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Annual Variations in Thermic Background in the waters of the Northwestern Atlantic Shelf

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A B S T R A C T

This paper gives a qualitative evaluation of year-to-year variability of water temperature in the area of the Northwestern Atlantic Shelf in the period between 1962 and 1966. The results of investigations are obtained as charts of distribution of mean seasonal water temperature in different layers, charts of anomalies, as well as plots of curves of water temperature variability for different parts of the shelf. The analysis suggests a conclusion of a cooling trend in shelf waters since 1964 to 1966 inclusive. The investigation is made to determine the conformity between the variability of water thermic conditions and a number of biological phenomena observed in the above-mentioned area for seven years in question.

I N T R O D U C T I O N

The paper deals with a subsequent study of the regime of the Northwestern Atlantic Waters, namely with the investigation of thermic background and its year-to-year variability on the basis of observational data collected by AtlantNIRO expeditions from 1962 to 1966. The generalization of collected data on thermic conditions of waters in the area under survey, except specific value, is very important in explanation of some biological phenomena related with the abundance and composition of plankton and variability of its fields, as well as with the spawning conditions of individual commercial fishes. It can help to discover the relationship between variability and trend of thermic background of waters and variability of commercial stocks during the above interval of time.

Material and Methods

The observations on water temperature in the Gulf of Maine, on USA shelf, Nova-Scotian Shelf and on Georges Bank for the period between 1962 and 1966 were used in these studies. This material consists of the observations on standard sections and of the data obtained when scouting. This, the investigations covered an extensive area of shelf waters including the Nova-Scotian Shelf, Georges Bank and the southern part of the Gulf and USA Shelf along 76°W. All the observations were classified by conventional squares of 20' latitude and 30' longitude (fig.1). Average water temperature for a season was estimated according to the observations covering a square, and this average value was referred to the centre of the square. These average values were considered to be true when not less than 2 observations being conducted in a square. According to these data, the charts of distribution of mean water temperatures by season were drawn for the layers of 0, 30, 50 m and bottom- 200 m. The choice of these layers is connected with the fact that 3 above-mentioned layers are characterized by the concentrations of plankton and ichthyoplankton, the layer bottom - 200 m being an optimum one for commercial concentrations of fishes. Seasons were classified in the following way: winter - January, February; spring - April, May; summer - July, August, September; autumn - October, November. Such a classification is conditioned by extremely irregular observations during the whole year round.

Annual variability of thermic background was traced using the deviations of observed values of water temperature from the average seasonal temperature calculated by the formula:

$$\Delta t = T - \bar{T}$$

where Δt - deviation oftemperature

T - observed temperature

$\bar{T}$ - average seasonal temperature

The charts of the distribution of water temperature anomalies for each season and year were made for the mentioned layers according to the deviations being found. As a result, 15 charts of the distribution of the average seasonal temperatures appeared. Due to the lack of observational data, only one chart of winter temperature anomalies was drawn for Om layer. In addition, we have drawn up 71 charts for the distribution of water temperature anomalies. The charts are so numerous that, unfortunately, we have no chance to refer to all of them in the paper.

The analysis of annual variability was made according to the formula:

$$Q = 0.1cHt^{o}w,$$

where Q - heat amount of water layer in kg-cal.

c - specific heat capacity of water

H - thickness of water layer in m

$t^{o}w$ - temperature of water layer in ^{o}C

Assuming the thickness of water layer to be 1 and water temperature anomalies to characterize the variation of heat amount of water layer (thermic background), that is $\Delta Q \approx c \Delta t^{o}w$,

where ΔQ - the variation of heat amount of 1 m water layer.

$\Delta t^{o}w$ - water temperature anomaly.

The charts of anomalies were summarized according to 4 geographical zones designated in the following way:

Nova-Scotian Shelf	(I)
The Gulf of Maine	(II)
Georges Bank	(III)
USA Shelf up to 70°W	(IV)

As each season is not equally provided by the data by seasons, it is impossible to make a strict quantitative analysis of these data. We offer the following gradation to reveal the character of annual variability of thermic background of waters according to the charts of temperature anomalies.

Anomalies	Sign
> + 2°C	+ +
from 0.5 to 2°C	+
from−0.5 to+0.5°C	0
from−0.5 to− 2°C	−
> − 2°C	− −

As a result, table 1 a was drawn up to demonstrate the degree of variability of water thermic condition by each area, season and layer for every year between 1962 and 1966. On the basis of the data of table 1a we have made table 1b which reflects the variability of thermic bachground for the whole area and table 1c which shows this variability by all the layers in sum. A sign in parentheses in tables 1b and 1c is indicative of the transition tendency from positive value to negative one. The final stage of investigations was plotting curves according to the data of table 1 (fig. 2-3) and analysing of these curves.

Results of the analysis

The results of the investigations show that the most noticeable variability was recorded in surface layer in the Gulf of Maine and on the Nova-Scotian Shelf. The curves of annual variability for these two areas well agree by phase and magnitude. Thus, in the end of 1962 and 1963 and at the beginning of 1964 the anomalies were positive in these areas and reached 4°C in some locations. In summer of 1963 and 1965 the anomalies

were negative with the peak of - 1.5°C. Curves are rather smooth for Georges Bank and USA Shelf, and fluctuations are noted within ± 2°C. This difference between two areas can be explained by their geographical position. The surface waters in the Gulf of Maine and in the area of the Nova-Scotian Shelf which are adjacent to the north part of the continent experience stronger influence of the intrusion of air-mass from the continent, which are quite different by nature, than those on Georges Bank and USA Shelf situated somewhat to the south and constantly influenced by the waters of Gulf Stream.
The maximum values of water temperature anomalies on Georges Bank were quite opposite as compared with the maximum anomalies on USA Shelf during the whole period investigated (fig. 2).

At the depth of 30 m curve trend for water temperature anomalies is rather chaotic, but in 1962, 1963 and early in 1964 positive anomalies are recorded almost over the whole area. Since the second half of 1964 the anomalies were negative, and only in winter of 1965 the anomalies were positive up to 1.3°C on Georges Bank and in the Gulf of Maine (fig.2b).

These changes of thermic background are in a good agreement with the results of the following works: J. Chase (1967), John B. Colton (1968), Lauzier L.M. (1965a), I.K. Sigaev (1969).

In the layer of 50 m fluctuations of water temperature anomalies on the average were not beyond ± 2°C during all five years. Curve trend for USA Shelf, the Gulf of Maine and the Nova-Scotian Shelf is analogous to that for the layer of 30 m, i.e. this confirms the cooling being occurred after 1963. Simultaneously, the curve trend for Georges Bank is almost of sinusoidal character which can be probably explained by frequent alteration of inflow of waters of Gulf Stream and Labrador origin (fig. 2c).

The character of the curves of water temperature anomalies for the layer bottom - 200 m is very close to the distribution of anomalies in 30 m and 50 m layers (cooling after 1963). In the area of Georges Bank and the Gulf of Maine, however, positive anomalies up to 1°C were recorded in the off-bottom layer in winter and spring of 1965. It is probably the result of intrusion of water masses from Gulf Stream and of their distribution in the pre-bottom layer in the Gulf (fig.2d).

The whole area is characterized by cooling occurred after 1964 (fig. 3a). The curve for Om layer is almost sinusoidal, and it is well explained by the atmospheric processes influencing this layer. The curve trend for 30 m and 50 m layers shows a process of cooling being evident after 1964. In contrast to this fact, Lauzier (1965) pointed to a process of warming in the layer of 30 m in summer 1964 (positive anomalies up to 1.5°C). In addition, in winter of 1966 in the layer bottom - 200 m positive anomaly up to 3°C is recorded all over the area. Maybe it is caused by scanty observations on Georges Bank and in the Gulf of Maine in winter period (fig. 2d, 3d).

Since 1964 a cooling trend has been observed all over the area as it is supported by a resulting curve for all the above-mentioned layers (fig. 3b) which was smoothed afterwards (fig.3c).

Thus, in spite of episodic and scanty observations, the analysis of the available material allows to conclude that the data obtained are quite adequate to reveal thermic variability of shelf waters of the area,and to show a relative cooling which is recorded after 1964 and is observed even in 1966.

D I S C U S S I O N

This paper is one of the works devoted to investigation of annual variability of the thermic background of shelf waters in one of the basic fishing grounds in the Atlantic Ocean. The majority of works of foreign authors is based on multi-year water temperature observations on land and coastal stations and lightships (S. Chase, 1967; LMLaurier, 1965a; R. Walter Welch, 1967). The results of these investigations are indicative of a process of cooling since 1950's and up to the date. Recent studies include water temperature data collected during sporadic surveys in several locations on the North-Western Atlantic Shelf. These data give a good picture of the character of thermic variability in the areas in particular seasons (John B.Colton, 1968) and in the period of several years (Sigaev I., 1969). An attempt is made in this study to combine all the available information concerning water temperature on a wide extension of the shelf to make the qualitative analysis and to trace the character of annual variability of seasonal thermic fields over the shelf area on the basis of the analysis. As it is evident from the results, our methods are quite adequate for the analysis of multi-year variability of the thermic background, and the results well agree with the conclusions of the above-mentioned papers. Some discrepancies can be attributed to various methods of the analysis, to scanty observations or to the lack of observations in individual areas and seasons.

The observed cooling of shelf waters might have a direct influence (for instance, on survival of fish eggs and larvae) or indirect one (on food availability) upon variations of abundance of some commercial species.

Thus, for instance, the decrease of silver hake abundance in the area of the Nova-Scotian Shelf has been recorded since 1964 (Konstantinov, Noskov 1965),but in the area of Georges Bank and the Gulf it is noted in the whole period since 1962 up to the data (Konstantinov, Noskov 1966). Simultaneously, the increase of abundance of such a species as yellowtail flounder has been observed (Robert L. Edwards, 1968).

In addition, the reduction of silver hake abundance during the period of survey is supported by the preliminary data obtained when comparing the area of habit of this species before cooling (according to unpublished data of Noskov A.S.) with its present area.

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A

year	winter				spring				summer				fall			
LEVEL 0 M																
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1962									--	o	-	++	--	-	--	
1963	+	+			++		+	--	+	++	o	--	-	+	-	+
1964	-	o			-	--	o	-	-	o	+	o	++	++	--	+
1965					-	+	-	-	o	o	-	+	-	+	+	--
1966	-	-			--	-	-	o	+	+	+	o	+	+	o	-

year	winter				spring				summer				fall			
LEVEL 30 M																
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1962					o		+	+	--	+	-	++	-	-	--	
1963	+	+			+	+	++	-	o	o	-	++	o	+	o	+
1964	-	o			-	o	o	o	++	o	+	-	+	+	--	o
1965					o	o	-	-	o	o	o	-	o	+	+	--
1966	-	-			o	-	-	o	o	--	+	-	o	o	+	o

year	winter				spring				summer				fall			
LEVEL 50 M																
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1962					+	o	+	++	+	+	-	++	+	+	-	
1963	+	+			+	+	+	o	o	+	-	++	o	+	+	o
1964	-	-			o	+	o	o	o	-	+	-	-	o	-	o
1965					o	-	-	-	o	-	+	--	+	-	+	-
1966	+	+			o	-	-	-	o	-	++	-	-	o	+	o

year	winter				spring				summer				fall			
LEVEL 200 M - BOTTOM																
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1962					o	o	+	++	+	+	-	+	+	+	-	
1963	o	o			+	+	+	+	o	+	+	++	o	+	o	++
1964	o	-			o	+	o	o	+	-	o	-	o	-	-	o
1965					o	o	-	o	o	-	+	-	o	-	++	-
1966	o	++			-	o	-	o	o	-	o	o	-	-	+	-

B

year	winter	spring	summer	fall	year
LEVEL 0 M					
1962			o (-)	--	-
1963	+	+	o (+)	o	+
1964	-	--	o	+ (+)	-
1965		-	o	o (-)	-
1966	-	--	+	o (+)	-

year	winter	spring	summer	fall	year
LEVEL 30 M					
1962		+	o	-	o
1963	+	++	+	+	+ (+)
1964	-	- (o)	+	o	o
1965		-	o (-)	o	- (o)
1966	-	-	-	o (+)	-

year	winter	spring	summer	fall	year
LEVEL 50 M					
1962		++	+ (+)	+	+ (+)
1963	+	+	+ (+)	+	+
1964	-	+ (o)	o (-)	-	-
1965		-	-	o	-
1966	+	-	o	o	o

year	winter	spring	summer	fall	year
LEVEL 200 M - BOTTOM					
1962		++	+	+	+ (+)
1963	o	+	+	+	+
1964	-	+ (o)	o (-)	-	-
1965		- (o)	o (-)	o	-
1966	+ (+)	-	o	-	o

year	winter	spring	summer	fall	year
1962		++	+	- (o)	+ (+)
1963	+	+	+	+	+
1964	-	o (-)	o	o (-)	o (-)
1965		-	-	o	-
1966	o	-	o	o	o (-)

C

Table 1. Qualitative evaluation of water heat amount along the levels of 0, 30, 50 m. and bottom - 200 m in 1962-1966

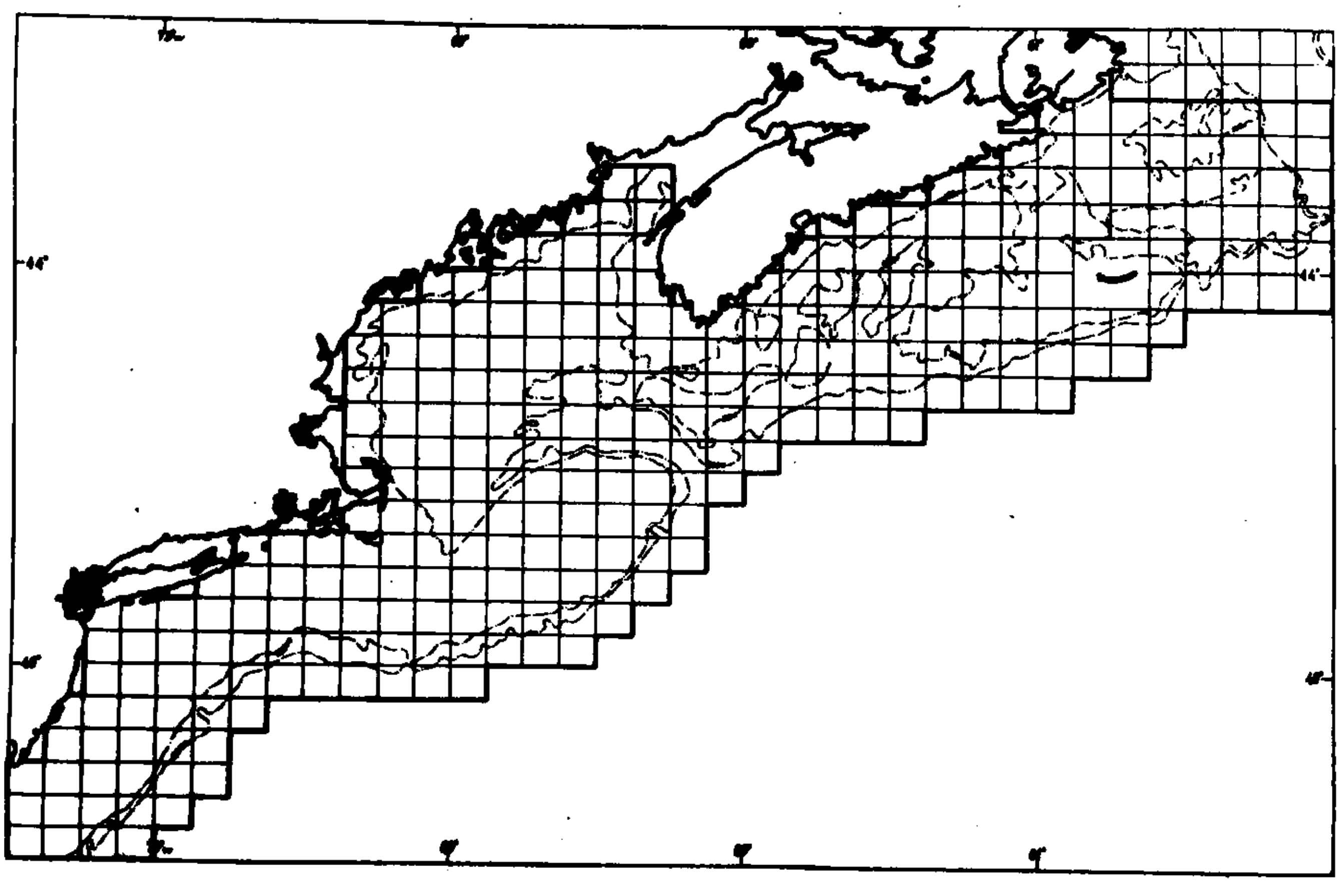

Fig. 1. A diagram of squares in the area of investigations

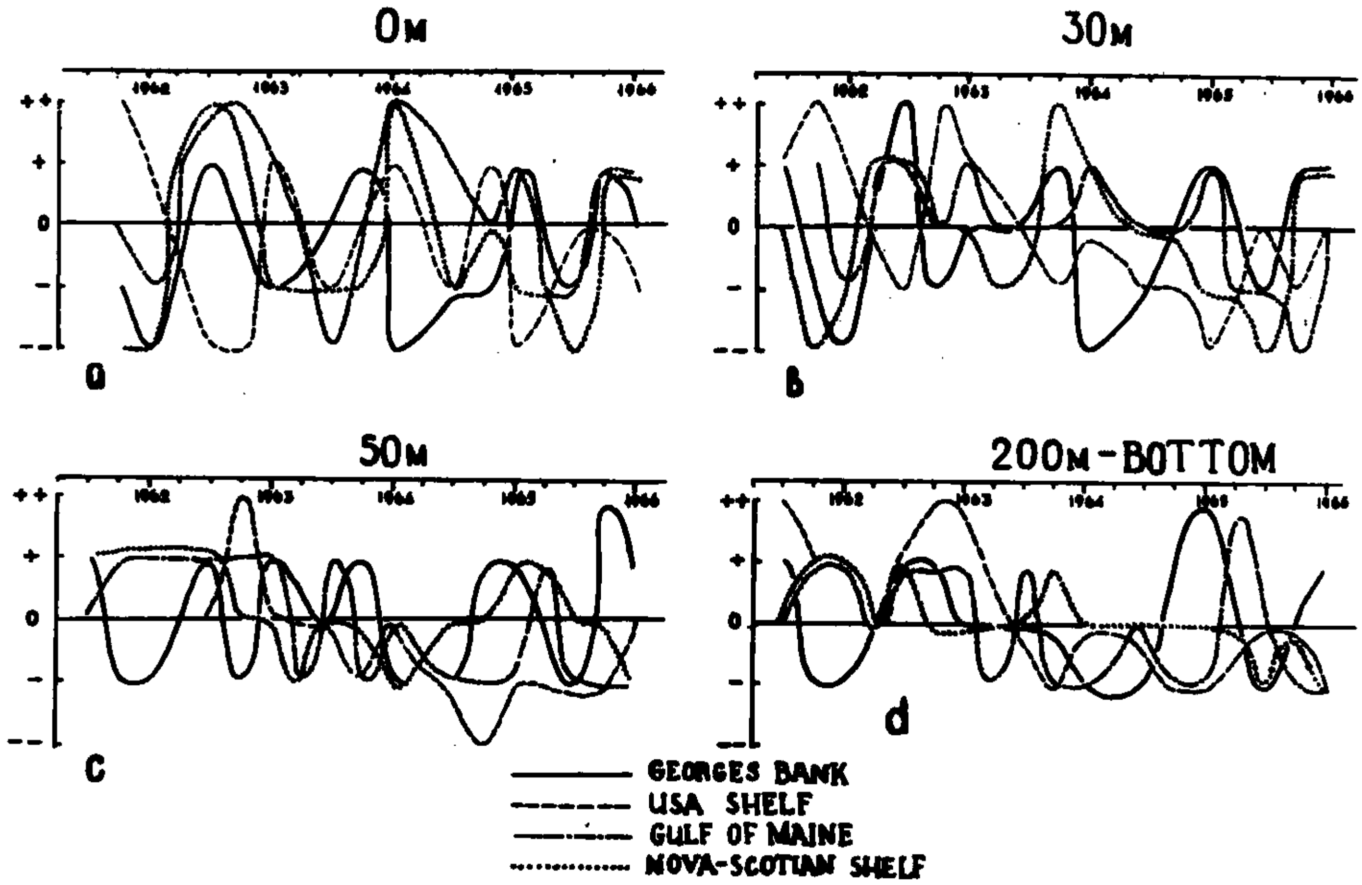

Fig. 2. Plots of variability of water heat amount in some locations of the shelf.

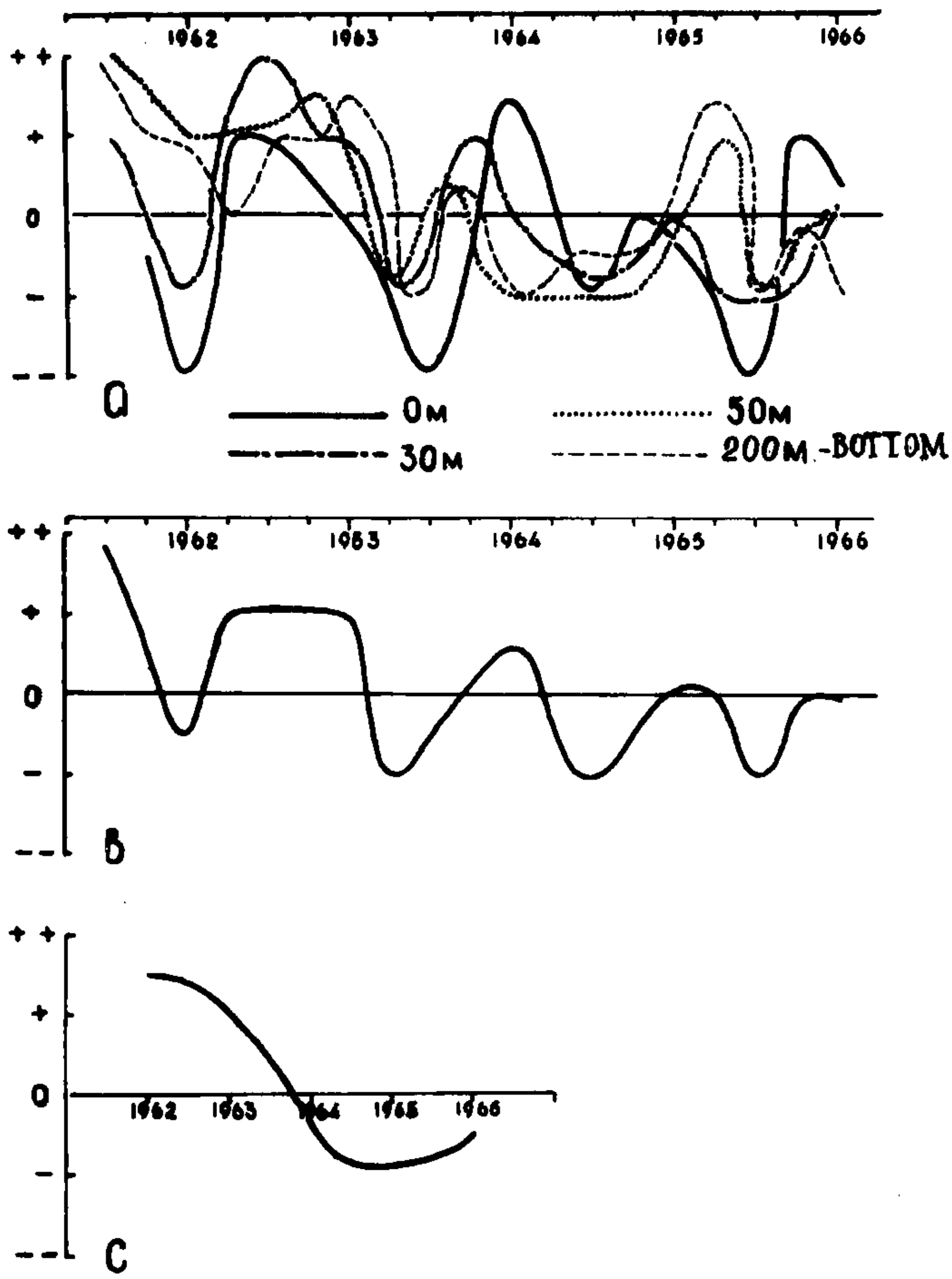

Fig. 3. a - Plots of variability of water heat amount by levels all over the area.
b - Resulting plot of variability of heat amount for all the areas in sum.
c - Trend.