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Hydrographic Conditions off the Labrador and Newfoundland in 1983-1984

by

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ABSTRACT

Peculiarities and trends of seasonal and year-to-year variations of hydrographic conditions were analyzed on the basis of the data on oceanographic observations collected by PINRO research vessels , generalised information on the sea surface temperature , climatic estimations and historical materials. A predominance of the water cooling processes off the South Labrador, northern and eastern areas of the Grand and Flemish Cap Banks, being followed by a formation of extreme negative temperature anomalies and salinity was elucidated for the period 1983-1984. In contrast, that period was characterized by a rising in water temperature off the Grand Bank southern slopes. A structure of geostrophic water motion, which testifies an accentuation of anticyclonic circulations over the Grand and Flemish Cap Banks is estimated in spring-summer 1984.

Probable biological effects of the elucidated anomalies of hydrographic conditions are also explained.

MATERIAL AND METHODS

Hydrographic observations were carried out by the research vessels "Suloy", "Poisk", "Gemma" and "Kokshaisk" during 6 cruises at 904 standard and trawl stations in January, March-June and in November-December 1983 and at 1268 stations during 9 cruises of the RVs "Suloy", "Poisk", "Kokshaisk", "Lensk", "Vilnyus" and "N.Kuropatkin" in January and in May-December 1984. Temperature and salinity observations, and also of oxygen, phosphates and silicon were made at standard depths to 2000 m depth. More detailed volume of observations was presented in the USSR National Reports for NAFO (Chumakov and Borovkov, 1984; 1985).

Mean temperature of different layers and its anomalies were determined by parts of sections, suggested by A.A.Elizarov (Elizarov, 1962)and V.V.Burmakin (Burmakin, 1972; 1976) and shown in square brackets in Fig.1. Temperature anomalies of the 0-200 and 200-500 m layers in the date of observations were taken from the curves of normal (average) yearly variation , determined earlier (Burmakin, 1972; 1976).

Mean monthly anomalies of the sea-surface temperature from faximile charts, averaged and determined for five-grade squares in the USSR Hydrometeorological Centre , were used to analyze inter-annual variations in 1983 and 1984. Mean monthly anomalies from the long-term mean norm of 1957-1971 for squares with centers in the points with the positions of 60°N 60°W, 60°N 55°W, 50°N 55°W, 50°N 50°W, 50°N 45°W, 42.5°N 52.5°W, 42.5°N 47.5°W, 42.5°N 42.5°W, shown in Fig.1 (in circles), were averaged for each of the chosen parallels: 60°, 50° and 42.5°N and corresponded to the northern, central and southern parts of the NAFO Divisions, i.e. to the Divisions of the Northern Labrador, Newfoundland and the south of the Grand Bank.

RESULTS

After anomalous water cooling of the Labrador Current in the 0-50 m layer of the Coastal branch and in the 50-200 m layer of the Atlantic component and anomalies at the level of moderately cold years in the 0-200 and 200-500 m layers in November 1982 (Burmakin, 1984) preservation and growth of negative anomalies were observed to the extreme level in 1983 and 1984 (Tables 1 and 2). In spring-summer periods of those years water cooling over the Grand Bank eastern slopes (sections 7-A, Flemish Cap, 4-A and CG-3) was characterized by the range of temperature anomalies of

-0.1+-2.5°, the most overcooling was the 0-200 m layer, including cold undersurface waters. At the end of autumn seasons (November) a very low temperature of the Coastal, Main and Atlantic components of the Labrador Current was observed off the Hamilton-Inlet Bank (section 8-A, parts A,B,C); temperature anomalies on the average were observed for the 0-200 m layer and occurred to be equal to -0.8+- 1.6°. It is natural that bottom waters in the 200-500 m layer were also covered by cooling in the areas investigated.

On the contrary, considerable positive anomalies from 1.5 to 7.0° in the 0-200 m layer and from 1.0 to 3.7° in the 200-500 m layer were registered on the southern (section CG-4) and southwestern (SW section) slopes of the Grand Bank. High positive anomalies in the south of the Grand Bank are caused by the Gulf Stream's meandering and, as a rule, are short-term (Burmakin and Sterkhov, 1978).

Phase opposition of anomalies variations in the 0-200 and 200- 500 m layers in the north and south of the area investigated during 1983-1984 is confirmed by the variations of the mean monthly anomalies of the surface temperature for knots of standard grid of five-grade squares at the parallels of 60°, 50° and 42.5°N (Fig. 2). In the Labrador Sea they were negative over the whole period and constituted on the average per a year: in 1983 +-0.9 and in 1984 +-1.2° at 60°N. At 50°N in the Coastal, Main and Atlantic components of the Labrador Current off the Newfoundland negative anomalies were observed in January-April, June, August, October and December 1983 and 1984; their mean year values were equal to -0.4 and -0.7° respectively. Exclusively positive anomalies with the mean year values in 1983 +1.5° and in 1984 - +0.9° were registered at 42.5°N southward of the Grand Bank in the waters of the northern periphery of the Gulf Stream.

In comparison with 1972-1980 mean year anomalies of the surface temperature , i.e. in the Labrador Sea +-0.11°, in the south of the Grand Bank +1.37° and in the Labrador Current and its Coastal branch +0.32° and +0.99° are presented in the report on review of environmental conditions in the Northwest Atlantic in 1983 by R.W.Trites and K.F.Drinkwater (R.W.Trites and K.F.Drinkwater, 1984). As it is evident , in the first two areas the observed anomalies were of the same sign as those estimated ones, and in the third one - they were of different signs.

Surface temperature positive anomalies of the Labrador Current contradicted the observed severe ice conditions, predominating northwestern winds and more intensive than usual moving of icebergs to the south of 48°N. Such contradiction was partly explained by a small number of data due to ice conditions off the Labrador Current. However, according to the data of the USSR Hydrometeorologic Centre, estimated anomalies eliminate the contradiction mentioned above, and, the reason is to choose the periods of averaging and the area boundaries to estimate mean anomalies.

Detailed analysis of the field of temperature anomalies and salinity of the Labrador Current waters was made according to the observations of the section 8-A in November 1984, compared to the norm during 1962, 1964-1977, and 1979-1980 (Borovkov, 1982). If in 1983 negative deviations from the norms localized in the interval of the 50-100 m depth in the western periphery of the Arctic front and reached maximum values of -3.0° by water temperature and -1.0°/₀₀ - by salinity (Chumakov and Borovkov, 1984), then in 1984 negative anomalies were predominant over the whole section and exceeded the record level of 1983 (Fig. 3). They reached maximum values of -3.2° by temperature in the 10-30 m layer of the Atlantic component and -0.6°/₀₀ - by salinity in the 150-200 m layer of the Main branch. Inconsiderable positive anomalies of salinity (to +25°/₀₀) were observed in the 0-50 m layer of the Coastal branch and were caused by water salting when cooling to the negative temperatures. A core of the warm waters on the slope in the 200-500 m depth with the temperature of over 4° and positive anomalies to +0.4°, which took place in 1983, was absent in 1984.

In the recent three years year-to-year variations by layers and branches of the Labrador Current are sufficiently characterized by water temperature anomalies on the section 8-A from the long-term mean norm for 1964-1984 (Table 3). If in 1982 a record cooling was registered in the 50-200 m layer of the Atlantic component and at the level of very cold 1972 in the 0-50 m layer of the Atlantic and Coastal branches, then in 1983 a record cooling localized exclusively in the 50-200 m layer of the all components of the Labrador Current, and by 1984 a new record cooling was again predominant in the upper 50-m layer. In the bottom 200-500 m layers the Main branch, i.e. the area of the frontal zone, was affected by the greatest cooling over the whole period of observations during 1983 and 1984.

As it is seen from Fig.4 alternation of anormally warm and cold periods in the 0-200 m layer takes place in 12-13 years, and absolute minimum of water temperature (-0.08°) was reached in 1984.

Powerful extension of the Labrador Current determined the anormalous horizontal distribution of water masses in 1984.

In winter (according to the data from the 29 Cruise of the RV "Suloy" and faximile charts) a considerably larger than usual moving of the North Atlantic Current further off the coast of the Grand Bank and Flemish Cap Bank was observed. Water temperature gradients in the bottom layer on the southern and eastern slopes of the Grand and Flemish Cap Banks were poor pronounced. Warm intermediate layer with the temperature of over 4° was registered in the 700-1000 m depth at the slope off the Baffin Land and Northern Labrador, what was by 100-150 m deeper than that of the long-term mean. In the Divisions of the Southern Labrador and Notre Dame an occurrence of warm layer was not observed.

In spring-summer the Labrador Current cold waters with negative temperatures in the 30-150 m layer distributed over the whole northern and eastern parts of the Grand Bank, and also the northern and eastern slopes of the Flemish Cap Bank up to 46°30'N, what was observed for the first time of observations since 1960.

In July-November an intensive intrusion of cold waters with negative anomalies into the southern slope of the Grand Bank to 51°W was observed in the bottom layers, where they came across with warm waters of the slopes with the temperature of 5-6° and formed a frontal zone at 200-250 m depth.

Such powerful development of the Labrador Current cold waters, especially in its Coastal branch, accounted for later than usual migrating of cod from the Grand and Hamilton-Inlet Banks to the coast in summer 1984. Nearly all its concentrations from juvenile to adult fish were registered beyond the coastal areas of territorial waters of Canada till late July. Thus, in such case we faced a classical example when "in very cold years only capelin appear near the coasts, because cod can not overcome a barrier of cold waters " (Elizarov et al., 1983).

Horizontal circulation

A series of charts of surface dynamic topography were plotted to estimate a structure and to determine peculiarities of horizontal circulation (Fig.5 and 6). The materials of deepwater hydrographic observations, collected during the cruises of the RVs "Suloy", "Poisk", "Vilnyus" were used as initial data; all calculations and plotting of the charts were made using the methods similar to that one used earlier (Borovkov and Kudlo, 1982) to provide for a comparison of the results.

To judge by the chart presented in Fig.5, in May-July 1984 a structure of water circulation over the Newfoundland shelf, including the Grand Bank, was determined by a combination of mesoscale dynamic disturbances of wave and vortex origin and also large scale transporting in the direction of the Labrador Current. Wave disturbances of field motion, which were reflected in the meandering of flow lines of geostrophic currents, were predominated in the northern part of the area investigated (Div. 3K, and partly Div.3L). Further south, over the Grand Bank, vortex formations exclusively of anticyclonic nature were predominant. The largest and the most developed anticyclonic vortex was observed over the central part of the bank; two others, less developed and relatively not large, localized in the vicinity, on the northeastern part of the bank.

According to a comparison of the data obtained with the materials of previous years, complex wave structure of horizontal motion of waters in the northern part of the Newfoundland shelf is not unusual: unstationary disturbances, connected with the meandering of flows, formation, evolution and destruction of different vortices, associated, most probably, with the dynamic formation of synoptic scale, are typical for this zone. Essential unstationary vortices of the field of currents in this area reflect, apparently, complex variable nature of reaction of currents to changing compelled forces in conditions of heavily breaking up bottom relief. Considerable vorticity of motion, being related to steadily existing disturbance of the ordered single-directed transporting and numerous dynamic "pockets", due to these peculiarities restricts a transporting of ichthyoplankton and promote distribution of juvenile over the vast area of the considered part of the shelf, rich in food zooplankton.

Dynamic situation, recorded in May 1984 over the Grand Bank, may be true for a type of circulation, the main distinguished feature of which is an occurrence of developed vast anticyclonic vortex in the central part of the bank. This type of water circulation, corresponding to the highest stage of evolution of quasi--stationary vortex, was observed repeatedly during the previous surveys (in May-June 1982, June 1981). The main anticyclonic vortex of the Grand Bank, as the anticyclone over the Flemish Cap Bank, reveals obvious signs of the topogenous dynamic formations, which for a first approximation are adequately described in the vortex theory by Proudman-Taylor(Kudlo, Borovkov and Sapronetskaya, 1984).

As for anticyclonic vortexes, observed in the north east of the of the Grand Bank, their existing also has a number of precedents for a history of observations. Differences in such formations from the main anticyclone of the Grand Bank and anticyclone of the Flemish Cap Bank concern not only spatial scales and a degree of development; the differences in the bottom relief in the areas of vortex localization are rather essential. Absence of isolated positive forms of the bottom relief in the northeast of the Grand Bank close to the vortices , localized in this area by size, does not allow to identify their nature with the anticyclones of the Grand Bank and Flemish Cap Bank mentioned above. For the present one can suppose that the anticyclones of the north-eastern part of the Grand Bank are either formed in this area, apparently, in the result of side friction in the periphery of the Labrador Current Main branch, or remain steady after the transporting from the areas of its formation located, possibly, to the northwest.

Three surveys carried out on the Flemish Cap Bank in late March-April and in late 1984 give reasons to judge by a predominance of the anticyclonic circulation in the periods mentioned, which reached its highest development in summer (Fig. 6). In spring the cyclonic vorticity of currents, related to a depression of the relief of dynamic heights, was observed against the total anticyclonic circulation in the central part of the bank. The formation of the structure mentioned is a phenomenon which is rather rare for the Flemish Cap area; according to the analysis of 34 dynamic charts for a period since 1977, similar situation when dynamic relief resembles a gigantic volcanic cauldron, was registered earlier only once, in late July - early August 1978. Probably, the mentioned superposition of the circulation forms is rather effective from the point of view of functioning of hydrodynamic trap of plankton, i.e. along with the stagnant zone inside the central vortex there is an additional, surrounding this vortex, the zone of absence of horizontal water moving, related to a change of sign of their turning.

CONCLUSIONS

In spring-summer 1983 and 1984 negative anomalies were predominant on the standard sections in the 0-200 and 200-500 m layers on the southern and eastern slopes of the Grand Bank, whereas on the southern and southwestern slopes the anomalies were positive.

The anomalous intrusion of the Labrador Current cold waters with negative temperature into the northern and eastern slopes of the Flemish Cap Bank , which has been registered for the first time since 1960, was observed to 46°30'N in April-July 1984.

A considerable cooling of waters on the shelf and Southern Labrador slope in November was estimated: the negative temperature anomalies and salinity in the Labrador Current reached record values over the period of observations since 1964, in 1983 in the 50-200 m and in 1984 in the 0-50 m layers of all components of the Labrador Current.

According to the data of the USSR Hydrometeorological Centre mean monthly surface temperature anomalies calculated by us for the parallels of 60°, 50° and 42.5°N properly confirmed an occurrence of negative and positive anomalies in the north and south of the NAFO area by temperature of layers on the sections both in 1983 and 1984: in the Labrador Sea and Labrador Current these anomalies were negative, but in the south of the Grand Bank - positive ones.

By a trend of year-to-year variations for 1964-1984 an extreme water cooling is shown to the most minimum values in November 1984.

A field of temperature anomalies in November 1984 on the section across the Hamilton-Inlet Bank was considered and a localization of maximum and minimum values of negative anomalies is shown.

A structure of fields of geostrophic circulation of waters in spring-summer 1984 was estimated and possible biological consequences of the peculiarities of hydrographic conditions were recorded.

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Table 1. Temperature anomalies in the 0-200 m layer in 1983-1984

Section	1983					1984				
	Mar	Apr	May	Jun	Nov	May	Jun	Jul	Aug	Nov
8-A (A)					-0,82					-I,20
8-A (B)					-I,I9					-I,2I
8-A (C)					-I,0I					-I,58
7-A			-0,7			-0,6				
FC (G)	-2,I	-0,4					-2,5			
4-A			-0,8			-I,5				
CG-3							-0,7	-I,4		
CG-4		7,0		5,4		I,5			0,6	
SW				I,8		I,5				

Table 2. Temperature anomalies in the 200-500 m layer in 1983-1984

Section	1983					1984				
	Mar	Apr	May	Jun	Nov	May	jun	Jul	Aug	Nov
8-A (B)					-I,I8					-I,35
8-A (C)					-0,I3					-0,23
7-A			-0,4			-0,2				
FC (G)	-0,2	-0,3	-0,4		-0,I		-0,6			
FC (H_2)	0,3	0,I			-0,4					
4-A			-0,6			-0,6				
CG-3							-0,7	-0,5		
CG-4		3,7		2,4		2,2			0,0	
SW				I,I		I,0				

Table 3. Temperature anomalies on the section 8-A in different layers of the Coastal (A), Main (B) and Atlantic (C) components of the Labrador Current in November 1982, 1983 and 1984 compared to the long-term mean norm of 1964-1984

Parts of 8-A section	Year	Layers, m			
		0-50	50-200	0-200	200-500
A	I982	-0,7I	-0,I7	-0,32	-
	I983	-0,63	-0,96	-0,82	-
	I984	-I,82	-0,95	-I,20	-
B	I982	-0,74	-0,I6	-0,3I	-0,5I
	I983	-0,74	-I,34	-I,I9	-I,I8
	I984	-I,48	-I,II	-I,2I	-I,35
C	I982	-I,68	-I,09	-I,26	-0,35
	I983	-0,90	-I,0I	-I,0I	-0,I3
	I984	-2,I7	-I,35	-I,58	-0,23
AB	I982	-0,75	-0,I0	-0,27	-
	I983	-0,69	-0,90	-0,84	-
	I984	-I,65	-I,02	-I,I9	-
ABC	I982	-0,9I	-0,25	-0,43	-
	I983	-0,7I	-0,88	-0,83	-
	I984	-I,68	-0,95	-I,I4	-

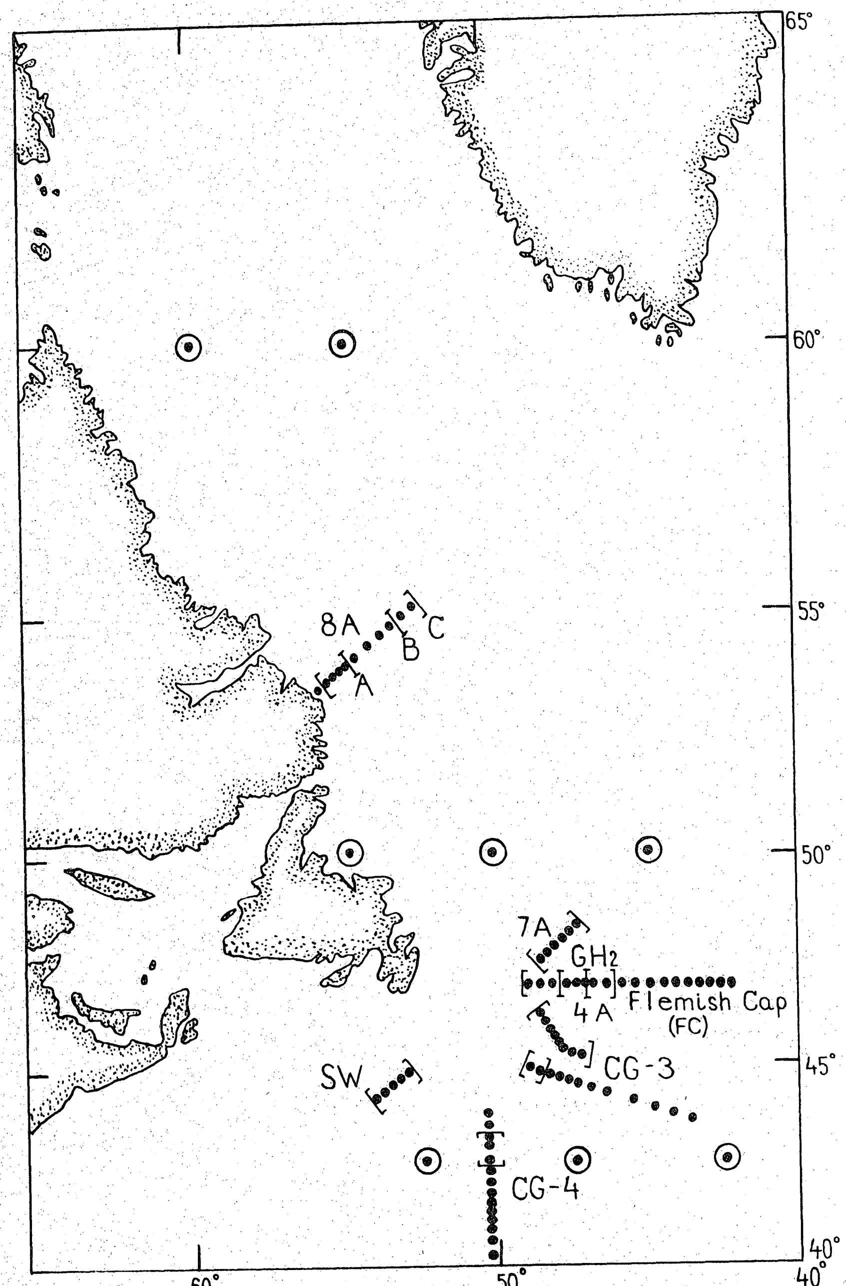

Fig.1. Position of standard oceanological sections off the Labrador and Newfoundland in 1983-1984.

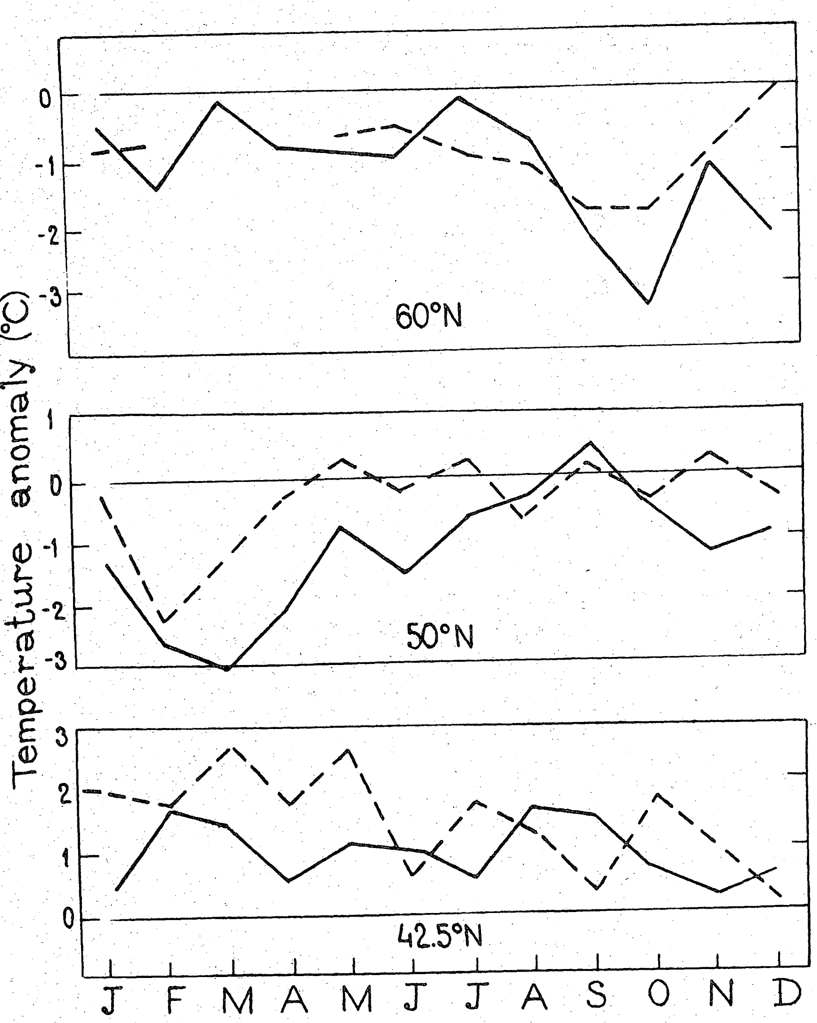

Fig.2. Anomalies of mean monthly surface water temperatures for the knots of standard grid of five-grade squares in 1983 (dotted line) and 1984 (continuous line).

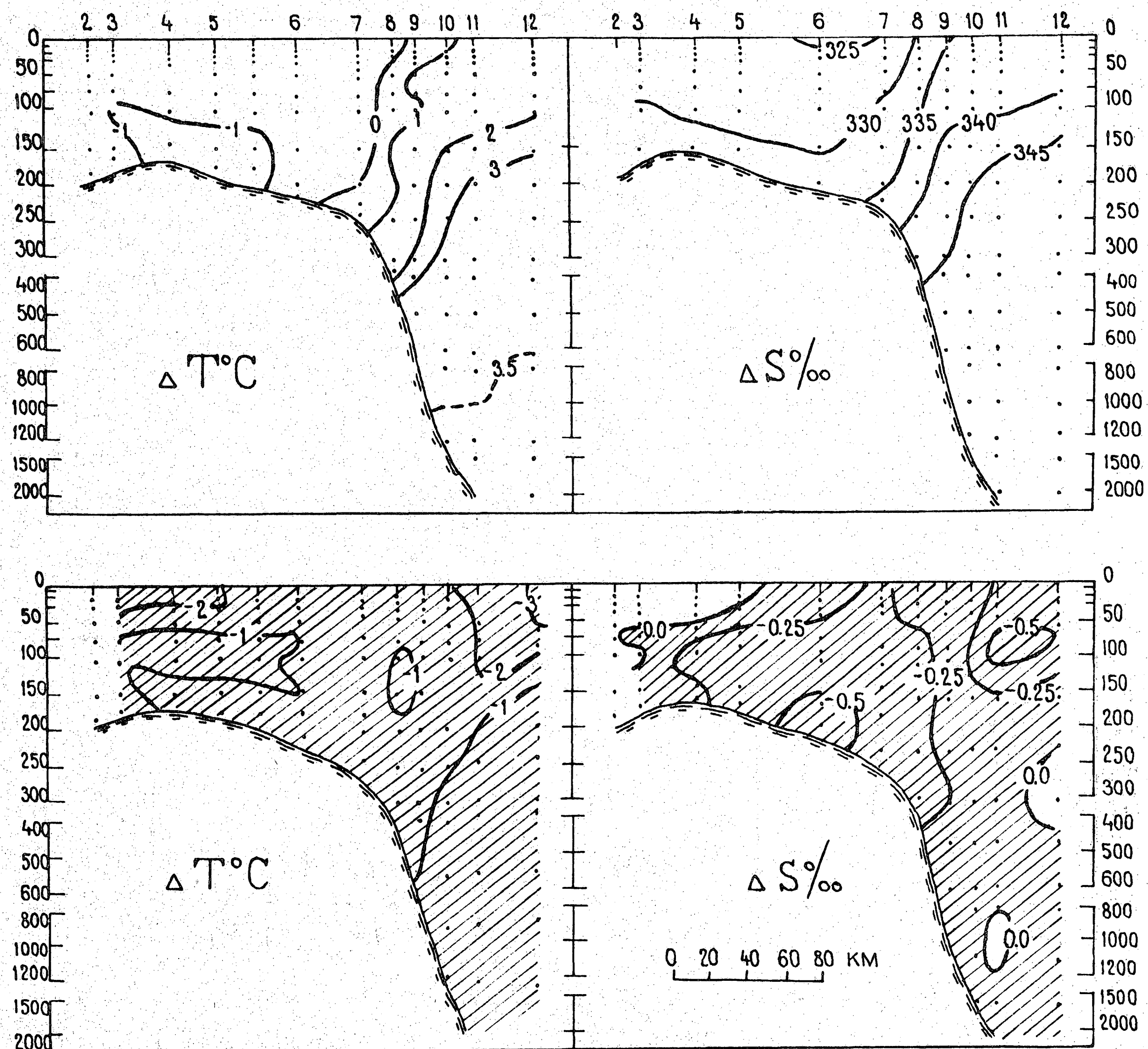

Fig.3. Temperature and salinity distribution and their anomalies on the section 8-A across the Hamilton-Inlet Bank at Southern Labrador in 1984.

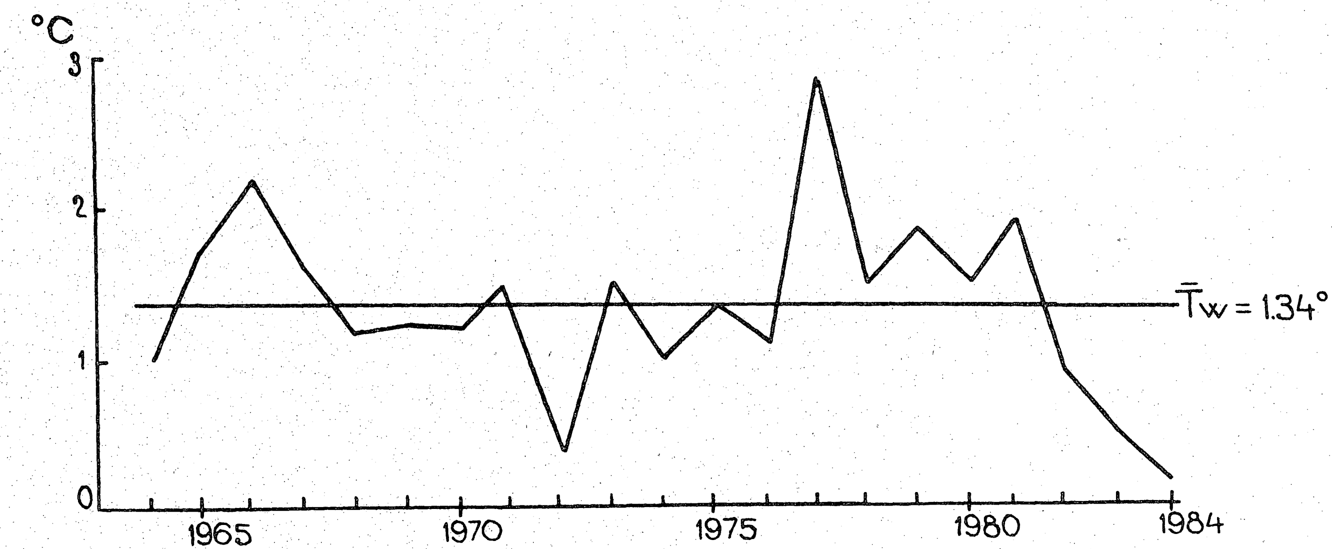

Fig.4. Long-term variation of mean water temperature in the 0-200 m layer of the Labrador Current on the section 8-A (ABC) in October-November 1964-1984.

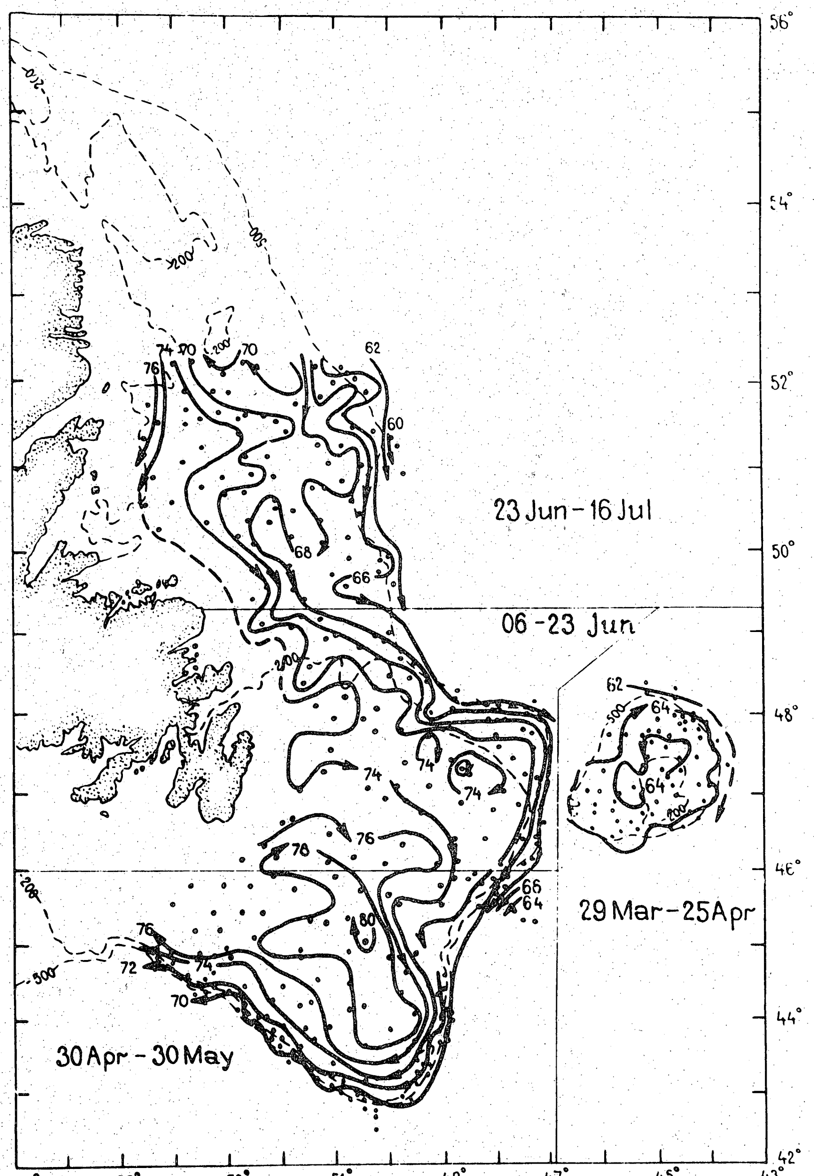

Fig.5. Dynamic topography of the sea surface relative to the level of 2 MPa (200 dB) in March-July 1984 (according to the data of the survey from the RV "Suloy" 30 Cruise). Isolines of conventional dynamic heights are drawn in 2 dynamic cm.

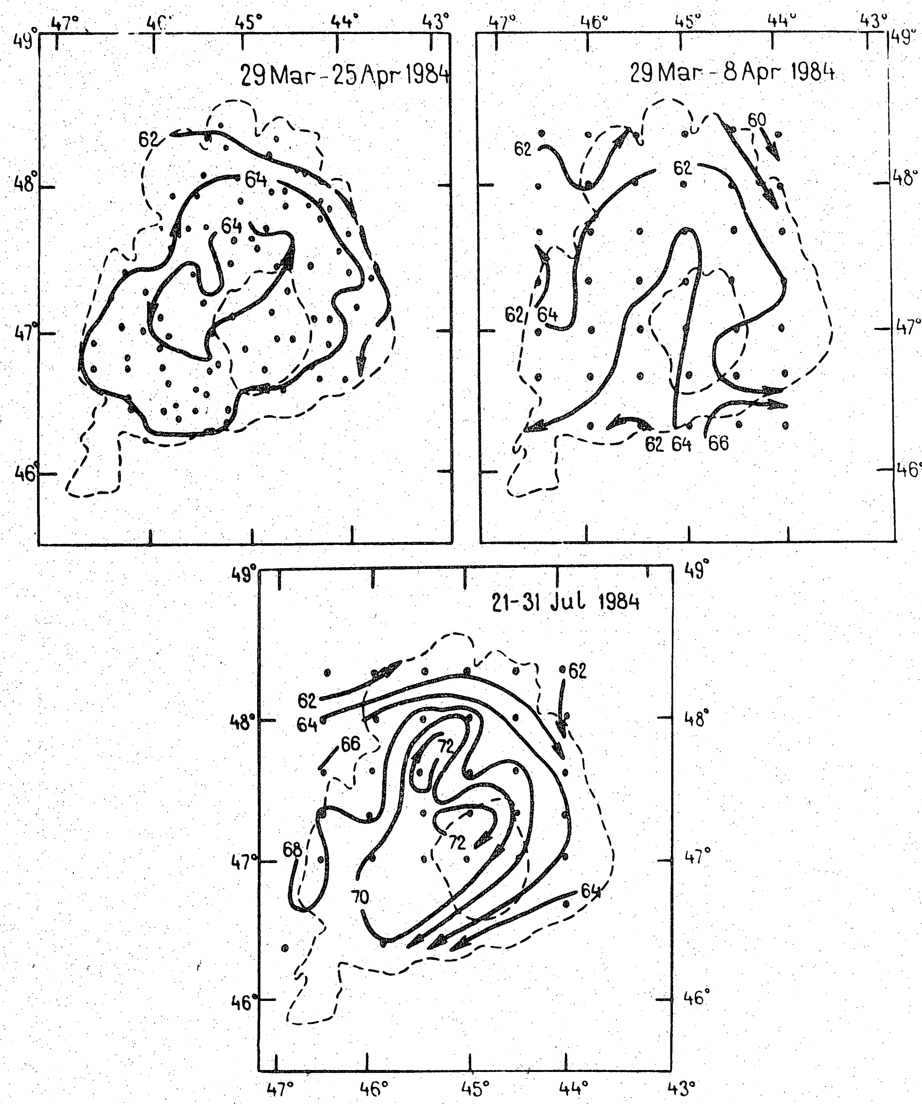

Fig.6. Dynamic topography of the sea surface relative to the level of 2 MPa off the Flemish Cap in spring -summer 1984. Schemes are plotted on the basis of the materials from the surveys of the RV "Suloy" 30 Cruise (29 March- 25 April), from the 2 Cruise of the RV "Poisk" (29 March -8 April) the 2 Cruise of the RV "Vilnyus" (21-31 July). Isolines of conventional dynamic heights are drawn in 2 dynamic cm.