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Contents

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Monthly Areal Precipitation Totals From 24-Hour Computer Forecasts

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[Manuscript received 28 January 1974]

ABSTRACT

A preliminary investigation of monthly rainfall patterns analysed from 24-hour computer forecasts of precipitation was performed. These patterns are compared with the observed precipitation and long-term normal patterns. Recommendations are made to incorporate the method into a verification program for the computer product.

1 Introduction

Numerical forecasts of precipitation amounts are produced operationally twice daily at the Canadian Meteorological Centre (CMC) in Montreal. As transmitted over the facsimile network, the forecasts depict areal accumulations of precipitation for two 24-hour periods beginning at 0000 GMT and 1200 GMT using 0.25, 0.5, 1.0, 2.0, 3.0, etc. inch isohyets. The vertical motion field at 700 mb and the precipitable water between 500 and 1000 mb for the beginning and the end of the 24-hour forecast periods are also displayed (Fig. 1). Detailed descriptions of the model may be found in the literature, Davies and Olson (1973), Kwizak and Davies (1969).

Although these precipitation forecasts are designed as input for other forecasts that are issued daily, eg. public, agriculture, forestry and municipal snow removal; if sufficiently accurate, the monthly totals of the computer produced precipitation fields could be used for hydro-meteorological and other climatological projects, particularly where observing networks are sparse. This possibility provided the stimulus for this investigation, which should be considered of a preliminary nature.

As a by-product of the investigation, it became apparent that the comparison between the computer-produced fields and the actual monthly precipitation provides a means for verifying the forecast. Over an extended period of time, systematic biases of the program to over or under-forecast precipitation for particular locations should become noticeable.

2 Investigation of Data

Charts for two months, April and May 1973, were examined separately using the forecast period 0000 GMT to 0000 GMT. This time period was chosen to conform with the observational date with which the forecasts would be compared. The Province of Ontario was taken as the test area and was further sub-divided by a line from Sault Saint Marie to Winisk.

The precipitation that was forecast to accumulate during each 24-hour period was graphically added to that accumulated during the previous days of the month. Since the 0.25 inch isohyet is the lowest value that is shown on the charts, it was necessary to draw the 0.1 inch isohyet subjectively for each 24-hour forecast.

The considerations for locating the 0.1 inch isohyet were:

(a) the symmetry of the computer-produced precipitation pattern, and
(b) the 700 mb vertical velocity pattern at the beginning and end of the forecast period.

3 Results

The total forecast April precipitation for Ontario is shown in Fig. 2 while the actual monthly precipitation[1] appears in Fig. 3. The maximum over northwestern Ontario was predicted by the computer method but the minimum over Georgian Bay and the maximum in the vicinity of Trenton were not; the Trenton maximum might be considered displaced, appearing in the Windsor area.

A graphical subtraction of the actual precipitation from the computer produced monthly total is presented in Fig. 4. The variation is seen to range from −1.5 inches in the northwest to +4.0 inches in the southwest. The computer forecast of the monthly precipitation was within 0.5 inches of the actual precipitation for 64 per cent of the test area. Conversely, the monthly precipitation amounts based on the computer data differed from the actual precipitation by more than 0.5 inches over more than a third of the area.

The normal precipitation[2] for the month was also examined (Fig. 5). It shows a more or less regular increase in precipitation from north to south across the Province.

Subtracting the actual precipitation from the normal shows (Fig. 6) variations ranging from −2.0 inches in the northwest to +1.5 inches near Lake Huron. The actual precipitation was within 0.5 inches of the normal precipitation for approximately 40 per cent of the test area.

In a similar manner, the actual precipitation for May 1973, the precipitation field based on the computer-produced values and the normal precipitation for May were analysed and are shown in Figures 7, 8, and 9.

The computer-based product shows some skill in forecasting the May precipitation pattern in northwestern Ontario but errors in amount in the southwest were as much as 7 inches. This error was mainly due to a 5-inch storm which was forecast to move slowly across the Windsor area during the last week of May and which in fact passed south of the area.

[1]Based on analysis of monthly data from the Climatological Station Network.
[2]Based on analysis of normal data from the Network for the period 1941–1970.

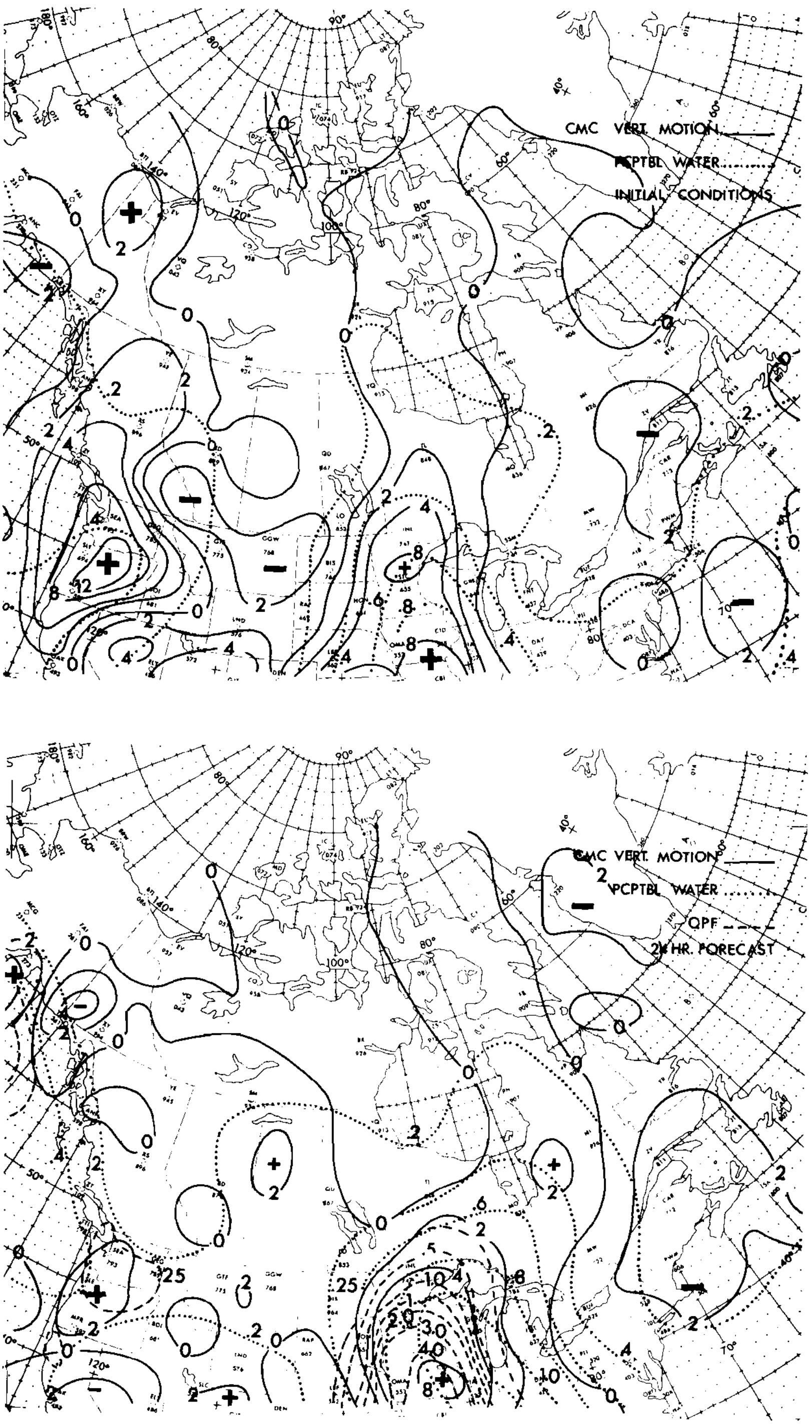

Fig. 1 CMC 24-hour quantitative precipitation forecast.

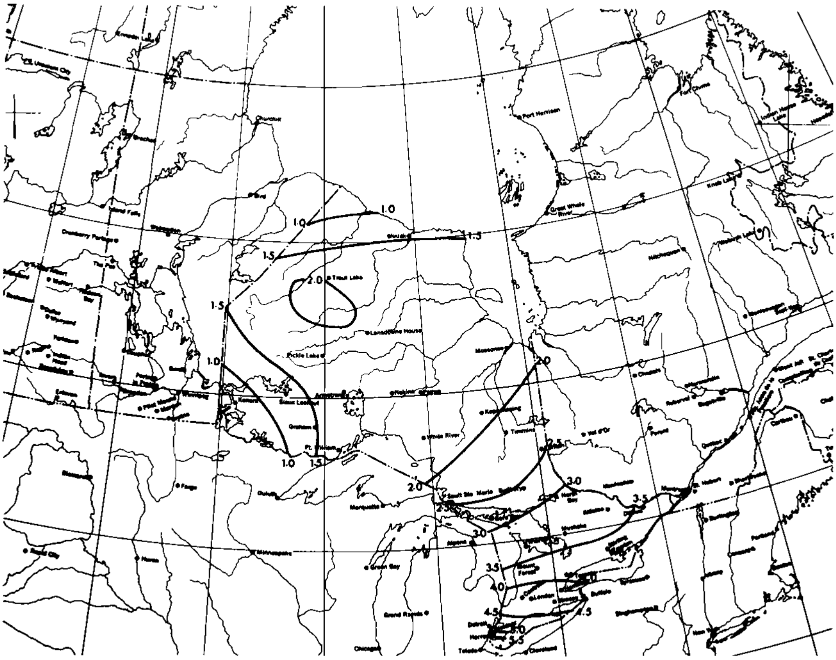

Fig. 2 Computer forecast precipitation – April 1973.

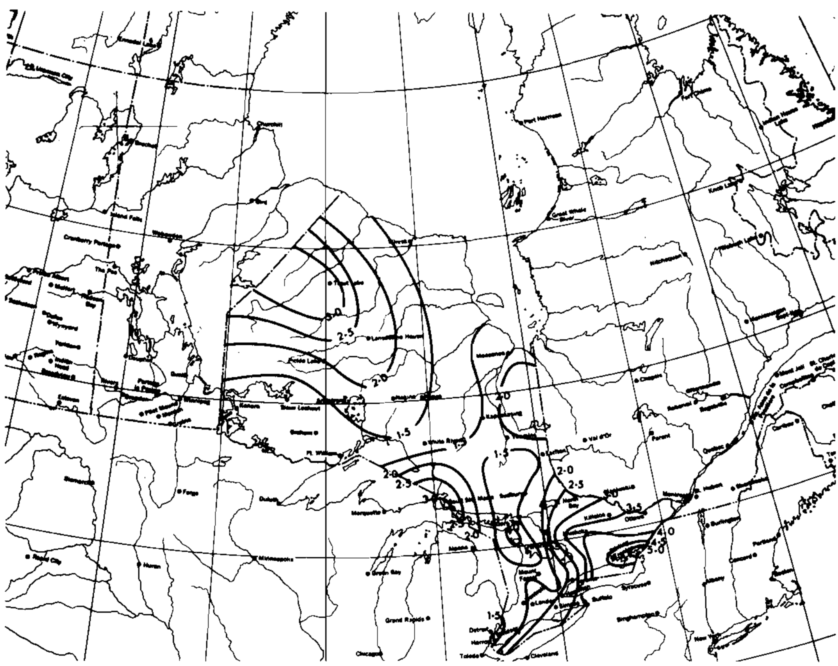

Fig. 3 Actual precipitation – April 1973.

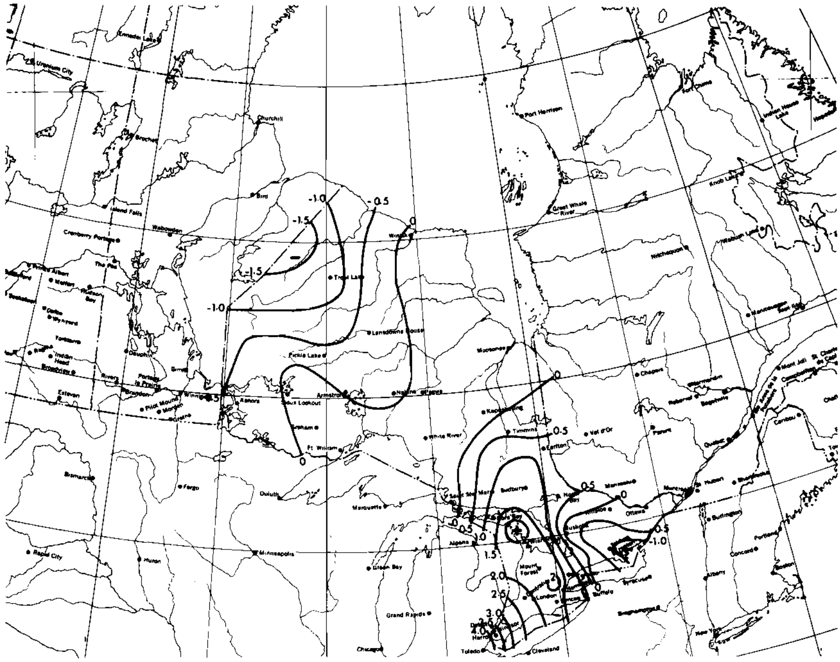

Fig. 4 (Forecast-actual) precipitation – April 1973.

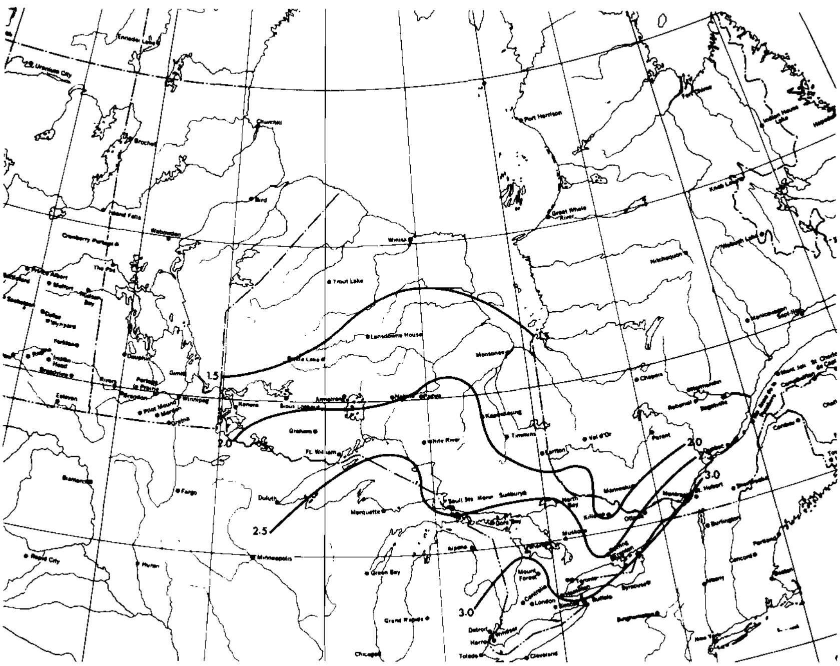

Fig. 5 Normal precipitation – April 1973.

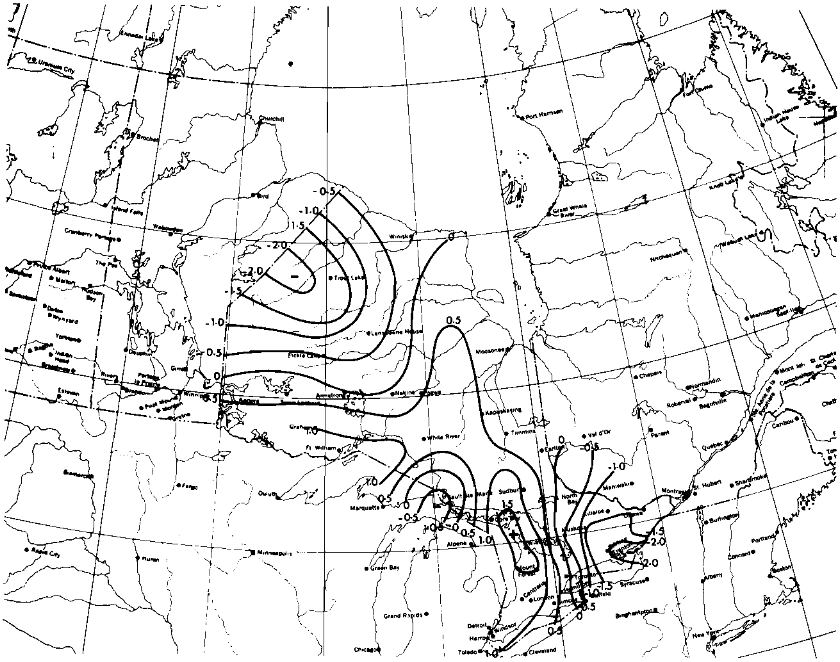

Fig. 6 (Normal-actual) precipitation – April 1973

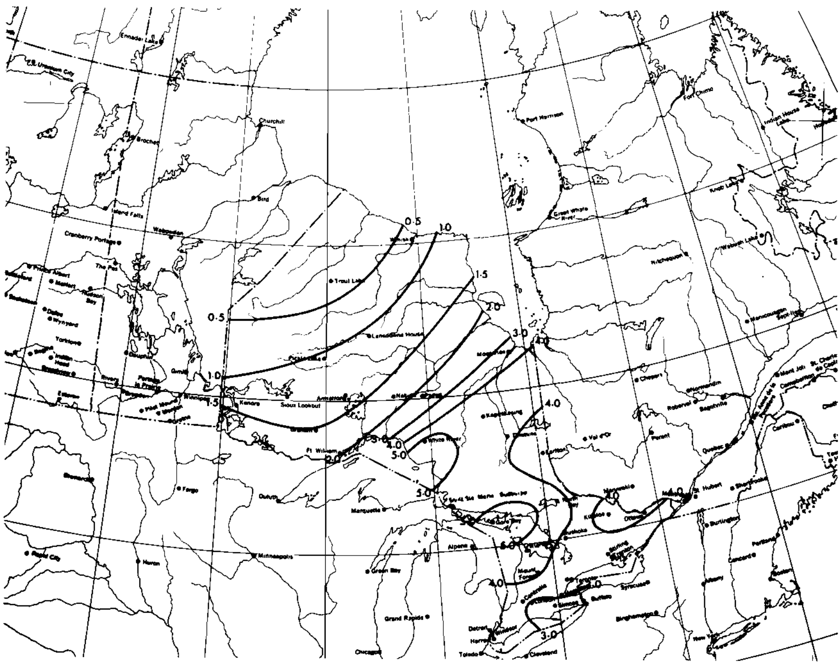

Fig. 7 Actual precipitation – May 1973.

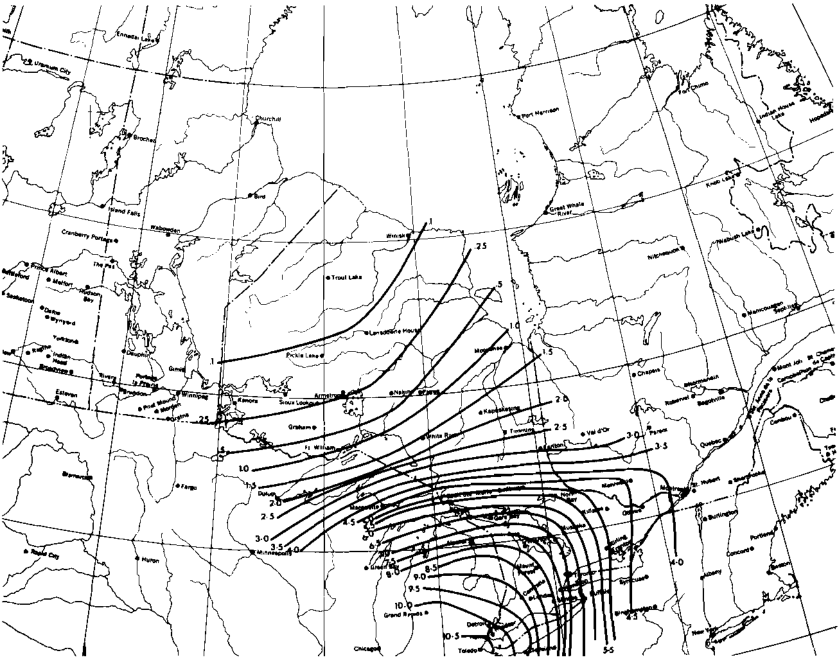

Fig. 8 Computer forecast precipitation – May 1973.

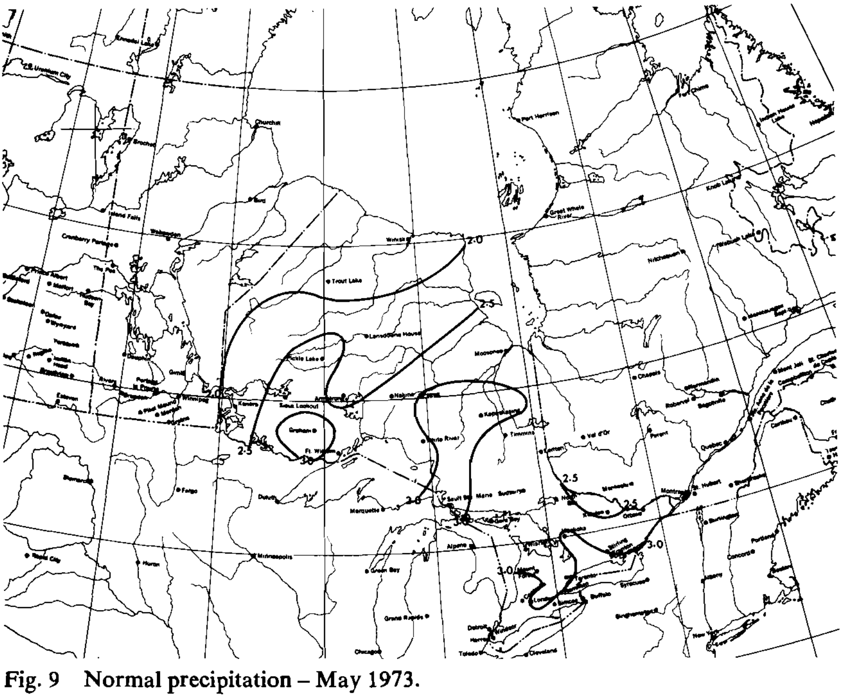

Fig. 9 Normal precipitation – May 1973.

TABLE 1. Monthly volumes of precipitation for Ontario (inches × miles² × 10³).

Month	Area	Actual	Computer	Normal
April	North	418	410 (− 1.9)[1]	362 (−13.4)
	South	404	456 (+12.9)	433 (+ 7.2)
	Total	822	866 (+ 5.1)	795 (− 3.3)
May	North	291	83 (−71.5)	463 (+59.1)
	South	650	766 (+17.9)	607 (− 6.6)
	Total	941	849 (− 9.8)	1070 (+13.7)

[1]Percentage difference from the actual volume.

A comparison was also made between the actual volumes of water which accumulated and those which would have accumulated with the computer-predicted rainfalls and also with the normal rainfalls. To evaluate the volumes, the precipitation patterns were copied onto equal area projections and a cut-and-weigh technique was used. The results are presented in Table I. The North area and the South area are those areas of Ontario divided by a line from Sault Ste Marie to Winisk.

4 Conclusions and recommendations

The method can only be as accurate as the precipitation forecasts; if in certain regions the QPF enjoys high success, so will this method of calculating areal precipitation. On the basis of this limited testing, all one can say is that gross errors over large areas can occur when the monthly areal precipitation is calculated using CMC's 24-hour QPF. Therefore, applying the technique to sparse data areas as a substitute for installing a climatological network does not appear to be feasible. The technique would likely show increased accuracy if 12-hour rather than 24-hour forecasts were used to calculate monthly totals. However, the extent of the improvement cannot be estimated.

The subjective method of estimating the 0.1 inch isohyet and the subjective nature of graphical addition are probable sources of error in this study. To properly evaluate the method, the study should be repeated using the grid points and grid-point values from the original program. This is extremely important since the computer forecasts are most accurate for amounts ranging from 0.01 inches to 0.25 inches (Davies, 1974).

The comparison between the grid-point computed data and actual precipitation observation should also be made on a day-to-day, yes/no basis as an ongoing verification program. The preparation of these data would provide an objective and operationally realistic method of evaluating the CMC/QPF model and would complement existing daily verification programs.

Summaries of daily information as well as weekly, monthly and seasonal comparisons of totals should be collated for regions and for individual areas of responsibility within regions. Distribution of such comparisons would allow operational meteorologists to verify the model within their own areas of responsibility; following which, subjective improvements and quality control within the region could be implemented.

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NOTICE OF FEES INCREASE

The following fees for 1975 were approved at the Eighth Annual General Meeting:

Member	\$20.00
Student Member	\$ 5.00
Sustaining Member	\$60.00 (min.)
Institutional Subscription	\$15.00

Diffusion of Vehicle Exhaust Fumes

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[Manuscript received 30 November 1973; in revised form 13 February 1974]

ABSTRACT

Diffusion of motor vehicle exhaust fumes is a function of not only the type of fuel and vehicle age but also of the vehicle movement, atmospheric wind, turbulence and thermal stability.

Two methods are used to examine these effects on the diffusion of the exhaust fumes: direct probing by means of road tests using a full-scale system and wind tunnel tests using a model.

Field tests have been conducted at the Meteorological Field Station at Woodbridge. The tests include a common stationwagon. A meteorological instrumented tower was used at the test site. Attention was given to the flow of the exhaust fumes by observing and photographically recording their entrainment and modification by the ground, wind speed and thermal stability.

Motor vehicle aerodynamics were studied in a specially designed wind tunnel. Streamlines passing over the roof of the vehicle swept down to the ground level and then divided to form a series of vortices. These in turn helped to elevate the exhaust fumes to a height which depends on the vehicle size.

1 Introduction

With the large increase in the number of vehicles one expects that the fuel consumption will have the same trend. About 21×10^6 gallons of gasoline and 1.4×10^6 gallons of diesel oil were consumed in 1970–1971 in Canada. Table 1 presents a breakdown of pollutants in percentage contributed by motor vehicles to the total pollutants, by weight, over metropolitan Toronto. Carbon dioxide and water vapour, which are also produced by combustion in gasoline and diesel engines are not considered as pollutants at the present time. However, it is believed that the increase of carbon dioxide and water vapour may have an effect on climate.

In general the diffusion of pollutants from a motor vehicle depends on the following factors:

(a) number of vehicles used, their type and age,
(b) geometry and configuration of highways and streets,
(c) emission rate and its dependence on the vehicle speed,
(d) aerodynamics of the vehicle and its spacing on the road,
(e) atmospheric variables, such as wind speed, wind direction and atmospheric thermal stability.

TABLE 1. Percentage of pollutants contributed by motor vehicles to total pollutants over metropolitan Toronto for the period 1969–1970.

Pollutants	Millions of kgm	Percentage of total
Carbon Monoxide	387.7	97.8%
Hydrocarbons	58.7	68.7%
Oxides of Nitrogen	20.2	18.56%
Oxides of Sulphur	1.6	0.56%
Particulates	2.2	6.2%

TABLE 2. Constituents of exhaust gas under different operating conditions for both gasoline and diesel engines.

Gasoline Engine

Constituent	Idling	Accelerating	Cruising	Decelerating
Carbon monoxide (per cent)	3.0–13.0	2.0–5.0	0.5–5.0	2.5–6.0
Hydrocrabons (per cent)	0.1–1.0	0.04–0.20	0.02–0.30	0.5–2.6
Oxides of nitrogen (p.p.m.)	15–45	600–2000	300–1000	12–30

Diesel Engine

Constituent	Idling	Accelerating	Cruising	Decelerating
Carbon monoxide (per cent)	0–0.1	0.1–0.3	0–0.1	0–0.1
Hydrocarbons (per cent)	0.01–0.06	0.018–0.025	0–0.15	0–0.06
Oxides of nitrogen (p.p.m.)	50–70	800–900	150–320	10–50

The first two factors have been discussed previously by many authors: see e.g. Chen and March (1970), May *et al.* (1970), Egan and Mahoney (1972) and Jefferies (1972). The remaining factors will be discussed here.

2 Emission rate

Every part of a motor vehicle acts as a source of air pollution. The main pollutants from a motor vehicle, whether it has a diesel or a gasoline engine, are carbon monoxide, hydrocarbons, oxides of nitrogen, sulphur dioxide, lead compounds, solid particles, heat and noise.

There are more than 200 additional compounds which originate from various types of additive in the fuel and the engine oil.

The composition of the exhaust gas for both gasoline and diesel engines depends to a great extent on the way the vehicle is driven, as is demonstrated in Table 2 (see e.g. Fitton, 1957).

It will be noted that the carbon monoxide for a gasoline engine is at a maximum when idling and minimum when the vehicle is cruising, while for a diesel engine carbon monoxide is at a maximum when accelerating and minimum when idling. This is due to the fact that during acceleration the air/fuel ratio in the diesel engine is least.

Hydrocarbon emissions from gasoline engiens are at a maximum when the vehicle is decelerating and minimum when the vehicle is cruising. For a diesel engine the hydrocarbons are highest when the vehicle is idling. The operating

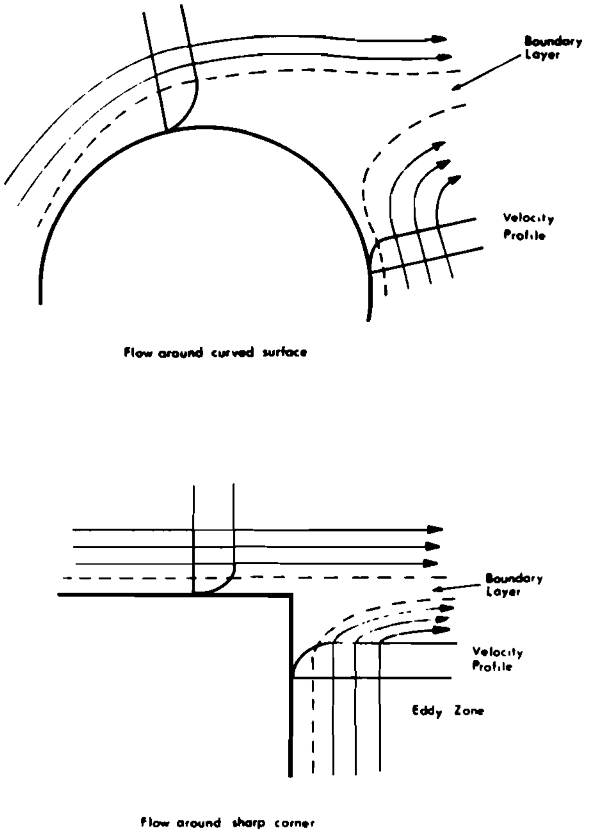

Fig. 1 Separation of boundary layers from a curved surface and a sharp corner.

conditions for maximum emission of oxides of nitrogen occur for both engines when the vehicle is accelerating.

In a city, a typical pattern of driving may be composed of four modes; namely idling, accelerating, cruising and decelerating, each with a different duration rate. In a typical city the duration rate of each mode may lie between 8 to 48% on idle, 15 to 40% on acceleration, 0 to 63% on cruise and 11 to 46% deceleration. This in turn depends on the width of the road, the density of the traffic and the distance between traffic signals.

3 Car aerodynamics

The diffusion of motor vehicle exhaust fumes is a function of the flow pattern around the vehicle. A motor vehicle is a bluff body; that is, during its motion a separation of the boundary layer occurs at the surface. The separation in turn forms a wide turbulent wake. Boundary layer separation occurs when the downstream side of the body is either cut off bluntly, or has a sharp edge (Fig. 1).

Since a motor vehicle body is made up of many curved and sharp edges one expects that the vehicle's wake is more complex than that of either a cylinder

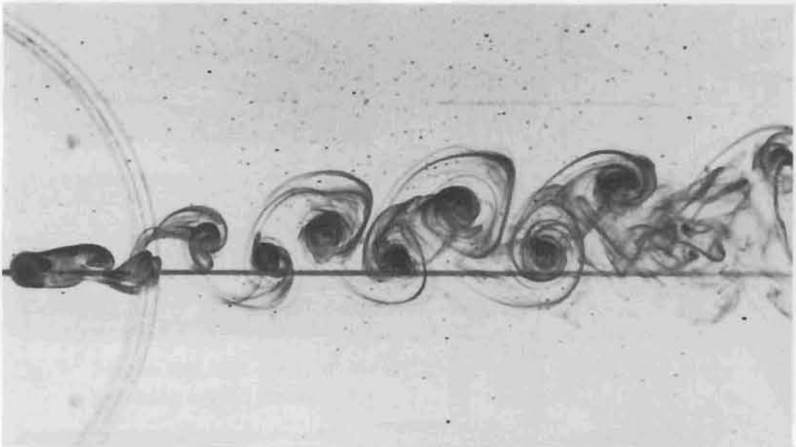

Fig. 2 Wake structure of a cylinder in two-dimensional flow.

or a cube. If a cylinder is exposed to a two dimensional flow regularly alternating vortices will form in the cylinder wake (Fig. 2). On the other hand, for a cube the wake is more complicated and highly turbulent. In this case the wake size and its turbulent intensity depend on the flow direction (Fig. 3). Using a wind tunnel, Carr (1969) examined the aerodynamics of a motor vehicle. He found that the drag force of the vehicle model increased progressively during the transition from a rectangular body shape to a fully detailed car model.

One also should mention that the aerodynamics of an automobile differ from that of the well-known airfoil. In the case of a motor vehicle the flow of air is around a body which is close to the ground. Due to the proximity of the vehicle to the ground, the local air speed between the body and the ground will increase, and this in turn develops a negative lift (see e.g. Mason and Savran, 1973).

Also the flow occurs not only on the upper and lower surfaces of the vehicle but also along both sides. Bumpers, door handles, antenna and windshield wipers further influence the flow patterns.

To examine the flow patterns around a motor vehicle, wind tunnel studies were carried out in the Atmospheric Environment Service environmental wind tunnel (Fig. 4) using models of a passenger car and a station wagon. The tunnel speed was maintained at 20.1 meters per sec. (45 mph). The flow patterns were made visible in two ways; using tufts made out of silk and attached smoothly to the surface of both vehicles and using smoke from burnt oil. In some cases two vehicles were used to examine the effect of spacing on the behaviour of the wake. Figure 5 is an example of some of the experimental observations. In conjuction with these results, photographs of the flow pattern around a station wagon (Fig. 6) obtained by the use of the National Research Council water tunnel (see e.g. Dobrodzicki, 1972) were also used. The streamlines are seen to pass over the roof of the vehicle and sweep down toward the ground level (Fig. 7). Other streamlines pass under the vehicle. In the case of the passenger

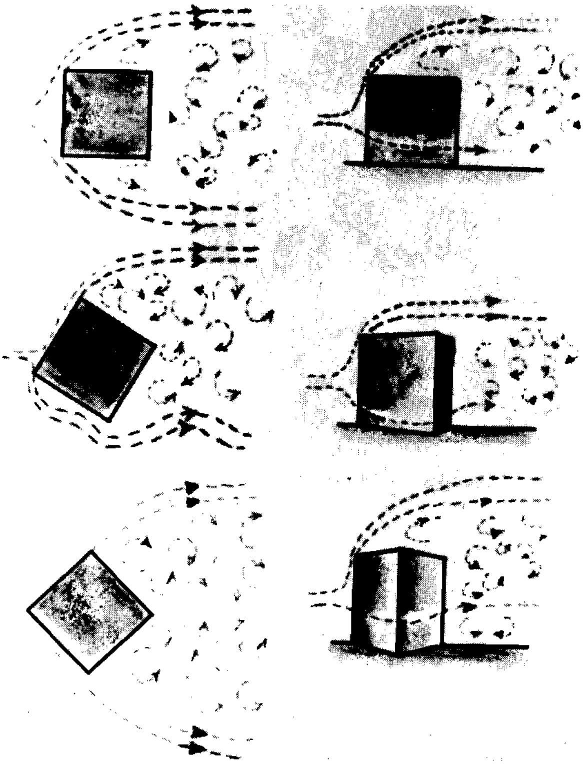

Fig. 3 Wake structure of a cube in a two-dimensional flow.

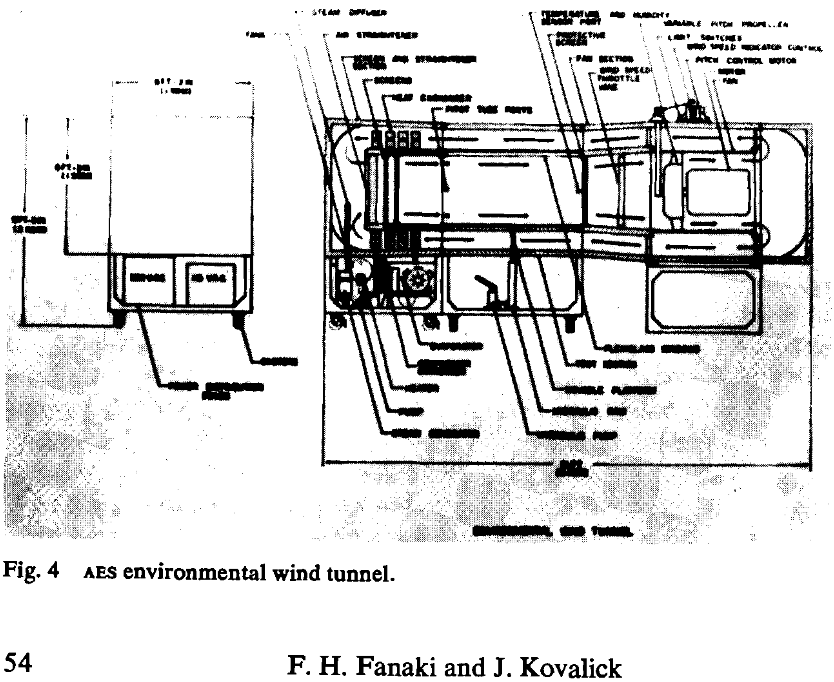

Fig. 4 AES environmental wind tunnel.

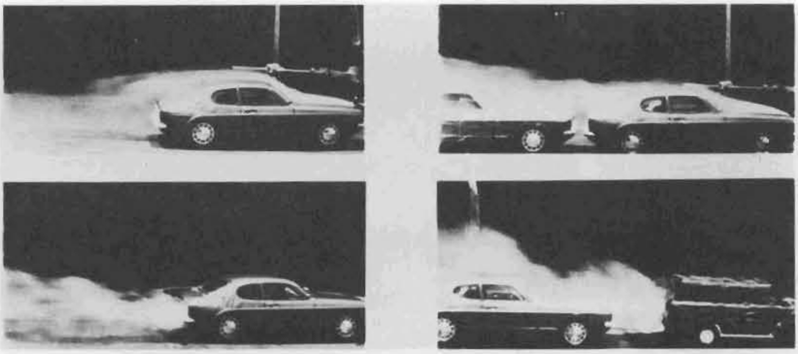

Fig. 5 **Smoke and tuft visualization of flow patterns around and in the wake of a model car using a wind tunnel.**

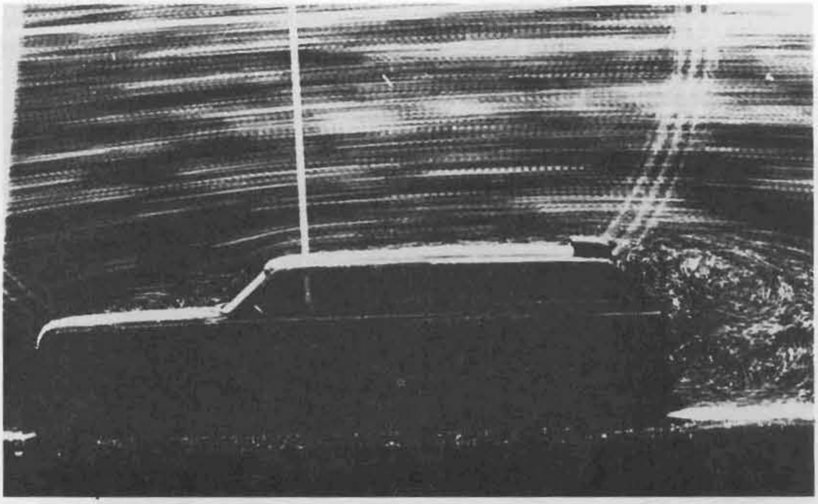

Fig. 6 **Flow patterns around a model of a station wagon.**

car the sweeping streamlines meet to form a series of vortices. In the case of a station wagon, two circulating cells are formed behind the vehicle before the trailing vortices are formed. The cells' dimensions depend on the vehicle width and height. When two similar vehicles are placed one behind the other, the diameter of the wake of the latter car increases slightly. However, if the station wagon is shielding the passenger car, the wake diameter increases to 1.5 times its original value. There is a limit to the distance between the vehicles within which a noticeable shielding effect may occur. For two station wagons this distance is nearly equal to 7h where h is the vehicle height.

4 Atmospheric variables: field study

Expulsion of the exhaust fumes from a full scale vehicle moving at 8.9 m/sec (20 mph) was examined. Since the vehicle exhaust is usually invisible, the vehicle was fitted near the tail pipe with a smoke generator having an emission

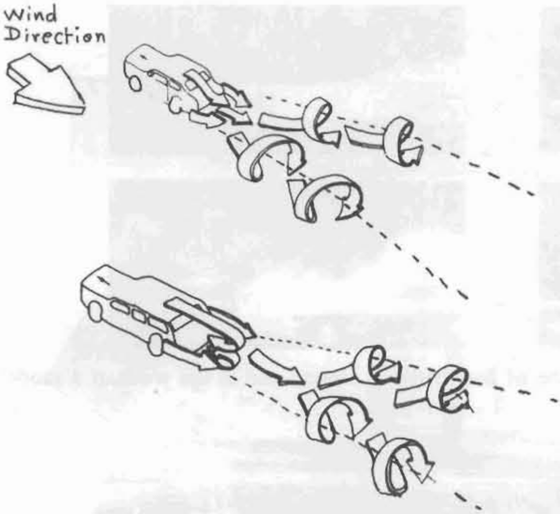

Fig. 7 Detail of flow patterns in the wake of a car.

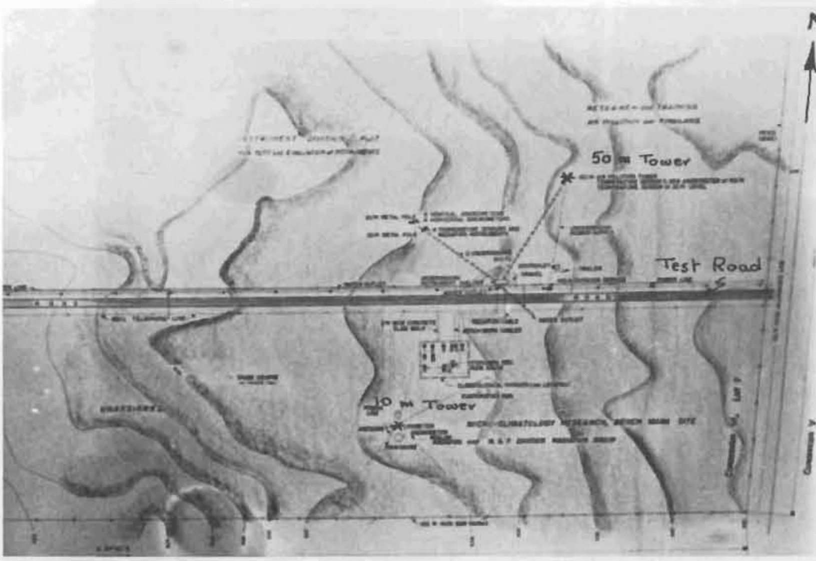

Fig. 8 Meteorological Field Station at Woodbridge, Ontario.

rate and temperature similar to that of the vehicle (i.e. exit velocity = 13.7 m/sec; exhaust gas temperature = 227 C).

The field tests were made at the Meteorological Field Station at Woodbridge, Ontario, over a flat surface. The site has a straight unpaved road running from east to west (Fig. 8). The location of nearby meterological towers is indicated in the figure. Two time-lapse 35 mm cameras were used to photograph the smoke plume. One camera was located along the road side with its optical axis parallel to the road and the second was located a few hundred feet away from

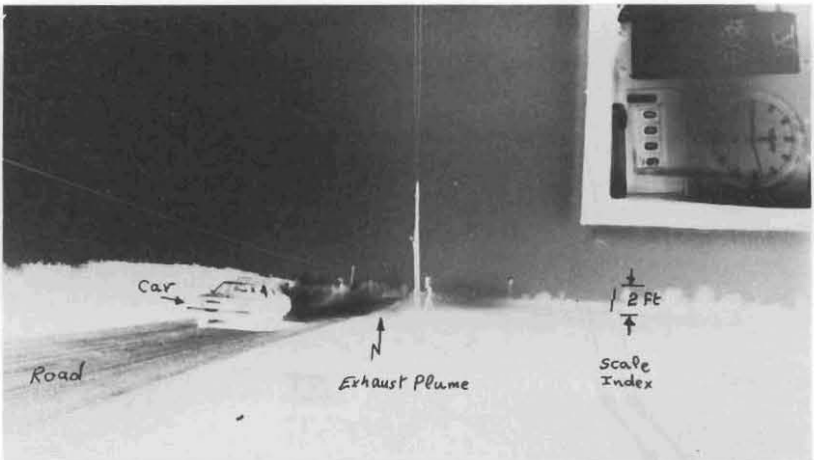

Fig. 9 Photographs of the exhaust plume.

the road and facing it. Two scale indices (each 0.61 m long) were positioned at the front of each camera at a known distance. With the smoke generator operating, the driver drove the vehicle through the test area with a constant speed of 8.9 m sec^{-1} (20 mph).

The cameras took 4 frames every second. Twenty-seven runs were conducted on three different days in April 1973. Figure 9 shows a sample of the photographs of the exhaust plume. It is noted that the smoke has a distinct boundary and can be seen from a distance of at least 500 m.

Wind speeds were obtained from four levels on the 10 meter tower; 0.36, 0.79, 1.6 and 6.4 m above the ground. Temperature measurements were made at 0.15, 0.36, 0.79, 1.6, 3.7 and 6.4 m above the ground, and at the ground surface. Several profiles are shown in Figures 10 and 11.

From examination of the vehicle plume, we are led to divide the plume into three regions (Fig. 12).

Region I is a region similar to the wake downwash region often observed on the lee-side of a building. Because the air flows along both the upper and lower surfaces of the vehicle, the effluent from the exhaust is lifted and may enter the vehicle through the back window.

In region II the wake becomes oscillatory and the two trailing vortices are greatly affected by ground friction and wind speed and direction. The trailing vortices dissipate rapidly as the wind speed increases. These vortices have low pressure cores and the effluent from the exhaust is drawn into them. Immediately after the generation of the trailing vortices the lateral separation of the vortex pair is equal to the vehicle width. After a few seconds of travel, however, the two vortices combine and their separation cannot be distinguished. (Region II acts as a transition region between region I and III.) Both regions I and II are highly turbulent and mixing of the exhaust fumes is vigorous.

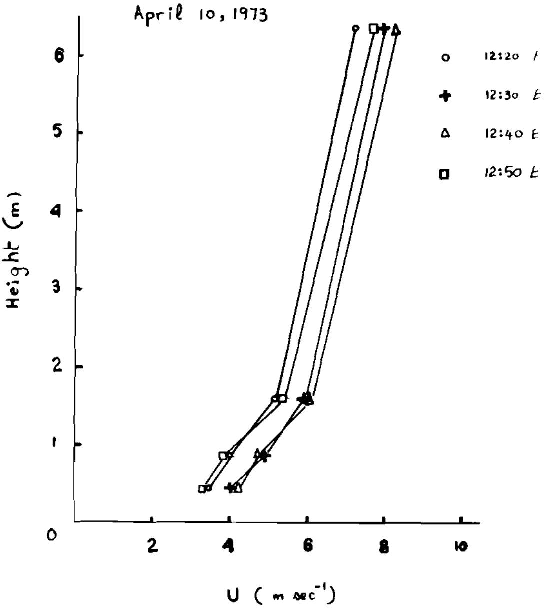

Fig. 10 Wind profiles.

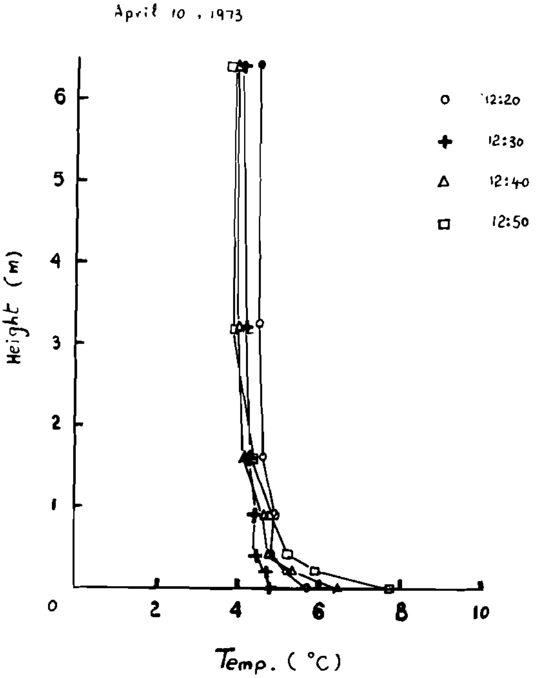

Fig. 11 Temperature profiles.

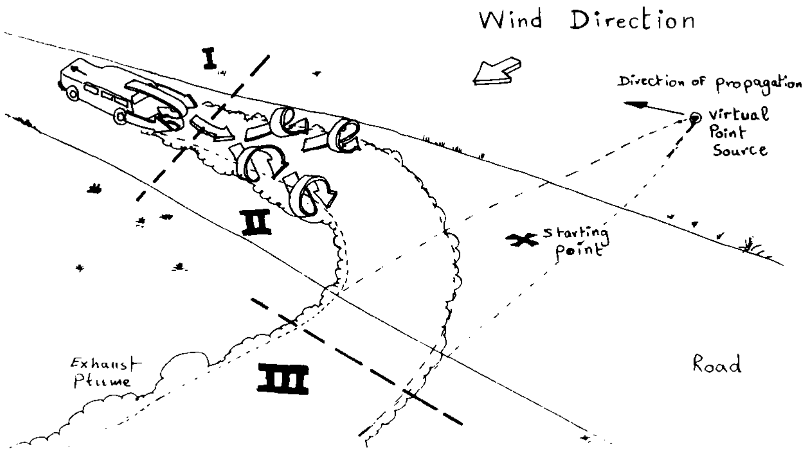

Fig. 12 Details of the exhaust plume under the effect of wind.

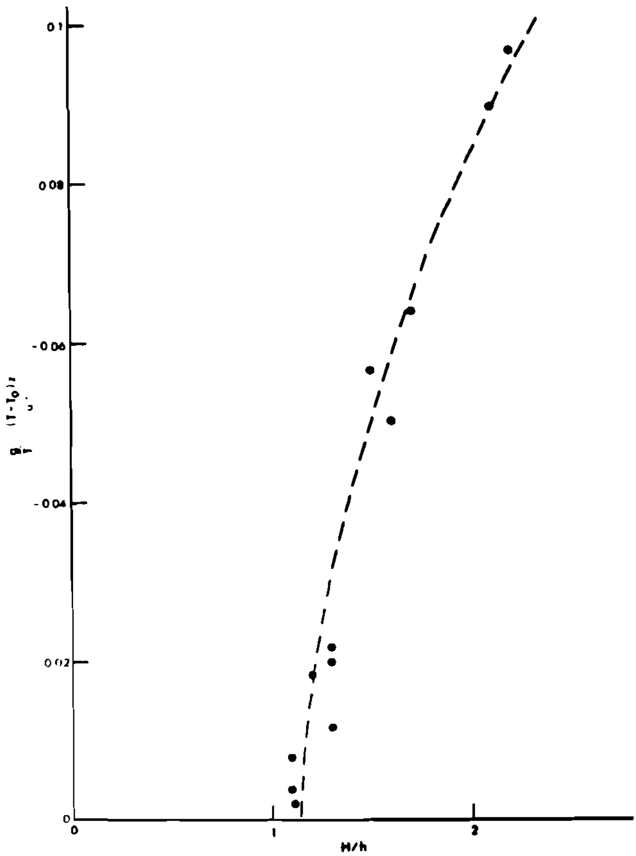

Fig. 13 Effect of instability on the exhaust plume height 50 meters downwind from the road.

Region III is free of the car influence and resembles a smoke plume from a ground source located at some distance from the road. The shape of the exhaust plume in this region depends on the atmospheric stability (Fig. 13). It is seen that the non-dimensional plume height H/h at 50 meters downwind from the road increases with increasing instability. The stability parameter used here is defined as

$$\frac{g(T-T_o)Z}{TU^2}$$

where

g = acceleration due to gravity (m sec^{-2})
$\bar{T}$ = average temperature (K)
T = temperature at height Z (K)
T_o = surface temperature (K)
$\bar{U}$ = average wind speed at Z (m sec^{-1})
Z = height above ground (m)
h = height of vehicle

Because the vehicle is moving, the virtual point source will move in the same direction producing a line source for region III. Providing one is 50 meters or more from the road the turbulence created by the motor vehicle can be neglected and one can then apply the usual continuous line source models to region III.

5 Conclusions

Emission from a motor vehicle depends on the pattern by which it is driven. In a city the pattern of driving is complicated by the geometry of the road, density of the traffic and the distance between traffic signals. One then expects models of motor pollution that are based on average route speed do not represent a realistic situation especially at intersections and expressway ramps.

If the distance between two vehicles moving in the same direction is less than 7h, where h is the height of the shielding car, one expects exhaust fumes from both cars to diffuse to higher levels than if the distance is larger than 7h.

The diffusion of the vehicle exhaust fumes occurs in three regions where three mechanisms act simultaneously:

(a) entrainment by eddies in the downwash wake region,
(b) mixing by the trailing vortices,
(c) additional mixing by the turbulence present in the ambient air.

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CALL FOR PAPERS – NINTH ANNUAL CONGRESS

The Ninth Annual Congress and Annual General Meeting of the Canadian Meteorological Society will be held at the University of British Columbia, Vancouver, B.C. at the end of May 1975, the exact date to be announced in due course. The theme of the Congress will be *The Role of the Pacific in the Climate of North America.* Papers on this or any other topic in meteorology are invited.

Titles and definitive abstracts (less than 300 words) should reach the Program Chairman Dr. T. Oke, Department of Geography, University of British Columbia, Vancouver, B.C. no later than *1 February, 1975.*

CALL FOR NOMINATIONS – 1974 AWARDS

Nominations are requested from members and Centres for the 1974 Society Awards to be presented at the 1975 Annual meeting. Three 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; and 3) the Graduate Student Prize for a contribution of special merit by a graduate student. The awards will be made on the basis of contributions during the 1974 calendar year. Nominations should reach the Corresponding Secretary not later than March 1, 1975.

Nominations are also requested from members and Centres for the award of citations to individuals or groups in Canada, who have made some outstanding contribution in helping to alleviate pollution problems or in developing environmental ethics. Nominations should reach the corresponding secretary not later than March 1, 1975.

A Preliminary Investigation of Winter Air Pollution Potential At Fort Simpson, Northwest Territories

D. Yap

Atmospheric Environment Service, Downsview, Ontario

[Manuscript received 17 June 1974]

ABSTRACT

Based on radio-sonde data collected during nine consecutive days in February 1974, an examination was made of the daytime variation of the winter mixing depth and air pollution potential in the Fort Simpson area of the Mackenzie Valley. Under anticyclonic weather conditions, mixing depths were generally low (< 100 m) or non-existent. The generation of a mixed layer was found to be primarily associated with extensive low- to mid-level cloud cover and precipitation. During this period of investigation, ventilation coefficients were extremely low. This suggests that the area has a great risk of high pollution potential in winter.

1 Introduction

Knowledge of the potential air quality problems at high latitudes is of great importance for the maintenance of effective environmental control on the development of the Canadian North. This requires, among other things, an understanding of the temperature and airflow characteristics in the lowest air layers of such an environment as these factors affect the transport and diffusion of air pollutants and hence the air pollution potential. In this regard, the investigation of Munn *et al.* (1970) is particularly informative. Their study suggests that the winter situation in the Canadian Arctic is of most serious concern because of the great risk of high pollution potential when radiation inversions persist for relatively long periods. One of the questions raised in that study relates to the region of the Mackenzie Valley. Here, no direct indication was available concerning whether inversions break up during the day in winter under conditions of prolonged cold, clear skies and light winds.

Partly in response to this sufficiently important question, an investigation was undertaken at Fort Simpson, Northwest Territories (located in the Mackenzie Valley) (See Fig. 1) in February 1974. During nine consecutive days (February 12–20) which included a spell of cold, anticyclonic weather conditions, a series of 35 low-level temperature and wind profiles were obtained from radio-sonde ascents for the period between early morning and late afternoon. An analysis of these data is given in this present paper. This provides some insight into the diurnal behaviour of the Arctic inversion and in addition, the wintertime pollution potential of the area.

2 Method of analysis

For purposes of analysis, the quantitative method to assess the air pollution

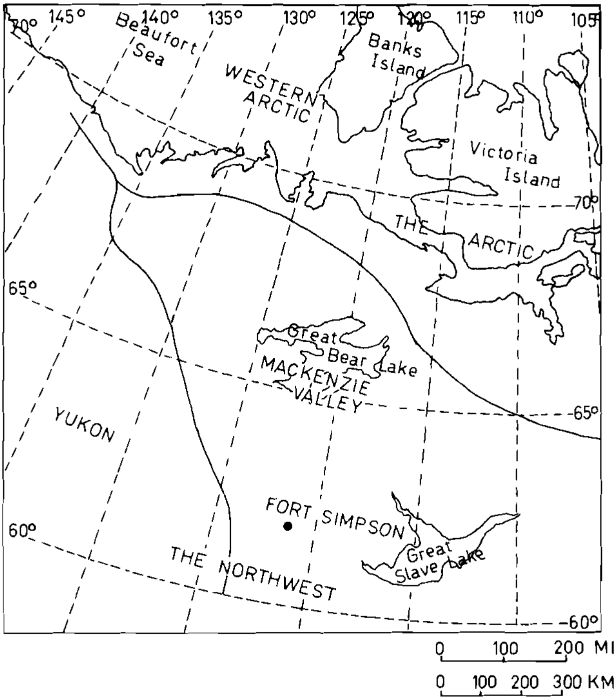

Fig. 1 Map of the Mackenzie Valley region.

potential of an area given in Holzworth (1967) is utilized. The basic parameters considered are:

(1) the height above the surface within which pollutants are mixed vigorously and significant turbulence occurs i.e. the mixing depth or mixing height.
(2) the average wind speed through this mixed layer.

On the assumption that mixing takes place at the dry adiabatic lapse rate, the mixing depth can be estimated from the intersection of the observed vertical temperature profile and an adiabatic profile that passes through the surface temperature.

3 Daytime variation in the mixing depth

Using the procedure outlined in section 2, mixing depths for the 35 vertical temperature soundings were estimated. The time sequence of these mixing depths during the daytime at Fort Simpson for the period February 12–20 is illustrated in Fig. 2. In addition, the total hours of sunshine each day are indicated. Some of the salient features are:

(1) largest mixing depths occurred only on days with little or no sunshine.
(2) on days with relatively high sunshine amounts, mixing was restricted to the lowest 100 m and was often non-existent during the daytime.
(3) extremely limited mixing can persist for long periods.

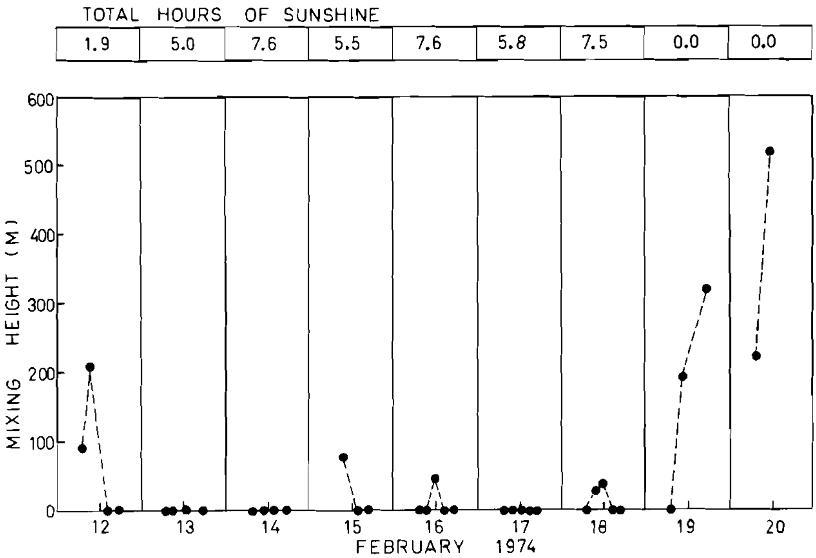

Fig. 2 Time sequence of daytime mixing depths at Fort Simpson, Northwest Territories.

a *The Effects of Cloud Cover, Precipitation and Wind-Induced Mixing*

The fact that appreciable mixing heights occurred on days with low sunshine totals strongly suggests the possible influence of cloud cover. Burns (1973) indicates that near the surface, the Arctic inversion may be weakened or temporarily destroyed by downward long-wave radiation emanating from cloud cover of sufficient thickness or by downward heat flux during wind-induced turbulent mixing. Through these processes, instability can develop near the surface which would then result in the establishment of a mixed layer. An examination of the prevailing synoptic weather conditions (based on data from Fort Simpson Airport) shows that estimated mixing depths in excess of 100 m occurred consistently under extensive low- to mid-level cloudiness (9/10 to 10/10 sky cover; cloud base less than 3000 m above ground). In addition to extensive cloud cover, incidences of mixing heights greater than 100 m were sometimes accompanied by precipitation and moderate surface wind speeds (Table 1). In view of the dry adiabatic mixing assumption, the method applied to estimate the mixing depth is not strictly valid for those cases in which precipitation occurred. However, estimates derived in this manner should at least indicate the minimum depth of the mixed layer under precipitation conditions (mixing height estimates are always greater for saturated than for dry adiabatic mixing, but at very low temperatures the differences become practically negligible).

In an attempt to isolate the relative importance of cloud cover, precipitation, and wind-induced mixing on mixing depths, the stability of the air layers close to the ground was examined as a function of surface wind speed for different sky cover conditions. These are shown in Figs. 3 and 4. If the influence of cloud amounts less than 5/10 can be neglected, then Fig. 3 illustrates primarily the

TABLE 1. Synoptic weather conditions associated with mixing depths in excess of 100 m.

Date	Time (MST)	Mixing depth (m)	Sky cover	Low-to Mid-level cloud bases (m) and amounts	Precipitation	Surface Wind Speed (m sec^{-1})
1974						
Feb. 12	0900	210[1]	10/10	1000 (10/10)	light snow	4.0
19	1025	190[1]	9/10	1800 (7/10); 2500 (2/10)	very light snow	2.7
19	1730	320[1]	10/10	900 (10/10)	very light snow	6.7
20	0715	220	9/10	2400 (9/10)	nil	3.6
20	1113	520	10/10	2800 (9/10)	nil	4.0

[1]dry adiabatic mixing assumed.

effects of wind speed and thermal convection. Except for one case, the results show that the air is stable or potentially stable (zero mixing depth) for all wind speeds. In general, inversions prevail for surface wind speeds less than 3.5 m sec^{-1}. At higher wind speeds the inversions are destroyed (suggesting wind-induced mixing), but the air remains potentially stable. It is therefore inferred from these few cases that wind-induced mixing tends to destroy the Arctic inversion but is not sufficient to generate a finite mixed layer. Potentially stable or unstable conditions predominate in the air near the ground under extensive cloud cover (see Fig. 4). Inversions seldom occur. The importance of cloud cover and precipitation in the generation of a mixed layer are indicated on Fig. 4.

b *The Effects of Thermal Convection*

Fig. 3 also illustrates the effect of thermal convection. Under relatively sunny skies, daytime heating of the lowest air layers near the ground through thermal convection appears to be negligible in most cases as the air is stable or potentially stable. Instability occurred only once under light wind conditions. This gave a mixing depth of only 50 m. These results suggest that extremely limited mixing or zero mixing is probably common during the day in winter under conditions of prolonged cold, clear skies and light winds in the Fort Simpson area. Hence, the risk of high pollution potential is suggested.

4. Ventilation coefficient

An estimate of the meteorological contribution to air pollution potential in the Fort Simpson area can be deduced from the resultant ventilation coefficient, obtained from the product of the mixing height and the mean wind speed in the mixing layer. Values for the 35 cases are shown in Table 2. As a rough guide, an afternoon value of less than 6000 m^2 sec^{-1} is sometimes used as an indicator of high pollution potential (McBoyle, 1973). Daytime estimates of the ventilation coefficients in this region of the Mackenzie Valley are extremely low and thus indicate high pollution potential. It appears that such conditions can persist for relatively long periods in winter.

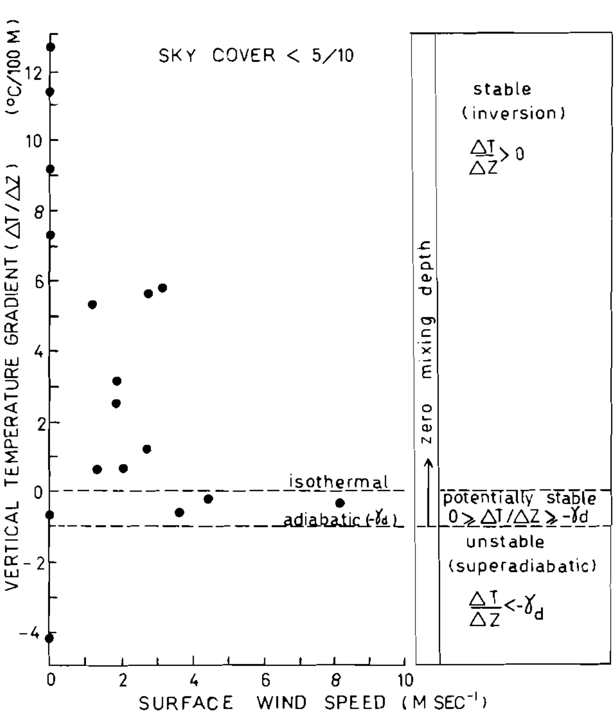

Fig. 3 Vertical temperature gradient in the lowest air layers versus surface wind speed for sky cover $<5/10$.

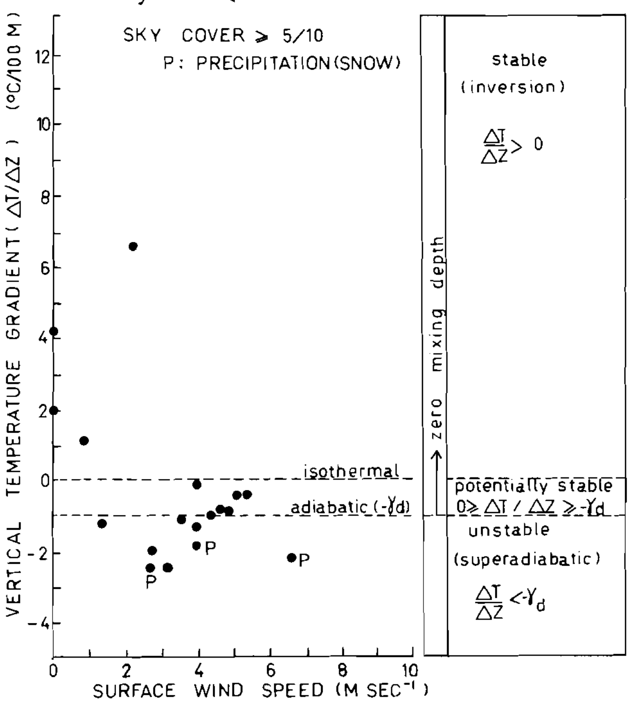

Fig. 4 Vertical temperature gradient in the lowest air layers versus surface wind speed for sky cover $\geq 5/10$.

TABLE 2. Daytime winter ventilation coefficients at Fort Simpson.

Date	Time (MST)	Ventilation Coefficient ($m^2\ sec^{-1}$)	Date	Time (MST)	Ventilation Coefficient ($m^2\ sec^{-1}$)
Feb. 12, 1974	0715	396	Feb. 17, 1974	0705	0
	0900	840		1002	0
	1400	0		1220	0
	1730	0		1448	0
				1640	0
Feb. 13, 1974	0715	0			
	0850	0	Feb. 18, 1974	0656	0
	1300	0		0923	93
	1730	0		1115	108
				1420	0
Feb. 14, 1974	0725	0		1626	0
	1055	0			
	1318	0	Feb. 19, 1974	0705	0
	1700	0		1025	513
				1730	2144
Feb. 15, 1974	0930	104			
	1330	0	Feb. 20, 1974	0715	792
	1644	0		1113	2080
Feb. 16, 1974	0712	0			
	0925	0			
	1130	0			
	1420	0			
	1700	0			

5 Conclusion

From this preliminary study, it is inferred that daytime winter mixing depths in the Fort Simpson area of the Mackenzie Valley are generally low or non-existent under anticyclonic weather conditions, and can persist for several days. The generation of a mixed layer in this region is often associated with extensive low- to mid-level cloud cover, enhanced occasionally by wind-induced mixing and precipitation. Wind-induced turbulence (assumed for surface wind speeds equal to or greater than 3.5 m sec^{-1}) destroys the Arctic inversion, but it appears to be insufficient to create a mixed layer as the air near the ground remains potentially stable. In general, the effects of thermal convection in creating instability at the surface are very small and often negligible. The generally low mixing depths are frequently coupled with light winds through the mixed layer. Accordingly, winter ventilation coefficients are extremely low on most days and there is a great risk of high pollution potential.

Acknowledgment

The author wishes to thank Dr. R.E. Munn for his suggestions and review of the manuscript. Particular thanks are due to Mr. J. Kovalick for the collection and reduction of the field data and to Mr. R. Berry for his comments.

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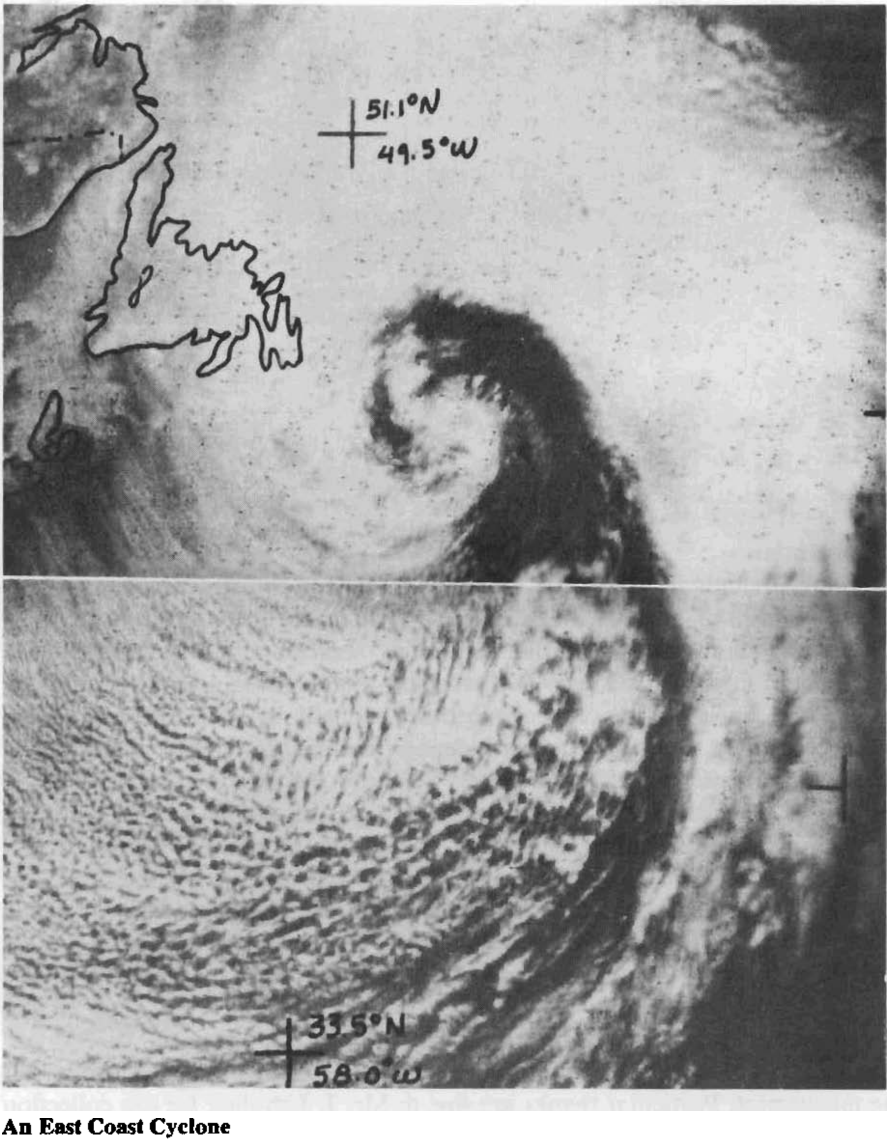

An East Coast Cyclone

ESSA 8 APT photograph 1425 GMT March 11, 1974. St. John's, Newfoundland, reported two feet of snow in 24 hours. Cyclone continued to deepen to 938 millibars. Winds in excess of 80 knots reported on the island.

W. D. Lawrynuik

COMMENT ON "TETROON STUDIES IN THE CROWSNEST PASS AREA"

D. Skibin

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Ben-Gurion University of the Negev, Beer-Sheva, Israel

Tetroon flights were tracked in the rough topographical environment of the Crowsnest pass area (Leahey and Hicklin, 1973). Interesting results were presented and discussed in this study. A dependence of the vertical velocity on the horizontal wind direction has been noted but remained unexplained. We wish to suggest a model for possible explanation of this phenomenon and others.

Clearly one can group the tetroon flights into three groups. Trial 1, in which the flow was westerly (see Fig. 2 in Leahey and Hicklin, 1973); trials 2 and 3 with a WSW flow and trial 4 with a WNW flow. (There seems to be disagreement between the wind station measurements and tetroon trajectory directions. It may be that the wind vane readings were consistently backed by $2\pi/16$ due to instrumental error.) Since the valley axis is in the west-east direction, it seems reasonable that trial 1 would be the least affected by topography; indeed, the ground surface profile under this trajectory is relatively level. Therefore, a comparison between the trajectories of trials 2-4 and that of trial 1 would reveal the effect of topography and eliminate some of the other effects.

Let us consider first trial 1. There seem to be two distinct portions of this flight. From the release point to about 600 m downwind the tetroon had nearly constant upward motion with an elevation angle of about 17 degrees. From this point on, the upward motion was five times less, at an elevation angle of about 3.5 degrees. Measurements (Table 1, *loc. cit.*) indicate very strong thermal instability (lapse rate of 2-3 C/100 m between 4 and 30 m above the ground. Such great instability is usually accompanied by strong convective upward motion, which may explain the fast lifting of the tetroon up to heights which are more than twice the theoretically computed ones. It has been mentioned (*loc. cit.*) that the sky was partially (and occasionally fully) covered with clouds. Since it was mid-September, at not too low a latitude, such a strong superadiabatic lapse extending up to 30 m above the ground would be unlikely unless the clouds were thin and high. At any rate, a significant amount of incoming solar radiation should have been present in order to produce strong instability. Even though the tetroons were made of mylar, strong heating of them may have occurred and, with the aid of the convective currents below, may have caused further uplift of the tetroon.

Let us neglect the difference in the hour of the day in which the different flights were conducted and compare the other trials to the "uninterrupted" or "reference" trajectory of trial 1. It seems justified to do so, since there does not appear to be a significant difference between the uplifts in trials 2 and 3 (at heights above 100 m) though trial 3 was in the evening three hours after trial 2, and the low-level thermal instability was much less.

Comparison between tetroon heights in trials 2 and 3 and that of the "reference" trial 1 (Fig. 3 *loc cit.*) shows that up to about 1 km downwind from the release point the heights of tetroons 2 and 3 were lower than expected. It seems that there existed downdrafts or relative downdrafts (updrafts smaller than in the reference case). Between 1 and 5 km the tetroons showed a rate of ascent much greater than that of trial 1, which indicates relatively large updrafts.

On the other hand, in trial 4 there existed a downdraft (or relative downdraft) between 0 and 5 km from the release point.

It is evident that the air carrying tetroons 2 and 3 descended from the ridge approximately 4 km WSW of the release point. The air carrying tetroon 4 descended from the ridge more than 8 km WNW of the release point. It is well established that wind flow over mountain ridges can produce waves in their lee side. The existence of such lee waves depends on the topographical features as well as wind speed and stability. A very good graphical representation of this phenomenon and the clouds associated with it can be found in Scorer (1972). It is suggsted that such lee waves existed in the valley at the time of the experiments. In trials 2 and 3 the portion of the trajectory up to 1 km downwind distance from the release point was under the influence of the (relative) downward current in the lee side of the ridge 4 km upwind. Between 1 and 5 km the tetroon experienced the upward motion of the wave crest. In trial 4 the ridge which created the lee waves was twice as far from the release point compared to trials 2 and 3. Therefore, the tetroon was under the influence of the downdraft of the second wave, at a distance more than a full wave length (approximately 8 km) from the ridge.

A comparison was made between σ_y and σ_z derived from the tetroon flights and those of Pasquill (1961). The derived values were 1.5 to 2.5 times greater than Pasquill's. The Pasquill stability category which was taken into account was not specified, but from the discussion it seems that category D was considered. It is indeed true that at heights of a few hundred meters above the ground, especially at wind speeds over 10 m/sec, stability D seems to be the best estimate of dispersion conditions (Slade, 1968). However, it should be noted that conditions were highly unstable, at least up to 30 m above the ground, with upward convective motion above this height. Furthermore, in Pasquill's table the stability category is defined as C even at high wind speeds when the insolation is strong, which seems to be the case at the time of the experiments. Pasquill's σ_y is 1.5 times larger for stability C than D. The ratio between the appropriate values of σ_z is 2. It may be that the discrepancy that R_y and R_z are greater than unity results from the inappropriate determination of the stability category. This case emphasizes that the exact determination of Pasquill's stability category is very important (Skibin, 1972). This is since the results of using Pasquill's system (Turner, 1970) for purposes of hazards evaluation (for instance) are very sensitive to the stability determination. This point should be further stressed since Pasquill's system is well known and widely used in spite of its shortcomings.

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REPLY

Douglas Leahey & Hugh Hicklin

Western Research & Development Ltd.
Calgary, Alberta

We agree that the vertical velocities indicated by the tetroon trajectories are probably terrain induced. There seems to be no persuasive reason, however, for assuming that a lee wave phenomenon was responsible.

Dr. Skibin is correct in assuming that we used Pasquill's coefficients for a neutral atmosphere in determining values for R_y *and* R_z. This should have been more clearly indicated in our paper.

BOOK REVIEWS

COMPUTER PROCESSING OF METEOROLOGICAL DATA. S.L. Belousov, L.S. Gandin, and S.A. Mashkovich, Leningrad 1968, translated from Russian by Israel Program for Scientific Translations, Jerusalem, 1971. International Scholarly Book Services, P.O. Box 4347, Portland, Oregon. $15.00 (U.S.)

This book is divided into five chapters which deal successively with (1) Initial Computer Processing of Meteorological Data, (2) Theoretical Foundations of Objective Analysis of Meteorological Fields, (3) Objective Analysis Methods and Their Application under Operational Controls, (4) Objective Analysis for Data-Sparse Areas, and (5) Automatic Data Processing in Numerical Weather Forecasting. The scope is ambitious but the treatment is generally successful.

The first, third and last chapters suffer somewhat from an abundance of detail of questionable significance. The bit rates of data transmission or techniques of buffered storage or the timing of the analysis/forecast cycle are of rather limited interest and scant historical importance since such matters are ephemeral in nature. However, some of the data are useful (such as the description of the international teletype code) and informative (such as the contour interpolation methods) for those of us somewhat removed from the operational environment.

The second chapter is an excellent review of optimum interpolation analysis expanding on Gandin's earlier book with more empirical data available on the statistical covariance of the meteorological variables. The last section of the chapter includes a generalization of the method to allow the combination of observations of different variables to specify a particular variable, and also offers some caveats to its use.

The third and fourth chapters contain an extensive review of operational systems practiced by various meteorological sources and research contributing to developments in objective analysis techniques. Just enough discussion is presented to give the main points and whet the reader's appetite for more. This can be a little frustrating. In several instances a sentence begins "Note that ..." when in fact it cannot be noted without obtaining the original source. The utility of optimum interpolation in providing a measure, "the interpolation error" for the evaluation of analysis schemes is fully elucidated in these sections.

In the rapid evolution of data processing, this book is quite naturally somewhat dated. A major current source of data, satellite temperature profiles, did not exist at the time of publication. Consequently research and techniques in dealing with asynoptic data or four-dimensional assimilation are not included. Perhaps as a result, the role of forecast models in aiding data analysis is treated rather lightly. But these absences do not detract from a sound treatment of a broad subject, and the book should appeal to both applied and theoretical meteorologists.

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TRACE ELEMENTS IN THE ATMOSPHERE. H. Israël and G.W. Israël. Ann Arbor Science Publishers Inc., Ann Arbor, Michigan, 1974, 158 pp., $15.00.

The purpose of this monograph, according to the authors writing in the foreword, is to provide a knowledge of the life cycles of atmospheric trace gases and aerosols and thus to impart an understanding of their effects on the environment. "It is directed simultaneously to the specialist and the layman in order to give both an overall view of our present knowledge and position in this field."

This field, the physics and chemistry of atmospheric trace constituents, is one in which up-to-date text and reference books are not numerous; high-quality ones are needed. Although the present book does contain valuable material on the topics of atmospheric aerosols and atmospheric radioactivity, it does not treat adequately a number of other aspects of atmospheric trace elements.

Following a brief introductory chapter comes a disappointing chapter on atmospheric gases and trace gases. The water vapour cycle is allotted a mere one-half page and other selected gaseous trace constituents receive a similar cursory treatment. Despite the considerable activity in this area during the past ten years only three references in this chapter are more recent than Junge's book of 1963.

The next two chapters, on atmospheric aerosols and atmospheric radioactivity, respectively, provide considerably more comprehensive treatments of these topics. Chapter three includes a discussion of the physics, chemistry, meteorology and climatology of aerosols while chapter four treats radioactive decay, the formation of atmospheric radioactivity and the atmospheric radioactivity cycle. Theoretical derivations are included where necessary and good use is made of diagrams in illustrating ideas and results. The extensive research work of one of the authors (H.I.) is referenced heavily in these chapters to provide first-hand information and examples on many topics.

Chapter five, Anthropogenic Sources of Atmospheric Trace Elements (Air Pollution), is also a brief and rather disappointing treatment of sources. A discussion of the relative importance of natural and anthropogenic emissions would have been desirable. This last chapter also includes a short and not completely adequate section on meteorological aspects of local air pollution.

The overall impressions one obtains of the book are of a very non-uniform treatment of the subject material, and, at a time when there is much activity in the atmospheric sciences, of a treatment which is not up-to-date. Consequently, the authors have not adequately fulfilled their aims.

The book is a translation from the German of "Spurenstoffe in der Atmosphäre": at times the English is neither precise nor smooth-flowing. In a few places the type is unacceptably blurred – page 17 in my copy. Some diagrams have typographic errors or words still in German (Figures 5 and 12, for example). In the text the word "imission" – denoting something akin to "ground-level concentration", in European usage – is spelled with both one "m" and two "m's". More care could have been taken in the preparation of the manuscript, as well as in choosing a more precise title – if not in the preparation of chapters other than three and four.

Before a potential purchaser invests a hefty $15.00 in this book he should be aware of its limitations as well as of its areas of useful coverage. It cannot be described as a book that every atmospheric scientist should have on his desk.

D.M. Whelpdale
Atmospheric Environment Service
Toronto

SASKATCHEWAN HAIL RESEARCH PROJECT LAUNCHED

Thanks to the financial support of the AES, the period 1973–74 has seen the emergence of the Saskatchewan Hail Research Project (SHARP), with headquarters located at the Department of Geography, University of Regina. The aim of this new project is to collect climatological information on hailfall in southern Saskatchewan. This is done both by enlisting the aid of farmers and rural residents as volunteer observers through the distribution of business-reply postcards, and by telephoning or writing to persons living in areas which have been affected by a given hailstorm.

The data derived from the hail reports, which include a variety of parameters concerning the hailfall, when accumulated over several summers, will allow comparisons between southern Saskatchewan hail-storms and those of Alberta. Techniques which may be forthcoming to suppress hail damage in Alberta could then be evaluated regarding any modifications that might be required in eventual application to southern Saskatchewan. The project should also provide an indication of the true frequency of hail in the area and contribute towards improvement in the forecasting of hail situations.

Operations during 1973 were mostly concentrated on an ara of 2200 sq. mi. around Regina and Moose Jaw, with the basic aim of generating publicity and good relations among the local rural community, and familiarity with the best methods of collecting information on especially interesting storms. With these objectives achieved, SHARP has embarked on a greatly expanded program in 1974.

A kit containing three post-paid hail-report cards plus instructions on filling them out was mailed to about 25,000 farmers in southcentral and southeastern Saskatchewan in late April and early May. As reports are received, they are logged and plotted on area maps, and the data from them punched on to computer cards.

Close contacts are maintained with the Regina Weather Office and the Saskatchewan Municipal Hail Insurance Association. The project must be aware as soon as possible of any hailstorms reported. Some of the storms are studied in greater detail by "surveying" – contacting farmers and soliciting reports from them to obtain supplementary data – and this must be started very soon after a storm. There is no effective weather radar in the area, and thus no immediate indication of hail activity and no record of echoes against which the dates and times of hail reports can be checked. A "convective weather log" is maintained for checking purposes instead.

The project owes a great deal in its conception to experience in Alberta. It must be stressed, though, that SHARP is not a comprehensive hailstorm research project in the sense that Alberta Hail Studies was. SHARP has neither the expertise nor the resources to attempt this. The basic operating premise is that a detailed climatology of surface hailfall, together with surveys of a number of individual storms, will produce sufficient information for valuable comparisons with Alberta hailstorms.

Anyone interested in receiving SHARP reports and publications is invited to contact:

Dr. A.H. Paul
Director
Saskatchewan Hail Research Project
Department of Geography
University of Regina
Regina, Saskatchewan S4S 0A2

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INFORMATION FOR AUTHORS

Editorial policy. *Atmosphere* is a medium for the publication of the results of original research, survey articles, essays and book reviews in all fields of atmospheric science. It is published quarterly by the CMS with the aid of a grant from the Canadian Government. Articles may be in either English or French. Contributors need not be members of the CMS nor need they be Canadian; foreign contributions are welcomed. All contributions will be subject to a critical review before acceptance. Because of space limitations articles should not exceed 16 printed pages and preferably should be shorter.

Manuscripts should be submitted to: the Editor, *Atmosphere*, West Isle Office Tower, 5th Floor, 2121 Trans-Canada Highway, Dorval, Quebec H9P 1J3. Three copies should be submitted, typewritten with double spacing and wide margins. Heading and sub-headings should be clearly designated. A concise, relevant and substantial abstract is required.

Tables should be prepared on separate sheets, each with concise headings.

Figures should be provided in the form of three copies of an original which should be retained by the author for later revision if required. A list of legends should be typed separately. Labelling should be made in generous size so that characters after reduction are easy to read. Line drawings should be drafted with India ink at least twice the final size on white paper or tracing cloth. Photographs (halftones) should be glossy prints at least twice the final size.

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

Footnotes to the text should be avoided.

Literature citations should be indicated in the text by author and date. The list of references should be arranged alphabetically by author, and chronologically for each author, if necessary.

RENSEIGNEMENTS POUR LES AUTEURS

Politique éditoriale. *Atmosphère* est un organe de publication de résultats de recherche originale, d'articles sommaires, d'essais et de critiques dans n'importe lequel domaine des sciences de l'atmosphere. Il est publié par la SMC à l'aide d'une subvention accordée par le gouvernement canadien. Les articles peuvent être en anglais ou en français. Il n'est pas nécessaire que les auteurs soient membre de la SMC; les contributions étrangères sont bien-venues. A cause des limitations d'espace les articles ne doivent pas dépasser 16 pages dans le format final. Tout article sera soumis à un critique indépendant avant d'être accepté.

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Les graphiques doivent être présentés en trois copies dont les originaux devraient être conservés par l'auteur au cas où ils seraient nécessaire de les reviser. Une liste des légendes des graphiques doit être dactylographiée séparément. L'étiquettage doit être de grand format de façon à ce qu'il soit facilement lisible après réduction du format. Le traçage des lignes doit s'effectuer au moyen d'encre de chine en doublant, au moins, le format final, le tout sur papier blanc ou sur papier à calquer et identifié adéquatement. Les photographies (demi-teintes) devraient être présentées sur épreuves glacées au double du format final.

Les unités. Le Système International (SI) d'unités métriques est préférable. Les unités devraient être abrégées seulement lorsqu'elles sont accompagnées de nombres, ex: "10m", mais "plusieurs mètres".

Les notes de renvoie au texte doivent être évitées.

Les citations littéraires doivent être indiquées dans le texte selon l'auteur et la date. La liste des références doit être présentée dans l'ordre alphabétique, par auteur et, si nécessaire, dans l'ordre chronologique pour chaque auteur.

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. At nine local centres of the Society, meetings are held on subjects of meteorological interest. *Atmosphere* as the scientific journal of the CMS is distributed free to all members. Each spring an annual congress is convened to serve as the National Meteorological Congress.

Correspondence regarding Society affairs should be directed to the Corresponding Secretary, Canadian Meteorological Society, c/o Dept. of Meteorology, McGill University, P.O. Box 6070, Montreal, P.Q. H3C 3G1

There are three types of membership – Member, Student Member and Sustaining Member. For 1974 the dues are $15.00, $5.00 and $50.00 (min.), respectively. The annual Institutional subscription rate for *Atmosphere* is $10.00.

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Toute correspondance concernant les activités de la Société devrait être adressée au Secrétaire-correspondant, Société météorologique du Canada, Département de Météorologie, l'Université McGill, C.P. 6070, Montréal, P.Q. H3C 3G1

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