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Overview of Oceanographic Conditions off the Northwest Atlantic in 1989

by

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INTRODUCTION

The paper reviews oceanographic conditions in NAFO Subareas 0, 2 and 3 from the Northwest Atlantic in 1989. The overview is based on the data obtained during two cruises conducted by PINRO in spring-summer (March-June) and autumn-winter (September-December). Data on monthly temperature anomalies on the sea-surface, air temperature and atmospheric pressure at sea level 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 1989 are compared to those of the previous 1988 and long-term mean conditions.

MATERIAL AND METHODS

Observations over water temperature and salinity were made at irregular greeds of trawl stations and standard sections 11-A (Cumberland), 34-A, 38-A and 8-A (Fig.1).

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 depths over 2000 m (5-10 m above the bottom). Water temperature was measured by protected reversing thermometers; when a proper depth the reversing unprotected thermometers were used for control.

Water samples were taken at all standard depths using Hansen-type bathometers BM-48 for determining of salinity. Salinity was determined by a relative conductivity (UNESCO, 1978) using inductive salinity meter MK SH-601.

Data on monthly values of atmospheric pressure at sea level, temperature in a surface air layer and their anomalies for the Northern hemisphere are charted in the Hydrometeorological Center (Moscow). Long-term mean monthly values of atmospheric pressure and temperature based on the data for 1931-1960 were taken as a norm.

Data on anomalies of mean monthly temperatures in the regular grid points also charted in the Hydrometeorological Center, were used to characterize a thermal state of water in a sea-surface layer. A part of the grid points concerning with the area surveyed is shown in Fig.1. Long-term mean monthly values for 1957-1971 are used to estimate temperature anomalies.

Ice conditions were analyzed by facsimile charts in the Hydrometeorological Center (Murmansk), sent from Brachnell (England).

Meteorological observations

Atmospheric pressure

Autumn-winter period of 1988-1989 was characterized by sharply anormal large-scale processes of atmospheric circulation over the North Atlantic, the most important of which are:

- higher intensity of atmospheric circulation;
- cooling in subtropics and essential heating in moderate latitudes;
- lower background of atmospheric pressure over the Polar basin compared to some previous years;
- extreme growth of North Atlantic oscillation.

An attempt to select the years, similar by a character of development to the baric processes in 1988, on the base of the data for 1955-1987 has elucidated none of the years from this series to be similar to 1988 to a certain extent (V.M. Bulaeva, Hydro-Meteorological Institute, Leningrad; personal communication).

Along with an intensification of Iceland and Azores centers of atmospheric effect an extremely low background of atmospheric pressure over the Norwegian-Greenland Basin was observed early in 1989 and the mean monthly anomalies of atmospheric pressure over Greenland constituted -12 - 14 hPa in January-March (Fig.2). An intensive meridional air exchange has taken place along the western and eastern peripheries of this depression.

In April-July the fields of mean monthly atmospheric pressure over the Northwest Atlantic have been characterized by relatively minor anomalies, beeing varied from -4 hPa over the southern Greenland to 6 hPa to the east of the Newfoundland. Negative anomalies 2-4 hPa were predominant in the southern area from July to October and insignificant positive ones - in the southern part.

In November over Canada the area with a considerably lowered background of atmospheric pressure began to form with the mean monthly anomalies of atmospheric pressure beeing reached to -6 hPa over the Labrador. In December the center of depression shifted to the east and negative anomalies reached to 14-16 hPa off the Flemish Cap Bank.

Air temperature

Powerful northern air flows predominant over the northwestern Atlantic Ocean in January-March caused essential cooling in that area and mean monthly values of temperature in the surface air layer over the Davis Strait and Labrador Sea in that period were by 2-6°C lower than a norm (Fig.3). The peak of cooling has been registered in March.

From April to October air temperature over the most part of the Northwest Atlantic differred from the norm insignificantly. Positive anomalies over the Newfoundland and Southern Labrador and negative ones over the Northern Labrador and Davis Strait have been predominant.

In November-December "a seat" of cold was formed over the Northwest Atlantic; mean monthly temperature of air over Novaya Scotia was by 6°C and over Newfoundland - 4°C below than the norm.

Oceanographic observations

Sea-surface temperature

For convenience in analyses the data on temperature anomalies of sea-surface layer available for 1989 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°C and 1°C.

To judge by the results from the 1989 classification (Table 1) temperature values corresponding to "the norm" were predominant in Subareas 2 and 3 and their recurrence made up 68% 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 75 and 64% for Subarea 3 (points 8-19). Relative shortage of heat was mainly observed in the first half-year in the off sea area investigated (points 2, 6, 10 and 13), occupied with the waters of subarctic type of vertical structure. "The norm"-temperatures were predominant during the year over the Grand Newfoundland Bank and to the south of it (points 12, 15, 18), however, in autumn months (September-November) the temperature of sea-surface layer in the area was above the norm.

Table 2 presents the recurrence of the sea-surface temperature from different classes in Subareas 2 and 3 during recent years. As can be seen from the Table mean annual temperatures in the sea-surface layers were increasing from 1986 to 1988, as evidenced by essential increase of recurrence of "the norm" and "above the norm" temperatures and decrease of recurrence of "below the norm" temperatures. In 1989 the temperature of sea-surface layers has decreased as evidenced by a growing recurrence of the "below the norm" temperatures. Thermal state of water in the sea-surface layers from the Northwest Atlantic in 1989 was close to the level of 1987 in mean annual aspect.

Thermohaline water structure in the Davis Strait

Oceanographic observations were conducted by RV "Kapitan Shaitanov" in the Davis Strait to the south of 66°N within the fishing zone of Canada in October. Temperature and salinity measurements were made at standard depths of 43 random and 15 standard stations along the sections 34-A and 11-A (Cumberland). Positions of these stations are given in Fig.1.

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 enter the Strait with the Baffin Land Current and are mainly distributed in the depths below 500 m. Waters of this type were characterized by variations in temperature vertically from -1.7°C to 1.0°C and salinity - from 31.0 to 34.0psu.

Temperature variations in waters with subarctic type of vertical structure were registered from 0.5 to 4.1°C and salinity - from 32.2 to 34.9 psu. Waters of this type are formed as a result of mixing of waters from the East-Greenland and Baffin Land Currents with waters from the Irminger Current and occupy the deep-water southeastern area investigated.

Arctic frontal zone observed at the 400-600 m depths, was a physical boundary between the water masses with the mentioned types of vertical structure. Fig.4 presents vertical distribution of temperature and salinity in the western area of the Davis Strait (section Cumberland).

Comparative analysis of fields of water temperature and salinity for 1989 and 1988 has elucidated an increase in these characteristics on the average by 0.5°C and 0.15 psu. in the surface

30-50-meter layer in a narrow zone at the Baffin Land. This was resulted from essential radiative heating in spring-summer. Considerable shortage of heating was registered in the lower layers over the Baffin Land Shelf. Mean water temperature in the Baffin Land Current in 50-200 m layer on the section Cumberland was by 0.4°C lower compared to 1988. Fig.4 presents deviations in temperature and salinity from the level of 1988. As can be seen in the figure cold intermediate layer in 1989 had a vertical development due to which waters with the negative temperatures in a near-bottom layer occupied the most part of the Baffin Land Shelf (Fig. 5a).

In the area of distribution of transformed Atlantic waters in mid-water was much lower than in the previous year. Mean water temperature in 0-200 m layer in this area was by 1.2°C and in 200-500 m - by 0.6°C lower than in 1988. In a near-bottom layer water temperature deviations over the most part of the Baffin Land Shelf exceeded -1°C (Fig. 5b).

Probably, such essential decrease in temperature in the area of distribution of mixed waters was caused not only by notable cooling of mid-water in autumn-winter, but, to a great extent, by decreasing of heat advection in the Davis Strait by the Irminger Current.

Thermohaline structure of waters in Subarea 2

Oceanographic observations were carried out on the shelf and the Labrador continental slope in Subarea 2 by RV "Kapitan Shaitanov" in September-November. Water temperature and salinity measurements were made at standard depths of 30 random stations and 17 stations of the Sections 8-A and 38-A.

Data on vertical distribution of water temperature and salinity obtained as a result of observations allow to characterize a thermohaline structure of waters in this area as a component of arctic and subarctic types. The arctic type includes the waters with temperature variations vertically from -1.7°C to 2.5°C and salinity - from 31.5 to 34.5 psu. The waters of this type occupied mainly the shelf area. Waters of subarctic type of vertical structure, characterized by higher values of temperature and salinity and lower stratification of these parameters, were distributed over the deep waters of the Subarea. The higher 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 another one. Plots of temperature and salinity on the section 8-A illustrate the above mentioned scheme of thermohaline structure and are presented in Fig.6.

Since 1964 the observations over the section crossing the Labrador Current off the Hamilton Bank have been conducted regularly by the PINRO vessels in autumn. Long-term mean values of temperature and salinity for each depth at all stations of the section were estimated for 1964-1986. Distribution of temperature and salinity anomalies on the section (Fig.6) allow to draw a conclusion about notable radiative heating of the surface 100-m layer over the Labrador Shelf (Stations 18-23) and essential shortage of heat in a near-bottom layer on the shelf and in the mid-water of the Irminger component of the Labrador Current.

The long-term mean temperatures for different layers and branches of the Labrador Current off the Hamilton Bank are given in Fig.7. In 1989 mean water temperature of the cold component of the Labrador Current in 0-200 m layer was at the level of the long-term mean and was by 0.2°C lower compared to 1988 (Fig.7a). The temperature of this layer in the Irminger component was by 0.6°C lower than the norm and by 0.5°C lower compared to 1988 (Fig. 7b). Deviations from the norm in 200 - 500 and 500-1000 m layers made up 0.3 and 0.5°C, respectively (Figs. 7c,d).

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 RV "Kapitan Shaitanov" - in September and from November to December. During the RV "Persey III" cruise standard observations over the temperature and salinity were made at 440 random stations on the Newfoundland Shelf and Flemish Cap Bank.

Range of variations in temperature and salinity in this area was wide which has been 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 vertical 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 beeing wedged out in the southwestern slopes of the Grand Bank was predominant. In the southern and southeastern Subarea waters with subarctic type of structure, the distribution of which is related to the Gulf Stream - North Atlantic Current system predomineted. Intermediate position between the waters with subarctic and subtropical types of vertical structure occupies the slope waters which are the product of their mixing.

Values of water temperature in a near-bottom layer in points of regular half-degree grid were calculated according to the data of the oceanographic survey on the Newfoundland Shelf and their deviations from the long-term mean values for 1972-1986 and level of 1988 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 1989 was somewhat lower than the norm (Fig.8a) and the level of 1988. The highest negative anomalies, beeing exceeded -2°C, were registered in the southwestern and southern slopes of the Grand Bank. Positive anomalies of temperature of the near-bottom waters were observed in a rather narrow coastal zone and on the northern slope 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 < = 1.5
the norm	-0.5 < =	A/S < = 0.5
below the norm	-0.5 >	A/S > =-1.5
much below the norm		A/S < -1.5

Distribution of standardized temperature anomalies are given in Fig.8b 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 in the relatively shallow part of the Grand Bank at depths below 200 m as well as in the local areas of the continental slope in Divs. 3K and 3L relative to the long-term mean temperature and with allowance for the year-to-year variations. The maximum rise in temperature was observed in the coastal zone of the Newfoundland.

Fig.9 presents the long-term mean water temperature in separate areas of the Newfoundland Shelf. As Fig. 9 shows the mean water temperature in Divs. 3NO was by 1.0°C and in Div. 3KL - by 0.2°C lower than the norm, estimated for 1972-1986. In 1989 the area occupied by the waters with the "below the norm" and "much below the norm" temperatures in Divs. 3N and 3O was approximately 2 times higher than in 1988 and constituted about 70% of the total area of the divisions. In Div. 3K this area has increased from 33 to 54%. Such area occupied by the waters with negative temperatures in a near-bottom layer was only registered in the coldest periods (1973-74, 1976 and 1985).

In autumn 56 random stations were made on the Newfoundland Shelf. In late November - early in December water temperature in a surface layer over the Grand Newfoundland Bank varied from 1.1°C in the areas of distribution of the Coastal and Main branches of the Labrador Current to 8°C over a top of the Bank. Adequate variations were registered in a near-bottom layer from -1.5 to 8°C. Salinity on the sea-surface varied from 31.9 psu. in a coastal zone to 33.4 psu. in the northeastern bank and from 32.4 to 34.8 psu. - in a near-bottom layer.

Comparative analysis of the temperature fields for 1989 and 1988 has elucidated a decrease in temperature in the northern part of Div. 3NO and in the north and east of Div. 3L and somewhat heating in the southern area of the Grand Bank and on its northeastern slope.

Table 3 presents values of mean temperature in a near-bottom layer and area occupied by waters with different temperature in autumn during the recent 4 years. As can be seen in Fig.3 in 1988 and 1989 the area occupied by the waters with temperature below -1°C has increased considerably over the Grand Bank, mainly in Div. 3L, compared to the previous years. However, at the same time the area with the water temperature exceeding 3°C in Divs. 3L and 3N has increased whereby the mean temperature by field in Divs. 3LNO has remained invariable.

Considering the fact that the mean by field water temperature in Div. 3NO was by 0.8°C lower in spring than in 1988 its notable rise in summer should be noted.

Geostrophic circulation on the Newfoundland Shelf in spring-summer

Estimations and charts of 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 served as primary materials.

Fig. 10 presents kinematic scheme demonstrating a combination of a streamed flow above the Grand Newfoundland 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 over the eastern slope of the Funk Island Bank. A number of dynamic formations of different sign vorticity was pronounced over the shelf area, among which anticyclonic vortex localized on the southern Grand Bank had the highest geometrical dimensions. Total anticyclonic vorticity of current field was observed over the Flemish Cap Bank.

When comparing the schemes of water circulation in spring 1988, given in the paper by Borovkov and Tevs (1989), it follows that the flow over the northeastern and eastern slopes of the Grand Bank was more retarded in 1989. Anticyclonic meander in the Funk Island Bank area was less pronounced than in 1988 and quasi-permanent anticyclonic vortex in the southern Grand Bank was shifted to the south and extended along the bank slope. Values of dynamic heights in the area of their distribution were registered to be higher.

Ice conditions

In the Davis Strait and Labrador Sea in autumn 1988 icing processes started in November and were intensive. Ice coverage in these basins exceeded the norm by 5-6% in December. Intensive icing processes were also continuing in January-February 1989. In February ice tongue, beeing shifted along the eastern slopes of the Grand Bank of the Newfoundland, riched the western slope of the Flemish Cap Bank. Mean monthly ice coverage of the Labrador Sea made up 50% what was by 10% higher than the norm and the highest for the recent 5 years.In March ice coverage in the Labrador Sea approached the long-term mean level and that in the Davis Strait - exceeded the norm by 13%.

In April a rapid reduction of the area of drifting ice in the Labrador Sea has began. Ice tongue extending along the eastern slopes of the Grand Bank, shifted to the northwestern direction with a velocity about 60 miles per a decade. At the same time a deglaciation and recession of ice masses from the Newfoundland coast were registered. By the end of the month the southern edge of drifting ice was pronounced approximately along 50°N. Mean ice cover was close to the norm.

In the same period 82% of the Davis Strait area was covered with ice. Ice cover in the Starit was by 18-22% higher than the norm and the highest for the recent 20 years. In March-April the ice from the east and west of Greenland have been mixed in the southwest of Greenland. In May ice cover in the Davis Strait has notably reduced and the total ice coverage was only by 10% higher than the norm. No drifting ice was observed in the Labrador Sea in June and in the Davis Strait - in August.

In autumn ice formation in the Davis Strait began in November and in the Labrador Sea - in the first decade of December. In early days of the period ice conditions were close to the long-term mean , but already during the last 5 days of December their intensification was noted.

CONCLUSIONS

An extremely low background of atmospheric pressure over the

Norwegian-Greenland Basin in autumn-winter 1988-89 caused an intensive transport of air flows from the north over the north-western part of the Atlantic Ocean which has given rise to essential cooling of water masses in that area , a decrease in heat advection because of the Irminger Current and intensification of cold Baffin Land and Labrador Currents. By reason of this a decrease in temperature of a surface layer to 50°N from January to March has exceeded a common climatic decrease in temperature of this layer approximately by 3 times during winter.

Winter and spring months in the Northwest Atlantic were characterized by severe ice conditions. In February the highest ice cover for the last 5 years was registered in the Labrador Sea and the highest for the last 20 years in the Davis Strait - in April. In March-April the ices from the east and west Greenland have been mixed in the southwest of Greenland - rather infrequent case.

Intensive cooling and decrease of heat advection caused a notable decrease in water temperature over the Newfoundland Shelf. In spring the area occupied by waters with the "below the norm" temperatures in a near-bottom layer has increased approximately by 2 times in Divs. 3NO and 3K from 1988 to 1989. Mean water temperatures in a near-bottom layer in these divisions were by 1.0 and 0.2°C lower than the norm and level of the previous year in these divisions, respectively.

Intensive radiative heating in spring-summer could not compensate negative effect of the mentioned above factors. In autumn a decrease of the area occupied by the transformed Atlantic waters was observed in the Baffin Land and Labrador divisions, and a notable deficiency of heat, relatively to the level of 1988, was registered in the area of these waters distribution. Mean temperature in the upper 200-m layer from the area of mixed waters (Subarea 0B) was by 1.2°C and in the Irminger component of the Labrador Current - by 0.6°C lower compared to 1988. Negative deviations of mean temperature in 200-500 m layer made up 0.6 and 0.3°C , respectively, in these divisions.

As a result of intensive radiative heating in spring-summer water temperature in the upper 200-m layer of the Labrador Current Cold component was close to the norm and level of 1988. However, a rise in intensity of the cold intermediate layer because of anomalous cooling in winter caused a notable increase of the area occupied in a near-bottom layer with the negative temperatures on the Baffin Land, Labrador and Newfoundland Shelves.

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BOROVKOV, V.A., and I.I. TEVS. 1988. Temperature of Bottom Waters Over the Newfoundland Shelf in Spring-Summer 1972-86. NAFO SCR Doc., 88/97, Serial No. 1554, 16 p.

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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	Okt	Nov	Dec
	1			.	.	.	.	.	.	−	.	.	+
	2	.	.	−	−	−	.	.	.	−	−	−	.
	3						.	.	.	.	.	.	.
2	4	.	.	.	.	.	.	.	−	−	−	−	−
	5	.		−		.	.	.	+	.	.	.	.
	6	.	−	−	−	.	.	.	.	.	−	.	.
	7	.	.	.	.	.	.	−	−	.	.	.	.
	8					+	.	+	.	+	.	.	.
	9	.				−	.	.	.	.	.	.	.
	10	−	−	−	−	−	.	.	−	.	+	.	.
	11	.			.	.	.	+	+	.	.	.	.
	12	.	.	−	.	.	.	.	.	+	+	+	.
	13	.	.	−	−	.	+	−	−	.	.	.	−
3	14	.	.	.	.	.	+	.	.	.	−	.	.
	15	.	.	.	.	.	.	.	+	+	+	+	.
	16	−	−	.	.	.	.	.	−	−	.	.	.
	17	−	.	−	−	.	+	.	+	−	+	+	.
	18	.	.	.	+	+	+	.	.	+	+	.	+
	19	.	.	.	.	.	.	.	.	+	.	+	.

+ - 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 in 1986 - 1989 (%).

Class	above the norm			the norm			below the norm		
NAFO Subarea	2	3	2+3	2	3	2+3	2	3	2+3
1986	5	8	7	56	49	52	39	43	41
1987	2	14	10	71	68	69	27	18	21
1988	4	21	15	86	66	73	10	13	12
1989	2	18	13	75	64	68	23	18	19

Table 3. Mean water temperature in a near-bottom layer (°C) by divisions and their area (%), occupied by waters with different temperatures in autumn 1986 - 1989.

Years	Mean temperature (°C)				Area (%) with the temperatures: below -1°C				below 0°C				above 3°C			
	3L	3N	3O	3LNO	3L	3N	3O	3LNO	3L	3N	3O	3LNO	3L	3N	3O	3NO
1986	0.8	2.4	2.4	1.5	0	0	0	0	27	5	0	19	10	43	39	22
1987	0.3	1.6	1.2	0.7	0	0	0	0	53	19	17	41	3	10	11	6
1988	0.2	2.0	1.5	0.7	23	5	6	14	52	10	11	38	2	33	11	8
1989	0.2	2.2	1.5	0.8	32	5	11	23	55	14	17	41	10	29	17	16

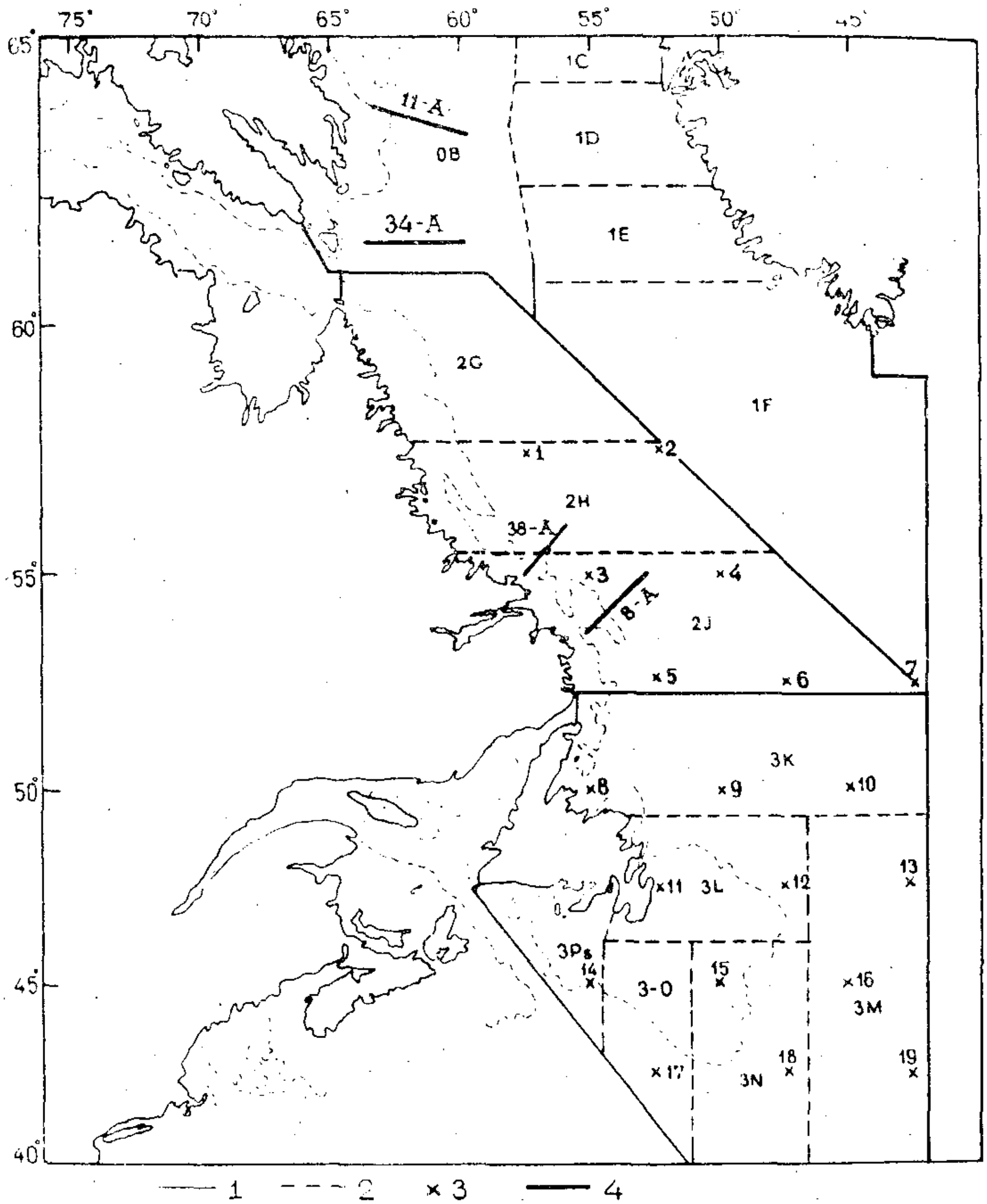

Fig.1. Boundaries of NAFO Subareas (I) and Divs.(2), position of regular grid points where the data on mean monthly temperature of sea-surface water layer (3) and standard sections (4) in the Northwest Atlantic were obtained.

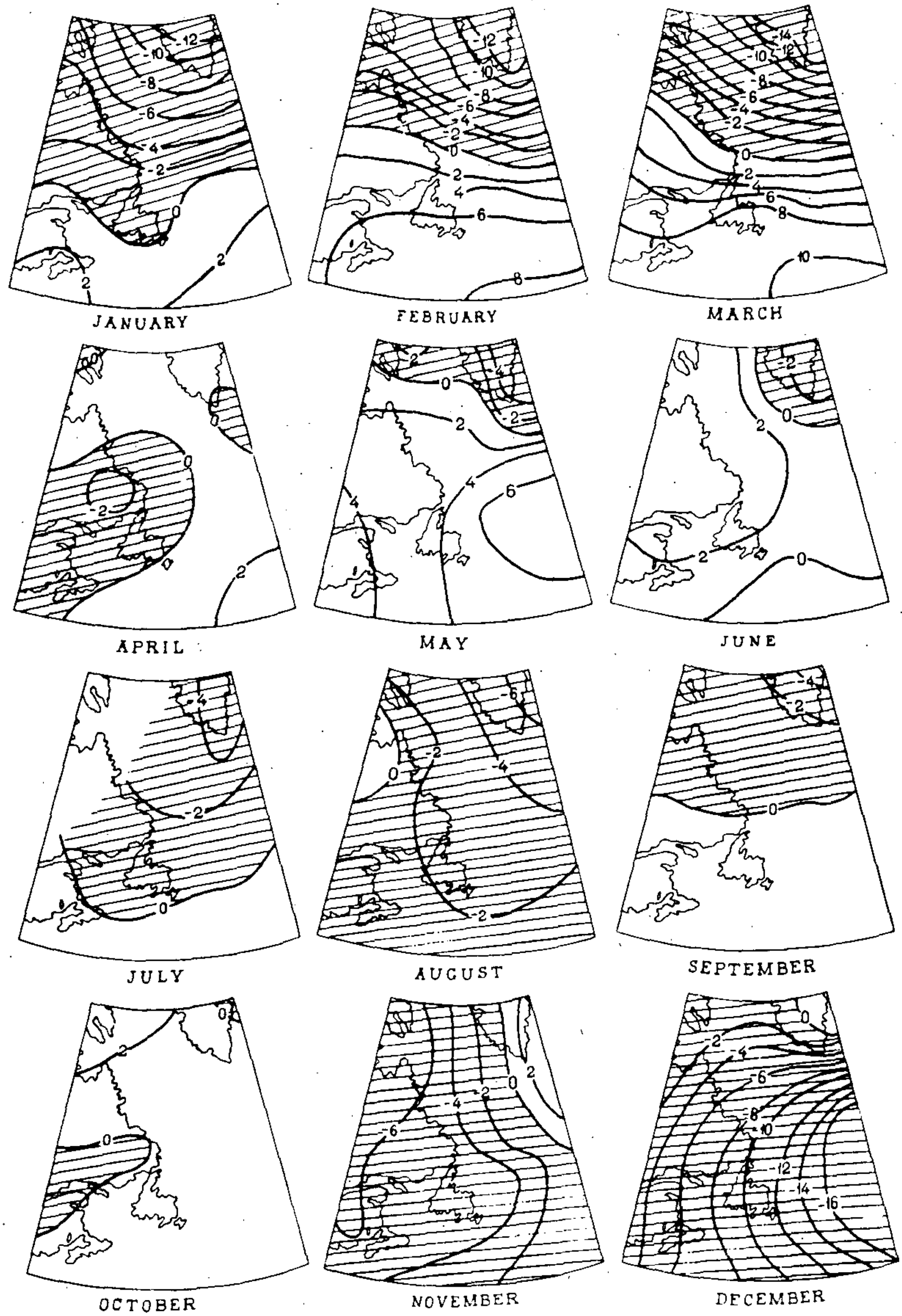

Fig. 2. Monthly atmospheric pressure anomalies at sea level over the Northwest Atlantic in 1989, (hPa)

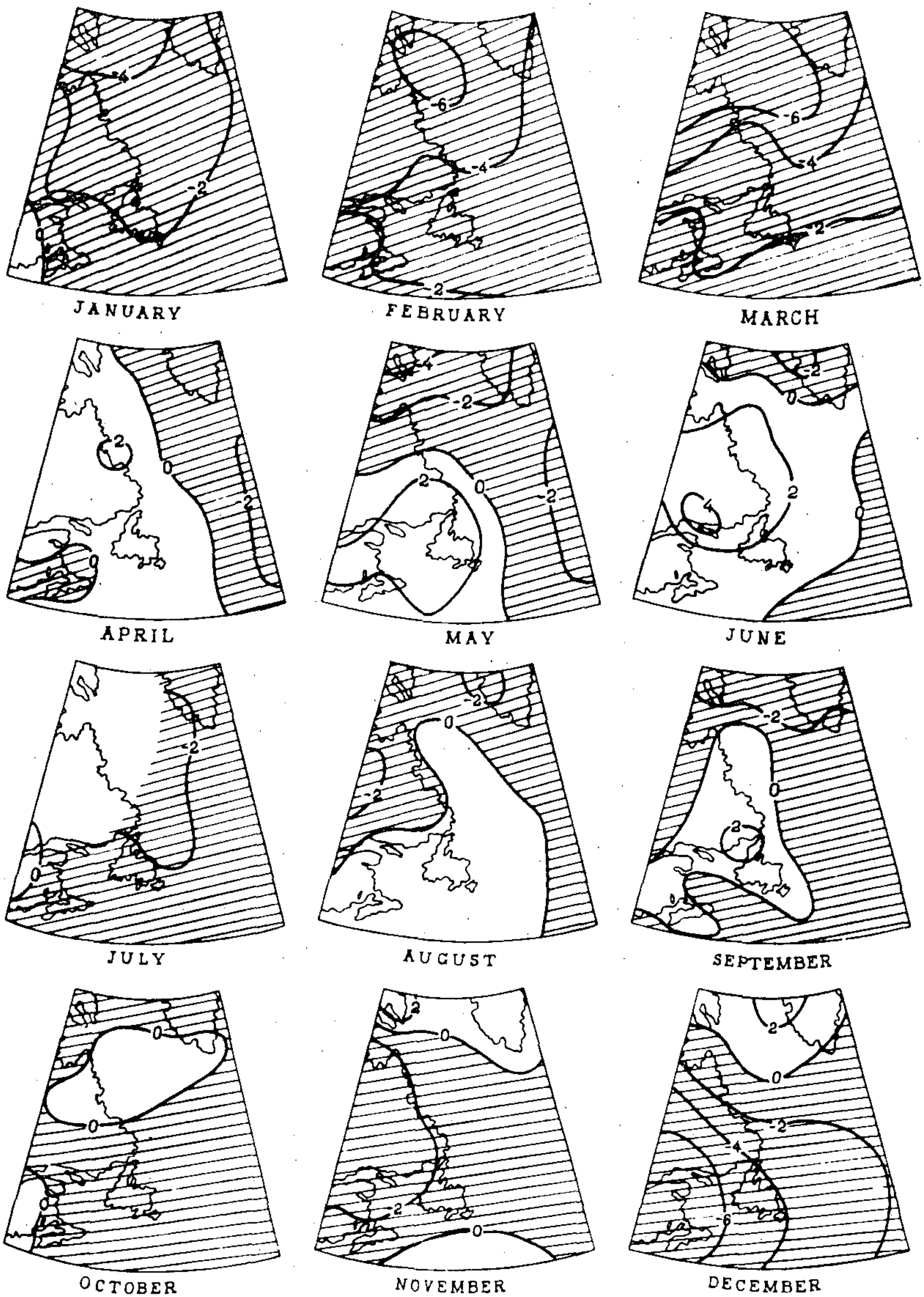

Fig.3. Monthly air temperature anomalies in near the ground surface over the Northwest Atlantic in 1989 (°C)

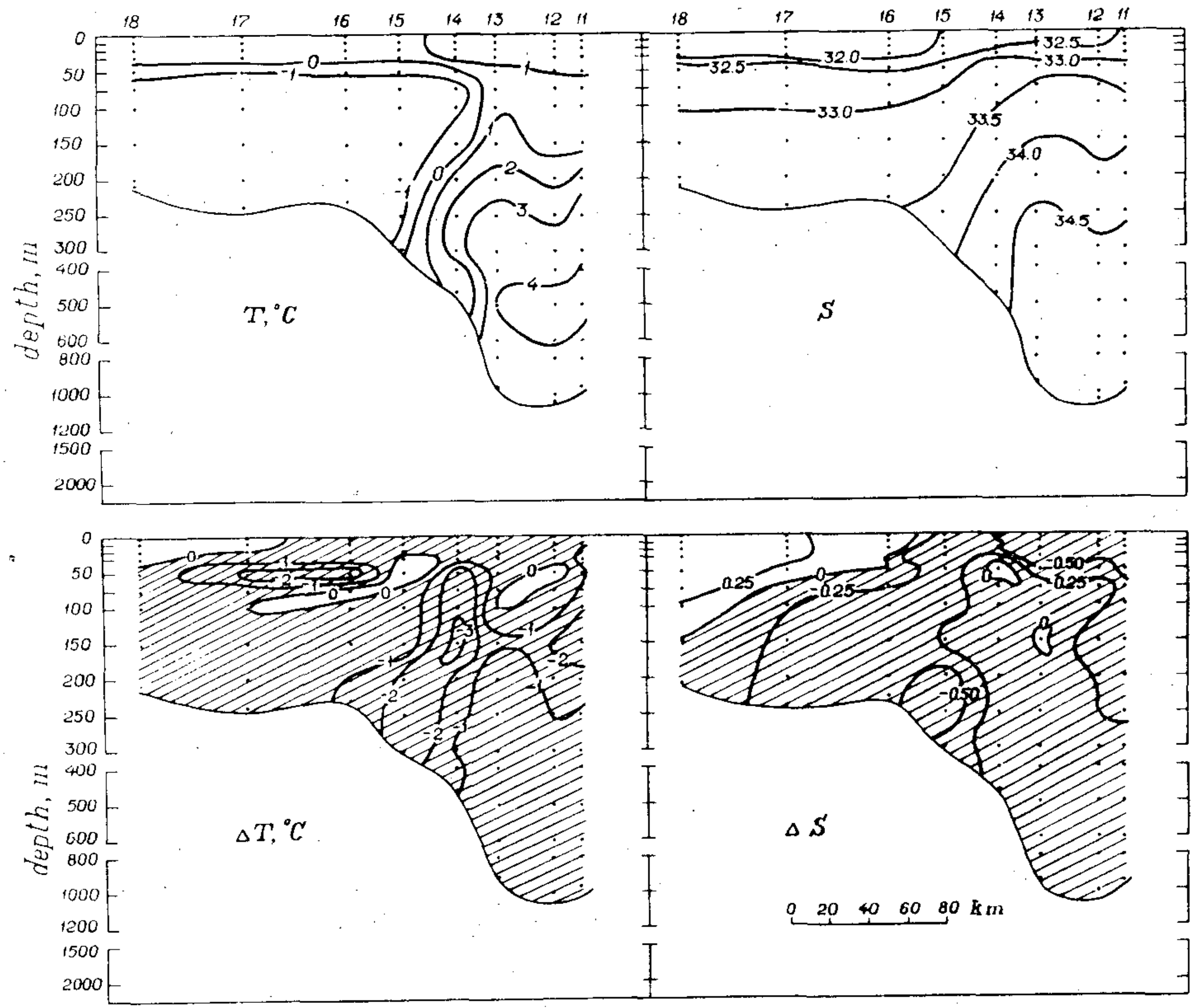

Fig.4. Distribution of water temperature (T°C), salinity (S) and their deviations from the level of 1982 (Δ T°C and Δ S) on the Section 11-A (Cumberland) in October 1989 (°C)

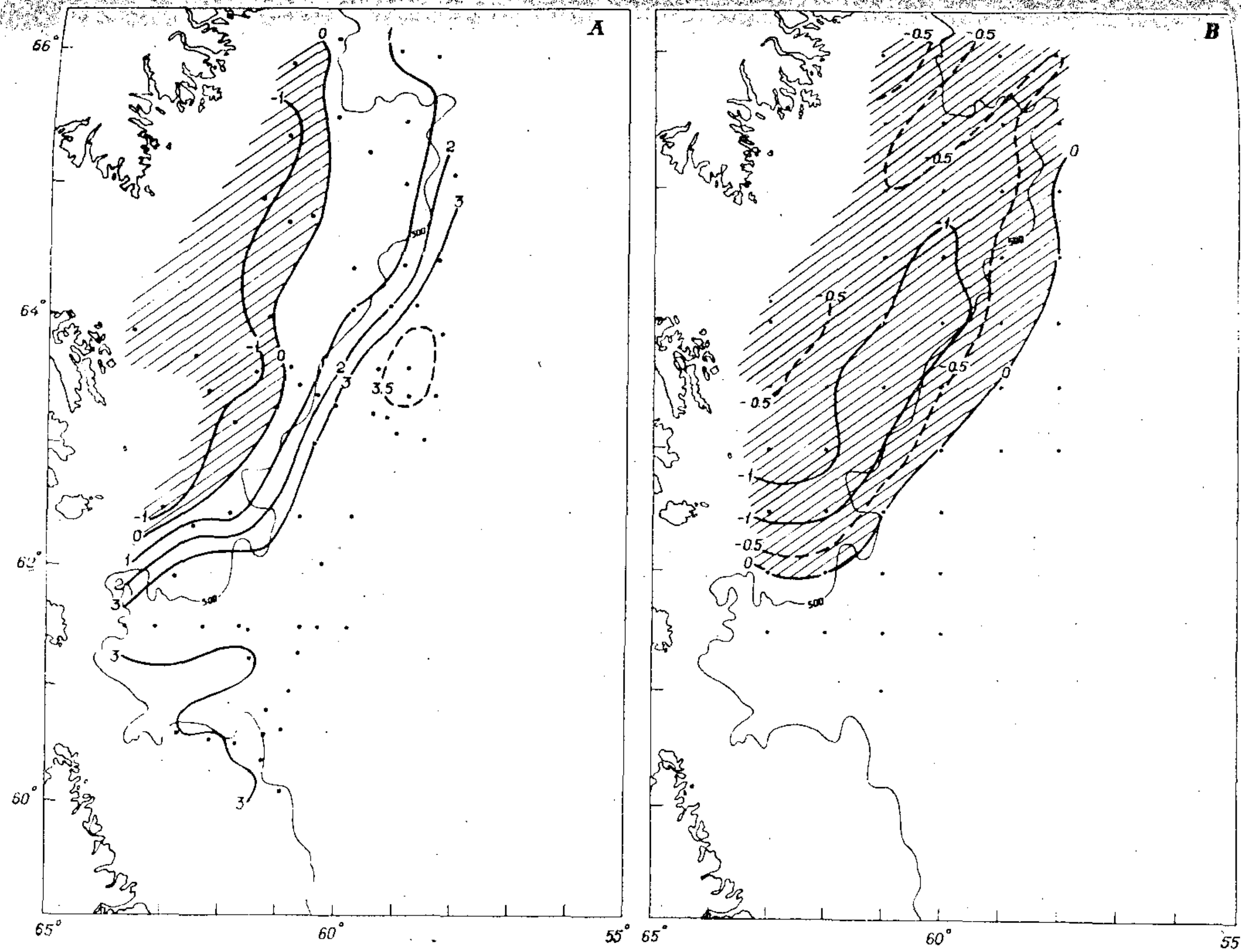

Fig. 5. Distribution of temperature (A) and deviations from the level of 1988 (B) in a near-bottom layer on the Baffin Land Shelf in October 1989 (°C)

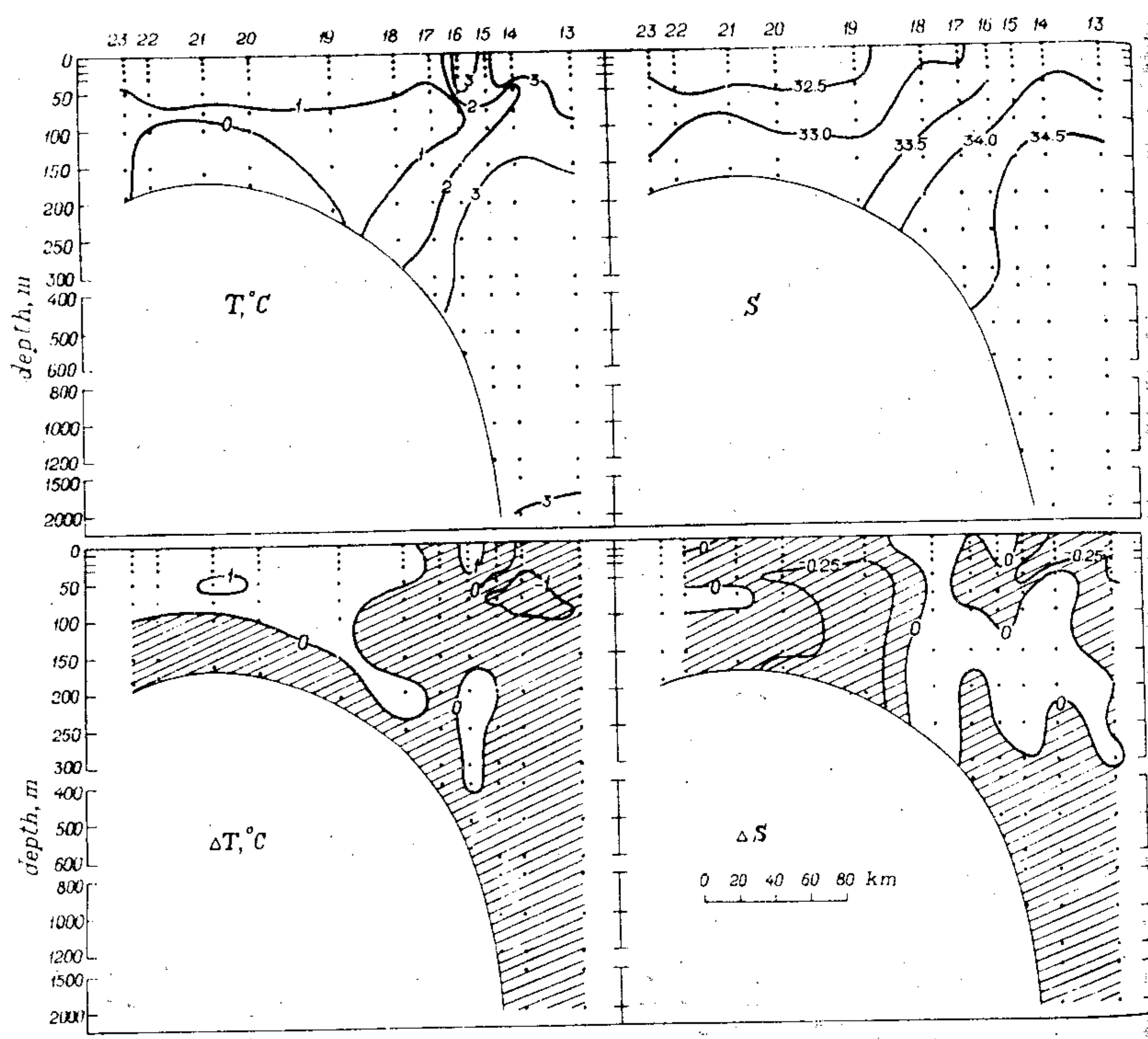

Fig.6. Distribution of water temperature (T°C), salinity (S) and their anomalies (Δ T°C and Δ S) on the Section 8-A in late October 1989

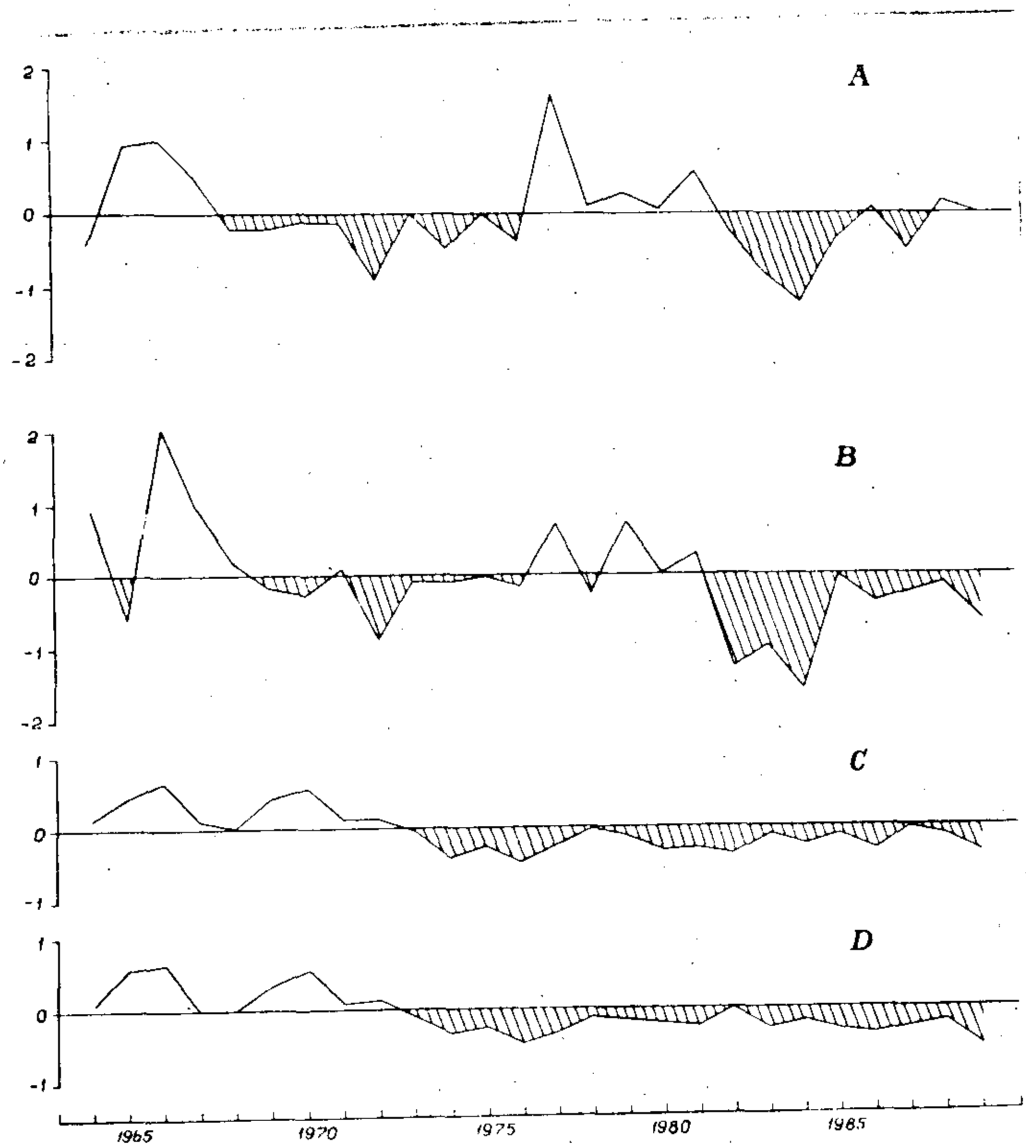

Fig.7. Anomalies of mean water temperature in 0-200 m layer of the Cold (A) and in 0-200m(B), 200-500 m (C) and 500-1000 m (D) of the Irminger Components of the Labrador Current (°C)

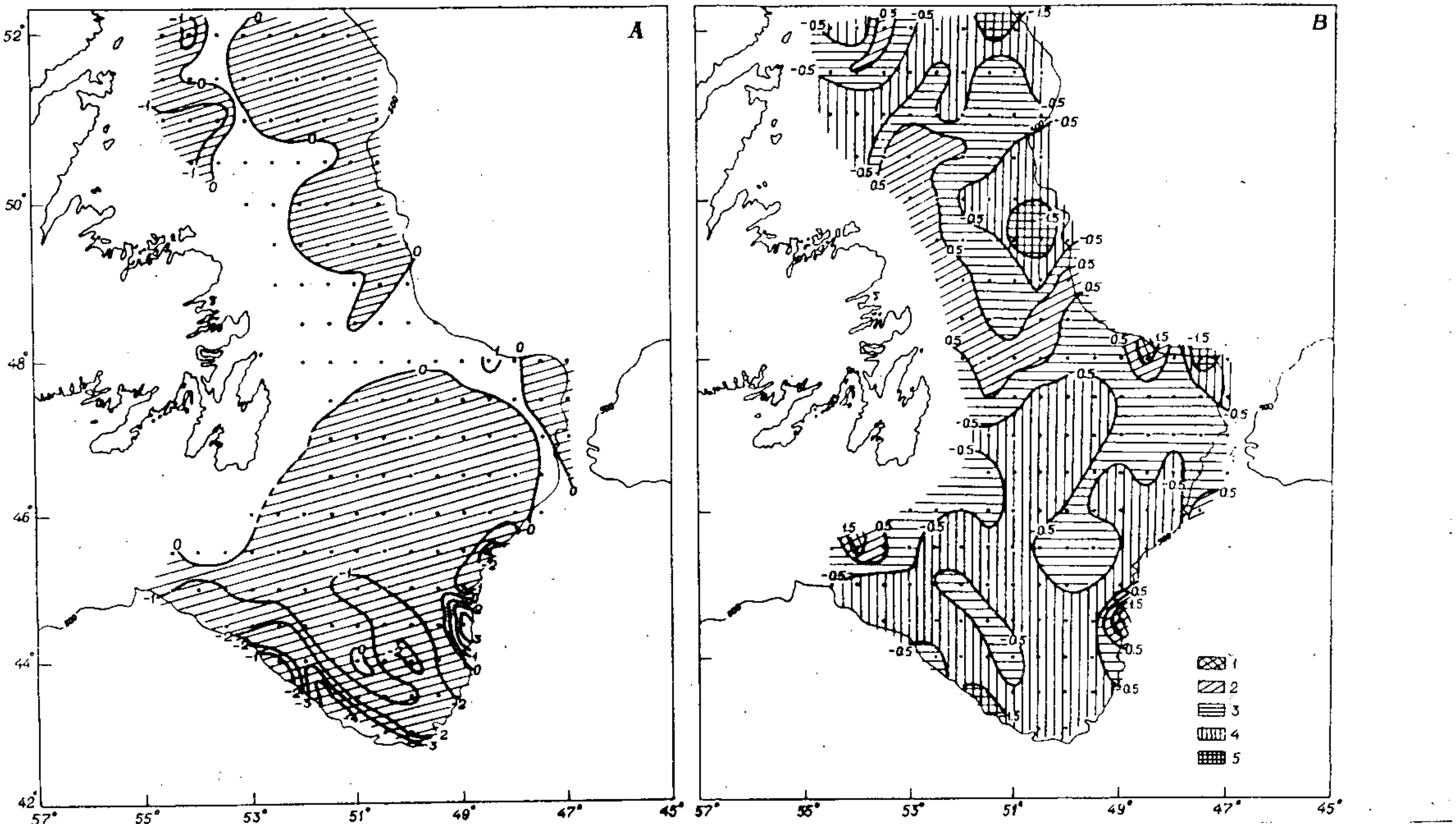

Fig. 8. Distribution of anomalies (A) and standardized anomalies (B) of bottom water temperatures on the Newfoundland Shelf in spring 1989

1. – much above the norm
2. – above the norm
3. – the norm
4. – below the norm
5. – much below the norm

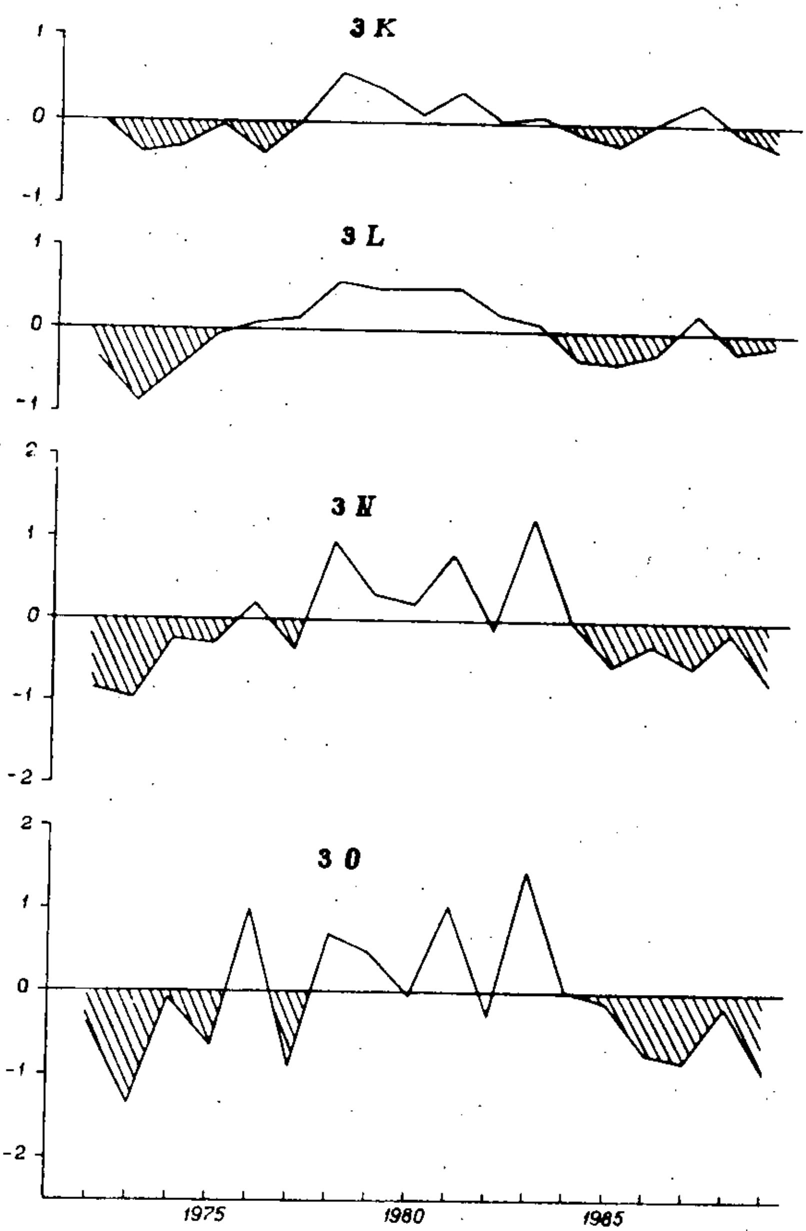

Fig.9. Anomalies of mean by field bottom water temperature in the Newfoundland Shelf divisions in spring (°C)

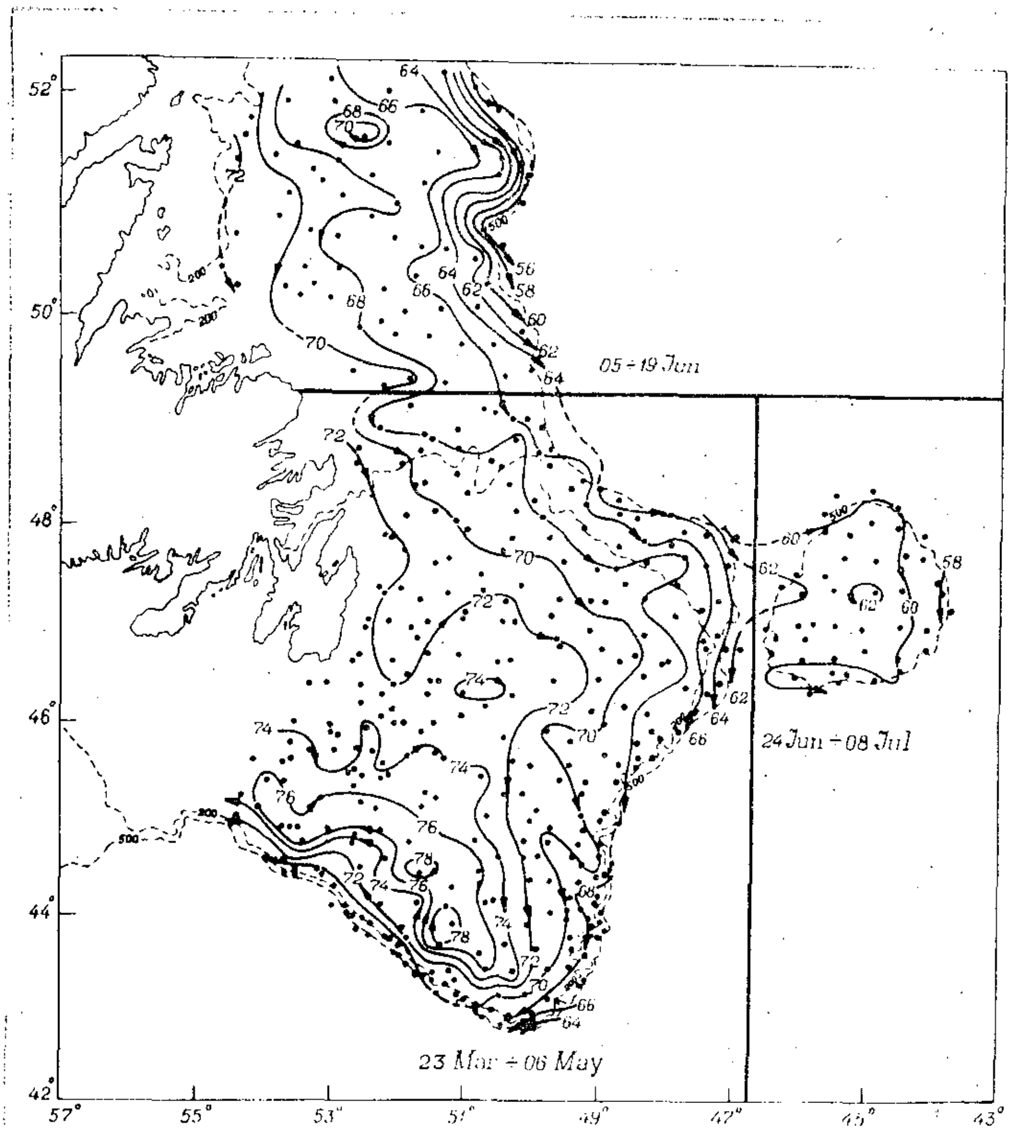

Fig.10. Dynamic topography of sea-surface relative to the 2 MPa level in spring 1989. Dynamic height isolines are given in 2 dyn.cm distance