SEVERITY OF CLIMATE IN THE WESTERN ARCTIC ISLANDS AND ITS POSSIBLE IMPACT ON CARIBOU

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ABSTRACT

Several meteorological variables have been examined for the period 1950-1989 to determine winter and summer conditions unfavourable to caribou in three climatic regions of the Canadian Arctic Islands. The frequency of unfavourable winters increased in the 1980s in the northwestern region, and in the 1970s in the south-central and western regions. Relatively dry summers and wet winters during the 1970s may have caused serious shortages of forage. Freezing rain and snowfall also show increasing trends. The results could be used with other environmental and biological factors to study the implications for caribou and other wildlife in the Arctic.

NOTE: An appendix entitled "Tables of unfavourable winter conditions (at different sites and the area average)" is available through the Department of Renewable Resources Library.

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INTRODUCTION

Climate severity may play a significant role in the population dynamics of wildlife in the Canadian Arctic Islands. Caribou are a particular example of the possible impact of weather and climate on wildlife. The caribou population on Banks Island declined from an estimated size of 11,000 in 1972 to 2,700 ± 340 (standard error) in 1989 (A. Gunn pers. comm.). Caribou die-offs have been attributed mainly to malnutrition, as deep snow and ice from freezing rain reduce availability of forage.

Miller et al. (1977) studied populations of Peary caribou and muskoxen on the western Queen Elizabeth Islands from 1972 to 1974. They suggested that a series of years with unfavourable snow and ice conditions made forage either unavailable or restricted, and thus caused decreases in numbers of both species. A further study of foraging behaviour (Miller et al. 1982) indicated that caribou select poorly vegetated and windblown snow-free patches because of the relative availability of forage. Ground-fast or basal ice formed in the autumn before and during initial snowfalls, and springtime formation of ground-fast ice during the period of snow melt are believed to be important factors in the wide-spread forage restrictions (Gunn et al. 1989). Relatively dry summer conditions, poor growing seasons and frequent occurrence of frost result in poor vegetation and shortage of forage.

The objective of this study is to analyze selected meteorological data in the western islands of the Canadian Arctic over a relatively long period (1950-1989) in order to determine the frequency of unfavourable and favourable winter and summer conditions, and detect possible trends in the data.

The Arctic has a relatively low density of meteorological stations and most of the stations have coastal locations which would introduce a bias into the results (Maxwell 1980, Jacobs 1989). Therefore, no attempt will be made to draw direct causal relations between climate and its possible impacts on caribou. However, the analysis should still be useful in a qualitative sense and the results could be used to supplement other factors which may have implications for caribou and other wildlife distribution.

STUDY AREA

The study area (Figure 1) covers the western islands of the Canadian Arctic. Ten climatological stations from the Northwest Territories (NWT) were selected to represent the area for data analysis. The stations fall into three different climatic regions (Maxwell 1980, 1981) as listed below (see also Figure 2):

Climatic Region I:	Mould Bay Resolute
Climatic Region II:	Cambridge Bay Gjoa Haven Gladman Point Pelly Bay Spence Bay Coppermine
Climatic Region III:	Holman Sachs Harbour

Maxwell (1980, 1981) used 5 major climatic controls for the regional divisions: cyclonic activity, the sea ice-water regime, broad-scale physiographic features, and net radiation. Region I (the Northwestern) and Region II (the South-Central) are of a kind in terms of cyclonic activity and relief. Anticyclonic activity is a maximum over these areas as far as the Canadian Arctic Islands are concerned. Region I, however, is more closely related to the Arctic Ocean in terms of climatic characteristics. On the other hand, Region II possesses many of the characteristics of the continental regime of the adjacent mainland.

Region III (the Western) is distinguished by the alternation of cyclonic and anticyclonic activity, which is found in the Arctic islands only here. Other regions of the Arctic Islands are all

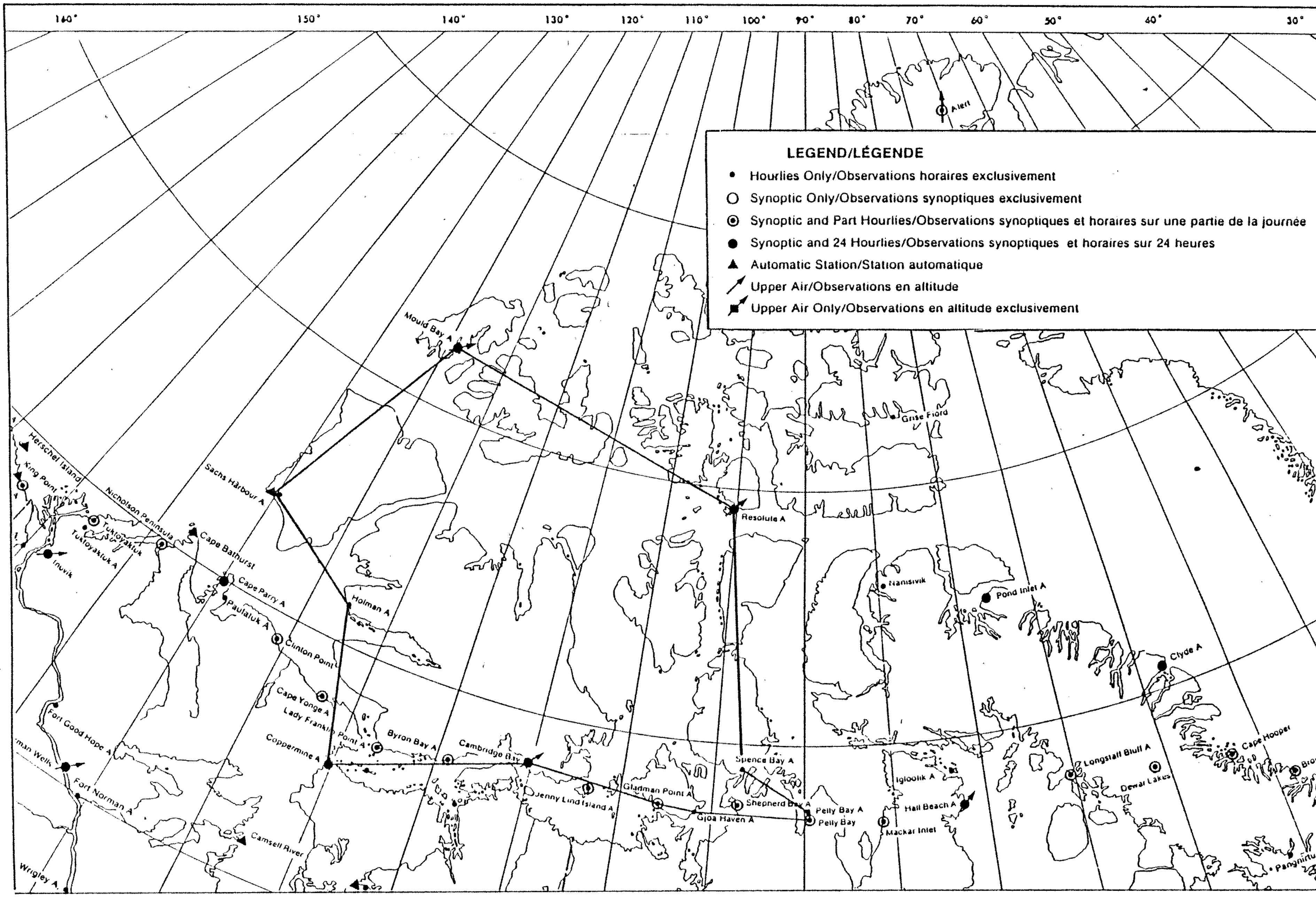


Figure 1. The study area, roughly outlined by connecting the 10 stations.

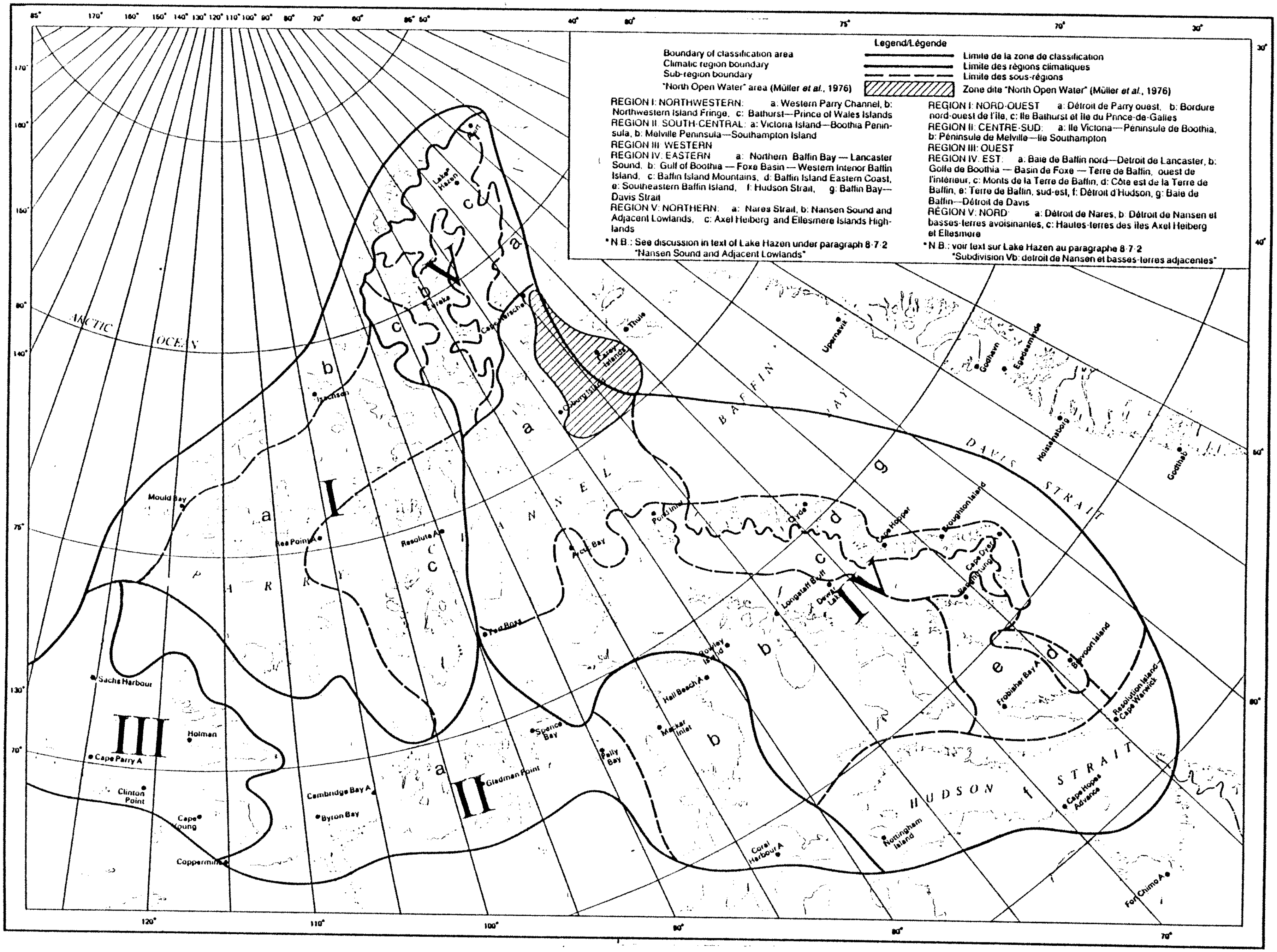


Figure 2. Climatic regions of the Canadian Arctic Islands (from Maxwell, 1980)

markedly anticyclonic or markedly cyclonic in character. In addition, increasing amounts of annual net radiation characterize region III when compared to regions I and II.

It may be noticed in Figure 2 that Coppermine (region II) is located almost on the boundary between regions II and III. Since these boundaries are not rigidly defined, Coppermine's data were also incorporated into region III in order to improve the representation of the area.

CLIMATOLOGICAL DATA

The data used in this study consist of monthly values of selected climatic variables considered useful for their impacts on caribou population dynamics (A. Gunn pers. comm.).

The data were extracted from the climatological digital archives of the Canadian Climate Centre and cover the period 1950-1989. The variables studied are:

(a) Freezing rain (number of days)
(b) Total snowfall (cm)
(c) Depth of snow cover (last day of the month)
(d) Temperature
(e) Wind speed
(f) Frost (number of days)
(g) Total precipitation (mm)
(h) Thawing (above 0°) and growing (above 5°) degree-days

METHODS OF ANALYSIS

The monthly and seasonal data were analyzed to examine the annual variability and detect possible trends over the period 1950-1989, subject to data availability. The seasons are defined as follows: early winter (September, October and November), mid-winter (December, January and February), late winter (March, April and May) and summer (June, July and August).

The frequency distribution of each meteorological variable was examined and the portion lying in each tail, greater than 1.5 standard deviations (SD), was considered an indicator of either unfavourable or favourable conditions. The 1.5 SD was chosen because it provided a reasonable cut-off point for variables whose distributions are mostly skewed.

Unfavourable winter conditions

The variables and times of the year used in identifying unfavourable winter conditions are (A. Gunn pers. comm.):

(a) Frequent occurrence of freezing rain during early, late or all winter (9 months).
(b) Excessive snow cover (last day of month, January - May.
(c) Heavy snowfall during early, mid, late or all winter.
(d) Heavy frost before snowfall (usually in August).
(e) Warm air temperature (above 0^{o}) during snowfall (usually in August and September).

Favourable winter conditions

The variables and times of the year used in determining favourable winter conditions are:

(a) Low or no occurrence of freezing rain during early, late or all winter.
(b) Shallow snow cover (last day of month, January - May).
(c) Light snowfall during early, mid-, late or all winter.
(d) Extreme cold (mid- or all winter).
(e) Strong wind speed (all winter).

Unfavourable and favourable summer conditions

The variables used in determining unfavourable (favourable) summer (June, July and August) conditions are:

(a) Heavy (light) frost.
(b) Light (heavy) precipitation
(c) Small (large) accumulation of thawing degree-days.
(d) Small (large) accumulation of plant growing degree-days.

Trend analysis

The method of moving averages (Harnett 1982) was used to smooth the time series and detect possible trends during the study period (1950-1989). A five-year moving average was applied to remove the small inter-annual variability without losing too many cycles or features in the time series. No attempt will be made here to calculate a 'trend line' because data gaps exist at several locations and the analysis is basically qualitative at this stage.

RESULTS

Unfavourable and favourable winter and summer conditions for climatic regions I, II and III are summarized in tabular form. A cell marked by an "X" in the tables indicates that the value of the variable in that cell exceeded 1.5 SD.

Frequency of unfavourable winters

Severe weather conditions for each winter season are presented in Tables 1 to 3 for the three climatic regions.

It is noted from Table 1 that climatic region I recorded frequent, unfavourable conditions during the 1980s. Increased incidence of freezing rain and greater snowfalls were more frequent during this period when compared to earlier years. On the other hand, regions II and III reported frequent unfavourable conditions during the 1970s (Tables 2 and 3). Freezing rain, heavy snowfall and deep snow cover were common.

Frequency of favourable winters

Tables 4 to 6 highlight favourable winter conditions for the three climatic regions. No specific pattern is seen from the tables. It is noted, however, that in region I (Table 4), freezing rain was uncommon from the late 1950s to the early 1970s. Besides, the winter seasons 1949-50, 1956-57, 1984-85 and 1987-88 had

Table 1. Unfavourable winter conditions for climatic region I.

Winter Season	Freezing Rain Erly SON	Freezing Rain Late MAM	Freezing Rain 9-mon Winter	Snow Depth (last day of) J	Snow Depth (last day of) F	Snow Depth (last day of) M	Snow Depth (last day of) A	Snow Depth (last day of) M	Total Snowfall Erly SON	Total Snowfall Mid DJF	Total Snowfall Late MAM	Total Snowfall 9-mon Winter	Frost & No Snow AUG	Warm Temp during Snowfall AUG	Warm Temp during Snowfall SEP
49-50															
50-51															
51-52															
52-53														X	
53-54															
54-55															
55-56						X	X	X							
56-57															
57-58															
58-59															
59-60															
60-61					X	X	X								
61-62															
62-63															
63-64															
64-65															
65-66															
66-67															
67-68														X	
68-69															
69-70															
70-71											X				
71-72														X	
72-73															
73-74				X				X							
74-75	X		X												
75-76															
76-77															
77-78															
78-79															
79-80		X													
80-81		X									X				
81-82		X												X	
82-83													X		
83-84															
84-85	X	X	X												
85-86									X			X			
86-87	X		X					X							
87-88		X	X							X				X	
88-89									X	X	X	X		X	
89-90									X						

Table 2. Unfavourable winter conditions for climatic region II.

Winter Season	Freezing Rain			Snow Depth (last day of)					Total Snowfall				Frost & No Snow	Warm Temp during Snowfall	
	Erly SON	Late MAM	9-mon Winter	J	F	M	A	M	Erly SON	Mid DJF	Late MAM	9-mon Winter	AUG	AUG	SEP
49-50					X	X	X								
50-51															
51-52															
52-53										X					
53-54															
54-55															
55-56															
56-57															
57-58				X	X	X	X								X
58-59															X
59-60															
60-61															
61-62															
62-63															
63-64															
64-65															
65-66															
66-67															
67-68															
68-69															X
69-70															
70-71															
71-72								X			X	X			X
72-73									X			X	X		
73-74									X						X
74-75				X					X			X	X		
75-76									X			X			
76-77		X				X	X			X	X				
77-78								X							
78-79											X		X		
79-80		X		X	X		X			X	X		X		
80-81															
81-82															X
82-83															
83-84															X
84-85															
85-86															
86-87	X							X		X			X		
87-88		X	X												X
88-89															X
89-90															

Table 3. Unfavourable winter conditions for climatic region III.

	Freezing Rain			Snow Depth (last day of)					Total Snowfall				Frost & No Snow	Warm Temp during Snowfall	
Winter Season	Erly SON	Late MAM	9-mon Winter	J	F	M	A	M	Erly SON	Mid DJF	Late MAM	9-mon Winter	AUG	AUG	SEP
49-50															
50-51															
51-52															
52-53				X	X	X									
53-54															
54-55				X	X	X									
55-56															
56-57															
57-58															X
58-59								X							
59-60															
60-61															
61-62															
62-63															
63-64															
64-65															
65-66															
66-67															
67-68								X					X		
68-69															
69-70															
70-71															
71-72															
72-73		X	X						X						
73-74	X		X												X
74-75	X		X										X		
75-76									X		X	X			
76-77		X				X	X		X	X		X			
77-78	X		X			X		X			X				
78-79											X	X	X		X
79-80											X				
80-81															
81-82															
82-83															
83-84															
84-85															
85-86		X													
86-87															
87-88										X					
88-89				X	X	X	X	X							
89-90															X

Table 4. Favourable winter conditions for climatic region I.

Winter Season	Freezing Rain Erly SON	Freezing Rain Late MAM	Freezing Rain 9-mon Winter	Snow Depth (last day of) J	Snow Depth (last day of) F	Snow Depth (last day of) M	Snow Depth (last day of) A	Snow Depth (last day of) M	Total Snowfall Erly SON	Total Snowfall Mid DJF	Total Snowfall Late MAM	Total Snowfall 9-mon Winter	Winter Temp. Mid DJF	Winter Temp. 9 mon	Wind Speed 9-mon Winter
49-50				X	X	X	X								
50-51															
51-52															
52-53						X									
53-54													X		
54-55															
55-56															
56-57		X							X	X		X			
57-58															
58-59		X					X								
59-60															
60-61	X	X	X												
61-62		X													
62-63	X														X
63-64															
64-65															X
65-66															
66-67		X		X	X										
67-68		X													
68-69		X													
69-70															
70-71		X													
71-72		X											X		
72-73															
73-74															
74-75															
75-76															
76-77															
77-78		X													X
78-79															
79-80															
80-81															
81-82															X
82-83										X				X	
83-84															
84-85							X	X			X				
85-86															X
86-87		X												X	
87-88				X	X	X		X							
88-89															
89-90															

Table 5. Favourable winter conditions for climatic region II.

	Freezing Rain			Snow Depth (last day of)					Total Snowfall				Winter Temp.		Wind Speec
Winter Season	Erly SON	Late MAM	9-mon Winter	J	F	M	A	M	Erly SON	Mid DJF	Late MAM	9-mon Winter	Mid DJF	9 mon	9-mc Winte
49-50															
50-51															
51-52															
52-53															
53-54															
54-55															
55-56															
56-57		X													
57-58															
58-59		X													
59-60	X														
60-61			X												
61-62															
62-63		X	X												
63-64															
64-65															
65-66				X	X	X		X			X	X			
66-67				X	X	X	X		X	X		X			
67-68															
68-69															
69-70			X												
70-71															
71-72			X										X		
72-73														X	X
73-74															
74-75															X
75-76															X
76-77															
77-78															
78-79	X														
79-80															
80-81															
81-82															
82-83														X	
83-84															
84-85								X							
85-86				X	X	X	X								
86-87														X	
87-88															
88-89															
89-90															

Table 6. Favourable winter conditions for climatic region III.

	Freezing Rain			Snow Depth (last day of)					Total Snowfall				Winter Temp.		Wind Speed
Winter Season	Erly SON	Late MAM	9-mon Winter	J	F	M	A	M	Erly SON	Mid DJF	Late MAM	9-mon Winter	Mid DJF	9 mon	9-mo Winte
49-50															
50-51															
51-52				X	X	X	X	X	X	X		X			
52-53							X	X							
53-54										X		X			
54-55															
55-56															
56-57															
57-58		X													
58-59		X													
59-60															X
60-61															
61-62		X													
62-63															
63-64															
64-65		X											X		
65-66															
66-67															
67-68															
68-69															
69-70															
70-71															
71-72		X											X		
72-73															
73-74															
74-75													X		
75-76															
76-77															
77-78															
78-79															
79-80															
80-81							X								
81-82															
82-83														X	
83-84															X
84-85															
85-86				X		X									
86-87															
87-88															
88-89															
89-90															

particularly favourable snow conditions.

Snow conditions were also very favourable in the winters of 1965-66, 1966-67 and 1985-86 in region II (Table 5), and during 1951-52 in region III (Table 6).

Frequency of unfavourable and favourable summers

Tables 7 to 9 summarize unfavourable and favourable summer conditions in the three climatic regions. In region I, the summers of 1958, 1960 and 1962 were particularly favourable (Table 7). The summer of 1967 had favourable precipitation, but was unfavourable in terms of frost occurrence and poor thawing degree-days.

In region II, the highly unfavourable summers were 1972 and 1978 (Table 8). On the other hand, the summers of 1973 and 1975 had good accumulations of thawing and growing degree-days, with the exception of poor precipitation in 1975.

In region III, the highly unfavourable summers were 1959, 1967 and 1978, with the last one being exceptionally cold and dry. The most favourable summers are 1954, 1988 and 1989 (Table 9).

Trends

The presence or absence of trends was examined for the following climatic variables:

Table 7. Unfavourable / favourable summer conditions. (for climatic region I).

Summer Season	Unfavourable Frost	Unfavourable Precip	Unfavourable Thawing D-Days	Unfavourable Growing D-Days	Favourable Frost	Favourable Precip	Favourable Thawing D-Days	Favourable Growing D-Days
1950								
1951								
1952								
1953								
1954								
1955								
1956								
1957								
1958					X		X	X
1959								
1960					X	X		
1961								
1962					X		X	X
1963								
1964								
1965								
1966								
1967	X		X			X		
1968								
1969								
1970								
1971								
1972								
1973								
1974								
1975								
1976	X							
1977		X			X			
1978								
1979								
1980								
1981								
1982								
1983								
1984								
1985								
1986								
1987								
1988								
1989								

Table 8. Unfavourable / favourable summer conditions.
(for climatic region II).

Summer Season	Unfavourable Frost	Unfavourable Precip	Unfavourable Thawing D-Days	Unfavourable Growing D-Days	Favourable Frost	Favourable Precip	Favourable Thawing D-Days	Favourable Growing D-Days
1950								
1951								
1952		X						
1953								
1954								X
1955								
1956								
1957								
1958								
1959				X				
1960						X		
1961								
1962								
1963								
1964		X						
1965								
1966								
1967								
1968								
1969								
1970								
1971								
1972	X		X					
1973							X	X
1974								
1975		X					X	X
1976	X							
1977								
1978	X		X	X				
1979	X							
1980								
1981								
1982								
1983								
1984								
1985								
1986								
1987								
1988								
1989								

Table 9. Unfavourable / favourable summer conditions. (for climatic region III).

	Unfavourable				Favourable			
Summer Season	Frost	Precip	Thawing D-Days	Growing D-Days	Frost	Precip	Thawing D-Days	Growing D-Days
1950								
1951								
1952		X						
1953								
1954							X	X
1955								
1956								
1957								
1958								
1959			X	X				
1960						X		
1961								
1962								
1963								
1964	X							
1965								
1966								
1967	X		X	X				
1968								
1969								
1970								
1971								
1972								
1973						X		
1974								
1975								
1976								
1977								
1978	X	X	X	X				
1979								
1980								
1981					X			
1982								
1983								
1984						X		
1985								
1986								
1987								
1988							X	X
1989							X	X

Freezing rain

Figures 3 to 5 show the 5-year moving average of freezing rain (number of days/season) for the three climatic regions. In region I, the increasing trend with a cyclical pattern is obvious (Figure 3). Similarly, Figure 4 shows an increasing but less profound trend for region II. In region III, Figure 5 shows that the 1970s had higher incidence of freezing rain than the rest of the period. In addition, a small increasing trend is also noted over the period of record.

Snow depth

The smoothed time series plots for the depth of snow cover (last day of the month) are shown in Figures 6 to 8. In region I, the plot for June in Figure 6 suggests that there is a weak trend toward decreasing snow cover, beginning in the mid 1960s. Similar observations are seen in regions II and III for the month of May (Figure 7 and Figure 8) from the late 1950s to the early 1980s.

Total snowfall

The smoothed time series plots for the total snowfall amounts (cm) are shown in Figures 9 to 11. In region I, Figure 9 suggests a trend of increasing snowfall. No consistent trend is evident for region II (Figure 10). In region III, the increasing trend is evident for the 9-month winter data (Figure 11). In addition, the excessive snow amounts during the 1970s are seen in the plots of regions II and III.

Figure 3.

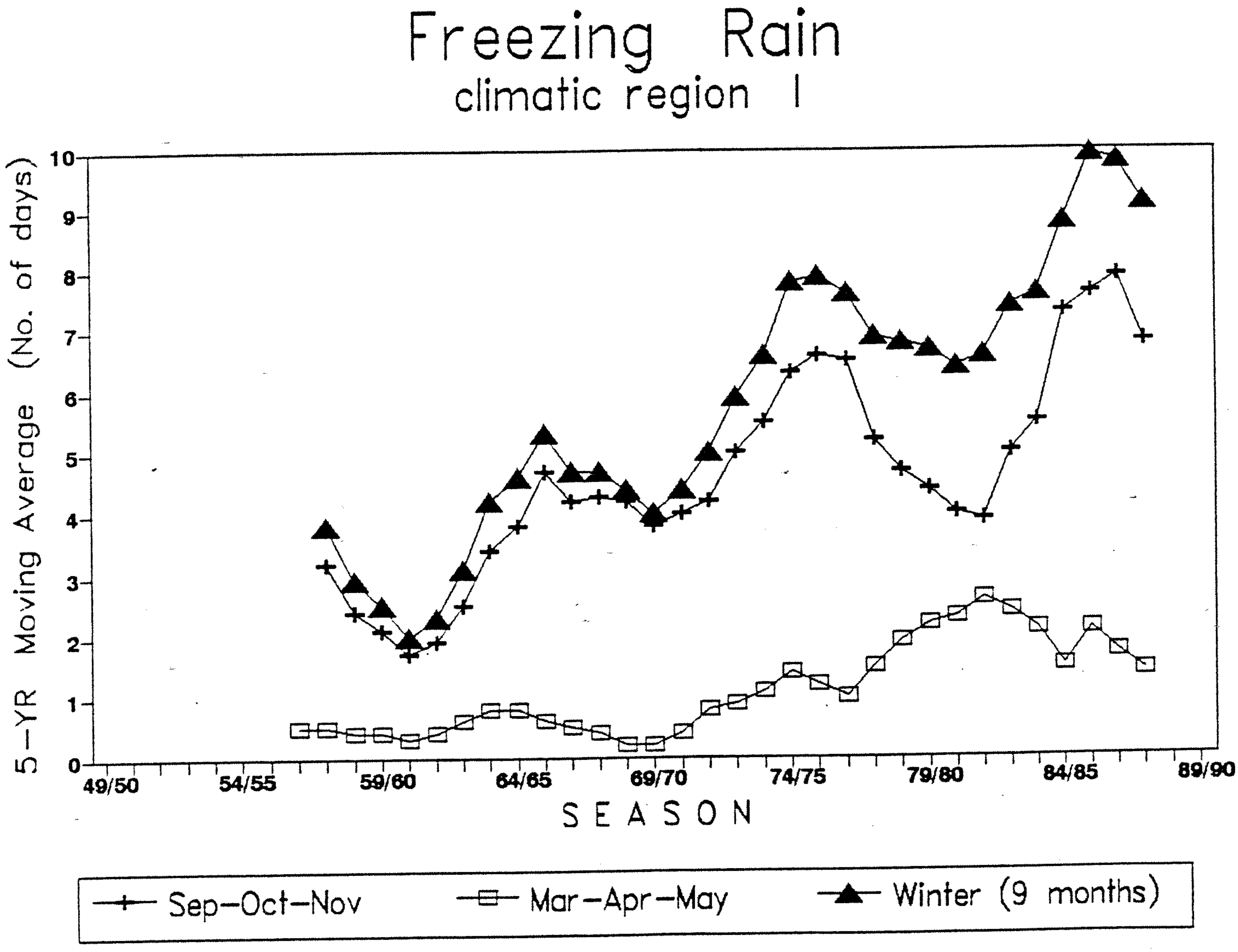

Freezing Rain
climatic region I
5-YR Moving Average (No. of days)
10
9
8
7
6
5
4
3
2
1
0
49/50
54/55
59/60
64/65
69/70
74/75
79/80
84/85
89/90
SEASON
Sep-Oct-Nov
Mar-Apr-May
Winter (9 months)

Figure 4.

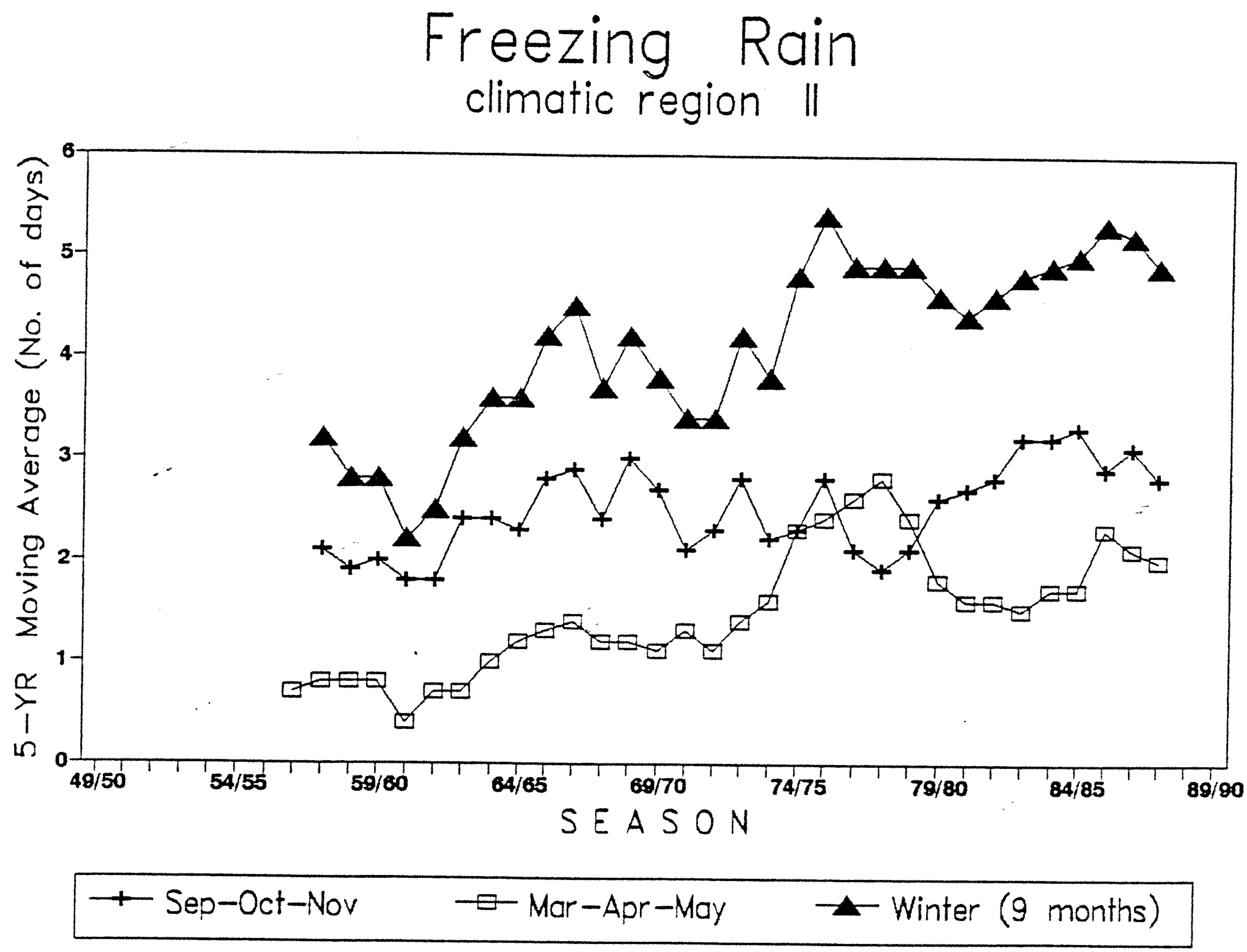

Freezing Rain
climatic region II
5-YR Moving Average (No. of days)
0
1
2
3
4
5
6
49/50
54/55
59/60
64/65
69/70
74/75
79/80
84/85
89/90
SEASON
Sep-Oct-Nov
Mar-Apr-May
Winter (9 months)

Figure 5.

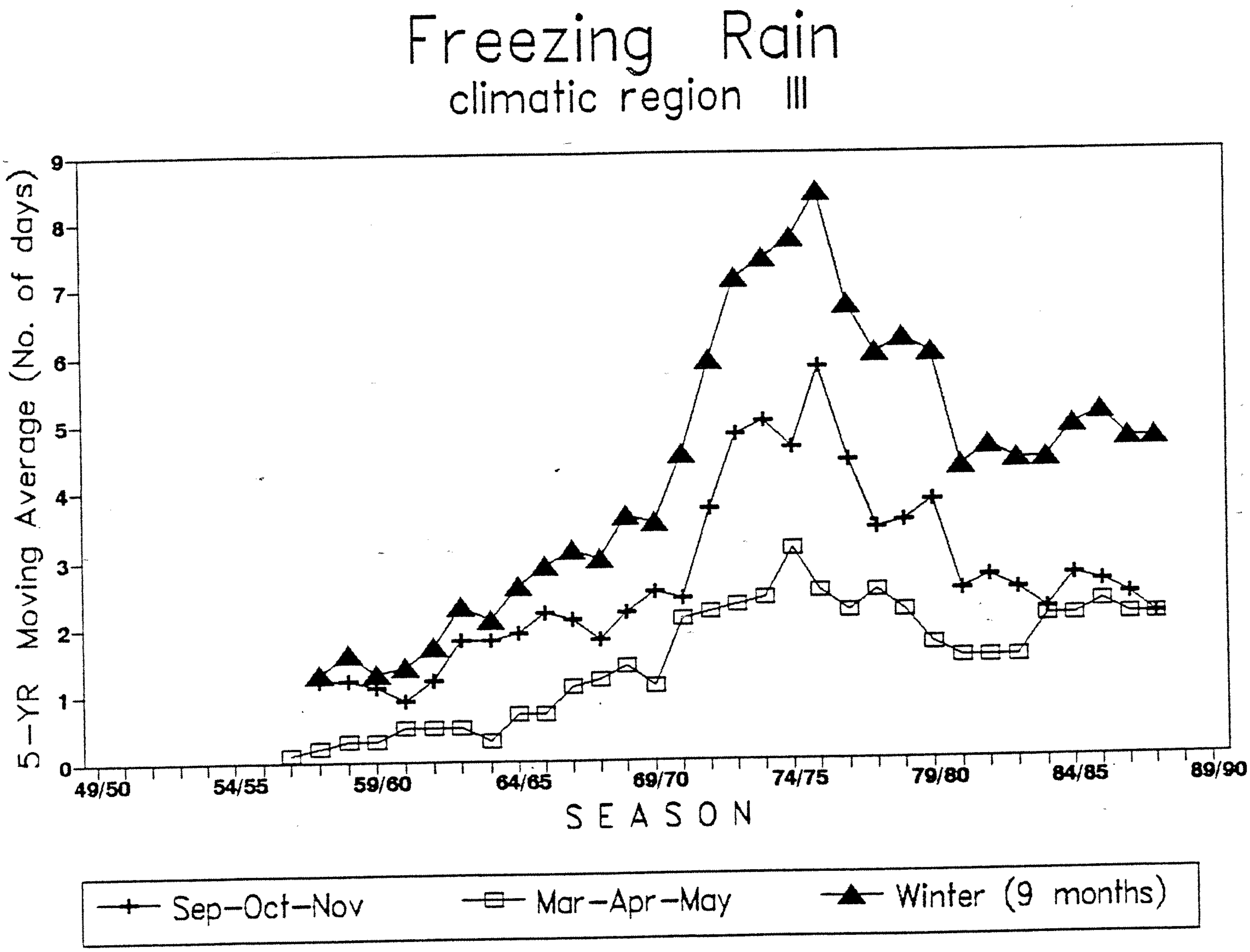

Freezing Rain
climatic region III
5-YR Moving Average (No. of days)
0
1
2
3
4
5
6
7
8
9
49/50
54/55
59/60
64/65
69/70
74/75
79/80
84/85
89/90
SEASON
Sep-Oct-Nov
Mar-Apr-May
Winter (9 months)

Figure 6.

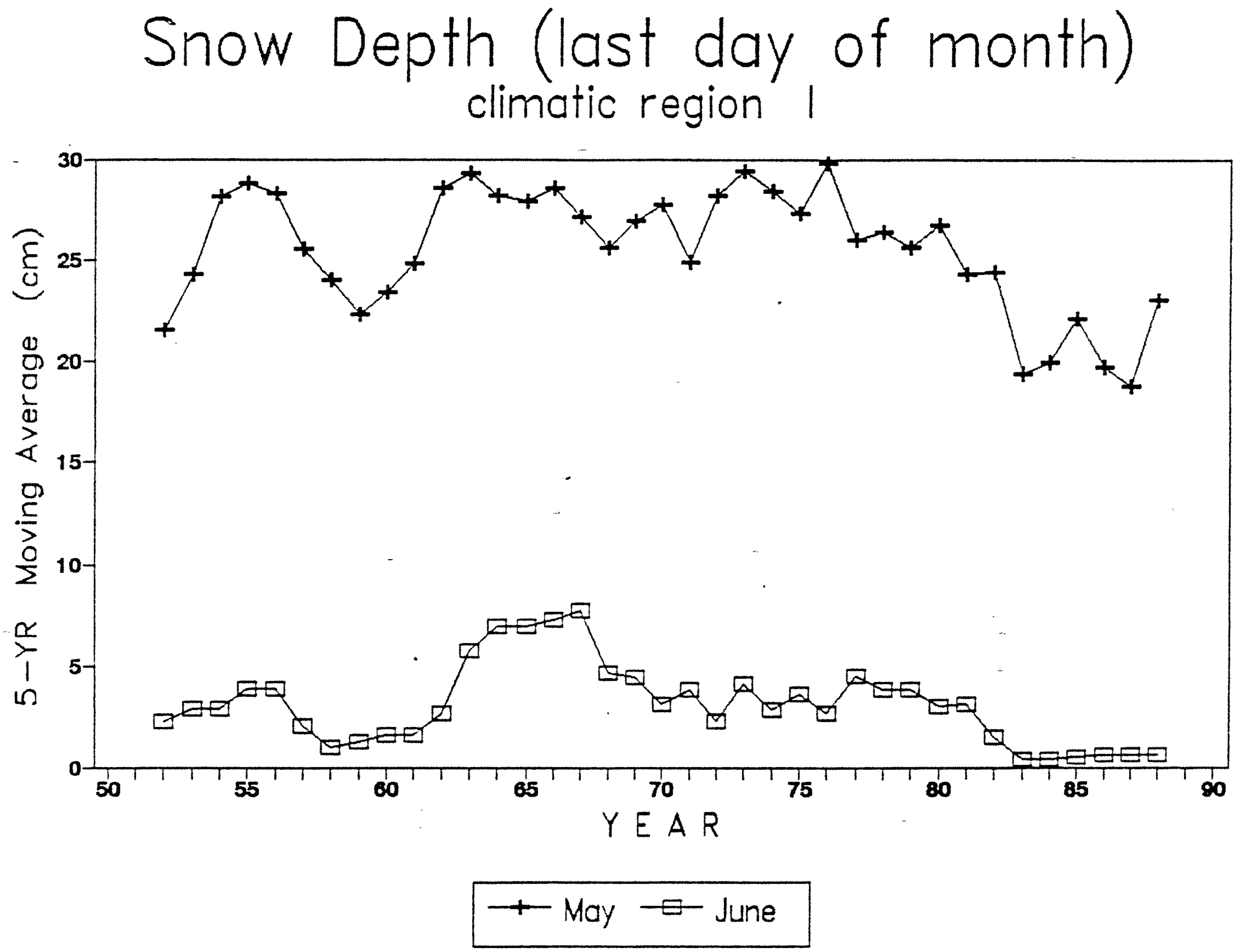

Snow Depth (last day of month)
climatic region I
5-YR Moving Average (cm)
30
25
20
15
10
5
0
50
55
60
65
70
75
80
85
90
YEAR
May
June

Figure 7.

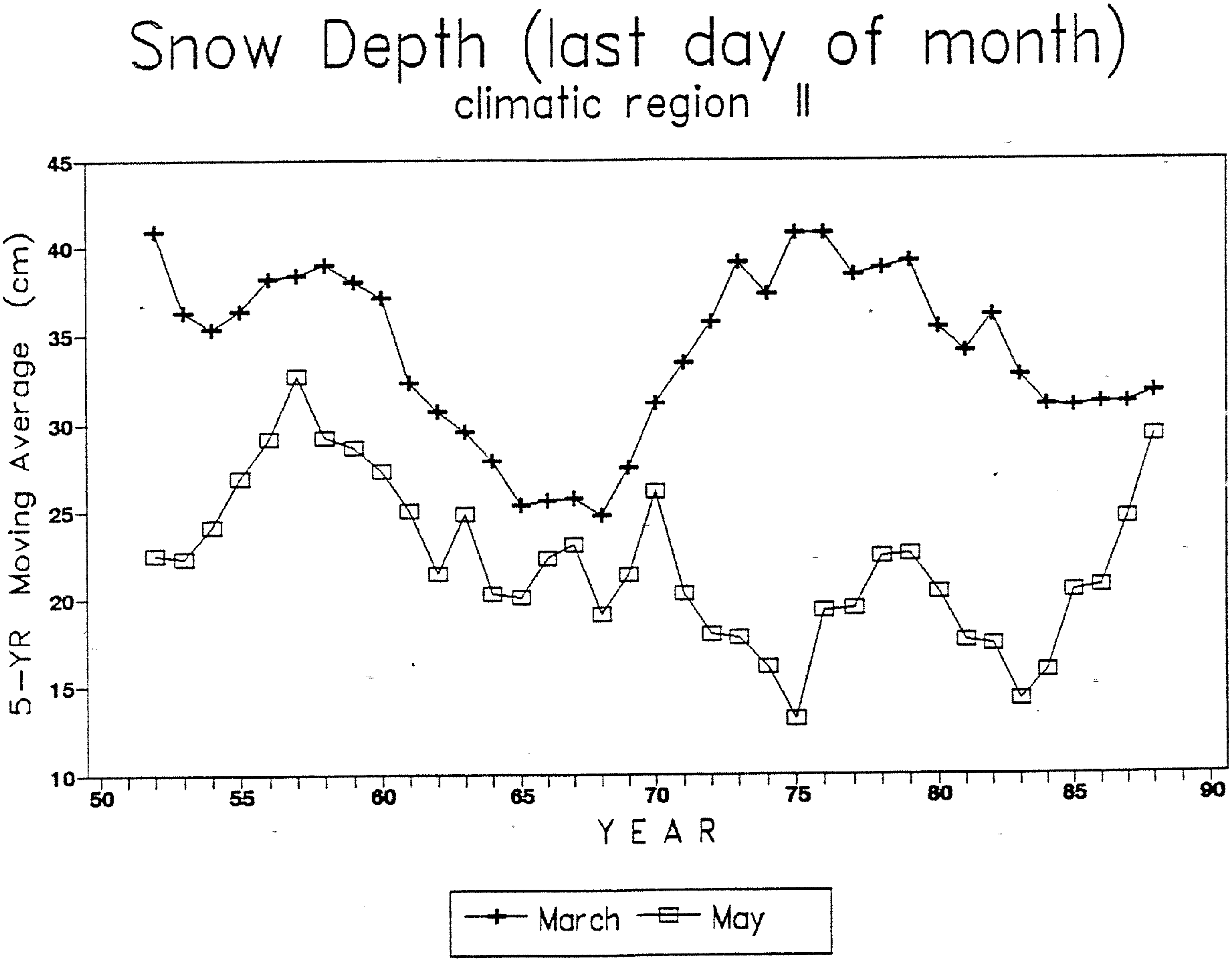

Snow Depth (last day of month)
climatic region II
5-YR Moving Average (cm)
45
40
35
30
25
20
15
10
50
55
60
65
70
75
80
85
90
YEAR
March
May

Figure 8.

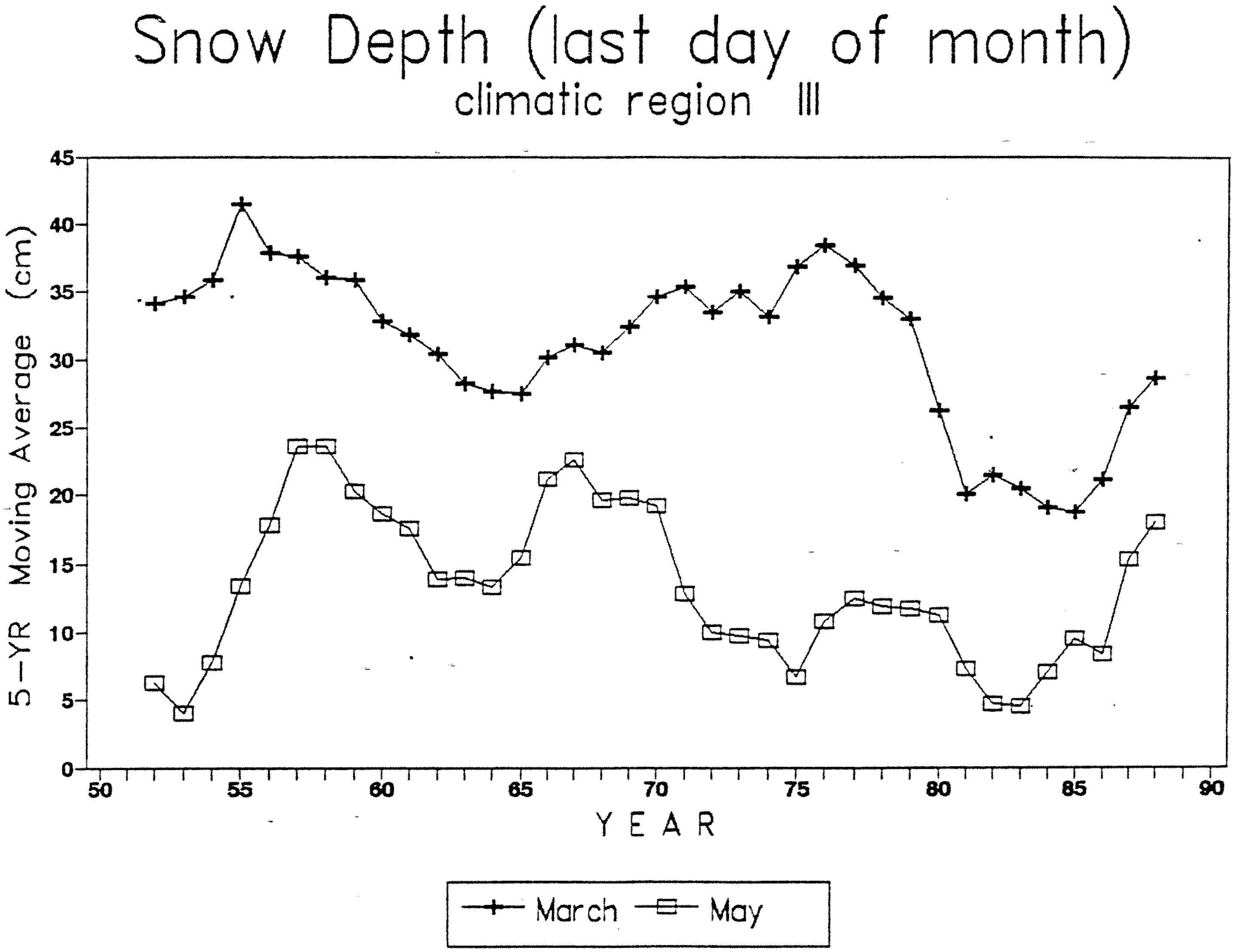

Snow Depth (last day of month)
climatic region III
5-YR Moving Average (cm)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
YEAR
March
May

Figure 9.

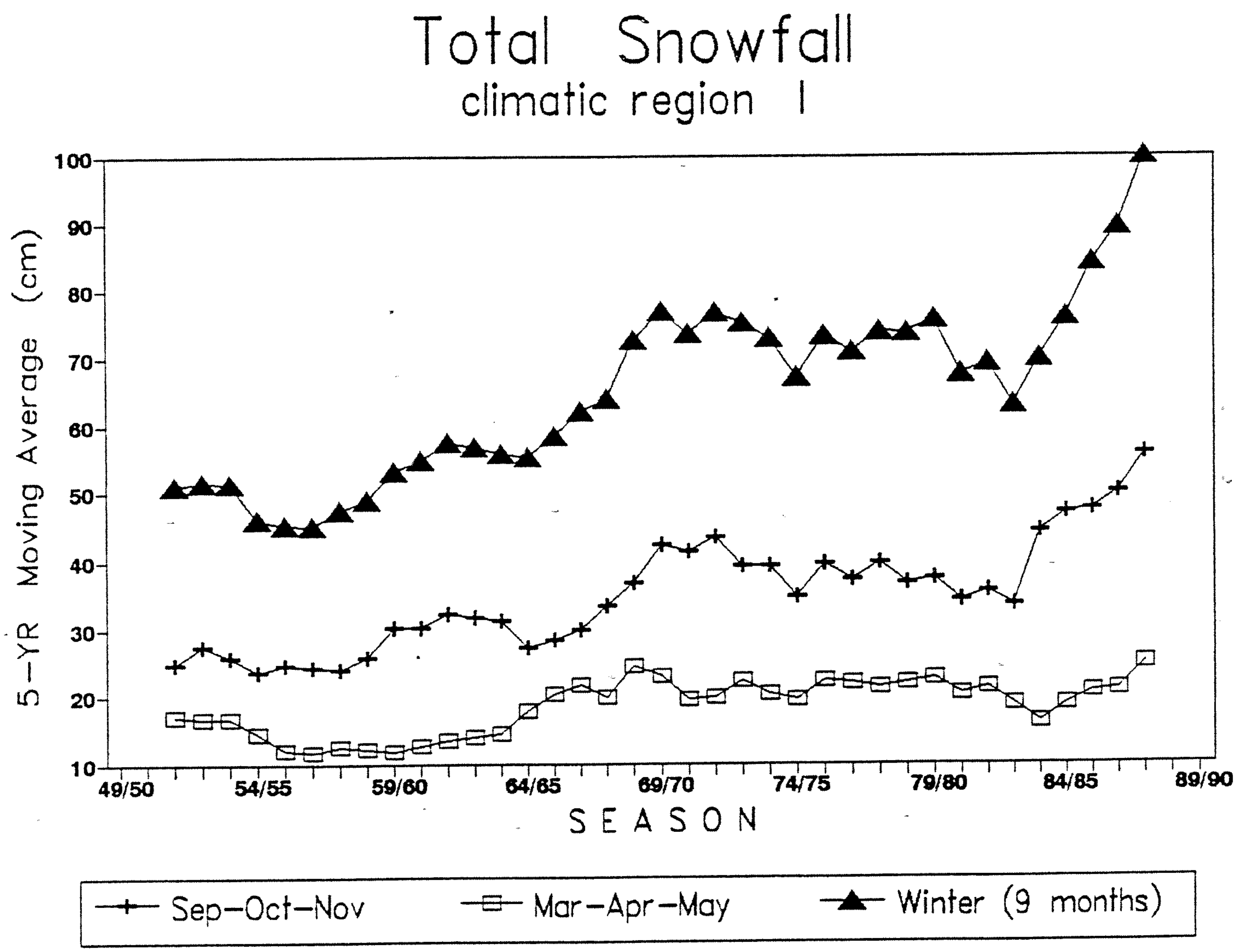
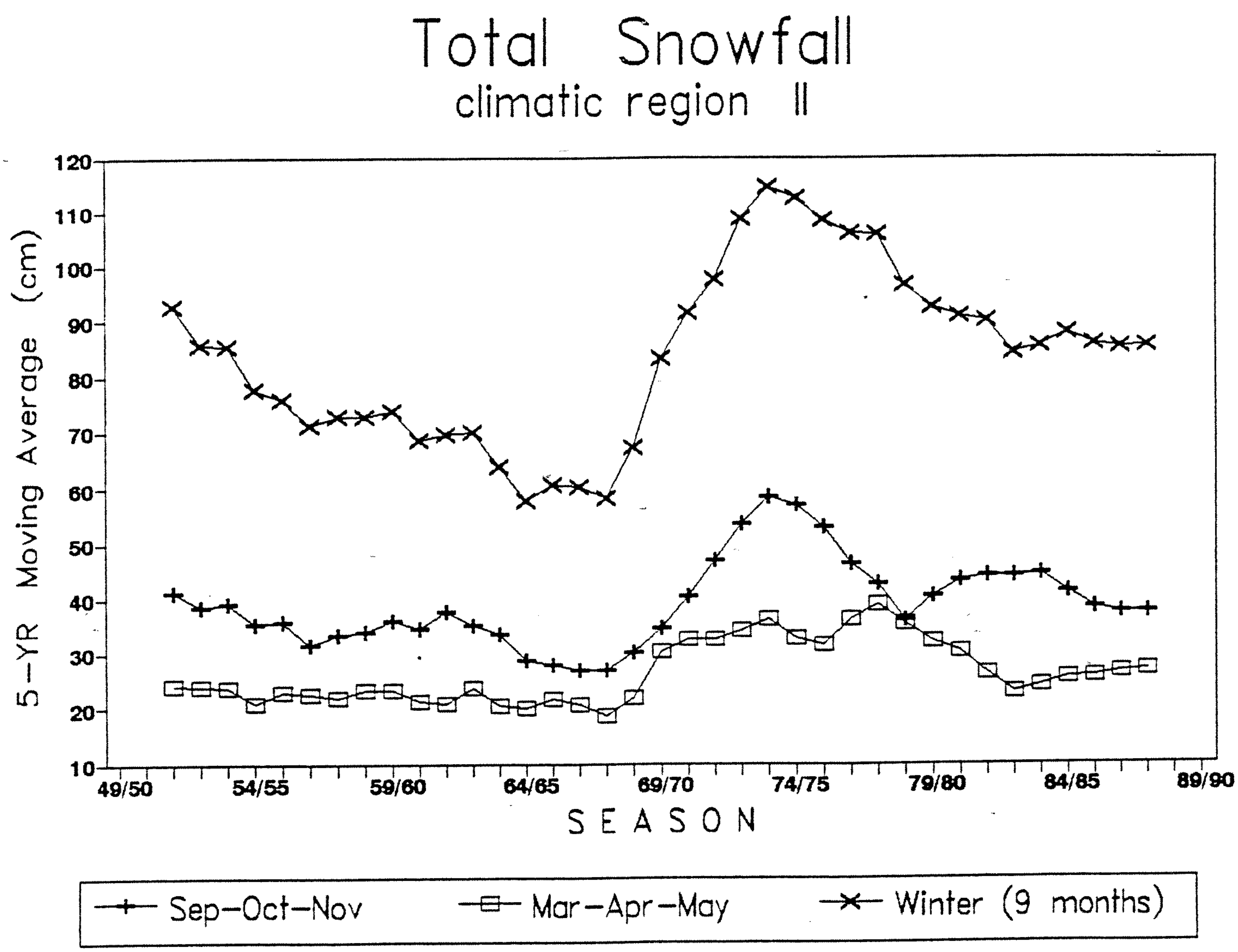
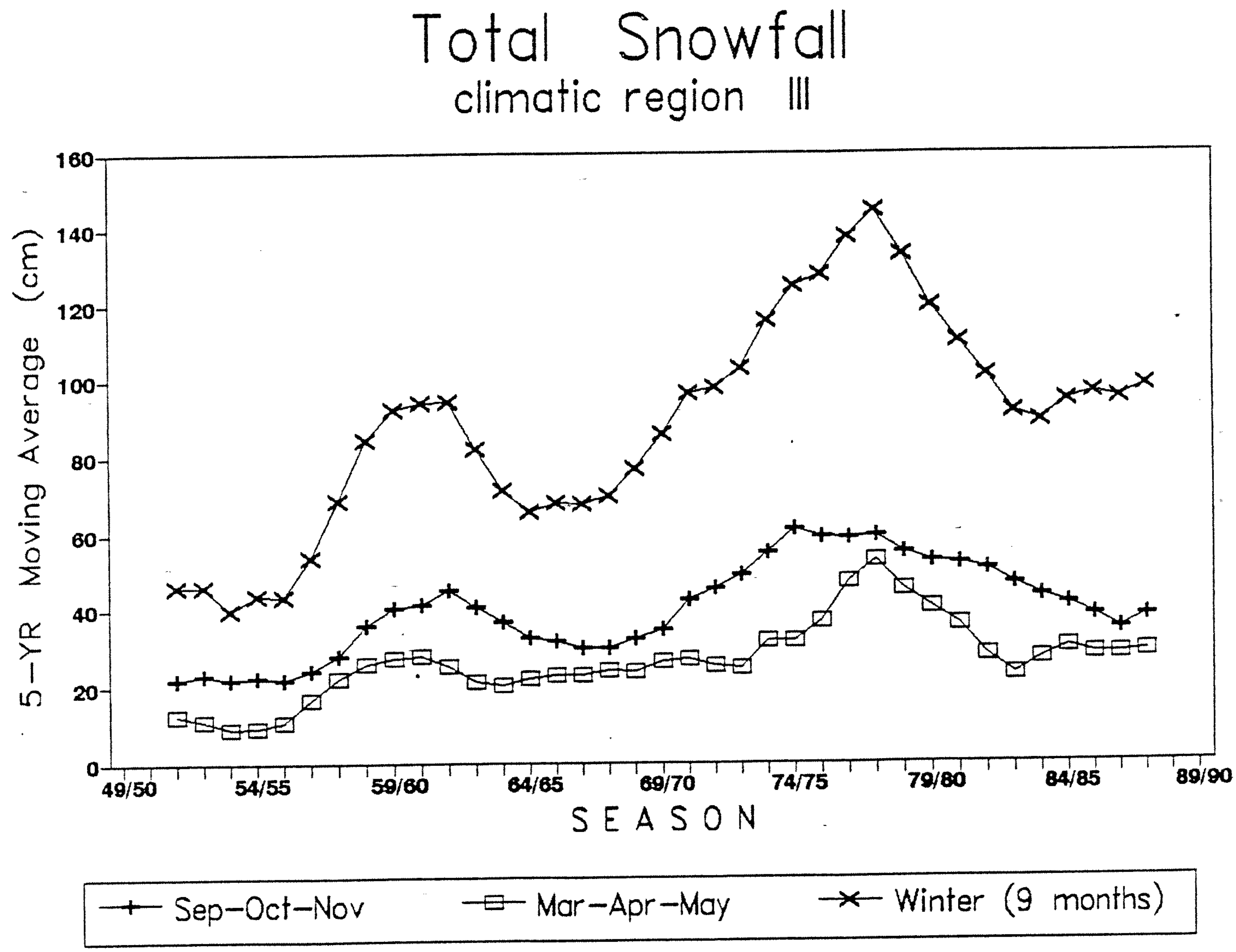

Total Snowfall
climatic region I
5-YR Moving Average (cm)
100
90
80
70
60
50
40
30
20
10
49/50
54/55
59/60
64/65
69/70
74/75
79/80
84/85
89/90
SEASON
Sep-Oct-Nov
Mar-Apr-May
Winter (9 months)

Figure 10.



Total Snowfall
climatic region II
5-YR Moving Average (cm)
120
110
100
90
80
70
60
50
40
30
20
10
49/50
54/55
59/60
64/65
69/70
74/75
79/80
84/85
89/90
SEASON
Sep-Oct-Nov
Mar-Apr-May
Winter (9 months)

Figure 11.


Total Snowfall
climatic region III
5-YR Moving Average (cm)
160
140
120
100
80
60
40
20
0
49/50
54/55
59/60
64/65
69/70
74/75
79/80
84/85
89/90
SEASON
Sep-Oct-Nov
Mar-Apr-May
Winter (9 months)

Total precipitation

The plots of the total summer and winter precipitation are shown in Figures 12 to 14 for the three climatic regions. These plots reveal a significant observation when comparing winter against summer precipitation. The 1970s are characterized by relatively dry summers and wet winters. This observation is remarkable for regions II and III (Figure 13 and 14), and less so for region I (Figure 12).

Degree-days

The smoothed time series plots for thawing and growing degree-days are shown in Figures 15 to 17 for the three climatic regions. The study period is characterized by several fluctuations but no obvious trend is seen in any of the regions. It is noted, however, that the 1950s had above average thawing degree-days in the three regions.

Figure 12.

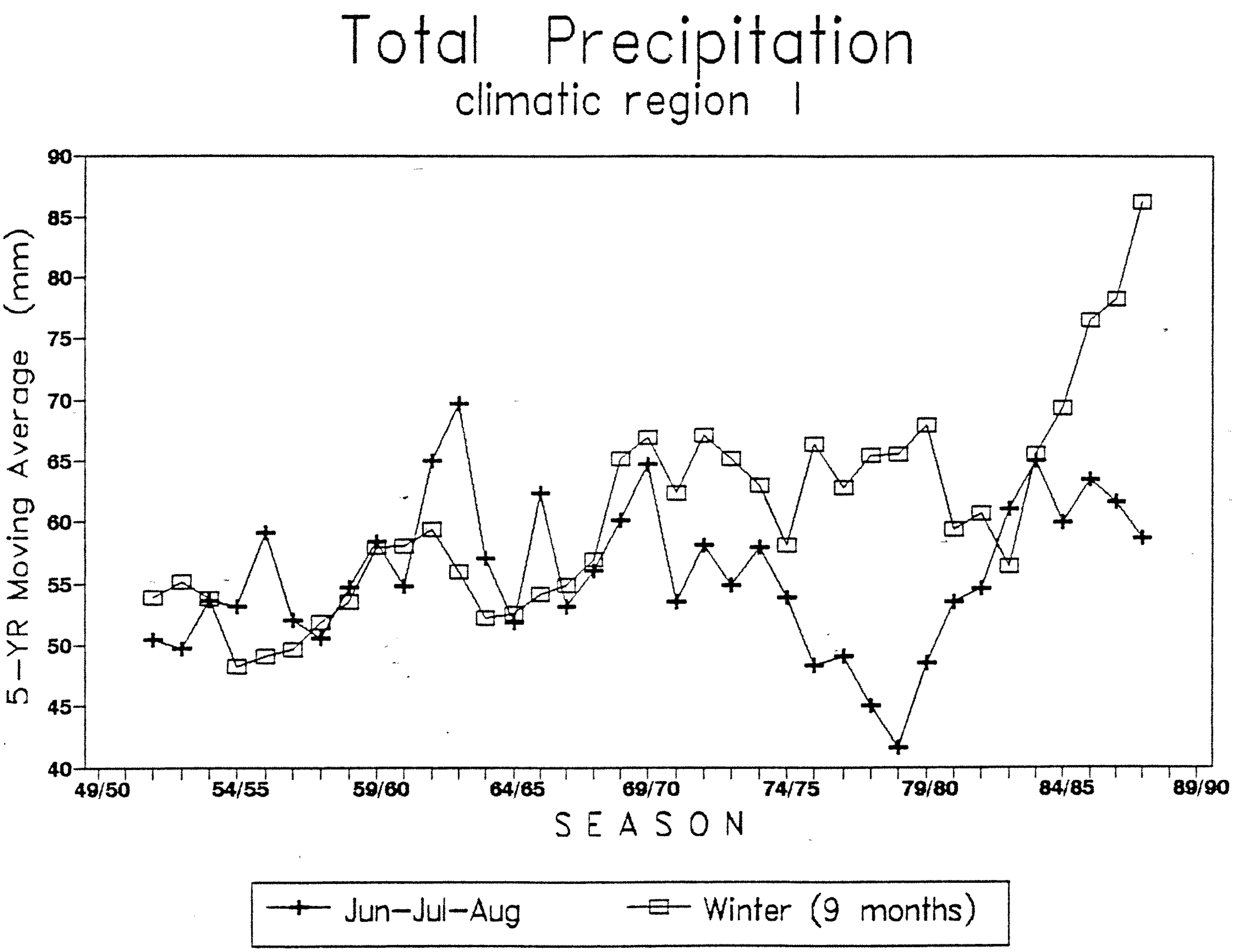

Total Precipitation
climatic region I
5-YR Moving Average (mm)
90
85
80
75
70
65
60
55
50
45
40
49/50
54/55
59/60
64/65
69/70
74/75
79/80
84/85
89/90
SEASON
Jun-Jul-Aug
Winter (9 months)

Figure 13.

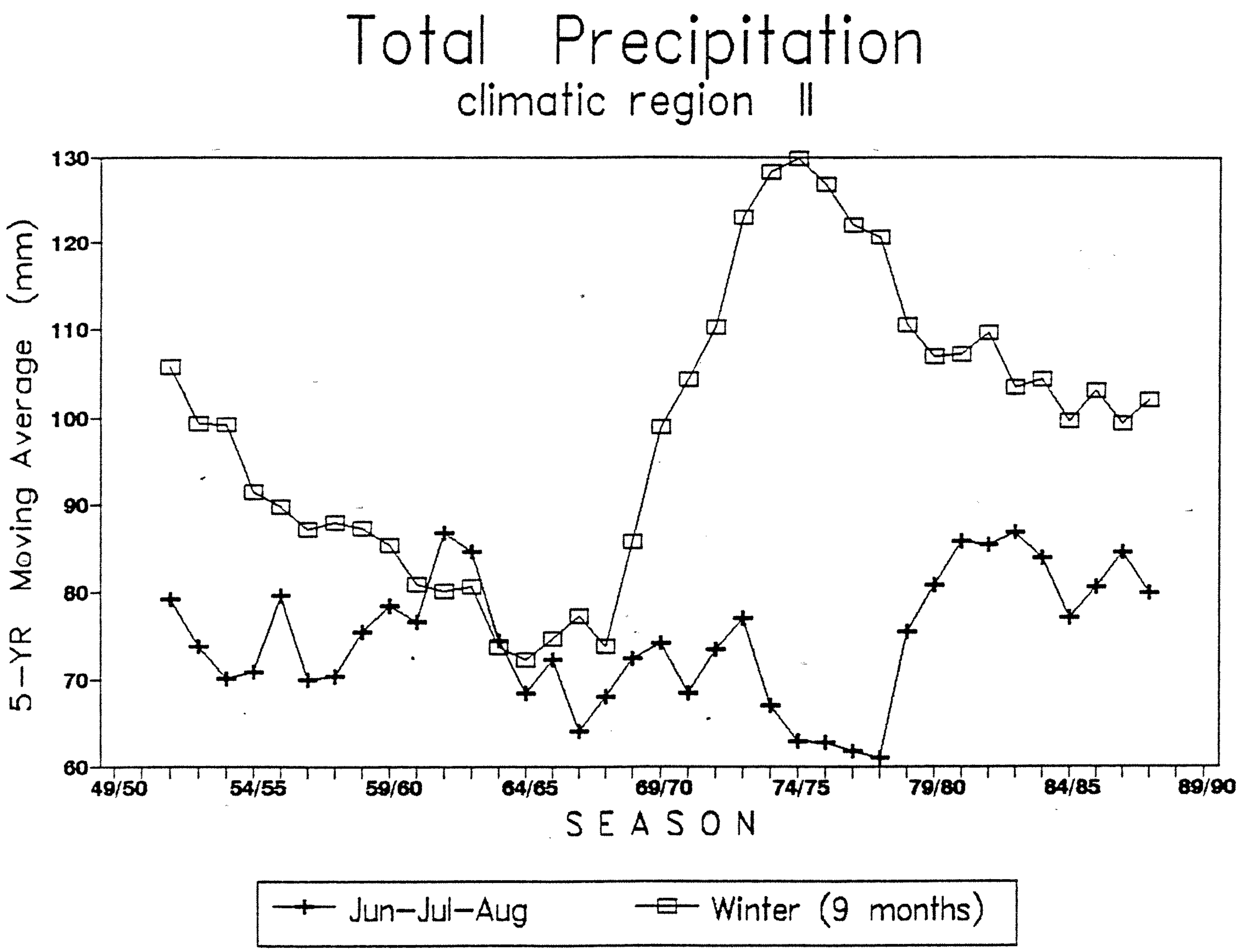
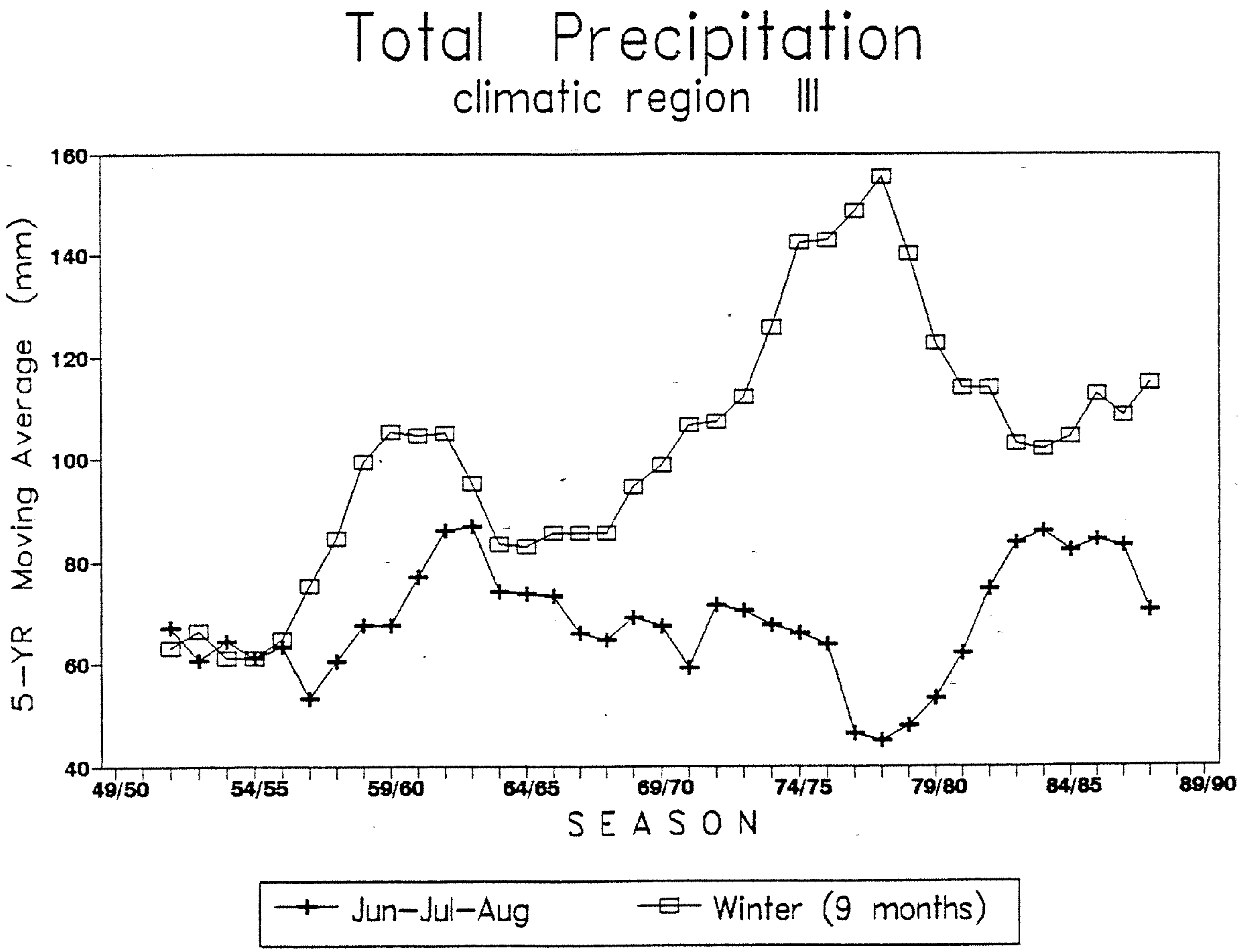

Total Precipitation
climatic region II
5-YR Moving Average (mm)
130
120
110
100
90
80
70
60
49/50
54/55
59/60
64/65
69/70
74/75
79/80
84/85
89/90
SEASON
Jun-Jul-Aug
Winter (9 months)

Figure 14.



Total Precipitation
climatic region III
5-YR Moving Average (mm)
160
140
120
100
80
60
40
49/50
54/55
59/60
64/65
69/70
74/75
79/80
84/85
89/90
SEASON
Jun-Jul-Aug
Winter (9 months)

Figure 15.

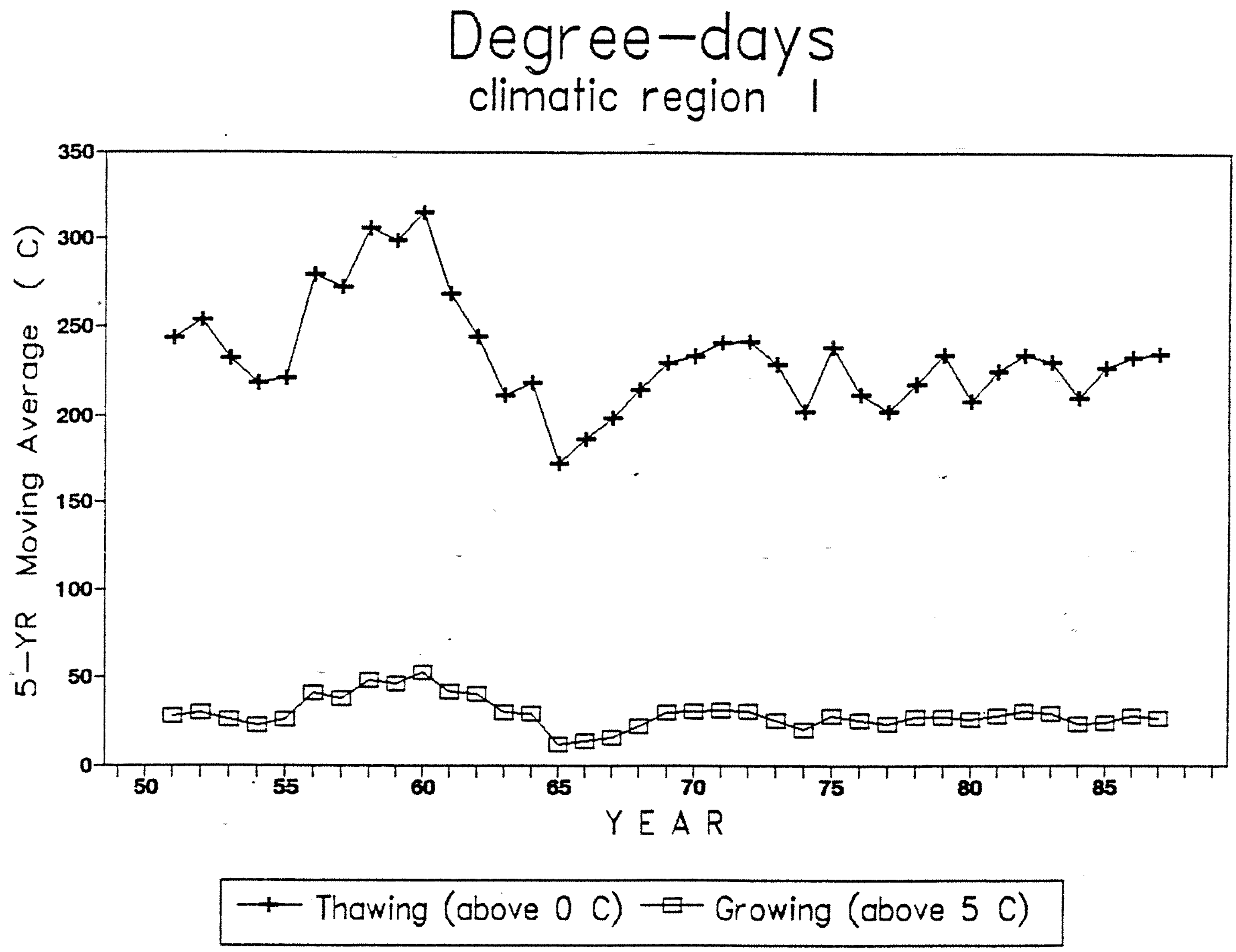

Degree-days
climatic region I
5-YR Moving Average (C)
350
300
250
200
150
100
50
0
50
55
60
65
70
75
80
85
YEAR
Thawing (above 0 C)
Growing (above 5 C)

Figure 16.

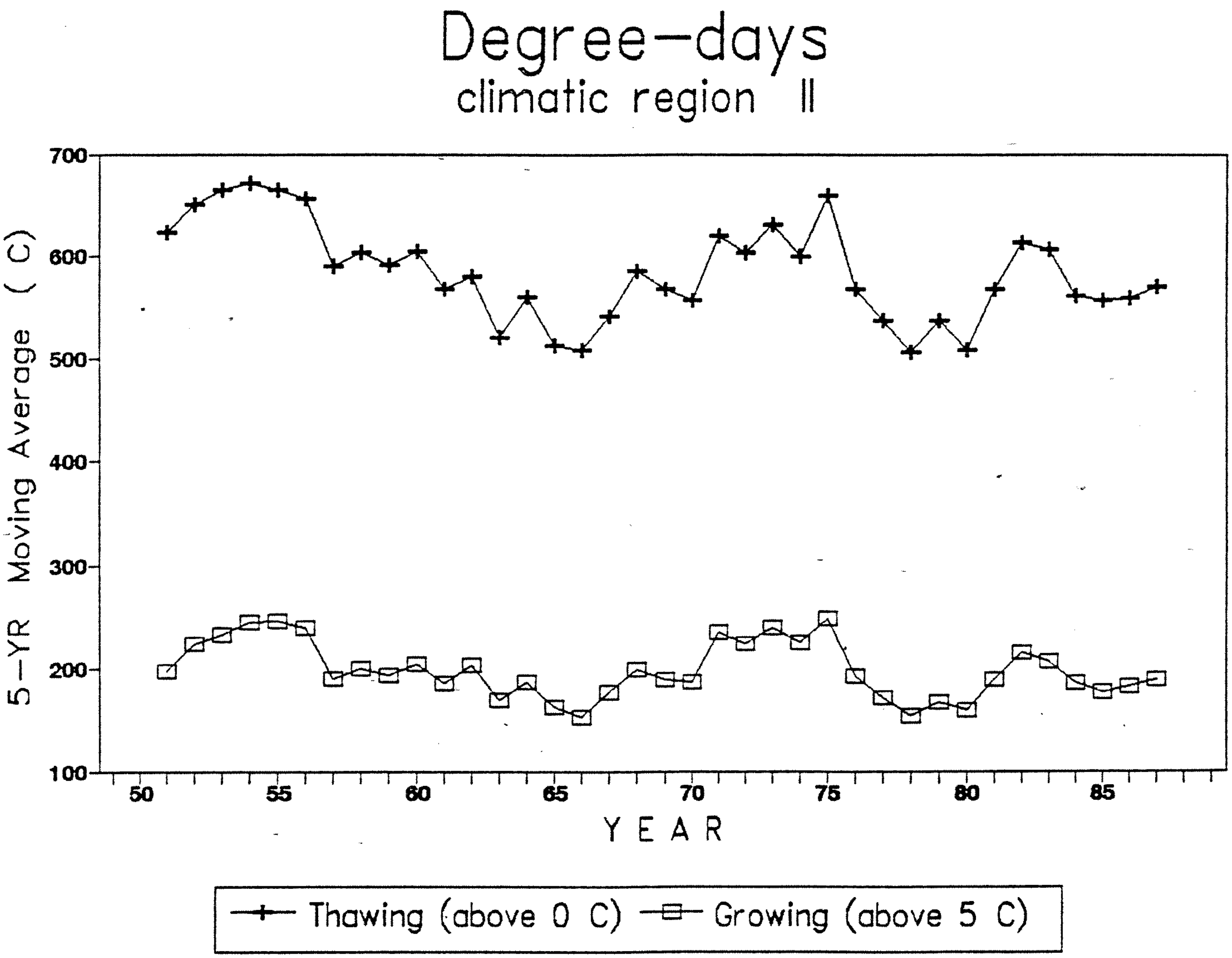
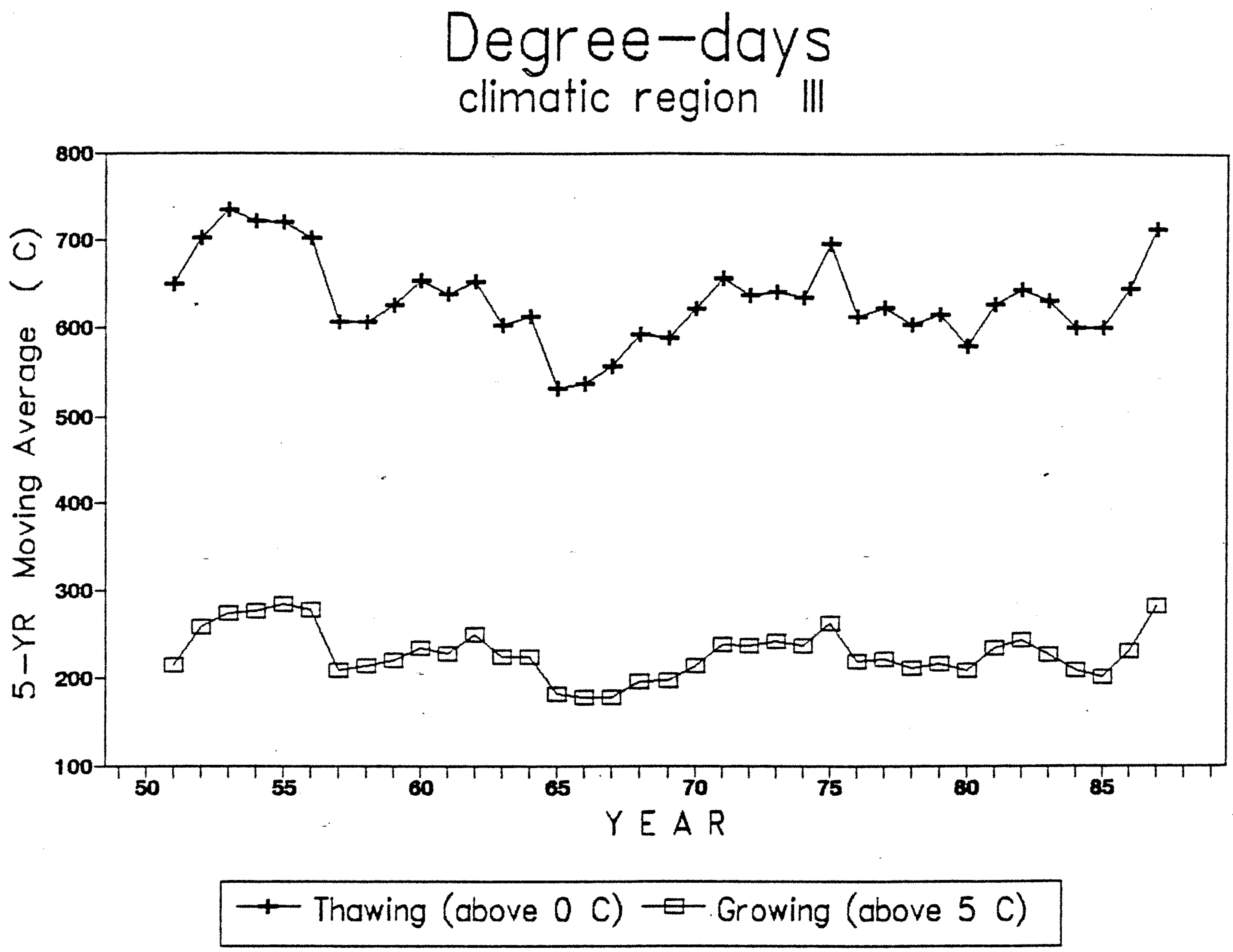

Degree-days
climatic region II
700
600
500
400
300
200
100
5-YR Moving Average (C)
50
55
60
65
70
75
80
85
YEAR
Thawing (above 0 C)
Growing (above 5 C)

Figure 17.


Degree-days
climatic region III
5-YR Moving Average (C)
800
700
600
500
400
300
200
100
50
55
60
65
70
75
80
85
YEAR
Thawing (above 0 C)
Growing (above 5 C)

DISCUSSION

In this study, various meteorological elements from 10 arctic stations have been analyzed to determine unfavourable and favourable winter and summer conditions for caribou, and possibly other wildlife species, in three climatic regions of the Canadian Arctic Islands. It should be emphasized that most arctic stations have coastal locations and this may introduce a bias into the analysis of some or all variables.

The question of bias in the climatic data and the degree of their spatial representativeness has been studied by Jacobs (1989) for Baffin Island (NWT). His study indicates that the data did not support a causal relationship between climatic constraints and the distribution and numbers of muskoxen and caribou. The analysis in the present study is basically qualitative and should be considered with other factors which may influence the population dynamics of caribou and similar wildlife.

This study indicates that the frequency of unfavourable conditions increased during the 1980s for climatic region I, and during the 1970s for regions II and III. Relatively dry summers and wet winters during the 1970s could have seriously restricted the availability of forage. Scattered favourable and unfavourable conditions are also observed in other periods.

The study also suggests that there is a trend for increasing frequency of freezing rain, although this meteorological phenomenon remains relatively rare in the Arctic. Another trend for increasing amounts of snowfall is also seen in regions I and III. However, there is some indication that the depth of snow cover, late in the season, is decreasing during a significant portion of the study period. Foster (1989) also found that for much of the North American arctic tundra the data of snow disappearance has been occurring earlier in the spring since the late 1960s.

These observations could be used with other environmental and biological factors to study possible implications for wildlife. It should be noted, however, that different species may respond differently to unfavourable weather and climate. Conditions severe enough to kill caribou may not cause mortality of muskoxen (Gunn 1990). Thorough investigations of climate impacts on wildlife are needed and would be very useful in climate change studies (Diamond 1990).

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