Trends in River Ice Cover in Atlantic Canada

William A. Brimley[1] and Cindy N. Freeman[2]

Abstract

Scientists working on climate change are searching for historical data to help ground truth the large global circulation models as a means of refining the scale of their predictions. During the preliminary screening of hydrometric data in the development of a Reference Hydrologic Basin Network for studying climate change and its effect on water resources, a data base was discovered which had previously not been included in normal analyses. This information is the data qualifier B (backwater due to ice) which is appended to the daily flow values to alert the user that ice conditions existed and that data was estimated using different procedures than those used for open water conditions.

Preliminary analyses of these data indicate that there were some definite trends in the data. Stations in Nova Scotia and on the Island of Newfoundland showed that the number of days with ice in the river has significantly increased since 1952 (when the data became part of the record). Initial comparisons of ice data with winter season temperatures showed that there was a cause and effect relationship between the temperature and ice, but it did not explain it completely

The findings are examined and recommendations for future analysis made.

[1] Regional Hydrologist, Atmospheric Science Division, Atmospheric Environment Br., Environment Canada.
[2] Graduate Student, Department of Physics, Dalhousie University, Halifax, NS.

Introduction

The complexity, as well as the possible consequences of inaction, of the climate change issue warrants a thorough look at all historic data which may provide additional information on the behaviour of our 'natural' as well as modified hydrologic systems. The spectre of global warming as a result of increased CO_2 in the atmosphere is a major concern of scientists and governments around the world. The impact of any detectable change in climate over a vast area is being perceived by some as both positive and negative, depending upon the season and the geographic location.

Some Canadians are hopeful of warmer winters without understanding the dynamics of the changes. Statements such as, " the earth's climate is getting warmer," are based on very broad averages of all places and all seasons. Because of these generalities and the cyclic nature of climate on many levels it is very difficult to actually interpret the data and determine whether any notable change is due to anthropogenically induced factors influencing climate, some long term climate cycle or a combination of both. The cause is only important if it can be modified. If the cause is a natural cycle it is still important to understand it so that adaptive measures can be developed. The challenge to science is to determine what the effects are likely to be, what can be done to slowdown or reverse these effects and what must be done to adapt or reduce the negative impacts on our natural and managed ecosystems.

While much of the climate change research has been focused on the global circulation models, studies on the ground are focusing on the boundaries of ecosystems where some species may already be surviving at the limit of their range. It is believed that changes will occur here first. The coastal zone is one of these boundary areas as the ocean is both a physical barrier between terrestrial ecosystems and a major influence on the coastal climate. Ice, whether it is in glaciers, the ocean or the rivers plays a significant role in the Canadian environment acting as nature's bulldozer, as a seasonal and long term storage of water, as a threat to structures, as a bridge or barrier to migrating species and as a climate modifier. Changes in ice patterns may have many impacts on local communities and their ecosystems. What is proposed here is to examine the ice data in a regional sample of streams in Atlantic Canada and in particular the change in the number of days that ice is present in the streams.

Rigorous statistical testing of the data have not been completed nor have all of the questions been addressed. Attempts are made to explain some of the factors influencing the data and to reference other data that may help explain the initial findings.

This brief paper is presented as a work in progress and is intended to bring forward this information base and to describe the observations to date. It is hoped that this will provide others working with river ice, hydrologic forecasting, water and ecosystem management and climate change etc. with an additional point of reference.

Untapped Database

During a recent review of all hydrometric stations in Atlantic Canada, 47 hydrometric stations were screened under a standard set of criteria for inclusion in a network of long term stations to address the climate change issue. The stations identified in the Atlantic Region (Nova Scotia, Prince Edward Island, New Brunswick, and Newfoundland and Labrador), are listed in Appendix A and located on the maps in Figures 1 and 2. These stations are part of a nation-wide effort to develop a 'Reference Hydrologic Basin Network' for the support of long term monitoring and the study of climate change on the water resource (Yuzyk,1997).

A data qualifier used in hydrometric monitoring identifies the days in which ice conditions were present in the stream. Streamflow data that are computed from the recorded water levels during times when ice is present in the stream are identified with a 'B' designator indicating that the data was collected under ice conditions. These data have never been examined in the Atlantic Region and the information that they hold has been untapped.

The work to date has briefly examined the ice data of all the 47 stations with some significant trends showing up along the southern coast of New Brunswick as well as Nova Scotia and most of Newfoundland. The present paper deals only with the Figure 1 Figure 2

observations from seven of these stations (Table 1) during the winter periods between 1955 and 1994. This period was selected to maximize the data contribution from these stations and to produce a regional cross sectional picture. Long term climate data is also available, however many of the hydrometric gauge sites may not be in close enough proximity to these sites to provide the response required. For this study the best available climate were selected.

Table 1 - Hydrometric Stations

Province	Station No.	Station Name
NB	01AK001	SHOGOMOC STREAM NEAR TRANS CANADA HIGHWAY
NB	01BP001	LITTLE SOUTHWEST MIRAMICHI RIVER AT LYTTLETON
NS	01EF001	LAHAVE RIVER AT WEST NORTHFIELD
NS	01EO001	ST. MARYS RIVER AT STILLWATER
NS	01FB001	NORTHEAST MARGAREE RIVER AT MARGAREE VALLEY
NFLD	02YL001	UPPER HUMBER RIVER NEAR REIDVILLE
NFLD	02ZK001	ROCKY RIVER NEAR COLINET

Caveat

It must be understood that the data on river ice should only be considered valid at the gauging station site and may not be transferable to the entire watershed. Hydrometric gauging sites generally have a natural or artificial control at the site where the current downstream of the gauge is greater than that above. This will generally keep the stream ice free longer, whereas a lake or slow section of a stream may freeze up in the late fall and remain frozen until spring a faster moving section may go through several freeze/breakup cycles. This is especially true in Nova Scotia and the southern portions of New Brunswick and Newfoundland which are close to the ocean where the winter temperatures fluctuate greatly from the ocean's influence as the winds swing around on the movements of low and high pressure systems that appear to move endlessly through the region. However, this does not preclude that there is no value in this information, on the contrary the spatial dimension lies in the number of stations available with data ranging from 25 to 40 years in length.

Examining the Data

The first question to address is what is the source and quality of these data. The determination of ice in the stream is a vital part of the information required to secure a good flow record. When streams are covered with ice the channel hydraulics change from that of an open channel to that resembling a closed conduit or pipe. The normal open water stage-discharge relationship no longer applies. During the data reduction phase, where the measured water level is transformed into a flow value, the hydrometric technician must determine when there is ice in the river sufficient to create backwater at the hydrometric control. This information is used to ensure that the stage-discharge relationship is applied correctly to the water level data.

Backwater calculation procedures have been used since the Water Survey of Canada (presently Atmospheric Environment Branch, Environment Canada) began gathering data, however only since 1952 has this information been included in the published record. To designate this ice condition a 'B' is appended to the daily flow value in the published record as a flag to the user. Examples of these published records are the Annual Surface Water Data publication (Water Survey of Canada, 1990) which was last published on paper in 1990 and its successor the Annual Summary on the CD-Rom database, HYDAT, Version 4.95(Environment Canada, 1997).

Collectively, this information has provided a new database on the presence of ice in streams, if only at specific locations. Granted, these data are provided on a daily basis and one might argue that the transition from open water to complete cover may take longer. It can be stated that the formation/breakup of ice on stream is a characteristic of that stream so analyzing this parameter in a times series should not be a problem. While air temperature will be a major factor in developing an ice cover, other factors will also come into play. Some geographical factors such as the slope of the watershed, the slope of the stream channel, size, depth and distance of upstream lakes (which may provide warmer water) remain relatively constant. However, the climatic and hydrologic conditions before freeze-up, and the contributions of flow from groundwater will vary.

To date only the total ice days for the entire winter season have been examined.

Climate Data

Temperature data have been used to provide additional information to help explain the increasing trend of ice noted in the stream data. Initially temperature data were included as a seasonal mean value to coincide with the seasonal total of the number of days of river ice, however it was noted that the seasonal mean temperature value was too coarse to provide any detailed comparison with the ice data. In an attempt to find a climate indicator that may have some application to this problem, the characteristics of the formation and break up of ice were considered. Since temperatures below -4^{0}C will support the freezing of water it was decided to determined the number of days in which the maximum daily temperature was below -4^{0}C. While not totally successful this indicator was able to provide more meaningful response to the ice data than mean temperature data.

The graphs in Figures 3 through 9, show the number of days of ice at a hydrometric station and the climate indictor data from the closest climate station. The climate data has been formatted to give the number of days where the maximum daily air temperature is less than -4°C. Note that while the hydrometric data are from the period 1955 to 1994 (the winter beginning Fall 1993) the climate information for longer periods was used where available to provide some insight into the characteristics of the climate data over the longer term.

Discussion

In discussing specific years it is important to note that the water year is being used. The data under 1980 would begin in October 1980 and include the winter and spring of 1981.

Looking first at central New Brunswick, represented by Shogomoc Stream Figure 3a, this figure shows an gradual increase in the number of days of ice from 1959 to 1978 with rapid decrease through 1983 and then a steep rise to a new level. The overall picture shows a significant increase of over 20 days in a 40 year period. The long term climate data in Figure 3b shows a more complete picture. It appears support the trend but does not completely support a year to year relationship. The important feature to note is that prior to 1965-69, the variance was much greater. The construction and influence of the Mactaquac headpond may be a factor worth invesigating here.

In northeastern New Brunswick represented by the Little Southwest Miramichi River (Figure 4a) the ice data appears to have no trend for the data period, however the climate information appears to indicate a gradual increase in the number of ice making days.

In southern Nova Scotia represented by the LaHave River (Figure 5a) a definate trend is evident with an increase in ice days of approximately 35 days over the period. The climate data at Liverpool - Big Falls (Figure 5b) while supporting this trend in direction, only partially supports the year to year variation.

Moving north and east to the St. Marys River (Figure 6a) and in turn to the Northeast Margaree River (Figure 7a) the trend appears to increase incrementally from 50 to 90 days over the period. Again this is supported by the climate data only in direction.

In western Newfoundland the representative station on the Upper Humber River show a trend similar to central and northern Nova Scotia however, here it appears that the climate station at Deer Lake Airport agrees with the ice trend of approximately 70 days. The climate station and the hydrometric station are within 10 km. of each other.

Finally, for eastern Newfoundland, represented by Rocky River the trend appears to decrease until 1983 then dramatically increase 50 days in 5 years. The climate stations at Terra Nova National Park (Figure 9b) and St. John's Airport (Figure 9c) are showing similar trend patterns and this is coinciding reasonably well with the ice data.

Oceanic Factors

The question remains, what is occurring here. To get some insight into this, one must cross the land/ocean interface. Recent studies of long term data on ocean temperatures (Drinkwater, 1996) shows that the winter temperatures off the coast of Newfoundland and Nova Scotia have been dropping since about 1969. The factors here are complex and closer study is warranted. The driving force appears to be the intensity of the North Atlantic Oscillation (Icelandic low pressure systems and Bermuda-Azores highs) which result in stronger Northwest winds to the Labrador Sea carrying cold Arctic winds further south. The extent of this current which dominates the upper layer of the coastal waters during the winter months may help to explain the climate and the ice trends.

Conclusions and Recommendations

There appears to be a link between the winter ocean currents and the formation of ice in Atlantic Basin Streams. The moderating effect of the oceans that has traditionally kept these streams open longer appears to have diminished since the late nineteen sixties.

The ice data constitutes a new data source that has not been fully examined, yet it links the oceans and climate with the terrestrial ecosystems. The other 40 hydrometric stations can also be used in spite of their shorter periods of record to fill in some of the gaps in the knowledge base.

The ice data used as seasonal totals provides a general overview of the changes occurring, however, the seasonal time frame is too coarse to provide solid statistical relationships between the climate and the ice. Ice data should be reference by dates or segmented into smaller time spans such that it is possible to determine which parts of the winter show the most change. For example is ice arriving earlier, leaving later or is the ice cover more consistent during the months of January through March.

Climate data used were not always from sites which are not close enough to be truly representative for most hydrometric stations. A better relationship should be developed between ice and air temperature thus providing a some predictive element on the condition of ice. It should be noted from the long term climate data at Fredericton (Figure 3b) that the winter temperatures prior to 1953 produced more cold days and the interannual pattern was more erratic. Other long term climate sites should be examined further.

The link to the temperatures of winter ocean currents should be investigated further.

The impacts of a changing ice regime should be investigated and links to other environmental data such as fisheries, agriculture, forestry, wildlife etc. should be made.

References

Drinkwater, K.F., 1996. Atmospheric and Oceanic variability in the Nortwest Atlantic During the 1980s and Early 1990s, J. Northw.Atl. Sci., Vol. 18: 77-97.

Environment Canada, Atmospheric Environment Service,1997. Surface Water and Sediment Data, HYDAT version 4.95, Downsview.

Environment Canada, Water Survey of Canada, 1991. Surface Water Data Atlantic Canada 1990, Ottawa.

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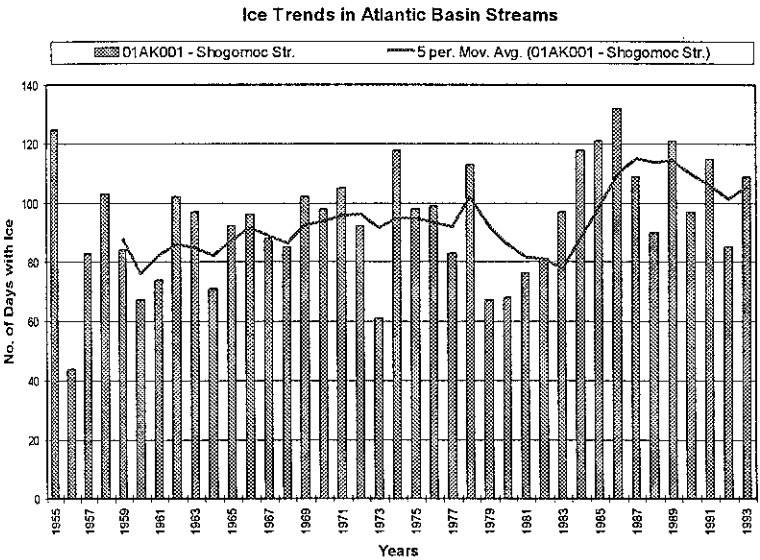
Figure 3a and 3b -- Central New Brunswick



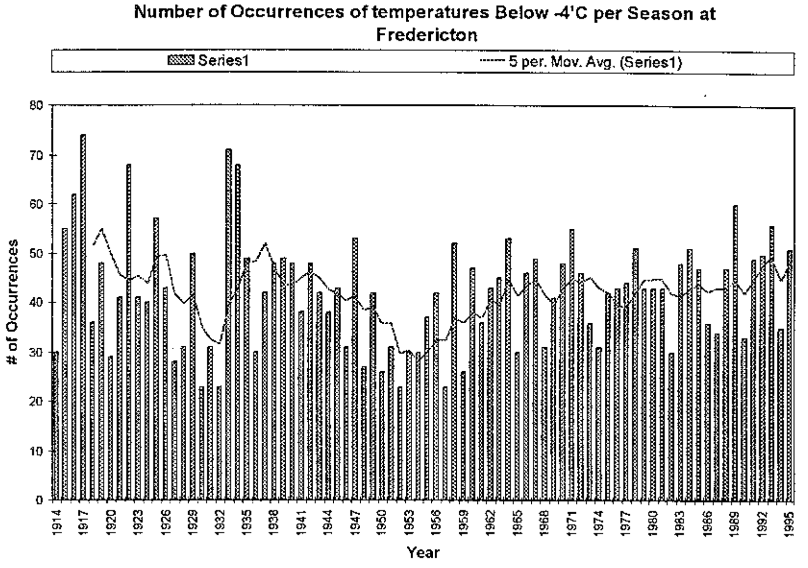
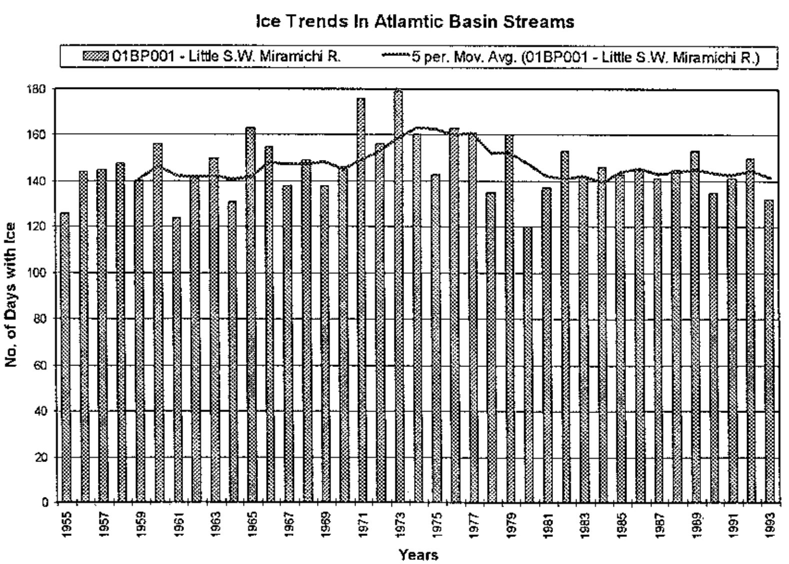


Figure 4a and 4b - Northeastern New Brunswick



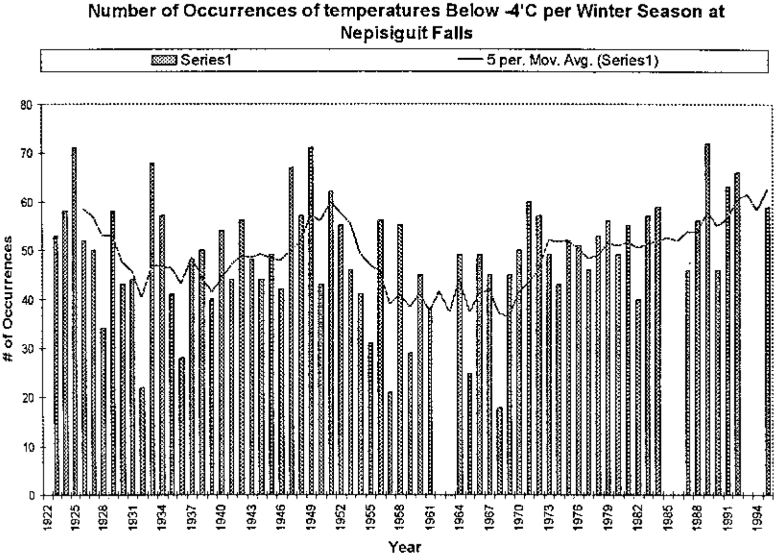
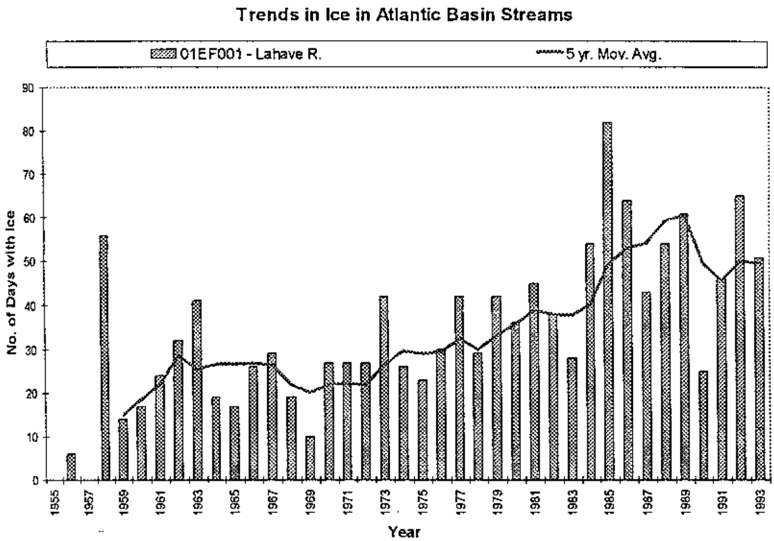


Figure 5a and 5b Southern Nova Scotia



Number of Occurrences of Temperatures Below -4'C per Season (Nov-Apr) at Liverpool-Big Falls

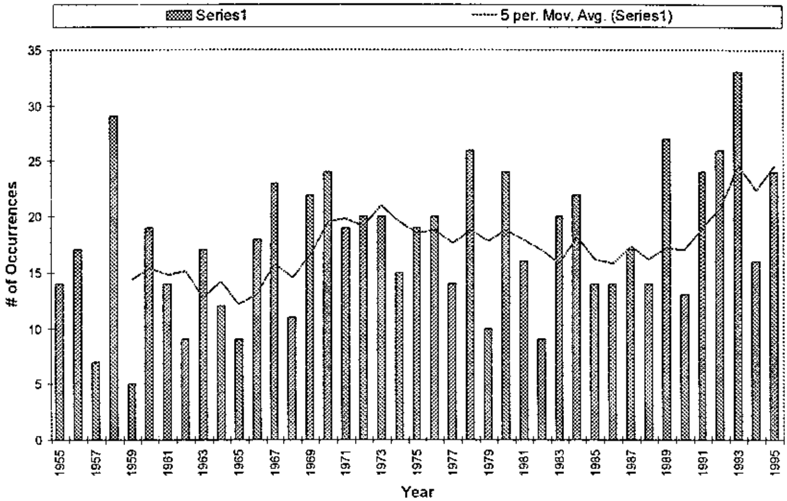
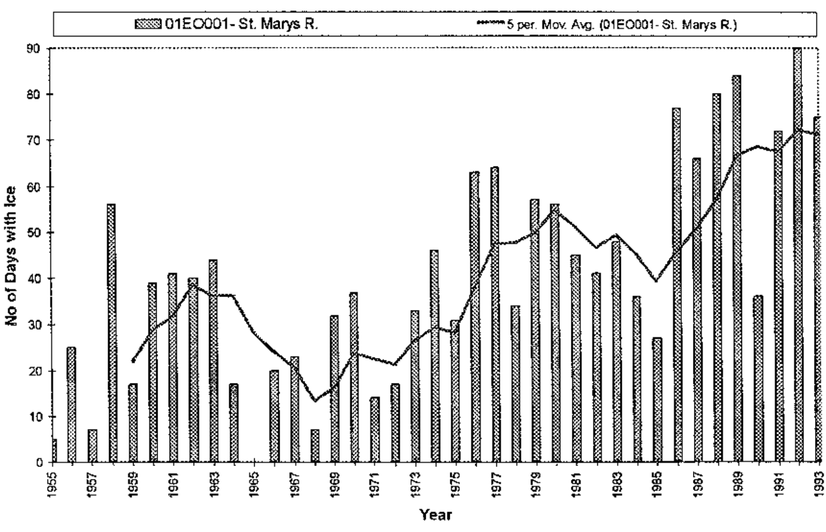


Figure 6a and 6b Central Nova Scotia

Ice Trends in Atlantic Basin Streams



Number of Occurrences of Temperatures Below -4'C per Season (Nov-Apr) at Collegeville

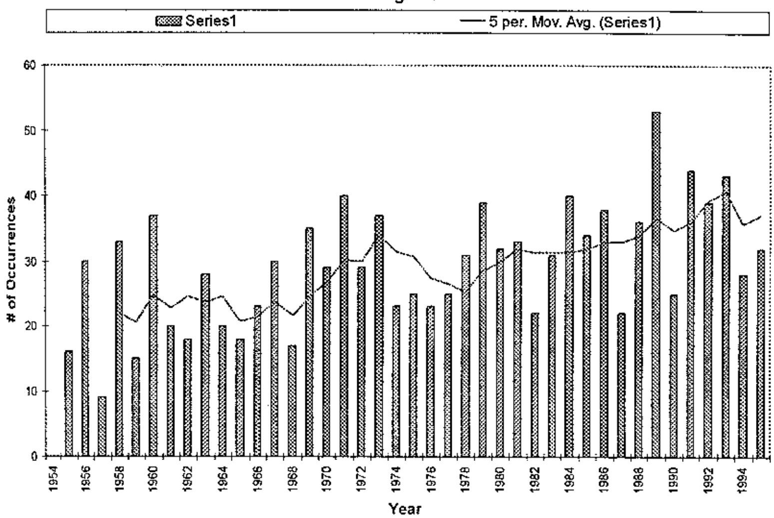
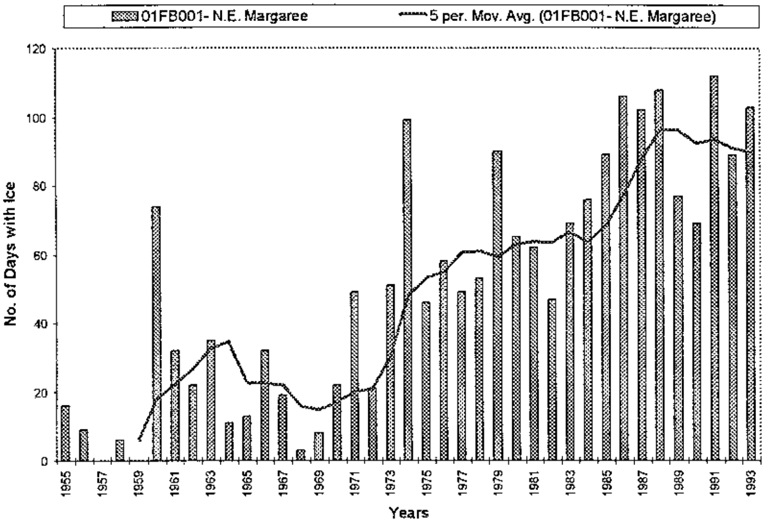


Figure 7a and 7b - Northern Nova Scotia (Cape Breton Island)

Ice Trends In Atlantic Basin Streams



Number of Occurrences of Temperatures Below -4'C per Winter at Cheticamp

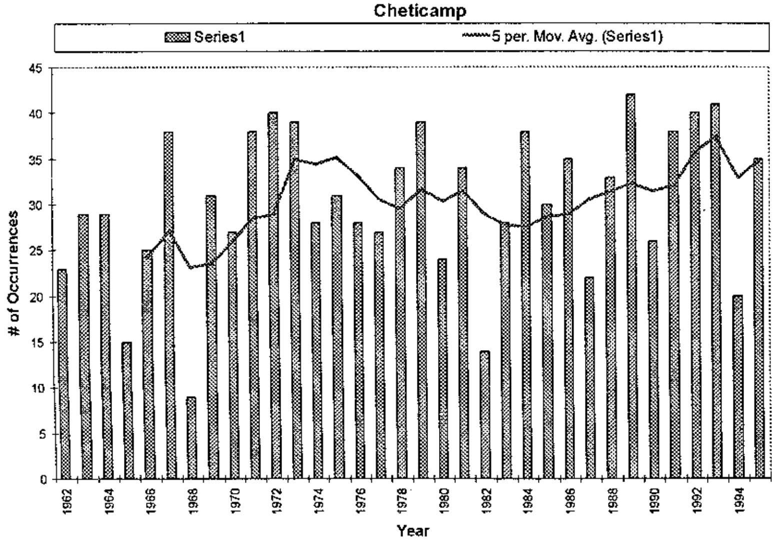
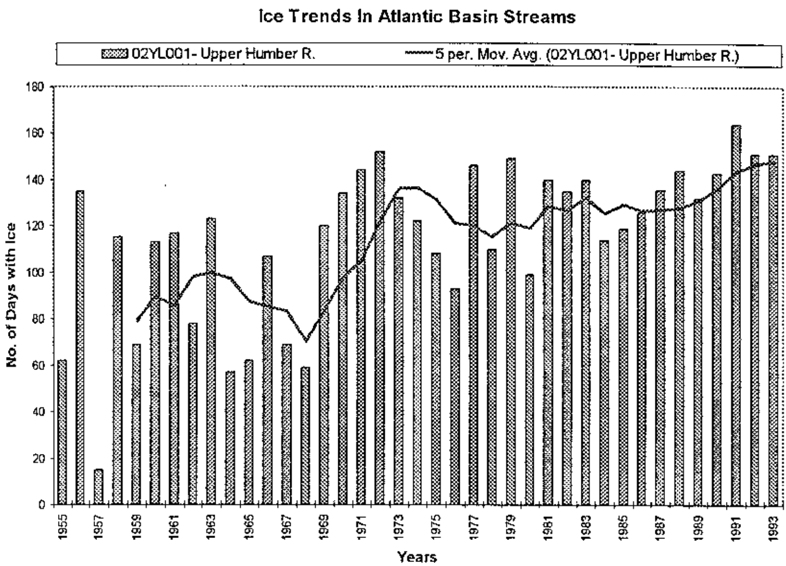


Figure 8a and 8b - Western Newfoundland



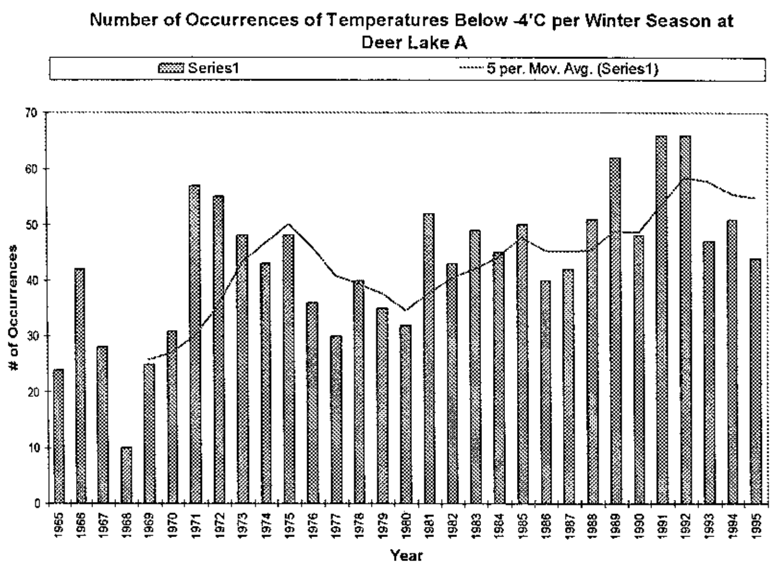
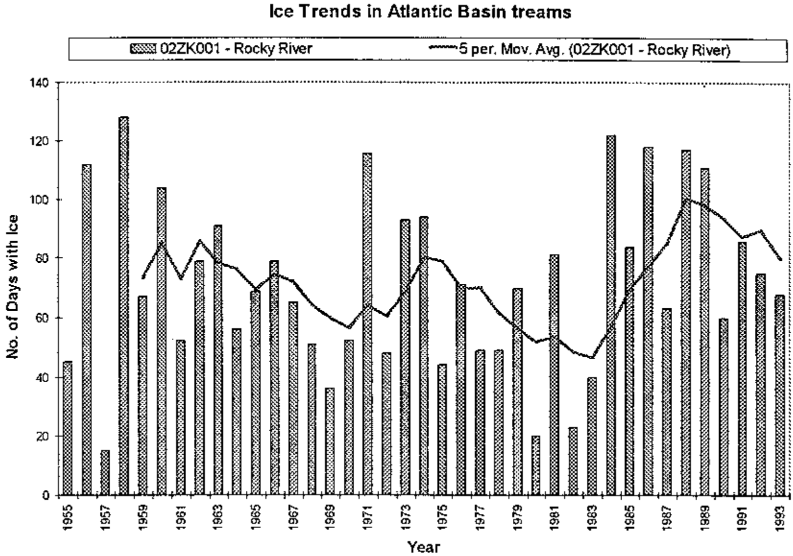


Figure 9a and 9b - Eastern Newfoundland



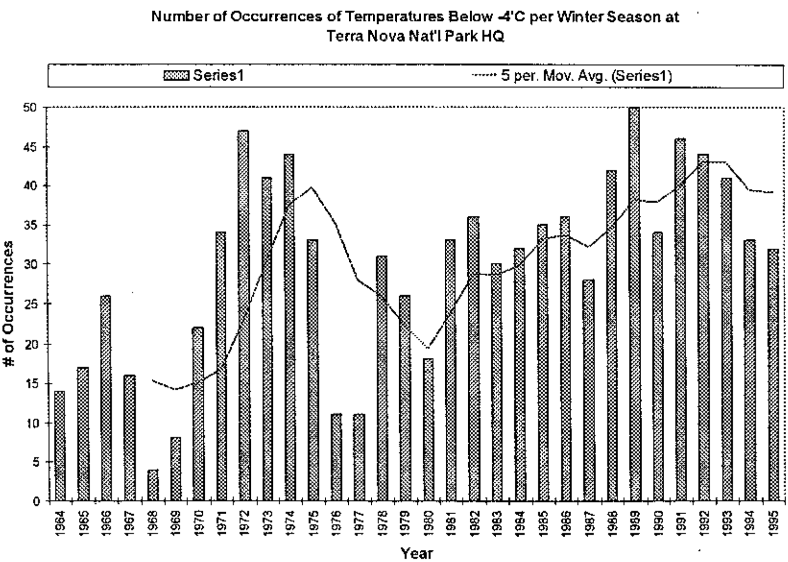


Figure 9c - Eastern Newfoundland (continued)