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Precipitation, discharge and temperature variability in Atlantic Salmon Rivers in Acid Rain Impacted Southern Uplands Area of Nova Scotia

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ABSTRACT

This paper provides analysis of long-term variation in precipitation, air temperature and discharge in the Southern Uplands area of Nova Scotia. Data at the Halifax Airport Meteorological station were used to analyze precipitation and air temperature trends on an annual and seasonal basis. Discharge data were used for two rivers in the study area, namely the LaHave and St. Marys rivers.

On an annual basis, air temperature in the study area varied 5.1 °C to 7.4 °C with a long-term average of 6.1°C. Annual precipitation ranged between 1048 mm and 1931 mm with an overall average of 1445 mm. No trends were observed in the mean annual air temperatures and annual precipitation. Variability in annual precipitation was also reflected in variability of mean annual discharge at the two studied rivers, LaHave and St. Marys River. The mean annual flow at LaHave River ranged between 17.6 m^3/s and 49.6 m^3/s with an overall average of 34.4 m^3/s. The mean annual discharge at St. Marys River ranged between 28.5 m^3/s and 63.9 m^3/s with and overall mean of 43.0 m^3/s. Annually, the variability in both precipitation and discharge were similar as reflected by the coefficient of variation in the order of 20%. No significant trends were detected in the annual discharge at both rivers.

On a seasonal basis, it was observed that the air temperature and precipitation were more variable than annually. On a seasonal basis, significant trends were observed in mean spring air temperatures ($p < 0.005$) and mean summer temperatures ($p < 0.04$). The mean spring air temperatures showed an increase of 0.4 °C per decade, while mean summer air temperature increased by 0.2 °C per decade. No significant trends were observed in mean seasonal precipitation at $p < 0.05$.

Also on a seasonal basis, discharge showed higher variability than air temperatures and precipitation with coefficient of variation between 27% and 58%. No significant trends were detected at LaHave River seasonally and St. Mary River showed a slight increase in mean winter discharge ($p < 0.05$) of 1.5 m^3/s per decade. Highest variability for discharge was observed for annual extreme events such as high and low flows. For instance, minimum annual discharge showed a coefficient of variation of 83% (St. Marys River) and 89 % (LaHave River). No trends were detected in maximum or minimum annual discharge at both studied rivers.

Given the wide range of annual precipitation and discharge, it was expected that annual deposition of acid precipitation could also vary significantly. Also studies have shown that pH can be highly related to stream discharge and therefore any variability in discharge, either annually or seasonally, can affect annual or seasonal mean pH values.

RÉSUMÉ

Cet article présente une analyse des variations à long terme des précipitations, de la température de l’air et du débit dans la région des hautes terres en Nouvelle-Écosse. On a utilisé les données de la station météorologique de l’aéroport de Halifax pour analyser les tendances des précipitations et de la température de l’air sur une base annuelle et saisonnière, et les données de débit pour deux rivières, soit la rivière LaHave et la rivière St. Marys.

Sur une base annuelle, la température de l’air varie de 5,1 °C à 7,4 °C, avec une moyenne à long terme de 6,1 °C. Les précipitations annuelles varient de 1048 mm à 1931 mm, avec une moyenne de 1445 mm. Aucune tendance n’a été observée dans les moyennes annuelles de la température de l’air et des précipitations. La variabilité des précipitations annuelles se retrouvait dans celle du débit moyen annuel des deux rivières étudiées, LaHave et St. Marys. Le débit moyen annuel de la rivière LaHave variait de 17,6 m3/s à 49,6 m3/s, avec une moyenne globale de 34,4 m3/s. D’autre part, le débit moyen annuel de la rivière St. Marys variait de 28,5 m3/s à 63,9 m3/s, avec une moyenne globale de 42,0 m3/s. Sur une base annuelle, la variabilité des précipitations était du même ordre de grandeur que celle du débit, ce que montre un coefficient de variation d’environ 20 %. Aucune tendance significative n’a été observée dans le débit annuel des deux rivières.

Il a été observé que la variabilité saisonnière de la température de l’air et des précipitations était plus grande que leur variabilité interannuelle. Sur une base saisonnière, on a noté une tendance significative dans la température moyenne de l’air au printemps ($p < 0,005$) et en été ($p < 0,04$). La température moyenne printanière de l’air a montré une hausse de 0,4 °C par décennie, et celle de l’été une hausse de 0,2 °C par décennie. Aucune tendance significative n’a été observée dans les précipitations saisonnières moyennes à $p < 0,05$.

Sur une base saisonnière, le débit a également montré une plus grande variabilité que la température de l’air et les précipitations, avec un coefficient de variation compris entre 27 % et 58 %. On n’a noté aucune tendance significative saisonnière du débit de la rivière LaHave, mais une légère augmentation du débit hivernal moyen de la rivière St. Marys, de 1,5 m3/s par décennie ($p < 0,05$). La variabilité maximale du débit a été observée pour des événements annuels extrêmes de débits maximums et de débits minimums. Par exemple, les débits minimums extrêmes ont présenté un coefficient de variation de 83% (St. Marys) et de 89% (LaHave). On n’a noté aucune tendance des débits minimums et maximums des deux rivières.

Étant donné l’ampleur de la plage des précipitations et du débit annuels, on s’attendait à ce que le dépôt acide annuel varie également de façon significative. De plus, des études ont montré que le pH peut être fortement lié au débit et que, par conséquent, toute variabilité du débit (annuel et saisonnier) peut influer considérablement sur ses valeurs annuelles ou saisonnières moyennes.

INTRODUCTION

Hydrological conditions can be important in the management of fisheries and aquatic resources. Streamflow variability affect stream biota at different life stages and also during different seasons of the year. Salmonids can be affected by stream discharge such as high flows (Elwood and Waters 1969; Erman *et al.* 1988) or during low flows, which is often associated with high river water temperatures (Cunjak *et al.* 1993; Edwards *et al.* 1979). Changes in water quality as a function of river discharge has been observed (Cluis et al. 1988; Feller and Kimmins 1979). Studies have shown an inverse relation between pH and discharge (Caissie et al. 1996; St-Hiliaire et al. 1998). Such studies show that it is important to consider flow conditions when studying pH in rivers. Also, air temperature can be an important parameter as it influences the timing of the snowmelt and ultimately influence pH values. In order to increase our understanding of environmental conditions of particular Atlantic salmon rivers, for the purpose of assessing potential impact of acid rain, we need to study the stream hydrology and associated extreme events or trends.

The objective of the present study is to analyze hydrological data for 2 Atlantic salmon rivers within the acid impact rivers for use in aquatic resource management. Meteorological data will also be analyzed at one station representative of the study area. The specific objectives are: a) to analyze changes in precipitation and air temperatures on an annual and seasonal basis, b) to analyze changes in streamflow conditions for 2 rivers, annually and on a seasonal basis c) to study long-term trend of air temperature, precipitation and discharge using the 10-year moving average, and d) to carry out statistical analyses to determine potential linear trends in air temperature, precipitation and discharge both annually and on a seasonal basis.

METHODS

Historical data on air temperature and precipitation were obtained from Environment Canada to study the changes in these parameters. Mean annual air temperatures and precipitation were calculated as well as mean seasonal values. Seasons were divided in four and included winter (Jan. to Mar.), spring (Apr. and May), summer (Jun. to Sep.) and autumn (Oct. to Dec.). Streamflow data were analyzed using hydrometric data from gauged rivers in the study region. These data were obtained from the Environment Canada HYDAT database. Mean annual discharge was analyzed as well as mean seasonal discharge. Extreme hydrological conditions were studied by analyzing maximum and minimum discharge both annually and on a seasonal basis.

The 10-year moving average was calculated for each time series (air temperature, precipitation and discharge) to observe long-term trends and changes. A statistical analysis was carried out for each time series using SAS to observe any linear trends over time. Trends during the whole time series were analyzed, and for a few cases recent trends (last 15 years) were also investigated.

STUDY SITES

The study region comprises the Southern Uplands Area of Nova Scotia, and data on air temperature and precipitation from the Halifax Airport meteorological station were used. Monthly data were used to calculate annual and seasonal values. Also, data from two river systems in the study area were used in the hydrological analysis, namely the LaHave River (station 01EF001) and St. Marys River (station 01EO001). The two rivers were selected based on their geographical location, which represents well the study area. Also these rivers have long-term data, which is valuable in trend analysis. The study sites are shown in Figure 1.

The drainage basin of the studied rivers are of similar size at 1250 km^2 for LaHave River and 1350 km^2 for St. Marys Rivers (Table 1). These rivers have long series of discharge data dating from 1916 to 1998, over 80 years of record. The mean annual flow (MAF), which is a function of drainage area, varies between 34.4 m^3/s for LaHave River and 43.0 m^3/s for St. Marys River. To compare discharge between basins of different sizes, the mean annual runoff was used. This represents the mean annual flow (MAF) expressed in unit discharge in mm (discharge per drainage area). The runoff characteristics depend on parameters such as the amount of rainfall, soil type, and others. LaHave River showed a runoff of 870 mm and St. Mary River showed 1007 mm. The mean annual precipitation at the two rivers was very similar with a value of 1420 mm at LaHave River and 1350 mm for St. Marys River.

RESULTS

Mean annual air temperature at the Halifax Airport (1961-1998) varied between 5.1 °C in 1972 to 7.4 °C in 1998 (Figure 2a; Table 2). The overall mean annual air temperature was calculated at 6.1 °C (std = 0.6 °C). The long-term variations as calculated by the 10-year moving average showed that the period ending in 1984 experienced the highest decadal temperature at 6.4 °C. Precipitation data showed that annual precipitation varied between 1048 mm in 1965 to 1931 mm in 1972 with an overall mean annual precipitation of 1446 mm (std = 219 mm; Figure 2b). The long-term mean precipitation as calculated by the 10-year moving average peaked at the period ending in 1980 at 1562 mm and a decrease has been observed since. The 10-year average ending in 1998 was calculated at 1340 mm, which was the lowest in the time series. No significant linear trends were detected in the mean annual air temperatures and precipitation using the whole time series and during the last 15 years.

On a seasonal basis, mean winter temperatures varied between –6.6 °C in 1993 to –2.0 °C in 1998 at Halifax Airport with an overall mean winter temperature of –4.6 °C (std = 1.1 °C; Figure 3a; Table 2). Recent decadal temperatures, as calculated by the 10-year moving average, have been colder with values close to –5.0 °C compared to those of the period ending in 1984 at –4.1 °C. It was also noted that the 1990s showed high variability in mean winter temperatures. Spring temperatures varied between 3.8 °C in 1967 to 8.9 °C in 1998 (Figure 3b), with a mean spring temperature of 6.5 °C (std = 1.0 °C). Long-term temperatures have been on the increase from 1970s to early 1990s with a slight decrease leading to the period ending in 1998. The mean spring air temperature showed a significant increase ($p < 0.005$) of 0.4 °C per decade. Summer temperatures have ranged from 14.8 °C (1986) to 17.4 °C (1990) with an overall mean summer value of 16.3 °C (std = 0.6 °C; Figure 3c). Long-term mean summer temperature as calculated by the 10-year moving average showed that recent decadal temperatures have been the highest in the time series at 16.7 °C. Mean summer temperatures also showed a significant increase ($p < 0.04$) with an increase in temperature of 0.2 °C per decade. Autumn temperatures varied between 0.1 °C in 1989 to 4.8 °C measured in 1961. The mean autumn temperature was calculated at 2.9 °C (std = 1.1 °C); decadal temperatures remained close to average temperatures (Figure 3d). Variability in mean annual and seasonal air temperatures was calculated using the standard deviation (Table 2). Similar variability was observed throughout the seasons with a standard deviation of 1.0 °C and 1.1 °C, except for summer which showed slightly lower variability (std = 0.6 °C).

Precipitation on a seasonal basis showed mean winter values ranging from 230 mm (1970) to 579 mm (1972) with an overall mean winter precipitation of 388 mm (std = 84 mm; Figure 4a; Table 2). The 10-year moving average has shown a slight decrease in 1990s from a peak value of 437 mm for the period ending in 1980. Mean spring precipitation varied between 93 mm (1992) and 373 mm (1990) with an average of 226 (std = 63 mm; Figure 4b). The long-term mean spring precipitation reached a peak during the period ending in 1990 with a slight decrease thereafter. Mean summer precipitation varied between 235 mm (1997) and 571 mm (1977) with a mean value of 392 mm (std = 104 mm; Figure 4c). The 10-year moving average showed a slight decrease in the 1990s. Autumn precipitation varied between 224 mm (1984) and 640 (1972) with an average autumn precipitation of 439 mm (Figure 4d). Long-term autumn precipitation as calculated by the 10-year moving average showed a decrease in 1980s and a slight increase in the 1990s. Trend analysis showed that the mean autumn precipitation showed a slight decrease over time ($p < 0.07$) of 30 mm per decade. The annual variability in precipitation as measured using the coefficient of variation showed that the lowest variability was observed annually at 15% (Table 2). On a seasonal basis the variability was in the range of 22% to 28%.

Discharges were calculated for two rivers in the Southern Uplands Area of Nova Scotia, namely for the LaHave and St. Marys Rivers, which are two long-term data stations in the area (1916 to 1998). Mean annual discharge varied significantly at these two stations (cms = m^3/s; Figure 5). LaHave River showed a mean annual discharge ranging from 17.6 m^3/s (1965) to 49.8 m^3/s (1959) with an average value of 34.4 m^3/s (std = 6.9 m^3/s; Figure 5a; Table 3). Long-term values as calculated by the 10-year moving average, showed an increase from 1920s to the 1960s with the highest decadal discharge observed in period ending in 1979 at 39.2 m^3/s. St. Marys River mean annual discharge varied between 28.5 m^3/s (1960) and 63.9 m^3/s (1972) with an overall average annual flow of 43.0 m^3/s (std = 7.3 m^3/s; Figure 5b). The 10-year moving average also increased from the 1920s to late 1970s with the highest decadal discharge observed in period ending in 1980 at 47.6 m^3/s. No significant trends were detected in the mean annual discharge at both LaHave and St. Marys River.

On a seasonal basis, LaHave River discharge showed a marked variability in winter (Figure 6a; Table 3). Winter discharge ranged from 18.2 m^3/s (1940) to 87.3 m^3/s (1979) with a mean winter flow of 46.5 m^3/s (std = 14.5 m^3/s; Figure 6a). The long-term mean winter flow, as calculated by the 10-year moving average, also showed a marked variability with decadal winter flow reaching a peak in the period ending in late 1950s. Mean spring flows varied between 28.4 m^3/s (1995) and 116 m^3/s (1923) with a mean value of 55.9 m^3/s (std = 17.1 m^3/s; Figure 6b). Long-term spring flows were close to average value. Mean summer flows were highly variable with values ranging from 1.91 m^3/s (1921) to 30.5 m^3/s (1973; Figure 6c). The mean summer flow was calculated at 12.4 m^3/s

(std = 7.4 m^3/s). The long-term mean summer discharge remained between 10 m^3/s and 15 m^3/s as shown by the 10-year moving average. Mean autumn discharge ranged from 11.1 m^3/s (1965) to 82.0 m^3/s (1959), with an overall mean value of 37.4 m^3/s (std = 16.4 m^3/s; Figure 6c; Table 3). The 10-year moving average increased slightly from 1930s to the period ending in 1981 with a 10-year mean of 48.2 m^3/s.

On a seasonal basis, St. Marys River discharge also showed a marked variability in winter mean flows (Figure 7a). Mean winter discharge ranged from 15.9 m^3/s (1970) to 101 m^3/s (1953) with an overall average winter flow of 49.4 m^3/s (std = 16.2 m^3/s; Figure 7a; Table 3). The long-term mean winter flow, as calculated by the 10-year moving average, also showed a marked variability with decadal winter flow reaching a peak in the period ending in 1956. Mean winter flows at St. Marys River, although highly variable, showed a significant increase ($p < 0.05$) of 1.5 m^3/s per decade. Mean spring flows varied between 38.6 m^3/s (1966) and 132 m^3/s (1956) with an average value of 73.8 m^3/s (std = 19.9 m^3/s; Figure 7b). Long-term mean spring flows were close to average value with a slight decrease in the past 30 years. Summer flows were highly variable with values ranging from 3.19 m^3/s (1921) to 39.9 m^3/s (1970; Figure 7c; Table 3). The mean summer flow was calculated at 17.5 m^3/s (std = 9.6 m^3/s). The long-term mean summer discharge expressed by the 10-year moving average varied between 12 m^3/s and 22 m^3/s. Autumn discharge ranged from 18.9 m^3/s (1984) to 96.7 m^3/s (1990), with an overall mean of 50.1 m^3/s (std = 17.2 m^3/s; Figure 7c; Table 3). The 10-year moving average increased slightly from 1930s to the period ending in 1976 with a 10-year mean of 63.1 m^3/s.

Peak discharge (maximum) and low flows (minimum) were also considered on an annual basis at the two river sites. Peak flows at St. Marys varied between 190 m^3/s (1965) and 974 m^3/s (1971) with a mean annual flood of 410 m^3/s (std = 142 m^3/s; Figure 8a; Table 3). Long-term mean peak flows at St. Marys remained close to 400 m^3/s as shown by the 10-year moving average. Peak flows at LaHave River varied in the range of 94.3 m^3/s (1966) to 1080 m^3/s (1956; Figure 8b). The mean annual flood was calculated at 228 m^3/s (std = 123 m^3/s). The long-term mean annual flood at LaHave River remained close to 200 m^3/s except for the period ending from 1956 to 1966, which showed higher values as influenced by the extreme flood of 1956. No signficant trends were detected in annual maximum discharge at both rivers.

Low flows at St. Marys River varied between 0.15 m^3/s (1942) and 7.65 m^3/s (1964), with a mean low flow of 2.06 m^3/s (std = 1.7 m^3/s; Figure 8c; Table 3). The 10-year moving average for low flow (daily minimum per year) showed two periods of low values, in the period ending in 1953 with a decadal value of 1.19 m^3/s and in 1998 at 1.49 m^3/s. Low flows at LaHave River ranged from 0.125 m^3/s (1960) to 9.4 m^3/s (1927), with a mean annual low flow of 2.08 m^3/s (std = 1.85 m^3/s; Figure 8d). The long-term minimum annual low flow showed a decrease over the year at LaHave River with the lowest decadal value in 1998 at 1.04 m^3/s. No signficant trends were detected in annual minimum discharge at both rivers.

Similar to the annual maximum and minimum discharges, a statistical analysis was carried out on peak flows and low flows on a seasonal basis. No significant trends were observed on a seasonal basis for such extreme hydrological conditions for both LaHave and St. Marys Rivers.

Variability in the mean annual and seasonal flows was calculated using the coefficient of variation (Cv; Table 3). The lowest variability was observed for the mean annual discharge with a coefficient of variation of 20% for LaHave River and 17% for St. Marys River. On a seasonal basis the most variability in mean seasonal discharge was observed in summer for both rivers at 58% (LaHave River) and 55% (St. Marys River). Other seasons showed similar variability with value in the range of 27% to 34%, except for mean autumn discharge for LaHave River, which showed slightly higher variability at 44%. The variability was higher for maximum annual discharge with coefficient of variation of 54% for LaHave River and 35% for St. Marys River. The most variability was calculated for minimum annual discharge with coefficient of variation of 89% (LaHave River) and 83% (St. Marys River; Table 3).

DISCUSSION AND CONCLUSIONS

The hydrological conditions in the Southern Uplands Area of Nova Scotia showed a relative high degree of variability in most studies parameters, especially precipitation and discharge. Significant trends were observed in both mean spring air temperatures ($p < 0.005$) and mean summer air temperatures ($p < 0.04$) at the Halifax Airport meteorological station (1961-1998). Both were increases, and the spring increase in temperatures was calculated at 0.4 °C per decade while the increase in summer was calculated at 0.2 °C per decade. Air temperature is an important factor in determining the timing of the spring high flow as well as many biological factors. Such significant change in air temperature could affect the period of low pH values in the spring.

Relatively high variability was observed in precipitation with Cv greater than 20% (Table 2). On an annual basis, precipitation can vary between 1050 mm to 1930 mm. The precipitation can be reflective of the acid deposition in a study area. Such a wide range of annual precipitation, which can deviate as much as 36% from the mean, can significant influence the range of acid deposition. Variability of precipitation within season was similar with a Cv of between 22% and 28%. No significant trends ($p < 0.05$) were calculated in the mean annual and seasonal precipitation at Halifax.

Two long-term data (1916 to 1998) stations in the Southern Uplands Area of Nova Scotia were used to study changes in river discharge. The rivers were LaHave River and St. Marys Rivers. Mean annual discharge showed no significant trend over the years, although the river discharge can vary significantly from year to year. Mean annual discharge ranged from 17.6 m^3/s to 49.8 m^3/s for LaHave River with a mean value of 34.4 m^3/s. Mean annual discharge ranged from 28.5 m^3/s to 63.9 m^3/s at St. Marys River with a mean value of 43.0 m^3/s. Studies have shown significant relations between pH and discharge (Caissie et al. 1996; Feller and Kimmins 1979). Such studies have shown that discharge can explain from 37% to 76% of the variability in pH for rivers in British Columbia and New Brunswick. Such inverse relation between pH and discharge means that years with higher mean discharge will ultimately result in lower mean pH. Variability in discharge is therefore important when studying variability in pH, especially if the mean annual discharge can vary between –50% and +50% of the mean annual flow, as was the case in this study.

Depending on the origin of future storm events in the Southern Uplands Area of Nova Scotia (and resulting deposition), increase in spring air temperatures, could potentially change snowmelt runoff processes. The increase in summer temperatures could add stress to fish, which are already subject to stress due acidification.

In conclusion, pH can be influence by many environmental parameters such as air temperature, discharge, and the amount of precipitation (i.e. amount of acid deposition). It is therefore important to understand the variability in such parameters. Also, results showed in the present study that seasonal pH would be expected to be more variable than the mean annual values based on seasonal variability in both precipitation and discharge. Annually, precipitation and discharge showed similar variability. Discharge showed higher variability seasonally than annually with Cv ranging from 30% to 58% compared to value of below 20% on an annual basis. The summer would show the highest variability in mean pH due to the highest observed variability in mean summer discharge.

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Table 1. Hydrologic characteristics of analyzed Atlantic salmon rivers in Nova Scotia.

Parameters	**LaHave River**	**St. Marys River**
Area[1]	1250	1350
N (years)	83	83
MAF (m^3/s)	34.4	43.0
Runoff (mm)	870	1007
Cv (%)	59	54
Precipitation (mm)	1420	1350

[1] Area = Drainage area in km^2; N = Number of years of data; MAF = Mean Annual Flow in m^3/s; Runoff = Unit discharge (discharge per unit of area) in mm; Cv = coefficient of variation of monthly flows.

Table 2. Annual and seasonal variation in air temperature (°C) and precipitation (mm) at Halifax Airport Meteorological station (1961 to 1998).

Period	**Min.**	**Year**	**Max.**	**Year**	**Mean**	**Std**	**Cv (%)**
			Air temperatures (°C)				
Annual	5.1 °C	1972	7.4 °C	1998	6.1 °C	0.6 °C	
Winter	-6.6	1993	-2.0	1998	-4.6	1.1	
Spring	3.8	1967	8.9	1998	6.5	1.0	
Summer	14.8	1986	17.4	1990	16.3	0.6	
Autumn	0.1	1989	4.8	1961	2.9	1.1	
			Precipitation (mm)				
Annual	1048 mm	1965	1931 mm	1972	1446 mm	219 mm	15 %
Winter	230	1970	579	1972	388	84	22
Spring	93	1992	373	1990	226	63	28
Summer	235	1997	571	1977	392	104	27
Autumn	224	1984	640	1972	439	114	26

Table 3. Annual and seasonal variation in discharge (m^3/s) for two selected rivers (LaHave and St. Marys River) in the Southern Uplands of Nova Scotia.

Period	Min.	Year	Max.	Year	Mean	Std	Cv (%)
			LaHave River (NS)				
Mean annual	17.6 m^3/s	1965	49.8 m^3/s	1959	34.4 m^3/s	6.9 m^3/s	20 %
Mean winter	18.2	1940	87.3	1979	46.5	14.5	31
Mean spring	28.4	1995	116	1923	55.9	17.1	31
Mean summer	1.91	1921	30.5	1973	12.4	7.4	58
Mean autumn	11.1	1965	82.0	1959	37.4	16.4	44
Max. annual	94.3	1966	1080	1956	228	123	54
Min. annual	0.13	1960	9.4	1927	2.08	1.85	89
			St. Marys River (NS)				
Mean annual	28.5 m^3/s	1960	63.9 m^3/s	1972	43.0 m^3/s	7.3 m^3/s	17 %
Mean winter	15.9	1970	101	1953	49.4	16.2	33
Mean spring	38.6	1966	132	1956	73.8	19.9	27
Mean summer	3.19	1921	39.9	1970	17.5	9.6	55
Mean autumn	18.9	1984	96.7	1990	50.1	17.2	34
Max. annual	190	1965	974	1971	410	142	35
Min. annual	0.15	1942	7.65	1964	2.06	1.7	83

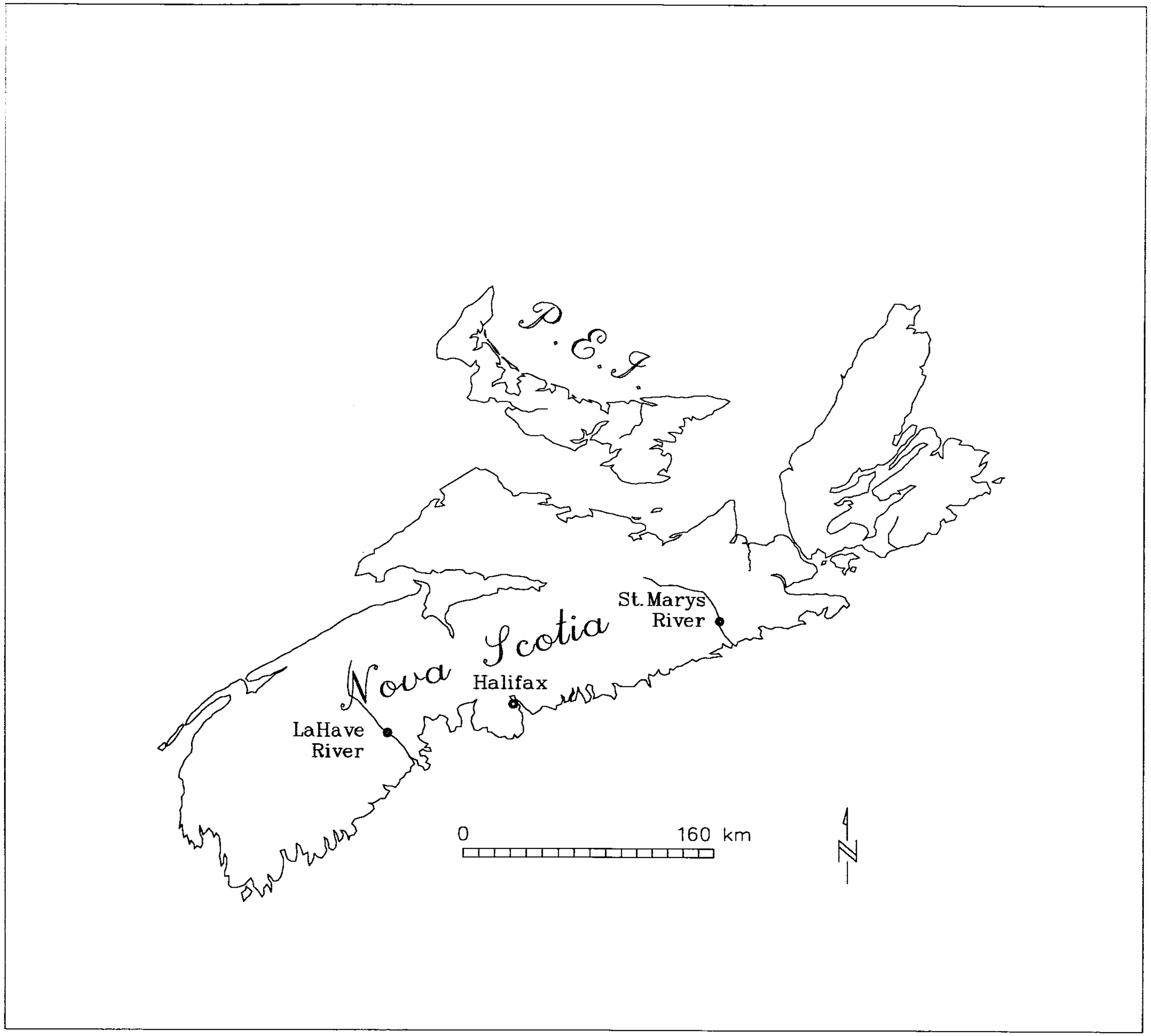

Figure 1. Location of hydrometric and meteorological stations in Nova Scotia.

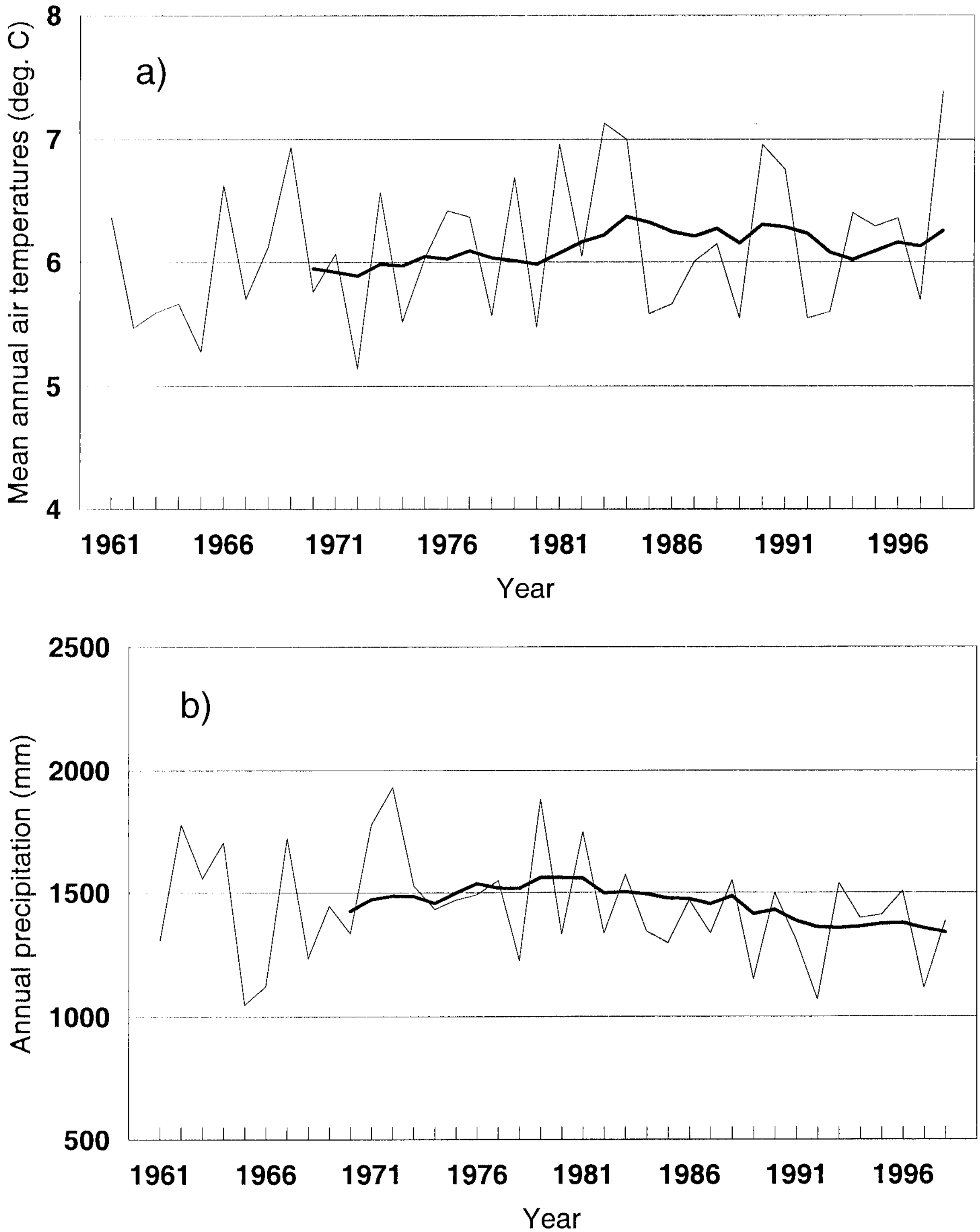

Figure 2. Mean annual precipitation (mm) and air temperatures (°C) at Halifax Airport from 1961 to 1998. Darker line represents the 10-year moving average.

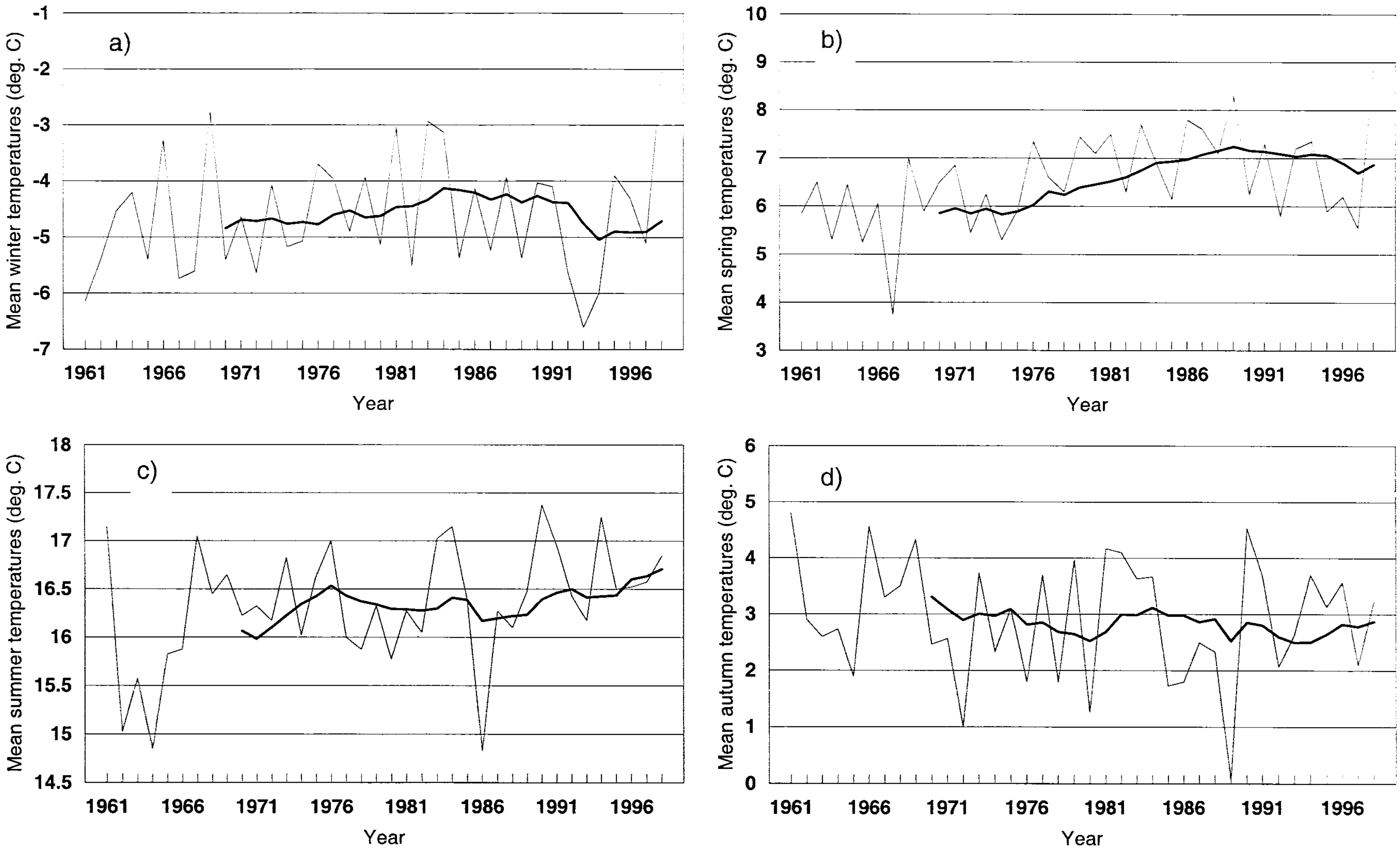

Figure 3. Mean seasonal temperatures (deg. C) at Halifax Airport from 1961 to 1998. Darker line represents the 10-year moving average.

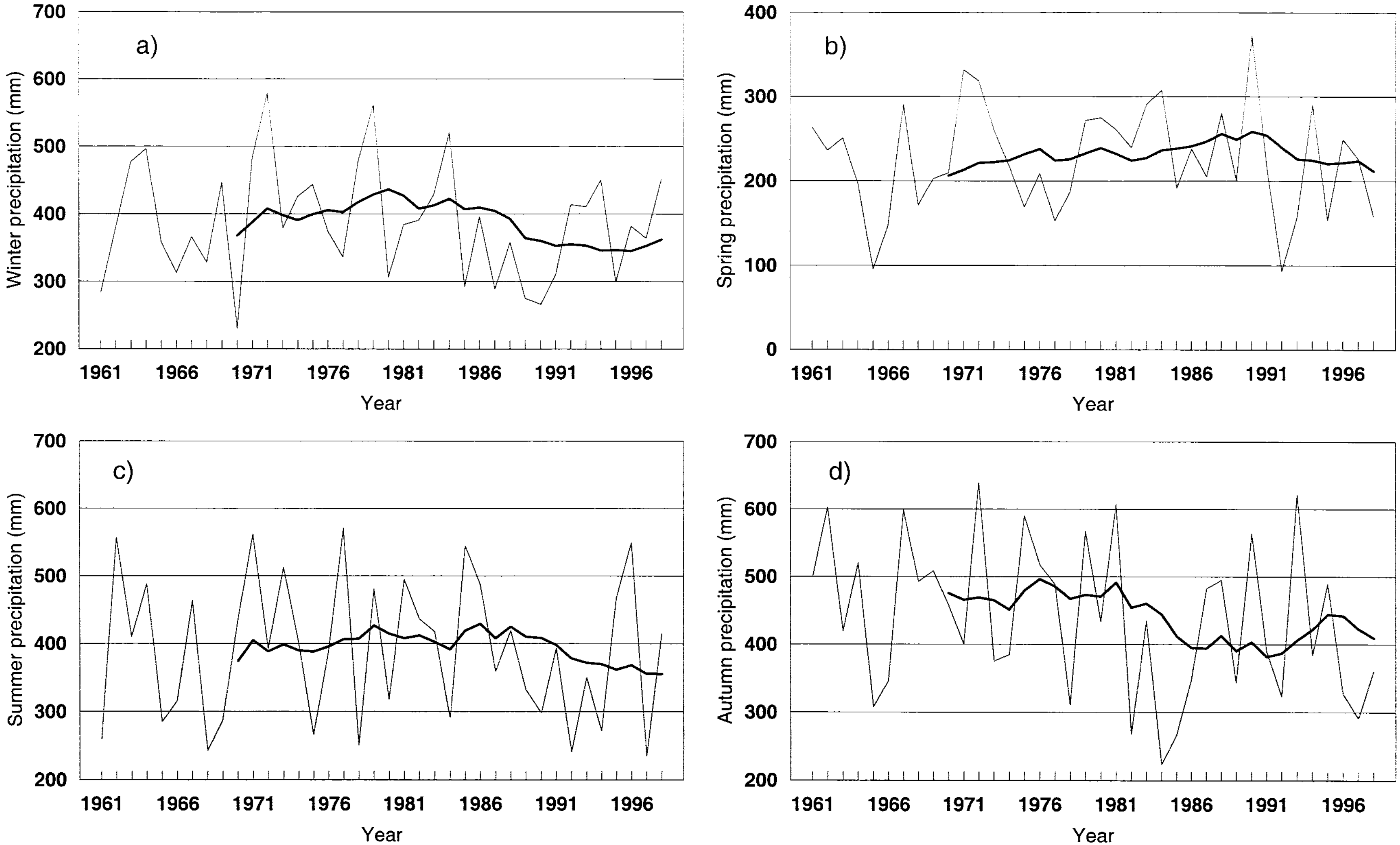

Figure 4. Mean seasonal precipitation (mm) at Halifax Airport from 1961 to 1998. Darker line represents the 10-year moving average.

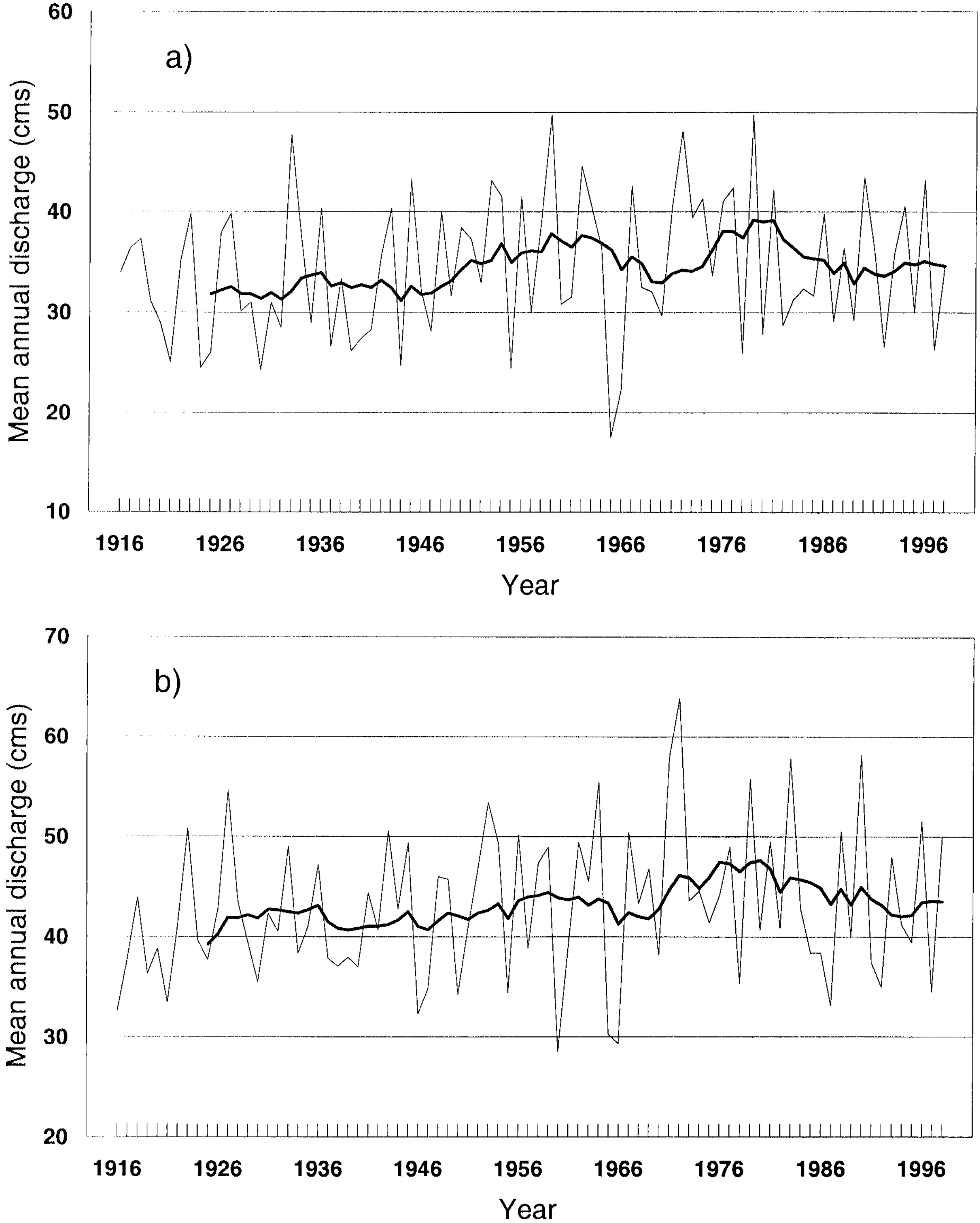

Figure 5. Mean annual discharge (cms) for a) LaHave River and b) St. Marys River. Darker line represents the 10-year moving average.

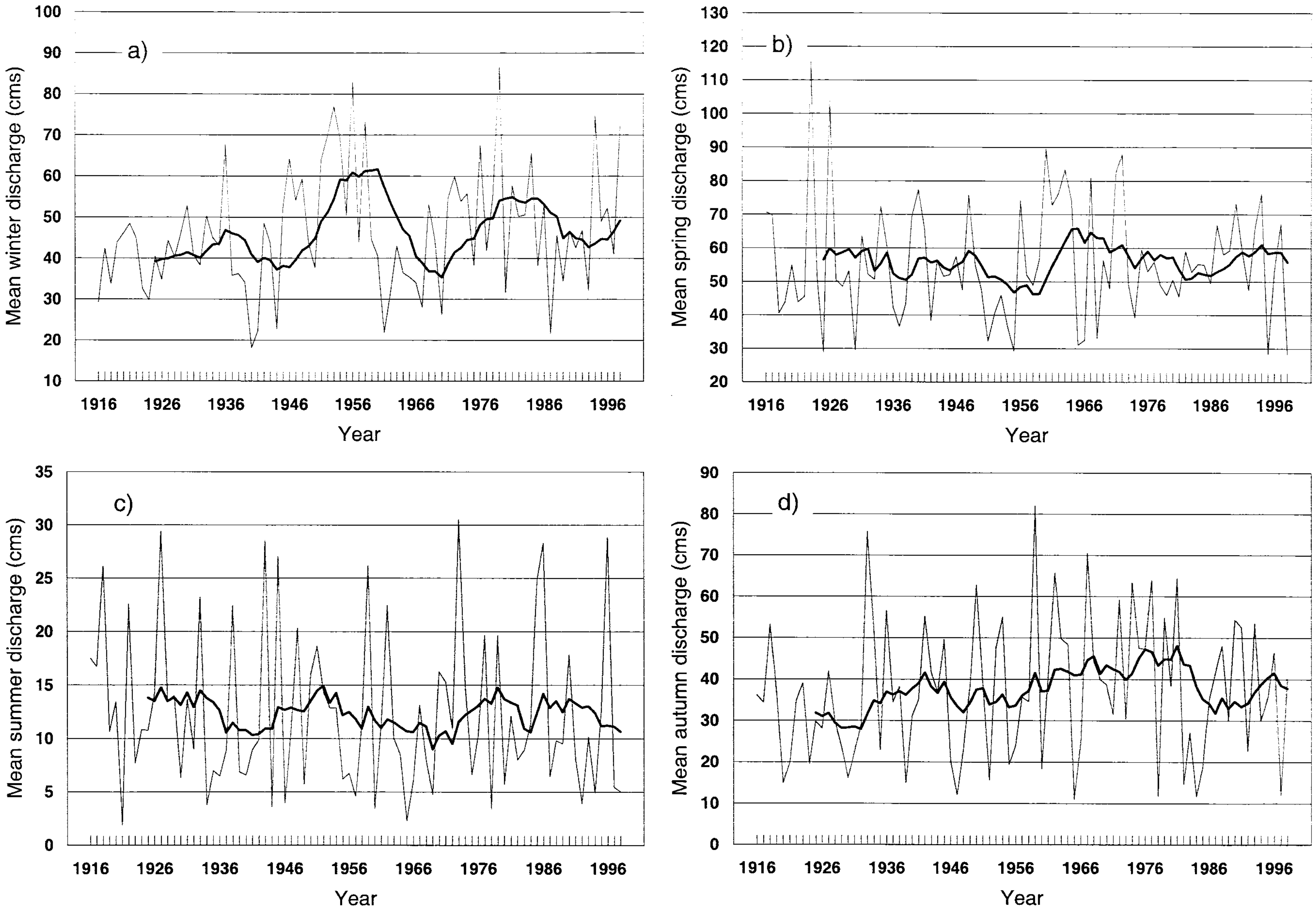

Figure 6. Mean seasonal flow for LaHave River (NS) 1916 to 1998. Darker line represents the 10-year moving average.

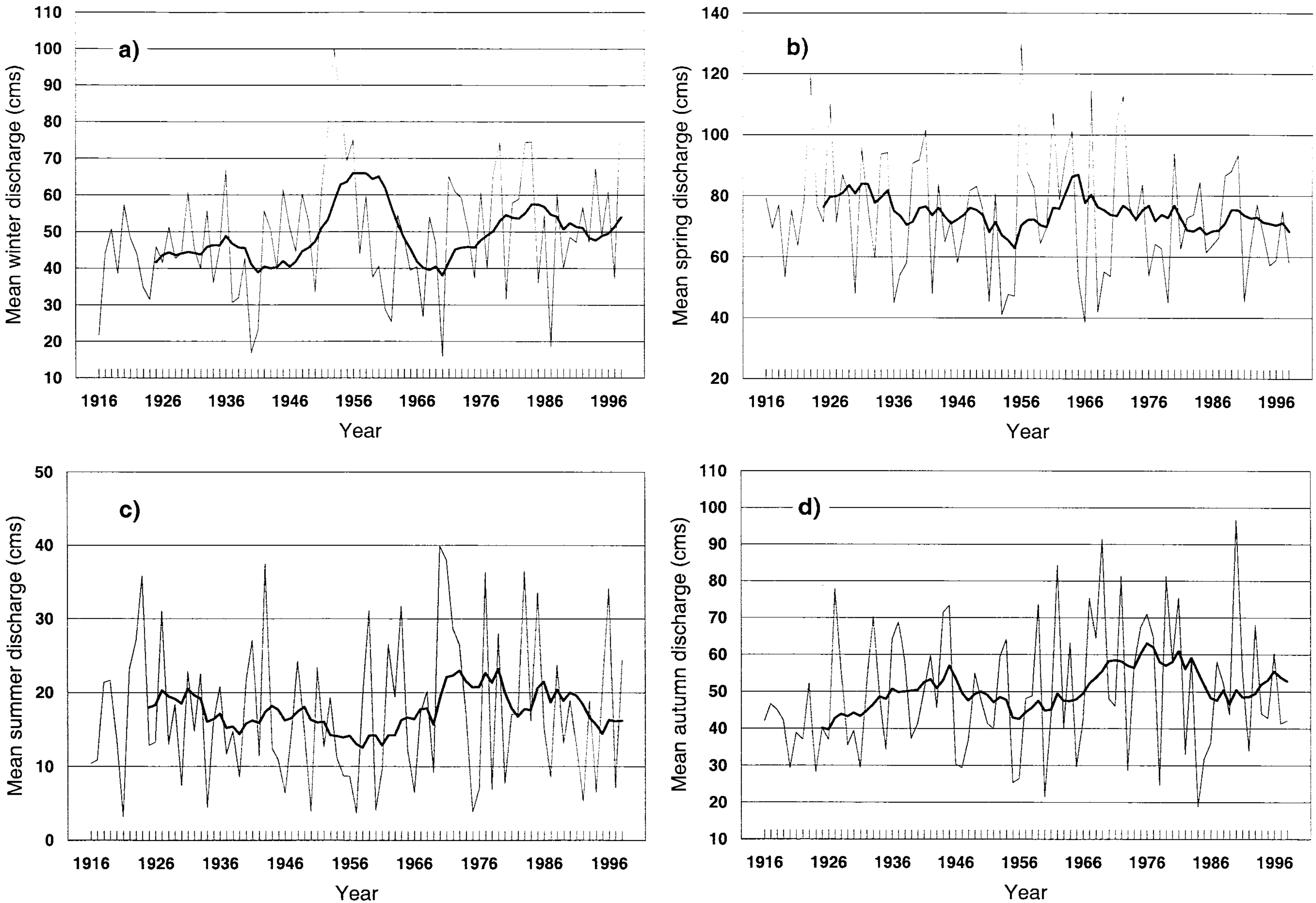

Figure 7. Mean seasonal flow at St. Marys River (NS) from 1916 to 1998. Darker line represents 10-year moving average.

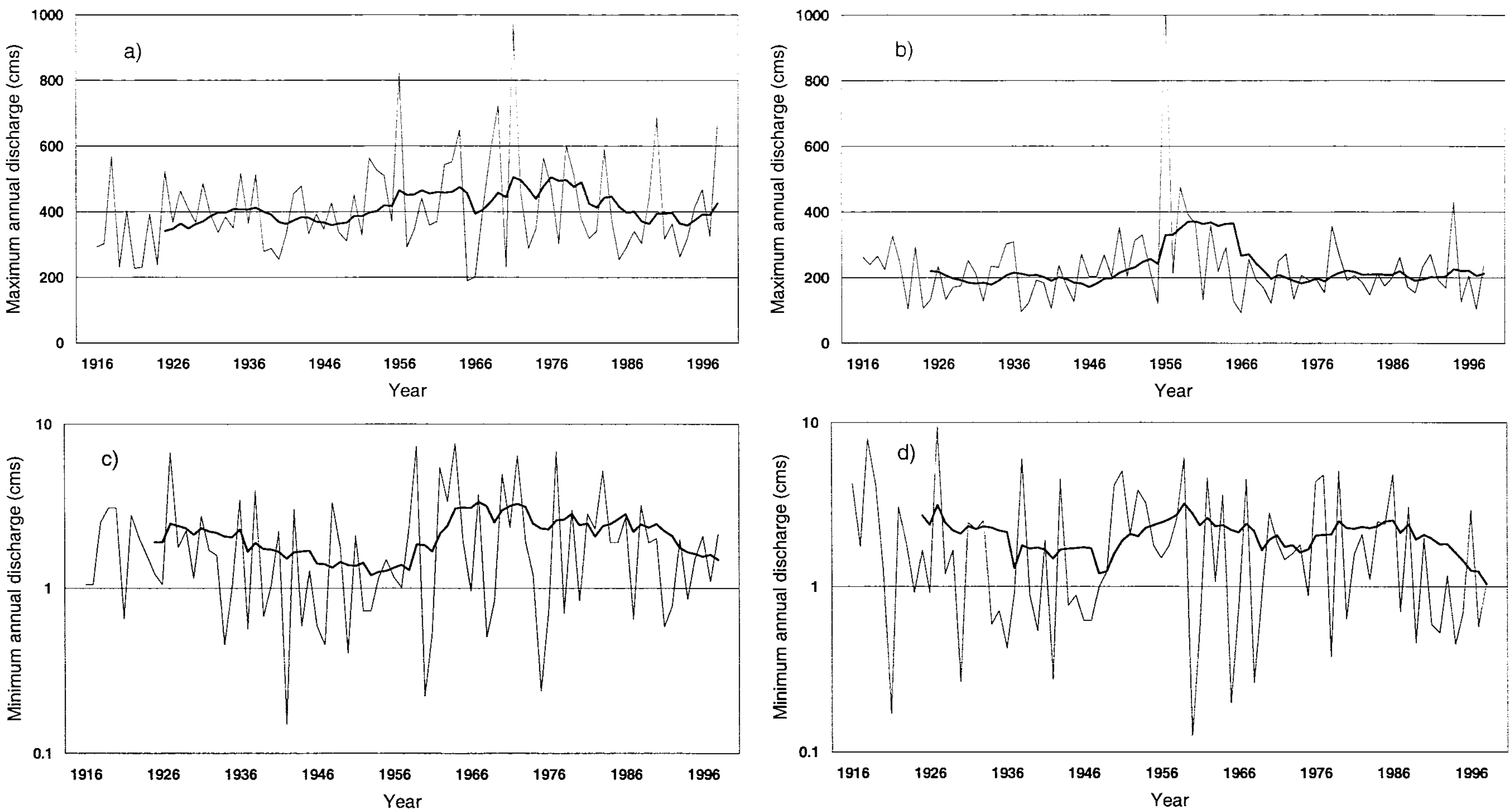

Figure 8. Maximum and minimum annual flow for St. Marys and LaHave Rivers (NS); a) maximum at St. Marys R.; b) maximum at LaHave R.; c) minimum at St. Marys R.; and d) minimum at LaHave R.