Hudson Bay and Ungava Bay Runoff Cycles for the Period 1963 to 1983

S. J. Prinsenberg, R. H. Loucks, R. E. Smith, and R. W. Trites

Physical and Chemical Sciences Branch
Scotia-Fundy Region
Department of Fisheries and Oceans

Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, Nova Scotia
B2Y 4A2

October 1987

Canadian Technical Report of Hydrography and Ocean Sciences
No. 92

Pêches et Océans
Fisheries and Oceans

Canada

Canadian Technical Report of Hydrography and Ocean Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. The subject matter is related generally to programs and interests of the Ocean Science and Surveys (OSS) sector of the Department of Fisheries and Oceans.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out of stock reports will be supplied for a fee by commercial agents.

Regional and headquarters establishments of Ocean Science and Surveys ceased publication of their various report series as of December 1981. A complete listing of these publications is published in the *Canadian Journal of Fisheries and Aquatic Sciences*, Volume 39: Index to Publications 1982. The current series, which begins with report number 1, was initiated in January 1982.

Rapport technique canadien sur l'hydrographie et les sciences océaniques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Le sujet est généralement lié aux programmes et intérêts du service des Sciences et levés océaniques (SLO) du ministère des Pêches et des Océans.

Les rapports techniques peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annuel des publications scientifiques et techniques du Ministère.

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Les établissements des Sciences et levés océaniques dans les régions et à l'administration centrale ont cessé de publier leurs diverses séries de rapports en décembre 1981. Une liste complète de ces publications figure dans le volume 39, Index des publications 1982 du *Journal canadien des sciences halieutiques et aquatiques*. La série actuelle a commencé avec la publication du rapport numéro 1 en janvier 1982.

Canadian Technical Report of

Hydrography and Ocean Sciences No. 92

September 1987

HUDSON BAY AND UNGAVA BAY RUNOFF CYCLES FOR THE PERIOD 1963 TO 1983

by

S. J. Prinsenberg, R. H. Loucks*, R. E. Smith* and R. W. Trites

Physical and Chemical Sciences Branch
Scotia - Fundy Region
Department of Fisheries and Oceans

Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, N.S.
Canada B2Y 4A2

* R. H. Loucks, Oceanography Ltd., 24 Clayton Park Drive, Halifax, N.S. B3M 1L3

Cat. No. Fs 97-18/92E ISSN 0711-6764

Correct citation for this publication:

Prinsenberg, S. J., Loucks, R. H., Smith, R. E. and Trites, R. W. 1987. Hudson Bay and Ungava Bay Runoff Cycles for the period 1963 to 1983. Can. Tech. Rep. Hydrogr. Ocean. Sci. 92: viii + 71 p.

ABSTRACT

Prinsenberg, S. J., Loucks, R. H., Smith, R. E. and Trites, R. W. 1987. Hudson Bay and Ungava Bay runoff cycles for the period 1963 to 1983. Can. Tech. Rep. Hydrogr. Ocean. Sci. 92: viii + 71 p.

Time series of monthly mean runoff rates for a twenty-one year period from 1963 to 1983 are presented as plots and listings for eight drainage areas of Hudson Bay and Ungava Bay. A detailed description is given for the method to derive the runoff values for regions where no gauged data were available. Using surface oceanic currents, a time series of the freshwater flux exiting Hudson Strait is calculated and its seasonal variability compared to salinity variations over the Newfoundland Shelf and to the runoff rates of the St. Lawrence River.

RÉSUMÉ

Prinsenberg, S. J., Loucks, R. H., Smith, R. E. and Trites, R. W. 1987. Hudson Bay and Ungava Bay runoff cycles for the period 1963 to 1983. Can. Tech. Rep. Hydrogr. Ocean. Sci. 92: viii + 71 p.

Les auteurs présentent ici sous forme de graphiques et d'énumérations des séries chronologiques de débits de ruissellement mensuels moyens pour une période de vingt et un ans qui va de 1963 à 1983, pour huit bassins versants de la baie d'Hudson et de la baie d'Ungava. Est aussi donnée la description détaillée d'une méthode permettant de déterminer des valeurs de ruissellement dans les régions dépourvues de données de jaugeage. À l'aide des courants océaniques de surface, une série chronologique du flux d'eau douce sortant par le détroit d'Hudson est calculée et sa variabilité saisonniére est comparèe aux variations de salinité au-dessus de la plate-forme de Terre-Neuve et aux débits de ruissellement du fleuve Saint-Laurent.

TABLE OF CONTENTS

TABLE CAPTIONS

FIGURE CAPTIONS

1.0 INTRODUCTION

Monthly runoff data between 1965 and 1975 for rivers draining into Hudson Bay and James Bay have been used by Prinsenberg (1980) to obtain a climatic seasonal runoff cycle prior to man-made alteration due to hydroelectric developments in James Bay. This climatic runoff cycle was further used to interpret possible runoff effects on biological production downstream in coastal areas (Sutcliffe *et al.* 1983). In order to study the relationships between runoff and marine environment more closely, and in particular, their year-to-year variations, one requires a time series of Hudson Bay system runoff over an extended period.

There are now approximately twenty years of river discharge observations available from several rivers in the Hudson Bay system. The purpose of this report is to assemble this data by regions around Hudson Bay and use them to estimate eight regional discharge time series. Later these regional series are combined, using two ocean drift speed scenarios, into a time series for a freshwater flux exiting Hudson Strait between 1963 and 1983. The important freshwater contribution arising from ice melt is not treated here but it should be noted that during the spring, ice melt dominates river runoff in a ratio of 2:1 (Prinsenberg, 1984). Finally, correlation analysis was done between the freshwater fluxes exiting Hudson Strait, the salinity variation on the southern Newfoundland shelf and St. Lawrence River discharge to determine if any associations and plausible cause-effect relationships are present.

2.0 DESCRIPTION OF DRAINAGE AREAS AND RUNOFF CALCULATIONS

Hudson Bay, James Bay, Foxe Basin and Hudson Strait were divided into eight regions; five for Hudson Bay, and one each for James Bay, Foxe Basin, and Ungava/Hudson Strait (Figure 1, Table 1). Runoff received by each region was obtained by combining all available gauged river data from each drainage area or if ungauged using proxy data from neighbouring drainage areas for which gauged data was available.

The total drainage area under consideration covers 3.64×10^6 km^2. It is twice as large as the neighbouring MacKenzie River drainage area (1.8×10^6 km^2) located to the northwest and three and one-half times as large as the St. Lawrence-Great Lakes area (1.0×10^6km^2) located to the east and south (Canadian Government, 1973). As expected, ungauged areas are mostly located in the northern part of the drainage area (Table 1).

Rivers are usually gauged by Water Survey of Canada (WSC) at locations inland from the coast, therefore gauged data requires a correction factor to account for the drainage area between the location of the gauge and the river mouth as well as drainage areas of the ungauged smaller rivers near the coast.

Some records are incomplete, particularly in the early years of the period of interest (Table 2). Records for several rivers also contain small random data gaps throughout the period. These data gaps were filled by interpolating from monthly means and records of adjacent rivers.

Lack of data for coastal areas and lack of data due to incomplete records are taken into account by prorating surrogate gauged data by the ratio of total regional ungauged area to gauged area.

In cases where gauged data becomes available part way through the period of interest (Table 2), this simple prorating technique could be checked. In some cases the derived estimates were poor in comparison to gauged data. Two areas may be incompatible for interpolation using the prorating technique because of various time lag effects due to length of rivers, presence of lakes and variability in vegetation and climate. To improve the estimates, monthly discharge factors were used which varied seasonally for each river set. For the particular month, the discharge factor is the ratio of the average discharge for the presently ungauged river to the average discharge from the reference river. These estimates are referred to as yield/areal prorating estimates and improved the estimates for ungauged drainage areas compared to those from the simple areal prorating method where the discharge factor was held constant throughout the year. Discharge factors are listed in Appendix A..

2.1 Region I , the SW sector of Hudson Bay

Gauged data exists for several major rivers; the Seal, Nelson, Churchill, Hayes and Gods. Data from the Severn River was added to this region's total because it discharges into Region I of Hudson Bay even though it orginates from another major drainage basin located in northern Ontario (Table 1).

The Churchill River has been regulated since 1928 and the Nelson River since 1960. It was necessary to estimate data from 1963-71 for the Churchill, from 1963-73 for the Hayes and from 1963-69 for the Gods and Severn Rivers. The longer records of the Seal and Nelson Rivers were used as references to estimate data for these rivers using the yield/areal prorating method.

Coastal drainage estimates for the northern section (principally, the Seal River) were obtained by using a factor of 0.87 on the Seal.River data. The factor was derived from drainage area estimates for the Caribou, North and South Knife and lower Churchill Rivers.

Coastal drainage estimates for the southern section were derived by using a factor of 1.5 on the Gods River data. (The Gods River is a tributary of the Hayes River). The sum of estimated drainage areas of several smaller rivers (i.e. Burntwood, Grass, Limestone, Kettle, upper Nelson, lower Nelson, lower Hayes, Kaskattawan and Owl Rivers) is 1.5 times the published (WSC) drainage area of the Gods River.

The coastal region of the Severn River is accounted for by using a factor of 0.28 of the Severn data (the factor derived from combining estimated drainage areas of the lower, Severn River and ungauged areas east and west of the river).

The runoff into the southwestern sector of Hudson Bay (Region I) is thus obtained by the following equation whose values are listed in Appendix B (Table B.1).

$$\text{Runoff into Region I} = \text{Nelson} + 1.87(\text{Seal}) + \text{Churchill} + \text{Hayes} + 1.5(\text{Gods}) + 1.28(\text{Severn})$$

2.2 Region II, the NW sector of Husdon Bay

The major runoff contributors to this region (Chesterfield Inlet) are the Thelon, Kazan and Quoich Rivers. Only the Kazan has a 20-year record (1965-84). It was necessary to estimate data for 1963-65 for the Kazan and 1963-72 for the Thelon Rivers by extrapolating data from the Seal, a neighbouring river in the adjacent region (Table 2). A monthly variable calibration coefficient was used on the Seal River data to account for differences in the timing of the spring runoff peak.

Estimates of discharge values for the coastal region were obtained by using the Quoich River data corrected by a factor of 8.36. The Kazan River was not used as a surrogate for the coastal region, although it has the longer period of record because it lies too far inland and to the south of the coastal area in question.

The runoff into the northwestern sector of Hudson Bay is thus obtained by the following equation whose values are listed in Appendix B (Table B.2).

$$\text{Runoff into Region II} = \text{Thelon} + \text{Kazan} + 9.36(\text{Quoich})$$

2.3 Region III and IV, the NE sector of Hudson Bay

The Innuksuac, Kogaluk, Povungnituk, Kovik and other smaller rivers in Northern Quebec drain into the northeast sector of Hudson Bay. None are gauged. The drainage area of the Innuksuac is equivalent to the Little Whale, an adjacent gauged northern river in middle Quebec; the total drainage area of the Kogaluk, Povungnituk and Kovik Rivers are equivalent to that of the Arnaud River (a neighbouring gauged river in the northern Ungava Bay region) and combined area of the other smaller rivers as equivalent to the Little Whale drainage area (Table 2). The ungauged coastal region of all is equivalent to another drainage area of the Arnaud River.

The runoff into the northeast sector of Hudson Bay was thus estimated by the following equation whose values are listed in Appendix B (Table B.3).

$$\text{Runoff into Region III/IV} = 2.0(\text{Arnaud} + \text{Little Whale})$$

2.4 Region V, the SE sector of Hudson Bay

The rivers included in the SE drainage sector of Hudson Bay are the Denys, Great Whale, Little Whale and Nastapoca Rivers.The Winisk River from northern Ontario was included in this middle Quebec region because its discharge quickly drifts into Region V of Hudson Bay. The coastal areas north of the LaGrande River including the Roggan River of northern James Bay are also included. The Nastapoca River is not gauged and the records for the Winisk and Little Whale Rivers are incomplete for the early years. The coastal regions are accounted for by including two additional gauged Denys units and a factor of 1.6 on each unit of river data (Table 2).

The runoff into the southeast sector of Hudson Bay is thus given by the following equation whose values are listed in Appendix B (Table B.4).

$$\text{Runoff into Region V} = 1.6\,[3.0\,(\text{Denys}) + \text{Great Whale} + \text{Little Whale} + \text{Winisk}]$$

2.5 Region VIa, James Bay (Ontario)

Ontario's runoff into James Bay was calculated from the gauged Ekwan, Attawapiskat, Albany, Moose and Abitibi Rivers. The Albany has been regulated since 1939, and the Moose and Abitibi since 1963. The coastal area for all these gauged rivers roughly equals the Attawapiskat drainage area multiplied by a factor of 3 (Table 2). It was necessary to estimate data for portions of the 1963-68 period for the Ekwan, Attawapiskat and Albany Rivers using data from the Moose and Abitibi Rivers.

The runoff into western James Bay was estimated by the following equation whose values are listed in Appendix B (Table B.5).

$$\text{Runoff into Region VIa} = \text{Ekwan} + 4.0(\text{Attawapiskat}) + \text{Albany} + \text{Moose} + \text{Abitibi}$$

2.6 Region VIb, James Bay (Quebec)

Quebec's runoff into James Bay was derived from three river systems: the Nottaway, Broadback and Rupert; the Eastmain and Caster; and the LaGrande and Roggan. The Caster and Roggan Rivers are not gauged. The LaGrande and Eastmain Rivers are subject to hydroelectric development with the Eastmain being diverted into the LaGrande Complex during 1980.

There are data gaps for the Rupert throughout 1963 and for the Nottaway and Broadback during 1982-83. The Rupert was prorated in terms of two additional Broadback drainage areas to estimate 1963 data (Table 2). After 1981, data for the Nottaway and Broadback Rivers was estimated using the Rupert River as a surrogate. A monthly variable coefficient was used to accommodate differences in the timing of the discharges. The coastal area for the first two river systems was prorated as of two Broadback drainage areas. For simplification, the coastal area north of the LaGrande River was transferred to Region V.

The runoff into eastern James Bay was estimated by the following equation whose values are listed in Appendix B (Table B.6.).

$$\text{Runoff into Region VIb} = \text{Nottaway} + 3.0(\text{Broadback}) + \text{Rupert} + \text{Eastmain} + \text{LaGrande}$$

2.7 Region VII, Ungava and Hudson Strait

This drainage area includes the Arnaud, Feuilles, Koksoak, Caniapiscau, Baleine and George Rivers. All are gauged. The Koksoak and the Caniapiscau Rivers were partially diverted into the Caniapiscau Reservoir as part of the LaGrande Complex during 1983. The Koksoak River is gauged where the Melezes River enters.

After August 1979, no record exists for the George River. In order to estimate its runoff after 1979, the George River drainage system was taken to be equivalent to 1.1 Baleine and 0.1 Arnaud drainage areas.

The Ungava coastal region was taken to be 1.3 times the combined drainage areas of the Arnaud and Baleine Rivers. The coastal drainage area of Hudson Strait was prorated on the basis of Region II data (5%) with widened uncertainties.

The runoff into Hudson Strait and Ungava Bay was estimated by the following equation whose values are listed in Appendix B (Table B.7).

$$\text{Runoff into Region VII} = 2.3(\text{Arnaud} + \text{Baleine}) + \text{Feuilles} + \text{Melezes} + \text{Caniapiscau} + \text{George} + \text{Hudson Strait coast}$$

2.8 Region VIII, Foxe Basin

Gauged data is unavailable. For this reason, estimates were made by prorating Region II data by an areal factor of 0.31 and appropriately widening the estimates of uncertainty (Table 4).

2.9 Uncertainties in Regional Time Series

An attempt was made to determine the uncertainties in runoff data. The Water Survey of Canada provides only a qualitative statement of the accuracy of river discharge data. Given that Hudson Bay system rivers are difficult to gauge because of frequent ice and enormous spring runoffs, we took, due to lack of any other information, the standard deviation uncertainty of gauged data to be ±5%. For data synthesized for an ungauged period by hindcasting using yields from a gauged period and or from a neighbouring gauge record, the standard deviation uncertainty is determined from the 'fit' of the 'model'. For data synthesized for an ungauged drainage basin by simply multiplication of a neighbouring gauged discharge by the ratio of total area to gauged area, the standard deviation uncertainty was taken again due to lack of further information as 15%. Further we make the assumption that the uncertainties appropriate to the various component river basins combine as the square root of the sum of squares to yield the estimated deviation uncertainty in the regional signal. Since many assumptions were used in the calculation of the uncertainties, their numerical values should only be used as a guide to show that the reliability of the data has increased with the years and which region has more reliable data than another.

2.10 Total-System Time Series of Runoff

The second objective of this work is to obtain a monthly series of the total runoff landward of the mouth of Hudson Strait using time lags reflecting available information on the mean surface-layer circulation of the system. It should be noted that precipitation and evaporation over the receiving waters are ignored for the present even though over Hudson Bay they account for a net yearly loss of a 20 cm layer of freshwater (Prinsenberg, 1980).

Summation of the runoffs from each region was done using two different estimates for the surface circulation speeds which move the freshwater between the regions. The base-drift case (Table 3) uses documented speeds of data collected in late summer at offshore locations. These circulation speeds most likely underestimate the speeds occuring during the spring in the inshore regions where most of the runoff dilution is found. The fast-drift scenario uses higher estimates of drift speeds, supported in some cases by measurements. Runoff totals for a third zero-drift case using zero phase lags were also obtained. It sums the runoff rates entering the total area regardless of the location. To start the time series at January 1963, historical 21-year mean runoff rates were used prior to January when required, due to phase lags.

2.11 Effect of Uncertainties in Drift-Speed and Lag

The uncertainties in the estimates for the total runoff time series arise in two ways; from the measurement uncertainties in the regional series and from possible timing errors in estimating the drift-speeds and lags (Table 3). The effect of a one-month uncertainty in timing has been evaluated for the fast-drift scenario for each month throughout the year.

For example, to estimate the timing error for the total August runoff, one works backward by the number of months lag from each region. The effect of a one-month timing error for this region for this month is measured by the standard deviation of the difference between the region's runoff for that particular month and that for the next month. Taking Region I with six months lag as an example, the standard deviation of the February-March difference in runoff is used as an estimate of the standard deviation uncertainty due to a one-month error in lag for this particular month and Region I contribution to the uncertainty of total August runoff.

The standard deviation contributions to the uncertainty of the total are combined by converting measurement and timing errors to percentage variances and adding, then weighting by the fraction of total runoff contribution by the particular area, and finally taking the square root of the sum to give the standard deviation uncertainty of the total August runoff.

In summary, the basic assumption utilized is that the uncertainties are random, not systematic, so that

$$(A \pm a) + A \pm b) + \ldots. = A + B + \ldots. \pm (a^2 + b^2 + \ldots.)^{\frac{1}{2}}$$

and, standard deviation measurement uncertainty (m) combines with the deviation timing uncertainty (t) to yield a total uncertainty u given by

$$u = [m^2 + t^2]^{\frac{1}{2}}$$

3.0 RESULTS

3.1 Runoff Rates of Regions

The data listed in Table 4 show the relative importance of the eight regions of the total Hudson Bay drainage area. The percentage of the total average runoff received is listed along with the fraction of the gauged area of each region, and finally the composite standard deviation measurement uncertainty for each region. Separate entries are given for time periods of different gauge coverage. More details concerning the uncertainties attributed to data from particular rivers are given in Appendix A.

The results of Table 4 show that the total runoff of the Hudson Bay system is partitioned mainly between three areas–Hudson Bay proper, James Bay and Ungava Bay in a ratio of 4.5 to 3 to 2. The seasonal cycles of historical 21-year averaged runoff rates for these main drainage areas are shown in Figure 2 with HB-W as western Hudson Bay, HB-E as eastern Hudson Bay, JB as James Bay and UB as Ungava Bay. James Bay's spring runoff peak occurs the earliest due to its southern location, followed by Ungava Bay and Hudson Bay. James Bay's cycle also shows the fall peak associated with increased precipitation in the fall. Although, the yearly mean runoff rates into both James Bay and Ungava Bay are lower than into Hudson Bay, the runoff per unit area of ocean is larger and thus have a greater affect on the salinity stratification in the adjacent receiving areas. In general more gauged data has become available in later years with the northern areas lagging those in the southern areas (Table 4). This spatial and temporal shift to more gauged data is also reflected by a decrease in the estimated uncertainties for these areas and time periods.

3.2 Tables and Plots of Regional Time Series

The time series for the eight regions are tabulated in Appendix B, Tables B.1 to B.8, and plotted in Figures 3 to 9. The time series for Foxe Basin, prorated from Region II, is not plotted. The plots show the monthly runoff and the monthly anomaly for the period 1963 to 1983. The monthly runoff values show a strong spring freshet ranging from below three times the winter low values for Region I to twenty-five times for Region VII. Southern regions also show an autumn peak due to rain storms in the fall.

The effects of river regulation by hydroelectric developments, which transfer runoff from spring to subsequent seasons, can be seen, for example, in Region I for the Churchill River diversion in 1977 and in Region VIb for the LaGrande Complex in James Bay after 1980. Appendix B also show time-series plots except that each year is folded back over the previous year in order to show visually the interannual runoff variability for each subregion. The magnitude of the interannual variability shown by the figures are numerically given below the tables of Appendix B as the standard deviation from the 21-year mean for each month and yearly mean.

3.3 Composite Hudson Strait Estimated Runoff Time Series

Table 5 shows the combined standard deviation uncertainty for 1963 for the total runoff signal (fast-drift and base-drift scenarios) exiting Hudson Strait. The one-month timing uncertainty for each contributing region was calculated and combined with the local measurement uncertainties. Finally the uncertainties of the contributions were combined to yield a standard deviation uncertainty for each month total runoff exiting from Hudson Strait. The result is that individual monthly estimates of total system runoff have a high standard deviation of uncertainty arising more from lack of information about ocean drift rates then from measurement inaccuracies. The uncertainties can exceed the coefficient of variability in data. Thus we are forced to retreat to consideration of seasonal or annual averages.

The time series of Hudson Bay system accumulated river discharge are plotted in Figures 10 and 11, using the base-drift and fast-drift scenarios respectively. These signals are also tabulated in Appendix B, Tables B.11 and B.12 along with the zero-drift case in Table B.10.

The zero-drift case's seasonal cycle of low winter and high spring runoff rates clearly visible in Figure B.10 are not detectable in the base-drift case Figure B.11 and Figure 10. The runoff peak of the various regions arrive at different times at the entrance of Hudson Strait and reinforce each other less as is the case for a simple summation of the runoffs using zero phase lags (Table B.10). The freshwater flux cycle for the base-drift case (Table B.11) is inconsistent with the occurrence of a strong salinity minimum occurring in the Labrador Current off St. John's in October (Table 6) and presumed to occur in Hudson Strait in August. A Labrador Current speed averaging 50 cm/s would account for a time lag of 40 days. The fast-drift case would provide a peak of freshwater flux off St. John's in October. However, the strong salinity minimum may not be related directly to runoff but instead to the ice-melt of the annual ice-cover. Runoff does however influence the surface circulation and together with the wind stress determines the movement of the ice-cover.

The 21-year mean freshwater fluxes for the two drift scenarios leaving Hudson Strait (Figure 12) show that the spring peak seen in the zero-drift case in June is spread throughout the year for the base-drift case but occurs for the fast-drift case in August although with a broader peak. These cases, however, use constant phase lags which actually vary seasonally in response to the runoff itself. More information on the seasonal variability of the surface circulation and salinity distribution for the total area is required to determine the proper phase lags and thus the timing of the freshwater flux due to runoff leaving Hudson Strait.

3.4 Correlation Results

The following results are a preliminary effort to determine if the freshwater flux through Hudson Strait and from St. Lawrence River correlate with the salinity stratification and winter wind anomaly observed on the southern Newfoundland shelf. This work is only just begun and our comments in this section serve mainly as suggestions for future research.

Annual averages from runoff time series for Region I show weak correlation in the scatter plot (Figure 13) with RIVSUM, the composite series of St. Lawrence rivers' discharges (Table 6).

Region I represents the large drainage area of the Prairies which neighbours in the northwest to the Great Lakes area represented by RIVSUM. Although, both these areas are affected by the same continental weather patterns, only a weak correlation is shown. On the other hand, the scatter plot between Region VII (Ungava Bay) and the St. Lawrence River (Figure 14) show a negative weak correlation suggesting that the Ungava Bay region may be affected more by the Atlantic coastal weather patterns than the continental weather patterns. The precipitation rates of the continental and Atlantic weather patterns appear to be out of phase with each other. The James Bay Region VIb is affected by both and shows no definite correlation feature (Figure 15).

Figure 13 may also reflect some of the man-made effects on the environment. The diversion of the Churchill River in 1975 and the increased irrigation on the Prairies has decreased the runoff of Region I since 1975 (ignoring the two post El Nino years of 1973 and 1974). At the same time land clearing due to large urban developments around the Great Lake Basins may have increased the runoff there. This could perhaps explain the shift in location from the '66–'75 year runoff group to the '76–'83 year group in Figure 13. The runoffs of 1963 to 1965 were very low in both regions indicating a prolonged dry spell for the North American continent.

In Figure 16, the freshwater flux of the fast-drift scenario, is compared to the RIVSUM. The correlation is practically zero, yet the two year grouping still occurs. The statistical data for Figures 13 to 16 comparing regional and total runoff cycles of Hudson Bay with that of the St. Lawrence is listed in Table 7.

As shown in Figure 17, there is a negative correlation, significant at something less than the 90% level after correction for autocorrelation, between the annual average runoff at the mouth of Hudson Strait and the geostrophic winds over the Labrador Shelf for winter of the same year. This suggest that anomalous southeast winds carry moist air and are associated with high runoff.

Figure 18, relates the freshwater flux of the fast-drift case with Station 27 salinity. No correlation is found. However again here, as in Figures 11 and 14, the possibility arises that some other factor is imposing a separation into two groupings (e.g. bimodal). The results of Figure 19, fast-drift runoff versus Station 27 temperature, are similar. The statistical data for Figures 17 to 19 is listed in Table 8.

4.0 CONCLUSION

For the twenty-one year period of 1963-1983, time series of monthly mean runoff rates were obtained for eight drainage areas covering Hudson Bay, Foxe Basin and Hudson Strait. The data was presented in table and figure formats. Monthly mean runoff cycles of the total and subregions of Hudson Bay and Hudson Strait region show strong seasonal variability with low winter values and high spring values. The runoff ratios of spring to winter values range from 25 to 1 in northern areas to 5 to 1 in James Bay and to less than 3 to 1 for the large drainage area of the Nelson River. Contributions for the total region's yearly mean runoff value of $2.7 \times 10^4 m^3 s^{-1}$ is partitioned mainly between three regions; Hudson Bay, James Bay and Ungava Bay in a ratio of 4.5 to 3 to 2. Summations of the monthly runoff rates were done using three oceanic circulation conditions; zero-drift, base-drift and fast-drift. The zero-drift case is simply a summation of the subregions while the base-drift and fast-drift cases calculated time series of monthly freshwater fluxes leaving Hudson Strait using two different circulation conditions. Correlation analysis was done with the runoff rates (subregions and total) and oceanographic and atmospheric conditions of the Labrador Sea. It was found that the annual runoff variability is partly influenced by (correlated with) the continental weather patterns through the western drainage regions and partly by Atlantic Ocean weather patterns through Ungava Bay and James Bay drainage regions.

ACKNOWLEDGEMENTS

We thank Dr. K. F. Drinkwater and Mr. F. Jordan for their assistance in reviewing the manuscript. The majority of the analysis was undertaken through contract work by R. H. Loucks Oceanography Ltd. and supported by funds from the Office of Energy and Research Development (OERD) of the Department of Energy, Mines and Resources.

Mrs Burhoe is thanked for typing the various drafts of the report, and Mr. A.D. Cosgrove for overseeing the cartographic work.

BIBLIOGRAPHY

CANADIAN GOVERNMENT (1973) The national atlas of Canada. Fourth Edition. Department of Energy, Mines and Resources, Surveys and mapping Branch, Ottawa. 254 p.

DRINKWATER, K. F. (1986) Physical oceanography of Hudson Strait and Ungava Bay. Chap. 13 in I. P. Martini (ed.) Canadian Inland Seas, Elsevier, Amsterdam. pp. 237-264.

GOVERNMENT OF QUEBEC (1963-1984) Annuaire hydrologique. Ministere des Richesses Naturelles. Direction generale des Eaux. Que.

PRINSENBERG, S. J. (1980) Man-made changes in the freshwater input rates of Hudson and James Bays. Cdn. J. Fish. Aq. Sci. 37(7): 1101-1110.

PRINSENBERG, S. J. (1984) Freshwater contents and heat budgets of James Bay and Hudson Bay. Cont. Shelf Res. 3(2): 191-200.

PRINSENBERG, S. J. (1986a) The circulation pattern and current structure of Hudson Bay. Chap. 10 in I. P. Martini *(ed.) Canadian Inland Seas, Elsevier*, Amsterdam. pp. 187-204.

PRINSENBERG, S. J. (1986b) On the physical oceanography of Foxe Basin. Chap. 12 in I. P. Martini (ed.) Canadian Inland Seas, Elsevier, Amsterdam. pp. 217-236.

PRINSENBERG, S. J., and N. G. FREEMAN. (1986) Tidal heights and currents in Hudson Bay and James Bay. Chap. 11 in I. P. Martini (ed.) Canadian Inland Seas, Elsevier, Amsterdam. pp. 205-216.

SUTCLIFFE, W. H. Jr., R. H. LOUCKS, K. F. DRINKWATER, and A. R. COOTE. (1983) Nutrient flux onto the Labrador Shelf from Hudson Strait and its biological consequences. Cdn. J. Fish. Aq. Sci. 40: 1692-1701.

WATER SURVEY OF CANADA (1985) Historical streamflow summary to 1984. For all provinces except Quebec. Environment Canada, Inland Waters Directorate, Water Resources Branch, Ottawa.

Table 1. Gauged and ungauged drainage areas in (1000 km^2) of the eight subregions of the Hudson Bay - Ungava Bay Region.

Region	Discharge Gauged	Discharge Estimated	Area Subtotal	Comulative Total	% of Total
I (Prairies & NW Ont.)	1542.5	166.6	1709.1	1709.1	46.9
II (NW Territories)	255.0	240.0	495.0	2204.1	13.6
III & IV (N Que.)	0.0	80.0	80.0	2284.1	2.2
V (Mid-Que./NE Ont.)	101.4	77.0	178.4	2462.5	4.9
VIa (W James Bay)	252.0	111.5	363.5	2826.0	10.0
VIb (E James Bay)	256.4	43.5	299.9	3125.9	8.3
VII (Ungava/Hudson St.)	263.1	96.3	359.4	3485.3	9.9
VIII (Foxe Basin)	0.0	155.0	155.0	3640.3	4.2

Table 2. Gauged and ungauged drainage areas and period of gauging for individual rivers.

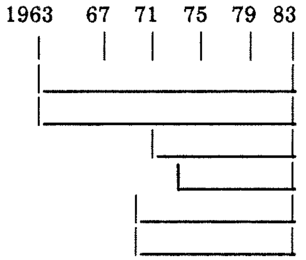
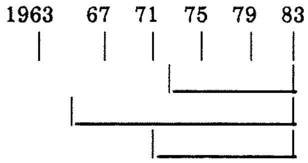
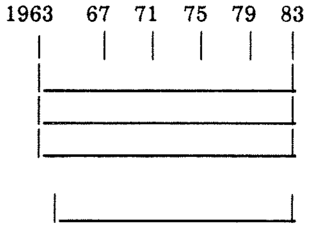
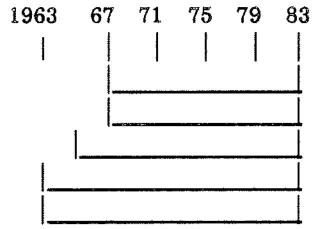
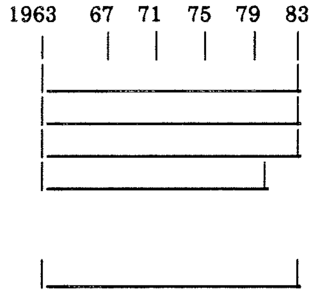
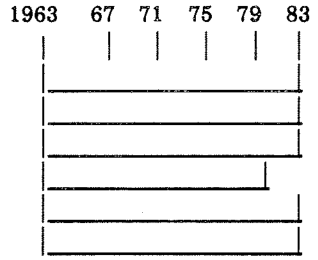
River and Region	Gauged Drainage Area (× $10^3 km^2$)	Ungauged Drainage Area (× $10^3 km^2$)	Gauged Period (years)
Region I (Man.+N. Ont.)			
Seal	48.2	41.93	
Nelson	1010.0		
Churchill	287.0	98.25	
Hayes	103.0		
Gods	(65.5)		
Severn	94.3	26.40	
Total	1542.5	166.60	
Region II (N.W.T.)			
Thelon	154.0		
Kazan	72.3	240.0	
Quoich	28.7		
Total	255.0	240.0	
Region III/IV (N. Que.)			Not gauged
Innuksuak	–	16.5	
Kogaluk	–	13.0	
Povungnituk	–	27.5	
Kovik	–	10.0	
Others	–	13.0	
Total	0.0	80.0	
Region V (Mid. Que.)			
Denys	4.7	3.5	
Great Whale	36.3	5.9	
Little Whale	10.4	6.3	
Nastapoca	–	20.0	
Winisk	50.0	29.0	
Total	101.4	77.0*	

Table 2 (continued). Gauged and ungauged drainage areas and period of gauging for individual rivers.

River and Region	Gauged Drainage Area ($\times 10^3 km^2$)	Ungauged Drainage Area ($\times 10^3 km^2$)	Gauged Period (years)
Region VIa (James Bay-West)			
Ekwan	10.4	14.4	
Attawapiskat	36.0	27.5	
Albany	118.0	15.0	
Moose	60.1	15.9	
Abitibi	27.5	38.7	
Total	252.0	111.5	
Region VIb (James Bay-East)			
Nottaway	57.5	8.0	
Broadback	17.7	3.0	
Rupert	40.9	9.0	
Eastmain	44.3	11.5	
Castor	–	12.0	
LaGrande	96.6	1.3*	
Roggan	–	11.0*	
Total	256.4	43.5*	
Region VII (Ungava Bay and Hudson Strait)			
Baleine	29.8	10.2	
Arnaud	26.9	23.0	
Melezes	42.7	12.3	
George	35.2	12.8	
Caniapiscau	86.8	–	
Feuilles	41.7	14.0	
Hudson Strait	–	24.0	
Total	263.1	96.3	
Region V (Mid. Que.)			
No rivers	–	155.0	

* $12.3 \times 10^3 km^2$ of region VIb is accounted for in Region V.

Table 3. Drift speed and time lag estimates used in synthesizing a total runoff signal.

Region	Drift speed (cm/s)		Time lag to mouth of Hudson Strait (months)	
	base-drift	fast-drift	base-drift	fast-drift
I -SW Hudson Bay	5[i]	20	6	2
II-NW Hudson Bay	5[i]	20	8	3
III-NE Hudson Bay	10[i]	20	1	1
IV-E Hudson Bay	5[i]	20	2	1
V - SE Hudson Bay	10[ii]	20	4	2
VIa-W James Bay	10[ii]	20	6	3
VIb-E James Bay	10[i,ii]	20	5	2
VII-Ungava Bay	30[iv]	30	0	0
VIII-Foxe Basin	30[iii]	50[iii]	2	1

Footnotes on references:
i. Prinsenberg, 1986a; ii. Prinsenberg & Freeman, 1986; iii. Prinsenberg, 1986b;
iv. Drinkwater, 1986.

Table 4. Estimated standard deviation measurement uncertainties in regional time series of runoff.

Region	% of Total Runoff	Fraction of Area Gauged	Est. Uncertainty %
I 74-83	24	.91	3.2
I 72-73		.85	3.3
I 70-71		.68	6.0
I 66-69		.62	6.6
I 63-65		.62	6.7
II 73-83	10	.52	7.5
II 72-72		.21	10.6
II 66-71		.15	16.1
II 63-65		.00	16.4
IV* 63-83	3	.00	25.0
V 66-83	8	.57	3.9
V 64-65		.29	8.9
V 63-63		.23	8.9
VIa 68-83	13	.71	4.9
VIa 66-67		.58	12.6
VIa 63-66		.25	16.4
VIb 82-83	19	.61	4.4
VIb 64-81		.86	2.7
VIb 63-63		.72	3.3
VII 79-83	21	.63	3.2
VII 63-78		.73	3.2
VIII 73-83	3	.00	21.0
VIII 72-72		.00	23.0
VIII 66-71		.00	26.0
VIII 63-65		.00	26.0

* Includes Region III

Table 5. The uncertainties (% of mean) of the total runoff exiting Hudson Strait in 1963 for the fast-drift and base-drift cases.

	Fast-drift	Base-drift
January	13	15
February	12	12
March	13	14
April	26	27
May	17	17
June	22	15
July	15	12
August	15	13
September	12	18
October	13	16
November	14	14
December	15	15

Table 6. Time series data used for correlations. Winter wind anomaly data provided by Dr. K. R. Thompson, Dept. of Oceanography, Dalhousie University, while remaining data by Dr. K. F. Drinkwater, Bedford Inst. of Oceanography.

Year	St. Lawrence RIVSUM 100 m^3/s	Labrador Shelf Wind Anomaly m/s	Station 27 Salinity ‰	Station 27 Temperature °C
1963	84	-0.49	32.04	3.48
1964	86	-3.66	32.25	2.57
1965	89	-5.44	32.14	2.69
1966	100	-6.56	32.09	3.05
1967	106	-2.40	32.01	3.40
1968	102	-2.40	31.95	3.35
1969	109	-2.73	31.96	3.24
1970	106	-2.42	31.58	3.40
1971	102	-4.00	31.73	3.20
1972	114	-0.98	31.95	2.27
1973	127	-2.65	31.87	2.62
1974	127	-3.25	31.77	2.16
1975	110	-2.07	32.11	1.90
1976	123	-0.29	32.06	2.84
1977	106	-4.23	31.86	3.11
1978	110	-4.42	32.00	3.07
1979	118	-2.48	32.04	3.26
1980	113	-2.72	32.03	2.53
1981	115	-	31.92	3.37
1982	106	-	32.12	3.18
1983	115	-	31.75	3.25

Table 7. Statistics for comparison regional and total runoffs rates with St. Lawrence runoff shown in Figures 13 to 16.

	St. Lawrence	Prairies Region I	Ungava Bay Region VII	James Bay Region VIb	Hudson Strait Fast-drift
Mean (100m^3/s)	108.00	59.20	55.70	52.90	269.70
Variance (10^{4}m^6/s^2)	132.25	89.20	37.21	56.25	428.00
C. of Variance	0.11	0.15	0.11	0.14	0.08
% Std. Dev. Unc. (/yr)	–	2.00	1.00	1.00	5.00
Signal/Noise	–	7.50	10.00	12.00	1.60
Correlation*	1.0	0.24	-0.37	-0.05	-0.07
Data in Figure	13-16	13	14	15	16

* with RIVSUM

Table 8. Statistics for comparison Labrador Shelf parameters and Hudson Strait fresh-water flux (fast-drift) as shown in Figures 17 to 19.

	Hudson Strait Fast-drift	Station 27 Temperature	Station 27 Salinity	Labrador Shelf NW Wind
Mean	268.7×100 m^2/s	2.95°C	31.96	-2.96m/s
Variance	428.0×10^4	0.20	0.02	2.43
C. of Variance	0.08	0.15	0.004	-0.53
Correlation*	1.00	-0.11	-0.08	-0.43
See Figure	–	19	18	17

* with Fast-drift Hudson Strait freshwater flux.

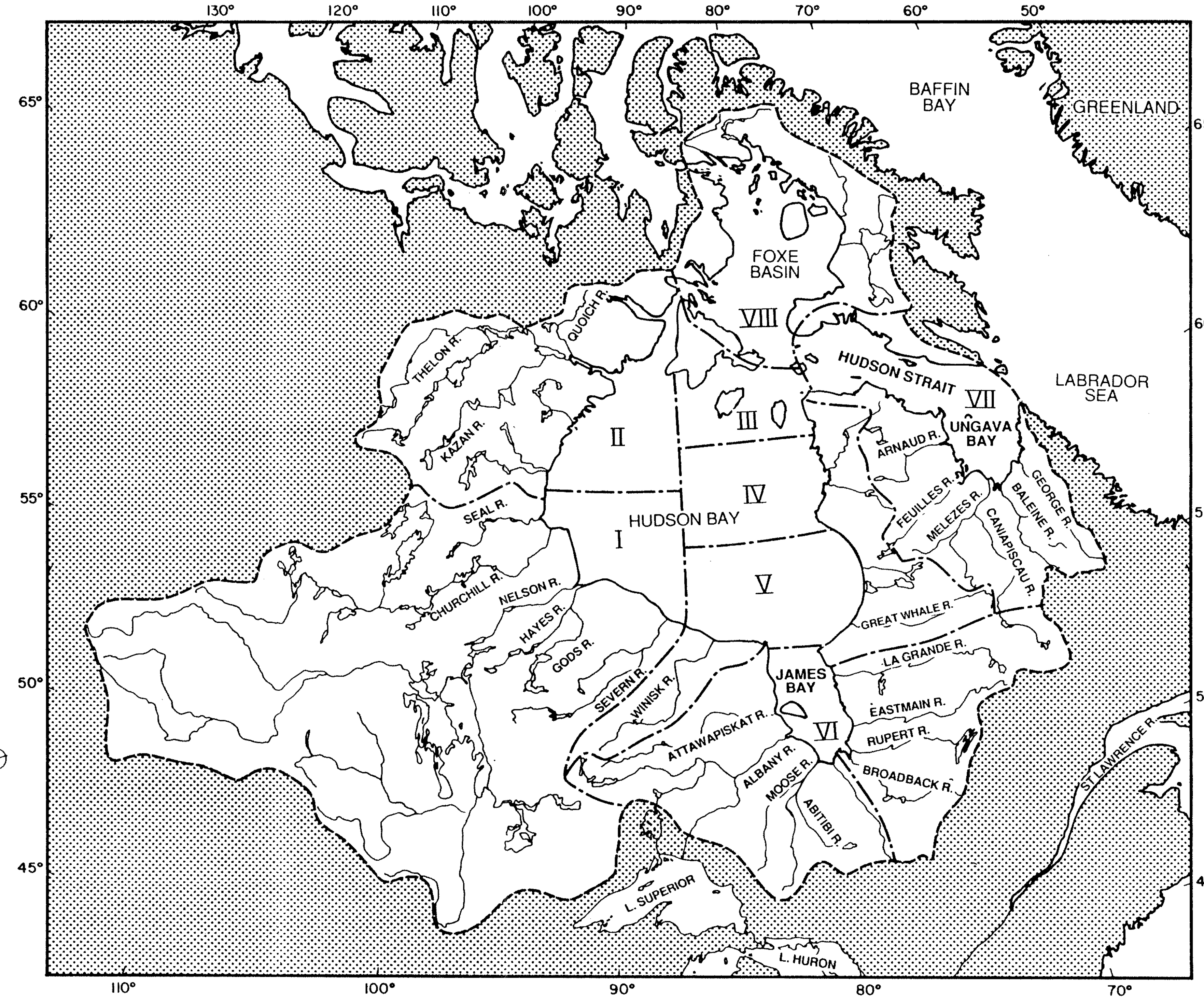


Figure 1. Map of Hudson Bay drainage areas and receiving seawater regions.

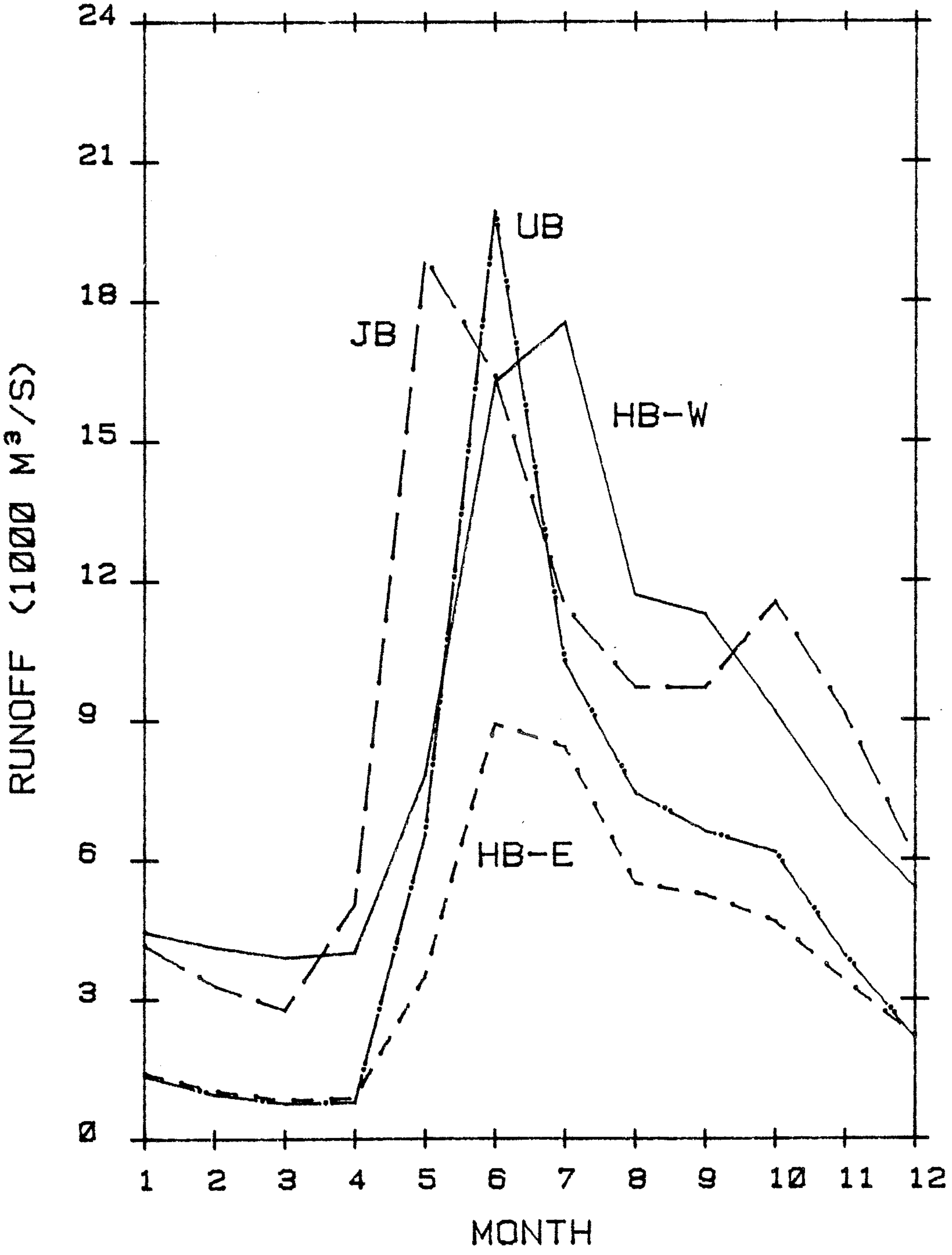


Figure 2. Twenty-one year averaged monthly runoff cycles for James Bay (JB), western Hudson Bay (HB-W), eastern HudsonBay (HB-E) and Ungava Bay (UB).

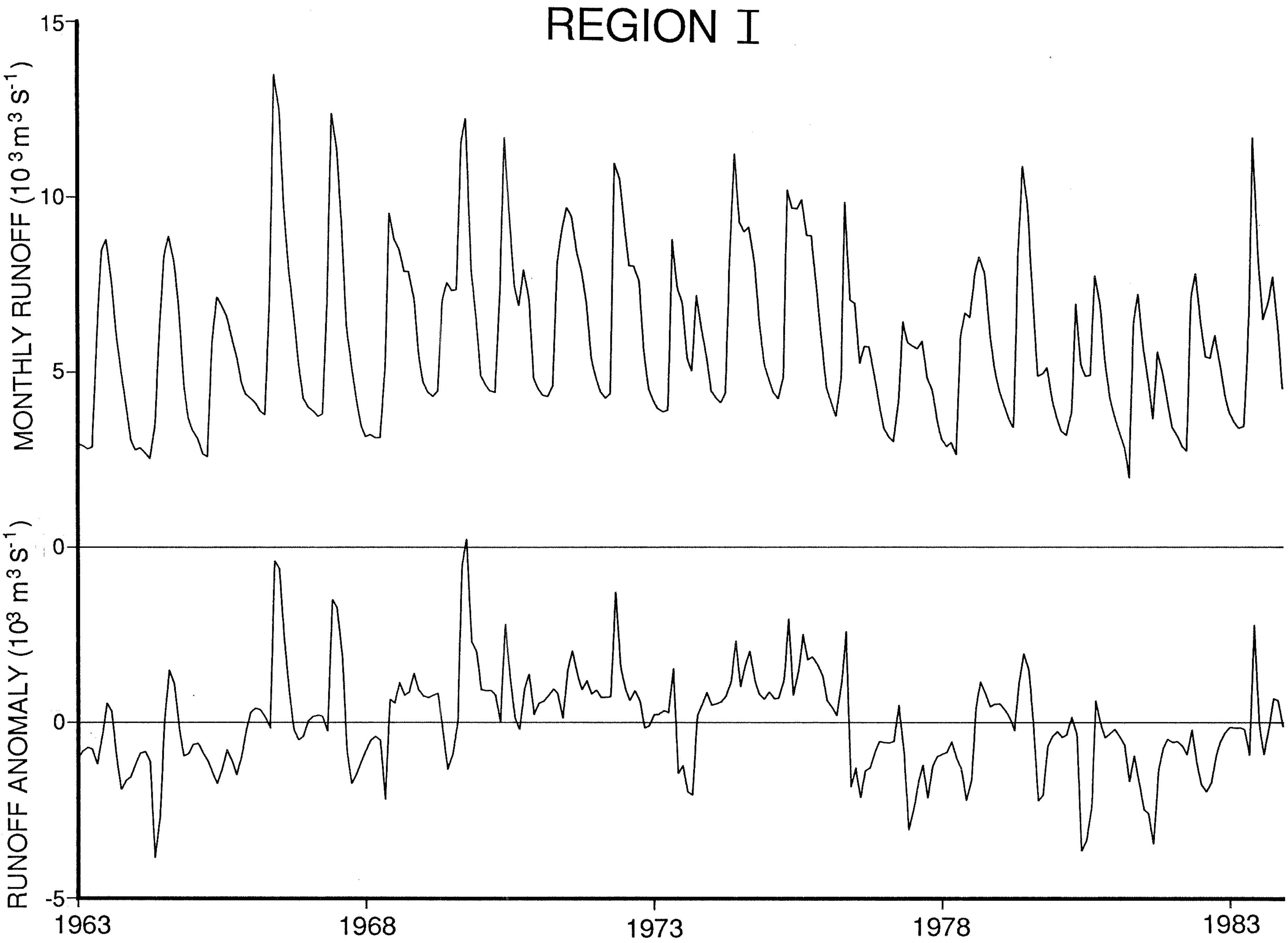


Figure 3. Monthly runoff and anomaly of Region I, southwestern Hudson Bay for 1963-1983.

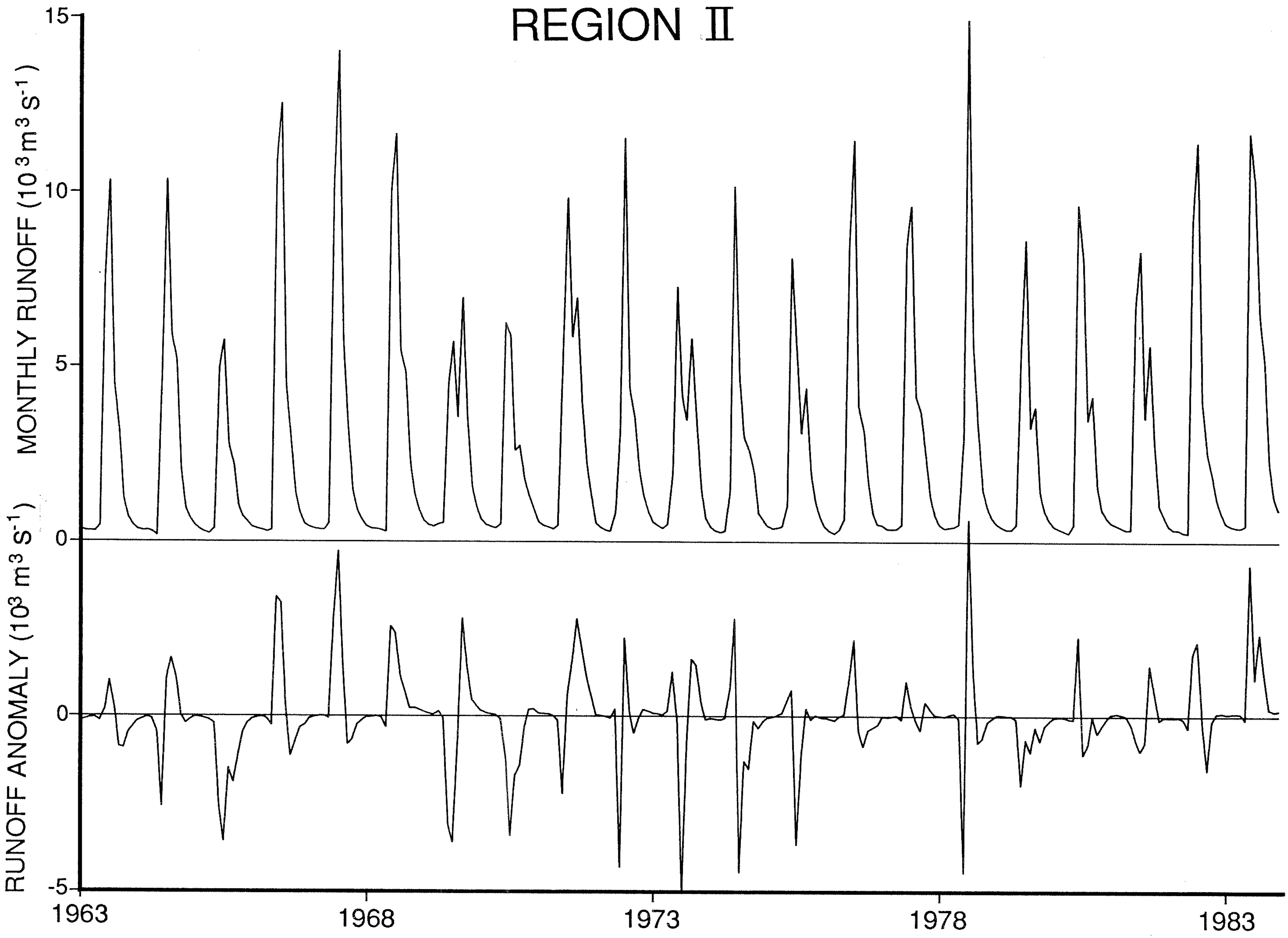


Figure 4. Monthly runoff and anomaly of Region II, northwestern Hudson Bay for 1963-1983.

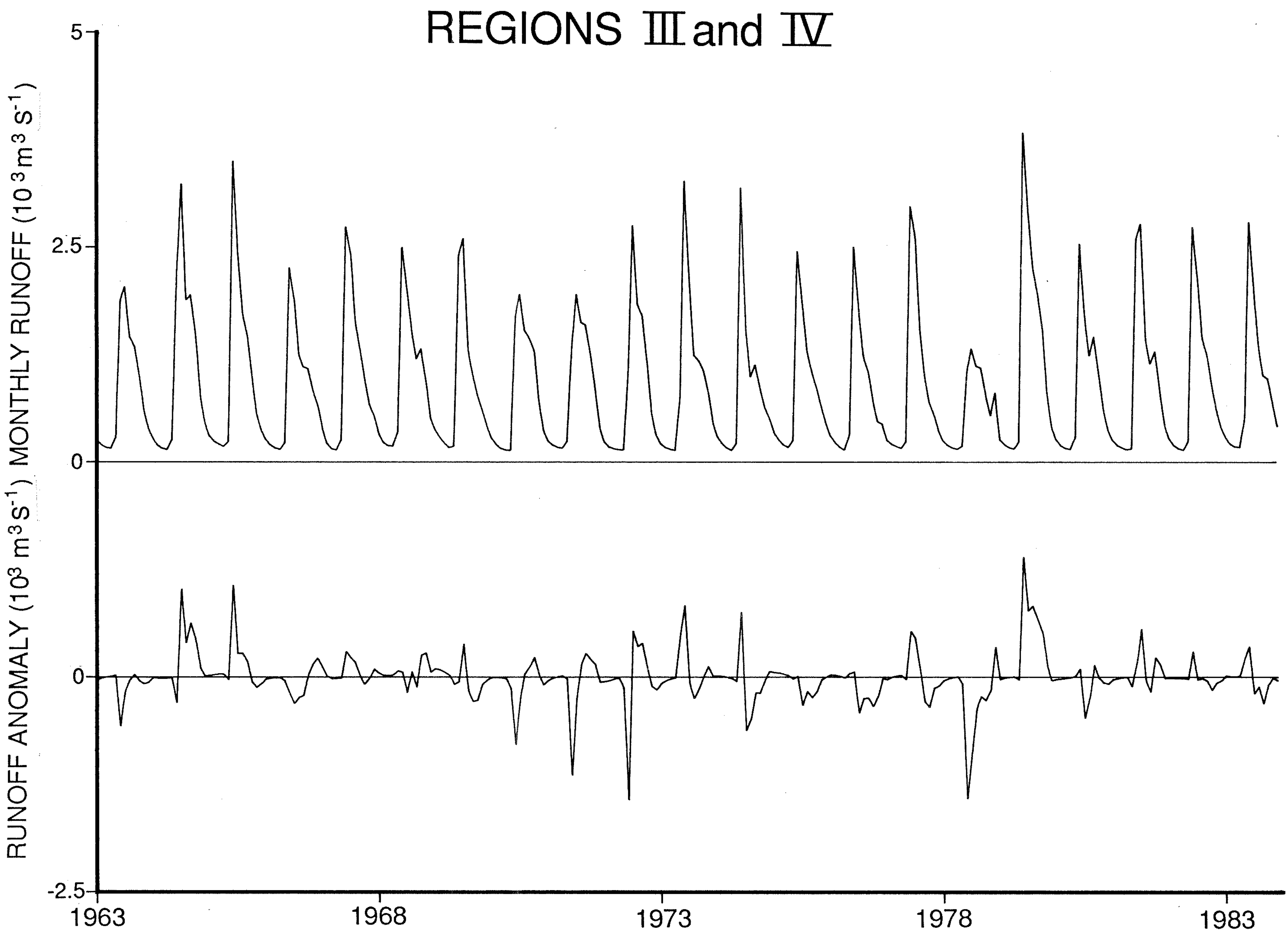


Figure 5. Monthly runoff and anomaly of Regions III and IV, northeastern and eastern Hudson Bay for 1963-1983.

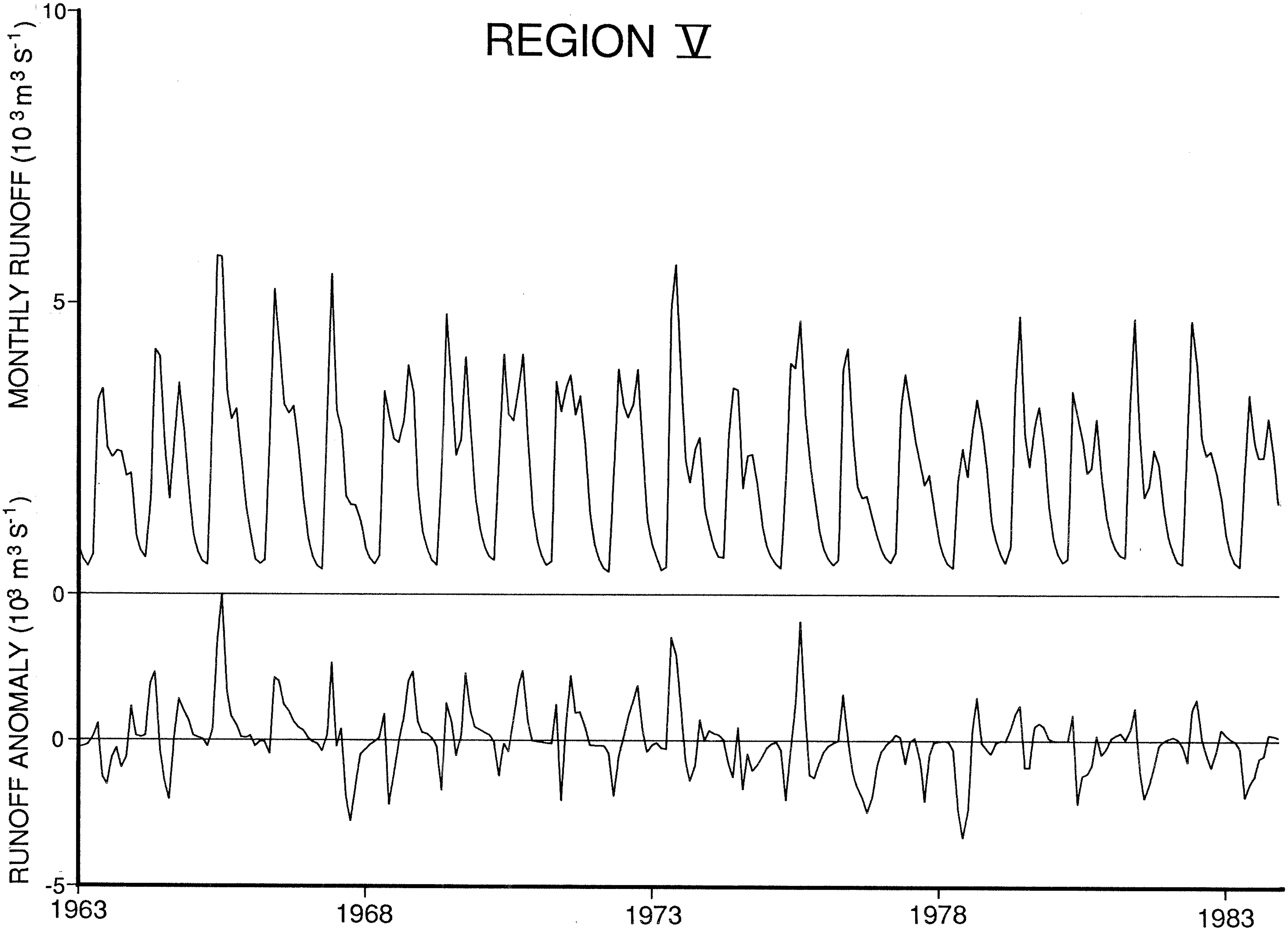


Figure 6. Monthly runoff and anomaly of Region V, southeastern Hudson Bay for 1963-1983.

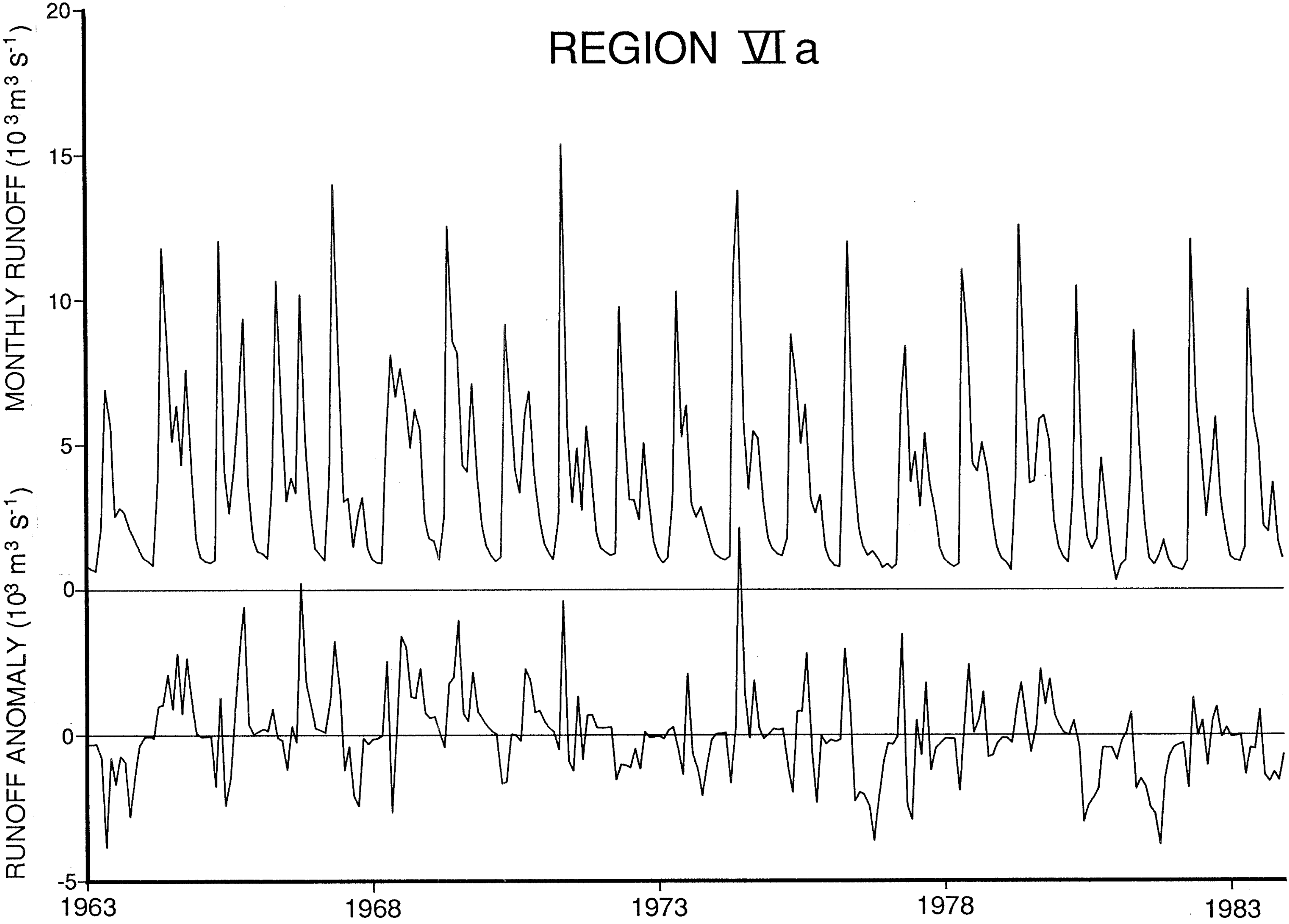


Figure 7. Monthly runoff and anomaly of Region VIa, western James Bay for 1963-1983.

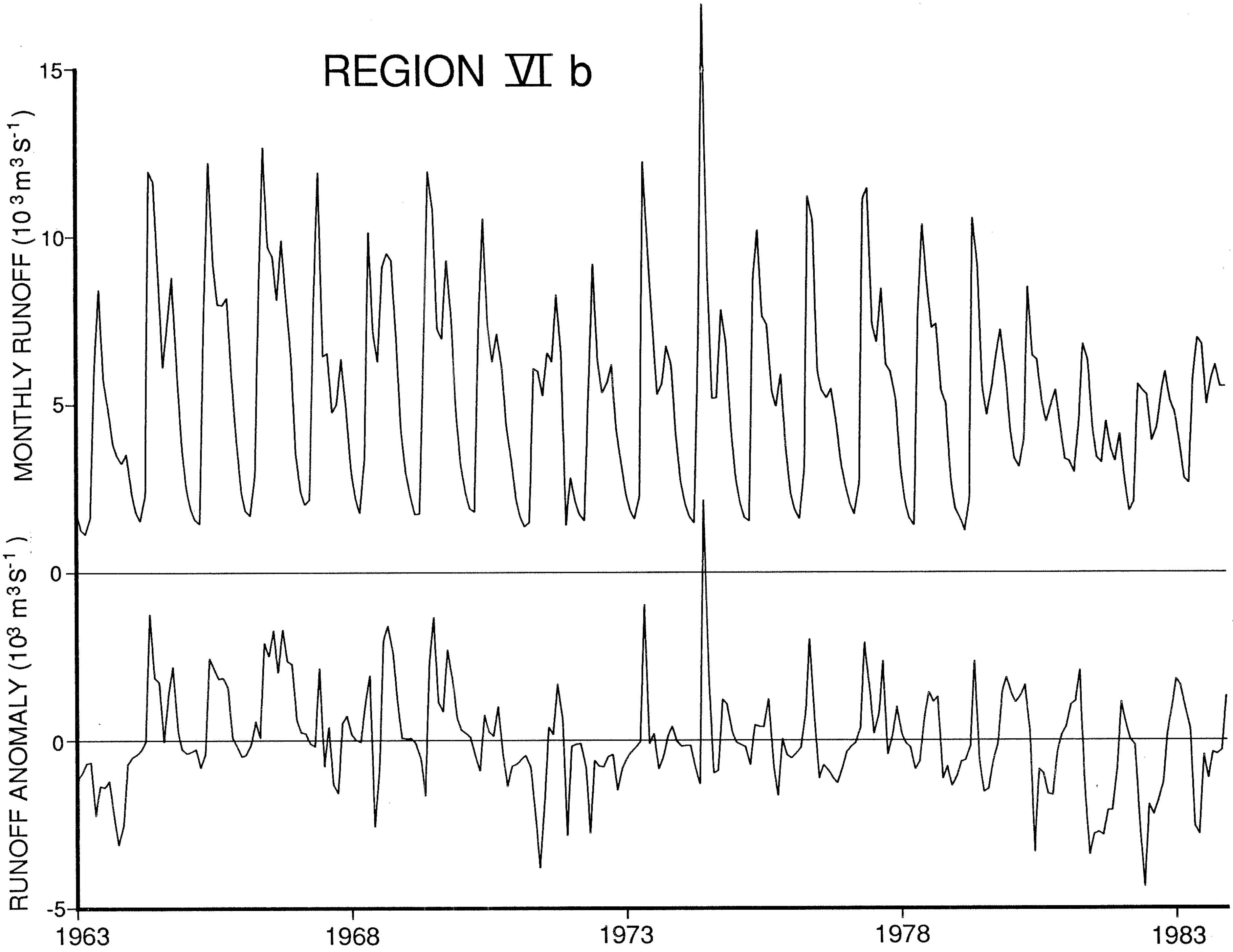


Figure 8. Monthly runoff and anomaly of Region VIb, eastern James Bay for 1963-1983.

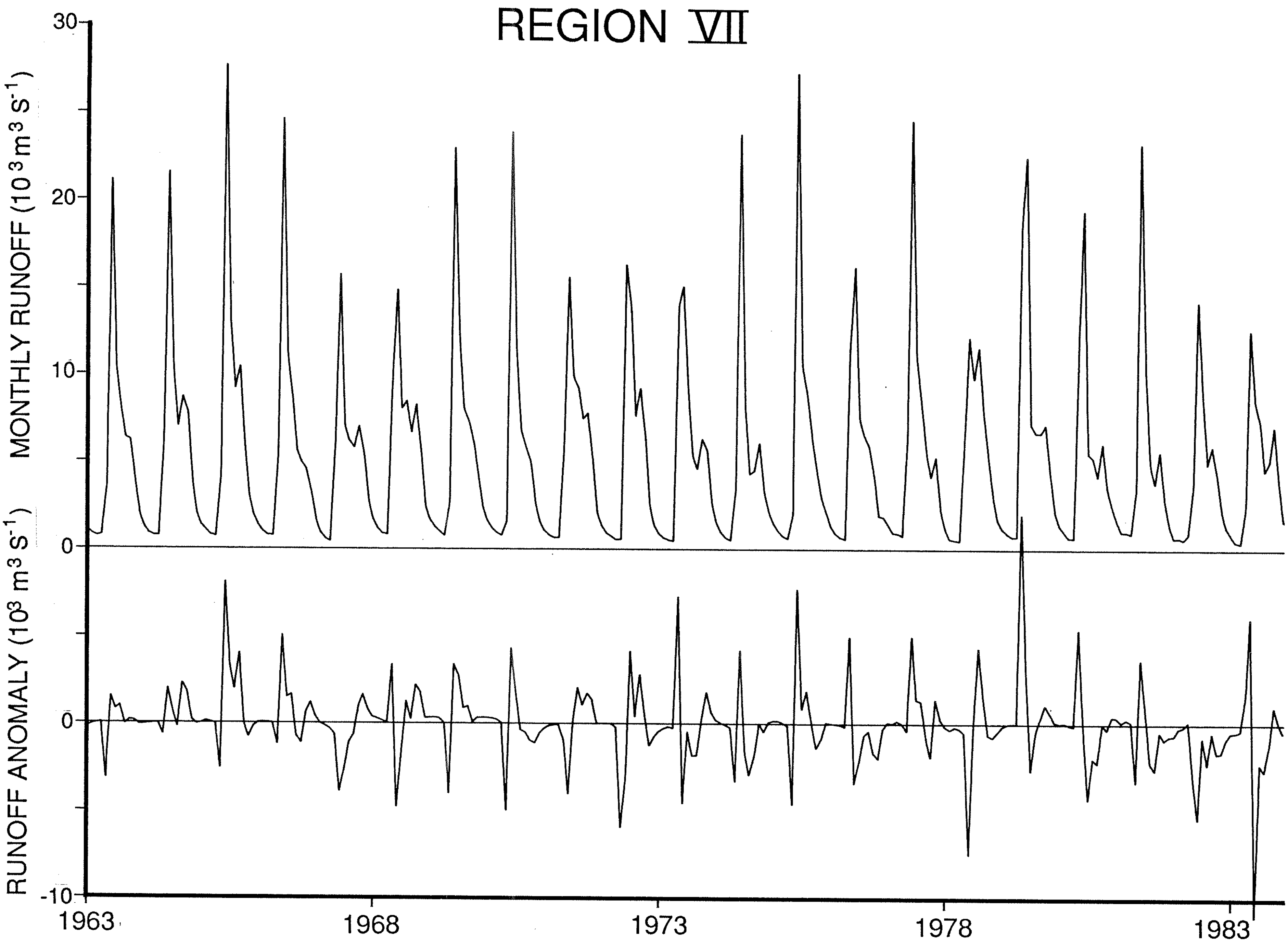


Figure 9. Monthly runoff and anomaly of Region VII, Ungava Bay for 1963-1983.

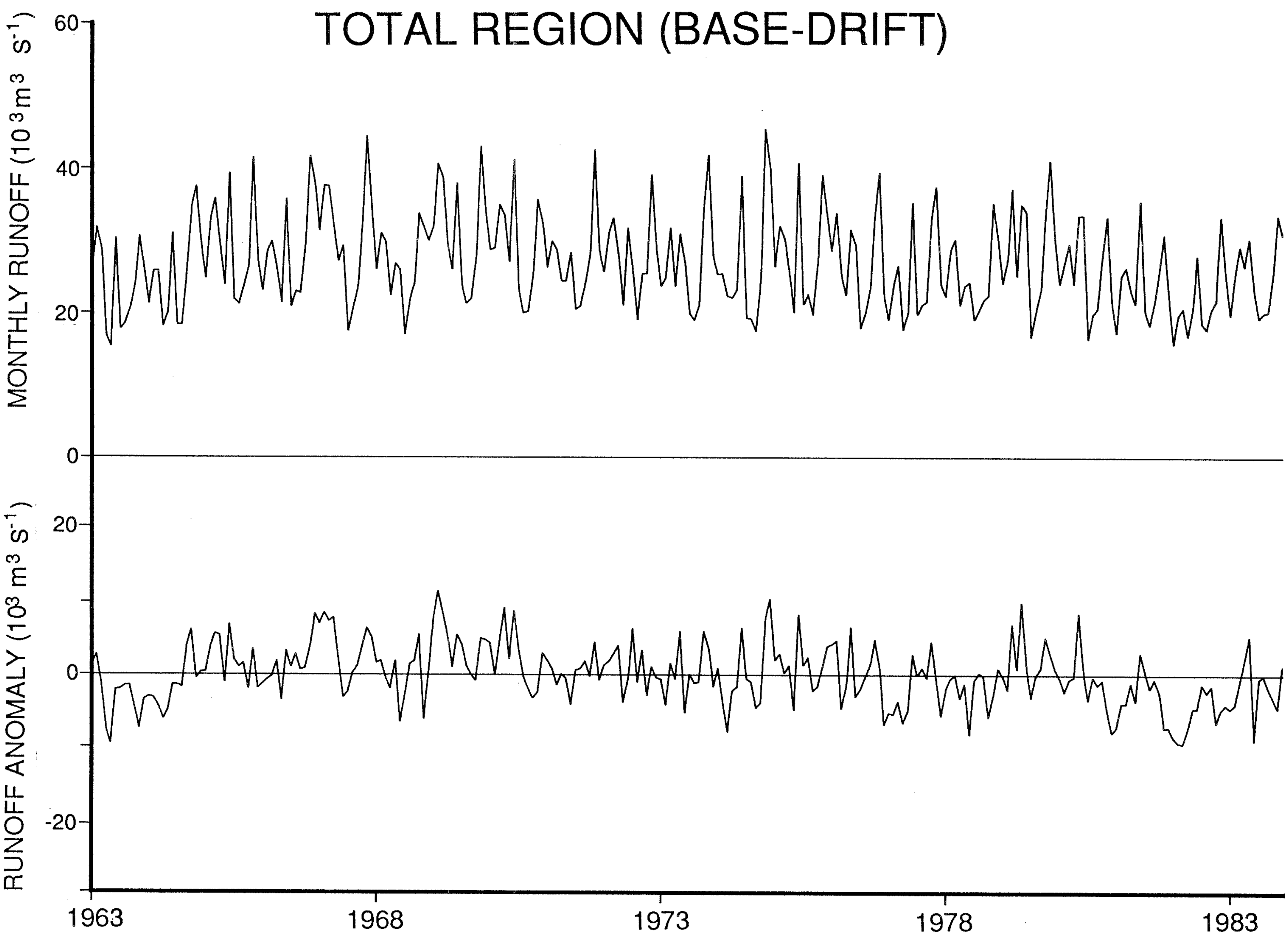


Figure 10. Monthly runoff and anomaly of the base-drift case for 1963-1983.

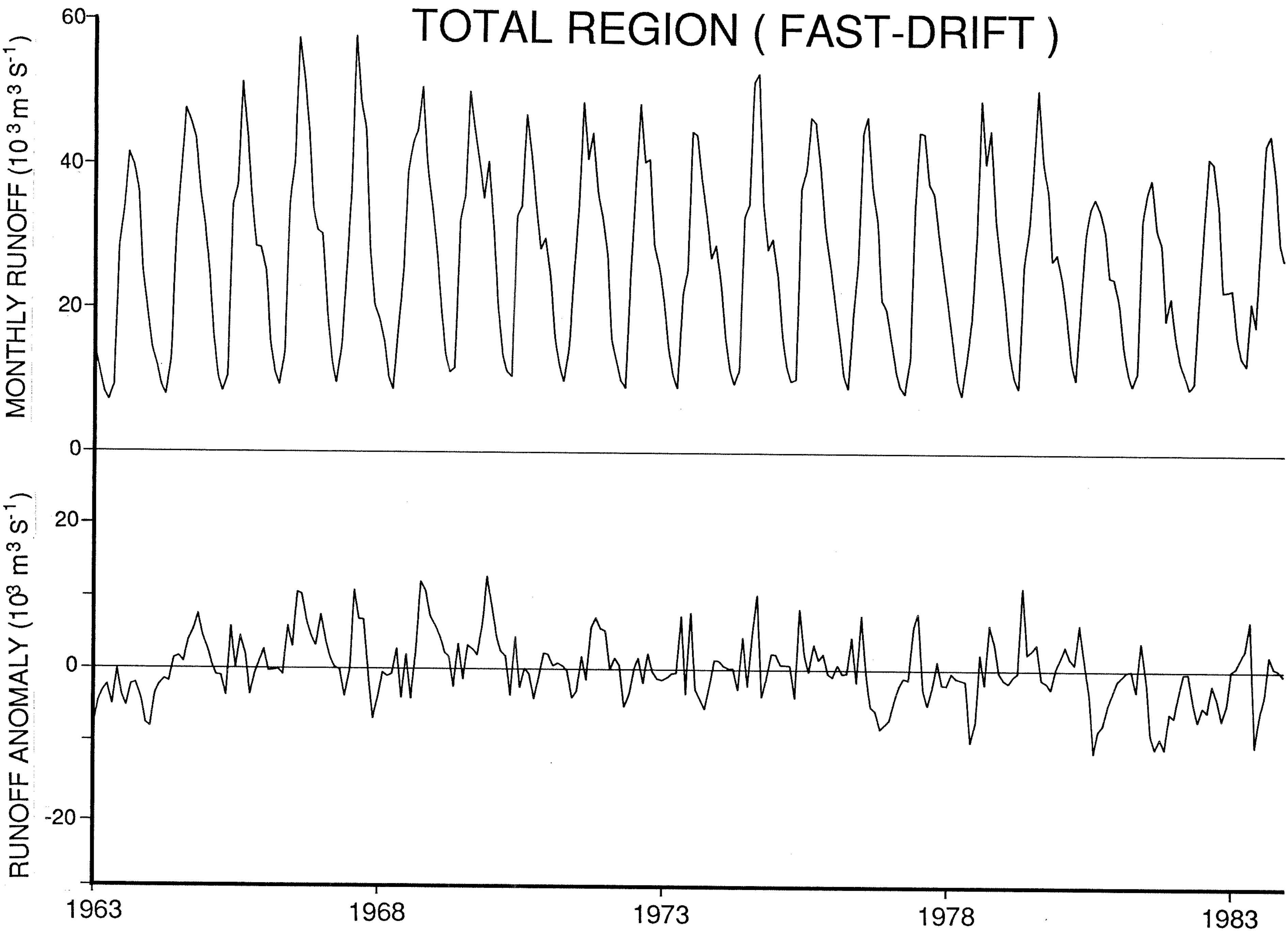


Figure 11. Monthly runoff and anomaly of the fast-drift case for 1963-1983.

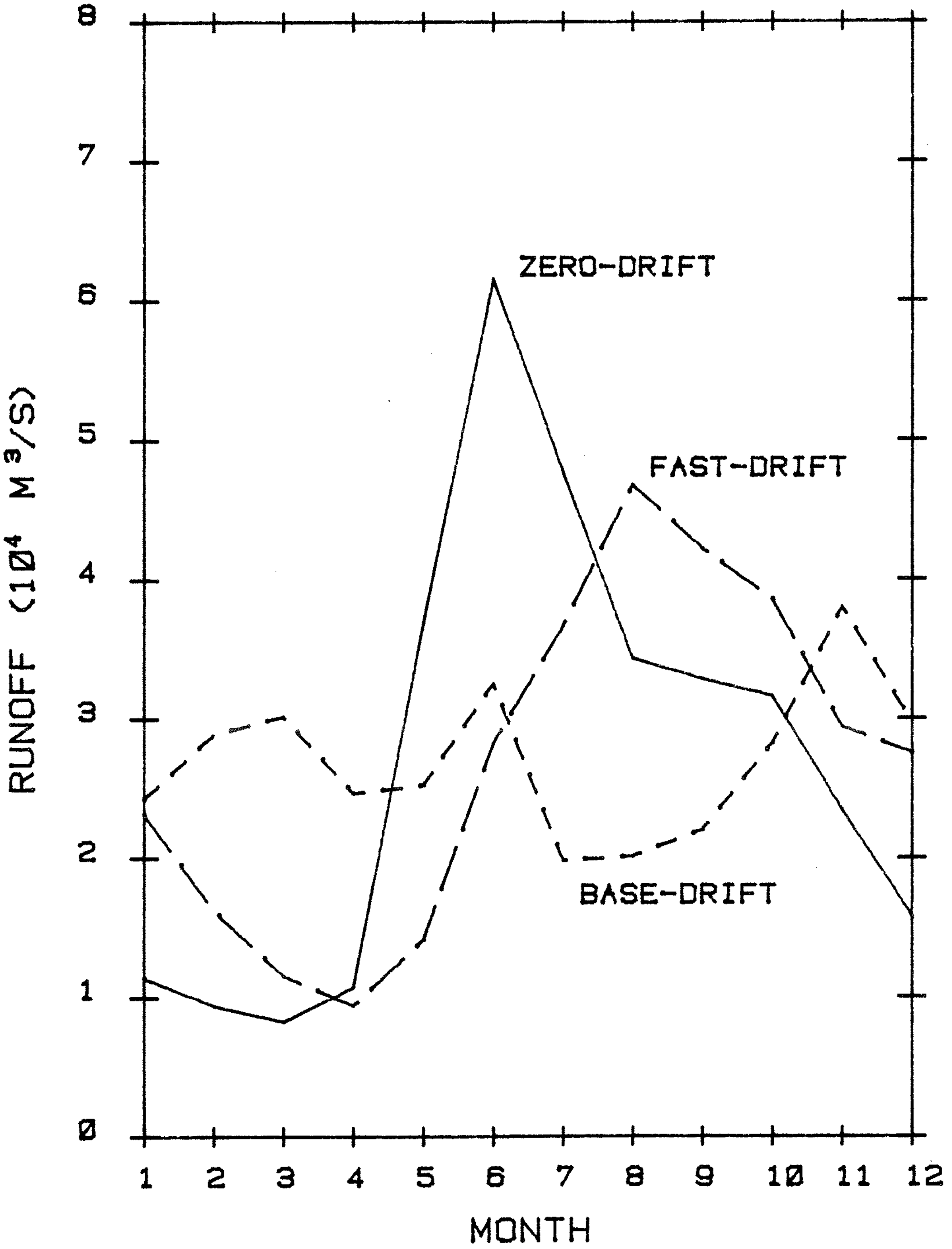


Figure 12. Monthly runoff cycle (21-year average) for the zero-drift, base-drift and fast-drift cases.

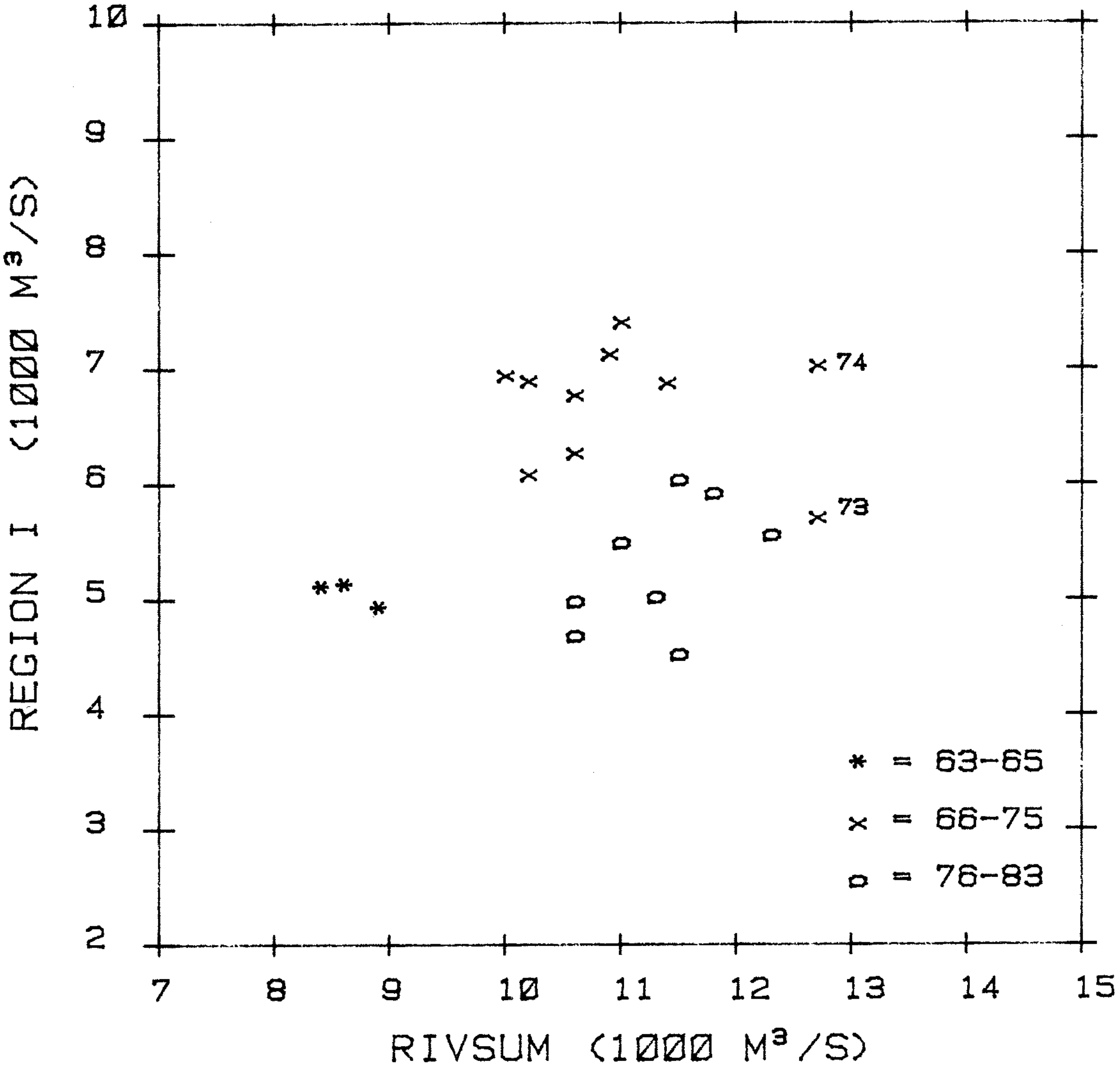


Figure 13. Scatter diagrams of annual averaged runoffs of Region I, southwestern Hudson Bay, and St. Lawrence River (RIVSUM) for 1963-1983.

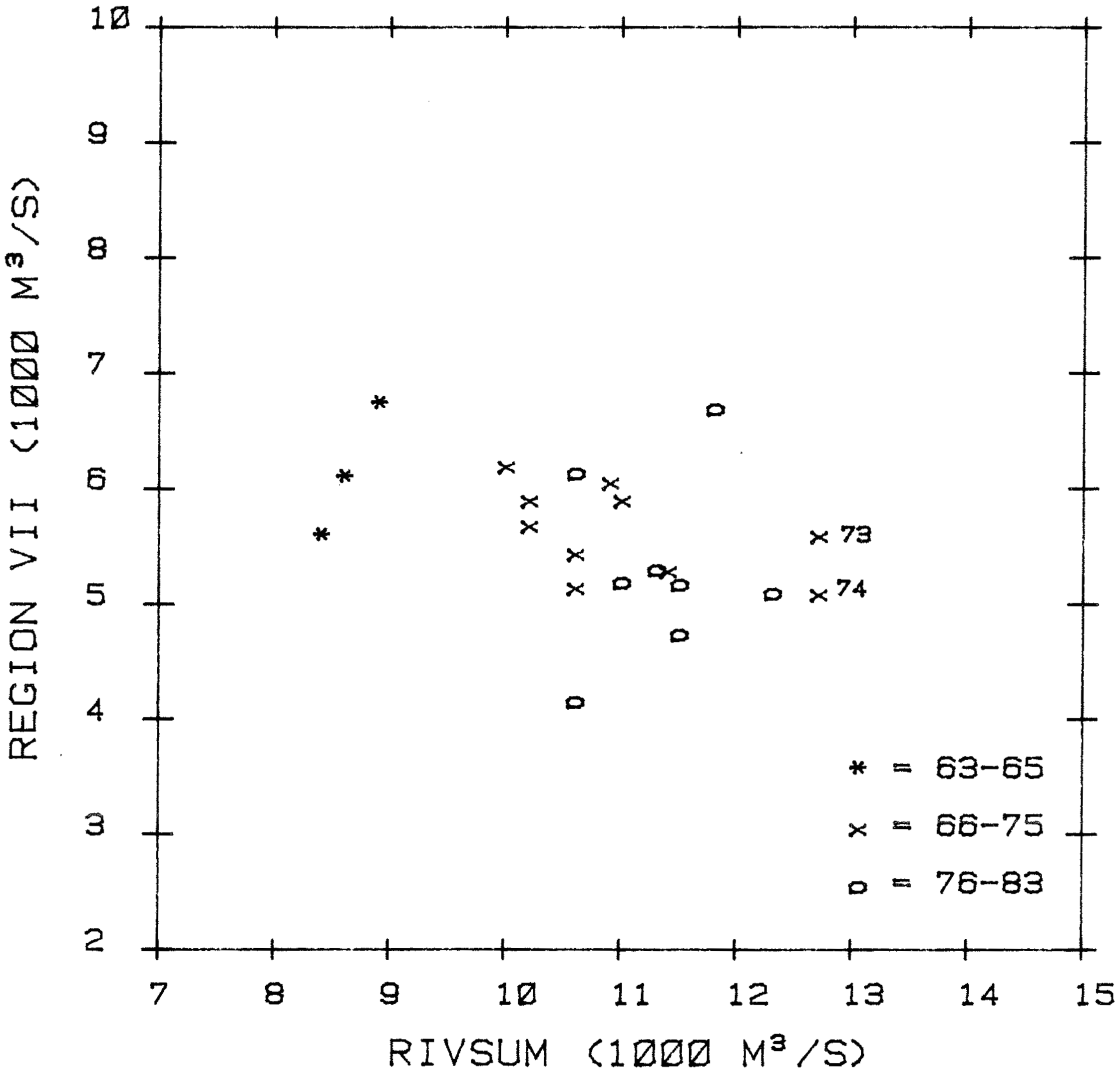


Figure 14. Scatter diagram of annual averaged runoff of Region VII, Ungava Bay and St. Lawrence River (RIVSUM) for 1963-1983.

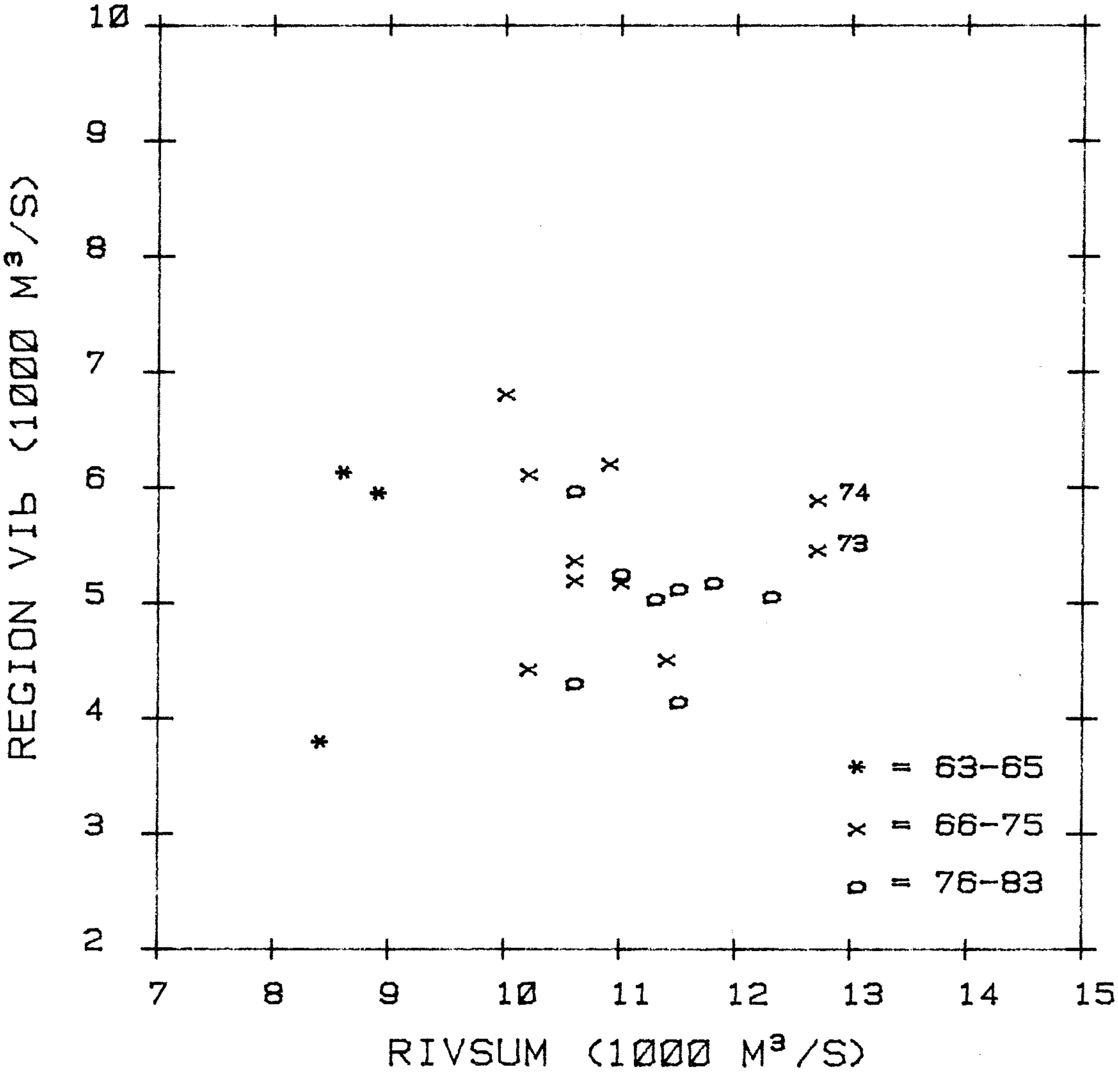


Figure 15. Scatter diagram of annual averaged runoffs of Region VIb (eastern James Bay) and St. Lawarence River (RIVSUM) for 1963-1983.

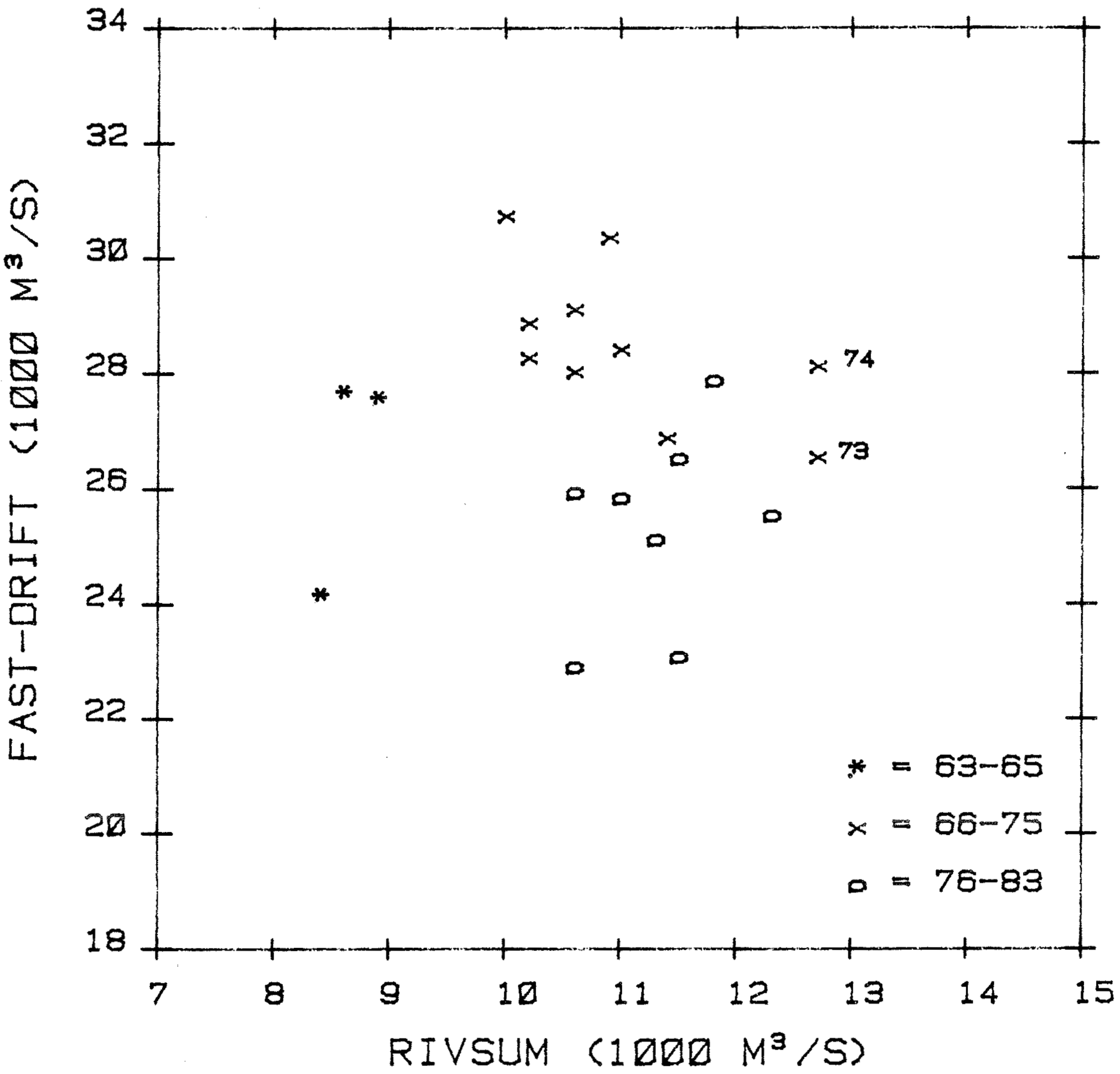


Figure 16. Scatter diagram of annual averaged runoffs of fast-drift case and St. Lawrence River (RIVSUM) for 1963-1983.

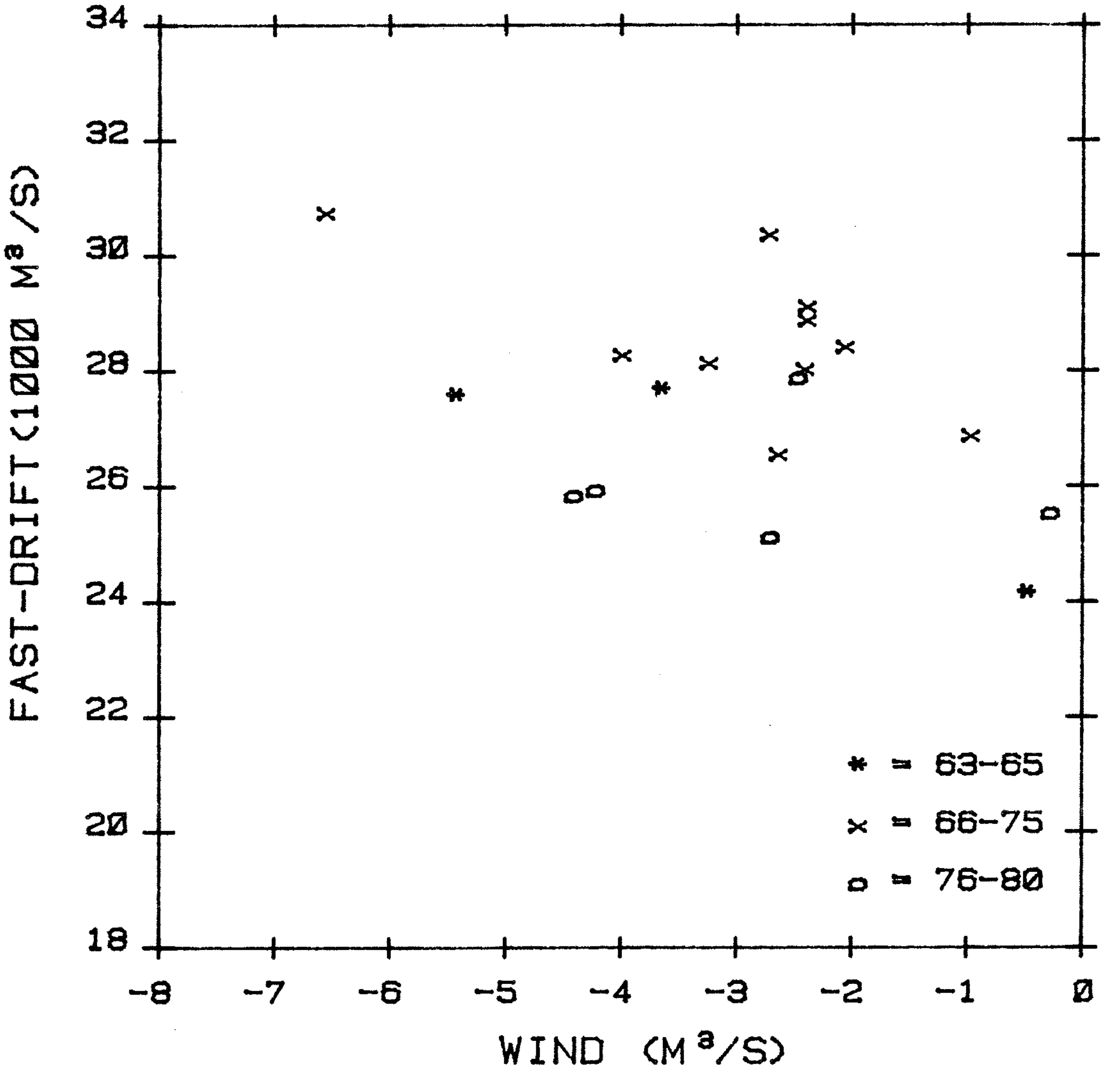


Figure 17. Scatter diagram of annual averaged runoffs of fast-drift case and average winter geostrophic wind anomaly over the Labrador Shelf.

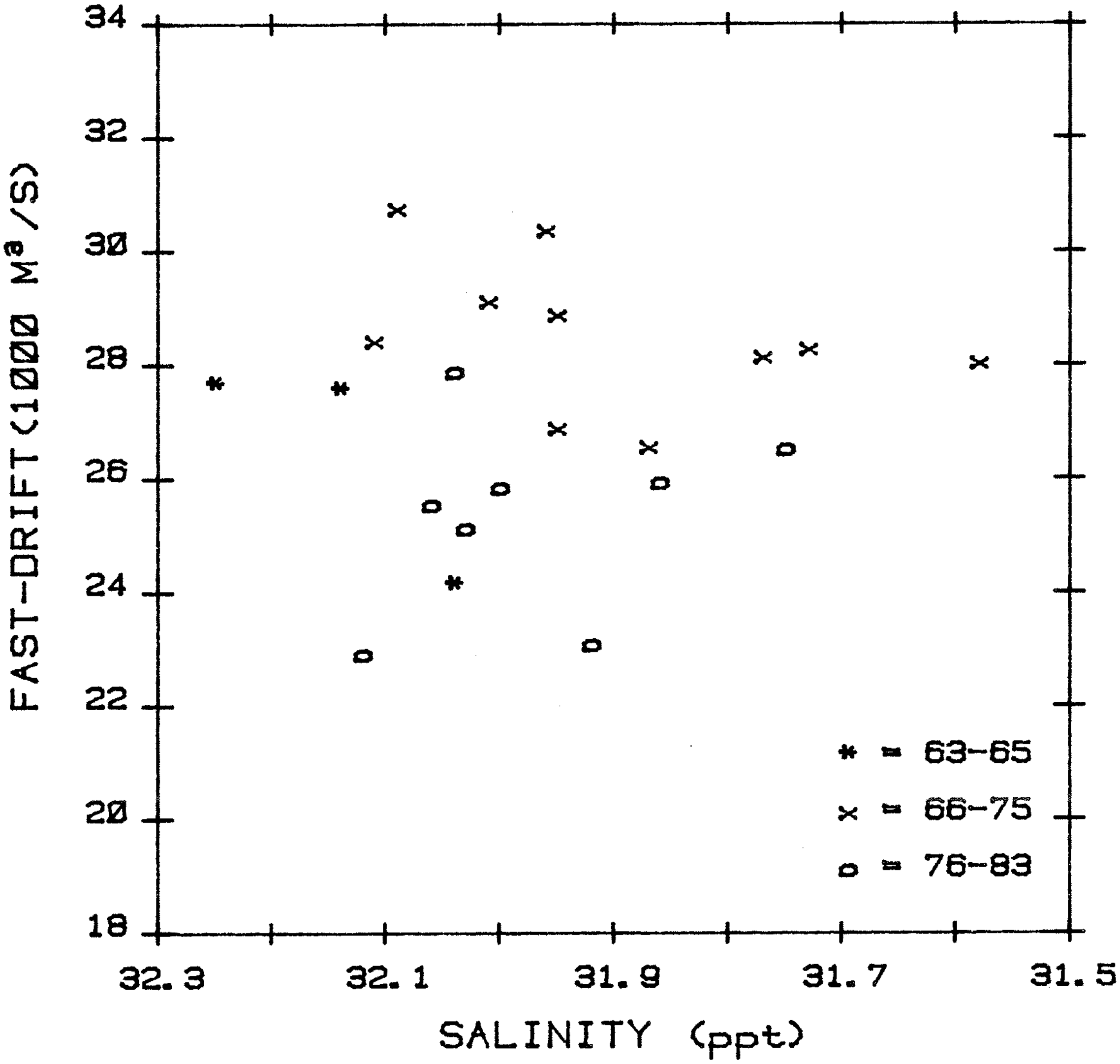


Figure 18. Scatter diagram of annual averaged runoffs of fast-drift case and salinity values at Station 27.

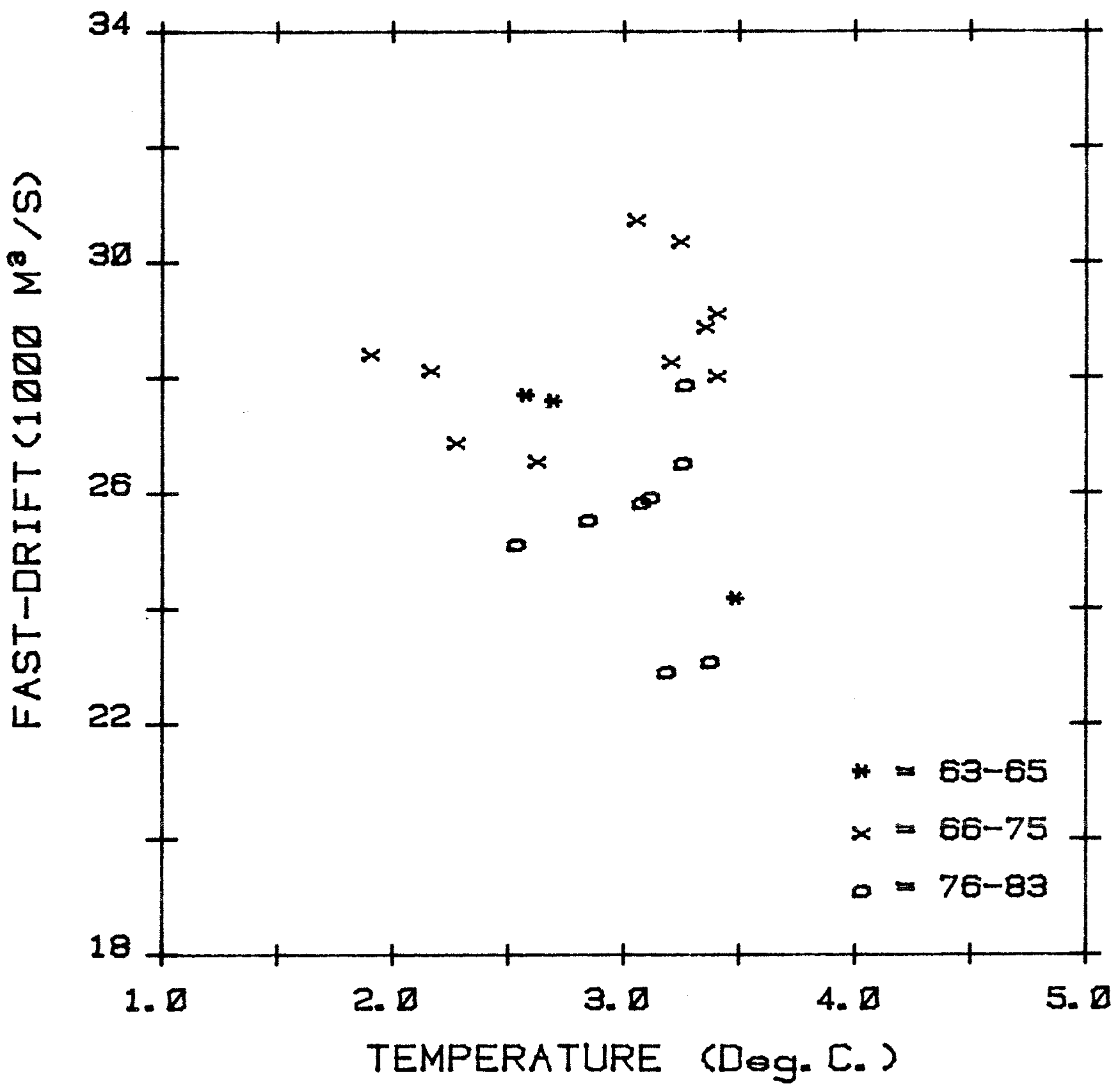


Figure 19. Scatter diagram of annual averaged runoffs of fast-drift case and temperature at Station 27 (10-50 m).

Appendix A. Tables of estimated uncertainties and monthly discharge factors.

Table A.1. Monthly standard deviation uncertainties* (%) of rivers or their substitutes contributing to runoff of Region I .

	63-65	66-69	70-71	72-73	74-83
Nelson	5	5	5	5	5
Seal	5/15	5/15	5/15	5/15	5/15
Churchill	30/Seal	30/Seal	30/Seal	5	5
Hayes	34/Seal	34/Seal	15/Gods	15/Gods	5
Gods	5/15	5/15	5/15	5/15	5/15
Severn	25/Seal	15/Winisk	5/15	5/15	5/15
Total (Table 4)	6.7	6.6	6.0	3.3	3.2

* The second uncertainty refers to ungauged area.

Table A.2. Monthly standard deviation uncertainties (%) of rivers on their substitutes contributing to runoff of Region II.

	63-65	66-71	72	73-83
Thelon	25/Seal	25/Seal	25/Seal	5
Kazan	20/Seal	5	5	5
Quoich	25/29/Seal	25/29/Seal	5/15	5/15
Total (Table 4)	16.4	16.1	10.6	7.5

Table A.3. Monthly standard deviation uncertainties (%) of rivers or their substitutes contributing to runoff of Region III and IV.

	63	64-83
Northern Rivers	25/Little Whale	25/Little Whale
Southern Rivers	25/Arnaud	25/Arnaud
Total	25	25

Table A.4. Monthly standard deviation uncertainties (%) of rivers or their substitutes contributing to runoff of Region V.

	63	64-65	66-83
Denys	5	5	5
Great Whale	5/15	5/15	5/15
Little Whale	10/18/G. Whale	5/15	5/15
Winisk	25/29/G. Whale	25/29/G. Whale	5/15
Total	8.9	8.9	3.9

Table A.5. Monthly standard deviation uncertainties (%) of rivers or their substitutes contributing to runoff of Region VIa.

	63-66	66-67	68-83
Ekwan	35/ Moose	29/Albany	5
Attawapiskat	35/ +	29/Albany	5/15
Albany	20/ Abitibi	5	5
Moose	5	5	5
Abitibi	5	5	5
Total	16.4	12.6	4.9

Table A.6. Monthly standard deviation uncertainties (%) of rivers or their substitutes contributing to runoff of Region VIb.

	63	64-81	82-83
Nottaway	5	5	10/Rupert
Broadback	5/15	5/15	10/Rupert
Rupert	15/Broadback	5	5
Eastmain	5	5	5
LaGrande	5	5	5
Total	3.3	2.7	4.4

Table A.7. Monthly discharge ratios for river substitutions.

Month	Region I					Region V	
	Seal for Churchill	Gods for Hayes	Winisk for Severn	Seal for Severn	Seal for Gods	G. Whale For Winisk	G. Whale For L. Whale
Jan.	3.76	1.49	1.49	1.91	1.40	0.76	0.22
Feb.	4.63	1.45	1.58	1.87	1.62	0.77	0.23
Mar.	5.46	1.43	1.70	1.92	1.87	0.75	0.24
Apr.	4.36	1.35	1.38	1.80	2.15	0.97	0.20
May	2.03	1.58	1.57	2.85	1.94	1.12	0.10
June	1.48	1.72	1.58	1.73	0.88	0.77	0.20
July	1.55	1.54	1.50	1.53	0.79	0.81	0.19
Aug.	1.97	1.52	1.67	1.74	0.90	0.80	0.19
Sept.	2.13	1.52	1.55	1.70	1.06	0.79	0.20
Oct.	2.22	1.45	1.28	2.05	1.31	0.95	0.20
Nov.	2.44	1.36	1.28	2.24	1.30	0.86	0.22
Dec.	2.73	1.44	1.46	2.10	1.26	0.72	0.21

	Region II			Region VIa		Region VIb
	Seal for Thelon	Seal for Quoich	Seal for Kazan	Albany for Ekwan & 4x Attawa-spiskat	Moose and Abitibi for Albany	Rupert for Nottaway& 3x Broadback
Jan.	2.01	0.04	0.73	1.98	0.49	1.50
Feb.	2.07	0.03	0.73	1.72	0.44	1.40
Mar.	2.33	0.04	0.81	1.52	0.35	1.40
Apr.	2.02	0.04	0.83	0.66	0.45	1.90
May	0.83	0.04	0.46	1.26	0.73	3.40
June	2.56	0.72	1.25	1.70	0.85	3.20
July	2.92	0.98	1.70	1.76	1.00	2.50
Aug.	2.08	0.47	1.56	1.98	1.62	2.00
Sept.	1.77	0.60	1.29	2.22	1.24	2.00
Oct.	1.73	0.27	1.02	1.99	1.12	2.20
Nov.	1.89	0.13	0.94	2.05	0.89	2.10
Dec.	1.96	0.07	0.86	2.40	0.52	1.90

Appendix B. Tables and plots of monthly runoff rates for subregions.

Monthly runoff rates for each of the subregions of the total Hudson Bay-Hudson Strait drainage area are listed in table format and shown by time-series plots. Rates are listed for the period of January 1963 to December 1983 along with the 21-year historical means and yearly means. Total runoff rates (sum of all regions) are given by files 10, 11 and 12 as a zero-drift, base-drift and fast-drift scenarios using the phase lags for each subregion as listed below the tables. The tables and figures are found at:

Subregion	Region #	File #	Pages
Hudson Bay SW	I	1	50-51
Hudson Bay NW	II	2	52-53
Hudson Bay NE	III	3	54-55
Hudson Bay E	IV		
Hudson Bay SE	V	5	56-57
James Bay W	VIa	6	58-59
James Bay E	VIb	7	60-61
Ungava Bay	VII	8	62-63
Foxe Basin	VIII	9	64-65
Total (Zero-drift)	–	10	66-67
Total (Base-drift)	–	11	68-69
Total (Fast-drift)	–	12	70-71

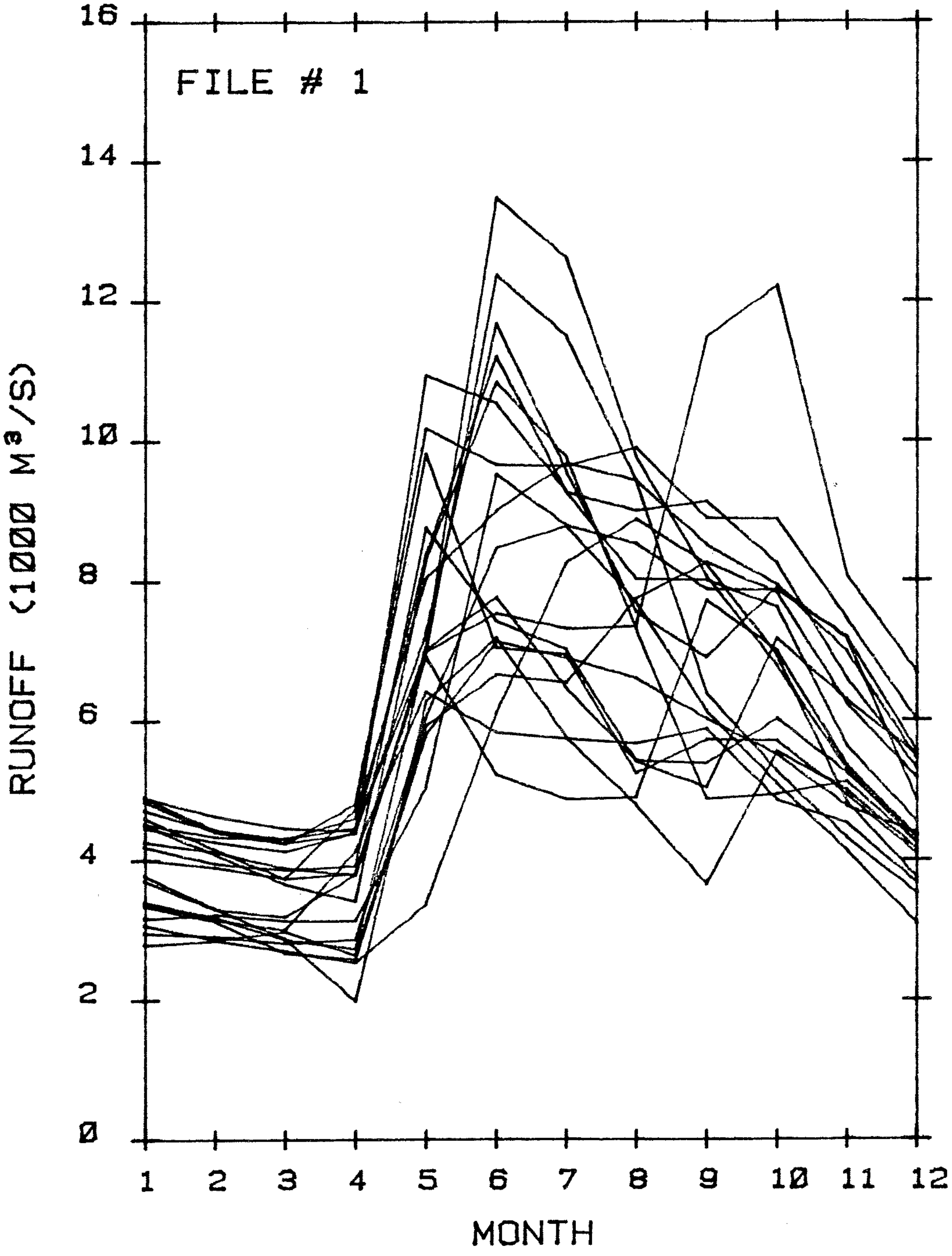


Figure B-1. Runoff cycles of 1963 to 1983 for SW Hudson Bay, Region I .

Table B-1, Monthly Runoff Rates for SW Hudson Bay, Region I.

FILE # 1 (Rates in 10 cubic meters per second)

YR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
63	295	291	281	287	604	847	878	769	613	509	413	309	508
64	278	285	270	253	338	611	826	888	823	692	483	374	510
65	334	312	267	258	580	714	690	660	602	550	476	438	490
66	426	412	389	379	706	1348	1261	977	805	678	528	425	694
67	401	390	373	381	698	1238	1149	943	639	526	431	352	627
68	317	322	313	314	505	953	878	852	787	786	718	554	608
69	471	443	431	447	699	754	731	735	1148	1222	807	667	713
70	489	463	446	442	725	1168	956	755	689	791	716	485	677
71	452	433	430	460	804	900	968	943	850	793	698	544	690
72	489	444	425	439	1094	1053	927	802	800	762	563	454	688
73	419	396	387	392	876	743	701	541	503	717	628	549	571
74	446	427	413	441	836	1121	926	899	913	824	659	530	703
75	484	441	424	482	1018	966	964	990	888	887	745	598	740
76	460	416	373	474	982	704	694	524	572	570	493	409	556
77	339	315	300	415	642	583	574	567	588	485	452	367	469
78	307	287	298	264	593	666	654	774	826	782	623	516	549
79	451	409	366	342	831	1084	976	731	487	494	512	424	592
80	370	330	319	380	692	523	487	490	772	699	535	432	502
81	378	331	288	198	628	719	576	479	365	555	499	415	452
82	340	319	287	273	701	778	646	542	538	603	523	433	499
83	383	356	338	344	631	1166	830	648	690	768	640	452	604
AVG	397	372	353	365	723	888	823	738	709	700	578	463	592
StD	67	59	60	82	172	231	190	164	174	167	111	86	89

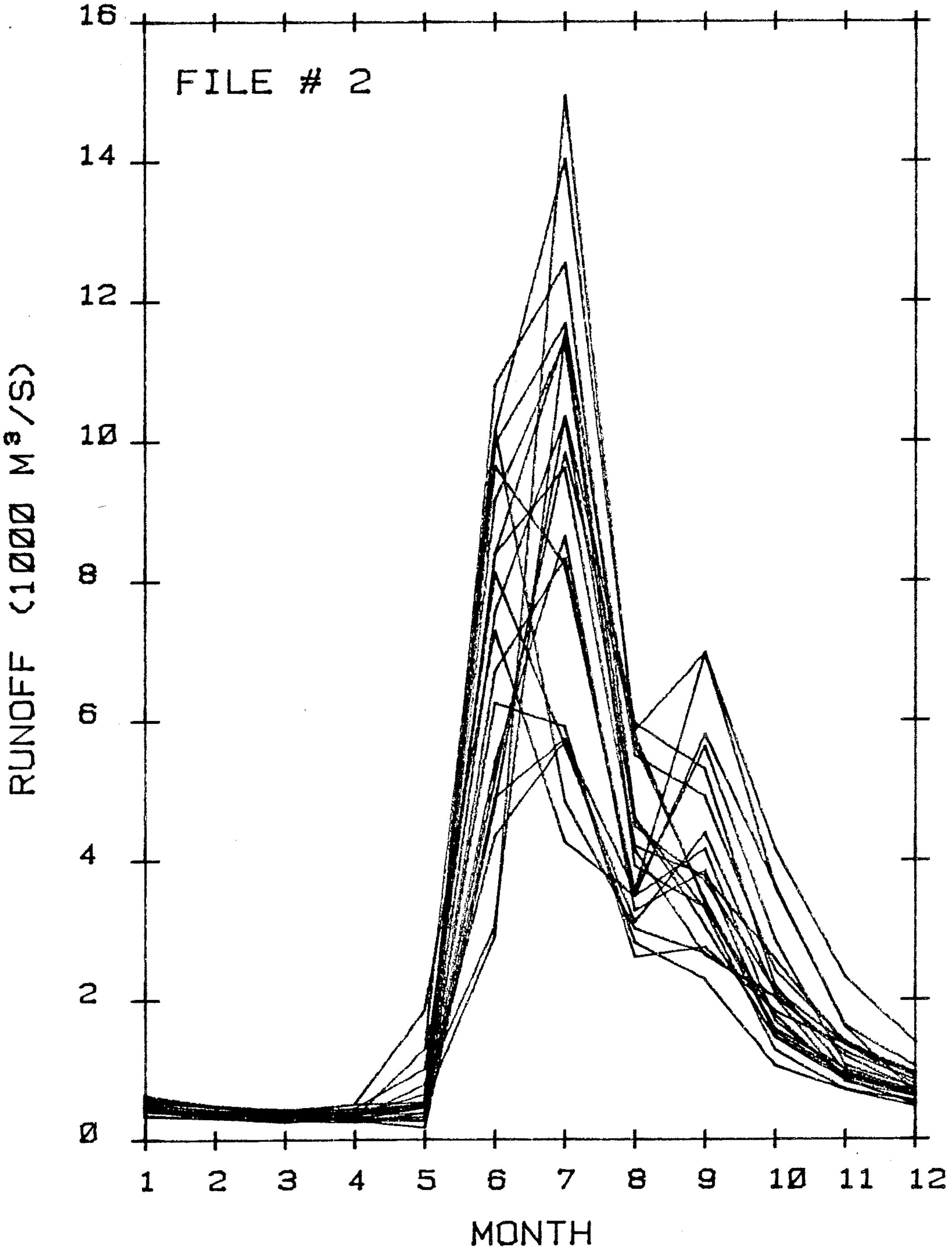


Figure B-2. Runoff cycles of 1963 to 1983 for NW Hudson Bay, Region II.

Table B-2, Monthly Runoff Rates for NW Hudson Bay, Region II.

FILE # 2 (Rates in 10 cubic meters per second)

YR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
63	35	31	31	30	46	754	1032	461	330	128	70	47	249
64	34	31	33	27	17	480	1035	596	530	221	96	65	264
65	47	35	28	25	39	490	574	282	229	106	71	55	165
66	41	36	33	28	33	1080	1254	460	305	146	85	51	296
67	42	38	36	35	53	1015	1403	580	338	154	93	63	321
68	45	37	36	32	28	995	1167	550	491	242	141	93	321
69	60	48	43	51	54	435	571	356	697	363	163	105	245
70	64	49	43	40	51	626	591	261	276	183	136	96	201
71	56	47	42	37	47	517	984	585	697	417	233	139	317
72	53	42	35	31	80	307	1155	449	370	214	137	90	247
73	57	47	39	51	187	729	427	349	581	364	162	66	255
74	43	31	27	32	132	1017	486	302	267	204	82	62	224
75	45	38	41	45	102	812	565	311	440	209	119	72	233
76	44	31	24	36	66	838	1150	392	332	178	85	50	269
77	48	37	36	38	50	837	961	420	377	259	136	78	273
78	50	38	42	43	51	292	1494	566	343	158	101	69	271
79	52	42	37	37	51	541	864	328	386	148	89	62	220
80	45	38	32	27	50	965	822	349	417	170	91	68	256
81	54	48	41	37	38	670	832	355	563	286	106	74	259
82	46	36	36	28	26	914	1144	416	264	204	125	85	277
83	55	48	44	44	50	1171	1038	666	534	239	132	93	343
AVG	48	39	36	36	59	737	931	430	417	219	117	75	262
St.D	8	6	6	8	38	253	298	116	135	80	38	21	41

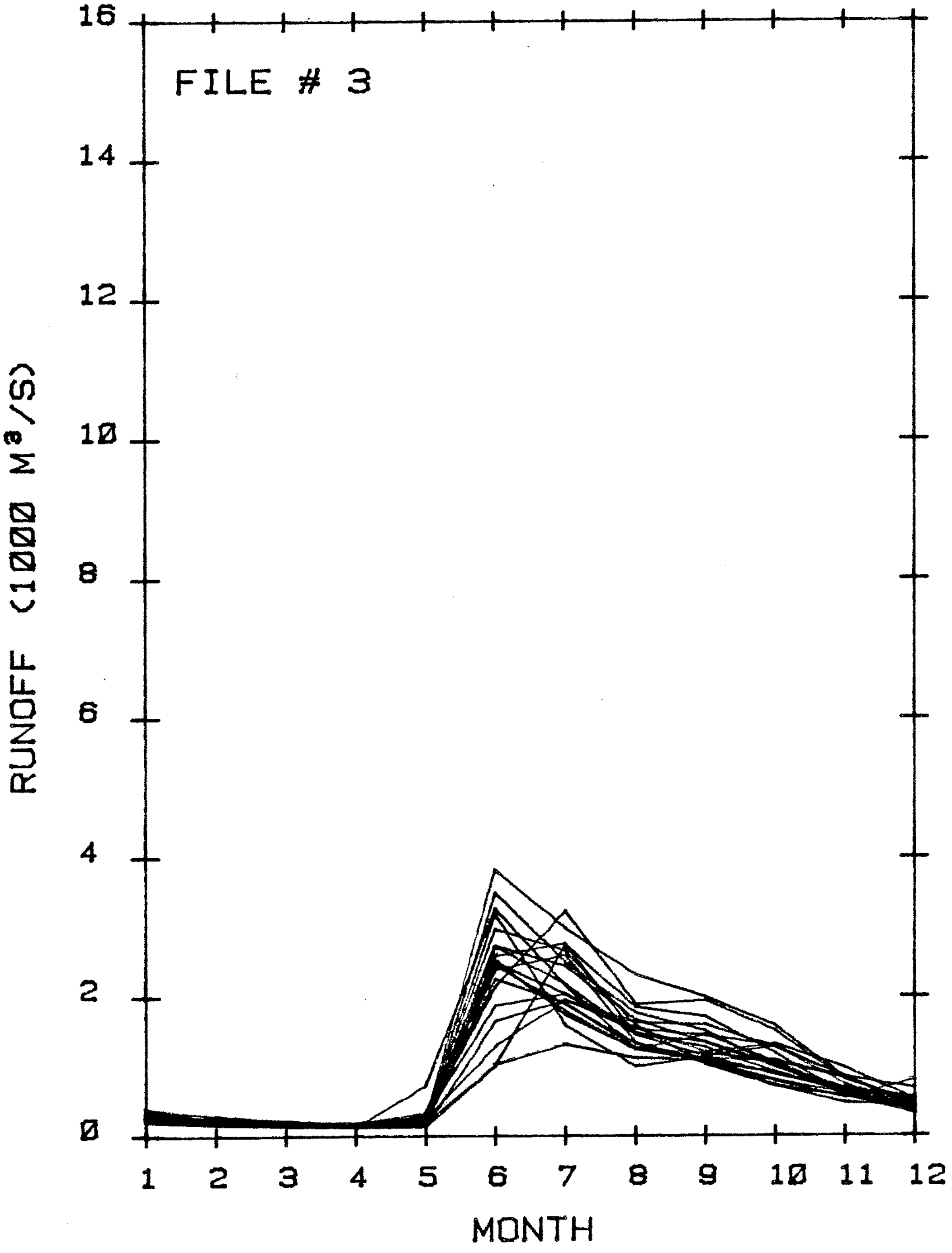


Figure B-3. Runoff cycles of 1963 to 1983 for E Hudson Bay, Regions III and IV.

Table B-3, Runoff Rates for E Hudson Bay, Regions III and IV.

FILE # 3 (Rates in 10 cubic meters per second)

YR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
63	25	20	17	16	29	187	203	145	135	102	62	40	82
64	28	20	16	14	26	214	323	189	194	151	80	47	109
65	30	24	21	19	24	350	249	177	150	100	58	38	103
66	26	20	16	15	23	226	191	125	110	108	84	68	84
67	40	22	15	14	26	274	244	166	134	98	68	55	96
68	33	23	19	18	34	250	204	155	120	132	97	52	95
69	38	29	22	17	19	239	260	133	103	79	62	42	87
70	28	20	16	14	14	166	195	153	144	129	73	37	82
71	24	20	17	16	24	130	195	162	159	126	84	40	83
72	23	17	15	15	15	101	275	185	171	118	58	31	85
73	21	17	15	14	73	327	216	124	118	107	82	47	97
74	30	22	17	14	22	319	159	99	113	88	65	52	83
75	34	26	20	17	25	245	189	132	108	89	66	46	83
76	31	23	18	14	31	250	180	124	107	72	47	44	78
77	25	21	18	17	24	297	266	159	103	71	57	36	91
78	24	19	16	15	19	103	132	111	109	79	54	81	64
79	26	20	17	16	24	383	299	231	199	159	84	42	125
80	26	19	16	15	29	254	174	124	146	105	63	38	84
81	25	19	17	15	16	259	277	145	114	129	84	44	95
82	27	19	16	14	24	273	218	147	127	91	63	42	89
83	30	21	18	17	48	279	202	138	101	97	68	42	88
AVG	28	21	17	16	27	244	222	149	132	106	70	46	90
StD	5	3	2	1	13	73	48	29	29	24	13	11	12

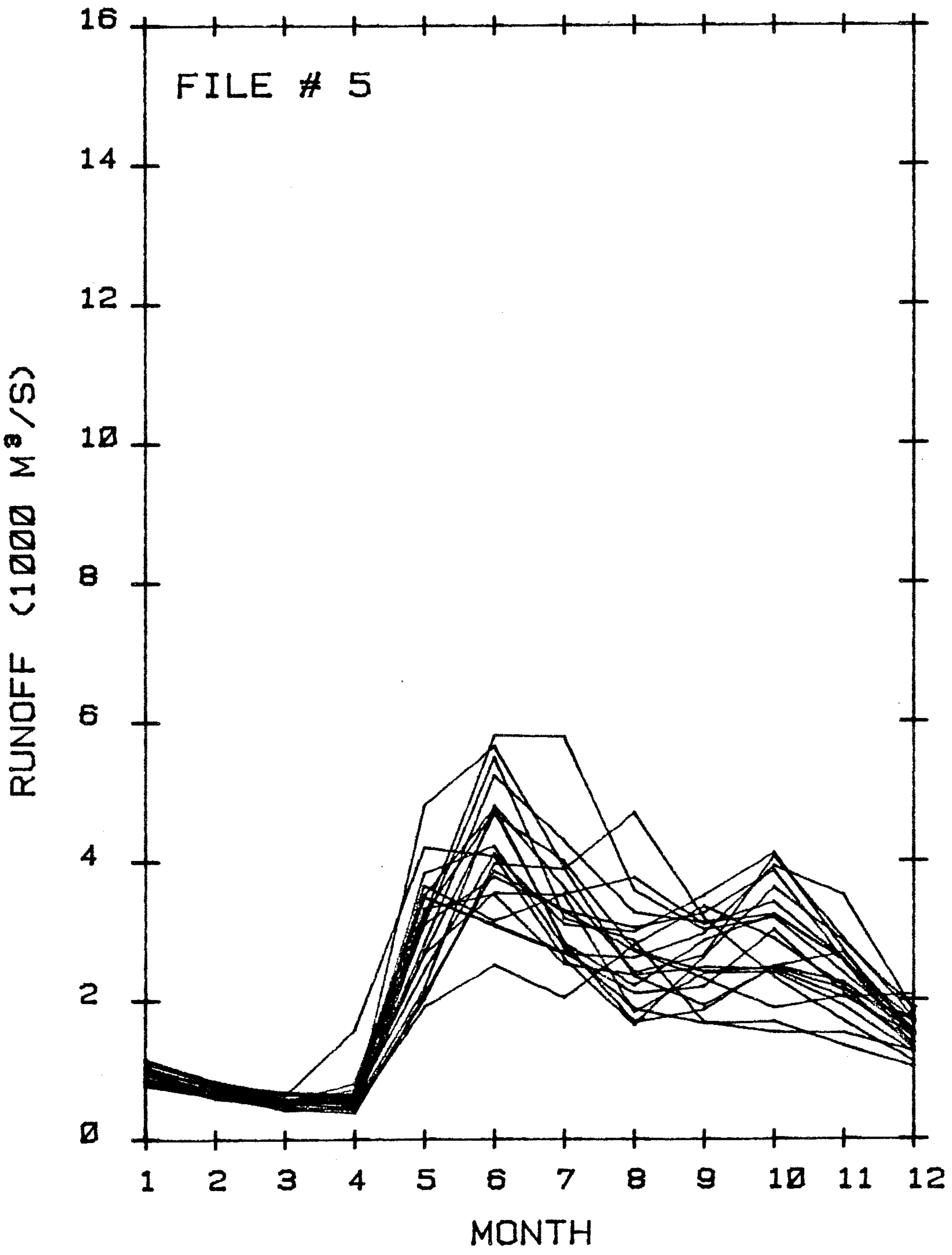


Figure B-4. Runoff cycles of 1963 to 1983 for SE Hudson Bay, Region V.

Table B-4, Monthly Runoff Rates for SE Hudson Bay, Region V.

FILE # 5 (Rates in 10 cubic meters per second)

YR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
63	84	59	48	68	332	353	251	236	247	244	203	209	194
64	104	75	63	158	420	407	260	164	262	362	284	187	229
65	105	74	56	51	320	581	579	358	301	319	239	155	261
66	105	59	53	59	280	524	429	326	311	323	256	168	241
67	102	67	49	43	310	549	318	286	168	154	153	127	194
68	81	62	52	67	349	307	267	261	296	393	351	184	222
69	110	81	59	50	218	480	362	239	264	407	288	175	228
70	116	84	65	59	243	411	309	298	350	411	272	151	231
71	95	66	51	57	365	314	353	376	308	341	258	144	227
72	88	61	45	39	209	386	329	304	325	386	257	132	213
73	89	66	42	47	481	566	390	235	193	248	269	151	231
74	115	82	65	64	267	354	351	183	239	241	192	124	190
75	85	65	53	46	202	397	388	470	318	233	170	112	211
76	79	62	51	61	383	422	276	188	166	170	135	104	175
77	79	63	55	73	309	378	328	270	231	189	206	149	194
78	96	69	53	46	191	251	203	280	335	288	219	129	180
79	95	70	55	81	350	477	283	221	286	322	258	156	221
80	98	70	56	62	348	309	269	210	219	301	210	139	191
81	102	80	68	64	323	473	282	168	186	249	226	152	198
82	102	76	58	53	268	469	399	273	240	247	215	171	214
83	108	74	55	49	208	343	267	236	236	303	243	158	190
AVG	97	70	55	62	304	417	328	266	261	292	233	151	211
St.D	11	8	6	24	75	90	79	73	54	74	48	25	22

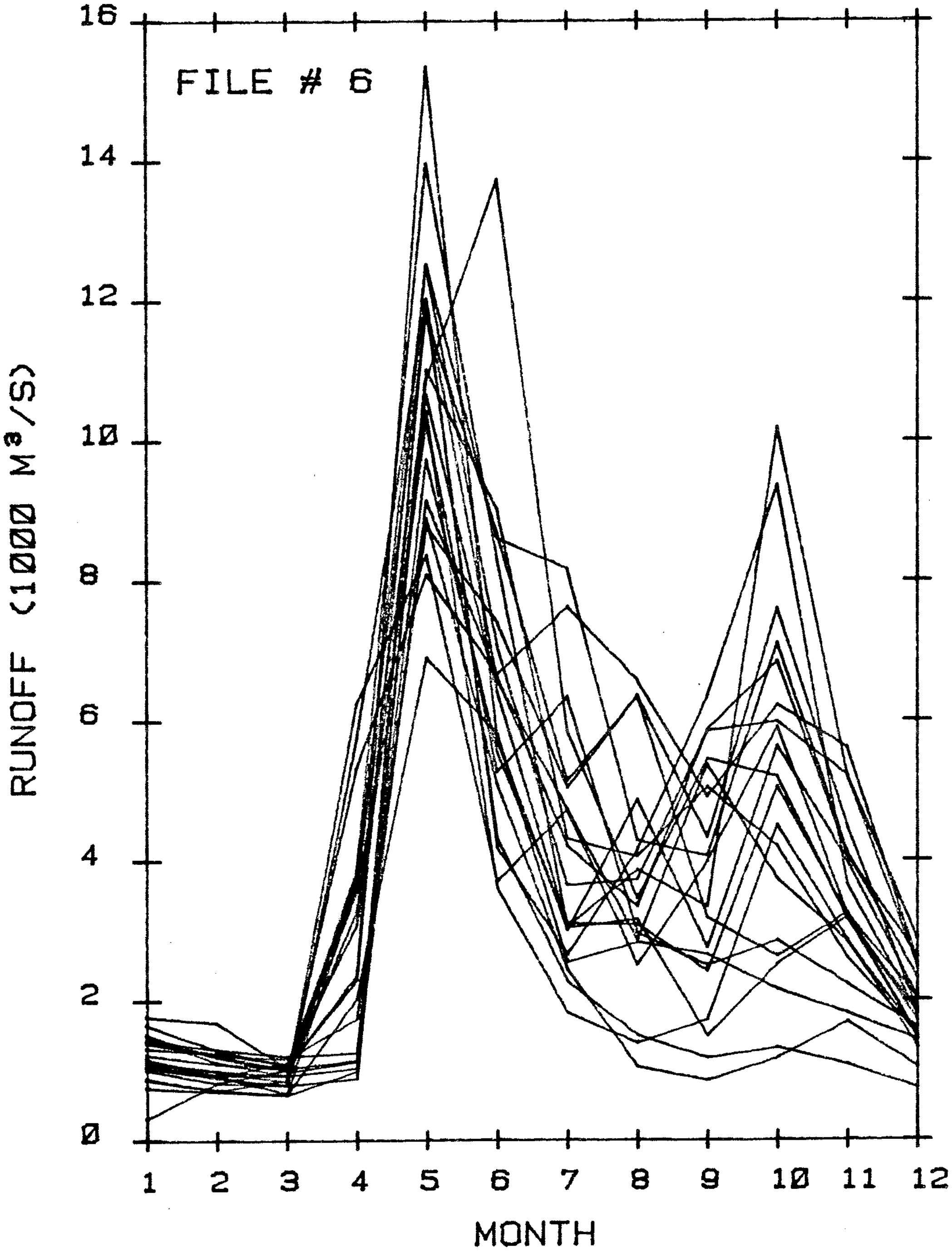


Figure B-5. Runoff cycles of 1963 to 1983 for W James Bay, Region VIa.

Table B-5, Monthly Runoff Rates for W James Bay, Region VIa.

FILE # 6 (Rates in 10 cubic meters per second)

YR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
63	87	72	65	203	691	582	254	283	265	215	181	143	253
64	111	99	84	380	1179	869	513	636	432	759	449	183	474
65	113	99	93	104	1203	419	265	415	634	936	365	181	402
66	131	125	109	370	1066	642	305	387	333	1018	520	287	441
67	142	121	102	387	1397	832	304	316	148	251	318	146	372
68	105	93	92	533	810	666	763	657	490	622	560	252	470
69	177	168	104	238	1253	860	817	428	406	710	410	231	484
70	151	119	98	113	915	664	421	334	586	684	408	262	396
71	165	129	105	230	1536	573	300	487	275	563	399	203	414
72	143	130	120	126	974	556	310	309	241	505	321	171	325
73	117	92	111	308	1026	526	634	296	250	286	223	161	336
74	122	109	103	114	1087	1374	585	345	545	519	317	181	450
75	140	121	116	175	878	741	503	636	318	263	325	146	363
76	101	81	78	574	1197	433	227	150	117	132	108	74	273
77	88	71	87	625	837	370	473	286	537	373	284	149	348
78	105	89	78	88	1102	901	431	405	505	419	261	150	378
79	108	93	66	368	1253	708	365	373	585	598	521	247	440
80	149	111	92	328	1043	362	182	138	172	450	285	133	287
81	32	83	101	356	889	510	244	104	85	117	169	104	233
82	75	70	64	99	1202	659	473	250	398	591	323	203	367
83	112	100	96	144	1030	611	508	217	198	366	172	109	305
AVG	118	104	94	279	1075	660	423	355	358	494	329	177	372
StD	32	24	16	160	199	223	170	151	166	240	120	54	73

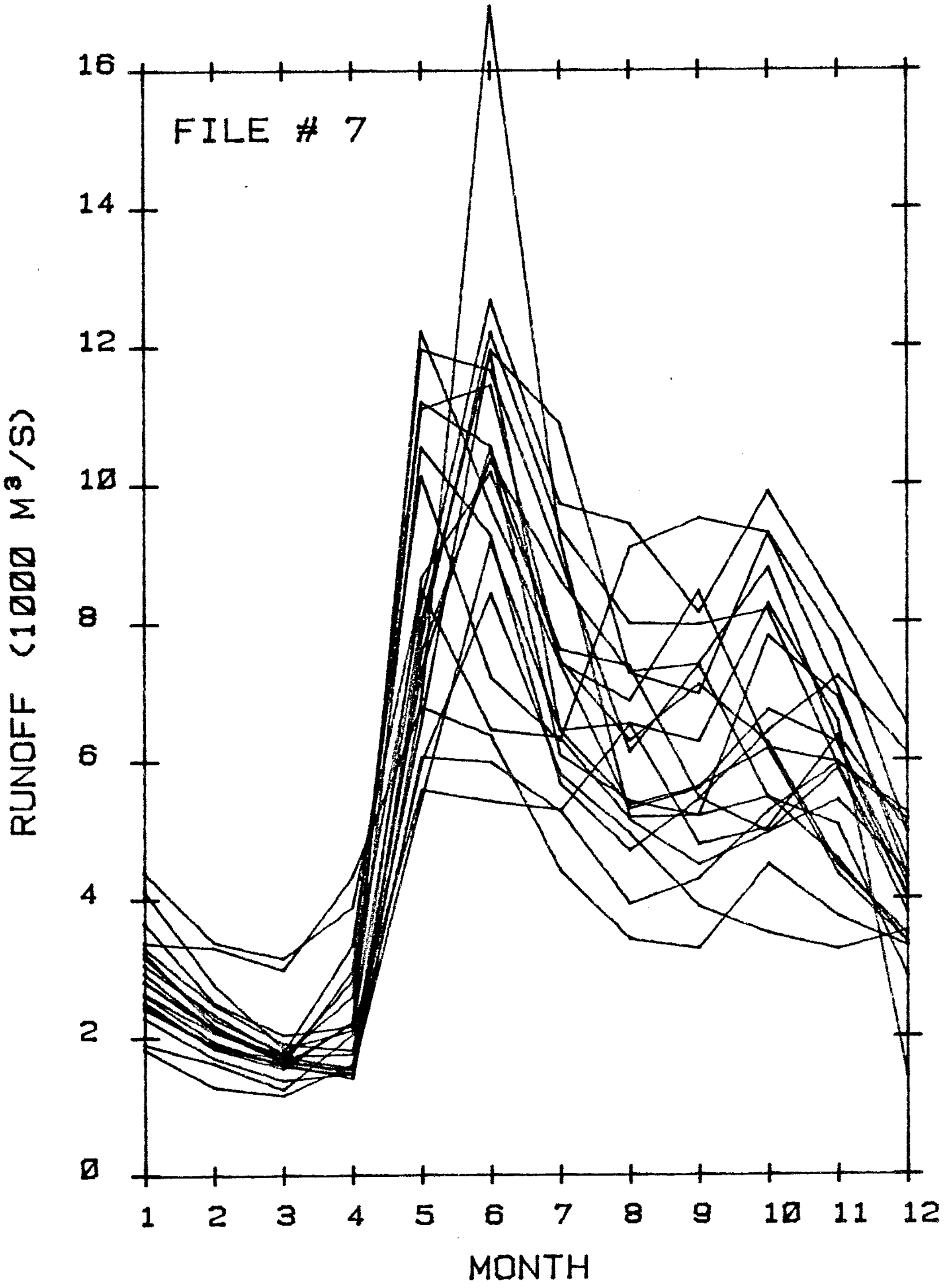


Figure B-6. Runoff cycles of 1963 to 1983 for E James Bay, Region VIb.

Table B-6, Monthly Runoff Rates for E James Bay, Region VIb.

FILE # 7 (Rates in 10 cubic meters per second)

YR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
63	182	128	115	162	598	843	582	495	388	350	326	353	377
64	248	184	155	224	1196	1165	895	612	739	879	625	398	610
65	261	194	158	146	779	1222	936	798	796	818	592	405	592
66	251	184	170	284	829	1267	972	942	813	989	820	651	681
67	366	250	203	217	802	1192	645	654	478	503	635	497	537
68	316	226	178	334	1013	721	628	908	951	929	703	431	612
69	305	234	174	176	656	1195	1087	727	696	929	772	495	621
70	330	247	191	181	730	1054	747	628	710	625	448	348	520
71	228	170	137	149	607	599	527	653	627	827	656	142	443
72	281	214	172	155	545	917	644	536	563	618	436	337	451
73	242	189	160	222	1223	968	741	530	560	673	625	420	546
74	281	211	167	148	691	1693	923	518	520	781	690	454	590
75	293	213	164	153	865	1018	761	737	546	495	588	380	518
76	245	187	160	298	1120	1054	608	541	520	547	456	337	506
77	264	207	174	260	1110	1144	742	686	845	618	597	523	597
78	323	217	161	140	757	1036	863	728	739	546	506	288	525
79	190	162	124	205	1054	926	567	469	544	642	721	610	518
80	439	338	314	390	850	645	634	514	449	496	542	438	504
81	337	331	298	434	679	636	442	341	327	450	374	332	415
82	412	277	184	211	559	542	529	393	429	527	597	513	431
83	479	388	280	266	564	698	678	501	573	617	553	553	513
AVG	299	226	183	226	820	978	721	615	610	660	584	424	529
StD	75	61	51	81	213	272	166	152	159	174	124	113	75

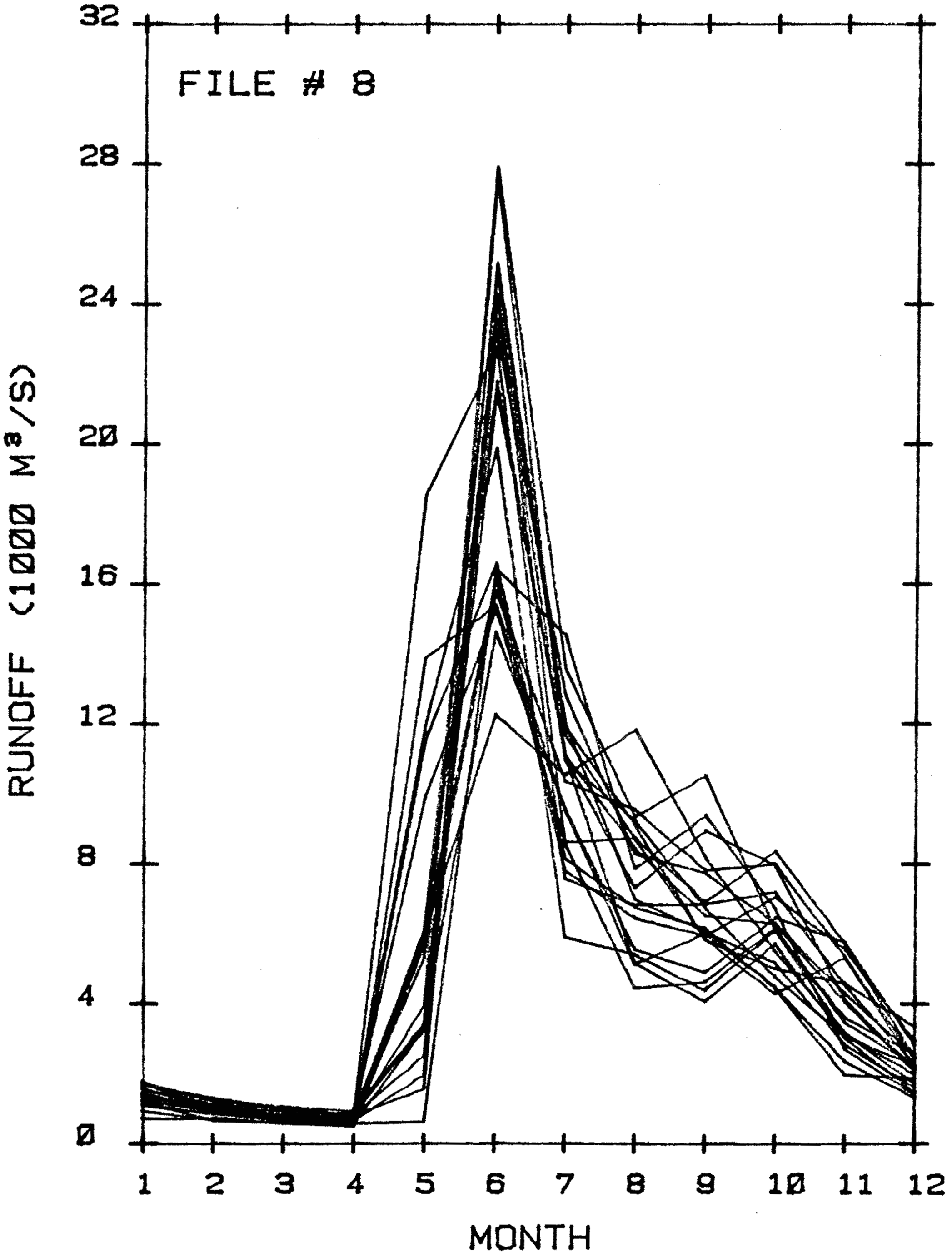


Figure B-7. Runoff cycles of 1963 to 1983 for Ungava Bay, Region VII.

Table B-7, Monthly Runoff Rates for Ungava Bay, Region VII.

FILE # 8 (Rates in 10 cubic meters per second)

YR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
63	112	87	74	81	340	2148	1111	845	652	628	405	206	557
64	128	89	76	76	588	2179	1107	731	896	796	413	211	608
65	137	107	80	73	397	2792	1360	934	1054	612	314	197	671
66	139	101	79	77	533	2516	1193	911	582	501	459	334	619
67	174	94	61	46	591	1620	782	645	594	706	557	295	514
68	172	120	90	84	989	1531	863	875	690	837	573	249	589
69	169	130	104	81	255	2318	1284	828	774	631	431	253	605
70	168	124	97	81	158	2420	1200	700	606	518	285	162	543
71	108	83	69	69	567	1581	1036	956	782	800	536	221	567
72	137	95	75	58	63	1644	1453	786	940	673	271	142	528
73	92	68	56	53	1389	1540	955	556	489	647	577	282	559
74	157	100	68	55	330	2430	859	445	463	617	347	225	508
75	153	110	79	65	198	2768	1093	924	675	478	308	223	590
76	137	93	70	61	1152	1659	816	676	616	446	196	187	509
77	143	97	93	80	615	2499	1167	872	588	429	535	243	613
78	120	64	58	53	604	1228	1053	1184	821	552	318	171	519
79	121	95	78	78	1852	2275	758	683	685	720	455	226	669
80	139	102	71	69	1193	1988	591	541	438	611	361	256	530
81	173	106	103	92	324	2357	1104	517	406	572	303	148	517
82	70	72	61	91	343	1463	957	512	602	448	235	132	416
83	87	49	42	225	1259	916	800	486	532	715	405	170	474
AVG	135	94	75	78	654	1994	1026	743	661	616	394	216	557
StD	29	19	15	35	461	512	212	188	164	117	112	51	61

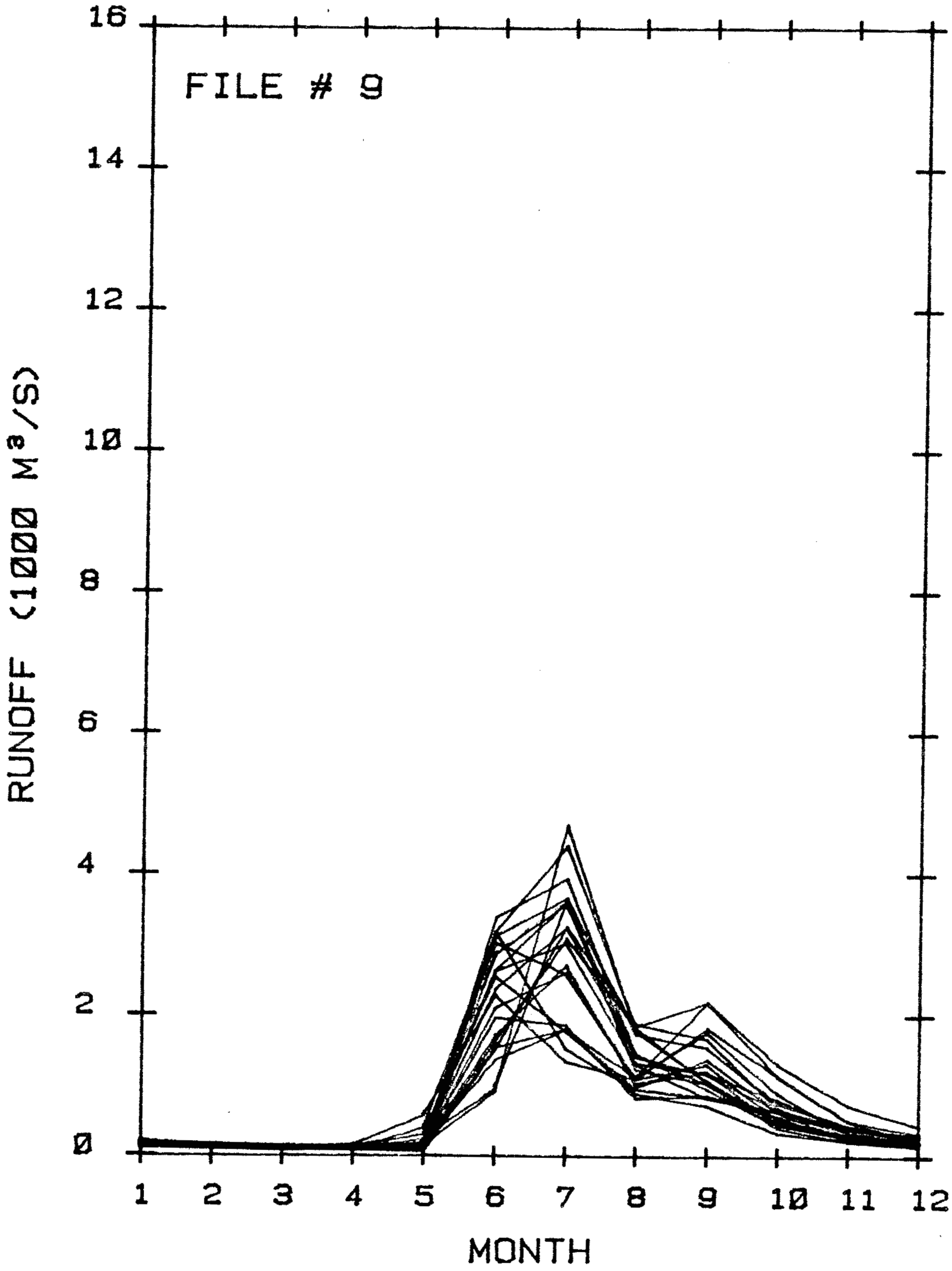


Figure B-8. Runoff cycles of 1963 to 1983 for Foxe Basin, Region VIII.

Table B-8, Monthly Runoff Rates for Foxe Basin, Region VIII.

FILE # 9 (Rates in 10 cubic meters per second)

YR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
63	11	10	10	9	14	234	320	143	102	40	22	15	77
64	11	10	10	8	5	149	321	185	164	69	30	20	82
65	14	11	9	8	12	152	178	87	71	33	22	17	51
66	13	11	10	9	10	335	389	143	95	45	26	16	92
67	13	12	11	11	16	315	435	180	105	48	29	20	99
68	14	12	11	10	9	308	362	171	152	75	44	29	100
69	19	15	13	16	17	135	177	110	216	112	51	32	76
70	20	15	13	12	16	194	183	81	85	57	42	30	62
71	17	14	13	11	15	160	305	181	216	129	72	43	98
72	16	13	11	10	25	95	358	139	115	66	42	28	77
73	18	15	12	16	58	226	132	108	180	113	50	21	79
74	13	10	8	10	41	315	151	94	83	63	26	19	69
75	14	12	13	14	32	252	175	96	136	65	37	22	72
76	14	10	8	11	20	260	356	122	103	55	26	16	83
77	15	12	11	12	15	260	298	130	117	80	42	24	85
78	15	12	13	13	16	91	463	175	106	49	31	21	84
79	16	13	11	11	16	168	268	102	120	46	28	19	68
80	14	12	10	8	16	299	255	108	129	53	28	21	79
81	17	15	13	11	12	208	358	110	174	89	33	23	80
82	14	11	11	9	8	283	355	129	82	63	39	26	86
83	17	15	14	14	15	363	322	206	166	74	41	29	106
AVG	15	12	11	11	18	229	289	133	129	68	36	23	81
StD	2	2	2	2	12	78	92	36	42	25	12	7	13

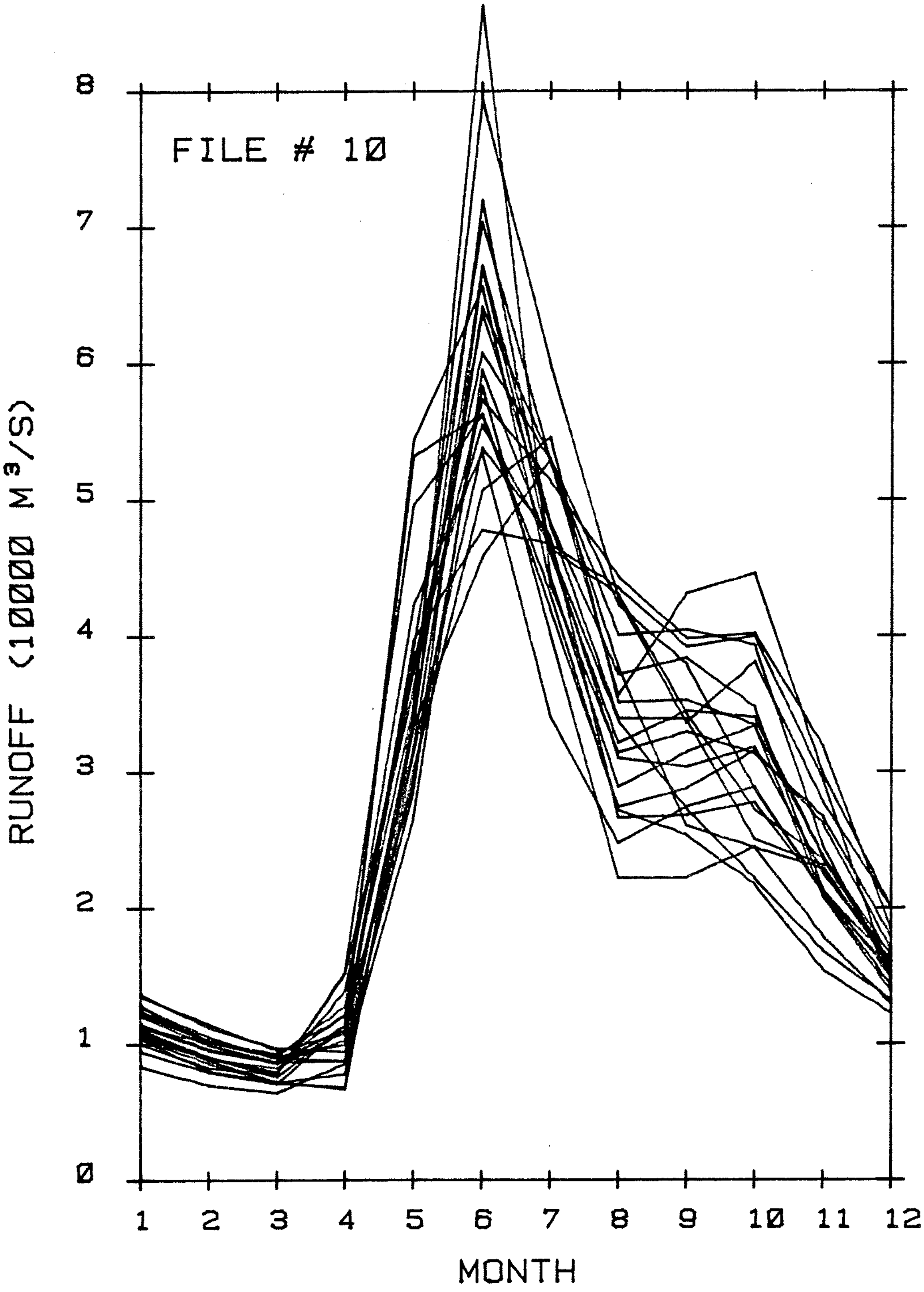


Figure B-10. Runoff flux cycles of 1963 to 1983 leaving Hudson Strait (Zero-drift).

Table B-10, Runoff Fluxes leaving Hudson Strait (Zero-drift).

FILE # 10 (Rates in 100 cubic meters per second)

YR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
63	83	70	64	86	265	595	464	338	273	222	168	132	230
64	94	79	71	114	377	608	528	400	404	393	246	149	289
65	104	86	71	68	335	672	483	371	384	347	214	149	274
66	113	95	86	122	348	794	600	427	336	381	278	200	315
67	128	99	85	113	389	704	528	377	261	244	229	155	276
68	108	90	79	139	374	574	514	443	398	402	319	184	302
69	135	115	95	108	317	642	529	356	431	445	298	200	306
70	136	112	97	94	285	670	460	321	345	340	238	157	271
71	115	96	86	103	396	478	467	435	392	400	294	148	284
72	123	102	90	87	300	506	546	351	353	334	208	138	262
73	105	89	82	110	531	563	420	274	288	316	262	170	267
74	121	99	87	88	341	863	444	289	314	334	238	165	282
75	125	103	91	100	332	720	464	430	343	272	236	160	281
76	111	90	78	153	495	562	431	272	253	217	155	122	245
77	100	82	77	152	360	637	481	339	339	250	231	157	267
78	104	80	72	66	333	457	530	423	379	287	211	143	257
79	106	90	75	114	543	657	438	314	329	313	267	179	285
80	128	102	91	128	422	535	342	248	274	289	212	152	243
81	112	101	93	121	291	583	402	222	222	245	179	129	225
82	109	88	72	78	313	538	473	266	268	277	212	161	238
83	127	105	89	110	380	555	465	310	303	318	225	161	262
AVG	114	94	82	107	368	615	477	343	328	316	234	158	270
StD	13	11	9	24	74	98	56	65	56	62	41	20	24

Phase lags (months)

Region #	Lag
1	0
2	0
3	0
5	0
6	0
7	0
8	0
9	0

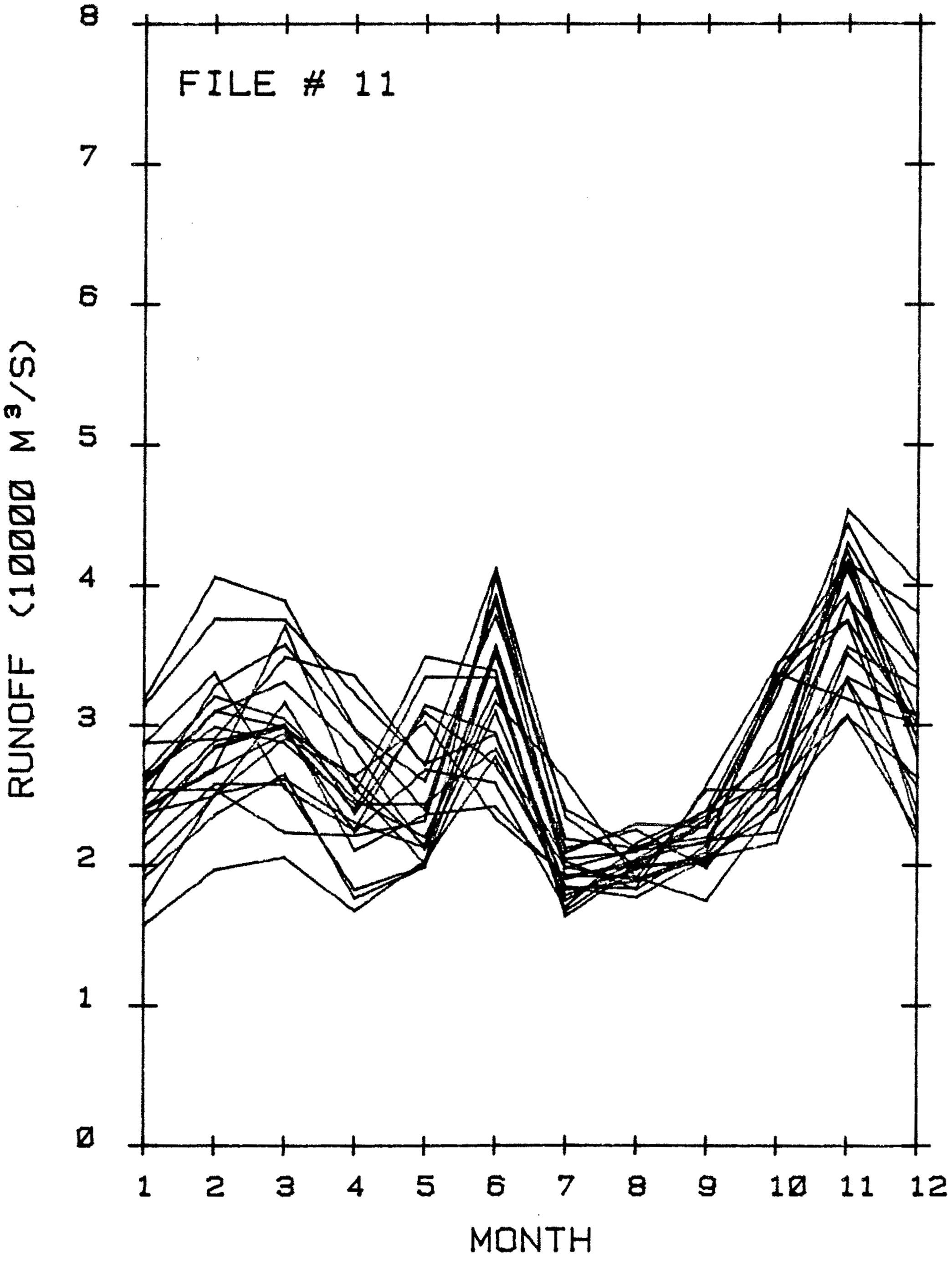


Figure B-11. Runoff flux cycles of 1963 to 1983 leaving Hudson Strait (Base-drift).

Table B-11, Runoff Fluxes leaving Hudson Strait (Base-drift).

FILE # 11 (Rates in 100 cubic meters per second)

YR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
63	240	289	300	247	220	327	183	189	205	239	306	262	251
64	213	258	258	182	200	310	184	184	258	344	375	300	255
65	248	328	358	297	239	393	219	212	236	263	415	278	290
66	231	284	299	262	214	357	209	230	227	291	417	380	283
67	314	376	375	322	272	293	175	204	232	321	444	348	306
68	260	310	298	224	268	259	170	216	239	337	319	300	267
69	318	406	388	297	260	379	240	213	220	274	430	344	314
70	287	290	349	335	271	412	235	200	202	250	356	326	293
71	263	299	287	244	244	283	205	210	239	280	425	289	272
72	257	309	331	283	211	317	262	191	254	254	391	292	279
73	237	249	317	237	309	272	199	190	210	342	418	280	272
74	253	254	223	221	232	389	193	192	175	244	454	401	269
75	264	320	304	256	201	407	212	226	198	266	390	336	282
76	286	338	255	225	315	294	179	198	233	331	394	228	273
77	191	236	265	177	199	352	198	211	216	328	374	240	249
78	223	285	301	211	237	242	191	204	218	224	351	305	249
79	241	270	371	251	349	339	167	201	229	334	410	305	289
80	240	267	295	240	334	334	164	198	206	275	332	217	258
81	172	251	262	231	213	354	203	183	214	258	307	224	239
82	157	197	206	168	203	278	185	177	205	216	332	255	215
83	197	250	291	264	302	234	193	200	202	250	334	308	252
AVG	242	289	302	246	252	325	198	201	220	282	380	296	269
StD	41	47	47	43	46	52	24	13	19	40	45	48	23

Phase lags (months)

Region #	Lag
1	6
2	8
3	2
5	4
6	6
7	5
8	0
9	2

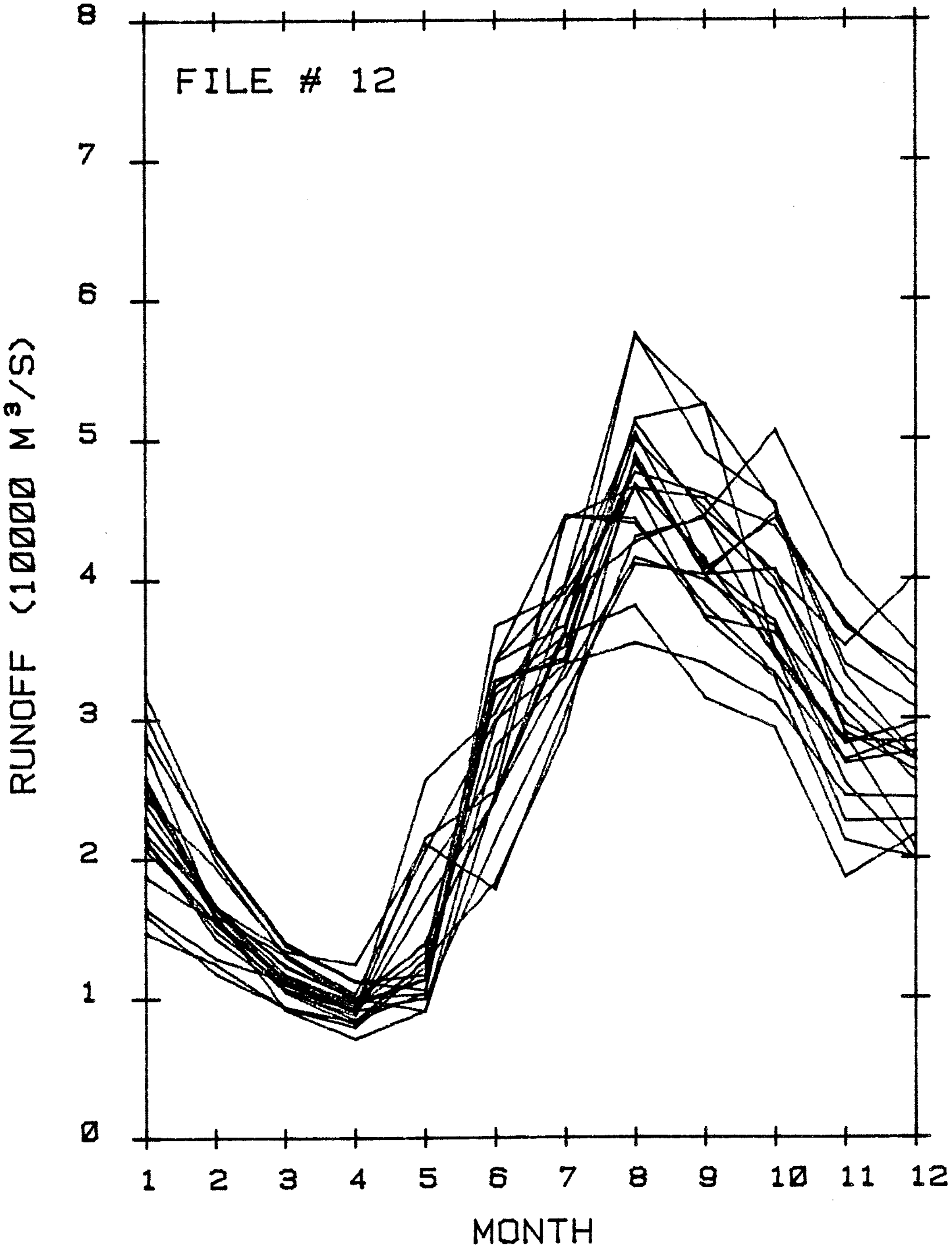


Figure B-12. Runoff flux cycles of 1963 to 1983 leaving Hudson Strait (Fast-drift).

Table B-12, Runoff Fluxes leaving Hudson Strait (Fast-drift).

FILE # 12 (Rates in 100 cubic meters per second)

YR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
63	229	161	92	71	91	280	330	415	399	365	254	199	240
64	147	125	93	79	123	296	383	476	460	437	369	322	276
65	258	166	106	84	104	340	367	512	443	349	284	283	275
66	254	157	113	93	133	341	397	573	524	451	339	307	307
67	303	200	130	96	140	244	361	576	490	453	288	206	291
68	187	155	105	87	169	242	386	426	445	506	402	348	288
69	289	206	138	111	117	317	352	500	449	404	352	403	303
70	318	208	140	112	105	327	341	468	414	344	282	297	280
71	248	165	124	99	139	243	337	485	407	443	365	331	282
72	281	160	131	100	90	247	366	483	403	407	290	262	268
73	213	149	110	90	215	248	445	440	381	331	270	288	265
74	240	165	117	96	114	327	344	514	525	348	282	297	281
75	249	167	122	100	103	366	390	465	457	399	316	270	284
76	218	167	110	90	187	265	442	466	371	329	212	200	255
77	160	118	93	83	128	341	445	443	373	361	306	255	259
78	207	156	104	81	127	183	292	489	402	448	332	272	258
79	215	143	107	91	256	305	395	504	409	369	268	277	278
80	244	194	132	103	205	299	339	354	339	311	245	243	251
81	214	153	115	95	113	322	360	381	314	293	186	217	230
82	164	129	112	91	100	213	317	411	403	348	226	227	228
83	229	166	134	124	211	178	304	430	443	391	296	270	265
AVG	232	162	116	94	141	282	366	467	422	385	293	275	270
StD	44	24	14	12	46	53	42	54	52	54	53	50	21

Phase lags (months)

Region #	Lag
1	2
2	3
3	1
5	2
6	3
7	2
8	0
9	1