ISSN 1195-8898

CMOS BULLETIN SCMO

Canadian Meteorological and Oceanographic Society

La Société canadienne de météorologie et d'océanographie

December / décembre 1999

Vol. 27 No. 6

CMOS Bulletin SCMO

"at the service of its members
au service de ses membres"

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Cover page: Emissary fall sky in Ottawa with Cirrus fibratus often forming high up in the troposphere, close to the tropopause. Upper troposphere cirrus has been suggested as a factor in midlatitude ozone depletion, and is therefore a possible climatic link between the troposphere and stratosphere (cf. article *The Stratosphere and Climate*, by Prof. Theodore G. Shepherd on page 174).

Page couverture: Ciel annonciateur d'automne sur Ottawa, montrant des Cirrus fibratus qui se forment souvent très haut dans la troposphère, près de la tropopause. On soupçonne les cirrus élevés d'être impliqués dans la déplétion de l'ozone aux latitudes moyennes, et donc un lien possible entre la troposphère et la stratosphère (cf. l'article par le prof. Theodore G. Shepherd, *The Stratosphere and Climate,* à la page 174).

....from the President's Desk

Two of the priorities I mentioned at the beginning of my term as President were to improve the visibility of the Society and to increase its involvement in public education and lobbying for science. A number of things have taken place in both of these areas.

Representatives of CMOS recently met with Director General of Policy and Corporate Affairs for AES, Nancy Cutler, and other senior AES officials and agreed on enhanced cooperation on public outreach matters. This will include a special session at the next CMOS Congress in Victoria.

CMOS has agreed to assist AES's Eldon Oja in organising for next summer a pilot session for high school teachers of meteorology, modelled on the US's Project Atmosphere. Project Atmosphere is sponsored by the USNWS and the AMS. It would be great to have a Canadian version established and CMOS welcomes this AES initiative. CMOS, through its link with the Canadian Council for Geographic Education (CCGE), can provide publicity and promotion and contacts with experts, as well as contacts with the high school geographers who teach meteorology. CMOS and CCGE each year jointly sponsor the attendance of a Canadian teacher at Project Atmosphere. CMOS's new Committee on School and Public Education has an obvious role to play here as well.

The Partnership Group on Science and Engineering for the past few years has held on Parliament Hill a series of events known as "Bacon and Eggheads". MPs, Senators and their staffs, senior bureaucrats and the media are invited to share breakfast and to listen to lectures by leading scientists in a variety of fields. We hope that in the process they will absorb some enthusiasm for science, an understanding of the accomplishments of leading Canadian scientists and a sense of its importance to the welfare of all Canadians. The series was started in May 1998 with a lecture on climate change from University of Victoria oceanographer Prof. Andrew Weaver. On 16 November 1999 York University atmospheric chemist Prof. Diane Michelangeli spoke on the linkages between a number of atmospheric issues and the interdisciplinary challenges that these issues pose. Past-President Bill Pugsley and Vice-President Peter Taylor arranged Diane's participation at very short notice and Diane rose to the challenge with an excellent overview for the assembled parliamentarians. The event was well attended and the audience included a record number of MPs and several well-known reporters.

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Inside / En Bref

Printed in Ottawa, Ontario, by M.O.M. Printing
Imprimé sous les presses de M.O.M. Printing, Ottawa, Ontario.

By the time you read this, Greg Flato will have completed the last of his CMOS/CICS lectures in the west and Bob Schemenauer will have completed his initial swing through the eastern centres for the 1999/2000 CMOS/AES travelling lectures. CMOS is very grateful to the Atmospheric Environment Service for financial support for Dr. Schemenauer's tour. This is in addition to the annual grant that CMOS receives from the AES.

Once again, I remind all of John Reid's call for members for a planned new Special Interest Group (SIG) to promote the highest quality of weather services for Canadians. Here is a chance to get involved. Contact John via e-mail at jedr@intranet.ca or by regular mail (57 Vanhurst Place, Ottawa, ON K1V 9Z7).

Ian D. Rutherford
President / Président
CMOS / SCMO

Typos

Two typos errors have been noticed in Table 1 of "UBC Neural Network Model Forecasts another La Niña Winter", by William W. Hsieh and Benyang Tang *(CMOS Bulletin SCMO, Vol.27, No.5, page 144)*. For the period 1950-59, the correlation skill at 15-month lead time should be '0.08', not '8' as printed. For the 1960-69 period, the skill at 3-month lead time should be '0.78', not '78'. The corrected table is shown below:

Test period	3-month	6-month	9-month	12-month	15-month
1950-59	0.72	0.53	0.4	0.36	0.08
1960-69	0.78	0.63	0.57	0.55	0.43
1970-79	0.91	0.77	0.72	0.66	0.51
1980-89	0.85	0.73	0.66	0.71	0.77
1988-97	0.85	0.69	0.51	0.56	0.55
1950-97	0.83	0.67	0.56	0.54	0.42

Table 1. Cross-validated correlation skills for various test periods

Traducteur de réserve

La SCMO recherche un traducteur anglais-français de réserve, pour des résumés dans *Atmosphere-Ocean* et le *CMOS Bulletin SCMO*, de même que pour des textes de nature générale.

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Next Issue - Prochain Numéro

Next issue of the *CMOS Bulletin SCMO* will be published in February 2000. Please send your articles, notes, reports or news items at the earliest to the address given at page ii. We have an **URGENT** need for your article.

Le prochain numéro du *CMOS Bulletin SCMO* paraîtra en février 2000. Prière de nous faire parvenir au plus tôt vos articles, notes, rapports ou nouvelles à l'adresse indiquée à la page ii. Nous avons un besoin **URGENT** d'articles.

Oups!!!

Malheureusement, une erreur s'est glissée lors du processus d'impression du *CMOS Bulletin SCMO*, Vol.27, No.5. La description de la page couverture indiquée à la page ii n'était pas la bonne. La description aurait dû se lire comme suit:

Page couverture: Image radar CAPPI 2 km montrant une supercellule de précipitation intense seulement 25 km au nord-nord-est de l'aéroport de Saskatoon (YXE), à 7:45 PM le 4 juillet 1996. Les couleurs indiquent les valeurs de la reflectivité en dBz, du bleu pâle, 13 dBz, au rouge, 46 dBz, puis au pourpre, 50+ dBz. RDF indique la position du courant descendant de l'arrière flanc, T la position de la tornade, FFD la position du courant descendant de l'avant flanc, RIN et flèche indiquent le jet d'air capté à l'arrière, et le flux capté par l'orage est indiqué par INFLOW et une flèche. Pour plus de détails, lisez l'article à la page 137.

Nous nous excusons auprès de l'auteur, Steve Knott, et auprès de nos lecteurs.

Oops!!!

Unfortunately, during the printing process of the *CMOS Bulletin SCMO*, Vol.27, No.5, a mistake was made. The description of the cover page as shown on page ii was not the right one. The description should have been:

Cover page: 2-km CAPPI radar image showing a High Precipitation Supercell just 25 km north-northeast of Saskatoon Airport (YXE) at 7:45 PM 04 July 1996. Colours indicate reflectivity values in dBz, from light blue, 13dBz, to red 46 dBz to purple 50+ dBz. RFD signifies location of rear flank downdraft, T indicates tornado location, FFD indicates forward flank downdraft of storm, RIN and arrow signify Rear Inflow Jet and thunderstorm inflow is indicated by arrow and INFLOW. For more details, please read the article on page 137.

We apologize to the author, Steve Knott, and to our readers.

Paul-André Bolduc
Editor, CMOS Bulletin SCMO.

"Spring - Slippy, drippy, nippy.
Summer - Showery, flowery, bowery.
Autumn - Hoppy, croppy, poppy.
Winter - Wheezy, sneezy, breezy."

- A satirical mistranslation of the names given to the months at the time of the French Revolution - G.F. Chambers.

Changes in Precipitation Patterns in Halifax, Nova Scotia 1890 - 1998

by Paul Mandell[1]

Résumé: Le Rapport sur l'état de l'environnement nº 95-1 (1995) a fait l'hypothèse que "les variations des configurations dans la distribution saisonnière ou régionale des précipitations, par exemple, ou dans la répartition de la pluie ou de la neige, peuvent être plus utiles pour déterminer les causes possibles (de l'augmentation des précipitations comme la cause d'un réchauffement climatique) du système climatique. Toutefois, pour identifier de tels changements, il sera nécessaire d'avoir beaucoup plus d'analyses de données climatiques." (voir page 36). Afin d'étudier si les configurations de la pluie et de la neige ont été modifiées en raison d'un réchauffement climatique en Nouvelle-Écosse, on a obtenu d'Environnement Canada un ensemble de données mesurant: la précipitation, la chute de neige totale, la moyenne des températures mensuelles, la chute de neige totale et la précipitation totale pour 109 années de la même station à Halifax, en Nouvelle-Écosse. Ces données ont été analysées en vue de changements possibles de la configuration saisonnière des précipitations.

Introduction

State of the Environment Report No 95-1 (1995) hypothesized that "variations in other patterns - in the seasonal or regional distribution of precipitation, for example, or in the proportion of rain or snow - may be more useful in pointing to possible causes (of increased precipitation as effect of a warming climate) within the climate system. However, identifying changes of this kind will require considerably more analysis of the climate data." (pg. 36)

In order to investigate whether patterns of rain and snowfall have shifted as a result of a warming climate in Nova Scotia, a data set which measured total rainfall, mean monthly temperature, total snowfall and total precipitation for 109 years from the same station in Halifax, Nova Scotia was obtained from Environment Canada. This data was analyzed for possible shifts in seasonal patterns of precipitation.

Results and Discussion

Figure 1 shows moving average mean monthly snowfall (1890-1998) with trend line. The trend appears downwards but is not statistically significant using the Mann-Kendall test for trend (Gilbert, 1987).

Figure 2 shows the moving average mean rainfall per month from 1890-1998. The trend is not statistically significant. The total rainfall has not changed significantly in Nova Scotia since 1890.

Figure 3 demonstrates, however, that the pattern of rainfall has shifted in Nova Scotia with a statistically-significant trend ($p<0.05$) towards more rain falling in the winter. In order to investigate the strength of this shift, a dimensionless ratio of rain/snow was computed for each month in winter from 1890-1998.

Figure 4 shows a moving average of this ratio of snow/rain with a trend line indicating a steep increase in the ratio of rainfall to snowfall in winter in Nova Scotia. The trend is significant ($p<0.01$).

Figure 5 shows that rainfall in the summer has decreased significantly ($p<0.01$) in Nova Scotia since 1890.

The data on rainfall and snowfall seems to indicate the following trends:

1) more rain falling in winter;
2) less rain falling in summer.

Having delineated a trend towards shift in precipitation in Nova Scotia, the data was analyzed to determine if there were temperature changes that might account for the observed shifts in precipitation.

Trends in monthly temperature were analyzed from 1890 to 1998. Figure 6 shows the moving mean yearly temperature in Nova Scotia since 1890. The trend is upwards and statistically significant ($p<0.01$).

The trends for mean monthly temperatures from 1890 to 1998 were upward and statistically significant ($p<0.05$) using the Mann -Kendall test for trend for all months of the year with the exceptions of October and January.

[1] Dalhousie University, Department of Earth Sciences, Halifax, N.S.

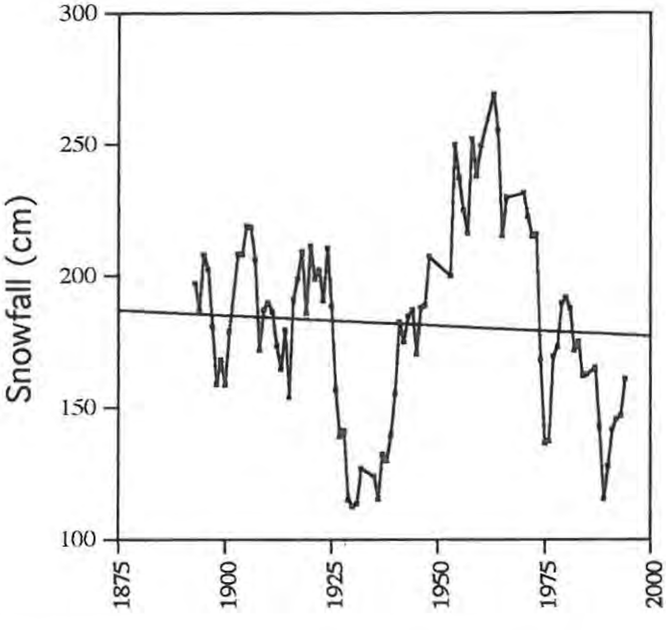

Figure 1: Moving Average of Mean Snowfall (1890-1998) with trend shown as a continuous straight line.

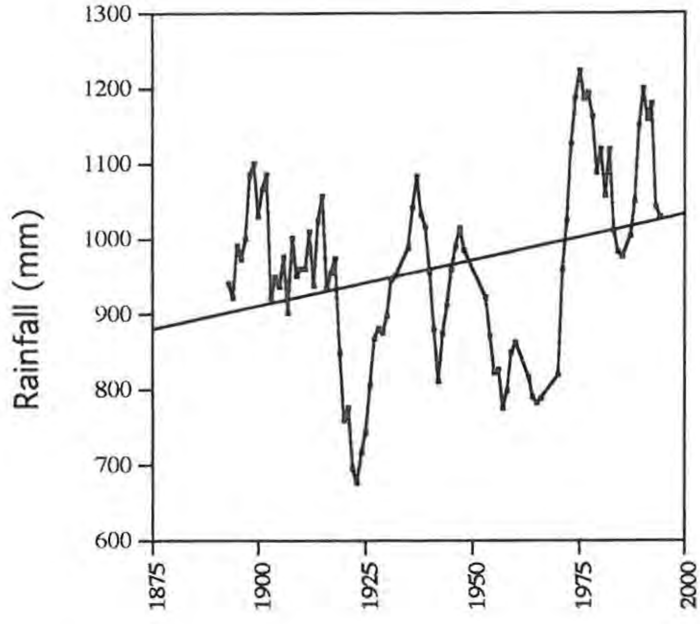

Figure 3: Moving Average of Rainfall in Winter (1890-1998) with trend shown as a continuous straight line.

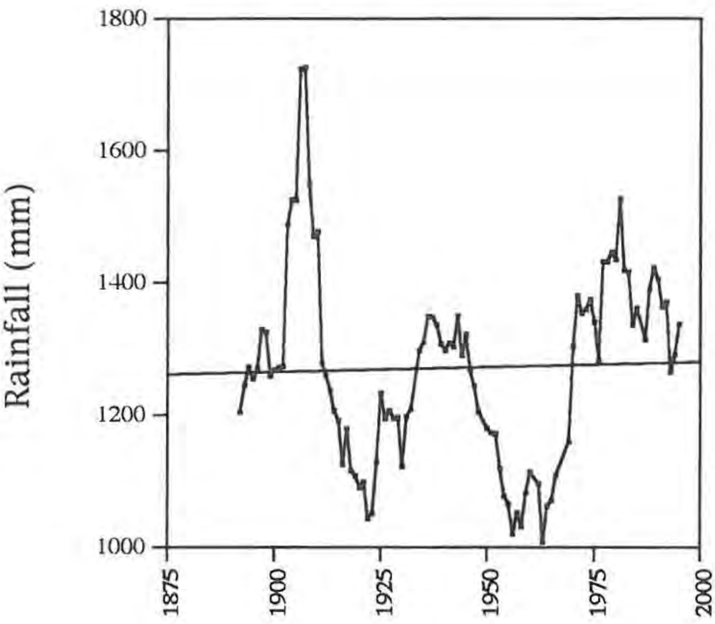

Figure 2: Moving Average of Mean Rainfall (1890-1998) with trend shown as a continuous straight line.

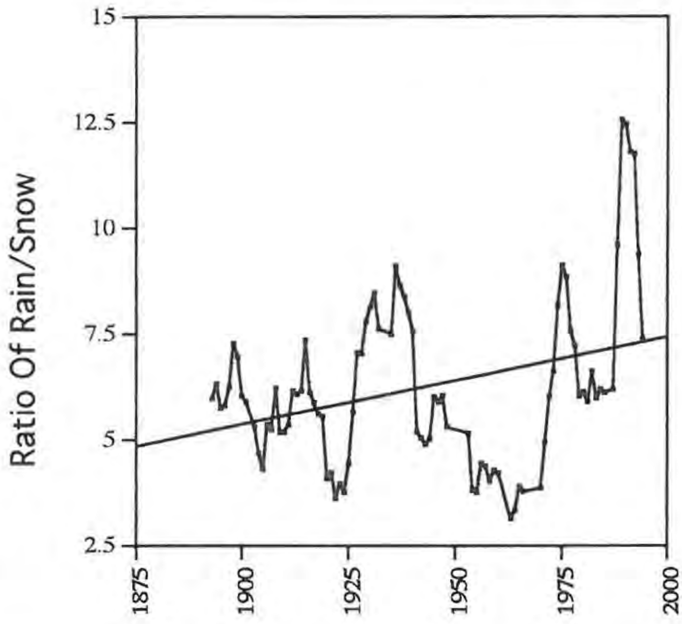

Figure 4: Moving Average of Ratio of Rain / Snow (1890-1998) with trend shown as a continuous straight line.

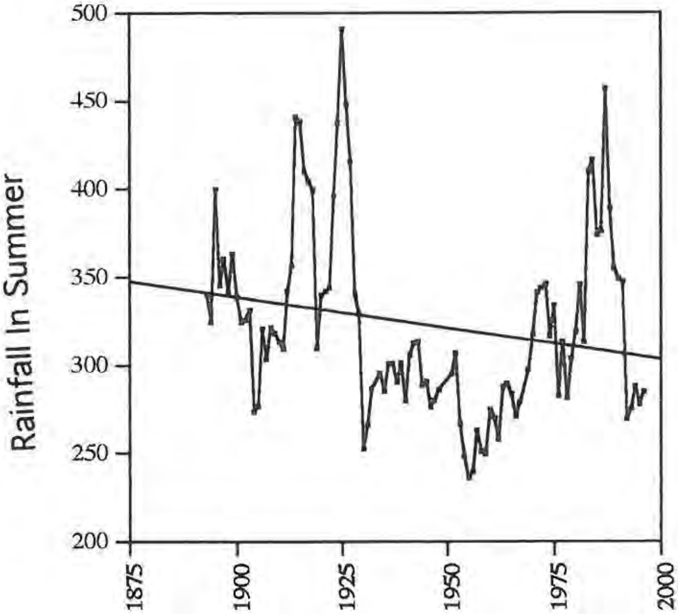

Figure 5: Moving Average of Rainfall in Summer (1890-1998) with trend shown as a continuous straight line.

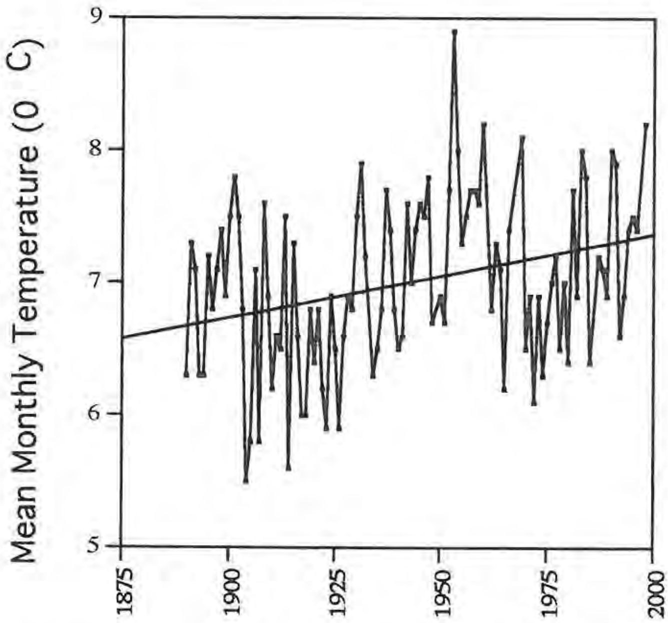

Figure 6: Moving Average of Mean Monthly Temperature (1890-1998) with trend shown as a continuous straight line.

Conclusions

The shift in precipitation is consistent with predictions made by the GCM for the Northern Hemisphere (Houghton et al, 1990). The results of this shift may be responsible for Nova Scotia's current drought caused by significant losses of water to Nova Scotia's lakes, rivers and aquifers from four possible sources:

Water loss-source # 1

As the ground is frozen in the winter, the shift in precipitation from rain to snow means that the rain falling in winter is not absorbed by the frozen ground and flows to the sea. Therefore the aquifers begin losing recharge.

Water loss-source # 2

The decline in snowpack mean less runoff in the spring and the aquifers, rivers and lakes thus lose water from two significant sources.

Water loss-source # 3

A trend towards decreasing rainfall in summer is a third source of loss of water to aquifers, lakes and rivers in Nova Scotia.

Water loss-source # 4

Trends towards warmer temperatures especially in summer also mean that higher evaporation rates will occur in Nova Scotian lakes and rivers further contributing to water loss.

It may be useful to look at long-term data sets from other areas experiencing drought in Canada (New Brunswick, PEI, Newfoundland, Ontario and Quebec) to see if more evidence can be found to further support the hypothesis that shifts in precipitation patterns may be a factor in causing these droughts.

References

1) State of the Environment Directorate. 1995. *A state of the environment report;* SOE report No 95-1. ISBN 0-662-23601-2.

2) Houghton, J.T., Jenkjins, J.G., and Ephraums, J.J. 1990 *Climate Change;* The IPCC Scientific Assessment. New York. Cambridge University Press.

3) Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring.* New York: Van Norstand Reinhold Company.

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Anthropogenic Vegetation Transformation and Maximum Temperatures on the Canadian Prairies

by R. L. Raddatz[2]

Résumé: L'agriculture a transformé près de 60 % de l'herbage des Prairies de graminées vivaces naturelles qu'elles étaient à des récoltes annuelles, en particulier du blé de printemps. À certains sites sélectionnés pour représenter des régions ecoclimatiques arides et transitionnelles d'herbages et aussi pour représenter un échantillon de saison de croissance, l'évapotranspiration a été modélisée pour les graminées vivaces et le blé de printemps. Pour chaque type de végétation, des courbes de flux de chaleur sensible représentatives de saison de croissance ont subit des calculs approximatifs à partir des valeurs moyennes de l'évapotranspiration et des courbes représentatives du bilan radiatif. On a fait l'hypothèse que le paysage actuel était divisé dans un rapport 60 : 40 entre le blé de printemps (plus d'autres cultures de grande production avec des modèles semblables utilisant de l'eau) et les graminées vivaces. Les valeurs moyennes quotidiennes de flux de chaleur sensible pour ce paysage ont subit des calculs approximatifs et ont été comparées à des valeurs moyennes quotidiennes pour des herbes mélangées naturelles et primaires. Les différences de flux ont été utilisées pour les calculs approximatifs de la modification incrémentielle de la moyenne des températures maximales quotidiennes qui ont peut-être contribué à l'expansion de l'agriculture à travers les Prairies. Cette transformation de l'agriculture, avec des modifications apportées dans la moyenne des températures maximales quotidiennes au cours de la saison de croissance, a été comparée à partir du changement observé au début de ce siècle, soit de 1901 à 1930, lorsque l'agriculture a subit une expansion à travers les prairies, et jusqu'à la période normale actuelle, soit de 1961 à 1990. Il est évident que l'expansion de l'agriculture n'a pas été le facteur dominant responsable des changements observés. Le signal pour une transformation de la végétation (c'est-à-dire plus chaud au début et à la fin de la saison de croissance, et plus frais à la mi-saison) n'est pas évident d'emblée pour le changement observé de la normale des températures maximales quotidiennes pour les périodes de 1901/1930 à 1961/1990. Néanmoins, l'étendue de l'impact estimé de la transformation de la végétation dominante en agriculture sur la moyenne régionale des températures maximales quotidiennes, doit être prise en considération lorsqu'on tente de quantifier l'influence sur le climat de l'augmentation de la concentration des gaz à effet de serre.

1. Introduction

The balance of evidence suggests that an anthropogenic increase in "greenhouse" gas concentrations since pre-industrial times has caused the climate to become warmer (IPCC WG1 1995). Man can also have an incremental impact on the climate by agronomic activities that transform the dominant type of vegetation (Budyko 1982 ; Bamston and Schickedanz 1984 ; Cotton and Pielke 1995 ; Raddatz 1998). The conversion of native vegetation to agricultural cropland modifies (1) the surface albedo and thus the magnitude of the net radiation and, (2) the portion of the net radiation expended in the evapotranspiration of water (latent heat flux). Both of these changes affect the magnitude of the flux of sensible heat to the lower atmosphere. In this way, a change in the dominant vegetation can have an impact on a region's maximum temperatures. The separation of the influence of landscape changes on regional temperatures from that associated with the increased atmospheric concentration of "greenhouse" gases is necessary before the true magnitude of the latter can be assessed (IPCC WG1 1995).

This study looked at the Canadian Prairie grassland eco-climatic zone where, by the 1930's (Rowe and Coupland 1984), agricultural cultivation had converted about 60% of the area from native mixed perennial grasses (Stripa - Bouteloua association) to annual field crops, predominantly spring wheat (Triticum aestivum L.). For a transitional grassland site, Winnipeg, MB (49° 54' Lat., 97° 14' Long.), and an arid grassland site, Swift Current, SK (50° 17' Lat., 107° 41' Long.), modelled mean daily evapotranspiration (ET) values for spring wheat, averaged over the 1988 - 1995 growing-seasons, were used to typify agricultural cropland. Modelled mean daily evapotranspiration values for mixed perennial grasses, for the same locations and averaged over the same period, were used to typify the original native grassland. For each type of vegetation, representative growing-season (April - October) sensible heat flux curves were approximated from these ET values and representative net radiation curves (Raddatz 1998). The present day landscape was assumed to be a patchwork quilt - a 60:40 split between spring wheat, plus other annual field crops with similar water-use patterns, and perennial grasses The mean daily sensible heat flux values for this landscape were approximated and compared to the mean daily values for the original native mixed grasses. These flux differences were used to approximate the incremental change in mean daily maximum temperatures that may have been brought about by the introduction of agriculture to the Canadian Prairies. The availability of temperature time-series (1895-1995) for both Winnipeg and Swift Current, that have been adjusted to remove inhomogeneities (Vincent and Gullet 1999; Vincent et al. 1999), allows the mean daily maximum

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temperatures for various historical time intervals to be compared with current temperatures without concern for the continuity of observing practices or locations. Changes in temperatures from an earlier period to the present may then be attributed to a combination of natural and anthropogenic forcing (Environment Canada 1995).

For this study, the change in mean daily growing-season maximum temperatures from the early part of this century, 1901-1930 when agriculture was expanding across the Prairies (Rowe and Coupland 1984), to the current normal period, 1961-1990, was calculated. The observed change was compared with the change in mean daily maximum temperatures that might reasonably be attributed to anthropogenic vegetation transformation. This comparison was used to address the following question: Should the impact of the transformation of the dominate vegetation by the expansion of agriculture across the Prairies be taken into account when attempting to quantify the influence of increased "greenhouse" gas concentrations on the region's mean daily maximum temperatures?

The Canadian Prairie grasslands eco-climatic zone is briefly described, Section 2. In Section 3, the simulation of representative mean growing-season latent heat flux curves and the estimation of the sensible heat flux curves for native mixed perennial grasses and for spring wheat are outlined. The calculation of the incremental change in mean daily maximum temperatures that might reasonably be attributed to differences in the mean sensible heat flux values over the current 60:40 landscape of annual field crops and mixed perennial grasses relative to the original native grasses is explained. The vegetation transformation-induced difference in the mean daily maximum temperatures during the growing season is compared to the observed change between 1901-30 and 1961-90 in Section 4. Section 5 contains the conclusions drawn from this study.

2. Canadian Prairie Grassland Eco-Climatic Zone

The Canadian Prairie grassland region occupies about 520,000 km^2 of Manitoba, Saskatchewan and Alberta. This eco-climatic zone consists of a vast arid core and border strips of transitional grassland adjoining the boreal zone to the east and to the north, and the cordilleran zone to the west. Its southern edge is the international boundary with the United States (Canada Committee on Ecological Land Classification 1989). In its natural state, the arid grassland was a mixed prairie characterized by progressively shorter grasses from east to west (Ripley and Redmann 1976) and the transitional grassland was a mosaic of open areas and aspen groves (Canada Committee on Ecological Land Classification 1989). A combination of cool-season or C3-type and warm-season or C4-type grasses gave both an early spring and a mid-summer flush of growth (M. Entz 1995, personal communication; Parton et al. 1994). Today, most of the arable soils in the grassland have long since been cultivated. The transformation of the dominant type of vegetation to annual field crops began with the Red River settlement in 1811. It reached its present extent (i.e., nearly 60% of the total area or about 300,000 km^2) by 1931 due to the rapid expansion of agriculture in the early part of this century (Rowe and Coupland 1984).

3. Estimation of Latent and Sensible Heat Fluxes

A representative net radiation curve (Raddatz 1998) for a Prairie growing-season (April - October) was constructed by linearly interpolating composite normal (1951-1980) daily values for each month (Environment Canada 1984). The composite values were simple averages of the normals for the two points on the southern Prairies for which these data are available - Lethbridge, AB (49° 37' Lat., 112° 48' Long.) and Bad Lake, SK (51° 19' Lat., 108° 25' Long.). The net radiation measurements, at both locations, were made over non-irrigated lawn surfaces. The albedo for this sort of surface has been reported to be about 0.25 (Pielke and Avissar 1990). The albedo for a natural (uncut, non-irrigated) prairie was observed by Ripley and Redmann (1976) to be about 0.17. A representative growing-season net radiation curve for native mixed perennial grasses was, therefore, approximated by increasing the composite net radiation normals by 8% to account for the difference in albedo. This net radiation curve was then assumed to be applicable to all sites in the Prairie grassland eco-climatic zone (Fig. 1 and Fig. 2). Land sown to spring wheat, before emergence and until complete vegetation-cover is achieved, has a lower albedo than mixed perennial grasses. Bare (cultivated) dark soils generally have an albedo of 0.5 to 0.15 (Oke 1987). To approximate the representative growing-season net radiation curve for spring wheat, the values for the pre-emergence and foliage expansion periods were increased by 7% over those for native grasses. From complete ground cover through the fall stubble period, the albedo and, therefore, the representative net radiation values for spring wheat were assumed to be the same as for the native grasses (Fig. 1 and Fig. 2).

Daily evapotranspiration rates for native perennial grasses and spring wheat for the 1988 - 1995 growing-seasons were modelled at Winnipeg, MB, chosen to represent the transitional grassland region, and at Swift Current, SK, chosen to represent the arid grassland region. The methodology has been described elsewhere (Raddatz 1989; Ash et al. 1992, 1993 ; Raddatz et al. 1996), therefore, only a brief description is given here. The phenology of spring wheat was simulated from actual planting dates (estimated by the provincial departments of agriculture), temperatures and photoperiods using a biometeorological time-scale (Robertson 1968). For native perennial grasses, active growth was assumed to begin after 1 April following the first occurrence of five consecutive days with mean temperatures greater than 5°C. Growth was directly related to accumulated degree-days (above 5°C) and ceased with the first killing frost (minimum temperature (-5°C) in the fall. Daily potential evapotranspiration, or the vertical flux of moisture from ground with unlimited soil moisture and complete

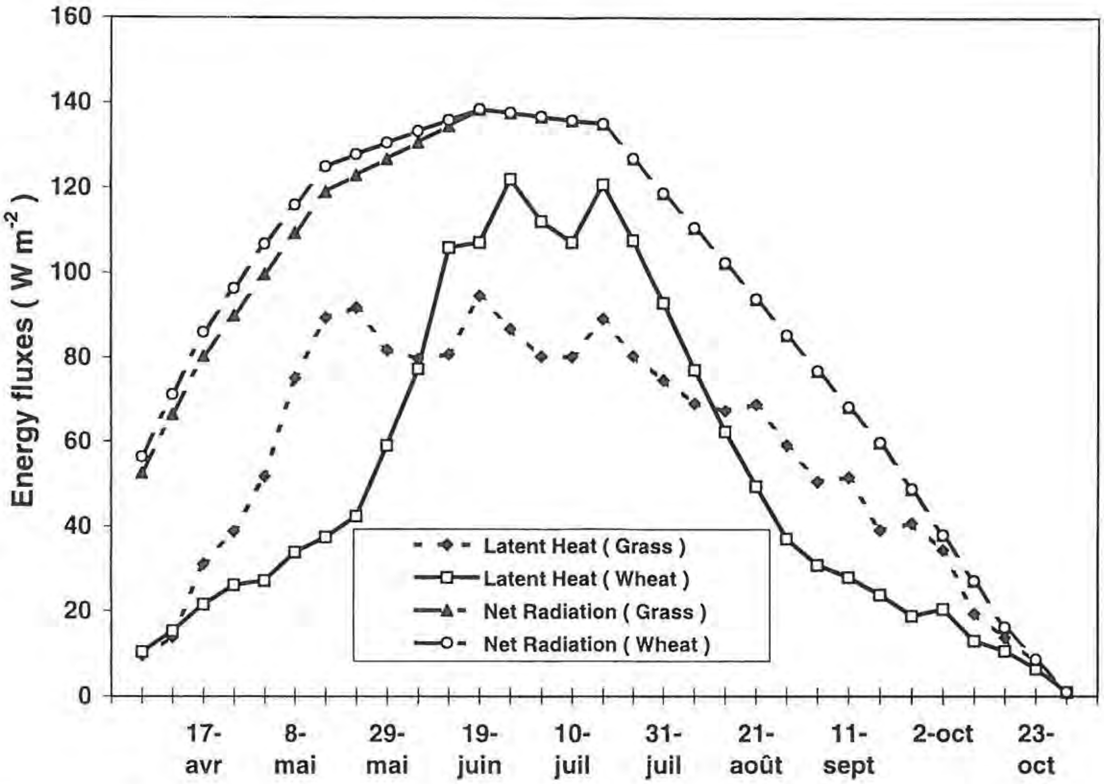

Figure 1: Representative growing-season latent heat curves (based on average daily modelled evapotranspiration, 1988-1995) and net radiation curves (linearly interpolated from representative 1951-1980 normals) for native mixed perennial grasses and for spring wheat at Winnipeg, MB in the transitional grassland eco-climatic zone.

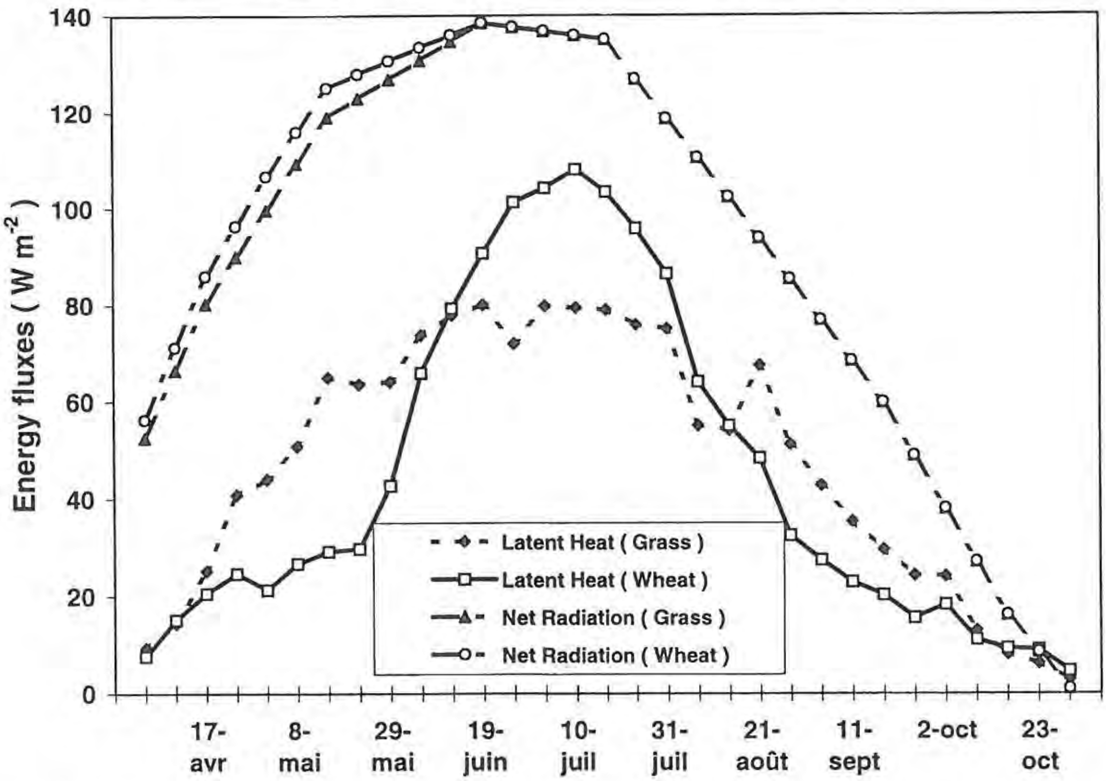

Figure 2: Representative growing-season latent heat curves (based on average daily modelled evapotranspiration, 1988-1995) and net radiation curves (linearly interpolated from representative 1951-1980 normals) for native mixed perennial grasses and for spring wheat at Swift Current, SK in the arid grassland eco-climatic zone.

vegetation cover, was estimated from a simple linear regression relationship with daily climatological observations, and the incident solar radiation not accounting for the effects of the atmosphere (Baier and Robertson 1965 ; Baier 1971). For spring wheat, during the foliage expansion stage and subsequent senescence stage, the degree of vegetative cover (i.e., the fraction of the cropped surface area that is shaded by vegetation) limits the evapotranspiration or crop water demand to a percentage of its potential value. This was simulated by multiplying the daily potential evapotranspiration rates by a consumptive-use factor which rose slowly through the vegetative stage from a pre-emergence value of 0.3. It peaked at 1.0 during the reproductive stage then slowly dropped as the crop ripened to a post-senescence value of 0.3. In contrast, for mixed perennial grasses, the consumptive-use factor was stepped upward from 0.3 to 1.0 after the active-growth date in the spring and it was kept at that level, due to both a spring and mid-summer flush of growth, until a killing frost occurred in the fall (Hobbs and Krogman 1968). The supply of available moisture in the root zone (available moisture equals field capacity minus wilting point) further limits evapotranspiration and determines the actual water use. In the model, water use as a percentage of water demand, dropped linearly when the soil moisture in the root zone was less than 50% of the available water-holding capacity. It became zero at 0% capacity (Ash et al. 1992). This simulated canopy resistance - the result of stomata closing in response to the depletion of soil moisture (Blackman and Davis 1985). For spring wheat, the root zone depth (5-120 cm) and thus the size of the soil moisture reservoir was a function of crop stage (Rasmussen and Hanks 1978). For mixed perennial grasses, the root zone depth was kept at the maximum value (120 cm). For each type of vegetation, water-balance accounting was used to track the addition of infiltrating precipitation and the loss of moisture from the root zone by evapotranspiration and deep percolation (Baier et al. 1979).

The mean daily evapotranspiration, ET (mm d^{-1}), values for each week during the 1988 - 1995 growing-seasons were averaged by location and by vegetation type. These values were converted to mean daily latent heat flux values, QE (W m^{-2}), by multiplying by (w , the density of water (1.0 x 103 kg m^{-3}) and by Lv , the latent heat of vaporization (2.45 x 106 J kg^{-1}):

$$Q_E = L_v \, p_w \, ET \qquad (1)$$

The mean daily Q_E values were plotted (Fig.1 and Fig.2) to generate representative growing-season latent heat flux curves for each vegetation type at the sample sites, Winnipeg for the transitional grassland and Swift Current for the arid grassland (Raddatz 1998). These growing-season latent heat curves for spring wheat and for mixed perennial grasses are based on a number of assumptions. Nevertheless, the compatibility of these curves with the independently determined representative net radiation curves suggest they are reasonably well modelled.

Since the heat transferred to the soil each day by conduction is small (Oke 1987), the flux of sensible heat to the atmospheric boundary layer is approximately the difference between the net radiation and the latent heat flux curves (Fig.1 and Fig.2). This calculation was performed for both native perennial grasses and for spring wheat. The mean daily sensible heat flux values over the present day landscape, assumed to be a patchwork quilt - a 60:40 split between spring wheat, plus other annual field crops with similar water-use patterns, and mixed perennial grasses, were determined and compared to the mean daily values calculated for the original native grasses. These flux differences were then used to approximate the incremental change in mean daily maximum temperatures that may be attributed to the introduction agriculture to the Canadian Prairies. The change in the mean daily maximum temperatures, (T, was estimated by (Oke 1987):

$$\Delta T = \Delta Qs \, \Delta t \, / \, (Ca \, \Delta Z) \qquad (2)$$

where ΔQs (W m^{-2}) is the mean daily difference in the sensible heat flux to the boundary-layer, ΔZ (m) is the depth of the convective boundary-layer, Δt (s) is the time interval, and Ca is the heat capacity of air (1200 J m^{-3} K^{-1}). It can be seen that the incremental change in mean daily maximum temperatures depends on the depth of the boundary-layer and the time interval. In order to characterize the typical situation, ΔZ was assumed to be 1000 m, the mean depth of the convective boundary-layer for the Canadian Prairies (Strong 1997), and Δt was set equal to the interval between sun-rise and the time of maximum temperature - here assumed to be two-thirds of the daylight period (Raddatz 1993).

4. Incremental Change in Mean Daily Maximum Temperatures

A comparison of the representative growing-season latent heat curves for mixed perennial grasses and for spring wheat at the sample sites (Fig.1 and Fig.2) revealed three periods when the values are significantly different. These periods are, therefore, of primary interest in the evaluation of the impact of the transformation of the dominant type of vegetation by agriculture on the region's mean daily maximum temperatures. The periods are:

1) the early growing-season pre-emergence and post-emergence periods for spring wheat when the vegetation cover is lower for annual crops than it is for perennial grasses and, therefore, the surface heat expended for evapotranspiration is also lower;

2) the mid-growing-season rapid foliage expansion and reproductive periods for spring wheat when the latent heat flux is generally higher for annual crops than it is for perennial grasses due to the greater availability of soil moisture - a result of the typical lag in the vegetation cover

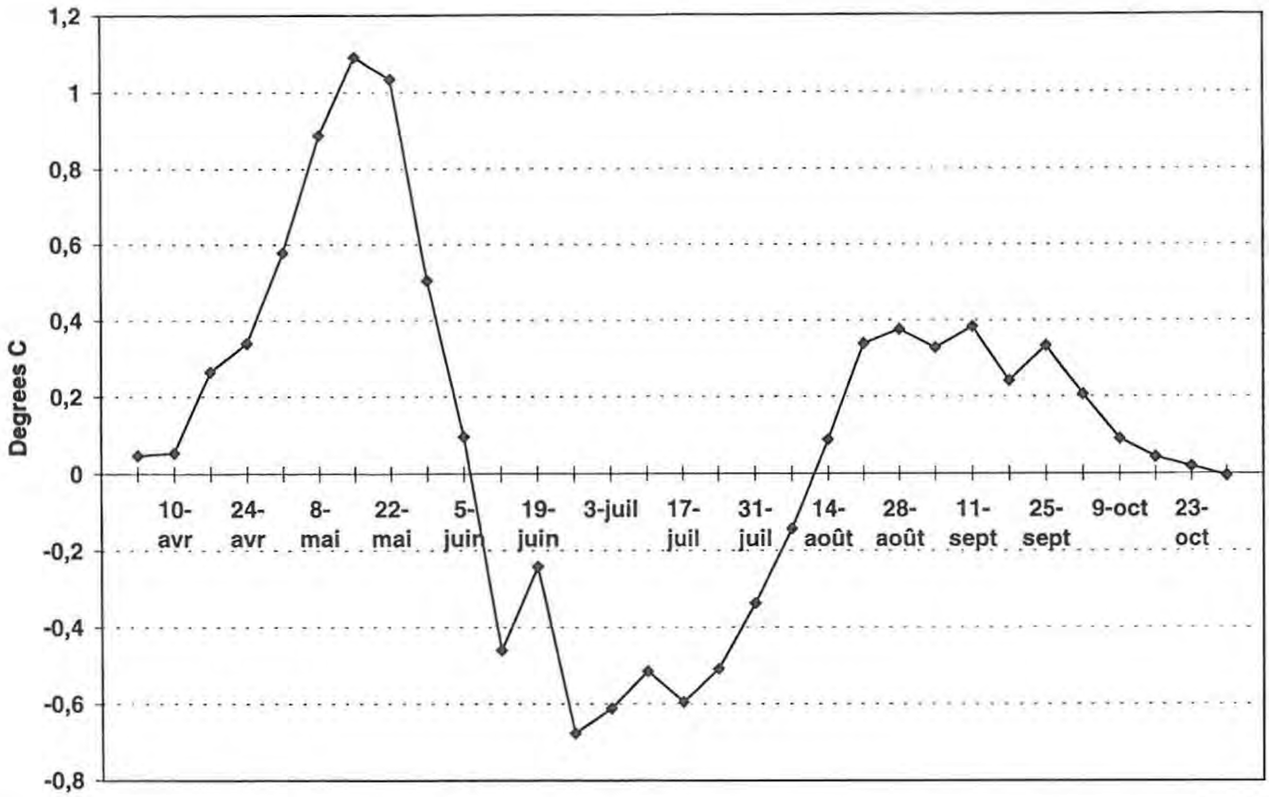

Figure 3: Change in the mean daily maximum temperatures over a 60:40 landscape of spring wheat and perennial grasses versus a 100% native mixed grass surface during the growing-season at Winnipeg, MB in the transitional grassland ecoclimatic zone.

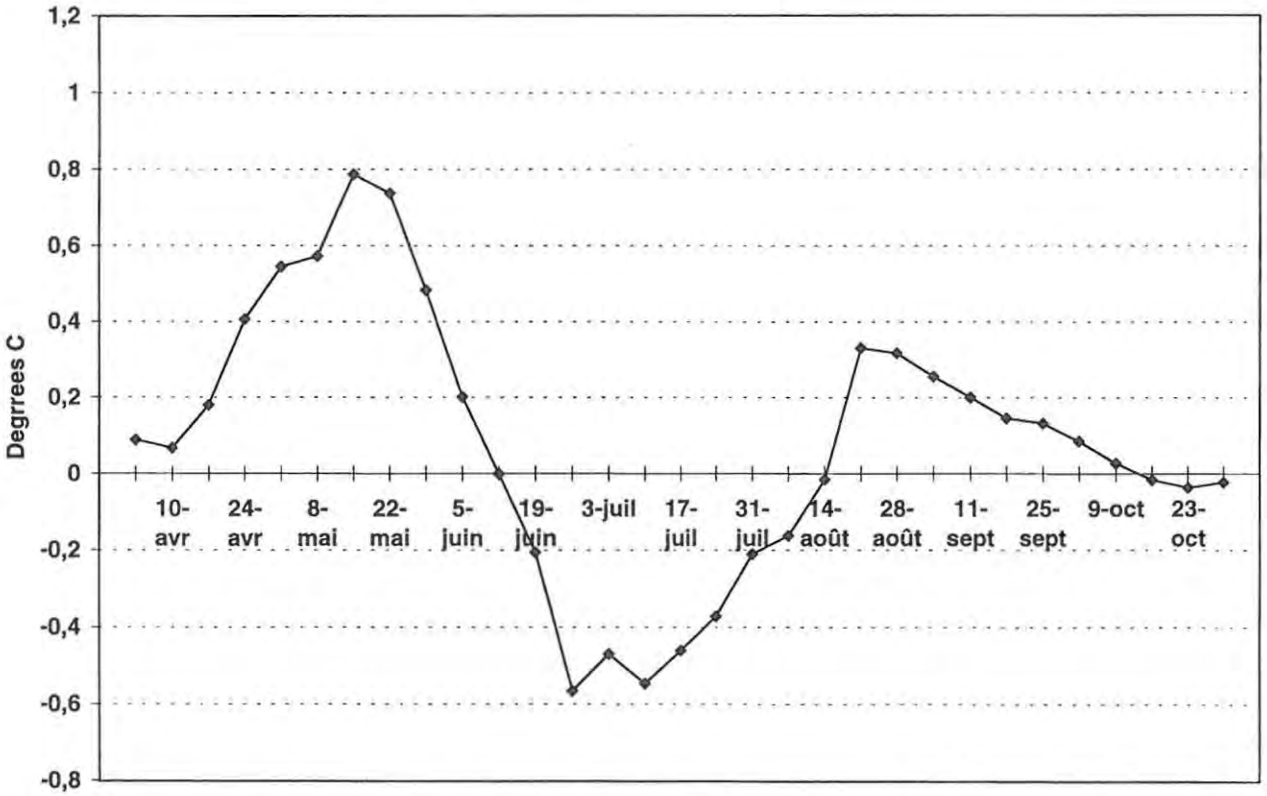

Figure 4: Change in the mean daily maximum temperatures over a 60:40 landscape of spring wheat and perennial grasses versus a 100% native mixed grass surface during the growing-season at Swift Current, SK in the arid grassland ecoclimatic zone.

and, therefore, the lower early season water demand of annual crops versus perennials; and

3) the late growing-season senescence and post-harvest periods for spring wheat when the latent heat flux is lower for annual crops than it is for perennial grasses due to the cessation of transpiration by annual crops.

For Winnipeg, MB, in the transitional grassland ecoclimatic zone, during the early growing-season, the incremental change in mean daily maximum temperatures over today's patchwork quilt landscape of annual field crops and perennial grasses relative to the original native grasses ranged from 0.1 to 1.1 °C ($\Delta Qs \approx$ 2 to 35 W m^{-2}). In the late growing-season, this same vegetation transformation may have produced incremental mean daily maximum temperature increases of 0.0 to 0.4 °C ($\Delta Qs \approx$ 0 to 14 W m^{-2}). Mid-growing-season mean daily maximum temperatures may be -0.1 to -0.7 °C ($\Delta Qs \approx$ -5 to -21 W m^{-2}) cooler over the present landscape compared to the original native grasses (Fig.3). This result is similar to the 0.7 °C of cooling attributed to the transformation of grasslands into both dry and irrigated agricultural lands simulated for the northern Colorado plains by Chase et al. (1999) using a sophisticated regional atmospheric model (Pielke et al. 1992). Mid-season cooling is also consistent with the irrigation induced deficit in maximum temperatures of 1-2 °C observed over northern Texas by Barnston and Schickedanz (1984) and the "oasis effect" described by Budyko (1982).

Amalgamated by calendar month, the estimated change in mean daily maximum temperatures was: +0.3 °C for April, +0.9 °C for May, -0.5 °C for both June and July, +0.2 °C for August, +0.3 °C for September and 0.0 °C for October. From the homogenous data-base for Winnipeg, the observed change in mean daily maximum temperatures from the early part of this century, 1901-1930 when agriculture was expanding across the Prairies, to the current normal period, 1961-1990, was +0.6 °C for April, +1.2 °C for May, +0.5 °C for June, +0.1°C for July, +0.3 °C for August, -0.1 °C for September and +0.4 °C for October.

For Swift Current, SK, in the arid grassland ecoclimatic zone, during the early growing-season, the incremental change in mean daily maximum temperatures over today's patchwork quilt landscape relative to the original native grasses ranged from 0.0 to 0.8 °C ($\Delta Qs \approx$ 0 to 25 W m^{-2}). In the late growing-season, this same vegetation transformation may have produced incremental mean daily maximum temperature increases of 0.0 to 0.3 °C ($\Delta Qs \approx$ -1 to 11 W m^{-2}). Mid-season mean daily maximum temperatures may be -0.0 to -0.6 °C ($\Delta Qs \approx$ -0.5 to -18 W m^{-2}) cooler over the present landscape relative to the original native grasses (Fig.4). These incremental temperature changes were a little less than in the transitional grassland as the mean daily latent heat flux values, for both spring wheat and perennial grasses, were lower (Fig.1 and Fig.2) due to greater moisture supply limitations in the arid eco-climatic zone. (Raddatz et al. 1994).

Amalgamated by calendar month, the estimated change in mean daily maximum temperatures was: +0.3 °C for April, +0.6 °C for May, -0.2 °C for June, -0.4 °C for July, +0.1 °C for August, +0.2 °C for September and near 0.0 °C for October. From the homogenous data-base for Swift Current, the observed change in mean daily maximum temperatures from the early part of this century, 1901-1930, to the current normal period, 1961-1990, was +0.5 °C for April, +0.9 °C for May, +1.4 °C for June, +0.6 °C for July, +1.2 °C for August, +0.4 °C for September and +1.0 °C for October.

5. Conclusions

It is evident from the comparisons in the previous Section that the anthropogenic vegetation transformation of 60% of the area of the Prairie grassland from native perennial grasses to annually cropped land was not the main factor contributing to higher mean daily maximum temperatures during the growing-season in the current normal period, 1961-1990, than in the early part of this century, 1901-1930. The "vegetation transformation signal" (i.e., warmer in the early and late portions of the growing-season and cooler in the middle) was not readily evident in the observed changes. Nevertheless, the size of the estimated impact of the transformation of the dominate vegetation by agriculture on the region's mean daily maximum temperatures suggests that it should be taken into account when attempting to quantify the influence of increased "greenhouse" gas concentrations on the climate.

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"Sweet Phosphor, bring the day
Whose conquering ray
May chase these fogs;
Sweet Phosphor, bring the day!"
- Frances Quarles, 1592-1644. Emblems.

The Stratosphere and Climate

Theodore G. Shepherd[3]

Résumé: The traditional view in climate science has been that the stratosphere, which represents only about 10-20% of the atmosphere in terms of mass, can play only a limited role in climate change. However, there has been increasing evidence in recent years that the stratosphere is a sensitive component of the climate system, which can affect the troposphere through various coupling mechanisms. This article reviews the current state of knowledge, and discusses possible mechanisms for this coupling.

1. The role of wave driving

The temperature structure of the stratosphere represents a balance between radiative and dynamical heating. The radiative heating includes solar forcing, thermal emission, and thermal absorption of radiation from the troposphere. To a very large extent, radiative transfer in the stratosphere is a clear-sky process and is well understood (Andrews et al. 1987); the only significant exception to clear-sky conditions occurs in the aftermath of a large volcanic eruption, when the stratospheric aerosol layer is enhanced many-fold. The radiative equilibrium state is dynamically stable nearly everywhere and there are no rapid small-scale adjustments to be considered as there are in the troposphere with convective adjustment. The one place where stability is not guaranteed is in the tropics, where the seasonal migration of the solar heating maximum about the equator leads to a process of quasi-horizontal inertial adjustment (Dunkerton 1989). This process has not received much attention, presumably because it is resolved to some extent in climate models, but it is still not well understood in detail. Of particular concern in this respect is the fact that the "traditional" form of the hydrostatic primitive equations, widely used in climate models, becomes invalid at the equator (de Verdière et al. 1994).

The dynamical heating is caused by vertical (diabatic) motion which arises partly in response to the radiative heating, but is primarily caused by the breaking and dissipation of Rossby waves and gravity waves emanating from the troposphere (Andrews et al. 1987). The extent to which the wave-induced forcing is the dominant factor increases as one considers longer time scales, reaching a wave-induced "downward control" regime (Haynes et al. 1991) in the steady-state limit. Thus, on climatological time scales one can regard the stratospheric temperature field as being pulled away from radiative(-inertial) equilibrium by wave-induced forces. In the extratropical stratosphere, the wave-induced forces are almost exclusively westward and act to drive air poleward, thus producing a meridional mass circulation that is generally rising in low latitudes and sinking in high latitudes (Holton et al. 1995). The resulting dynamical heating is negative in low latitudes and positive in high latitudes.

The dominant wave-induced forcing in the stratosphere is believed to come from tropospherically generated planetary-scale Rossby waves, and this forcing maximizes in wintertime. This is partly because that is the season of greatest tropospheric baroclinicity (hence greatest surface winds and topographic forcing) and greatest land-sea thermal contrasts, and partly because radiative considerations imply summertime stratospheric easterlies which prohibit planetary-wave propagation (Charney and Drazin 1961). The maximization of planetary-wave forcing in the wintertime is reflected in the fact that the meridional mass circulation, although two-celled, is dominantly directed towards the winter pole (e.g. Eluskiewicz et al. 1996), and leads to a significant warming (and weakening) of the polar night vortex relative to its radiatively-determined state (Andrews et al. 1987). This points to a mechanism whereby differences in wave-induced forcing lead directly to differences in stratospheric polar night temperatures. Such differences are most apparent in the asymmetry between the Northern and Southern Hemispheres: the Southern Hemisphere, with less zonal inhomogeneity, produces less planetary-wave forcing and therefore less dynamical warming of the vortex (this is why the ozone hole appeared in the Antarctic rather than the Arctic); in the Northern Hemisphere, the forcing is sometimes strong enough to completely destroy the vortex in a "sudden stratospheric warming". By the same token, interannual variability and long-term trends in wave-induced forcing can lead directly by this mechanism to corresponding changes in stratospheric temperatures. It is important to note that the temperature effect of wave-induced forcing is to a first approximation zero in the global mean, at any pressure level, because rising motion in one place must be compensated by sinking motion elsewhere; thus the signature of such changes is compensating temperature changes in the tropics and extratropics. This compensation has been noted in the annual cycle (Yulaeva et al. 1994), with the coldest tropical temperatures occurring in Northern Hemisphere winter when the wave-induced forcing is greatest (Rosenlof 1995).

There nevertheless remain significant uncertainties in both qualitative and quantitative aspects of the wave-induced forcing. A qualitative uncertainty is that while the wave-induced forcing is greatest in the winter hemisphere, the maximum radiative imbalance and maximum upwelling in

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tracer fields are found on the summer side of the equator (Eluskiewicz et al. 1996; Randel et al. 1998). This difference could be due to the nonlinear Hadley circulation described by Dunkerton (1989), arising from the inertial adjustment process described above, or it could imply missing forces within the tropics (Plumb and Eluskiewicz 1999). However, it will be difficult to test the latter hypothesis for two reasons: first, the required forces are very small, and second, the quality of stratospheric wind analyses in the tropics is very poor (Waugh 1996; Coy and Swinbank 1997).

2. The role of subgridscale waves

The principal quantitative uncertainties in wave-induced forcing have to do with the role of gravity waves, which are essentially undetected in stratospheric analyses. Inferences regarding the role of gravity waves have therefore had to come from systematic errors in climate models. The most notable such error is the tendency of all middle atmosphere GCMs to suffer from excessively cold polar temperatures in the winter stratosphere, together with an excessively strong polar night jet. This "cold pole" problem is especially notable in the Southern Hemisphere, where the wintertime cold pole bias can reach 40 K in the upper stratosphere (Boville 1995). Based on the arguments presented above, it is clear that the cold pole problem is most plausibly attributed to insufficient wave drag. On the presumption that the planetary-wave forcing in GCMs is reasonable (since planetary waves are well resolved even by relatively coarse models), attention naturally focuses on gravity waves. Although some gravity waves will be represented in GCMs, their horizontal wavenumber spectrum of kinetic energy is shallow (Koshyk et al. 1999) and for most models, most of the drag will be unrepresented; typical horizontal length scales are believed to be in the range 10-200 km.

It is widely accepted that the drag exerted by breaking and dissipating gravity waves is responsible for the pole-to-pole solstitial circulation in the mesosphere (Andrews et al. 1987). The principle of "downward control" (Haynes et al. 1991) shows how mesospheric wave drag can affect temperatures in the stratosphere, particularly in the polar night where there is strong sensitivity of temperatures to dynamical heating (because of the long radiative time scale). A 2-D modelling study with parameterized drag (Garcia and Boville 1994) showed that polar downwelling driven by mesospheric drag could eliminate the cold pole problem in the Southern Hemisphere middle stratosphere. Several middle atmosphere GCMs (Manzini and Bengtsson 1996; Butchart and Austin 1998) have eliminated most of the cold pole problem by using a strong Rayleigh friction in the upper stratosphere or mesosphere. Although such "tuning" with Rayleigh drag may be an effective way of obtaining reasonable mean states, it can lead to erroneous meridional circulations in response to climate perturbations because Rayleigh drag is not momentum-conserving (Shepherd et al. 1996). More physically-based gravity-wave drag parameterization schemes have been developed (Lindzen 1981; Medvedev and Klaassen 1995; Hines 1997), but there is little consensus on the most appropriate framework. More seriously, in all these schemes the amplitude and shape of the gravity-wave spectrum must be determined empirically, but current measurements provide little information on either of these quantities.

As the resolution of climate models increases, more of the gravity-wave spectrum is explicitly resolved and the cold pole bias tends to reduce as more wave drag is explicitly represented (Hamilton et al. 1995; Jones et al. 1997). However, even calculations performed with the GFDL SKYHI GCM at 0.6 degree resolution (which can resolve gravity waves longer than about 100 km) reveal a cold bias of up to 20 K in the upper stratosphere. Thus, given the extreme computational cost of ultra-high-resolution simulations, this is not a feasible approach at the present time. Moreover, there is no guarantee that the gravity-wave spectrum will be realistic, since the principal forcing mechanisms will be physical parameterizations such as convective adjustment in the troposphere, acting near the grid scale of the model.

Although most attention with regard to gravity-wave drag has focused on the Southern Hemisphere, it is interesting that gravity-wave drag has been found to be crucial for obtaining realistic simulations of the Northern Hemisphere winter in moderate resolution GCMs (Boville 1995; Beagley et al. 1997). A major scientific issue in climate change involves possible changes in the Arctic wintertime vortex and the impact of those changes on ozone depletion (Shindell et al. 1998; WMO 1999, Chapter 12; see further discussion below). The fact that the realism of present-day simulations of the Arctic vortex may depend critically on a parameterization unconstrained by measurements is therefore a cause for concern.

Until recently, a consistent failing of middle atmosphere GCMs has been their inability to simulate the quasi-biennial oscillation (QBO). It has been recognized for a long time that the QBO is driven by wave drag, but it remains unclear exactly which waves are involved (Dunkerton 1997). Now the situation with GCMs is changing rapidly. First, QBO-like oscillations were found in highly simplified GCMs with better than 1 km vertical resolution and very little horizontal dissipation (Takahashi 1996; Horinouchi and Yoden 1997). Horinouchi and Yoden (1997) found their QBO to be forced by a broad spectrum of waves, including equatorial and large-scale inertia-gravity waves. Subsequently, QBO-like oscillations were found in very high resolution versions of some GCMs (although these simulations are typically quite short). Yet more recently, several groups have found such oscillations in moderate resolution GCMs using a parameterized gravity-wave drag that is sensitive to critical lines. It should be noted that a "QBO-like oscillation" simply means a downward propagating oscillation between equatorial easterlies and westerlies with a quasi-regular period. Whether the period is close to biennial is not really a key feature, since the period is expected to depend on the amplitude of the tropical wave-drag forcing (either resolved or parameterized) which is unlikely to be correct. It remains unclear exactly what is required for a model to produce a QBO-like oscillation, and whether the oscillations that have been seen are occuring for the right reasons. Some models exhibit curious parameter dependences, and some show a tendency for an intriguing seasonal synchronization.

3. The role of transport and mixing

In contrast to the troposphere, long-lived chemical species in the stratosphere are generally not well-mixed. This is a consequence of the distinguishing feature of the stratosphere, its stable stratification, which inhibits vertical motion. Thus transport time scales in the stratosphere are long --- on the order of several years, to be contrasted with weeks to months in the troposphere. (Indeed, rather than being defined by a change in static stability, the tropopause may alternatively be thought of as a boundary in terms of transport time scales.) It follows that the distribution of radiatively active trace gases in the stratosphere is an important component of climate forcing, including the shape of the tropopause itself. This distribution is controlled by dynamics in two ways. First, through the temperature distribution which affects chemical reaction rates; and second (generally more importantly), through transport and mixing by winds.

The same meridional mass circulation that produces dynamical heating and cooling also transports chemical species poleward in the stratosphere; this is the so-called Brewer-Dobson circulation, first inferred from ozone and water vapour distributions (Andrews et al. 1987). Mass conservation then implies that air enters the stratosphere in the tropics and returns to the troposphere in the extratropics. The overturning timescale of the Brewer-Dobson circulation based on pure advection is about five years (Rosenlof 1995). However, quasi-horizontal mixing due to breaking planetary waves alters the picture, producing the characteristic picture of quasi-horizontal tracer distributions with an upward bulge in the tropics for long-lived tracers (such as CH_4 and N_2O) with tropospheric sources and stratospheric sinks (Jones and Pyle 1984; Randel et al. 1993). The control of stratospheric chemical distributions by transport and mixing induced by breaking planetary waves points to a possible feedback mechanism between tropospheric dynamics and radiative forcing, via the stratosphere. Thus, it is essential to understand what controls the Brewer-Dobson circulation. In the last several years, there have been significant advances in the understanding and quantification of this process.

A key quantity determining the stratospheric distribution of long-lived trace gases is the length of time it takes to get from the tropical tropopause (the entry point to the stratosphere) to the location in question. Because of mixing, there is no single pathway, but rather a distribution of pathways; an air parcel at a given location is composed of many components with different transport histories and, therefore, different transit times. The distribution of such transit times is known as the "age spectrum" (Kida 1983), and the mean of the distribution is the "mean age" (Hall and Plumb 1994). Although the age spectrum cannot be measured directly, the mean age can be inferred from measurements of long-lived tracers with linear trends, such as SF_6 (e.g. Volk et al. 1997); this provides a valuable constraint on models. Generally speaking, model ages are too "young" (Waugh et al. 1997), suggesting that the models mix too rapidly. This suggests a potential climate drift problem for simulations with full chemical-radiative interactions, and it can be expected to compromise predictions of stratospheric residence times (e.g. of halogens). These problems may be expected to become more evident in the coming years as groups begin to perform long simulations using full chemical modules.

The picture of a meridional mass circulation modified by quasi-horizontal mixing has been refined in several respects in the last few years. Transport "barriers" have been identified at the edge of the polar vortices (Juckes and McIntyre 1987), where they play a crucial role in severe ozone depletion, as well as in the subtropics (Plumb 1996). The isolation of tropical upwelling, together with the annual cycle of temperature at the tropical tropopause discussed earlier (Yulaeva et al. 1994), leads to a remarkable phenomenon dubbed the "tropical tape recorder" (Mote et al. 1996): since the tropical tropopause is a local temperature minimum, it controls the amount of water vapour entering the stratosphere --- Brewer (1949) "freeze drying" process --- and the annual cycle in temperature is therefore imprinted on the water vapour distribution, which gets carried upward with remarkably little attenuation. From this signal one can infer a vertical transport time scale of about 0.2-0.4 mm/s (greatest in NH winter) --- corresponding to only 20-40 m per day --- which is consistent with ascent rates derived from diabatic circulation calculations (Rosenlof 1995; Eluskiewicz et al. 1996).

Because the tropopause is higher in the tropics than in the extratropics, there is a dynamical distinction to be made between isentropic surfaces lying entirely within the stratosphere and those which intersect the tropopause (lying in the stratosphere only in the extratropics). The former are well isolated from the troposphere, while on the latter, known as the "lowermost stratosphere" (Holton et al. 1995), rapid quasi-horizontal isentropic mixing with the troposphere is possible. In this region, evidence of intrusions of tropospheric air is evident from transport studies (Chen 1995) as well as direct dynamical-chemical signatures (Dessler et al. 1995; Folkins and Appenzeller 1996; Pan et al. 1997). Any air mixed into this region cannot drift upwards into the deep stratosphere and will eventually have to find its way back into the troposphere. Nevertheless, the degree of inmixing is a key factor in radiative forcing of climate through its control of the water vapour and ozone distribution in the lowermost stratosphere, which is the part of the stratosphere most crucial for the radiative balance at the surface.

A key factor affecting tropospheric climate is the height of the tropopause. It is rather remarkable that this question, so basic to climate, remains poorly understood. The traditional approach, based on radiative-convective adjustment, is to regard the tropopause as corresponding to the top of the region of moist convection. While this seems to be a reasonable explanation in the tropics, the extratropical tropopause is strongly affected by baroclinic eddies (Holton et al. 1995). There are, moreover, important feedbacks from the stratosphere itself. The dynamical heating associated with the Brewer-Dobson circulation acts to raise the tropopause in the tropics and to lower it in the extratropics. In addition, the radiative equilibrium temperature is determined by trace gas distributions in the stratosphere, particularly ozone and water vapour, and these distributions are controlled by the transport and mixing processes described above. In particular, the poleward and downward transport of ozone in the Brewer-Dobson circulation acts, through radiation, to lower the tropopause in the extratropics. Thus, the latitudinal variation in the height of the tropopause is controlled to a considerable extent by stratospheric processes.

4. Coupling mechanisms between the stratosphere and troposphere

There are three principal mechanisms by which the stratosphere can affect tropospheric climate. The first is through radiative transfer, either by changes in the amount of solar radiation that reaches the surface (e.g. after a volcanic eruption), or by changes in the amount of downwelling longwave radiation emitted by the stratosphere (e.g. because of stratospheric ozone depletion). The impact depends very sensitively on the vertical, latitudinal, and seasonal structure of the changes in the radiatively active substances, particularly in the vicinity of the tropopause (Forster et al. 1997; Hansen et al. 1997). The fact that the distribution of radiatively active substances is controlled by the Brewer-Dobson circulation together with quasi-horizontal inmixing into the lowermost stratosphere emphasizes that climate models need to represent these processes with sufficient fidelity in order to capture this sensitivity.

Quite apart from their role in tropospheric climate, stratospheric temperature trends are an important element in climate change detection (Santer et al. 1996). There has been important progress in quantifying those trends, confirming a cooling of the lower stratosphere over the past two decades (WMO 1999, Chapter 5). The overwhelming contribution to this cooling is ozone depletion (Ramaswamy et al. 1996).

The second and third mechanisms by which the stratosphere can affect tropospheric climate take account of the basic dynamical fact that tropospherically forced waves propagate up, while zonal-mean anomalies propagate down (Haynes et al. 1991). Thus, the second mechanism is that the stratosphere can affect the "upper boundary condition" of the troposphere by affecting the propagation characteristics of tropospheric waves. This possibility goes back to the classic work of Charney and Drazin (1961), but there has been remarkably little investigation of this issue, a notable exception being Boville and Cheng (1988). The possibility of wave reflection at the tropopause has obvious implications for regional climate perturbations.

The third mechanism is then the downward propagation of zonal-mean anomalies, whose mechanism is "downward control" (Haynes et al. 1991). Such downward influence has been seen in model studies (Boville 1984; Kodera et al. 1996). Since the zonal-mean anomalies are themselves caused by wave-induced forces whose ultimate origin is the troposphere, this provides a purely dynamical troposphere-stratosphere feedback loop, which may account for the well-documented troposphere-stratosphere anomaly correlations seen in observations (Baldwin et al. 1994; Perlwitz and Graf 1995). Indeed, there has been much recent interest in the possibility that the North Atlantic Oscillation could be coupled with the strength of the wintertime Arctic vortex (Thompson and Wallace 1998), thereby accounting for the unusual strength (and coldness) of the Arctic vortex through most of the 1990s and the resulting halogen-induced severe ozone depletion (WMO 1999, Chapter 7). Whether the stratospheric vortex is an essential component in a feedback loop involving the NAO, or simply responds to the NAO, remains unclear: in long-term climate simulations with coupled models, Shindell et al. (1999) found that the stratospheric vortex was essential, while Fyfe et al. (1999) found that it was not. (However, even a model without a real stratosphere will presumably still have some capacity for this mechanism in its uppermost levels.)

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Note from the Editor: Original background paper submitted to the current IPCC Climate Assessment.

Environment Canada Study of Deaf, deaf, Deafened, and Hard of Hearing Canadians

by Edwina Lopes, Environment Canada[4]

Abstract: Environment Canada conducted a public opinion study of Deaf, deaf, deafened, and hard of hearing Canadians to assess their awareness of and access to weather information. The study also examined their reaction to and level of acceptance of scrolling weather warnings on television screens.

- Over 95% of all respondents say that weather information is very or somewhat important; however, about 60% of respondents believe that they do not receive enough or as much information as hearing Canadians.

- The community relies more heavily on television as a source of information in contrast to Canadians generally, who rely fairly evenly on radio and television.

- Overall more than 80% of respondents recall receiving a weather warning but, within the community, only 70% of the Deaf (those who use sign language) recall one.

- More than 90% of respondents would find it useful to have a severe weather message scroll across their television screen. While most of the community prefer a message appearing at the bottom of the screen, the Deaf were less amenable to a scrolling message if it interfered with closed captioning.

The issues identified by the survey will be important considerations in developing a national weather alert system for Canadians. Consultation with the key representative organisations of the Deaf, deaf, deafened and hard of hearing Canadians, would improve the reach and delivery of the system.

Introduction

In 1999, the Weather and Environmental Prediction (WEP) Program of Environment Canada conducted a public opinion research study of Deaf, deaf, deafened and hard of hearing Canadians: a) to obtain information on the use, awareness and satisfaction of Environment Canada's weather programs, products, and services; and b) to determine if they would be adversely affected by crawler messages on their television screen informing the public of possible severe weather (these messages may interfere with closed captioning). The results of the study are compared to a 1997 Environment Canada national survey of approximately 4,500 Canadians.

The Deaf, deaf, deafened and the hard of hearing are considered very distinct groups by the associations and using the proper terminology shows respect for their differences. The Deaf rely on sign language and are considered part of the "Deaf" community. The deaf do not rely on sign language and do not consider themselves part of the "Deaf" community. Those individuals who are deafened have suffered a loss of hearing later in life; and, therefore, consider themselves part of the hearing community. The hard of hearing have suffered some hearing loss and are still part of the hearing community.

According to the 1991 Health and Activities Limitations Survey conducted by Statistics Canada, there are between 2.5 million and 3 million Canadians that have some degree of hearing loss. Based on the American census model, it is estimated that Canada has approximately 260,000 profoundly deaf people.

Methodology

A study of the Deaf, deaf, deafened and hard of hearing community posed unique challenges as a telephone survey was inappropriate and a written questionnaire had to take into consideration the fact that approximately 65% may be functionally illiterate.

The three key national organisations, the Canadian Association of the Deaf (CAD), the Canadian Hard of Hearing Association (CHHA) and The Canadian Hearing Society (CHS) allowed their logos and names to be used in association with the study and assisted in its distribution. Emergency Preparedness Canada provided some background information used to develop the questions.

A bilingual mail-back questionnaire was developed and pre-tested using focus groups in Toronto and Montreal in the fall of 1998. The survey package was distributed in early January 1999 to 5,000 individuals across Canada through 45 advocacy groups and associations representing a cross-section of the Deaf, deaf, deafened and hard of hearing communities.

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The survey package contained the questionnaire and a short letter explaining the purpose of the study and the support of the CAD, CHHA, and CHS. The letter also guaranteed respondent confidentiality. A business reply envelope was included and all responses were addressed to a market research firm hired by Environment Canada. A draw for 25 posters and weather trivia calendars encouraged participation. The questionnaire consisted of 17 weather-related questions, 7 demographic questions, and an area for written comments. One thousand five hundred (1,500) questionnaires were returned, resulting in a response rate of 30%, significantly higher than the average of 10% for a mail-out survey.

Results

The demographic information revealed the following.

- There were two distinct groups - approximately 40% of respondents were Deaf or deaf, and 60% were deafened or hard of hearing.

- The percentage of male/female respondents was comparable to the Canadian population (57%/42% versus 51%/49%).

- Response by province was also comparable to the Canadian population, except for British Columbia and Quebec where there was under-representation and over-representation, respectively.

- Response by education level was also comparable to the Canadian population.

- There was significant over-representation in the 55-plus age group compared to the Canadian population. Older respondents were more likely to be hard of hearing (63%) and younger respondents were more likely to be Deaf (61%).

- The predominant language used by the respondents was English followed by sign language and French. Respondents communicate most frequently by teletype, followed by relay services, internet/e-mail, and fax, with the Deaf and deaf more likely to use teletype and relay services.

Weather information is important to the majority (95%) of respondents and is very important to more than half (62%) of the respondents. Individuals who identified themselves as Deaf or who use sign language are more likely to say that weather information is very important (74% and 73%, respectively).

A similar response was given regarding the importance of obtaining weather information on a daily basis: 92% indicated that it was important and 58% indicated that it was very important. Again, individuals who identified themselves as Deaf or who use sign language are more likely to say that daily weather information is very important (67% and 69%, respectively).

In terms of frequency of seeking weather information, a majority (88%) indicated that they seek weather information once a day or more often - the most frequent response was twice a day (59%). The preferred time to seek weather information is in the morning (80%) followed by the evening (69%).

While there is a strong interest in weather information and forecasts, ability to access weather information varied. Overall, respondents indicated that they can always (40%) or usually (42%) obtain weather information when required, with access increasing with the age of the respondent.

Comparing these results to our 1997 National Survey of Canadians, the findings are similar.

- Ninety-four percent of respondents seek weather information once or more a day.

- The preferred time to access weather information is in the morning (80%) and in the evening (58%).

- The majority of respondents (54% always and 32% usually) had access to weather information - this is somewhat higher than the survey of the Deaf, deaf, deafened and hard of hearing community.

In the 1999 survey, the top three uses of weather forecasts by respondents are to know what to wear (75%), transportation (66%) and planning outdoor recreation activities (62%). (See Figure 1)

Members of this community are extremely reliant on television for their weather information - 74% rely on the Weather Network, followed by other television stations in general (48%) - or the newspaper (48%). Figure 2 illustrates the responses. In contrast, the 1997 National Survey identified radio followed by television as the primary source of Canadians generally (Figure 3). Internet use is also higher in the Deaf, deaf, deafened and hard of hearing communities (15% versus 0.5%).

Similarly, television was the primary source for weather warning information, followed by being informed by a family/friend (Figure 4). This contrasts with the 1997 National Survey of the general population where television, followed by radio, were identified as the primary sources (Figure 5).

Eighty percent of respondents have received a weather warning with recall being lowest among the Deaf (69%) and highest among the deafened (87%) or hard of hearing (86%). On a regional basis, recall is highest in Ontario (88%) and lowest in Quebec (72%).

Figure 1 – Use Of Weather Information - 1999 Survey of Deaf, deaf, Deafened, and Hard of Hearing Canadians

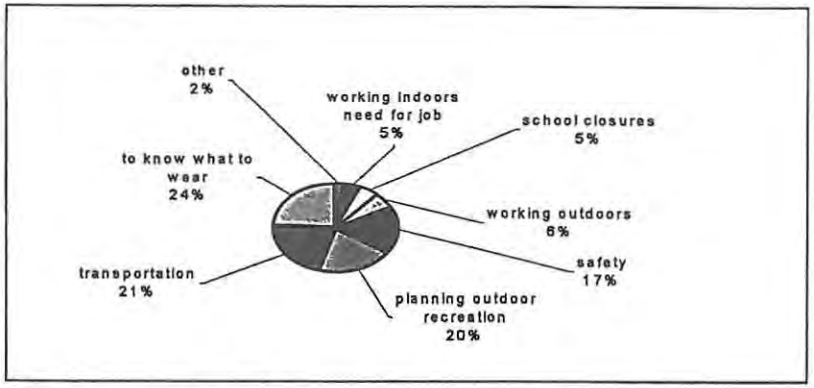


Figure 2 – Sources For Weather Information - 1999 Survey of Deaf, deaf, Deafened, and Hard of Hearing Canadians

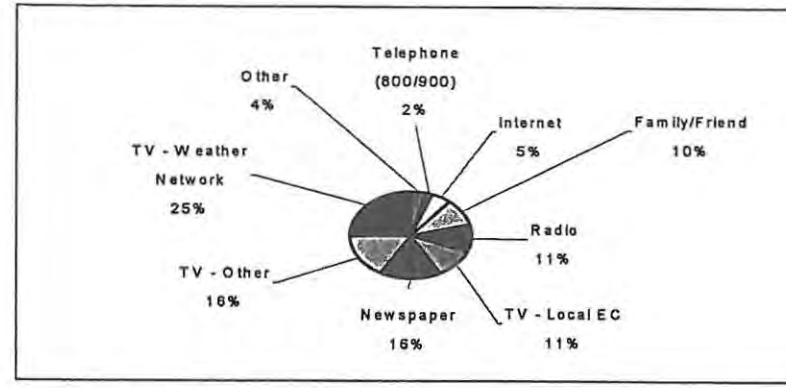


Figure 3 – Sources For Weather Information - 1997 National Survey

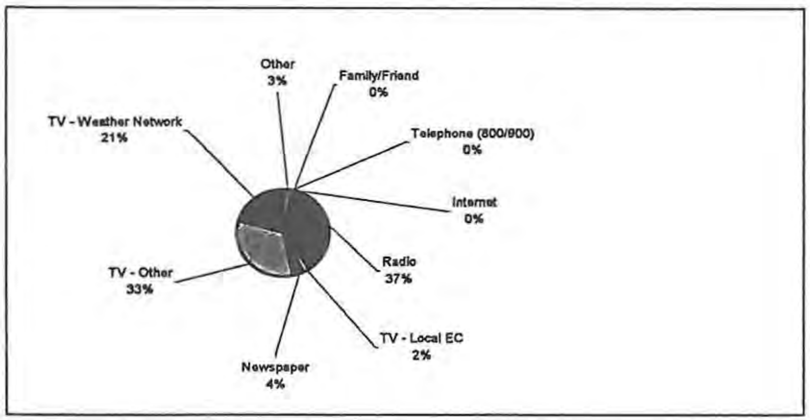


Figure 4 – Information Sources For Weather Warnings - 1999 Survey of Deaf, deaf, Deafened, and Hard of Hearing Canadians

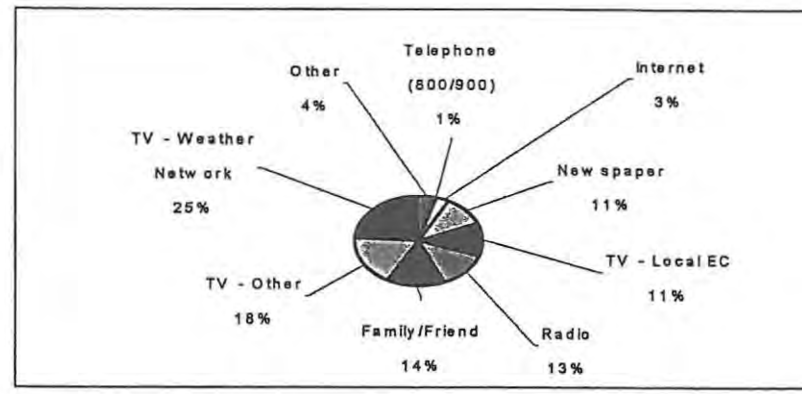


Figure 5 – Information Sources For Weather Warnings - 1997 National Survey

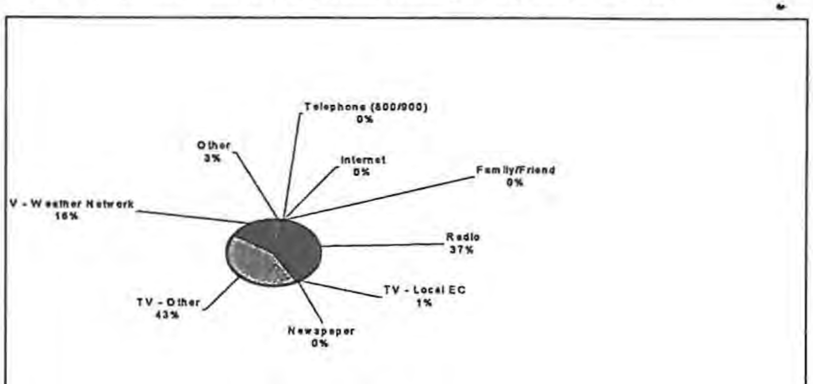
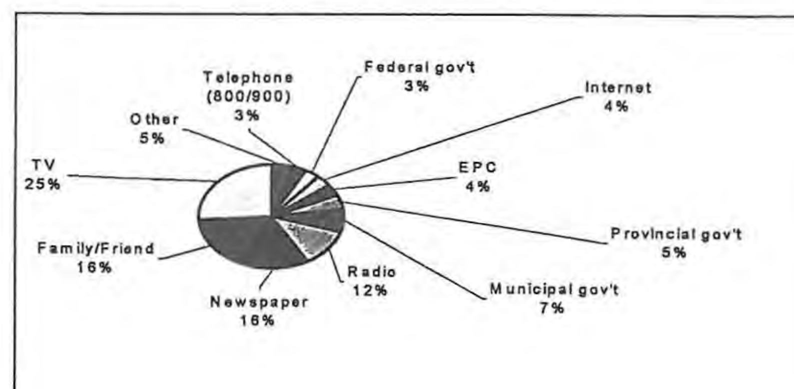


Figure 6 – Information Sources For Disaster Information - 1999 Survey of Deaf, deaf, Deafened, and Hard of Hearing Canadians



The majority (95%) of respondents indicated that it is important to know when severe weather is approaching, of which 67% indicated that it is very important. Support for and interest in weather warning information is substantial and uniform across key demographic, attitudinal and behavioural sub-groupings. The importance is strongest amongst those who indicated that daily weather forecasts (87%) and weather forecasts in general (85%) are important to them, and those who are Deaf (80%) and those who use sign language (80%).

When respondents were asked if they receive enough weather and disaster information to protect themselves, three-quarters (75%) indicated that they did. This response was highest amongst the hard of hearing (84%) and lowest amongst the Deaf (43%) and deaf (35%).

The 1997 National Survey reported similar results. Respondents indicated that they "always" or "most of the time" received enough notice to properly react to a warning about a storm heading towards their area 75% of the time in the summer and 86% of the time in the winter.

While, in the 1999 survey, many respondents indicated that they get enough weather and disaster information to protect themselves, a majority (57%)believe that people in the hearing community receive more information with this figure rising to 68% among the Deaf. The hard of hearing and those over the age of 55 are more likely to say each group receives the same amount of weather information.

The majority (92%) of respondents would find it useful if a message scrolled across their television screen indicating that Environment Canada had issued a weather warning. If the message scrolled over the closed captioning, however, only 70% found this acceptable with only 65% of the Deaf of this opinion.

In terms of behaviour, 43% would turn off the captioning to view the message if it was behind the closed captioning on the television screen, whereas 29% would not. Only 36% of the Deaf would turn off the captioning.

Given a choice, the preferred placement for closed captioning on their television screen is at the bottom (60%), followed by the top (27%) and middle (3%).

A further question asked where respondents would obtain disaster information. Given the reliance on television for weather and weather warning information, it is not surprising that 82% would obtain disaster information from the television. This was followed most frequently by family, friends and co-workers at 50% and newspapers at 49% (Figure 6). Those who are hard of hearing are more likely to obtain disaster information from the radio (62%).

Conclusions

The study reveals that the Deaf, deaf, deafened, and hard of hearing are more restricted in obtaining weather information. Deaf individuals indicated that they could only obtain basic weather information from the words and symbols used during a weather forecast telecast. Closed captioning or a person signing on television would better communicate weather information, including weather alerts.

Barriers and perceptions were identified that need to be addressed in developing a national weather alert system for Canadians. The concerns of the community need to be taken into account while stressing the benefits of such a system. Co-operation with key representative organisations is required to ensure that the needs of the Deaf, deaf, deafened and hard of hearing Canadians are addressed.

References

1) 1999. A Report to Environment Canada: Focus Group Assessment of Deaf, deaf, deafened and hard of hearing survey. Questionnaire and Report. Environics Research Group.

2) 1999. Results of a Survey among the Deaf, deaf, deafened and hard of hearing into the Provision of Weather Services. Environics Research Group.

3) 1991. Health and Activity Limitation Survey, Statistics Canada, Ottawa.

Stop the Press!

Professor Tim Oke appointed to American Meteorological Society's Special Board on Urban Environment

The American Meteorological Society has recently set up this new Board which is to deal with matters ranging from urban vegetation-atmosphere interaction, to mesoscale interactions between cities and their surroundings, to the urban heat island effect and many more such issues. Professor Oke of the University of British Columbia, a long-time, active CMOS member, is the only non-USA scientist appointed to the Board.

Fundamentals of atmospheric modeling

by Mark Z. Jacobson

Cambridge University Press 1999 656 pp.

Book reviewed by André April[1]

This text presents fundamental equations that describe physical, chemical and dynamical processes in the atmosphere, and it provides numerical methods to solve the equations. Along with classic methods of simulating dynamical meteorology, the text contains several numerical techniques for simulating gas and aerosol. The book has been developed from the author's graduate courses and research at Stanford University and contains some interesting exercises and computer programming assignments. Each new term used in the book is written in boldface type and then conveniently defined just afterwards.

The text begins with the basics: the energy equation of thermodynamics and the continuity equation. There is no parameterization of the source and sink term at this level. The text continues with the momentum equation and each of its terms are derived in the cartesian and spherical coordinates. Atmospheric waves are also discussed (acoustic, Lamb, gravity and Rossby). The vertical coordinates in the equations are transformed from altitude to pressure, sigma-pressure and sigma-altitude coordinates.

Chapter 6 presents ordinary and partial differential equations, and numerical methods for solving partial differential equations. Methods for solving partial differential equations include finite-difference and series expansion methods. Numerical solutions are given for the advection-diffusion equation. It is an interresting chapter, but a more intensive development of the subject was expected.

Chapter 7 presents a finite-difference solution to the equations of atmospheric dynamics in spherical-sigma pressure coordinates. Chapters 6 and 7 are probably the most interresting parts.

Subsequently, parameterizations that describe boundary-layer and soil processes are discussed. Parameters important for modeling the boundary layer are presented. The text continues with a discussion of cloud formation and thermodynamics of moist air. Cumulus parameterization for simulating the effect of subgrid scale clouds in a model are also described, but the subject is not complete. An introduction to radiative phenomena with a solution of the radiative transfer equation is presented. The next chapter discusses the homogeneous and heterogeneous nucleation rates from classical theory. A parameterization for the homogeneous nucleation of sulphuric acid and water is presented. The text continues with a description of a numerical scheme to simulate coagulation in a Eulerian model. The scheme is a semi-implicit solution for the coagulation equation.

An equation for the condensation of water vapour onto a single, homogeneous drop is derived. The growth equation is extended to other gases, to a population of drops, and to particles with multiple components. Two numerical solutions to the growth equation (an exact numerical solution and a semi-analytical solution) are discussed. This is followed by a short chapter presenting particle sedimentation velocities and gas, and particle dry-deposition velocities.

In Chapter 11, chemical species, structures and reactions rate coefficients are described with the use of Lewis structures. Following this description, pathways are described for the free troposphere, urban regions (classical site of photochemical smog of Los Aangeles) and stratosphere.

In Chapter 13, numerical methods for solving ordinary differential equations arising from such reactions are given. The methods discussed are the use of Taylor series, Euler, exponential, quasi-steady-state, multistep implicit-explicit and Gear's methods. This leads to a discussion of reactions and methods for solving aqueous chemistry with growth processes. Altogether the atmospheric chemistry provides a very good discussion, mostly for the meteorologist who is not familiar with the subject and wants a good overview.

The last chapter discusses model design, application and testing. To illustrate these steps, the design of an existing model is briefly discussed. This important chapter is again too short and the reader would appreciate a more complete exposé on that important subject. The volume finishes with a complete reference list, but some errors in the authors' names were noted.

To conclude, this is a valuable text-book for graduate and upper-level undergraduate courses in atmospheric sciences and meteorology. It will also be useful for courses in earth and environmental sciences. The book provides a good, up-to-date overview of the subject.

André April

[1] Service de l'environnement atmosphérique, Mirabel, Québec, Canada.

Submission to the House of Commons Standing Committee on Finance September 10, 1999

Partnership Group for Science and Engineering (PAGSE)

Investments in Research and Innovation Blueprint for 2000

Creativity in research is one of the key underpinnings for improved innovation and economic development in Canada. Our youth are the torchbearers for the success of our country in the next century. In positioning future generations to be well-prepared to assume leadership in the knowledge-based economy, Canada needs to be a principal stakeholder in research and innovation. By nurturing creativity, fostering excellence, managing brain circulation, establishing new global partnerships, creating and developing clusters, as well as carving out niches for "in-house" studies, Canada will be at the forefront in the community of nations.

PAGSE recommends that four initiatives form the basis for strategic investments by the Government, in the 2000 budget, in the area of research and innovation.

1. CELEBRATE AND NURTURE EXCELLENCE

-Retaining and recruiting trailblazing researchers and innovators.

Central to this strategy is the implementation of policies designed to develop and expand Canadian expertise. In addition, Canada attracts foreigners, some of whom pursue a career in research and innovation. A certain proportion of foreigners remain here while others return to their country of origin or elsewhere. Canada also loses some of our citizens to other countries. We recommend the adoption of the principle of BRAIN CIRCULATION as a net benefit to Canada.

We recommend that the following steps be taken to drive the equilibrium significantly in our favour:

- Creation of "Prime Minister's New Investigator Awards" Program for new university researchers (Granting Councils).

- Establishment of an "Enhanced Opportunities for Tomorrow" Program for rising stars (Granting Councils / CFI).

- Establishment of a "Rediscover Canada" Program to provide sustained support so as to repatriate mid-career Canadian researchers now working in other countries (Granting Councils / CFI).

- Reduction of personal taxes for competitive take-home pay.

2. ESTABLISH NEW GLOBAL PARTNERSHIPS

-Adding value to Canada and strengthening the competitive position of Canadian researchers.

Collaborative research, on a global basis, can add genuine value to Canada. To maximize our opportunities, we recommend that the Government:

- Facilitate access by Canadians to major international facilities and enable foreigners, working in collaboration with Canadians on such projects, to perform key experiments in Canada. (An investment for this initiative should be made in the Canada Foundation for Innovation.)

- Allow cash contributions by foreign companies to be eligible for matching funds (leveraging) by Granting Councils in university-industry partnerships. Such contributions will result in job creation, and will stimulate foreign investment in industrial research and manufacturing in Canada.

3. CREATE AND DEVELOP CLUSTERS

-Accelerating development of emerging and priority areas.

The development of clusters and networks for research and development is pivotal to enhancing the quality of life of our citizens. As Michael Porter said "Paradoxically the enduring competitive advantages in a global economy lie increasingly in local things - knowledge, relationships, and motivation that distant rivals cannot match". Several clusters do exist in Canada including biopharmaceuticals (Montreal), Information Technology (Ottawa), and Agri-food (Saskatoon), amongst others. We recommend:

- Government develop an action plan to accelerate the creation and development of clusters. Niche areas should be carved out so as to seize competitive advantage. Possibilities include medical devices, fuel cells, nanotechnology, etc.

- Creation of a new Tricouncil initiative to promote multidisciplinary collaboration at one centre. This program would fast-track world-class team developments, and cross-sectorial research, resulting in clusters of excellence which can markedly enhance industrial development and improve Canada's competitiveness on the international scene.

4. PROVIDE NEW OPPORTUNITIES FOR RESEARCH IN GOVERNMENT LABORATORIES

-Standards, information and innovation.

Government research laboratories play a pivotal role in assuring quality standards, in working with industry to apply inventions for economic benefit, in alliances with researchers in other countries (international S+T) and, in specific cases, discovery research. Government lab researchers can also create value by providing unbiased scientific information for policy formulation (e.g. regulatory issues). Necessary government restructuring has created loss of focus in direction and leadership concerning research in government laboratories. The time is now ripe for investment in research in government. We recommend Government:

- Assess current capabilities and skill sets of researchers, as well as the capacity for research in government departments.

- Identify areas of potential or real overlap, across departments and agencies, with a view to enhance cooperation and collaboration, as well as to minimize duplication.

- Establish priorities for research for future wealth generation in the country.

- Develop a 4 year action plan for implementation, with the necessary financial resources to fulfill the objectives of the plan.

NOTES re-Section 4:

a) We highly recommend that, in order to attain several of the noted goals, a committee be created of practising researchers from outside government. We caution against the hiring of consultants, or the appointment of a substantial number of senior administrators from universities and industry for this task.

b) In making recommendations, we are also cognizant of the appreciably different role and function of an agency such as NRC, CRC, or the Canadian Space Agency, as compared with research in a line department (e.g. Health Canada).

c) Over the next three years, implement a peer review system to determine which scientific projects will be carried out in science-based departments (similar to a program now being implemented in Japan).

A-O 37-4 PAPER ORDER

AN INTRODUCTION TO STRATOSPHERIC CHEMISTRY by Darryl J. Chartrand, Jean de Grandpré and John C. McConnell.

SEMI-LAGRANGIAN AND COSMIC ADVECTION IN FLOWS WITH ROTATION OR DEFORMATION by Gary Brassington and Brian Sanderson.

DECADAL-TO-INTERDECADAL FLUCTUATIONS OF ARCTIC SEA ICE COVER AND THE ATMOSPHERIC CIRCULATION DURING 1954-1994, by Dingrong Yi, Lawrence A. Mysak and Silvia A. Venegas.

FUSION OF DUAL-FREQUENCY SAR IMAGERY OF SEA ICE by Bryan Kerman.

A REVIEW OF DIMETHYLSULFOXIDE IN AQUATIC ENVIRONMENTS by Peter A. Lee, Stephen J. de Mora and Maurice Levasseur

Books in search of reviewer
Livres en quête d'une critique

1) Numerical Simulations in the Environmental and Earth Sciences, by F. Garcia Garcia, G. Ciosneros, A. Fernandez-Eguiarte, and R. Alvarez.

2) The Earth's Plasmasphere, by J.F. Lemaire and K.I. Gringauz.

3) Ocean-atmosphere interaction and climate change, by B. A. Kagan.

4) Statistical Analysis in Climate Research, by H. von Storch.

Book reviewers should provide a useful critique of the book within two-three months. They get to keep the book as a reward!

La critique doit être soumise dans les deux ou trois mois. Comme boni, le livre est donné en cadeau.

Richard Asselin
Directeur des publications / Director of Publications

Copies of Atmosphere-Ocean 37-2 needed!

A handling mistake has caused our stock of extra copies of A-O 37-2 to be discarded, leaving us short a few copies to meet client requirements. We therefore appeal to Members who do not keep their copy after reading it, to return their copy of this issue only to us. If you wish to do this, please contact us by phone (613) 562-5616, fax 562-5615, or e-mail CAP@physics.UOttawa.ca. For this service, we will refund the first ten persons a flat $10.00, to cover mailing cost and handling.

Thank you for your help.

Richard Asselin
Director of Publications

THE INSTITUTE FOR CATASTROPHIC LOSS REDUCTION

THE CHAIR IN SEVERE WEATHER AND EARTHQUAKES

The Institute for Catastrophic Loss Reduction is a unique partnership between the Insurance Council of Canada (ICC) and The University of Western Ontario (UWO). Its purpose is to reduce the escalating losses of lives and property encountered due to natural disasters. The Institute will strengthen the research base, improve communications, and over time, build a network of agencies and institutions with the common aim to mitigate these catastrophes. The Institute is being funded by the ICC, UWO and the Government of Ontario for an initial period of five years with an overall budget of seven and a half million dollars.

The Institute will appoint two chairs to provide leadership in establishing research in the area of catastrophic loss reduction and developing the network. The currently advertised position is in the area of Severe Weather and Earthquakes.

Applications are invited for the first of these chairs which will be directed at engineering and scientific issues relating to establishing safer communities. These issues include seismic hazards and severe weather-related hazards such as wind storms, flooding, ice storms and blizzards and the mitigation of their effects. The chair would have experience in some or all of these issues as well as an understanding of mitigation measures, and risk assessment. The successful applicant is expected to have a Ph.D. or equivalent experience in civil or structural engineering, meteorology or construction. Applicants will be expected to have excellent communication skills and preferably be eligible for registration as a Professional Engineer in Ontario. The individual will be expected to initiate a vigorous research program and supervise graduate students. They would need the leadership skills to establish partnerships with other institutions, and to form a research network.

This is an industry chair and the successful applicant will have a reduced teaching responsibility during the term of the industrial funding. Applications close February 1, 2000 for an appointment date of April 1, 2000 (or as soon as possible thereafter). Salary and rank will be commensurate with experience and research record. The appointment will be a five-year (renewable) contract appointment and may be at the Professor or Associate Professor level.

The position is subject to budget approval. In accordance with Canadian Immigration requirements, this advertisement is directed to Canadian citizens, and permanent residents of Canada. The University of Western Ontario is committed to employment equity, welcomes diversity in the workplace, and encourages applications from all qualified individuals including women, members of visible minorities, aboriginal persons and persons with disabilities.

If you share our commitment to excellence in teaching and research and are eager to pursue a rewarding academic career, please forward your curriculum vitae, a statement of how you would contribute and provide leadership, and the names of three referees to:

Dr. R.K. Rowe, P.Eng., Chair
Department of Civil and Environmental Engineering
Tel: (519) 661-2139; FAX: (519) 661-3779; Email: r.k.rowe@eng.uwo.ca

Additional information can also be gained from:

Dr. A.G. Davenport, P.Eng., Research Director
Institute for Catastrophic Loss Reduction
Tel: (519) 661-3338; FAX: (519) 661-3339; Email. agd@blwtl.uwo.ca

Société canadienne de météorologie et d'océanographie

Énoncé de politique sur le changement climatique

Connaissance accrue requise pour une prise de décision plus songée

La Société canadienne de météorologie et d'océanographie (SCMO) est un organisme scientifique à but non lucratif qui représente les scientifiques et professionnels canadiens des domaines atmosphérique et océanographique. Depuis 1963, le but de la SCMO a toujours été la promotion de la météorologie et de l'océanographie au Canada. La SCMO possède un comité spécial chargé d'examiner les questions scientifiques d'actualité.

La **Société canadienne de météorologie et d'océanographie**, citant le Protocole de Kyoto négocié par le Canada et d'autres nations, ainsi que le débat en cours au sujet du changement climatique, émet cet énoncé de politique d'intérêt pour tous ceux concernés.

La **SCMO** soutient qu'une vision commune de la science du changement climatique et de la variabilité est essentielle au développement de politiques et de programmes efficaces sur le changement climatique, tout en s'occupant des engagements énoncés dans le Protocole de Kyoto en 1997.

La **SCMO** appuie le processus d'évaluation scientifique périodique du climat entrepris par le Groupe intergouvernemental sur l'évolution du climat et corrobore la conclusion de son second rapport d'évaluation, qui déclare que la plupart des éléments semblent suggérer que les humains aient une influence certaine sur le climat global.

La **SCMO** appuie également les conclusions de l'Étude pan-canadienne sur les impacts et l'adaptation à la variabilité et au changement climatique, qui démontre que notre réponse sera cruciale dans l'évaluation des bénéfices et des coûts environnementaux, économiques et sociaux du changement climatique pour le Canada.

La **SCMO** reconnaît que les incertitudes actuelles dans la vision commune scientifique du climat limitent notre capacité de prévoir précisément la nature des changements futurs. Il est notamment incertain jusqu'à quel point et dans quelles régions le Canada connaîtra une plus grande incidence d'extrêmes dans le climat (inondations, sécheresses, tempête de verglas). Par contre, nos connaissances permettent d'affirmer qu'il faut réduire les activités humaines qui peuvent amener un changement climatique et concevoir des techniques permettant de s'adapter au changement climatique.

Ainsi, parmi les efforts scientifiques nécessaires, la **SCMO** recommande d'accentuer la surveillance du climat et la recherche qui vise à:

- Comprendre et prévoir les changements et variations de climat;
- Comprendre l'impact de la variation climatique sur notre environnement et notre société;
- S'adapter à l'impact du changement climatique et à atténuer cet impact.

Les scientifiques canadiens possèdent les compétences requises pour contribuer de façon significative aux connaissances mondiales dans tous ces domaines. En tant que pays influencé par le climat, le Canada devrait être grandement motivé à comprendre et aborder les changements de son propre climat.

Ottawa, Novembre 1999.

Canadian Meteorological and Oceanographic Society

Policy Statement on Climate Change

Improved Knowledge Needed for Smarter Decisions

The Canadian Meteorological and Oceanographic Society (CMOS) is the non-profit scientific organization representing Canadian atmospheric and oceanic scientists and professionals. Since 1963, the goal of CMOS has been the advancement of meteorology and oceanography in Canada. CMOS has a special committee charged with the examination of timely scientific issues.

The **Canadian Meteorological and Oceanographic Society**, noting the Kyoto Protocol negotiated by Canada and other nations, as well as the ongoing debate about climate change, issues this policy statement for the information of all concerned.

CMOS asserts that a common understanding of the science of climate change and variability is an essential basis for developing effective programs and policies on climate change, including addressing the commitments laid out in the Kyoto Protocol of 1997.

CMOS endorses the process of periodic climate science assessment carried out by the Intergovernmental Panel on Climate Change and supports the conclusion, in its Second Assessment Report, which states that the balance of evidence suggests a discernible human influence on global climate.

CMOS also endorses the conclusions of the Canada Country Study: Climate Impacts and Adaptation, which shows that our response will be critical in determining the environmental, economic and social costs and benefits of climate change for Canada.

CMOS recognizes that current uncertainties in the scientific understanding of climate limit our ability to predict the nature of future change accurately. In particular, it is unclear to what degree and in which regions Canada will experience an increase of weather extremes (floods, droughts, ice storms). However, there is sufficient understanding to justify reducing the human activities which can induce climate change and developing techniques to adapt to climate change.

Thus, among the necessary scientific endeavours, **CMOS** recommends enhanced monitoring of climate and further research aimed at the following:

- understanding and predicting changes and variations in climate;
- understanding impacts of climate variation on our environment and society;
- adaptating to and mitigating the impacts of climate change.

Canadian scientists have the capabilities to make a significant contribution to the global body of knowledge in all of these areas. As a country that is dominated by climate, Canada should have a strong motivation to understand and deal with changes to its own climate.

Ottawa November 1999.

***** Reminder *****

2000 CMOS Prizes and Awards

Just to remind everyone that the deadline for the submission of nominations is 11 January 2000. The list of prizes and awards is available on the CMOS Web site:

http://www.cmos.ca

Please submit your nominations to:

Mr. Mike Leduc, Secretary
CMOS Prizes and Awards Committee
Atmospheric Environment Service
Toronto Regional Centre
4905 Dufferin Street
Downsview, Ontario
M3H 5T4

Tel: (416) 739-4474; Fax: (416) 739-4603

We are counting on you!

***** Rappel *****

Prix et Mentions de la SCMO - 2000

Juste pour vous rappeler que la date limite pour la soumission des mises en nominations est le 11 janvier 2000. Toutes les informations sur les différents prix et mentions de la SCMO sont disponibles sur le site internet suivant:

http://www.scmo.ca

Veuillez s'il-vous-plaît faire parvenir vos nominations à:

M. Mike Leduc, Secrétaire
Comité SCMO pour les prix et mentions
Service de l'environnement atmosphérique
Centre régional de Toronto
4905 rue Dufferin
Downsview, Ontario
M3H 5T4

Tél: (416) 739-4474; Fax: (416) 739-4603

On compte sur vous!

Reminder to Members

An opportunity now exists for members or non-members to nominate Fellows to the Society, keeping in mind that nominees must be members in good standing. In considering the nominations of Fellows, consideration should be given to the following general criteria:

Research, Teaching, Technology, Professional Services, Administration in academia, industry, government or other institutions, Communication and interpretation of atmospheric and oceanographic phenomena, Weathercasting, International meteorological and/or other oceanographic affairs.

Each nomination should be signed by the primary sponsor and supported by two others, at least one of whom must be from an establishment other than that of the nominee.

Applications forms are available from the Executive Director in the CMOS office or on the CMOS website. The contact on the CMOS Executive is Mr. Bill Pugsley who can be reached either through the CMOS office or at:

Tel: (613) 731-0145; e-mail: puglsey@freenet.carleton.ca

Nominations are to be postmarked no later than **April 15, 2000.**

Rappel aux membres

Les nominations pour les Fellows de la Société sont maintenant acceptées. Les personnes mises en candidature doivent être des membres en règles de la Société. Les critères suivants devraient être pris en considération lorsqu'une candidature est soumise:

Recherche, enseignement, technologie, services professionnels, administration dans les universités, l'industrie, le gouvernement et dans les autres institutions, communication et interprétation des phénomènes atmosphériques et océaniques, la prédiction de la météo, les affaires internationales en météorologie et/ou océanographie ou autres.

Chaque candidature doit être signée par le commanditaire principal et doit être endossée par deux autres, dont au moins une personne venant d'un établissement autre que celui de la personne mise en nomination.

Les formulaires d'application sont disponibles au bureau du directeur exécutif ou sur le site internet de la SCMO. La personne ressource au sein de l'éxécutif est M. Bill Pugsley qui peut être rejoint au bureau de la SCMO ou à:

Tél: (613) 731-0145; courriel: pugsley@freenet.carleton.ca

La date butoir du **15 avril 2000** devra être respectée.

Call for Papers
CMOS 2000
34th Annual CMOS Congress

The Vancouver Island Centre of the Canadian Meteorological and Oceanographic Society (CMOS) will host the 34th Annual CMOS Congress at the University of Victoria from 29 May to 2 June, 2000. The theme is "The Role of the Pacific in Climate and Weather". Contributions are particularly sought on analysis, modelling, and theoretical aspects of this topic including Pacific weather, climate and climate change, El Niño/Southern Oscillation, Pacific decadal oscillation, Arctic/Antarctic oscillation, ocean observations and analysis, and biogeochemical cycles. Sessions will be held on a broad array of other aspects of atmospheric and oceanic science and contributions are sought in all areas of meteorology and oceanography.

Abstracts will be received until February 4, 2000. Authors are strongly encouraged to submit abstracts, of less than 300 words, interactively through the conference web site:

http://www.cccma.bc.ec.gc.ca/cmos2000/

The electronic submission of abstracts produces a faster approval process for authors and greatly facilitates the organization of the scientific program and the printing of the program and abstracts volume. Submissions may also be sent by mail to:

George Boer, Co-Chair
CMOS2000 Congress Scientific Program Committee
Canadian Centre For Climate Modelling And Analysis
Atmospheric Environment Service
University Of Victoria
P. O. Box 1700
Victoria, B.C. V8W 2Y2 Canada

Commercial exhibits will be on display during the Congress. For further information contact either:

- George Boer, Co-Chair
Scientific Program Committee
George.Boer@ec.gc.ca, (250)363- 8226;
- John Fyfe,
Local Arrangements Committee
John.Fyfe@ec.gc.ca, (250) 363-8236; or
- Diane Masson,
Commercial Exhibits
MassonD@pac.dfo-mpo.gc.ca, (250) 363- 6521.

Invitation à Présenter des Communications
SCMO 2000
34e Congrès annuel de la SCMO

Le Centre de l'Île de Vancouver de la Société canadienne de météorologie et d'océanographie (SCMO) seront les hôtes du 34e Congrès annuel qui se tiendra à l'Université de Victoria du 29 mai au 2 juin 2000. Le thème de la conférence est "L'influence de l'océan Pacifique sur le climat et le temps". Particulièrement recherchées sont les contributions touchant à l'analyse, la modélisation ainsi que d'autres aspects théoriques reliés à ce domaine de recherche tels le temps sur le Pacifique, le climat et les changements climatiques, l'oscillation El Niño et l'oscillation australe, les oscillations décennales du Pacifique, les oscillations Arctiques et Antarctiques, observations et analyses océaniques, et les cycles biogéochimiques. Par ailleurs, de nombreuses séances couvriront un large éventail de sujets tant en sciences atmosphériques qu'océaniques, aussi acceptons-nous les communications touchant tous les domaines de la météorologie et de l'océanographie.

On peut faire parvenir des résumés jusqu'au 4 février 2000. Les résumés ne doivent pas dépasser 300 mots. Nous encourageons fortement les auteurs à nous les soumettre électroniquement en utilisant le site Internet du congrès à l'adresse suivante :

http://www.cccma.bc.ec.gc.ca/cmos2000/

La soumission des résumés par voie électronique accélère le processus d'approbation pour les auteurs et facilite l'organisation du programme scientifique et l'édition des volumes du programme et des résumés. On peut également nous les soumettre par courrier régulier à:

George Boer, coprésident
SCMO Congrès 2000 - Comité du programme scientifique
Centre canadien de la modélisation et de l'analyse climatique; Service de l'environnement atmosphérique
Université de Victoria; B.P. 1700
Victoria, B.C. V8W 2Y2 Canada

Une exposition commerciale aura lieu pendant le Congrès. Pour obtenir plus de renseignements, contactez soit:

- George Boer, coprésident
Comité du programme scientifique
George.Boer@ec.gc.ca, (250) 363-8226;
- John Fyfe,
Comité local d'organisation
John.Fyfe@ec.gc.ca, (250) 363-8236); ou
- Diane Masson,
Exposition commerciale
MassonD@pac.dfo-mpo.gc.ca, (250)363-6521.

CMOS-ACCREDITED CONSULTANTS
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Applied Meteorology, Operational Meteorology
Broadcast Meteorology

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Bill Thompson

Flood Warning, Marine Applications
Integrated Monitoring and Prediction Systems
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CANADIAN METEOROLOGICAL AND OCEANOGRAPHIC SOCIETY

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Web: www.meds-sdmm.dfo-mpo.gc.ca/cmos/

MEMBERSHIP APPLICATION / RENEWAL FORM
DEMANDE D'ADHÉSION / RENOUVELLEMENT

☐ NEW APPLICATION / NOUVELLE DEMANDE ☐ RENEWAL / RENOUVELLEMENT

MEMBER SINCE / MEMBRE DUPUIS

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