Northwest Atlantic Fisheries Organization

Serial No. N1883 NAFO SCR Doc. 91/11

SCIENTIFIC COUNCIL MEETING - JUNE 1991

Oceanographic Conditions in NAFO Subareas 0, 1, 2 and 3 in 1990

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INTRODUCTION

Oceanographic conditions are analysed on the basis of materials of surveys carried out according to PINRO programs in the spring/summer period in NAFO Subarea 3 and in the autumn/winter period in NAFO Subareas 0, 1, 2, 3. In addition, the information on ice and meteorological conditions is borrowed from national Hydrometeorological Centres.

Conditions characteristic for 1990 are compared with the long-term mean conditions, trends of conditions variation in recent years are set.

MATERIAL AND METHODS

Observations over water temperature and salinity were made following the irregular grid of trawl stations and standard sections 11-A (Fylla Bank - 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 in the near-bottom layer (5-10 m above the bottom) in case the depth was less than 2000 m. Temperature was measured by protected reversing thermometers while unprotected reversing thermometers were used for control of proper depth.

Water samples were taken at all standard depths using 1-litre Nansen bottles BM-48 for determining the salinity by relative conduction (UNESCO, 1978) measured with MK SH-601 electric salinometer.

To characterize meteorological conditions the data are used on mean monthly sea-surface atmospheric pressure, air temperature in the near the ground layer and their anomalies compiled in the form of charts by the USSR Hydrometeorological Centre (Moscow). Long-term mean monthly temperature and atmospheric pressure based on the data for 1931-1960 are used to estimate anomalies.

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

Materials kindly presented by the Murmansk Hydrometeorological Centre were used for analysis of ice conditions.

METEOROLOGICAL CONDITIONS

Atmospheric pressure

Primary atmospheric circulation over the North Atlantic in early 1990 was similar to that in 1989 and was characterized by a higher intensity. The main feature of its development was associated with anomalously low atmospheric pressure over the North and Norwegian-Greenland basins.

Fig. 2 presents mean monthly sea-surface atmospheric pressure anomalies in the Northwest Atlantic. As is seen from the Figure the mean monthly pressure anomalies over Greenland reached -12-20 hPa in January-March.

In April atmospheric pressure values approached the norm. In the north of the area anomalies decreased to -6 hPa while over the south-eastern part positive anomalies of the order of 6-8 hPa were preserved.

From May to October the atmospheric pressure field over the NW Atlantic was close to the long-term mean one, anomalies varied from -4 to +4 hPa. Neither negative nor positive anomalies dominated over any area.

In November an area of low atmospheric pressure formed over the southern part of NAFO Subarea 3. East of Newfoundland anomalies of mean monthly atmospheric pressure reached -8 hPa. In December the depression centre shifted to Greenland where anomalies of mean monthly pressure made up -6 hPa. South of 60°N positive anomalies prevailed which in the Flemish Cap Bank area reached 6 hPa.

Air temperature

Winds of north direction prevailing over the north-western part of Atlantic ocean in January-March caused a strong cooling in this area. In this perbd mean monthly air temperature was 4-8°C below the norm over Davis Strait and Labrador Sea (Fig. 3). The highest absolute anomalies were registered in February.

In April-May air temperature over the greater part of Northwest Atlantic was 1-3°C below the norm. From June to November negligible in magnitude positive anomalies prevailed over Newfoundland and South Labrador whereas negative ones dominated over North Labrador and Davis Strait.

In December a centre of cold formed over North Labrador and Davis Strait, mean monthly temperature was 2-4°C below the norm. In NAFO Subarea 3 air temperature was close to the norm in this period.

OCEANOGRAPHIC OBSERVATIONS

Ocean surface temperature

For convenience in analysis the data on water temperature anomalies in the surface layer were separated into 3 classes - "above the norm", "the norm" and "below the norm", the boundaries between them being chosen arbitrarily and referred to the values of temperature anomalies -1.0°C and 1°C.

To judge by the results from the 1990 classification (Table 1) temperature values corresponding to "the norm" were predominant in Subareas 2 and 3 and their recurrence made up 64% 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 58% - for Subarea 3 (points 8-19). Relative shortage of heat was observed during the greater part of the year in the off-shore area surveyed (points 2, 6, 10, 12 and 13) occupied with waters of subarctic vertical structure.

Table 2 presents the recurrence of the sea-surface temperature from different classes observed in Subareas 2 and 3 in recent years. As is seen from the Table the mean yearly temperature in the surface layers increased from 1986 to 1988 as evidenced by an appreciable increase in recurrence of "the norm" and "above the norm" and decrease in recurrence of "below the norm". Since 1989 the temperature in the surface layers started to decrease which is corroborated by the increased recurrence of "below the norm". The downward trend was observed most clearly in the Newfoundland area where the recurrence of "below the norm" increased from 13% in 1988 to 30% in 1990.

Temperature conditions in Davis Strait in the autumn period

Oceanographic observations were carried out by RV "Kapitan Shaitanov" to the south of 66°N (Divs. 1BCD and OB) in the Davis Strait in October -early November. In this period temperature and salinity measurements were made at standard depths of 43 episodic and 24 regular stations along the sections 34-A and 11-A (Fylla Bank-Cumberland). Position of these sections is shown 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 structure enter the Strait with the Baffin Land Current and are, mainly, distributed in the area with depths above 500 m. Waters of this type were characterized by variations in temperature vertically from -1.7°C to 1.4°C and salinity from 31.2 to 34.2 psu.

Temperature and salinity variations in waters with subarctic type of structure occurred within 0.2-6.2°C and 32.5-34.9 psu. Waters of this type occupied deepwater southeastern and eastern parts of Davis Strait.

Arctic frontal zone was a physical boundary between the waters with the mentioned types of vertical structure. In 1990 it was located in the western part of the Strait more off-shore than in previous years and passed over the 700-1000 m depths. In the eastern part of Davis Strait the frontal zone is referred to the 400-600 m isobaths.

The pattern of temperature and salinity distribution in the Strait area abound with intrusion of water masses of different types is indicative of marked vorticity of the current field. A complicated structure of the western Strait waters is distinctly seen in graphs of vertical temperature and salinity distribution on Cumberland section shown in Fig. 4.

A comparative analysis of water temperature distribution on Cumberland (Fig. 4) and 34-A sections and water temperature fields in Div. OB (Fig. 5b) in 1990 and 1989 showed up the following peculiarities:

- water temperature in the 0-50 m layer was, on the average, 1.3°C lower than in 1989;
- mean water temperature in the 50-200 and 200-500 m layers on Cumberland section in 1990 was higher than in 1989 by 0.6 and 1.0°C on the shelf and by 1.6 and 0.3°C on continental slope. Temperature in the near-bottom layer increased considerably as well (Fig. 5b).
- near-bottom water temperature in 1990 was lower than in 1989 over greater part of slope and in the trough of Hudson Strait.

The marked temperature rise in intermediate layers on the Baffin Land shelf indicates the increased advection of heat contributed to this area by the Irminger component of the West Greenland Current.

Temperature conditions in Subarea 2 in the autumn period

Oceanographic observations were carried out by RVs "Kapitan Shaitanov" and "Vilnius" on the shelf and continental slope of Labrador in September-November. Water temperature and salinity measurements were made at standard depths of 15 episodic stations in Divs. 2G and 2J and 17 stations on sections 8-A and 38-A (Fig. 1).

Data on vertical distribution of water temperature and salinity obtained as a result of observations allow to characterize a thermohaline structure of waters in the area as a component of subarctic and arctic types. Plots of temperature and salinity distribution on section 8-A illustrate the scheme of thermohaline structure and are shown in Fig. 6.

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 mean values of temperature and salinity for each depth at all stations of the section were estimated for 1964-1986. Distribution of their anomalies on the section (Fig. 6) allows to draw a conclusion about essential cooling of the Labrador Current waters.

Long-term mean temperature variations in different layers and branches of Labrador Current in the Hamilton Bank area are shown in Fig. 7. In 1990 mean temperature in the 0-200 m layer of the Current cold component was 0.6°C lower than the long-term mean one and 1989 temperature (Fig. 7a). Temperature in the same layer of the Irminger component was also 0.6°C below the norm and similar to that in 1989 (Fig. 7b). Anomalies in the 200-500 and 500-1000 m layers made up -0.2 and -0.3°C respectively (Fig. 7 c, d).

Temperature conditions in Subarea 3

Oceanographic observations were carried out by RV "Persey-III" from March to June and by RVs "Kapitan Shaitanov" and "Vilnius" in September and November-December. During the RV "Persey-III" cruise standard observations over the temperature and salinity were made at 354 episodic stations of the Newfoundland shelf and Flemish Cap Bank. According to the data from this survey water temperature values were calculated in the near-bottom layer in points of regular half-degree grid and their deviations from the long-term mean values were estimated for 1972-1986 (Borovkov and Tevs, MS 1988).

According to these estimates water temperature practically over the whole Newfoundland shelf in March-May 1990 was below the norm (Fig. 8a) and the previous year level. The highest negative anomalies exceeding 2°C were registered on the south-western and southern slopes of Grand Bank. Slight positive anomalies were just observed in local areas of continental slope in Divs. 3K and 3L.

Near-bottom water temperature anomalies (A) were compared to the corresponding values of root-mean-square deviations (S), which is the measure of year-to-year variations in near-bottom temperature, to characterize their significance. Standardized anomalies (A/S) obtained were divided 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 is presented in Fig. 8b and, in general outline, corresponds to the distribution of absolute anomaly values. The most essential water cooling in the near-bottom layer relative to the long-term mean temperature with allowance for year-to-year variations was observed over Grand Bank at the depths less than 200 m and in local areas of continental slope in Divs. 3K and 3L.

Fig. 9 presents the long-term mean variations of the near-bottom temperature in separate areas of Newfoundland shelf. As is seen from the Figure the mean temperature in Divs. 3NO and 3KL was 1.6 and 0.7°C below the norm for 1972-86, respectively.

The area of Divs. 3NO occupied with waters having temperature "below the norm" and "much below the norm" exceeded 90% of total area of Divisions. In Divs. 3KL the area increased from 45% in 1989 to 80% in 1990. There was no analogous strong cooling of the near-bottom waters for the whole period of observations on the Newfoundland shelf since 1971.

In autumn 97 episodic stations were made on the Newfoundland shelf. In September the surface water temperature on the eastern slope of Funk Island Bank was, on the average, 1.5°C lower than in 1989. There occurred relative increase in vertical thickness of a cold intermediate layer and lower temperatures were observed in the layer. Water temperature in the 250-800 m and near-bottom layers was 0.3-0.7°C and 0.1-0.4°C higher than in 1989, respectively, which is indicative of the increase of heat advection at the depths.

Table 3 lists values of near-bottom water temperature, averaged by Divs. 3N and 3O, and area of these Divisions occupied with waters having different temperature in the autumn period. As is seen from the Table the mean temperature in 1990 was much higher than that of two previous years. Heating in Div. 3O followed the reducing of area occupied with negative temperature waters.

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 (MS 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 a kinematic scheme demonstrating the combination of jet stream over the Grand Bank slopes with retarded circulation in the shelf area.

The jet stream velocity corresponding to the Labrador Current Main branch was maximum in the eastern slope of Funk Island Bank. A series of dynamic formations of different vorticity was pronounced over the shelf, among which the anticyclonic vortex localized on the southern Grand Bank had the largest dimensions. A general anticyclonic vorticity of current field was observed over the Flemish Cap Bank.

It follows from comparison between water circulation schemes in spring 1990 (Fig. 10) and 1989 (Borovkov and Tevs, MS 1989) that current velocity was slower in 1990 in the north-eastern and eastern Grand Bank slopes. Dynamic height values were lower in the area resulting from relative increase of water density due to water mass cooling. Anticyclonic meander was less pronounced in the Funk Island Bank area and no material change was found in the position of quasi-stationary anticyclonic vortex and direction of its major axis on the southern Grand Bank.

Ice conditions

In autumn 1989 ice formation in the Davis Strait started in November while in the Labrador Sea - during the first ten days of December and the process was very intensive. Already in early January 1990 the whole Labrador shelf was covered with ice and during the third ten days the ice cover reached northern slopes of Grand Bank. Overall ice coverage of Labrador Sea exceeded the norm by 6% in January. In February the area of drifting ice continued to increase and southern edge of ice reached 46°N.

In March the ice cover of Labrador Sea and Davis Strait exceeded the norm by 15-20%, its southern edge was situated 180-200 miles more southward than usual.

In April the area of drifting ice started to reduce rapidly in the Labrador Sea and by early May the whole Grand Bank area was completely free of ice. Southern edge of drifting ice lied at 50°N in this period though even in June the ice cover of Labrador Sea still exceeded the norm by 13-17%.
The Labrador shelf was entirely free of drifting ice in the second half of July. In the Davis Strait separate ice fields remained until mid-September.

In autumn the ice formation started in the Labrador Sea during the last ten days of November.

CONCLUSIONS

In autumn-winter 1989-90 the intensification of cyclonic activity in the North Atlantic was followed by extremely deep cyclonic depression over Iceland and anomalously high recurrence of north winds over the NW Atlantic areas. Due to the increase in cold air advection the winter anomalies of mean monthly air temperature made up -8°C in the area.

Anomalously low air temperatures led to a strong water cooling and intense ice formation. Overall ice cover in the Labrador Sea and Davis Strait exceeded the long-term mean by 15-20% in this period.

Mean near-bottom water temperatures were 1.6 and 0.7°C below the norm in Divs. 3NO and 3KL, respectively, in the spring period. The area occupied with near-bottom waters having temperatures "below the norm" and "much below the norm" exceeded 90% in Divs. 3NO and 80% in Divs. 3KL. No analogous strong cooling of the near-bottom waters has been registered for the whole period of observations carried out on the Newfoundland shelf since 1971.

In autumn 1990 the sea surface water temperature in the Baffin Land area was, on the average, by 1.3°C lower than that in 1989. A relative temperature rise by 0.6 and 1.2°C was observed in the 50-200 and 200-500 m layers on Cumberland section, respectively, which was associated with intrusion of subarctic waters to the Baffin Land shelf.

The Labrador Current water temperature was, in fact, 0.3-0.6°C below the norm and 1989 level throughout the whole water column in the Hamilton Bank area.

In November-December the near-bottom waters in Divs. 3NO and deep waters in the 250-800 m layer in Div. 3K turned to be warmer than in 1989.

REFERENCES

BOROVKOV, V.A., and B.P.KUDLO. MS 1982. Geostrophic circulation of water in the Labrador and Newfoundland areas in spring-summer 1981. NAFO SCR Doc., No.17, 9 p.

BOROVKOV, V.A., and I.I.Tevs. MS 1988. Temperature of bottom waters over the Newfoundland shelf in spring-summer 1972-86. NAFO SCR Doc., 88/97, Serial No.1554, 16 p.

BOROVKOV, V.A., and I.I.TEVS. MS 1989. Overview of oceanographic conditions off the Northwest Atlantic in 1988. NAFO SCR Doc., 89/10, Serial No.N1574, 16 p.

BOROVKOV, V.A., and I.I.TEVS. MS 1990. Overview of oceanographic conditions off the Northwest Atlantic in 1989. NAFO SCR Doc., 90/10, Serial No.N1721, 22 p.

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 - 1990 (%).

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
1990	1	12	8	75	58	64	24	30	28

Table 3. Mean water temperature (°C) of the near-bottom layer (°C) by Divisions and their area (%), occupied with waters having different temperatures in autumn 1986 - 1990.

Years	Mean temperature (°C)			Area (%) with the temperatures: below 0°C			above 3°C		
	3N	3O	3NO	3N	3O	3NO	3N	3O	3NO
1986	2.4	2.4	2.3	5	0	3	43	39	40
1987	1.6	1.2	1.4	19	17	20	10	11	9
1988	2.0	1.5	1.5	10	11	11	33	11	17
1989	2.2	1.5	1.8	14	17	17	29	17	23
1990	2.0	3.0	2.3	14	6	11	29	50	34

In November-December the near-bottom waters in Divs. 3NO and deep waters in the 250-800 m layer in Div. 3K turned to be warmer than in 1989.

REFERENCES

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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.

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Years	Mean temperature (°C)			Area (%) with the temperatures: below 0°C			above 3°C		
	3N	3O	3NO	3N	3O	3NO	3N	3O	3NO
1986	2.4	2.4	2.3	5	0	3	43	39	40
1987	1.6	1.2	1.4	19	17	20	10	11	9
1988	2.0	1.5	1.5	10	11	11	33	11	17
1989	2.2	1.5	1.8	14	17	17	29	17	23
1990	2.0	3.0	2.3	14	6	11	29	50	34

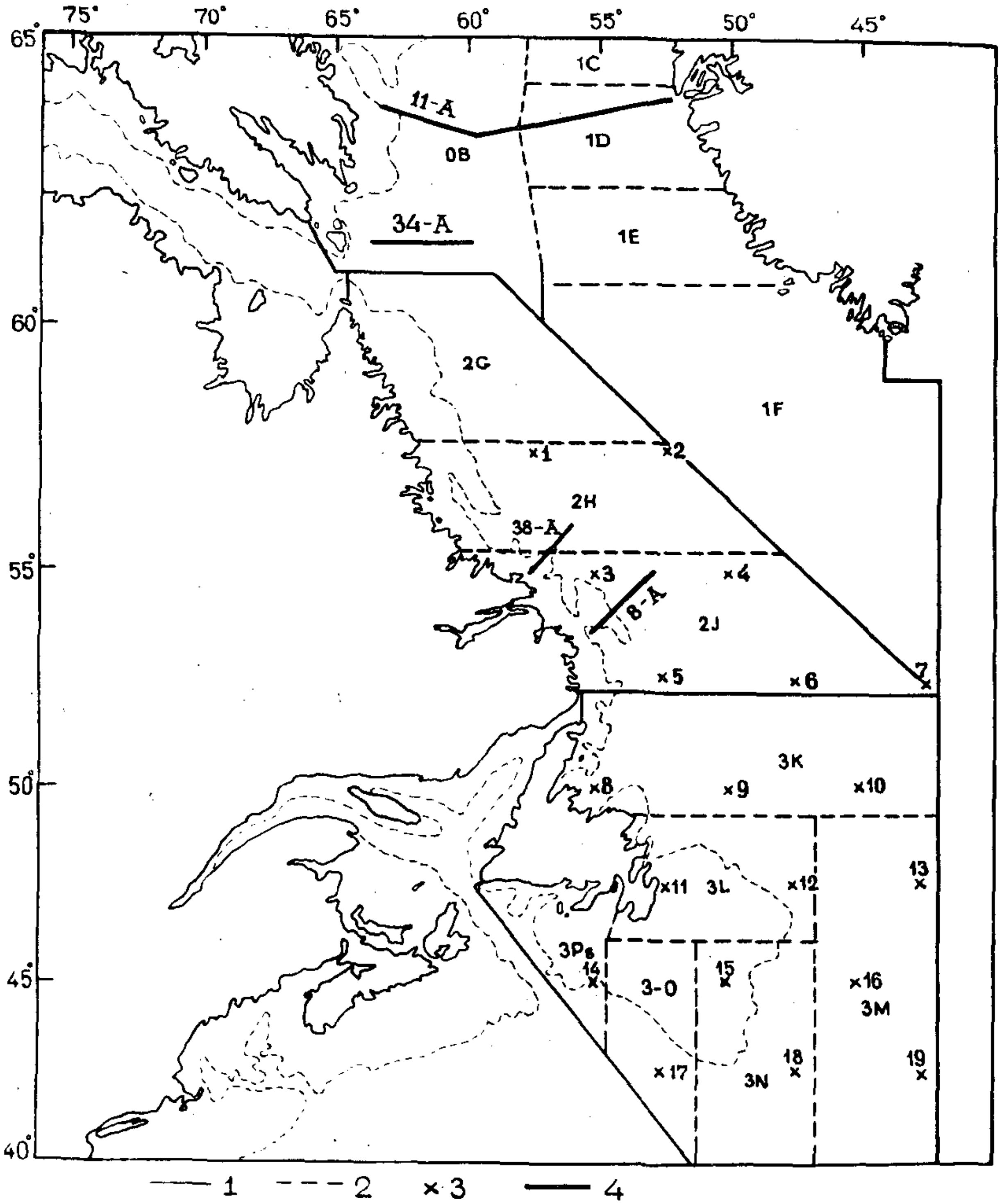

Fig. 1 Boundaries of NAFO Subareas (1) and Divs. (2), position of regular grid points where the data on mean monthly temperature in the sea-surface layer (3) and on standard sections (4) were obtained in the NW Atlantic.

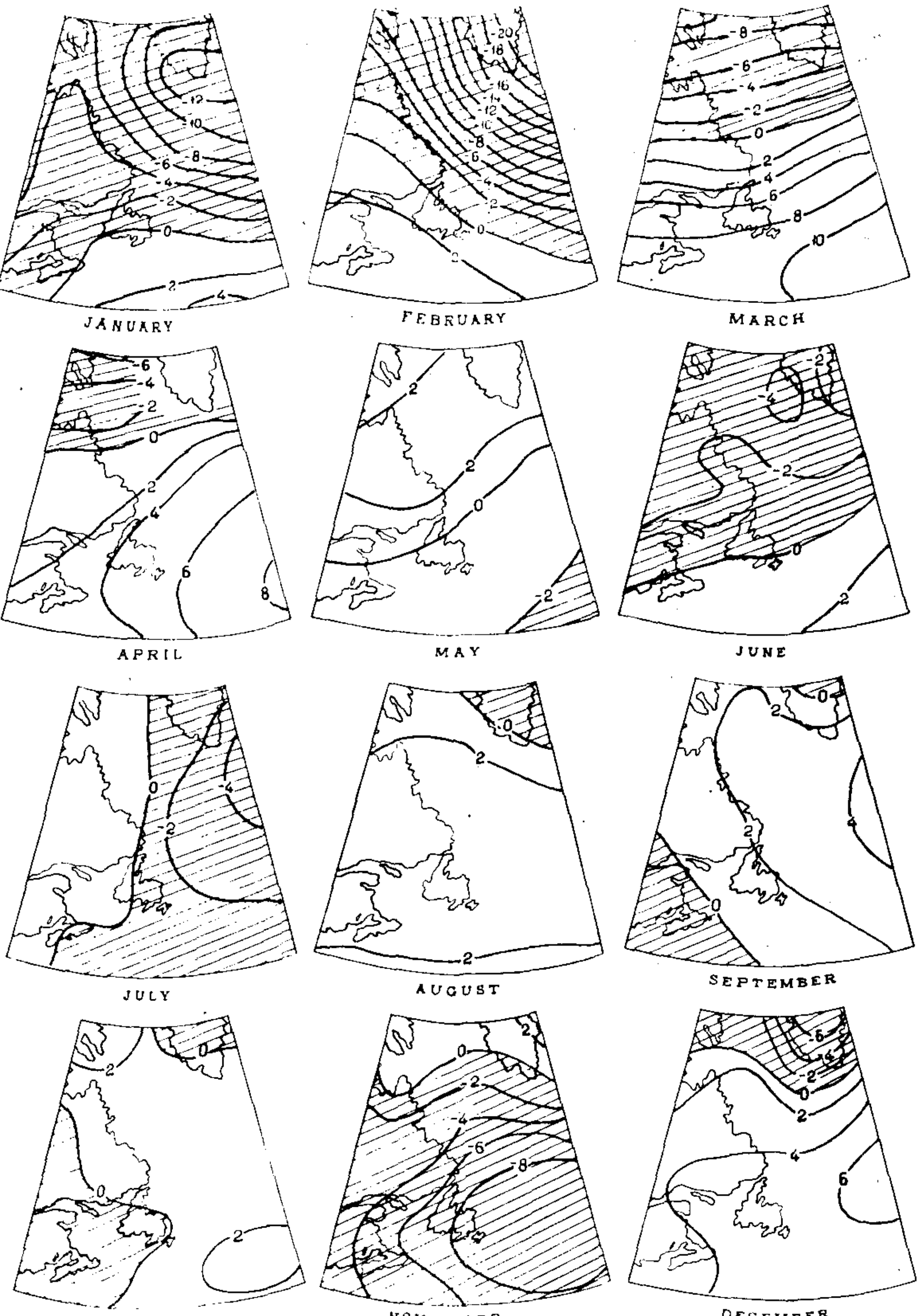

Fig. 2 Monthly air pressure anomalies (hPa) at the sea level over the NW Atlantic in 1990.

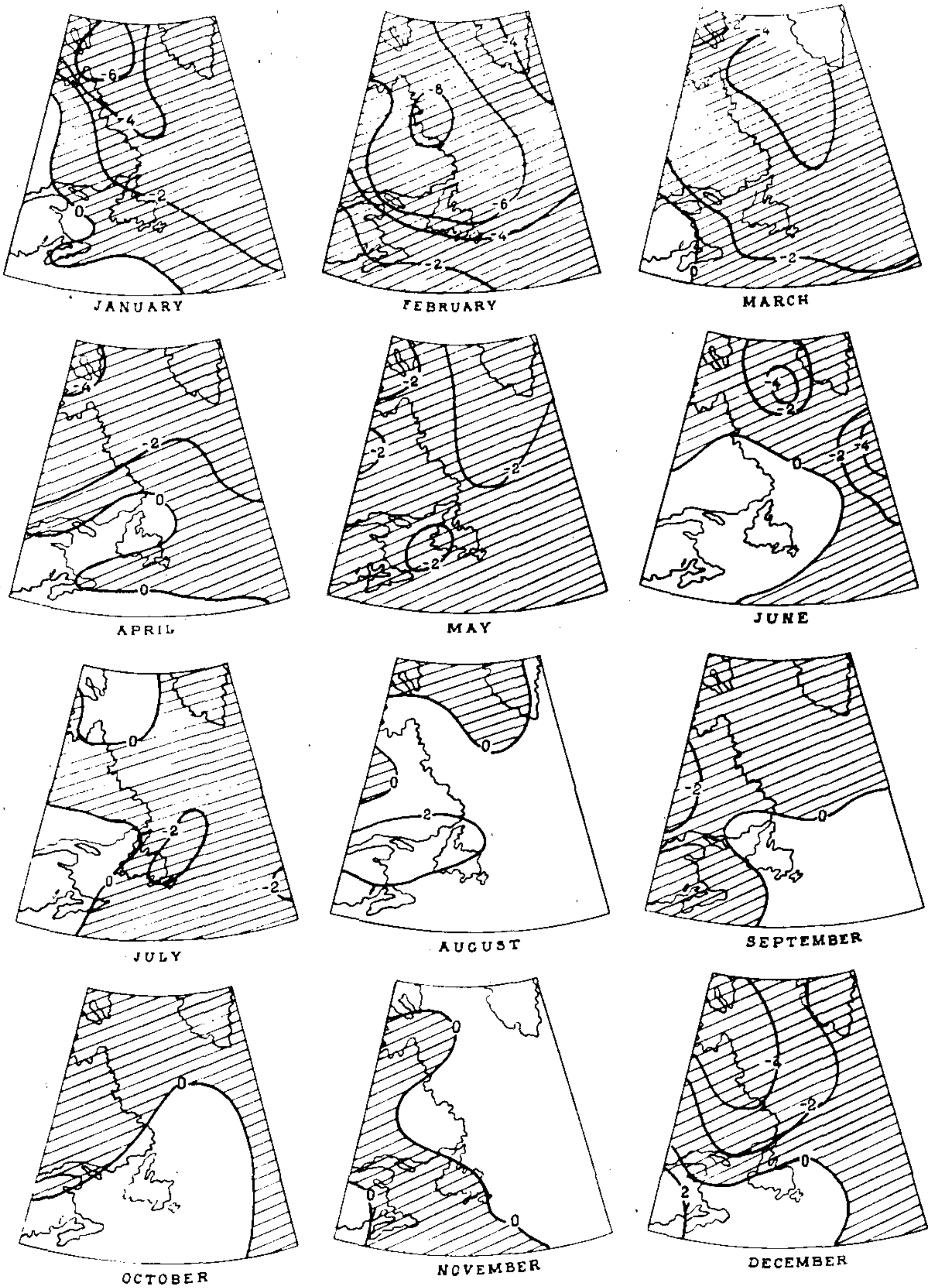

Fig. 3 Monthly air temperature anomalies (°C) in the near-the-ground layer over the NW Atlantic in 1990.

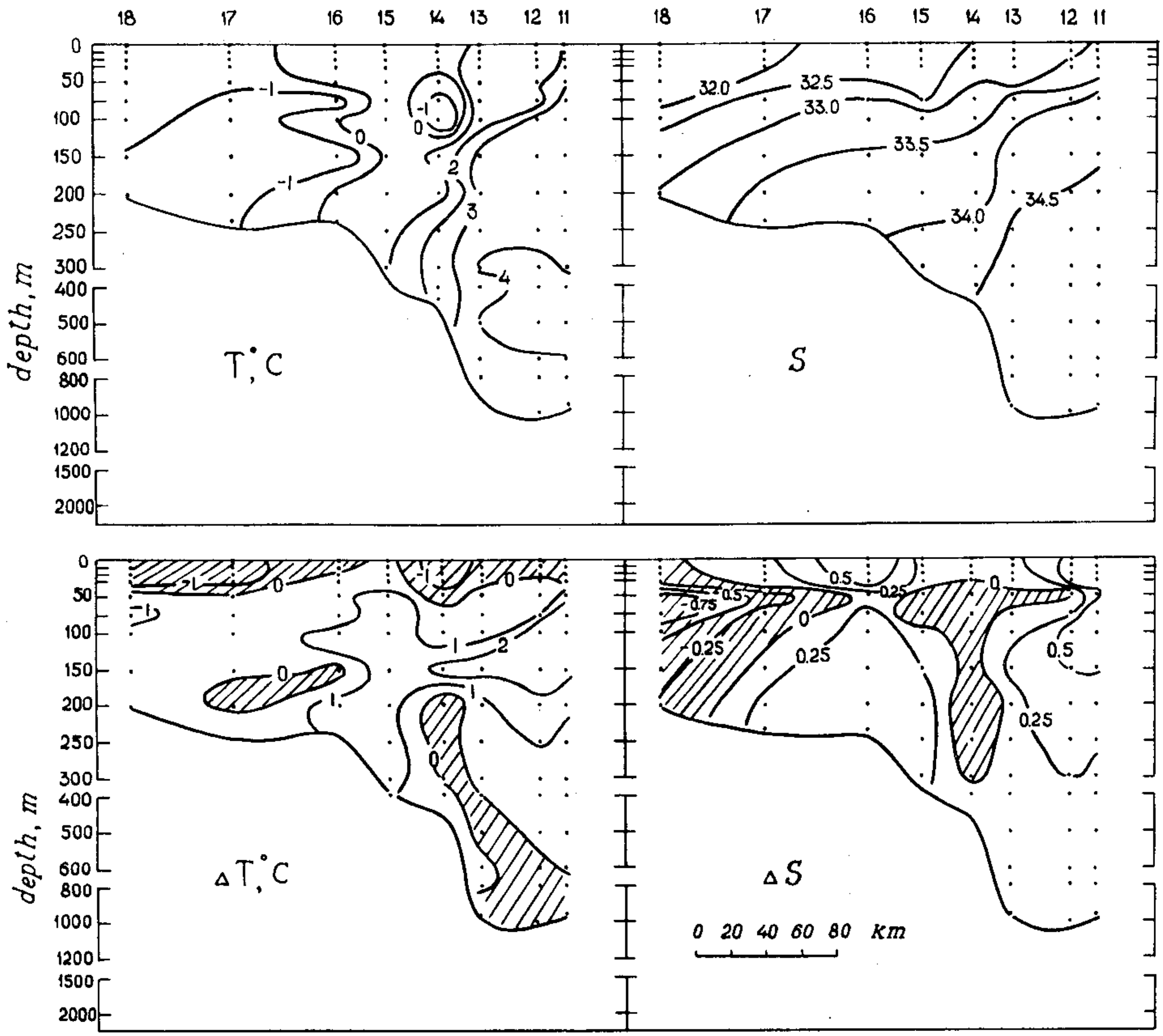

Fig. 4 Distribution of water temperature (T°C), salinity (S) and their deviations from the 1989 level (Δ T°C and Δ S) on section 11-A (Cumberland) in October 1990.

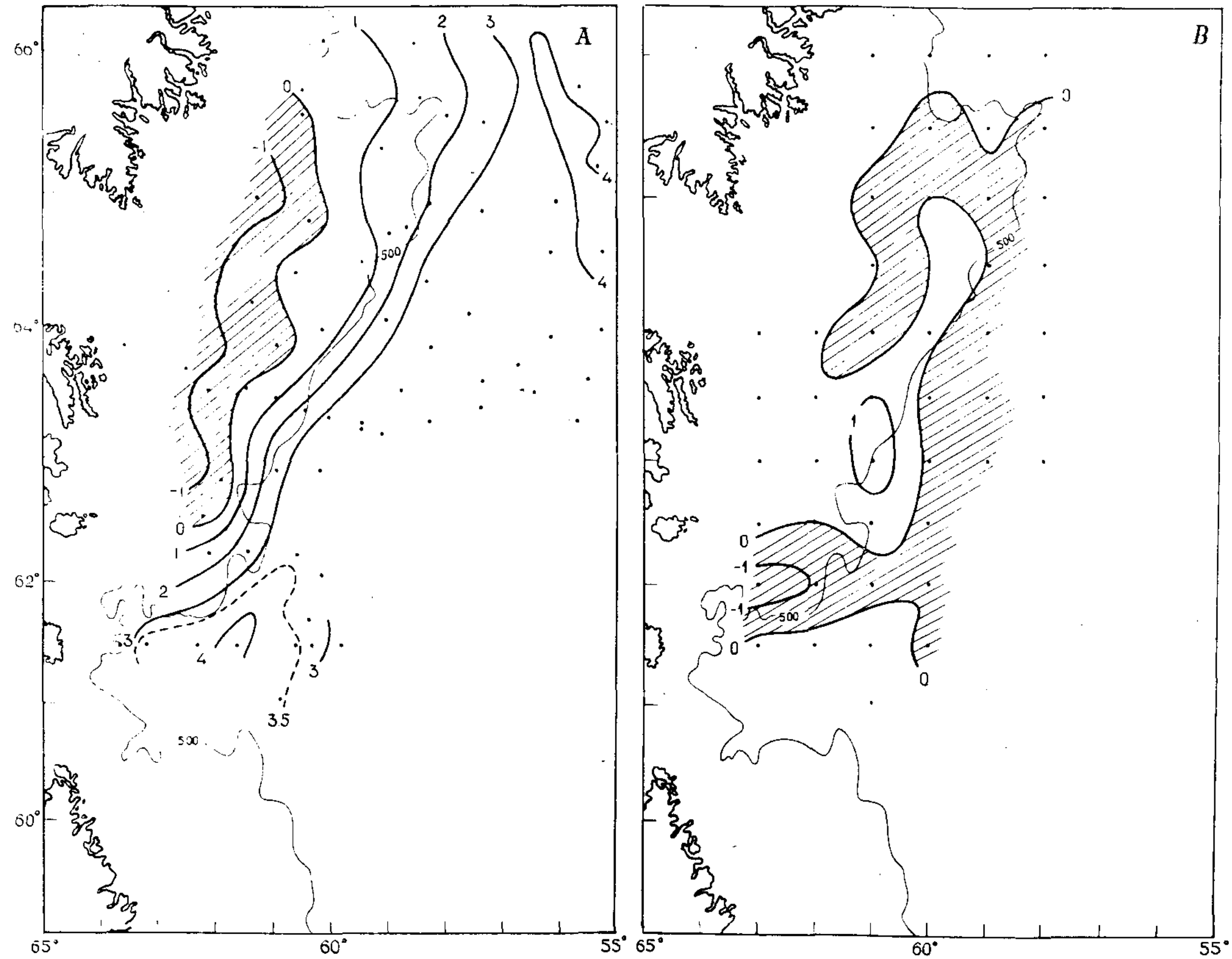

Fig. 5 Distribution of temperature (A) and temperature anomalies relative to 1989 level (B) in the near-bottom layer on the Baffin Land shelf in October-November 1990.

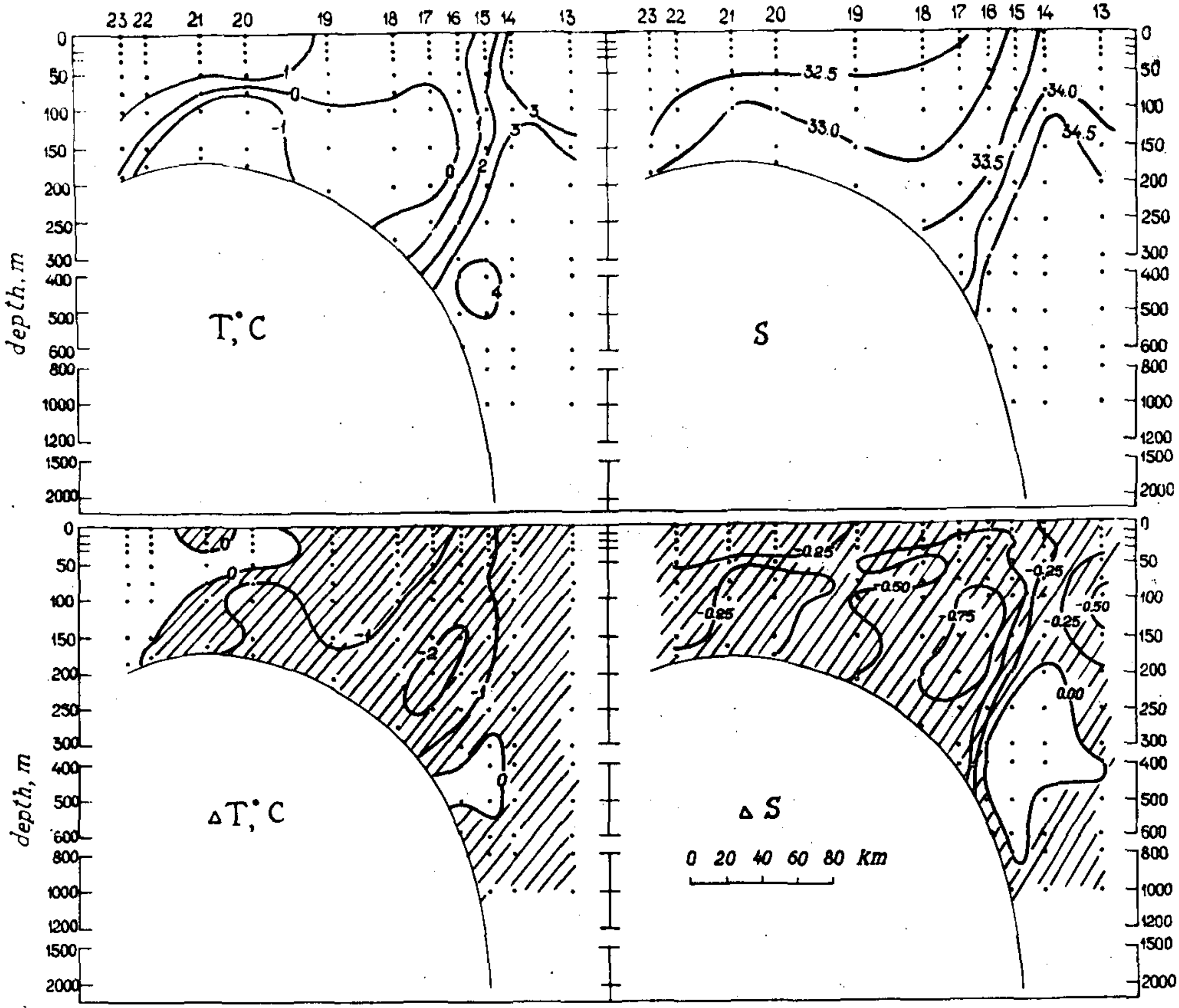

Fig. 6 Distribution of water temperature (T°C) and salinity (S) and their anomalies (Δ T°C and Δ S) on section 8-A in late October 1990.

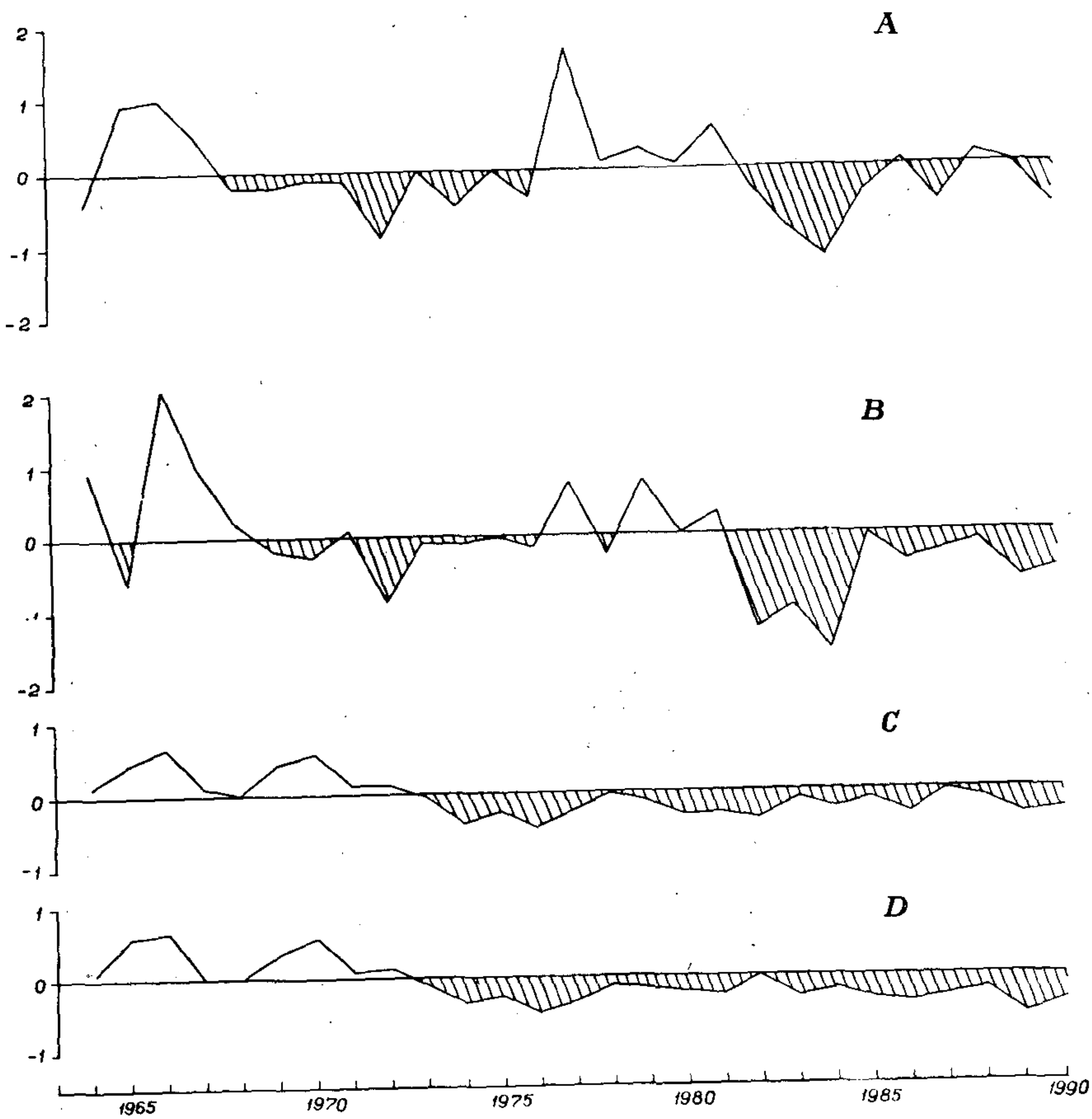

Fig. 7 Mean water temperature anomalies (°C) in the 0-200 m layer of cold (A) and in the 0-200 m (B), 200-500 m (C) and 500-1000 m (D) layers of Irminger components of the Labrador Current.

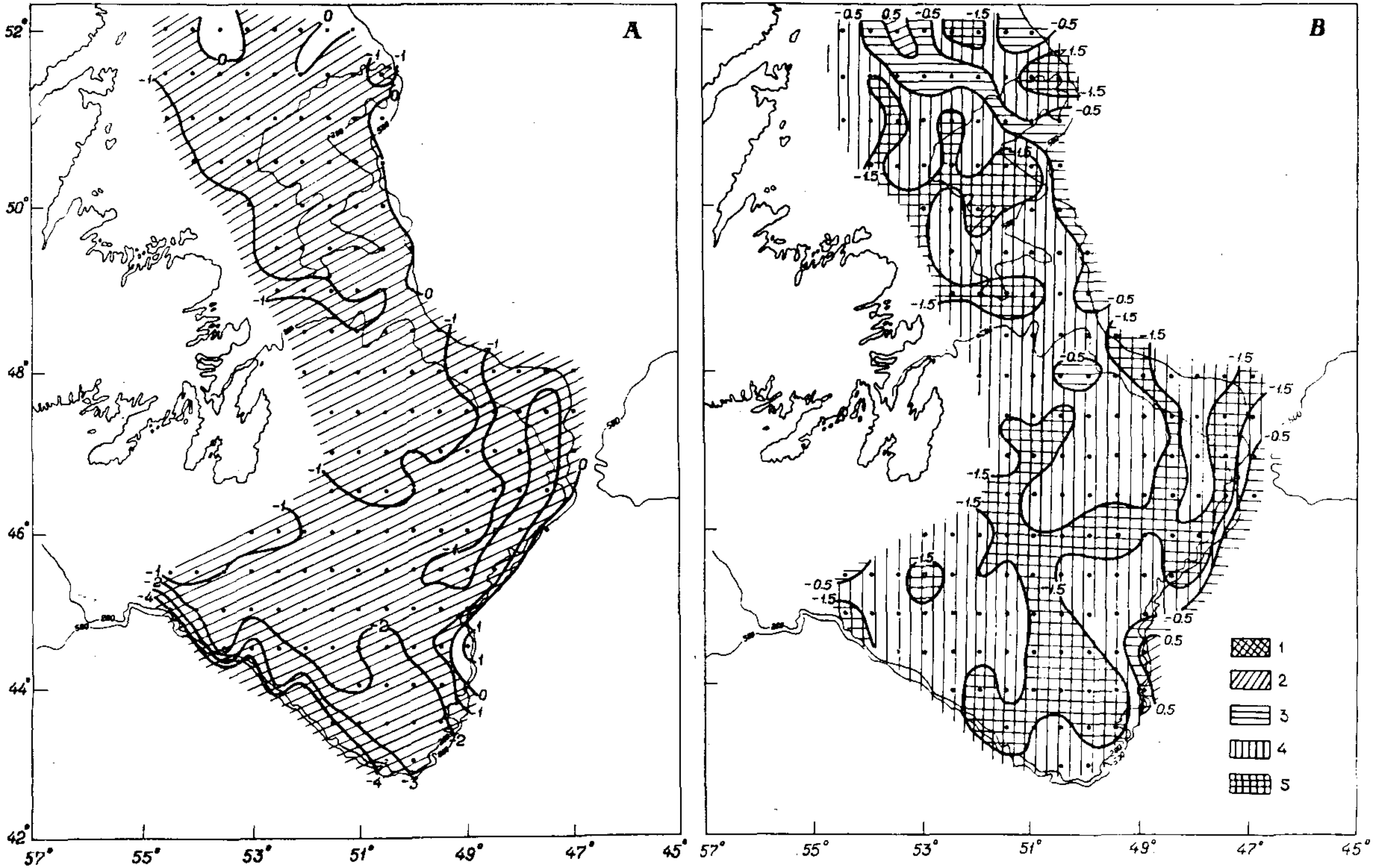

Fig. 8 Distribution of anomalies (A) and standardized anomalies (B) of the near-bottom water temperature on the Newfoundland shelf in spring 1990
1 - much above the norm; 2 - above the norm; 3 - the norm; 4 - below the norm; 5 - much below the norm.

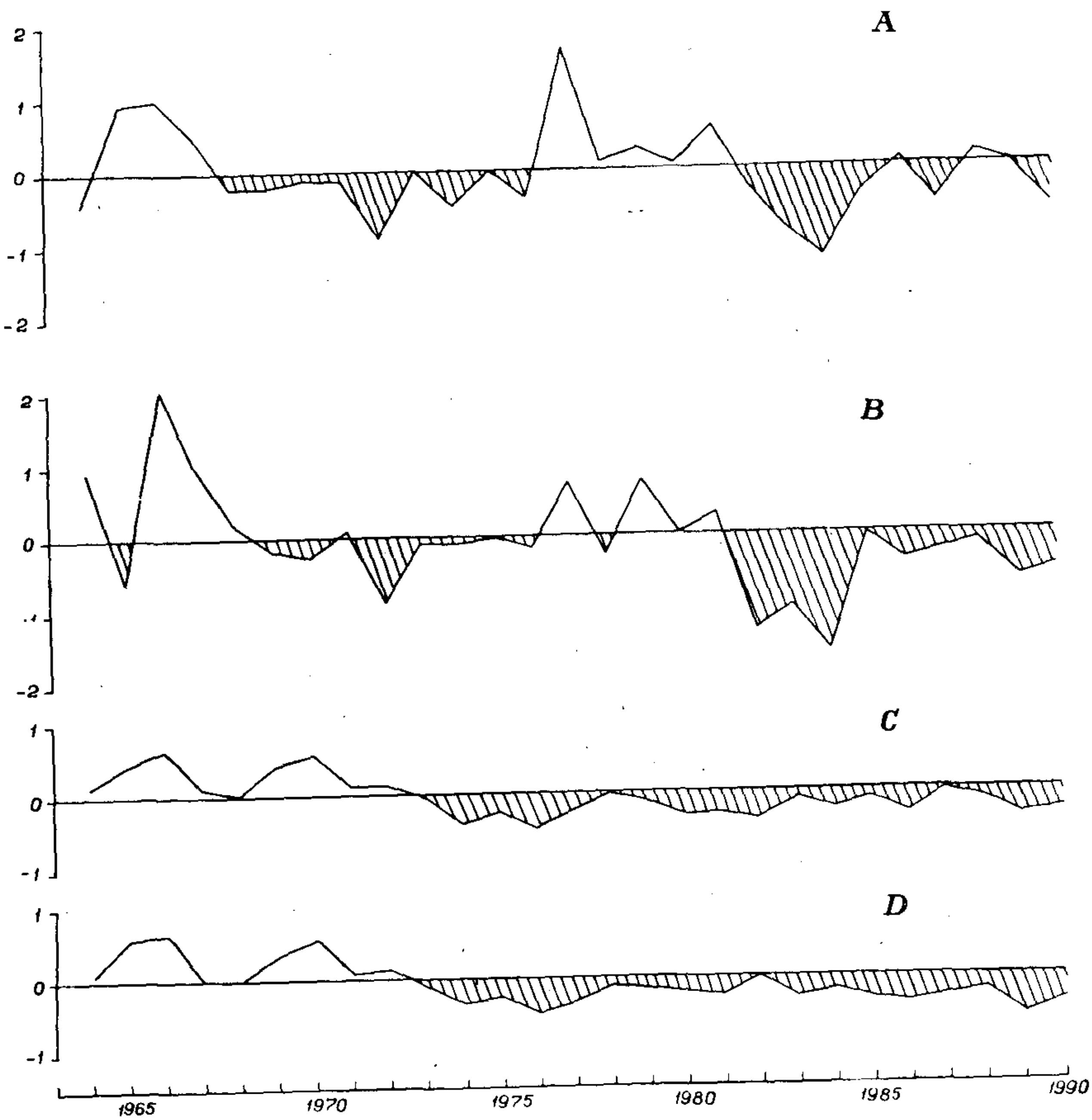

Fig. 7 Mean water temperature anomalies (°C) in the 0–200 m layer of cold (A) and in the 0–200 m (B), 200–500 m (C) and 500–1000 m (D) layers of Irminger components of the Labrador Current.

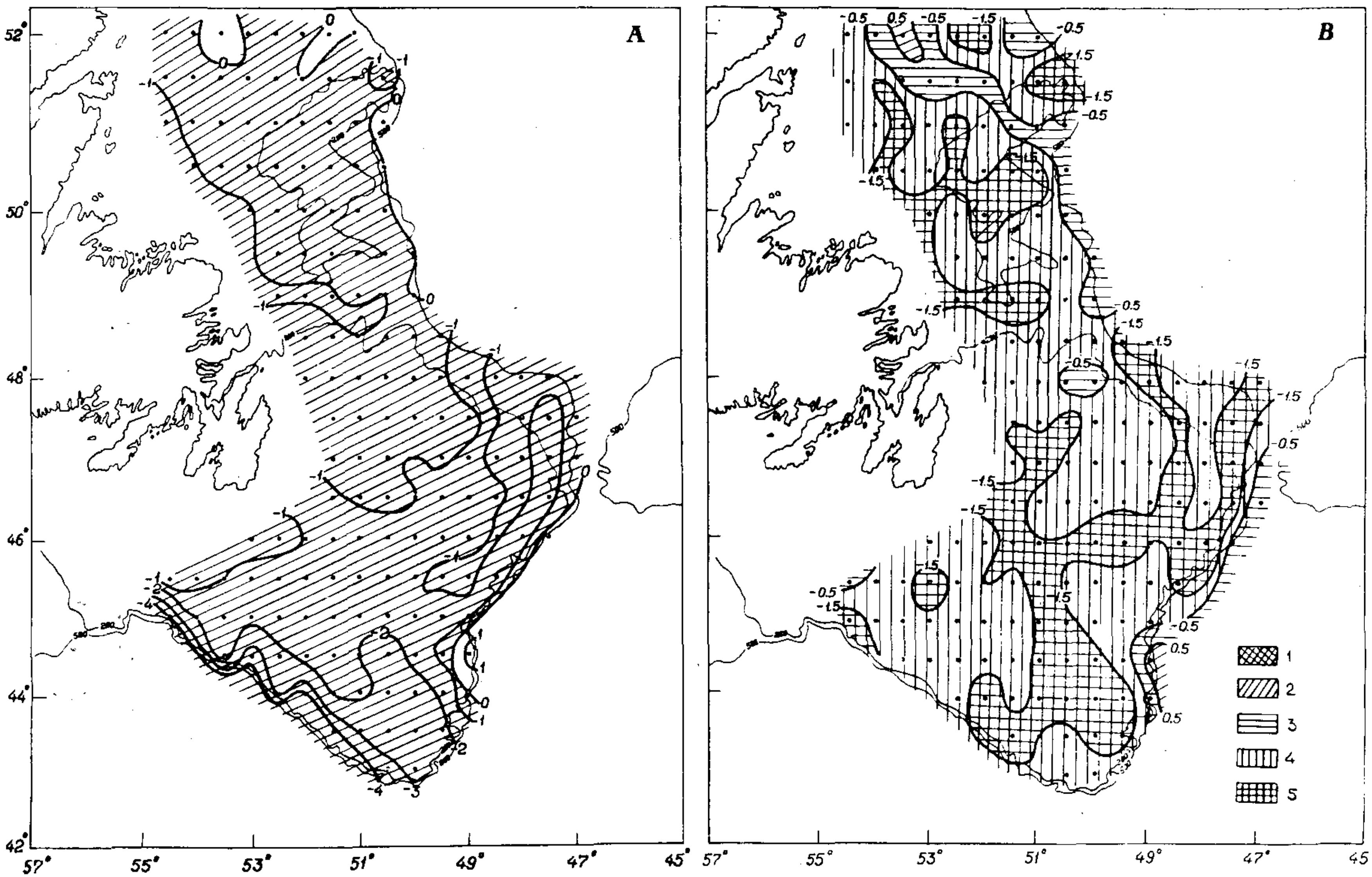

Fig. 8 Distribution of anomalies (A) and standardized anomalies (B) of the near-bottom water temperature on the Newfoundland shelf in spring 1990
1 - much above the norm; 2 - above the norm; 3 - the norm; 4 - below the norm; 5 - much below the norm.

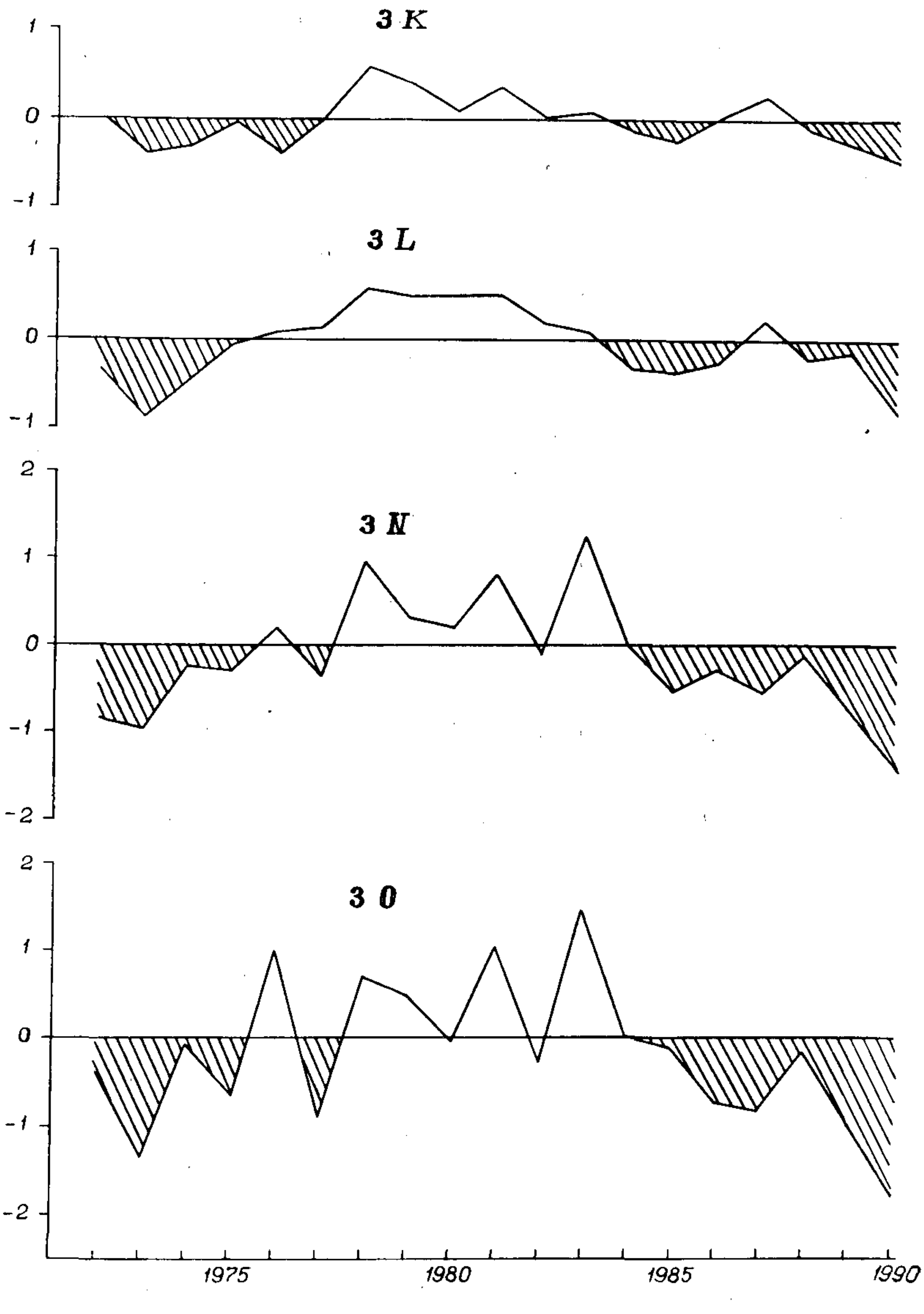

Fig. 9 Anomalies of mean near-bottom water temperature (°C) in Divisions of the Newfoundland shelf in spring.

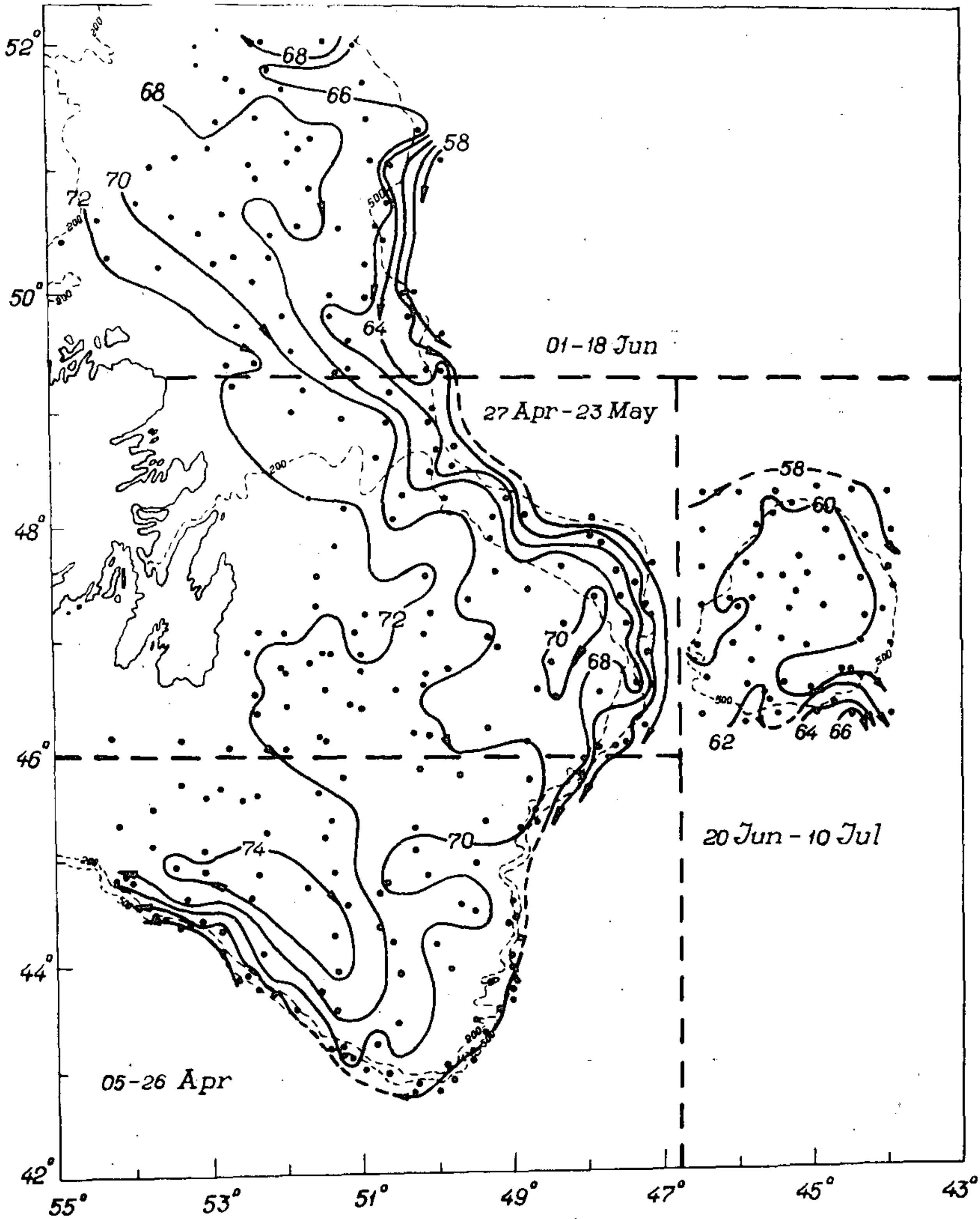

Fig. 10 Dynamic topography of sea surface relative to the 2 MPa level in spring 1990. Dynamic height isolines are drawn in 2 cm distance.