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Persistence of Light Surface Winds in Canada

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ABSTRACT

The persistence of light surface winds (less than or equal to 3 m s^{-1} or 7 mi h^{-1}) is one meteorological factor in air pollution potential. Surface wind data were obtained from 111 Canadian synoptic and aviation weather stations for the period 1957–66. Generally speaking, persistent light winds occur most frequently in British Columbia, the Yukon and northern Alberta. In the ten provinces of Canada, the frequency of occurrence of light winds is a minimum in the spring and a maximum in the winter. In the Yukon and the Northwest Territories it is a minimum in the summer and a maximum in the winter. The seasonal variation is least in the mountain valleys and greatest elsewhere. The spatial and seasonal variations in persistent light winds suggest that, in the mountain valleys, topography is the major factor, while in other regions synoptic weather patterns are relatively important.

1 Introduction

Several factors contribute to air pollution potential. The height of the layer throughout which pollutants are diluted by vertical mixing (the "mixing height") and the strength of the mean wind within this layer are two such factors. A third is the strength of the surface wind. According to Gross (1970), persistent surface wind speeds equal to or less than 3 m s^{-1} (7 mi h^{-1}) contribute to high pollution potential. (It is useful to note at this point that pollution potential is not to be confused with pollution concentrations; the former is simply a measure of the dispersive capacity of the atmosphere. High pollution potential must be combined with a large input of pollutants to cause high pollution concentrations.)

In regional planning, it is important that the above three factors affecting air pollution potential be analyzed climatologically. Areas of high pollution potential could then be delineated and taken into consideration when planning future industrial development – especially in the North. On a synoptic scale, Munn *et al.* (1970) have investigated the climatology of surface-based inversions (zero mixing heights) in Canada. The present paper examines the persistence of light surface winds, again on a synoptic scale, and complements the above study of surface-based inversions. A third study, that of the climatology of "ventilation" (the product of mixing height and mean wind speed within the mixed layer) is underway and will be published at a later date. The combination of the three studies should hopefully lead to a pollution potential climatology of Canada on a regional scale. It is important to note that in applying this regional pollution potential to specific localities, account must be taken of important local effects such as those caused by large bodies of water, by urban development and by topographic features.

2 Observed occurrences of light winds

a *General Considerations*

Hourly surface wind speeds were used from all 111 of the Canadian synoptic and aviation weather stations that reported these data on a continuous basis during the period 1957–1966. Of interest were wind speeds of 3 m s^{-1} (7 mi h^{-1}) or less, which in this paper *are defined* as light winds. Tabulations of the monthly number of light surface winds at each station during the period 1957–1966 were made by Climatology Division of the Atmospheric Environment Service. Two non-overlapping persistence classes: 24–47 hours, and ≥48 hours were used in this study. For example, a light surface wind lasting 52 hours was counted only in the ≥48 hours category.

The numbers of occurrences in each persistence class are shown in the maps in Figs. 1 to 8 for spring, summer, autumn, and winter (Mar.–May, June–Aug., Sept.–Nov. and Dec.–Feb., respectively). In Fig. 1, the heavy dots show the locations of the observing stations. On all maps where the density of data permits, isopleths are drawn for 25, 50 and 100 occurrences in the ten-year period. These intervals were felt to be significant from the point of view of pollution potential since 25 occurrences of light winds in 10 three-month seasons is an average of about once per month.

The isopleths are not drawn in much of the North where the density of data is, unfortunately, too low. However, plotted numbers at station locations are left for the reader's information. Although it is impossible to draw general conclusions about the regions where isopleths are missing, the plotted numbers at Frobisher and Cambridge Bay suggest that persistent light winds occur fairly often at these locations and may contribute to a high pollution potential.

It became apparent that the persistence of light winds was influenced to a large extent by topography: the valleys in the Cordillera had more occurrences of light winds than flat localities such as the Prairies and those near large bodies of water. The isopleths were, therefore, drawn not only using the plotted numbers but also taking into consideration the topographic information shown in Fig. 9.

It should be emphasized that the maps show only synoptic features in the climatology of light winds; there may be local departures from the patterns due to valley and sea-shore influences on the wind. For instance, White River, Ontario experiences a large number of occurrences of light winds relative to other stations in northern Ontario. This station is located in a hollow where cold air drainage often takes place, causing low surface temperatures, stable stratification of the air and low surface wind speeds.

b *Light Winds Persisting for 24 to 47 Hours (Figs. 1–4)*

Generally speaking, British Columbia, northern Alberta and the southern Yukon experience by far the greatest number of occurrences of light winds lasting from 24 to 47 hours. Certain regions along the Cordillera, for example, experience over 100 occurrences in 10 summers (about 4 per month) while east of the Rockies, no locality experiences that number and most have less than 25 occurrences (about once per month).

In the ten provinces of Canada the frequency of occurrence of light winds is at a minimum in the spring and increases as the year progresses from spring through summer and fall and is at a maximum in the winter. For instance, the area contained within the 100-isopleth in western Canada increases several-fold from spring to winter. However, in the Yukon and at a few available stations in the Arctic, the frequency of occurrence of light winds is at a minimum in summer rather than in spring.

In central and eastern Canada, the relative spring-to-winter increase in the occurrences of light winds is even more pronounced than it is in western Canada. For instance, in the spring, almost none of Saskatchewan is contained within the 25-isopleth. As winter approaches, however, much of central Saskatchewan is contained within the 50-isopleth, and the 100-isopleth extends as far eastward as the Alberta-Saskatchewan border. In northern Ontario, the frequency of occurrence of light winds lasting 24 to 47 hours increases from 25 to 50 and even over 100 in some areas.

An interesting minimum in the pattern occurs consistently throughout the year in Alberta. In the winter and spring it is located on the Alberta-B.C. border; in summer and fall it may be found about 200 km east of the border.

c *Light Winds Lasting 48 Hours or Over (Figs. 5–8)*

As found in the case for light winds lasting 24 to 47 hours, British Columbia, northern Alberta and the Yukon suffered the most from light winds lasting 48 hours and longer. In these regions the spring-to-winter increase in the number of extended ($\geq$48 hours) light wind occurrences was very pronounced in contrast to the seasonal variations of light winds lasting less than 48 hours. For instance, in ten spring seasons, only certain areas in southern B.C. and in the Yukon experienced more than 25 occurrences of light winds lasting 48 hours or over. In ten winters, however, all of British Columbia and the northern half of Alberta had had more than 25 occurrences, and extensive portions, over 100. East of Alberta, throughout the year there were relatively few occurrences of light winds lasting 48 hours or over.

In the Yukon and the Northwest Territories light winds lasting 48 hours and longer occur least often in summer rather than spring, although the difference between those two seasons is not great. In Fig. 8, a minimum occurs in the pattern in mid-western Alberta just as it does in Figs. 1 to 4.

3 Discussion

a *Relationship Between Persistent Light Winds and Mean Wind Speeds*

In considering persistent light winds we were curious about the relationship which might exist between them and the mean wind speed. As an illustration, it would be possible for a certain location to have a large number of occurrences of light wind *and* a high mean wind speed if the winds were quite strong on the occasions when they were not light. It is, therefore, necessary to resist the temptation to relate persistent light winds to climatological data such as mean atmospheric pressure, as one might do with mean wind speeds.

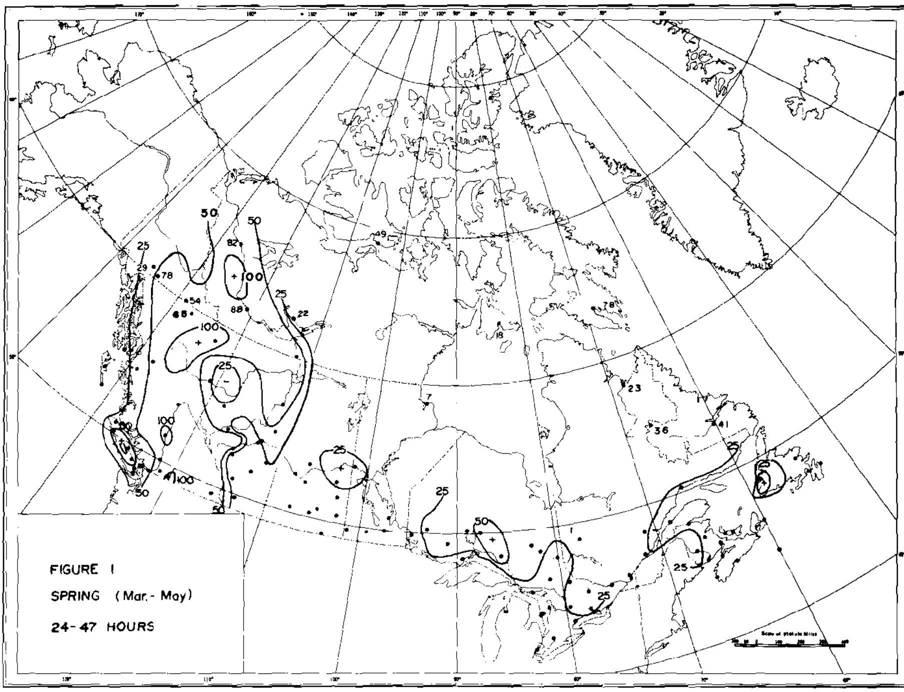
A qualitative comparison between unpublished climatological maps of mean wind speed and patterns in Figs. 1 to 8 revealed both similarities and differences. The regions of persistent light winds, such as the Cordillera, the northern half of the Prairie Provinces and northern Ontario, are also regions of relatively low mean wind speed. In addition, the minimum in the patterns in Figs. 1 to 8 in the Fort St. John-Swan Hills region of Alberta also corresponds to a "tongue" of relatively strong mean wind speeds extending northwestward from the southern Prairies.

On the other hand, the seasonal variations are different for the mean wind than for persistent light winds. Although the frequency of occurrence of persistent light winds is generally a minimum in the spring and summer and a maximum in the winter, the mean wind speed is a maximum in spring and a minimum in summer. Thus, in the summer, the winds are light but relatively steady while in the winter, strong winds are often interrupted by extended periods of light wind.

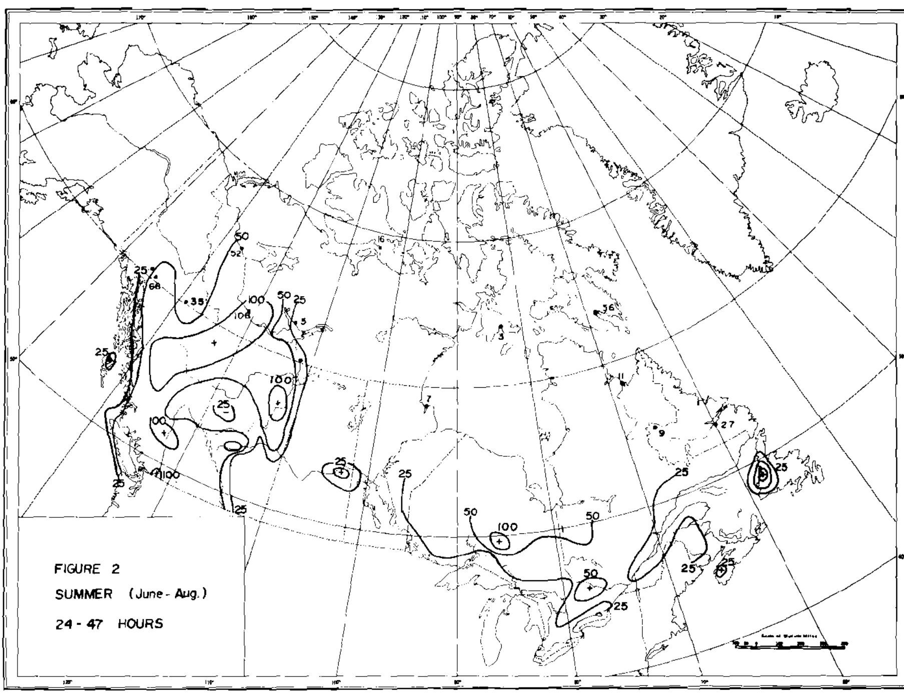
b *Topographic Influences*

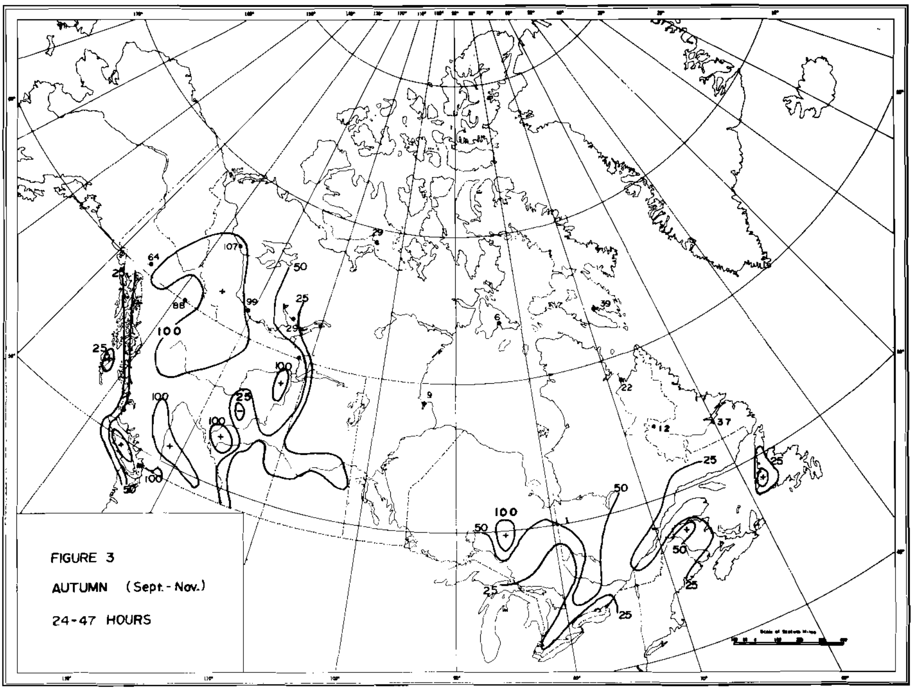
As pointed out above, the patterns in Figs. 1 to 8 appear to depend to a large extent upon topography. Flat areas of Canada such as the southern Prairies and those near large bodies of water seldom experience light winds, in contrast to the valleys of the Cordillera which have relatively frequent occurrences. (It should be pointed out that, while the observing stations are located in the floors of the valleys where the winds tend to be different from the synoptic wind (Munn, 1966), industry is also apt to be located in the valleys. Hence, these valley observing stations *are* representative from the point of view of industrial planning.)

Complex flows such as up- and down-slope winds as well as up- and down-valley winds can occur in valleys (Geiger, 1956; Munn, 1966). These valley flows are quite different from the regional wind inferred from the synoptic scale surface pressure patterns. They depend to a large extent upon the individual valley: its geometry and how it is oriented with respect to the sun and to the



Number of occurrences for the seasons indicated (1957–66) for persistent light winds lasting 24 to 47 hours.





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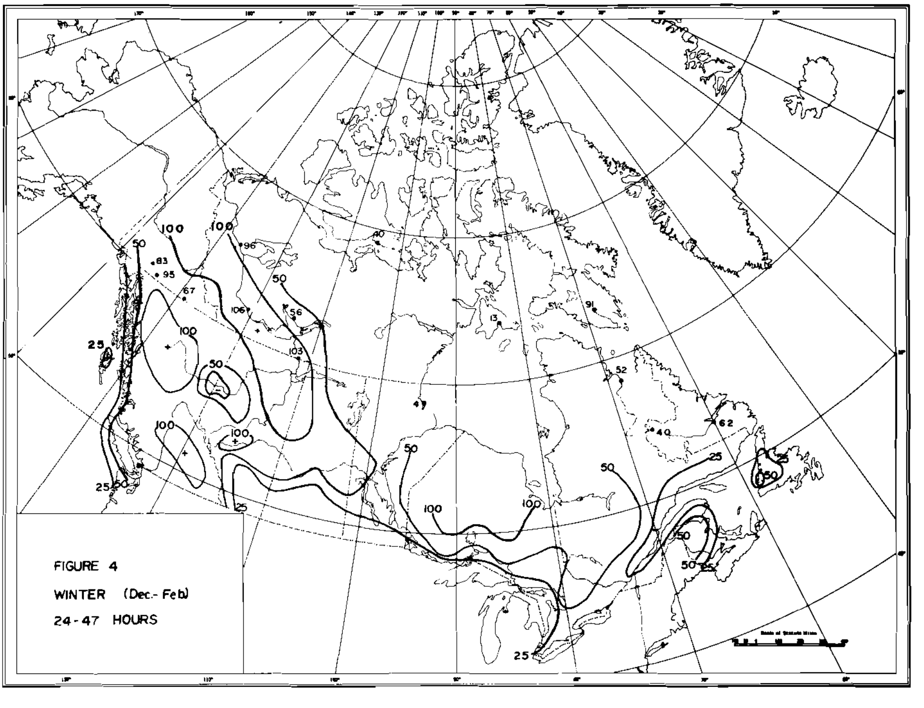
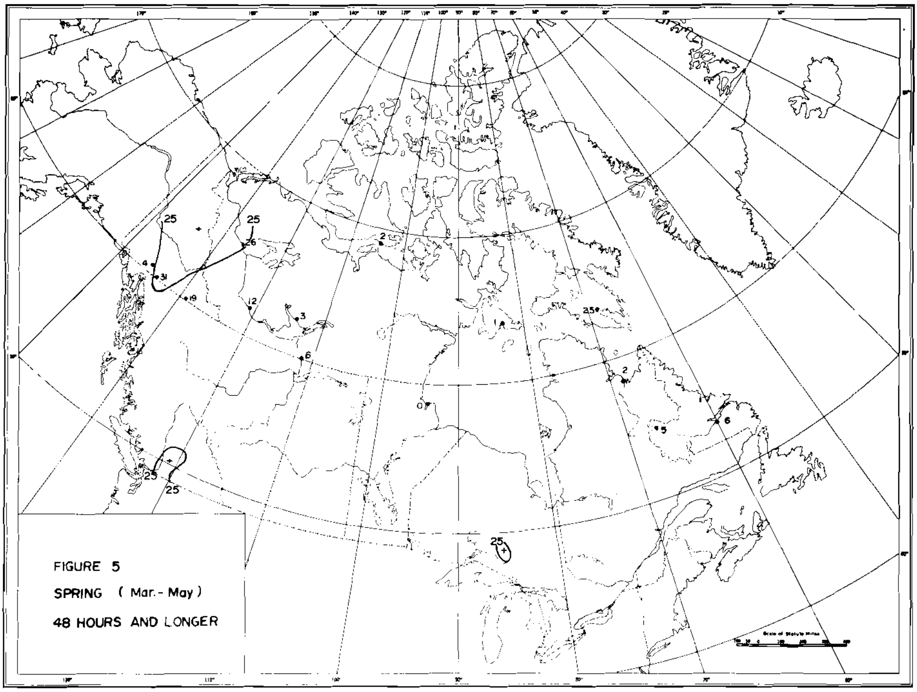
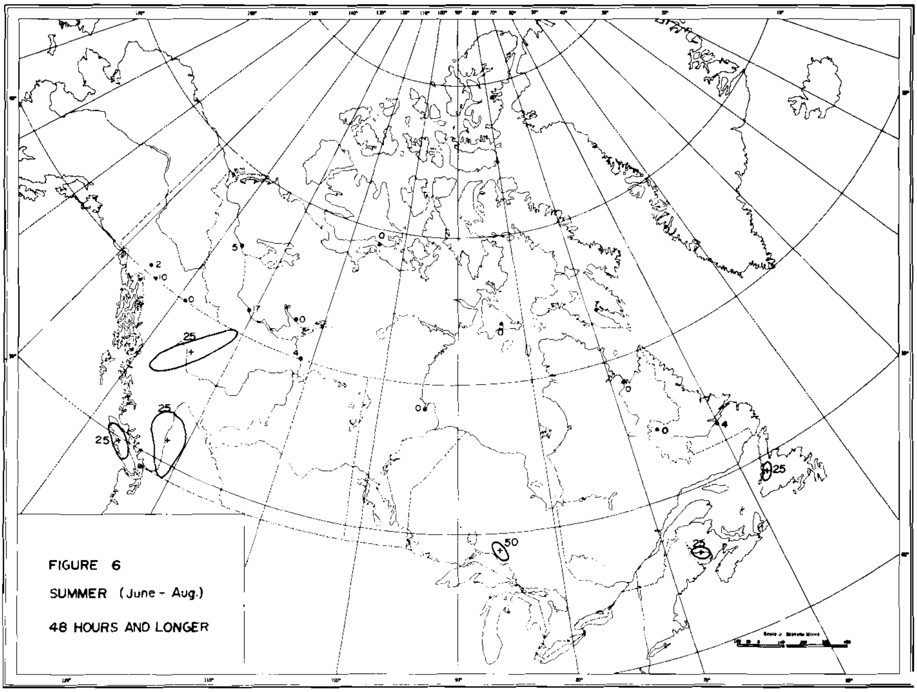
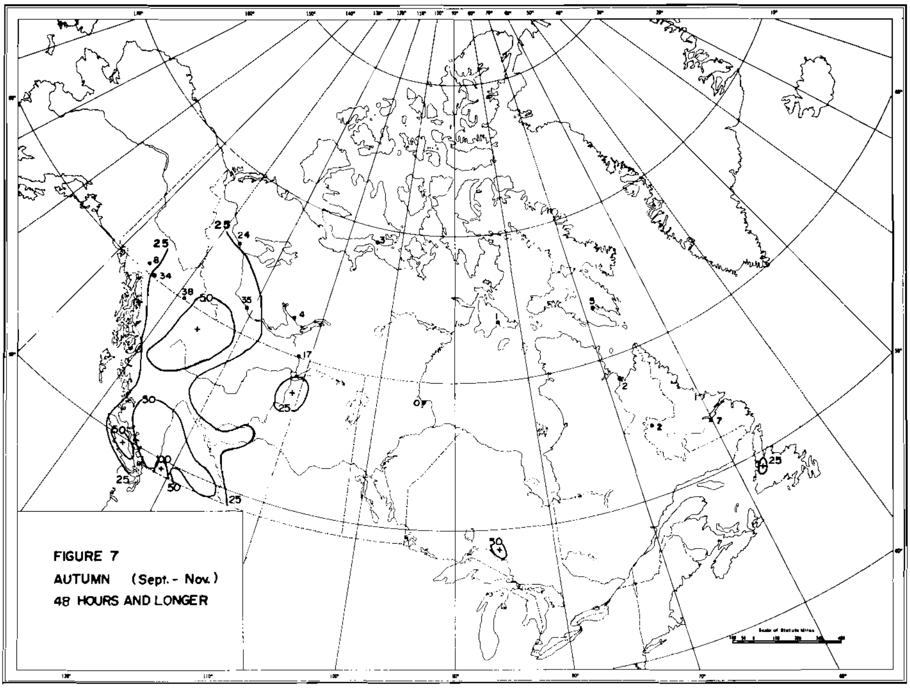


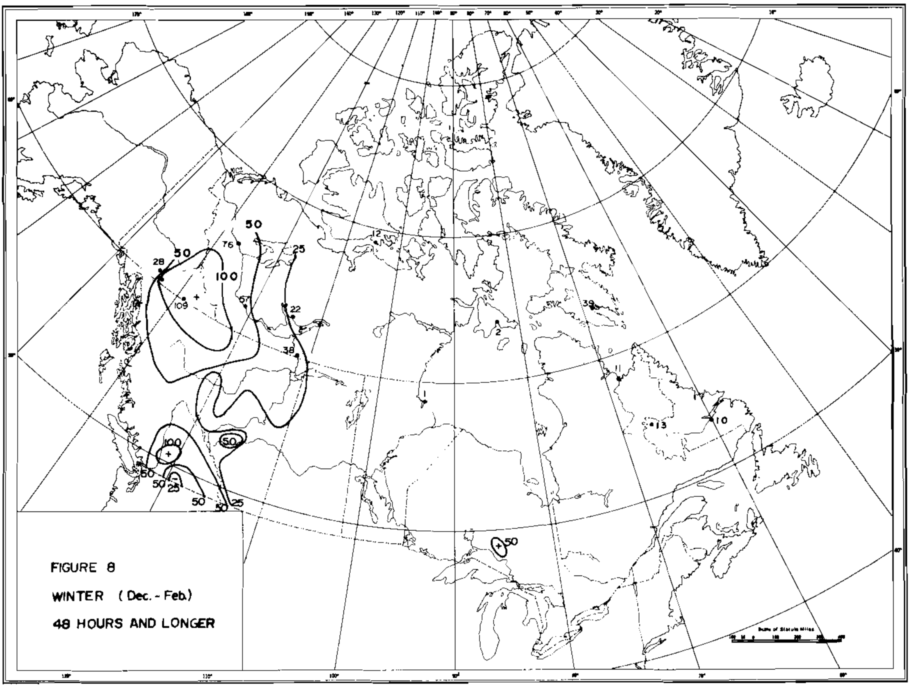


Number of occurrences for the seasons indicated (1957–66) for persistent light winds lasting 48 hours and longer.





Number of occurrences for the seasons indicated (1957–66) for persistent light winds lasting 48 hours and longer.



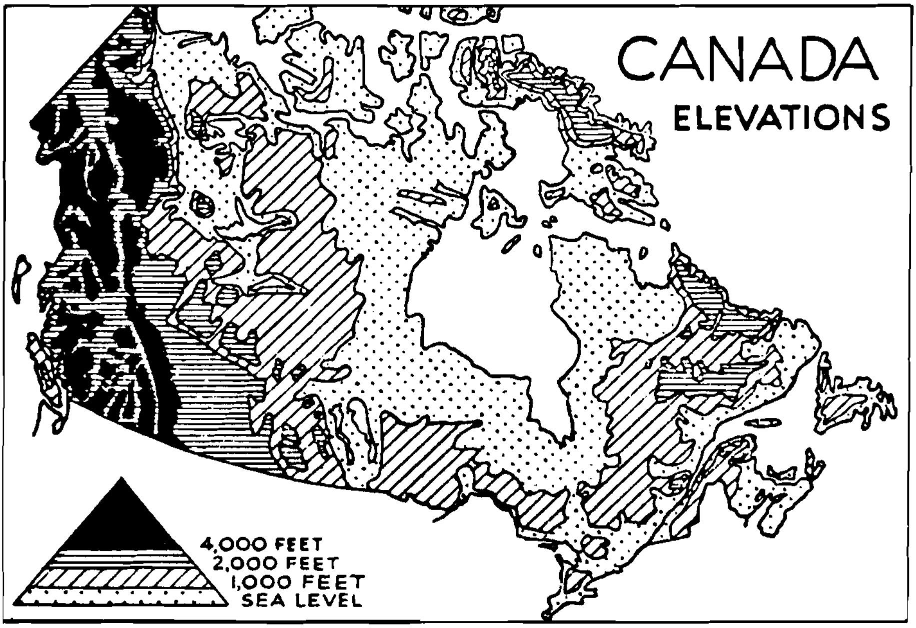


Fig. 9 Topographic height contours for Canada. From *A Regional Geography of Canada* by D.F. Putnam and D.P. Kerr. Copyright 1956: J.M. Dent and Sons Ltd., Toronto.

synoptic wind. It is, then, perhaps surprising that the valley stations in the Cordillera experience frequent light winds. One can only observe that the abovementioned complex flows in valleys must be interrupted at times so as to produce persistent light winds. Munn (1966) states that valleys are favourable locations for inversions because of cold air drainage and the trapping of air from cold outbreaks. Although these inversions are not as intense as they might be in isolated hollows, the stable temperature stratification of the air may be sufficient to prevent the downward transfer of the overlying air which moves with the speed of the synoptic wind, and thus the surface winds remain light. Cold air drainage often takes place at White River, Ontario and here again persistent light winds frequently occur.

Unlike the persistent light winds in the Cordillera, the region of relatively few persistent light winds in the Peace River-Swan Hills area of Alberta (the minimum in Figs. 1 to 4 and Fig. 8) could not be related to any particular topographic feature in that region. However, immediately to the west of the "minimum", the Rocky Mountains are lower and they have less east-west extent. One can speculate that in this region the mountains present less of a barrier to the wind. Indeed, not only are there fewer occurrences of light winds in this region, but the mean wind speeds are also relatively higher.

c *Synoptic Influences*

Because the patterns in Figs. 1 to 8 do change throughout the year, particularly in non-mountainous regions, there must be other factors besides topography influencing them. For instance, it has been noted that in the summer and autumn, the region within the 50-isopleth spreads eastward from Alberta and by winter extends into the northern parts of all provinces between Saskatchewan and Quebec. The seasonal variations of light winds and of mean wind speed are shown in the following table:

	Minimum	→	→	Maximum
Frequency of occurrence of persistent light winds	Spring	Summer	Autumn	Winter
Mean wind speed	Summer	Autumn	Winter	Spring

It appears that the synoptic weather patterns play an important role in non-mountainous regions. The synoptic pattern causing light winds is the stagnating anticyclone. In the spring, there are rapid passages of frontal cyclones over Canada. The strong circulations in the cyclones ensure that the mean wind speed is high and the rapid motions of the systems mean that an anticyclone, with its inherent light winds, does not remain very long over a given location. In summer, the circulations become weak and ill-defined. The mean wind speed decreases and persistent light winds occur somewhat more often than they do in the spring. In the autumn, better-defined cyclones and anticyclones are again found over Canada but they do not move as quickly as they do in the spring. Mean wind speeds increase, but the occurrences of stagnating anticyclones and of persistent light winds also increase. In winter, Canada is often under the influence of large cold anticyclones, with frontal cyclones to the south. The passage of intense frontal cyclones, however, causes the mean wind speeds to be high.

4 Conclusions

Generally speaking, persistent light winds (those lasting from 24 to 47 hours and 48 hours and over) occurred most frequently in British Columbia, the Yukon and northern Alberta. In the ten provinces, they occurred most frequently in the winter months and least often in the spring. In the Yukon and at the few available stations in the Northwest Territories, persistent light winds occurred least often in the summer. The seasonal variation was less pronounced in British Columbia, the Yukon and northern Alberta and more pronounced in the rest of Canada. Therefore, the contrast between western Canada and the rest of the country was less in winter than in spring.

The spatial and seasonal variations in persistent light winds suggest that, in the mountain valleys, topography is the major factor, while in other regions synoptic weather patterns are more important.

Due to the sparseness of data, general conclusions could not be drawn about the Arctic. However, at two locations from which data are available (Frobisher and Cambridge Bay) light winds lasting 24 to 47 hours occur on the average 2 to 4 times per winter month and may contribute to a high pollution potential.

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BOOK REVIEWS

LA MÉTÉO. Par Alcide Ouellet, Les éditions de l'homme ltée et les éditions Ici-Radio-Canada, 1971, 175 pages, $3.00. (Distributeur : Agence de Distribution Populaire Inc., 1130 est, rue de la Gauchetière, Montréal 132.)

L'auteur est le directeur du Bureau météorologique de Dorval et "la voix" montréalaise de la météo à Radio-Canada.

Il a bien réussi à interpréter la météorologie d'une façon populaire. Il n'y a rien de semblable pour les Canadiens anglophones.

Le livre est divisé en 23 chapitres qui sont tous concis et précis. L'auteur écrit avec humeur et clarté afin que le lecteur en général, non seulement le météorologiste, puisse bien comprendre. On peut s'instruire, en s'amusant, de l'almanach et des dictons aussi bien que des cartes météorologiques, des nuages, des prévisions et ses utilisations, de la climatologie, de la pollution de l'air, des instruments, etc.

Le dernier chapitre, "Météo-Vacances", se compose de 45 pages de données climatologiques moyennes pour des villes importantes du Canada et pour quelques villes du monde entier. Pour prendre des vacances, l'auteur ne vous conseille que de faire la comparaison entre les statistiques climatologiques. Mais si vous choisissiez Athènes ou Tokyo, il vaudrait mieux que vous consultiez les tarifs aériens et votre porte-monnaie.

Il y a 46 photos en noir et blanc et six pages de photos de nuages en couleur. Cependant, il n'y a pas de bonnes photos de nuages par satellite ou par radar. Elles auraient été très intéressantes dans ce livre. Les photos en noir et blanc sont bien choisies et très intéressantes, mais, pas toujours, bien reproduites. La définition de la température mouillée (p. 89) n'est pas tout a fait exacte.

Cette parution fournit vraiment des bons renseignements météorologiques dans leurs aspects les plus divers. Elle devrait être aussi très utile à ceux qui ne sont pas au courant des possibilités du service météorologique.

À un prix des trois dollars, ce livre-ci est, comme disent les anglais, "a best-buy".

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Book Reviews continued on page 56

Integration of a Semi-Implicit Model with Time-Dependent Boundary Conditions

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[Manuscript received 15 November 1971; revised 18 March 1972]

ABSTRACT

A semi-implicit barotropic primitive equations model is integrated over a limited area with time dependent boundary conditions using the standard mesh and a finer mesh. Following a theorem by Charney, a minimum number of variables are specified as boundary conditions for the limited area integrations in order to avoid mathematical over-specification. The comparison of coarse mesh limited area forecasts with the corresponding forecasts made over a much larger domain demonstrates that the essential features, namely the Rossby type perturbations, are handled almost perfectly. The fine mesh forecasts over the same limited area are also very good. Finally, the effect of specifying inaccurate boundary conditions, in the form of twelve-hour forecasts, is briefly illustrated.

1 Introduction

Starting with Hill (1968) several experiments have been performed successfully with so-called fine mesh models. This is not difficult except that in general a reduction of grid length must be accompanied by a shrinking of the forecast domain because of computer limitations. The problem of the specification of satisfactory lateral boundary conditions then becomes very acute. Ideally the boundary conditions should consist of pre-determined values of all the variables on the boundaries; in practice these are not always available or they may not be in agreement with the evolution of the variables inside the domain. The latter event leads to instability due to mathematical over-specification.

It is evident that if a limited area forecast is performed on the same mesh points as a larger area forecast with all its boundary variables specified exactly from the latter, the two forecasts will be identical. However if one imposes these same boundary conditions but performs the integration with a different mesh size, noise will inevitably be generated near some of the boundaries. Thus the forecast will in time be completely ruined unless heavy smoothing is imposed. In terms of the linear theory of characteristics the specification of all variables at the boundaries is equivalent to specifying both ends of the characteristic lines even though the slope of these lines is determined independently by the equations. Thus there must exist a minimum combination of all boundary variables of a given sub-domain which will be sufficient to duplicate exactly (over this sub-domain) the forecast made over the complete domain.

Recently Shapiro and O'Brien (1970) have obtained a successful integration of the filtered barotropic equation with minimum time dependent boundaries, whereas Wang and Halpern (1970) have managed to control the flow near the completely specified boundaries of a primitive equations barotropic model by averaging techniques. In this paper minimum time dependent boundaries as proposed by Charney (1962) have been imposed on a primitive equations barotropic model integrated by an implicit technique.

In Charney's (1962) proposal, a sufficient (minimum) set of boundary conditions for a primitive equations (dry) model requires that the wind component normal to the border be specified everywhere and that the potential vorticity, a conservative quantity of the basic equations, be specified at points of inflow only. This set is probably not unique and it is in fact not completely sufficient either since an assumption about the continuity of the normal wind component across the border is implicit in Charney's (1962) demonstration. Also, the use of potential vorticity would be very inconvenient in a baroclinic model because, in general, the gradient of potential temperature and the curl of the wind are not aligned with any of the coordinates of the grid. However Charney's derivation could have been made using the vertical component of absolute vorticity instead of potential vorticity. In fact, outside highly baroclinic regions the gradient of potential temperature is very nearly vertical and it will make little difference whether absolute or potential vorticity is specified. In the barotropic case, with which we will be dealing below, the potential vorticity is equal to the absolute vorticity divided by the total depth of the fluid, which is almost constant. Thus the use of either quantity will not make any difference. Having made this assumption, we have also assumed continuity of the normal wind component in order to define a computational boundary condition.

2 Basic equations

The model used describes a homogeneous incompressible fluid with a free top. It consists of the following finite difference equations:

$$\overline{u^*}^t_t = Q\tilde{v} - \overline{(\overline{\phi}^{2t})_x}^y - \overline{K}^y_x \tag{1}$$

$$\overline{v^*}^t_t = -\,Q\tilde{u} - \overline{(\overline{\phi}^{2t})_y}^x - \overline{K}^x_y \tag{2}$$

$$\overline{\phi}^t_t + m^2\Phi\overline{(\overline{u^*}^y_x + \overline{v^*}^x_y)}^{2t} = -\widetilde{\widetilde{m^2}[\widetilde{\phi'}(\overline{u}^y_x + \overline{v}^x_y) + \tilde{u}\overline{\phi'}^y_x + \tilde{v}\overline{\phi'}^x_y]} \tag{3}$$

where
$$u = \tilde{u}^*,\ v = \tilde{v}^*$$
$$Q = \tilde{f} + \widetilde{m^2}(\overline{v}^y_x - \overline{u}^x_y)$$
$$K = 0.5m^2(u^2 + v^2)$$
$$\phi = \Phi + \phi',\ \Phi\text{: average of } \phi$$
$$g_\alpha = \Delta\alpha^{-1}[g(\alpha + 0.5\Delta\alpha) - g(\alpha - 0.5\Delta\alpha)]$$
$$\overline{g}^\alpha = 0.5[g(\alpha + 0.5\Delta\alpha) + g(\alpha - 0.5\Delta\alpha)]$$
$$\overline{g}^{2\alpha} = 0.5[g(\alpha + \Delta\alpha) + g(\alpha - \Delta\alpha)]$$
and
$$\tilde{g} = \overline{(\overline{g}^y)}^x \tag{4}$$

In these equations u^* and v^* are the reduced wind images of the true wind components on the earth, U and V, in the x and y directions of the map ($u^* = U/m$, $v^* = V/m$); m is the map scale factor; ϕ is the geopotential of the top of the fluid, f is the Coriolis parameter, Q is the absolute vorticity, g stands for any dependent variable and α stands for any independent variable. It may be of interest to note that a rotation of axes by 45° would leave these finite differences unchanged except for the disappearance of all $-x$ and $-y$ operators and a re-definition of $\tilde{g}$ as

$$\tilde{g} = (\bar{g}^X + \bar{g}^Y)/2 \tag{5}$$

in the new coordinates (X, Y). Thus the finite differences used are really two-point centered differences with a grid-length of $\sqrt{2}\Delta\alpha$.

These equations are implicit; they are solved by substituting the finite-difference divergence of the first two equations into the third one. This leads to a Helmholtz equation for $\bar{\phi}^{2t}$ which is dealt with by relaxation. Complete details about this model can be found in Kwizak and Robert (1971).

The variables appearing in the Eqs. (1) to (4) are defined at grid points (u, v, ϕ, m^2, f, K) or in the middle of the grid boxes (u^*, v^*, Q). Operators $\overline{(\ )}^y_x$, $\overline{(\ )}^x_y$ or $\widetilde{(\ )}$ allow us to pass (with second order truncation error) from grid points to boxes and vice versa. No use is being made at present of the time-staggered lattice structure implied by these finite differences. The semi-implicit formulation allows a time step of at least one hour for $\Delta x = \Delta y = 381$ km at 60 N.

3 Boundary conditions

For simplicity in the description of the boundary conditions, we will assume that we deal only with the left edge of the grid. The boundary conditions are applied in the middle of the first boxes, where $\partial u^*/\partial t$ is given and where Q is either given for inflow points ($u^* \geq 0$) or computed by Lagrangian advection (upstream differences in space and forward differences in time) from the simplified equation

$$dQ/dt = 0 \tag{6}$$

for the outflow points. Experiments have shown that it is not necessary to use the complete vorticity equation for this purpose.

Each time step starts with u^*, v^* in all boxes and ϕ at all grid points. In order to complete one time step, it is required, according to the finite-difference equations (1) to (4), to know also the values of u, v, $\bar{\phi}^{2t}$ on the outside corners of the boundary boxes. We obtain u there by extrapolating linearly according to the computational boundary condition

$$\bar{u}^x = \overline{u^*}^y \tag{7}$$

and we find v from the known values of Q in the border boxes. Finally, substituting these values of u and v as well as $\partial u^*/\partial t$ into (1) at the border we are left with an expression for the normal gradient of $\bar{\phi}^{2t}$ which is used as a boundary condition of the second kind for the Helmholtz equation. The time extrapolation of u^* and v^* can now be made everywhere and the integration proceeds on.

For the reader interested in working out the exact details of the calculations of the outside values of v and $\bar{\phi}^{2t}$ it may be mentioned that the reduction of gradients of the form $\overline{(\ )}^y_x$ results in a complete set of algebraic equations which are mildly indeterminate and which may lead to two grid increment waves along the outside row of points. These difficulties are avoided by using an approximate inverse $\overline{(\ )}^{y^{-1}}$ to the $\overline{(\ )}^y$ operator as follows:

$$g = \overline{(\bar{g}^y)}^{y^{-1}} \approx \overline{g'}^y$$

where g' is equal to $\bar{g}^y$ unsmoothed twice with a Shuman (1957) filter using a coefficient (-0.25).

4 Results

Some experiments were performed with the barotropic primitive equations model in order to measure the success of the specification of the time dependence of the boundary conditions. A reference forecast for 36 hours was first made over a hemispheric region using solid wall boundary conditions $u^* = 0$, $Q = \tilde{f}$. For the first experiment, the forecast was repeated over an inner subset of the previous domain. This limited area was placed in such a way that a variety of situations would be experienced around the boundary, Fig. 1. The boundary conditions were extracted from the reference forecast and used according to the method described above. The reference and limited area forecasts, were then verified against the verifying analyses and between themselves. The data used were the 500-mb stream function for 00Z Feb. 21, 1969.

It is evident that if such an experiment were performed with a filtered model, which has only one variable, the forecast for the limited area should be identical to that for the large area. In the case of the primitive equations however, there are three variables (but the equations are of lower order) and it is not evident a priori that the forecast can be duplicated over a limited area by specifying only the normal wind component and the vorticity.

The results of this experiment can be seen in Figs. 2 (a), (b) for the height and 3 (a), (b) for the vorticity. There is practically no difference between the two forecasts. No compression of the flow or mass field is shown near the outflow areas. The 36-hour divergence pattern for the limited area forecast is also shown in Fig. 3 (d). Some divergence is clearly associated with the movement of the synoptic features but there is also a series of patterns along the axis of the jet which were not present in the full area forecast and which seem to be associated with weak gravitational activity, probably introduced spuriously by the boundary conditions. However this small amount of noise is tolerable and could be disposed of easily with time filters.

The comparison between the limited area and the large area forecast is continued in Fig. 4 which shows the difference between the height forecasts at

Fig. 1 The initial 500-mb analysis, 00Z Feb. 21, 1969. The inner rectangle is the boundary of the limited area. Contours at 6 dam.

0, 12, 24, 36 hours. The non-zero difference at initial time is due to the fact that the reverse balance equation is solved on each area in order to obtain the initial height field from the rotational part of the wind, as described by Kwizak and Robert (1971). The boundary condition for this Poisson equation is of the Neumann type similar to that of the Helmholtz equation, and thus does not ensure that the boundary values of the geopotential on the limited area will be identical to those on the large area. (The use of Dirichlet boundary conditions leads to more gravitational activity during the forecast than the use of Neumann conditions.) At any rate it is seen that the differences do not increase in the first 24 hours and remain small even at 36 hours. The standard deviations of these differences are given in Table 1.

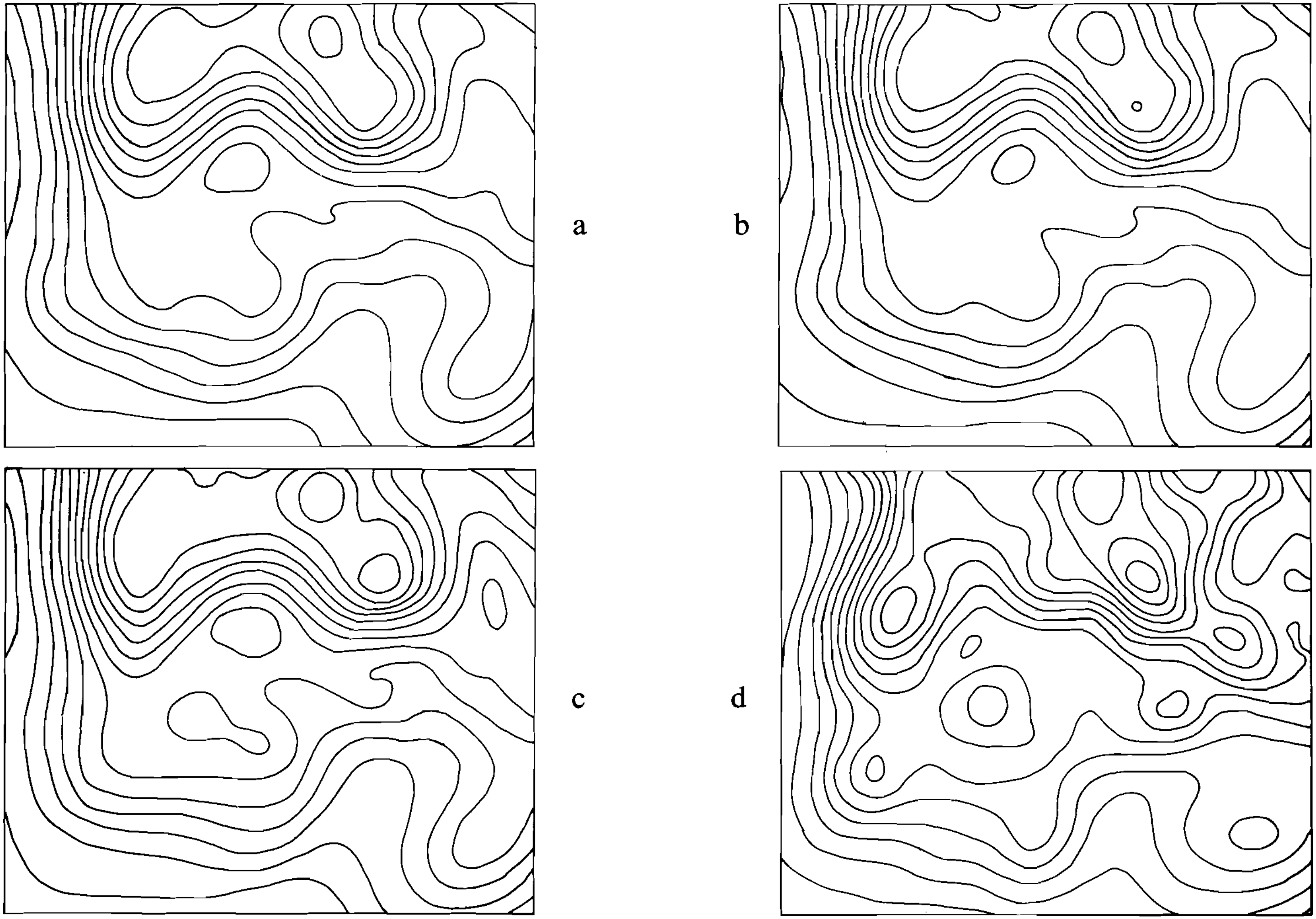

Fig. 2 36 hours after initial time, contours at 6 dam: (a) reference forecast made over the large area; (b) forecast made over the limited area; (c) forecast made over the limited area using $\Delta x = \Delta y = 190.5$ km; (d) verifying analysis.

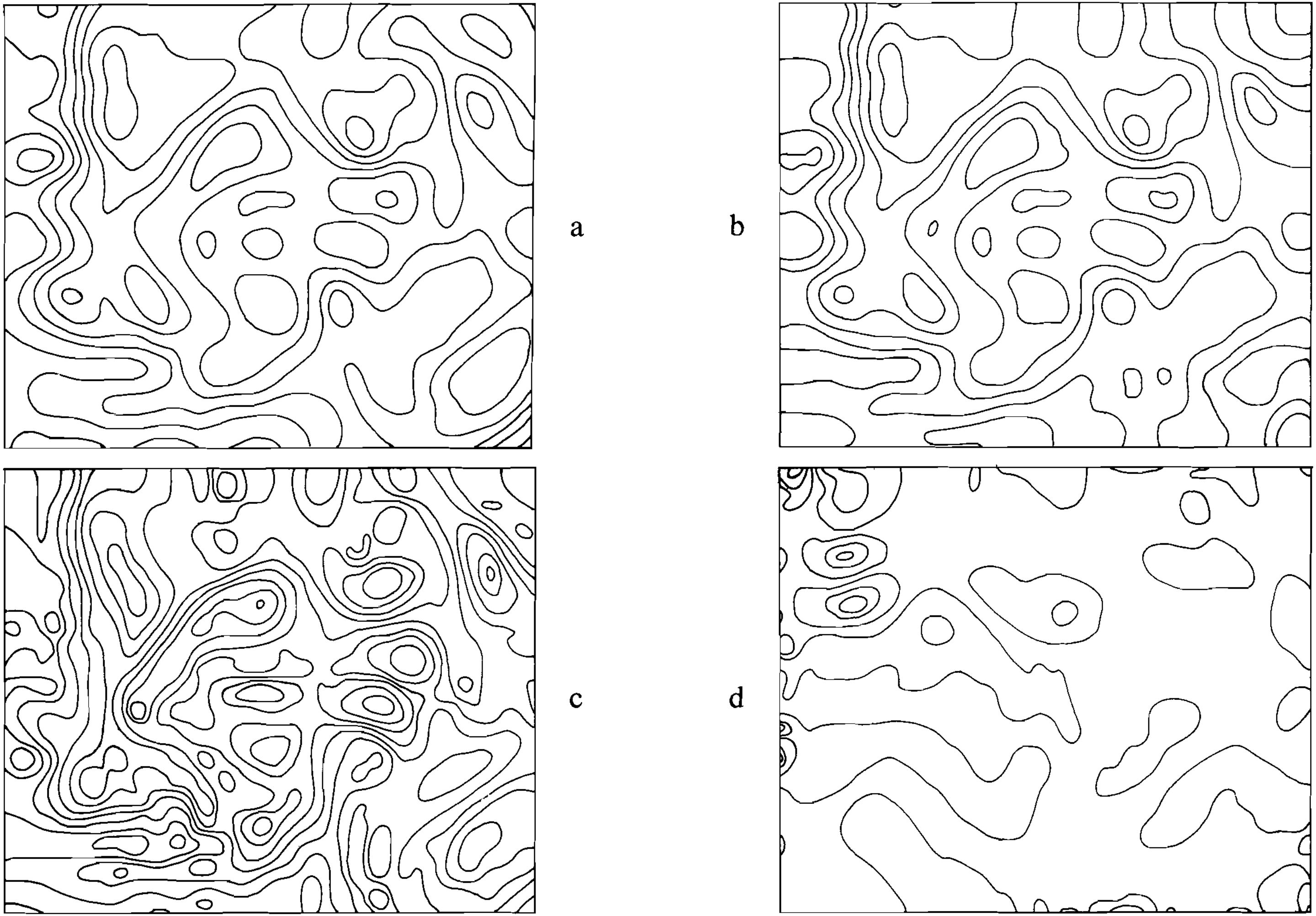

Fig. 3 (a), (b), (c): vorticity (contours at 2×10^{-5} sec^{-1}), after 36 hours in the large area, limited area and limited area half mesh forecasts, respectively; (d) : divergence (contours at 2×10^{-8} sec^{-1}) in the limited area 36-hour forecast.

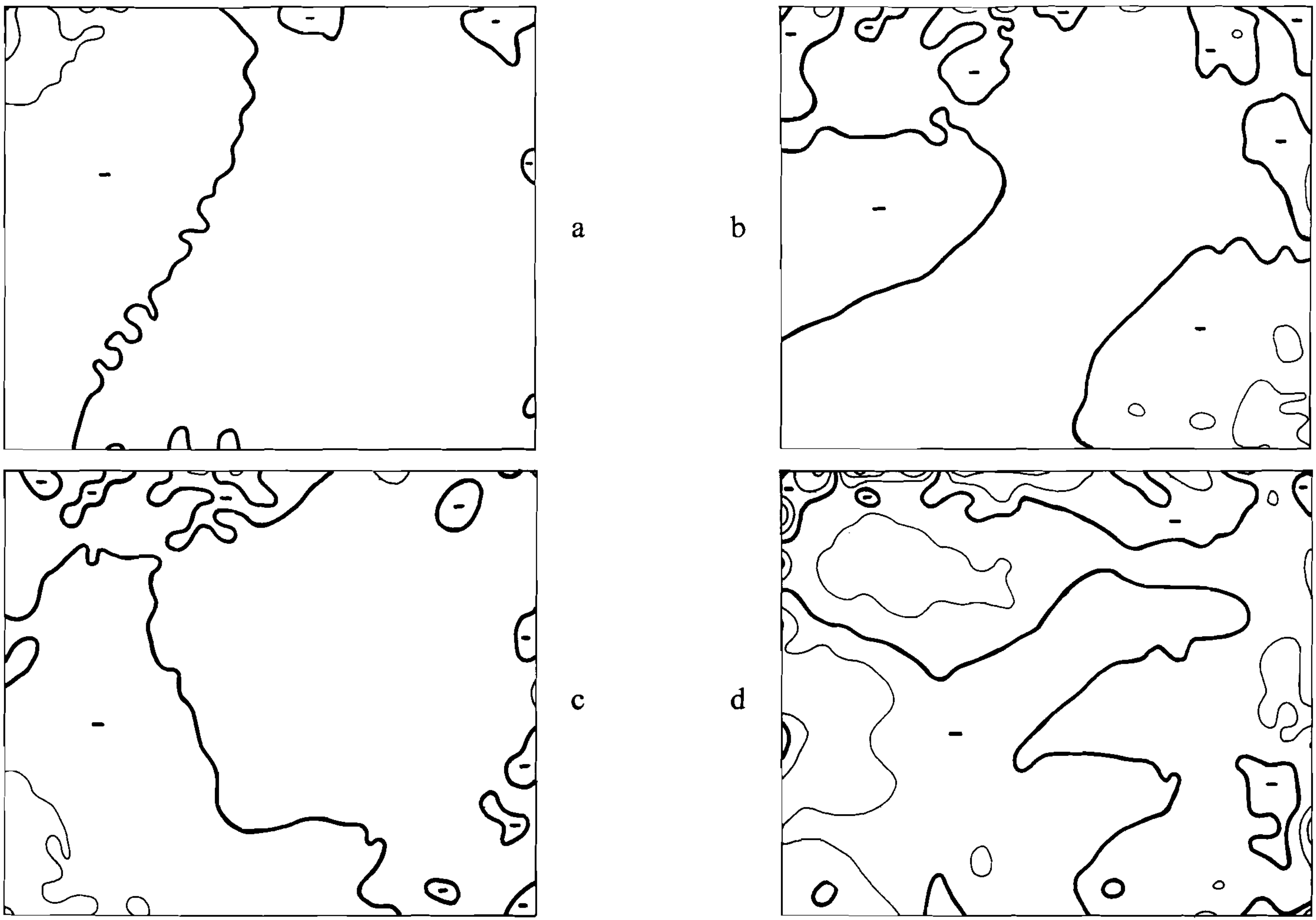

Fig. 4 (a), (b), (c), (d) : difference between the forecast made over the full area and the one made over the limited area (contours at 1 dam) at 0, 12, 24, 36 hours, respectively. The thick line is the zero-line.

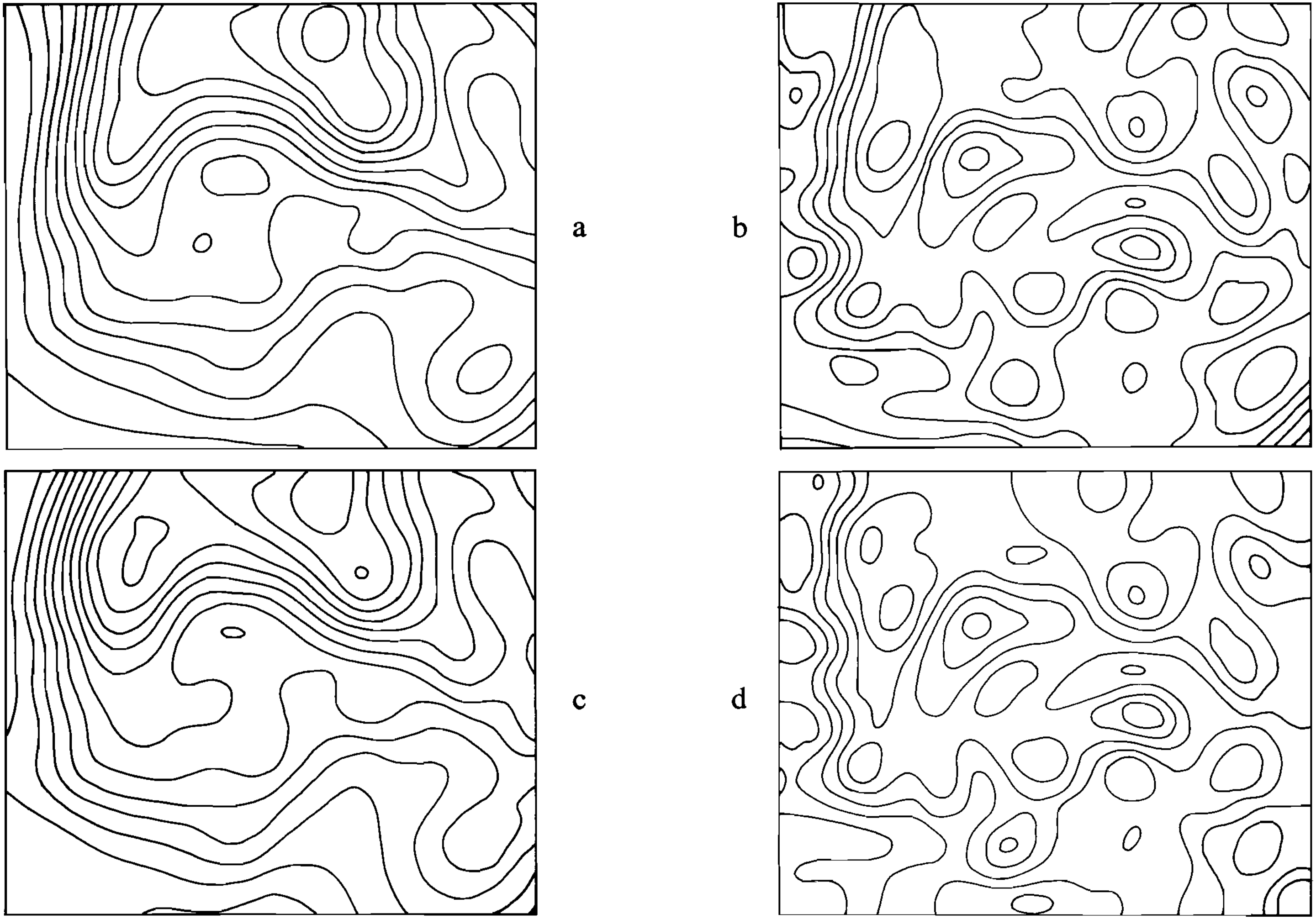

Fig. 5 24-hour forecast verifying at 12Z Feb. 22, 1969; (a), (b) : height and vorticity from full area forecast; (c), (d) : height and vorticity from limited area forecast using 12-hour predicted boundary values. The contours are at 6 dam and 2×10^{-5} sec^{-1}.

TABLE 1. Standard deviation (m) of the difference between the forecasts starting at t_0 = 00Z Feb. 21, 1969 and the verifying analyses at 0, 12, 24, 36 hours.

	Full Area Coarse Mesh				Verifying Analysis			
Time from t_0	0	12	24	36	0	12	24	36
Full Area					15.8	30.9	53.5	71.5
Limited Area Coarse Mesh	4.1	4.4	4.7	7.8	16.0	30.7	55.4	73.4
Limited Area Fine Mesh	10.0	12.8	17.2	20.5	8.1	29.7	55.0	74.0

A second experiment was performed on the same limited area with the grid length reduced to 190.5 km. Since the finite differences are of second order, this should decrease the truncation errors in the forecast by a factor of 4. The time step was also reduced to 30 minutes. The initial data were obtained by cubic interpolation of the stream function, from which the winds were computed, and finally the geopotential was obtained from the reverse balance equation as usual. The time-dependent boundaries were similarly interpolated in time and in the direction along the border. For expediency, no interpolation was made perpendicular to the boundary thus introducing a displacement error of one quarter of the original grid length in the specification of $\partial u^*/\partial t$ and Q.

Linear analysis of the system of Eqs. (1) to (4) shows that the phase speed of the Rossby waves is directly related to the responses (ratio of finite-difference operator to exact operator) of the space averaging and space differencing operators divided by the response of the time differencing operator. When the grid length and the time step are reduced, all of these responses increase, particularly in the high frequencies, in such a way that we should expect increased speed of small-scale systems as well as intensification of the vorticity field (the stream function having been unchanged). These features can be seen easily in the 36-hour forecasts of height and vorticity shown in Figs. 2 (c) and 3 (c) and they appear to bring the forecast closer to the verifying analysis, shown in Fig. 2 (d). Some statistics about this experiment are also given in Table 1.

A closer study of Table 1 reveals some interesting points. First, by examining the differences between the fine mesh and the coarse mesh forecasts, we note that they increase more or less linearly with time, as expected from the type of equation involved. Next, knowing that the truncation errors should be approximately four times larger in the coarse mesh than in the fine mesh forecast, we may conclude that these figures represent approximately three times the standard deviations of the truncation errors of the fine mesh forecast, 6.83 m (or 3/4 of the error of the coarse mesh one). Thus, with a mesh of 190.5 km, it would appear that truncation errors contribute only a very small percentage of the total height error variance of the forecasts (in this case about $(6.3/71.5)^2 = 1\%$). Similar conclusions have been obtained by Chouinard and Robert (1971) with a filtered barotropic model for different cases.

Secondly, with respect to the accuracy of the forecasts, we note that the initial heights from the reverse balance equation on the fine mesh are much closer to the actual ones (because of reduced truncation errors) but that the forecasts are not really any better than the coarse mesh ones, despite the more favourable subjective opinion which may have been formed by visual examination of Fig. 2. Thus a significant reduction of the truncation error has not led to any improvement in the forecast score! This is quite a common feature with fine mesh forecasts which have no added physical effects with respect to the coarse mesh forecasts. In fact it is well known that the numerous sources of errors in numerical forecasts are not independent of each other. In this case it is probable that the fine mesh verifications could be improved by slightly smoothing the forecasts or adding diffusion terms to the model.

Finally, a third experiment was performed in order to verify in a more operational context that the boundary conditions may be chosen arbitrarily and do not have to match the data inside the area. The boundary conditions extracted from the reference forecast starting from 00Z Feb. 21, 1969, were used again to make a limited area forecast starting 12 hours later (at 12Z Feb. 21, 1969). For comparison a full area forecast was also made from these more recent data. The results of this experiment are shown in Fig. 5 for the 24-hour forecasts of height and vorticity. (These maps verify at the same time as the 36-hour forecasts of the first two experiments.)

The limited area forecast using boundary conditions predicted 12 hours earlier (Fig. 5 (c), (d)) is very similar to the corresponding full area forecast (Fig. 5 (a), (b)) except in the top left corner, which is the region of strongest inflow. There the vorticity pattern of the limited area forecast has evidently taken on some of the characteristics of the reference forecast from the earlier time (Fig. 3 (a)), and the height field has adjusted correspondingly. This is not unexpected since more information from the reference forecast is specified at points of inflow than at points of outflow.

For the sake of interest the verification scores for this experiment are given in Table 2. Although the purpose of this paper is not to discuss how the time dependent boundary conditions should be obtained, one cannot help but notice

TABLE 2. Standard deviation (m) of the difference between the forecasts starting at t_0 = 12Z Feb. 21, 1969 and the verifying analyses at 0, 12, 24 hours.

	Full Area Coarse Mesh			Verifying Analysis		
Time from t_0	0	12	24	0	12	24
Full Area				15.3	32.1	46.3
Limited Area Coarse Mesh 12-h forecast boundaries	7.7	17.0	24.7	14.7	37.8	60.1

(remembering that this is only one case) that the use of a 12-hour prediction from a poor atmospheric model has caused a significant deterioration of the forecast over the limited area. The use of time constant boundaries might have done even worse! Nevertheless the 24-hour prediction over the limited area is significantly better than the 36-hour prediction over the full area.

5 Conclusions

Charney's (1962) proposal that the specification of the normal wind component and of the potential vorticity at points of inflow constitutes a correct set of boundary conditions for the integration of a primitive equations model has been tested and found to give excellent results with a simple one-level semi-implicit model. It was found possible to use the absolute vorticity instead of the potential vorticity; also a weak condition on the normal wind component had to be added. These boundary conditions generate only a very small amount of noise and they offer the possibility of making fine mesh limited area forecasts without difficulty. The use of inaccurate values (e.g., a 12-hour forecast) of the variables specified on the boundaries appears to result in significant errors inside the area in the regions of inflow, even after 24 hours. Results of similar experiments with a baroclinic extension of this model will be presented in a subsequent paper.

Acknowledgement

The author wishes to thank Mrs. Susan Pratt who carried out all of the programming necessary for this study and also reviewed the text of this paper.

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BOOK REVIEWS

AERODYNAMIC CHARACTERISTICS OF ATMOSPHERIC BOUNDARY LAYERS. By E.J. Plate. Available from NTIS, U.S. Dept. of Commerce, Springfield, Va. 22151, U.S.A. Order No. TID-25465, 1971, 190 pp., $3.00, (95¢, microfiche).

This book, in the AEC Critical Review Series, was written by Dr. Plate while he was a visiting scientist at Argonne National Laboratory. There are four chapters:

1. The neutrally stratified boundary layer over uniform terrain.
2. The stratified atmospheric boundary layer near the ground.
3. Free-convection layer.
4. Two-dimensional disturbed boundary layers.

This book contains a considerable amount of useful information, although it is not intended to be a definitive text. Dr. Plate is a wind-tunnel modeler and his perspective on boundary-layer problems will interest the meteorologist.

For a number of years there has been a need for a survey on the physics of the atmospheric planetary (Ekman) layer. Dr. Plate has devoted much of his text to a discussion of this layer but he has diluted his efforts by including such topics as canopy flows and shelterbelt effects. As a result, some of his subsections are so abbreviated that they will be unintelligible to anyone not already familiar with the literature. As an example, the subsection on pages 65–66, "The energy equation with radiation heat transfer," is certainly not a critical review of that topic.

There are a number of misprints, the most notable of which occurs in the Table of Contents: "Convulsions and suggestions for future research." Nevertheless, the book is good value at a price of only $3.00.

R.E. Munn
Atmospheric Environment Service
Toronto

NUMERICAL WEATHER PREDICTION. By George J. Haltiner. John Wiley & Sons, Inc., Toronto, 1971, 317 pp., $10.95 (U.S.).

Haltiner's splendid new treatise will probably be recognized as the standard introductory textbook on numerical weather prediction for the next decade. The basic concepts and fundamental techniques of this rapidly growing science are explained in a clear and informative style, yet always with an admirable brevity which is perfectly suited to the needs of graduate students. The value of the book is enhanced by the fact that every effort was made to ensure that it would be as up-to-date as possible when it emerged from the printing presses. Two of the references are dated in 1971. And a few tantalizing remarks are inserted here and there to indicate the general direction of recent new work whose validity or significance was perhaps not yet universally accepted a year or so ago. For instance, on page 101 the stability of a semi-implicit time integration scheme is analysed without assessing any of the implications; and on page 163 the idea that computed condensation rates should somehow depend on closeness to saturation is advocated without any justification by scale arguments.

The first chapter reviews the governing equations and also contains a useful section on map projections. Unfortunately, the mathematics includes a few misprints and missing brackets which are not representative of the printing standards of the rest of the book. Chapter 2 deals with the different types of wave motion that can arise from the linearized equations, concluding with a discussion of the role of inertial gravity waves in the geostrophic adjustment process. Chapter 3 takes 20 pages to subject the meteorological equations to a scale analysis which is so well done that the reader might be persuaded the technique is a more precise tool than it really is. There are no words of caution, for instance, about applications to interacting systems which are of different scales. Chapter 4 expounds on the mathematically elegant subject of integral constraints. It is a pity page 78 eluded the proof readers. Chapter 5 disposes of numerical methods in a business-like fashion. However, more emphasis might have been placed on the notion that different terms of the same differential equation can and should be evaluated by different kinds of finite-difference schemes.

The important aspects of filtered equations models are covered quite thoroughly in the next three chapters. Chapter 6 is devoted to the barotropic model. Chapter 7, notwithstanding the title, deals only with two-level baroclinic models. And Chapter 8 introduces multi-level baroclinic models and explains how to impose the lower boundary condition. It is amusing to note that the logical development of this excellent material on filtered models is disrupted by the author's (doubtless belated) decision to include the results of some of his own work on the effects of surface friction. As his research was carried out with a two-level model he summarized his findings on friction in Chapter 7. Unfortunately, this precedes the theoretical treatment of surface friction which comes in Chapter 8.

Chapter 9 deals with moisture and radiation. Maurice Danard's long-wave radiation model is presented in some detail; also, Katayama's solar radiation model. Chapter 10 discusses the special problems of tropical forecasting, and concludes with a detailed account of Arakawa's technique for parameterizing cumulus convection.

The sigma system of co-ordinates is introduced in Chapter 11, but without pointing out the disadvantages of increasing the number of terms in the equations, or the drawbacks of having a vertical co-ordinate which is dependent on the horizontal resolution. The important problem of aliasing arises when non-linear equations are integrated numerically. Chapter 12 treats the non-linear instability associated with this phenomenon, and may therefore be regarded as the natural sequel to Chapter 5 which deals with computational instability in linear equations. Surprisingly, the author expands his treatment of advection schemes to include spectral methods, which some people would think worthy of a separate chapter. Obviously, news of the success of the fast Fourier transform method did not arrive in California before the data cut-off time for publication.

The book reaches the climax of primitive equations integrations proper in Chapter 13. The highlight, of course, is a fairly comprehensive description of the U.S. Weather Bureau's operational and justly famous six-level model. Equal coverage is given to the U.S. Navy model which is not yet operational and therefore somewhat less well-known. The principal characteristics of the four main General Circulation models are mentioned without going into very much detail.

The final chapter deals with assorted topics which escaped the subject matter classifications of the earlier portions of the book. These include objective analysis, initialization, and smoothing and filtering. Examples of numerical analyses and forecasts are contained in an appendix. The book concludes with a useful list of 208 references and an index.

There are some curious omissions from the book as a whole. No mention is made of predictability. Yet the various aspects of the predictability problem are collectively coming to be regarded as the most fundamental challenge facing numerical weather prediction. Interest in this controversial field has been steadily building up for over five years, so its exclusion must have resulted from a deliberate decision on the part of the author, and not from some kind of oversight. Presumably, the reason was that it was difficult to say anything without the risk of having it become obsolete almost immediately. Another glaring gap in the text is the failure to inform the reader about the existence of the Global Atmospheric Research Program (GARP). Perhaps GARP was avoided because it would open up the Pandora's box of predictability, and throw in the boundary layer besides. Or could it be that the U.S. Navy is not bubbling over with enthusiasm for civilian adventures on such a grand scale?

To sum up, this reviewer's critique does not amount to much more than a few minor differences of opinion over emphasis and content, and in no way detracts from the value of the book. "Haltiner" (without Martin) will find its way on to the bookshelves of most meteorologists sooner or later. This means a second edition can be expected in about five years.

David Davies
Atmospheric Environment Service
Montreal

CORRESPONDENCE

To the Editor:

I would like to comment on the proposed activities of the CMS Standing Committee on Public Information (*Atmosphere* **9**, pp. 125–127).

It is unfortunate that in the description of the Committee's activities, the emphasis was placed on publicizing the CMS as an end in itself, rather than on the publicity that would result from information-services provided by the CMS.

I believe that it would be worthwhile for the CMS to make public pronouncements within its area of competence. Such a course of action would bring the science of meteorology to the public's notice and perhaps, thereby, increase the public's knowledge about meteorology. It would also serve to correct false impressions created by the promulgation of false or incorrect meteorological information.

Given the existing range of positions, however, on the subjects which were listed, it would be impossible for the Committee on Public Information to issue a statement that would reflect the opinion of the entire membership. "The Private Automobile: Ultimate Absurdity?; Land Use Planning; Ecological 'Prophets of Doomsday' ". Opinions on these and most other controversial topics are polarized. I would not care to have the "opposite pole" speaking for me through an official pronouncement from the Society particularly when the matter is more political than scientific.

Further it was suggested that letters-to-the-editor be signed as members of the CMS only if cleared by the Executive. Would I seek out a like-minded executive for authorization? Would the complete Executive be required to reach a consensus? Would local CMS centres rule locally? I believe we would be placing the Executive in an impossible position asking them to act in this editorial cum censorial capacity. Nor should the membership permit it.

If the CMS is to play a role in the public arena, it should be as an impartial arbiter on questions that only involve meteorology.

Public statements by the CMS should be based on recognized, accepted, scientific investigations. They should present meteorological facts on pertinent scientific questions, and avoid interpretations or personal opinions. They should refute invalid opinions based on misinformation through the presentation of substantiated information.

With restrictive terms-of-reference of this type, I would be in favour of "immediate responses" by the Standing Committee on Public Information in areas where it sees fit.

Personal interpretations of the political and social ramifications of scientific issues should be presented and publicized; but by the individual meteorologist, not by the CMS trying to speak with one voice when it doesn't exist.

P.G. Aber
Atmospheric Environment Service
Toronto

To Chairman, CMS Standing Committee on Public Information:
The following points might be noted in connection with Phil Aber's letter to the Editor.

As stated in the article in *Atmosphere*, the objective of the Standing Committee is to advise the executive on "matters, within the concern of the Society, requiring the provision of information to the public in general, or to specific groups". In that context, the purpose of immediate responses is twofold: to provide information, and to establish the reputation of the CMS as a body to which the news media and others can turn for information on the atmospheric environment. This is hardly publicizing the CMS as an end in itself.

The proposal that the CMS confine its role to that of "an impartial arbiter on questions that only involve meteorology" would defeat the purpose of the exercise. Statements should deal with the meteorological aspects of controversial questions and should concentrate on factual information. However, the reason for controversy is differences of opinion on what the scientific facts imply for human decision making and/or differences of opinion on the weight that should be assigned to various factors. CMS statements, to be meaningful, will usually have to contain an interpretation of meteorological knowledge and will often involve the personal opinion of an expert. The objective is to make available to the public a competent, professional interpretation based on the present state of our knowledge of the atmospheric environment.

The reviewing of statements by the executive is designed to guard against extreme positions being taken in the name of the Society. This admittedly is a difficult task. It is not expected that statements will represent the views of all the members of the Society. If statements do not find approval with the majority of the members, democratic methods are available which would permit the membership to change policy in this area.

D.K. Smith
Atmospheric Environment Service
Toronto

To the Corresponding Secretary:

In 1970 the International Council of Scientific Unions (ICSU) established SCOPE (Scientific Committee on Problems of the Environment) to (a) advance knowledge of man's inter-relations with his environment with particular attention to those influences and effects which are either global or shared in common by several nations; (b) to serve as a non-governmental, interdisciplinary and international council of scientists to provide advice on environmental problems for the benefit of governments and intergovernmental agencies.

SCOPE's present programme includes:

1) A commission on monitoring charged with preparation of a design for a coherent Global Environmental Monitoring system;

2) A commission on an International Registry of Chemical Compounds to provide a wide range of information to encourage and facilitate research in environmental toxicology and to function as an early-warning system on environmental hazards;

3) A committee on Chemical Analytical Methodology for materials put out by man which may significantly alter the biosphere;

4) A working group on Modified Ecosystems to assess present scientific knowledge and public policy affecting tropical ecosystems;

5) A working group on Institutional Arrangements to consider organizational frameworks for the period following the United Nations Conference on the Human Environment, Stockholm, June 1972.

SCOPE has been asked for non-governmental scientific advice by the Secretariat of the Stockholm Conference and it is likely that the provision of scientific counsel and advice to intergovernmental and governmental agencies will continue in the Post-Stockholm period. SCOPE's primarily non-operational role will include the identification of research needs, the design and promotion of research programmes, and carrying out special studies (including studies in depth). SCOPE's international framework lends itself readily to the adaptations required for this assignment whereby the world's scientific community will be able to bring knowledge, science and technology to bear in a creative attack on priority problems of the environment.

Canada formed the Canadian National Committee for SCOPE (CNC/SCOPE) in the summer of 1971, with members from industry, universities and government, through the sponsorship of the National Research Council which is the adhering member of ICSU. As Secretary of CNC/SCOPE, I have been directed to inform all organizations and associations in Canada composed of scientists, engineers, and certain other professionals interested in problems of the environment, about the liaison role of SCOPE and CNC/SCOPE, as explained above. We might like to ask your members certain questions from time to time in fulfilling this on-going role, but we are not soliciting views on environmental matters in general.

We respectfully request that you inform your members about this channel of communication between Canada's scientific community and the intergovernmental community. Your comments and observations in helping CNC/SCOPE to better serve the Canadian scientific community in accordance with its mandate will be welcomed.

I. Hoffman, Secretary
CNC/SCOPE, NRC, Ottawa

NOTES FROM COUNCIL

The following were accepted as members by Council:
March 28, 1972

Member	Kurt V. Abrahamsson Richard Louis Cohn Edmund H. Dale	Douglas M. Leahey John M. Padovan George Edgar Piatt
Student Member	Frederick Joseph Herfst	Anwar Sultan Saddozai

April 26, 1972

Member	Ralph Harvey O'Brien James E. Ploc	Lyall Blanchard Swansburg Barrie James Wallworth
Student Member	Don Robert Inkster Donald Gordon Tatar	Ronald Whistance-Smith

May 23, 1972

Member	Pierre M. Chaîné Douglas Malcolm Dixon Norman Lyle Dressler John B. Elliott	Marianne English Edward Graeme Morrissey Arnold Pohl R.B. Saunders

Activities of the CMS Standing Committee on Public Information

A Reuter News Agency story which appeared in a number of Canadian Dailies on February 4th 1972 reported statements by Dr. Wernher von Braun to the effect that man will soon be in a position to exercise a high degree of control over day-to-day weather. The following is a typical presentation, from the Toronto Star:

Turning on the Sun

WEATHER CONTROL NEAR: SCIENTIST

HOUSTON (Reuter) – Dr. Wernher von Braun, the rocket pioneer and space visionary, predicted yesterday that within 25 years man will be able to control the weather so the sun will shine all day on some resorts and it will rain only at night.

"You could keep the tourist industry and the hotel men happy while the farmers are served at night," he told a news conference.

"These things may sound a little fantastic today, but I think they are entirely within the realm of the possible, at least in a limited, regional sense."

Von Braun is an administrator of the National Aeronautics and Space Administration. The German-born creator of the Saturn V moon rocket was listing some of the possible benefits from the U.S. space program, which he said was now settling down to realize its potential in the same way as the aviation industry after the first dramatic flights.

"The time of the great sensational feats is drawing to a close," von Braun said. "The space program is about to buckle down to business."

He said it won't be long before weather satellites begin to pay off financially, and this will lead to direct modulation of the weather.

He said satellites could eventually give a precise population picture of the entire world at any given time. Feed a computer with this information and "it could tell you exactly when to ship food to Bangladesh to avoid a famine there."

In the hope of bringing to public attention a more rational picture of the possibilities of weather control, the Committee invited Dr. A.D. Christie to prepare an article which would reflect the views of most informed scientists in this area.

The article prepared by Dr. Christie follows. Copies were forwarded to 107 Canadian Dailies under the cover of a press release, signed by the CMS President, requesting Editors to feature the article or at least quote from it.

Turning off the Stars

Dr. A.D. Christie

Reuter's news agency recently (4 Feb. 1972) assured a large audience for Dr. Wernher von Braun's tendentious, albeit naive, speculations on weather control as quoted from an address to students of the University of Houston. "Within 25 years man will be able to control the weather to the extent that the sun will shine all day on some resorts and it will rain only at night. You could keep the tourist industry happy while the farmers are served at night". Well, well!

Is it credulity or a keen sense of the sensational that persuades the press to swallow and regurgitate the indiscreet comments of our scientific virtuosi so avidly? Dr. von Braun's reputation as a rocket pioneer and space visionary is indisputable, but one would hesitate to consult a TV serviceman on neurosurgery – or vice versa. Imagination and innovation are at the root of creativity, but on the topic of weather or climate control Dr. von Braun's visions are more Disney than da Vinci. Were his controversial remarks purely intended to fire the interest of his student audience we might condone a soupçon of scientific licence. Could he, however, be rallying to the ecologists' banner when a space-race satiated electorate and Treasury show disenchantment, and are switching their fickle allegiance to 'quality of the environment'? As a meteorologist Dr. von Braun makes a fine weather vane – he senses well the winds of change.

There is no evidence to which I am privy that demonstrates faith can move either mountains or the atmosphere, so it behoves us to use scientific judgement in evaluating the dream of a "philosophers' weather stone" for generating golden days and nocturnal rain clouds with their agronomers' silver lining.

Weather comprises organized patterns of winds, temperatures, cloud, fog and precipitation. Weather control implies an ability to alter these patterns in space and time arbitrarily. The size and duration of the particular element of the atmosphere that we wish to control is an extremely important factor in assessing the possibility of effecting control over that element. Different physical processes control the nature of local and of global weather patterns.

Some limited success has been claimed in modifying a few special local phenomena (runway radiation-type fogs, hail, and regional rainfall distribution of orographic and convective type by cloud seeding, etc.) whose duration and size are individually small in global terms. It should, moreover, be clearly understood that the changes in the regional average precipitation patterns at least are barely detectable from 'normal' atmospheric variability though quite substantial changes in relation to selected cloud cells have been demonstrated. Moreover these cannot yet be interpreted unequivocally in terms of the processes controlling formation and growth of ice crystals and droplets.

By far the most influential weather patterns, however, are the cyclone-anticyclone vortex systems of continental scale that dominate all but subtropical regions on a global scale. The character of those systems is controlled by the nature of the global energy inputs and the earth's constant rate of rotation. It is, therefore, self evident that only by altering the distribution of global energy sources and sinks could we alter the character of the major large-scale weather systems. Any such alteration might conceivably change the size, number and intensity of such storm trains.

The criterion to meet the requirement for sunny days and rainy nights on a global scale is indeed fantastic. To quote an adage – and a physical law of continuity, – "what goes up must come down". In our atmosphere where the source of water is at the earth's surface and the temperature decreases with height, saturation and precipitation are generally associated with rising motion. The required pattern of rising and sinking air could only be consistently satisfied by a bipolar, stable, periodic pattern that progresses westward in a sun-synchronous fashion.

Many factors militate against man ever being in a position to redistribute arbitrarily the atmospheric heat sources and sinks to produce such a circulation pattern yet simultaneously satisfy the constraints of momentum, mass and composition balance. This is particularly so when only a few practicable ways to attempt to change the energy distribution exist. The inputs of sensible and latent heat from the surface may be changed by altering the terrain. The release of latent heat may be adjusted by appropriate cloud seeding. Finally the distribution of the radiatively important constituents in the free atmosphere may be augmented directly, or through the selective introduction of an appropriate substance whose effect in the relevant photochemical reaction scheme would contribute to the desired change of composition. The alteration of one factor in the atmospheric circulation leads to a complex chain of feed-backs in other processes that are, as yet, inadequately understood. Pending a much more extensive understanding of the complex coupled manner in which these processes interact it would be folly to propose attempting to produce these apparently simple patterns of weather, even if that were possible, before being convinced that the coupled changes (side effects) in other environmental factors would not be totally unacceptable. The medical profession can show us a profusion of examples in this respect. Without due care the atmosphere could be our ultimate guinea pig!

Returning to control of phenomena of local character then, to the extent that they are sub-elements in the global weather patterns, they both influence and are governed by the latter. Control of local events by seeding currently attempts intervention in the droplet growth phase of the cloud physics sequence, and in the case of hail suppression by selectively controlling the site of latent heat release by hail stone melt producing a local change in the convective stability, rather than modification of the large-scale meteorological conditions conducive to their development. Such criteria as the requirement for convectively unstable air combined with wind shear with height for cumulus cloud growth, rain and hail; and that for high pressure, light winds and sinking air for fog, are not markedly affected except locally by the seeding processes. Moreover control by seeding requires, as a prerequisite, that the meteorological conditions for initiation of appropriate cloud growth already exist. The establishment of these is attributable in the main to the large-scale circulation. Unless we can influence the latter, then, in a fashion that effectively establishes, on demand, the necessary criteria for the formation of the local fog and cloud phenomena, our ultimate control of the events themselves is illusory.

The outlook is not entirely bleak. There is good reason to believe that man may learn to manipulate his environment to the extent of altering the global statistical weather patterns, that is, the local or regional climate. The latter may be described in terms of probability distributions (stochastic patterns) for a variety of weather parameters. The statistics will be related to the nature of the weather patterns in the atmospheric circulation and, just as we now expect a certain quantity of rain from cumulus cloud in a given locale without being in a position to specify the location and intensity of rain associated with a specific cloud, we may well learn to modify the global energy inputs in a way that would alter regional climate. To provide an arid region with sufficient water to raise a basic crop may be equally meritorious, if less ambitious, than von Braun's pipe dream, though we dare not neglect the dangers of "robbing Peter to pay Paul". What are our territorial rights in the atmosphere?

Modification or control of the weather, on the scale discussed here, is an awesome matter since injudicious tampering with the atmosphere itself could result in deleterious, possibly irreversible, effects. For this reason it is essential that we extend our capability to model the earth-atmosphere system by mathematical techniques. Computer simulation by numerical methods gives promise of permitting us to predict the effects of introducing arbitrary changes in the environment in theory, before our fate is irrevocably sealed.

A reliable, accurate and global set of meteorological information is a prerequisite for development and testing of these models, as well as for the more immediate Global Atmospheric Research Program (GARP) which aims to improve the quality, and extend the range of meteorological prediction during the coming decade. Satellite remote sensing systems have evolved as invaluable observational tools, in many respects without peer, to facilitate these studies.

NASA has a reputation about which it may be justifiably proud in development and utilization of its satellite facilities for acquiring information that can contribute fundamentally and extensively, though indirectly, to man's control of his environment. Sensationalist claims, however, may well damage the reputation of the atmospheric sciences, even though they result in a short term bonus to von Braun's budget.

The press release and article were mailed out on March 14. It would be appreciated if members would advise the Committee if they have seen newspaper items based on the release. A number of newspapers have printed or quoted from the article.

An opportunity for CMS members to interest high school students in meteorology has come to the Committee's attention. Mr. K.H. Clark, the CMS representative to the Youth Science Foundation, has advised that the quarterly magazine *Science Affairs* could use easy-to-read articles on meteorological subjects.

Articles most in demand seem to be those which describe projects that can be carried out by students either singly or in cooperation. Members interested in contributing to *Science Affairs* should contact Mr. Clark (20–49 Tawny Rd., Ottawa K1G 1B8).

H.B. Kruger, Chairman
CMS Standing Committee on
Public Information.

Canadian Meteorological Society Brief

At the invitation of the Canadian Preparatory Committee for the U.N. Conference on the Human Environment (Stockholm, June 5–16, 1972), the following brief was submitted in April on behalf of the CMS.

Meteorology is the science of the atmosphere and of its interaction with the land-water interface. It is much more than Weather and Weather Forecasting. It is a vital scientific discipline concerned with or involved in all problems of the human environment. Interdisciplinary research in environmental problems must include meteorology, a fact often ignored or forgotten by environmentalists and ecologists. Interdisciplinary research programs must be coordinated on an international level. There is an urgent need for an international institutional framework to integrate the efforts of environmental specialists, possibly through interdisciplinary computer simulation modelling projects. Meteorology, which has undoubtedly the finest and longest record of international cooperation, can lead the way.

The world-wide weather networks, presently being improved by the World Weather Watch (WWW) program of the World Meteorological Organization (WMO), can serve as valuable monitoring networks for various environmental indicators. Meteorologists with much experience in the problem of analysis and prediction of meteorological parameters on a global scale, by highly sophisticated mathematical techniques, can bring their skills and experience to bear on the analysis and prediction of other environmental parameters.

The WMO and associated member countries are currently embarking on the most extensive international global research program ever attempted – The Global Atmospheric Research Program (GARP). This program requires extensive and positive support of all countries if it is to succeed. The success of GARP could lead to a solution of many of the problems of weather prediction and the prediction of climatic change and to the ability to simulate in a computer the climatic effects of man's activities.

Major climatic studies are needed to understand the environmental impact of large-scale man-induced influences such as the destruction of forests, land uses, water exploitation, etc. Acquisition of data and the development of predictive models to permit the quantitative prediction of changing atmospheric conditions on both macro- and micro-scales are essential to ensure adequate consideration of meteorological and climatic factors in ecological-environmental planning and regional development. Further, weather-climate information must be immediately available to provide information necessary to combat small-scale disasters.

We express some concern that economic planning and economic aid are not coordinated with environmental and ecological planning. For example, Canada provides economic aid to developing countries to establish new industries, atomic power plants, etc., but without participating in ecological or environmental planning to ensure that old mistakes are not simply multiplied and repeated. No effective air pollution studies or ecological studies are ever made before carrying out these industrialization projects. The impact on the environment of new industrial developments must become a primary concern of governments.

The science policy of governments must be arrived at through complete participation of scientists. Science budgets must not be simply allocated to what may be described as largely developmental activities. The need is for basic research completely unencumbered by the status quo. Seemingly unsolvable problems require completely new ideas which might lead to a completely new direction to man's progress.

Education is of great importance in our increasingly complex society. However, an education system which skirts environmental problems is not likely to lead to an enlightened opinion or responsible conduct with respect to the environment. The fact is that education in atmospheric and environmental sciences is woefully lacking in our high schools and universities. Special educational projects should be supported to correct this deficiency particularly as the atmospheric sciences will be the interdisciplinary link in most environmental problems.

C.M. Penner,
President,
Canadian Meteorological Society

REPORTS

SOMAS Meeting 22 February 1972

The Sub-Committee on Meteorology and Atmospheric Sciences held its 24th meeting in Ottawa on February 22, 1972. The committee received reports from the GARP Coordinating Committee and the GARP Scientific Committee.

The GARP Coordinating Committee has been successful in securing financial support from the National Research Council for the GARP activities of the International Council of Scientific Unions. It has also been designated as a grant award committee within NRC for GARP oriented research proposals, and for this function it will augment its membership by the addition of two members from the university community.

The GARP Scientific Committee recommended that there be a Canadian ship to participate in the GARP Atlantic Tropical Experiment (GATE) and noted that there is a need for fellowships in order to strengthen the participation of Canadian scientists in the GARP sub-programs, notably, the Air Mass Transformation Experiment (AMTEX) to be performed off the coast of Japan.

Friends of Climatology – 1972

The 1972 meeting of the Friends of Climatology was held in Toronto on Friday and Saturday, March 10 and 11. Co-sponsors of this year's meetings were the Atmospheric Environment Service Headquarters and the Centre for Research on Environmental Quality at York University. The theme of the meetings was *Climate and the Biosphere*, and 66 Friends registered for the sessions which were held in suburban Downsview at both York University and AES Headquarters.

Earlier, Friends of Climatology meetings had been held in 1970 at the University of Windsor, and at McMaster University in Hamilton in 1971. It is expected that the 1973 meeting will be held in Montreal, and that arrangements will be made by Friends at McGill and other universities in the area.

The featured speaker at the 1972 meetings was Professor G. Courtin of Laurentian University, who described his climatological and biological research programs on Devon Island, N.W.T.

A major objective of the Devon Island program is to develop predictive models which can be used to assess the probable impact of man as well as aid in the overall understanding of biological productivity. Since energy received via the atmosphere is a major input into the model, a meteorological network has been established to sample the conditions on three major land forms within the experimental area. The area was selected because of the land forms which enable researchers to measure migrations into and out of the area with greater than average precision. Foehn winds were a striking phenomenon afflicting the area. These have produced "flash flooding" with disastrous effects on the lemming population and also on measuring programs.

During the ensuing evening session three presentations were heard. Dr. W. Rouse of McMaster University described a field investigation of evaporation from an expanse of lichen in the James Bay area. A very high correlation was obtained between estimates obtained using the Bowen Ratio and an equilibrium model, indicating the utility of the model for estimating evaporation where diffusion resistance is the major factor as is the case with non-vascular plants such as lichen.

Dr. W. Frisken of York University disclosed that although man's present input into the earth's heat balance was trivial compared to the solar input, nevertheless if the present rate of increase continues a 1:1 ratio would be achieved in only 245 years. The present rate of heat input in the Lake Ontario area is much above the global average. Its probable impact would be to reduce the summer lake breeze and increase the severity of winter "lake" storms and the stability of the urban heat island.

Dr. R.E. Munn of the Atmospheric Environment Service introduced the subject of scale and emphasized the need for model studies. He observed that while meteorologists are tending to go from micro- to regional scales, the geographer-climatologist is doing the reverse. Many of today's vital environmental issues relate to engineering works of sufficient magnitude to upset the regional scale climate – these should be preceded by a critical evaluation involving model studies.

The meeting terminated with the impression that Climatology was no longer the "Cinderella science". It has a major role to play in the resolution of a vast array of problems relating to the biosphere – environmental, social, economic and political.

Centre de Québec – Rapport Annuel

L'assemblée générale du 24 avril dernier a couronné la huitième année d'existence de la Société de Météorologie de Québec et sa troisième année en tant que Centre de Québec de la Société météorologique du Canada. Voici un résumé des activités qui ont eu lieu depuis un an.

Six réunions d'information ont été présentées, dont voici les conférenciers et les titres dans l'ordre chronologique:

1er octobre 1971 : M. André Boucher
"Le développement hydro-électrique de la Baie James"

19 novembre 1971 : Dr. Walter Hitschfeld
"L'étude de la grêle à l'aide du radar"

7 décembre 1971 : M. Léo Lejeune
"L'extinction des feux de forêt"

18 janvier 1972 : M. Pierre Gosselin
"Mesure automatique de la neige"

14 mars 1972 : MM. C. East, A. Hufty et L. Lapointe
"L'atmosphère et la pollution"

4 avril 1972 : Dr. Maurice Danard
"Le rôle de la météorologie dans l'aménagement intégré d'un bassin versant"

La réunion où monsieur André Boucher a adressé la parole a attiré une assistance record (environ 175 personnes).

Quatre réunions du Conseil d'administration ont abouti aux réalisations suivantes:

a) Promotion de l'enseignement de la météorologie en français au Québec (grâce au travail de vos membres, des pressions ont été exercées sur les autorités de l'Université du Québec et nous pouvons annoncer comme premier résultat concret la mise en marche d'un programme de cours de météorologie au niveau du premier cycle à l'Université du Québec à Montréal),

b) Impression d'une carte de membre et de papier à correspondance identifiés par le nouveau sigle de la Société de Météorologie de Québec.

Cette année, quatre réunions d'information ont eu lieu à la Faculté d'Agriculture de l'Université Laval, les deux autres au Centre audio-visuel de la Commission des Ecoles catholiques de Québec, conjointement avec la Société Linnéenne de Québec. Nous tenons à remercier le docteur L.-J. O'Grady pour avoir mis les locaux du Département des Sols à notre disposition.

Les registres de notre Société comptent pour l'exercice qui prend fin, 31 membres-cotisants.

Le nouveau Conseil élu à l'assemblée générale se compose ainsi:

Président:	Raymond-M. Gagnon	
Vice-président:	Dr. André Hufty	
Conseillers:	Robert Boudreault	Léandre LeBlanc
	Michel Ferland	Guy Lemelin
	Antoine Hone	
Secrétaire-trésorier:	Gaétan Soucy	

M.F.

Toronto Centre

ENVIRONMENTAL CRISIS – REAL OR IMAGINARY?

On the evening of February 16, 1972, AES Headquarters was the scene of a lively meeting of the Toronto Centre in which a panel discussed the problems of communication between environmental scientists and the general public (including policy-makers). The question was whether or not scientific research had any effect upon policy-making and the motivation of the general public to improve the environment. The panel, consisting of Mr. R. Keir of the Ontario Dept. of the Environment; Mr. Brian Kelly of *Pollution Probe*; Dr. P.H. Jones of the University of Toronto; Mr. J.P. Bruce, Director, Canada Centre for Inland Waters and "Tiny" Bennett of the *Toronto Sun* was chaired by Dr. P.D. McTaggart-Cowan of the Science Council of Canada, lately of "Arrow" fame.

There was a general feeling among the panelists that communication between scientists and the public was inadequate and often did not motivate the man on the street to help in improving the environment. Mr. Keir stated that the news media were not doing as much as they should to provide expert information, perhaps because of a lack of money. Rising to the bait, "Tiny" Bennett reported some amazing episodes in which he, as a newspaperman, attempted to obtain environmental data from government scientists. These missions were usually carried out in smokey pubs and frosty telephone booths in Ottawa. Mr. Keir countered that he had never been instructed to unlawfully withhold information, although he admitted that the results of certain surveys were not immediately disclosed, since those involved were protected by law.

Mr. Bruce outlined some of the problems involved in using results of scientific research in policy-making. The trick is to know when you have just enough scientific evidence to make a decision but, unfortunately, the public often doesn't want to wait. Mr. Bruce maintained, however, that results of research had been used to give impetus to regulations regarding phosphates. (As an aside, Mr.Bruce brought up the interesting point that the general public should have access to beaches and waters that have been cleaned up at public expense.)

Dr. Jones emphasized the need for more public education and particularly the need for "teaching the teachers". Because of general ignorance about the environment, polarization of hard line attitudes had arisen between activist groups and industries, both of which were working to improve the environment! He maintained that we had to "humanize the scientists and scientize the humanists". He felt that, even if they were depressing, conflicting scientific views should be presented to the public to keep them in the picture.

Mr. Kelly stated that we are heading towards an environmental crisis at this time and that action must be taken before we reach it. He then showed some slides of the results of a study by the "Club of Rome," carried out at the Massachusetts Institute of Technology. A computer model made generally pessimistic predictions of world population, natural resources, pollution and the quality of life and indicated that averting an environmental crisis would require the careful manipulation of many factors such as population and resources and not just one or two.

The several wide-ranging questions from the audience of approximately 260 indicated that, although there was genuine concern for the environment, there were many misconceptions. The general consensus after the question period was that more environmental courses for adults should be given at low cost in local high schools by teachers qualified in the field. This would be the most direct means of bridging the present communications gap.

R.W.S.

ANNOUNCEMENTS

Third International Clean Air Congress

The 3rd International Clean Air Congress will be held at Düsseldorf FRG, August 27–31, 1973, in order to foster an exchange of know-how and experience in the different fields of air pollution control. Emphasis will be placed on the interdisciplinary approach to clean air. The Congress is promoted by the International Union of Air Pollution Prevention Associations (IUAPPA).

Fields of interest for presentation are:

Principal Subjects

Means and technical methods for the reduction of air pollution in heavily polluted regions

Ways of controlling air pollution in new paints (including design of technical and administrative regulations)

Clean air through new technologies (pollution-free plant, harmless raw materials and products)

Education and training; public relations

Profile Subjects

Influence of meteorological factors on air pollution

Physics and chemistry of atmospheric pollutants

Criteria for the determination of the effects of air pollution (effects on health, animals, vegetation and materials)

Air quality criteria and standards

New systems of measurement (emission and environment)

State of differing national legislation: the technical and economic consequences resulting therefrom

Role of fiscal policies and taxation in fighting air pollution

Clean air through regional and urban planning

Arranged by Branch Subjects

Combustion for domestic heating and industries

Combustion in power stations

Air pollution from road vehicles and aircraft

Mining (including processing, e.g., coking plants, briquette factories)

Cement, lime, brick and ceramic industries and building techniques

Iron and steel industry, nonferrous metal smelters, remelting works, foundries
Chemical industry
Petrochemical industry, refineries
Agriculture and animal husbandry
Waste disposal and recovery

Correspondence about the organization of the Congress or publication of the proceedings should be addressed to:

Secretariat,
4 Düsseldorf 1, Graf-Recke-Strasse 84
VDI-Haus, FRG

National Meetings of the American Water Resources Association

October 30–November 3, 1972

EIGHTH AMERICAN WATER RESOURCES CONFERENCE, St. Louis, Missouri.
Sponsored by AWRA in cooperation with other national scientific societies.
Contact: Dr. Terrence Harbaugh, General Chairman, Associate Professor, Department of Civil Engineering, University of Missouri, Rolla, Missouri 65401.
(Papers by invitation but mainly by contribution. Participation open to members and non-members.)

March, 1973

NATIONAL SYMPOSIUM on *Remote Sensing of Water Resources*
Sponsored by AWRA.
Contact: Dr. Robert K. Lane, General Chairman, Head, Physical Limnology Section, Canada Centre for Inland Waters, Burlington, Ontario, Canada.

Fall, 1973

NINTH AMERICAN WATER RESOURCES CONFERENCE, Seattle, Washington.
Sponsored by AWRA in cooperation with other national scientific societies.
Contact: Dr. Stanley P. Gessel, General Chairman, Associate Dean and Professor, College of Forestry, University of Washington, Seattle, Washington 98105.
(Papers by invitation but mainly by contribution. Participation open to members and non-members.)

INFORMATION FOR AUTHORS

Articles may be contributed either in the English or French language. Authors may be members or non-members of the Canadian Meteorological Society. Manuscripts for *Atmosphere* should be sent to the Editor, *Atmosphere*, P.O. Box 41, Willowdale, Ontario. After papers have been accepted for publication, authors will receive galley proofs along with reprint order forms.

Manuscripts for *Atmosphere* should be submitted in duplicate, typewritten with double-spacing and wide margins, each page numbered consecutively. Headings and sub-headings should be clearly designated and distinguished. Each article should have a concise, relevant and substantial abstract.

Tables should be prepared on separate sheets, each headed with a concise explanatory title and number.

Figures should be provided in the form of two copies of an original which should be retained by the author for later revision if required after review. A list of legends for figures should be typed separately on one or more sheets. Authors should bear in mind that figures must be reduced for reproduction, to be printed alone or with other figures. Labelling should be made in a 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, and adequately identified. 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 they are 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. Forms of abbreviation may be obtained by studying past issues of *Atmosphere*.

Italics should be indicated by a single underline.

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.