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Overview of Oceanographic Conditions off the Northwest Atlantic in 1988

by

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INTRODUCTION

The paper reviews oceanographic conditions in NAFO Subareas 0, I, 2 and 3 from the Northwest Atlantic in 1988. The overview is based on the data obtained during 3 cruises conducted by PINRO in spring-summer (March-June) and autumn-winter (September-December). Data on monthly temperature anomalies of the sea-surface and air temperature in the near the ground layer, charted in the Hydrometeorological Center (Moscow), were also used. Overview of ice conditions is based on the data obtained in the Hydrometeorological Center (Murmansk).

Conditions observed in 1988 are compared to those of the previous year and long-term mean conditions.

METHODS

Observations over water temperature and salinity were made at irregular grids of trawl stations and standard sections. Water temperatures were measured at standard depths of 0, 10, 20, 30, 50, 75, 100, 150, 200, 250, 300, 400, 500, 600, 800, 1000, 1200, 1500 and 2000 m. The measurements were made at the depth over 2000 m (5-10 m above the bottom). Temperature was measured by protected reversing thermometers. When a proper depth the reversing unprotected thermometers were used for control.

Water samples were taken at standard depths using Nansen-type bathometers BM-48 for a subsequent determining of salinity. Salinity was determined by a relative conduction measured in a laboratory using electric salinity meter MK SH - 601 according to the UNESCO formula (1978).

RESULTS

Air temperature

Data on mean monthly air temperature anomalies in the near the ground layer for northern hemisphere are given in charts compiled by the USSR Hydrometeorological Center (Moscow). Long-term mean monthly temperature based on the data for 1931-1960 are used to estimate anomalies. Fig.2 presents monthly air temperature anomalies over the Northwest Atlantic.

In January air temperature over the northwestern Atlantic Ocean was much lower than the long-term mean. The highest absolute values of negative anomalies (to 4°C) were observed at the Northern Labrador and in the southern Baffin Land. Negative air temperature anomalies were also registered at the Baffin Land in May-July and December. The lowest temperature, relative to the norm, in that area was observed in December (anomaly - 6°C). In other months temperature exceeding the norm was predominant over the Baffin Land and adjacent sea area; the most notable positive anomalies in that area (to 4°C and above) were registered in April.

Positive temperature anomalies were observed along the whole coast of the Labrador in April-May and October-November and the negative ones - in January, July and December. In other months anomalies in the northern and southern areas of the Labrador Shelf were inverse.

Air temperature anomalies were less pronounced off the Grand Newfoundland Bank compared to the northern areas and the absolute value did not exceed 2°C. Positive temperature anomalies were predominant in that area during the year.

Sea-surface temperature

Data on mean monthly water temperature anomalies in the regular grid points , given in charts of the USSR Hydrometeorological Center, were used to characterize the heat content of waters in a sea-surface layer. Fig.1 presents some points of the grid related to the area investigated. Long-term mean values for 1957-1971 are used to estimate temperature anomalies.

For convenience in analysis the data available for 1988 were separated into 3 classes: "above the norm", "the norm" and "below the norm"; the boundaries between them were chosen arbitrarily and referred to the values of temperature anomalies - 1.0°C and 1.0°C. To judge by the results from the 1988 classification (Table I) temperature values corresponding to "the norm" were predominant in Subareas 2 and 3 and their recurrence made up 73% for the whole set of regular grid points during the year. As for Subarea 2 (points 1-7) the recurrence of temperature for this class made up 86% and 66% - for Subarea 3 (points 8-19). Relative shortage of heat was mainly observed in the first half-year in the eastern area investigated (points 6, 9, 10, 13 and 16), occupied with subarctic waters and in the second half of the year - on the Grand Newfoundland Bank southwest slope (point 17). "Above the norm" temperature was predominant over the Grand Newfoundland Bank and in the deep waters to the southeast from it (points 11, 15, 18 and 19) during the year.

Table 2 presents the recurrence of the sea-surface temperature from different classes during last 3 years. The analysis of these data indicates a pronounced upward trend in surface water temperature in the area surveyed. From 1986 to 1988 recurrence of the "below the norm" temperature decreased by more than 3 times with an increase of recurrence of "the norm" temperature approximately by 1.5 times and "above the norm" in Subarea 3 - by more than 2 times. Recurrence of the "above the norm" temperature remained at the same level and made up 2-5% in Subarea 2 for the period considered.

Thermohaline water structure in the Davis Strait (Div.OB,Subarea I)

Oceanographic observations were conducted by RV "Kapitan Shaitanov" to the south of 66°20'N in the Davis Strait in October. Temperature and salinity measurements were made at standard depths of 50 random and 24 standard stations along the sections 34-A and II-A (Cumberland-Fylla Bank). Position of these sections is shown in Fig.I.

Oceanographic conditions in the Davis Strait are formed under the influence of water masses with two types of vertical structure - arctic and subarctic. Waters with arctic type of vertical structure were characterized by variations in temperature vertically from -1.7 to 2-3°C and salinity from 31.0 to 34.5 psu. Since the Baffin Land and East-Greenland Currents supply waters with arctic type of structure into the area investigated the waters of this type were distributed at the depths mainly below 500 m in the northwest, the western areas of the strait and along the Greenland western coast.

Temperature variations in waters with subarctic type of structure were registered from 3.3 to 6.2°C and salinity - from 33.7 to 34.9 psu. Intermediate maximum of temperature in a 50-600 m layer is a peculiarity of subarctic type of structure in a cold period of the year. Waters of this type of vertical structure are formed as a result of mixing of waters from the Baffin Land and East-Greenland Currents with waters from the Irminger Current which is an extension of the Gulf Stream. These waters occupied deep-water southeastern area of the Davis Strait.

Arctic frontal zone which was observed at the 500-600 m depths was a physical boundary between the water masses with the mentioned types of vertical structure. The most intensive section of the frontal zone was registered over the continental slope off the Baffin Land. Horizontal gradients of temperature on this section constituted about 0.15°C/km.

Compared to the previous year mean temperature of the upper

200-m water layer in the Baffin Land Current was higher by 0.1-0.2°C along the section II-A (Cumberland) and by 0.8-0.9°C - along the section 34-A. Water temperature of the Arctic component of the West-Greenland Current remained at the previous year level and its Atlantic (Irminger) component increased by 0.3°C. The most essential increase in water temperature (to 0.6°C in a 0-200 m layer and to 0.3°C in a 200-500 m layer), compared to 1987 level, was observed in waters with subarctic type of structure.

Data on mean water temperature anomalies in a 0-200 m layer for 1963-1985 obtained at the station to the west of the Fylla Bank presented in Stein (1986), were used to estimate a heat content of waters in a climatic aspect. Fig.3A presents the long-term mean water temperature anomalies in a 0-200 m layer at this station. As can be seen in the figure after the period of negative anomalies (1981-1984) a relatively warm period, ongoing also in 1988, came while a trend of decrease in temperature was registered from 1987 to 1988.

Thermohaline structure of waters in Subarea 2

Oceanographic observations were carried out on the shelf and the Labrador continental slope in Subarea 2 by RVs "Vilnyus" and "Kapitan Shaitanov" in September-November. Water temperature and salinity measurements were made at standard depths of 88 random stations and at 17 stations on the Sections 8-A and 38-A (Fig.1) as well as vertical profiles of temperature were obtained at 39 bathythermographic stations.

Data on vertical distribution of water temperature and salinity allow to characterize a thermohaline structure of waters as a component of subarctic and arctic types. The arctic type in the area investigated includes the waters with temperature variations vertically from -1.5 to 2-3°C and salinity from 31.5 to 34.5 - 34.7 psu. The waters of this type occupied mainly the shelf area. Waters of subarctic type characterized by higher values of temperature and salinity and lower stratification of these parameters were distributed over the deep waters of the Subarea. The horizontal gradients of temperature and salinity identifying the Arctic frontal zone, relative to background, were registered in a zone of transition from one type of structure to the other one. Plots of temperature and salinity distribution on the Section 8-A illustrate the above mentioned scheme of thermohaline structure and are presented in Fig.4.

Since 1964 observations over the section crossing the Labrador Current off the Hamilton Bank have been conducted regularly by the PINRO vessels in autumn. Long-term values for each depth at all stations of the section were estimated for 1964-1986. Distribution of temperature and salinity anomalies on the section allows to draw a conclusion about essential excess of heat in the surface 50-m layer in the area of distribution of the Labrador Current cold component (Stations 16-23, Fig.4). The frontal zone between the cold and Irminger components of the Labrador Current shifted by 18-23 miles to the east relative to the long-term mean position. Distribution of shelf waters , more extensive than usually, specified the essential negative temperature and salinity anomalies (to -1.8°C and -1.2 psu on a sea-surface) at the 14th and 15th stations of the section.

The long-term mean temperature anomalies in the 0-200 m layer for cold and Irminger components of the Labrador Current are presented in Figs. 3B and 3C. As can be seen in Fig., after a strong cooling in 1982-1984 which has no analogues for the whole period of observations on this section, water temperature of the Labrador Current approximated the long-term mean 1985-1986 level and after a minor decrease in 1986-1987 an upward trend was again observed.

Thermohaline structure of waters in Subarea 3

Oceanographic observations were carried out by RV "Persey III" in Subarea 3 from March to June and by RVs "Vilnuys" and "Kapitan Shaitanov" - from September to December. During the RV "Persey III" cruise standard observations over the temperature and salinity were made at 50 stations of 5 parallel cruise tracks to SSE from Div. 3L to 42-43°N and at 391 random stations on the Newfoundland Shelf and Flemish Cap Bank.

Range of variations in temperature and salinity in this area is wide which was specified by an intensive mixing of water masses with different types of vertical structure . The distribution of these water masses may be schematically presented as follows. The arctic type of structure predominates over the largest part of the Grand Newfoundland Bank in the shelf area in Div. 3K. In the northeastern Subarea and over the Flemish Cap Bank the subarctic type of structure being wedged out in the southwestern slopes of the Grand Bank was predominant. In the southern and southeastern area waters with subarctic type of structure , the distribution of which is related to the Gulf Stream - North-Atlantic Current system predominated. Intermediate position between the waters with subarctic and subtropical types of structure occupies the slope waters which are the product of their mixing.

In spring the upper 100-m water layer over the most part of the Newfoundland Shelf was warmer compared to 1987. Positive deviations in temperature made up mainly 0.3-1.2°C, the highest deviations (3-5°C) were observed over the southwestern slopes of the Grand Bank.

Values of temperature in a near-bottom layer in points of regular half-degree grid were calculated according to the data of oceanographic survey on the Newfoundland Shelf and their deviations from the long-term mean values for 1972-1986 and level of 1987 were estimated (Borovkov and Tevs, 1988). According to these estimates water temperature in a near-bottom layer over the most part of the Newfoundland Shelf in March-May 1988 was somewhat lower than the norm (Fig.5) and the previous year level. The highest negative water temperature anomalies (-1.5 - -1.8°C) were registered in the shallow waters of the Grand Bank. Essential positive anomalies (to 3°C) were observed on the bank eastern slope.

Compared to the previous year temperature variations were observed in the area of distribution of the Labrador Current Main branch where deviations amounted to -1.7°C. Positive deviations in temperature from the previous year level (to 0.7 - 0.9°C) were registered in shallow waters (depths below 100 m) and at the "tail" of the Grand Bank.

Near-bottom water temperature anomalies (A) were compared to the corresponding values of mean square deviations (S), which are the measure of year-to-year variations in near-bottom temperature, to characterize their significance. Standardized anomalies (A/S) obtained were separated into 5 classes:

much above the norm			$A/S > 1.5$
above the norm	0.5	$<$	$A/S \leq 1.5$
the norm	-0.5	$\leq$	$A/S \leq 0.5$
below the norm	-0.5	$>$	$A/S \geq -1.5$
much below the norm			$A/S < -1.5$

Distribution of standardized temperature anomalies are presented in Fig.5B and , in general outline, corresponds to the distribution of absolute values of anomalies. The most essential water cooling in a near-bottom layer was observed on the northeastern ledge and in the shallow waters on the southern bank as well as in the local areas of Div.3K relative to the long-term mean temperature and with allowance for the year-to-year variations. The maximum rise in temperature was observed on the Grand Bank eastern slope, in the area around the St.Pierr and Green Banks, in the coastal area of Div.3L and to the north of the Funk Island Bank.

Fig.6 presents the long-term mean anomalies of near-bottom water temperature in separate areas. As Fig.6 shows in 1988 near-bottom water temperature in Divs. 3K and 3L was close to the long-term mean level and somewhat lower, compared to the previous year. In Divs.3N and 30 temperature increased almost up to the norm, compared to 1987.

In autumn 165 random deep-water and 34 bathythermographical station were made on the Newfoundland Shelf as well as 6 stations of Section 6-A (Flemish Cap) in the Flemish-Pass Deep, which were made four times.

In November-December temperature of near-bottom water layer over a major part of Div. 3N was , on the average, by 1°C higher than in the corresponding period of the last year. It was also warmer on the northeastern ledge of the Grand Bank and in the coastal area of Div. 3K.

In the end of the year the most essential negative deviations of the near-bottom water temperature from the previous year level were observed in Div. 3O (to 2°C and over). Water temperature in a near-bottom layer was by 0.5-0.8°C lower in Div.3L and off the Funk Island Bank, compared to 1987.

Geostrophic circulation on the Newfoundland Shelf in spring-summer

Estimations and charts ofv the sea-surface dynamic topography were made according to the methods described in Borovkov and Kudlo (1982) to elucidate qualitative characteristics of water horizontal circulation in a surface layer. Results from detailed surveys in Divs. 3KLNO in spring-summer surved as primary materials.

Fig.7 presents kinematic scheme demonstrating a combination of a streamed flow above the Grand Bank slopes and a retarded circulation with the mesoscale wave and vortex disturbances in the shelf area.

The streamed flow velocity corresponding to the Labrador Current Main branch was maximum in the northeastern and eastern slopes of the Grand Bank. Comparing schemes of water circulation in spring 1987 and 1988 we conclude that in 1988 the current over the NE slopes of the Grand Bank is characterized by higher velocity and less vorticity, which, in its turn, made for a rapid southward shift of winter originated waters and their replacement by waters of spring-summer generation.

A number of formations of relative vorticity of different sign was pronounced over the shelf area, among which anticyclonic vortex localized on the southern Grand Bank had the highest geometrical dimensions . Compared to 1987 spring it was shifted to WNW as a result of which the current velocity over the southeastern Grand Bank much reduced.

Anticyclonic meander off the Funk Island Bank was more pronounced compared to the previous year. A cyclonic vortex which was not pronounced in 1987 was observed in the south-eastern Div. 3L this year.

Total anticyclonic vorticity of a current field was registered over the Flemish Cap Bank.

Ice conditions

Ice conditions in the Northwestern Atlantic were analyzed in Hydrometeorological Centre (Murmansk) using the facsimile charts from Brahnell.

In the Davis Strait in autumn 1987 icing processes started in the first decade of November and in the Labrador Sea - in the second decade of December which was by 1.5-2 and 2-3 decades later, respectively, than the long-term mean. However, icing processes in these areas were so intensive that during 10 days after their onset the ice cover was equal to the norm and was close to it until the end of ice period (September) in the Davis Strait and until March in the Labrador Sea. In April-June the total ice cover of the Labrador Sea was by 6-9% lower than the norm and by 9-18% lower than the ice cover in the previous year. No ice cover was observed in the Davis Strait by the end of July and the Labrador Sea - by the end of the second decade of July.

In autumn 1988 icing processes in the Davis Strait and Labrador Sea started in November and mean monthly ice cover in their area was close to the long-term mean. In December the ice cover in the Davis Strait exceeded the norm by 6% and by 5% - in the Labrador Sea.

On the whole, during the 1987-1988 ice period ice cover in the Davis Strait was close to the long-term mean and that in the Labrador Sea was somewhat lower.

CONCLUSIONS

In 1988 a heat content of waters in the Northwest Atlantic (Subareas 0, 1, 2 and 3) was close to the norm. Compared to 1987 an upward trend in water temperature was predominant.

In the Davis Strait the most essential rise in temperature was observed in its southern part where positive temperature deviations from the previous year level made up on the average 0.6°C in the upper 200-m layer.

Mean temperature of the Labrador Current waters off the Hamilton Bank in autumn has increased after the anomalously cold 1982-84 and reached in 1985-1986 the level of the long-term mean. After a minor cooling in 1986-1987 an upward trend in water temperature was also observed and in 1988 mean temperature in the Labrador Current waters was close to the norm.

In spring-summer 1988 water temperature in the near-bottom layer on the Newfoundland Shelf (Divs.3KL) was close to the long-term mean and somewhat lower compared to the previous year. In the southern part of the Grand Newfoundland Bank (Divs. 3NO) mean water temperature in the near-bottom layer approach the level of the norm and was somewhat higher compared to 1987.

Ice cover in the Davis Strait during the 1987-88 ice period was close to the long-term mean and in the Labrador Sea - somewhat lower than that one.

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Table 1. Temperature of the surface layer in regular grid points in NAFO Subareas 2 and 3 (Fig.1)

NAFO Sub-area	No. of point	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	I	.				.	+	.	-	-	.	+	.
	2	.	.	.	.	.	.	.	.	.	.	.	.
	3						.	.	.	.	.	.	.
2	4	.	.	.	.	.	.	.	.	.	.	.	.
	5	.			+	.	.	.	.	.	.	.	.
	6	-	-	-	-	.	.	.	.	.	.	.	.
	7	.	.	.	.	.	.	.	-	.	.	.	.
	8						.	-	.	.	.	.	.
	9	.	.		.	.	-	-	.	.	.	.	.
	I0	-	-	-	.	.	.	.	.	.	.	.	.
	II	.				+	+	-	+	.	+	+	+
3	I2	.	.	+	.	.	.	.	.	.	.	.	.
	I3	.	.	-	-	.	.	.	-	.	-	.	.
	I4	.	.	.	.	+	.	.	.	.	.	.	+
	I5	.	.	.	.	.	+	+	+	+	+	+	+
	I6	.	.	-	.	.	.	.	-	.	.	.	.
	I7	.	.	.	.	.	.	.	-	-	.	.	-
	I8	+	+	+	-	.	+	.	+	.	+	+	.
	I9	.	+	+	.	.	+	+	.	+	.	.	+

\+ - above the norm; . - the norm; - below the norm

Table 2. Recurrence of classes of water temperature in a surface layer in NAFO Subareas 2 and 3, %

NAFO Subarea :	2			3			2+3		
Years	1986	1987	1988	1986	1987	1988	1986	1987	1988
Above the norm	5	2	4	8	14	21	7	10	15
The norm	56	71	86	49	68	66	52	69	73
Below the norm	39	27	10	43	18	13	41	21	12

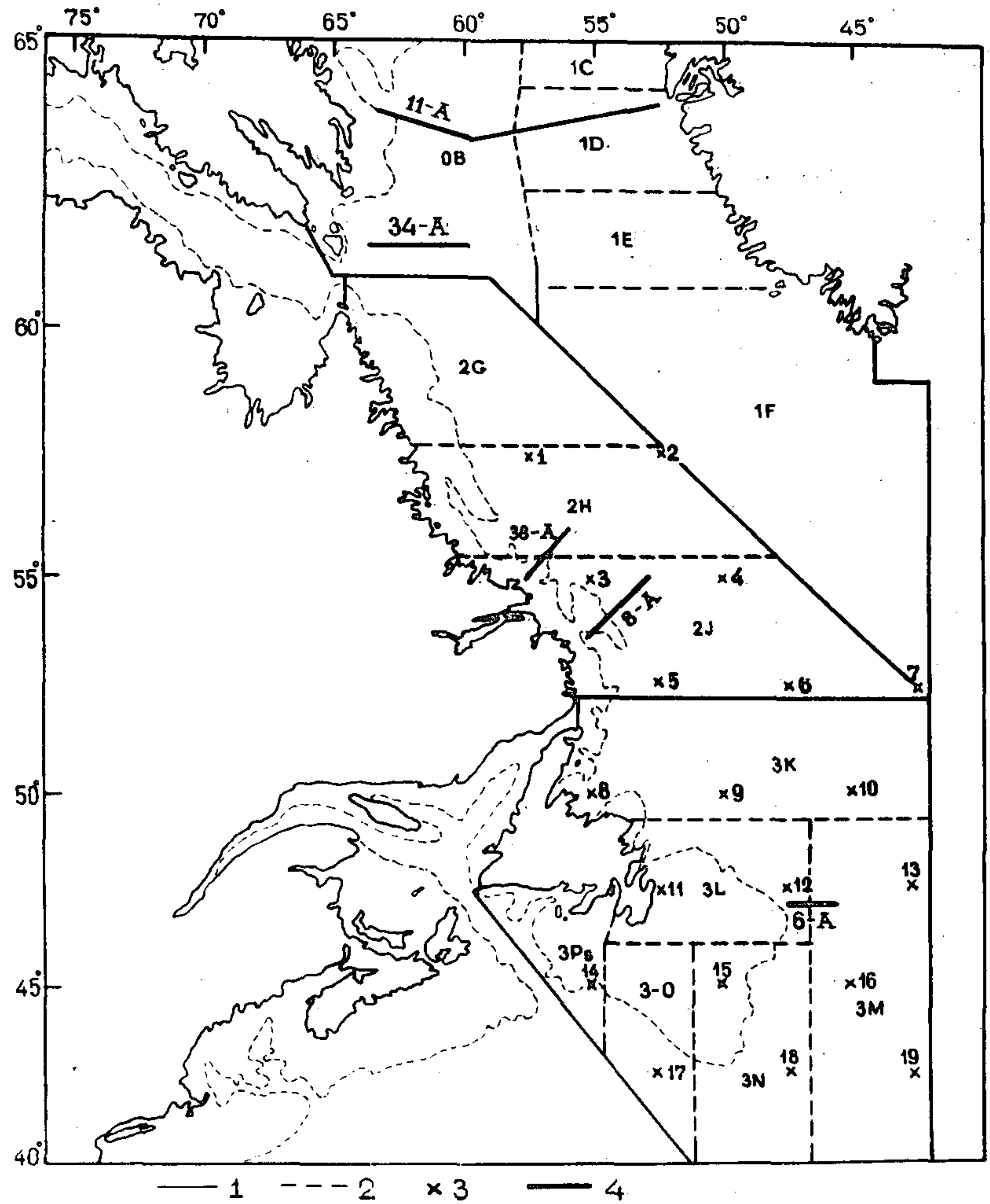

Fig. I. Boundaries of NAFO Subareas (I) and Divs.(2), position of regular grid points where the data on mean monthly temperature of sea-surface water layer (3) and standard sections (4) in the Northwest Atlantic were obtained.

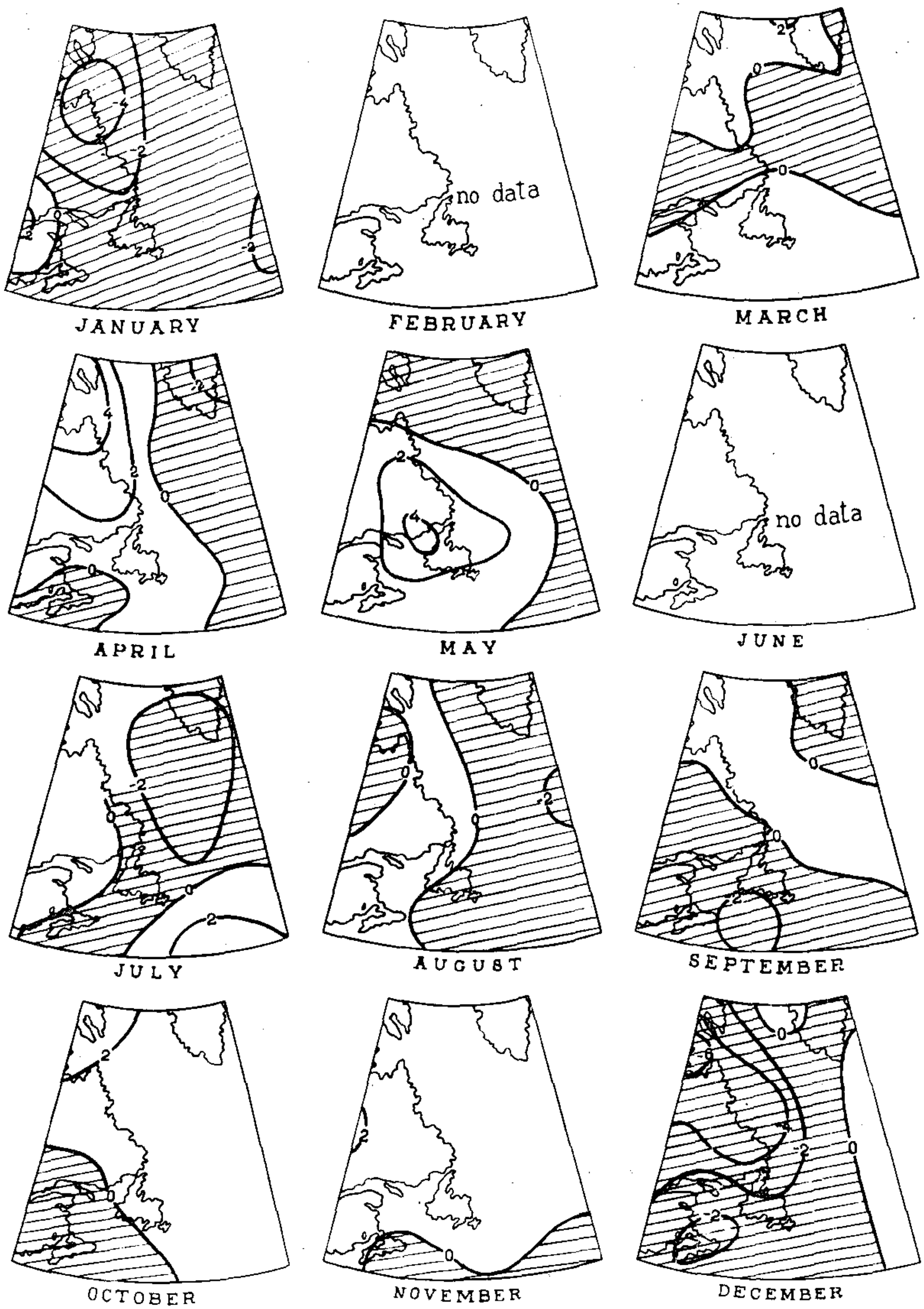

Fig.2. Monthly air temperature anomalies (°C) in the near the ground layer over the Northwest Atlantic in 1988

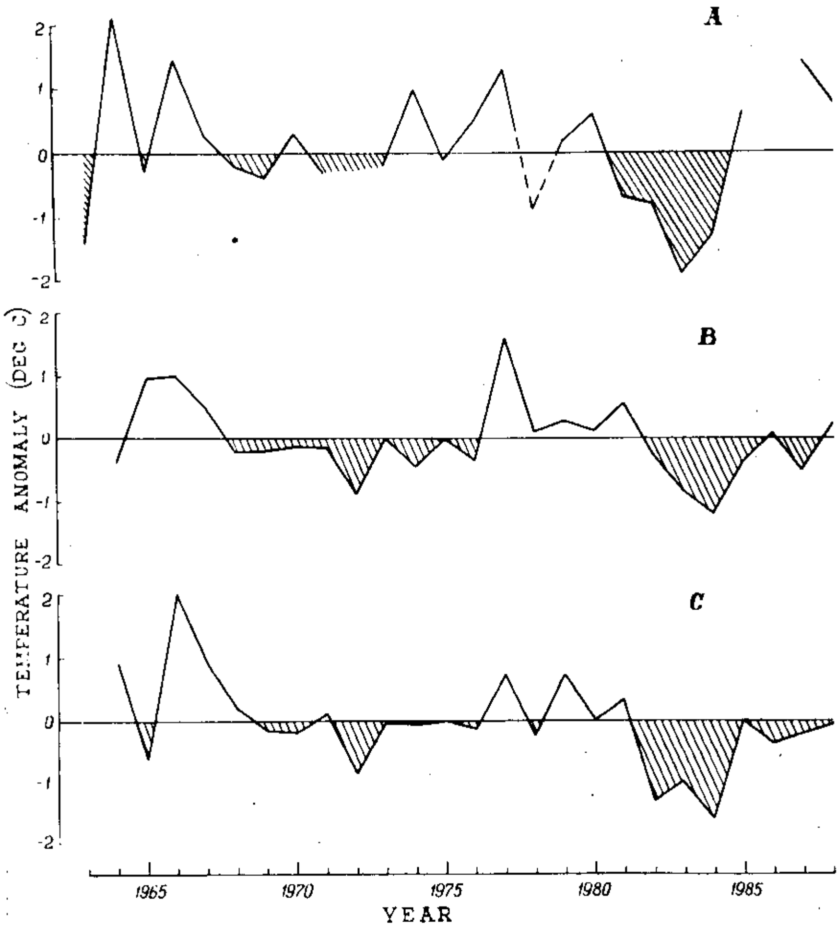

Fig. 3. Mean water temperature anomalies in the 0-200 m layer in autumn (°C)

A - at the station along 63°53'N, 53°22'W
(to the west of Fylla Bank)
1963-1985 - G.F.R. observations
(1978 - observations were made in late December;
1987-1988 - USSR observations)

B - in the Labrador Current cold component

C - in the Irminger component of the Labrador Current

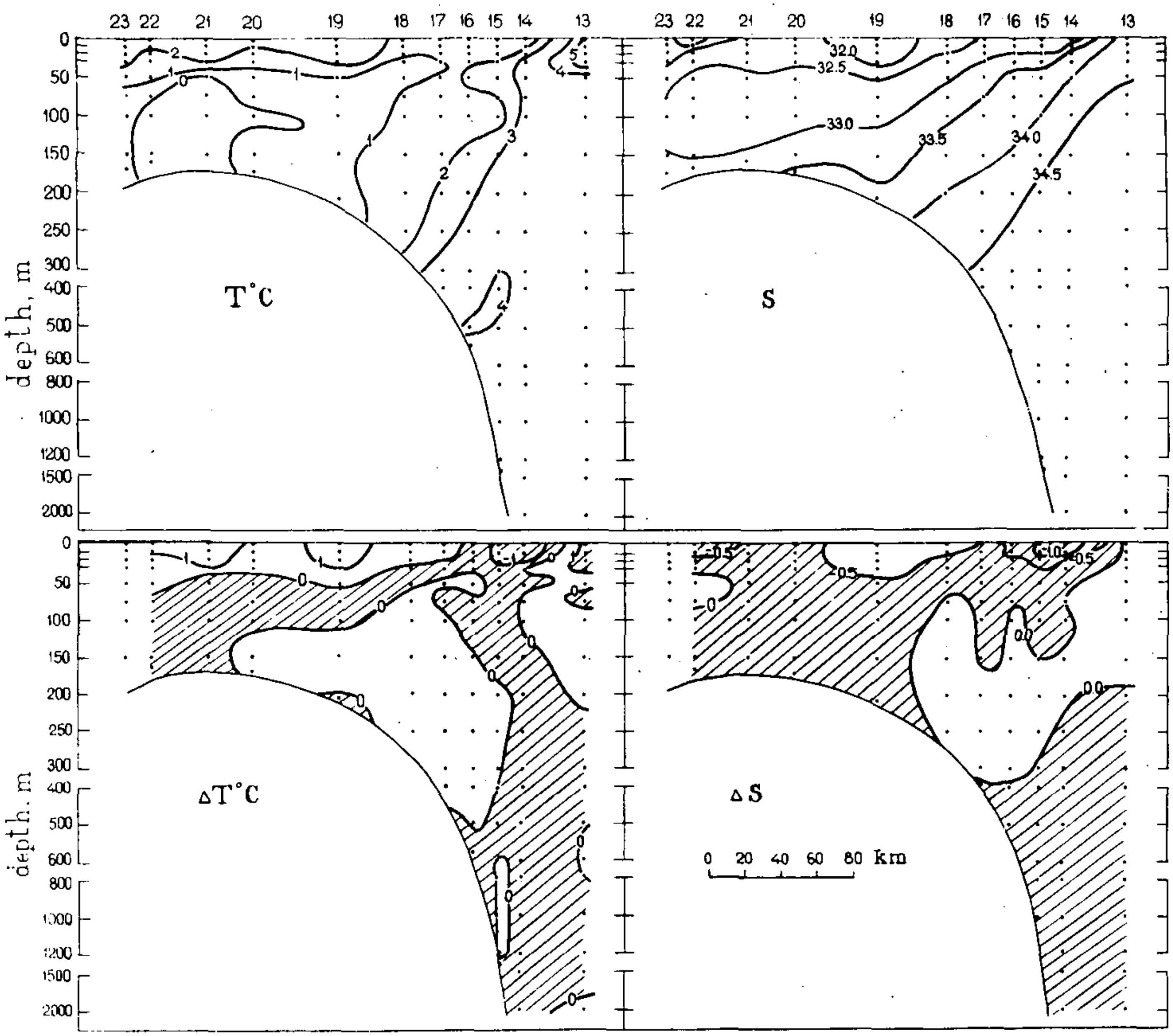

Fig. 4. Distribution of water temperature (T°C) and salinity (S, psu) on the Section 8-A in late October 1988 and their anomalies (Δ T°C and Δ S). Areas of negative anomalies are shaded.

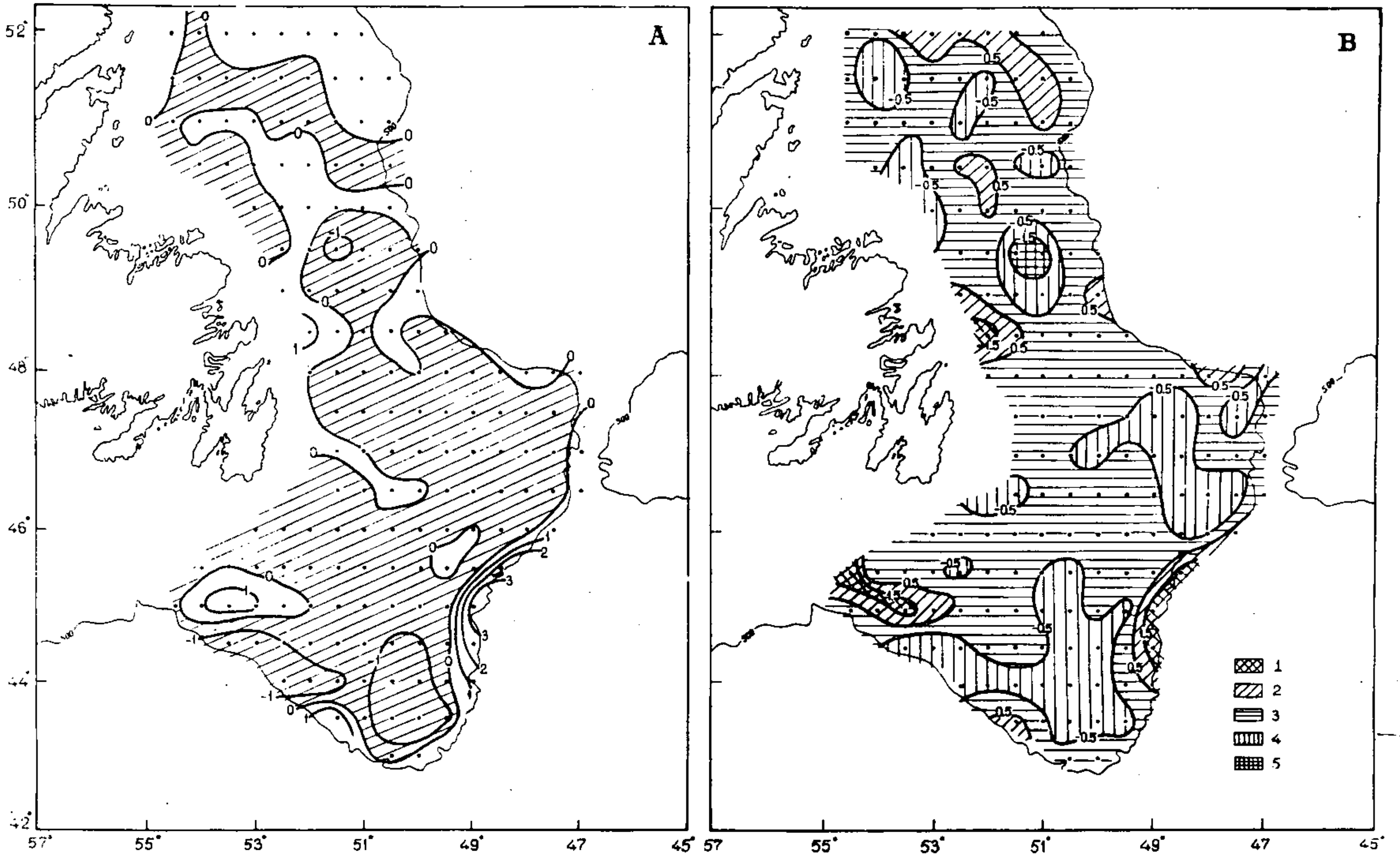

Fig.5. Distribution of anomalies (A) and standardized anomalies (B) of the near-bottom water temperature on the Newfoundland Shelf in spring 1988
1 - much above the norm; 2 - above the norm; 3 - the norm; 4 - below the norm;
5 - much below the norm.

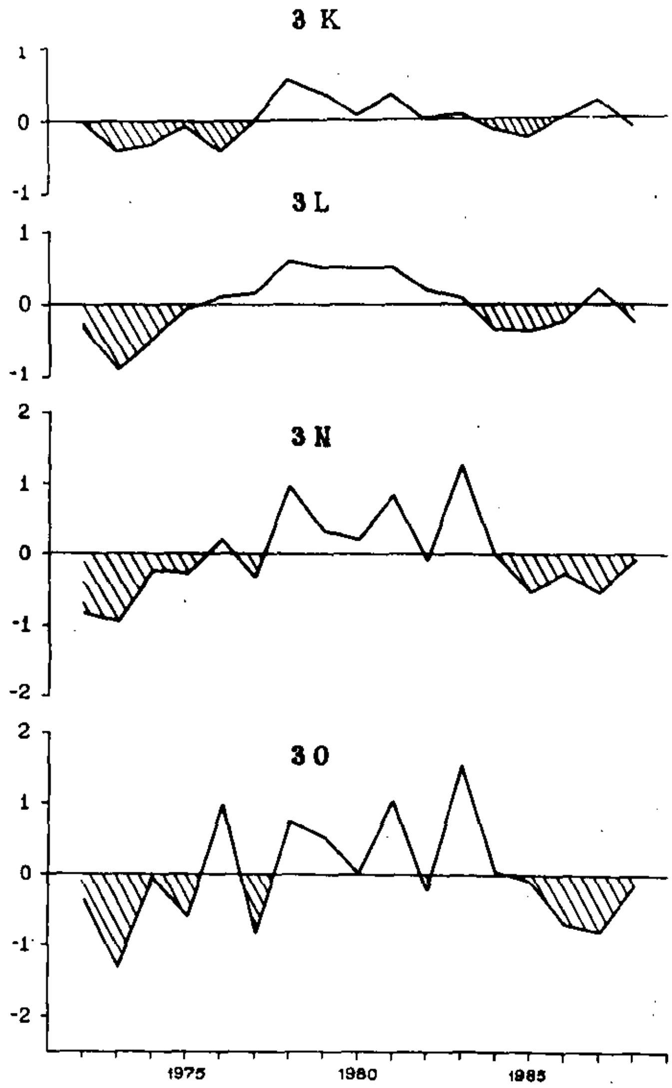

Fig. 6. Anomalies of mean near-bottom temperature in separate Divs. of the Newfoundland Shelf (°C)

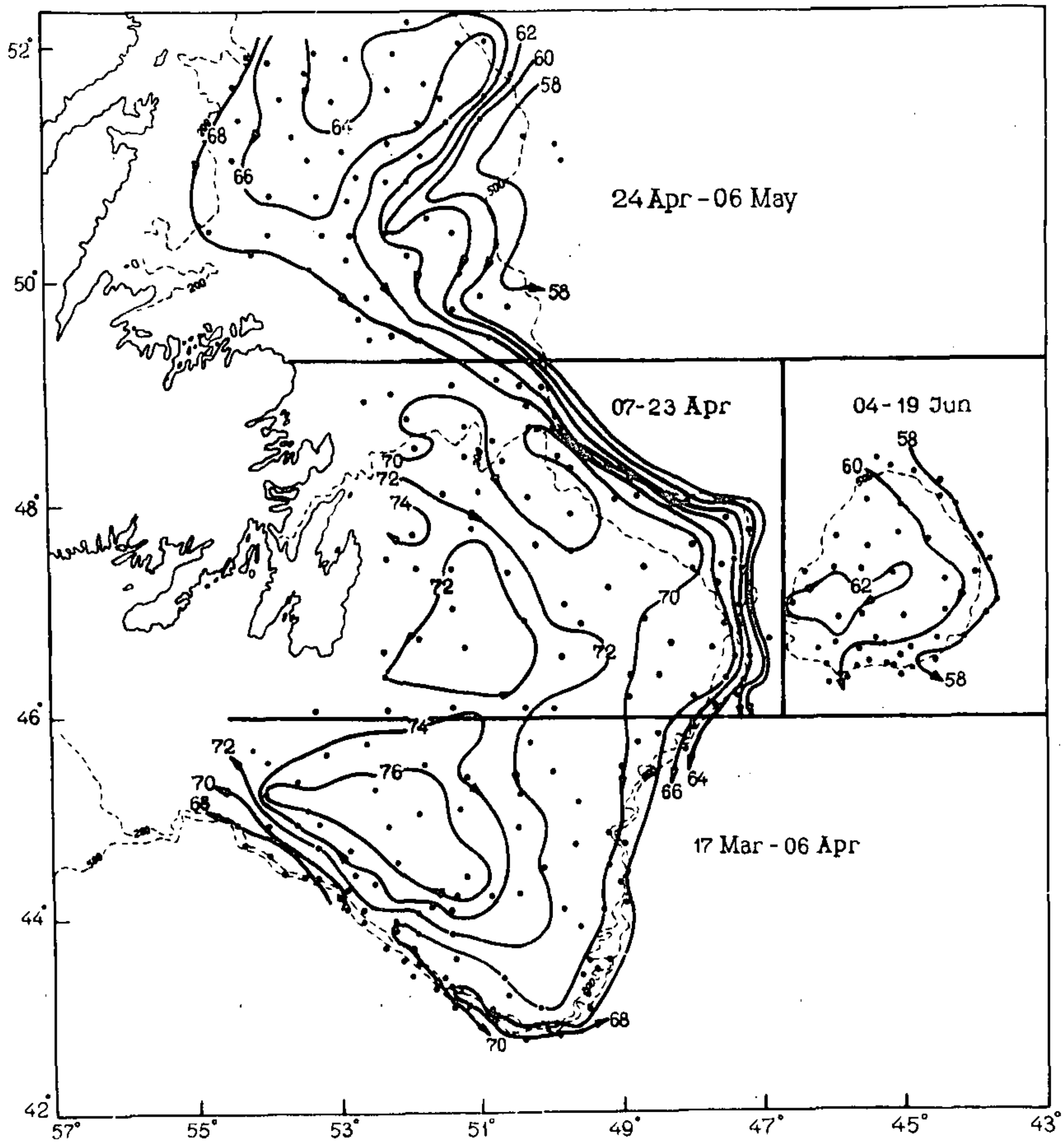

Fig. 7. Dynamic topography of sea-surface relative to the MPa level 2 in March-May 1988. Dynamic depth isolines are given in 2 cm distance.