replaces the old (and somewhat confusing and in practice, unwieldy) categories of Corporate and Sustaining Membership.

Arrangements to hold the 7th Annual Congress in Halifax are well underway. The Toronto Centre executive proposed that their Centre should host the 8th Annual Congress in 1974.

A fair amount of discussion was generated by the Editor's Report. Some members felt that the publication policy was not clearly defined. The majority agreed that *Atmosphere* should be allowed to develop and grow over several years' time. Even though the quality of articles was not considered to be that of a well-established scientific journal, the papers published were steadily improving.

Another amendment to the Constitution and By-Laws was approved. Starting in 1973, the editor will no longer serve as a member on the Executive Comthan by all Society members). More flexibility in handling editorial affairs can be achieved in this way.

Consideration will be given by the Executive to the proposal that the Society publish a high school meteorology text, with the active cooperation of interested and competent members.

As appropriate, the incoming and outgoing executive members were welcomed or thanked for their contributions to the Society. The lengthy but interesting meeting was adjourned at 10:00 p.m. about an hour late for the wine and cheese party at the Faculty Club.

## ASSOCIATED EVENTS

A second full day of activity followed the first – but with more variety. After the morning sessions, members enjoyed well-organized tours either at the micrometeorological research site, Ellerslie or at the Alberta Hail Studies Project installation, Penhold. In the evening, the Alberta Government hosted the Annual Banquet at the Royal Glenora Club where the Lieutenant-Governor of Alberta, the Honourable J.W. Grant MacEwan, addressed the members with many entertaining anecdotes dealing with the weather.

The Hon. J.W. Grant MacEwan and Prof. A.W. Brewer.

At the banquet Professor A.W. Brewer was presented with the Patterson Medal by Mr. L.T. Campbell of the AES Headquarters for his distinguished service to meteorology in Canada. Under his direction the studies in meteorology at the University of Toronto have expanded to a high level of excellence. As a natural result of his continuing interest in ozone research, a field in which he is internationally renowned, he is now the President of the International Ozone Commission of the IUGG. Dr. Brewer was deeply involved with the metamorphosis of the Canadian Branch, RMS into the CMS, and served as the first President, 1967–68.

Thanks are extended to the following CMS members who generously assisted with their time and skills in reporting on the proceedings of the Sixth Annual Congress for inclusion in this issue of *Atmosphere*.

| | | |
|---|---|---|
| C.B. Adamson | Dr. A.J. Chisholm | Dr. R.A. Treidl |
| A.L. Bealby | K.D. Gardner | M.S. Webb |
| F.E. Burbidge | R.G. Stark | R.J. Woodrow |


## BOOK REVIEWS

THE VALUE OF THE WEATHER. By W.J. Maunder. Methuen & Co. Ltd., London, 1970, 388 pp., $14.95; paperbound $6.50.

Meteorologists have traditionally devoted the major part of their effort to activities intended to improve the accuracy of their observations and forecasts while at the same time giving only minor attention to the impact of weather on the economy or to the economic value of improved weather services. Inability to demonstrate or document such values in a convincing manner may be one reason meteorology must often take second place behind other services in competition for necessary resources. On this basis Dr. Maunder's book is a welcome addition to what may be termed "economic meteorology".

By his own definition, the author's purpose is:

*to bring together, for the first time, the most significant and pertinent associations between man's economic and social activities and the variations in his atmospheric environment – specific attention is focused on economic activities and the weather, the economic analysis of the weather and the benefits and costs of weather information.*

Although the book is primarily a review of papers by many authors – with 750 references – Dr. Maunder is himself the author of a number of papers on this subject published in New Zealand, Canada and the United States and would appear well qualified to achieve his purpose.

Dealing first with the better known and more spectacular aspects, a chapter on "Weather Variations" discusses the general economic impact of violent storms – including hurricanes, tornadoes, hailstorms, lightning and blizzards – floods, drought, air pollution and atmospheric modification. The following chapter titled "Economic Activities" is in the author's words: ... *essentially a review of some of the studies that have been made linking the dollar value or potential dollar value of weather variations to specific activities in the primary, secondary and tertiary sectors of the economy.* Chapters IV, V, and VI deal respectively with "Sociological and Physiological Aspects", "Economic Analysis of Weather" and "Weather Knowledge: Benefits and Costs".

The principal value of Dr. Maunder's work is that it consolidates in one book many studies on the economic impact of weather and the economic application of weather information that are presently scattered through many sources. Tables are presented giving the annual losses from hurricanes, lightning, drought or hail, the effect of weather on construction activity, airline operations or traffic accidents, the

Discussions range through such diverse topics as human biometeorology, econoclimatic models, the economic utility of weather forecasts to weather and pastoral production.

There is little doubt that as a summary of current work in the field of economic meteorology Dr. Maunder's book serves a valuable purpose and should prove of considerable interest to those concerned with this field. On the other hand the meteorologist trained in physical sciences may be disappointed by the many ambiguous relationships and arbitrary assumptions that seem necessary in this area while all readers will be impressed with the limitations of available statistics (particularly in Canada!) and with the work remaining to be done.

F.J. Mahaffy
Atmospheric Environment Service
Toronto

## NOTES FROM COUNCIL

The following were accepted as members by Council:

July 5, 1972

| | | |
|---|---|---|
| *Member* | Gerald Klein | Youssef M'Roueh |
| *Student Member* | Alan Murray Purves | |

September 18, 1972

| | | |
|---|---|---|
| *Member* | Asit K. Hazra<br>Neil Clinton Meadows | John Michael Opdebeck |

## ANNOUNCEMENTS

**Remote Sensing of Water Resources – International Symposium**

The American Water Resources Association and the Canada Centre for Inland Waters announce an International Symposium on the *Remote Sensing of Water Resources*, a Symposium on the applications of remote sensing to water resource management. Emphasis will be placed on those studies which show definitive interpretations of water quality and quantity, or related environmental aspects.

The Symposium will be held *June 11–14, 1973*, at the Canada Centre for Inland Waters, Burlington, Ontario. The following principal themes will be explored by the Symposium:

1. Water resource applications of airborne remote sensing.

3. The role of remote sensing in integrated water resource management systems.

Abstracts should be 300–500 words in length, and should include the paper's title, author's name and affiliation. Typing should be single spaced, preferably in elite type, with left-hand margin of one inch and other margins not less than half an inch. Paragraphs should be indented five spaces and should be separated by one blank line. Ten copies of the abstract (one of which is the original typed copy) should be sent. Authors should also enclose their full mailing address on a separate sheet.

Upon acceptance authors will be notified and provided with instructions for submitting the full version of the Symposium paper (3 copies) which must be received by *April 15, 1973*. The papers will be published subsequently as the Proceedings of the Symposium.

Authors who wish to submit papers for the Symposium should send **a detailed abstract no later than January 15, 1973** to the Chairman of the Technical Program Committee:

Dr. K.P.B. Thomson
Canada Centre for Inland Waters
P.O. Box 5050
Burlington, Ontario, Canada
Telephone: (416) 637–4243

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**First World Congress on Water Resources**

The First World Congress on Water Resources will be held at Chicago, Illinois, September 24–28, 1973, under the sponsorship of the International Water Resources Association.

The theme will emphasize the international scope of "Water for the Human Environment." It is intended that these Congresses will establish an international forum on a biennial basis to bring together planners, administrators, managers, industrialists, lawyers, engineers, educators, researchers, biologists, chemists, meteorologists, physicists, oceanographers, and others interested in water resources.

Papers are invited on any subject related to the theme, however, special attention will be given to those dealing with the following subjects:

a) International cooperation and coordination in development of water resources for preservation of the human environment.
b) World-wide water needs, supply, and quality.
c) Water pollution and control from an international viewpoint, including their problems in the oceans.
d) New water resources technology and its effects on the human environment.

An original plus 4 copies of an abstract are to be submitted to reach the

Chairman of the Technical Program Committee of the Congress by **February 15, 1973.**

Dr. Herbert C. Preul
Civil & Environmental Engineering Dept.
University of Cincinnati
Cincinnati, Ohio 45221, U.S.A.

Abstracts are to be submitted in English and must provide the following:

a) Title of paper, authors, affiliation, and mailing address.
b) Abstract is to be from 400 to 500 words in length, typewritten and spaced with a one inch left margin and other margins not less than half an inch.

Abstracts will be reviewed by the Technical Program Committee of the Congress and authors will be notified of acceptance of the papers and given instructions for preparation of the manuscript by **March 15, 1973**. The length of a paper should not exceed 20 doublespaced typewritten pages of a size 8½ in. by 11 in. Final manuscripts will be due by **June 15, 1973**. Publication of the papers will be made in a Proceedings of the World Congress. Final papers may be in English (preferably), French, German, Russian, Spanish.

Suggestions on "Problems on Practical and Professional Nature of International Importance" are also invited (one-page) as topics for discussion in special sessions and work groups to be held during the Congress. Individuals whose suggestions have been selected as the topics will serve as Discussion Leaders.

For further information, please write:

Dr. Gabor M. Karadi
Secretary-General, IWRA
Science Complex Bldg.
University of Wisconsin – Milwaukee
Milwaukee, Wisc. 53201, U.S.A.

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**Eastern Snow Conference**

The Eastern Snow Conference is an international organization in eastern Canada and the north-eastern United States concerned with origin, precipitation, accumulation, character, melt, and runoff of snow from the viewpoints of meteorology, power generation, conservation, engineering, forestry and related fields.

The 30th Annual Meeting of the ESC will be held at Amherst, Mass., February 8–9, 1973.

For program and reservation information write:

Mr. Gordon R. Ayer, Sec'y.
Pine St., RFD
Charlestown, NH 03603, U.S.A.

(Please write in Block Letters)

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|---|---|
| *General* or *Student Member* | SURNAME ................................................ |
| | GIVEN NAMES ................................................ |
| | PERMANENT ADDRESS ................................................ |
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| | 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

*For categories of membership and annual fees, see note below.

## NOTICE TO CMS MEMBERS

Membership dues for 1973, as determined at the Sixth Annual Congress of the CMS, stand as follows:

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

## 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: 902–423–1161, 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.

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## 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.

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 181, Ontario, Canada.