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Oceanographic Conditions in NAFO Subareas 0, 2 and 3 in 1991

by

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INTRODUCTION

The paper includes analysis of oceanographic conditions in the North West Atlantic specific Subareas for 1991 based on the materials obtained during the investigations carried out by PINRO in spring-summer (Subarea 3) and autumn (Subareas 0,2,3) periods. Besides, data on sea surface temperature regime and ice conditions in the North West Atlantic, borrowed from national hydrometeorological centers, have been used.

Trends of variations in oceanographic conditions in recent years have been evaluated and comparison of them between long-term mean characteristics done.

MATERIAL AND METHODS

Observations over temperature and salinity were done during PINRO cruises by irregular grid of trawl stations and along standard sections 1-A (SW-Grand Bank), 2-A (Coast Guard - 4) 4-A, 6-A (Flemish Cap), 8-A, 34-A and 38-A. Fig.1 gives a position of these sections.

The observations were done by standard methods presented in preceding papers (Borovkov and Tevs, 1989, 1990, 1991).

Some of the oceanographic stations, occupied in autumn period (Subareas 0 and 2), were done by MGI-1201 CTD-sonde, measuring hydrostatic pressure, temperature and relative conductivity of sea water.

To characterise a thermal state of surface layer waters the data on mean monthly temperature anomalies in regular grid points, produced in charts by the USSR Hydrometeorological Center. A part of the given grid points for the area surveyed is presented in Fig.1. Long-term mean values for 1957-1971 were used to calculate temperature anomalies.

Analysis of ice conditions in the NW Atlantic was done by materials obtained from Hydrometeorological Center (Murmansk).

SEA SURFACE TEMPERATURE

For convenience sake when analysing the data on temperature anomalies of surface layer were divided into three classes -"above the norm", "the norm" and "below the norm". Boundaries between the classes were chosen conventionally and referred to -1° and 1°C anomalies.

To judge by results from classification (Table 1) during 1991, except August, temperature values, corresponding to "the norm", predominated over Subareas 2 and 3. Their recurrence during a year for the whole set of regular grid points made up 83%. In August essential negative water temperature anomalies of surface layer ,resulting from extremely late completion of ice season, were observed in the southern part of Subarea 2 and practically over the whole area of Subarea 3.

The recurrence of surface water temperatures from different classes in Subareas 2 and 3 for recent years is given in Table 2. As evidenced by the data listed in Table, a rise in temperature of surface layer from 1986 to 1988 was observed; considerable (1.5-2 times) recurrence increase in temperature from "the norm" and "above the norm" classes and decrease in temperature recurrence from "below the norm" class are indicative of this. The 1989 and 1990 were characterized by a cooling in a surface layer, being the most essential in Subarea 2 in 1989 and in Subarea 3 - in 1990. The recurrence of temperatures from "below the norm" class has increased by more than twice for that period in both Subareas and, respectively, much reduced for "the norm" and "above the norm" classes.

In 1991 an essential rise in surface layer temperature took place in both Subareas. Temperature recurrence from "below the norm" class has reduced relative to that in 1990 more than twice. Temperature recurrence of "the norm" class much increased, however, it remained at a very low level in "the above the norm" class.

TEMPERATURE CONDITIONS IN DIV.OB (BAFFIN LAND) IN AUTUMN PERIOD

Oceanographic observations were carried out by RV "Kapitan Shaitanov" in the Davis Straight within the Canadian fishing zone to the south of 66°N in November. 53 casual stations and 7 stations along the 34-A section in latitude of the Resolution Island have been ocupied in this area (Fig.1).Water temperature with a vertical structure arctic type pronounced along relatively shallow (below 500 m) areas, varied vertically from -1.6 to 1.5°C and and was lower in mid-water compared to 1990. Considerably relative cooling of waters was observed in the Hudson Strait .

In the zone of subarctic type of vertical structure in a deep-water south-east of Subarea water temperature varied vertically from 3.4 to 5.2°C. Intermediate maximum temperature was registered in a layer 100-600 m and was typical of this structure in autumn period. In the upper 300-m layer water temperature was much higher than in 1990. The highest rise in temperature (to 4-5°C) was observed in the section between 63 and 64°N.

Frontal zone between water masses with the types of vertical structure mentioned, shown by thicker distribution of isotherms, was pronounced over 300-500 m depths and was characterized by the highest gradients in the section from 62 to 64°N.

A chart of distribution of water temperature in bottom layer is given in Fig.2A. As indicated by Figure, negative water temperatures were pronounced in the coastal area below 300 m depth. Water temperature in a bottom layer over 500 m depths practically everywhere exceeded 3°C. Comparing this chart to those for temperature distribution for previous years (Borovkov and Tevs, 1990, 1991) a reduction in area of waters with negative temperature on the Baffin Land Shelf and increasing of area of warm waters with the above 3°C temperature , especially essential in the Hudson Strait deep, should be noted.

Tendencies to deviations in a bottom layer water temperatures from autumn 1990 to autumn 1991 are shown in Fig.2B. The Figure indicates a cooling in bottom layer waters in the Subarea shallows and northern part of the Hudson Strait deep in the period mentioned. Somewhat rise in temperature was registered in deepwaters of the Subarea. The highest rise in temperature took place in the Greenland-Canadian overfall where temperature in bottom waters was higher by 1°C against 1990.

TEMPERATURE CONDITIONS IN SUBAREA 2 IN AUTUMN PERIOD

Oceanographic observations were conducted by RVs "Kapitan Shaitanov" and "Vilnuis" on the shelf and continental slope of Subarea 2 in September-November. In total 105 causal stations and 17 stations in the 8-A and 38-A sections , the position of which is given in Fig.1, have been ocupied in that period.

Distribution of temperature and salinity in the 8-A section , crossing the Labrador current in the Hamilton Bank area, are well demonstrated by the hydrographic conditions in Subarea (Fig.3). The same Figure includes the deviations in temperature and salinity from the norm calculated for 1964-1986.

As can be seen in the Figure, temperature of the surface 30-m layer exceeded the norm by 0.4-0.6°C in the whole section. Salinity in this layer was below the norm, and negative deviations in salinity exceeded 0.5 psu at 14-17 stations.

Cold intermediate layer (CIL), typical of water mass with the arctic type of vertical structure, was pronounced in the range of depths from 50 m to the bottom in the Labrador Current Coastal branch (section A, 20-23 stations). Water temperature in this layer was by 0.2-0.6°C lower than the norm. In the Main branch (section B, 16-19 stations) and Irminger component of the Labrador Current (section C, 13-15 stations) CIL occupied the depths from 30 to 150 m. A core of CIL was in 50-75 m layer. Water temperature in the core was below 1°C , which was by 1.3-2.0°C lower than the norm.

In bottom layer of the Labrador Current Main branch temperature and salinity were extremely high, and exceeded the long-term mean values by 1°C and 0.5 psu and more at outward edge of the shelf.

Water temperature at depths over 300 m in the Irminger component was by 0.2-0.5°C lower than the norm.

Anomalies of mean water temperatures by layers in the Labrador Current separate branches are presented in Fig.4 for 1964-1991. The Figure shows a rise in temperature which has reached the norm in 1991 in the upper 200-m layer of the Labrador Current cold component (section AB) and in the 200-500 m layer of the Irminger component (section C). Mean temperature remained at the level of previous year in the 0-200 and 500-1000 m layers of the Irminger component what was below the norm by 0.3-0.4°C.

TEMPERATURE CONDITIONS IN SUBAREA 3

Oceanographic observations were conducted in Subarea 3 by RV"Vilnuis" in April-June and November-December, and by RV "Kapitan Shaitanov" - in September.

183 causal were occupied by RV "Vilnuis" in Divs. 3LNO and 3M , as well as 28 stations in standard sections 1-A, 2-A, 4-A and 6-A (Flemish Cap) in spring-summer (Fig.1). No oceanographic observations were done due to heavy ice conditions in Div.3K.

Distribution of water temperature in a bottom layer in spring period is presented in Fig.5A. The Figure indicates the most part of the Grand Newfoundland Bank *to be occupied with negative* temperature waters. Even on the southern slope of the bank the temperature below -1°C was registered which showed an extremely high intensity of the Labrador Current. Such situation has been noted only once (in 1990) since 1971. Positive temperatures were noted deeper 250m on the Grand Bank slope and in the shallows.

Deviations in temperatures from the norm for 1971-1990 have been estimated by values for water temperature , interpolated in points of regular half-degree grid (Tevs, 1991).

To characterize significance of anomalies their comparison between corresponding values of mean-square deviations , being a measure of year-to-year temperature variations, has been done. As a consequence, standardized anomalies obtained (A/S) were divided 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	$-0.5 > A/S >= -0.5$
- much below the norm	$A/S < -1.5$

Distribution of the standardized temperature anomalies is given in Fig.5B. Most part of the bank (about 66% of its area) was occupied by waters with "below the norm" and "much below the norm" temperatures. Waters with "the norm" temperatures occupied about 30% of the bank area and predominated in Div.3N where they accounted for 60% of the Subarea over the bank. Waters with "above the norm" and "much above the norm" temperatures were registered only in the local sites of the Grand Bank southeastern and northeastern slopes.

Fig.6 presents deviations of mean water temperatures in bottom layer by specific Subareas, estimated for 1971-1990. As indicated by Figure bottom temperature on the Grand Bank was much below the norm during recent three years. Peak of cooling in Divs. 3N and 30 was registered in 1990. In 1991 a rise in temperature took place in these Subareas and mean temperature in bottom layer increased by 0.7-1.0°C, however, it remained by 0.4 and 0.8°C below the norm. Mean temperature in bottom layer in Div.3L remained at the level of abnormally cold 1990 and was below the norm by 0.7°C. On the whole, water temperature in a bottom layer on the Grand Bank (Divs.3LNO) was by 0.7°C below the norm, however, by 0.5"C higher against 1990.

In September 15 oceanographic stations have been done by RV "Kapitan Shaitanov" in the Funk Island Bank eastern slope. Water temperature was higher in the whole mid-water compared to 1990. The highest rise in temperature (by 0.8°C on the average) was registered in a cold layer at 50-150 m depths. Water temperature was on the average by 0.3-0.4°C higher in surface 30-m and 200-500 m layers , compared to a similar period 1990.

In November 51 causal stations have been occupied by RV "Vilnuis" on the Grand Newfoundland Bank. Mean temperature and per cent of the area occupied by waters with different temperatures were calculated for Subareas observed using the water temperature values interpolated into the points of regular half-degree grid.Table 3 includes results from the calculations.

As can be seen in the Table, more than a half of the area (Divs. 3L and 3N) covered was occupied by waters with negative temperatures. Mean water temperature in a bottom layer was much lower than in 1990 and the lowest for a period since 1986.

As for Div.30, the area with negative water temperatures was also much larger against 1990, however, due to a high temperature in a central part of Div. the mean temperature occurred to be at the 1988 and 1989 level, and twice lower compared to 1990.

Oceanographic conditions observed in the Grand Newfoundland Bank are in autumn period have, on the whole, been the coldest since 1986.

If in 1990 , after abnormally cold conditions in spring the temperature conditions in Divs.3NO in autumn period were close to the norm,then in 1991 , after rather cold winter and spring , thermal state of waters in bottom layer remained at the extremely low level in autumn as well.

GEOSTROPHIC CIRCULATION ON THE NEWFOUNDLAND SHELF IN SPRING-SUMMER PERIOD

Calculations and charting of sea surface dynamic topography over the Grand and Flemish Cap Banks have been done to elucidate qualitative characteristic of horizontal circulation in a surface layer by the methods developed by Borovkov and Kudlo (1982). Results from detailed surveys conducted in Divs.3LNO and 3M in spring-summer period were taken as initial materials for the calculations.

Cinematic schemes of horizontal circulation on the Grand Bank in the periods from 27 April to 6 June (A) and from 6 June to 5 July (B) are given in Fig.7.

As indicated by Fig.7A the circulation in a period from 27 April to 6 June over the Grand Bank was characterized by a combination of streamy current over the bank slopes, corresponding to the Labrador Main branch Current, with a retarded circulation over the bank itself. The current had maximum velocity in the Flemish-Pass deep western slope. A number of dynamic formations of different vorticities among which anticyclonic vortex in the south of the bank and cyclonic meander in the northern part of Div.3L had the highest geometrical dimensions , was pronounced over the Grand Bank. General anticyclonic vorticity of current field was observed over the Flemish Cap Bank.

When comparing schemes of circulation for 1991 spring period to those similar for the previous years (Borovkov and Tevs, 1989 , 1990, 1991) a general rise in dynamic level was noted, which resulted from a relative decrease in water density due to a considerable water softening in surface layer as a result of ice melting which was more plentiful compared to previous years. No cyclonic meander has been noticed in Subarea 3L in preceding years.

In June (Fig.7B) the anticyclonic vortex in the south of the Grand Bank was formed in two centers and its southern boundary shifted to the north. A flow of the Labrador Current Main branch, carring relatively cold waters over to western direction considerably intensified over the bank "tail".

ICE CONDITIONS

Ice coverage in the Labrador Sea started in the third decade of November 1990 in a narrow coastal strip of the Northern and Central Labrador. Ice covering processes followed very intensively and the drifting ice edge attained the Grand Bank northern slopes by the end of January 1991. Mean ice coverage in the Labrador Sea and Davis Strait exceeded the norm by 10–17% for January-March.

In April-May the ice conditions remained very heavy and total ice coverage in the Labrador Sea and Davis Strait exceeded the norm by 15–18%. It was especially high off the Grand Bank where a position of the southern edge of drifting ice was close to the long-term maximum.

In July the ice coverage in the Labrador Sea exceeded the norm twice and even in August the drifting ice was noted in a narrow coastal strip of the Labrador. The main mass of ice was registered to the north of 65°N and to the west of 60°W in the Davis Strait in that period.

In autumn the ice covering in the Davis Strait commenced in November and was characterized by essential intensification. In the Labrador Sea ice covering started in the first decade of December in a narrow coastal zone in the whole Labrador Peninsula up to Bell-Isle Strait. In December mean ice coverage in the Labrador Sea and Davis Strait exceeded the norm by 6%.

CONCLUSIONS

Water temperature in a surface layer in NAFO Subareas 2 and 3 was close to the norm during the most part of 1991. Only in August considerable negative temperature anomalies were noted in the southern part of Subarea 2 and practically all over the whole Subarea 3.

In spring *bottom* temperature of waters on the Grand Newfoundland Bank was much (on the average by 0.7°C) lower than the norm, however, higher against 1990. Compared to the 1990 spring period the most essential rise in temperature took place in Divs.3NO (by 0.8-1.0°C). Bottom temperatures remained at the level of abnormally cold 1990 and were, on the average, by 0.8°C lower than the norm in Div.3L.

In autumn period mean temperature of bottom waters on the Grand Bank was the lowest for recent 7 years.

A cooling of waters over the shelf in Div.OB and rise in temperature in its deeper north-eastern and south-eastern areas took place in the period from the autumn 1990 to the autumn 1991.

In Subarea 2 in the same period a shifting of frontal zone to the west between the waters with arctic and subarctic types of vertical structure and input of waters with higher temperature and salinity on the shelf were noted. Anomalies of these characteristics reached 1°C and 0.5 psu on the Hamilton Bank eastern slope.

In autumn water temperature in the upper 200-m layer in the Labrador Current cold component on the 8-A section exceeded the previous year level by 0.7°C and reached the norm. Mean water temperature in the 0-200 and 500-1000 m layers of the Labrador Current Irminger component remained at the 1990 level and was by 0.3-0.4°C lower than the norm.

The 1991 was characterized by heavy ice conditions. Ice coverage in the Labrador Sea exceeded the norm by 13–18% during the most part of ice season. In April–May a position of drifting ice edge off the Grand Bank was close to the long-term maximum.

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

NAFO Sub-area	No. of points	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 in 1986–1991 (%)

Class	above the norm			the norm			below the norm		
NAFO Subareas	2	3	2+3	2	3	2+3	2	3	2+3
I986	5	8	7	56	49	52	39	43	4I
I987	2	I4	I0	7I	68	69	27	I8	2I
I988	4	2I	I5	86	66	73	I0	I3	I2
I989	2	I8	I3	75	64	68	23	I8	I9
I990	I	I2	8	75	58	64	24	30	28
I99I	2	8	5	87	80	83	II	I2	I2

Table 3. Mean water temperature in a near-bottom layer by divisions and their area (%), occupied by waters with different temperatures in autumn 1986–1991

Years	Mean temperature ("C)				Area (%) with the temperature below -1"C				below 0"C				above 3"C			
	3L	3N	3O	3LNO	3L	3N	3O	3LNO	3L	3N	3O	3LNO	3L	3N	3O	3LNO
I986	0.8	2.4	2.4	I.5	0	0	0	0	27	5	0	I9	I0	43	39	22
I987	0.3	I.6	I,2	0.7	0	0	0	0	53	I9	I7	4I	3	I0	II	6
I988	0.2	2.0	I.5	0.7	23	5	6	I4	52	I0	II	38	2	33	II	8
I989	0.2	2.2	I.5	0.8	32	5	II	23	55	I4	I7	4I	I0	29	I7	I6
I990	–	2:0	3.0	–	–	0	0	–	–	I4	6	–	–	29	50	–
I99I	–0	30.4	I.5	0.2	39	0	0	28	77	57	28	62	0	5	28	6

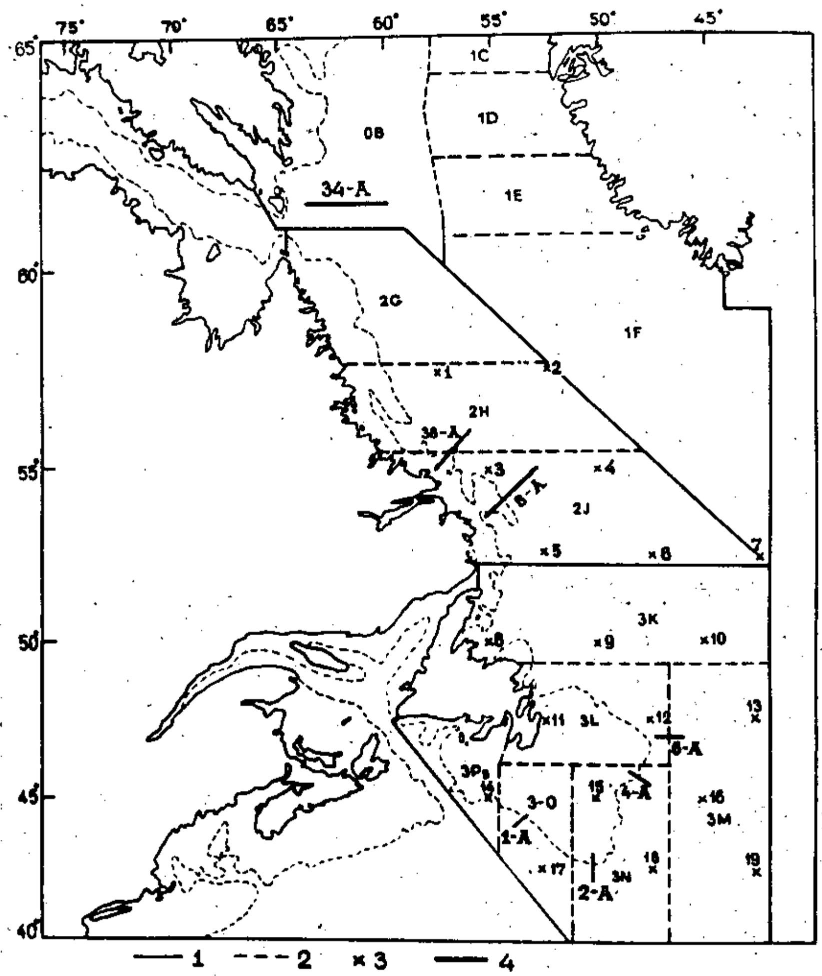

Fig. 1 Boundaries of NAFO Subareas (1) and Divs. (2), position of regular grid points where the data on mean monthly temperature in the sea-surface layer (3) and on standard sections (4) were obtained in the NW Atlantic.

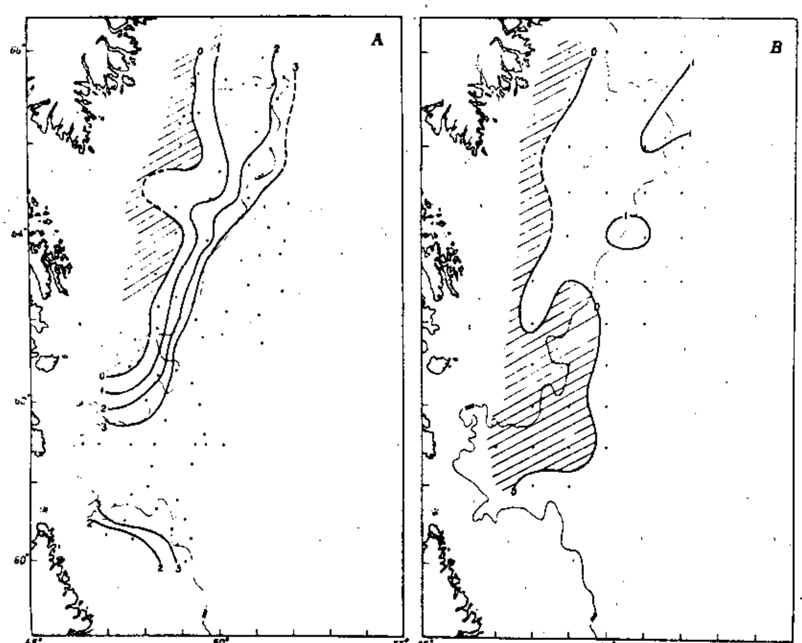

Fig. 2 Distribution of temperature (A) and temperature anomalies relative to 1990 level (B) in the near-bottom layer on the Baffin Land shelf in November 1991.

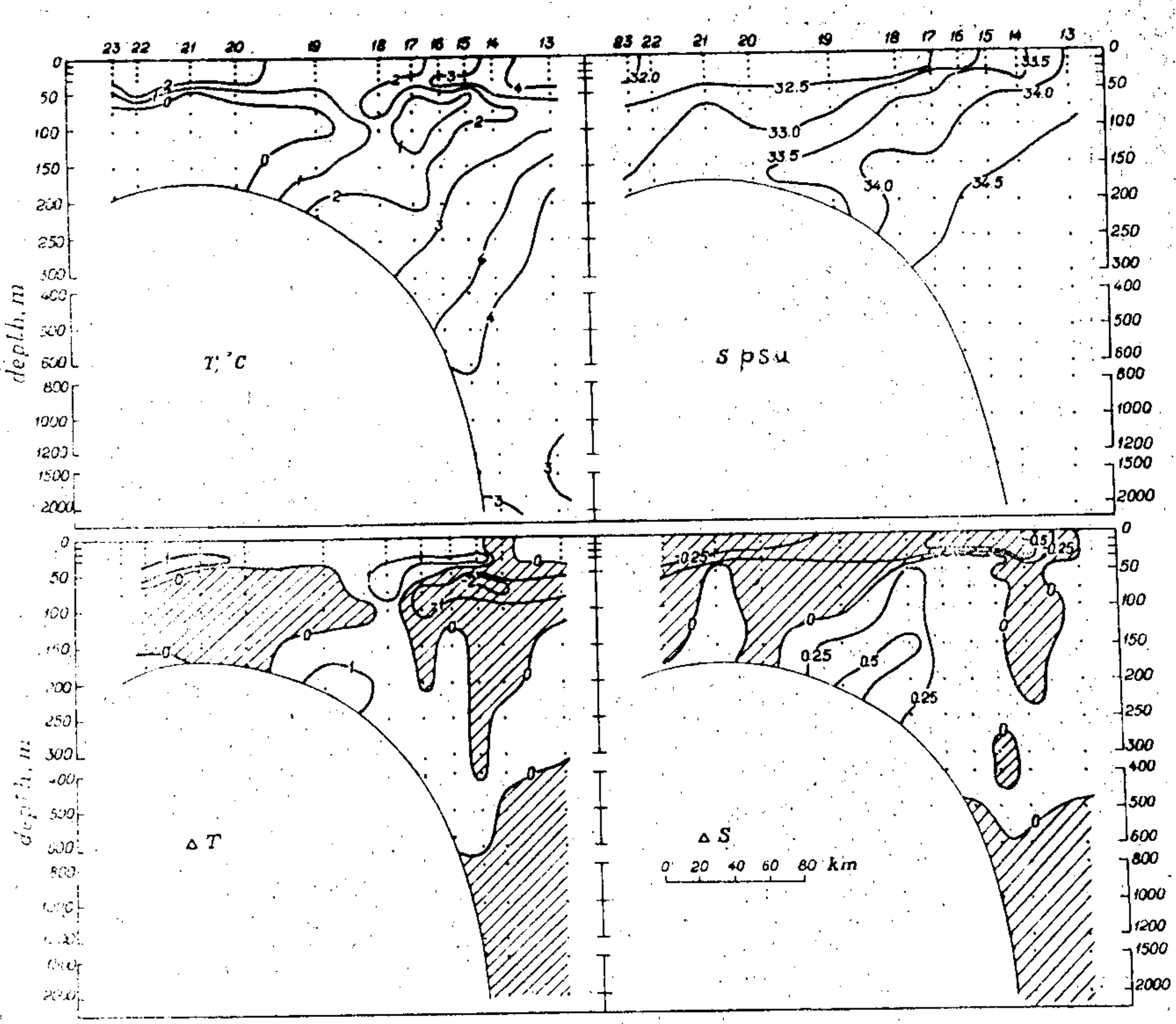

FIG. 2 Distribution of water temperature (T°C) and salinity (S) and there anomalies (ΔT and ΔS) on section 8-A in late October 1991.

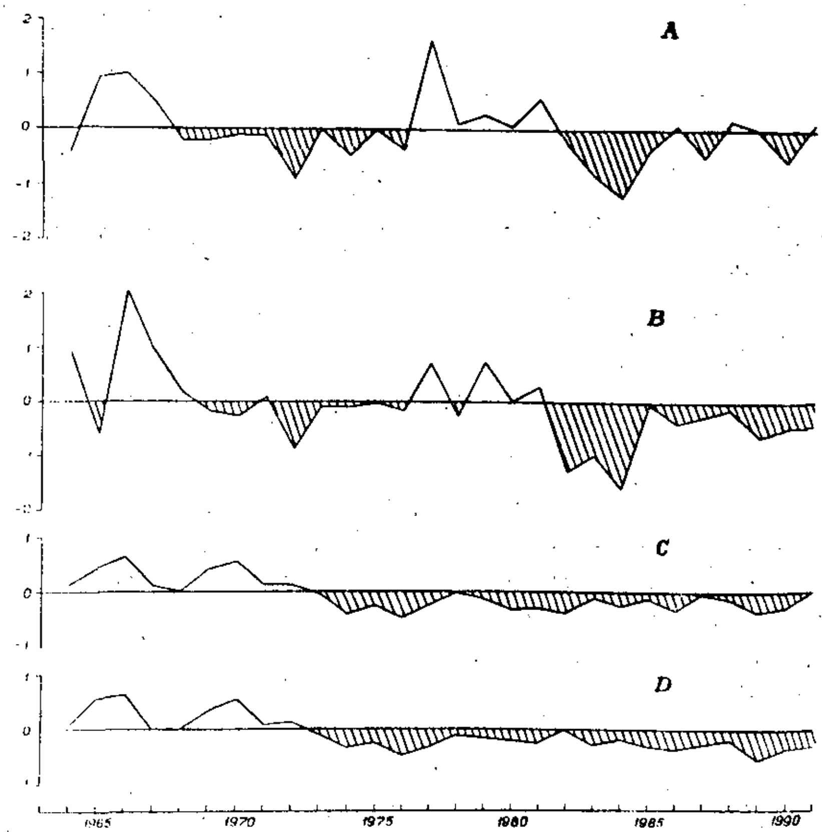

Fig. 4 Mean water temperature anomalies (°C) in the 0-200 m layer of cold component of the Labrador Current (A) and in the 0-200 m (B), 200-500 m (C) and 500-1000 m (D)

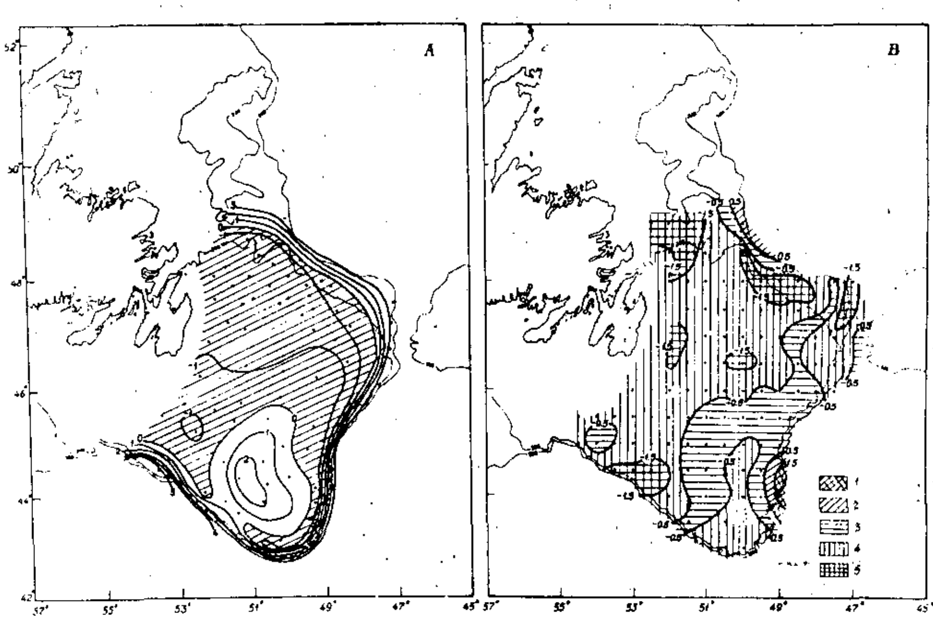

Fig. 5 Distribution of temperature (A) and standardized anomalies (B) of the near-bottom water temperature on the Newfoundland shelf in spring 1991.
1 - much above the norm; 2 - above the norm; 3 - the norm;
4 - below the norm; 5 - much below the norm.

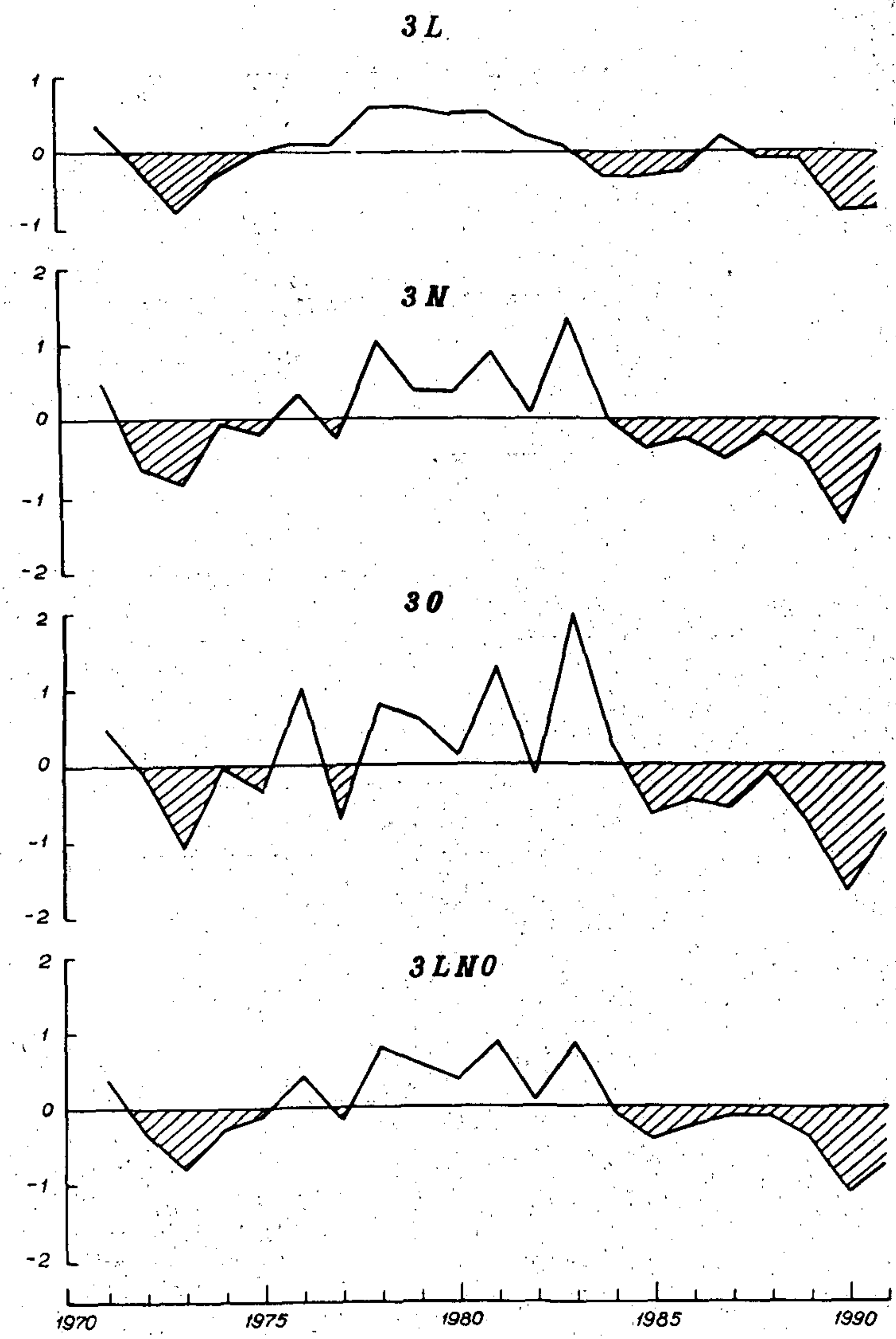

Fig. 6 Anomalies of mean near-bottom water temperature (°C) in Divisions of the Newfoundland shelf in spring.

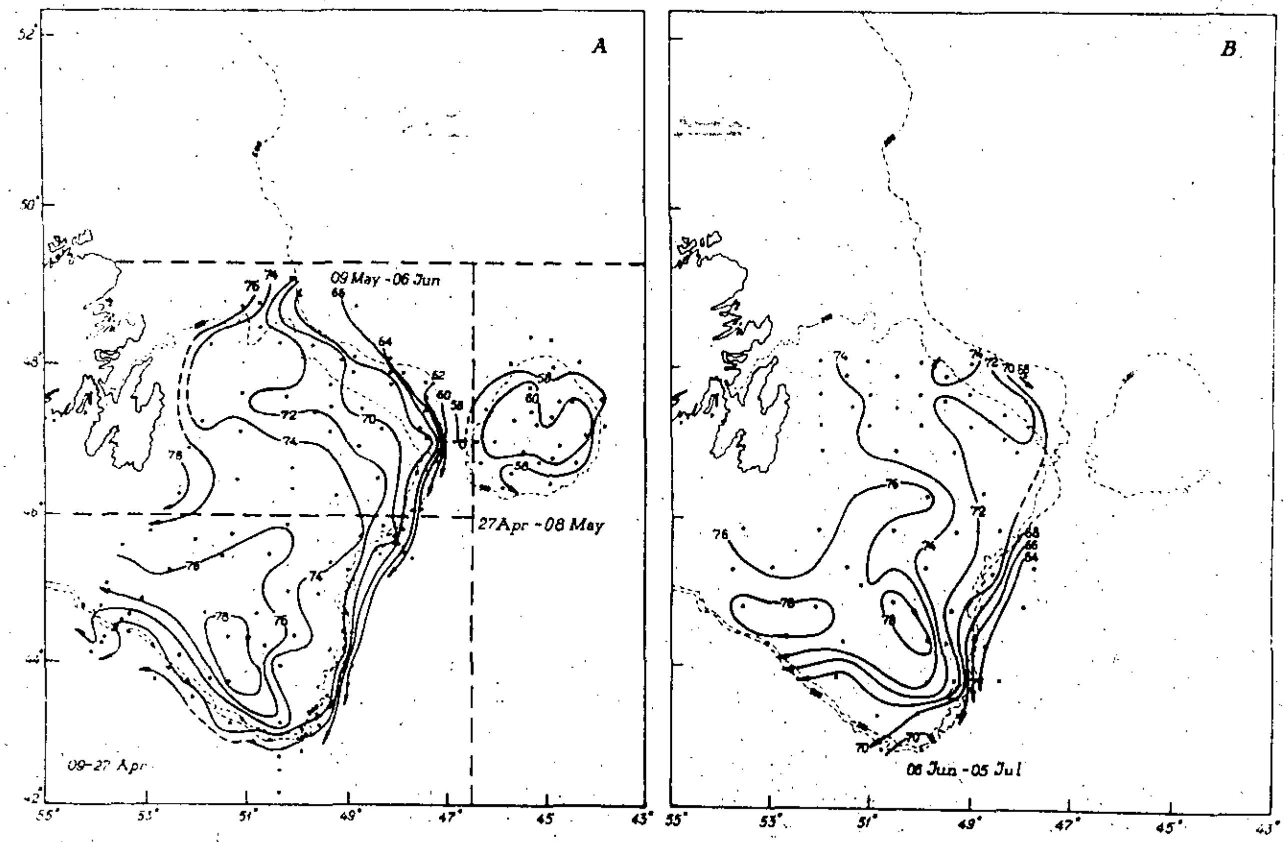

Fig. 7 Dynamic topography of sea surface relative to the 2 MPa level in 1991. Dynamic height isolines are drawn in 2 dyn.cm distance.