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Les auteurs peuvent choisir de soumettre leurs manuscrits aux "Articles", "Notes de Recherches", ou "Nouvelles et Commentaires". Ils doivent l'indiquer sur la lettre d'accompagnement du manuscrit. Les articles de recherche et les "Notes" sont indépendamment soumis à l'examen d'au moins deux appréciateurs anonymes. Le rédacteur en chef examine les "Nouvelles et Commentaires" conjointement avec le comité de rédaction. On accepte les articles soit en français, soit en anglais. Il faut envoyer un résumé, de préférence en français et en anglais.

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Foreword / Avant-Propos

Since 1967, the Climatological Bulletin has appeared twice a year. Volume 20 represents the first volume to include 3 issues. Hopefully, the Bulletin will continue to expand in size, so that in a few years time, it will become possible to publish on a quarterly basis, as do our sister publications, Atmosphere-Ocean and Chinook.

As part of the growth process, the Bulletin, with the encouragement of the CMOS Executive, is strengthening its contacts with provincial and regional groups, so as to enhance the exchange of information on meetings, research in progress, and other matters of interest. A member of our Board, André Hufty, is now acting as a liaison with l'Association de climatologie du Québec. Other members have similar, albeit less formal contacts with various groups across Canada. It is anticipated that these efforts will expand, now that the Board has reached its full complement of 9 members. With that, it gives me great pleasure to welcome Sus Tabata and Elaine Wheaton to the Board as Associate Editors. Their nominations were approved by CMOS Council at the meeting on October 28-29, 1985.

This issue includes a listing of the referees who generously donated their time and expertise to the Bulletin during the 1983-1985 period. Final responsibility rests with the Editor, but the participation of the wider scientific community in the review process does make a difficult job considerably easier.

Stewart J. Cohen

Synoptic Fire Climatology of the Lake Athabasca – Great Slave Lake Area, 1977-1982

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[Original manuscript received 24 May, 1985; in revised form 11 October, 1985]

ABSTRACT

The role of synoptic-scale weather in forest fire behaviour has been the object of study for several decades. These studies have been subjective in nature and to a large extent have involved a case study approach. To define the critical synoptic-scale fire weather types and to provide a mechanism of more effectively communicating this information to forest fire managers, an objective synoptic fire climatology was initiated. This paper reports on the first phase of this project. The Lake Athabasca and Great Slave Lake area was selected as the pilot study area for this project.

This analysis involved the subjective classification of 50 kPa and surface weather maps into previously defined weather types. The weather map data base consisted of the 0000 GMT and 1200 GMT weather maps for defined periods of major fire activity during the 1977-1982 forest fire seasons within the study area. Over eighty percent of the 50 kPa maps during the defined periods were characterized by a dominant long wave ridge over the study area with a short wave or long wave trough to the west or southwest of the ridge's position. In the case of the surface weather maps, over eighty percent of the classified maps were characterized by a low pressure system immediately to the west of the study area with a trough through central Alberta and high pressure areas both to the east and west of the surface trough position.

RÉSUMÉ

Le rôle des conditions météorologiques à l'échelle synoptique, dans le comportement des incendies de forêt, a fait l'objet d'études depuis plusieurs décennies. Ces études plutôt subjectives ont été basées, dans une grande mesure, sur des cas réels. Pour définir les divers types de conditions météorologiques à l'échelle synoptique qui sont propices aux incendies de forêt, et pour fournir un mécanisme de communication efficace des informations aux responsables de la lutte contre les incendies de forêt, on a entrepris une étude climatique objective, à l'échelle synoptique, des incendies de forêt. Le présent rapport présente la première phase de ce projet. La région du lac Athabasca et celle du Grand Lac des Esclaves ont été sélectionnées pour une étude pilote.

Pour cette étude on a dû classer subjectivement cartes météorologiques à 50 kPa et des cartes de surface, en fonction de divers types de conditions météorologiques déjà définies. Les données de base regroupaient les cartes météorologiques de 0000 TMG et de 1200 TMG pour des période actives bien définies des saisons propices aux incendies de forêt dans la région de l'étude, de 1977 à 1982. Plus de quartre-vingt pour cent des cartes à 50 kPa se sont caractérisées par une crête barométrique dominante de grande amplitude avec un creux barométrique de courte ou de longue amplitude à l'ouest ou au sud-ouest de la crête. Dans le cas des cartes de surface, plus de quatre-vingt pour-cent d'entre elles se sont caractérisées par un système de basse pression immédiatement à l'ouest de la région de l'étude, avec un creux barométrique au centre de l'Alberta, et avec des crêtes à l'est et à l'ouest du creux.

1. INTRODUCTION

In fire management there is a distinct advantage to be gained from being able to anticipate, well in advance, potential fire occurrence and behaviour. Recognition of the warning signs of a potentially hazardous situation or conditions would allow a fire management agency to plan and act accordingly (e.g., repositioning resources, developing evacuation plans, etc.). The information required to predict probable fire occurrence and behaviour is met in part by a knowledge of the current synoptic fire weather pattern (Schroeder et al., 1964; Brotak, 1980).

This synoptic fire climatology project was initiated for the purpose of better defining the role played by critical synoptic-scale weather types and to provide a means of integrating synoptic-scale weather information into the fire management decision making process. This project is designed to use both subjective and objective weather analysis procedures for the definition of the role played by synoptic-scale climatology using a four-phase approach. The analysis and integration procedures are to be developed in the first three phases within a pilot study area and then applied nationally in the fourth phase.

This paper reports on the findings of the first phase, a subjective weather typing analysis for the Lake Athabasca-Great Slave Lake area (see Figure 1). This area was selected because of its relevant significance in terms of recent forest fire incidence, and because of availability of weather map typing information. Weather maps, both 50 kPa and surface analyses, for 0000 GMT and 1200 GMT were subjectively classified using the map types defined by Kociuba (1974) for the "Alberta window". The weather maps typed were those for identified critical fire periods in the study area during the 1977-1982 forest fire seasons. This first phase is not a definitive study but rather exploratory, as it is designed to examine the potential for success of the proposed precedures to be developed in phases two and three.

The second and third phases of the project are designed to provide more definitive answers by utilizing an objective procedure. During these later phases the relative occurrence of "critical" synoptic-weather types will be

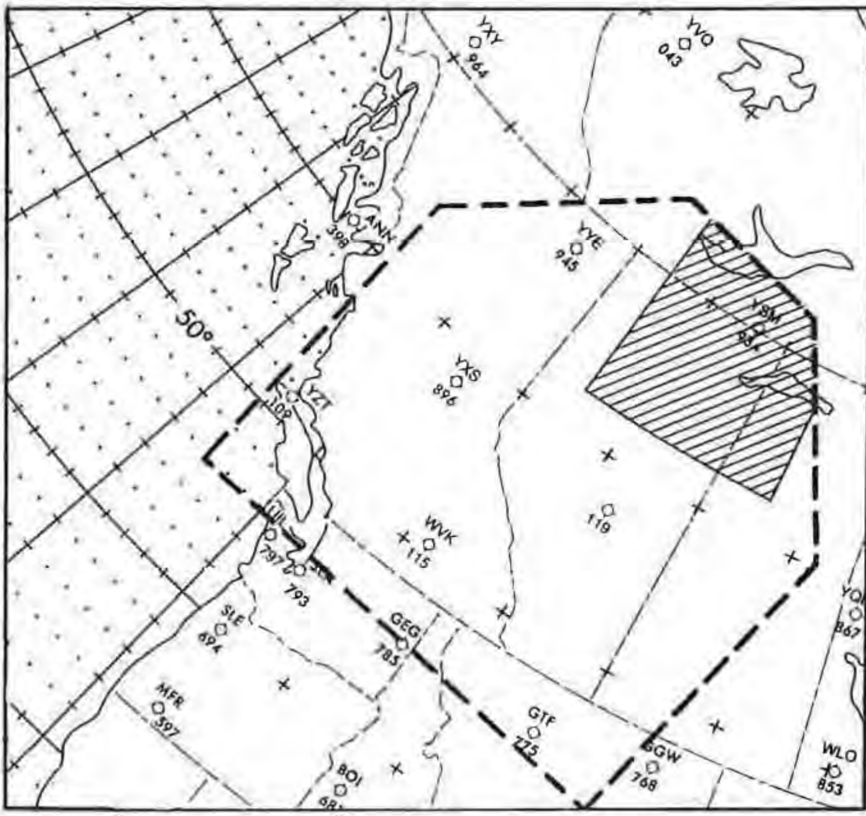

FIGURE 1. Alberta Window (outlined by a dashed line) and study area (shaded)

defined in terms of their associations with "critical" and "non-critical" fire periods. In addition, the description of the synoptic-weather types will be integrated with components of the Canadian Forest Fire Weather Index (FWI) System (Canadian Forestry Service, 1984) for the purpose of quantifying impact of the past and current weather on the level of fire danger.

The limitations of this study and, in fact, the limitation of the use of synoptic types in forecasting fire danger should be recognized. The antecedent weather and its effect on forest fuels in the area of concern must be considered in each case. Obviously, if the area has been under the influence of moist air prior to one of the defined "critical" weather types influencing the areas's fire weather, the fire danger will not be as severe as if the previous period had been dry. However, some weather types will enhance the fuel drying process, substantially increasing the volume of available fuel, thereby creating a potentially serious fire situation before the weather type has run its course. Integrating components of the FWI System with the objective synoptic fire information, as planned during the latter phases of this project, will address this shortcoming.

Certain characteristics of the upper-air flow patterns are closely related to periods of critical fire weather patterns. Those upper-air features that divert (or block) the flow of moister and/or cooler air away from a particular area represents a potential threat to that area's fire weather. The upper atmospheric flow pattern is normally undergoing continuous change. However, certain patterns will often exhibit a high degree of persistence, and upper-air ridges or troughs may remain quasistationary over an area, resulting in prolonged periods of warm and dry, or cool and damp weather, respectively. For example, a strong meridional ridge having a closed anti-cyclonic circulation can divert the flow of moisture-laden air and/or cooler air from the area under its influence. Such a system is frequently referred to as a "blocking ridge". Increases in the amount of available fuel can arise from this type of upper-air pattern, and since these flow patterns are normally slow moving, the associated extended periods of hot and dry weather enhances the fuel drying process.

Alexander et al. (1983), when detailing the behaviour of a wildfire near Lac la Biche, Alberta, on May 2, 1980 (DND-4-80) described the coincident 50 kPa upper-air circulation pattern and associated surface weather features. In this analysis of the DND-4-80 fire, they concluded that a blocking upper-air ridge which had dominated the Alberta weather during April, 1980 was responsible for the critical fire climate (i.e. intense fuel drying) evident throughout east-central Alberta during the early part of the 1980 forest fire season. The ensuing breakdown of the upper-air ridge and accompanying surface dry cold frontal passage created a fire environment (strong, gusty surface winds; low relative humidities; atmospheric instability; and the likely presence of a low-level jet) conducive to extreme fire behaviour.

Nimchuk (1983) examined the significant role played by weather in determining the severity of the 1981 forest fire season in Alberta. In particular, breakdowns of established upper-air ridges were associated with critical weather and fire behaviour. In describing the relationships between the synoptic-scale weather and fire behaviour, Nimchuk described three stages in the life cycle of an upper-air ridge. During the establishment stage, the weather was characterized by increasing temperatures, low humidities and light winds, which was associated with decreasing fuel moisture and low lightning risk. The second stage, identified by the initial weakening of the ridge by a transitory upper-air short wave trough, is normally associated with increasing atmospheric instability, increasing lightning activity, and temperature and moisture conditions conducive to maintaining the elevated fire danger. The final stage, breakdown of the 50 kPa ridge, was found to be the stage during which the potential of extreme fire behaviour was the greatest. The relative positioning of the upper-air ridge and approaching upper-air trough and the accompanying surface cold front, produces strong surface winds and a high thunderstorm risk prior to the passage of the cold front. The abrupt destruction of the upper-air ridge, and the intense surface low pressure which normally accompanies it, were also found to generate a greater chance of more extreme fire weather than in the case of a gradual breakdown.

Schroeder et al. (1964) investigated the problem of relating synoptic weather patterns to extreme fire behaviour in the continental United States. The major conclusions of this study linked extreme fire behaviour to the peripheral areas of surface high pressure systems and in the vicinity of dry cold fronts. By dividing the United States into fourteen regions, defined on the basis of synoptic climate, they were able to classify the synoptic features responsible for extreme fire behaviour as to their source and characteristics.

Brotak (1980) examined the meteorological conditions associated with major wildland fires in the United States, Australia and Canada and concluded that comparable, causal, synoptic-scale weather factors were associated with major fires in all three countries. The vast majority of wildland fires studied, which exhibited extreme behaviour, were associated with: a) the eastern portion of a small amplitude but intense short wave trough at 50 kPa; b) flow patterns which blocked low-level (85 kPa) moisture advection; c) a surface frontal system and in particular a surface cold front.

Newark (1975) examined the relationship between fire danger, as represented by the FWI component of the Canadian Forest Fire Weather Index System, and 50 kPa heights as depicted by a Hovmoller diagram. His examination of the 1974 forest fire season in northwestern Ontario showed that a close relationship existed between maxima in the 50 kPa height pattern and extreme values of the FWI.

Stocks and Street (1983) concluded from an examination of monthly fire statistics for northwestern Ontario, and mean upper-air analyses, that severe fire periods were directly related to prolonged periods of dry weather which were in turn associated with upper-air long wave ridging over central North America. The development and persistence of this type of circulation pattern over the centre of the continent effectively blocks the influx of atmospheric moisture into northwestern Ontario. In addition, this upper-air circulation pattern favours the establishment of a subsidence inversion over northwestern Ontario, and the advection at the surface of warm, dry air from southwestern United States. These combined weather conditions enhance the fuel drying process and set the stage for potentially severe fire episodes.

An individual weather map can be classified into categories or weather types through a description of the map's most significant features by subjective methods. This involves examining the individual weather maps (surface and upper-air) and categorizing them on the basis of the relative positioning and magnitude of the significant weather systems. The map types used to classify the weather maps were those proposed by Kociuba (1974) for the "Alberta Window" which includes the Great Slave Lake area. To define the weather map types, Kociuba undertook an objective analysis of surface and 50 kPa weather maps, using correlation methods similar to those refined by the Map Typing Project Office (1973). For the "Alberta Window" (see Figure 1) thirty-six 50 kPa and thirty-four surface weather types were defined on the basis of daily weather maps for the period January-December 1946-1971.

The critical fire periods for which the weather maps would be classified were delineated by examining selected, individual fire reports for the study area filed during the 1977-1982 fire seasons and interviewing the responsible fire management and fire weather personnel. The 1977-1982 fire seasons were selected because of the availability of more complete description of the fires that occurred and because most personnel involved with these seasons are still in place. Surface and upper-air weather maps were retrieved from the Atmospheric Environment Service (AES), Canadian Climate Centre archives and then catalogued according to the classification proposed by Kociuba (1974).

Subjective categorizing of weather maps presents several problems (Barry and Perry, 1973). In the first place, because of the continuous nature of the atmosphere, delimitating boundaries between types must be, out of necessity, somewhat arbitrary. In addition, problems can arise in defining the termination and/or initiation of a particular weather type. Weather systems, both at the surface and aloft can change both abruptly and gradually. An attempt to reduce the impact of these problems was made by having two meteorologists categorize the weather maps independently initially, and then attempt to arrive at a consensus when discrepancies occurred.

The subjective categorizing of the surface and upper-air weather maps for the Great Slave Lake area distinguished "weather types" which were more prominent during the defined severe fire periods. These weather types were of the same general nature as those found by earlier investigators: surface high pressure areas, particularly near its boundaries, passage of dry cold fronts and the breakdown of upper-air ridges.

2. ANALYSIS

Selected individual fire reports from the 1977-1982 forest fire seasons within the Great Slave Lake area, including the south-central Northwest Territories, northern Alberta and northern Saskatchewan, were obtained from the responsible agencies and examined for the purpose of defining the major forest fire activity periods during these years. These periods (see Table 1) were determined by using the recorded statements on the fire reports (e.g., intense fire-run, long-range spotting, and excursions across established fire lines). In addition, personal contact was made with individuals from the responsible fire management and fire weather agencies, for the purpose of further refining the definition of the critical fire periods.

Upper-air and surface weather maps were obtained from the AES

TABLE 1 Periods of Major Fire Activity within the Lake Athabasca – Great Slave Lake Area.

Year	Major Fire Period[1]	Year	Major Fire Period[1]
1977	May 11 – May 13	1981	May 15 – May 30
1978	June 25 – July 4		June 30 – July 3
1979	June 24 – July 6		Aug. 25 – August 28
	July 14 – July 17		Sept. 5 – Sept. 18
1980	Apr. 30 – May 8	1982	June 14 – June 30

[1] These periods were defined on the basis of fire reports, discussions with fire personnel and from previously defined periods reported in the fire literature. (e.g. Aug. 27, 1981). In all cases within some portion of the "Alberta window" numerous fire starts were reported. In addition, fires were difficult to control (burning out of control) with crowning and spotting reported. In some cases, concern was expressed by the reporting officer for human lives and property being threatened by fires burning during these periods.

archives for the defined periods. The weather map data base was restricted to analysis at 0000 GMT and 1200 GMT when both surface and upper-air maps were available. The typing of the weather maps was done by visually comparing the analyzed weather maps with the catalogued weather maps presented by Kociuba. The typing involved comparing the respective isobaric or contour patterns as to overall configuration, intensity of the depicted weather systems and the circulation pattern. Emphasis was placed on the weather systems and associated streamflow patterns in and within close proximity to the "Alberta Window".

The derived data set of weather map types was then used to describe the synoptic-scale weather systems most often associated with major fire activity periods. The weather types were examined for possible basic similarities. In addition, the results were compared to the findings of earlier investigators.

3. DISCUSSION AND CONCLUSIONS

The most prominent 50 kPa weather pattern during the 1977-1982 major fire activity periods was Kociuba Map Type 3 (Table 2). Figure 2 (a,b) illustrates Kociuba Map Type 3, and the 50 kPa analysis for May 25, 1981 at 1200 GMT, one of the maps classified as Map Type 3. This upper-air weather type is characterized by a 50 kPa low centred off the central British Columbia coast, and a broad 50 kPa ridge extending northwestward over the Great Slave Lake area from a high in the northcentral United States.

The most prominent surface weather type during the 1977-1982 major fire activity periods was Kociuba's surface map type 9 (Table 3). Figure 3 (a,b) illustrates Kociuba's Map Type 9 and the surface analysis for June 30, 1981 at 1200 GMT, one of the maps classified as Map Type 9. This surface weather type is characterized by a low pressure system west of the Great Slave Lake area, with a trough extending from the low southward through central

TABLE 2 Occurrence of 50 kPa Map Types Within the Alberta Window During the Identified Periods.

Kociuba 50 kPa Map Type	Number of Occurrences	Percent Occurrences	Cumulative Percent
3	41	20.2	20.2
8	26	12.8	33.0
1	18	8.8	41.8
9	18	8.8	50.6
2	14	6.8	57.4
7	13	6.4	63.8
18	12	5.9	69.7
22	11	5.4	75.1
5	7	3.4	78.5
26	7	3.4	81.9
29	6	2.9	84.8
19	5	2.4	87.2
23	4	2.0	89.2
31	4	2.0	91.2
split flow	4	2.0	93.2
13	3	1.5	94.7
20	3	1.5	96.2
16	2	1.0	97.2
4	2	1.0	98.2
28	1	0.6	98.9
33	1	0.6	99.4
34	1	0.6	100.0

Alberta. Also characteristic of this weather type are high pressure areas both east (over Manitoba) and west (off the British Columbia coast) of the surface trough position.

An examination of the 50 kPa map types most often associated with the identified periods (Table 2) reveals that similar weather patterns are characteristic of these types. Over eighty percent of the twice-daily 50 kPa weather maps associated with fire activity periods were categorized into Kociuba map types which had a 50 kPa long wave ridge over the Great Slave Lake area and a short wave or long wave trough to the west or south-west of the ridge's position. This upper-air weather pattern is the critical type other authors (e.g. Schroeder et al., 1964; Nimchuk, 1983) have found to be associated with periods of extreme fire behaviour. The upper-air ridging promotes the drying of forest fuels. The approach of the western trough produces a tightening of the pressure gradient and increasing atmospheric instability. This combination of relatively long-term preconditioning of fuel moisture levels and supportive atmospheric dynamics are the principal agents responsible for the critical fire weather that can in turn lead to extreme fire behaviour.

Similarities also exist in the surface weather pattern types most

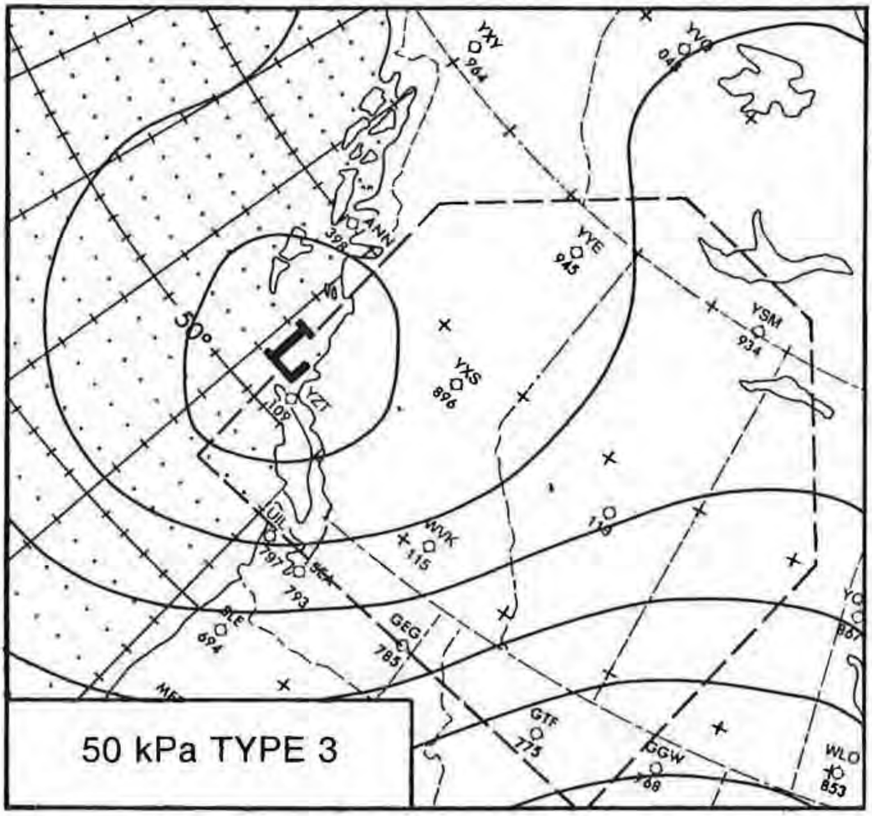

FIGURE 2a. Kociuba (1974) 50 kPa weather Map Type 3 found to be most prominent during the selected periods of the 1977-82 forest fire seasons.

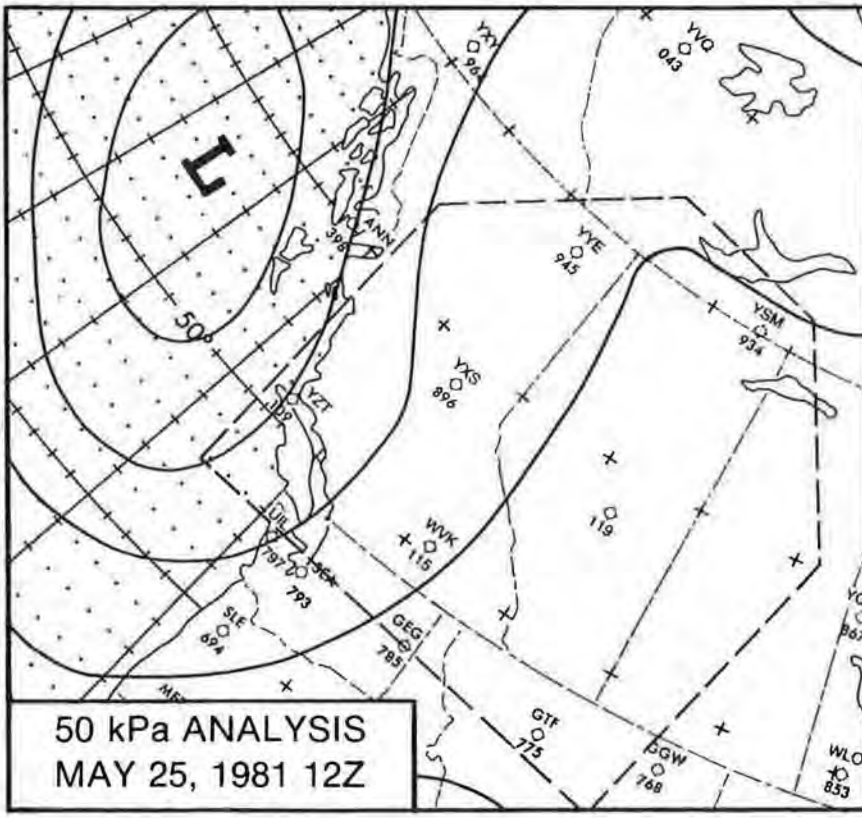

FIGURE 2b. The 50 kPa weather analysis for May 25, 1981 subjectively classified as being similar to Kociuba 50 kPa weather Map Type 3.

TABLE 3. Occurrence of Surface Map Types Within the Alberta Window During the Identified Periods.

Kociuba Surface Map Type	Number of Occurrences	Percent Occurrences	Cumulative Percent
9	53	25.9	25.9
12	36	17.6	43.5
4	20	9.8	53.3
10	18	8.8	62.1
25	16	7.8	69.9
5	11	5.4	75.3
29	8	3.9	79.2
21	7	3.3	82.5
14	4	2.0	84.5
13	4	2.0	86.5
24	4	2.0	88.5
27	3	1.5	90.0
1	2	1.0	91.0
3	2	1.0	92.0
18	2	1.0	93.0
20	2	1.0	94.0
23	2	1.0	95.0
26	2	1.0	96.0
30	2	1.0	97.0
2	1	0.6	97.6
6	1	0.6	98.2
16	1	0.6	98.8
17	1	0.6	99.4
22	1	0.6	100.0

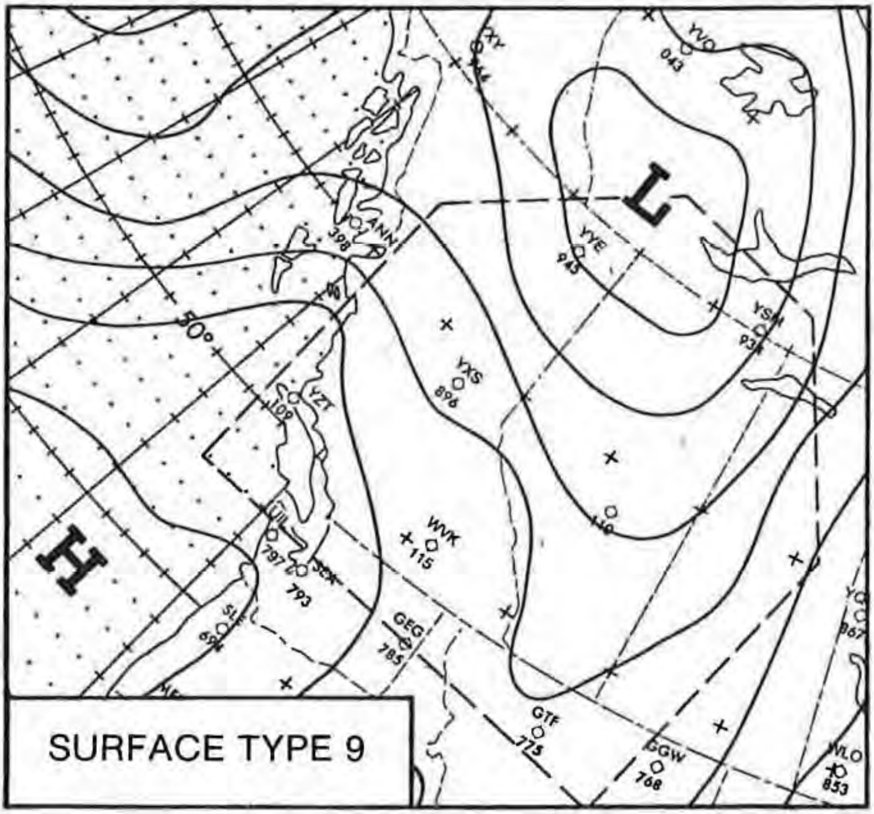

FIGURE 3a. Kociuba surface weather Map Type 9 found to be most prominent during the selected periods of the 1977-82 forest fire seasons

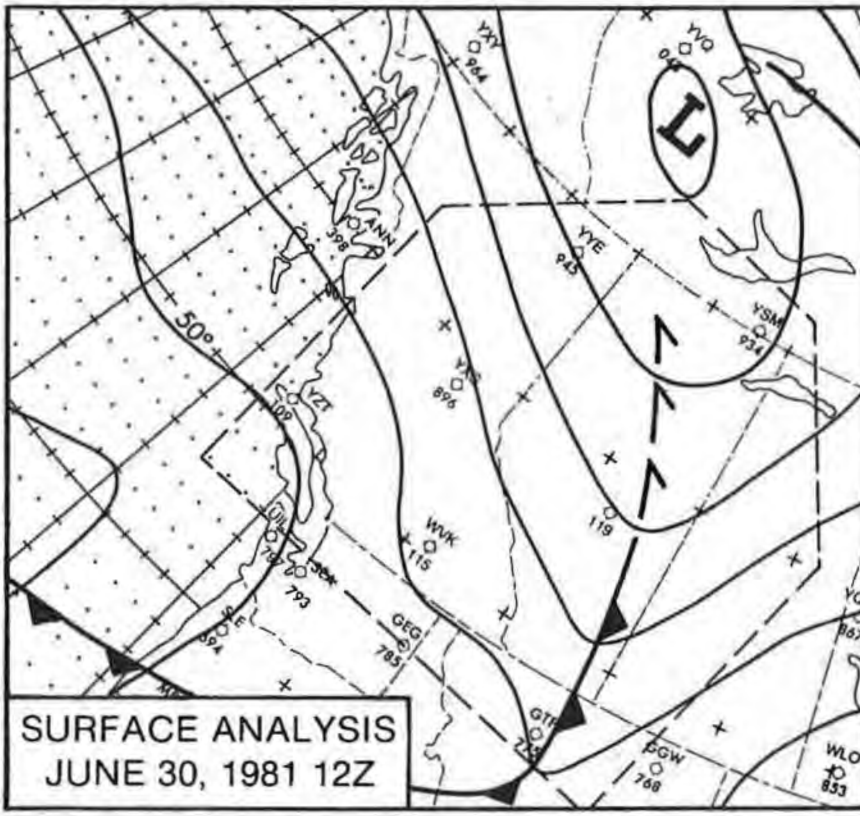

FIGURE 3b. Surface weather analysis for June 30, 1981 subjectively classified as being similar to Kociuba surface Type 9.

often associated with periods of major fire activity. Over eighty per cent of the twice-daily surface weather maps typed are characterized by a predominant low pressure area over or just to the west of the Great Slave Lake area, with large surface high pressure systems over the area to the east and west of the trough. These surface weather types are similar to those noted by other authors (e.g. Brotak, 1980; Stocks and Street, 1983; Nimchuk, 1983) as supporting extreme fire behaviour. The large high pressure systems block the flow of moisture into the Great Slave Lake area, enhance the short-term drying of forest fuels, and in conjunction with the surface troughs and associated fronts produce conditions which may lead to extreme fire behaviour (i.e. strong surface winds, instability and an increased potential for low-level jets (Byram, 1954; Street, 1979)).

The association between the selected 50 kPa and surface weather types is shown in Table 4. There does not appear to be a strong correlation between particular upper-air and surface map types. However, the more prominent surface weather types are those that would be supported by the more prominent upper-air weather types (see Palmén and Newton, 1969 for discussions on relationships between surface and upper-air features). The fact that there does not appear to be a preference for a particular surface type to be associated with a particular 50 kPa type is not surprising, considering the relative similarities of the selected weather types and the subjective nature of the typing. One preliminary conclusion that can be drawn from this analysis is that less frequently occurring 50 kPa types have a high number of occurrences

TABLE 4. Relationship Between the Classified 50 kPa Map Types and the Associated Surface Map Types Within the Alberta Window.

Kociuba 50 kPa Map Type		Associated Kociuba Surface Map Type (Number of occurrences/Percentage)								
Type Number	No. of occur-rences	Surface Map Type Number								
		9	12	4	10	25	5	29	21	Others
3	41	6/14.6	7/14.7	2/ 4.9	7/17.1	8/19.5	3/ 7.3	—	2/ 4.9	6/14.6
8	26	2/ 7.7	11/42.3	5/19.2	—	1/ 3.9	—	—	3/11.5	4/15.4
1	18	9/50.0	2/11.1	2/11.1	1/ 5.6	2/11.1	—	—	—	2/11.1
9	18	6/33.3	4/22.2	2/11.1	2/11.1	—	1/ 5.6	3/16.7	—	—
2	14	6/42.8	—	—	4/28.6	—	—	2/14.3	—	2/14.3
7	13	5/38.4	—	2/15.4	3/23.1	1/ 7.7	—	—	—	2/15.4
18	12	—	2/16.7	—	—	—	2/16.7	—	—	8/66.6
22	11	4/36.3	—	—	—	—	—	—	2/18.2	5/45.5
5	7	4/57.1	2/28.6	—	—	—	—	1/14.3	—	—
26	7	—	—	2/28.6	—	—	4/57.1	—	—	1/14.3
29	6	—	2/33.3	—	—	3/50.0	1/16.7	—	—	—
19	5	1/20.0	2/40.0	—	—	1/20.0	—	—	—	1/20.0
Other	25	10/40.0	4/16.0	5/20.0	1/ 4.0	—	—	2/ 8.0	—	3/12.0
Total	203	53	36	20	18	16	11	8	7	34

of the predominant surface types associated with them (Table 4). A more detailed analysis of these relationships will have to be made during the objective analysis phases of this project.

This subjective, synoptic-weather typing analysis shows that the typing of both upper-air and surface maps can lead to the identification of critical fire weather patterns. Even using the subjectively determined data set of periods of major fire activity during the 1977-1982 fire seasons, subjective weather typing was able to identify a predominant 50 kPa and surface weather type/pattern.

The success of this subjective weather typing approach supports the need for an objective analysis based study. Questions regarding the relative frequency of the critical fire weather types during the fire season, and whether these types are prominent during non-critical fire periods, need to be addressed. Such questions can most effectively be answered by using the complete data set of coincident 50 kPa and surface weather maps for a number of forest fire seasons. The amount of data involved and the discrimination necessary for a conclusive analysis supports the adoption of an objective procedure for the second phase of this project.

For the second and third phase, better definitions of the timing, nature, and periods of major fire activity will be required. Rather than subjectively determining the periods using fire reports and interviews with fire personnel, adoption of a procedure which defines the fire danger level based on the components of the FWI System might be more objective. This objective definition would be in line with current activities and initiatives within various fire agencies to determine their level of preparedness based on the components of the FWI System.

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News and Comments
Nouvelles et commentaires

TRACE GASES AND THE PROBLEM OF FALSE INVARIANTS IN CLIMATE MODELS – A Comment

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The great importance of computer climate models to our current understanding of climate change is indisputable. However, as with all unequivocal facts this notion demands to be put into perspective. This commentary is about fundamental limitations of climate simulation. It is intended as a reminder for those who are familiar with such limitations, and as an introduction for those who are not so familiar with them. At the outset it must be understood that the following arguments are really directed at modelling of *all* degrees of sophistication (including GCM's), even though the following discussion, for ease of illustration, centers primarily around radiative-convective models.

The general characteristics of radiative-convective models have become standardized over the last two decades. However, their origins date from the turn of the century work of Schwarzschild and Emden. That early work was revived and refined by a number of authors in what are now classical papers (Goody, 1949; Möller and Manabe, 1961; Manabe and Möller, 1961; Manabe and Strickler, 1964). The contemporary radiative-convective model first appeared in a paper by Manabe and Wetherald (1967). The current standard is fully described in the well-known review paper by Ramanathan and Coakley (1978).

There are four essential ingredients that characterize the modern version of this model: radiative equilibrium, convective adjustment to 6.5 K/km, absorbing layer cloud simulations, and fixed relative humidity. Only the first ingredient is based soundly on physical principle. The others are mere ad hoc characterizations of how the real atmosphere works: certainly useful for pedagogy but unsound for prediction.

Let me clarify the latter remark: if one were to interpret the radiative-convective model as a representation of the atmosphere by some real local state somewhere in the atmosphere, it would become quickly apparent that the normal model assumption of fixed relative humidity at subsaturation values is inconsistent with cloud formation, and inconsistent with a convective lapse rate shallower than the dry lapse rate of about 10 K/km. On the other hand, if one views such a model as representing "average" global conditions, one must consider an admixture of atmospheric regions where convection is occurring and regions where it is not. Therefore, it is difficult to conceive of the process of globally adjusting temperatures as "convective adjustment" in the true sense of the term, or to conceive of the reason for that adjustment as simply the removal of static instability.

The figure 6.5 K/km, that the lapse rate is adjusted to in these models, has no particular physical significance. It is an entirely empirically motivated value which takes its origins from observations made around the time of the first world war, in order to standardize settings on aircraft altimeters (e.g. Toussaint, 1919). Its current usage in the modelling context is more of a matter of tradition than any other reason. This is made evident by recent analyses that suggest the actual mass weighted tropospheric lapse rate is closer to 5 K/km (Stone and Carlson, 1979).

Cloud simulations in radiative convective models have no physical properties whatever other than radiative ones. The thermodynamics of formation and the associated moisture budgets are completely ignored. Moreover, the radiative properties of "average" clouds, in the context of the other model mechanics, cannot be unequivocally established unless the meaning of average in the modelling framework can be established first.

The notion of fixed relative humidity is an entirely ad hoc and heuristic construction. Although for the purposes of an initial guess it may make more intuitive sense than fixed absolute humidity, there really is *no* theoretical justification for it. Moreover, relative humidity really varies more than global temperature. Global temperature changes in model experiments are in the neighbourhood of 1%, whereas seasonal changes (Manabe and Wetherald, 1967) or general circulation model experiments (Manabe and Wetherald, 1975; Wetherald and Manabe, 1980) display deviations in local fractional relative humidity that are generally several times larger than the value of 1%.

An examination of the literature pertaining to radiative-convective model experiments concerning trace gases supports these criticisms, and leads to more fundamental concerns. The surface temperature change, due to the doubling of the carbon dioxide mixing ratio, doubled with the introduction of the assumption of fixed relative humidity. Moreover, the surface temperature perturbation associated with the fixed absolute humidity calculation was in the neighbourhood of 1.3 K, which is regarded as a perturbation of marginal significance, while the other calculations *were* significant having values as high as 2.9 K (Manabe and Wetherald 1967). While fixed absolute humidity was certainly incorrect, fixed relative humidity was of dubious plausibility, in part for the reasons mentioned above. However, a more serious reason for doubt is that the original notion of fixed relative humidity was conceived from observations of the current climate state *only*. The variance between the winter and summer data from our particular climate regime that was used could at best only be suggestive of an actual change to a genuinely different climate regime. Thus, trace gas model experiments were elevated to a level of importance by a change in non-physical assumptions: the former only slightly more implausible than the latter.

Trace gas experiments have been affected by other instances of alteration in heuristic detail. A notable example is the question of cloud altitude in different climate regimes. Cess (1974) made some suggestive, though far from conclusive, arguments that maintained that cloud top altitude fixed at a specific tropospheric temperature for all climate regimes (i.e. "fixed cloud top temperature") was more realistic than the previous assumption of clouds of fixed altitude. It happened that the new assumption produced surface temperature perturbations which later proved to be 1.5 times larger than previous calculations with clouds of fixed altitude (Reck 1979). No consensus was ever reached on this issue, unlike the question of relative humidity. It remained a lively controversy for a few years, and later fell out of style, still unresolved, ceasing to be topical. In any case, a slight change in the radiative-convective model clouds was enough to alter the outcomes of trace gas experiments to approximately the same degree as could be expected from the humidity question.

A more recent example is seen in the work of Hummel and Kuhn (1981) in which they everywhere adjusted the model lapse rate to the moist adiabatic lapse rate instead of the prescribed value of 6.5 K/km. They argued that this is a more realistic approach, and succeeded in reproducing the standard atmosphere very convincingly. Their arguments, though not unequivocal, were plausible enough; however, their carbon dioxide doubling surface temperature was 0.79 K, well below almost all other values using the traditional fixed adjustment! Certainly, if Hummel's and Kuhn's adjustment procedure were to prove to be correct for climatological changes, then the relevance of the carbon dioxide problem, and the related problem of rarer trace gases, would be greatly reduced. However, the essential point in this case is that their new assumption, which is certainly not burdened with more inconsistencies than the conventional adjustment procedures, produced virtually the same temperature profile for the current climate as the conventional models did, while performing quite differently in an experiment.

Hummel and Kuhn are not alone: a recent paper by Lindzen et al. (1982) compared a realistic "cumulus convection" scheme to the 6.5 K/km convective adjustment method. The simple adjustment procedure consistently produced perturbations in surface temperature about 1.5 times the perturbations produced by the "cumulus convection" method in carbon dioxide doubling experiments.

The impossibility of deciding which alternatives in non-physical model detail is correct, if any, may be characterized as a *problem of false invariants*. Each option is defined around some heuristic or ad hoc assumption of invariance; that is, some specific entities are held fixed by design in model experiments. For the examples regarding clouds and humidity, the assumed invariant is named in the description of the respective assumptions. Similarly, the invariant in the simple convective adjustment scheme is the lapse rate itself. For the case of moist adjustment, the invariant is the ratio of the real lapse rate to the moist lapse rate, which is held to the value unity. In the "cumulus convection" case, the invariants are contained in the details of the budget parameterizations as well as the assumption of universal convection. For each of the cases we must assume that at least one invariance option is false, since the different alternatives produce inconsistent results in model experiments. However, the problem is that there is at present no physically unequivocal way to select which, if any, option best represents the behaviour of the real atmosphere when undergoing some particular climate change. Hence, the description, *problem of false invariants*.

Many practical fields correctly utilize non-physical parametric simulations in order to model physical systems. The property that sets *all* climate models apart from these is that climate parameterizations are not verified or fitted over the range of use. That is, if one were to simulate flow in a pipe, for example, one would measure the flow over the range of conditions to be modelled and then fit the simulation to that data. The answers would be correct *by design*. Outside the range of conditions to be modelled strictly speaking nothing is known, from the standpoint of the simulation. Good, verified simulations need not be unique: two equally good simulations may agree within the domain of fitted conditions, but sharply disagree outside. This is the case, for example, for the different convective adjustment schemes above: they all agree in the fitted, verified domain (the current climate state), but disagree outside that domain.

There is really only one word to describe the use of a simulation outside its fitted domain: extrapolation. One should expect that the empirical lapse rate of our current climate state, for instance, may assume a significantly new value in a different climate state. There is no theoretical reason and no observational data from other climate regimes to suggest otherwise. Assuming it to be invariant is pure speculation and extrapolation.

General circulation models, as already suggested, have their share of parameterizations and this makes them subject to the problem of false invariants. There exists a common misconception that these sophisticated models are bald implementations of classical physics only, without any simplifying assumptions whatever. The various approximations of these models range, among others, from approximations to the primitive dynamical equations, for example the hydrostatic approximation (Phillips, 1957), to approximations of all aspects of the hydrological cycle – ocean dynamics (fixed sea surface temperature) and surface hydrology to moist convection and cloud physics – many of which contribute to the tricky problem of *sub-grid-scale phenomena*. Their effects generally are dealt with under the venerable but topical heading of *model error* (e.g. Boer, 1984) and are realized in the insidious problem of *climatological drift* (e.g. Wallace et al., 1983).

Although such models are certainly more sophisticated and more realistic than radiative-convective and other climate models, they are no different from these models in another respect: they are quasi-empirical and they have not been verified or fitted over their range of use. Therefore, strictly speaking, their determinations of climate states, other than the current climate regime, the only one to which they have been fitted, amount to extrapolation.

Little confidence can be placed on error estimates that one might construct from an experiment repeated with a variety of models each with different designs and empirical invariants (e.g. National Research Council 1982), because none of the members of the ensemble from which the error estimate is extracted have been fitted and verified for anything but the present climate state. There is no way to ensure that an ensemble of extrapolations approaches the *correct* mean behaviour. Certain knowledge of the presence of false invariants, which we do have for radiative-convective models, or simply the absence of tests for the model invariants' veracity, means nothing less than the loss of predictability.

It is ironical that Idso's recent works (e.g. 1980) regarding carbon dioxide and climate have been sharply criticized on the grounds that he implicitly assumed false invariants (i.e. neglected significant "feedbacks", see: National Research Council, 1982; MacDonald, 1982; also *Physics Today*, October, 1982 p. 49-50.) when such is very much the risk in the modelling mainstream with which Idso dissents. That is not to imply that Idso's position is correct, but that the principle positions to which he remains opposed are scarcely better in the context of the question of prediction. The ensuing debate in this connection has been premature, since the root of the modelling problem remains unresolved: what are the invariants for correct predictions?

There are only two courses, both difficult, open toward resolving this question. The first most obvious course is to reject all parameterizations and rely only upon the invariants of classical physics: energy, momentum, etc. The second, perhaps more realistic, course is to eliminate all simplifying assumptions and parameterizations to the maximum reasonable and practical extent. The resulting model must then be fitted to and verified for other climate regimes by using data from other climate states. Perhaps the only reasonable approach to the latter course is to attempt to simulate evidence from the historical and paleontological record using a general circulation model which includes fully interacting oceans and clouds.

Until such fully verified models exist, the degree of the climate response to perturbations in amounts of trace gases should not be regarded as known, even though the radiation physics in this matter is well understood. That is because the behaviour of the other crucial contributors to the surface energy budget, in an arbitrary climate regime, are subject to the problem of false invariants in our models. Pursuing the common analogy in this matter: we cannot predict the temperature of a greenhouse for a sunny day with confidence if we make ad hoc assumptions about the setting of the air conditioning or the extent to which the blinds are drawn.

Even though Idso's calculation of surface temperature sensitivity was substantially lower than most other estimates, it has been explained (National Research Council, 1982; MacDonald, 1982) that Idso's pure radiation calculations were in essential agreement with everyone else's. It was only how those calculations were connected to surface temperature perturbations that was controversial. Thus, the so called "greenhouse effect" measured in terms of surface temperature change (e.g. WMO, 1982) is not so much a radiation problem as a problem of model assumptions. It is almost completely academic to infer the effects of trace gases in this fashion.

Although climate simulation has been a great conceptual advance, full knowledge of the real importance of trace gases as triggers of climate change must await a better understanding of the mechanics of the climate engine.

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A STUDY OF CLIMATE AND FISHERIES: INTERANNUAL VARIABILITY OF THE NORTHEAST PACIFIC OCEAN AND ITS INFLUENCE ON HOMING MIGRATION ROUTES OF SOCKEYE SALMON

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1. INTRODUCTION

The rational management of many commercial fisheries is complicated by the influences that interannual environmental variations can have on fish stocks. The general topic of the relationship between climate variability and fisheries has been reviewed recently in a monograph by Cushing (1982). Perhaps the most dramatic example of environmental influence on fish is the near destruction of the Peruvian anchoveta fishery which occurs with each major El Nino-Southern Oscillation episode in the tropical Pacific (e.g., Quinn et al., 1978). Many other examples of the effects of climatic variations on fish populations have been documented. There have also been studies of the influence of climate on the migration routes of some fish species (e.g., the work on the annual migration of Atlantic mackerel reported by Murray et al., 1983). This latter type of investigation is of particular relevance for the Canadian west coast fishery, which is largely devoted to harvesting a number of Pacific salmon species.

The Fraser River in British Columbia produces between 2 and 20 million adult sockeye salmon (*Oncorhynchus nerka*) annually. Since in recent years the average yearly landed value of the sockeye is worth about $50 million to Canadian and American fishermen (I.P.S.F.C., 1954-1984), this fishery represents an economically important resource. Sockeye salmon from the Fraser River spend their first year in nursery lakes before migrating to sea as juveniles. These fish then disperse widely throughout the Gulf of Alaska, where most grow to maturity in two years. They then begin their homeward migration, returning to spawn in their natal streams in the Fraser River watershed. A complete understanding of how the salmon navigate in the open ocean is not available, but there have been suggestions that they use some combination of celestial or magnetic compass orientation along with other environmental cues (water temperature, currents, etc.; e.g., see Royce et al., 1968). To reach the Fraser River from their ocean feeding grounds, the sockeye can use either a northern or southern route around Vancouver Island (Figure 1, top). During the period 1953-1977, the majority returned via the southern route through Juan de Fuca Strait (average 80%, range 65-98%). Since 1978, however, a larger proportion has migrated each year via the northern route through Johnstone Strait (average 53%, range 22-85%) (I.P.S.F.C., 1954-1984). The percentage of sockeye returning via the northern route, referred to here as the "Johnstone Strait diversion," is shown in Figure 1 for the period 1953-84.

The large interannual fluctuations in the Johnstone Strait diversion (hereafter abbreviated as JSD) have created problems in the management of the sockeye fishery in southern British Columbia. Thus, it is important to understand the causal mechanisms that produce these remarkable fluctuations.

Since some of the more notable JSD's have occurred shortly after major El Nino-Southern Oscillation warming episodes in the Pacific (e.g., in

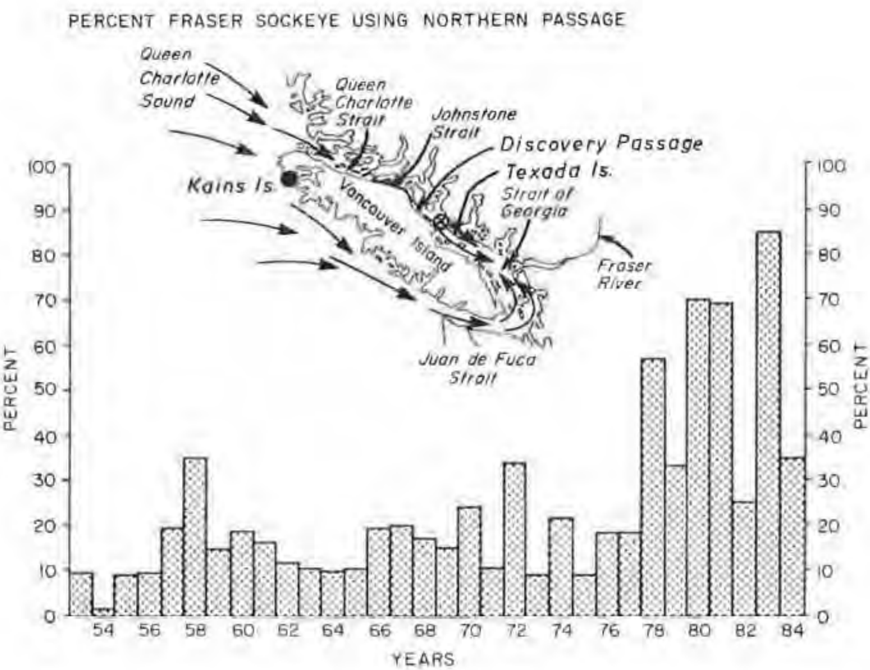

FIGURE 1. Insert at top: Migratory routes of adult sockeye salmon returning to the Fraser River around Vancouver Island. Histogram: The percentage of Fraser River sockeye salmon estimated to have used the northern route – the Johnstone Strait diversion (data from I.P.S.F.C.).

1957-58 and 1982-83), it has been suggested by a number of scientists that year-to-year changes in the ocean-atmosphere system may be the primary cause of the fluctuations in the JSD (I.P.S.F.C., 1954-84; Royal and Tully, 1961; Tully et al., 1960; Wickett, 1977). In this note, we shall give a brief review of past studies which tend to support this hypothesis, and then describe an ongoing investigation in which we are bringing together meteorological, oceanographic and biological information in order to increase our understanding of this fish-climate interaction phenomenon. Our study is being performed cooperatively between UBC's Department of Oceanography and the Fisheries Research Branch of the Federal Department of Fisheries, Nanaimo, B.C., and is partly supported by a three-year Strategic Grant from the Natural Sciences and Engineering Research Council (NSERC). To emphasize the multidisciplinary nature of this investigation, we have coined the project acronym MOIST: *M*eteorological and *O*ceanographic *I*nfluences on *S*ockeye *T*racks.

2. STUDIES OF HISTORICAL DATA

Since the relatively large 1958 JSD (35%) occurred during the second year of the strong 1957-58 El Nino-Southern Oscillation (hereafter called ENSO) episode, it was proposed by Tully et al. (1960) and Royal and Tully (1961) that the change in migration route for many of the Fraser River sockeye was a direct consequence of warm water intrusion from the south. Rather than making landfall on the west coast of Vancouver Island and then migrating south along the coast to the entrance of Juan de Fuca Strait, many of the fish approached from farther north than usual (to avoid the warm water intrusion?), made landfall north of Vancouver Island and then migrated south through Johnstone Strait.

Favorite (1961) and Wickett (1977), on the other hand, took the view that the relatively high diversions that occurred in some years prior to 1977 may have been related to the presence of anomalously low salinity water emanating seaward from Queen Charlotte Sound. Assuming that this water contained odours unique to individual streams, the returning sockeye might be expected to be attracted to it. Such relatively fresh water could be produced by higher than normal discharge from the Fraser River during spring.

As part of the earlier activities of project MOIST, the Fraser River discharge data and other environmental data were analyzed in relation to the JSD. For example, Groot and Quinn (1986) have shown that for the 1953-77 period, the Johnstone Strait diversion is highly correlated with the spring-time Fraser River discharge (Figure 2a). However, after 1977, during the regime of relatively high diversions, this correlation breaks down, and instead, the JSD is highly correlated with the sea surface temperature (SST) at the northern end of Vancouver Island (Figure 2b) (I.P.S.F.C., 1984; Groot and Quinn, 1986). Mysak (1986) has suggested that this marked change in behaviour after 1977 may be related to a significant warming trend in the northeast Pacific that began in

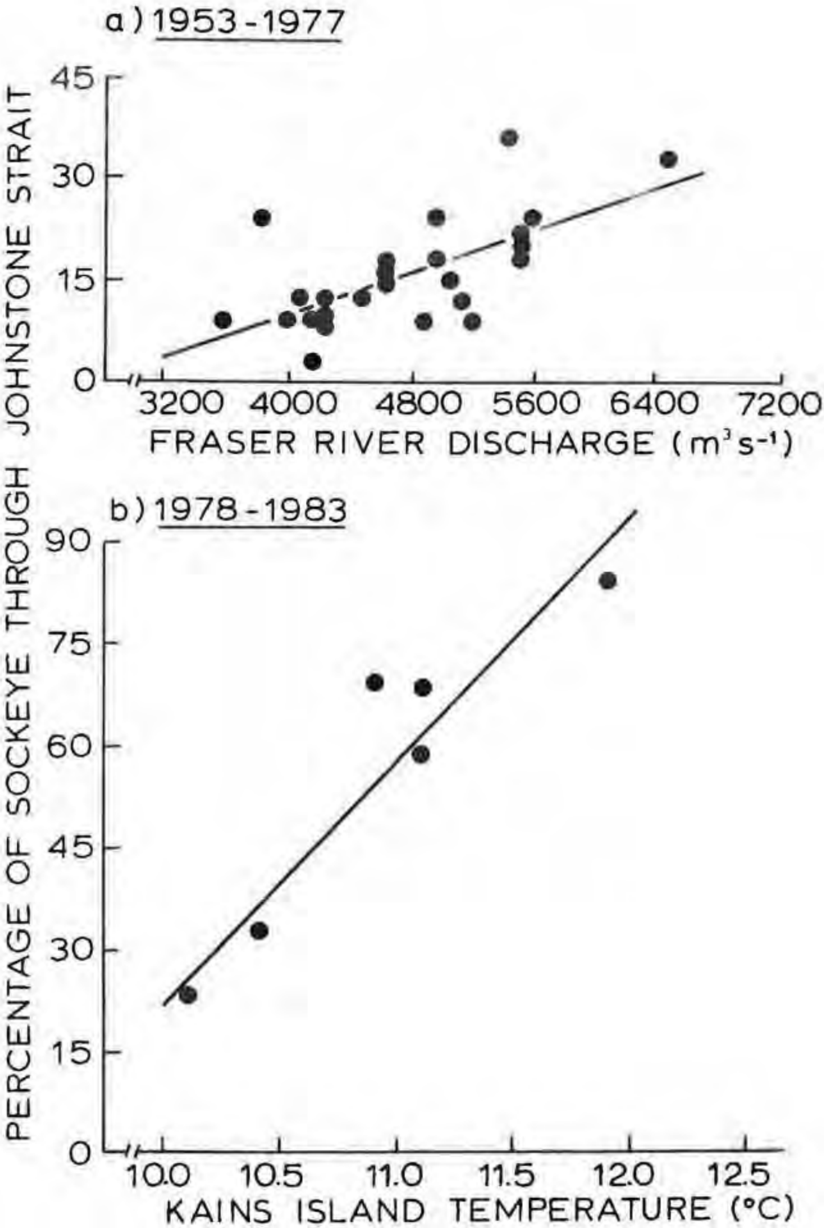

FIGURE 2 (a) Linear regression of the Johnstone Strait diversion during 1953-77 on the Fraser River discharge (averaged over April-June). The correlation coefficient is 0.68.
(b) Linear regression of the Johnstone Strait diversion during 1978-83 on temperature (averaged over April-June) at Kains Island, on the outside of the northern end of Vancouver Island (see Figure 1, top). The correlation coefficient is 0.93. (From Groot and Quinn, 1986.)

1976 or 1977 (Chelton, 1984; McLain, 1984) and which culminated with the very strong 1982-83 ENSO episode. Groot and Quinn (1986) believe that the Fraser River discharge and Kains Island temperature correlations may well reflect changes in the open ocean climate which affect the sockeye as they return to the Fraser River.

Hamilton (1985) used commercial sockeye catch data to estimate the JSD for the period 1906-1952 (Figure 3) and noted that typical diversion rates were 15%, but that in exceptional years such as 1915, 1926 and 1936, the estimated diversions rose above 40%. However, the very high JSD's that occurred after 1977 appear to be unprecedented. Hamilton also found a strong correlation between the JSD and the duration of the migration in coastal waters: during years of relatively high diversion, the run tends to be spread out over a longer period, which may indicate a wider ocean distribution prior to their return to the Fraser. In addition, he found a significant correlation between the JSD and the SST *change* in coastal waters off Vancouver Island over the last 18 months of the sockeye's ocean residence. Since the SST along the coast is negatively correlated with the ocean surface temperature in the central Gulf of Alaska (e.g., Emery and Hamilton, 1985; Hamilton and Emery, 1985), this result may indicate that the migration paths of the sockeye are affected by the ocean temperatures they encounter throughout their ocean residence.

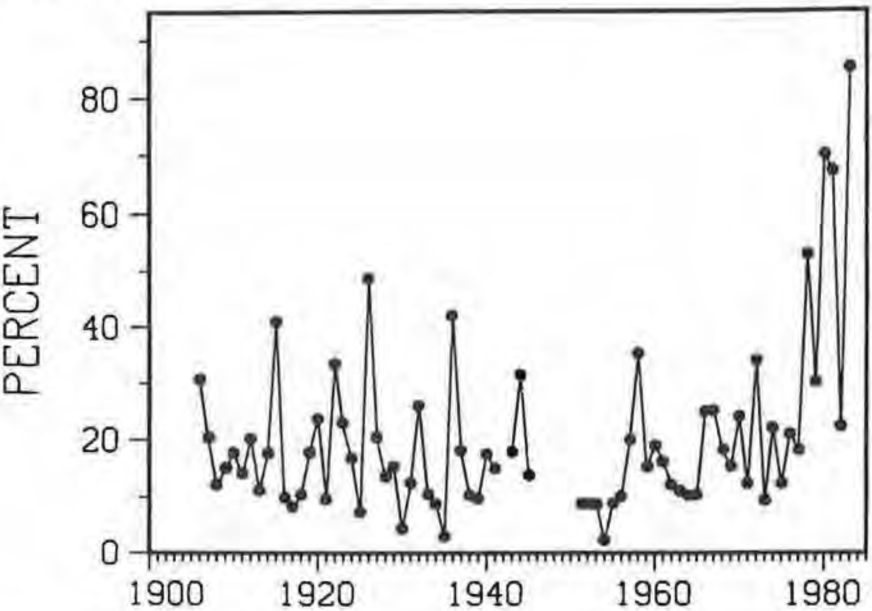

FIGURE 3. The annual estimated Johnstone Strait diversion of the Fraser River sockeye salmon. Values for 1906-52 are from Hamilton's analysis, whereas those for 1953-83 are from the IPSFC (1954-1984). (Figure from Hamilton, 1985.)

3. CURRENT AND PROPOSED RESEARCH ACTIVITIES OF PROJECT MOIST

To help understand the correlations between fish behaviour and the environmental conditions, investigators associated with project MOIST are (a) developing a large-scale numerical ocean general circulation model (OGCM) of the North Pacific Ocean (an extension of Weaver and Hsieh, 1986), (b) analyzing oceanographic and sockeye tracking data collected during summer 1985 from the "inside passage" of British Columbia: Queen Charlotte Strait – Strait of Georgia region (Quinn and Terhart, 1986), and (c) analyzing seining, echo-sounding, and satellite imagery data from the inside passage. From the OGCM, which is to be driven by the observed winds over a 30-year period and run on the supercomputer (Cyber 205) at the University of Calgary, we hope to obtain a realistic month-by-month simulation of the Alaska gyre in the northeast Pacific and of the offshore, near-surface temperature and salinity fields. Also, an eddy-resolving regional OGCM of the northeast Pacific is being developed to simulate the year-to-year changes in the eddy field in this region (P.F. Cummins, personal communication, 1985). An attempt will be made to relate the interannual signals in the outputs of these models with the JSD time series shown in Figure 1. We speculate, for example, that the JSD fluctuations will be correlated in some way with the simulated interannual variations of the ocean circulation to the west of the British Columbia-southeast Alaska coast. This conjecture is partly based on past studies which suggest that currents, current shears and mesoscale eddies may influence the homing migration routes and timing of the adult sockeye (Royce et al., 1968; Mysak, 1985; Hamilton and Mysak, 1986).

From the summer 1985 field data, collected during the tracking of 15 fish using ultrasonic telemetry, we can determine the depth distribution of homing sockeye in relation to the vertical distribution of temperature (T) and salinity (S) in three distinct water regimes: Queen Charlotte Strait and Johnstone Strait (weakly stratified), Discovery Passage (well mixed), and Strait of Georgia (strongly stratified) (Thomson et al., 1985). In the Strait of Georgia, for example, it was observed that some of the sockeye preferred one of two depths which were associated with the location of strong vertical gradients in T and S (Figure 4). In the well mixed region, on the other hand, the sockeye tended to swim in the upper 5 m of the water column. It is expected that these tracking results will shed further light on the correlations between fish behaviour and oceanic conditions described in Section 2.

Infrared images (obtained from NOAA 8 and 9 polar orbiting satellites) showing SST of the inside passage and Vancouver Island shelf were collected throughout the summer of 1985. They will be used, for example, to detect ocean surface fronts, and to study their evolution and decay. When compared with the field data and commercial sockeye catch data, these images should further elucidate the preference of returning sockeye for specific

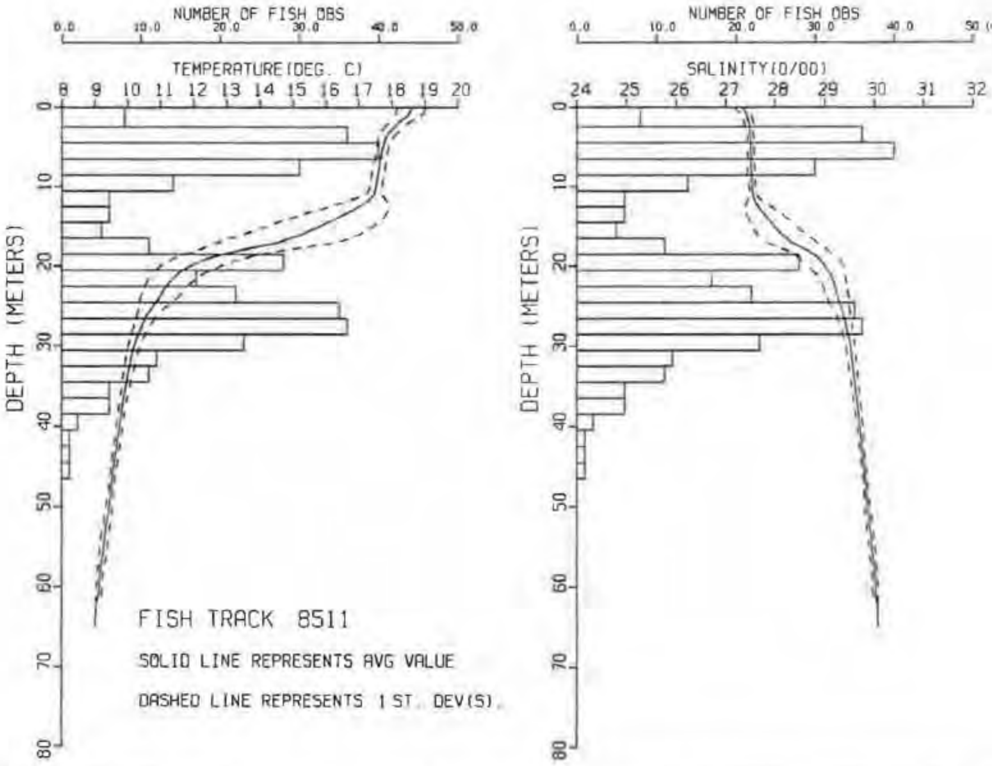

FIGURE 4. The number of fish observations at 2 m depth increments, indicating the total time in minutes that the fish spent in the depth intervals, compared with the local temperature (left) and salinity (right) depth profiles. Fish 8511 was tracked in the Strait of Georgia off the northern tip of Texada Island (see in Figure 1, top) on 7 August 1985 from 1321 to 1918 hr (local). The temperature and salinity were averaged over 14 CTD casts. (From Quinn and Terhart, 1986.)

temperature regimes and highlight the oceanographic differences of the two return routes (Johnstone Strait vs. Juan de Fuca Strait).

In the spring of 1986, laboratory experiments (using a design similar to that of Neill et al., 1972) will be initiated to determine the temperature and salinity preference of sockeye salmon. Other experiments will be conducted in which the fish can choose their vertical position in a tank with prescribed T and S gradients. These results will be compared with the fish tracking data collected in the inside passage in an attempt to gain a better understanding of the homing fish behaviour in relation to the environment.

In summer of 1986, a second large-scale field experiment will be conducted in the Queen Charlotte Strait – Strait of Georgia region, similar to that undertaken in summer of 1985. However, greater emphasis will be placed on making current measurements in the vicinity of the tracked fish. Also, it is planned to conduct some tracking studies in strong frontal regions (e.g., near the south end of the Discovery Passage). With this new information on the sockeye response to currents, as well as further data on T, S and fish-depth distributions (as shown in Figure 4), we expect to obtain a better understanding of the relationship between the JSD fluctuations and the numerical model simulated circulation in the northeast Pacific. Ultimately our goal is to use an OGCM with updated forcing wind fields to predict, approximately one month in advance, which route around Vancouver Island the majority of the homing Fraser River sockeye will take in any given year. Such information, we hope, will help fishery managers make better decisions on how to exploit this important renewable resource.

ACKNOWLEDGEMENT

The support for this research by NSERC Strategic Grant G-1485 is gratefully acknowledged. We thank T.P. Quinn for providing comments on a first draft of this paper, and B.A. Terhart for providing a copy of Figure 4 prior to publication. Also, the support and enthusiasm of the technical and student staff who have worked on project MOIST are greatly appreciated.

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THE 42ND EASTERN SNOW CONFERENCE, MONTREAL, 1985

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Association of Canadian Universities for Northern Studies, Ottawa, and Trent University, Peterborough, Ontario.

John Lewis
McGill University, Montreal, Quebec.

The 42nd annual Eastern Snow Conference (ESC) was held in Montreal on 6-7 June 1985. The ESC is a US – Canadian organization with broad interests in snow and other forms of ice. It meets in Canada and the United States in alternate years.

This year, almost 100 delegates heard 23 papers on topics such as, arctic navigation and sea ice, ice accretion on cables, snow and Inuit place names, snowmelt modelling in various situations, river ice jams, remote sensing of snow and ice, and snow pollution. There was a Panel Discussion on the current status of snow survey programs in North America.

The ESC Executive agreed that the 1985 Proceedings should include an up-to-date index of all papers presented at Eastern Snow Conferences and may contain a similar index of the Proceedings of the Western Snow Conference.

The Proceedings will be available next winter from J.E. Lewis, Department of Geography, McGill University, Montreal, P.Q. H3A 2K6.

Canada. (The Proceedings of the 1984 meetings can be obtained from B.E. Goodison, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario M3H 5T4, Canada). Complete sets of ESC Proceedings, 1951 – present, are now available for less than $300 from the Secretary of the Eastern Snow Conference, Don Dunlap, 335 George Street, Room 202, New Brunswick, NJ 08901, U.S.A.

Next year's meeting will be held at the Cold Regions Research and Engineering Laboratory, Hanover, N.H. on 5 and 6 June. Details from Jean-Louis Bisson, Hydro-Québec, 9th Floor, 2 Complexe Desjardins, Montreal, P.Q. H2Z 1A4, Canada.

ASSOCIATION OF AMERICAN GEOGRAPHERS ANNUAL MEETING, 1985

Stewart J. Cohen
Canadian Climate Centre
Atmospheric Environment Service
Downsview, Ontario

The Association of American Geographers Annual Meeting was held April 21-24, 1985, in Detroit, Michigan. There were 15 sessions on climatology and related topics, 9 of which were organized and sponsored by the Climatology specialty group of the AAG. These included poster sessions, papers, 2 panel sessions on climate impacts, and the now traditional guest speaker. In addition, there were several sessions on biogeography, natural hazards, water resources, perception, and geomorphology that included climatic issues. From the titles and abstracts, 79 papers were identified as within or of interest to climatologists. Of these, 14 were on hazards (particularly floods), 14 on regional studies (especially tundra and coastal environments), 11 on climatic change, and 10 on analysis methods (including climate models for microcomputers). Other topics included remote sensing applications, radiation and energy balance, urban climates, synoptic climatology, climate impacts, bioclimatology, and applied climatology.

The panel sessions on climate impacts were held on April 22. D. Liverman (Wisconsin) acted as chairperson for the first session, which consisted of short presentations. W. Riebsame (Colorado) presented an outline of the soon-to-be-released book on climate impact assessment, edited by Kates et al. It includes a chapter on perception of climatic change as well as a number of case studies, and was described as a sensitizing book, rather than a "cookbook" of methods. W. Easterling (Illinois State Water Survey) reviewed the CLIMPAX project, in which a number of pairs of regions will be analyzed. Each pair consists of a region with a stable climate during a particular time period, and a nearby region which experienced a step-wise shift in climate (e.g.

sharp increase in summer rainfall). J. Mather (Delaware) provided an overview of several studies currently underway at the University of Delaware, including a new Weather Stress Index, and impacts of weather on mortality, employee absenteeism, tourism, and automobile accidents. Considerable data are available from federal agencies in the U.S. D. Liverman described several studies in progress, all of them on agriculture. These include cold margins, dry margins, and a case study in Mexico. Finally, G. McKay and D. Phillips (Canadian Climate Center) described work done in Canada for the Canadian Climate Program, the Prairie Farm Rehabilitation Administration, and the International Institute for Applied Systems Analysis (IIASA) in Austria. A key point was the need for international co-operation between Canada and the U.S., and it was announced that in May 1985, a Memorandum of Understanding would be signed between both national climate programs.

The second panel session was a round-table discussion on problems and future issues. K. Hare (Toronto) asked several important questions regarding the participation of social scientists, the "selling" of impacts studies to social scientists, and whether we could gain any insight from epidemiologists, who do similar impacts work already. Others raised the problem of modelling technological change in advanced and third world societies. S. Cohen (Canadian Climate Centre) raised the question of selling impacts studies to physical scientists (other than climate change modellers). He also asked if it was possible to separate the impacts of climatic change from impacts due to movement of people into marginal areas. The general response was that they could not be treated separately. Other issues included networking, and the role of climatologists in the research effort. G. McKay suggested that the leader should be someone other than the climatologist, such as an expert in agriculture. In summary, the panel sessions represented an important airing of views, and would hopefully lead to further involvement by the wider community of geographers. However, there are considerable philosophical obstacles to be overcome before the climate impacts research effort can reach its full potential.

A special session on climatic change was held on April 23. W. Brinkmann (Wisconsin) examined the instrumental record of the past century and pointed out a number of problems in interpreting these data. These include changes in measurement of sea surface temperatures, the lack of a clear relationship between growing season length and mean annual temperature (e.g. length can increase during a cooling period), and the lack of evidence showing high variability during cooling. T. Karl (National Climate Data Center, Asheville) also reviewed the record, and found a recent increase in temperature variability, but no clear trend in precipitation, and no clear relationship between temperature change and variability. Urban effects were considered to be very significant in North America. W. Wendland (Illinois State Water Survey) listed possible factors that could influence 21st century climate, particularly volcanoes, CO_2, and on a local scale, urban effects. There would be several trends superimposed on each other, volcanic eruptions being the least predictable.

Later that morning, K. Hare was the featured speaker in a special session organized by the climatology group. The topic was "Climate and the Biosphere: the Role of Human Disturbance". He examined 3 issues: acid deposition, desertification, and catastrophism (including volcanic eruption and nuclear winter). In all cases, there are many unknowns including the exact nature of the relationship between vegetation and climate. We know little about dry deposition, and its effects on mature plants. We know that the expansion of the Sahara Desert is actually a reduction of plant cover on the desert margin due to man's overuse of the land, exacerbated by below average rainfall. Climate has aided in its decay, but we don't know if the feedbacks (e.g. increased albedo, decreased soil moisture and surface roughness) will prolong the drought. In general, not enough is known about the microscale to truly answer macroscale questions. Finally, there is great contrast between insidious change (desertification) and catastrophism. We seem to be more comfortable about modelling the latter, although we're still not totally prepared to talk about either.

There were dozens of other presentations made during the conference. A few of these are listed below:

K. Dewey (Nebraska) – snow cover climatology from satellite data

W. Rouse (McMaster) and R. Bello (York) – climate of the Hudson Bay Lowlands

L. Kalkstein (Delaware) – impact of weather on mortality

S. Cohen (Canadian Climate Centre) – impact of CO_2-induced climatic change on the Great Lakes

J. Rogers (Ohio State) – recent circulation changes over the North Atlantic

(Louisiana State) – 5 papers on climate and flooding in Louisiana (organized by R. Muller).

At the annual business meeting of the specialty group, chaired by J. Oliver (Indiana State), J. Burt (Wisconsin) announced that working models of the water and heat balances for microcomputers could be obtained. Just send $10.00 (US) and 3 IBM-compatible diskettes to Prof. Burt. Also, a revised Directory of Climatologists, with about 300 names, is available from A. Brazel (Arizona State) for $2.00 (US). An update will be produced in 1986. The 1986 AAG meeting will be held in Minneapolis, May 4-7.

SASKATCHEWAN CLIMATE ADVISORY COMMITTEE

Ken Jones
Secretary
SCAC

The Saskatchewan Climate Advisory Committee held its second annual workshop on October 10, 1985. The theme this year was "What is Climate Data Worth to You?" There were 35 members in attendance representing over 25 different agencies in Saskatchewan. Some valiant efforts were made by speakers to put a cost on climate data. Speakers were encouraged to write up their presentation and if enough papers are submitted, a publication of the workshop may be made.

The Saskatchewan Climate Advisory Committee now has 30 different agencies represented with members from Federal, Provincial and Municipal Governments and the private sector. Another workshop is planned for November 1986, with the general theme of "Computer Applications and Software Development in the Climate Field".

THE "WINTER CITY MOVEMENT", A THRUST TOWARDS IMPROVING OUR COLD CLIMATE ADAPTATIONS

Jack Royle

The three-year-old Livable Winter City Association (LWCA) is a Canadian organization that gives focus and leadership to an international stirring that has been called "the winter city movement." The movement reaches around the northern world to cold climate researchers and those concerned with the impact of our severe northern climate on many human patterns and activities.

LWCA members include architects, planners, climatologists, educators, psychologists, sociologists, engineers and a wide range of other disciplines. No similar organization exists outside of Canada. However, a proportion of the organization's members, and subscribers to its Newsletter are to be found in Scandinavia, Northern Europe and the U.S..

Environment Canada, and particularly the Canadian Climate Centre's Applications and Impact Division (CCAI) have informally supported LWCA from its birth. Rick Lawford (now with Ministry of State for Science and Technology) called the first organizational meeting, and assistance in a variety of forms has also been provided by other Environment Canada personnel including: Gordon A. McKay, now retired, former Director, Climatological Applications Branch, of Atmospheric Environment Service: Joan Masterton, Don Gullet, Linda Mortsch, Bruce Findlay, and Stewart Cohen.

The "Winter City Movement" had its more significant origins on opposite sides of the globe – in Sweden and Japan – after World War II. Possibly, the spectacular technological breakthroughs achieved during the war set some questioning minds to pondering how the new technology could be used to improve our adaptations to the severe and extreme northern climate. If humans can fly in comfortable jet planes high in the sky at temperatures far below zero Fahrenheit, couldn't something be done to soften the winter bleakness and discomforts of our northern cities and communities?

In Sweden, Ralph Erskine, a British-born architect who had made that country his home, began to point out to the Swedes that their towns and communities were designed and planned with little thought of the four or five months of snow and cold. They differed hardly at all from communities in Southern France or Italy. Yet Sweden lies between the 55th and 69th parallels of north latitude (if superimposed on northern Canada it would stretch roughly from Fort McMurray, Alta., to Victoria Island off the Arctic coast) and has several weeks of long dark nights, and abundant snows during its winters.

Erskine proceeded to design and build numerous structures and developments featuring climate-sensitive elements such as sun traps, roofs designed to use snow as insulation, and specially shaped and positioned buildings to serve as "windscreens" for whole towns or communities. His designs have brought him world renown and he is still active.

On the opposite side of the globe a few perceptive students in a northern Japanese university were also calling attention to the shortcomings of northern habitations and urban arrangements. Being outstanding students, they had little difficulty, on graduation, in finding positions of considerable responsibility in Hokkaido, Japan's northernmost island province. They remained in contact with one another and zealously worked together to make Hokkaido into one of the most viable and attractive regions of Japan in spite of its northness. And to date, they have achieved remarkable success in this endeavour. Visitors to Hokkaido and Sapporo, its principal city, declare they have found there an ardent "northern spirit", a determination to capitalize on a northern situation, unequalled in any other region or country.

One of the group, Takeshi Itagaki, became Mayor of Sapporo and has held the position for 20 years. Another became governor of Hokkaido. Others moved into key positions in large research and corporate organizations.

Led and prodded by this group, Sapporo and Hokkaido introduced startling innovations in a variety of fields. They built the world's first retractable glass dome for a major pedestrian street; built two and three-levels for portions of Sapporo downtown with pedestrians and motor vehicles segregated on their own levels. They established a "Northern Regions Center" in 1971, and also a more technical "Institute of Low Temperature Science".

They launched a winter festival in Sapporo that has become an important tourist attraction, bringing people not only from all parts of Japan but also from other countries. One special feature is an array of very large ice and snow sculptures, some of them two and three stories high. These depict world famous structures and other themes and are constructed on a wide park-like boulevard on Sapporo's main street.

They arranged international conferences to enable them to learn from other nations and to show others what they were achieving. They developed a concept for the grouping of all principal northern nations around the pole, calling this group of nations and states, "Hoppoken". The idea was put forward by Naohiro Dogakinai on assuming governorship of Hokkaido in 1971, "aimed at promoting exchange with other northern areas that have a rich experience and an excellent tradition of coping with life in a severe winter climate." (see Table 1).

A conference on "The Human Environments In The Northern Regions" brought representatives to Sapporo from Canada, U.S. and Europe. Later, in 1982, Mayor Itagaki invited mayors of other northern cities to meet with him in Sapporo in "The First Northern Intercity Conference."

Last September, a "Second Northern Intercity Conference" was held at Shenyang, China with much of the organization actually carried forward by the Japanese. The third "Northern Intercity Conference" is to be held at Edmonton in 1988, to coincide with a major world conference and exhibition dealing with northern design, industry and technology. Edmonton's Mayor Laurence Decore has given solid support to all attempts to make Edmonton a leader among northern cities. The city has created Winter Cities Conference Corporation, with Arni Fullerton, a noted northern architect and planner, as president. Purpose of the organization is to plan and organize conferences and exchanges that will accentuate Edmonton's northern leadership.

Winter Cities '86 Forum, to be held in the Edmonton Convention Centre this Feb. 15 to 19, will be one such conference. It will set the stage for the larger event of 1988, and will also draw together northerners of a wide range of experience and responsibilities to talk about solutions to northern problems and development of northern strategies.

TABLE 1. Average annual mean temperatures, all reporting stations – degrees C.

U.S.S.R.	1.53
Finland	2.94
Canada	3.28
Iceland	3.76
Sweden	3.83
Norway	4.20

The Japanese have coined a word to describe nations of the "winter latitudes" including those listed above. The word is "HOPPOKEN" which is interpreted as: "The Northern Region Co-operation Concept" suggesting that northern nations must work together to improve their adaptations to the severe climate.

Winter Cities '86 Forum will give Canadians and other northerners opportunity to tune into the marvels of Hokkaido. Four teams of experts will travel from Japan to make presentations and answer questions. Mayor Itagaki will be keynote speaker.

Of interest to many Canadian and northern U.S. cities that, even with three or four months of winter, seem to contend with one another in denying their northness, is the fact that Hokkaido stands between the 42nd and 46th parallels of north latitude, about the same as Canada's Lower Great Lakes region, and has an average annual mean temperature of 7.8 degrees C., identical with that of Toronto. Hokkaido has 5.9 million population.

The word on "winter city" developments in Sweden and Japan came late to North America, but now Canadians, particularly, have picked up the ball and are scampering with it.

Credit for being the first on this continent to take action goes to American Dr. William C. Rogers, who as Director of World Affairs Center of University of Minnesota, Minneapolis called together a "Livable Winter City Conference" in 1978.

Encouraged by a fairly good response by foreign countries and the U.S. media, Rogers called a second conference for a year later and this time set out to attract Canadians in particular, whom he felt must surely be concerned with the problem. In spite of persistent efforts, he managed to attract only two, Alfred Savage, then Commissioner of Public Works of Edmonton (now Chief General Manager of Toronto Transit Commission) and the author, a career technical journalist committed to a program of research and writing on the theme of northerners' need to accept their northern reality and to try to capitalize on it.

Word of the "winter city" developments then spread quickly to Canada's architects, planners, universities, developers and others. Ontario Ministry of Municipal Affairs and Housing featured the theme in several of its major conferences, and in one large evening session brought together Ralph Erskine, Dr. William Rogers, and Arni Fullerton. Famous Toronto architect Eberhard H. Zeidler, designer of Toronto Eaton Centre, Walter C. MacKenzie Health Sciences Centre in Edmonton, and other notable examples of climate-sensitive structures, presided.

It was apparent that much Canadian work was being done in designing and planning for improved winter livability, but in isolation and without cross-communication. For example, a large climate-designed town centre in Northern Ontario was built without knowledge of a similar structure that existed in northern Quebec. Effort and error thus were duplicated. Ottawa chose to create an open downtown mall without benefit of Minneapolis' experience in operating a similar amenity.

Canadian architects and engineers had long attracted worldwide attention for their skill in designing structures able to withstand or even capitalize on unusual and severe conditions of climate. Saskatchewan Research

Council had developed special technology for testing materials and methods, because generally-used testing procedures had so often proved inadequate in extremely low temperatures. These were examples of special skills and technology existing at scattered points in Canada. There was obviously a need for a focus and a medium for exchange of information. The Livable Winter City Association was created to meet that need.

LWCA, immediately on its launching, began producing a bi-monthly newsletter, and set out to organize chapters across Canada, and to rally as members and supporters, all who expressed interest in its ideas. Conferences were organized at various points across Canada. (Winter Cities '86 Forum will be jointly hosted by LWCA and the City of Edmonton).

Prof. Norman Pressman of University of Waterloo Department of Urban and Regional Planning, and Ms. Xenia Zepic, Senior Planner of Metropolitan Toronto Planning dept., as LWCA's national president and vice-president respectively, toured Scandinavia and Northern Europe on two occasions in 1985 to establish contact with "Winter City" activists and update on European experience. LWCA launched a national winter city design competition for students at the university level and published a book, "Reshaping Winter Cities" assembled and edited by Prof. Pressman.

Proof of the value of LWCA is the steady stream of letters that reach it from around the world. Wrote "Chuck" Knight, Mayor of Fort McMurray, Alta., recently: "What is a Livable Winter City? ... How can I get more information?" And from Morkved. Norway, Ole B. Skarstein commented: "I am very much interested in the ideas and concepts that originate in the Livable Winter City initiatives. In many ways, we are trying to initiate the same things in the cities and smaller communities in the far north of Norway. It is a challenging task, but carries promise of important rewards in the form of better and more stable living conditions in severe winter climates".

It all adds up to softening the "IMPACT" (CCAI's fortuitously chosen word) of the northern climate.

(NB: For additional information on LWCA, write The Livable Winter City Association, Ste. 301, 250 The Esplanade, Toronto, Ont., M5A 1J2)

Book Review / Critique de livre

L'HOMME ET LE CLIMAT. Jacques Labeyrie. Édition Denoël, Paris, France, 1985, 281 pp, 7 chapitres; 15 cm x 23 cm; 19,95$; ISBN 2-207-23103-8.

Ce livre sera assurément bien acceuilli par les passionnés de climatologie et il comble un vide puisque peu de livres de ce genre ont été publiés en français. Ce volume s'adresse au grand public pour lequel il est essentiel d'expliquer l'importance des phénomènes climatologiques et leurs conséquences.

Le volume se compose de sept chapitres: l'atmosphère de la terre; les éléments de la vie; les mécanismes du climat; les catastrophes climatiques; légendes, histoires et niveaux de la mer; les climats du passé; l'impact des activités humaines. Aucun des chapitres ne comporte de structure analogue à celle d'un volume académique puisque les sections, assez courtes, sont tout simplement séparées par des sous-titres.

Le premier chapitre contient des informations très intéressantes sur l'histoire de la Terre et de son atmosphère que l'on retrouve rarement dans un texte de ce genre. Au deuxième chapitre, l'auteur montre l'importance pour la vie du cycle hydrologique et discute longuement des aérosols de même que du rôle du climat dans la formation et le maintien des sols. Au chapitre 3, l'auteur discute des mécanismes du climat et il aborde les principales notions reliées aux systèmes météorologiques; malgré un effort véritable visant à apporter des explications claires, il est évident que l'auteur n'est pas complètement à l'aise avec les notions discutées dans ce chapitre. Au chapitre 4, l'auteur discute des tornades, des ouragans, des inondations, de la sécheresse, du El Nino, etc., et l'on sent bien son intérêt pour ces phénomènes mais aussi celui pour les populations désarmées du Tiers-Monde qui ont à subir les pires caprices du climat. Au chapitre 5, l'auteur aborde l'histoire et le climat dans un passé peu lointain puis au chapitre suivant, il aborde la théorie astronomique des changements climatiques et discute des différentes façons de retracer l'histoire du climat dans le passé lointain. Finalement, le dernier chapitre présente un court exposé sur la modification possible du climat par l'augmentation du dioxyde de carbone dans l'atmosphère.

Le volume se termine avec 20 annexes dont une bibliographie, plutôt sommaire, et une table des matières. Fidèle à la tradition française, le livre ne comporte pas d'index.

Le texte est très bien écrit et son rythme est vivace, ce qui en agrémente la lecture. Mentionnons que l'auteur ne discute pas du climat actuel (ni de sa classification) et n'aborde pas non plus l'importance du climat, sous tous ses aspects, dans la société actuelle. La modélisation, de même que la prévision à moyenne ou longue échéance, ne sont touchées qu'accessoirement. Le volume comprend 50 figures dont plusieurs, et c'est ce qui est dommage, sont dans un état lamentable et sans grande originalité.

Ce livre est très intéressant et il mérite d'être connu du grand public qui confond trop facilement météorologie et climatologie et qui n'est pas suffisamment familier avec les problèmes et l'importance de cette dernière. En ce sens, cet ouvrage éveillera sûrement de nombreux intérêts.

Richard Leduc
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List of Referees
Liste des arbitres

Volume 17(1), published in April 1983, was the first issue of the Climatological Bulletin to include refereed articles. During the 1983-1985 period, the Bulletin's Editor has benefitted from the time and advice provided by the people listed below. It is with sincere appreciation that their efforts are publicly acknowledged.

Stewart J. Cohen

Alexander, M.E.

Baier, W.
Ball, T.
Bowen, A.J.
Brotak, E.A.

Catchpole, A.J.W.
Chen, P.

Davies, J.A.

East, C.
Elder, F.P.

Findlay, B.
Folland, C.
Fraser, H.M.

Garnier, B.J.
Goodison, B.E.
Granberg, H.
Gray, D.M.
Greenland, D.

Hanna, S.R.
Hay, J.E.
Hayhoe, H.
Hengeveld, H.
Hillaire-Marcel, C.

Karl, T.R.
King, K.M.

LeDrew, E.

Mason, P.J.
McBoyle, G.
McGinn, R.A.
McKay, D.C.
Mukammal, E.
Murphy, A.H.

Nkemderim, L.C.

Occhietti, S.
Oke, T.R.
Oliver, J.E.

Paul, A.H.
Phillips, D.W.
Powell, J.M.

Ramanathan, V.
Reinelt, E.R.

Sanderson, M.
Singh, B.
Stanhill, G.
Steyn, D.
Stone, P.H.
Stuart, A.
Sulman, F.G.

Vigeant, G.

Wardle, D.I.
Wilson, C.
Woo, M.K.

Corrigendum

In the article by J. Guiot, Vol. 19(2), there is an error in the figure captions on pages 26-29. The captions at the top of each page should read "a)", "b)", "c)", and "d)" respectively, not "Figure 2a", "Figure 2b", etc. The caption at the bottom of page 26, referring to Figure 3, is correct. The four pages thus show Figures 3a, 3b, 3c, and 3d respectively.