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CLIMATE DATA FOR THE NORTHWEST ATLANTIC: SURFACE WIND STRESSES OFF EASTERN CANADA, 1946 - 1991

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SURFACE WIND STRESSES OFF EASTERN CANADA, 1946-1991

by

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ABSTRACT

Drinkwater, K.F. and R.G. Pettipas. 1993. Climatic data for the Northwest Atlantic: Surface wind stresses off eastern Canada, 1946-1991. Can. Data Rep. Hydrogr. Ocean Sci. 123: iv + 130 p.

Estimates of surface wind stress at 25 sites off eastern Canada (mostly over water) including the Labrador Sea, the Grand Banks, the Gulf of St. Lawrence and the Scotian Shelf are presented. Monthly mean stresses were calculated from 6-hourly geostrophic winds for the years 1946 to 1991. Seasonal averages of the wind stress were derived for the thirty year period 1961-90 and anomalies of stress from these means are displayed for the full dataset. Time series plots of the wind stress components at all 25 sites are also provided.

RÉSUMÉ

Drinkwater, K.F. and R.G. Pettipas. 1993. Climatic data for the Northwest Atlantic: Surface wind stresses off eastern Canada, 1946-1991. Can. Data Rep. Hydrogr. Ocean Sci. 123: iv + 130 p.

On présente des estimations de la force d'entraînement du vent en 25 points du large de la côte est du Canada, situés en mer pour la plupart, notamment dans la mer du Labrador, sur les Grands Bancs de Terre-Neuve, dans le golfe du Saint-Laurent et sur la plate-forme néo-écossaise. On a calculé les moyennes mensuelles de cette force en se fondant sur six vents géostrophiques horaires estimés pour les années 1946-91 et les moyennes saisonnières pour les années 1961-90. On présente également les anomalies de la force d'entraînement découlant de ces moyennes pour toute la série de données, ainsi que des graphiques chronologiques des composantes de la force d'entraînement aux 25 points considérés.

INTRODUCTION

The recent collapse of the northern cod fishery off Newfoundland and Labrador following several years of extremely cold winters has focused attention on the possible role of the environment in the decline of the groundfish stocks. Although the search for a relationship between particular environmental indices and recruitment has often resulted in the failure to show any significant result (Myers and Drinkwater, 1989; Myers et al., 1992) there have also been some promising findings (Sutcliffe et al., 1983; Koslow et al., 1987; Myers et al., 1993). Important in any examination of the role of the environment on fish stocks is the requirement for appropriate climate indices. The Bedford Institute of Oceanography, in cooperation with other regional Department of Fisheries and Oceans laboratories, is presently assembling a variety of climate indices including oceanographic, meteorological and hydrological datasets for climate and fisheries related studies. This document provides information on the surface wind stress fields off eastern Canada from 1946 to 1991 and represents the first in a series of reports on climate indices. Winds affect the ocean environment through a number of direct and indirect mechanisms including influencing the nature of the air masses over the water; the advance, formation and retreat of ice; the ocean circulation patterns; vertical mixing in the oceans; etc. Cod recruitment in northern waters has been shown to covary with the winds (Koslow et al., 1987) although searches for relationships between wind and recruitment have not always proved successful (Myers and Drinkwater, 1989). Our work complements the earlier study by Thompson and Hazen (1983) who presented seasonal winds over the North Atlantic between 1950 to 1980. The present study provides additional temporal and spatial information in the surface wind stress field off eastern Canada.

DATA AND METHODS

Six-hourly wind data estimated from gridded sea level pressure data for the period 1946 to 1991 and geostrophy were acquired from the Atmospheric Environment Service (AES). Wind vectors were generated for the centre

points of each grid square (381 km separation distance) formed by the pressure data. A description of the pressure data and calculation methods are found in Swail (1985). We obtained data from 25 sites off eastern Canada extending from the northern Labrador Sea to Georges Bank (Fig. 1). The data at all sites contain some gaps, of order hours to a few days during the period 1976-78 and several months in 1981 and 1983.

Swail et al. (1984) compared the geostrophic winds with measured surface winds and found the former to be higher than the latter. This was to be expected as no adjustment was made in the geostrophic estimates for frictional effects in the near surface boundary layer. The geostrophic winds were also found to lag surface observations slightly and to show higher directional persistence than measured winds. Overall, however, the geostrophic winds were considered to be good approximations to the true winds over the water at an elevation of about 30 m (Swail et al., 1984).

For our analysis we calculated the surface wind stress from the 6-hourly geostrophic winds after reducing the wind speeds by 20% and rotating the wind directions anticlockwise by 20° to account for the frictional effects near the surface following suggestions by V. Swail (personal communication, AES Downsview, Ontario). However, the true reduction will depend upon the stability of the air column. This leads to some uncertainty in the wind estimates, especially in the strength of the wind speed.

The stress amplitudes (τ) were calculated from the adjusted wind speeds (v) using the quadratic stress law, i.e.

$$\tau = c_d v^2$$

where c_d is the drag coefficient. The stress direction was the wind direction, after the 20° adjustment for frictional effects, plus 180° to convert it into oceanographic convention, i.e. the direction towards which the wind blows. The drag coefficient was taken from Large and Pond (1981) where

$$c_d = 1.14 \times 10^{-3} \quad \text{for speeds } < 10 \text{ m s}^{-1}$$

$$c_d = (0.49 + 0.065 V) \times 10^{-3} \quad \text{for speeds } (V) \geq 10 \text{ m s}^{-1}$$

A comparison with stresses estimated from the COADS (Comprehensive Ocean-Atmospheric Data Sets), based primarily upon ship observations, shows the COADS stresses to be upwards of 50% higher in winter than those we estimated, although the summer stresses are similar (J. Loder, BIO, personal communications). Cause of the wintertime difference and which dataset is more representative of the true conditions is as yet unresolved. Therefore, readers are cautioned that although our data are believed to reflect the variability pattern in the winds, there is still some uncertainty in the absolute strength of the wind stresses.

Our 6-hourly wind stresses were then vector-averaged to obtain the monthly mean wind stresses for each year between 1946 and 1991. Gaps up to 2 days duration were filled using linear interpolation. No monthly average was calculated if less than 50% of the possible data for that month were available. The only missing months were January and November, 1981, and February to June, 1983. Seasonal means were determined from the monthly averages where winter was defined as December of the previous year, January and February. Similarly, spring was comprised of March to May, summer of June to August and autumn of September to November. Long-term means for each season were calculated over the years 1961-90 (Fig. 2). The thirty-year period for climate normals is in compliance with standard procedures in meteorology and recommended by the World Meteorological Organization (WMO). Seasonal anomalies of the wind stress relative to the long-term means were calculated for each year and plotted as vectors (Fig. 3). No data were available for the spring of 1983. Time series of the filtered (25-month running mean) wind stress components, resolved along 45° (τ_x positive) and 315° (τ_y positive) are also provided (Fig. 4). Missing months were estimated by linear interpolation for the purpose of these plots.

The six-hourly or monthly mean data can be provided in ASCII format on diskette or tape upon request.

BRIEF DISCUSSION

The long-term mean wind stress pattern in winter (Fig. 2) consists of strong winds from the northwest over the Labrador Sea and the Gulf of St. Lawrence and winds more towards the east over the Scotian Shelf and Grand Banks. Similar patterns are found in the spring and the autumn but of reduced amplitude. In summer, however, winds are mostly from the southwest with the highest amplitudes found over the Grand Banks. Over the northern Labrador Sea the winds during the summer tend to be very light.

Examination of the season wind stress anomalies (Fig. 3) indicate that the largest variability occurs in winter and the least in summer. The amplitudes typically equal or exceed the means. It is interesting to note that during the early 1950s when high air and sea temperatures were observed from the Gulf of St. Lawrence to the Gulf of Maine, winter winds in these areas were predominantly onshore. In contrast, in this same region during the very cold mid-1960s winter winds were mostly offshore or eastward. This is consistent with the findings of Thompson et al. (1988) in their analysis of sea surface temperatures. Two of the coldest years off Newfoundland during the past 25 y, both in terms of air and sea temperatures and heavy ice conditions, were 1972 and 1991. Both these years show intense winds from the northwest in winter and above average winds from the northwest in spring.

The filtered time series for the Labrador Sea show the strong changes in τ_y (negative indicates from the northwest). The amplitude of τ_y typically doubled during the period 1971-72, being strongest on the western side of the Labrador Sea. The 1990s also show a maximum in the strength of the winds out of the northwest. The low frequency variability in the Gulf of St. Lawrence and on the Scotian Shelf is typically less than that over the Labrador Sea.

Acknowledgements

We thank those people who have contributed to the success of this project: M. Graça for transferring computer files and computing the wind stresses; I. Peterson for obtaining and providing the most recent geostrophic wind data; and V. Swail for his helpful discussions and suggestions. Thanks are also due J. Loder and D. Lawrence for their comments on an earlier draft of this report.

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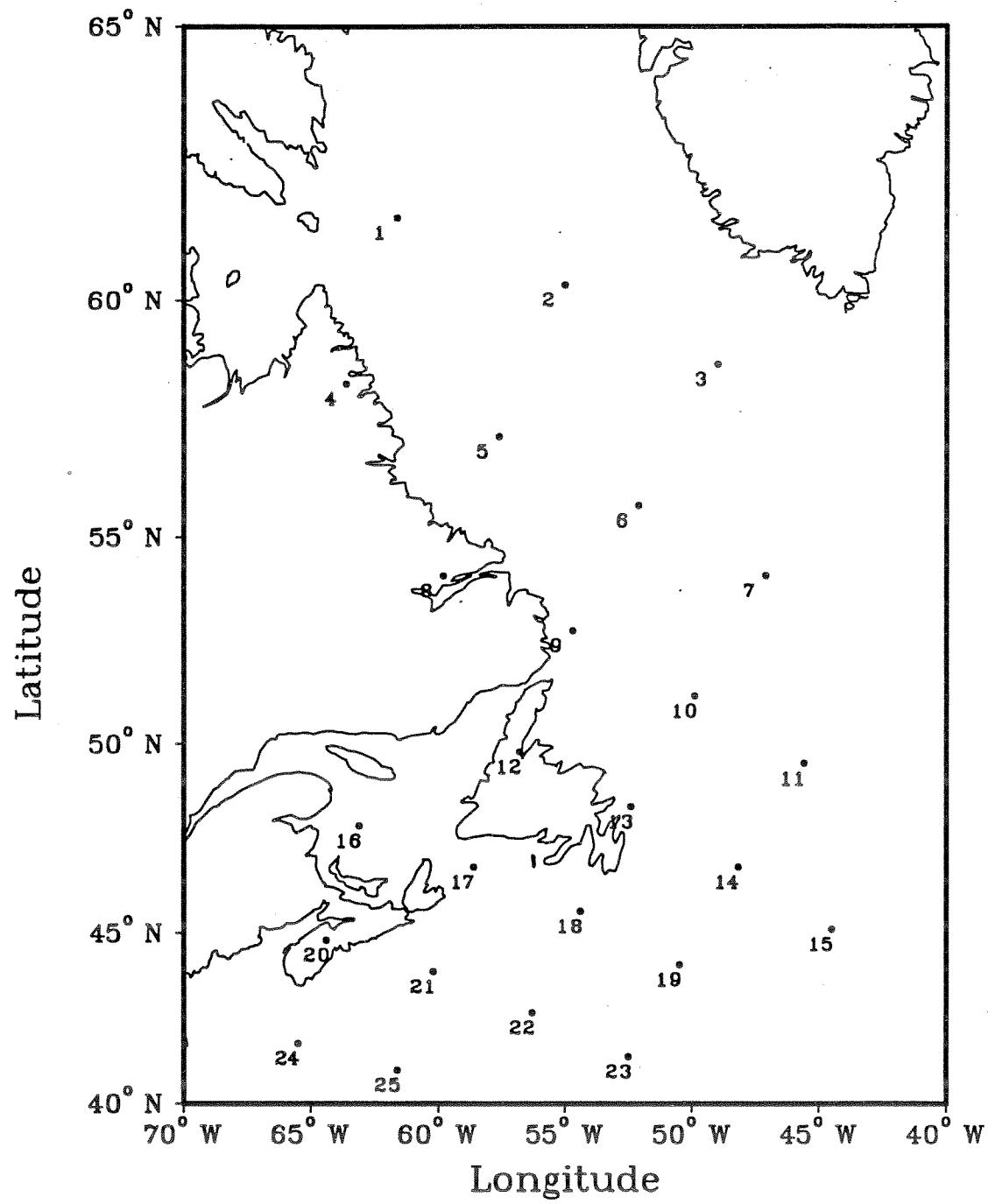
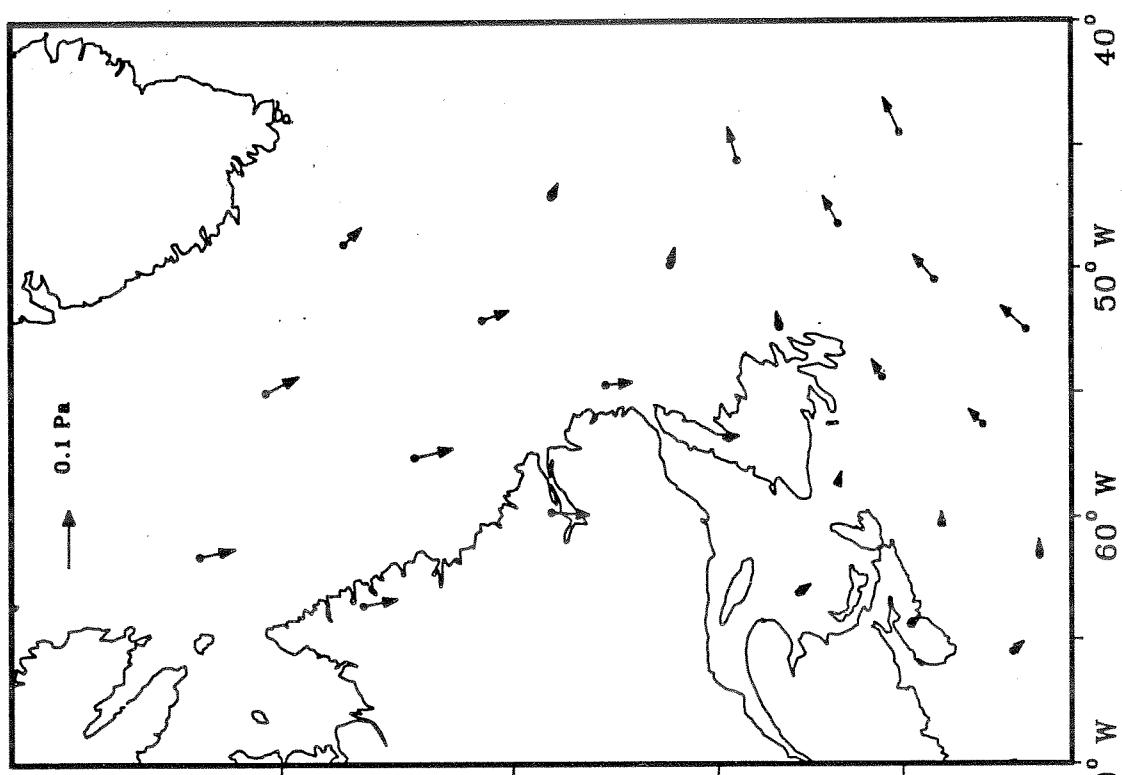


Fig. 1 Location of the geostrophic wind sites.

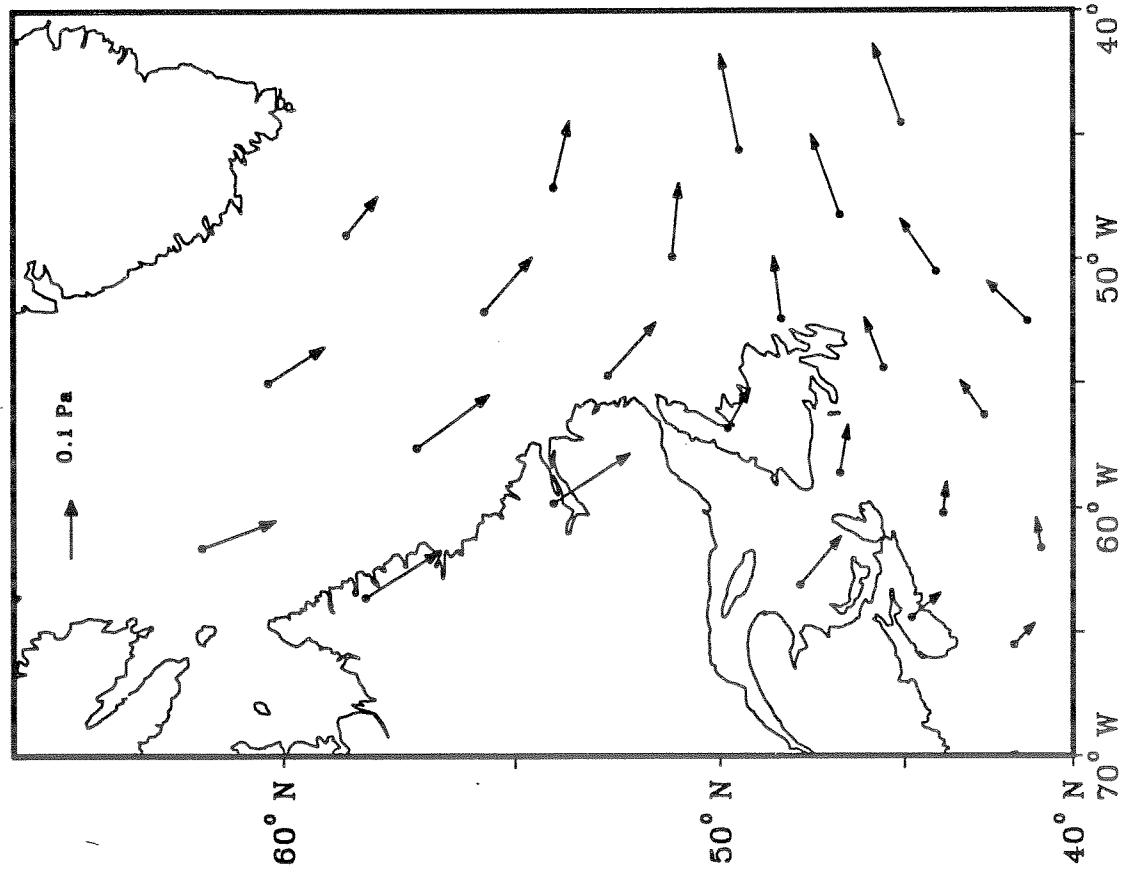
Figure 2

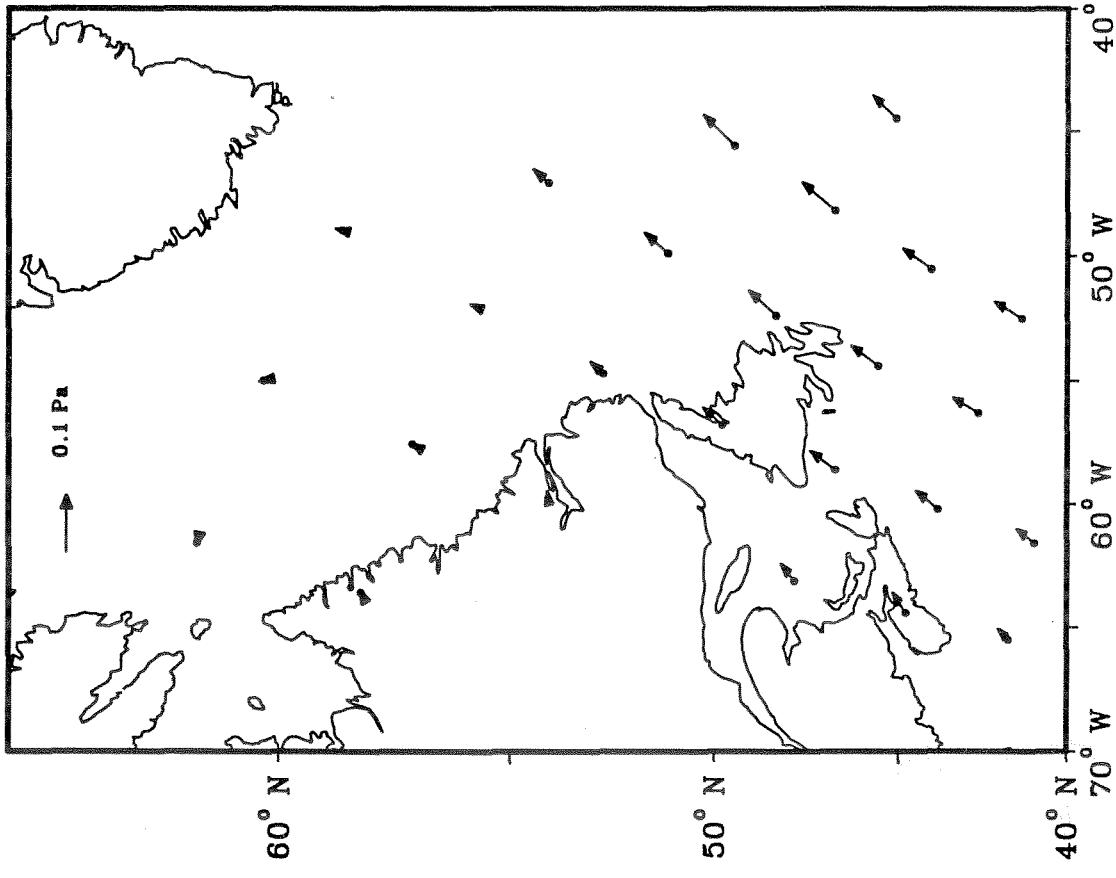
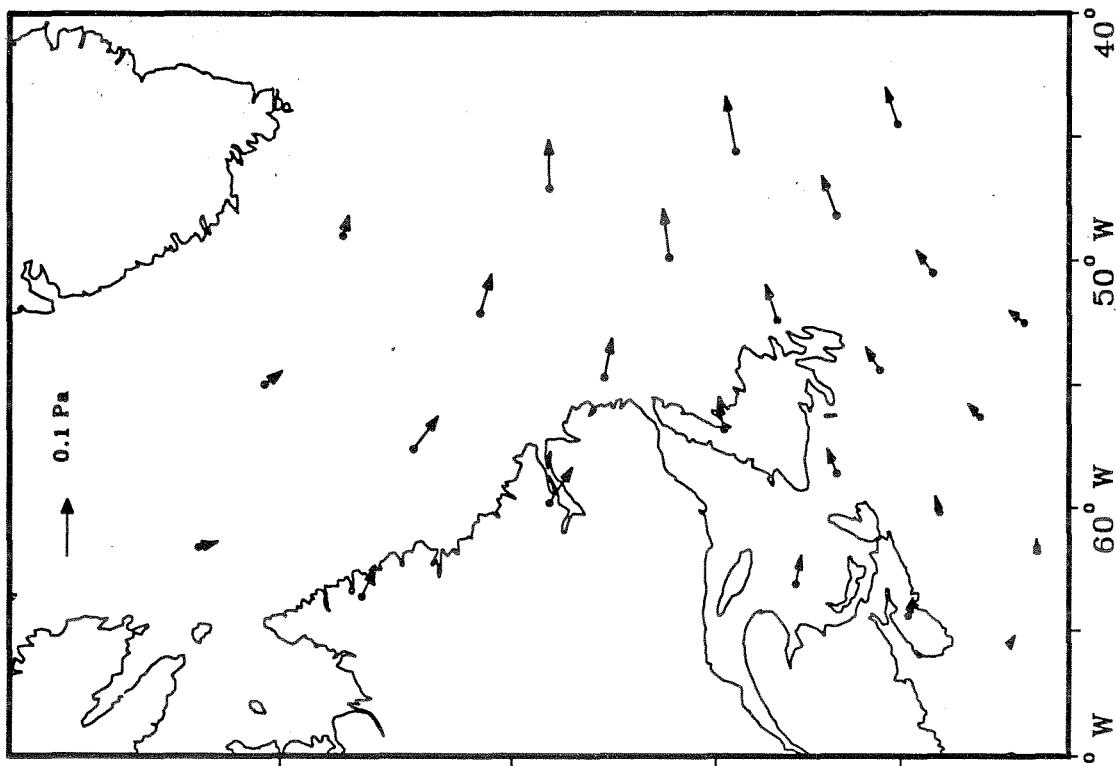
Mean seasonal wind stresses based upon the period 1961-90.

Spring



Winter





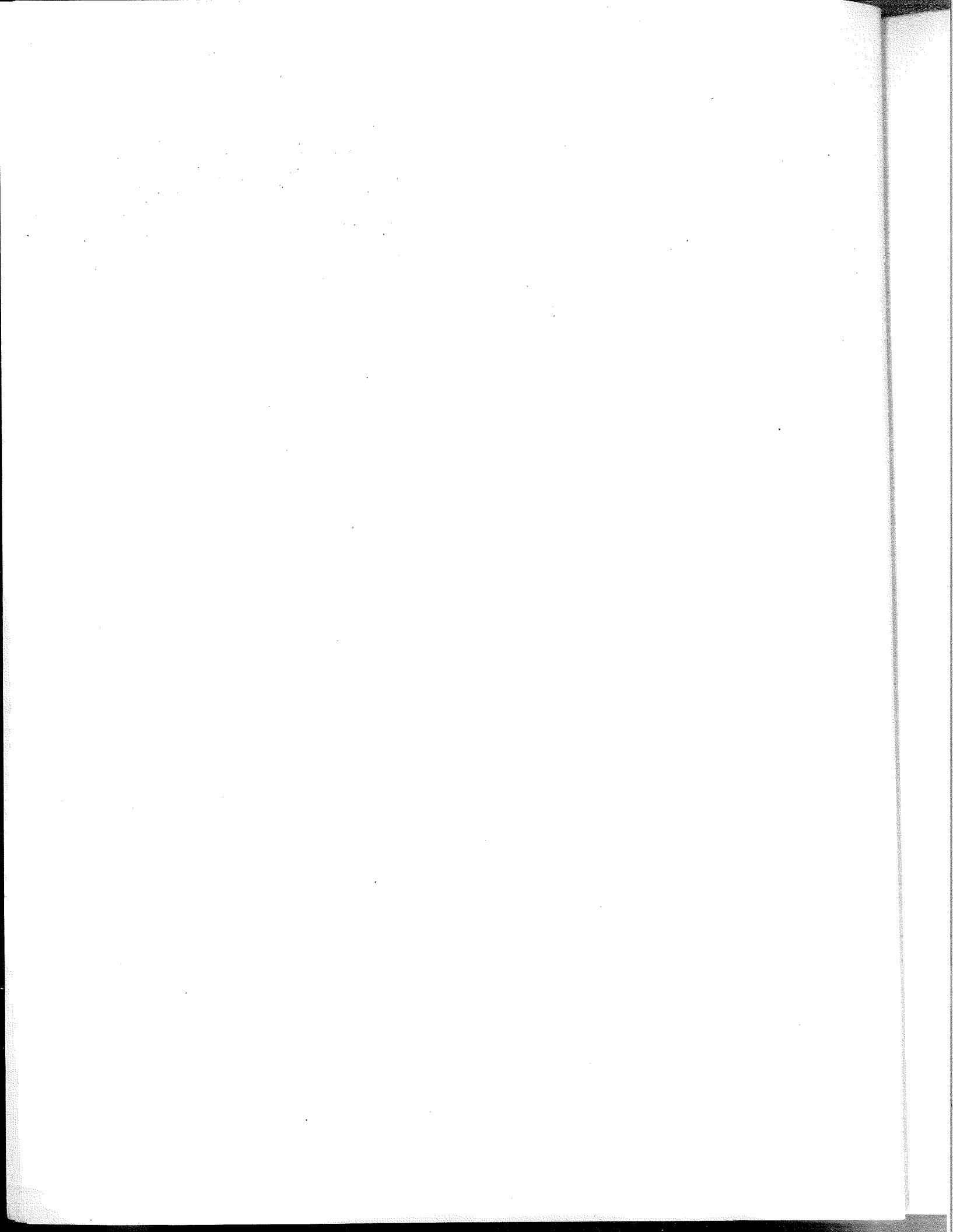
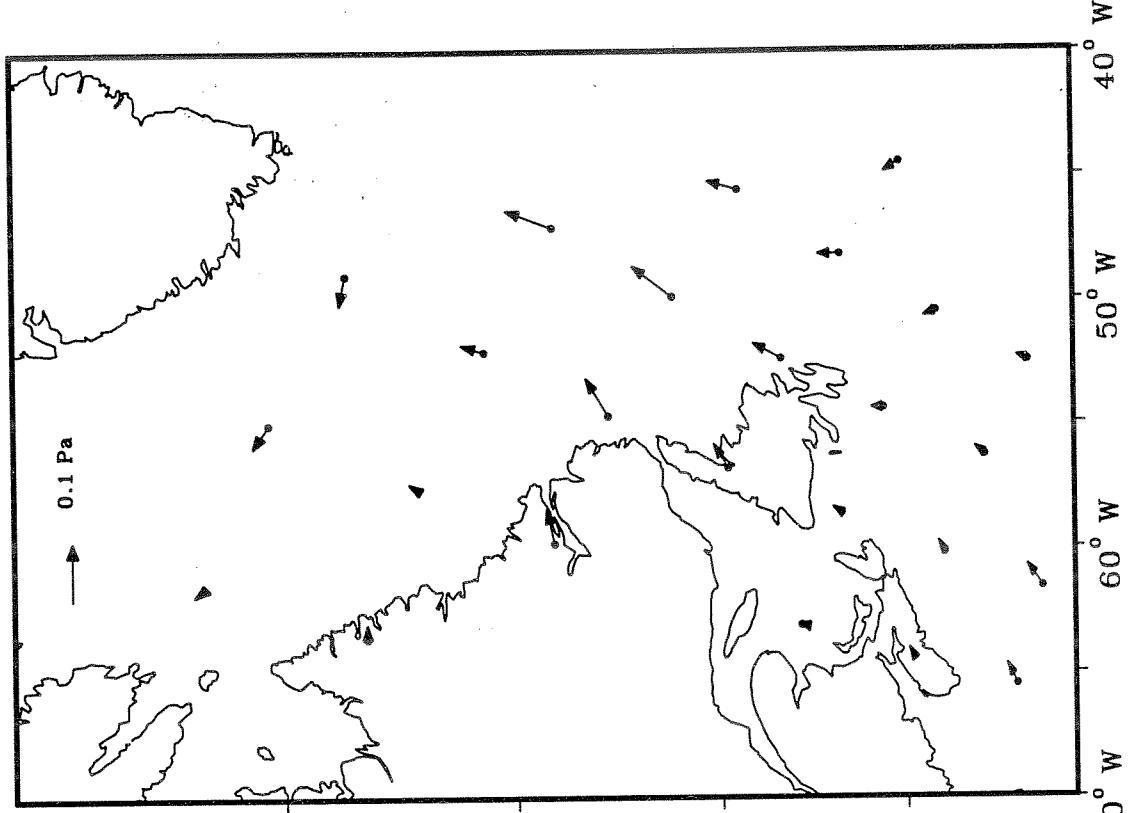


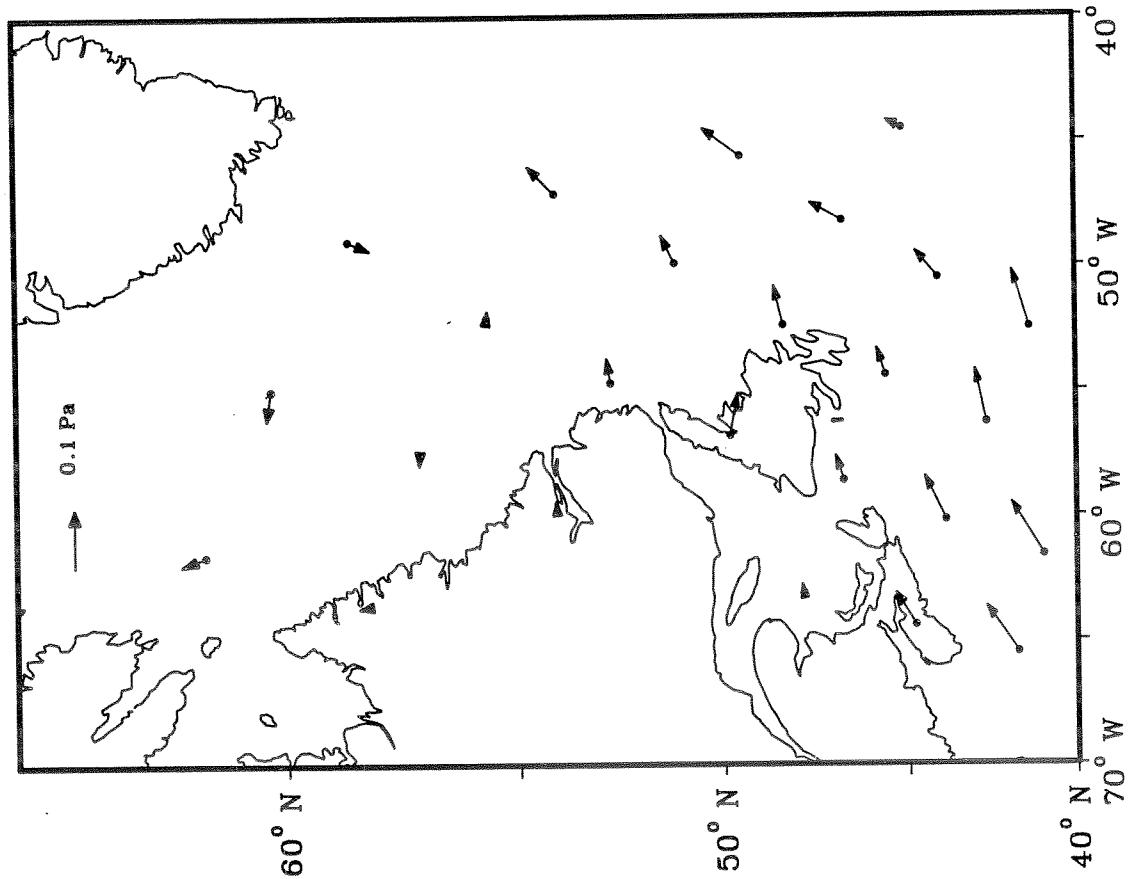
Figure 3

Seasonal anomalies of the wind stress relative to the 1961-90 means.

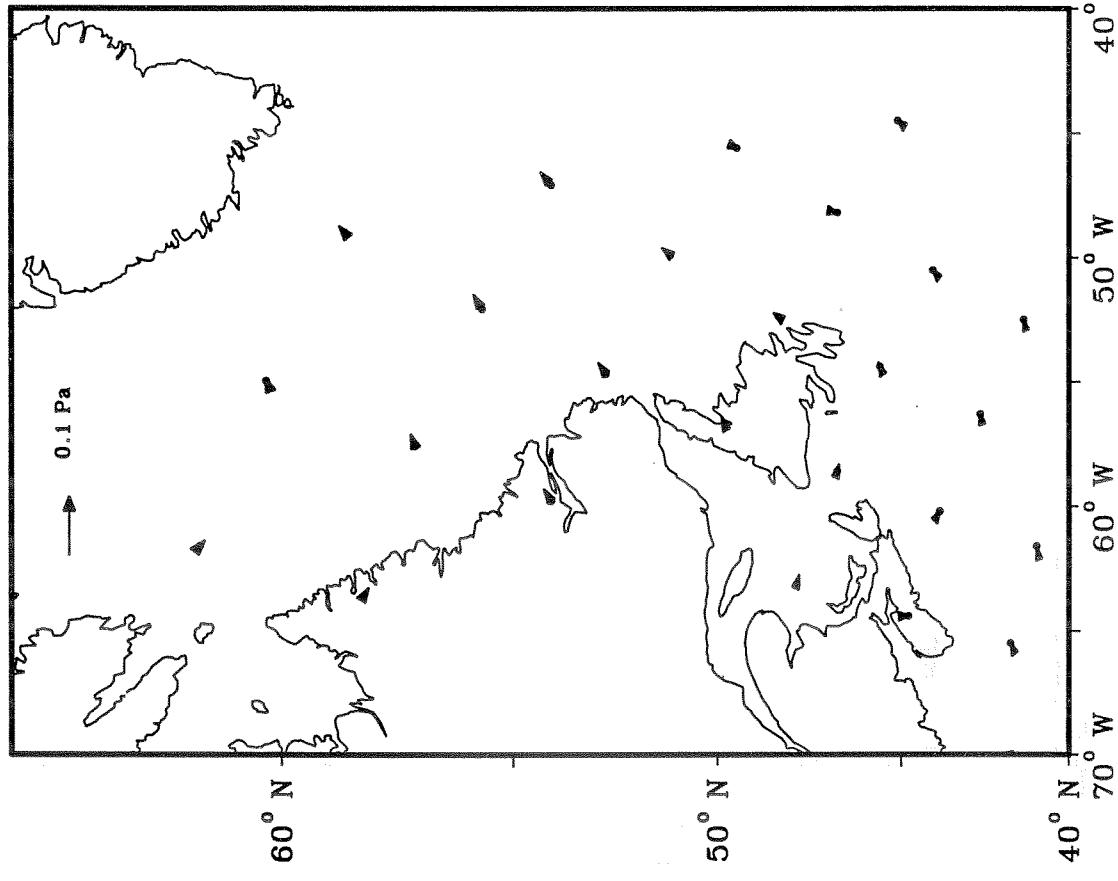
Spring 1946



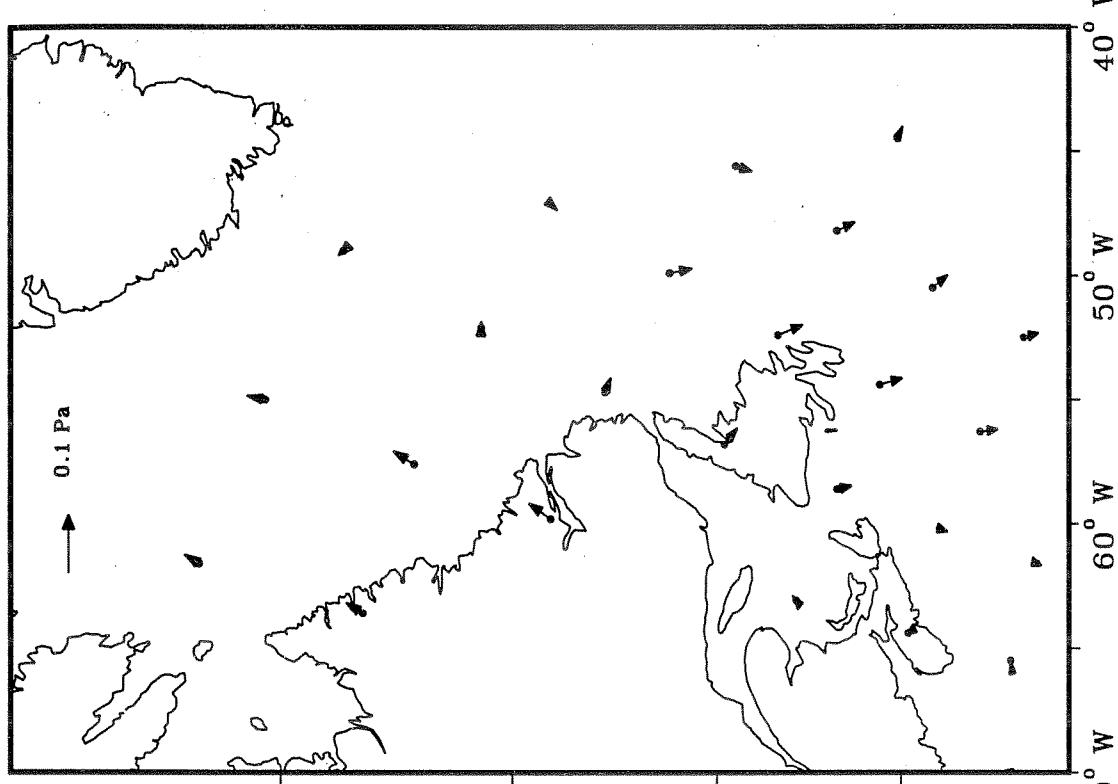
Winter 1946



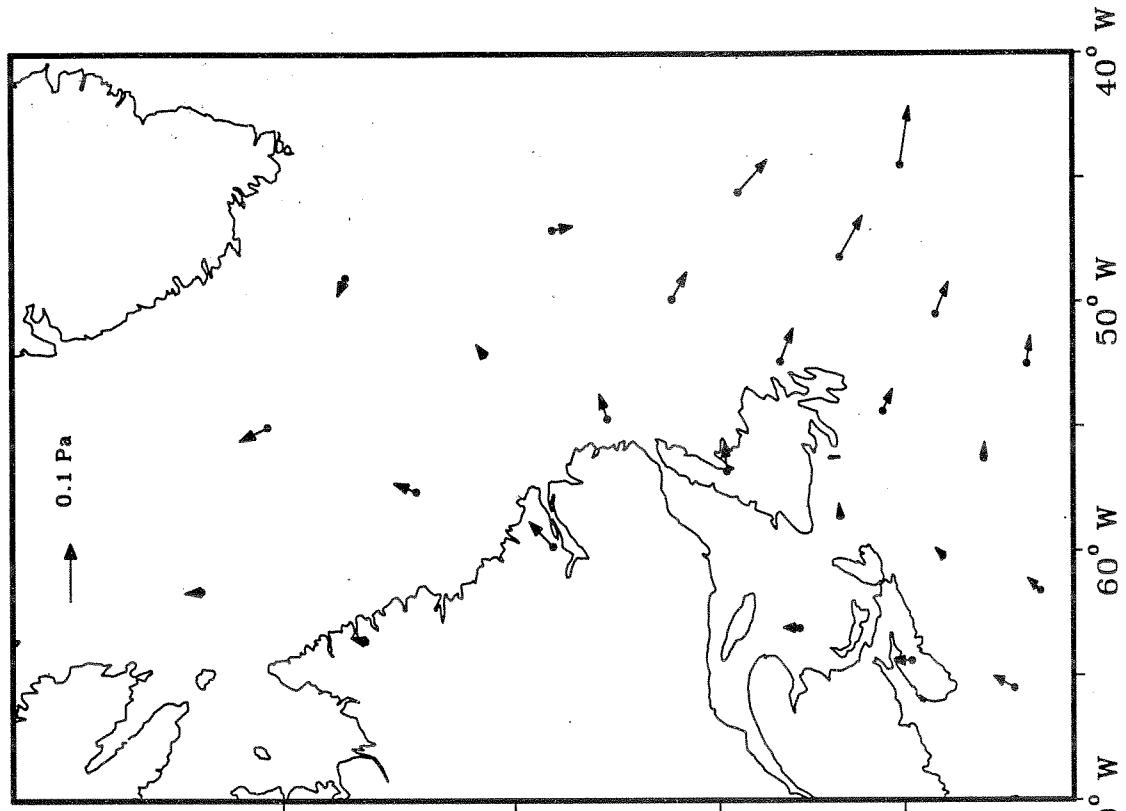
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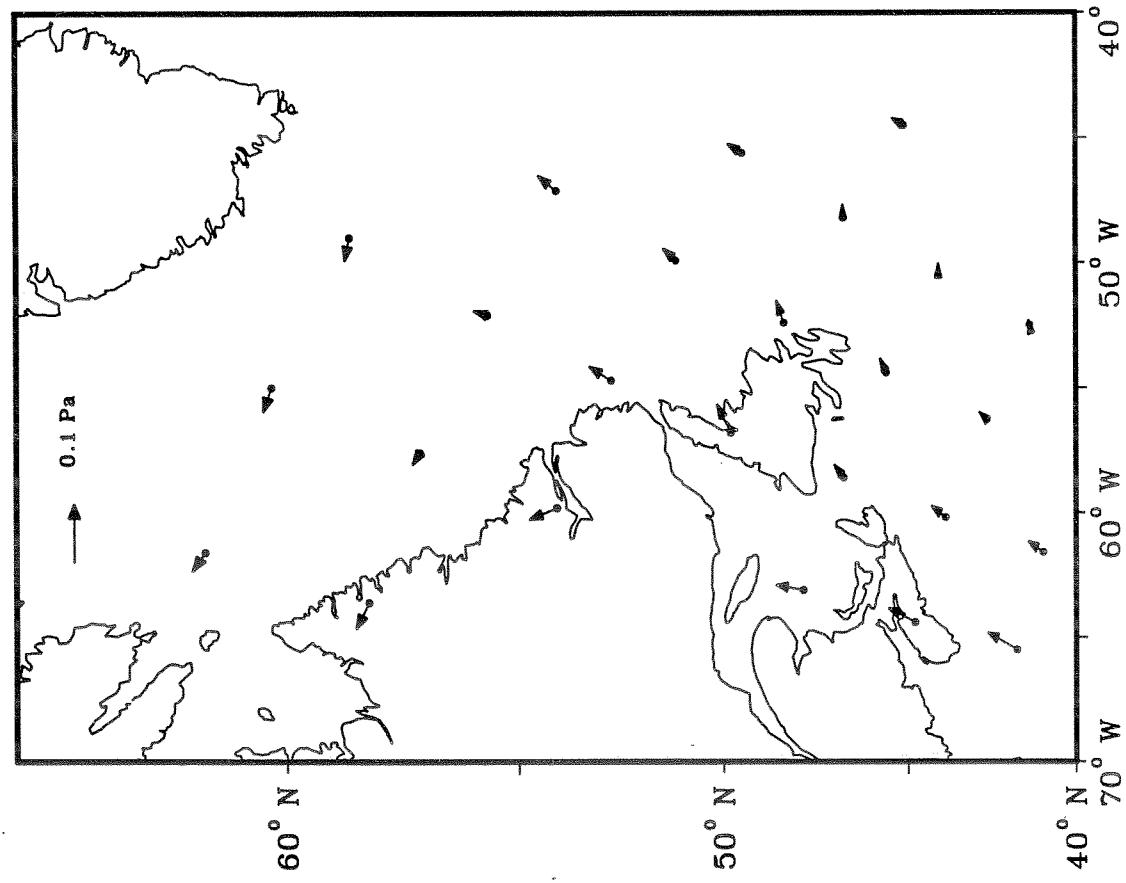
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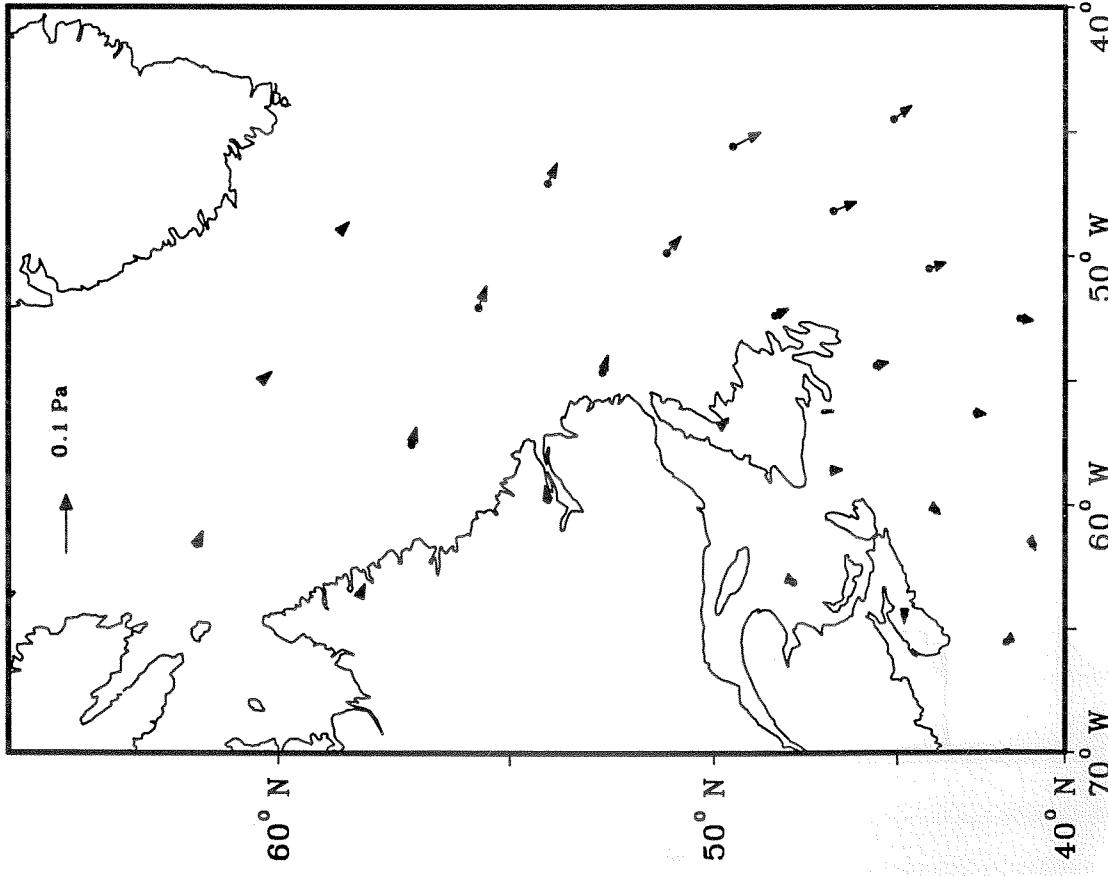
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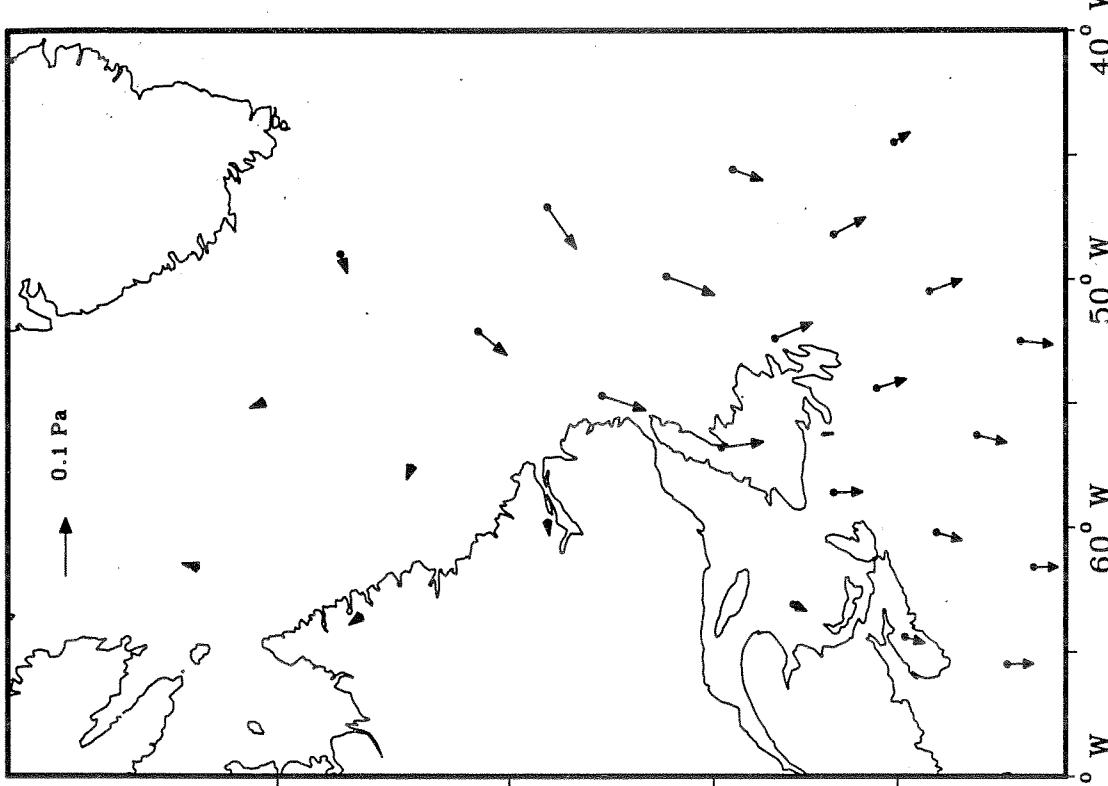
Winter 1947



Summer 1947

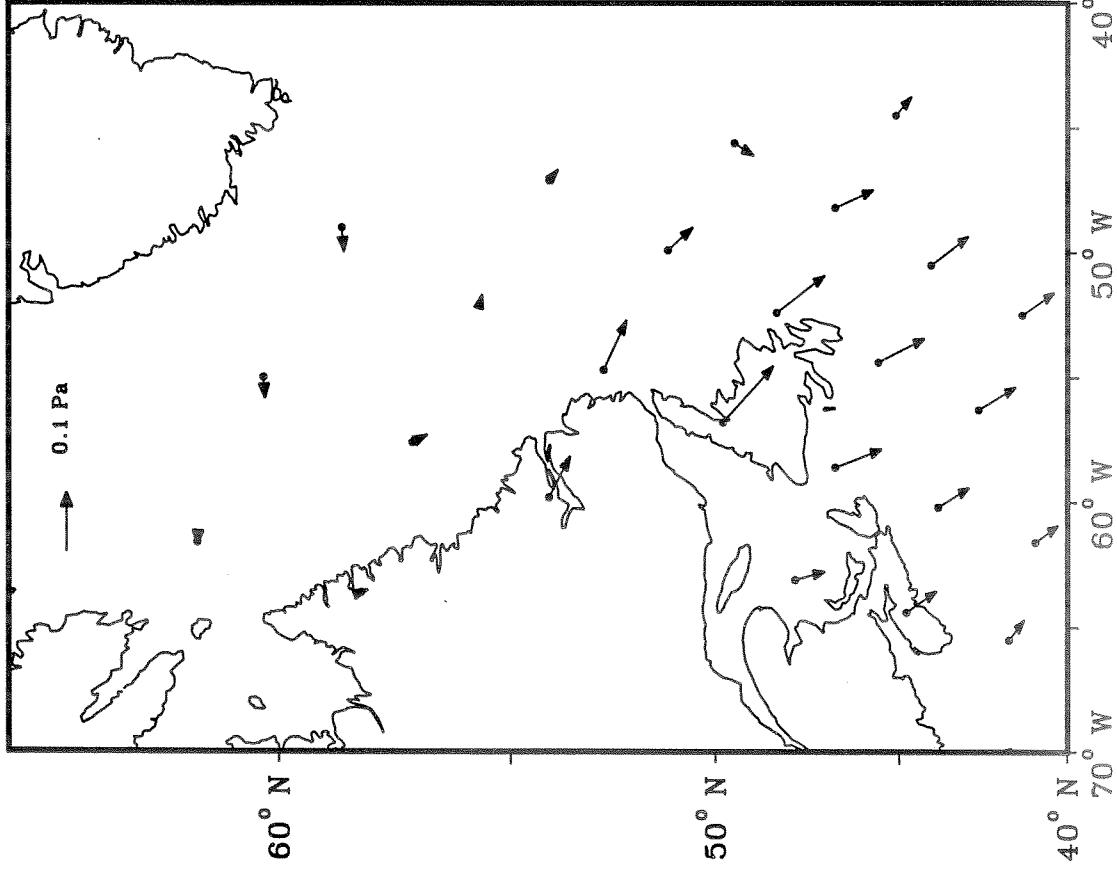


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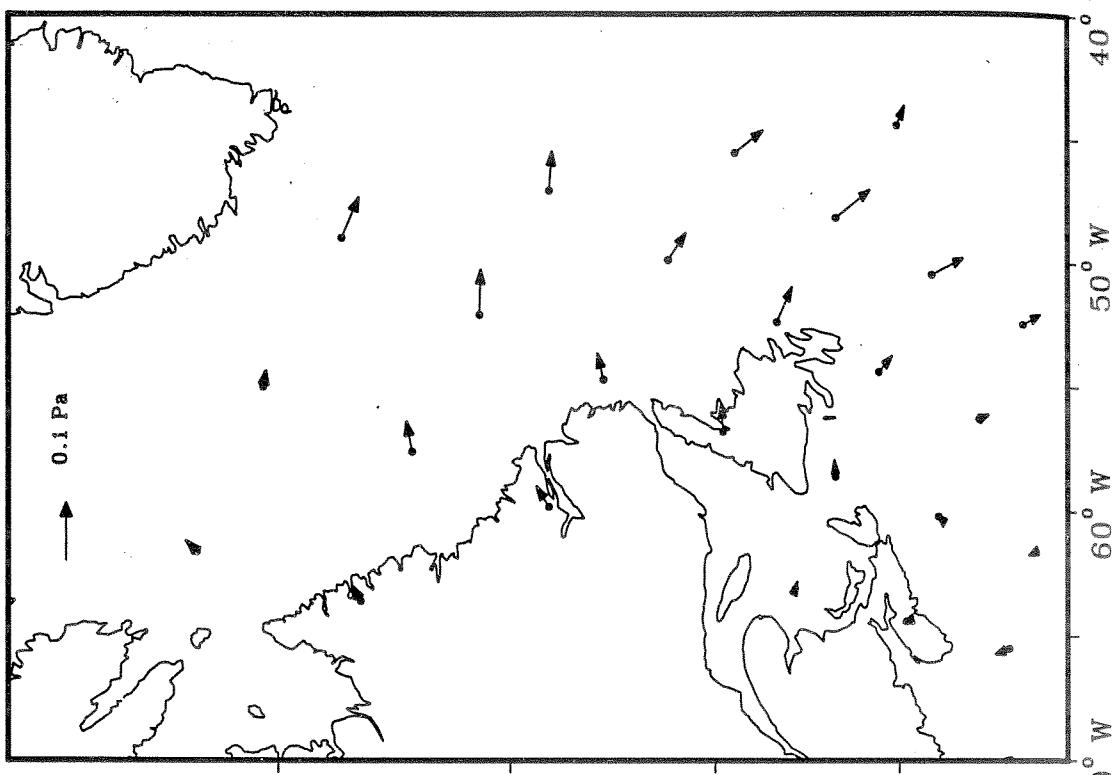


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70° N 60° N 50° N 40° N

Winter 1948

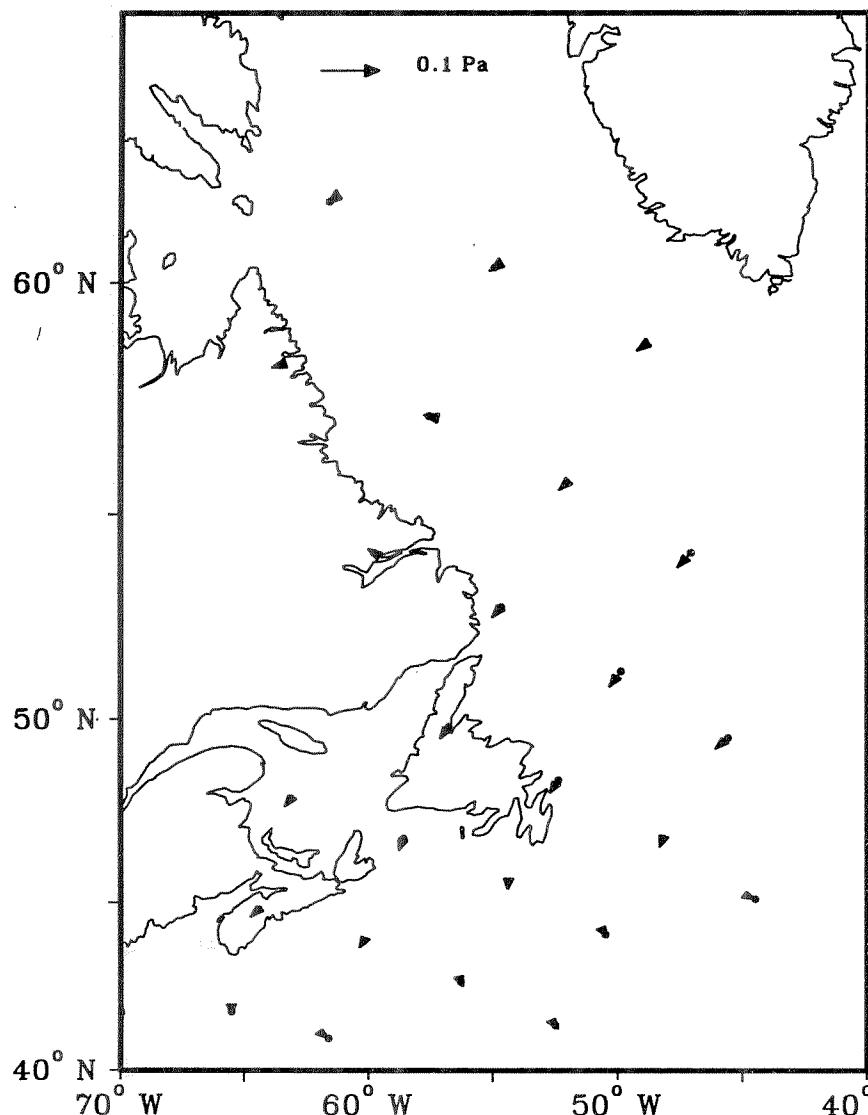


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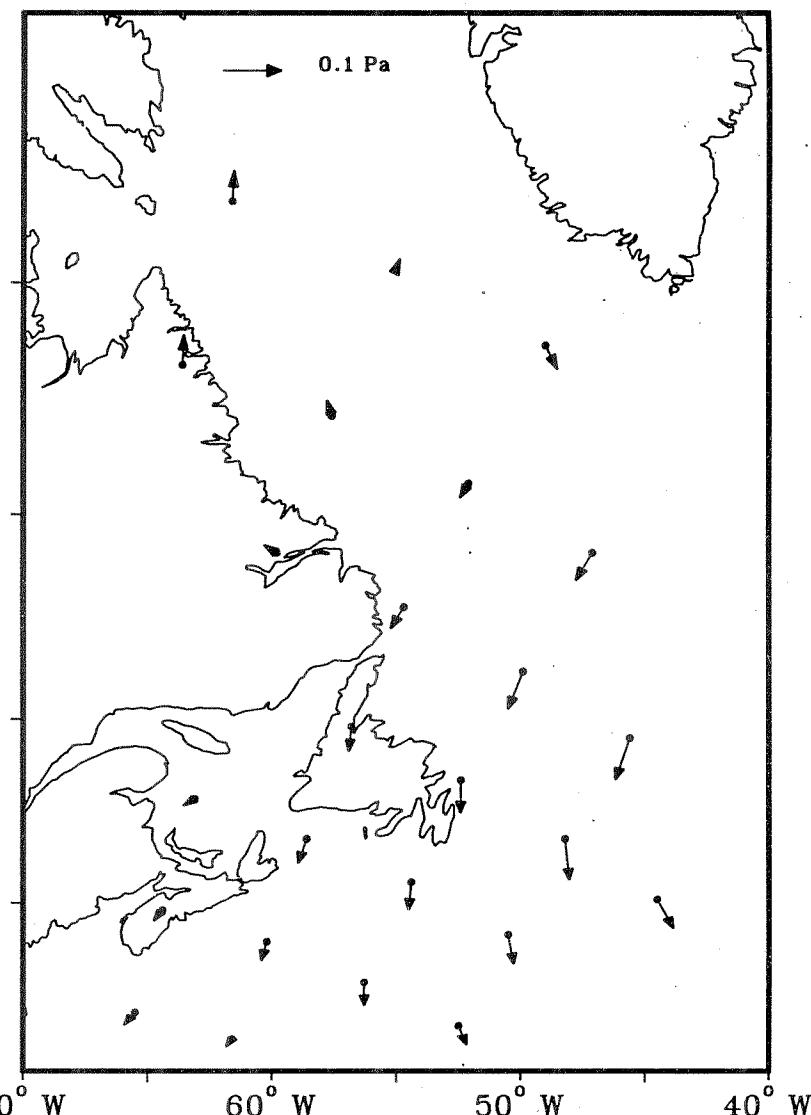


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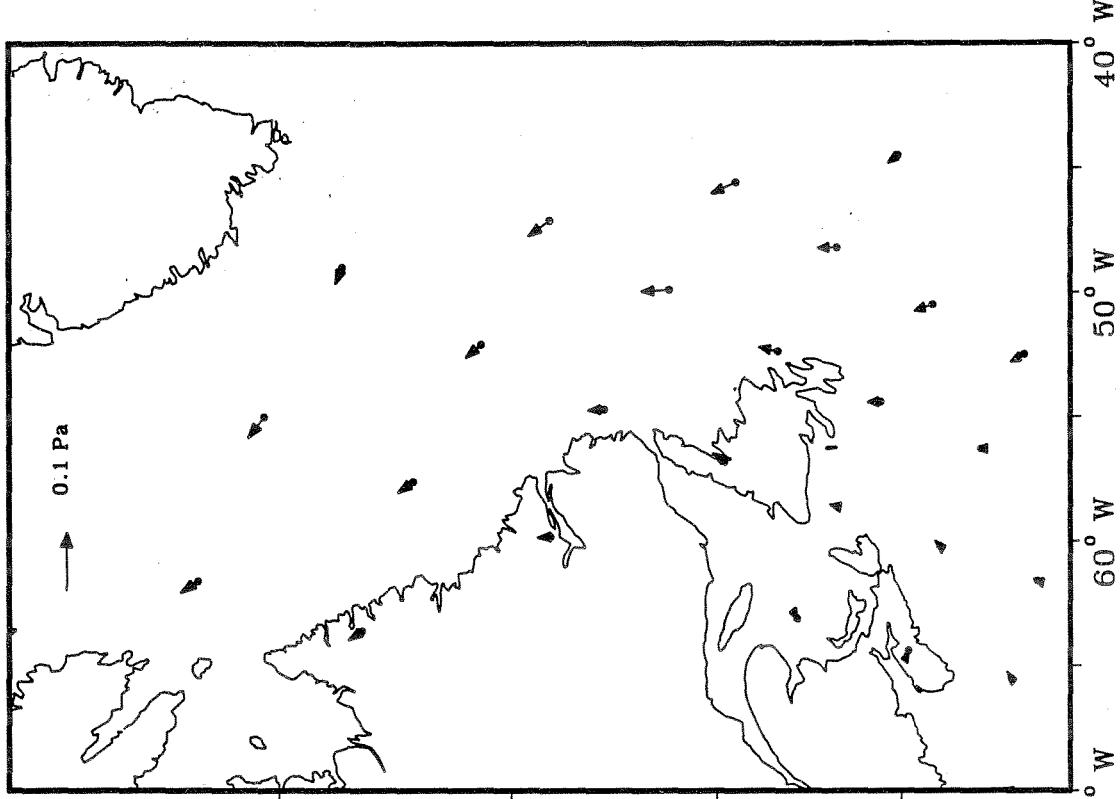
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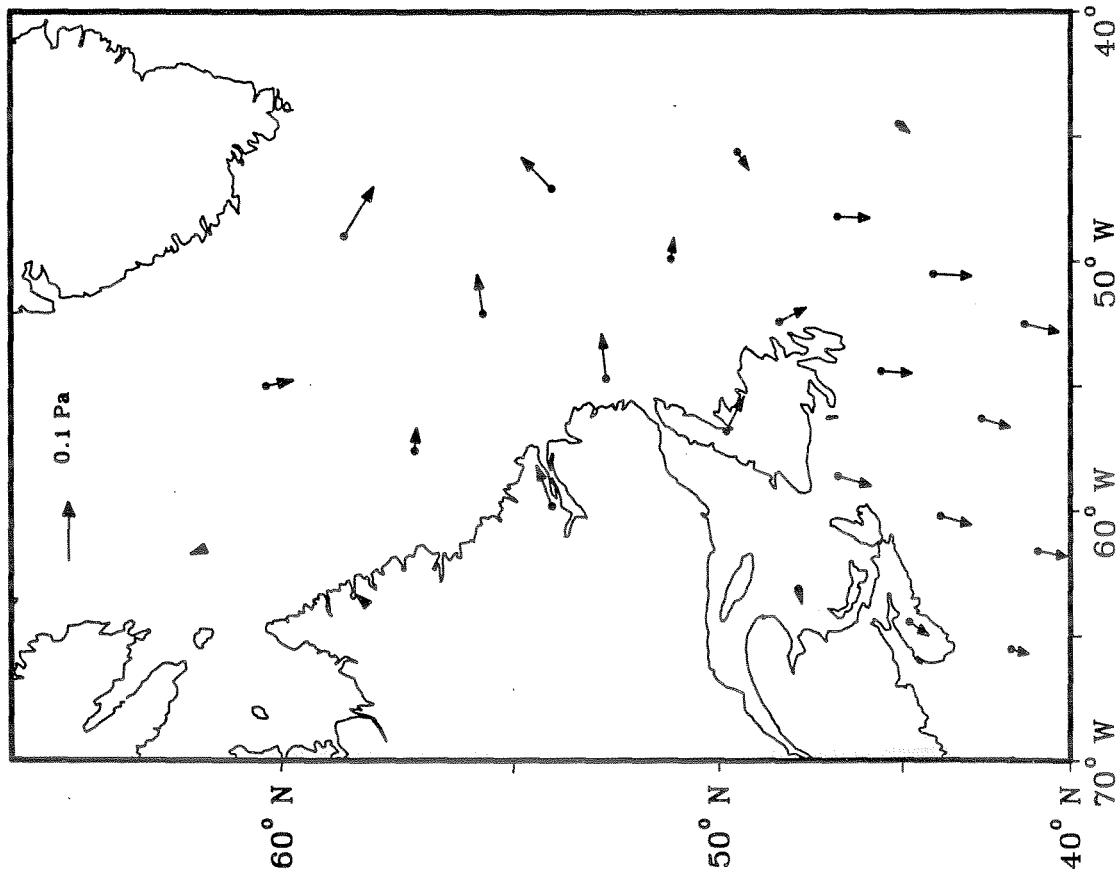
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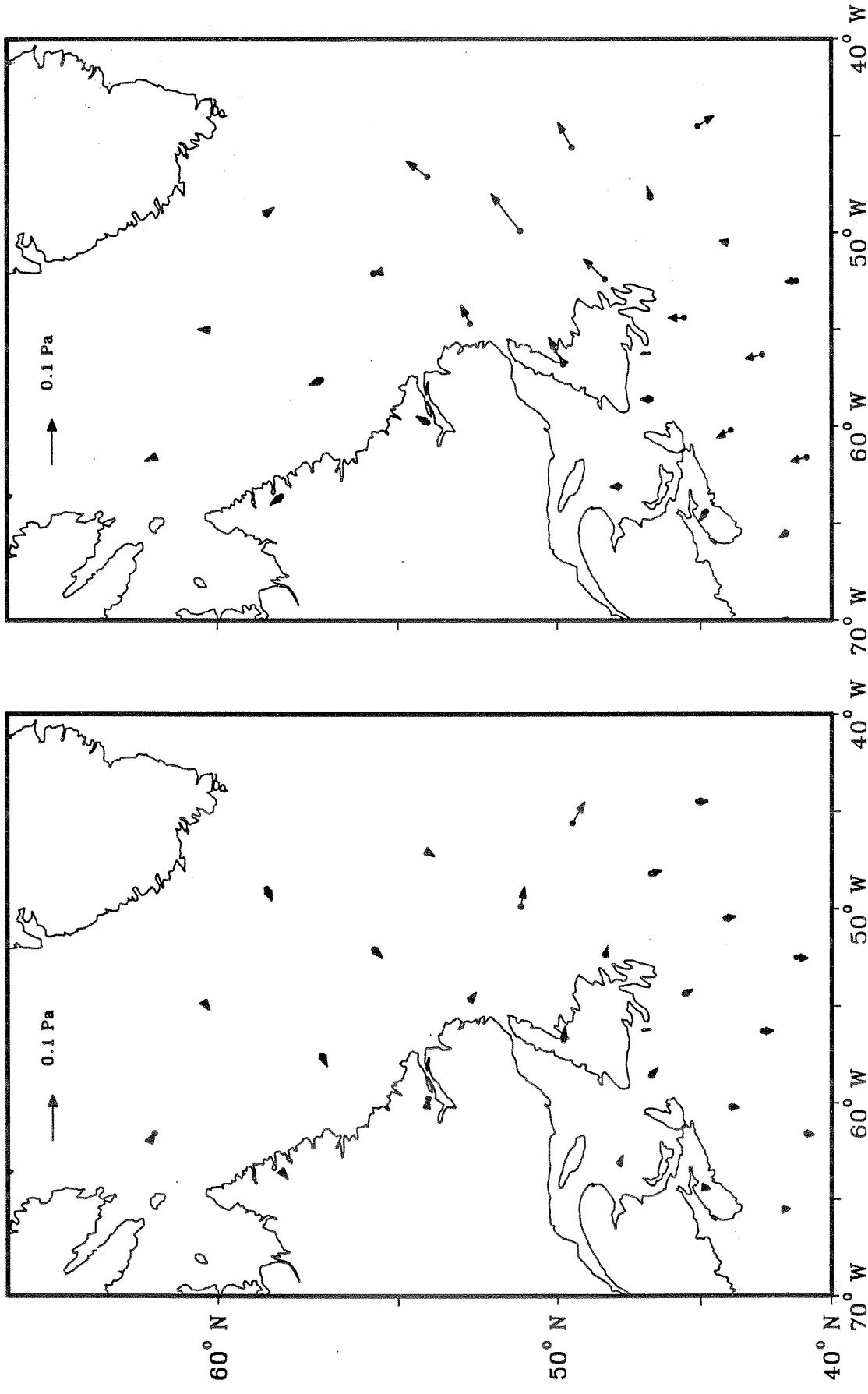
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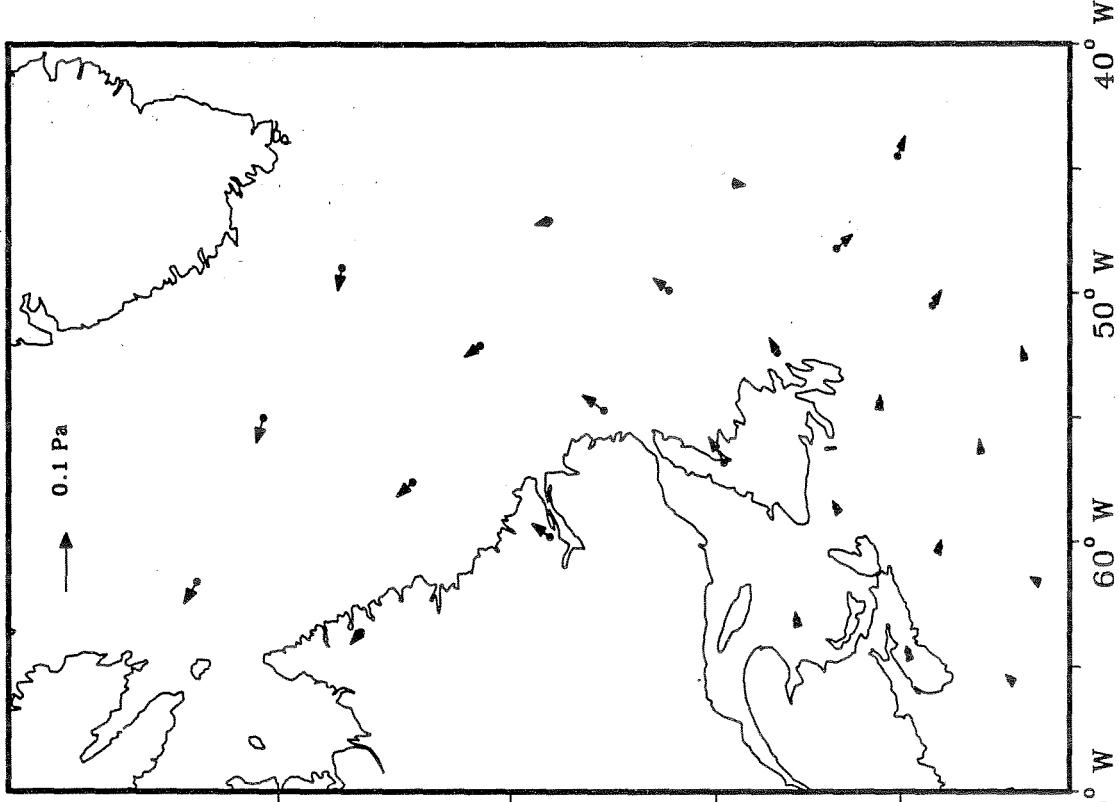
Winter 1949



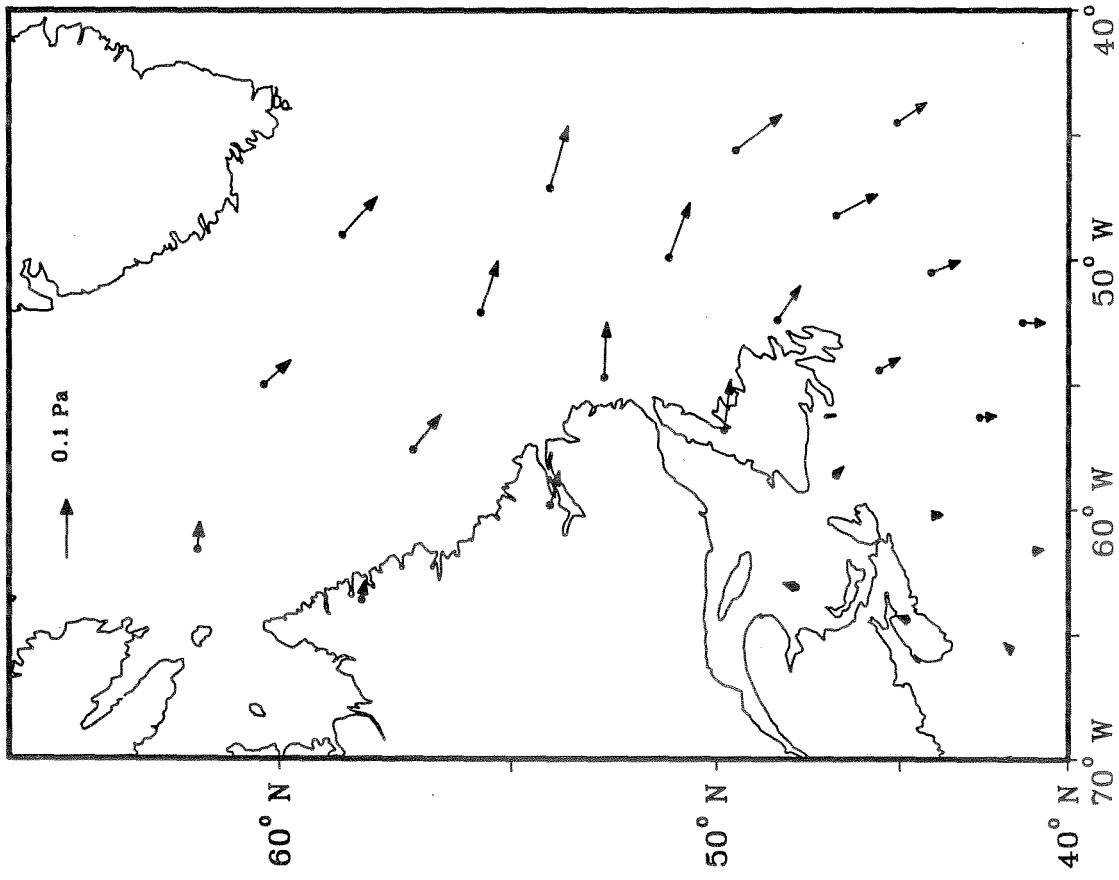
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Summer 1949



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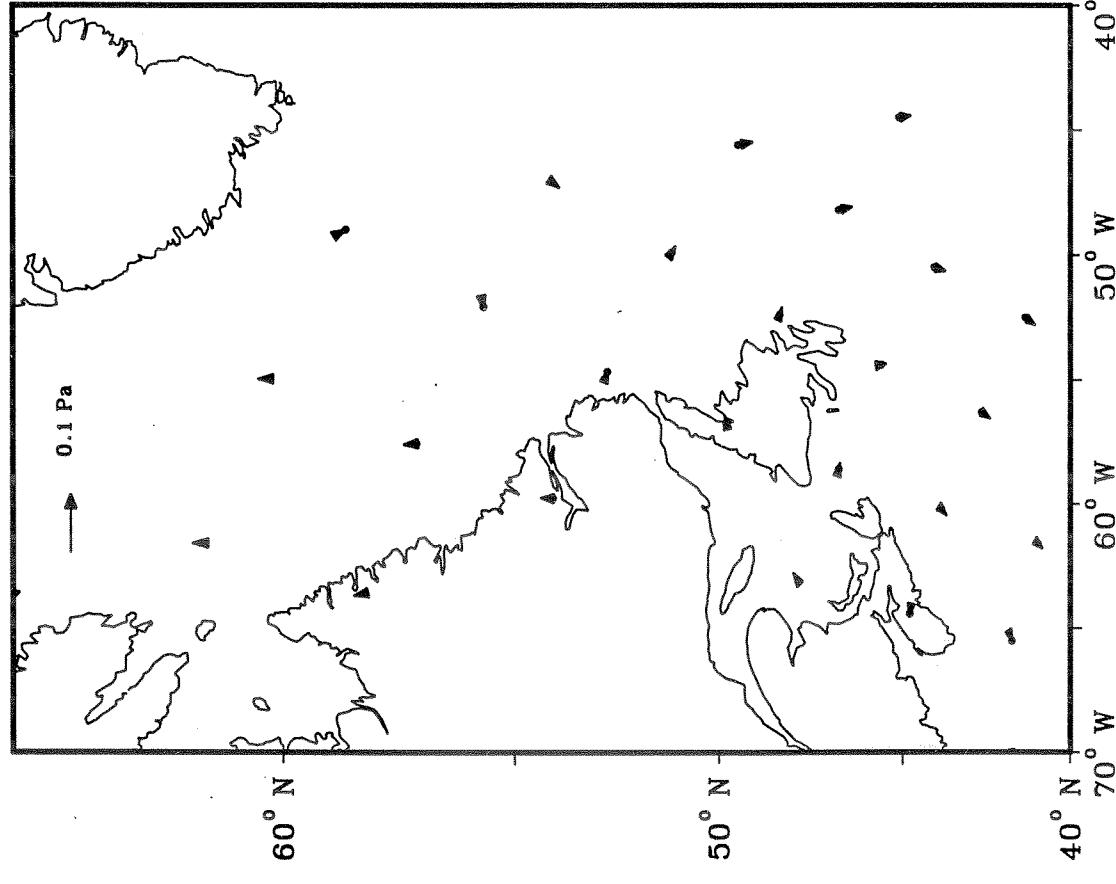


Winter 1950

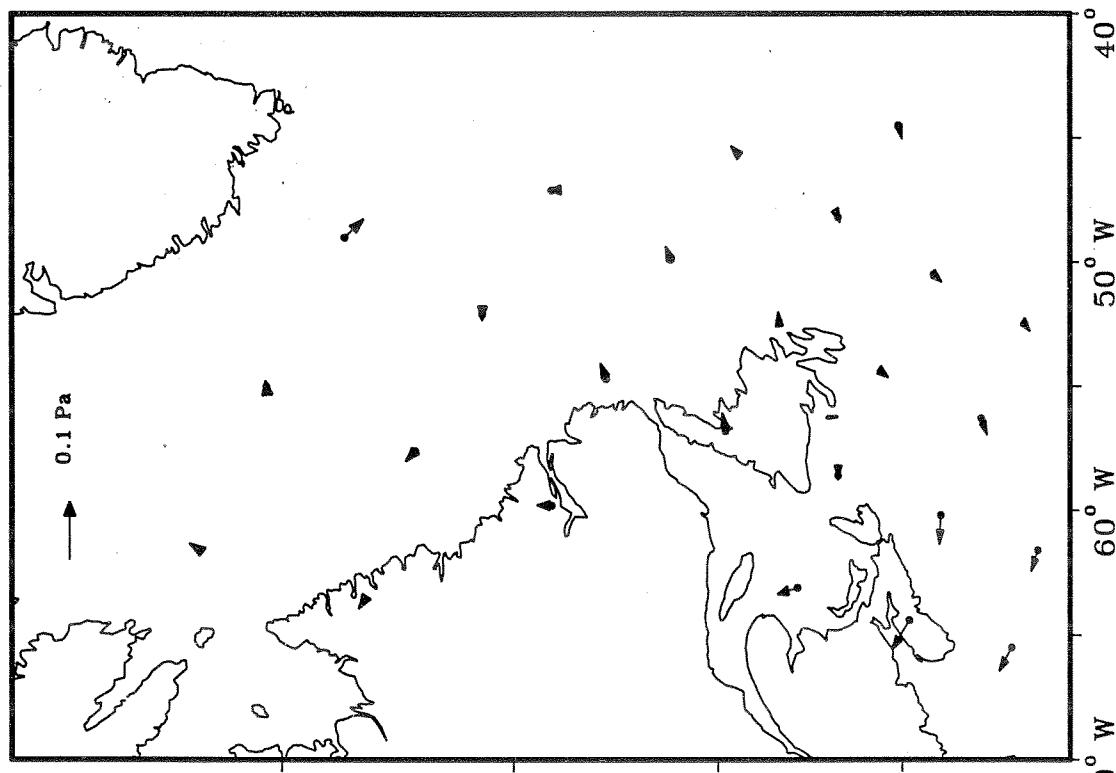


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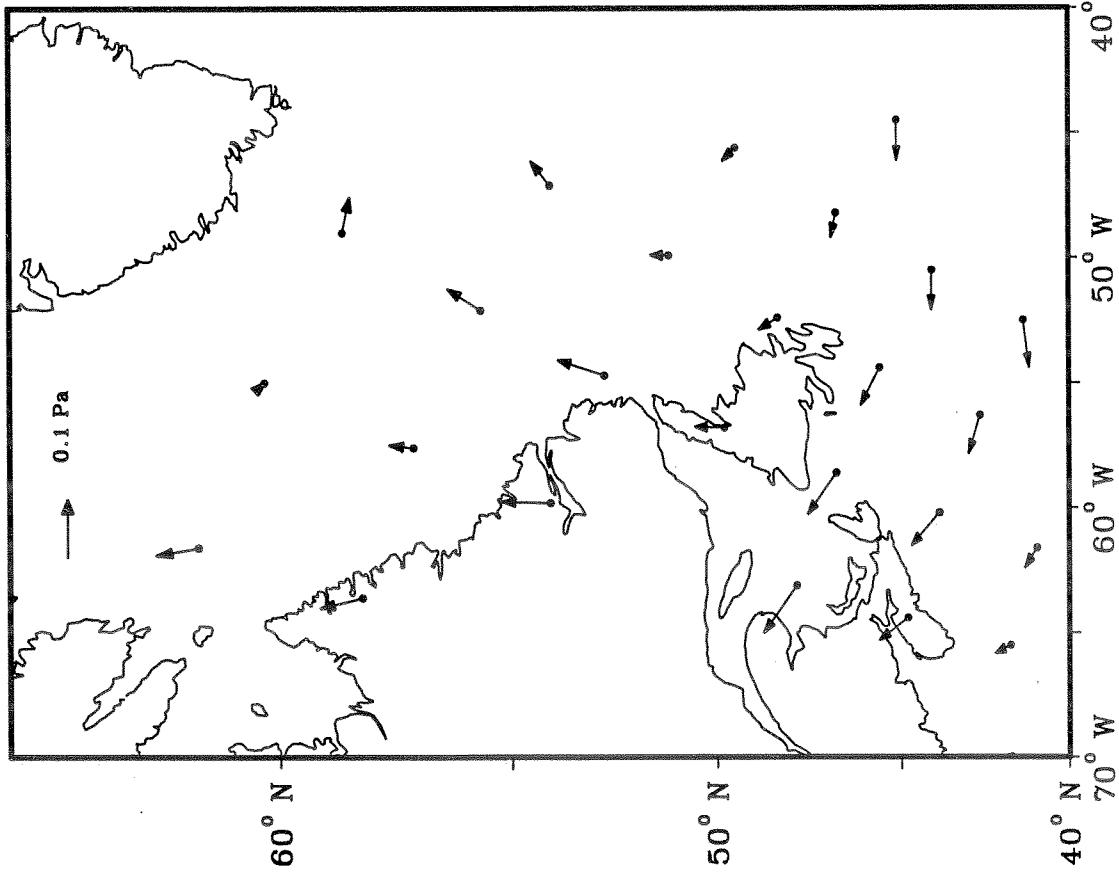
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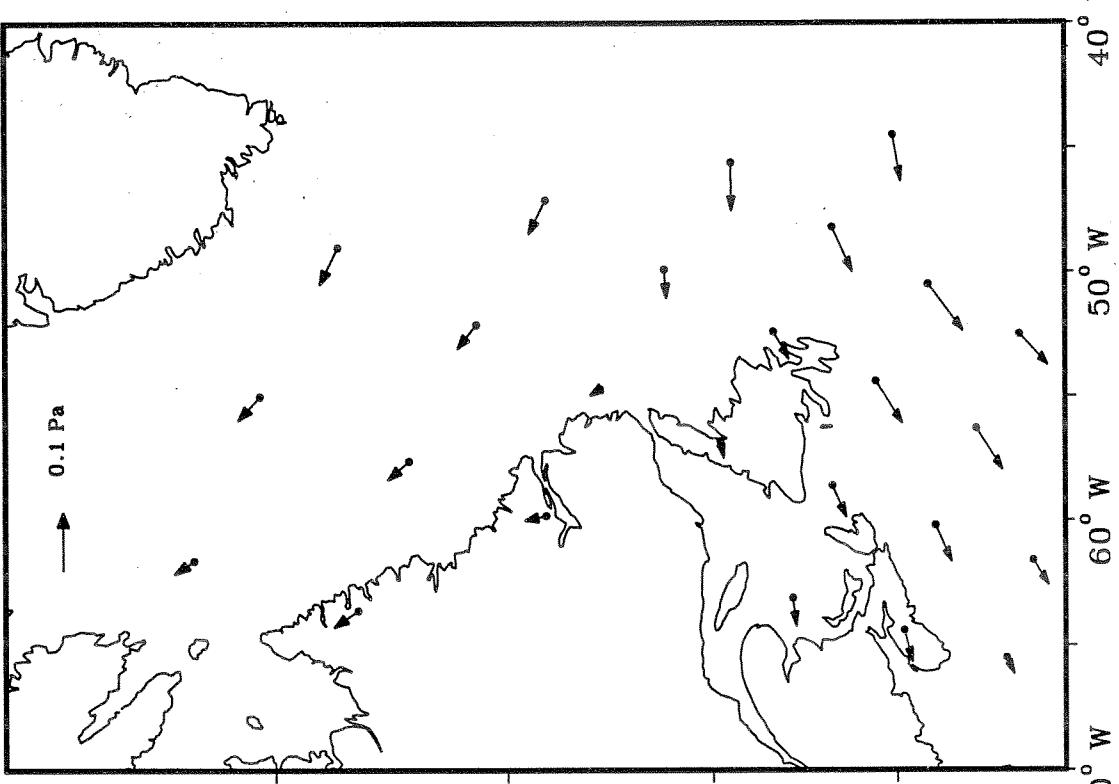
Fall 1950



Winter 1951



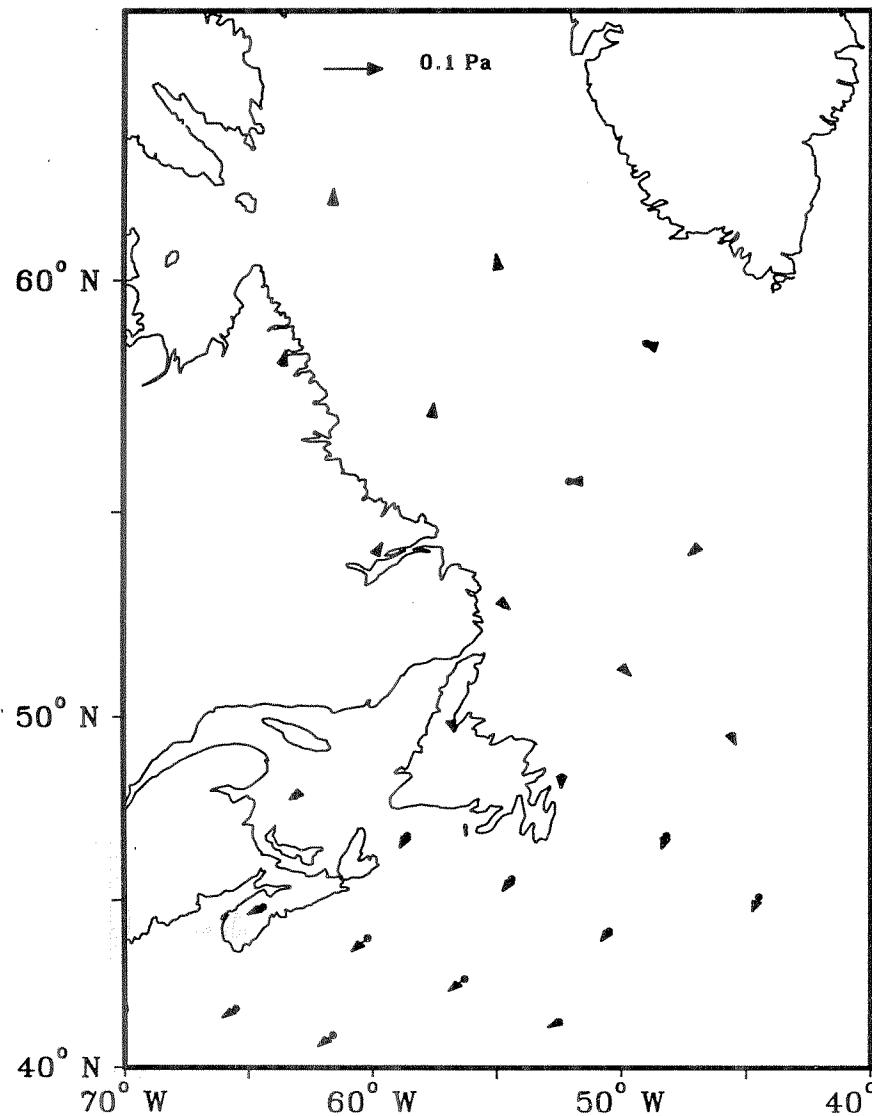
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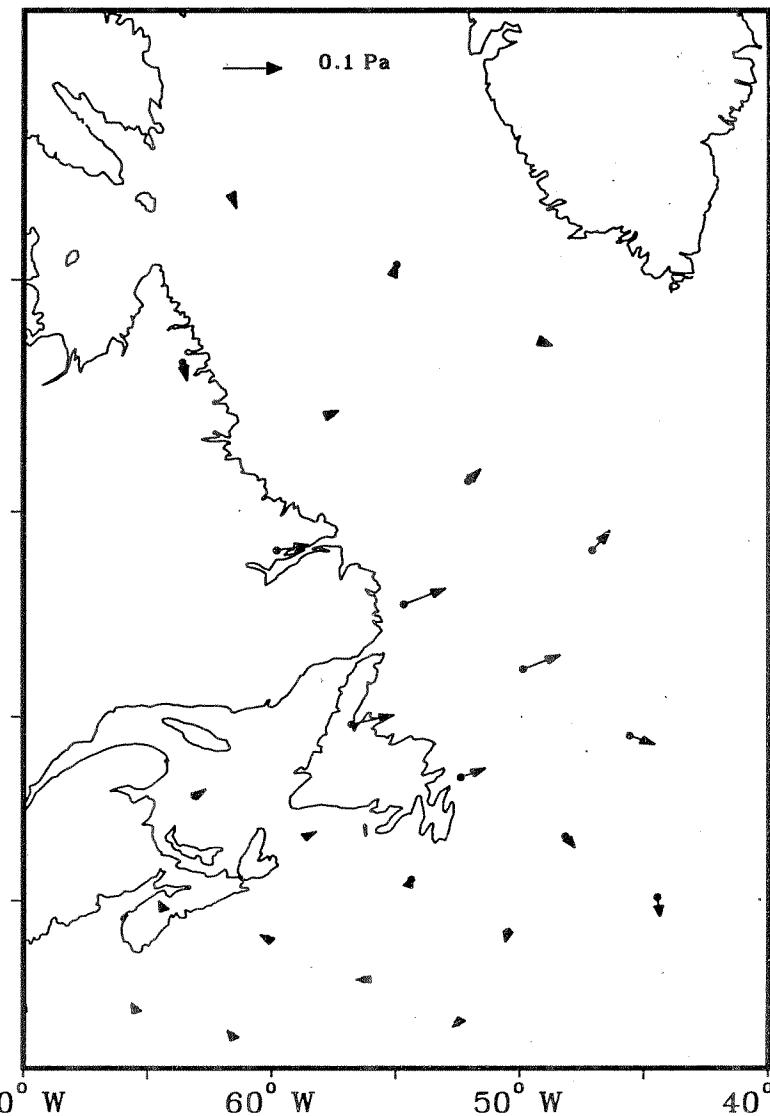
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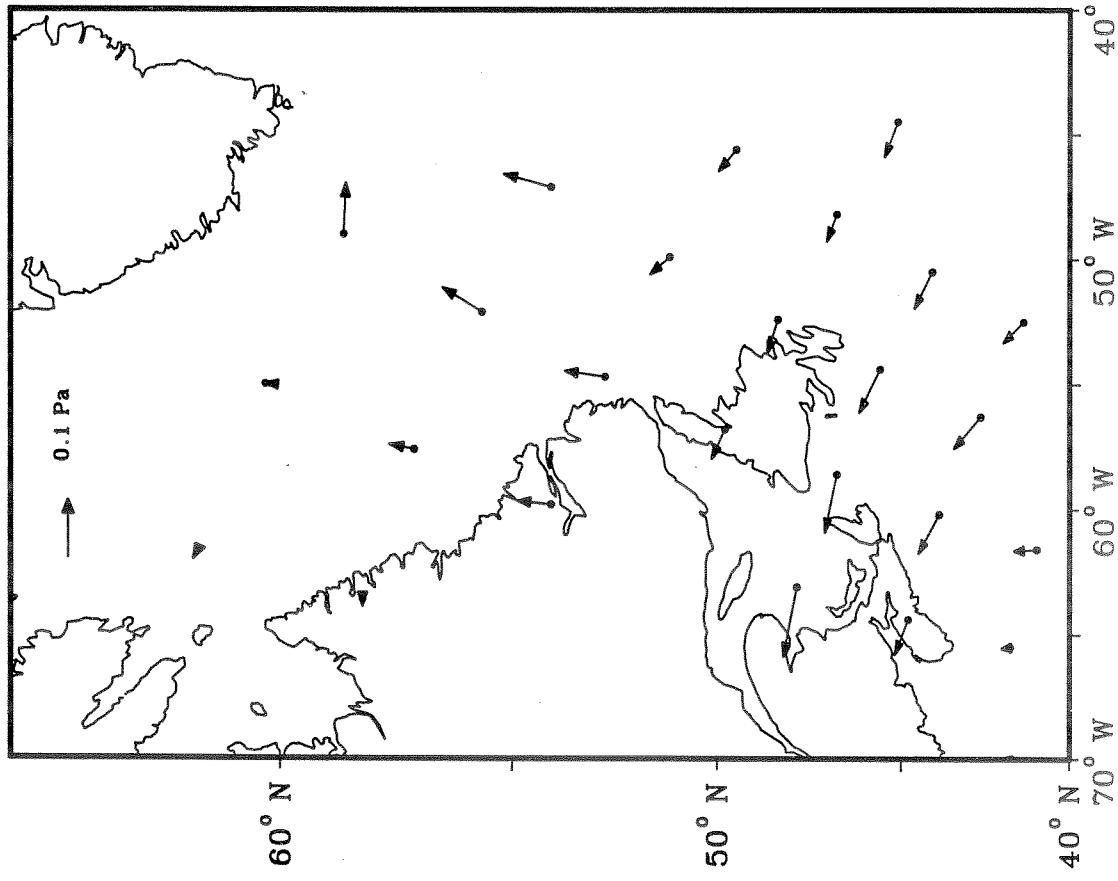
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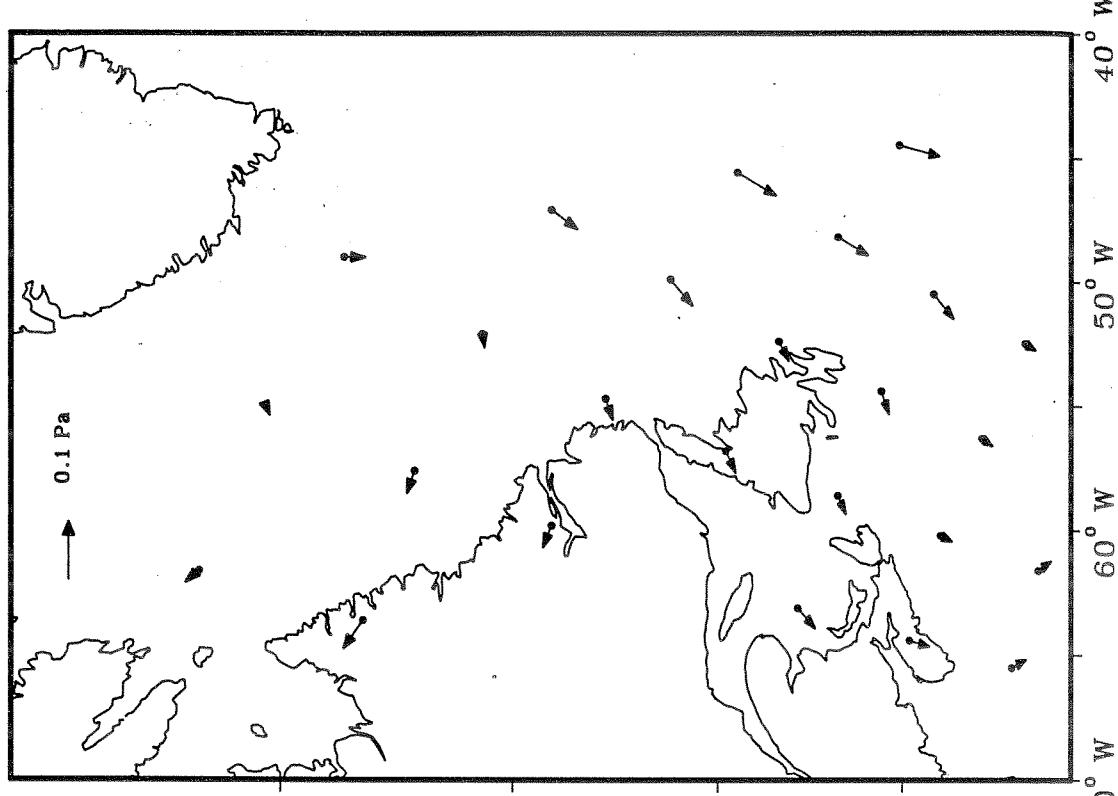
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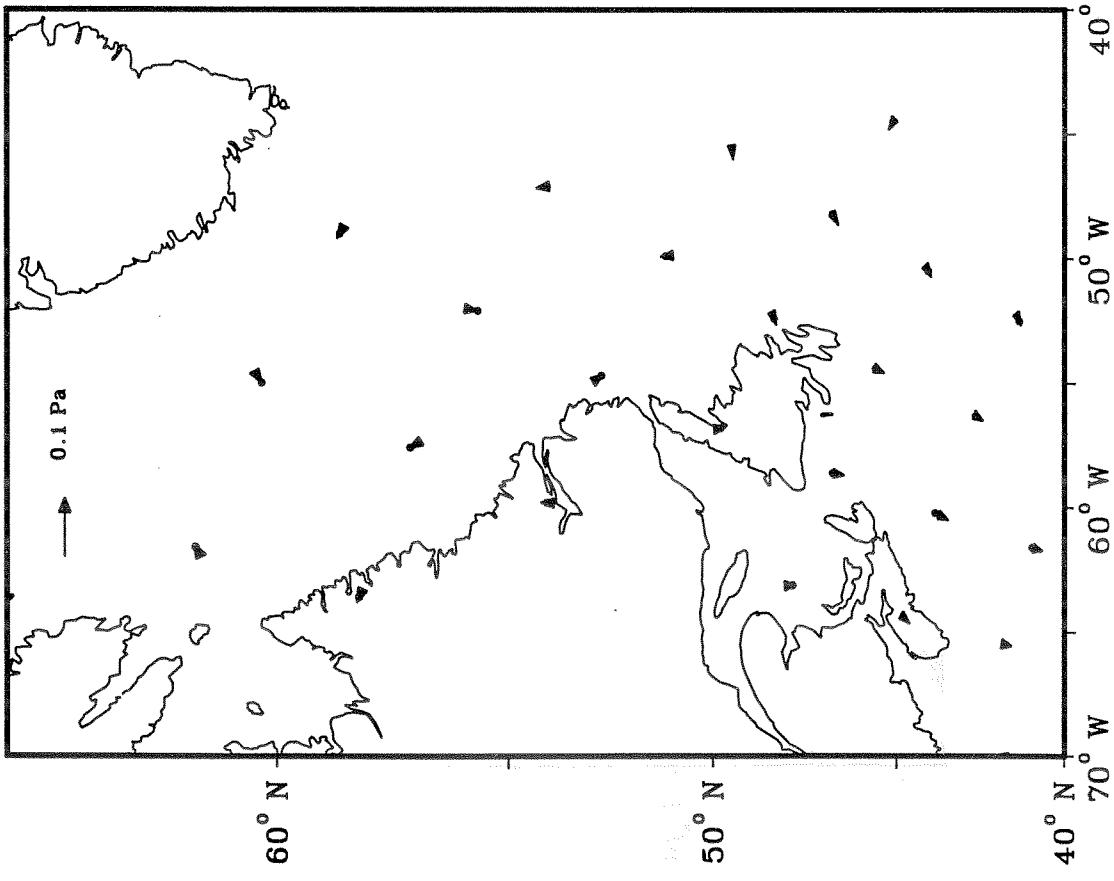
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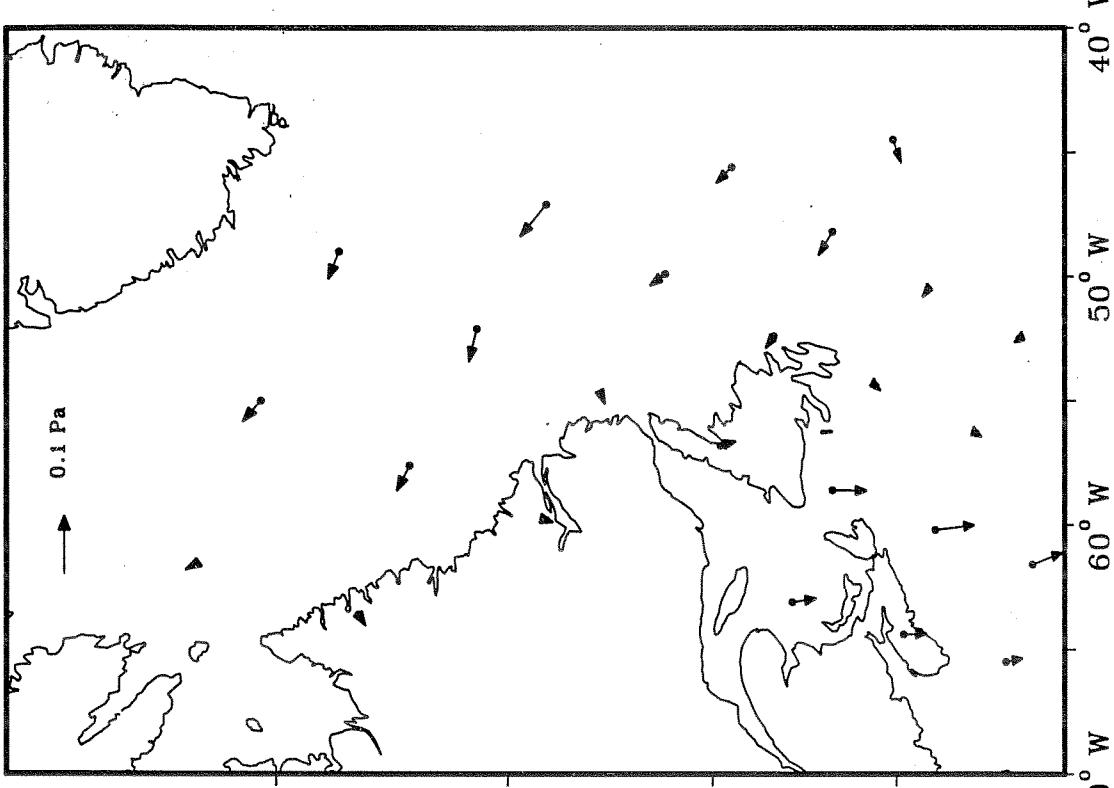
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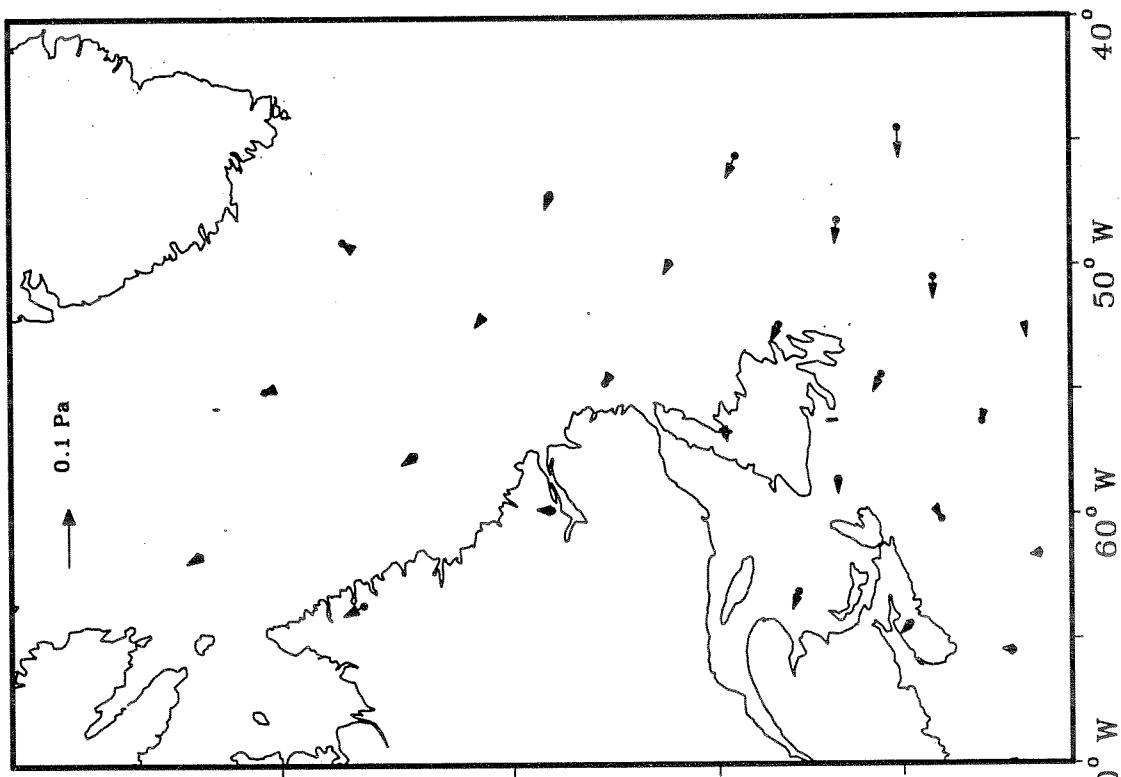


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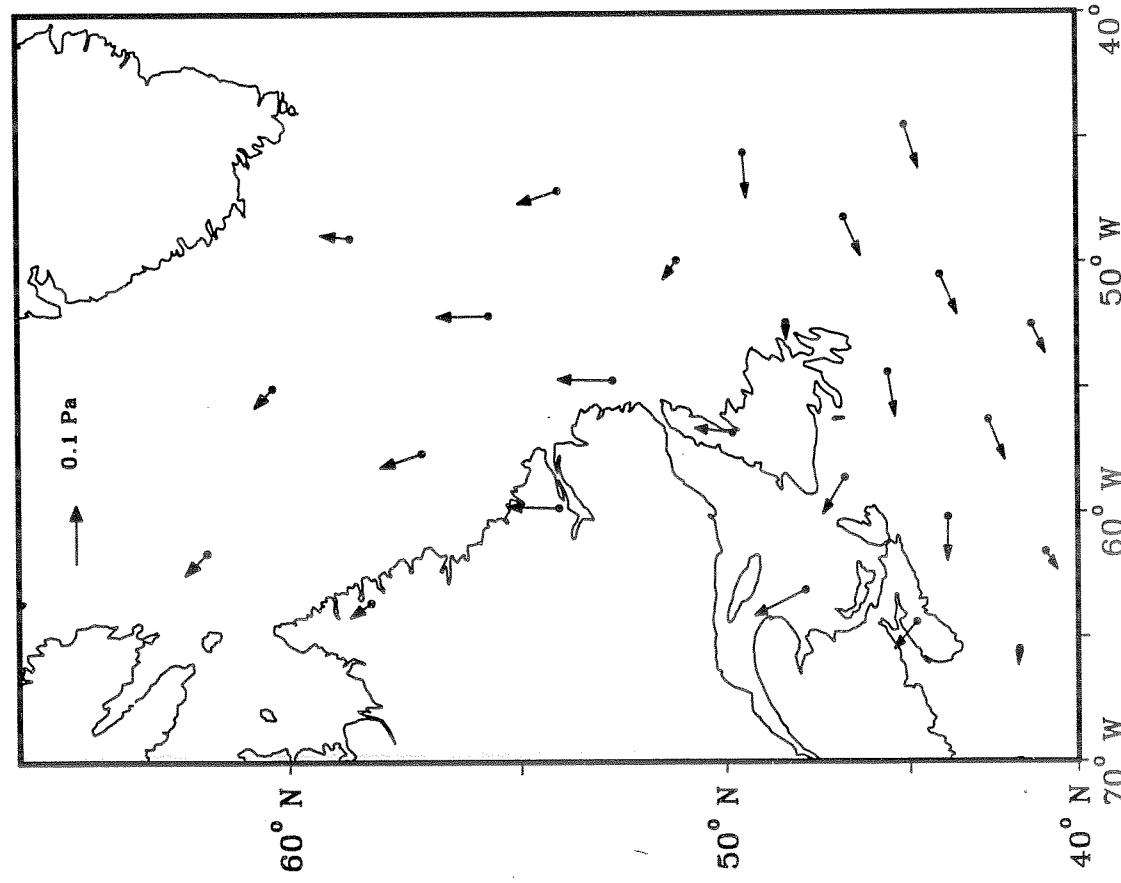


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Spring 1953



Winter 1953



70° W

60° W

50° W

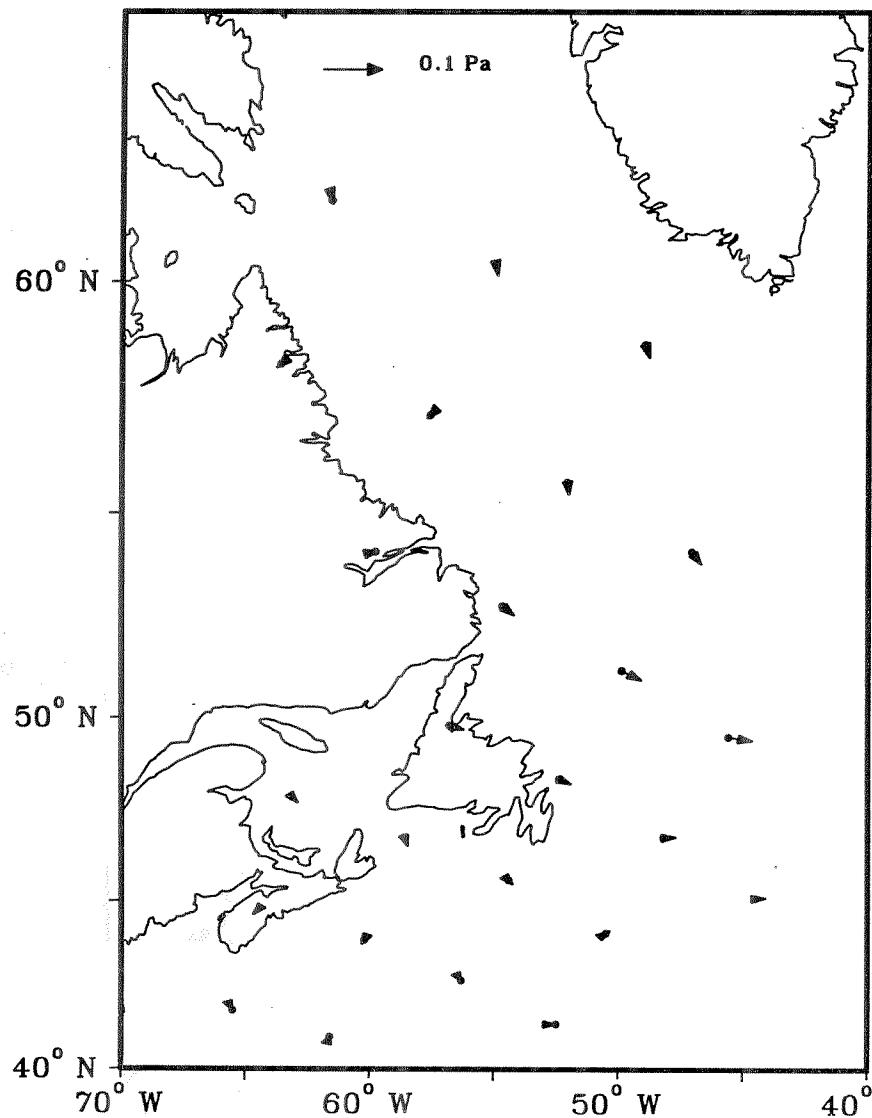
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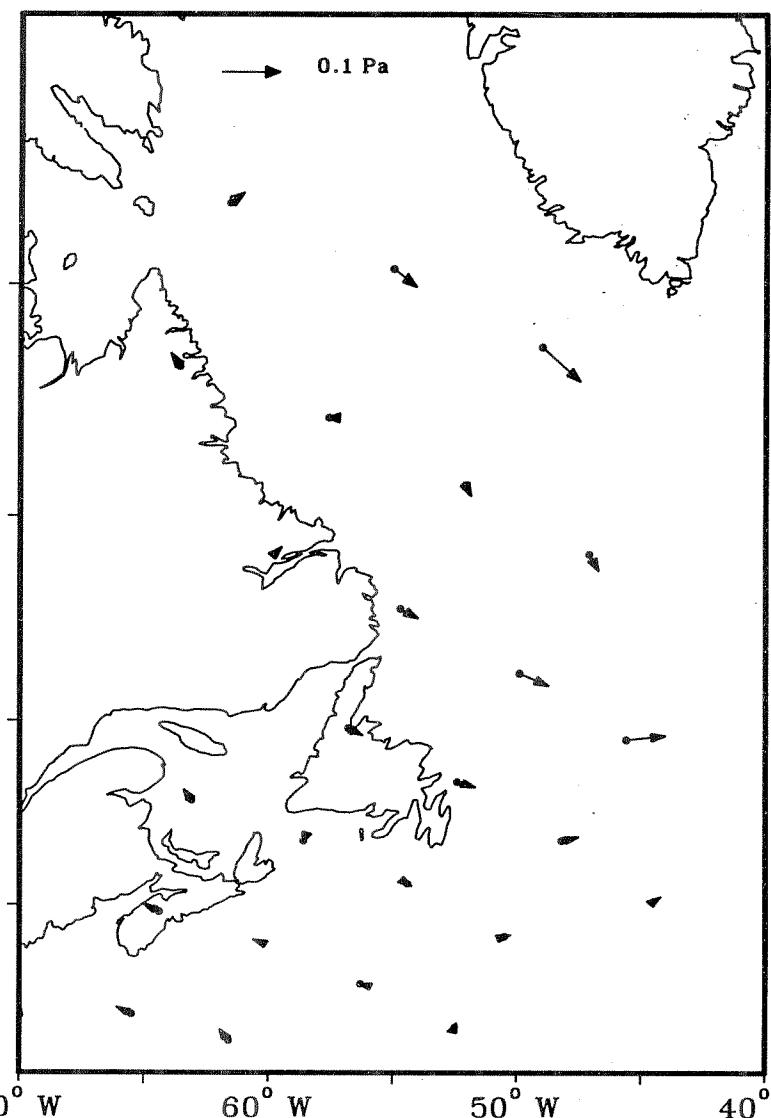
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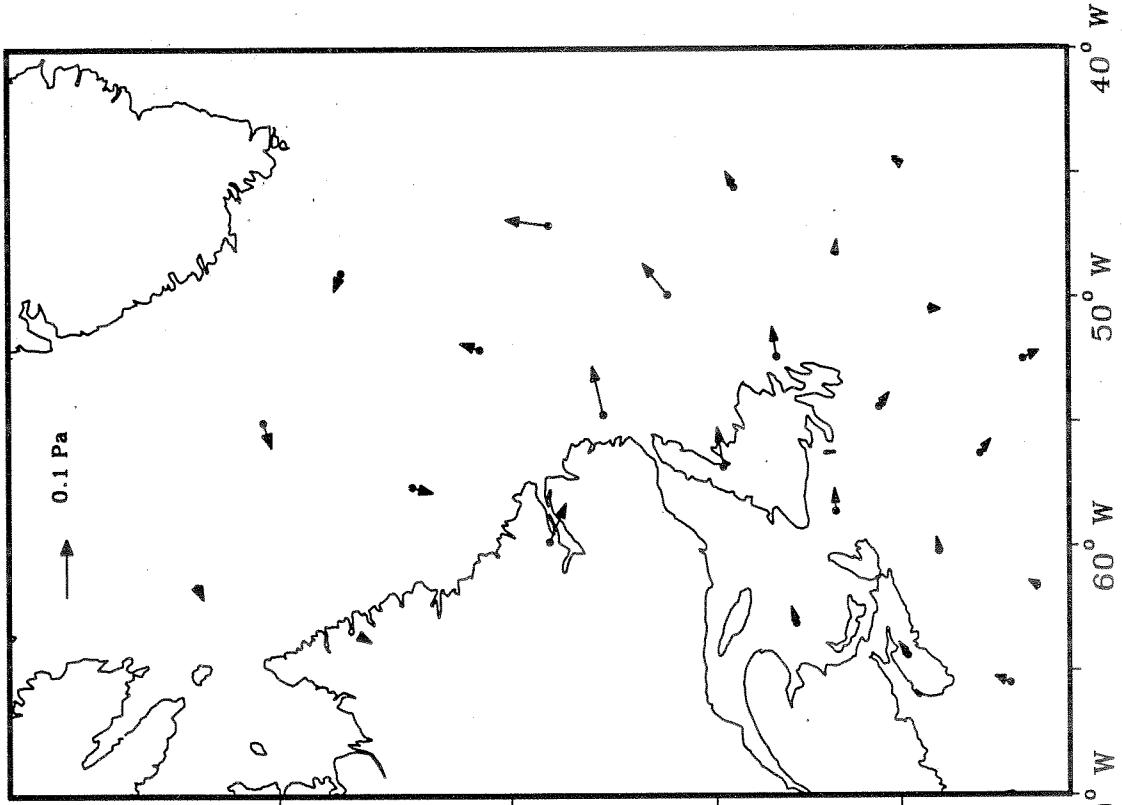
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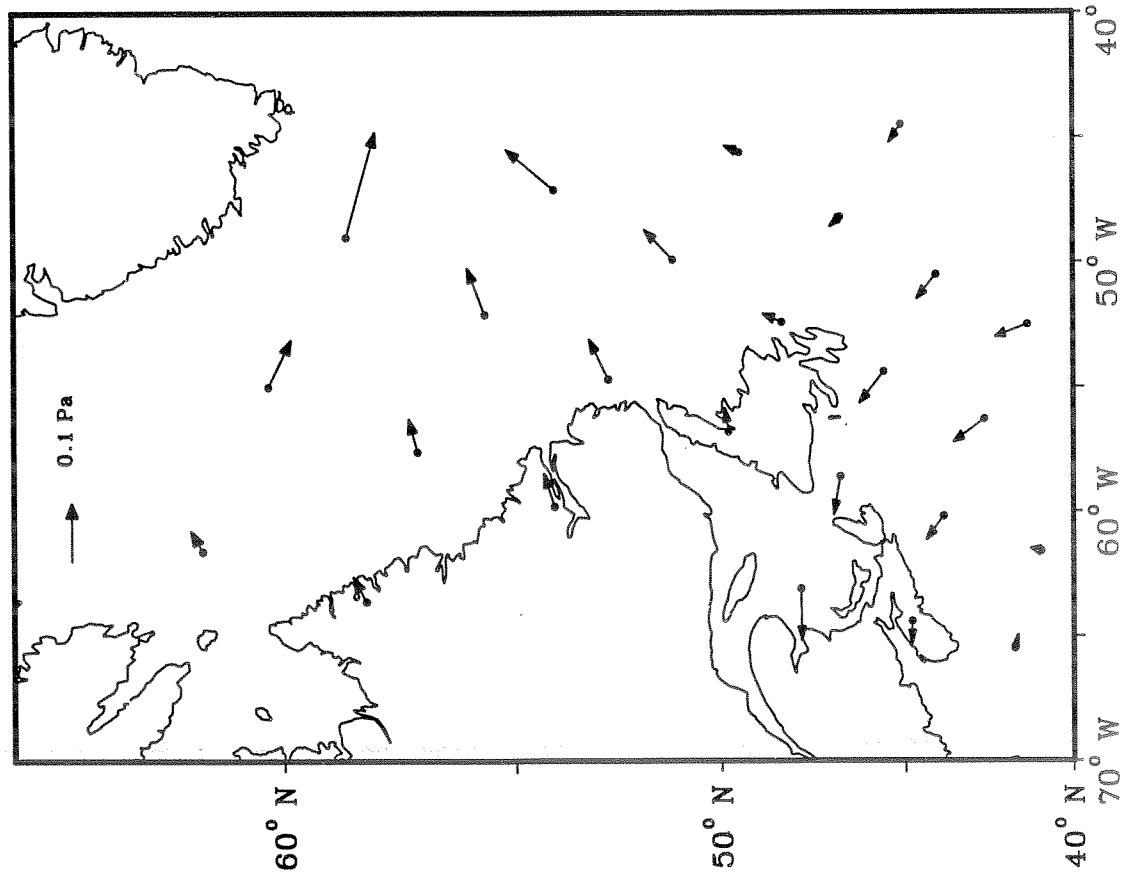
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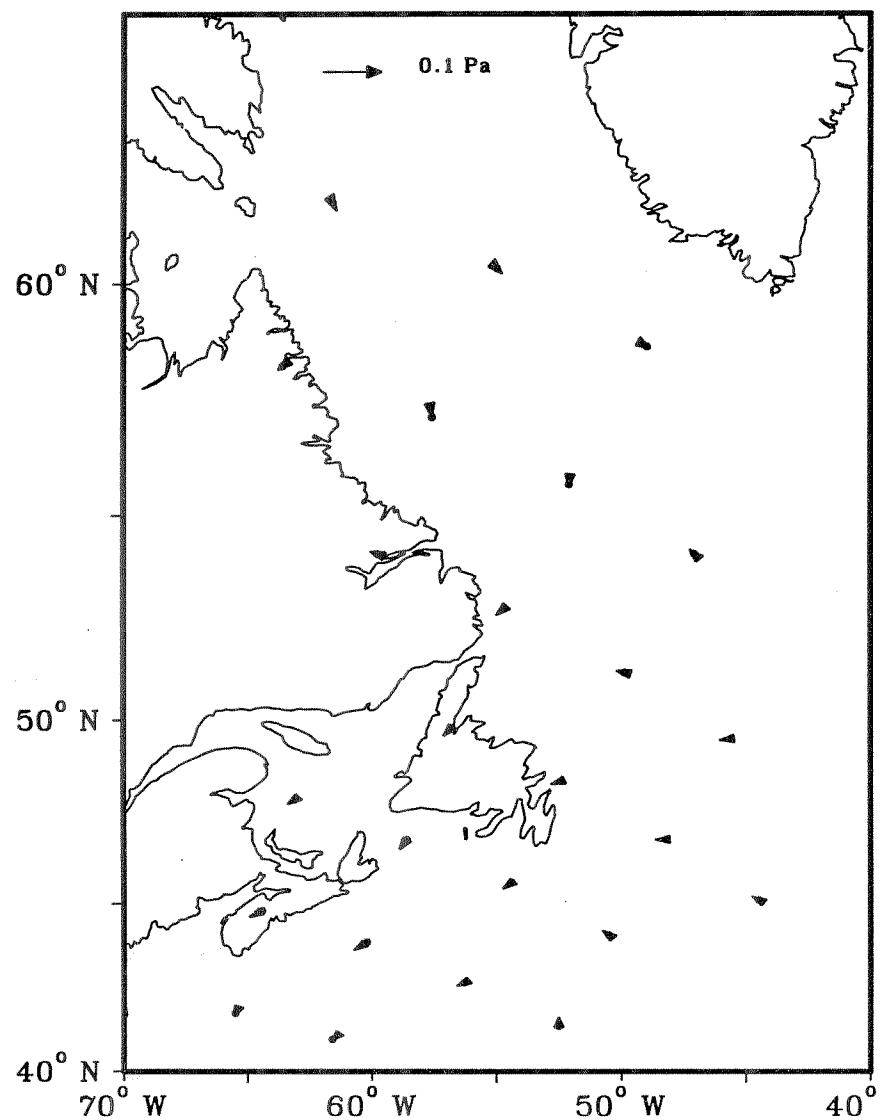


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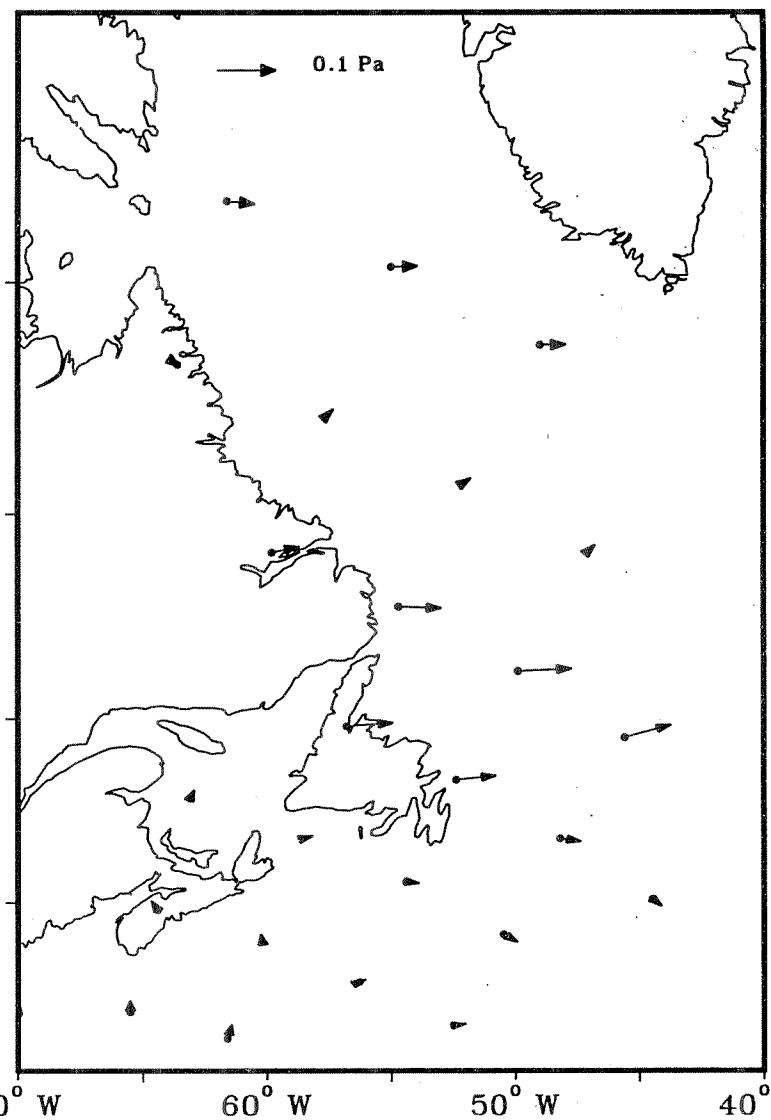


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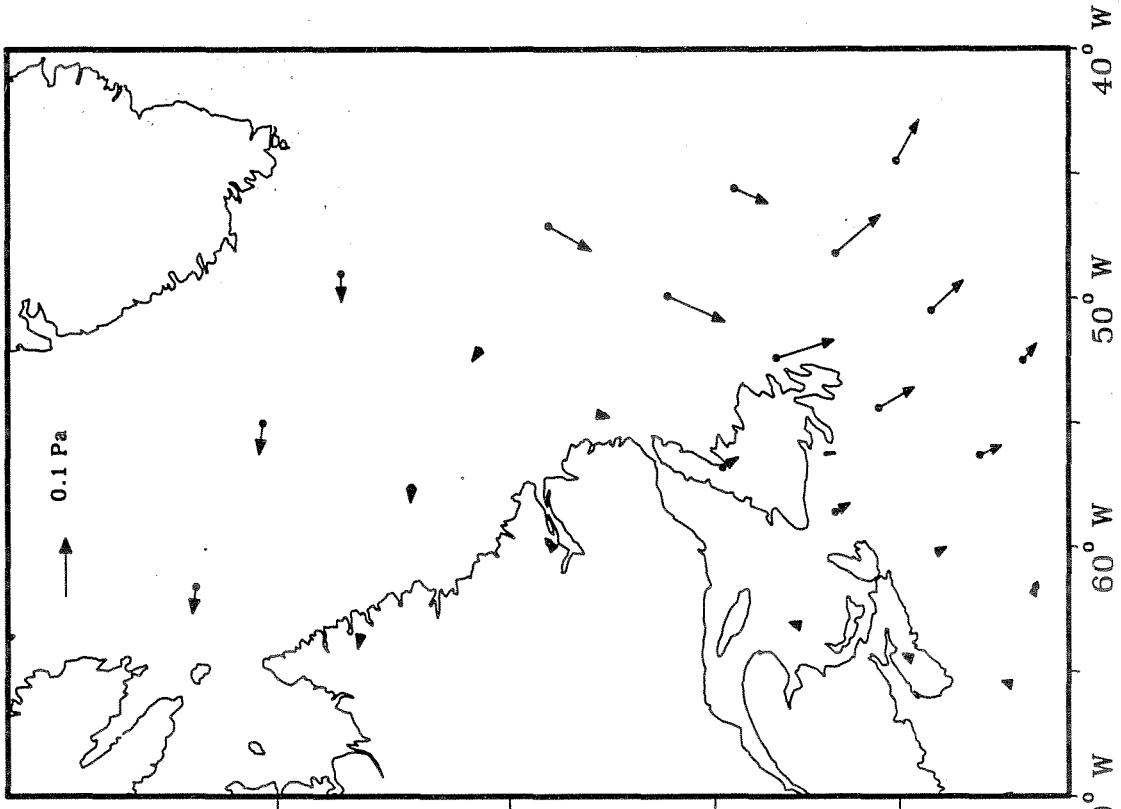
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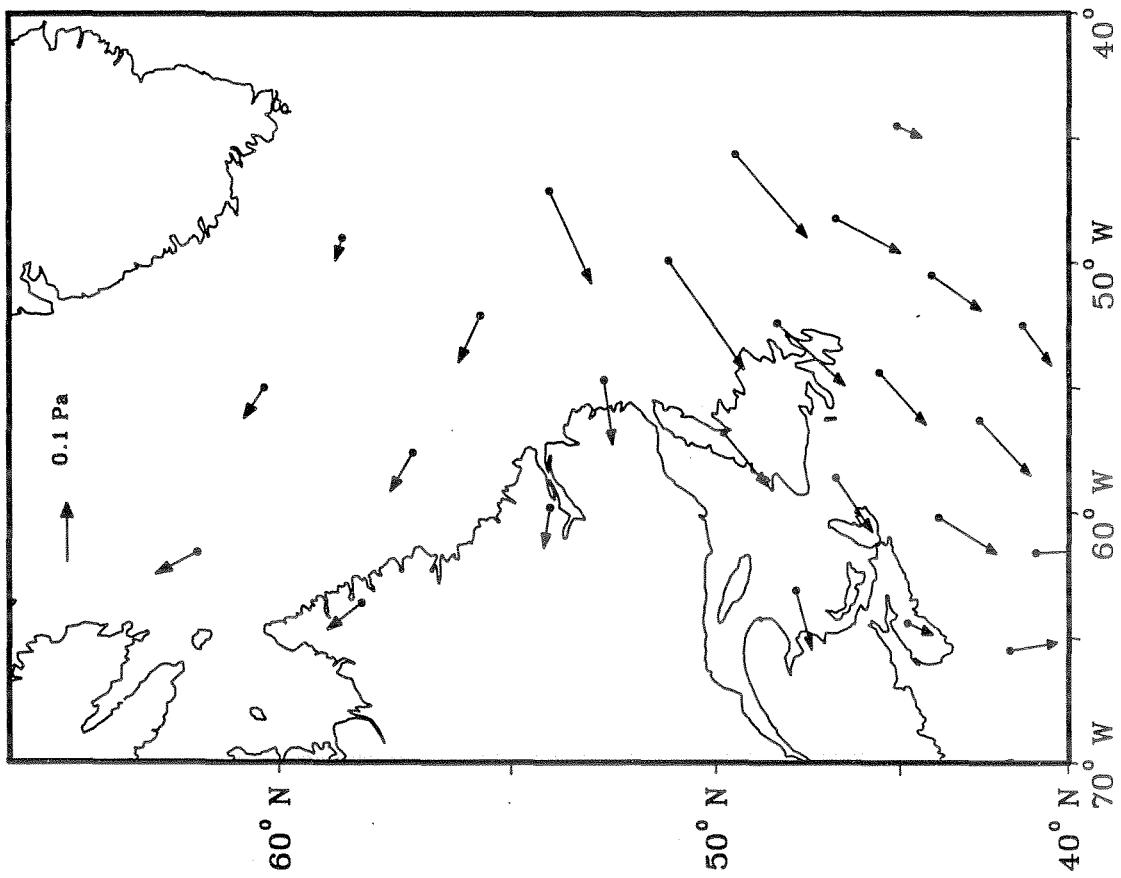
Fall 1954



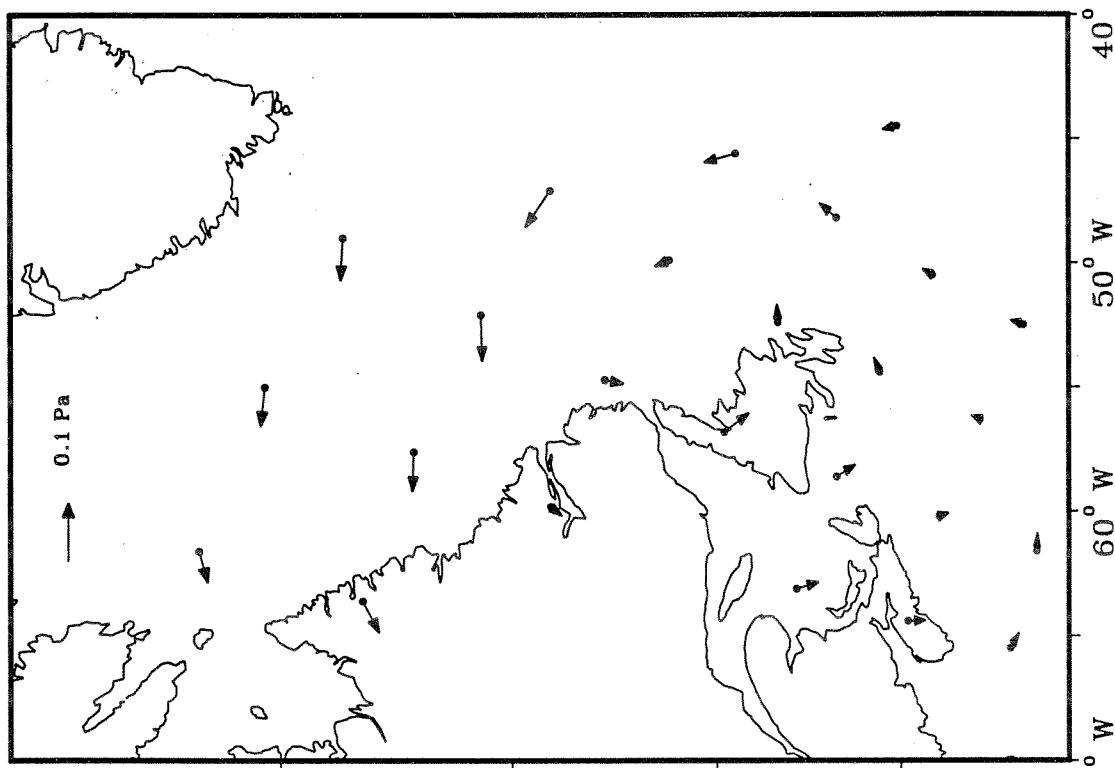
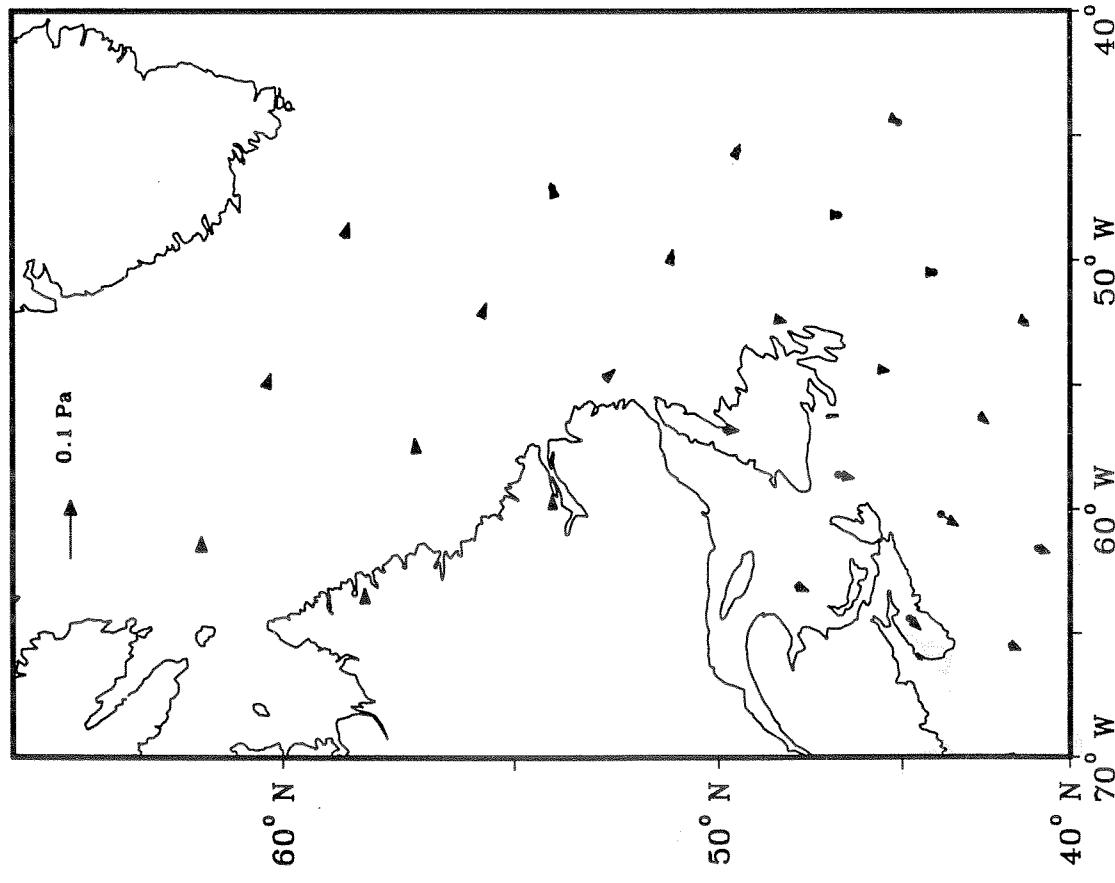
Spring 1955



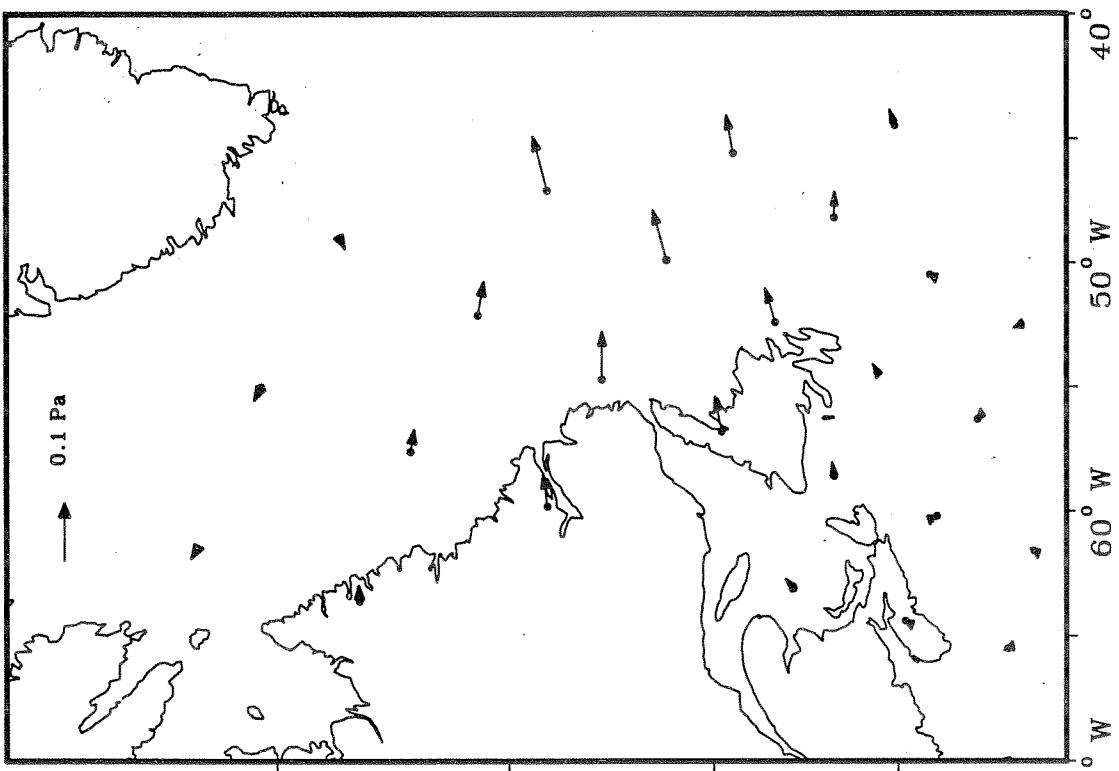
Winter 1955



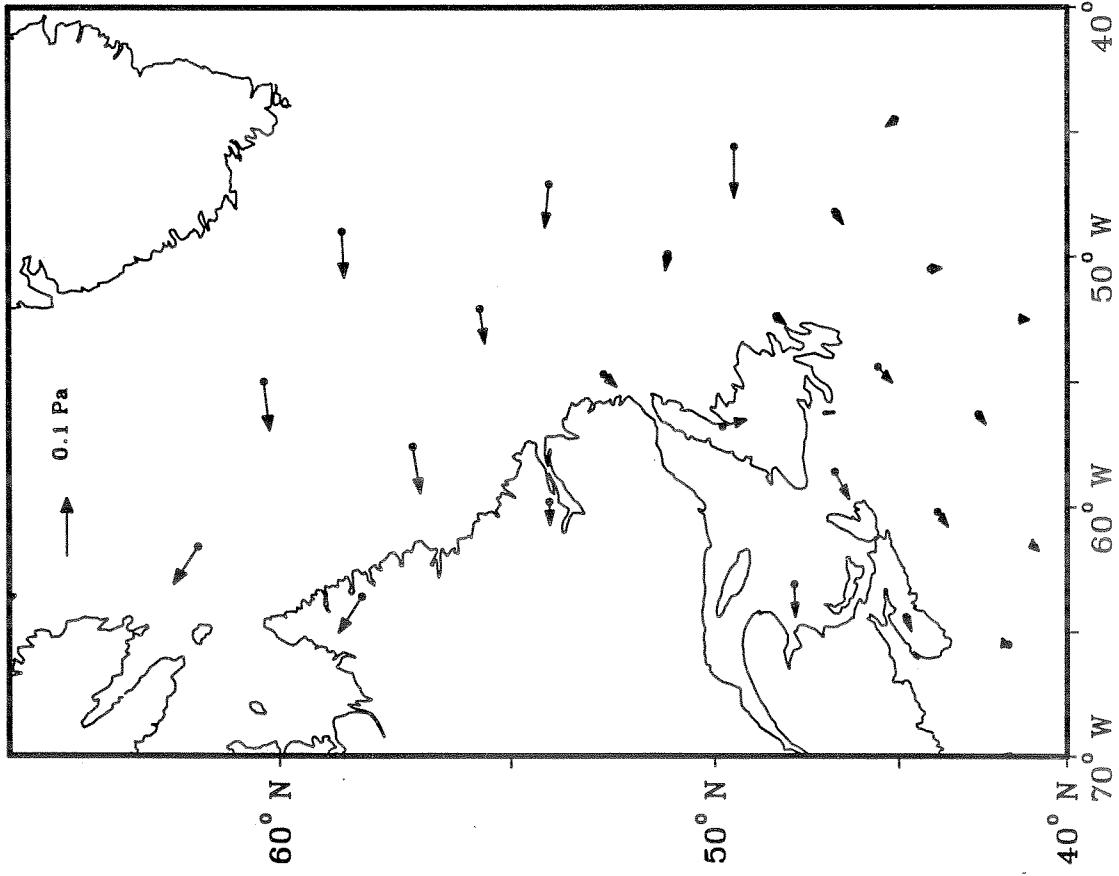
Fall 1955 Summer 1955



Spring 1956

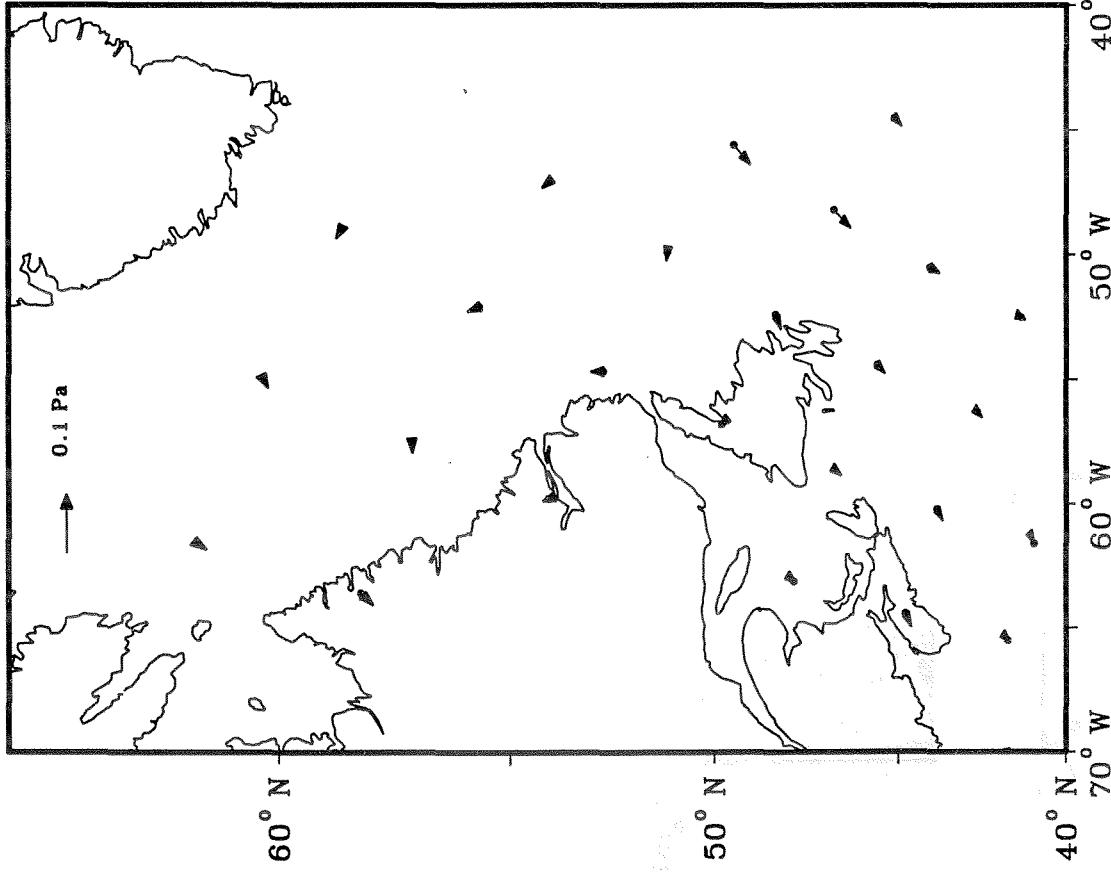


Winter 1956

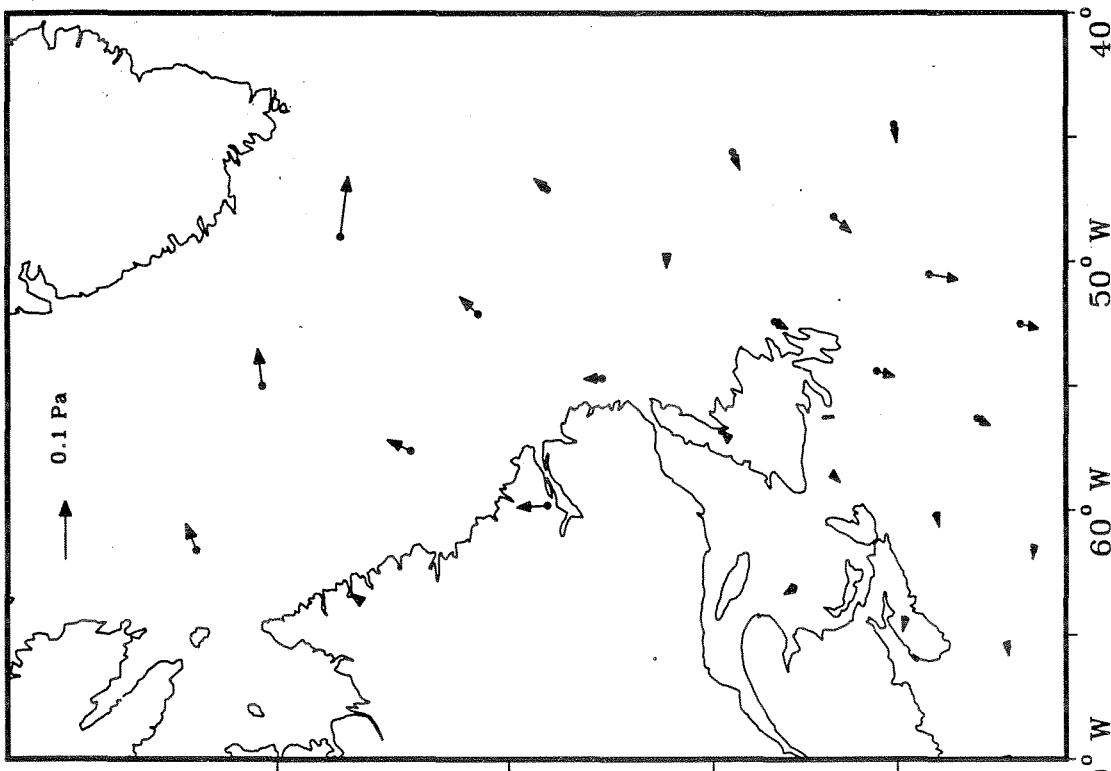


70° W 60° W 50° W 40° W 50° W 60° W 70° W 40° W

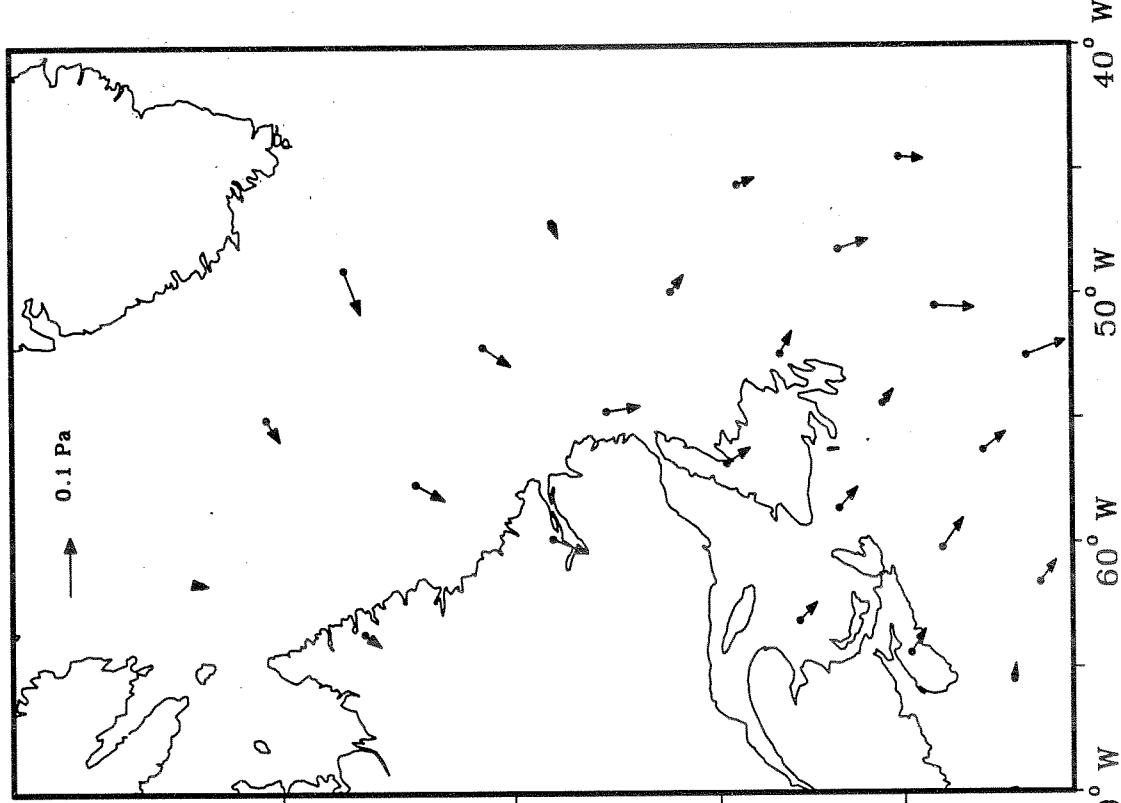
Summer 1956



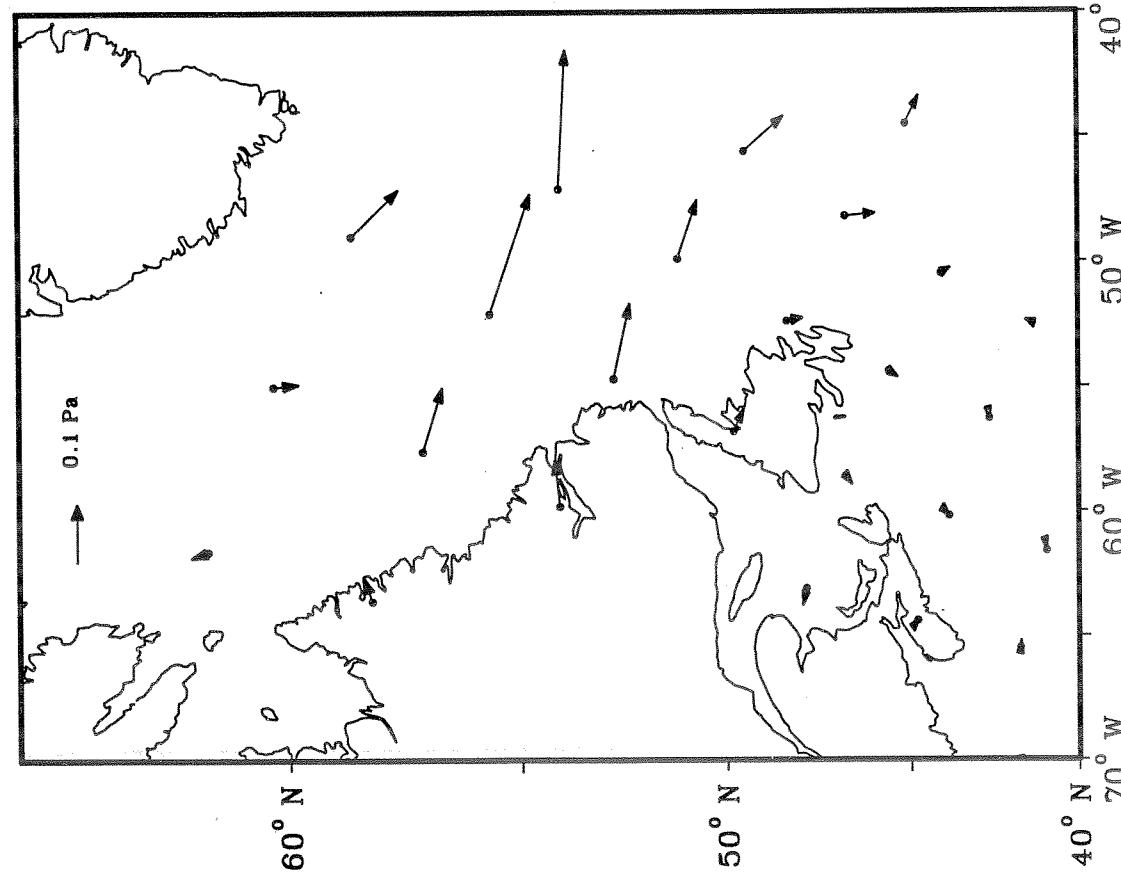
Fall 1956



Spring 1957



Winter 1957

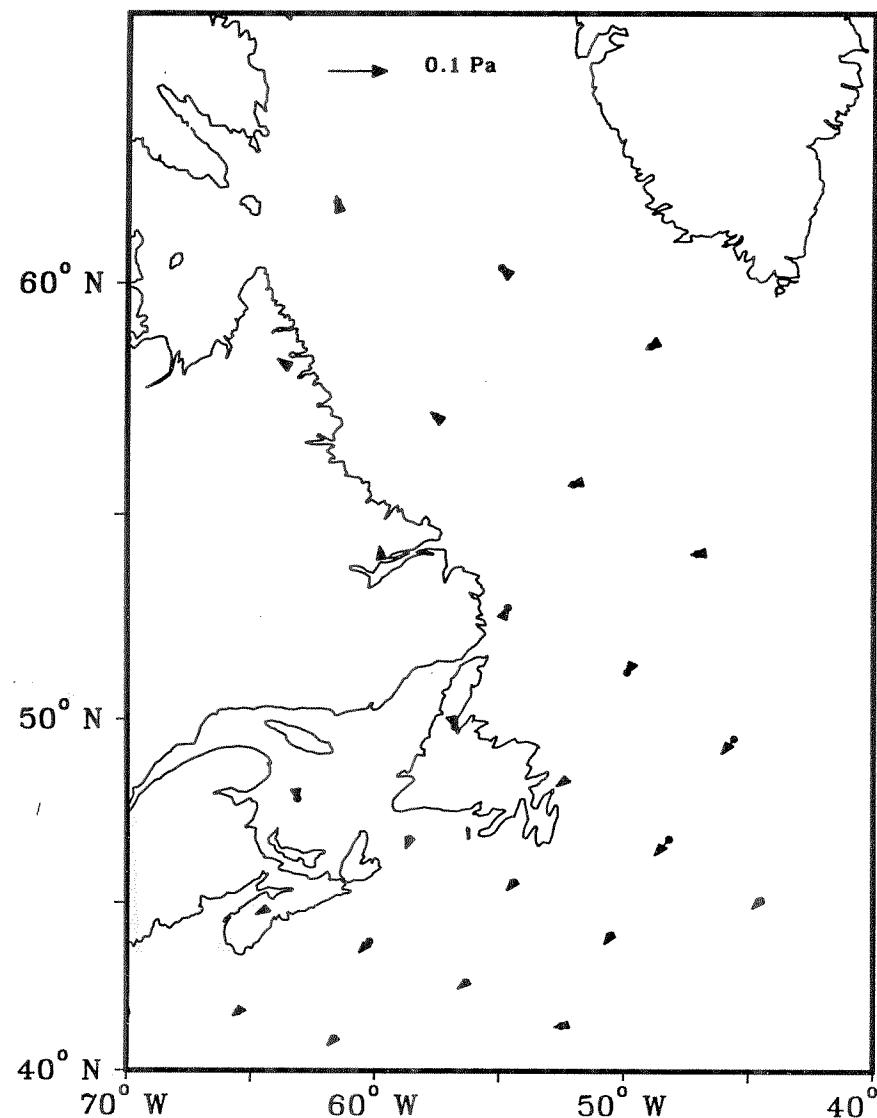


70° W 60° W 50° W 40° W 70° W 60° W

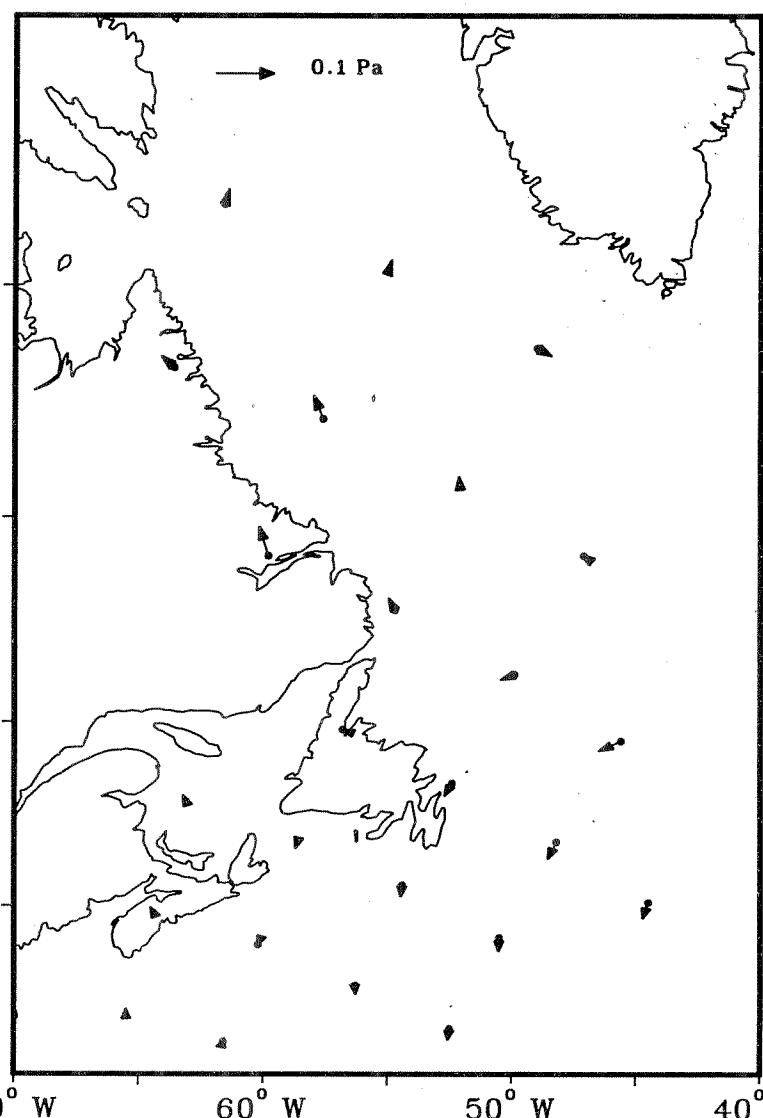
50° W

40° W

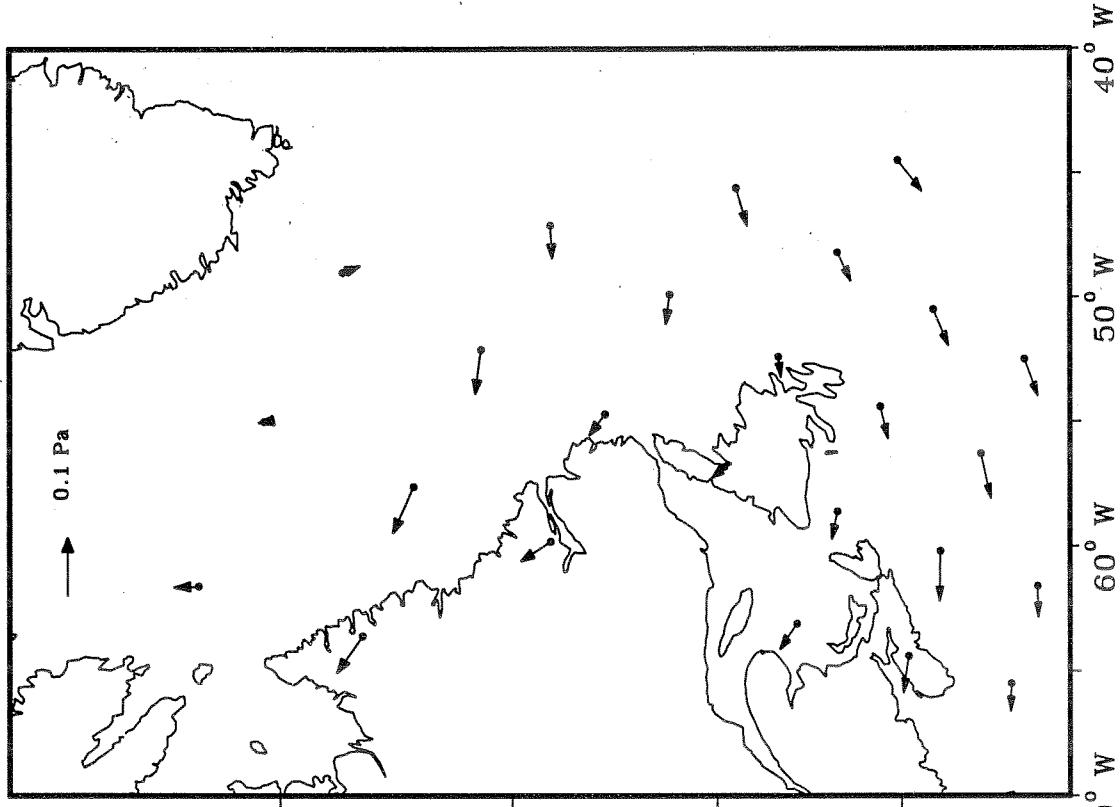
Summer 1957



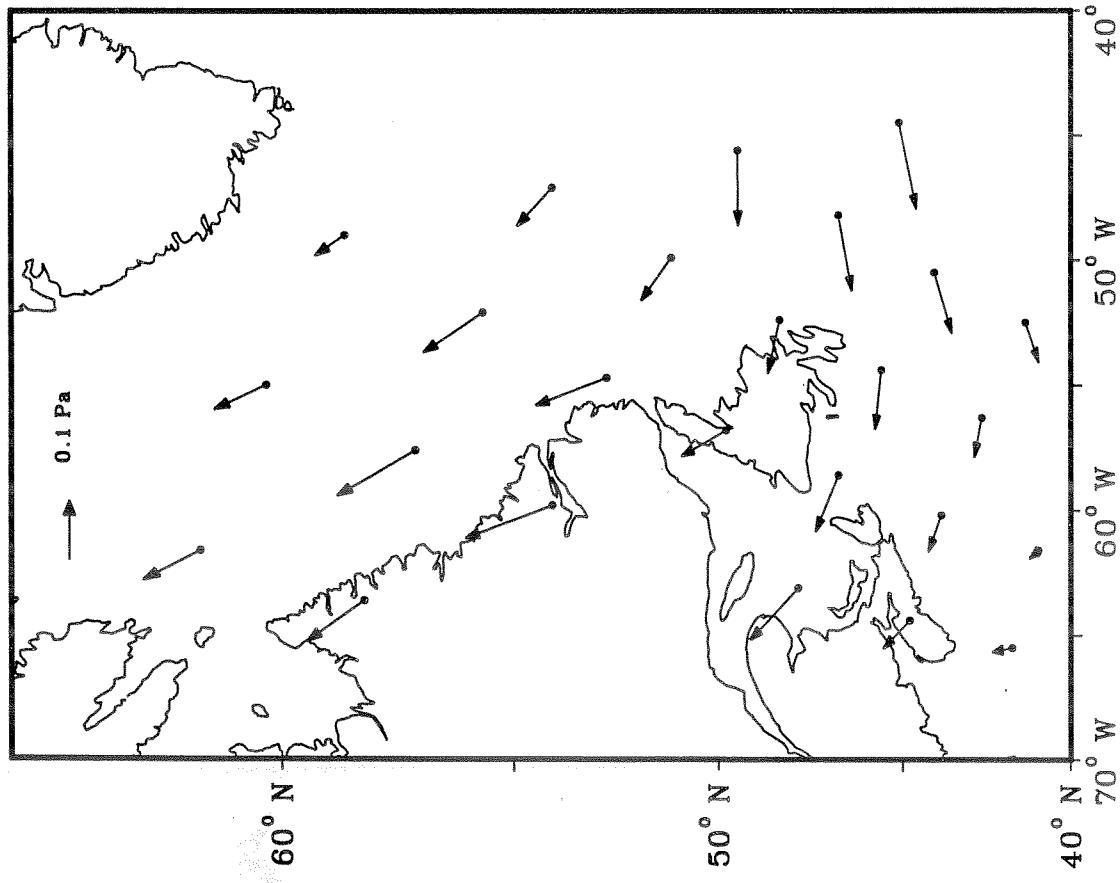
Fall 1957



Spring 1958

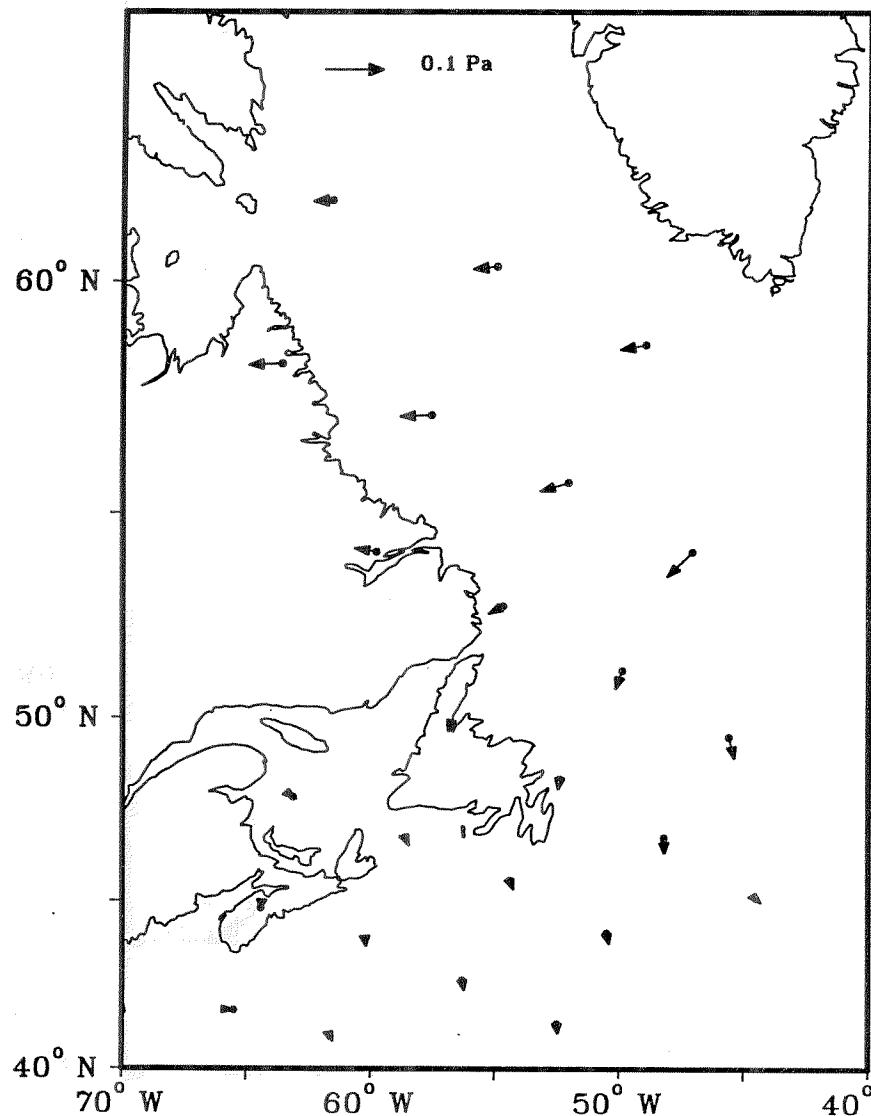


Winter 1958

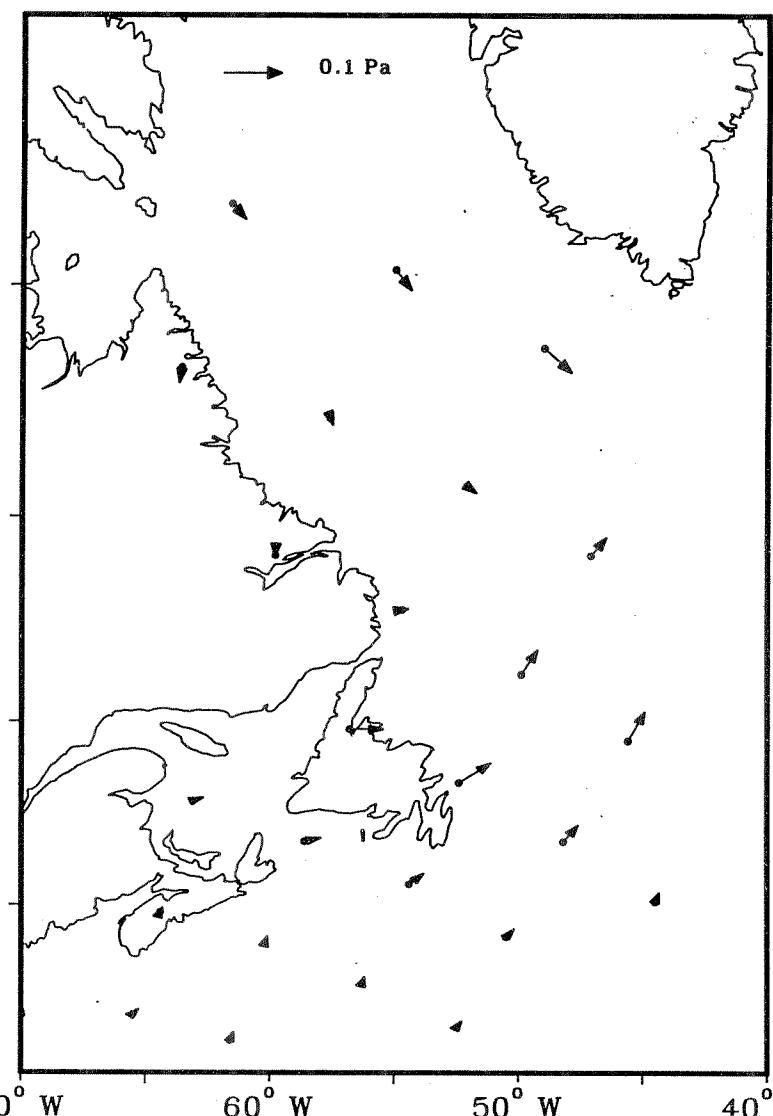


70° N 70° W 60° N 60° W 50° N 50° W 40° N 40° W

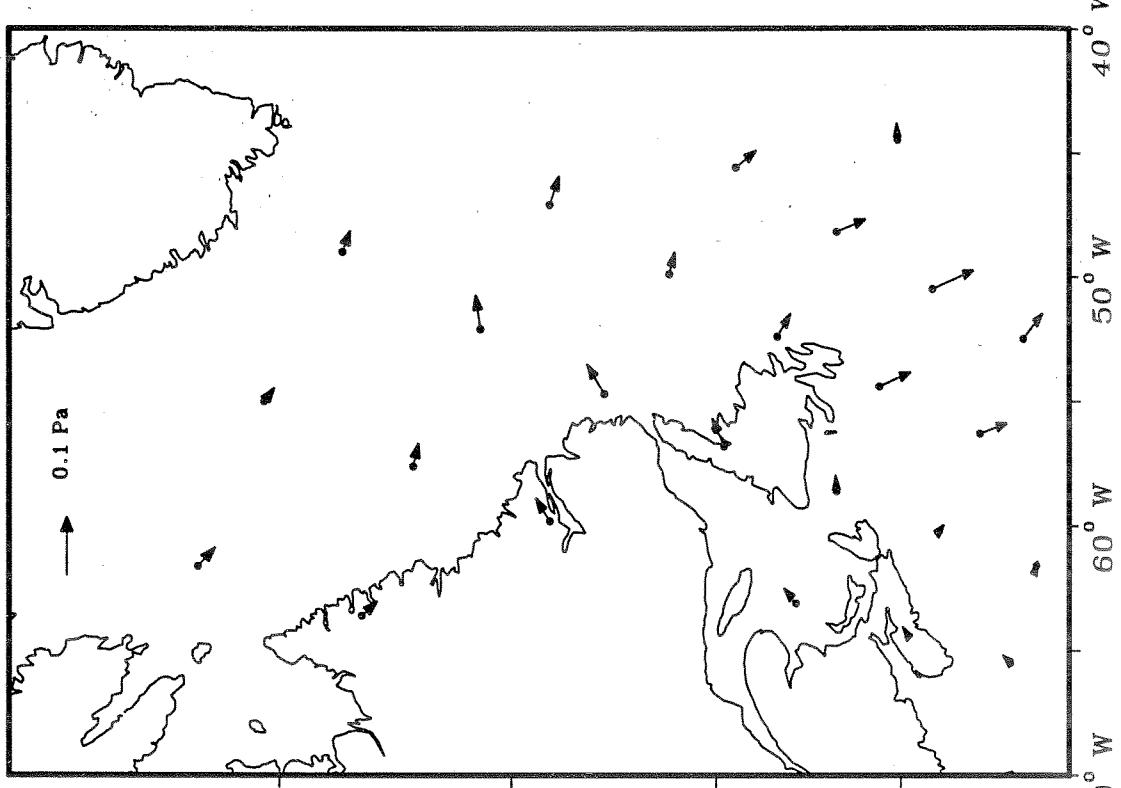
Summer 1958



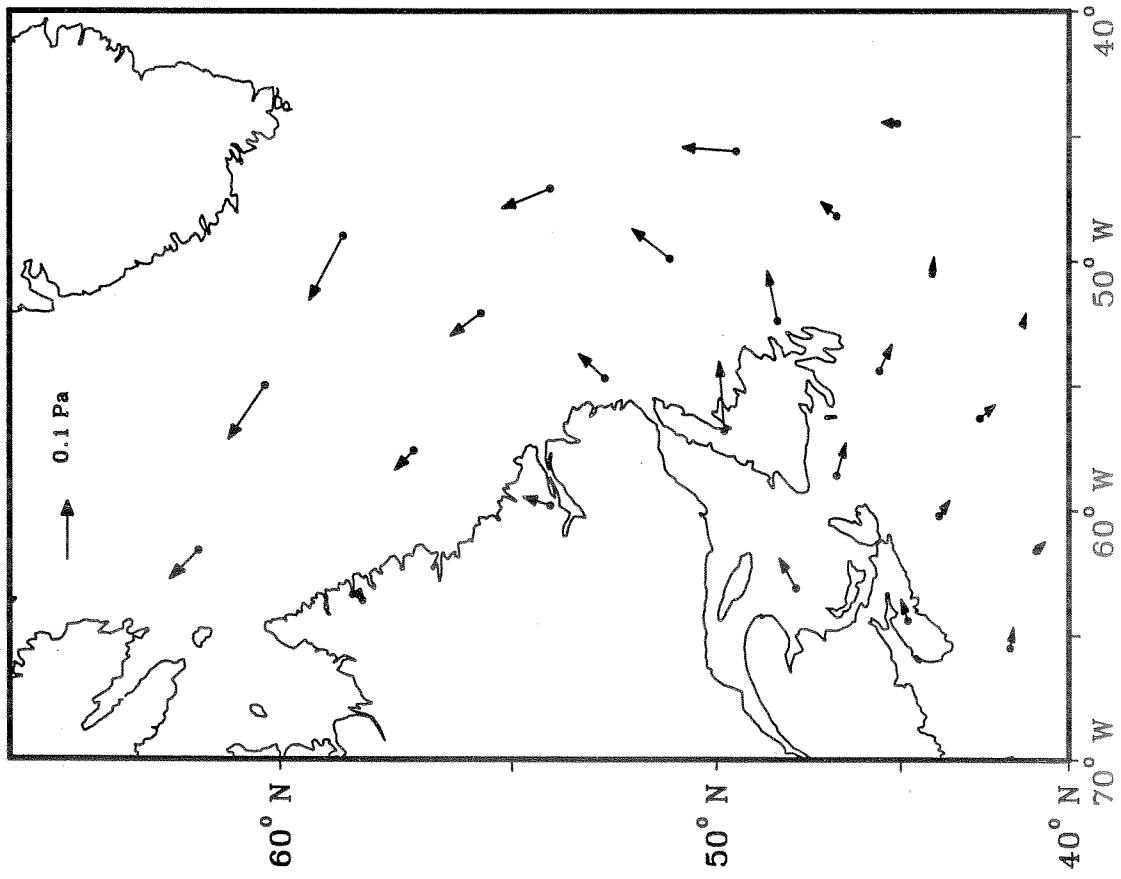
Fall 1958



Spring 1959

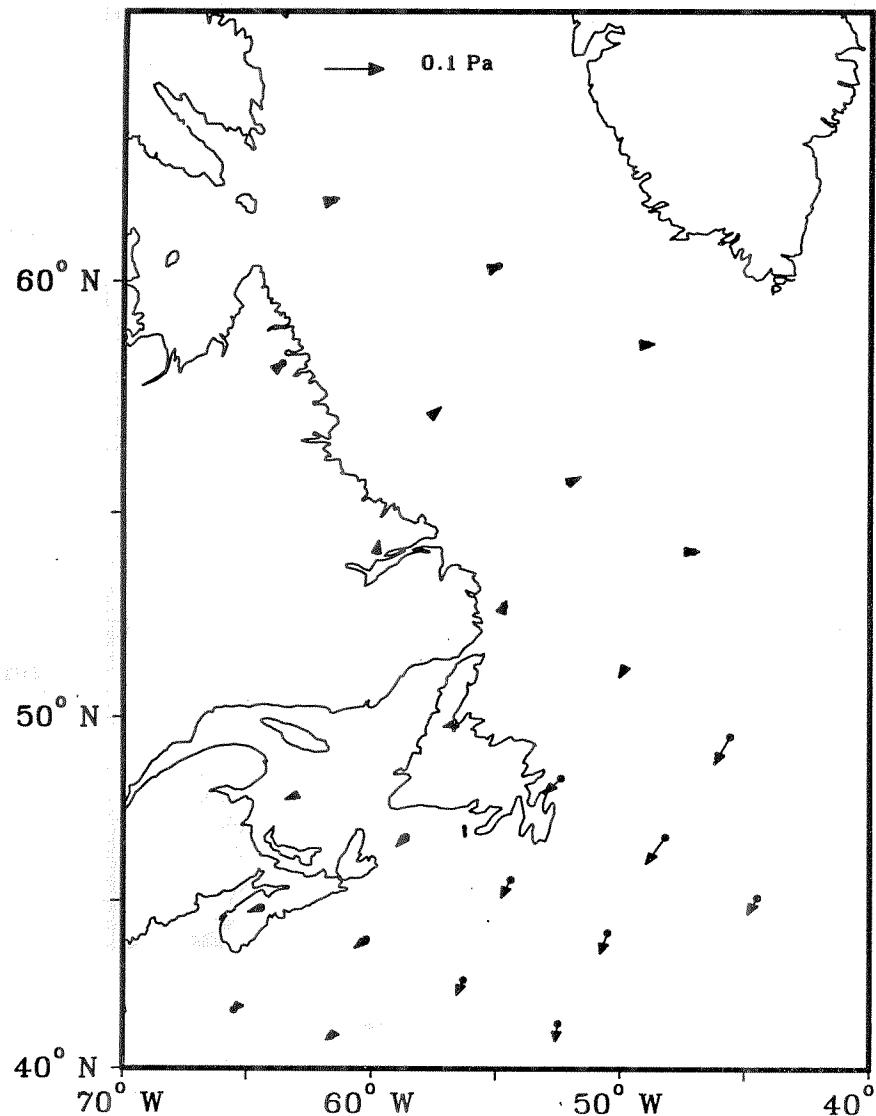


Winter 1959

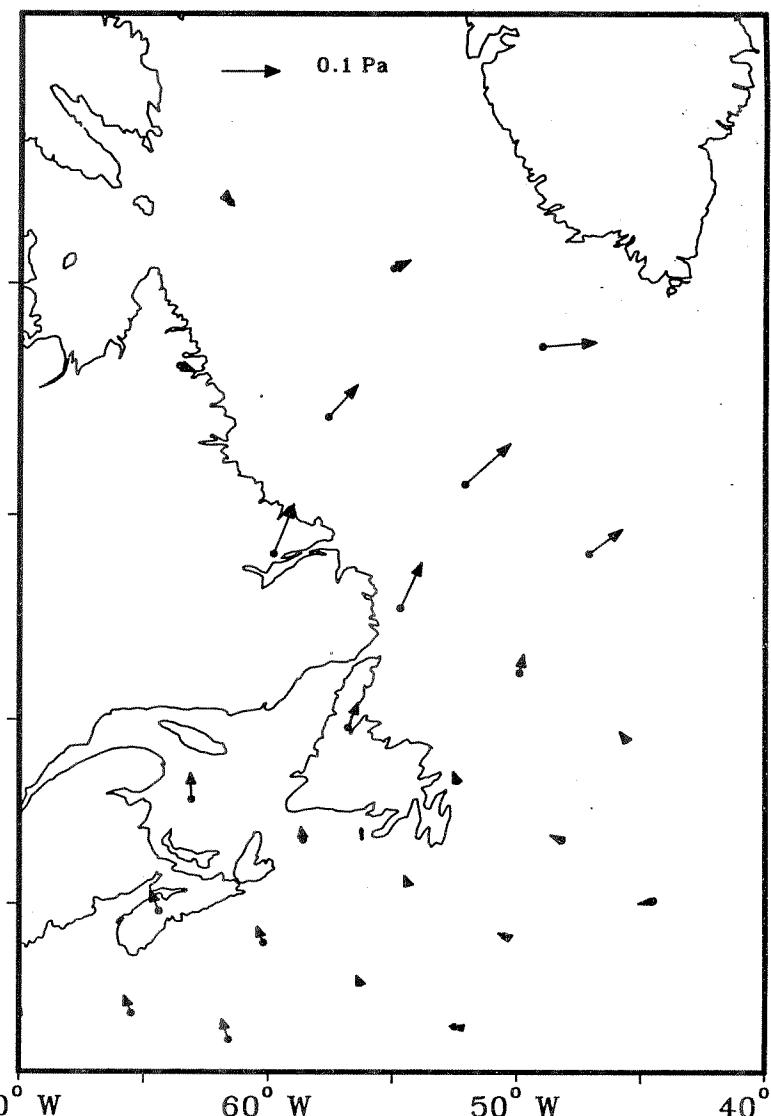


40° N 70° W 60° W 50° W 40° W 70° W 60° W 50° W 40° W

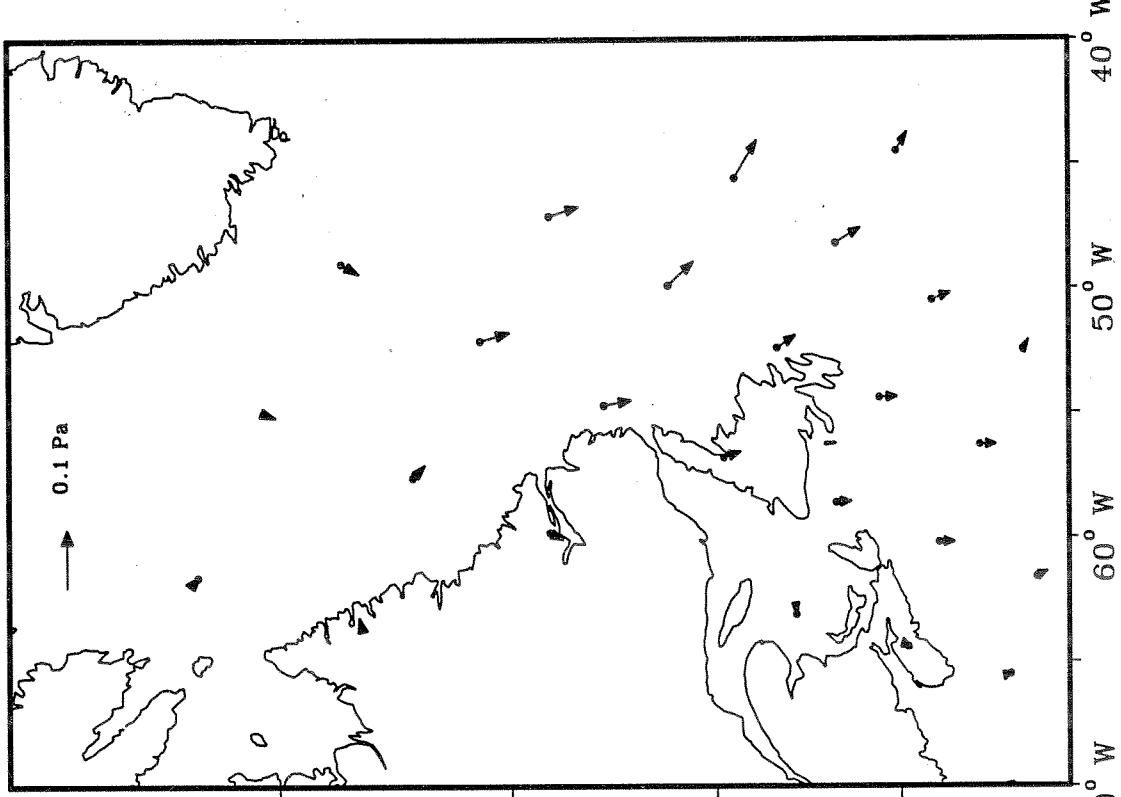
Summer 1959



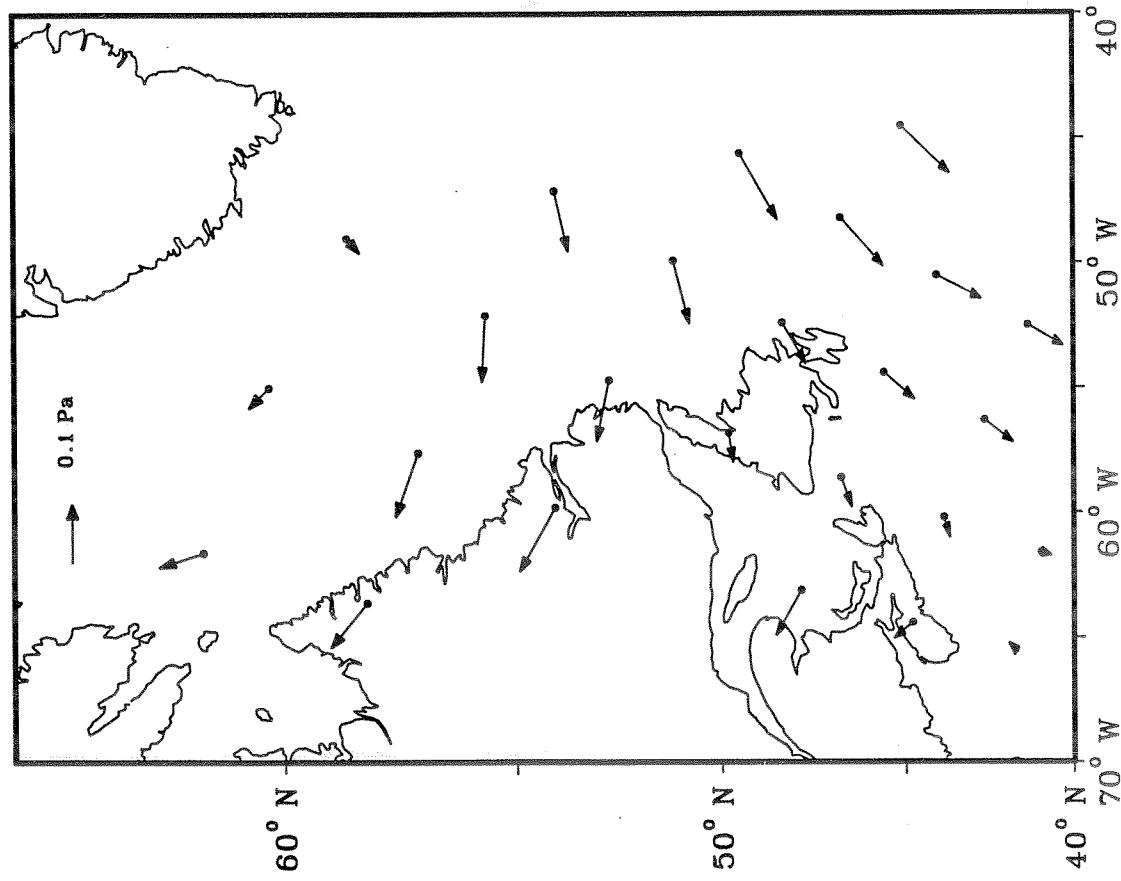
Fall 1959



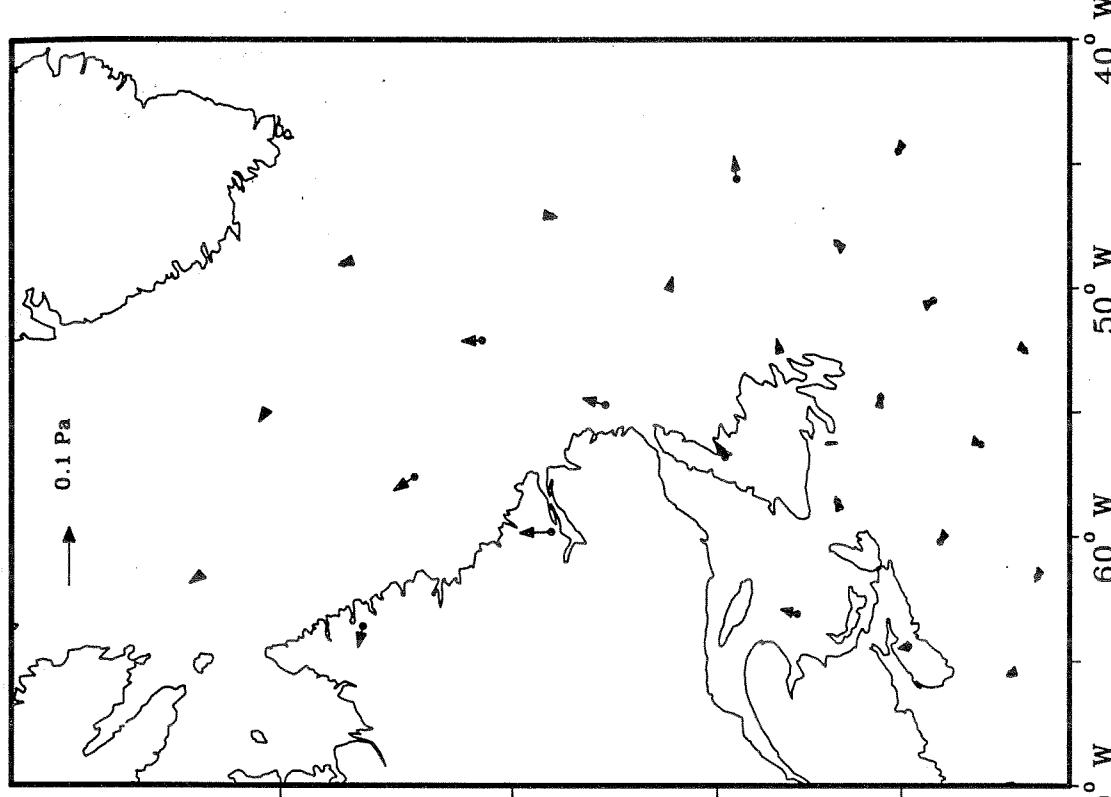
Spring 1960



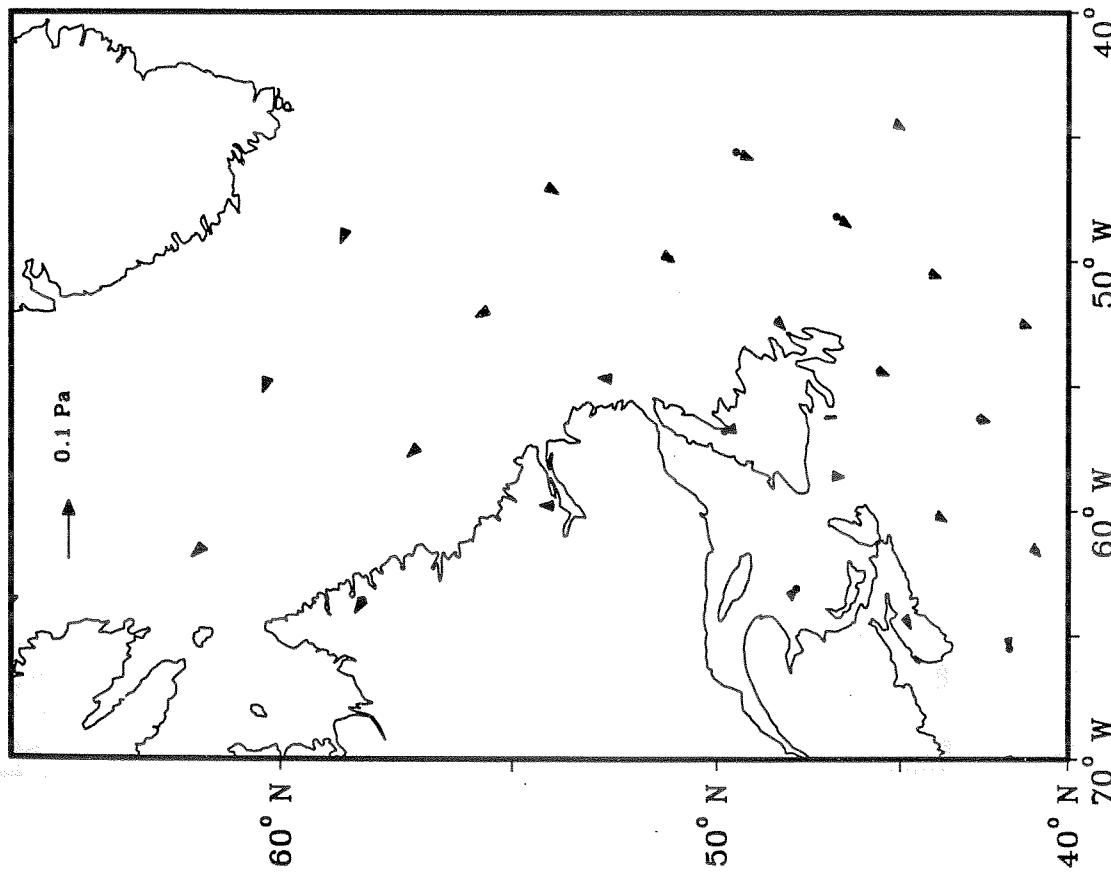
Winter 1960



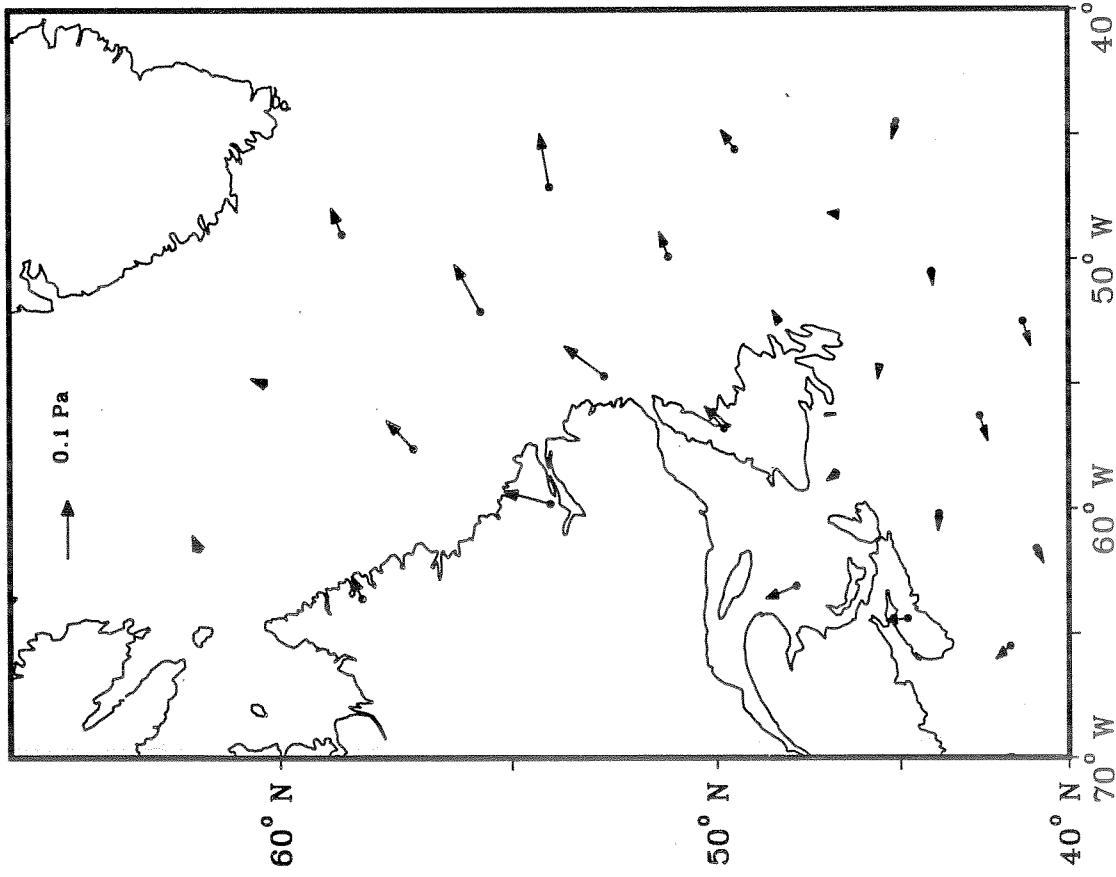
Fall 1960



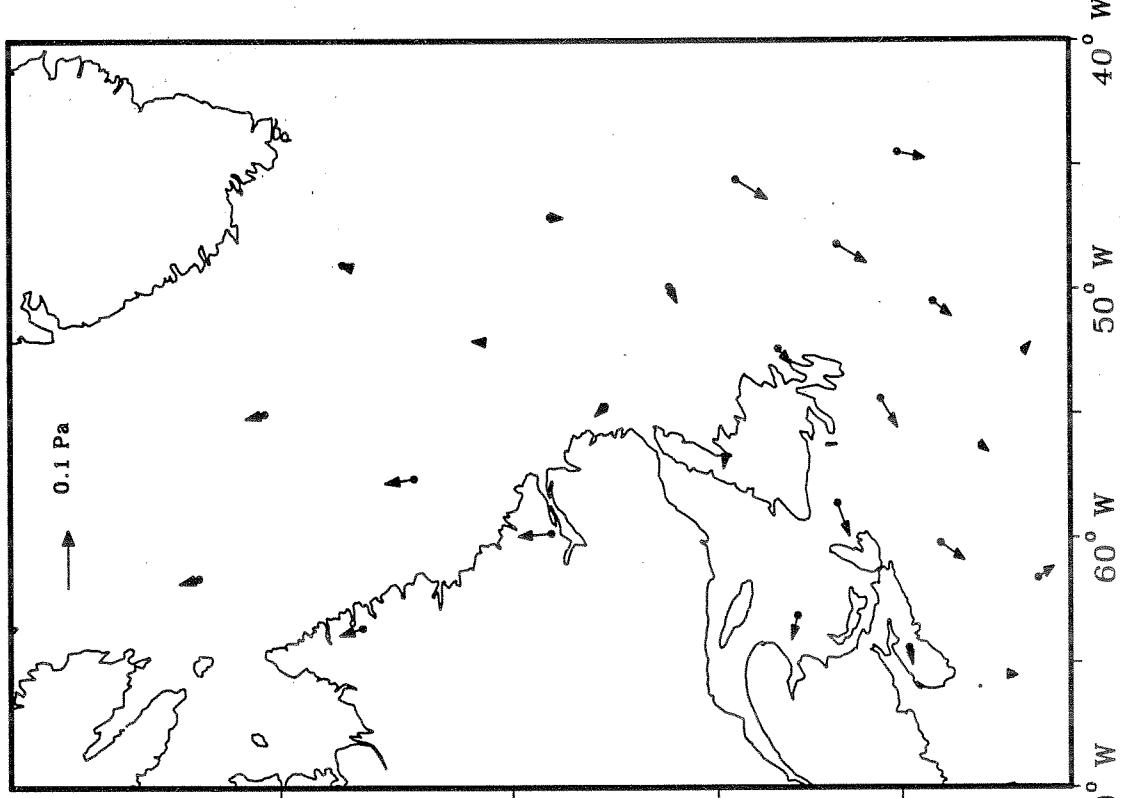
Summer 1960



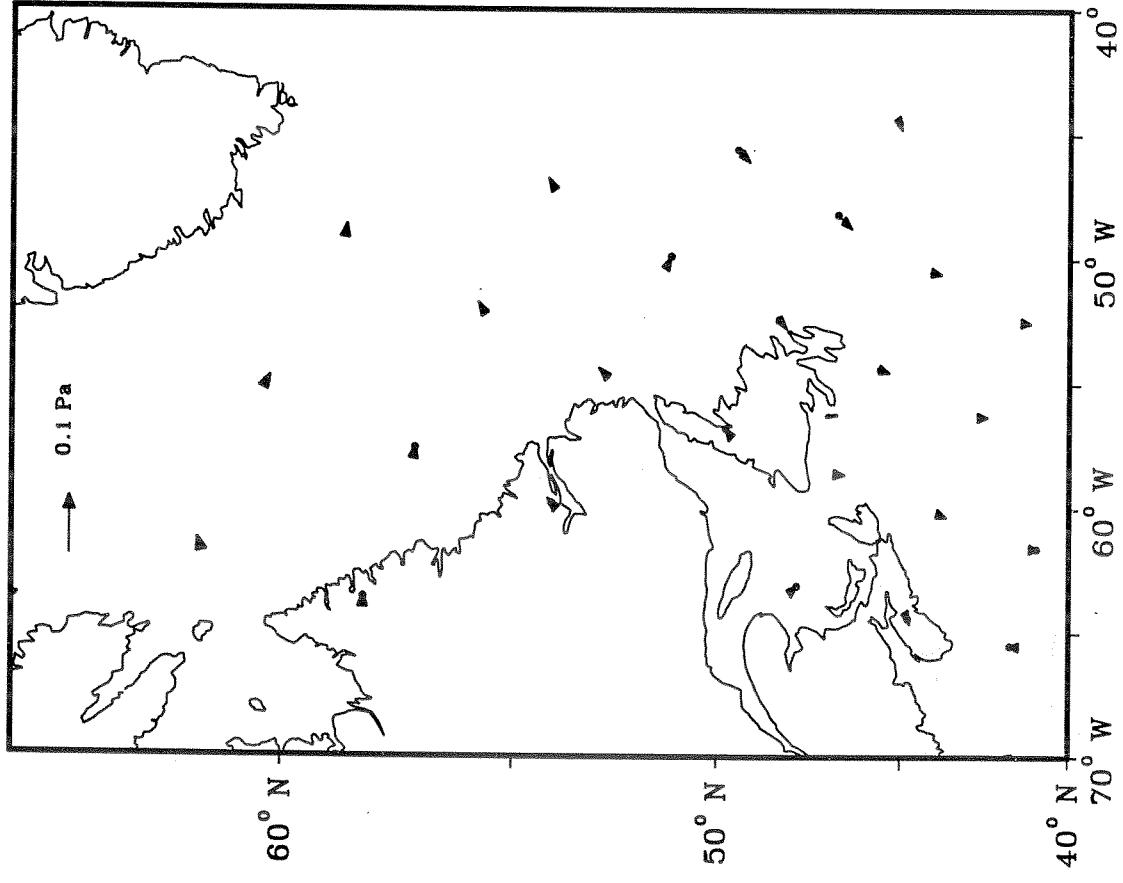
Winter 1961



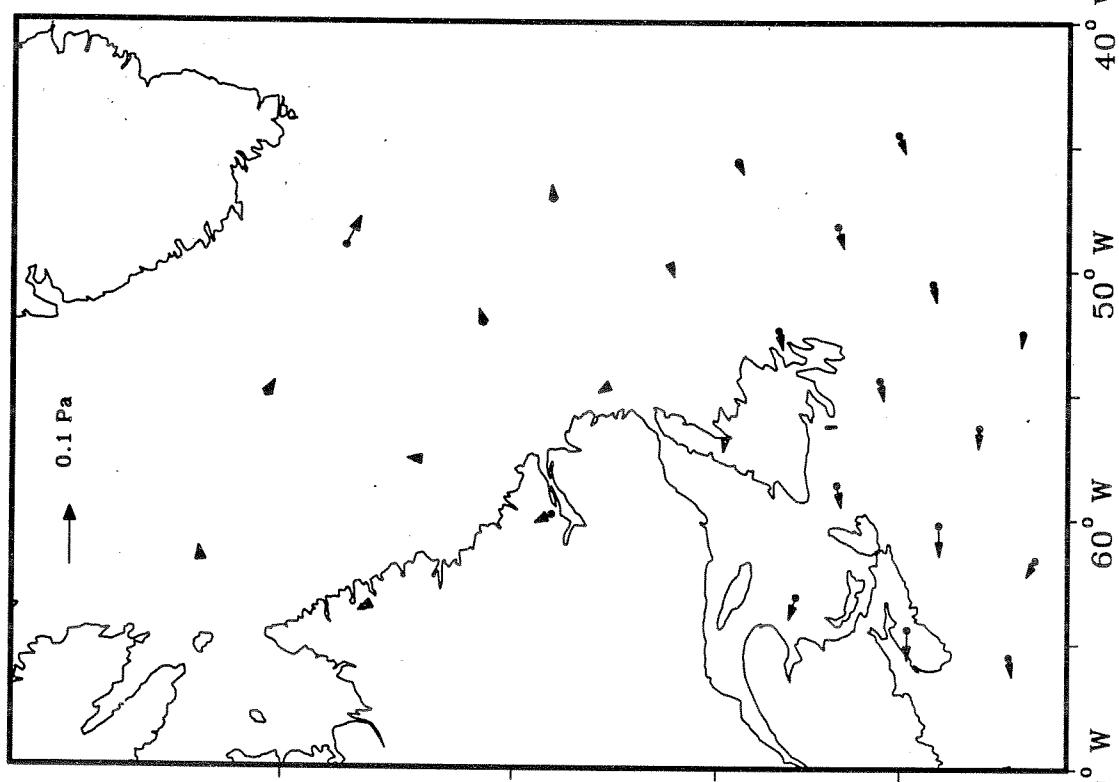
Spring 1961



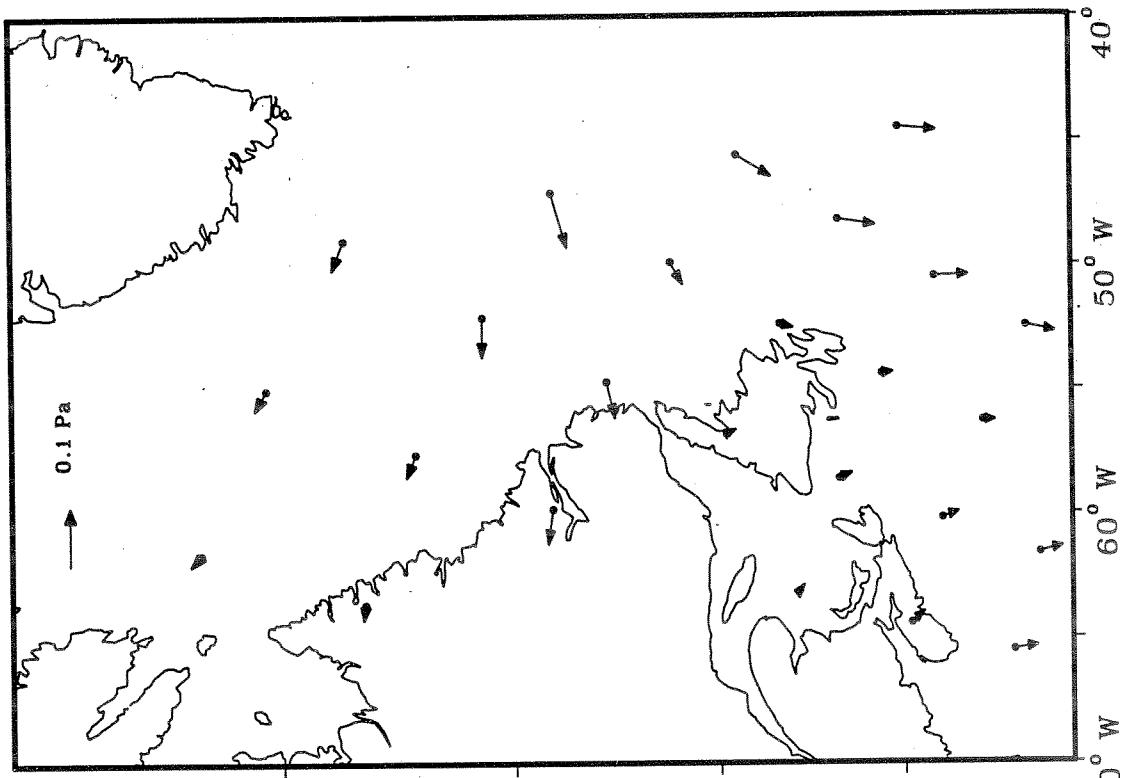
Summer 1961



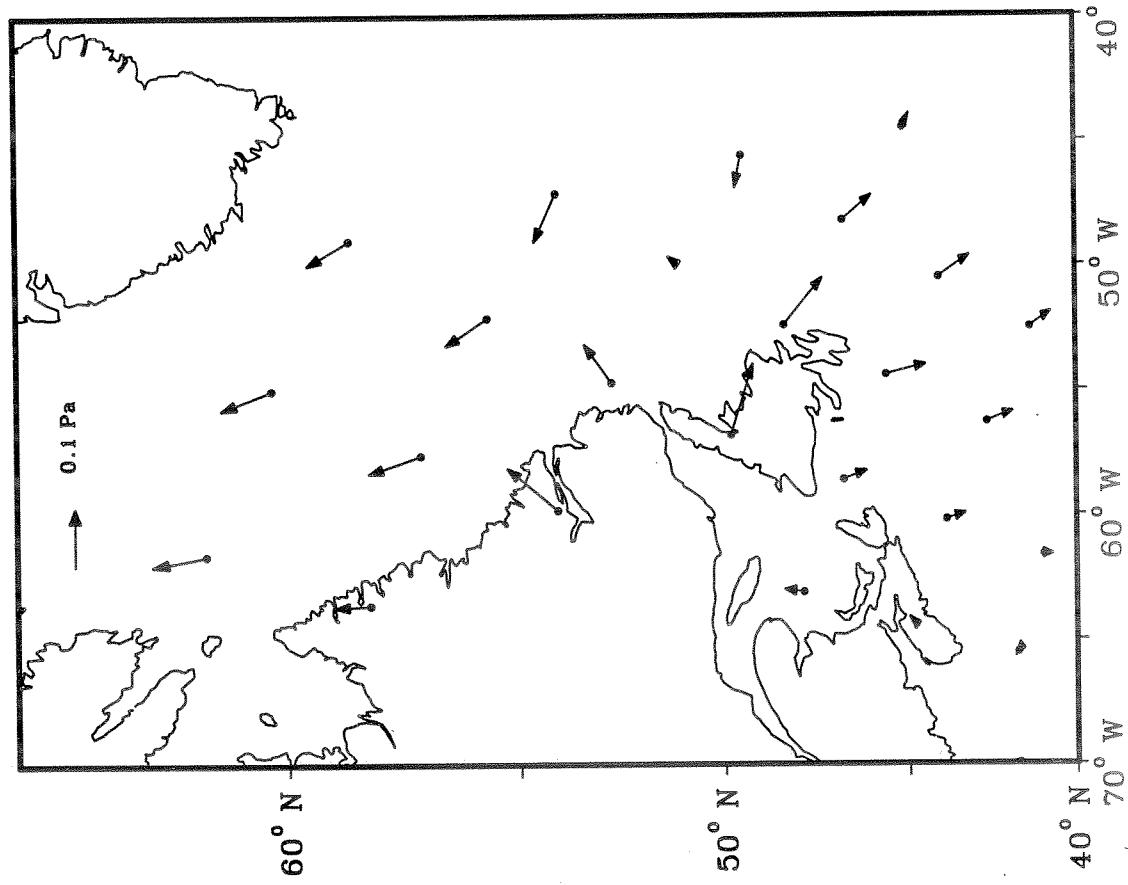
Fall 1961



Spring 1962

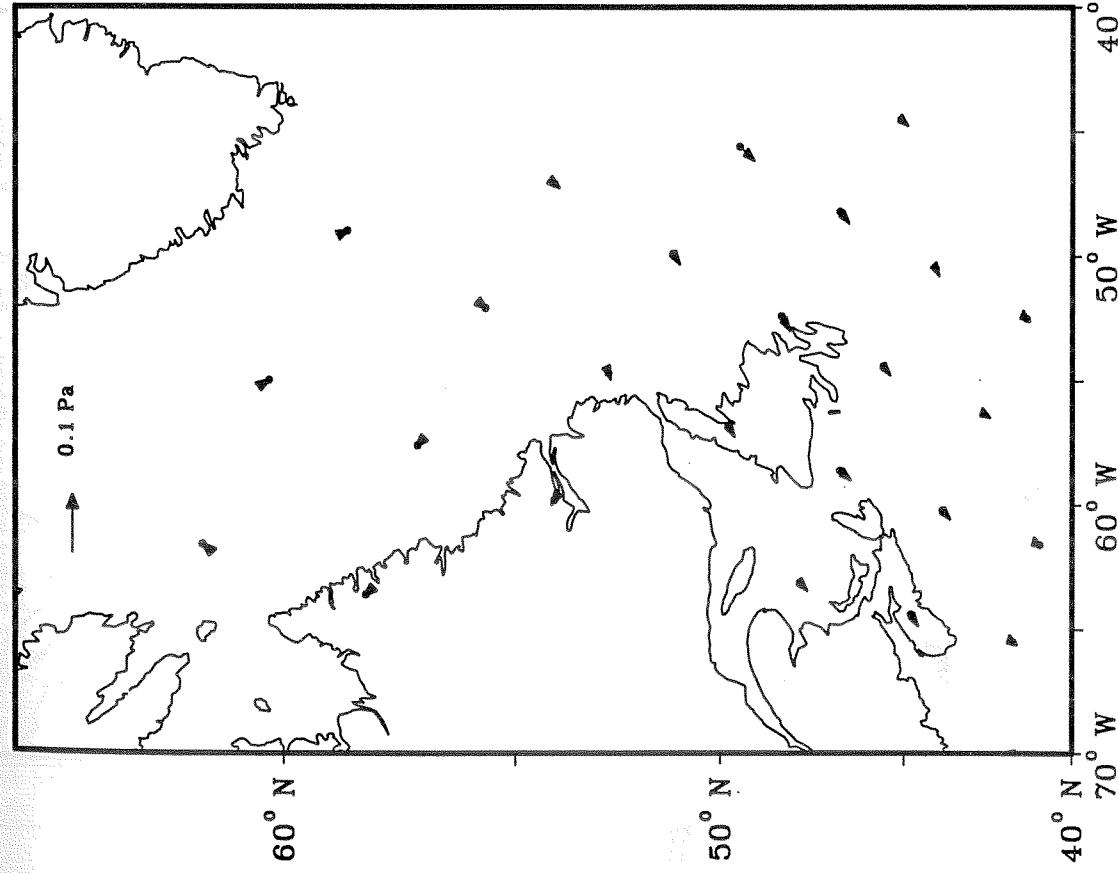


Winter 1962

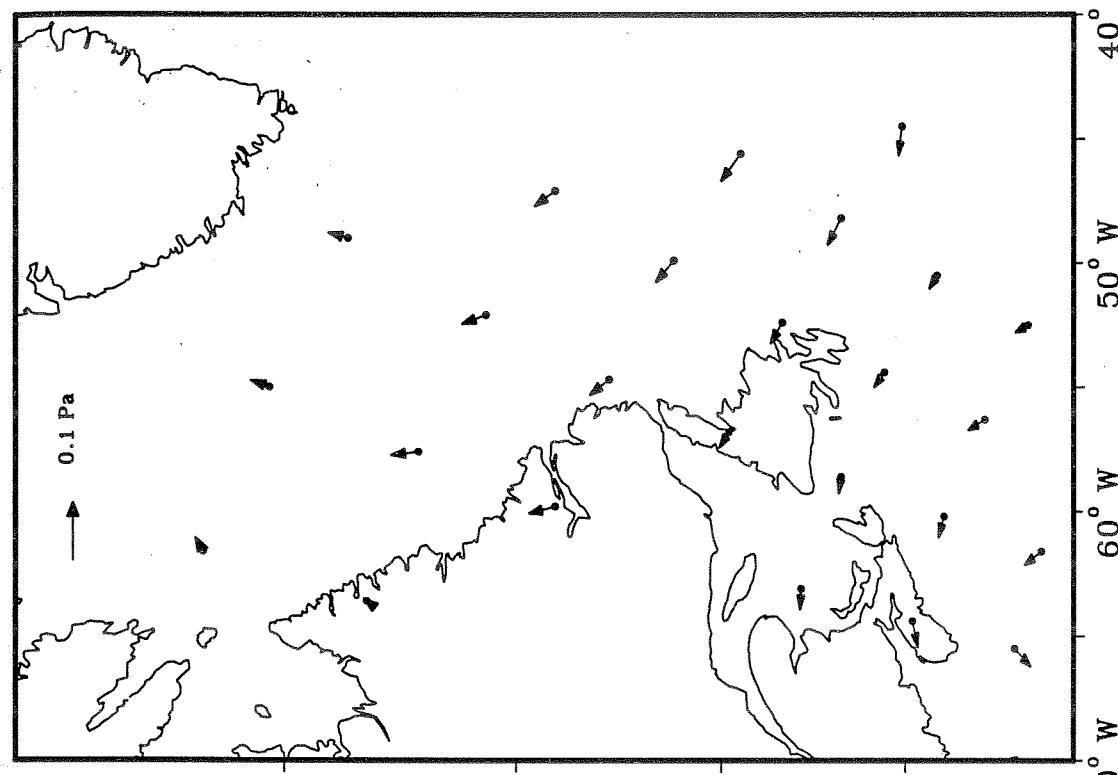


40° N
50° N
60° N
70° N
40° W
50° W
60° W
70° W

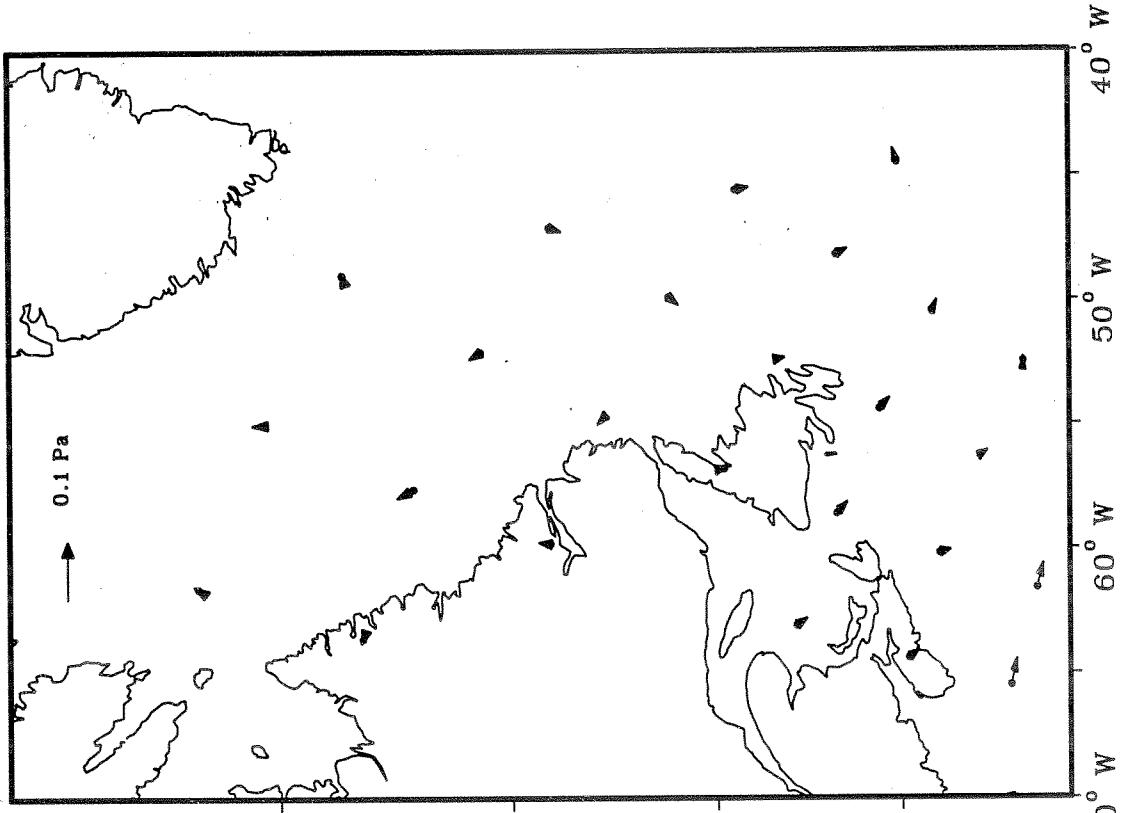
Summer 1962



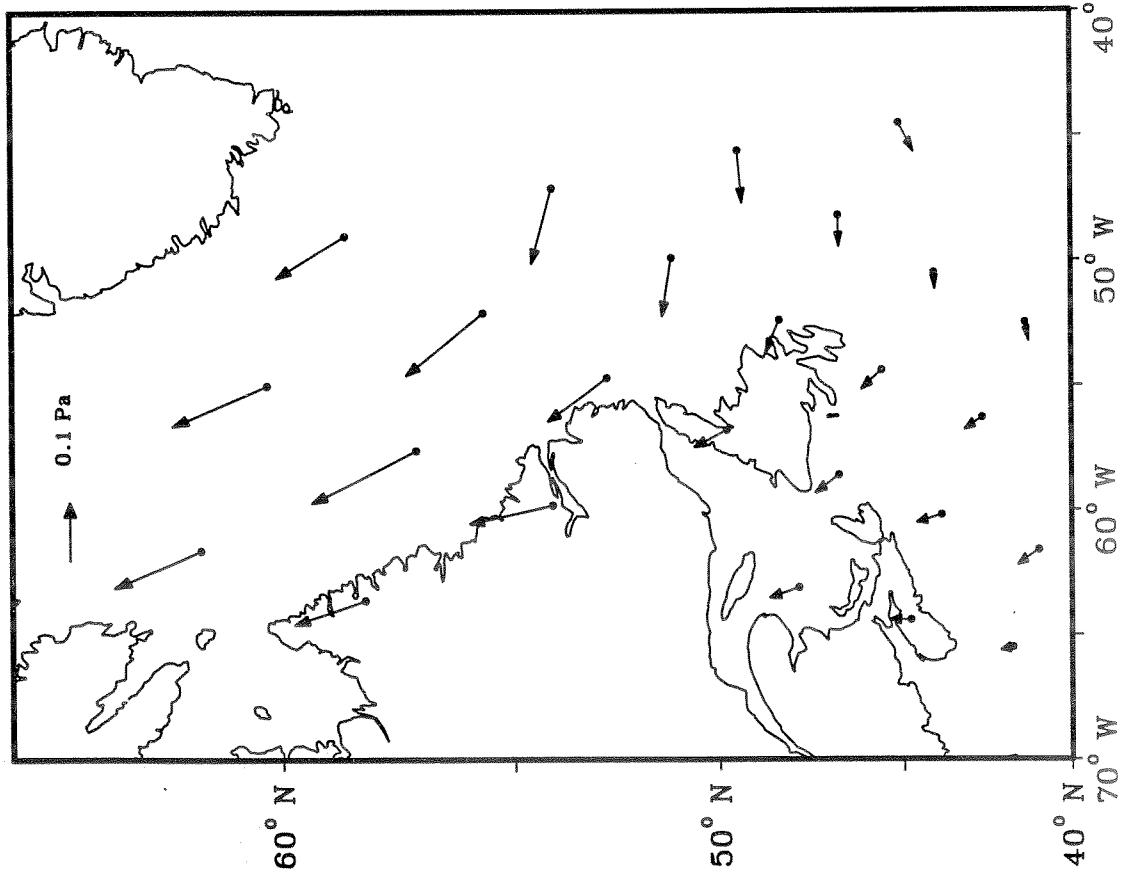
Fall 1962



Spring 1963

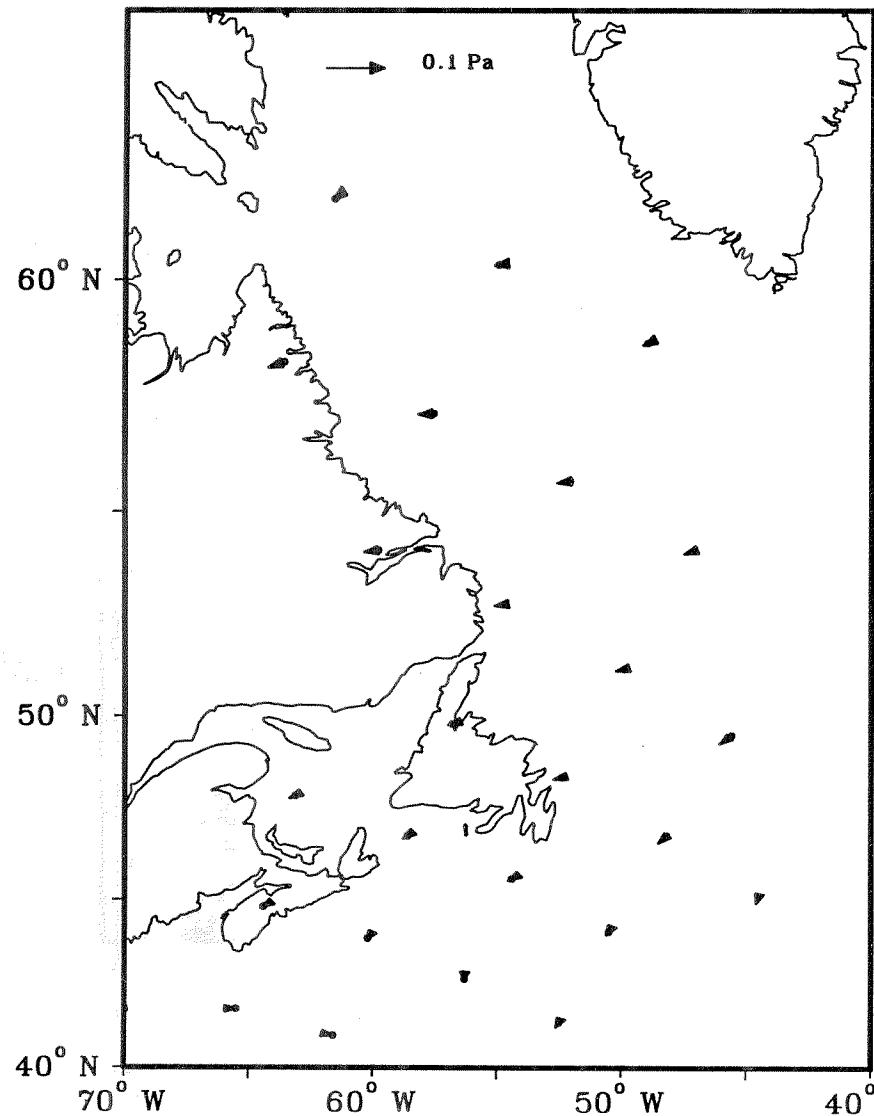


Winter 1963

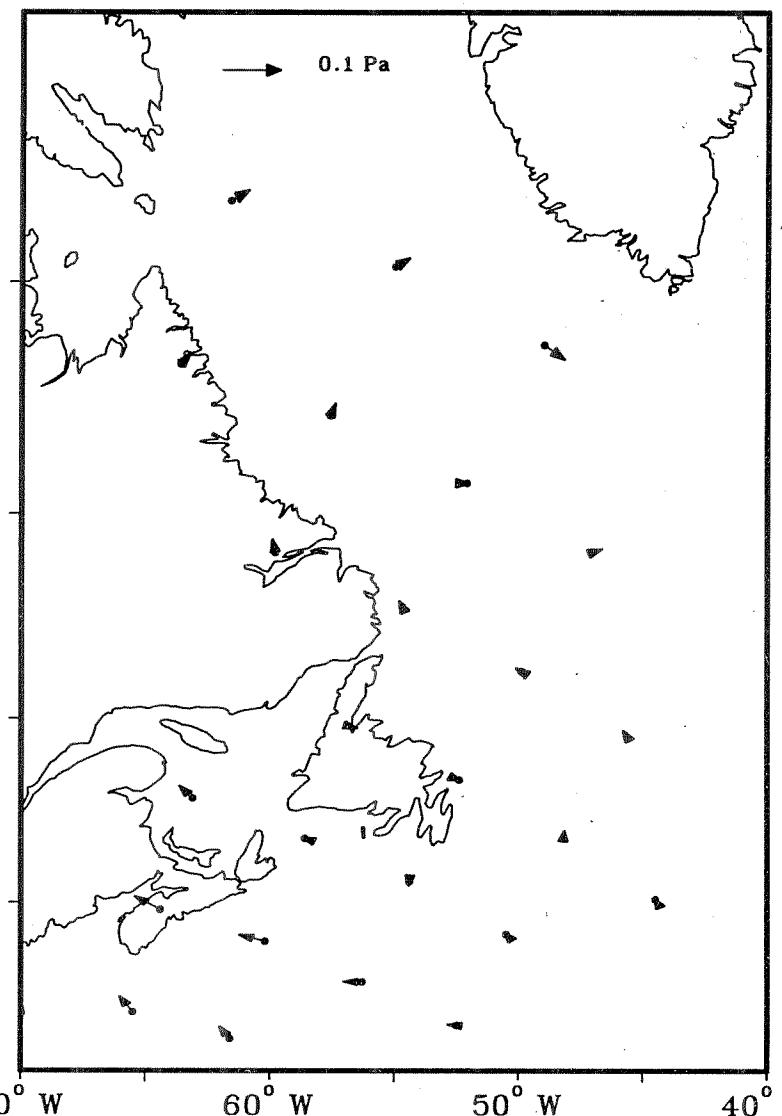


70° W 60° W 50° W 40° W 70° W 60° W 50° W 40° W

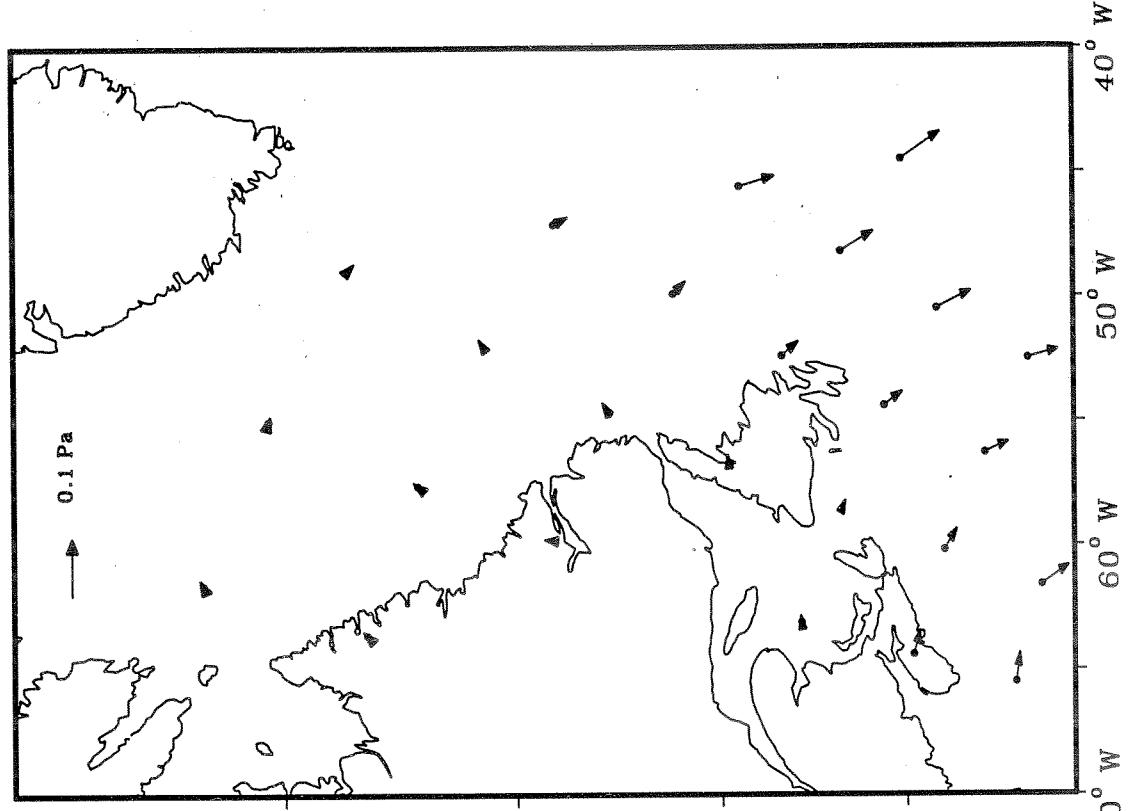
Summer 1963



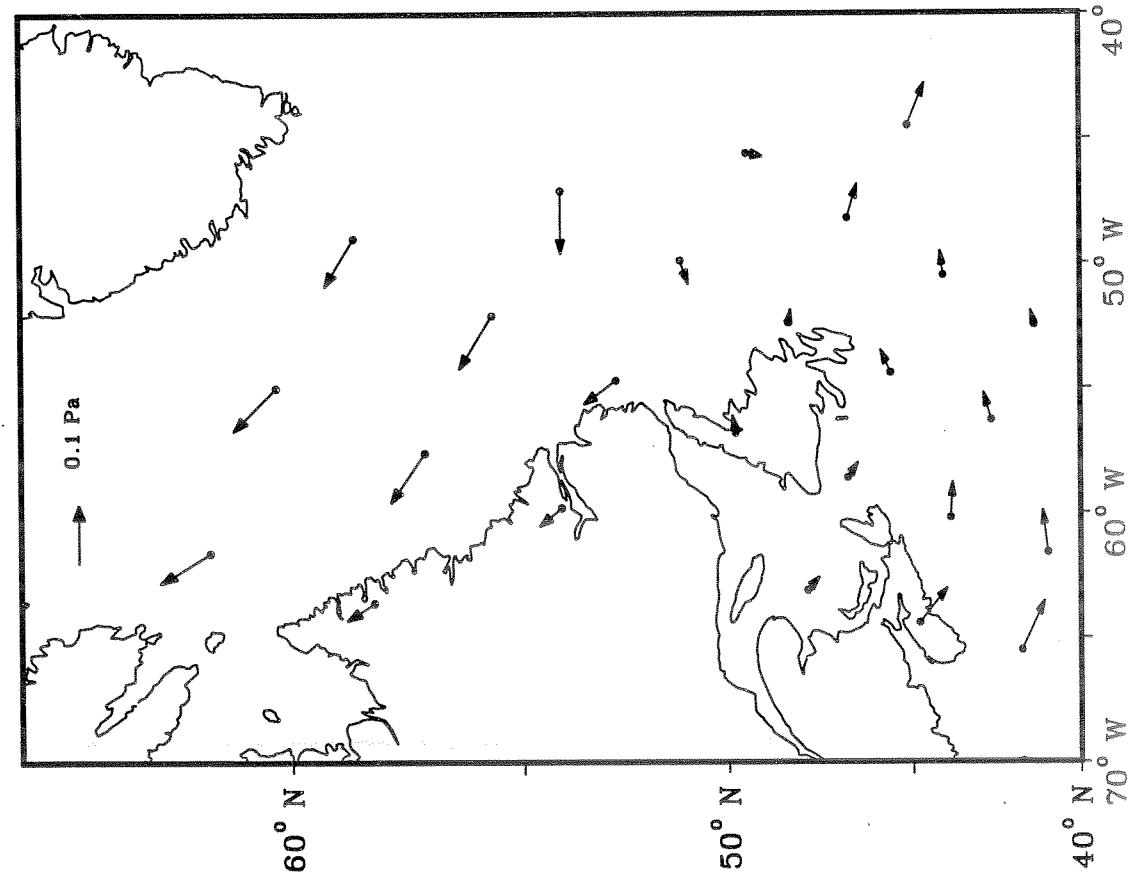
Fall 1963



Spring 1964



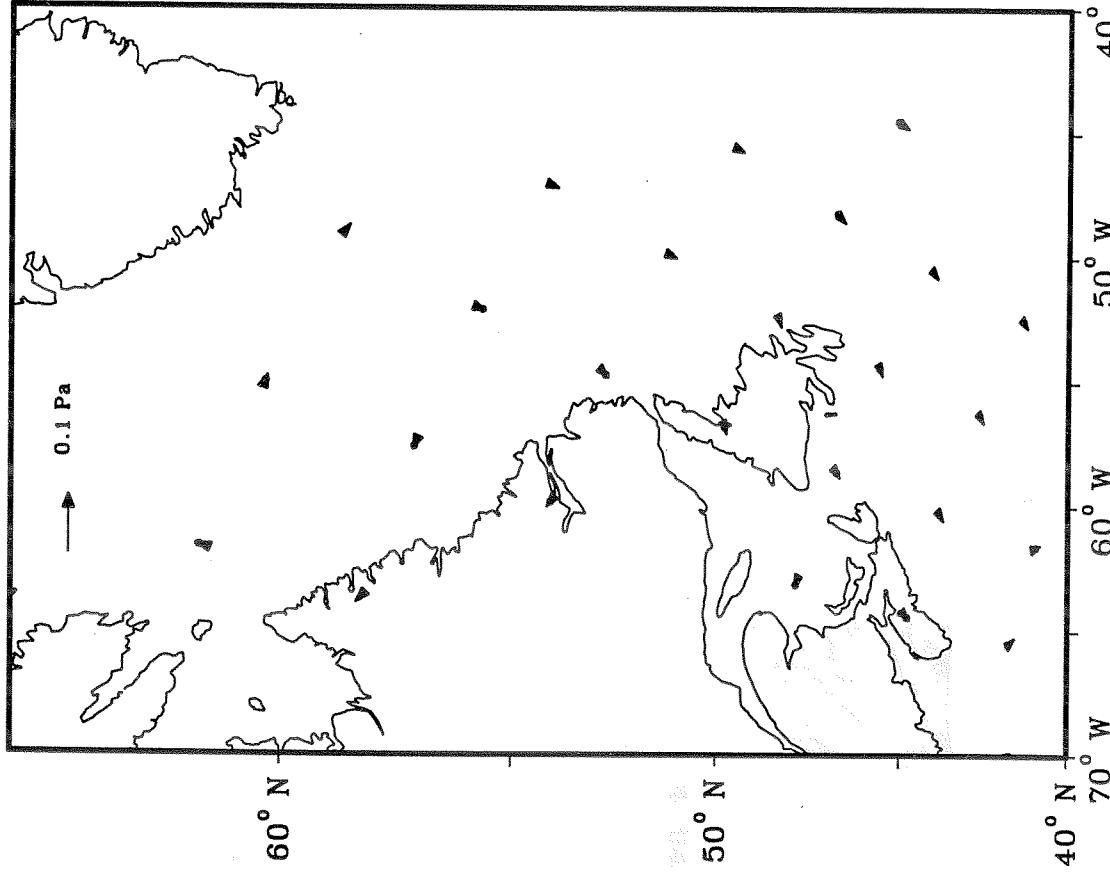
Winter 1964



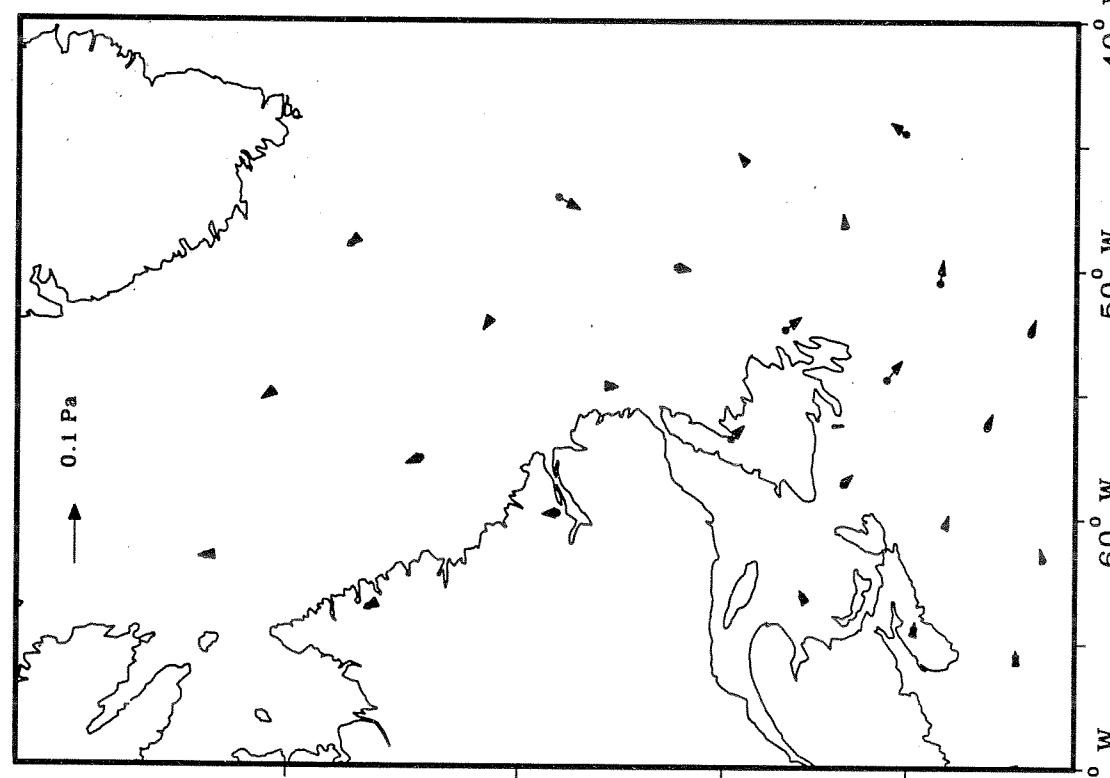
70° W 60° W 50° W 40° W

49

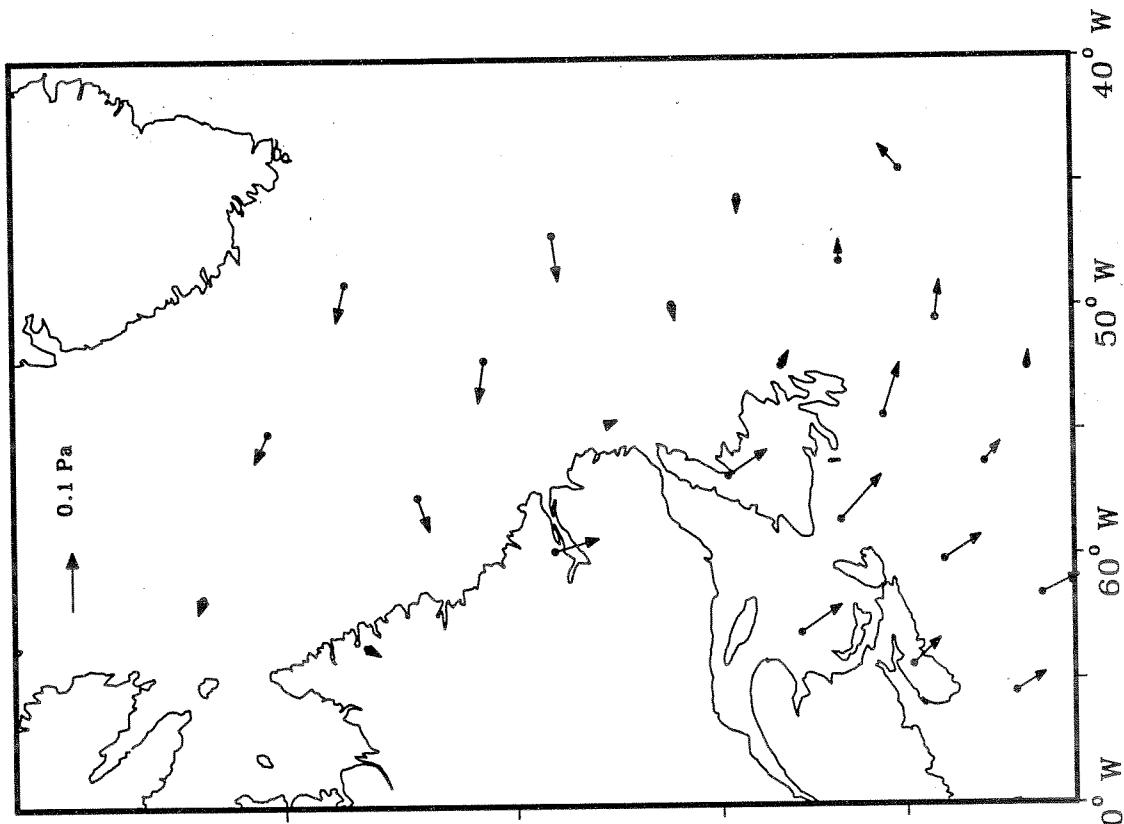
Summer 1964



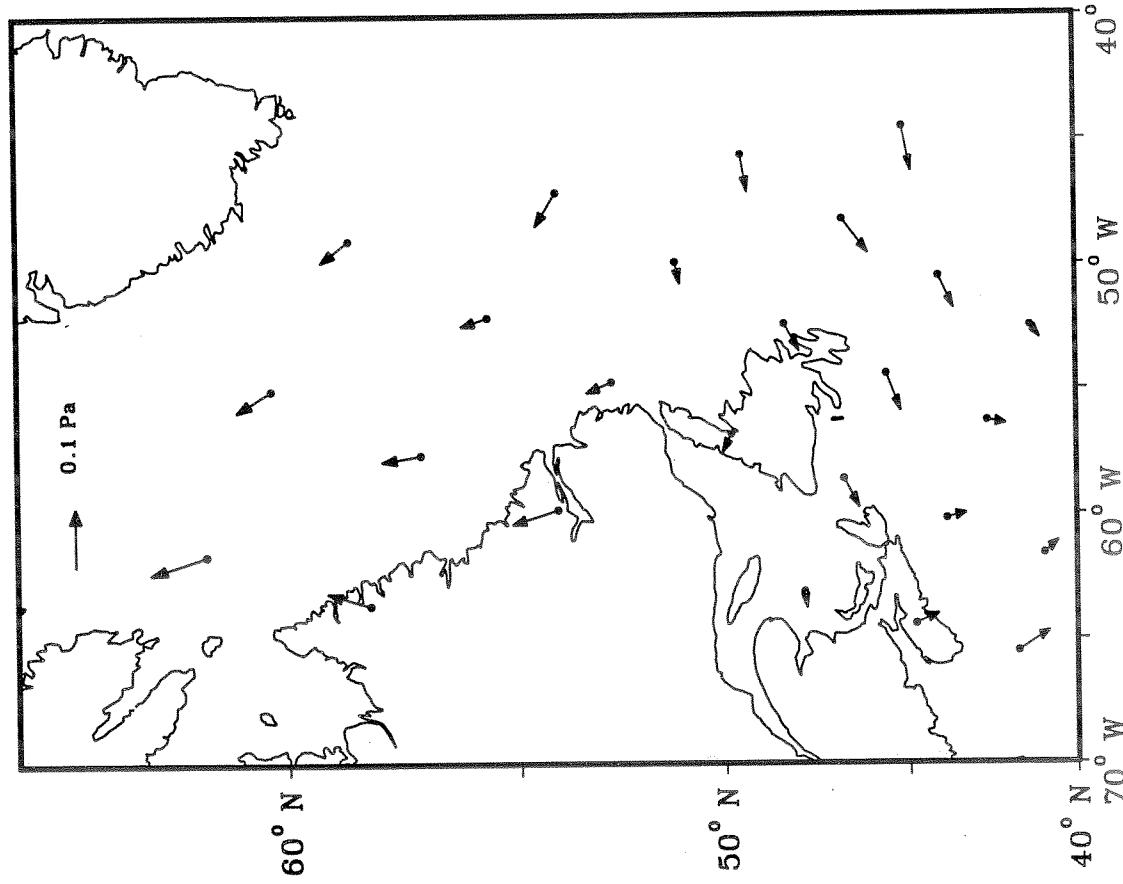
Fall 1964



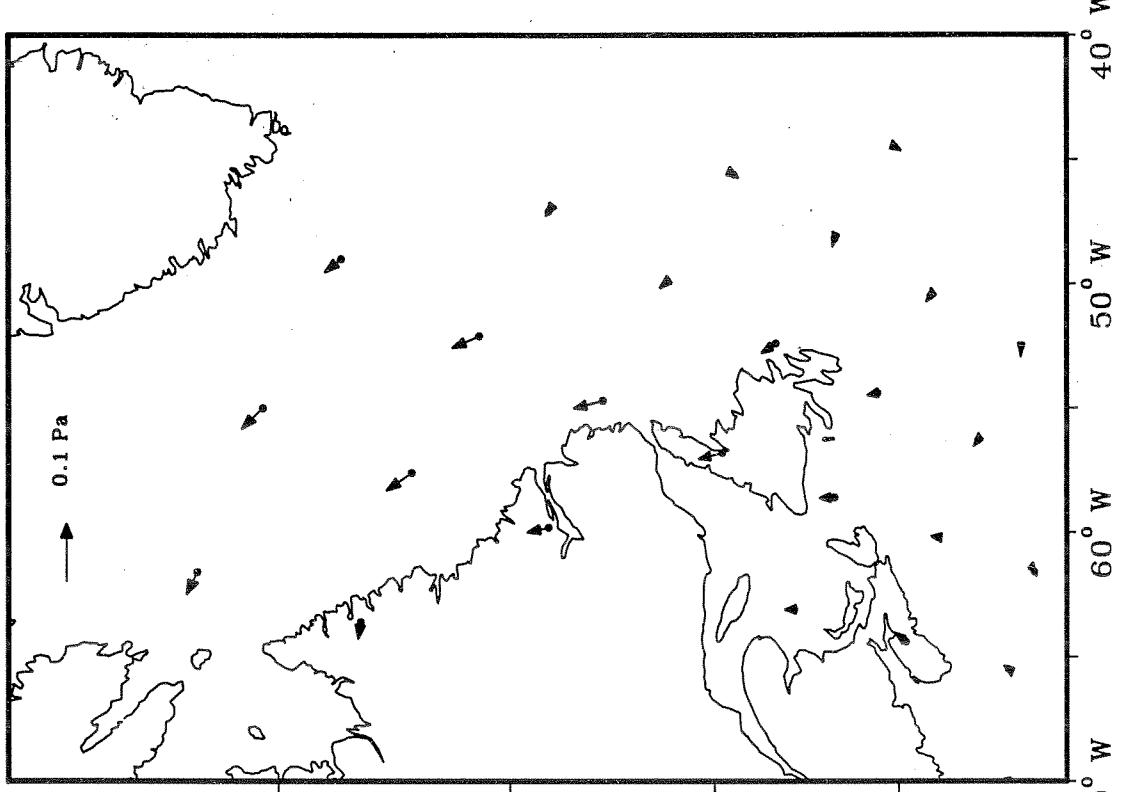
Spring 1965



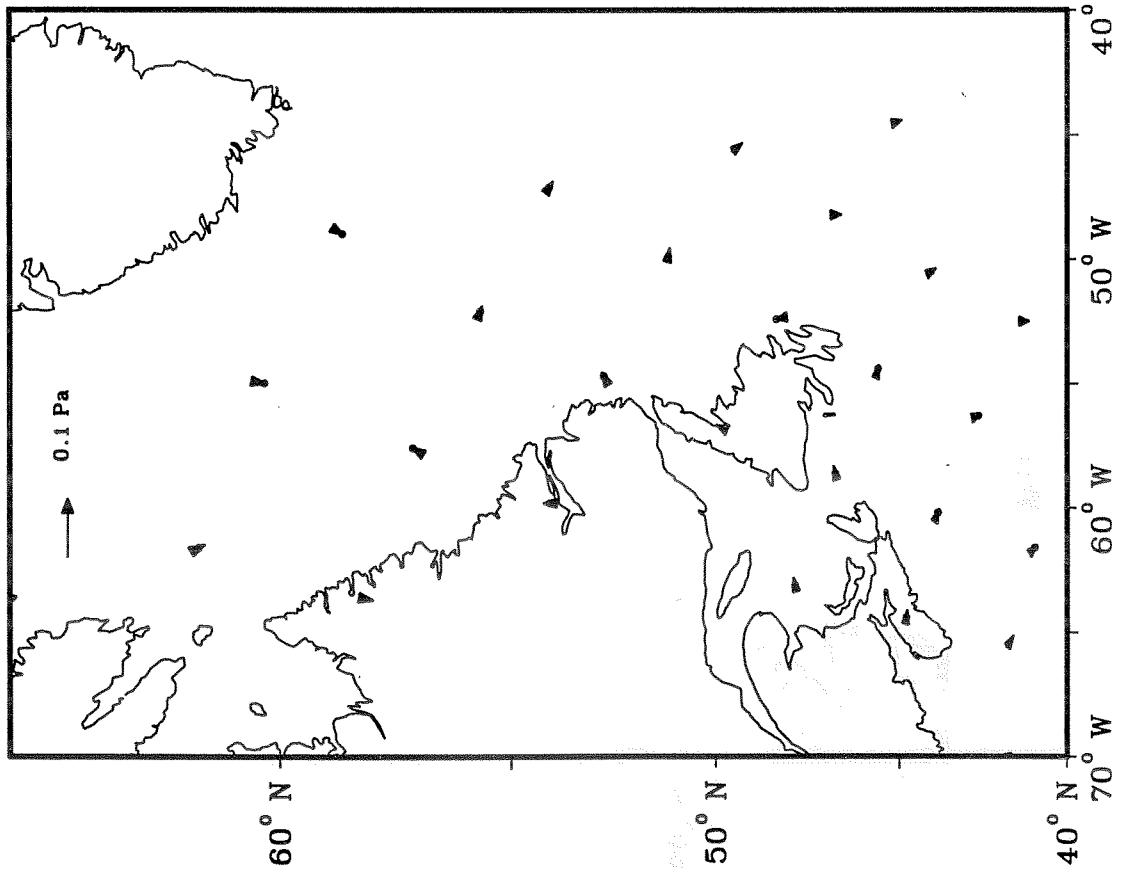
Winter 1965



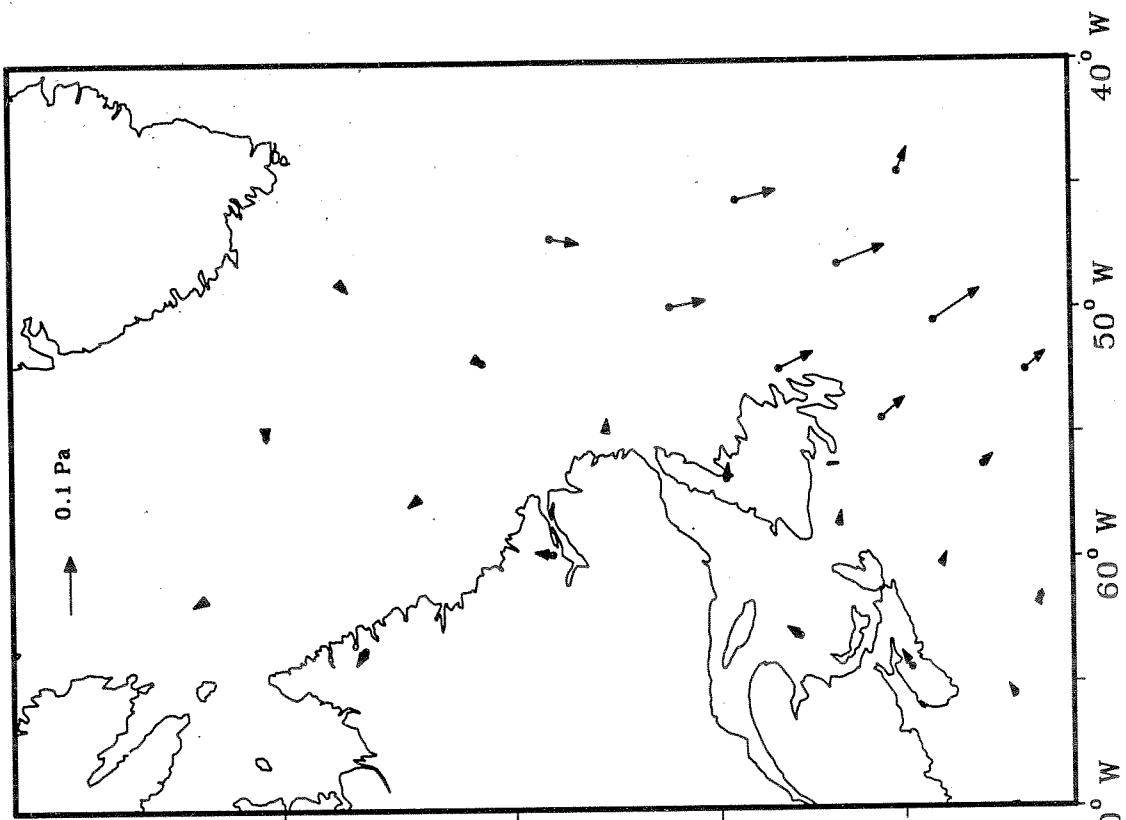
Fall 1965



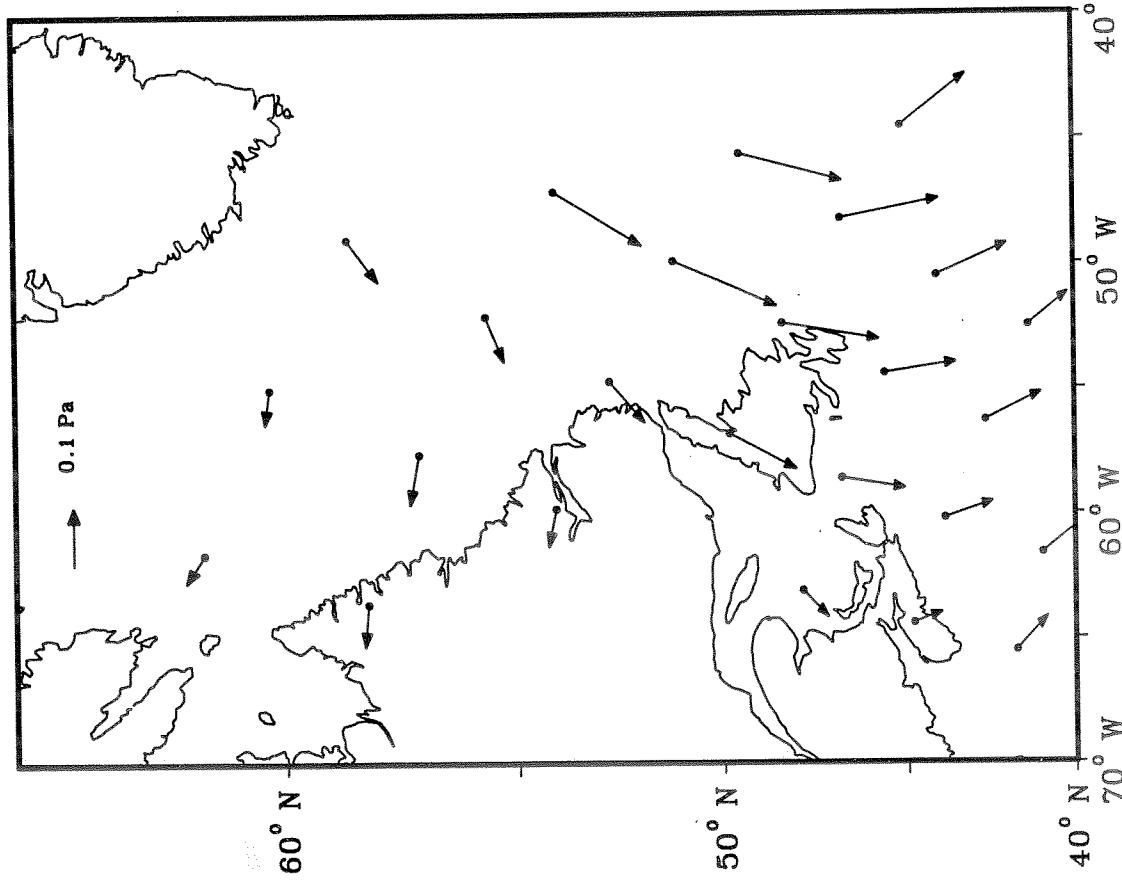
Summer 1965



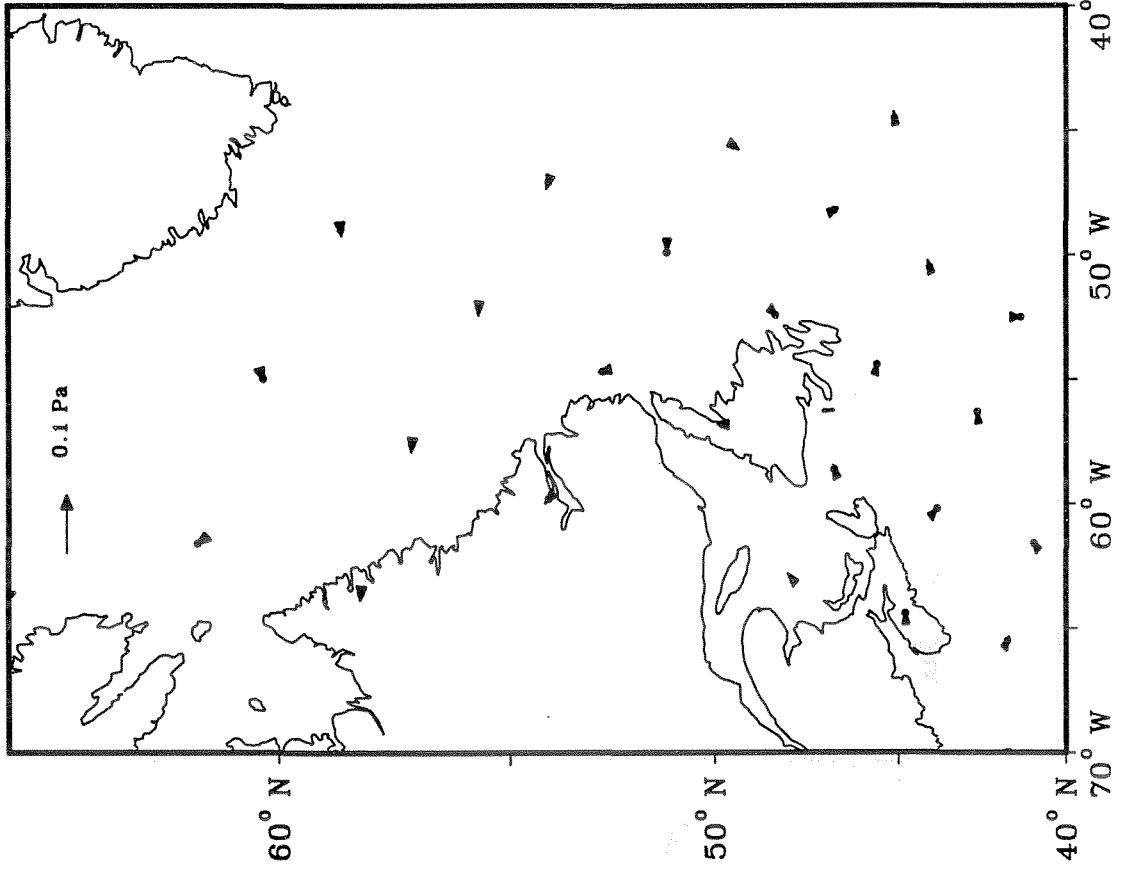
Spring 1966



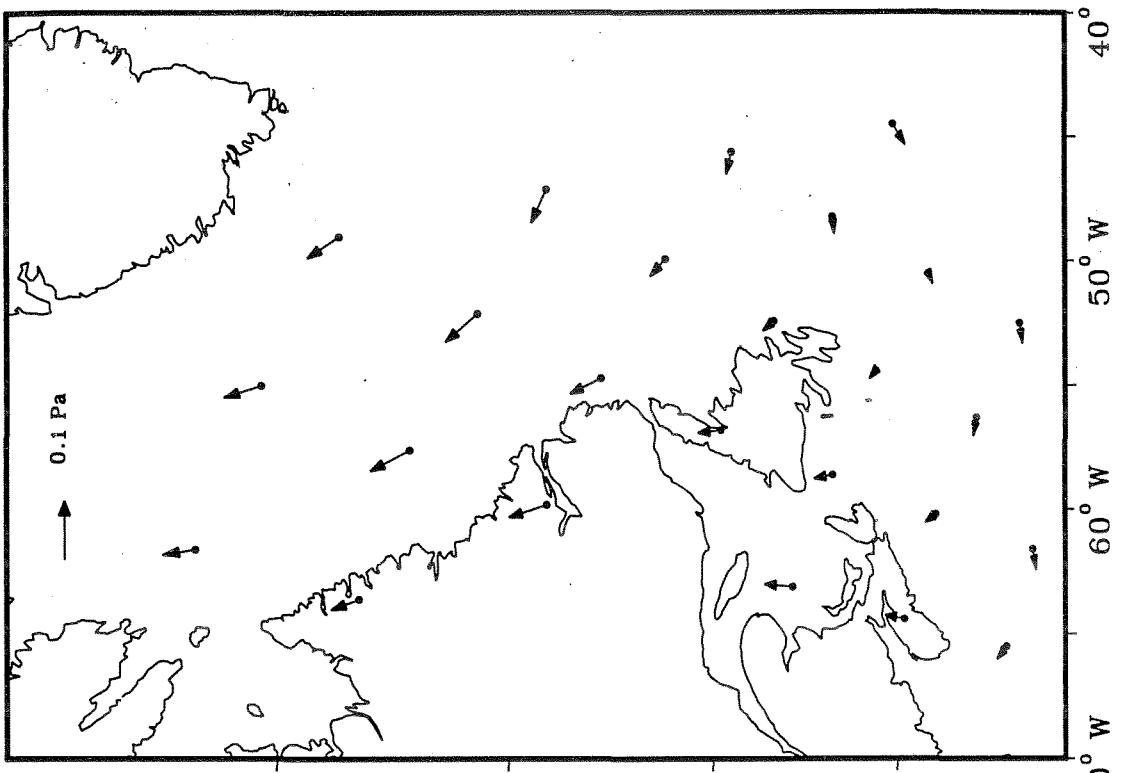
Winter 1966



Summer 1966



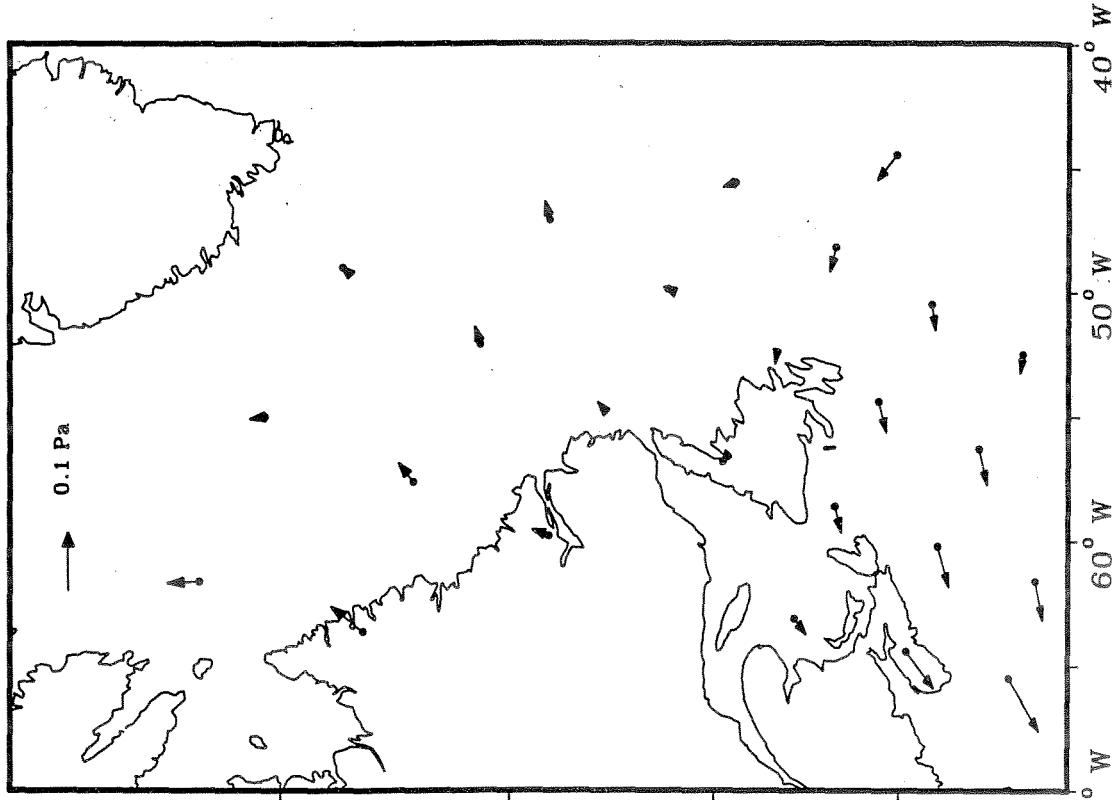
Fall 1966



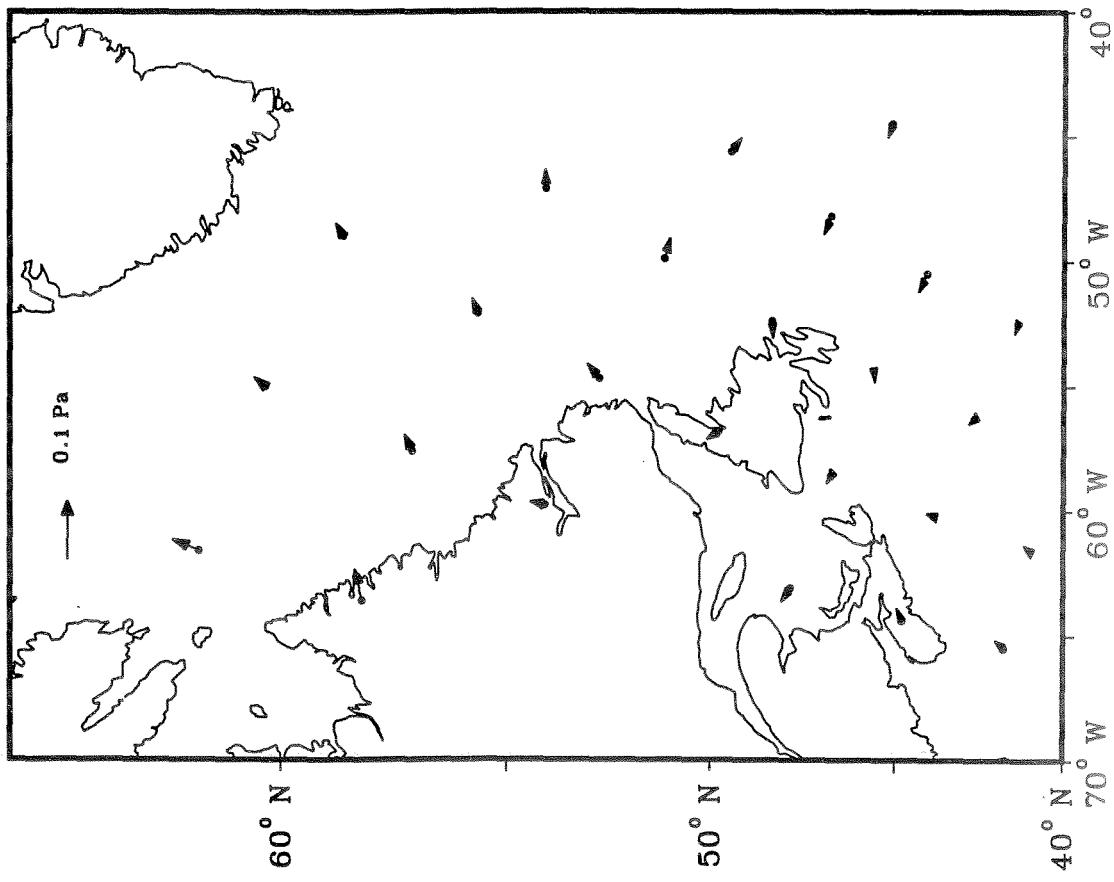
60° W 50° W 40° W 70° W 60° W 50° W 40° W

60° W 50° W 40° W 70° W 60° W 50° W 40° W

Spring 1967

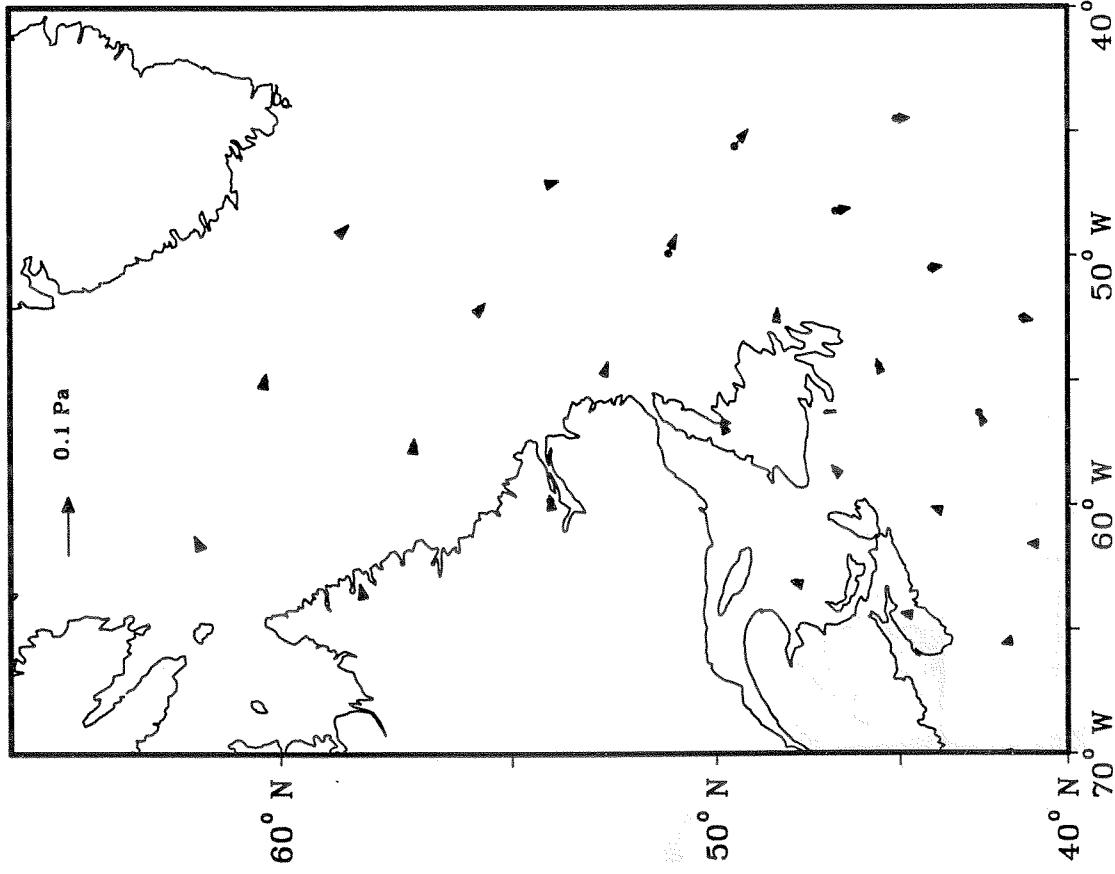


Winter 1967

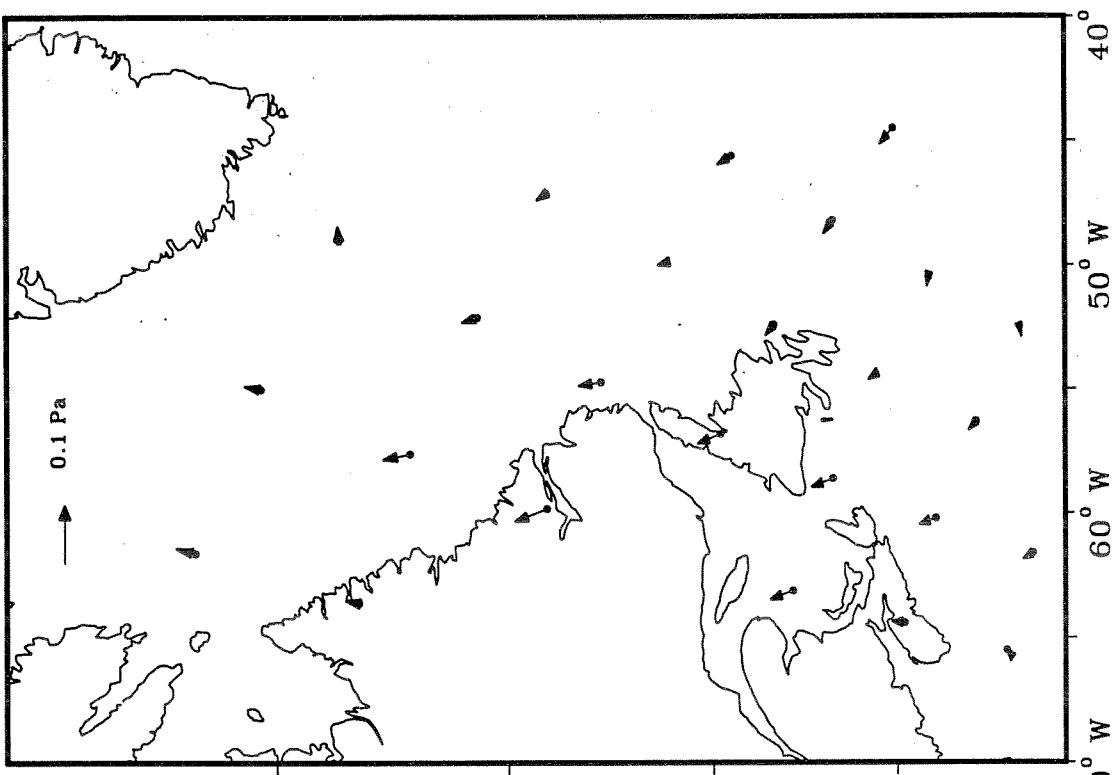


70° W 60° W 50° W 40° W 70° W 60° W 50° W 40° W

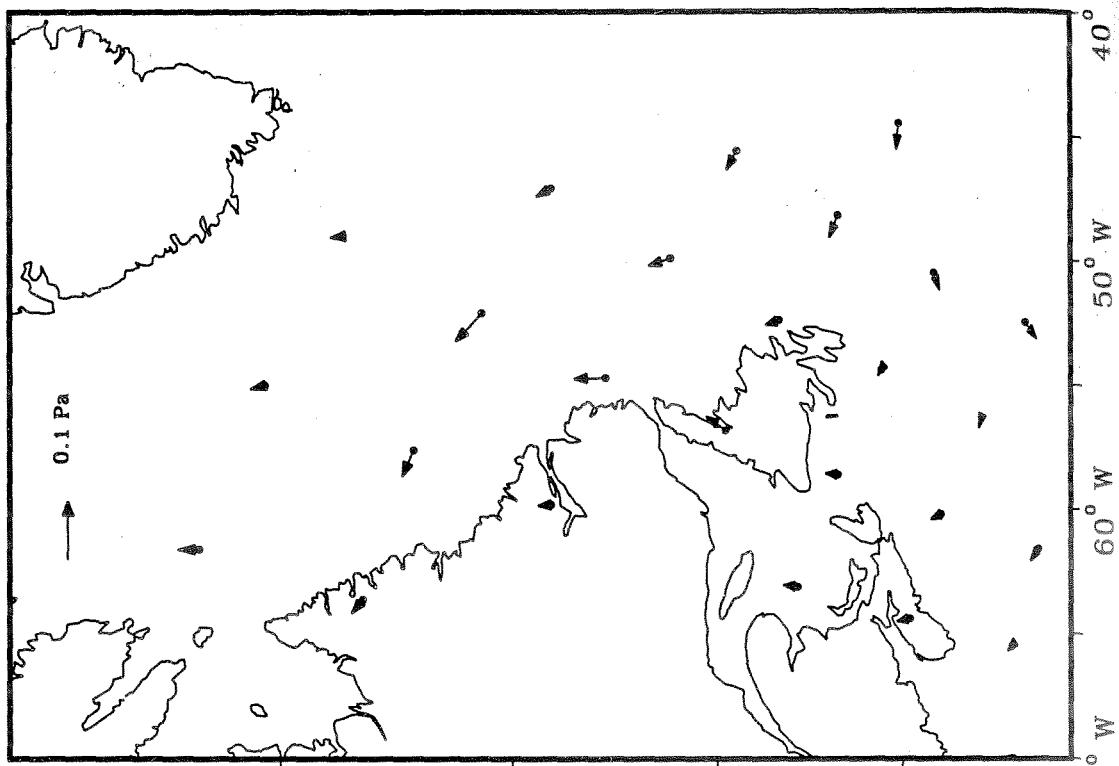
Summer 1967



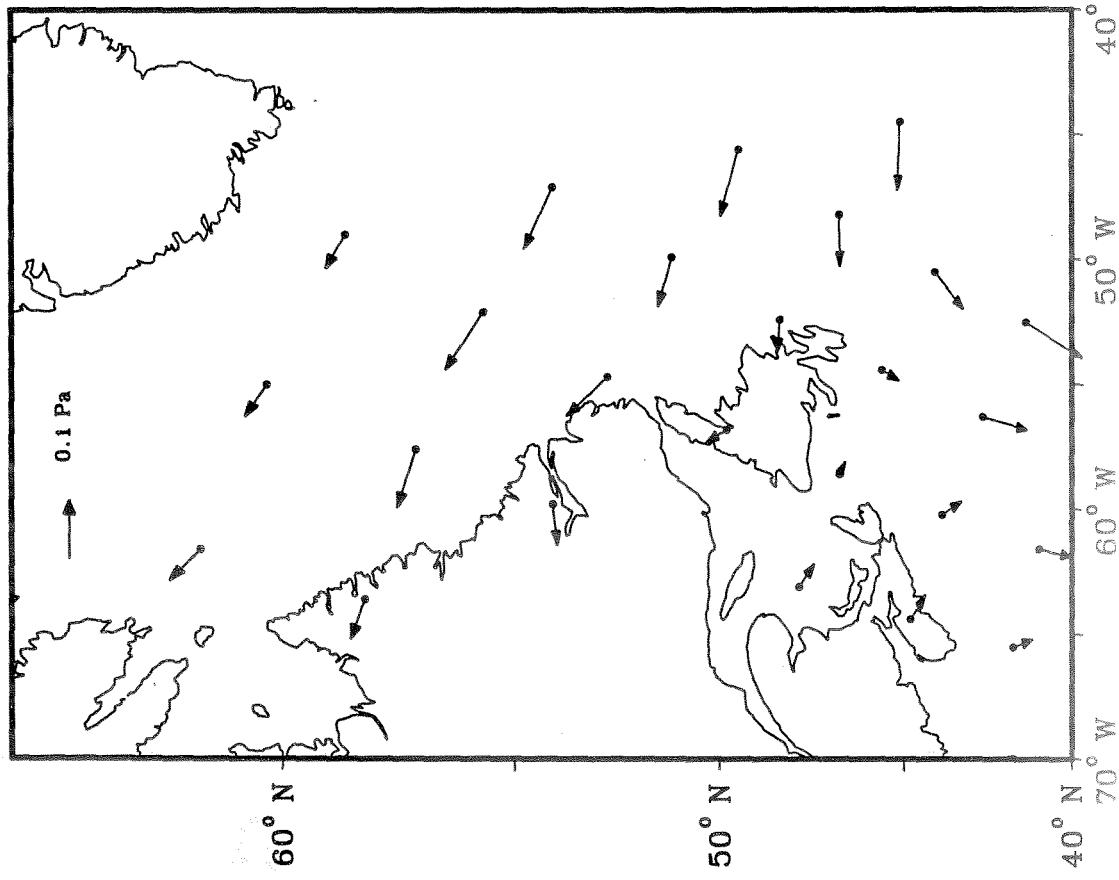
Fall 1967



Spring 1968

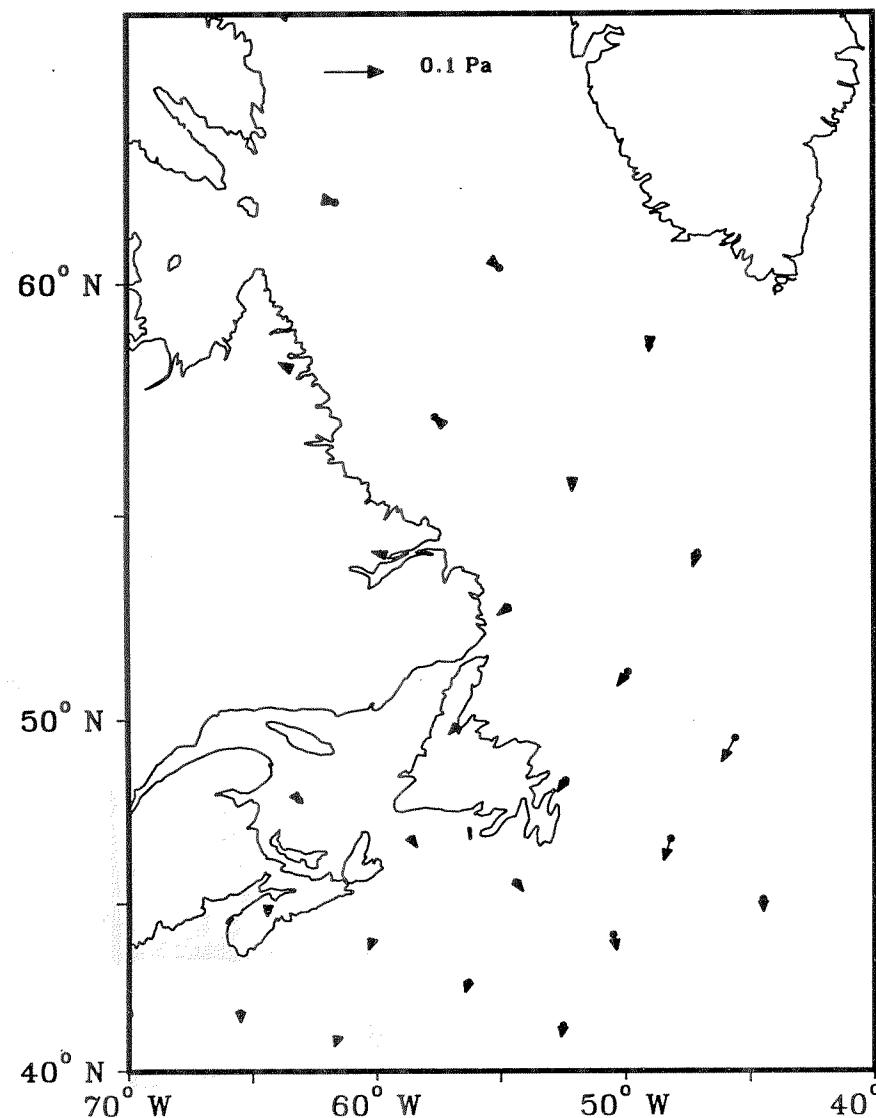


Winter 1968

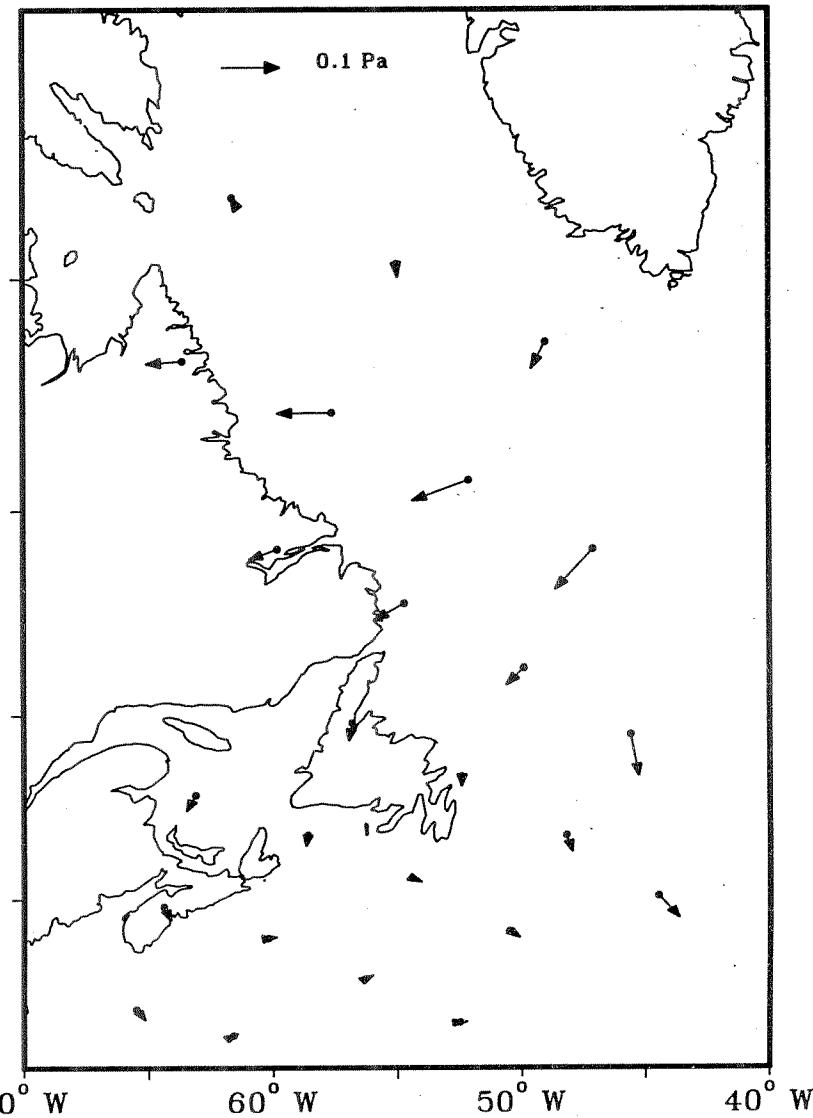


70° W 60° W 50° W 40° W 70° W 60° W 50° W 40° W

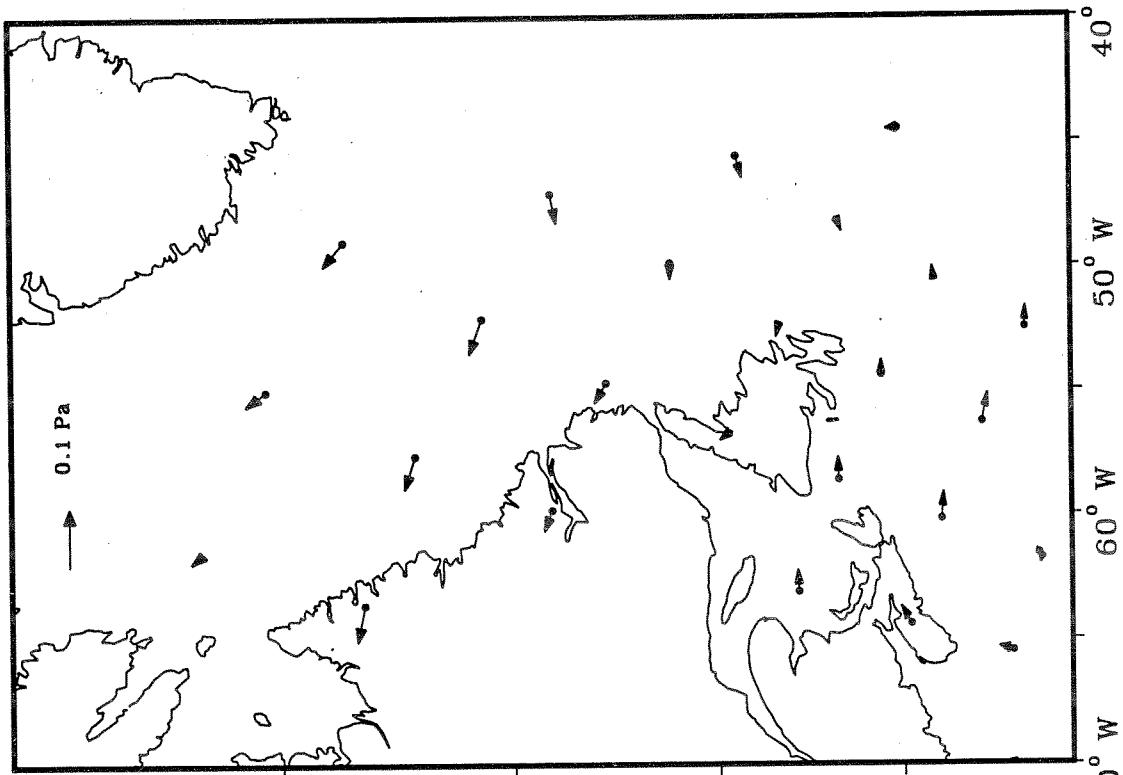
Summer 1968



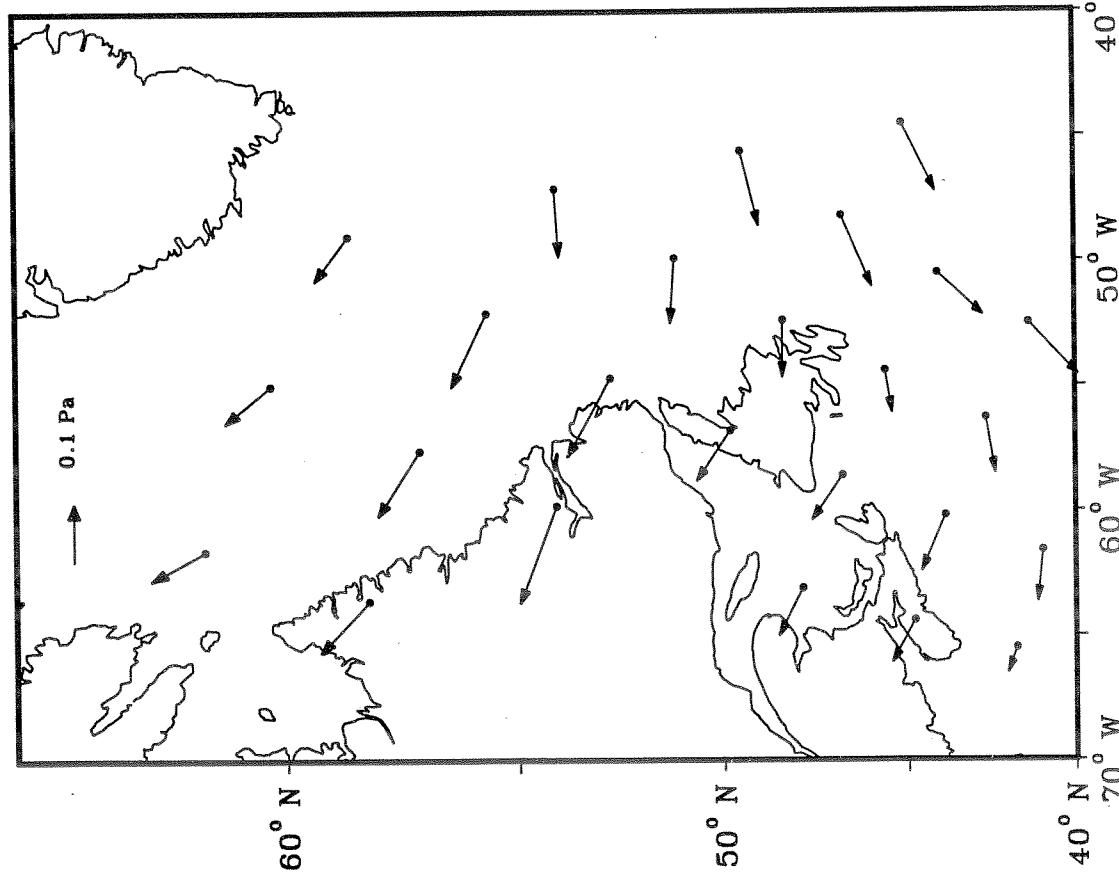
Fall 1968



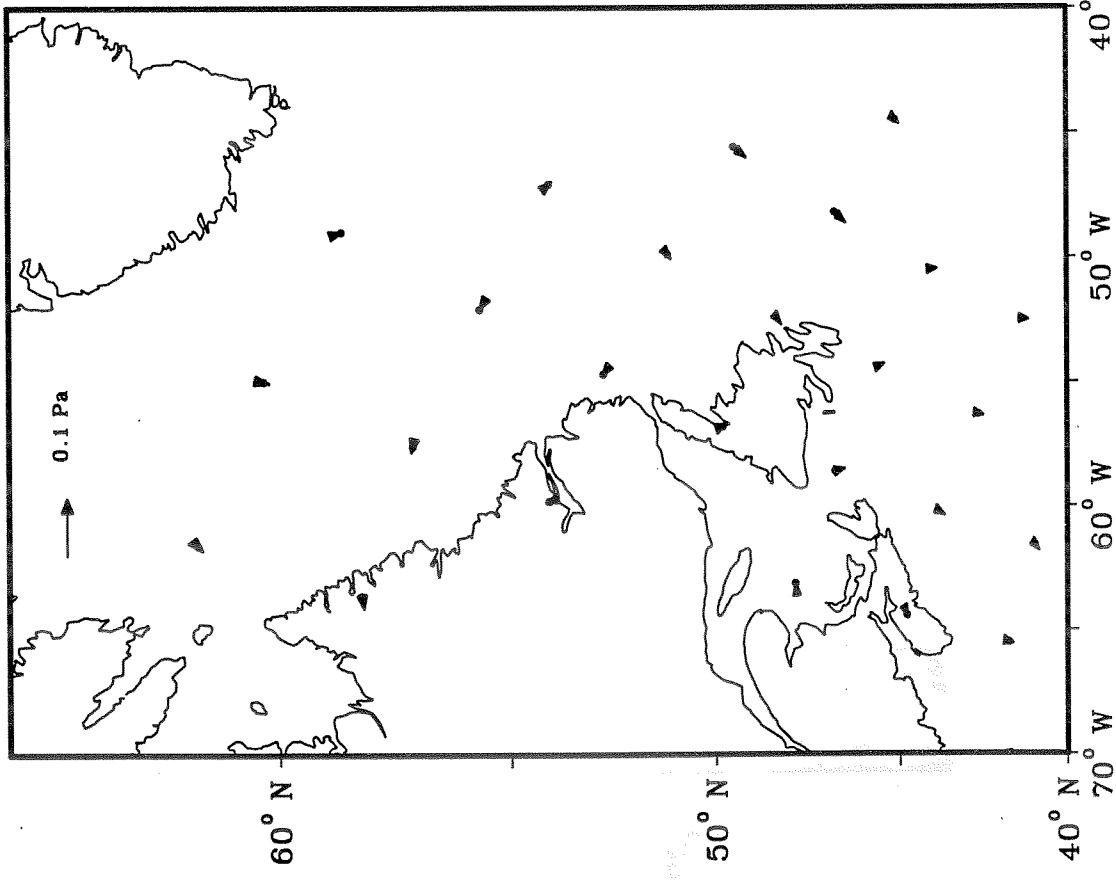
Spring 1969



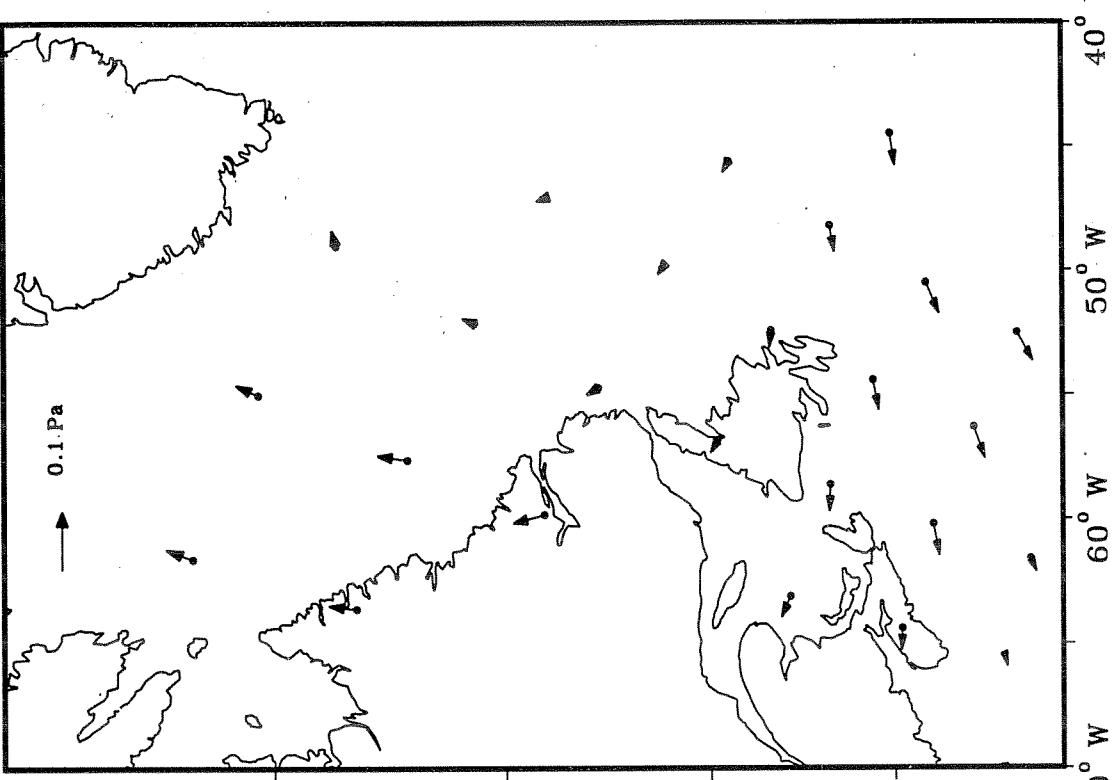
Winter 1969



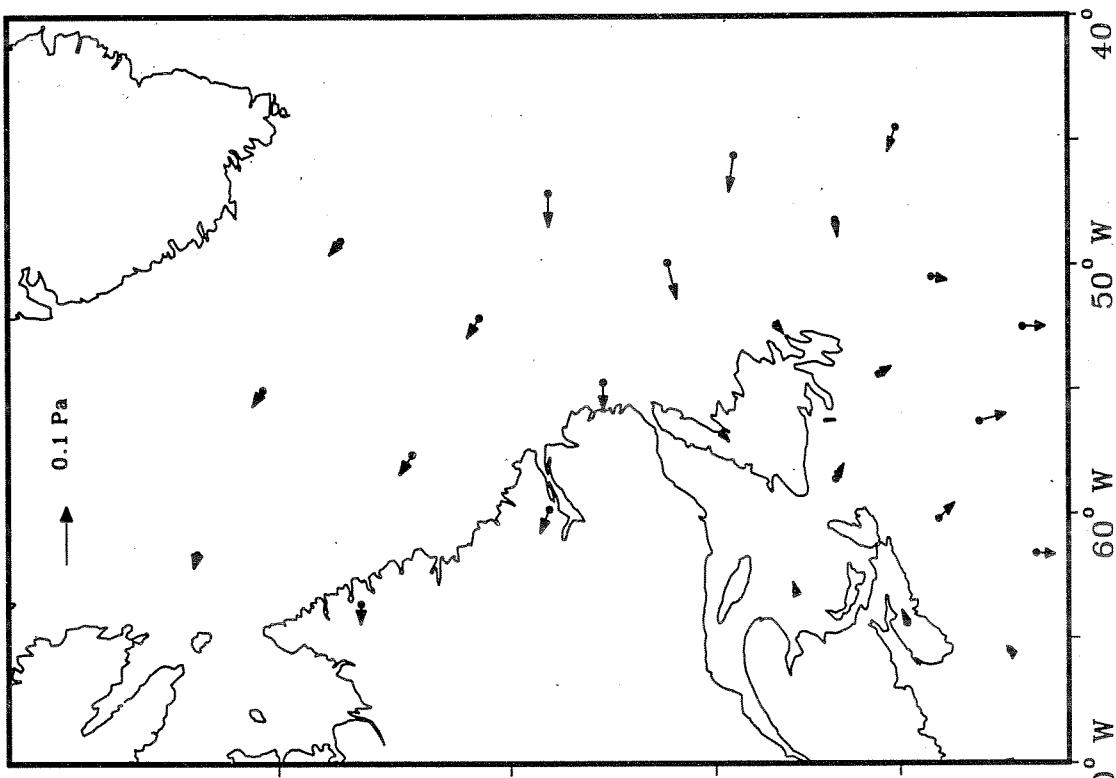
Summer 1969



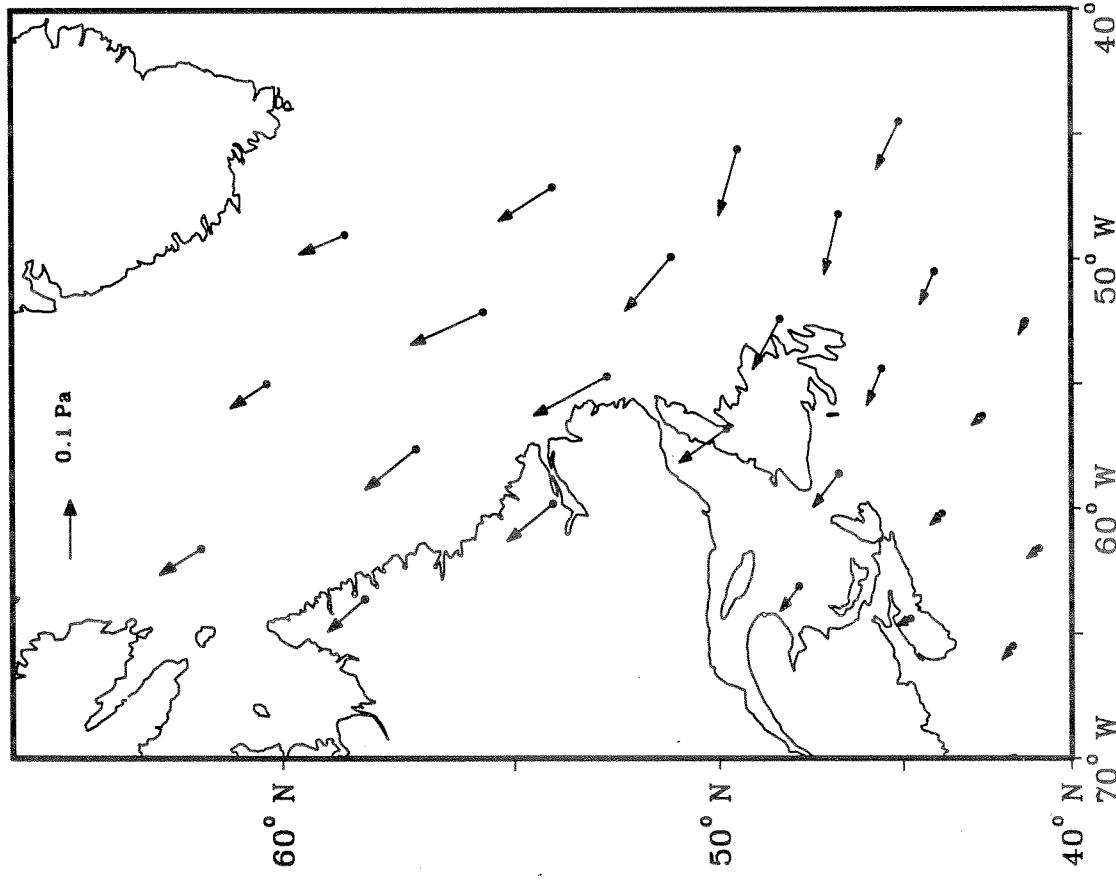
Fall 1969

40 W 50 W 60 W 70 W 80 W
40 W 50 W 60 W 70 W 80 W
40 W 50 W 60 W 70 W 80 W
40 W 50 W 60 W 70 W 80 W

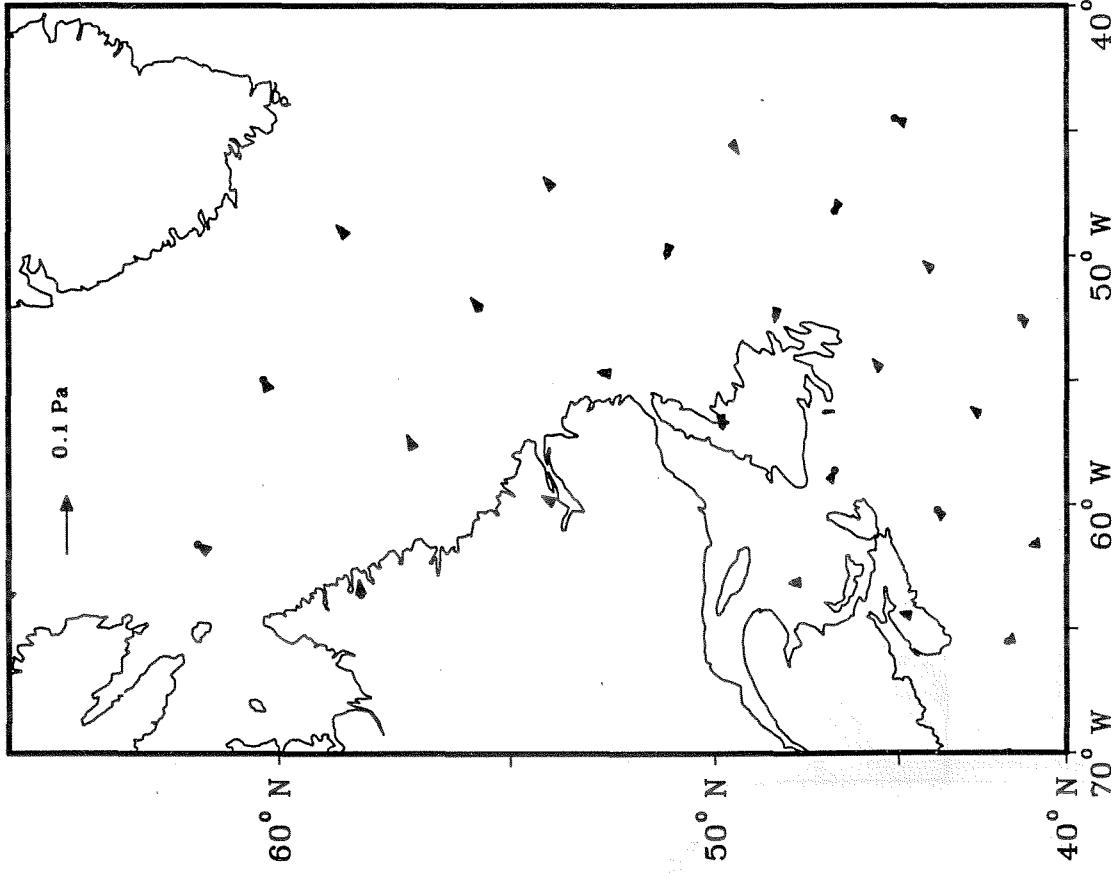
Spring 1970



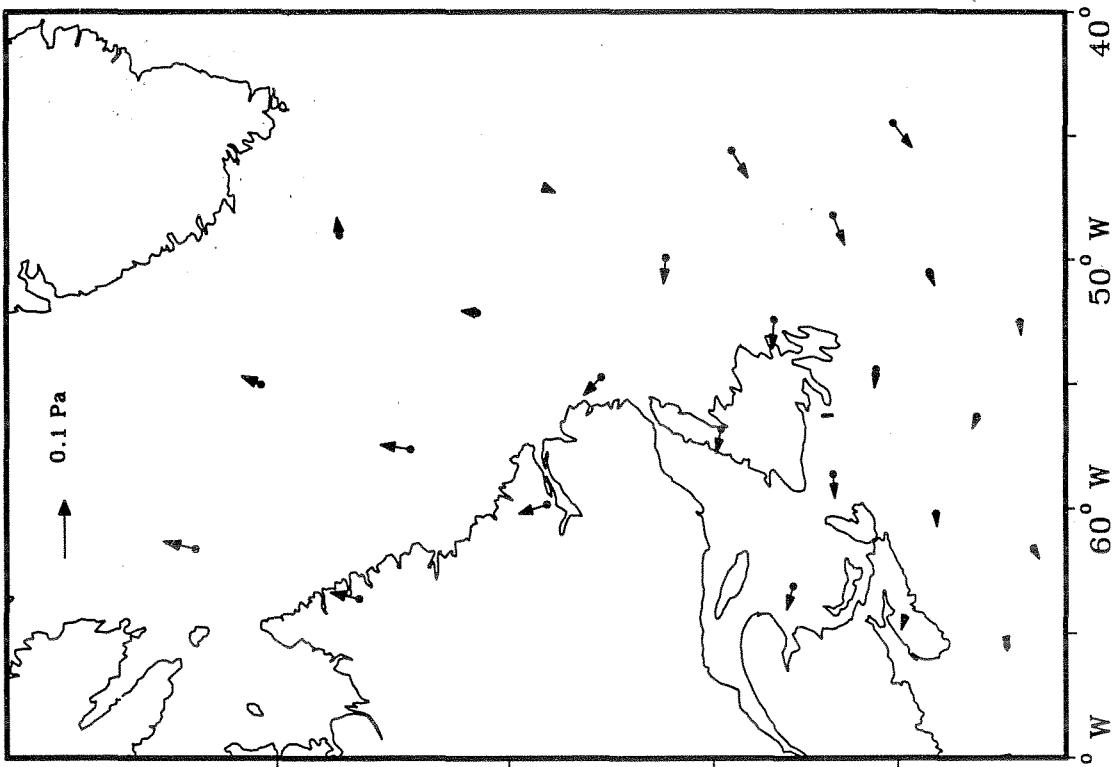
Winter 1970



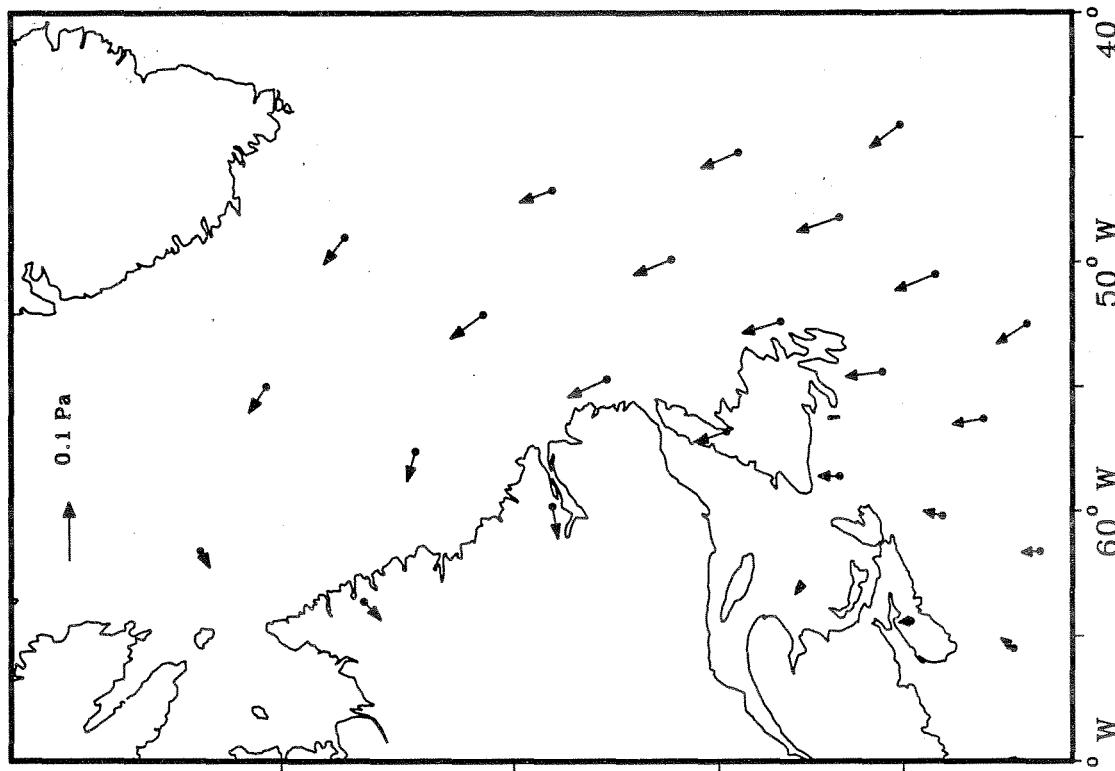
Summer 1970



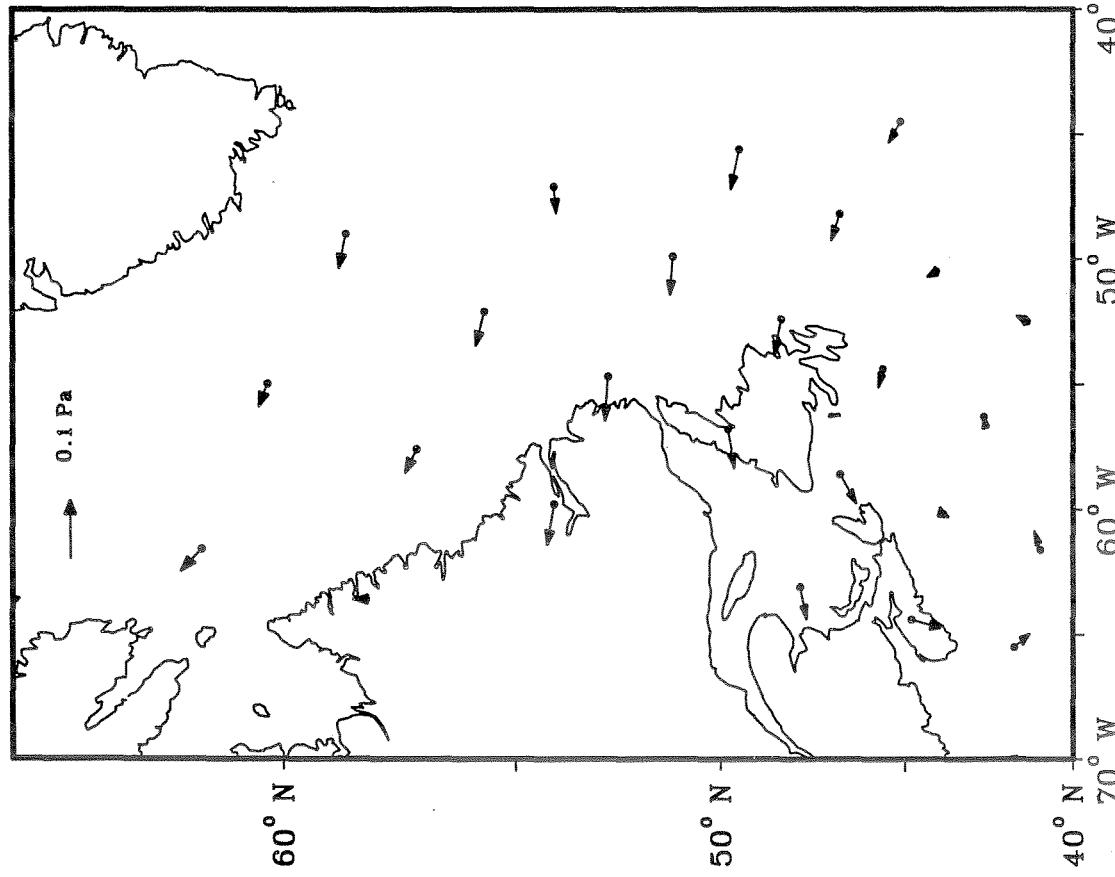
Fall 1970



Spring 1971



Winter 1971



70° W

60° W

50° W

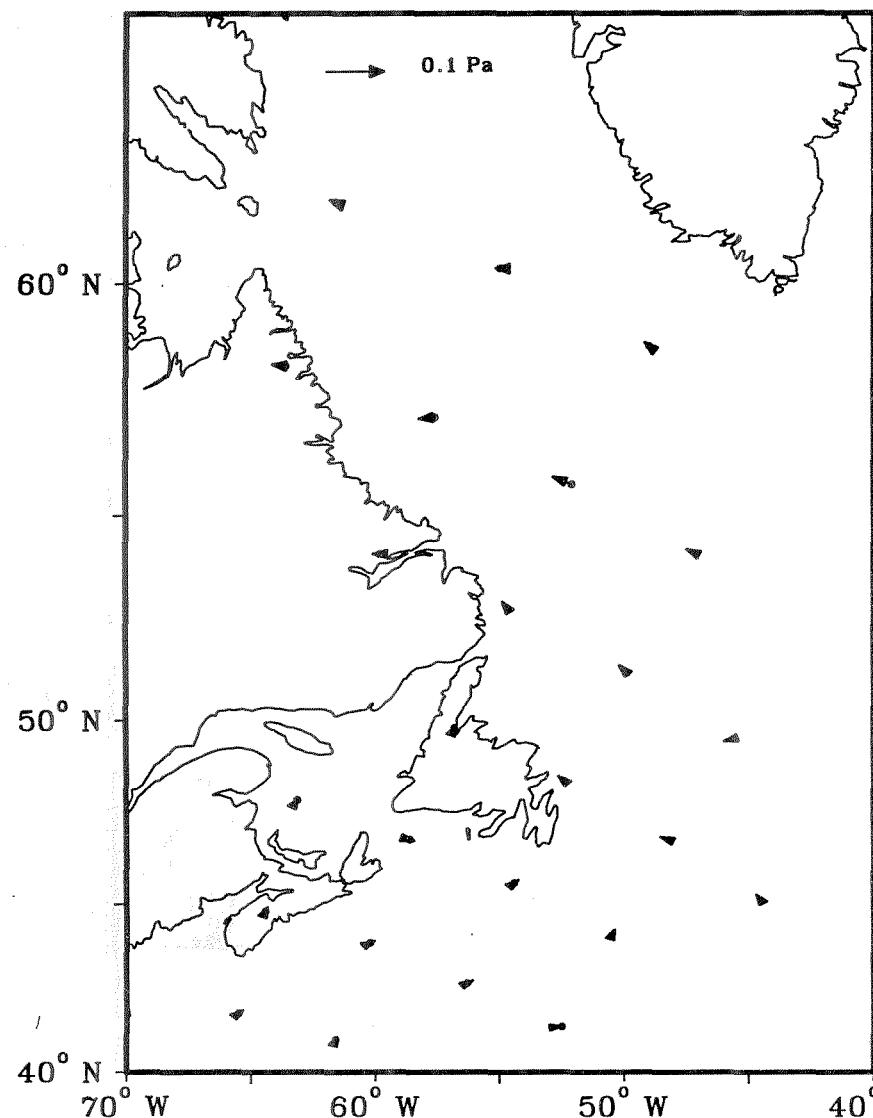
40° W 70° W

60° W

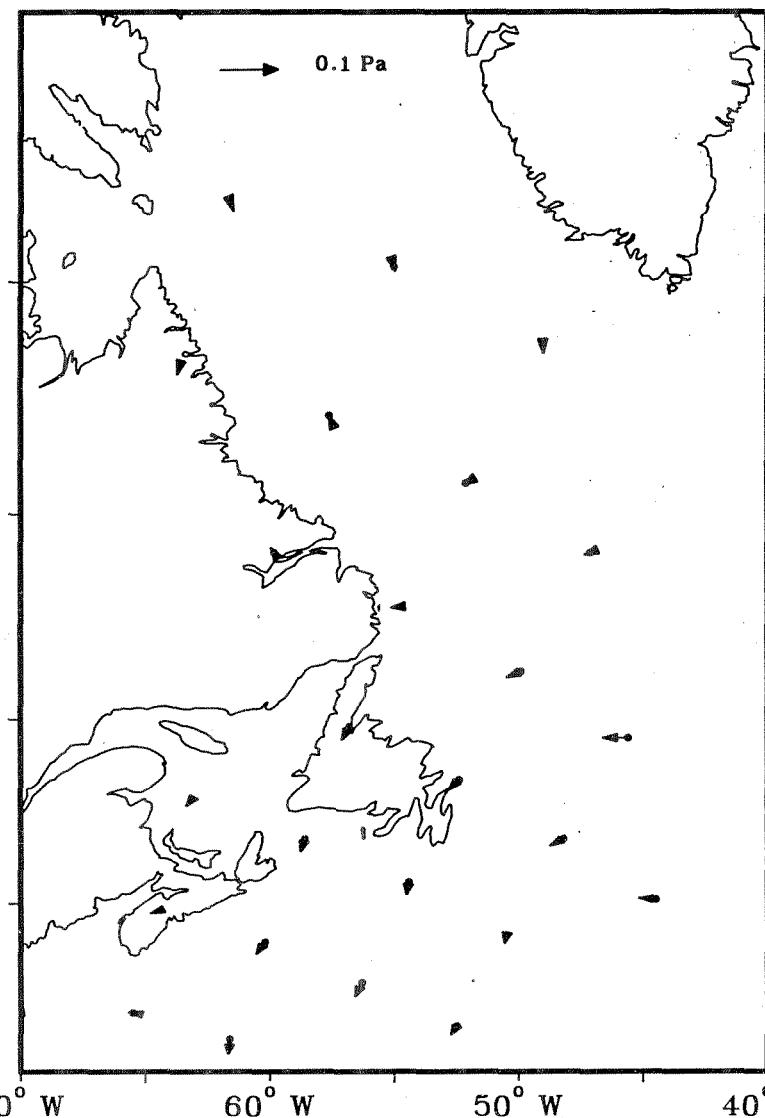
50° W

40° W

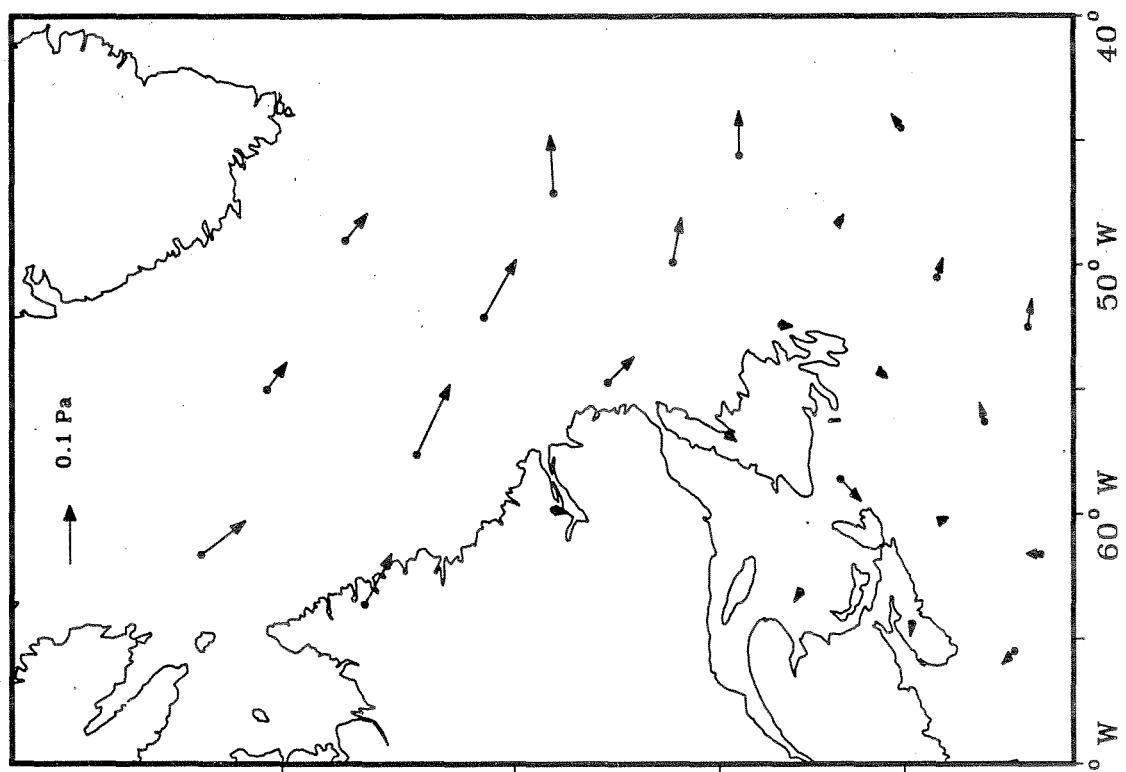
Summer 1971



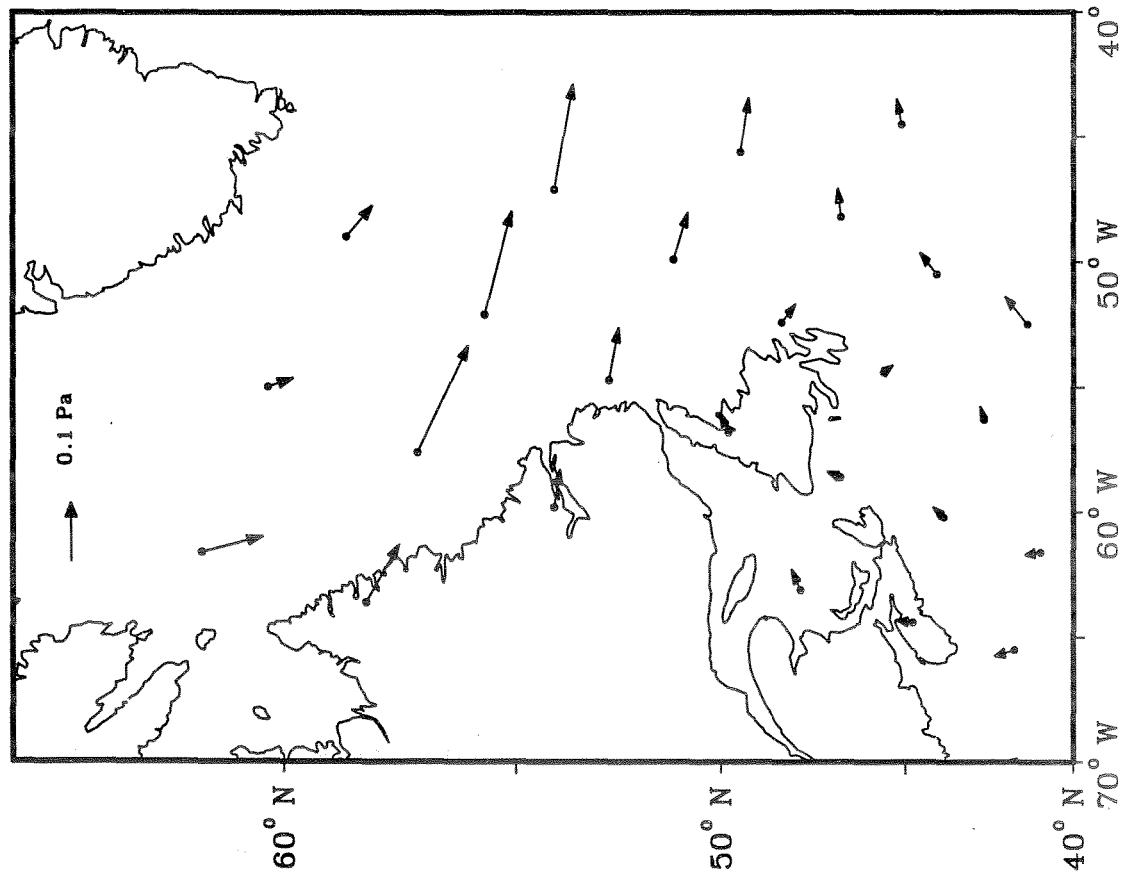
Fall 1971



Spring 1972



Winter 1972



70° W

60° W

50° W

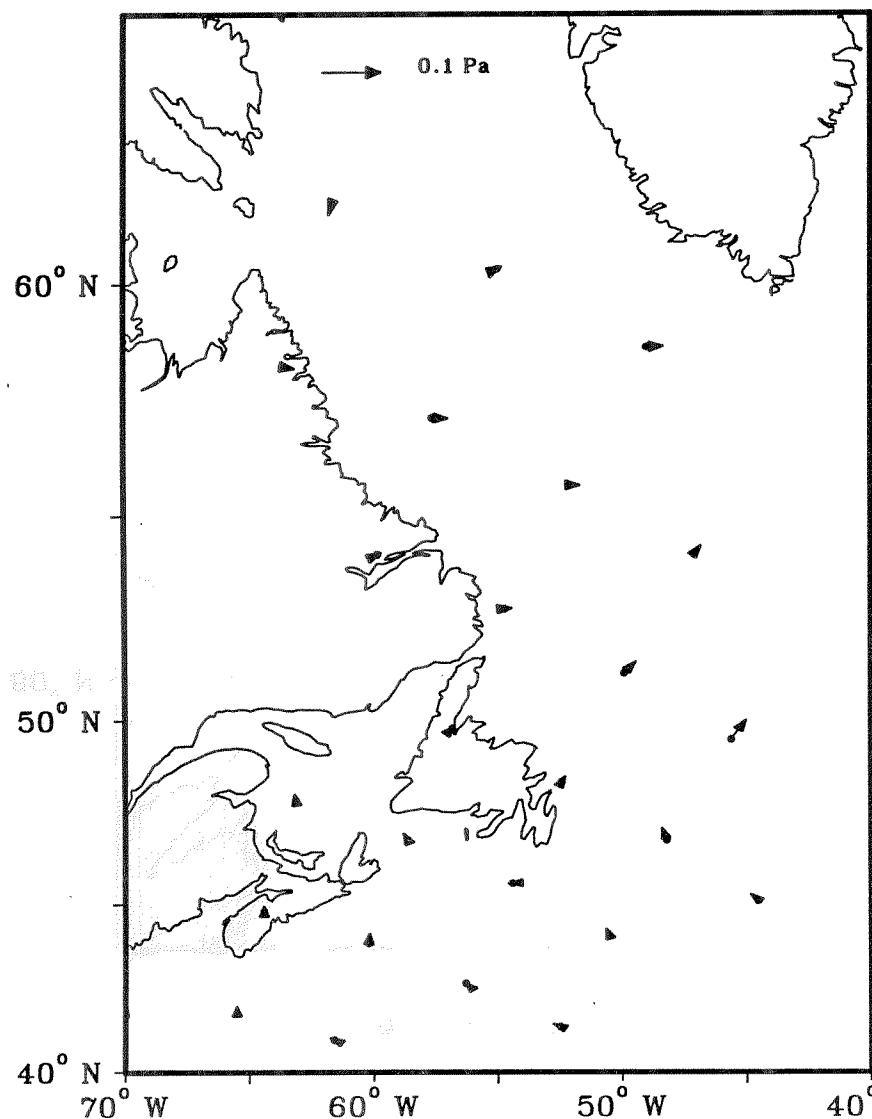
40° W 70° W

60° W

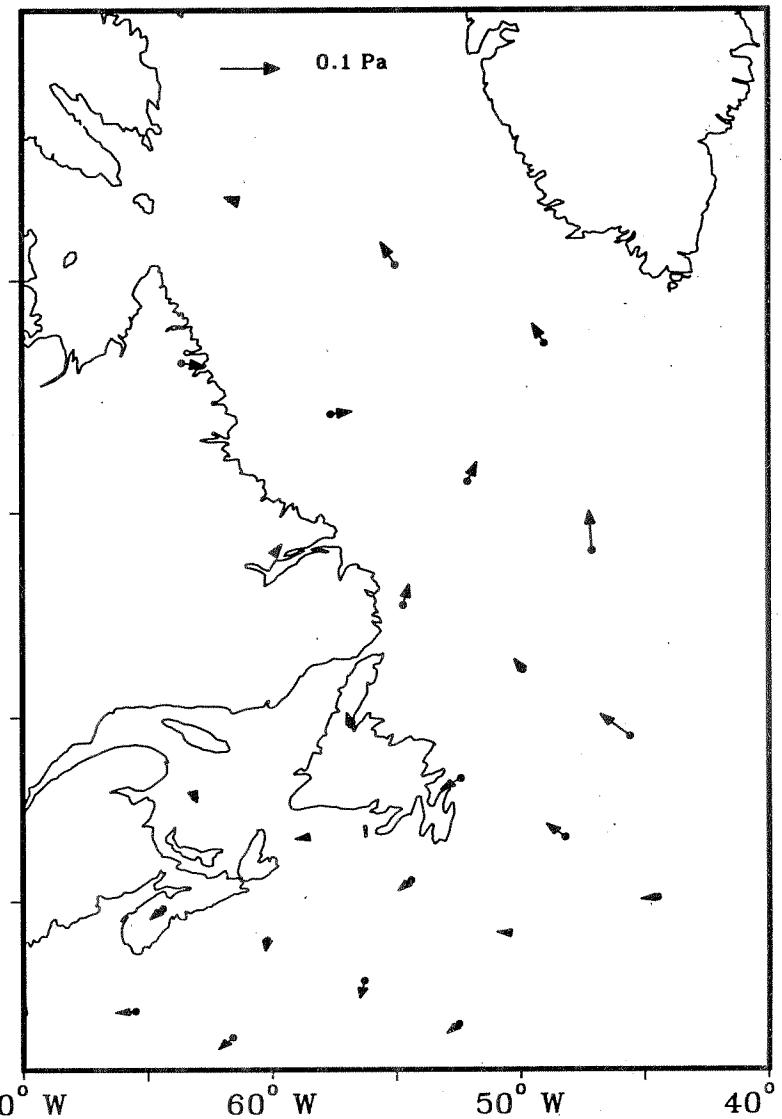
50° W

40° W

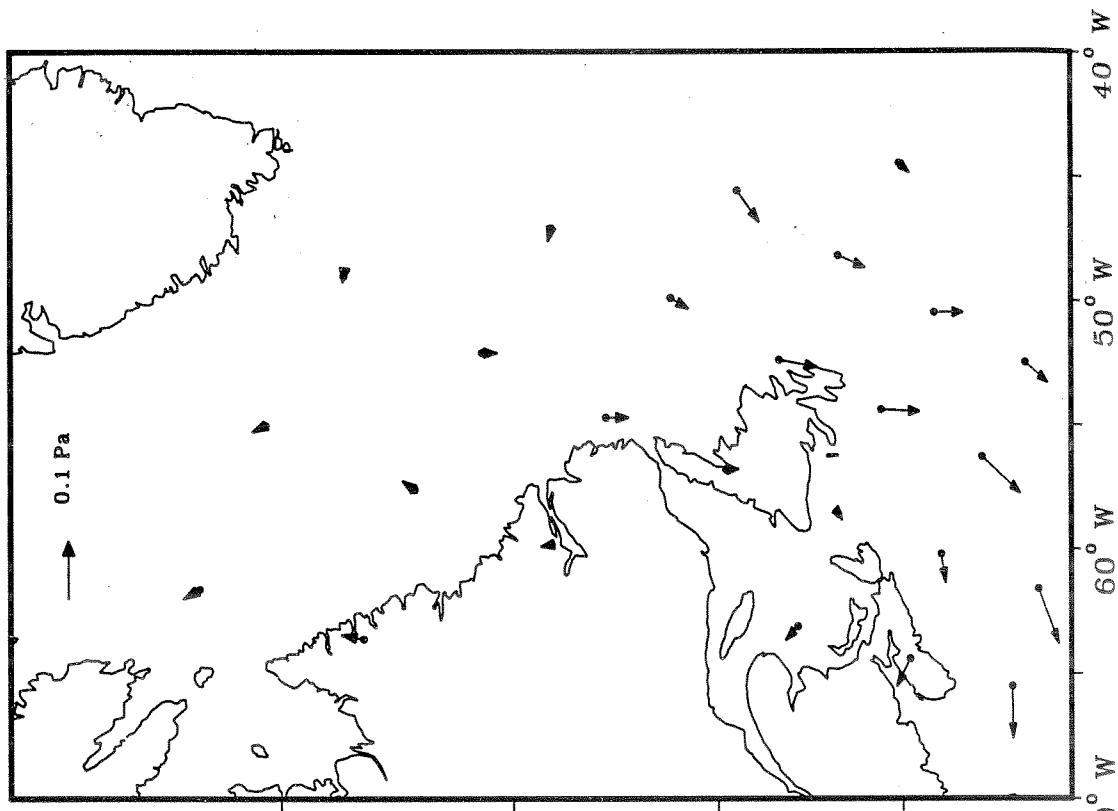
Summer 1972



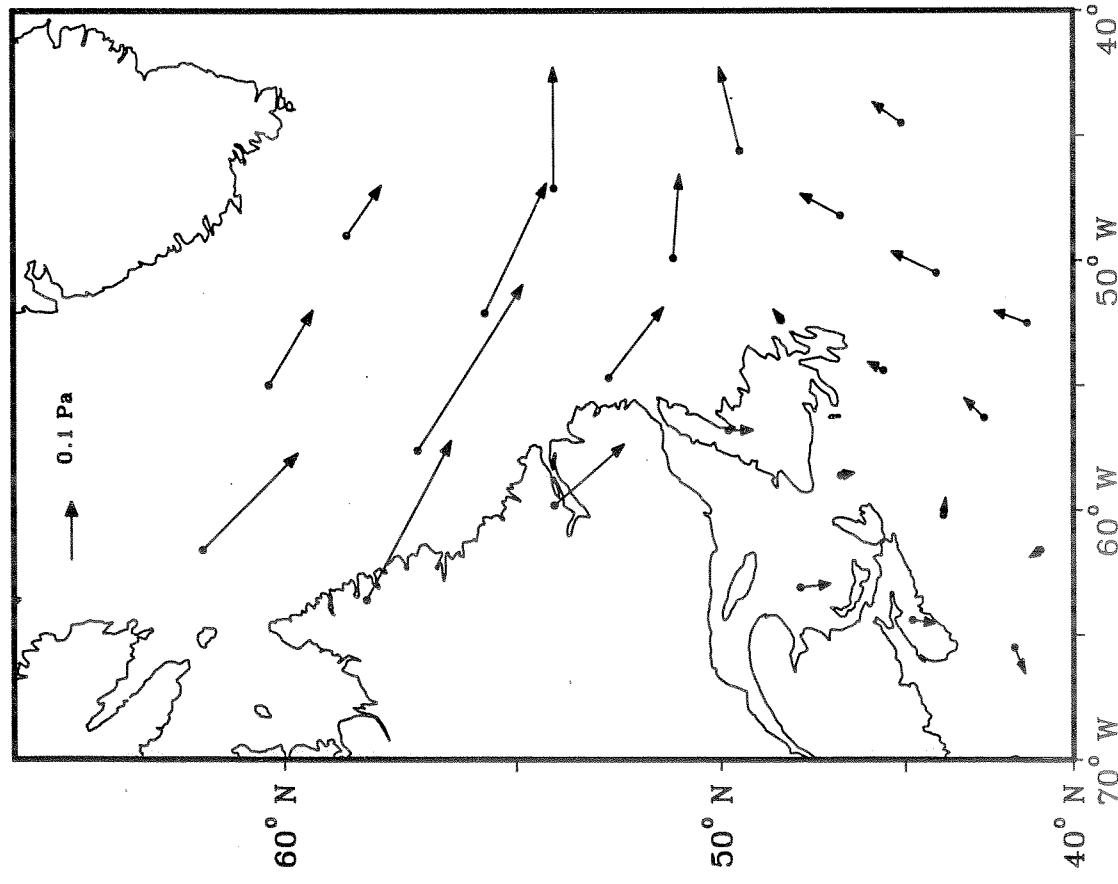
Fall 1972



Spring 1973

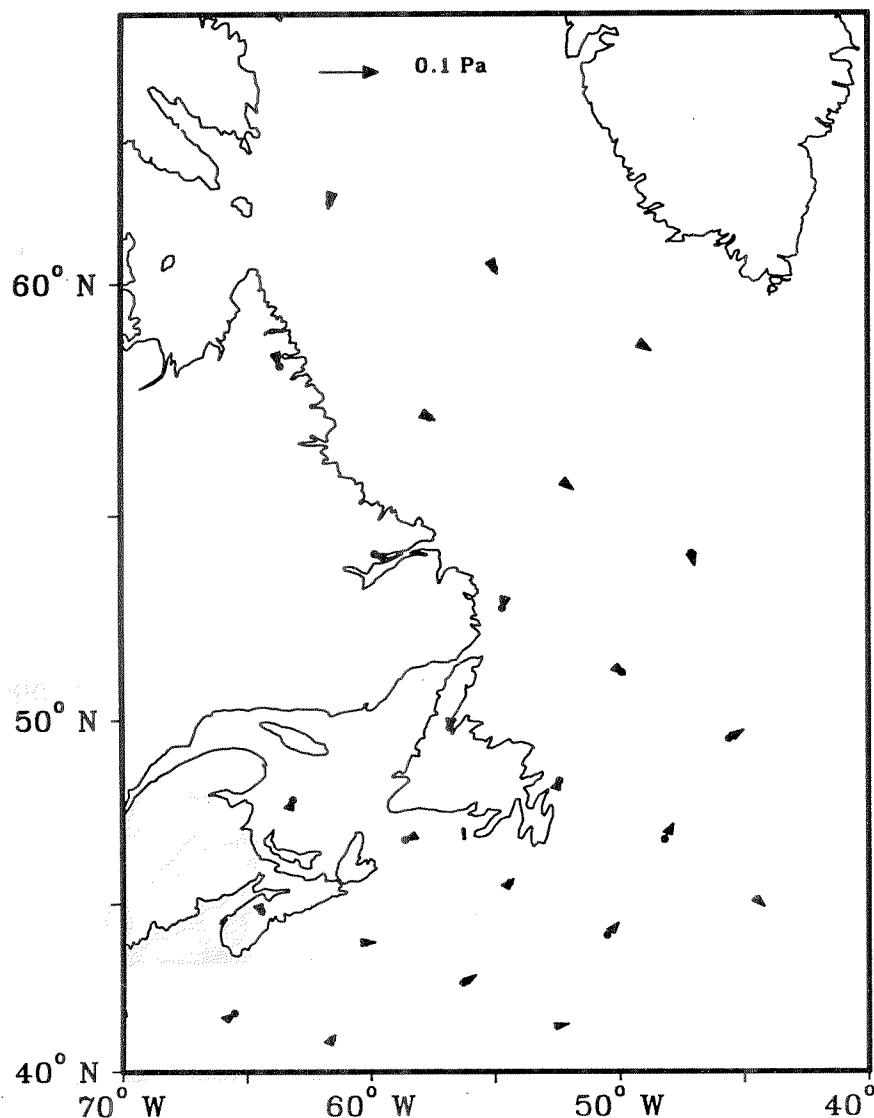


Winter 1973

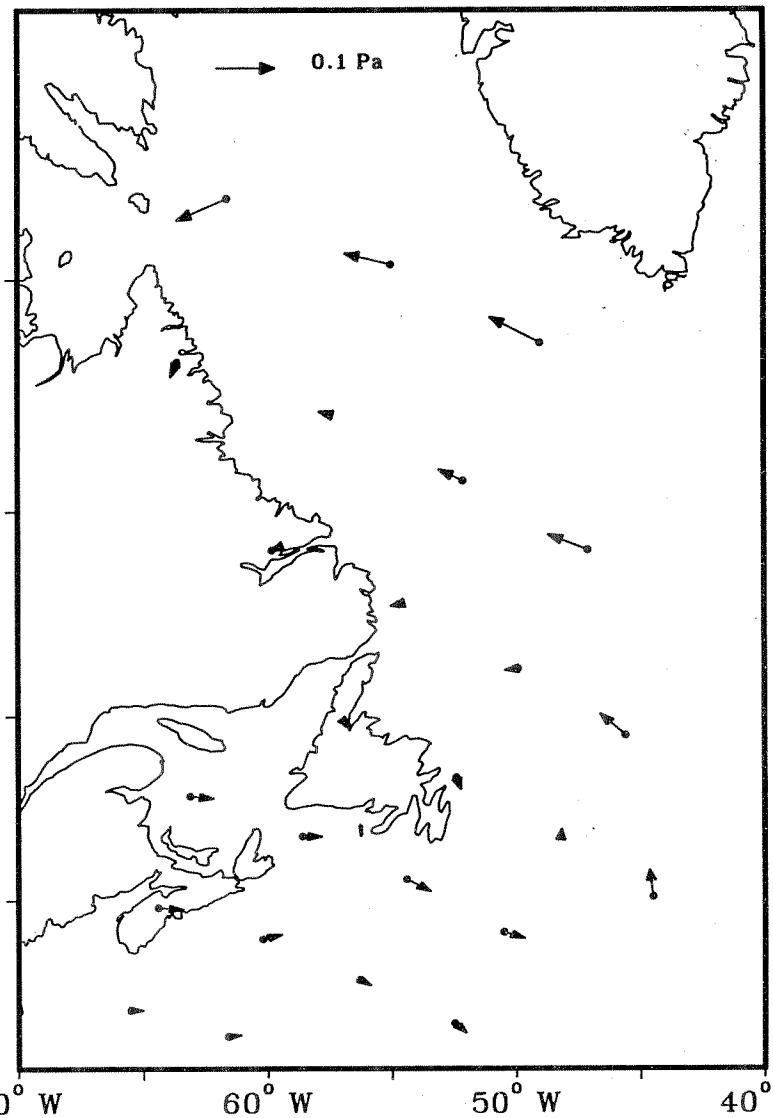


70° W 60° W 50° W 40° W 70° W 60° W 50° W 40° W

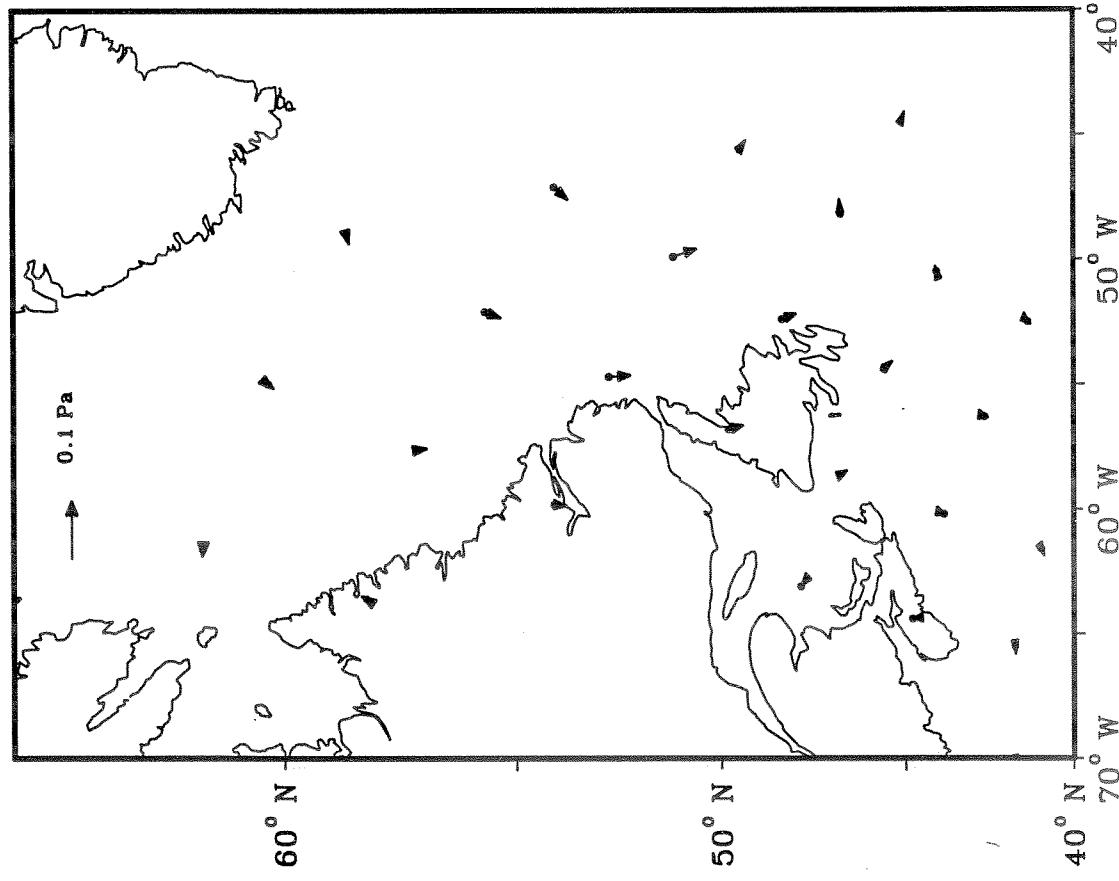
Summer 1973



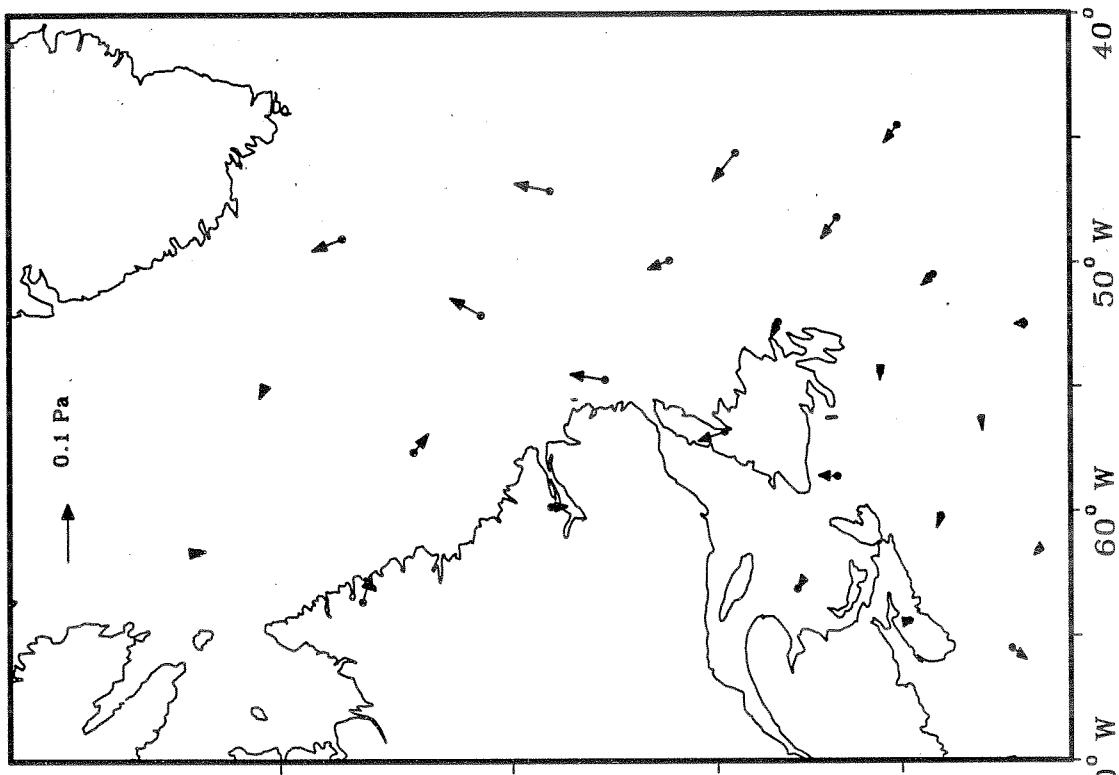
Fall 1973



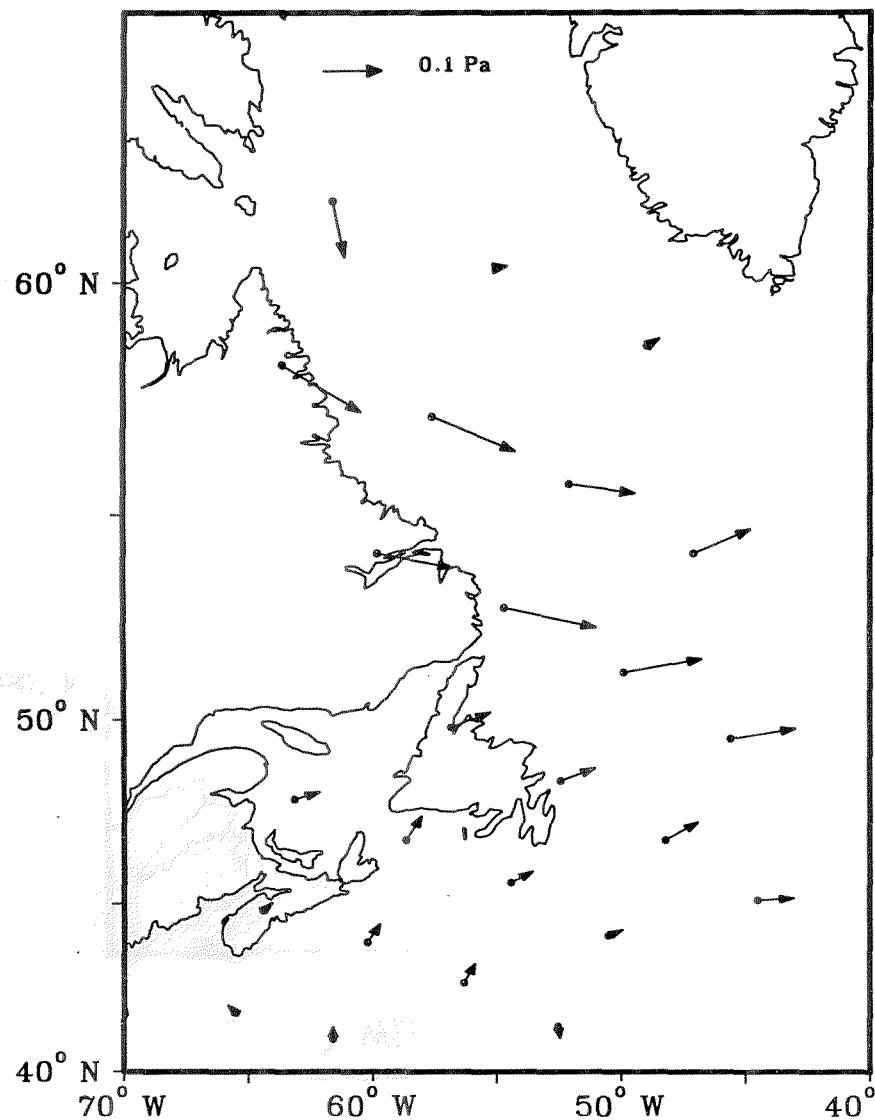
Summer 1974



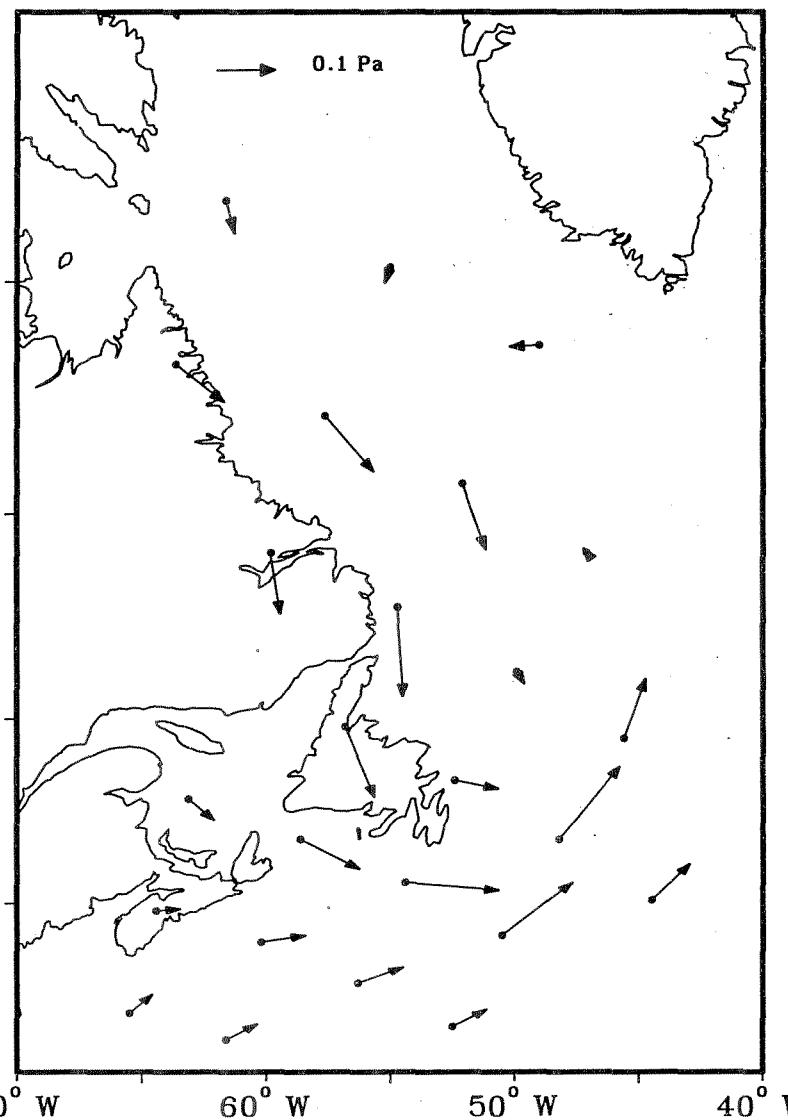
Fall 1974



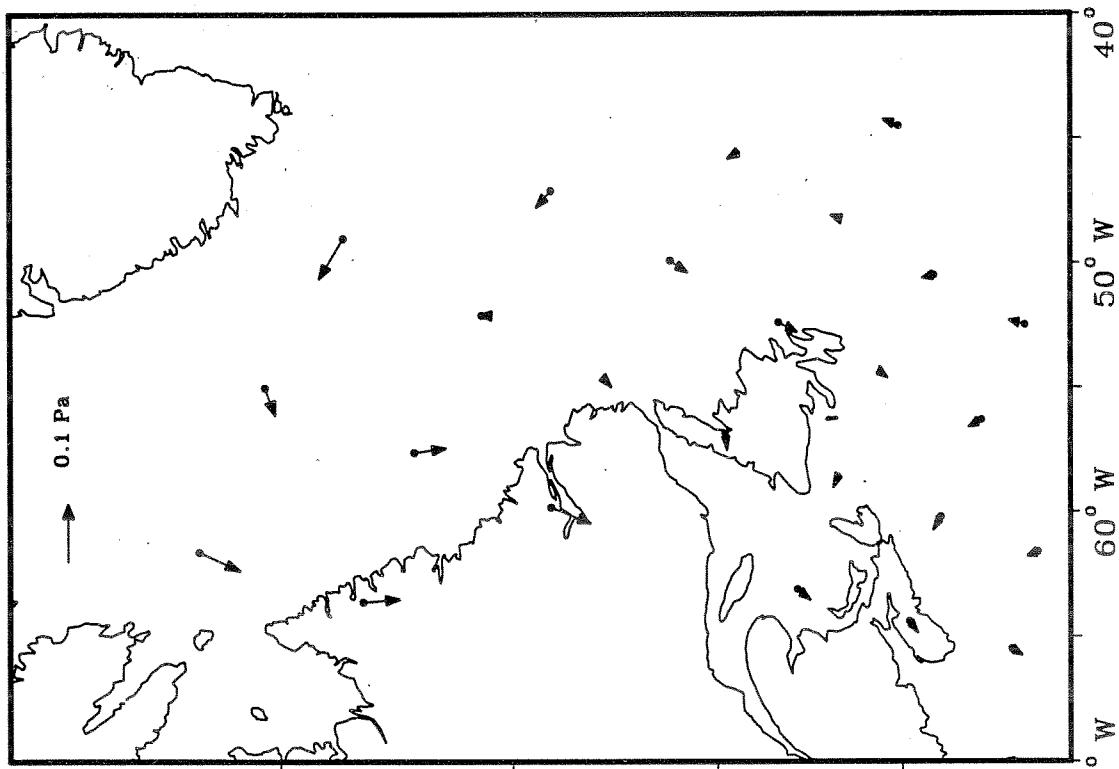
Winter 1974



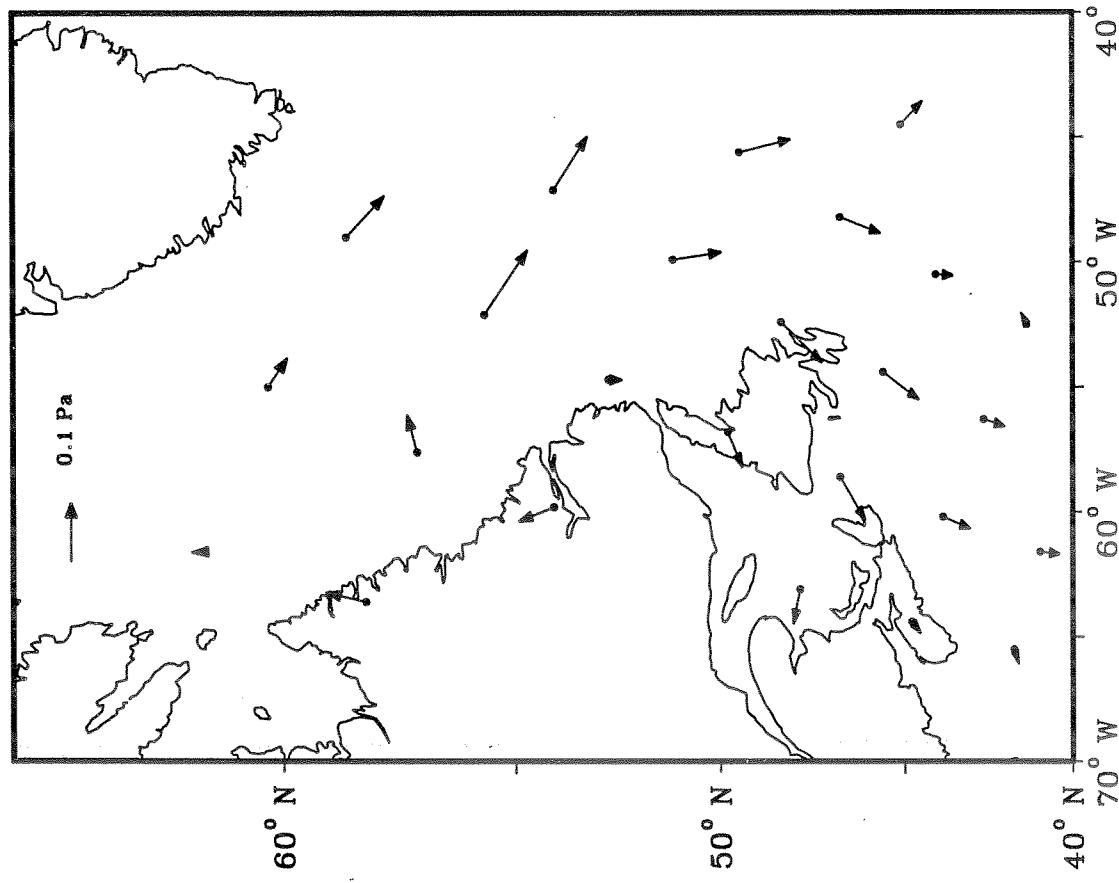
Spring 1974



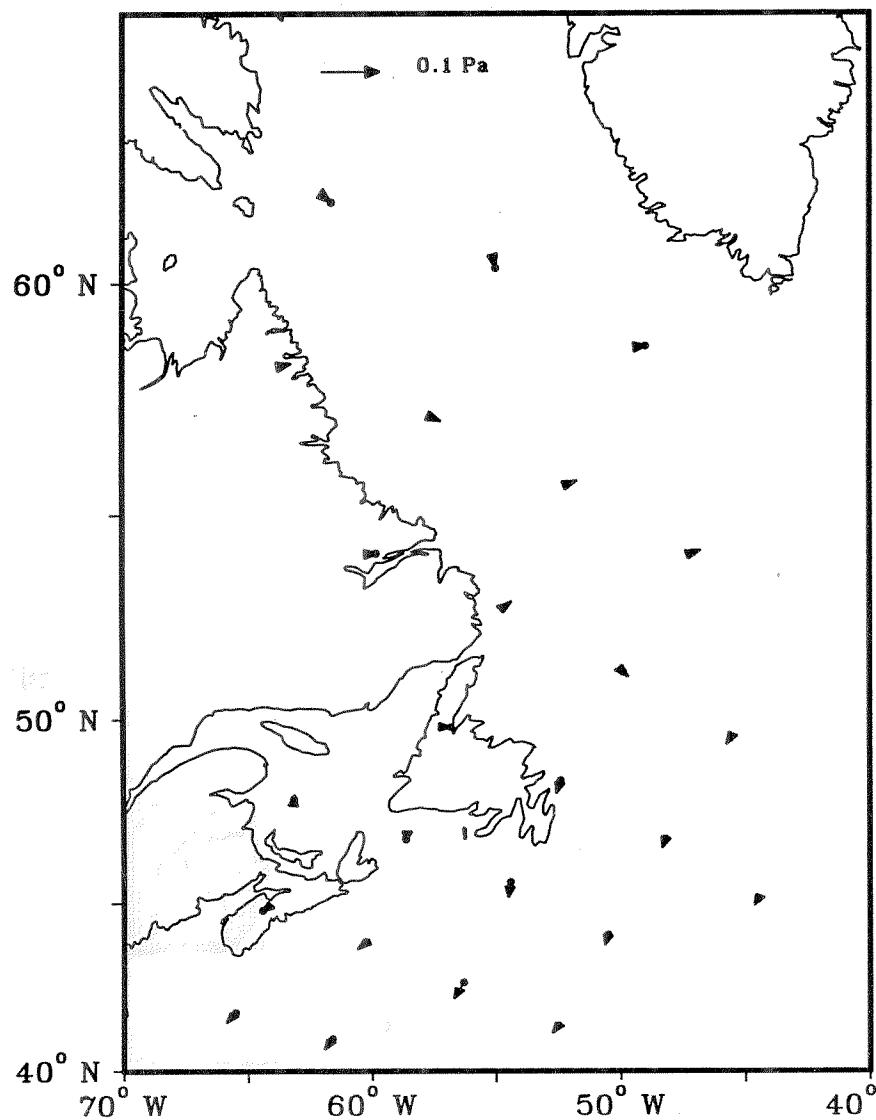
Spring 1975



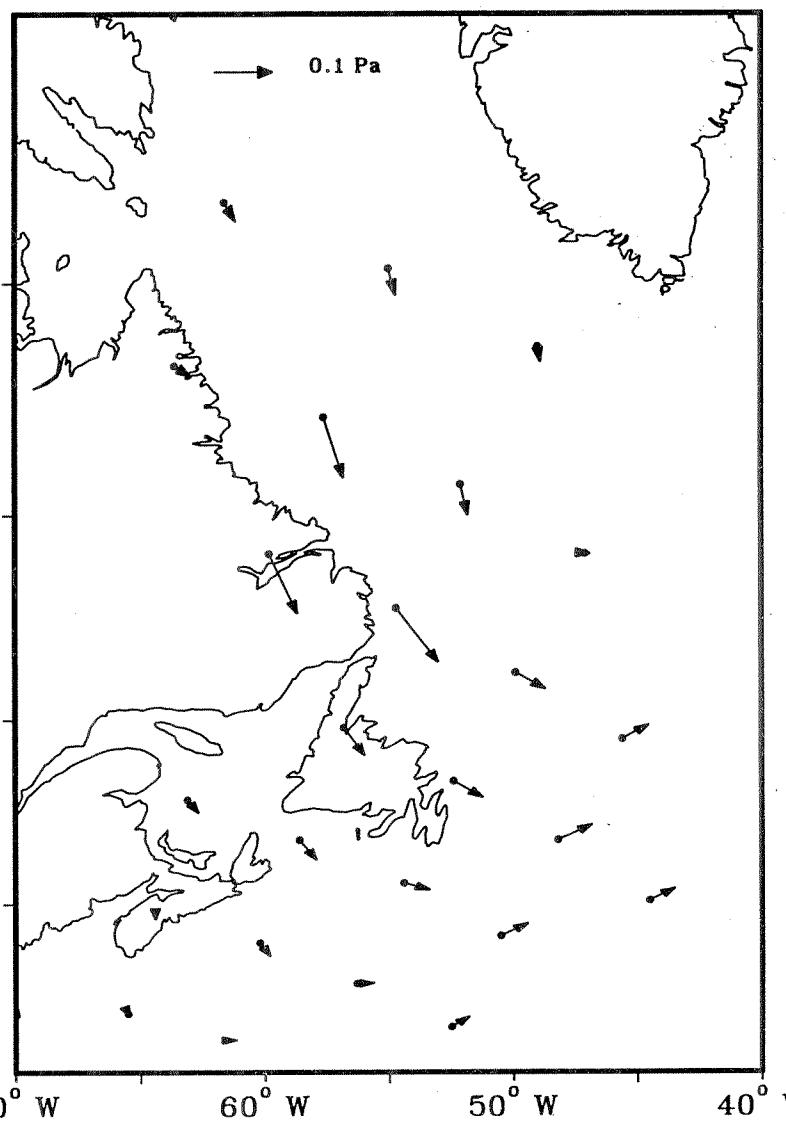
Winter 1975



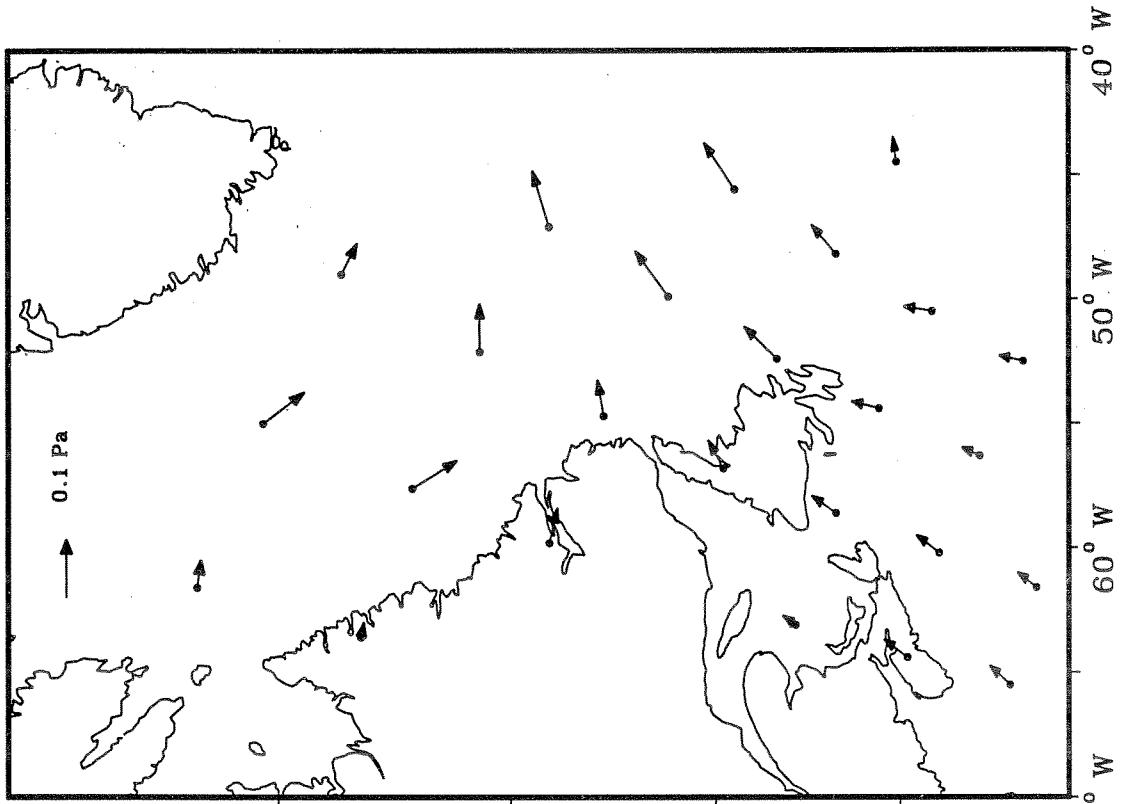
Summer 1975



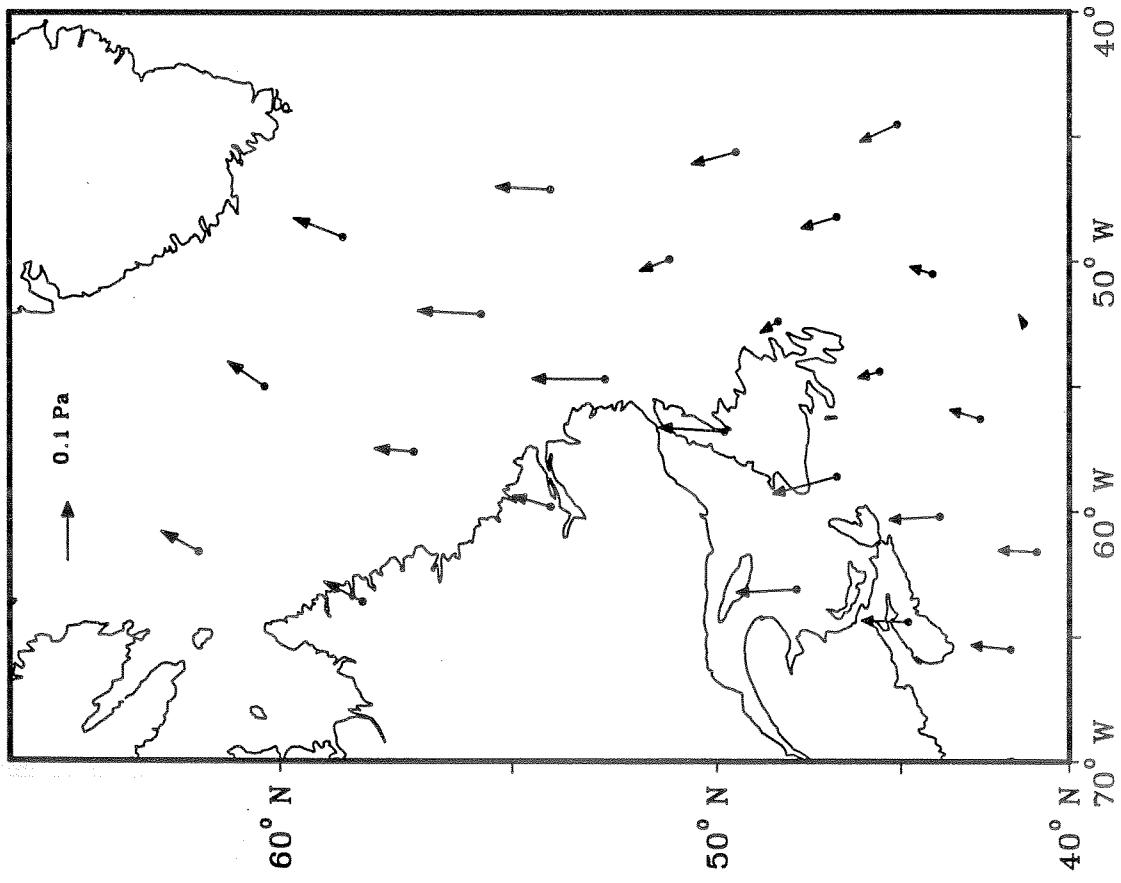
Fall 1975



Spring 1976



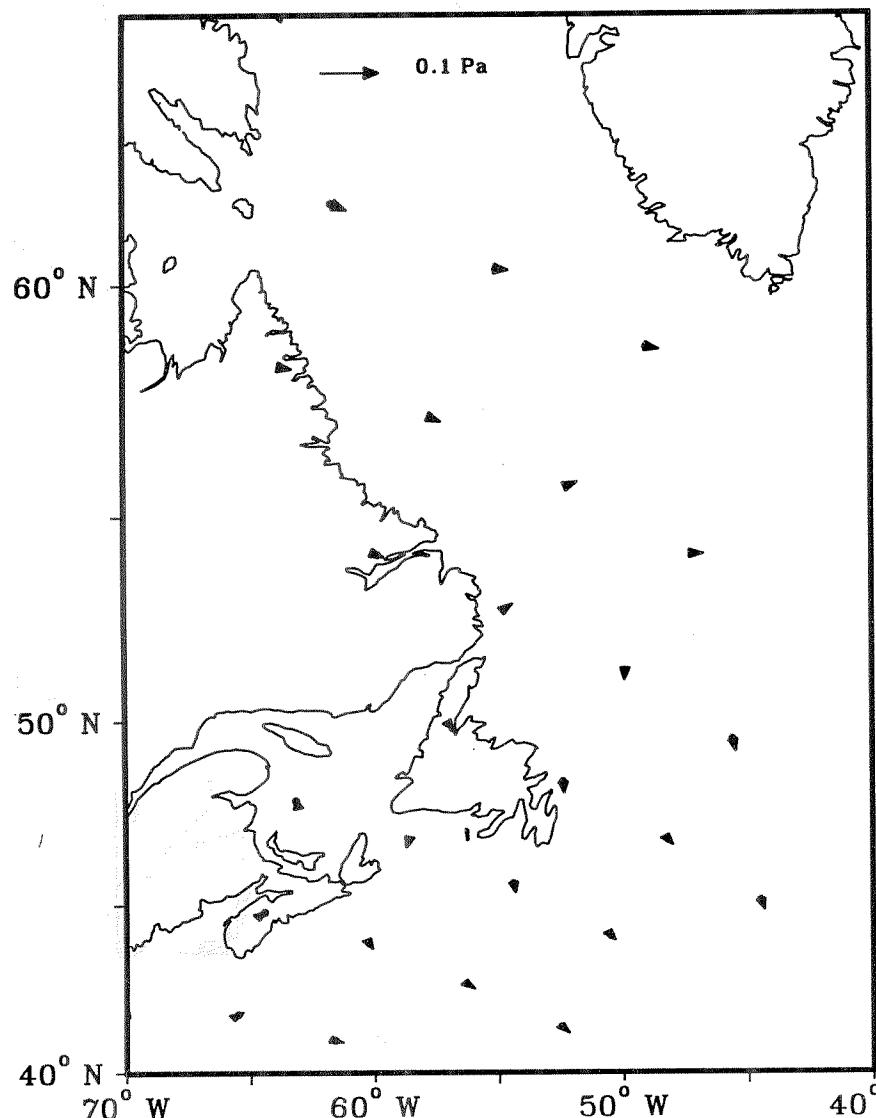
Winter 1976



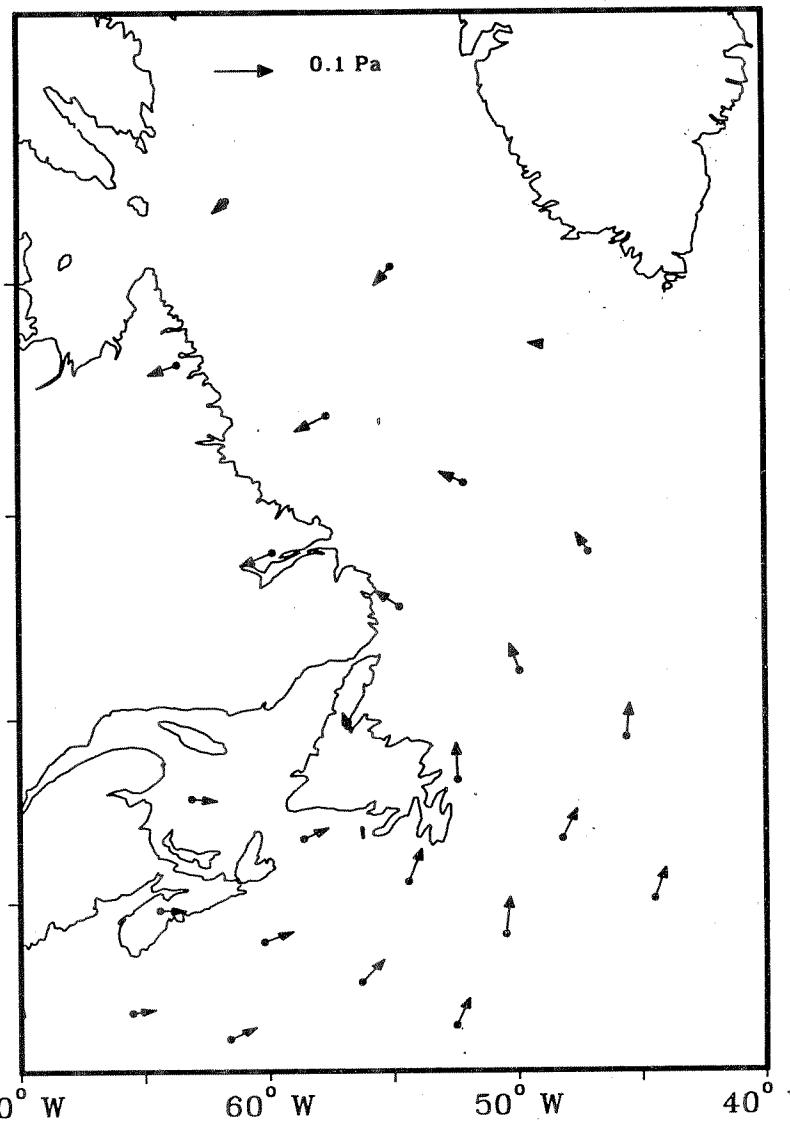
70° W 60° W 50° W 40° W 70° W 60° W 50° W

40° W

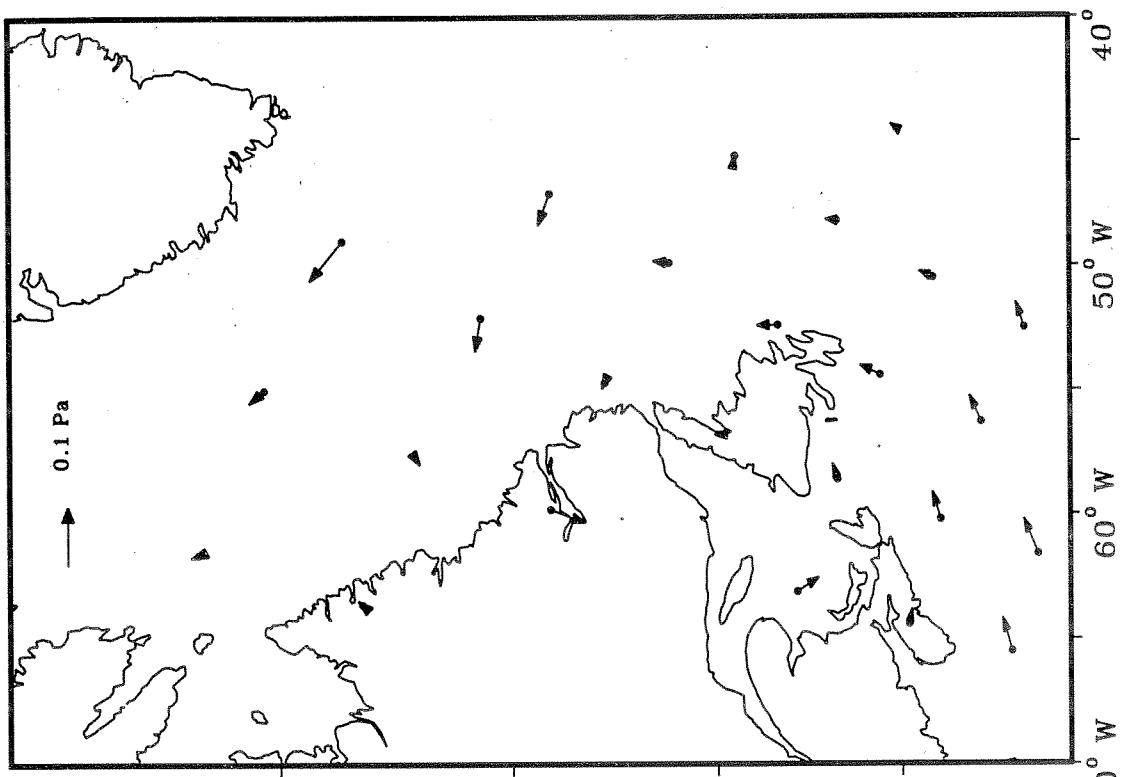
Summer 1976



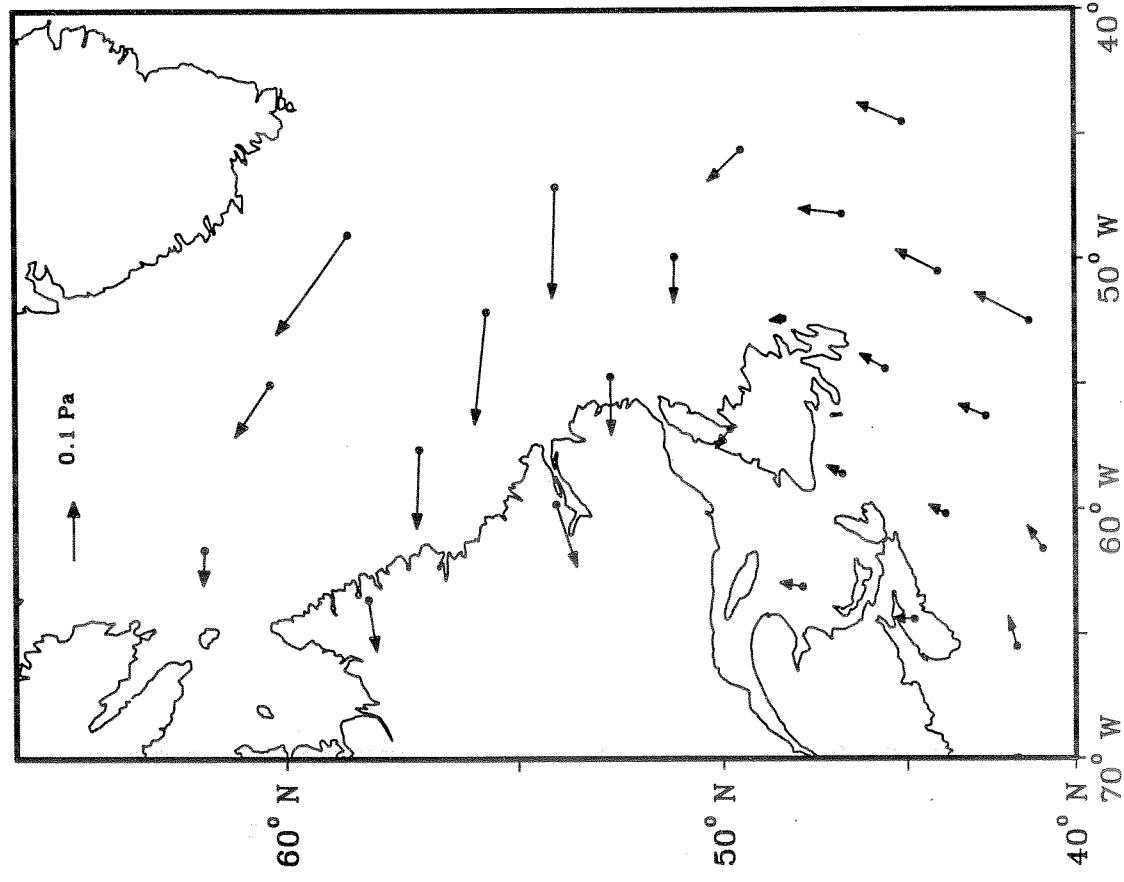
Fall 1976



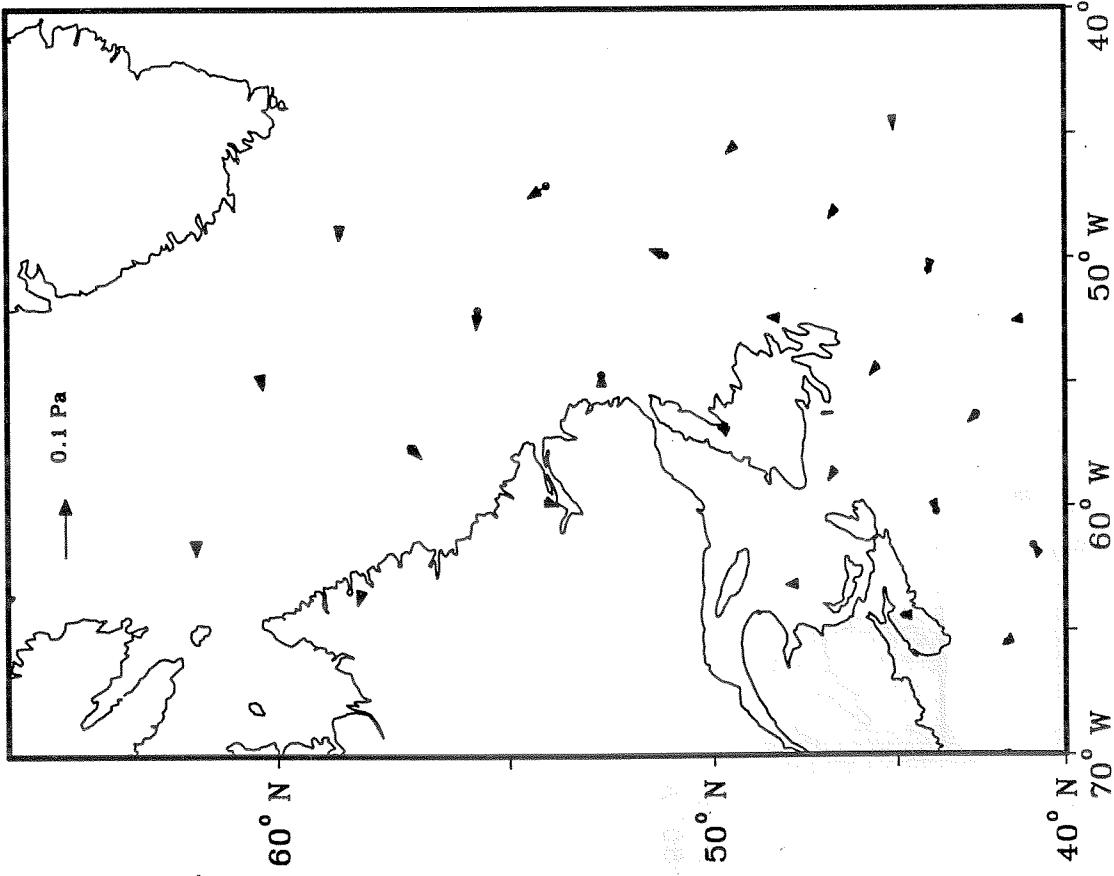
Spring 1977



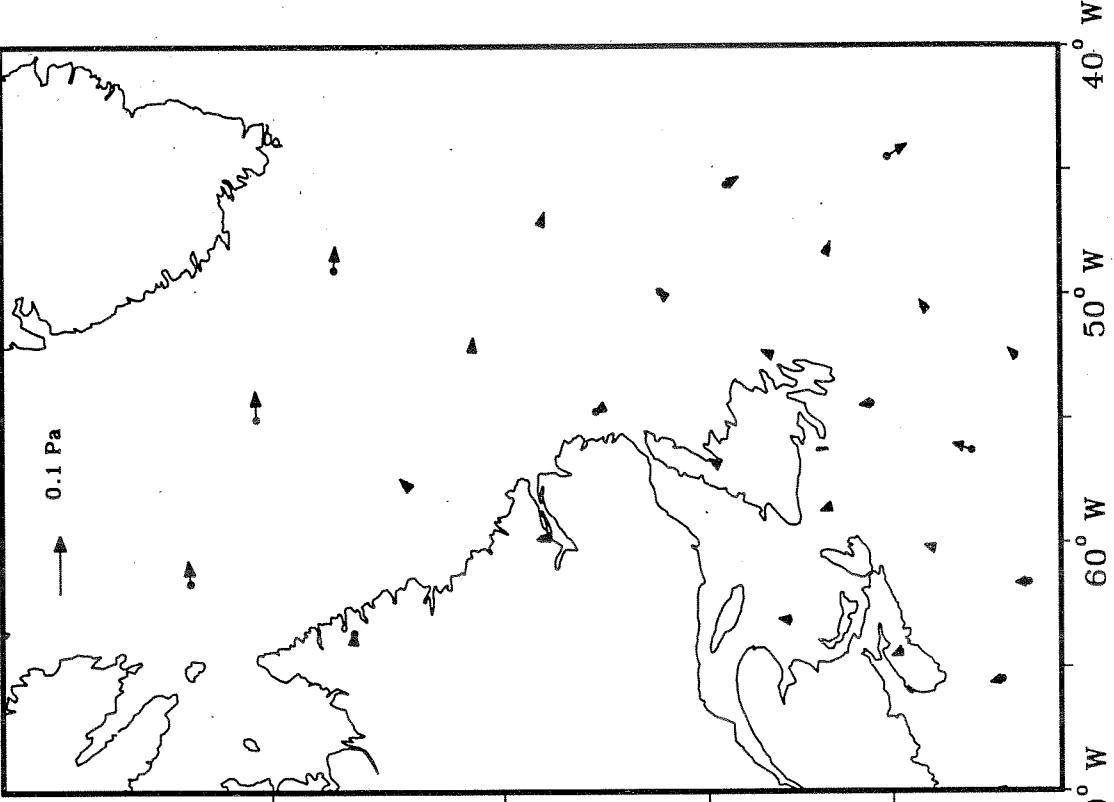
Winter 1977



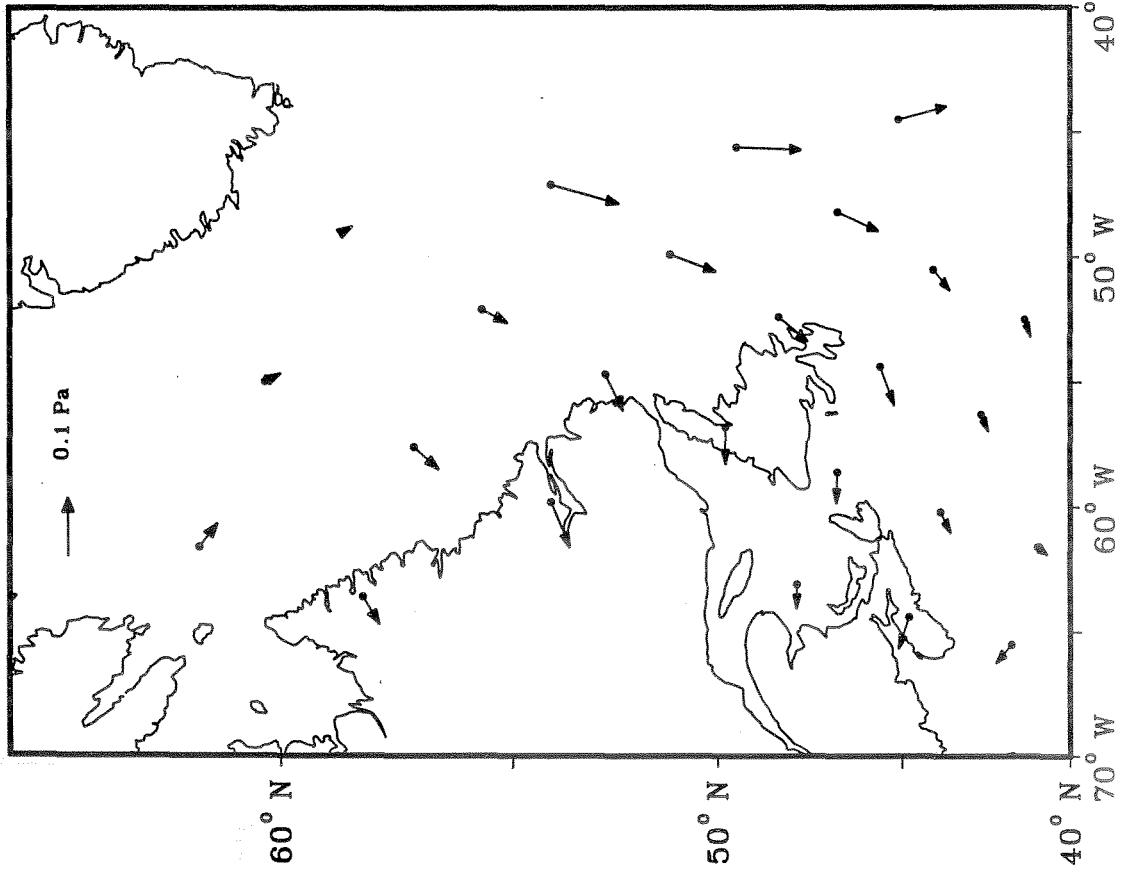
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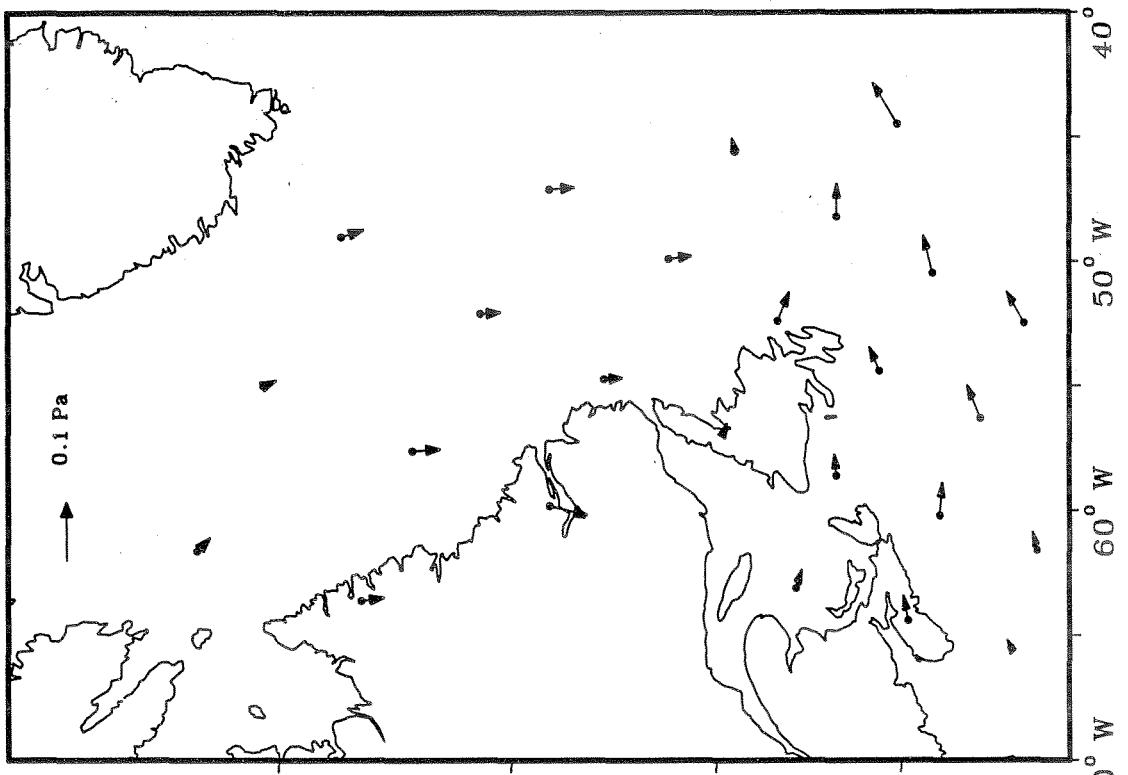
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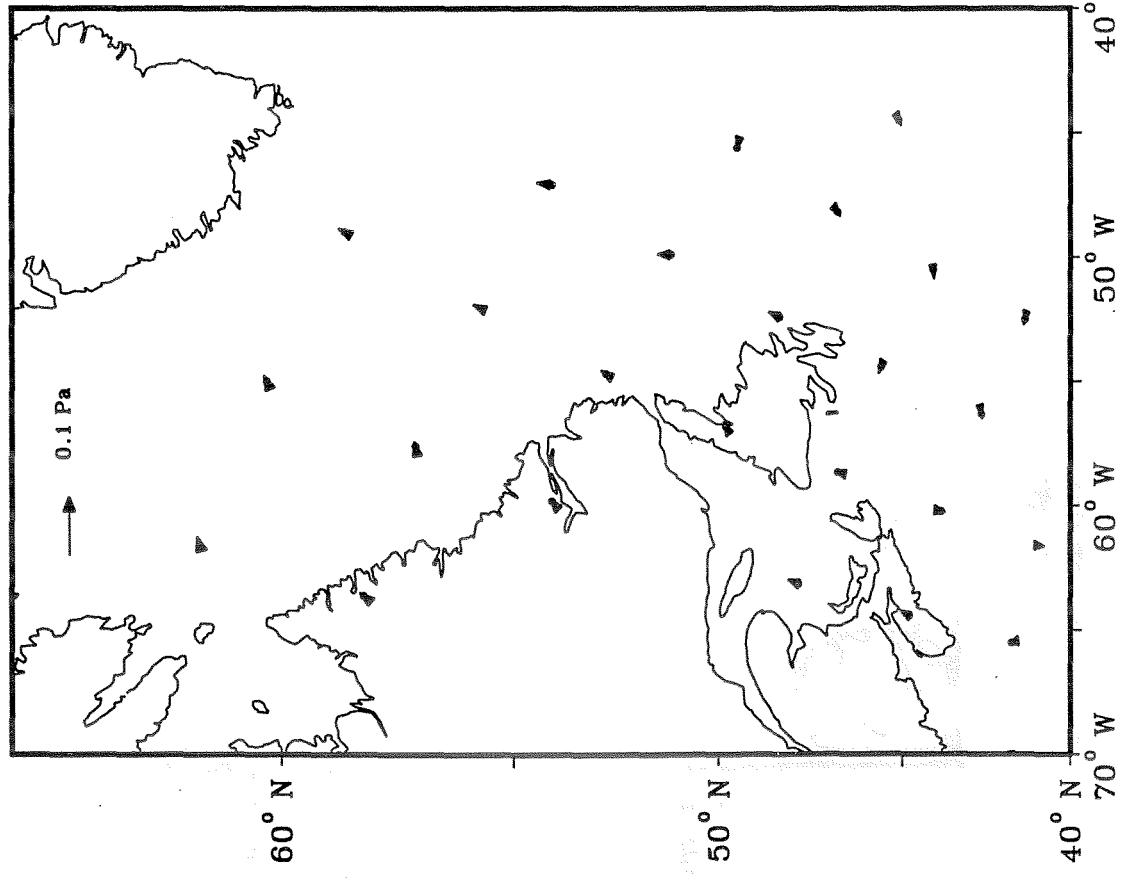
Winter 1978



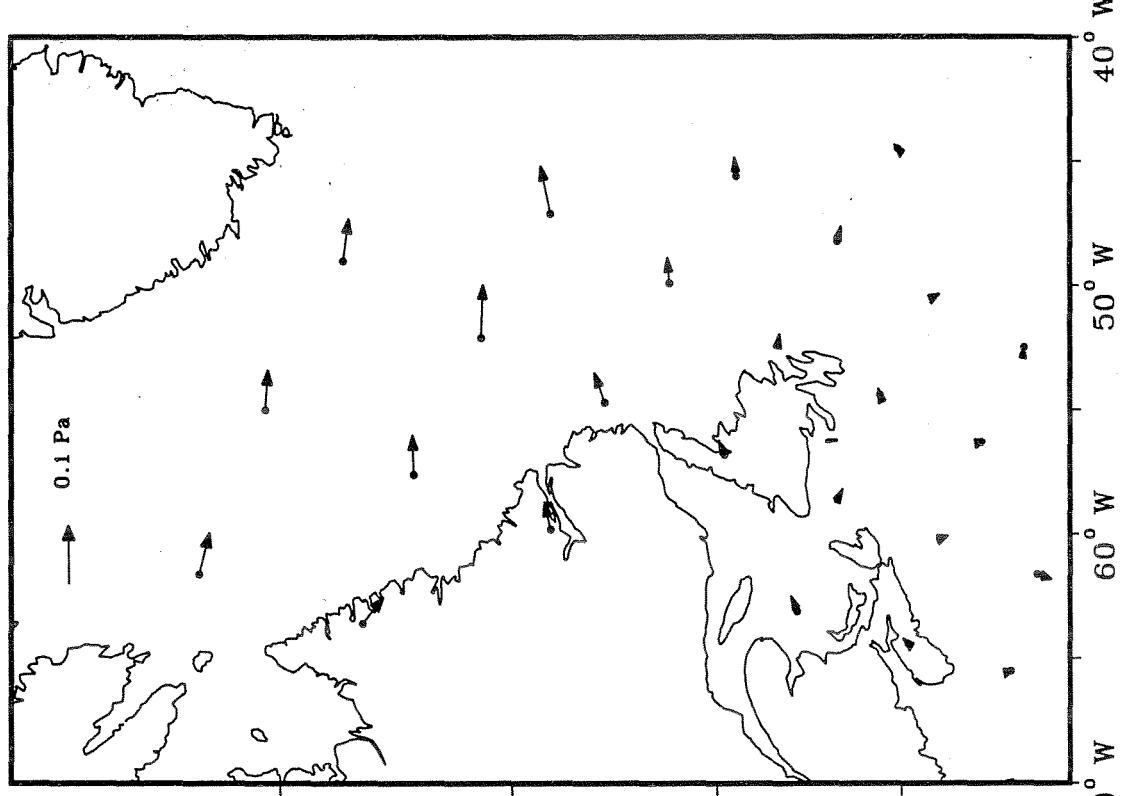
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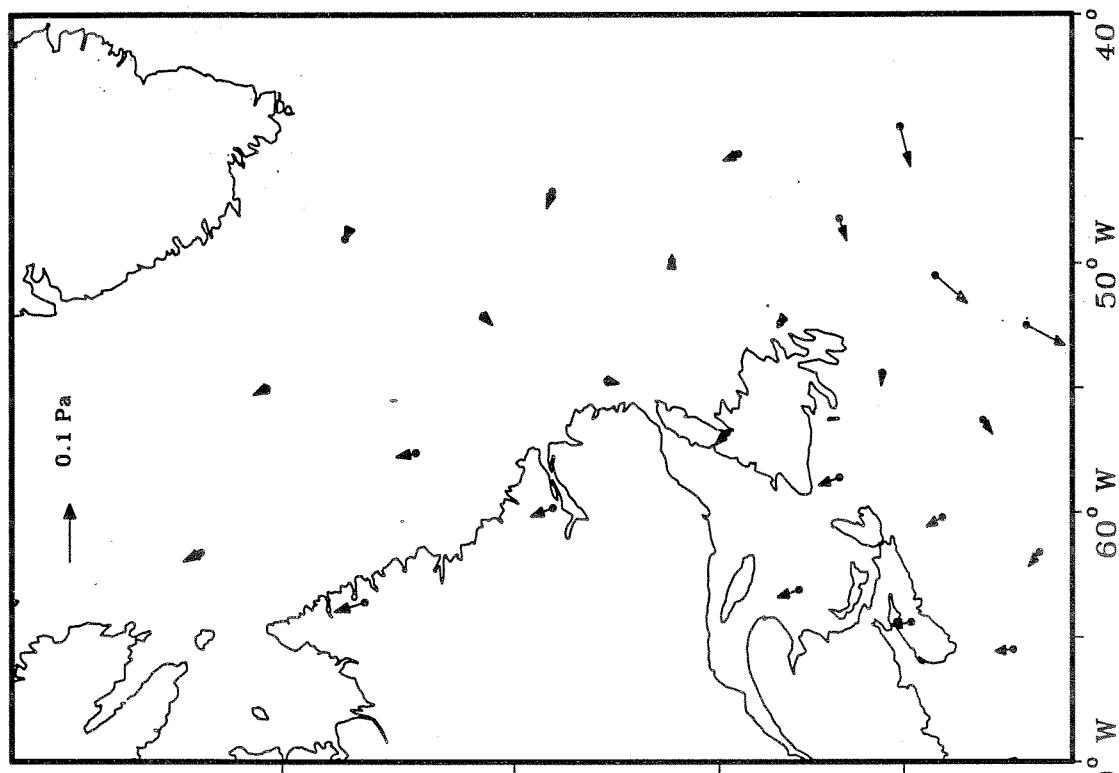
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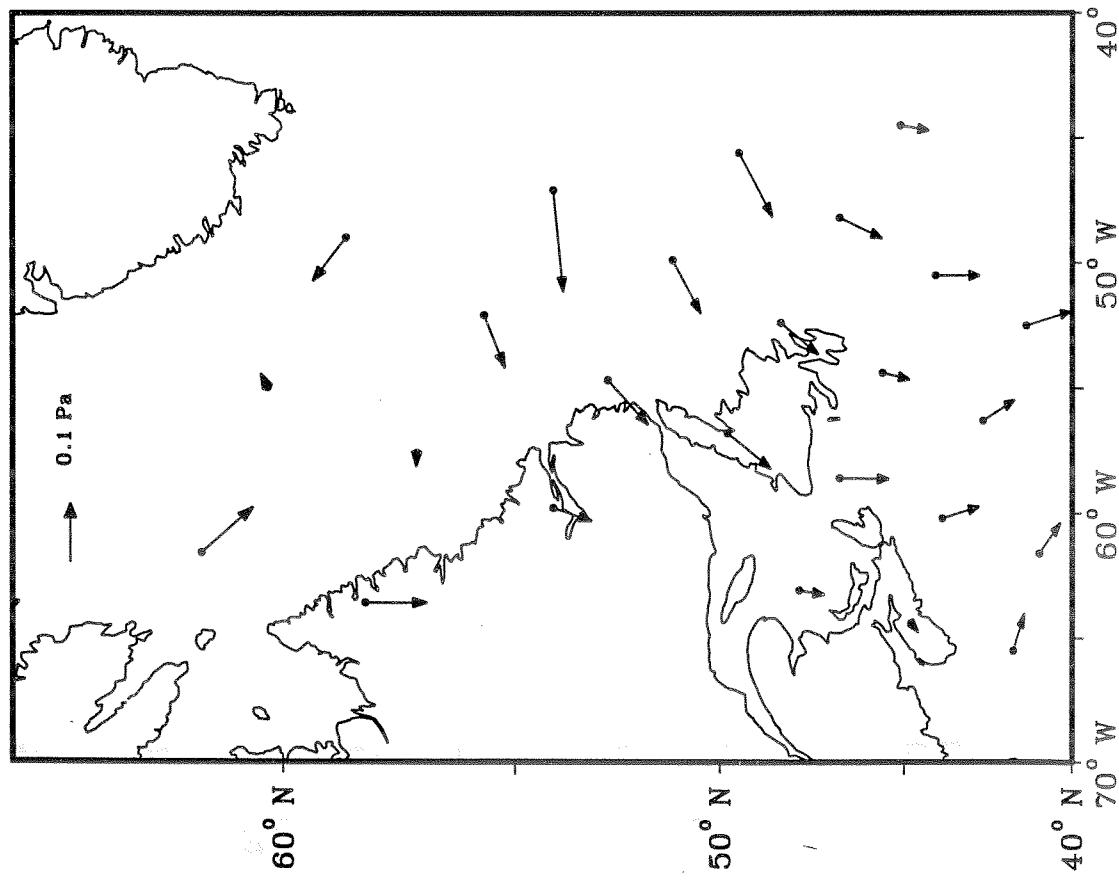
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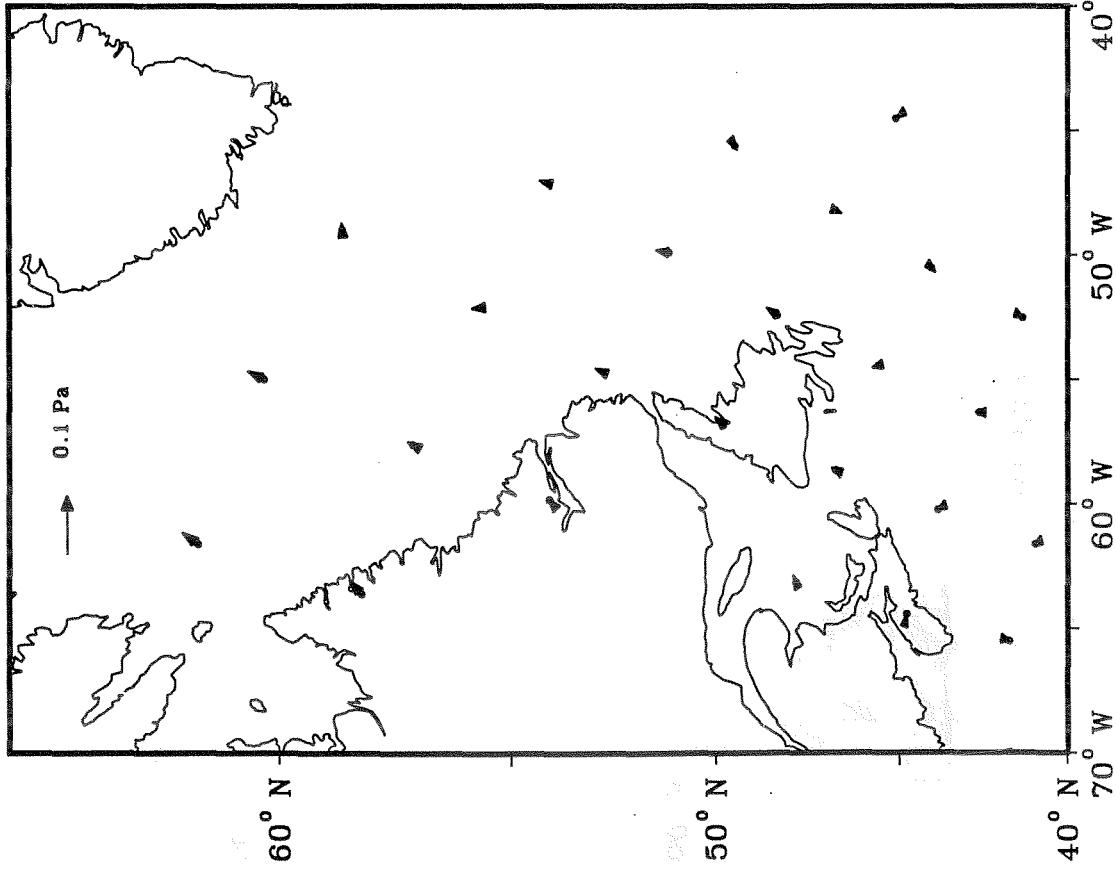
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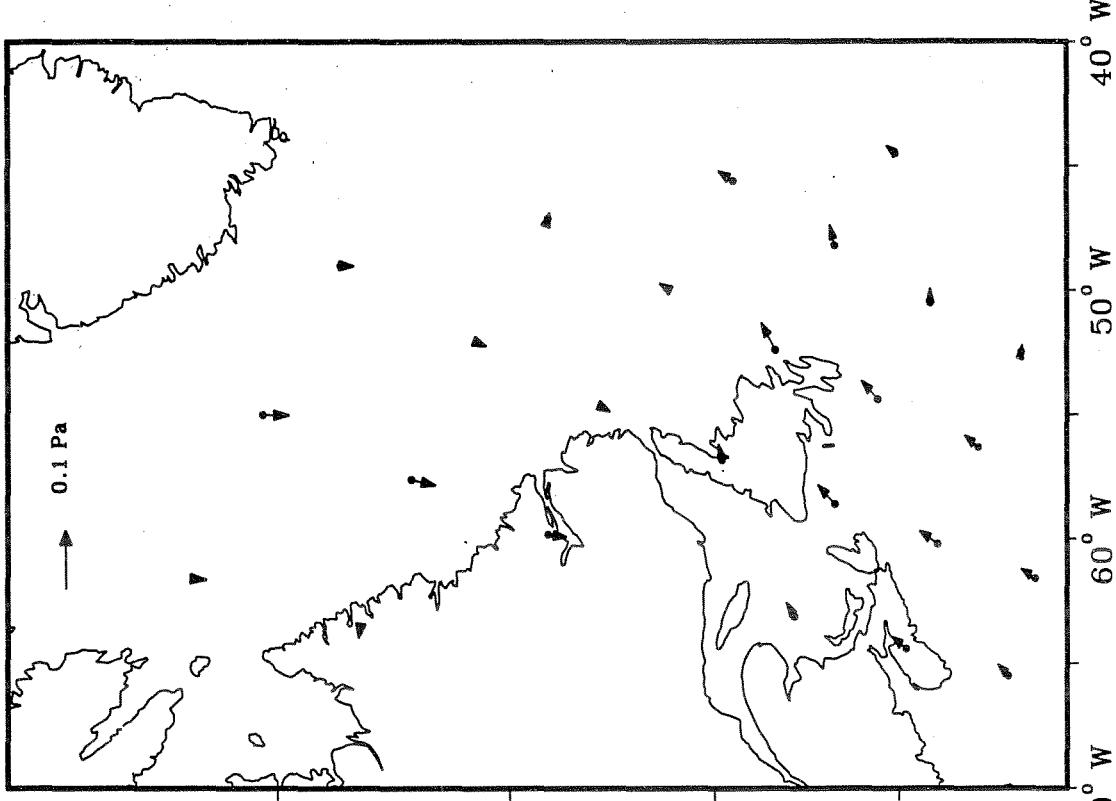
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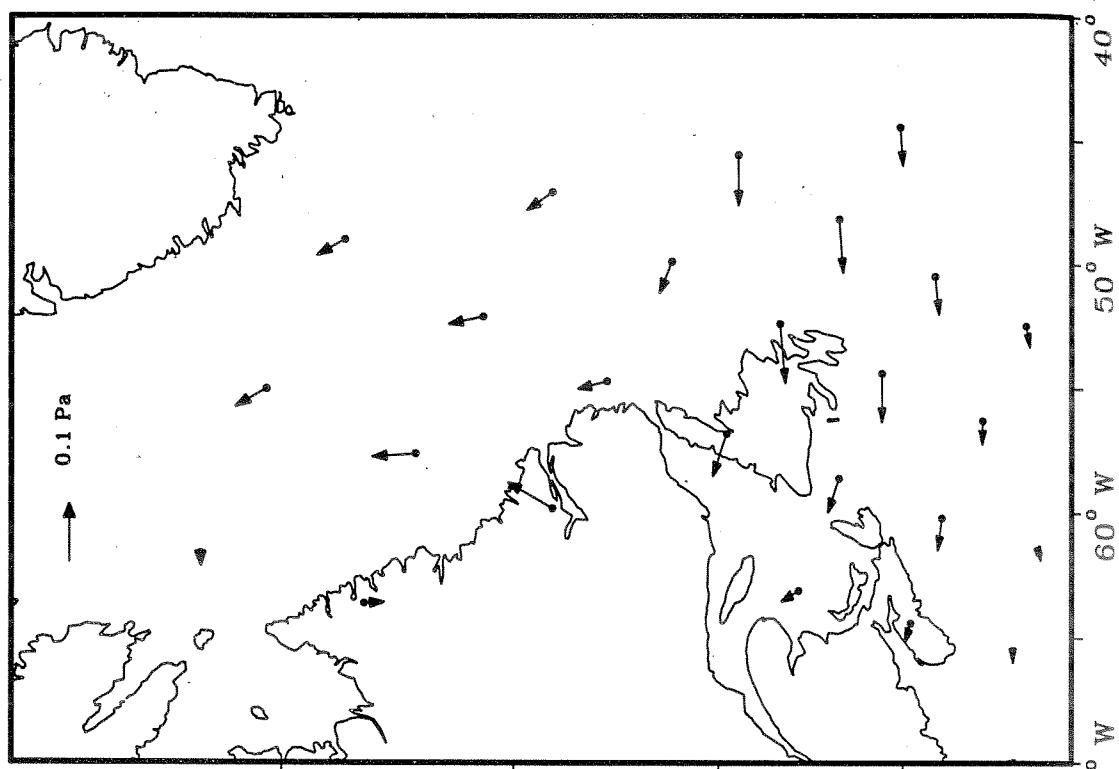
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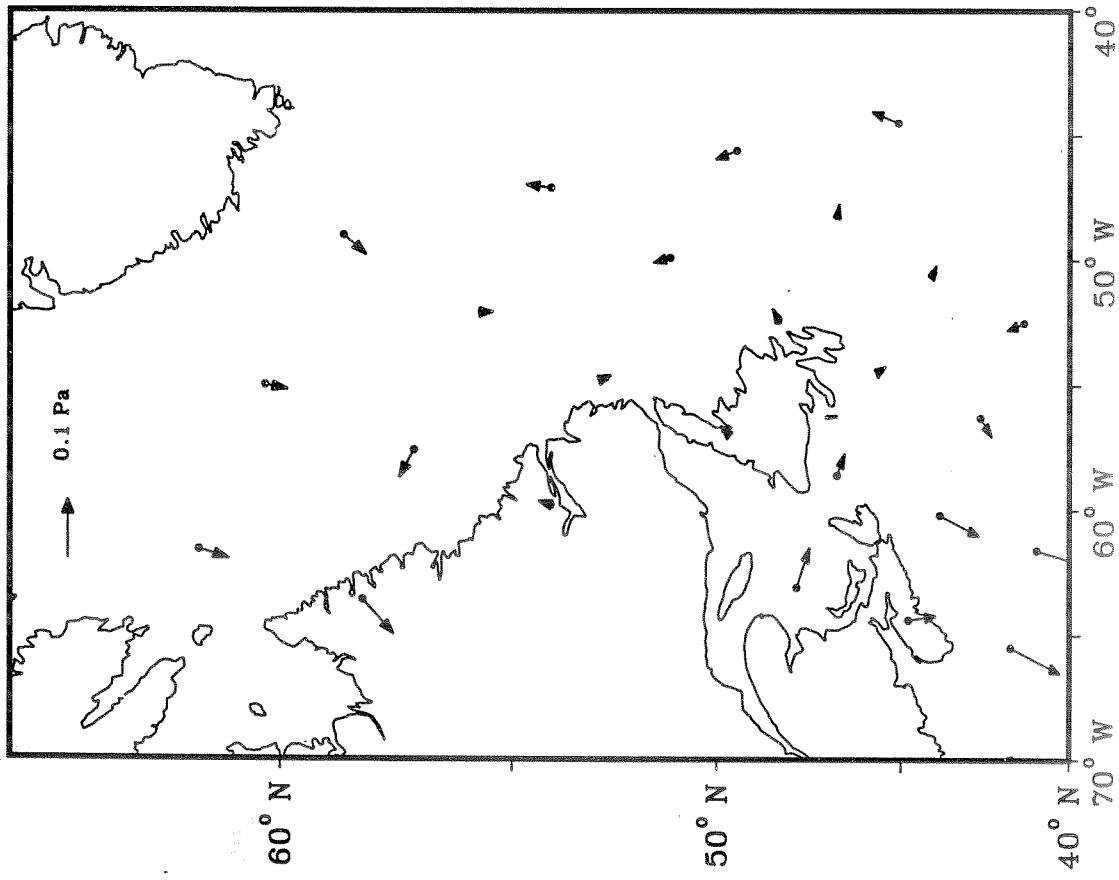
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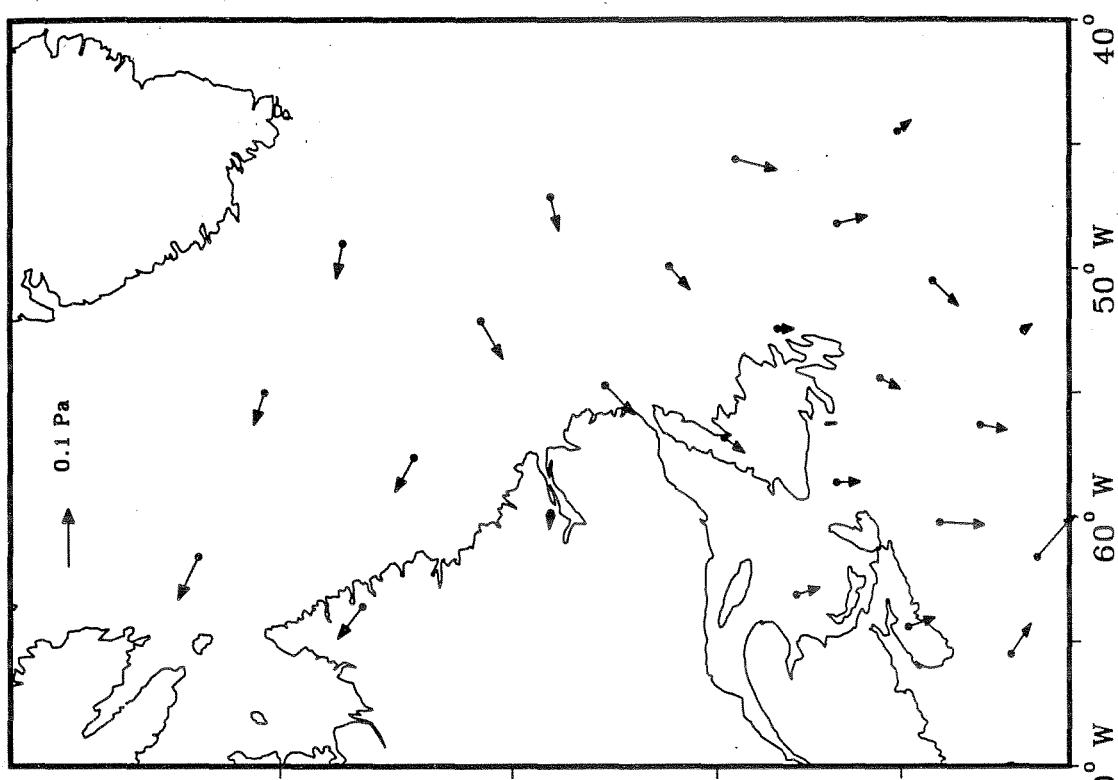
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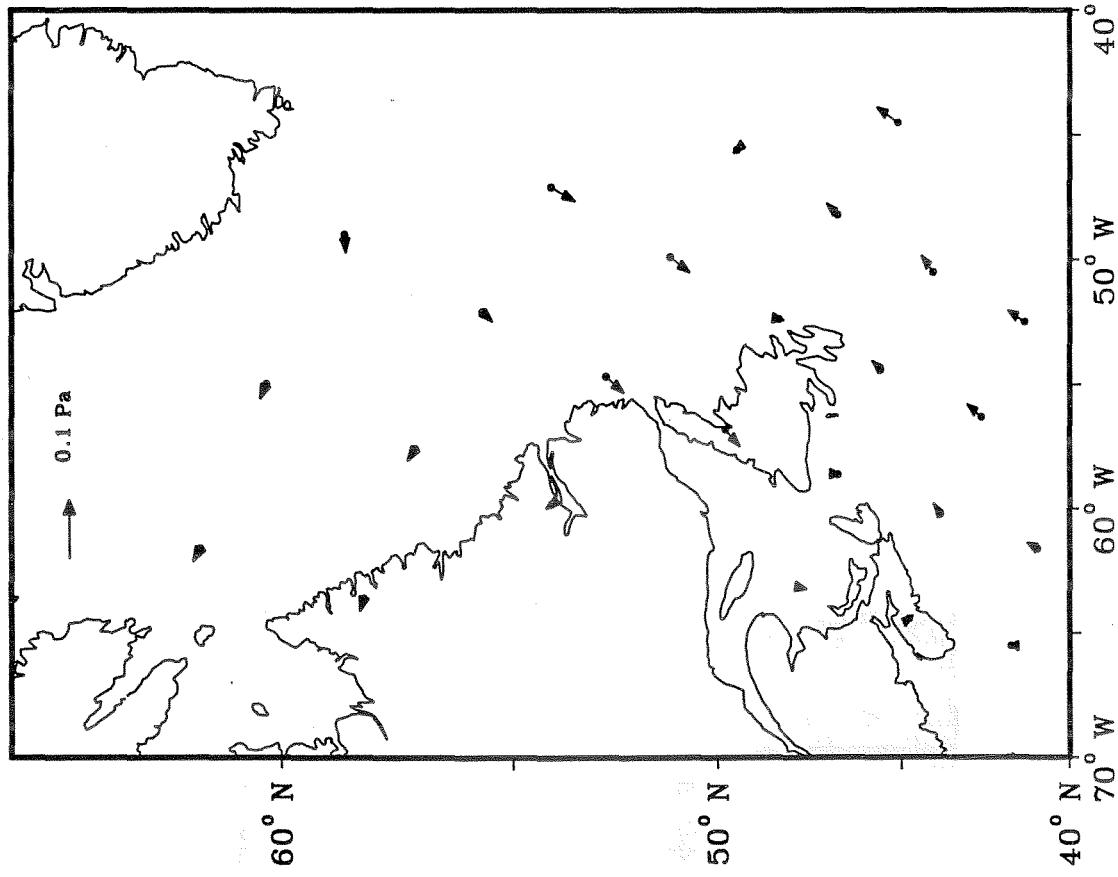
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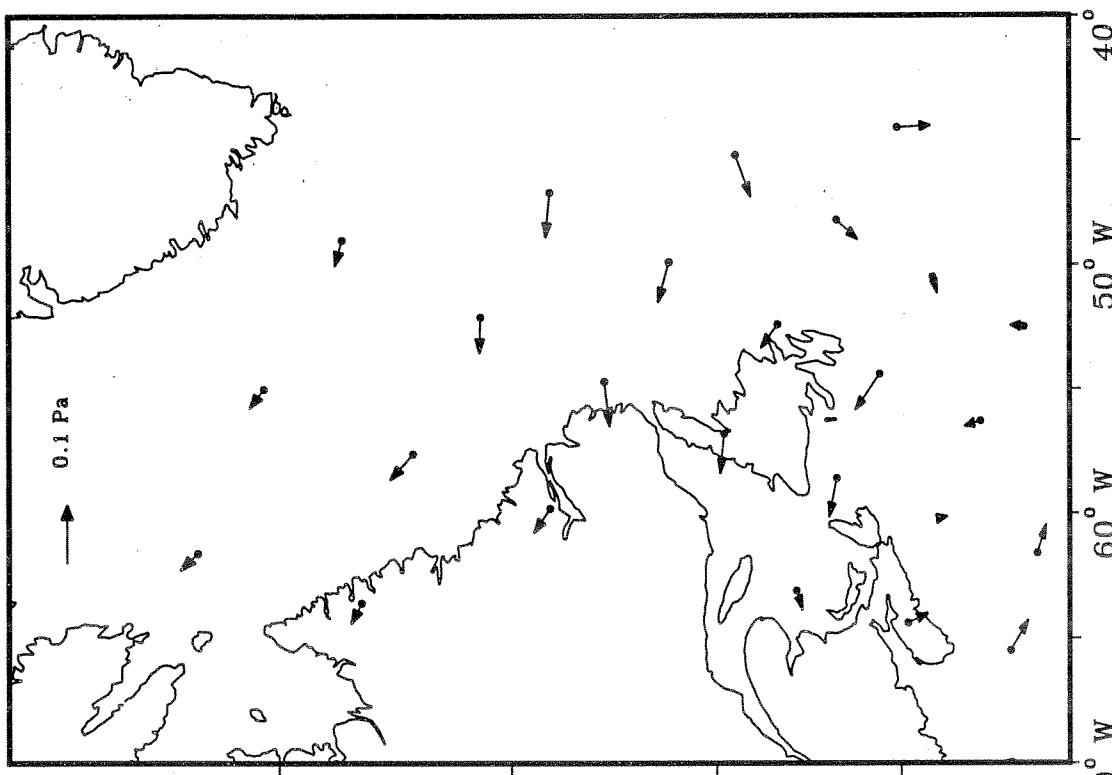
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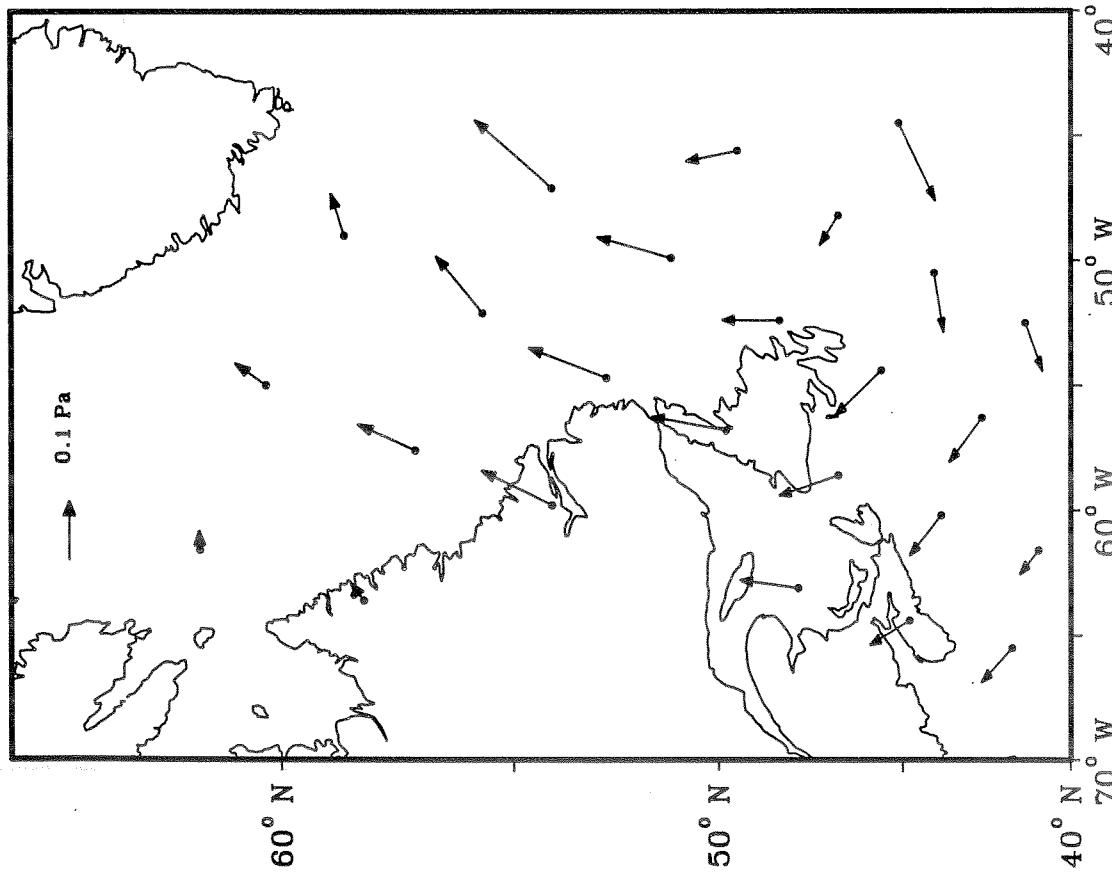
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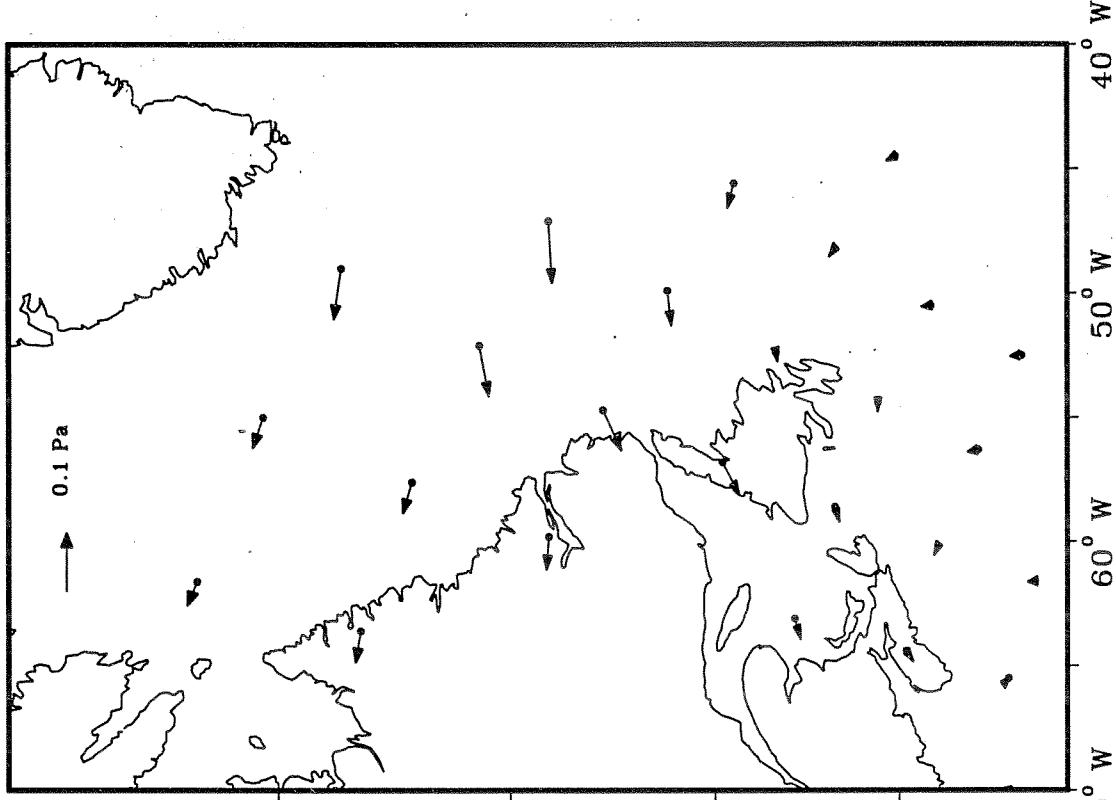
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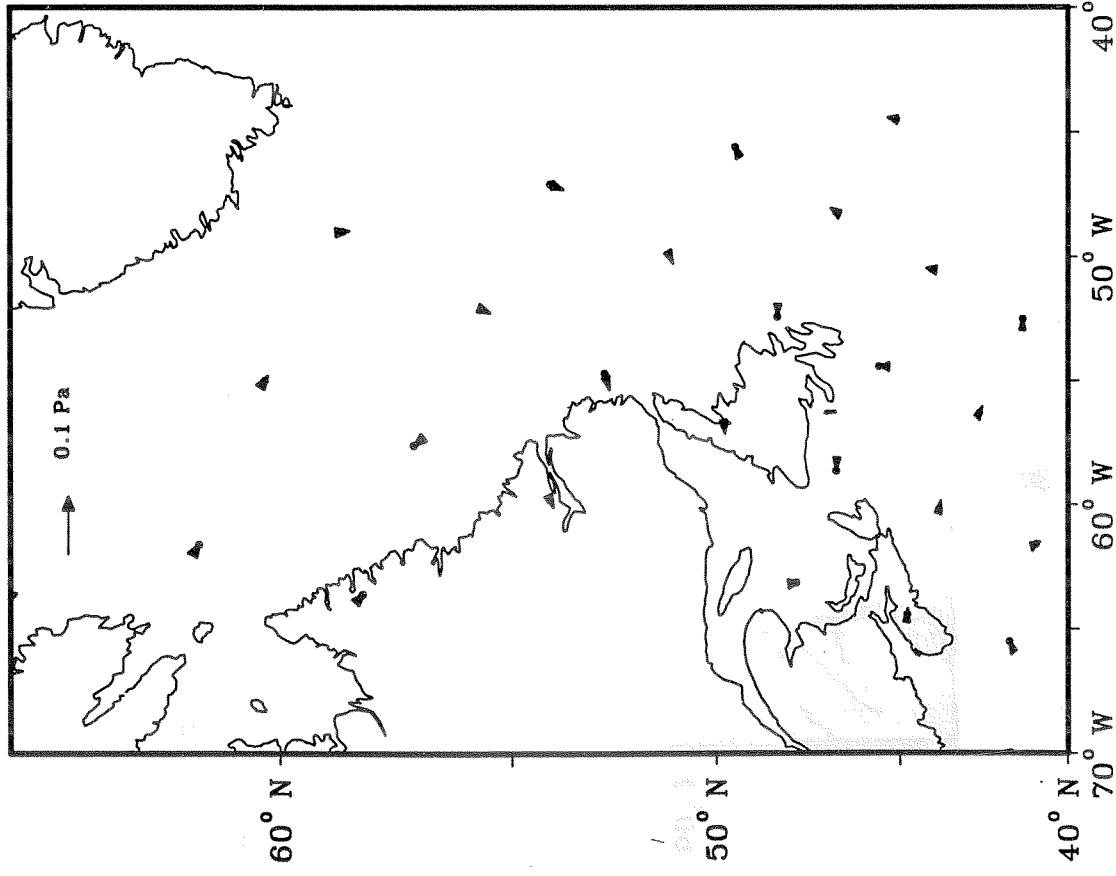
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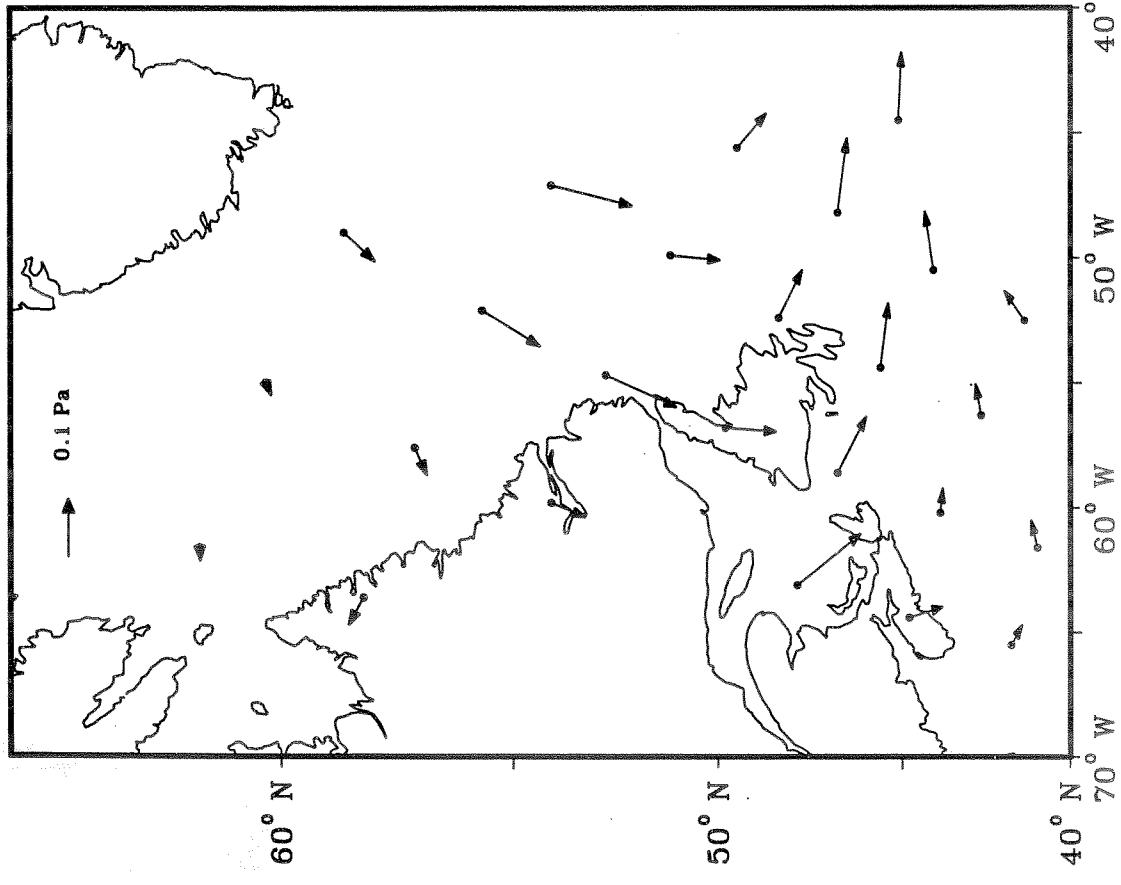
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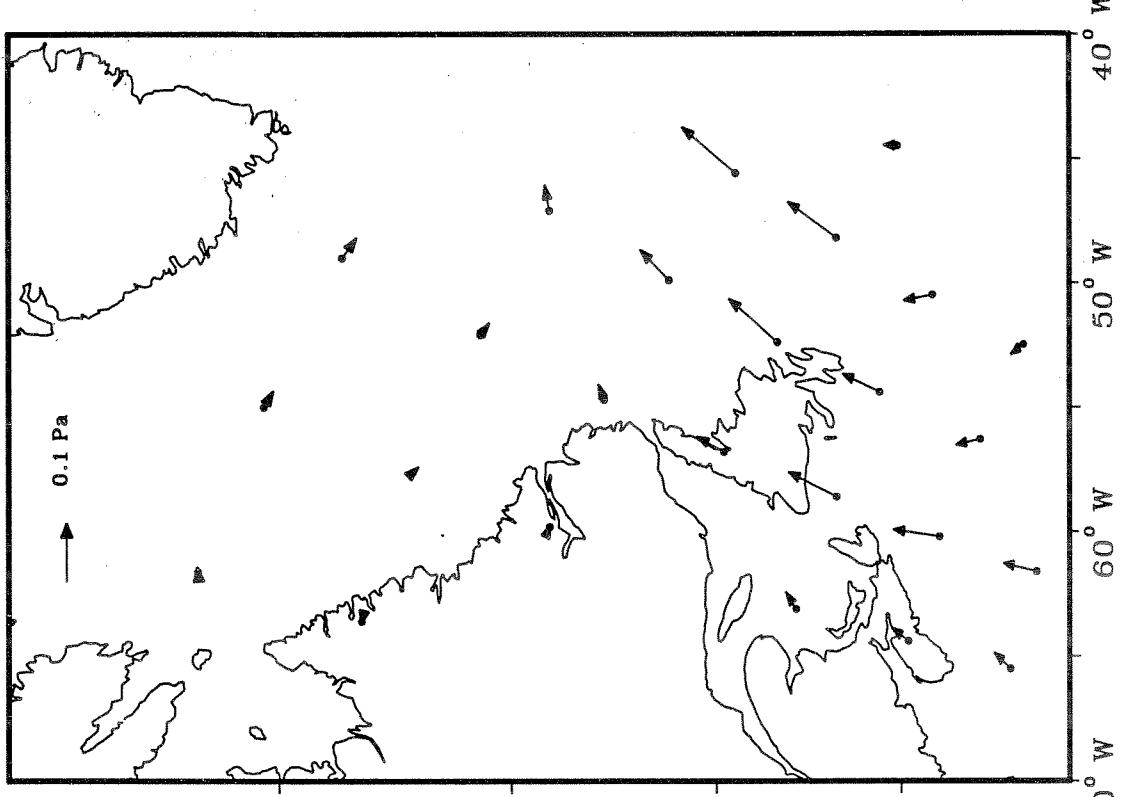
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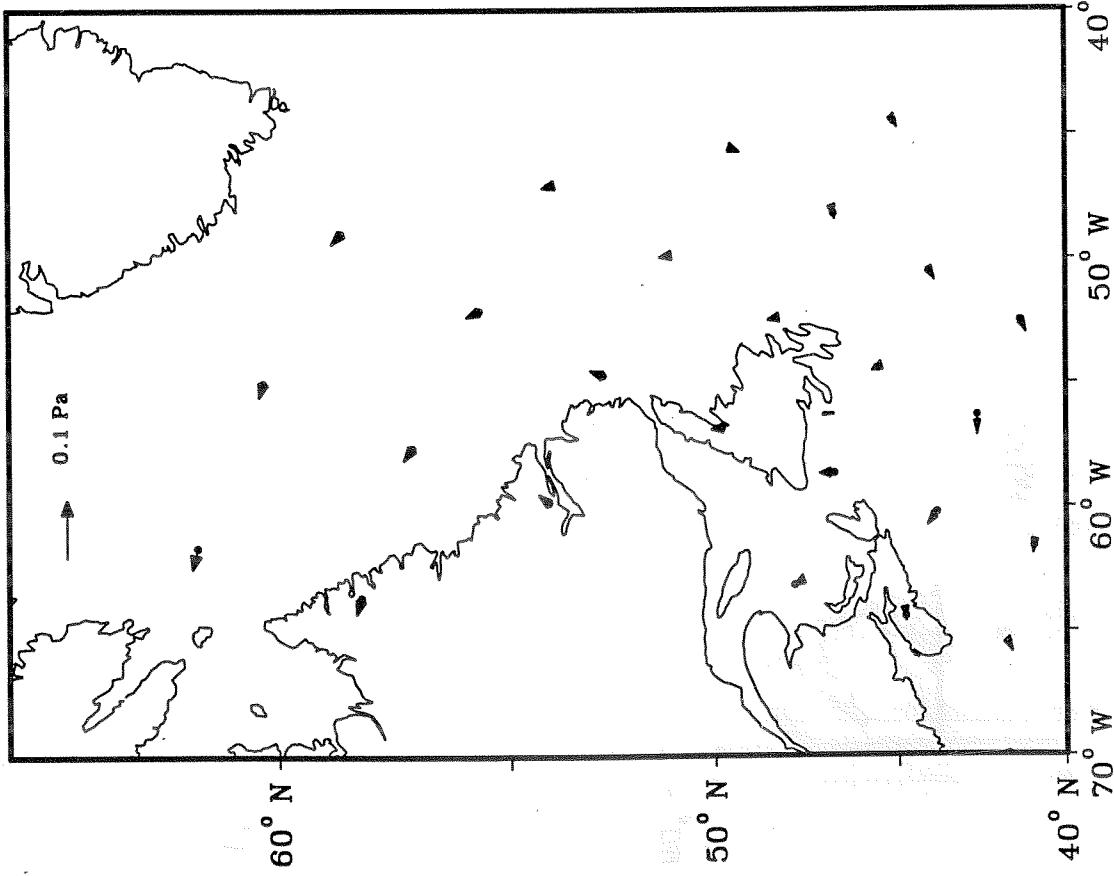
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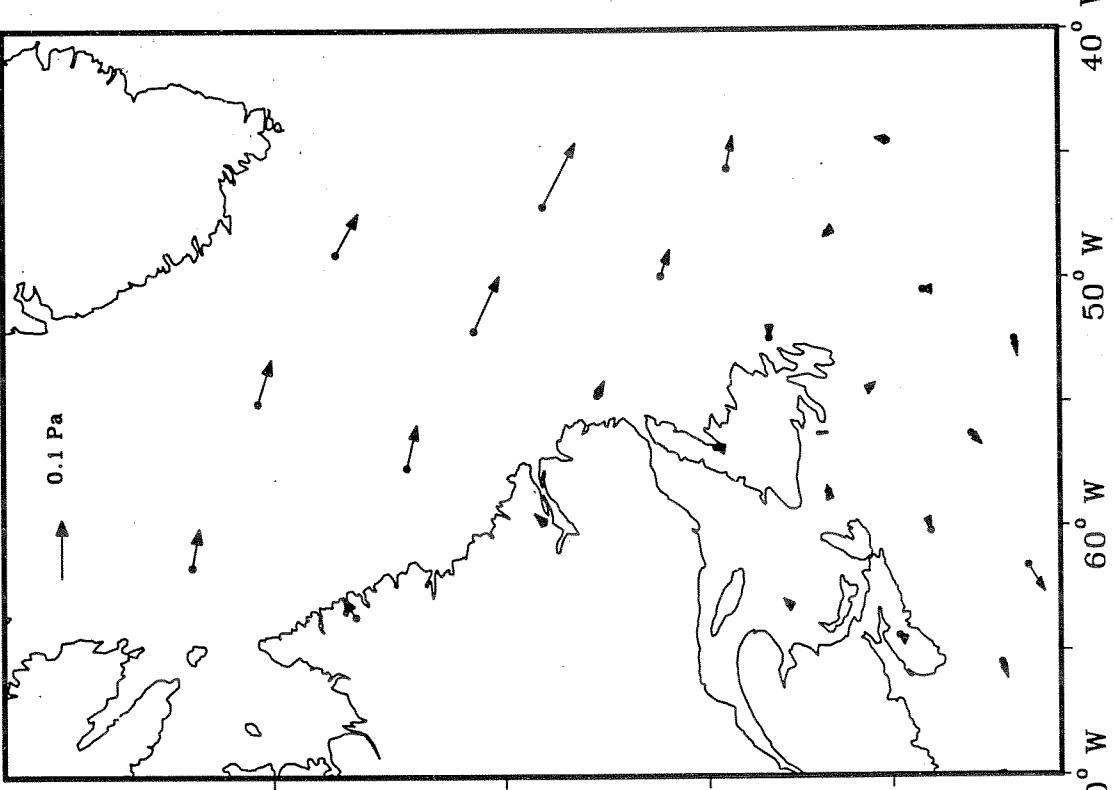
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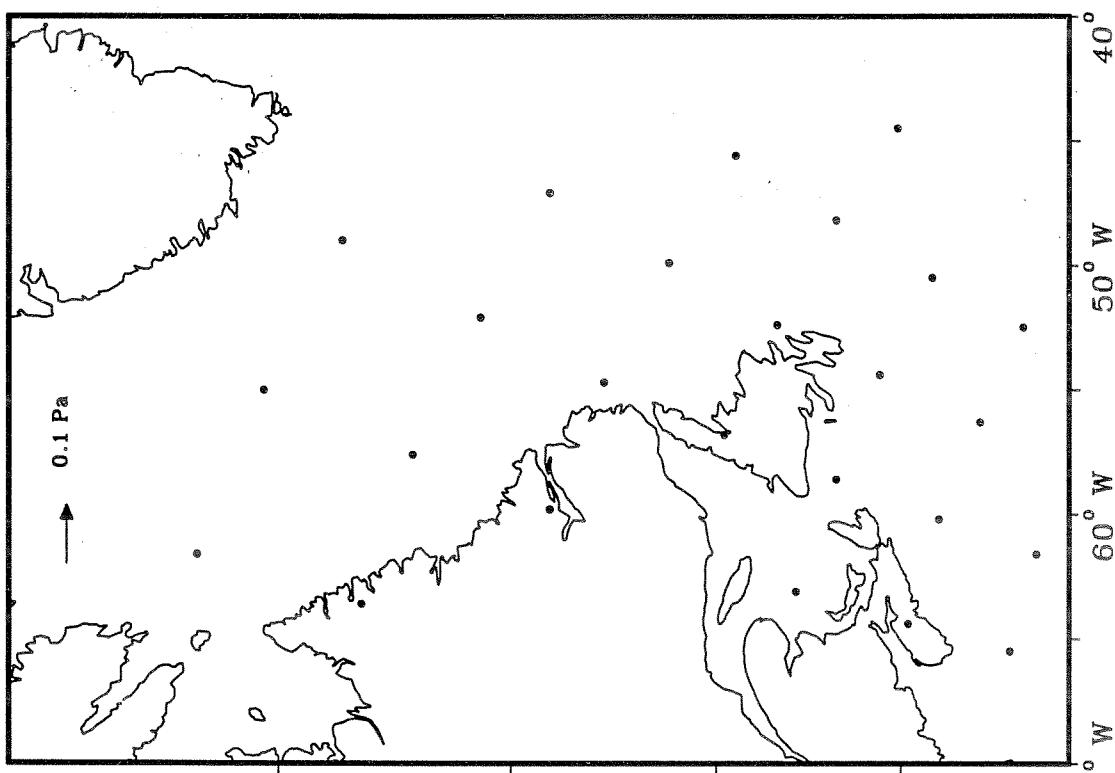
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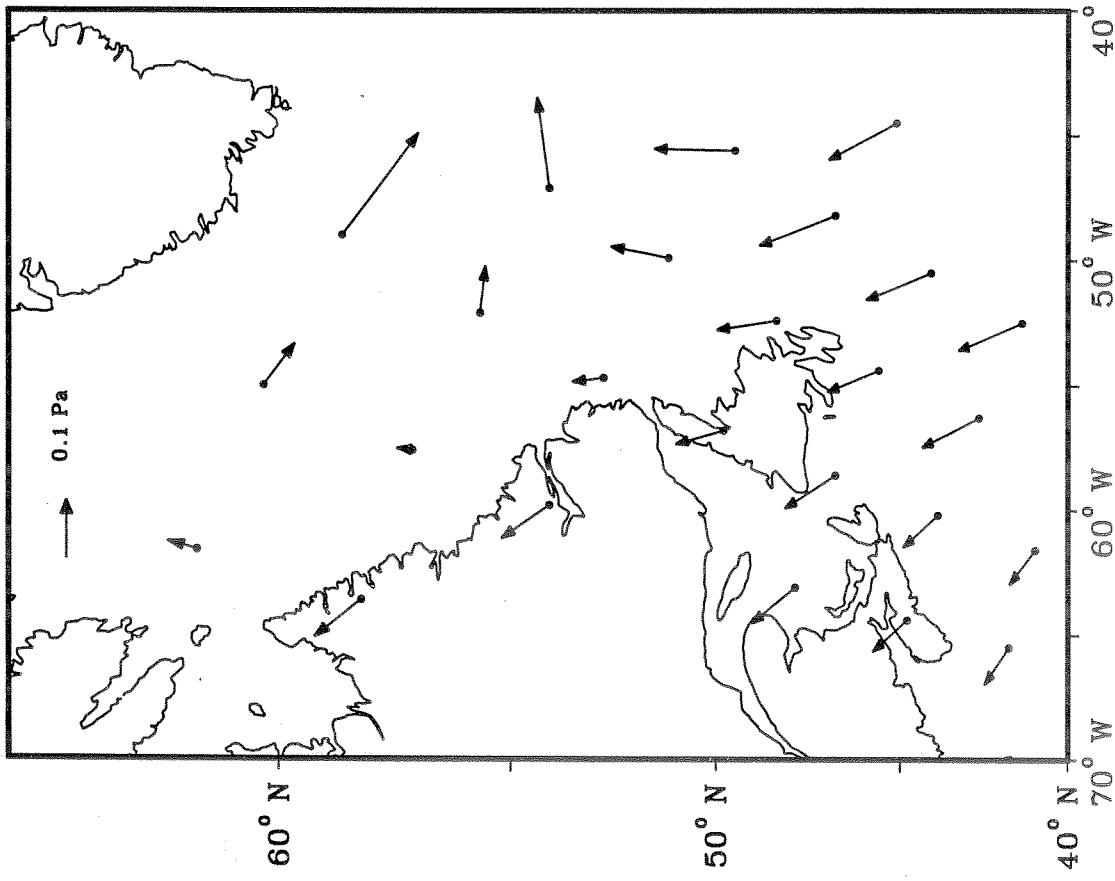
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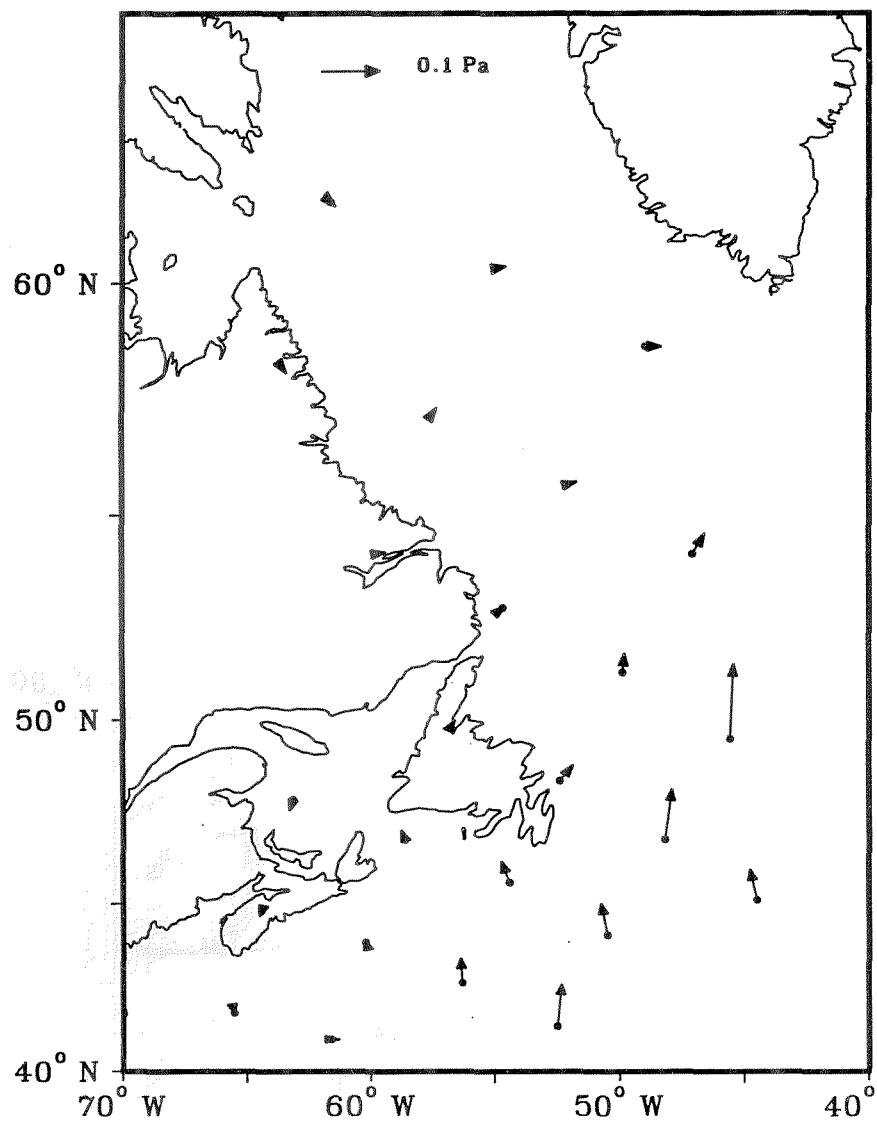
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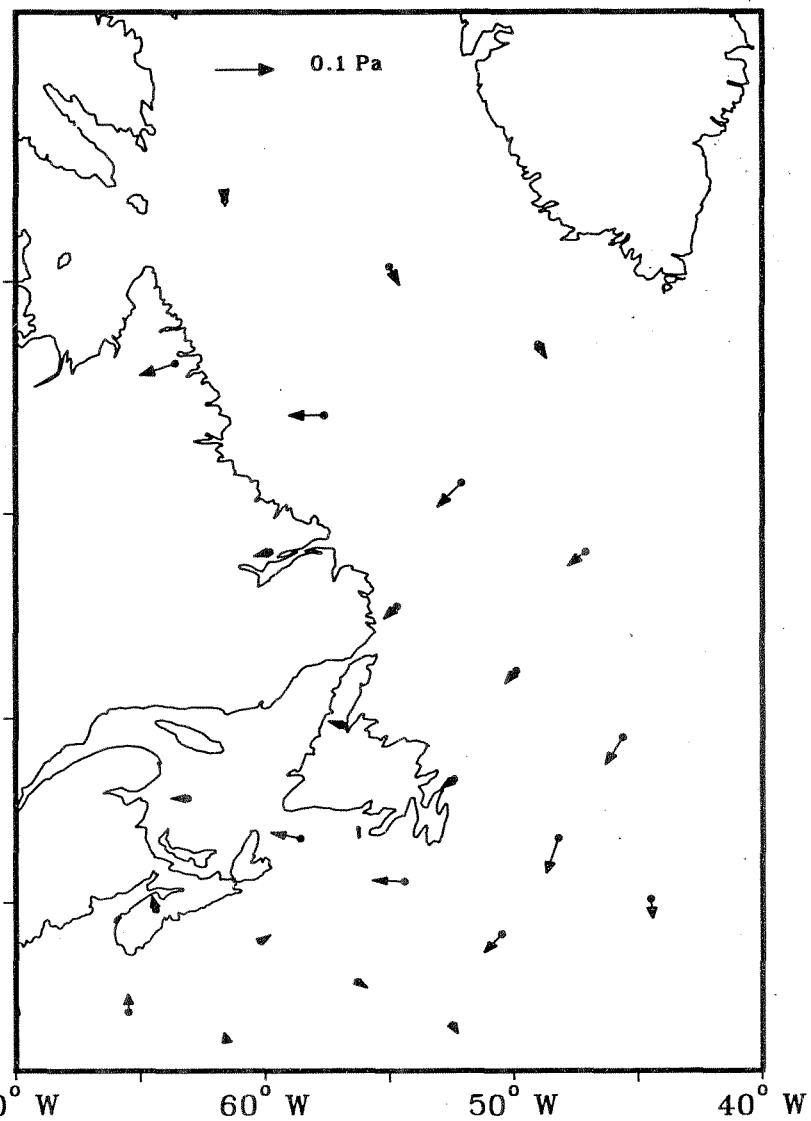
Winter 1983



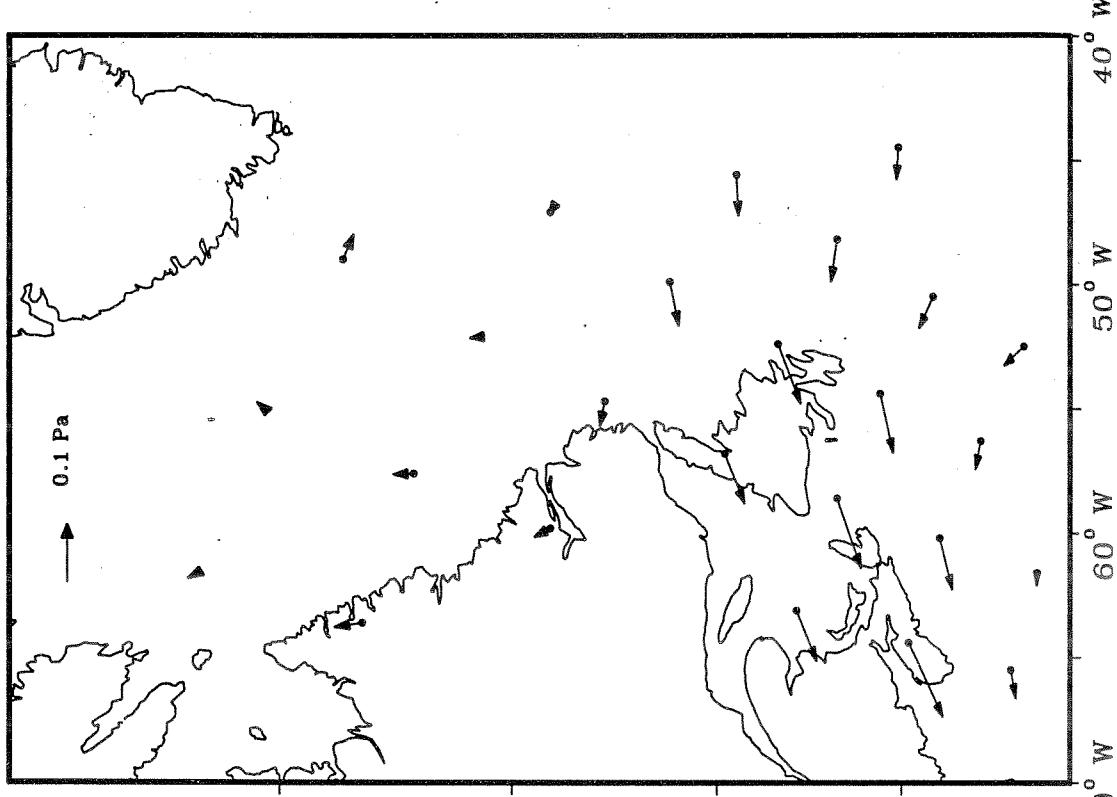
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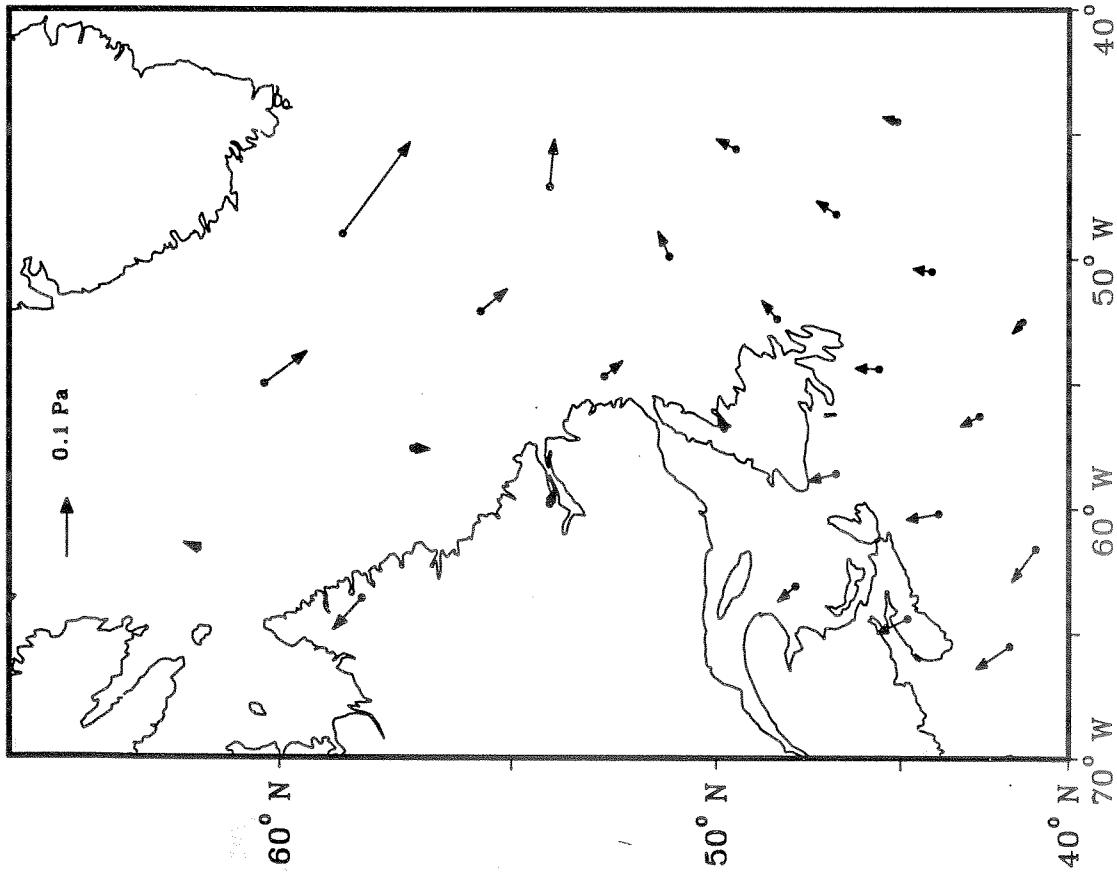
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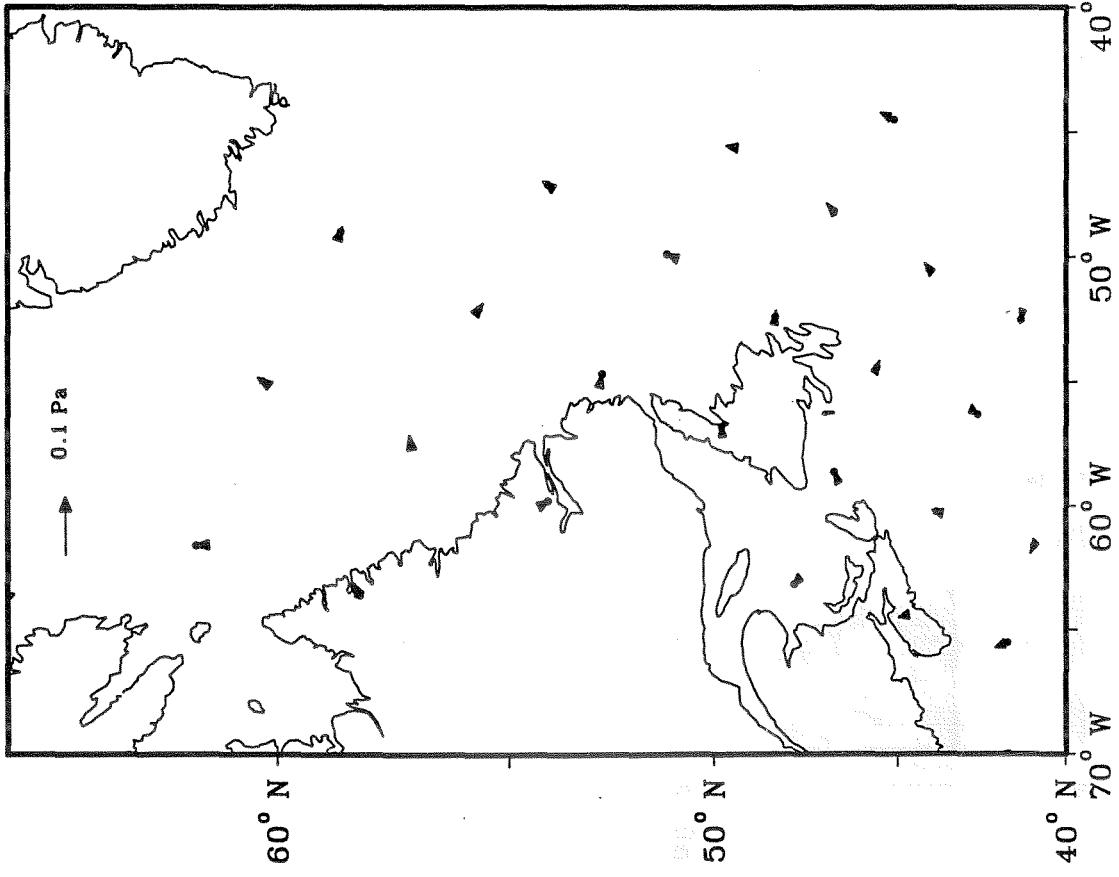
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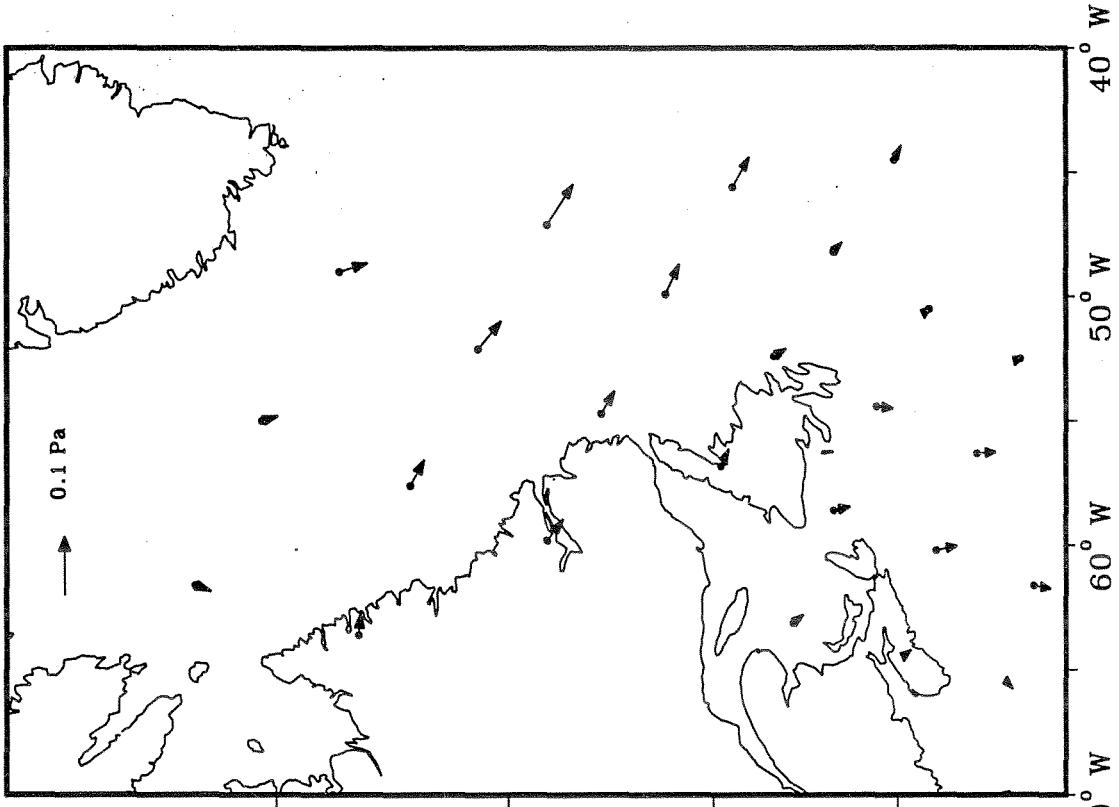
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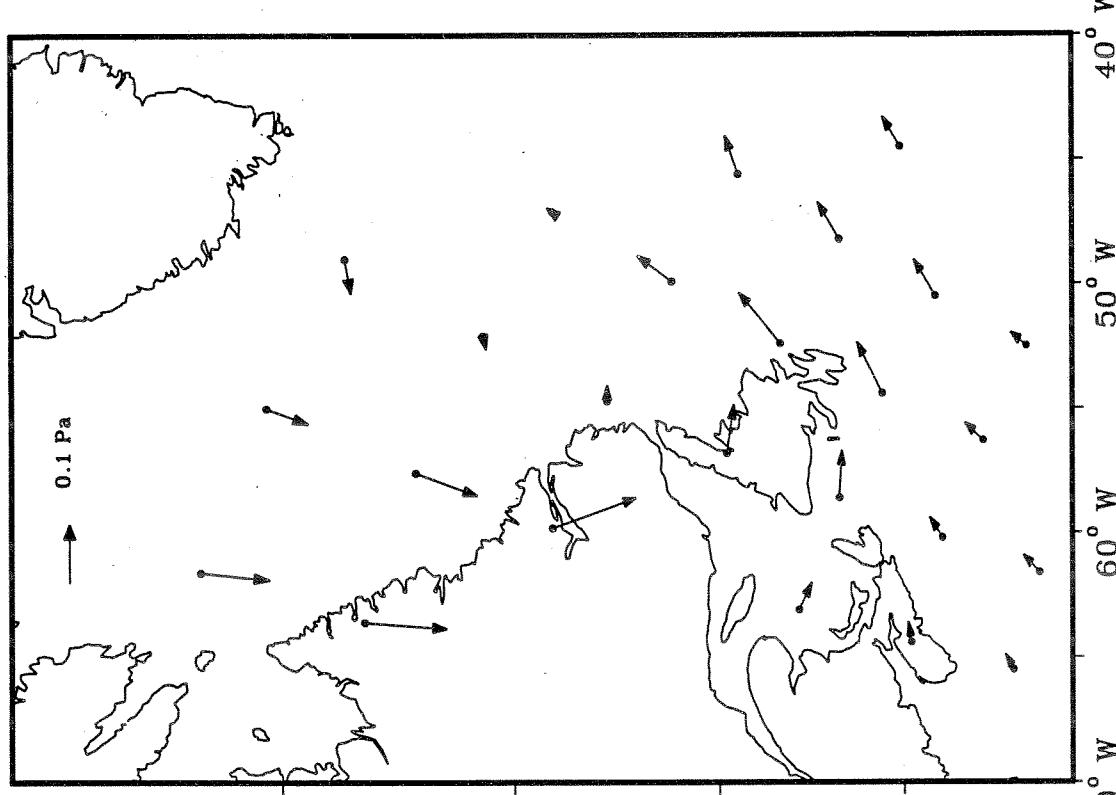
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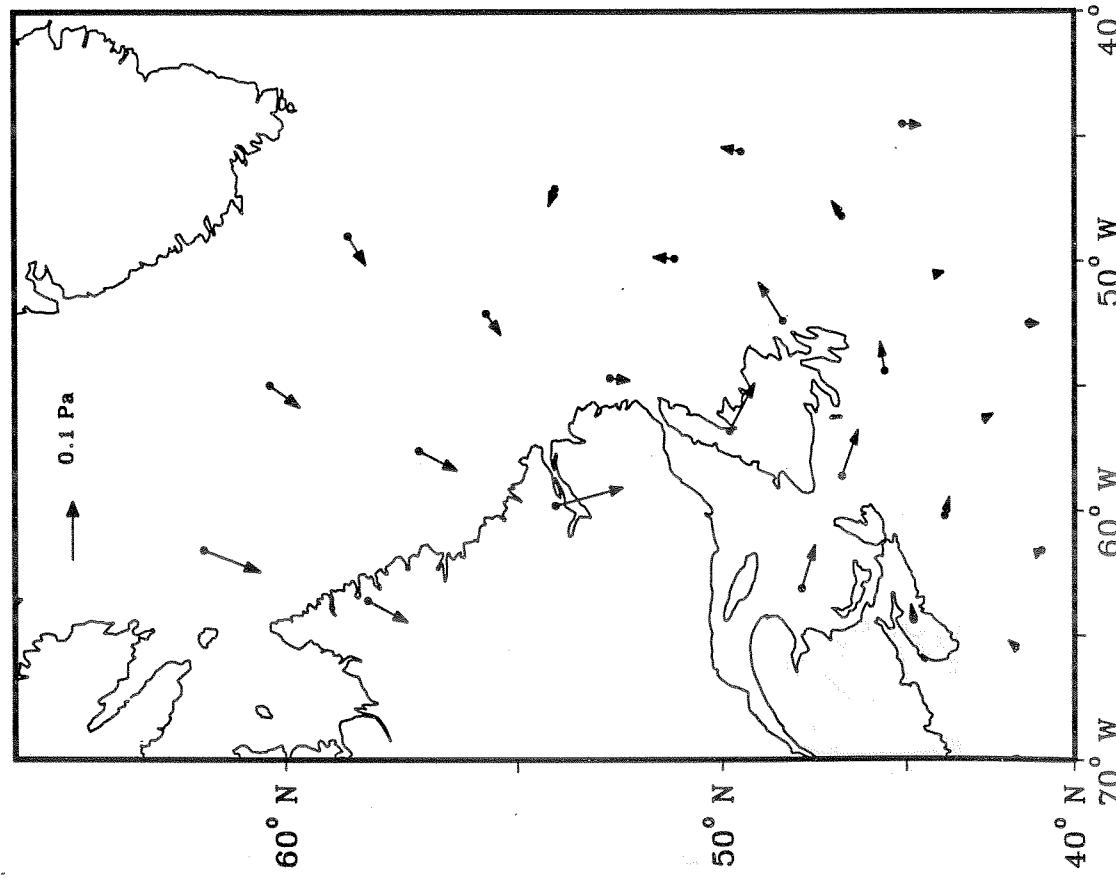
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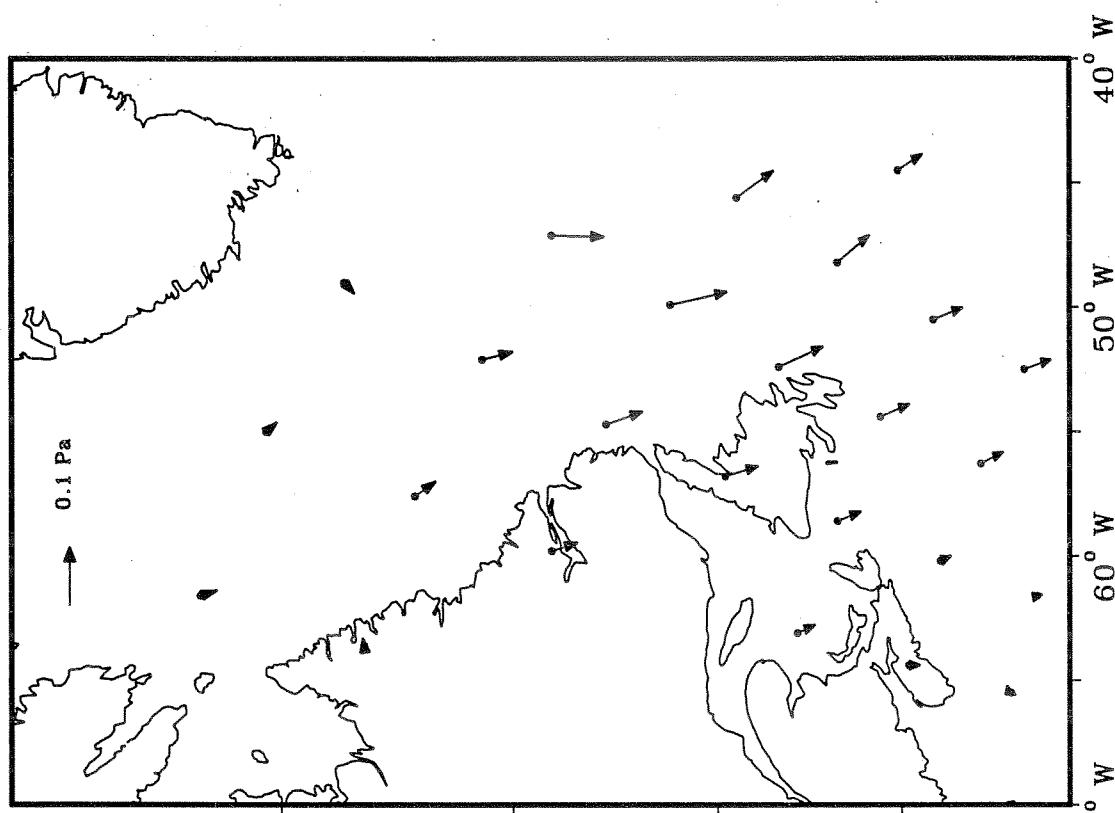
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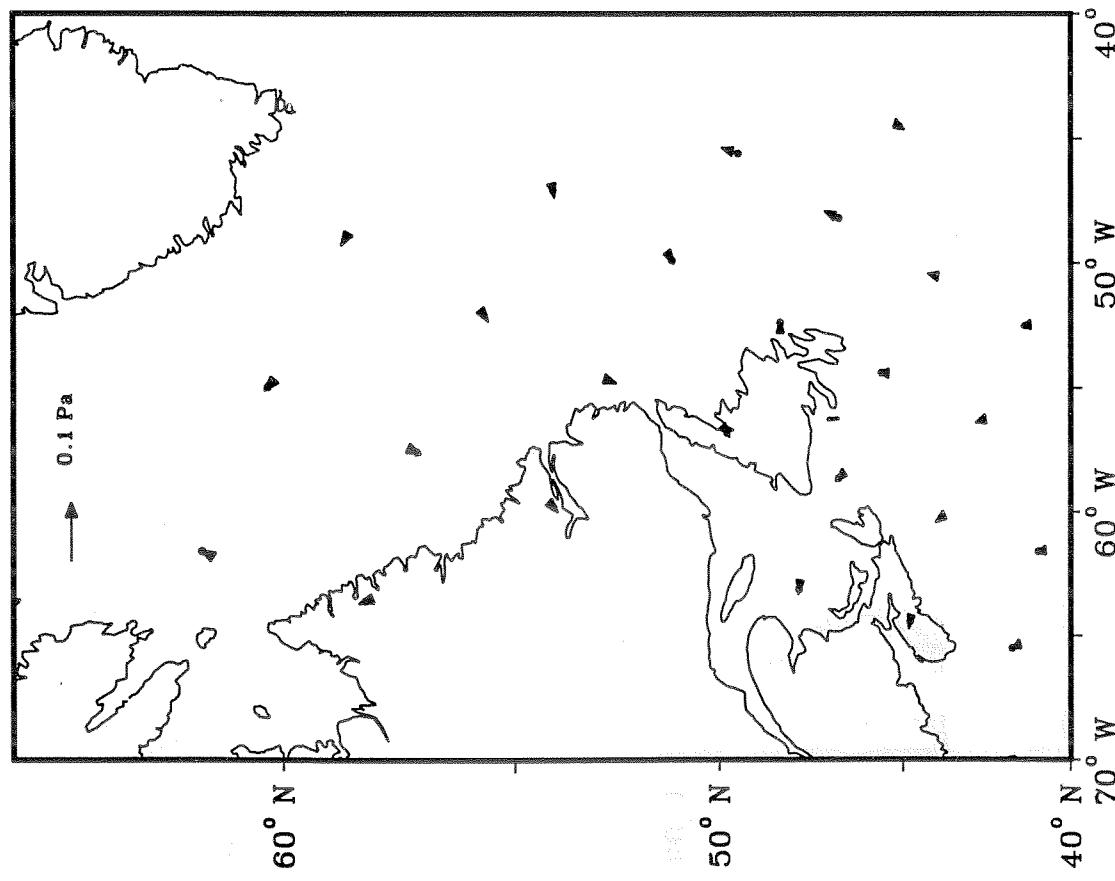
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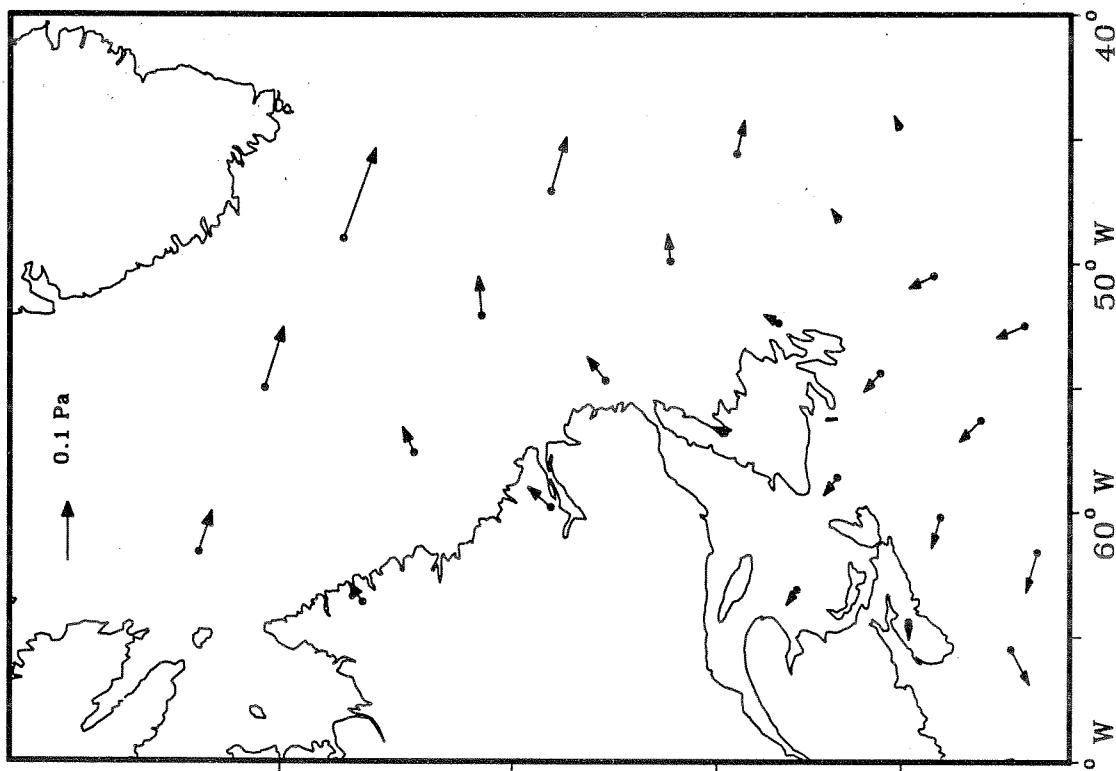
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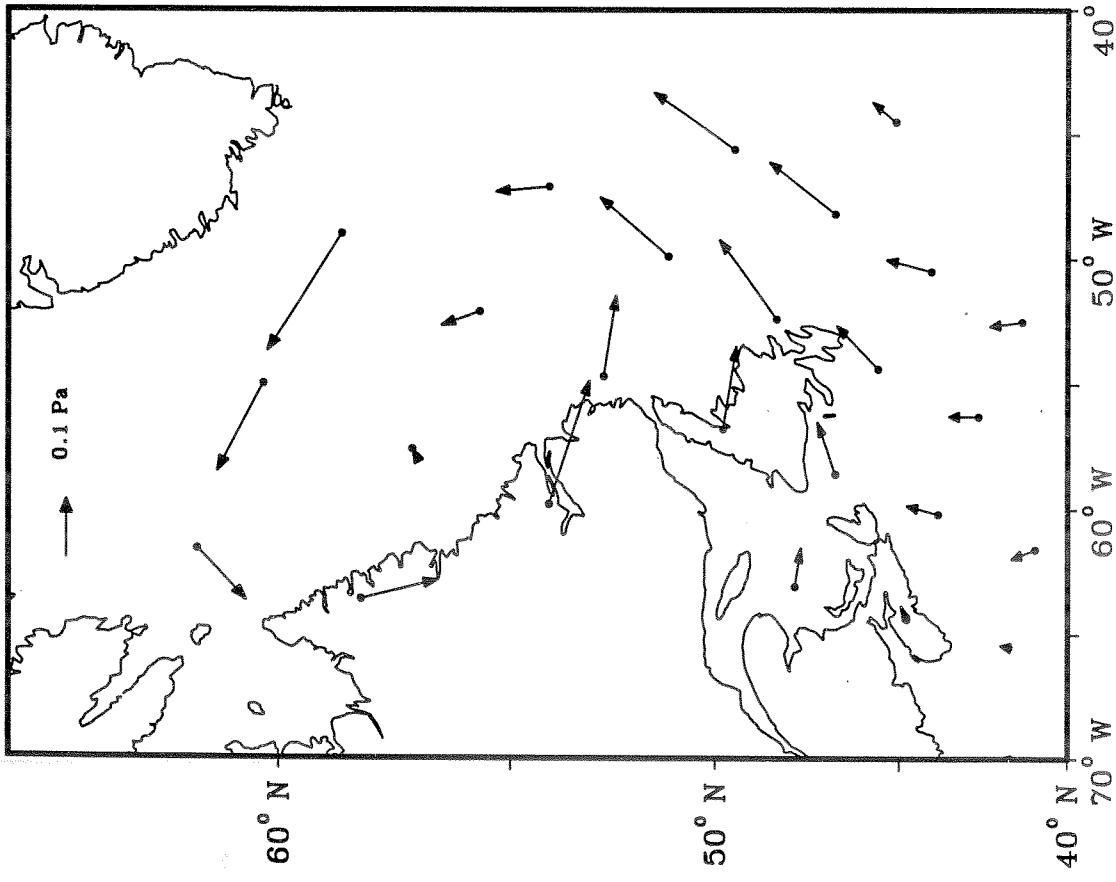
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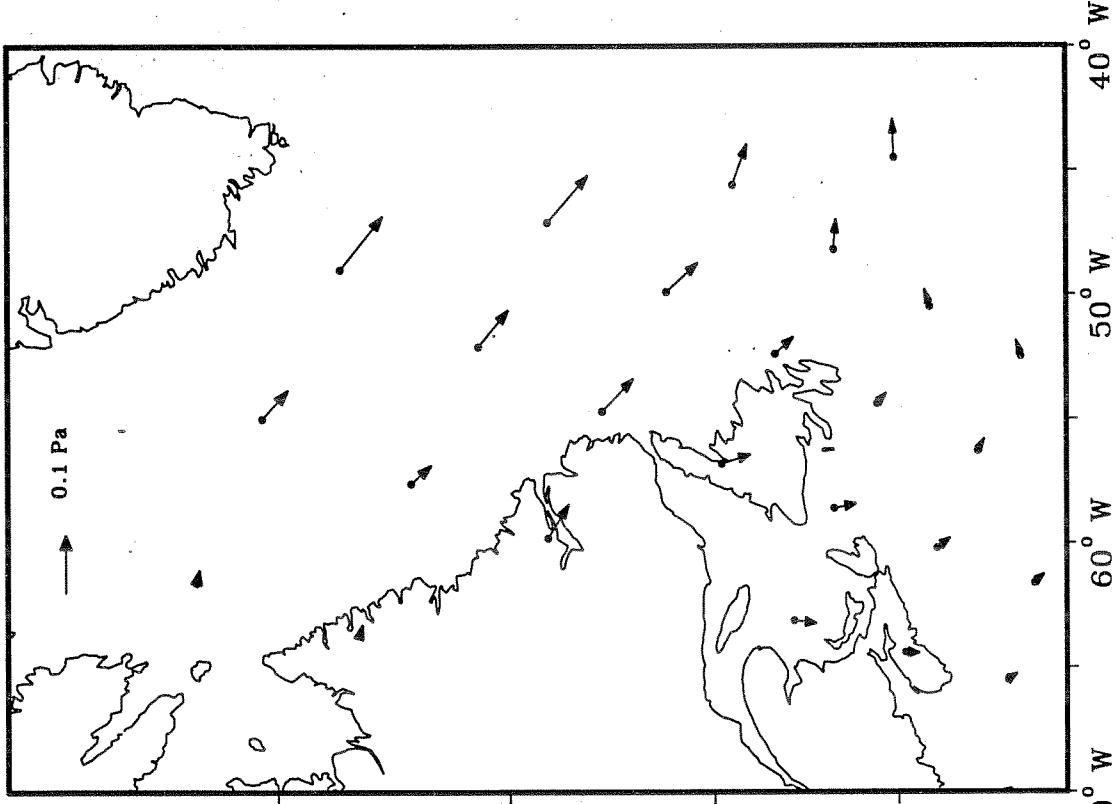
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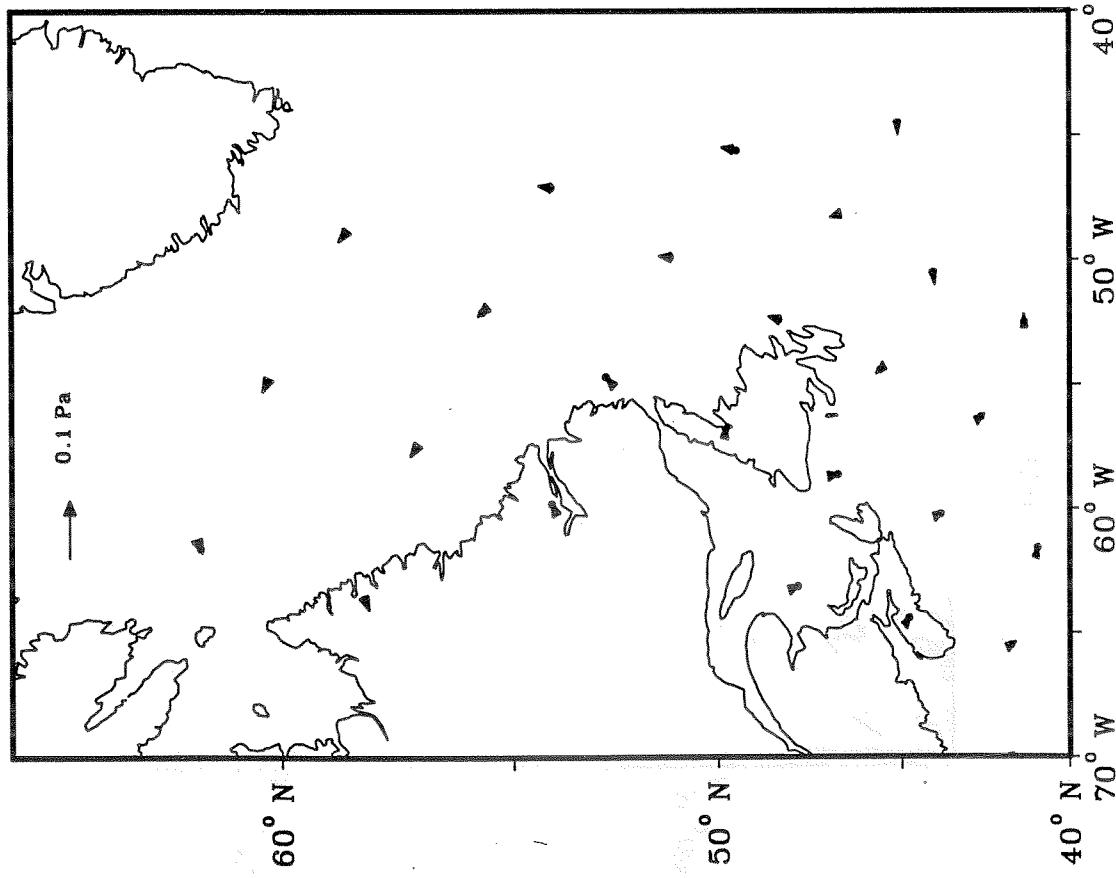
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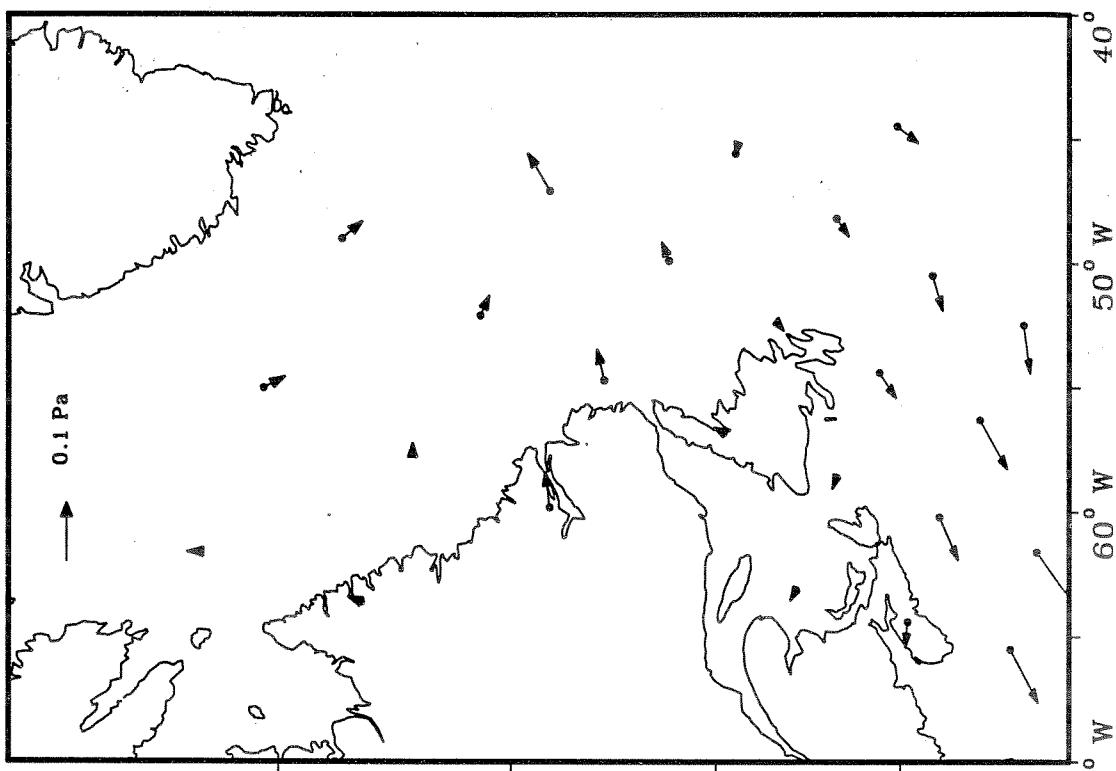
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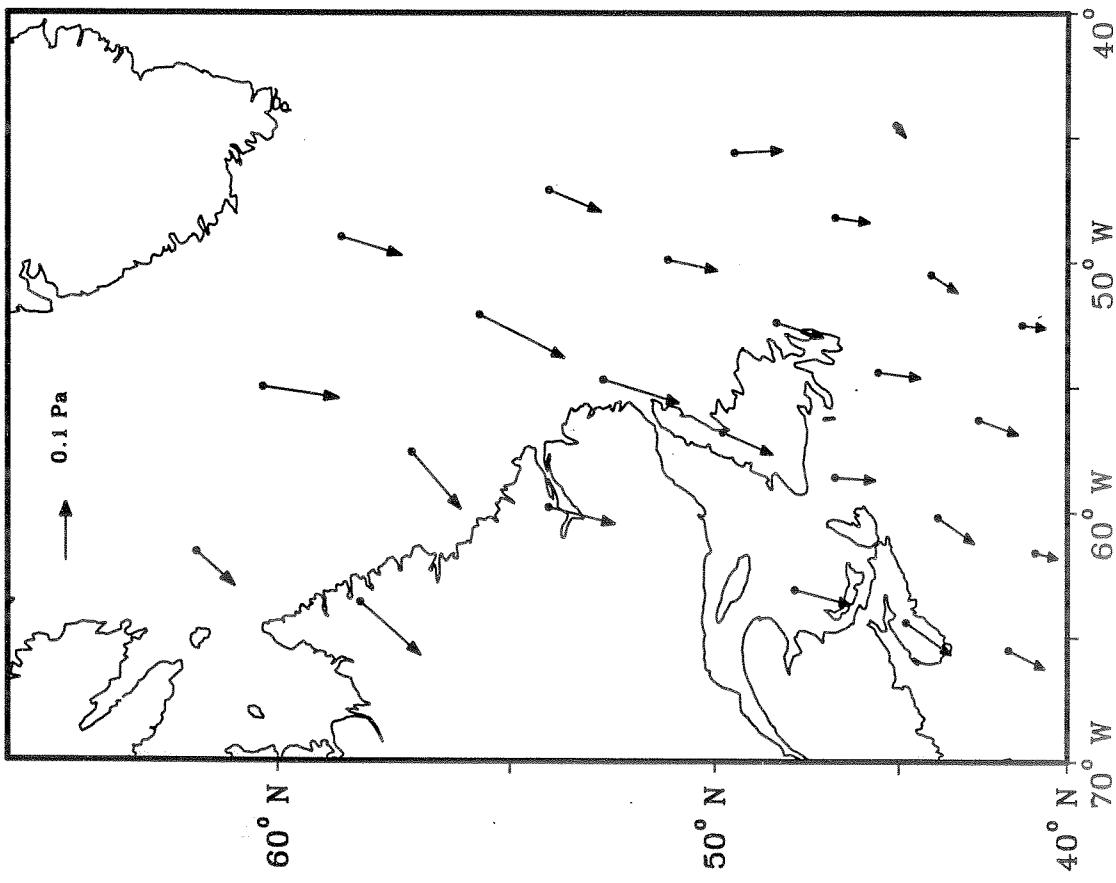
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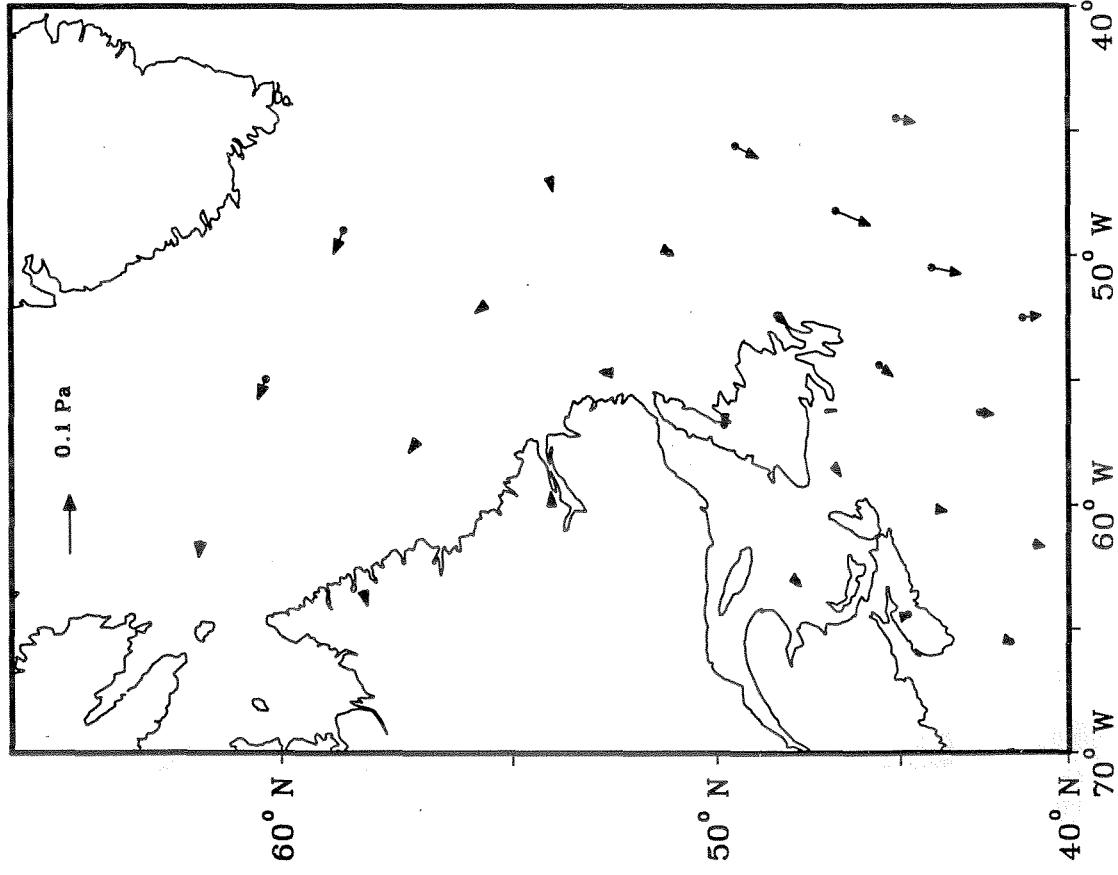
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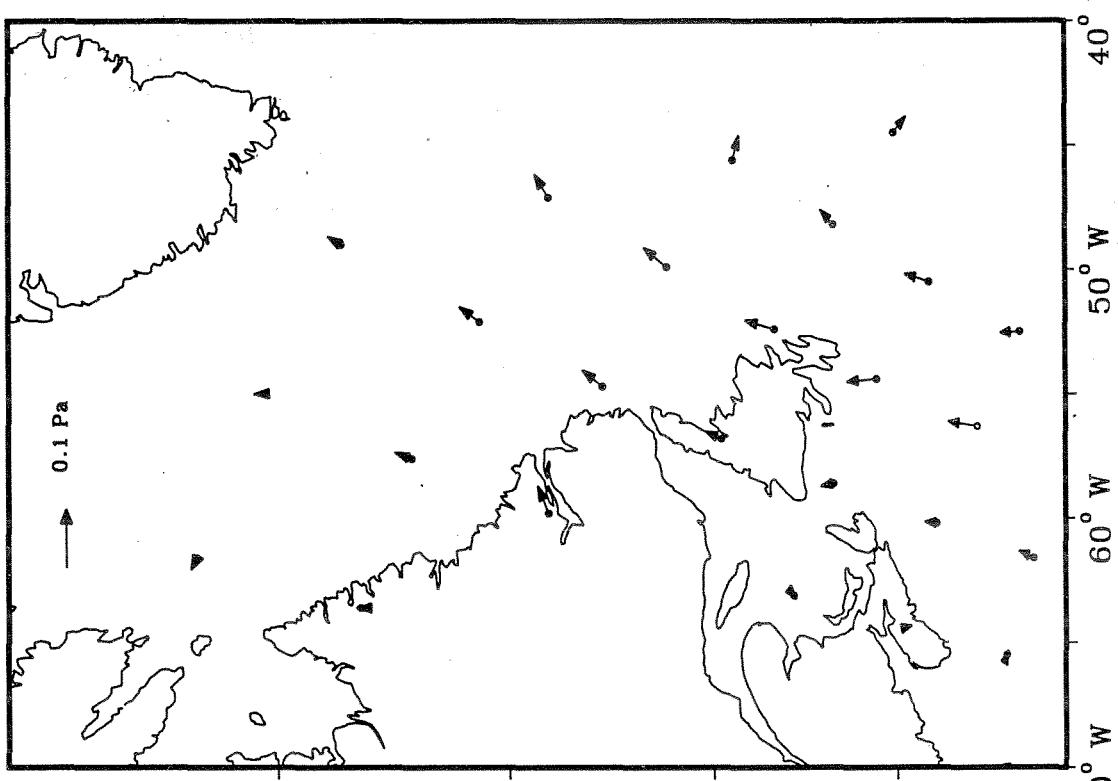
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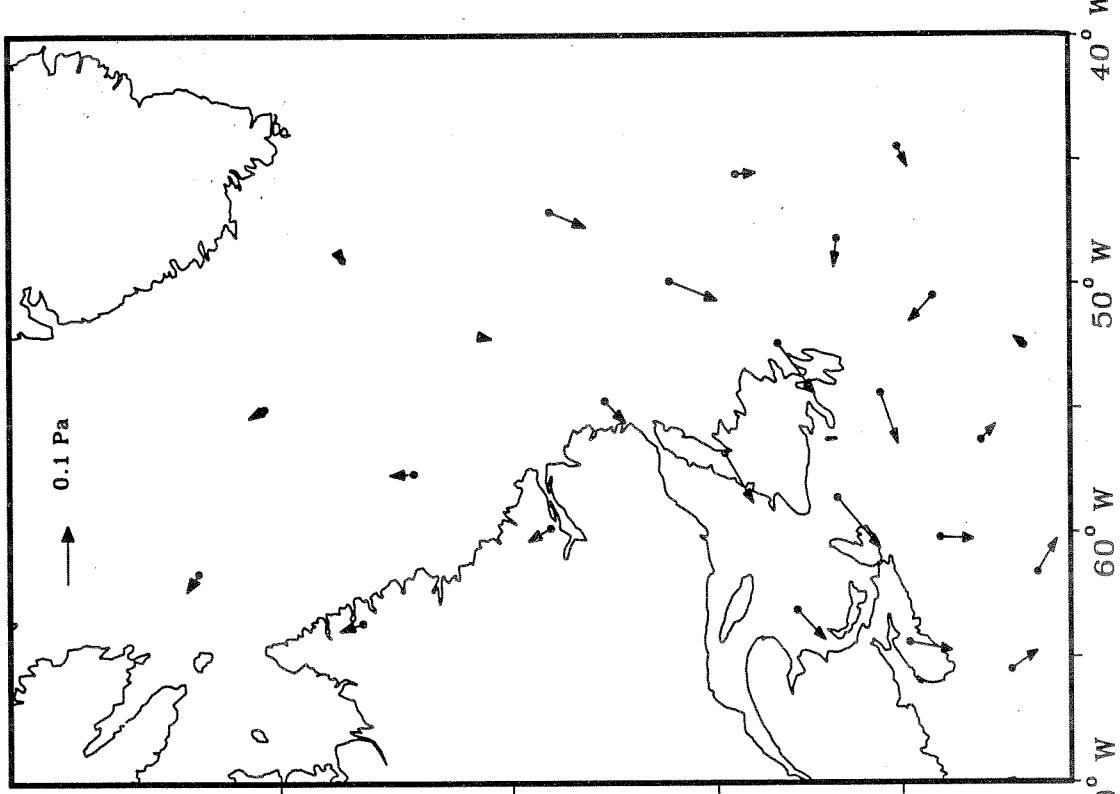
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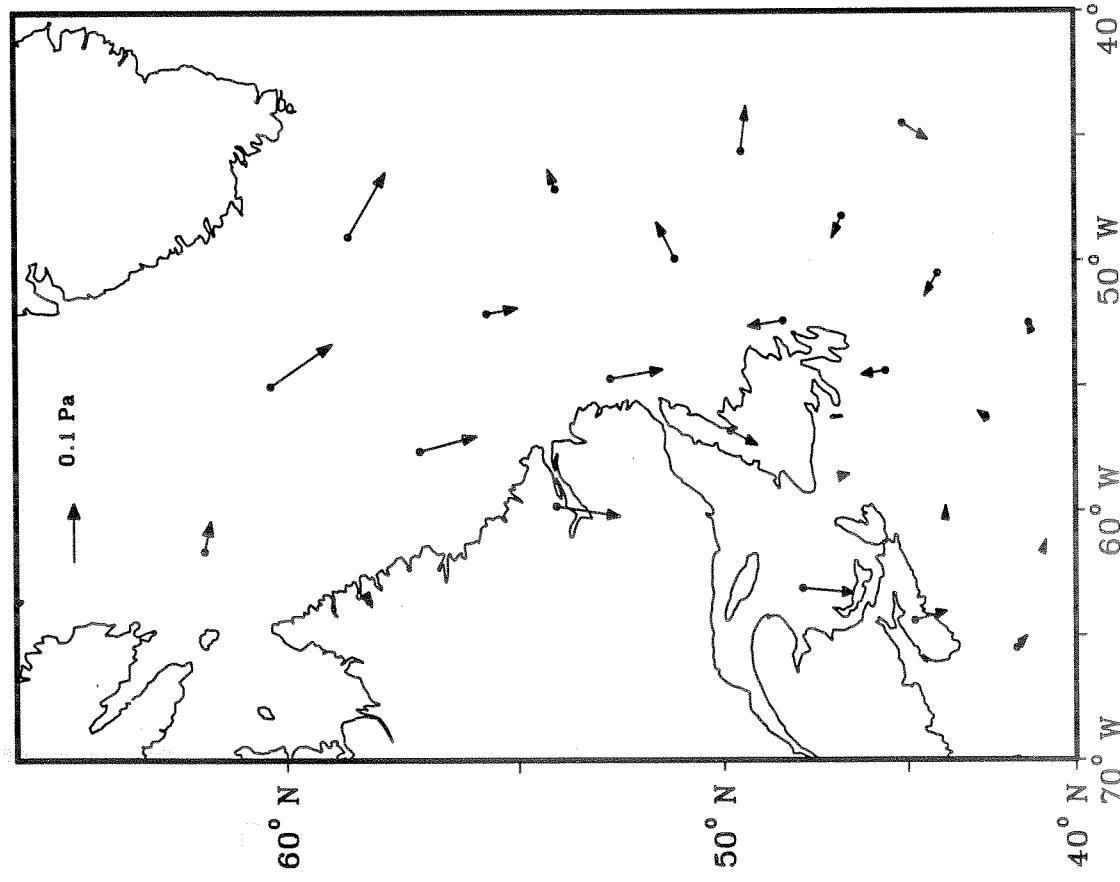
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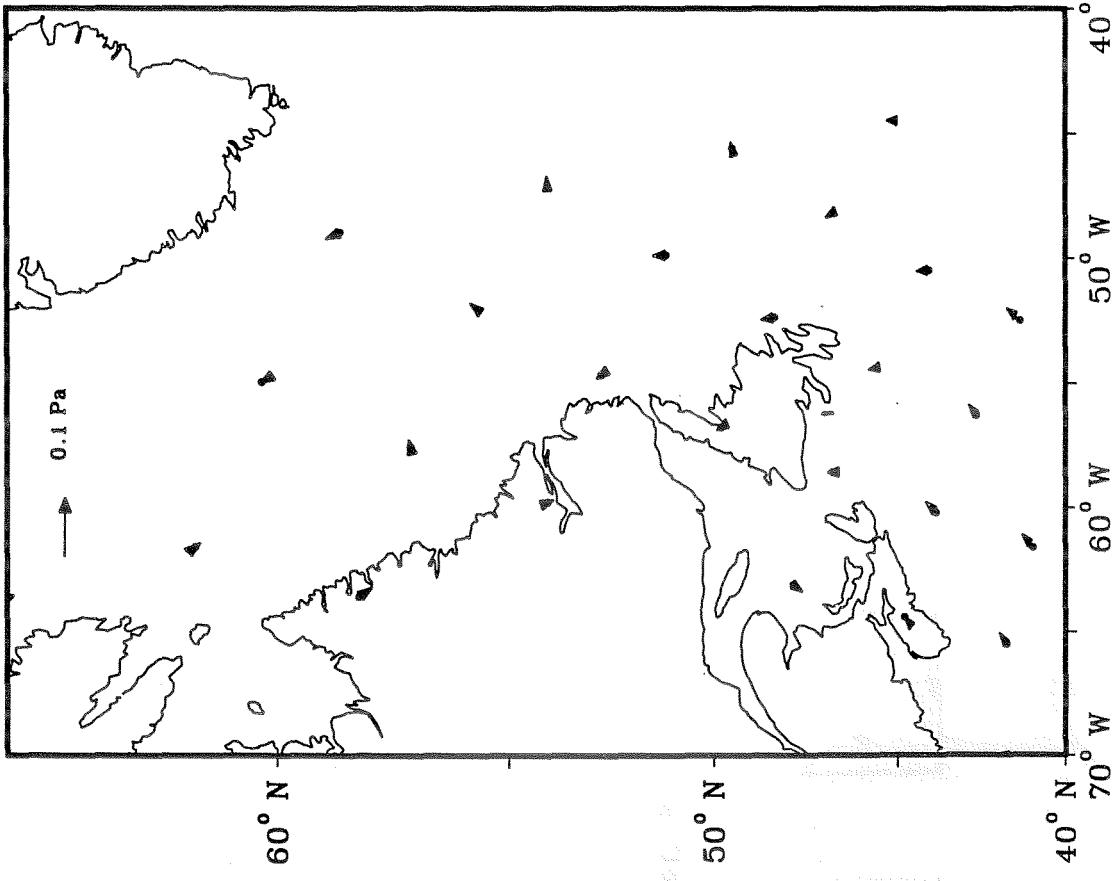
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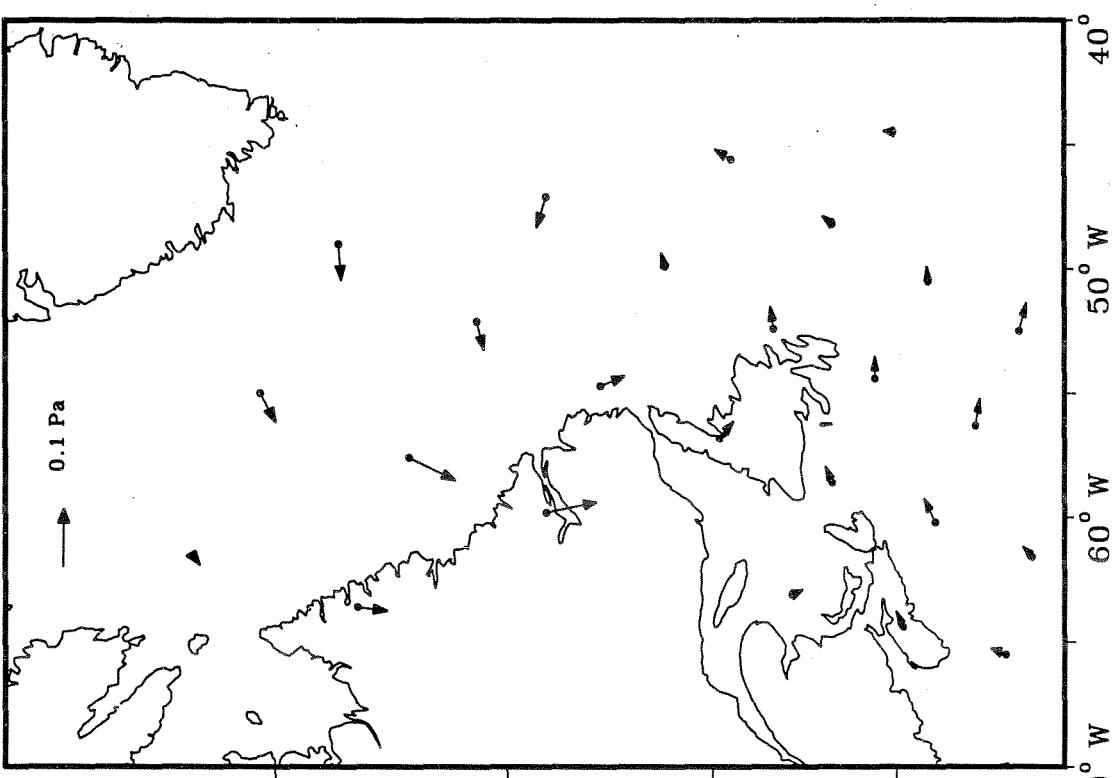
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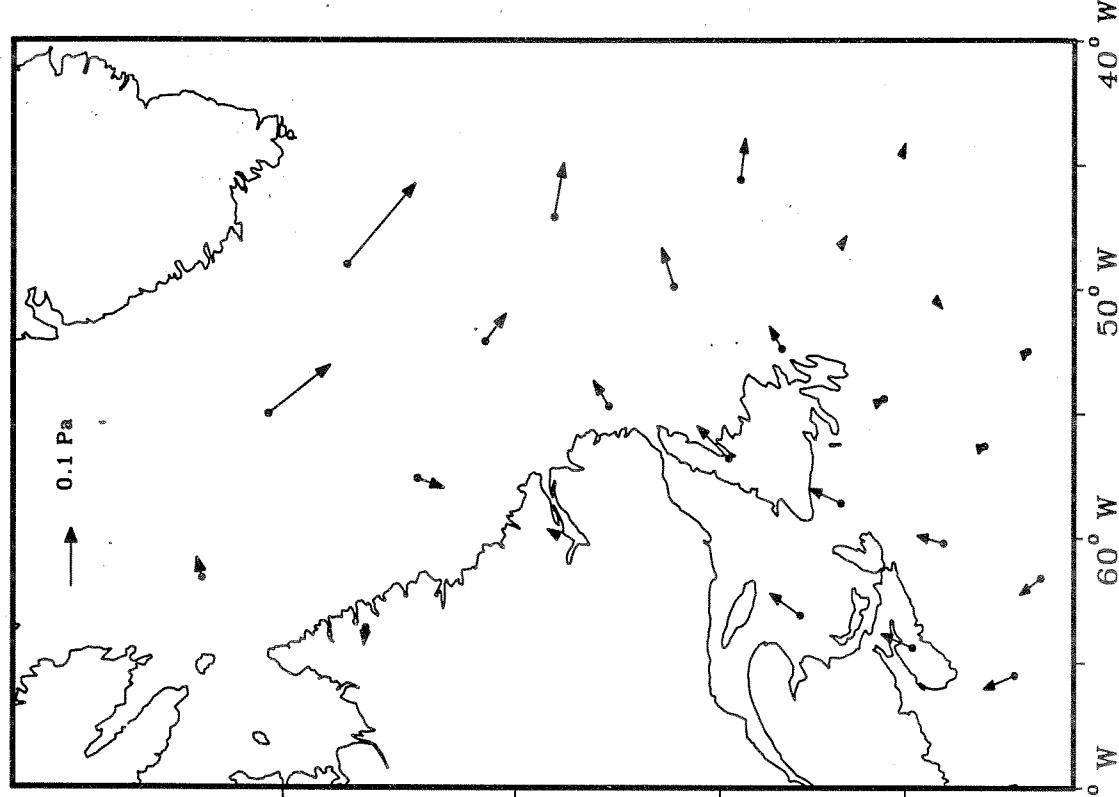
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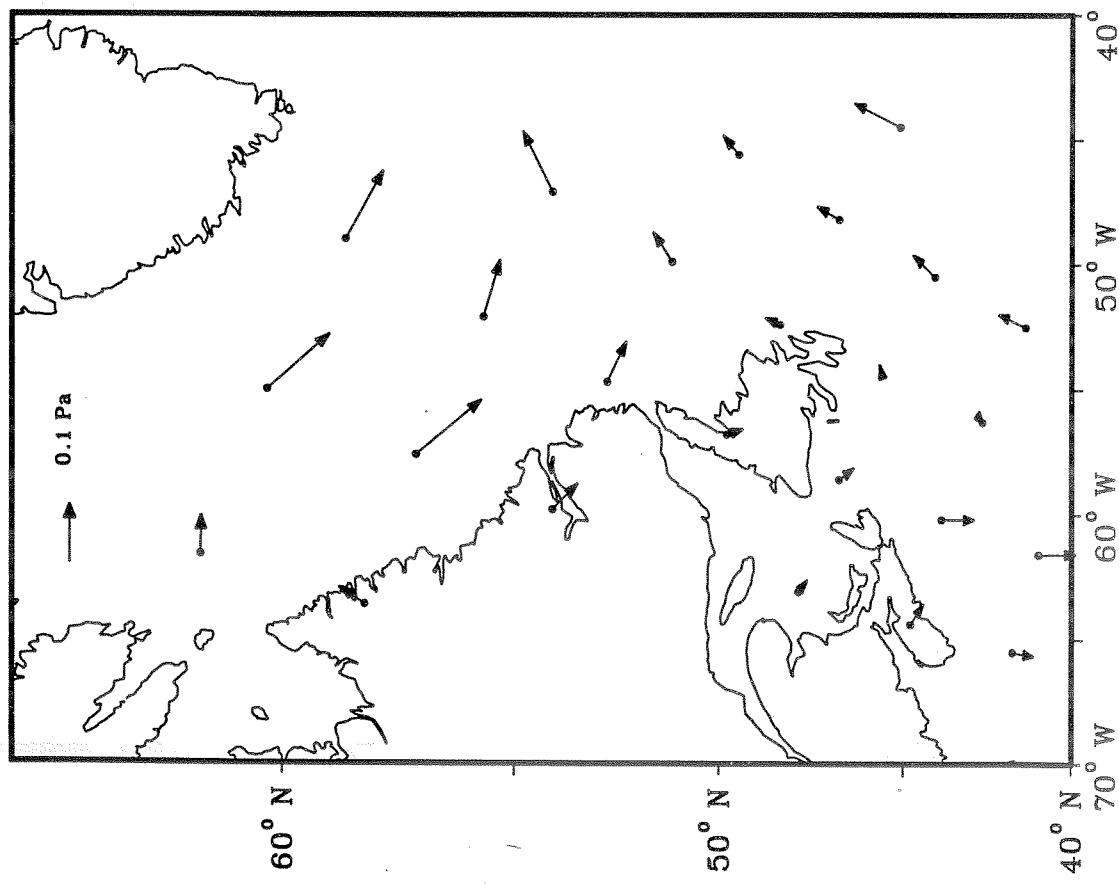
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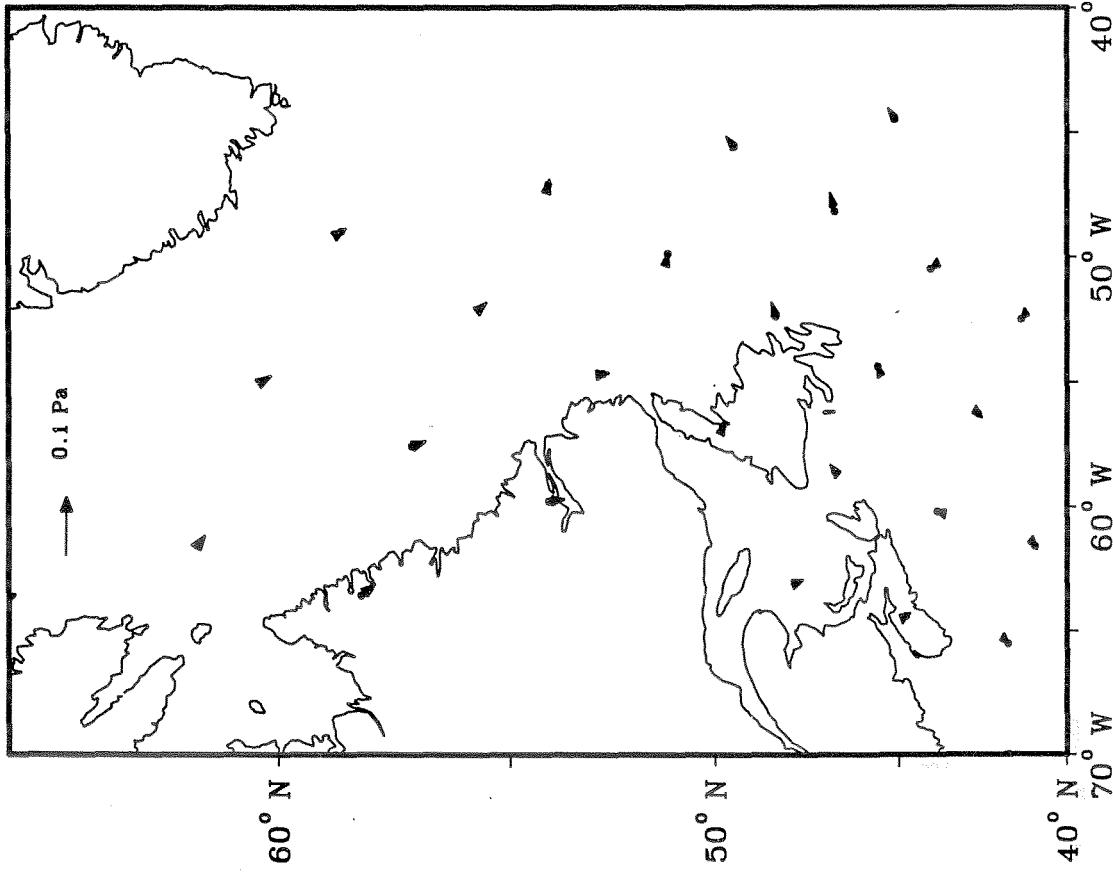
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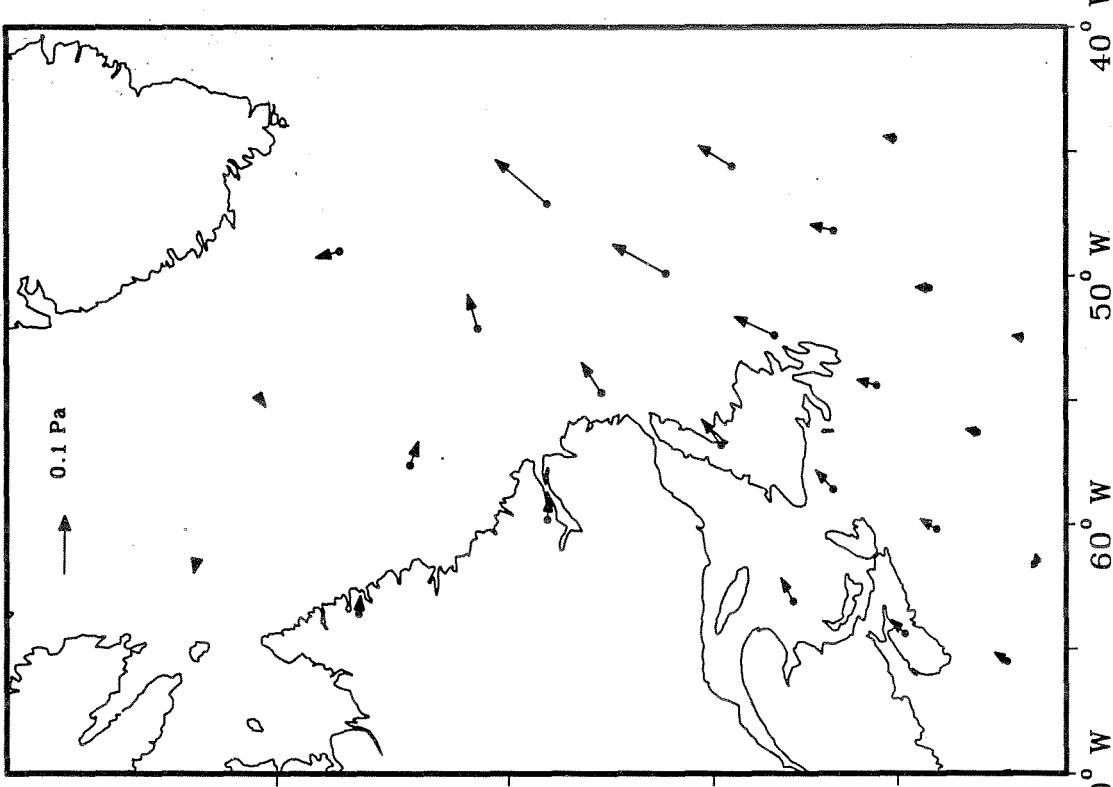
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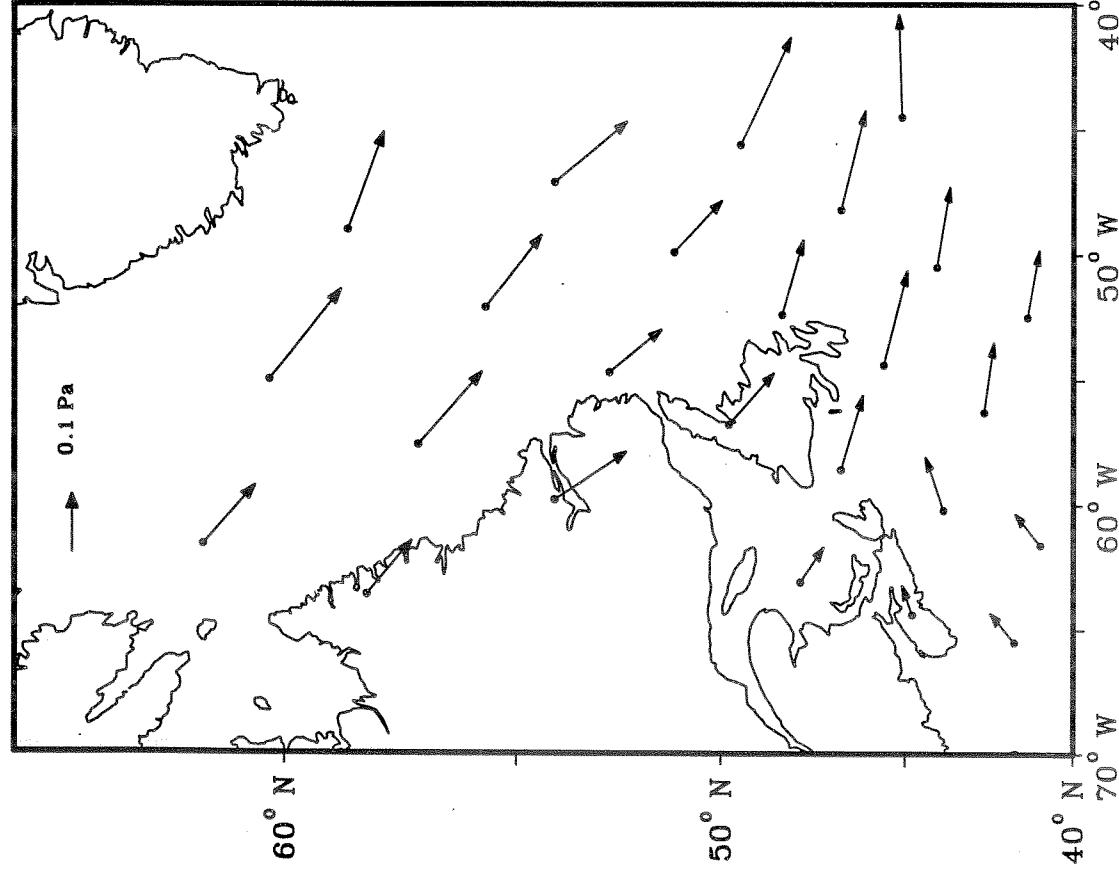
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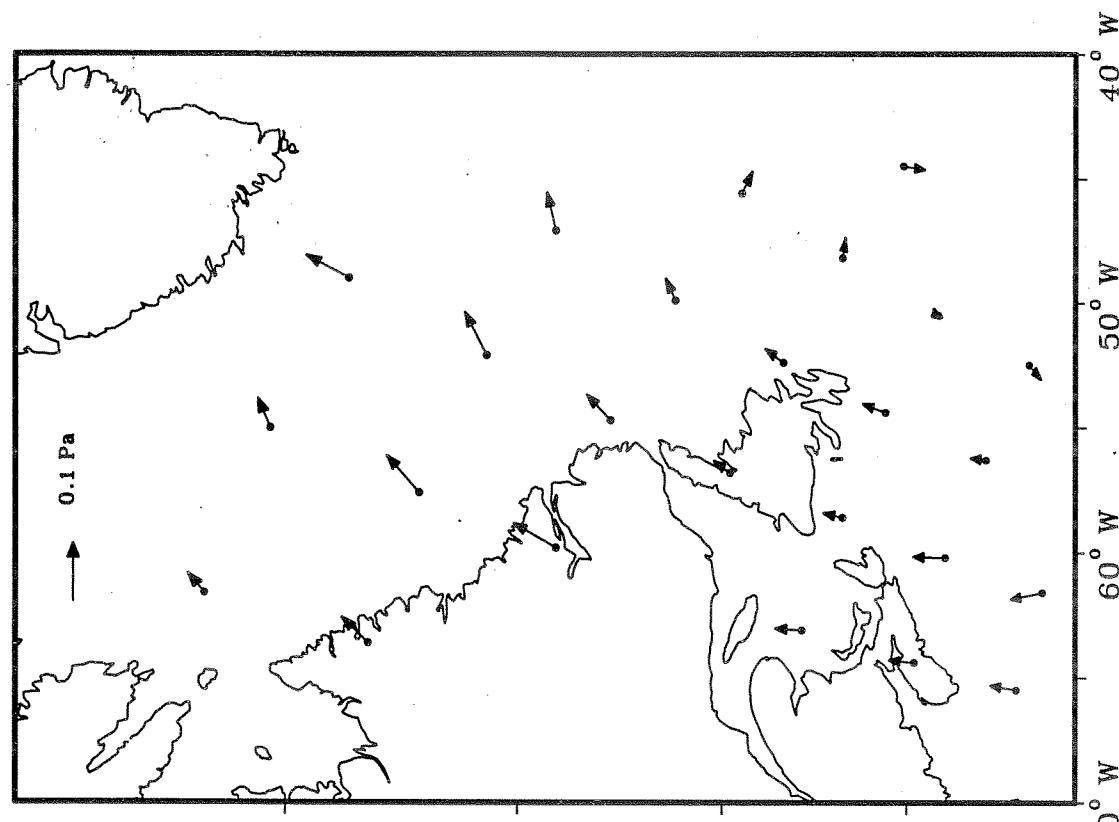
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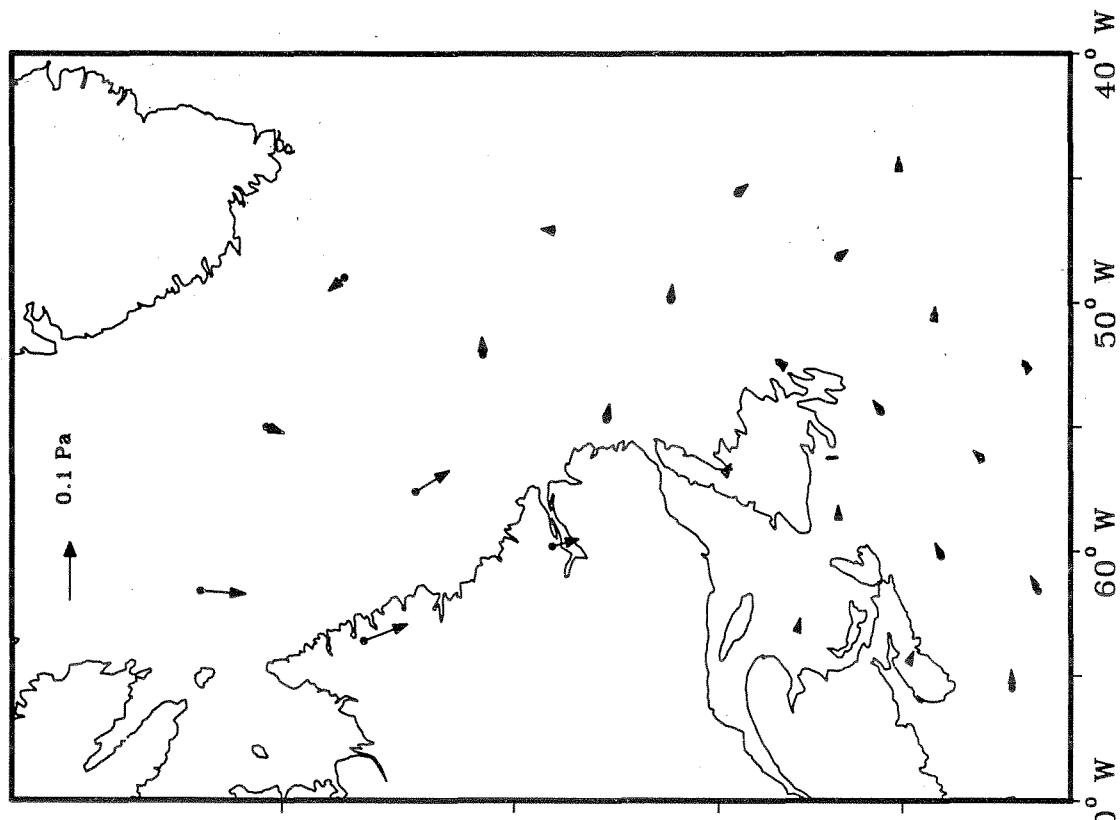


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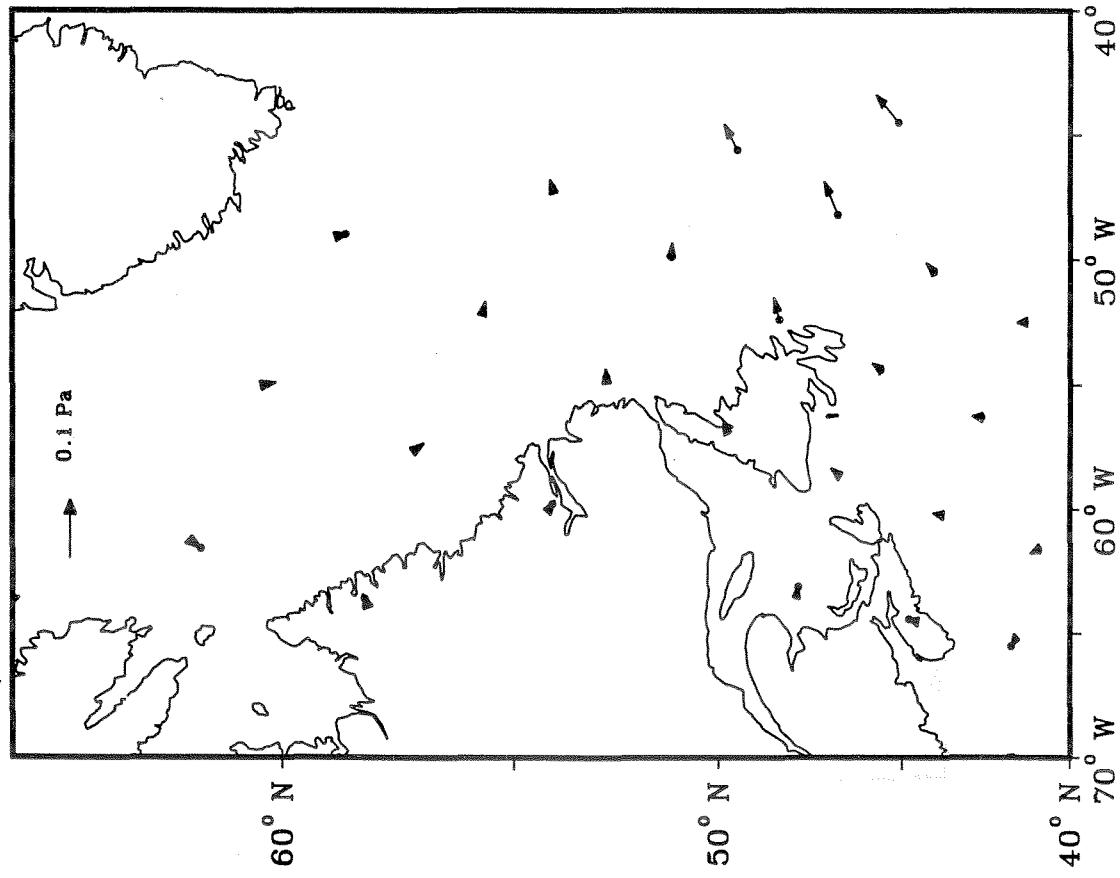


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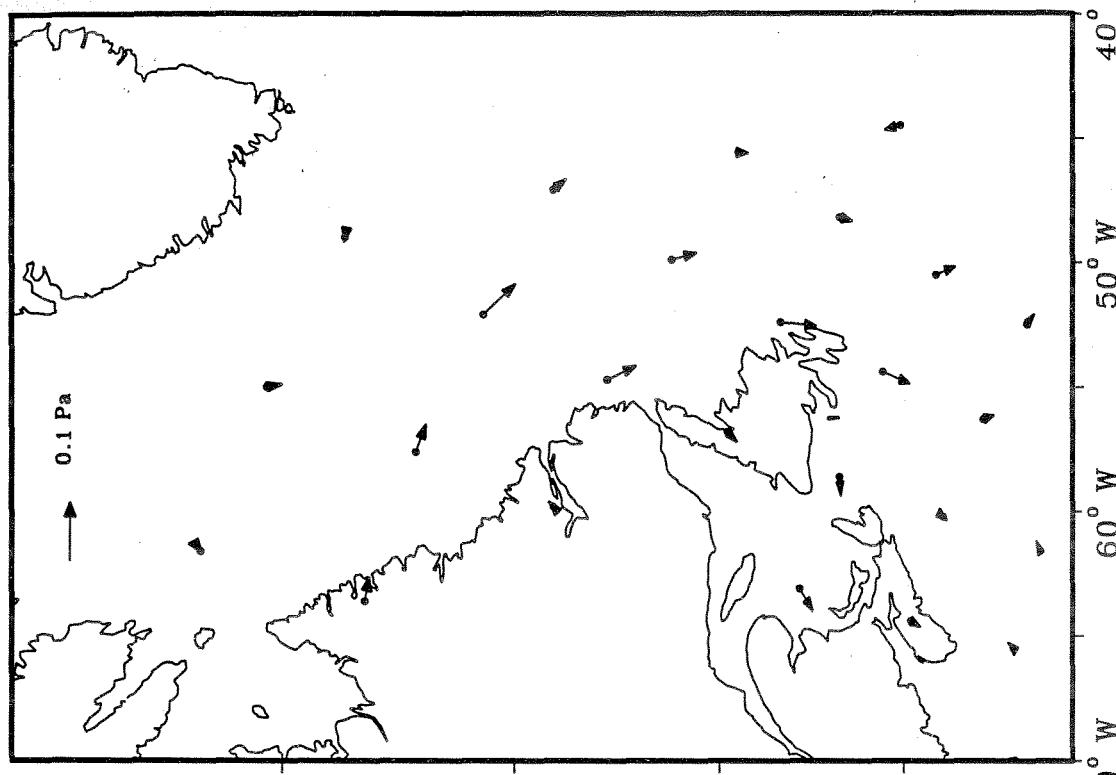
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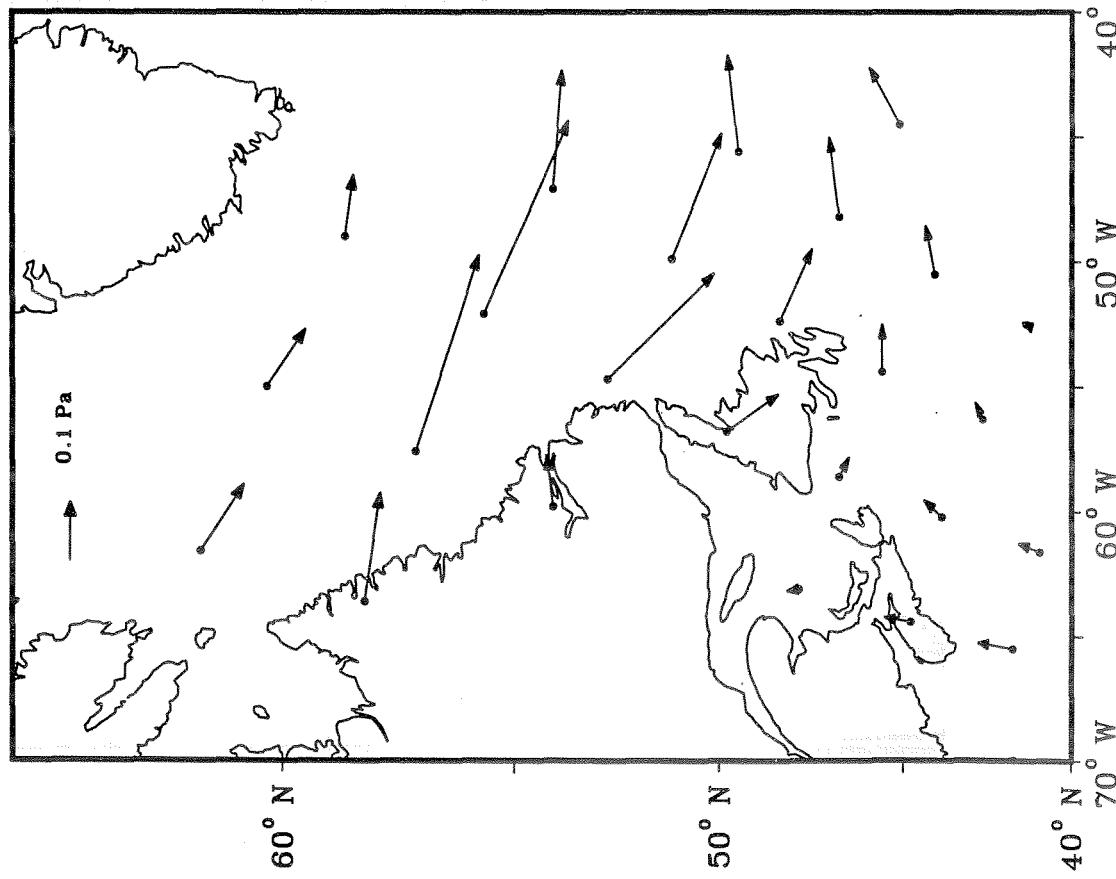
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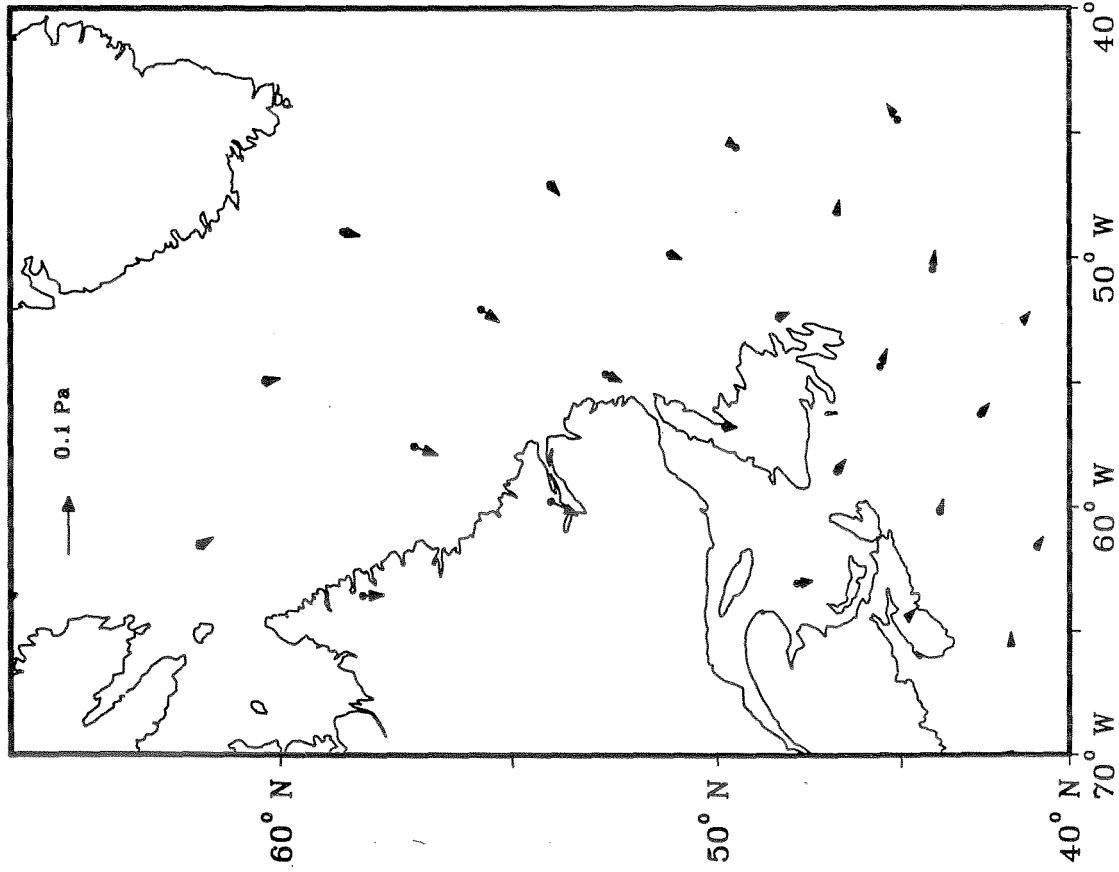
Spring 1991



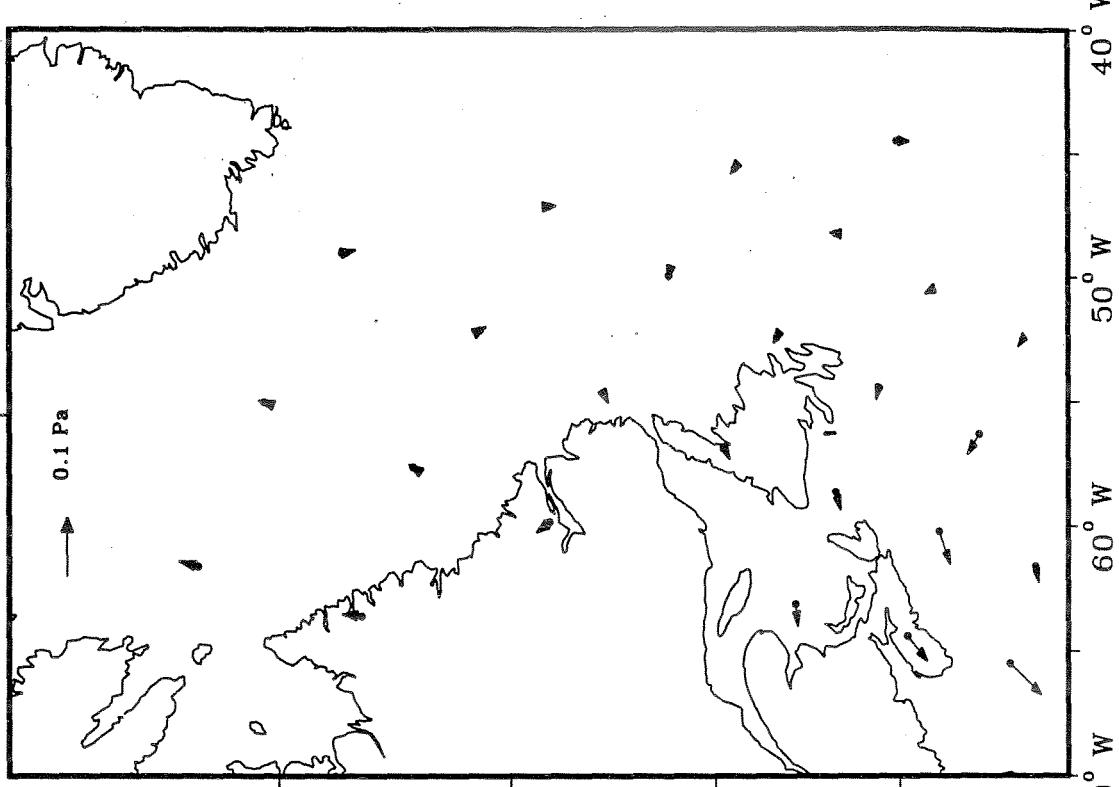
Winter 1991



Summer 1991



Fall 1991



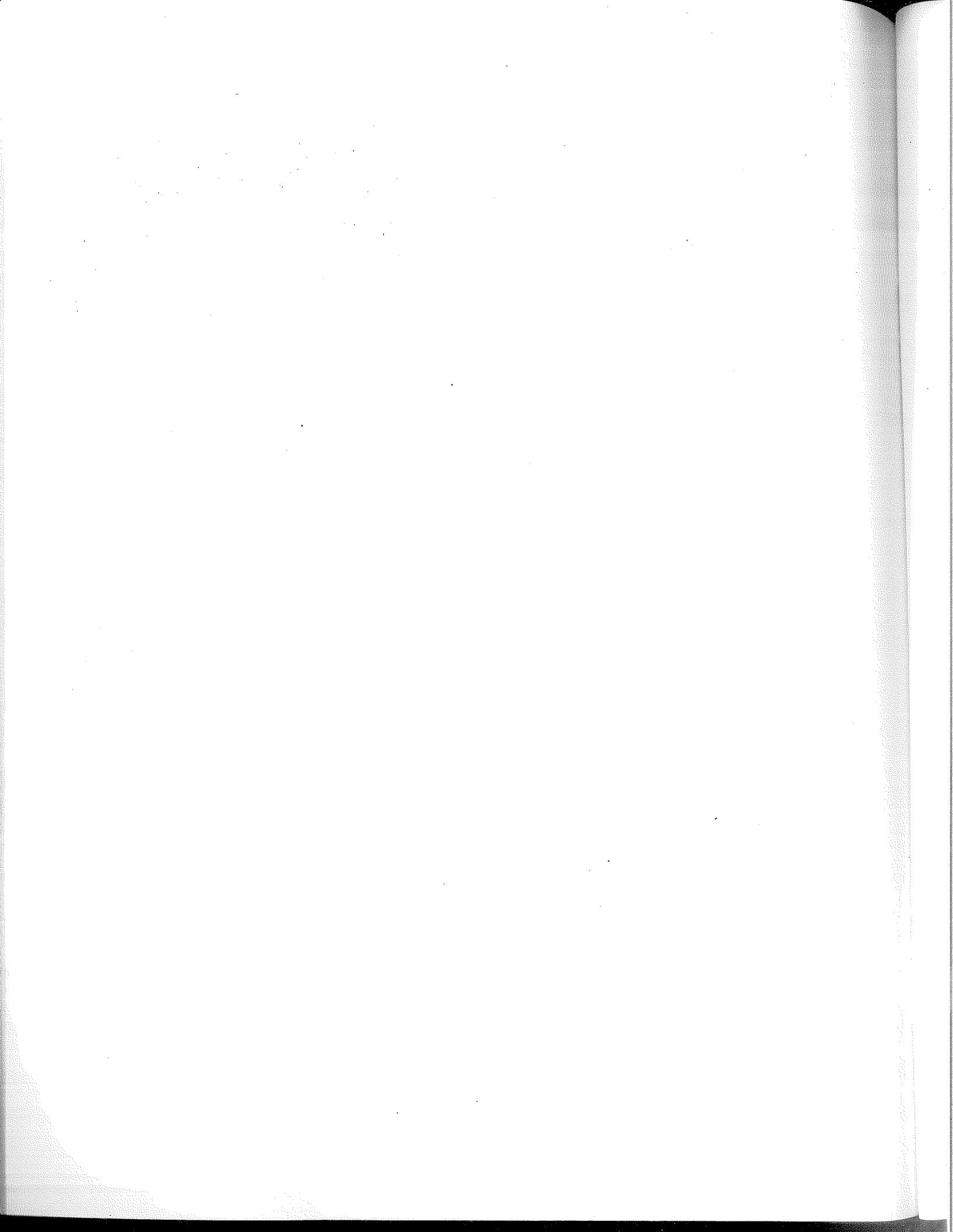
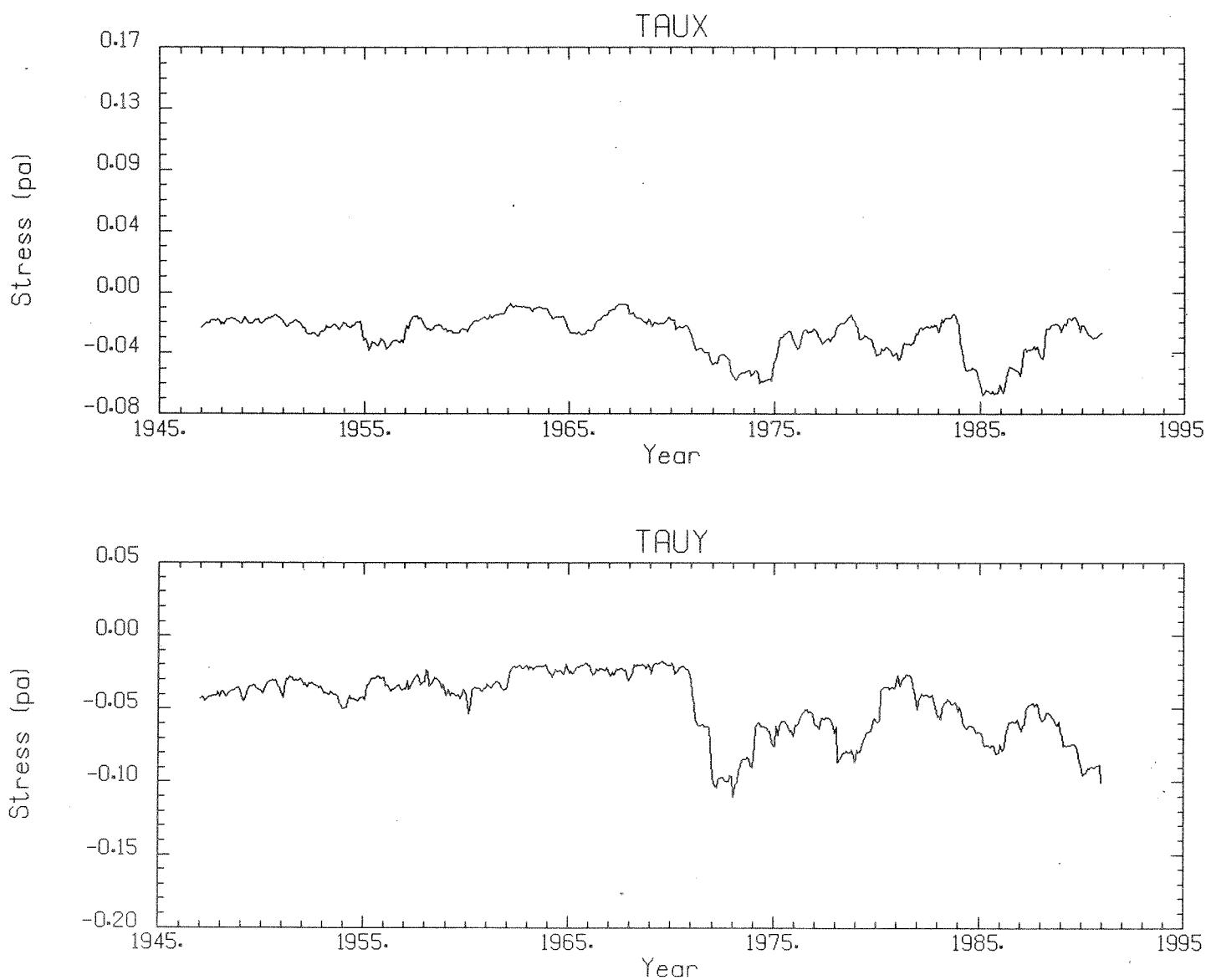
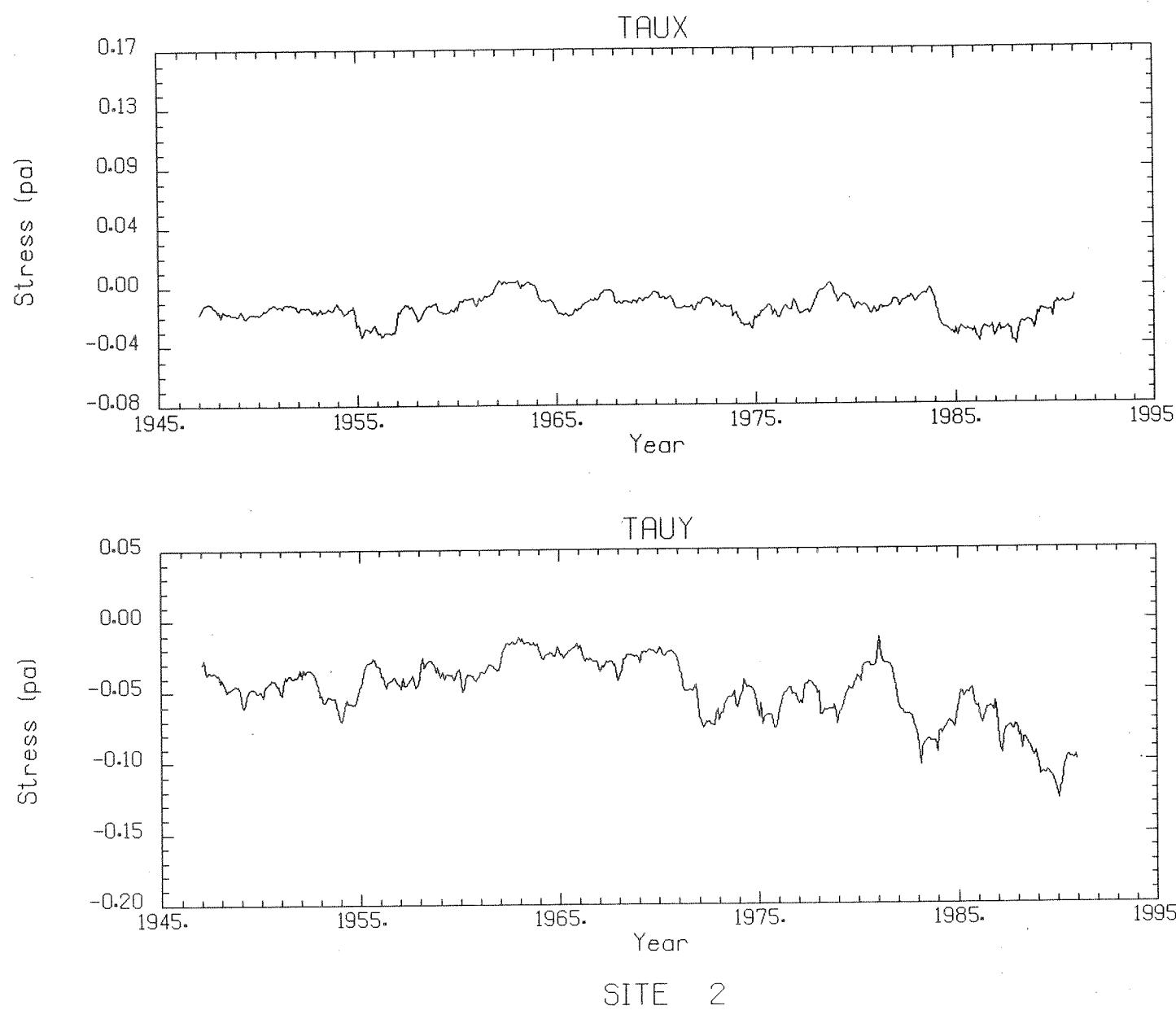


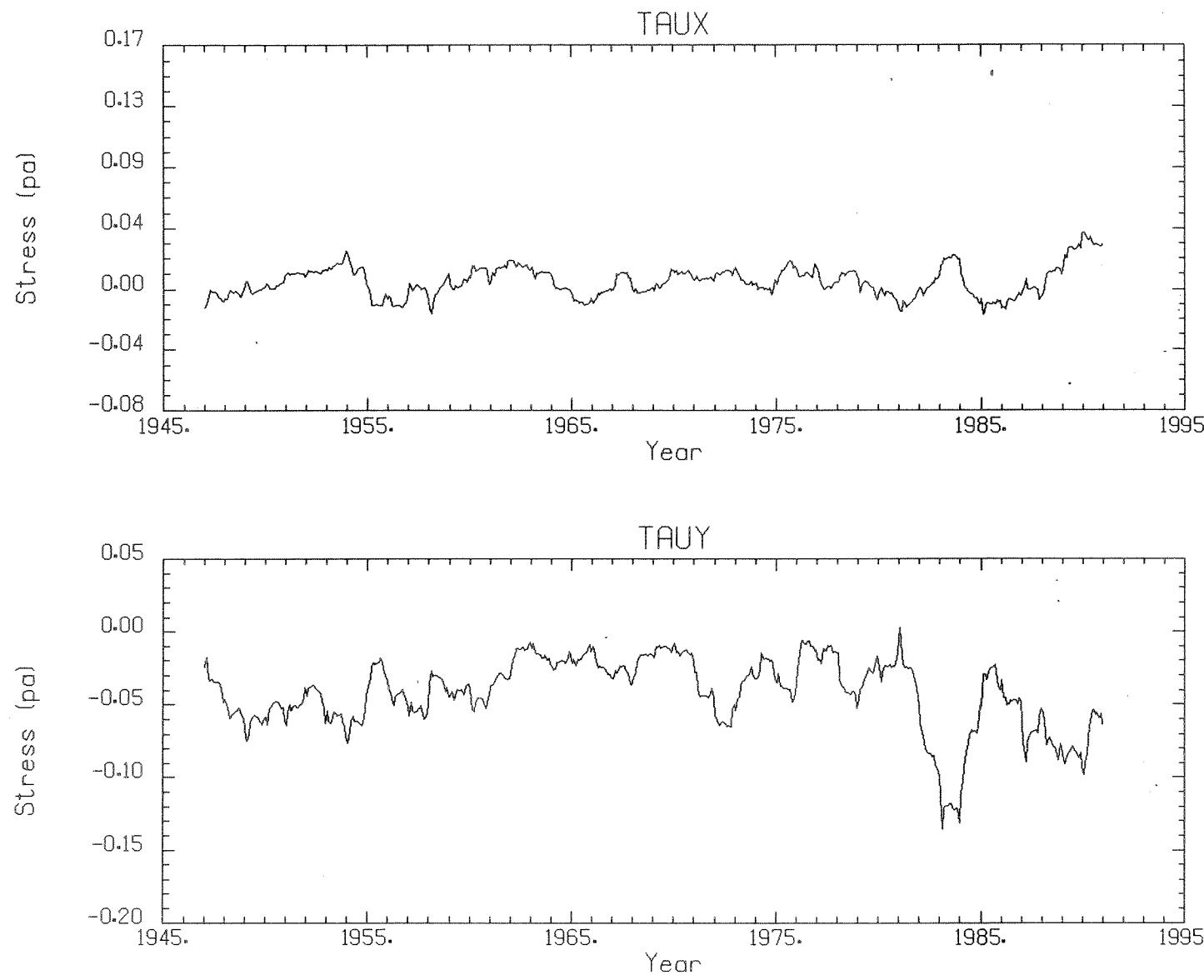
Figure 4

Filtered time series of monthly mean geostrophic wind stresses at each of the 25 sites off eastern Canada (Fig. 1). The filter was a 25-month running mean. τ_x is resolved along 45° (positive is a wind towards the NE) and τ_y is resolved along 315° (positive is a wind towards the NW).

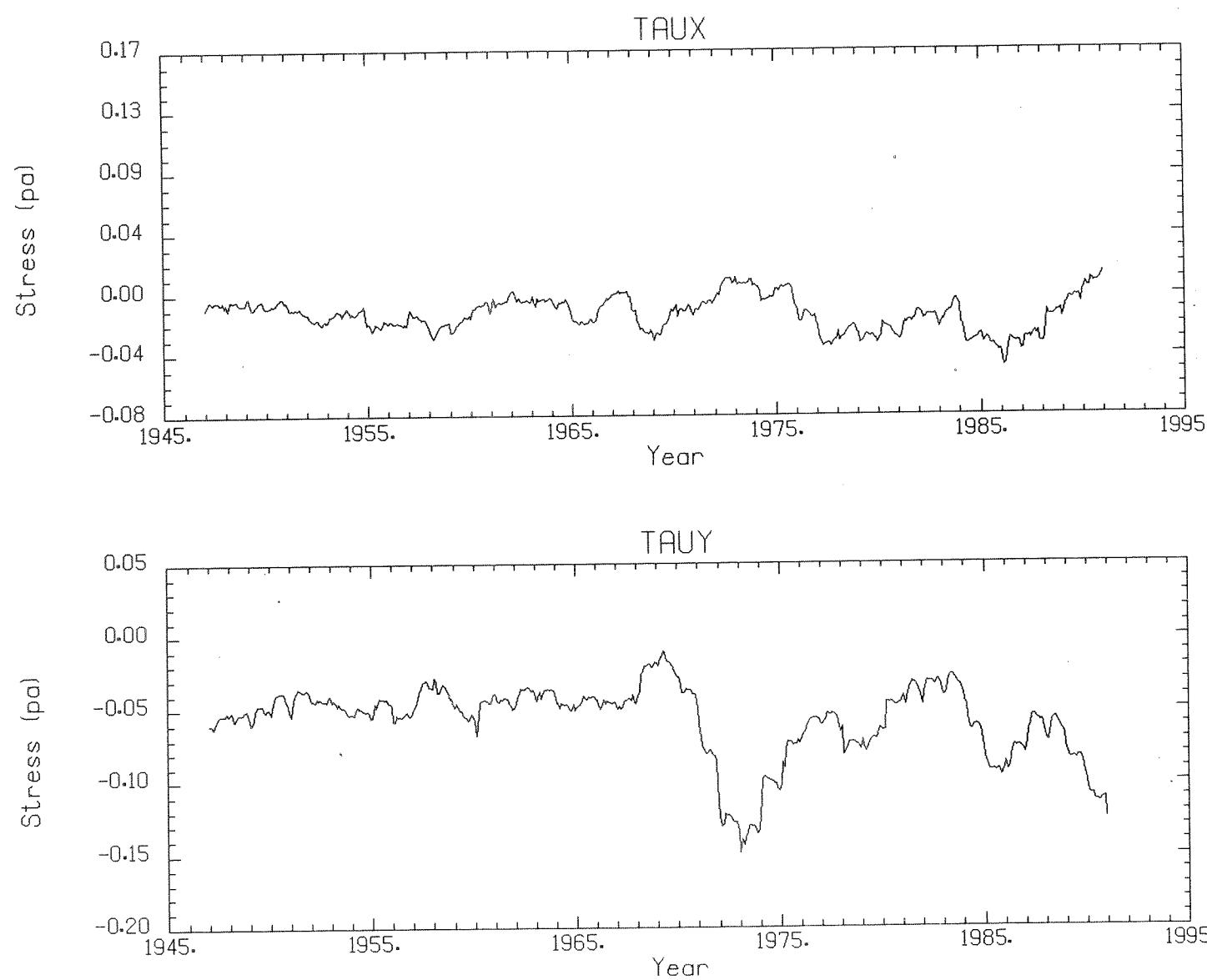


SITE 1

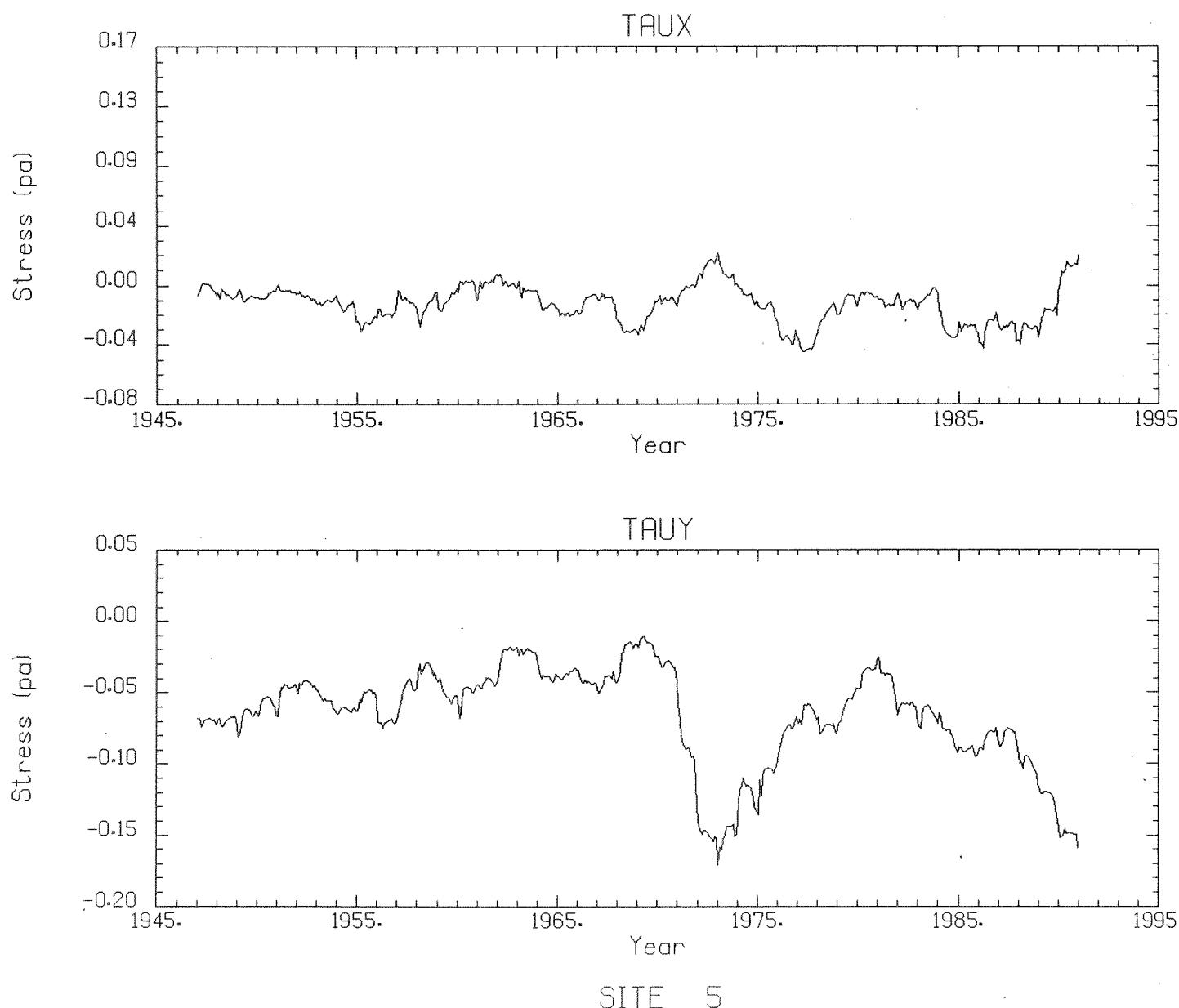


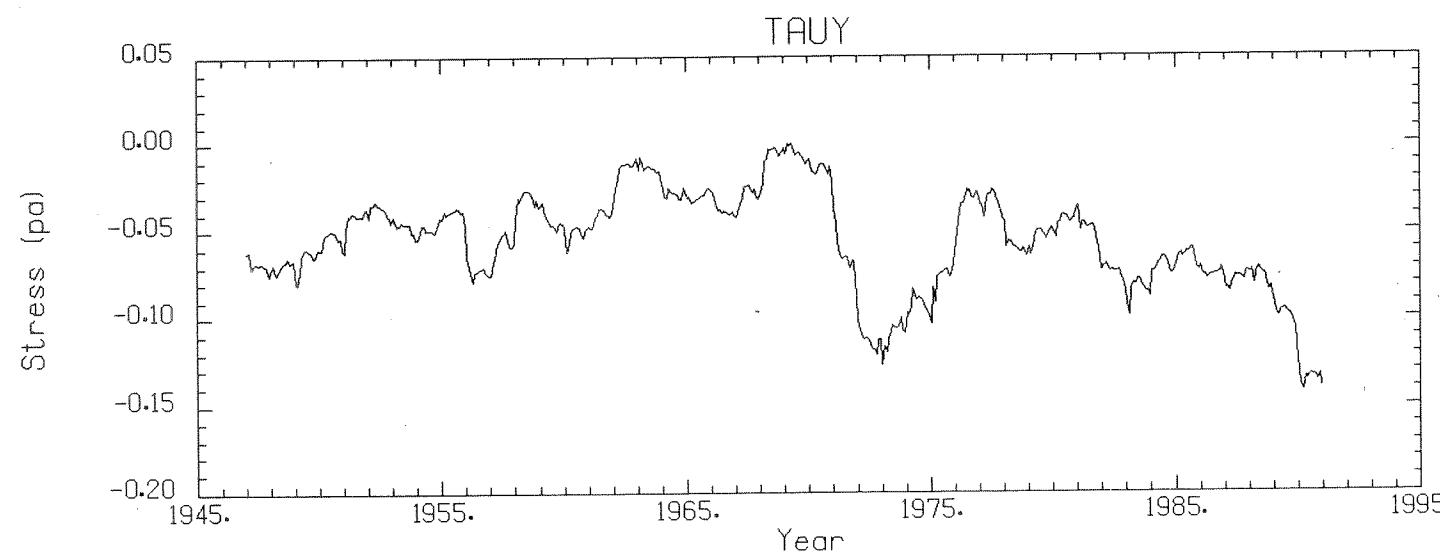
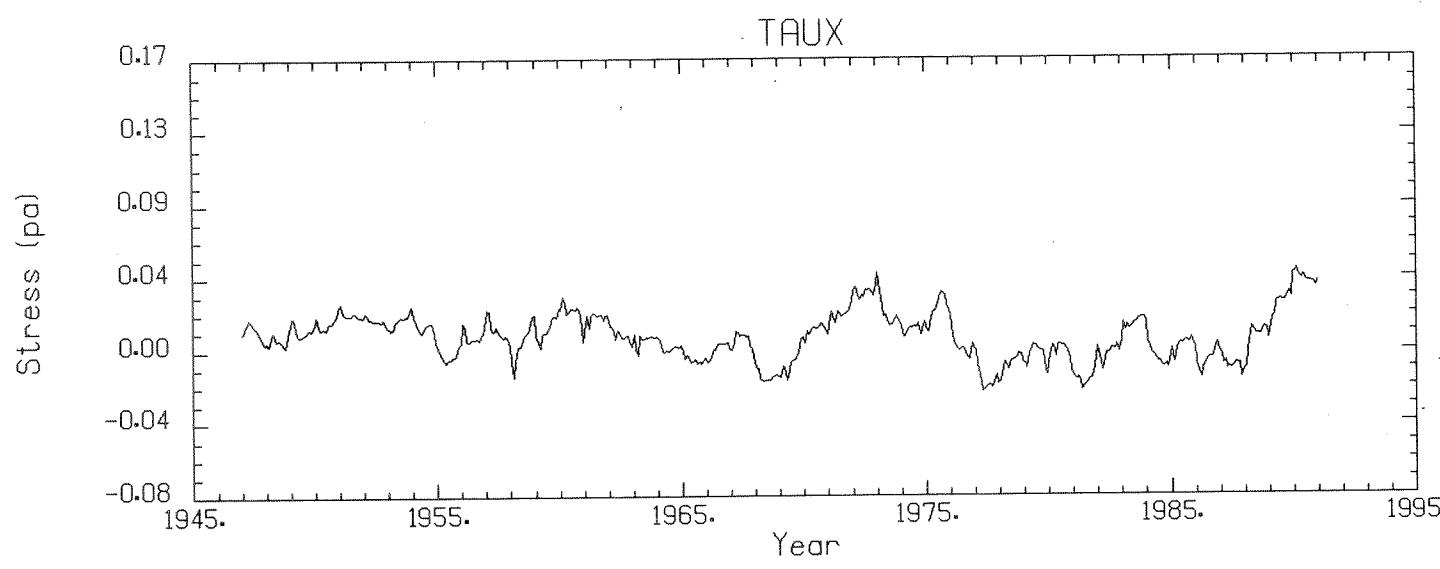


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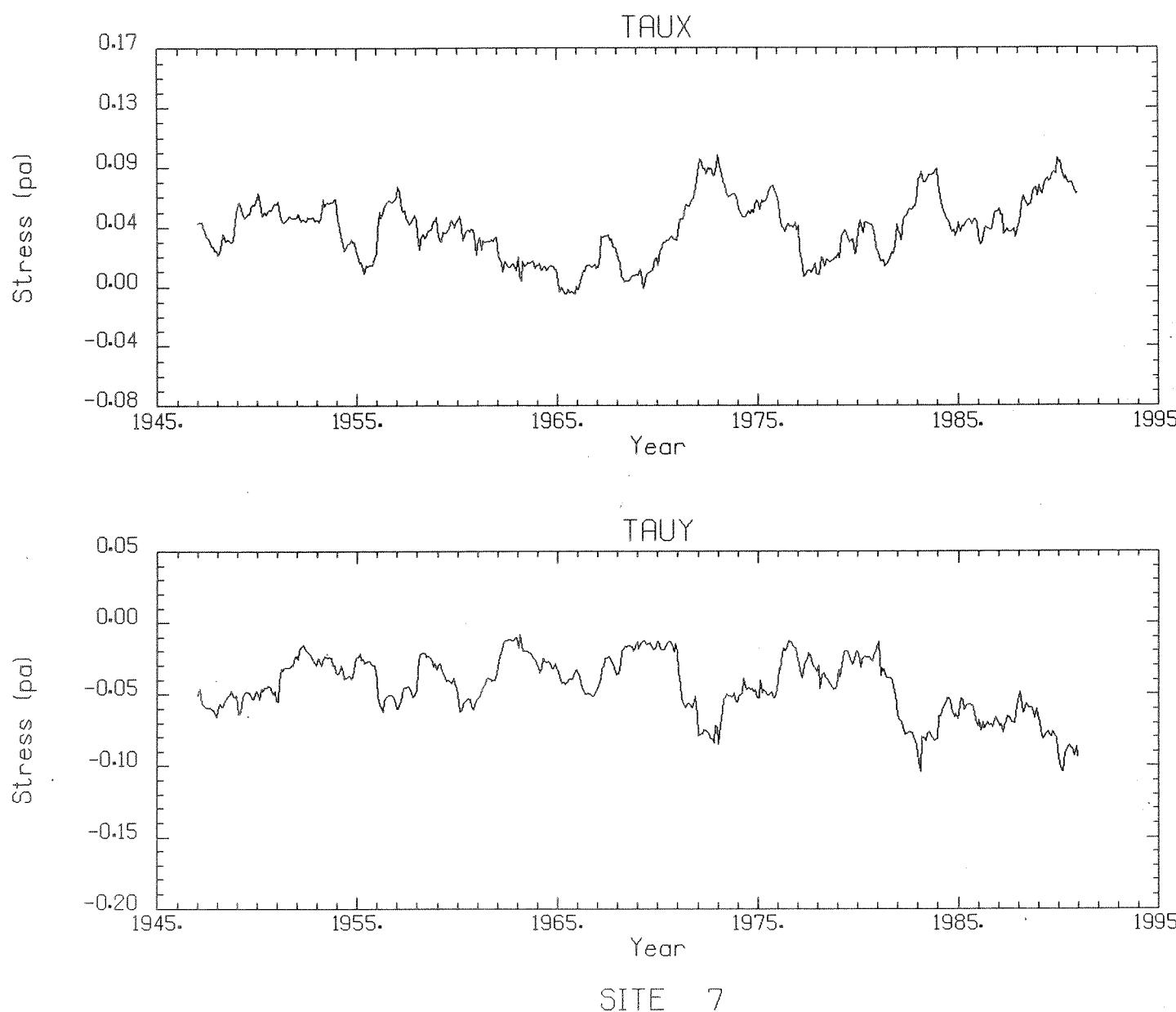


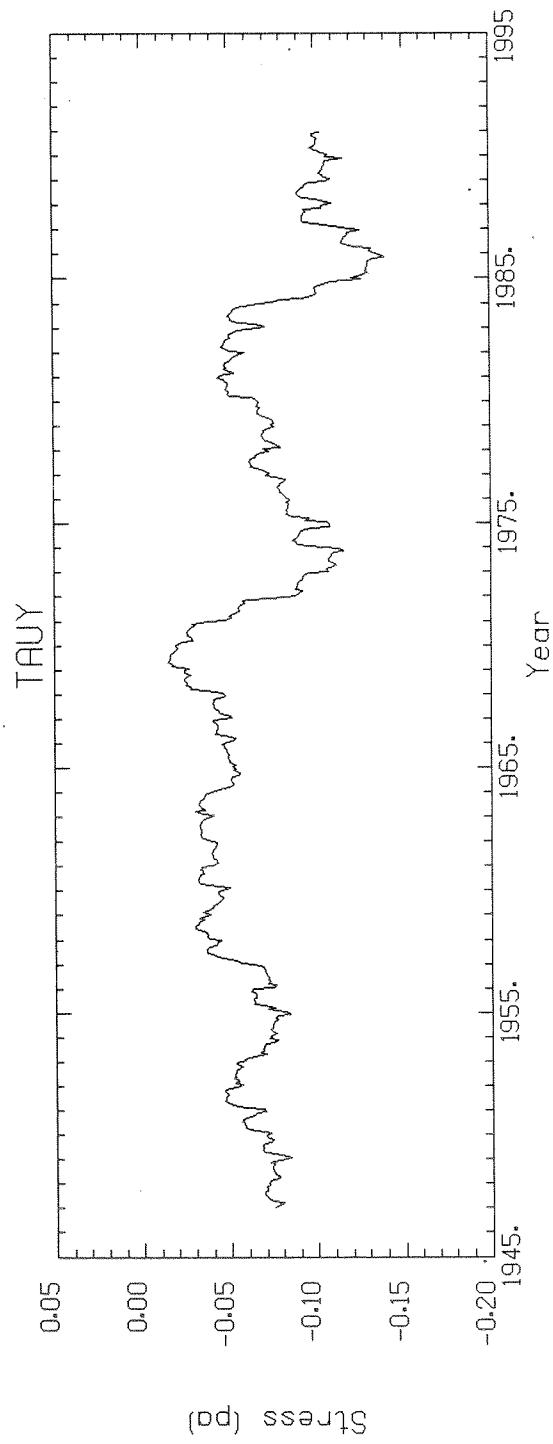
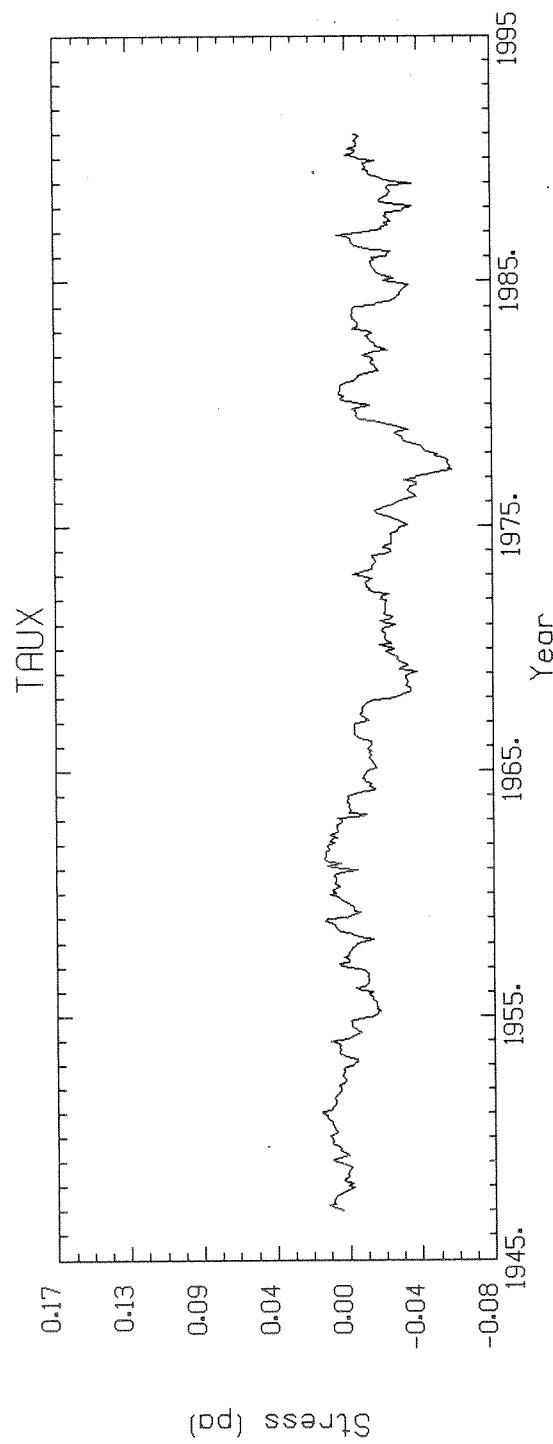
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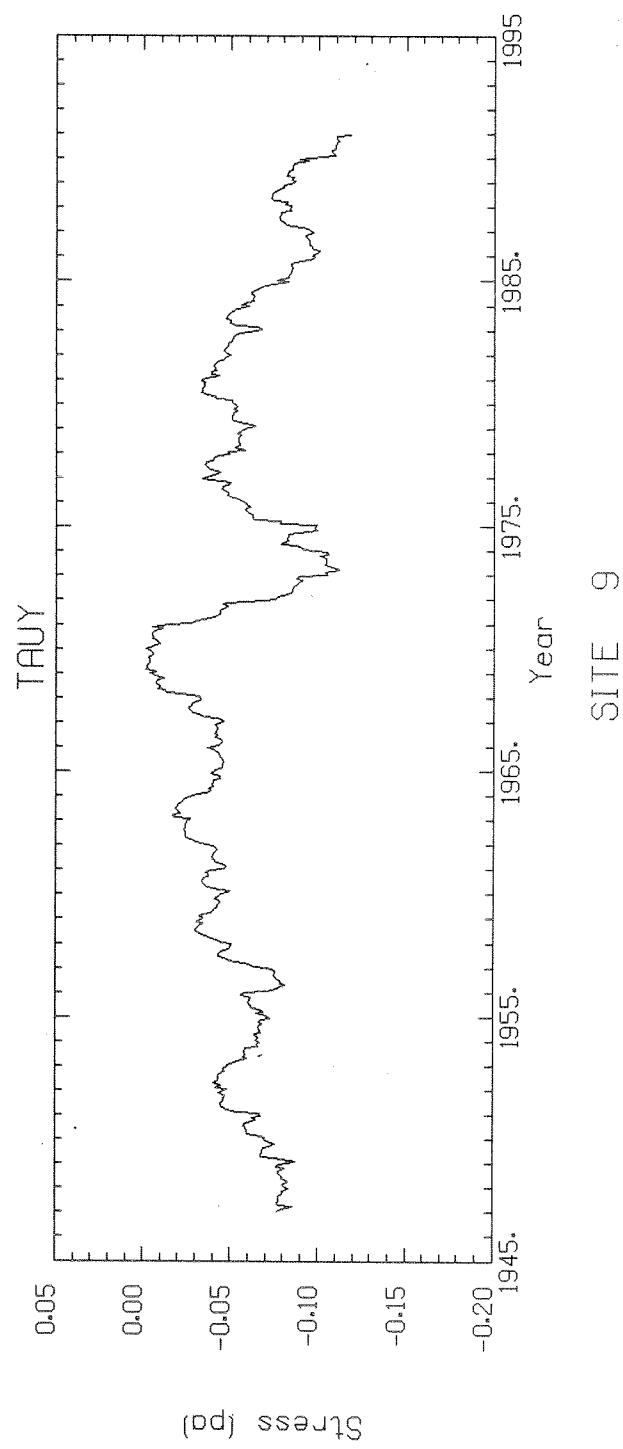
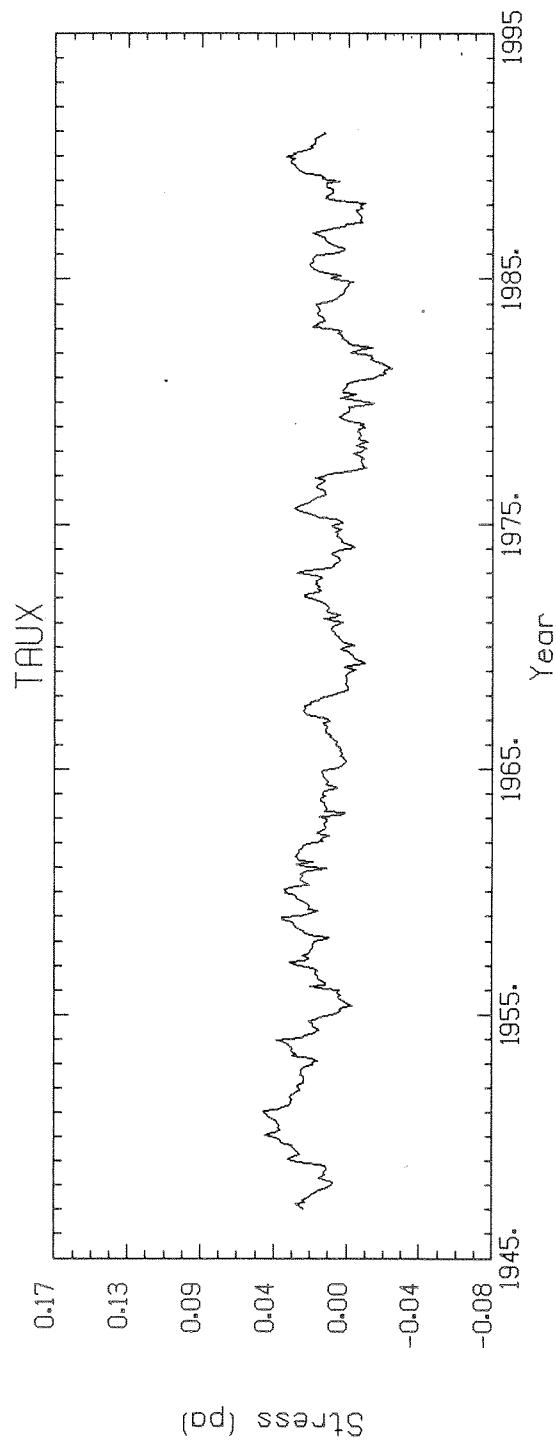


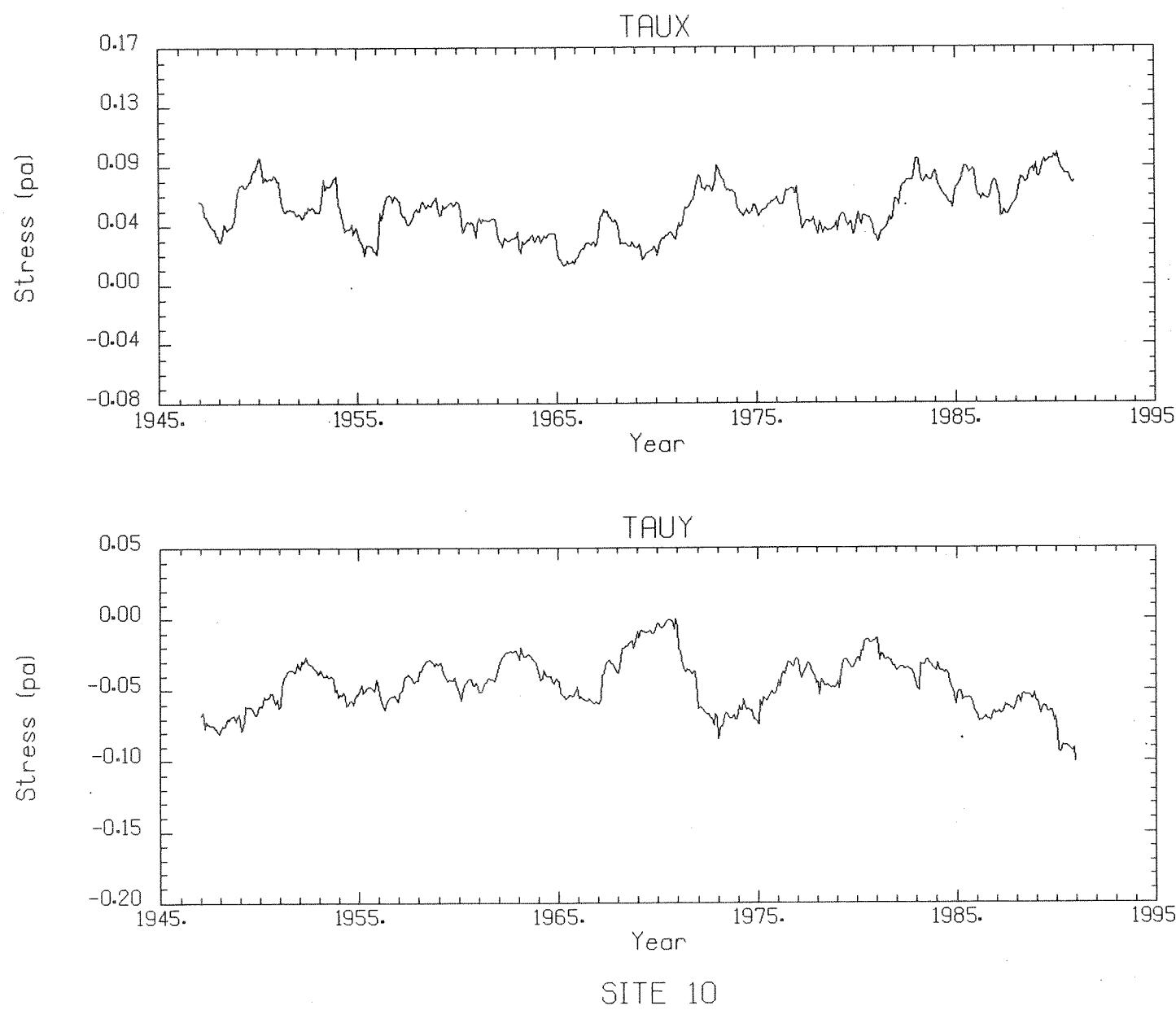
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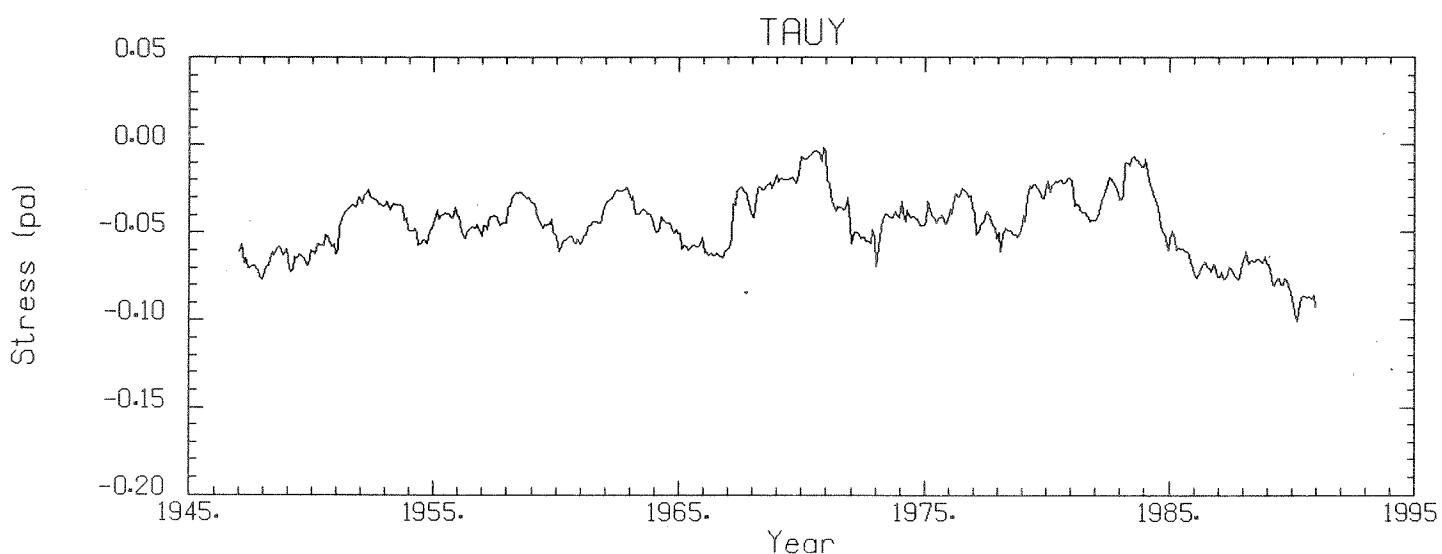
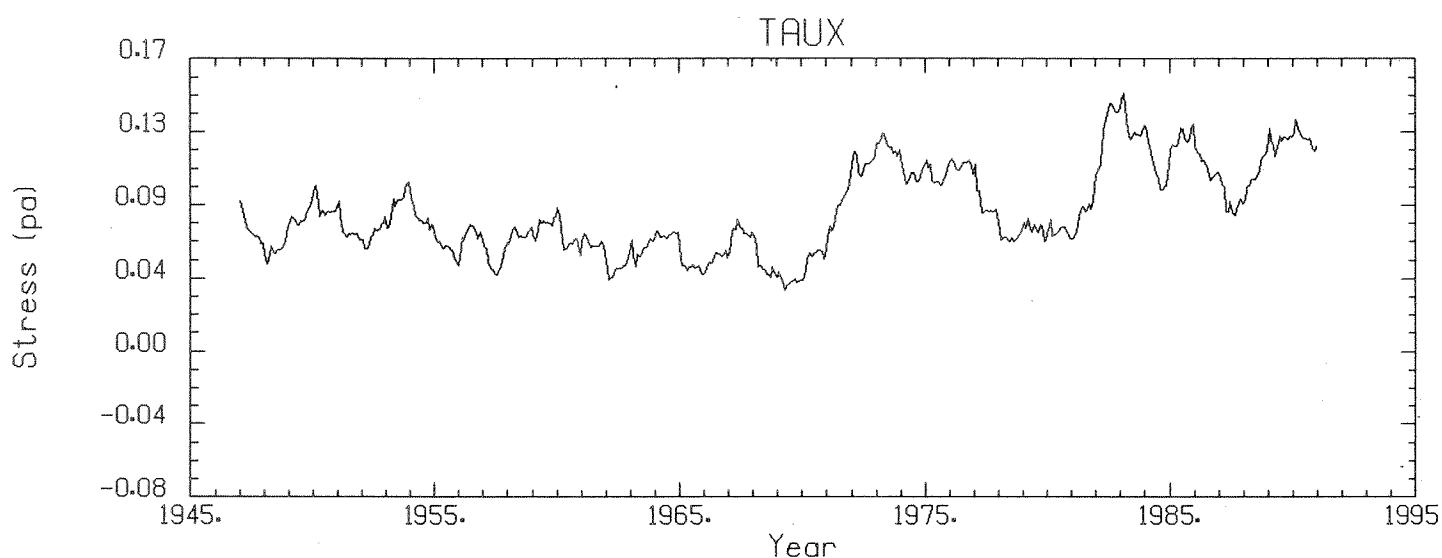




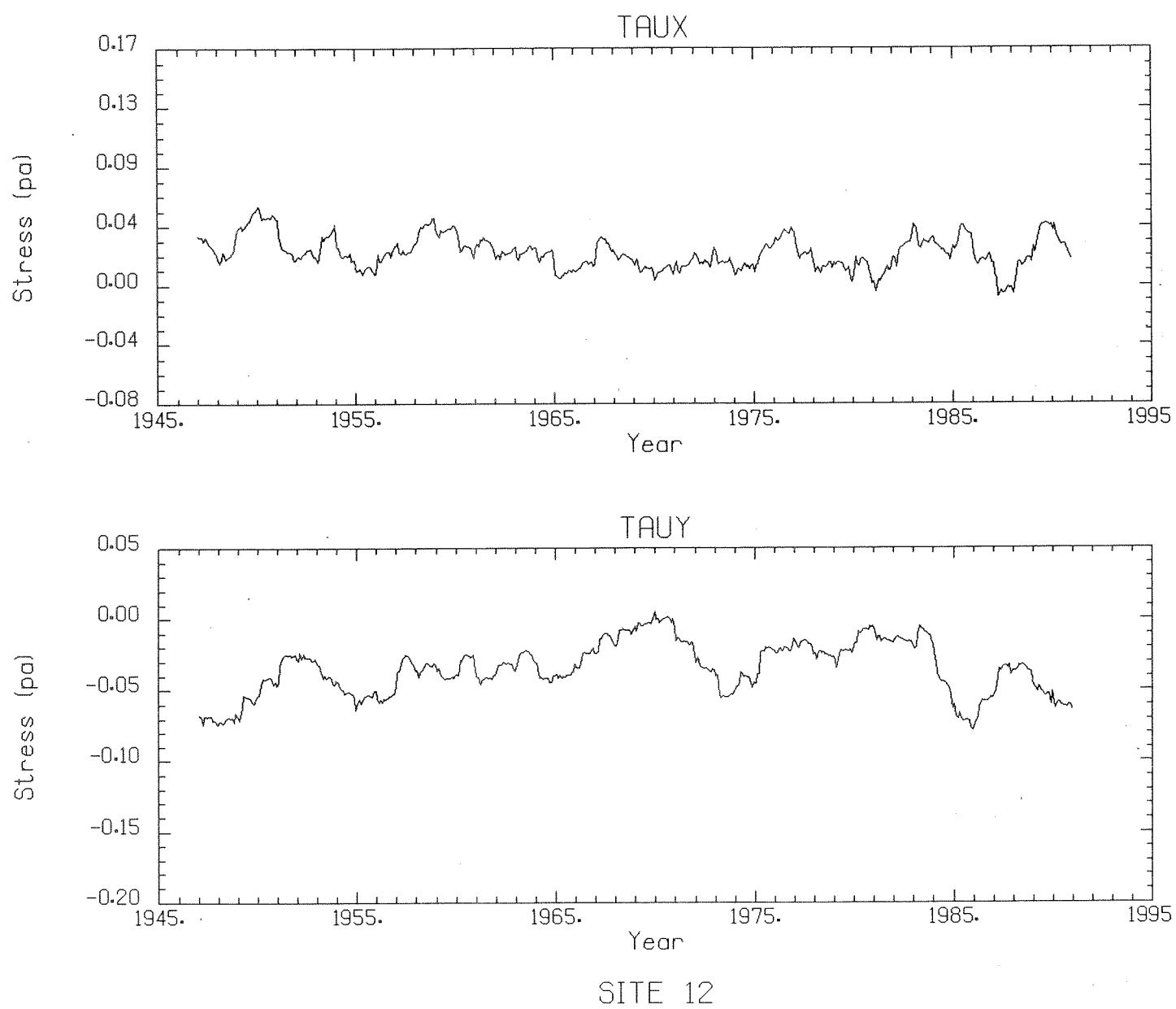
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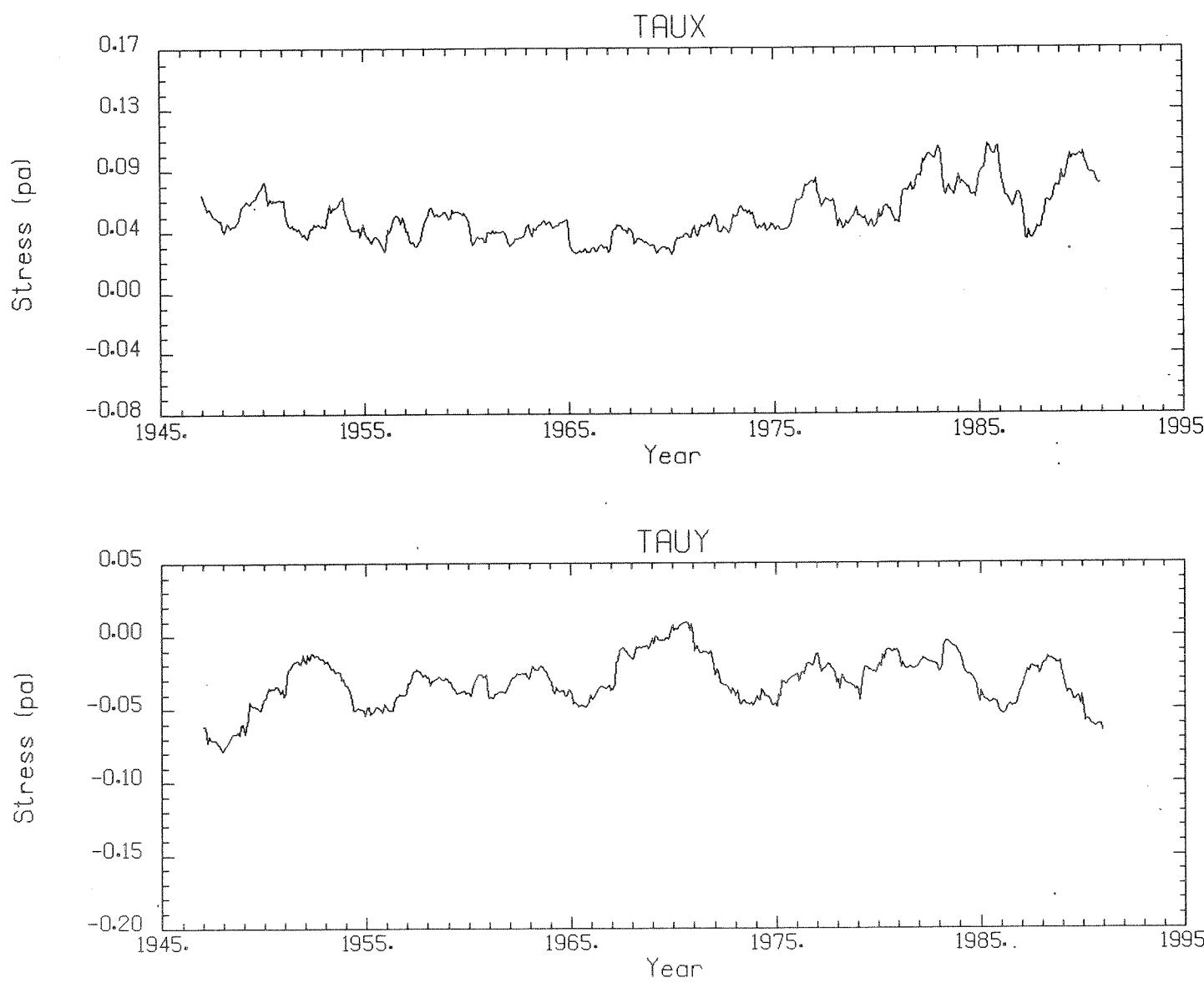




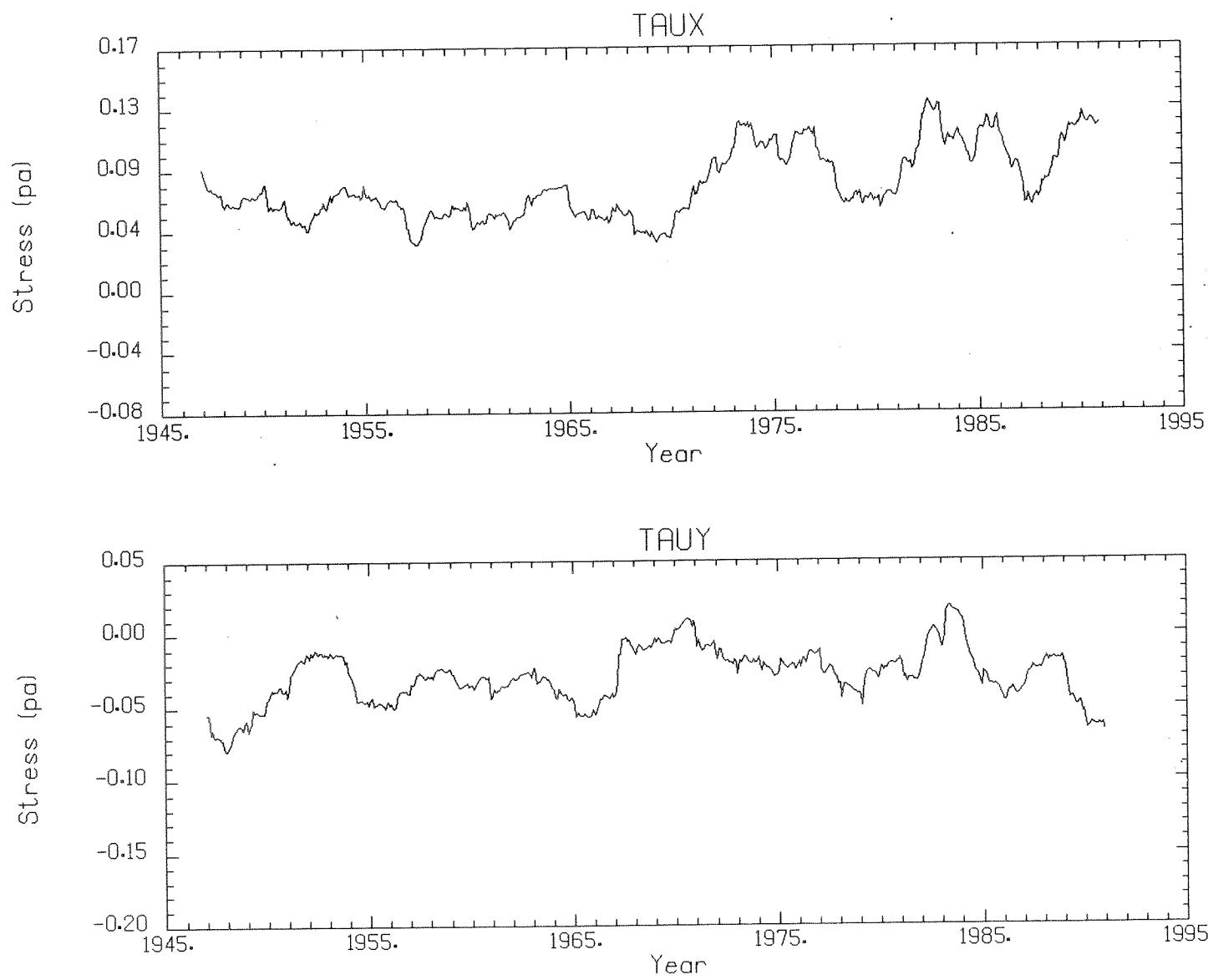


SITE 11

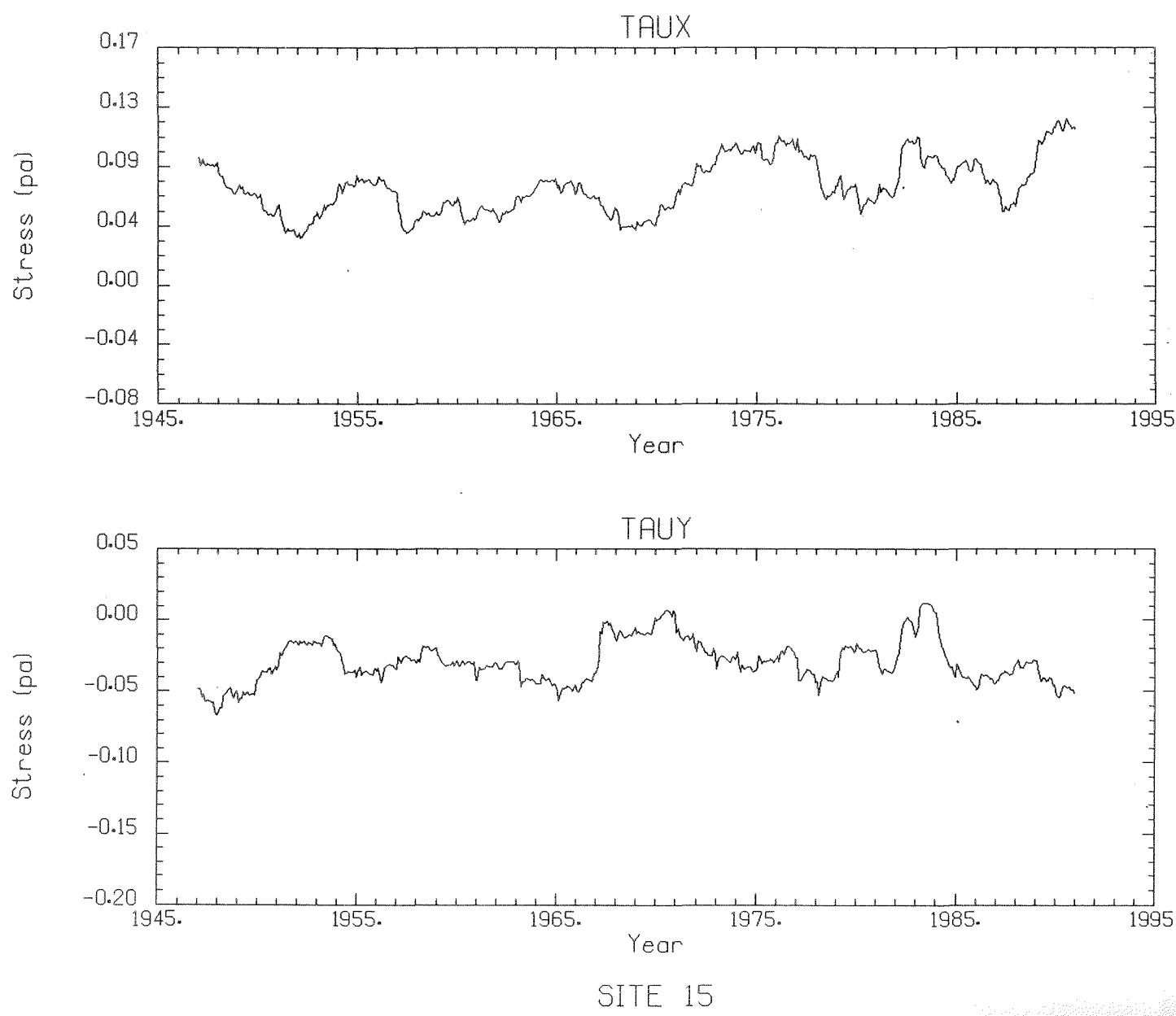


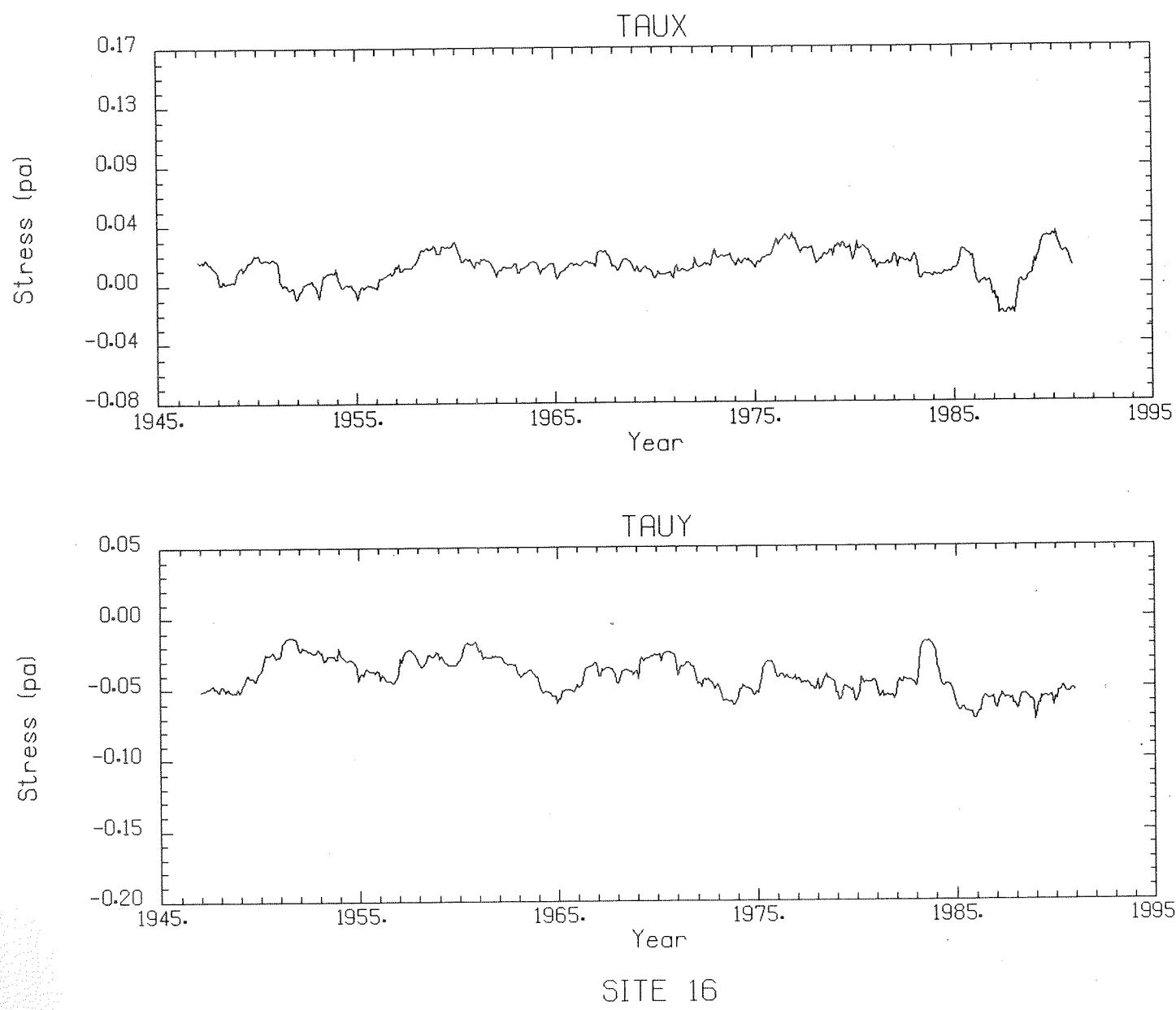


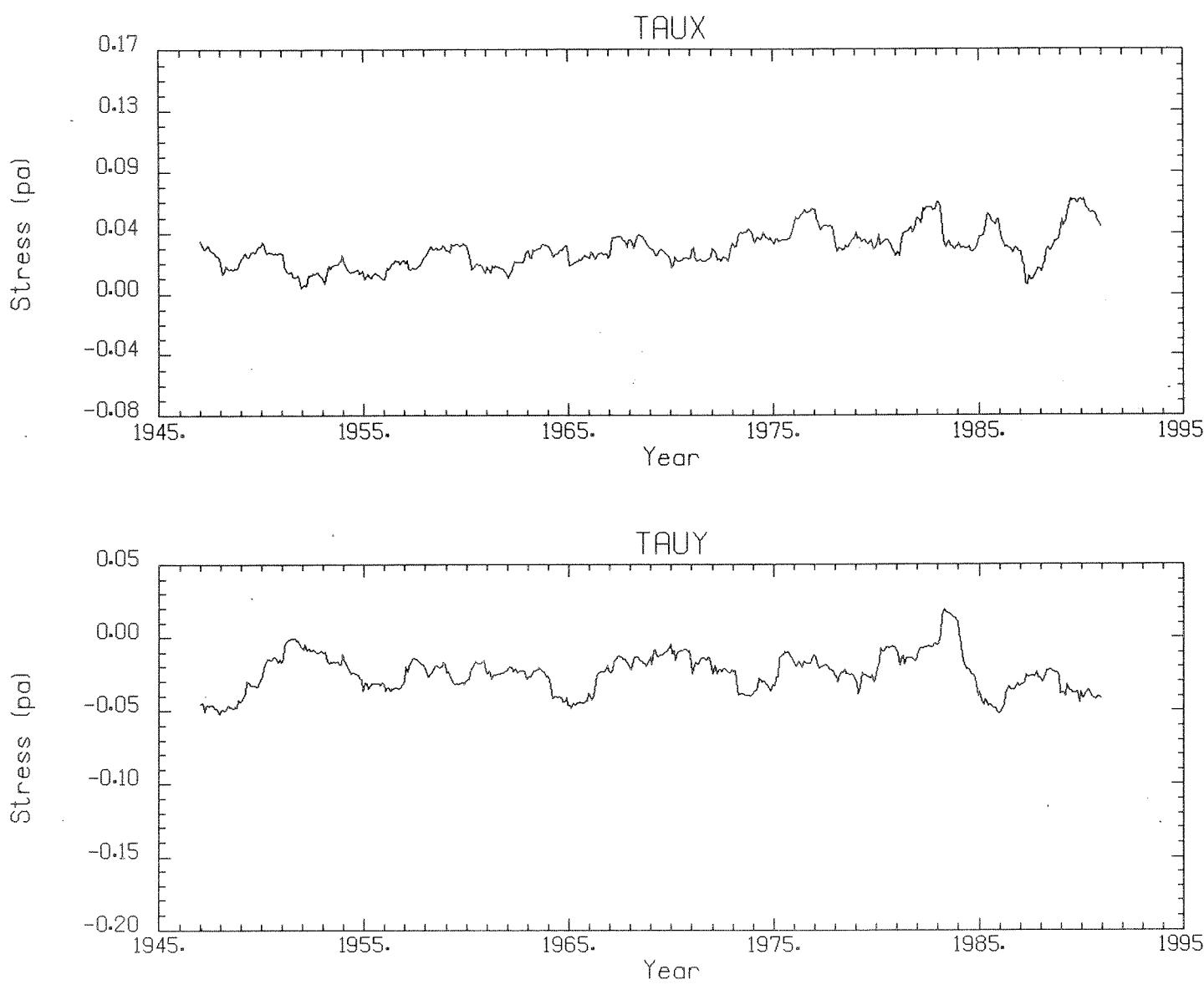
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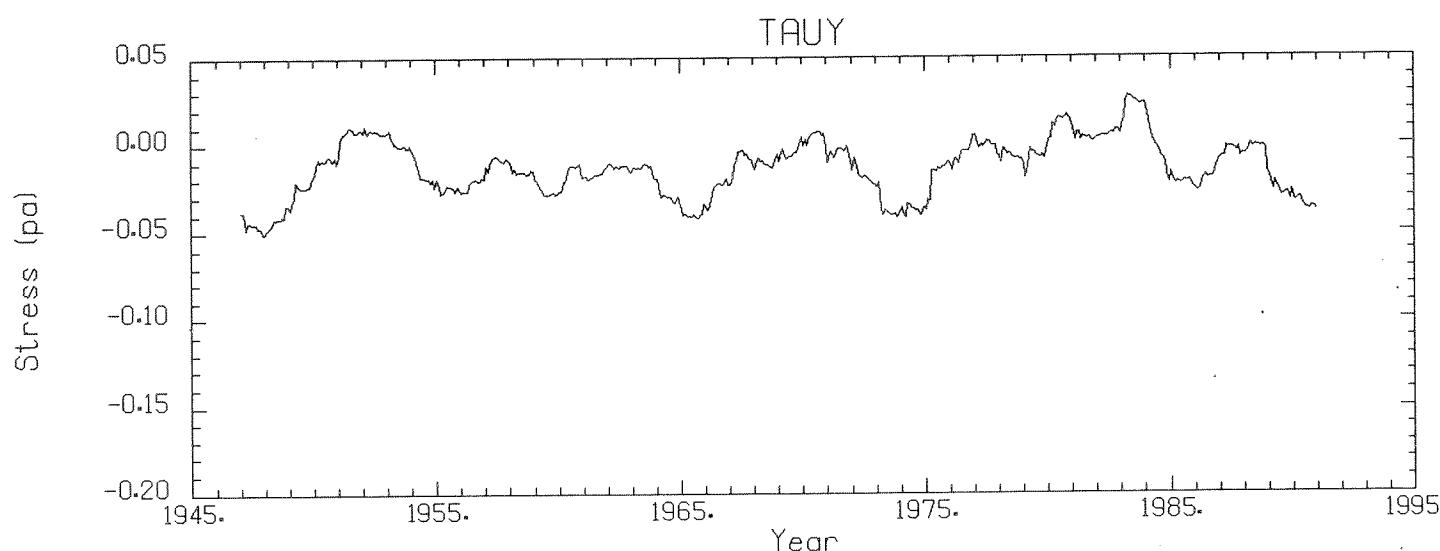
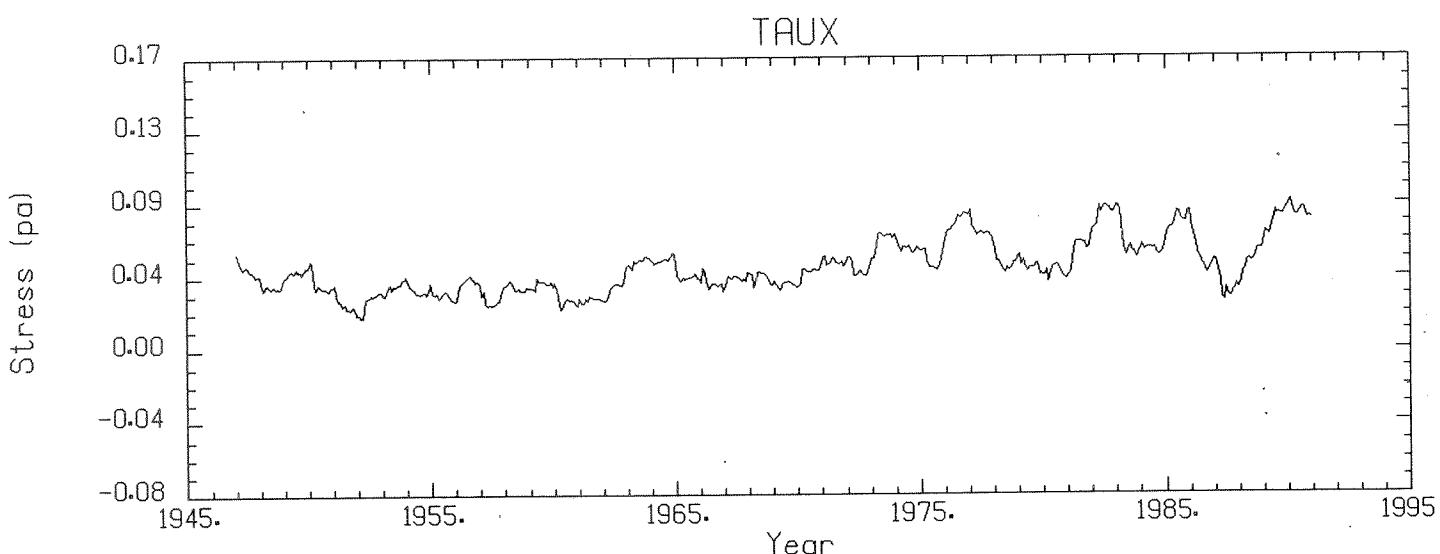
SITE 14



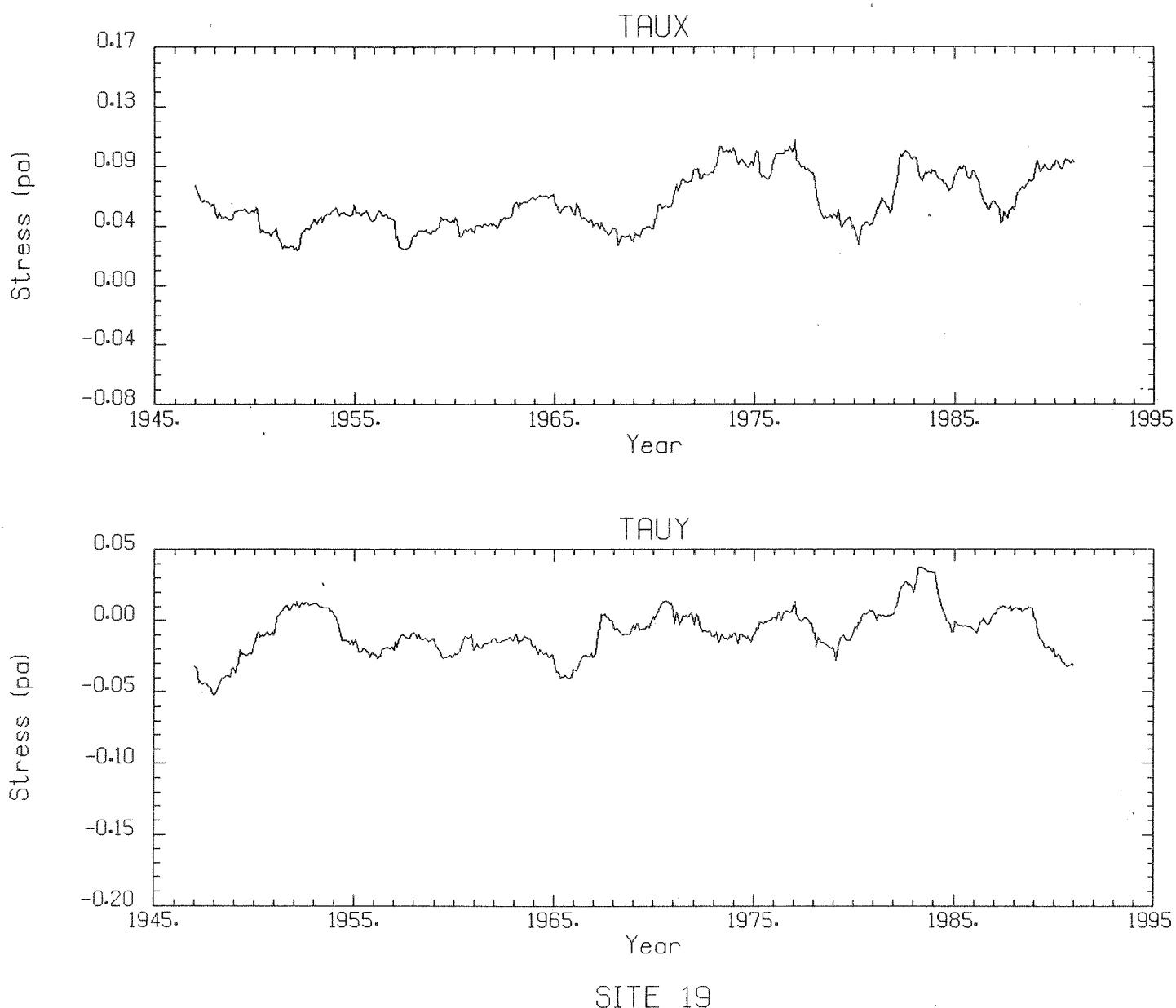


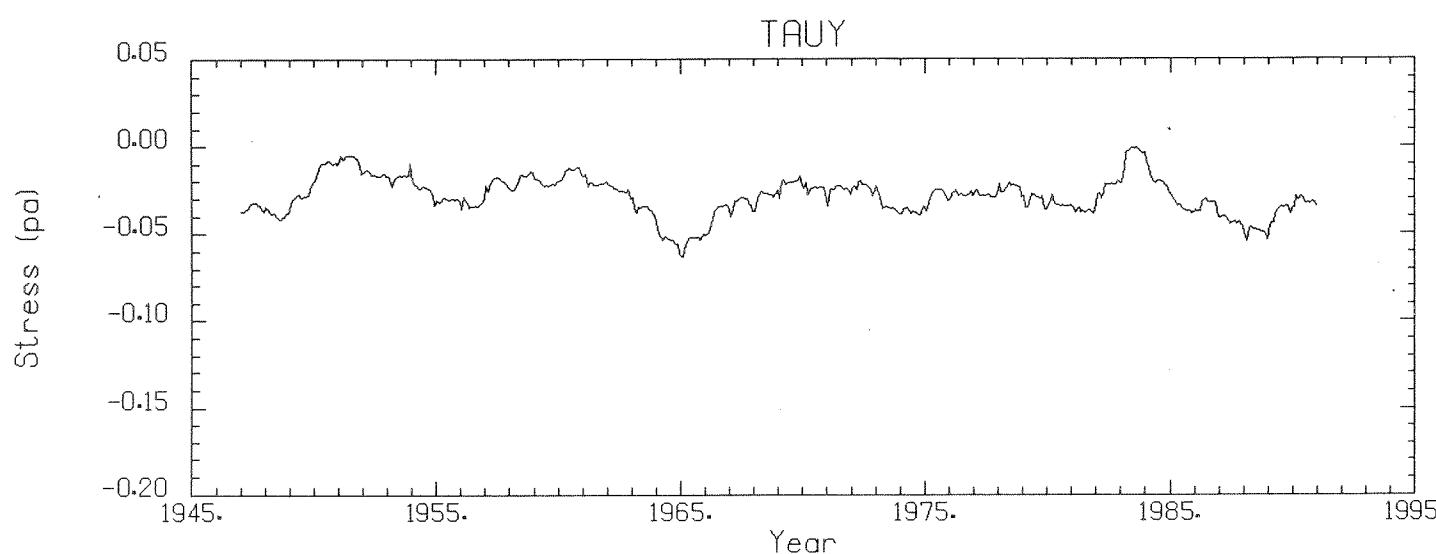
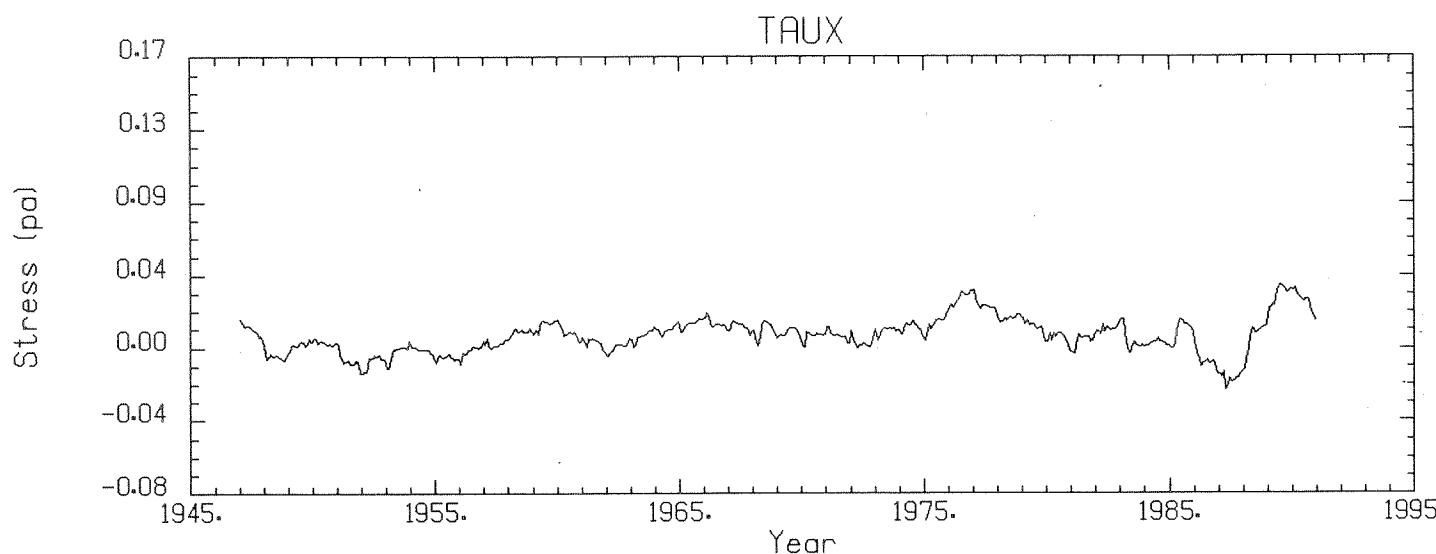


SITE 17

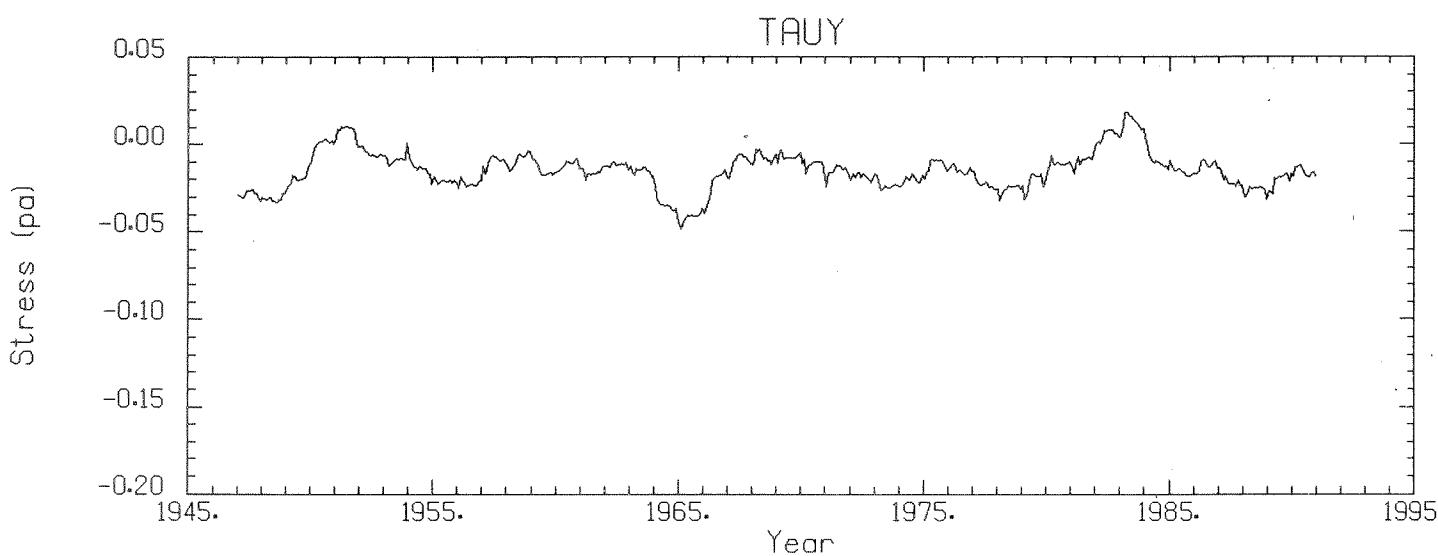
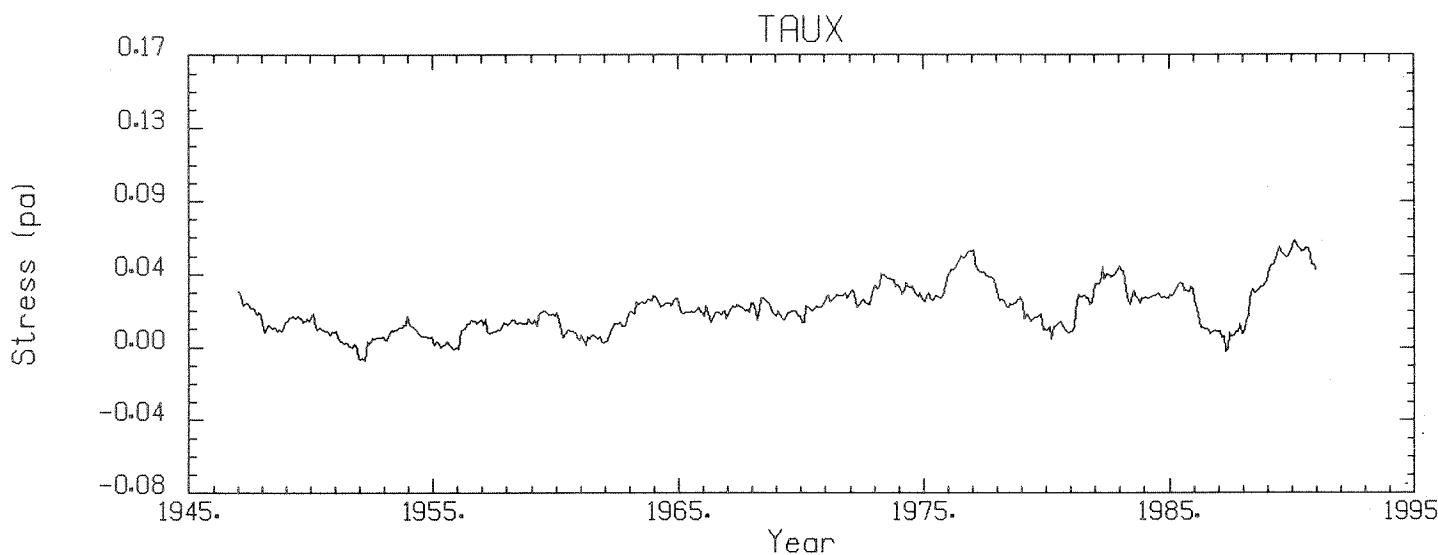


SITE 18

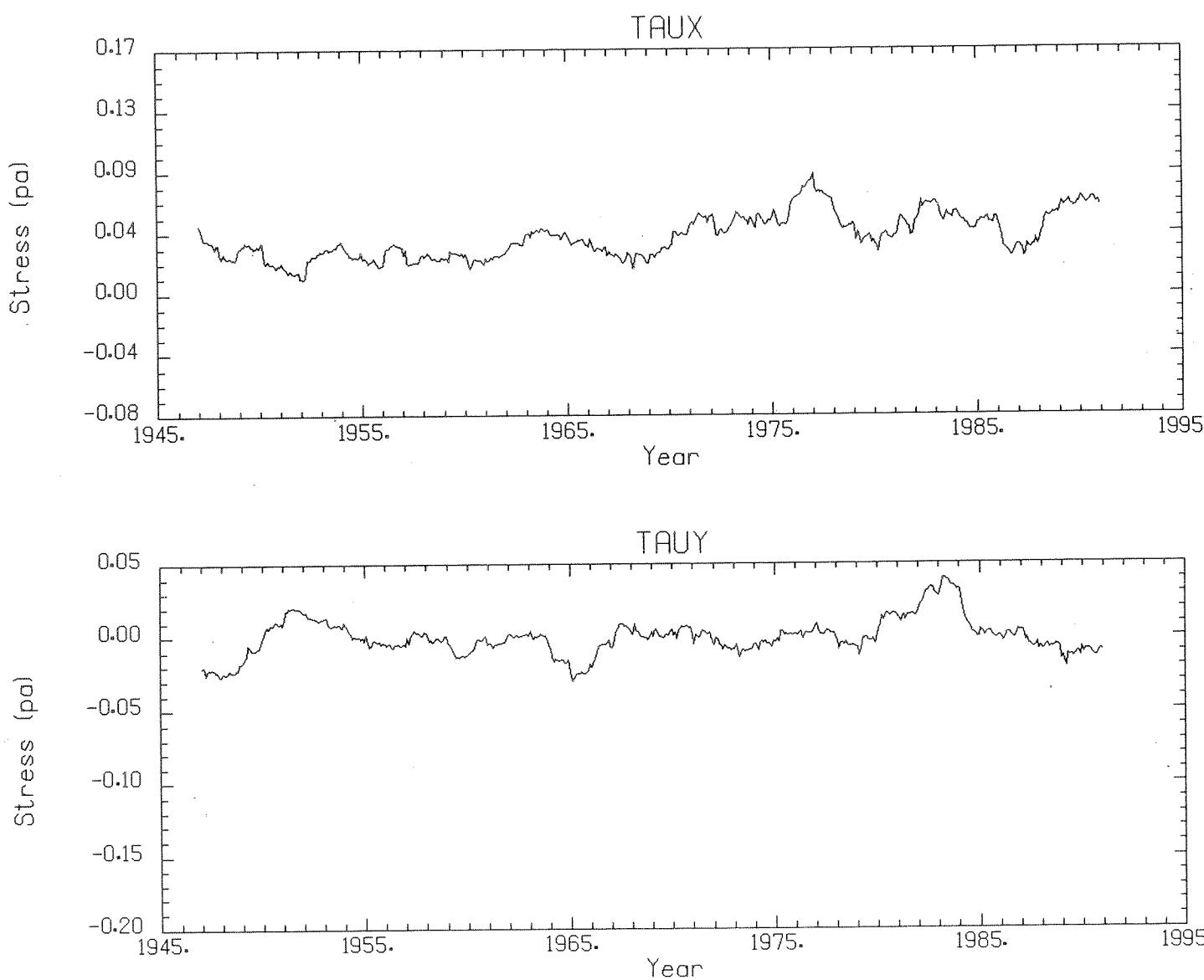




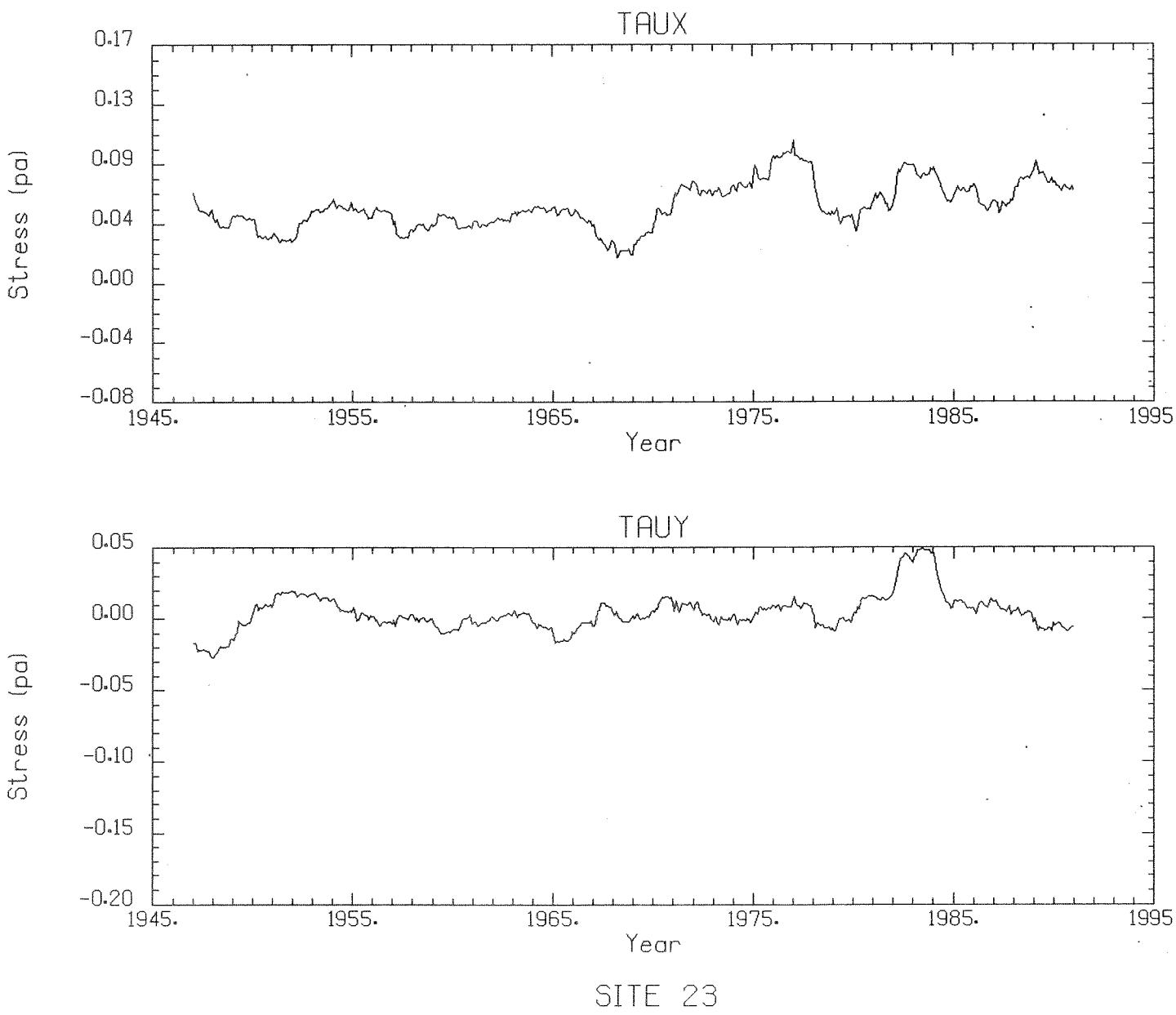
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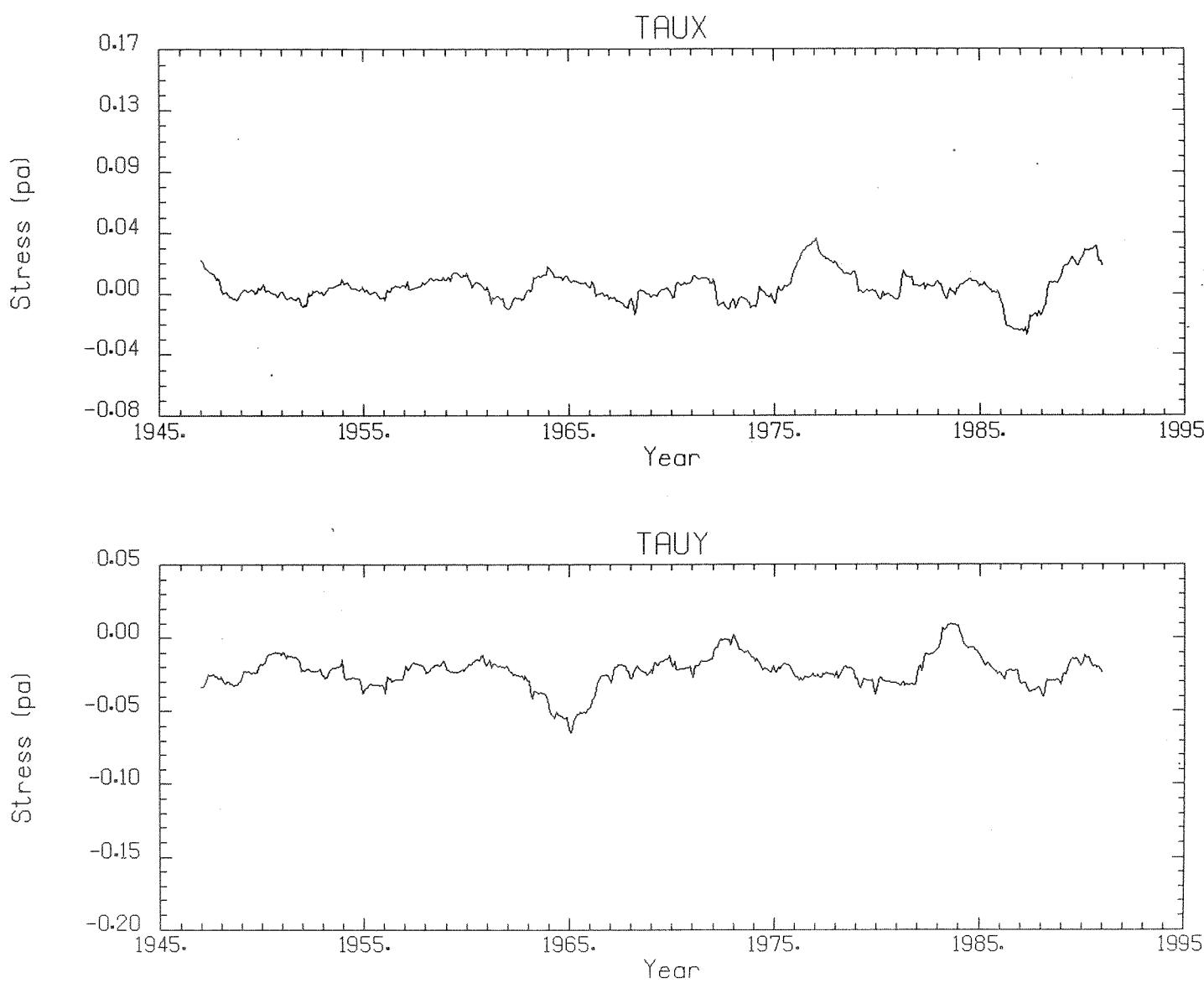


SITE 21

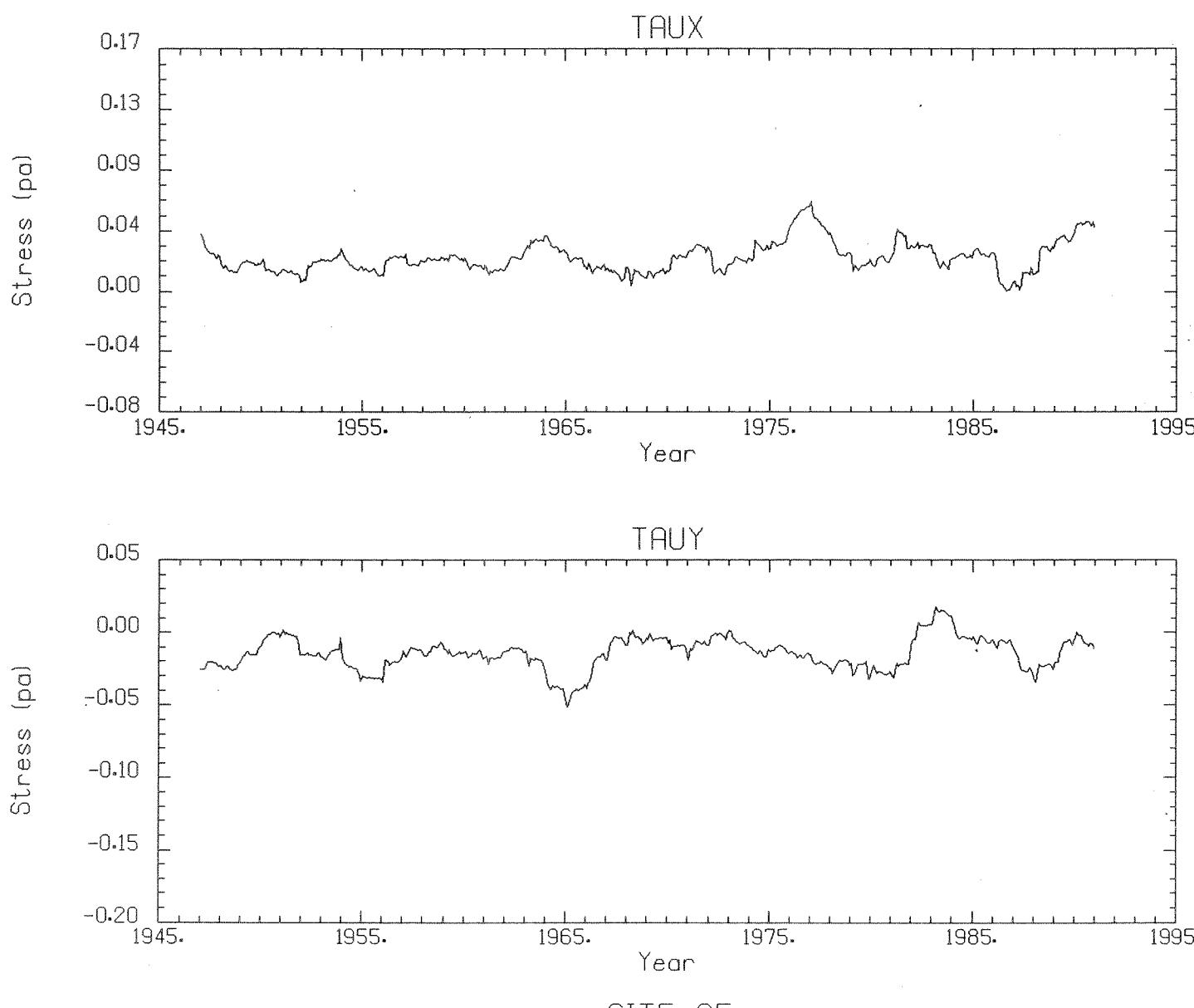


SITE 22





SITE 24



SITE 25