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# Temperature of Bottom Waters Over the Newfoundland Shelf in Spring-summer 1972-86

by

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## Abstract

**Based on materials of spring-summer oceanographic surveys undertaken by PINRO research vessels in 1972-1986 a statistical analysis of bottom water temperatures is carried out. An estimate of the climatic normal variations of long-term temperature characteristics is presented. During the period under survey the long-term variability of temperature had a cyclic character with a pronounced cycle of approximately 12 years. Long-term trends reflectin** the warming processes,prevailing during 1973-1978 inDiv.3KL and from 1973 to 1983 in Div.3NO were revealed. Subsequent cooling continued up to mid-1980's and was the sharpest in the southern part of the Grand Bank.

## Introduction

Systematized and summarized data on space-time variability of oceanographic factors are required to solve the number of problems concerning the study of environmental impact on the distribution of the commercial fishes.From the point of view of examining the reasons that determine pecularities of bottom fishes distribution,information on climatic and temperature conditions in bottom layer causes a certain interest,so do the data on annual variability of these conditions.The papers available(Templeman,1975; Keeley,1981; Akenhead,1986) containing survey data summarized over a period of many years along the oceanographic transects on the Newfoundland shelf give,due to their local character of information,a limited picture of temperature conditions in the bottom layer.More complete and detailed spatial characteristics may be obtained from the surveys,being carried out at points of rather dense grids covering the area under survey.

## Materials and methods

Data obtained from 15 spring-summer oceanographic surveys,conducted on the Newfoundland shelf by PINRO vessels,along with the fish stock size surveys(table1), served as the base materials. Each survey counted from 159 to 348 oceanographic stations distributed more or less evenly over the shelf and slope areas in Div.3KLNO. The water temperatures were taken with the deepwater reversing thermometers; unprotected reversing thermometers were used to control the depth of taking. All the survey data were scrutinized.

On the basis of these data the water temperature distribution in the bottom layer (3-10m above bottom) was charted. Then the temperature values were interpolated into fixed crossing points of a regular grid with both latitudinal and longitudinal 30 min steps, and also into several additional points. As a result of the above-mentioned procedure, samples consisting of a sequence of annual temperature values were formed for each of 166 points covered by the grid. With the help of well-known formulae a number of statistical characteristics such as, arithmetic mean, standard deviation, asymmetry and excess coefficients etc. were obtained for these samples. In accordance with recommendations on small volume samples analysis (Pustylnik,1968) in order to test a hypothesis of correspondence between temperature distribution and normal law the following criteria were applied:

$/A/ \leqslant 3\sqrt{D/A/}$ and $/E/ \leqslant 3\sqrt{D/E/}$; where /A/ and /D/ are asymmetry and excess coefficients modules respectively, D/A/ and D/E/ are these coefficients variances.The performance of this inequality is the condition of correspondence between random values distribution and normal law; otherwise the hypothesis of correspondece is rejected. Mean water temperature in Divisions was calculated as an arithmetic mean for the crossing points set inside the Division. The crossing points located at 46°N were included into mean temperature calculations both for Div.3L, and for Div.3NO.

Initial data and adopted methods of their processing provide no elimination of temperature variability effects throughout a year or less period range; in this connection one should take into consideration the presence of a short-period "noise" in long-term normals and in year-to-year temperature variability. This "noise" comprises a part of the seasonal variations in temperature, which are not eliminated on account of some time differences in a number of surveys(table1;Fig.1) and the fact, that spatial variability of bottom temperature seasonal variations in the surveyed shelf area is not studied enough. A certain idea of the "noise" seasonal component may be obtained from the data on normal annual water temperatures variations at Station 27(Keeley, 1981a)available in this paper.

Fig.2 taken from the above-mentioned paper shows the seasonal signal delay and attenuation with depth, and its dissapearence near the bottom at the horizon of 170 m. In the April-September period to which the analysed sets of spring-summer surveys data refer(Fig.1), maximal mean differences in temperature at Station 27 are characterized by the following values:

| horizon m | 0 | 50 | 70 | 100 | 120 | 150 | 170 |
|---|---|---|---|---|---|---|---|
| t max °C | 13.1 | 4.0 | 2.5 | 0.4 | 0.2 | 0.2 | 0.3 |

Judging by these values, seasonal variations over the mentioned period are essential in the surface layer down to the depth of 100m, whereas more or less steady temperature level, corresponding to the conservation phase of winter signal, is characteristic for the subsurface layer. Suppose the mentioned delay and attenuation features of seasonal temperature variations are steady over the surveyed area of the Newfoundland shelf, and also assume that the year-to-year seasonal temperature variations correspond to the climatic ones, in this case base data on bottom temperatures may be divided into two groups differing from each other by the "noise" level of seasonal origin. One of these groups, characterized by a high level of the "noise", must accumulate data, referring to the area with depths less or about 100m, the other, specified by low "noise" level - data on more deepwater areas. Certainly this classification may not be absolutely perfect, but all the same it may be useful for interpretation and further application of the estimates obtained.

**Results and discussion.**

Data test, accordingly to adopted criteria, showed, that more than 98% of bottom temperature samples corresponded to normal distribution law in crossing points of the grid. It makes possible to give a statistical description in most elementary characteristics terms. Mean values distribution(Fig.3) specifies temperature field structure by a combination of areas with different spatial variations of this parameter. Along with the zones of relatively smooth variations, refering to the northern deepwater shelf of the surveyed area and northern part of the Grand Bank, areas with frontal zones features, which are located closely or above the Grand Bank slopes may be observed. The presence of these frontal zones in long-term temperature mean field argue for their quasi-stationary character; the latter combined with the tendency of sharp bottom relief changes indicates the topographic character of the frontal zones. Within the surveyed area the most pronounced thermal frontal zone in the near-bottom layer occurs in the Grand Bank part adjacent to the southwest slopes with depths range from 200m up to 80-100 m; climatic temperature differences are 4-5°C there, and the corresponding temperature variations range is extended from 0-1°C to 5°C. ~~Frontal~~ zone above the northern and eastern Grand Bank slopes at depths from 150-200m to 500m is specified by relatively more moderate temperature differences ( about 3°C) and temperature variations range (from 0°C to 2-3°C). The least pronounced climatic frontal zone with temperature differences about 1°C and temperature range 1-2°C follows the submeridional line north of the Notre-Dame Bay at depths of 200-300m.

Judging by the temperature variation ranges, the first out of the mentioned frontal zones is formed by interaction between slope waters and either Labrador current waters(west of 54°W), or spreading more eastward, transformed shelf waters, which are the result of deviation of slope waters and those of Labrador current. The other two frontal zones are associated with the effect of bottom relief changes, the vertical thermal structure of Labrador current being heterogeneous; the latter is characterized by a fairly sharp temperature inversion at depths from 150-200m down to 300-350m* over the spring-summer period. A cool

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* These two zones are not frontal in common sense and should be refered to the vertical zonality type or "depth zonality".

near-surface layer is an inseparable component of this structure, it contains waters having a subzero temperature in winter. IN the surveyed area this layer reaches the bottom in the northern part of the Grand Bank;the 0°C isotherm in Fig.3 draws the contours of the climatic area of such a phenomenon.North of the Grand Bank, at depths from 300m to 500m,more or less even bottom temperatures distribution(2-3°C) is due to the attenuation with depth of the Labrador current thermal stratification. A small temperature perturbation,that may be found in Fig.3(2°C isotherm) refers to the top of the Funk Island Bank. Its presence is due to bottom relief pecularities and Labrador current waters structure.Fig.4 shows the standard error of temperature mean;the error ranges from /0.1/ to/0.6/°C preserving low values/<0.2/°C over a major part of the area. The most essential errors/0.4/-/0.6/ are located along the southern slopes of the Grand Bank.This reveals their connection with the most pronounced frontal zone state.As the value error in this case is defined by the temporal variability of characteristics, the extension of uncertainty mean interval reflects

the temperature variability rise outside and inside the frontal zone itself.

The property of thermal frontal zones to have elevated temperature temporal variability may be proved when comparing Fig.3 and Fig.5. However,one can notice that maximal variability in the "tail" part of the Grand Bank exists even in case of absence of climatic frontal zone reflected in temperature field.This discrepancy may be related to the nonstationary character of the frontal zone local part,because owing to this property,the averaging of particular situations causes a "washing away" of the fields structure nonuniformities.On the other hand,as the previous section shows,the nonfiltered part of seasonal variations would make some additional contribution to the bottom temperature variability in the shallow southern part of the Grand Bank.

When comparing standard deviations off the southern slopes of the Grand Bank(1.5-2.2°C) and its northern and eastern slope areas(0.7-1.1°C)corresponding to the frontal zones,one can find that temporal variability value in northern areas is 2-3 times less than in the south.The reasons of such differences are not known yet,and it only may be assumed that they are associated either with differences in current system stability, or with pecularities of frontal zones belonging to the "depth zonality" phenomenon.

Beyond frontal zones the bottom temperature variability has relatively small/< 0.6°C/ standard deviation values; since long the most steady temperatures have been registered in the Labrador current waters washing the bottom of the deepwater shelf north of the Grand Bank. Besides, cool subsurface waters, spreding to the bottom in the area east of the Avalon peninsula, show as well relative stability of their thermal properties.

By the distribution of asymmetry and excess indices (Fig.6 and 7) one can also judge on pecularities of bottom temperature temporal variability in Newfoundland shelf areas. For instance, in the deep west of the Funk Island Bank, on the Grand Bank northeastern and eastern slopes with depths beyond 300m, and in its eastcentral part the above-mean temperature values are prevailing.
Negative asymmetry coefficients, specifying mode shift, relative to the mean, into higher temperatures range testify to this. Such a skewness of the distribution curve is due to rare but considerable bottom temperature drops trend in the reported areas.

The reverse effect, corresponding to the positive asymmetry coefficients, occurs on the Grand Bank northeastern prominence, in some eastern parts of the deepwater shelf north of the Grand Bank, in its top and "tail" part, and also in the far southwest of the surveyed area. Rare but considerable warming trend, appearing in these areas, may be associated with some slope waters invasions into the shelf areas, which can be both on the usually cold frontal zone side, and in areas with the obvious lack of pronounced frontal zones. As for the Grand Bank northern areas, the Funk Island Bank etc. , the forms of the bottom temperature distribution curves are the closest to normal law; small in module asymmetry and excess coefficients argue for this. Over some parts of these banks slopes the bottom temperature variability is specified by small asymmetry coefficients, matching considerable negative (to -1.7) excess coefficients. This matching indicates the trend of polymodal, most possibly, two-top distribution forming. This fact may be associated with the alternation in prevalence of the two water masses in the reported areas. The mentioned pecularity of year-to-year temperature variations may be due to, for ex., changes in vertical development of cool subsurface layer and its capacity to reach the bottom. However, one should take into consideration the limited character of survey series and, hence, a possibly inaccurate value of asymmetry and excess coefficients.

Bottom temperature mean variations in Divisions throughout the spring-summer period and temperature normals calculated over 1972-1986 period for each Division are shown in Fig.8. The Fig. shows, that bottom waters mean temperature in Div.3K and 3L varies more or less quietely from year toyear , following the well-pronounced trends. Maximal range of bottom temperature takings throughout the surveyed period was 1.0°C in Div.3K and 1.4°C in 3L. Mean temperature for Div.3NO varied considerably(t° amplitude reached 2.6°C) from year to year, so a curve smoothing made by means of step-by-step pair averaging of initial series elements (dash line inFig. 8) was required for trends determination. Summarizing the bottom temperature mean variations we may state that in 1972-1986 variations over the longest periods followed the common rule in all the surveyed areas. In 1972-1976 bottom temperature aws below normal with minimal value in 1973. In 1976-1978 there occured a considerable rise in bottom temperature, especially well-pronounced in the most deepwater Div. 3K. Since 1978, a general cooling trend has appeared, and as a result of it the temperature in 1983 fell below normal level , having reached in1985 the minimum of 2.0°C in Div.3K and 0.1°C in Div.3L. In Div.3NO water temperature had the highest value of 3.1°C in 1983 and by 1985 it had dropped to 0.7°C. Since 1985 a warming trend has occured in all Divisions. The period between minimal temperature values is 12 years. The above-made conclusion on bottom temperature fall in Div.3L over the 1978-1985 period qualitatively is in agreement with the conclusions of Akenhead's paper(1986), which are based on data analysis of the surveys, conducted along the same Div. section, situated at 47°N.

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Table 1 Information on spring-summer oceanographic surveys, conducted in Newfoundland shelf area in 1972-1986 according to PINRO program.

| Year | Vessel, cruise number | Quantity of oceanographic stations | Beginning of survey | End of survey |
|---|---|---|---|---|
| 1972 | Persey-3, 8 | 313 | April,11 | July,5 |
| 1973 | Persey-3, 11 | 256 | June,8 | August, 26 |
| 1974 | Persey-3, 12 | 314 | June, 15 | August,19 |
| 1975 | Persey-3, 14 | 210 | July, 15 | September14 |
| 1976 | Persey-3, 15 | 289 | April,13 | June,20 |
| 1977 | Persey-3,18 | 194 | May,28 | July,22 |
| 1978 | Persey-3, 20 | 199 | May,30 | July,14 |
| 1979 | Suloy, 2 | 206 | April,8 | May,26 |
| 1980 | N.Kononov,2 | 202 | May, 8 | June,27 |
| 1981 | N.Kononov,4<br>Gemma,23 | 191 | June,11 | July,24 |
| 1982 | Suloy,25 | 159 | May, 3 | July,1 |
| 1983 | Suloy,27 | 210 | June,1 | July,27 |
| 1984 | Suloy,30 | 348 | April,30 | July,16 |
| 1985 | Genichensk,2 | 228 | May,3 | June,24 |
| 1986 | N.Kononov,34 | 238 | April, 20 | June,16 |

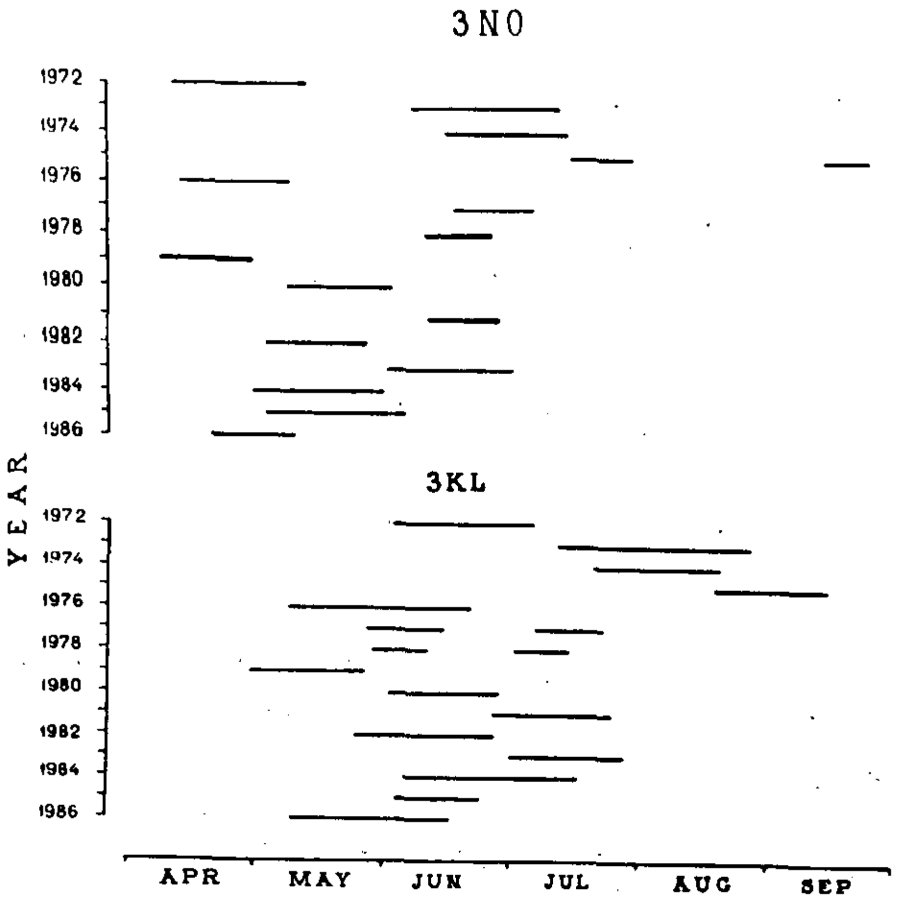

Fig.1. Periods of the oceanographic surveys in Div.3NO and 3KL.

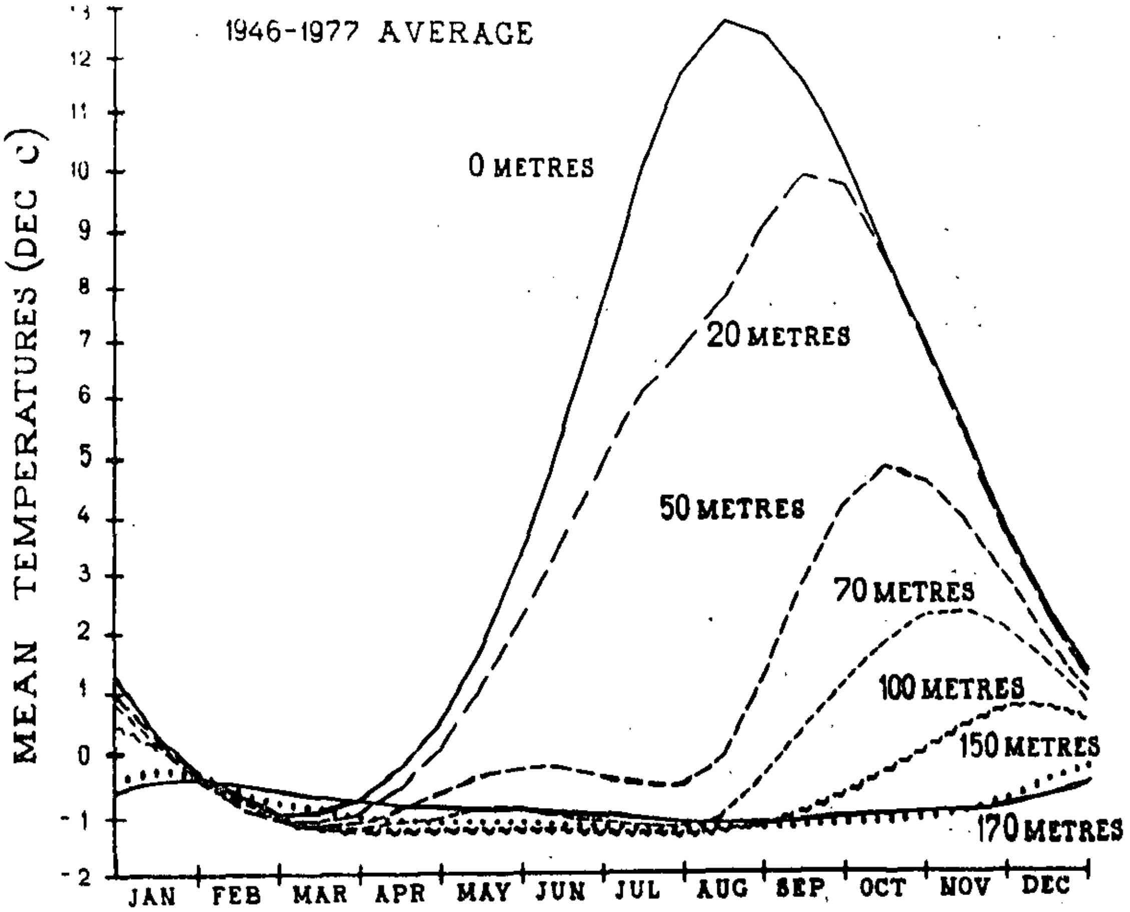

**Fig.2** Normal water temperatures(°C) annual variations at station 27(according to Keeley,1981a)

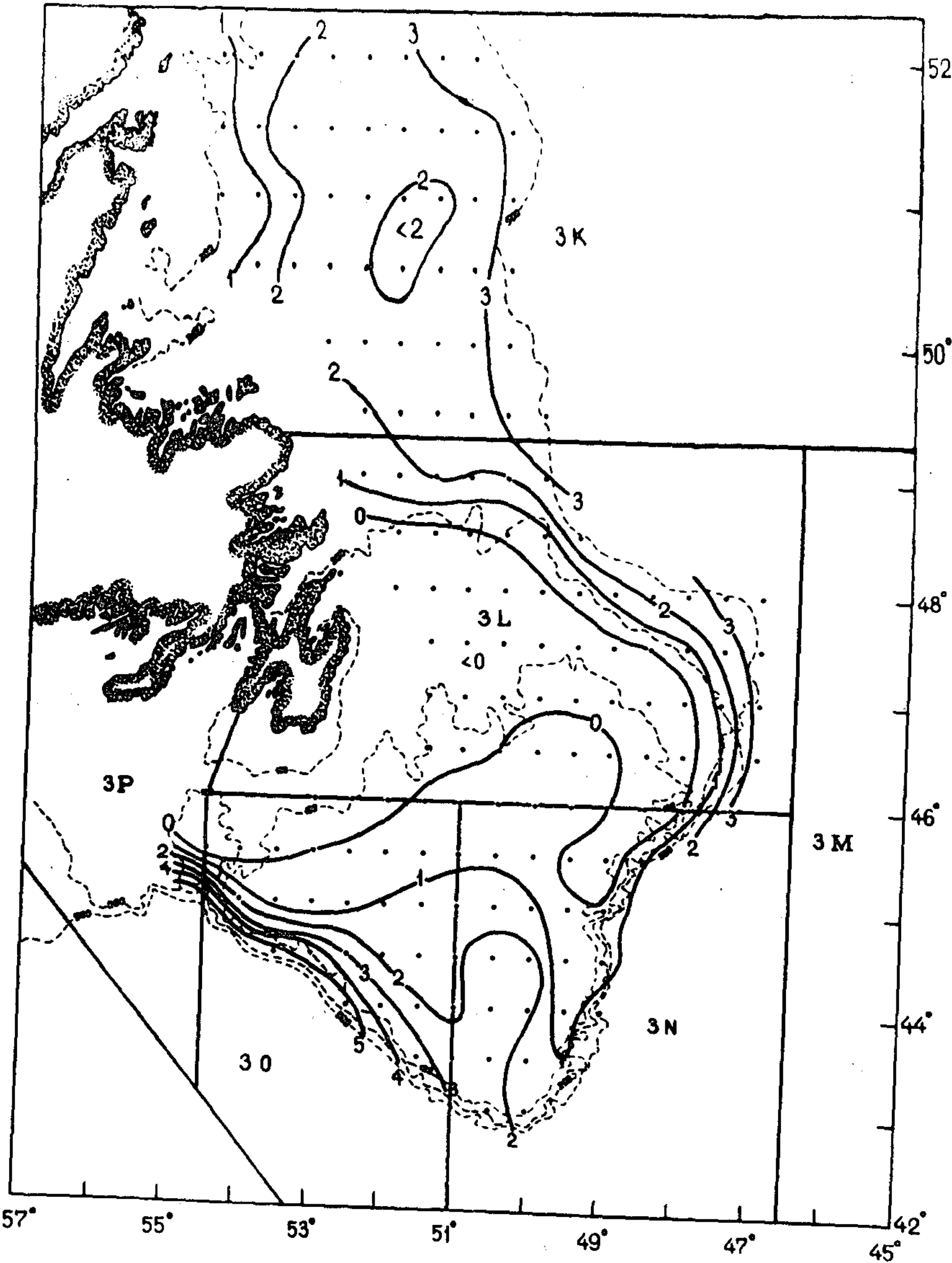

Fig.3 Distribution of mean water temperature(°C) values in bottom layer on the Newfoundland shelf over the spring-summer period, 1972-1986.

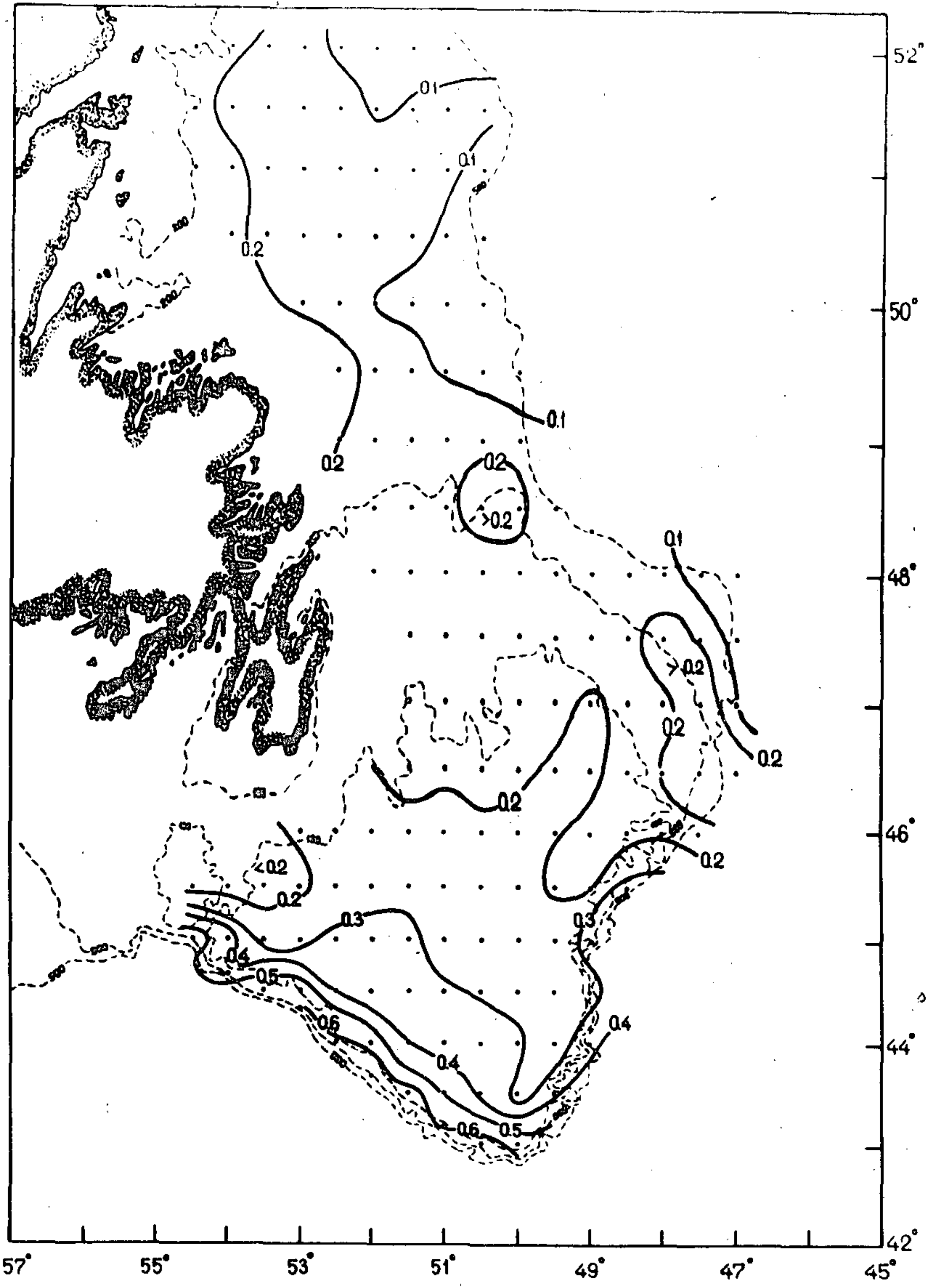

Fig.4 The error of mean water temperature(°C) values in bottom layer on the Newfoundland shelf.

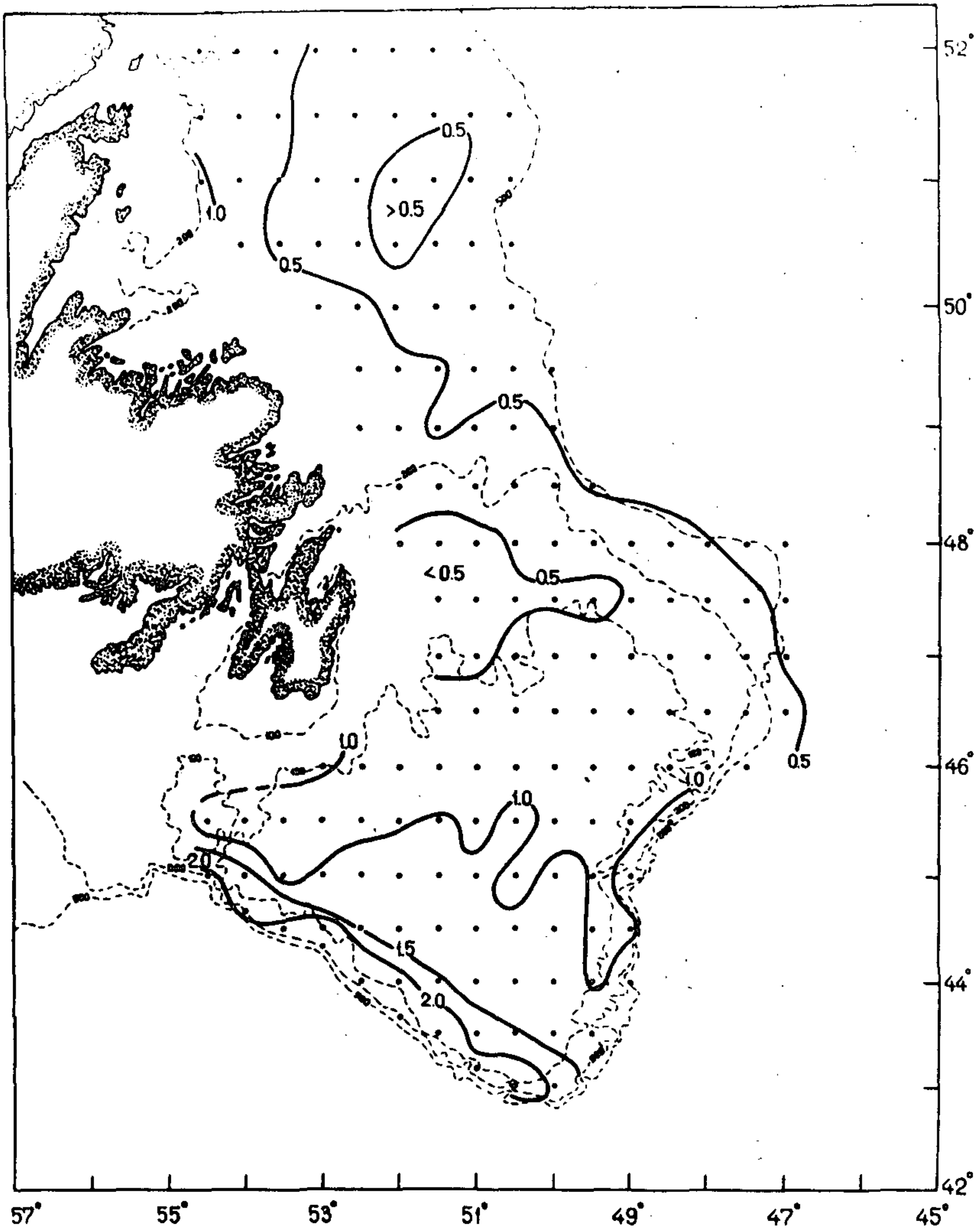

Fig.5 Standard deviation(°C) values of water temperature in bottom layer on the Newfoundland shelf.

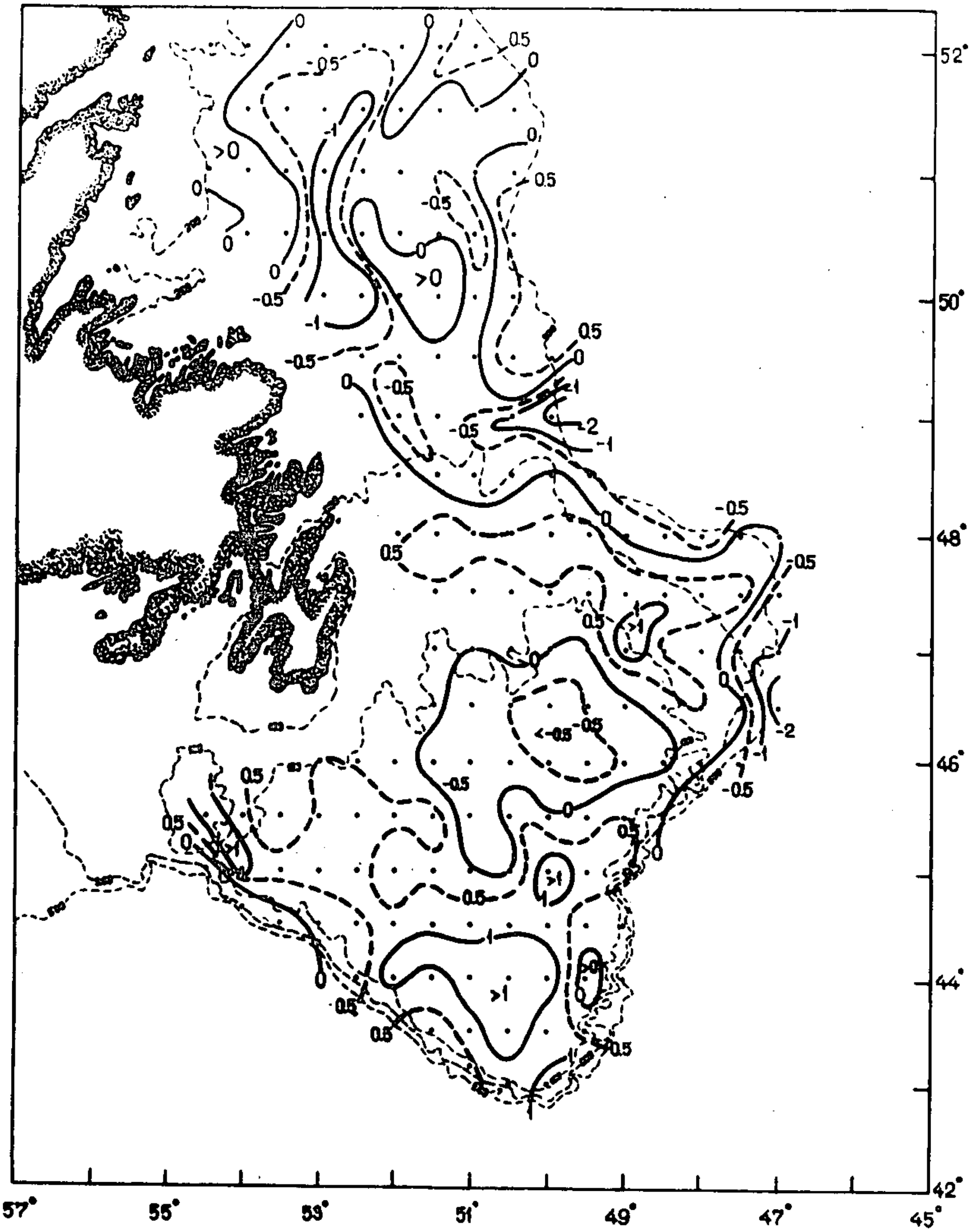

Fig.6 Distribution of asymmetry coefficients of water temperature in bottom layer on the Newfoundland shelf.

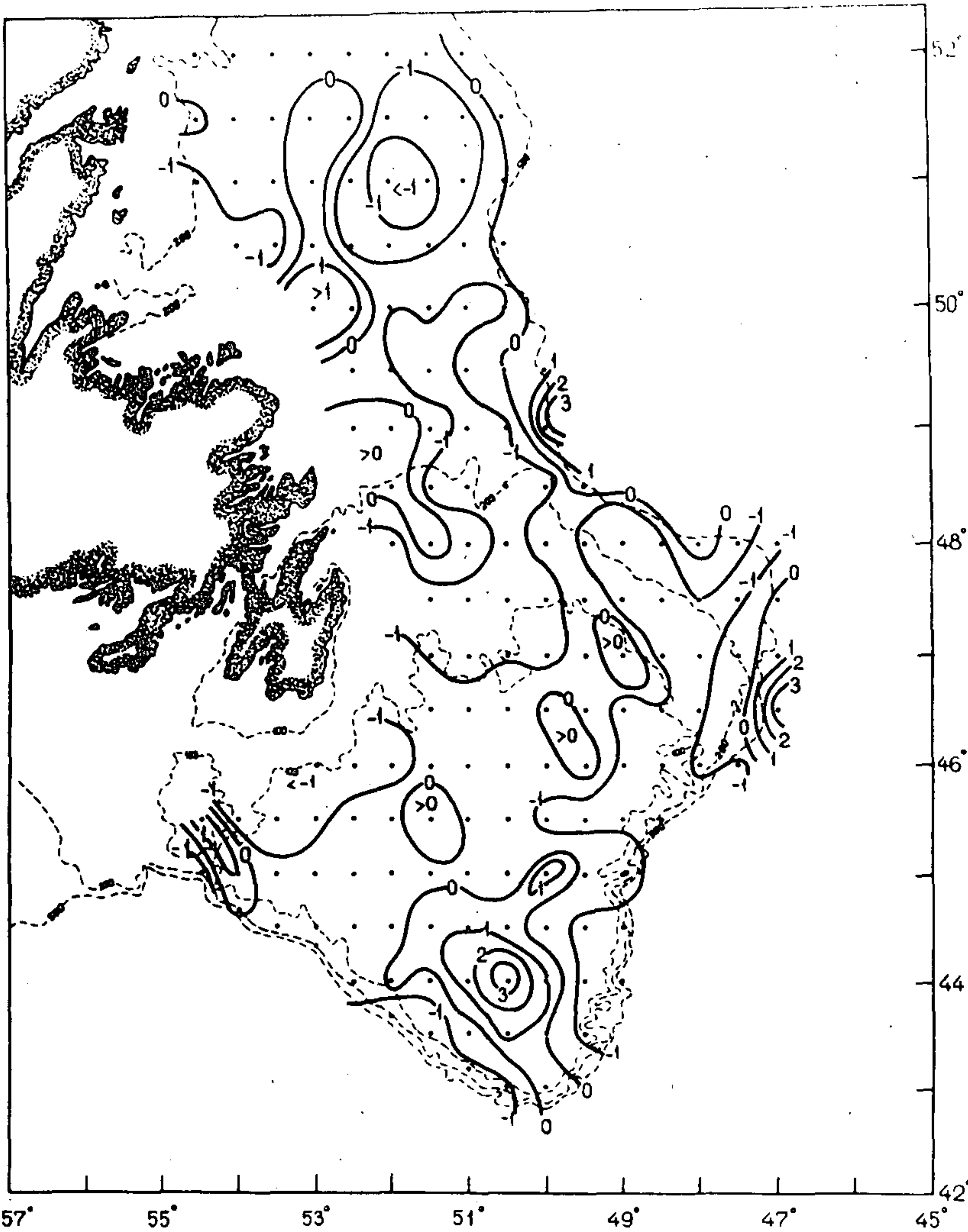

Fig. 7 Distribution of excess coefficients of water temperature in bottom layer on the Newfoundland shelf.

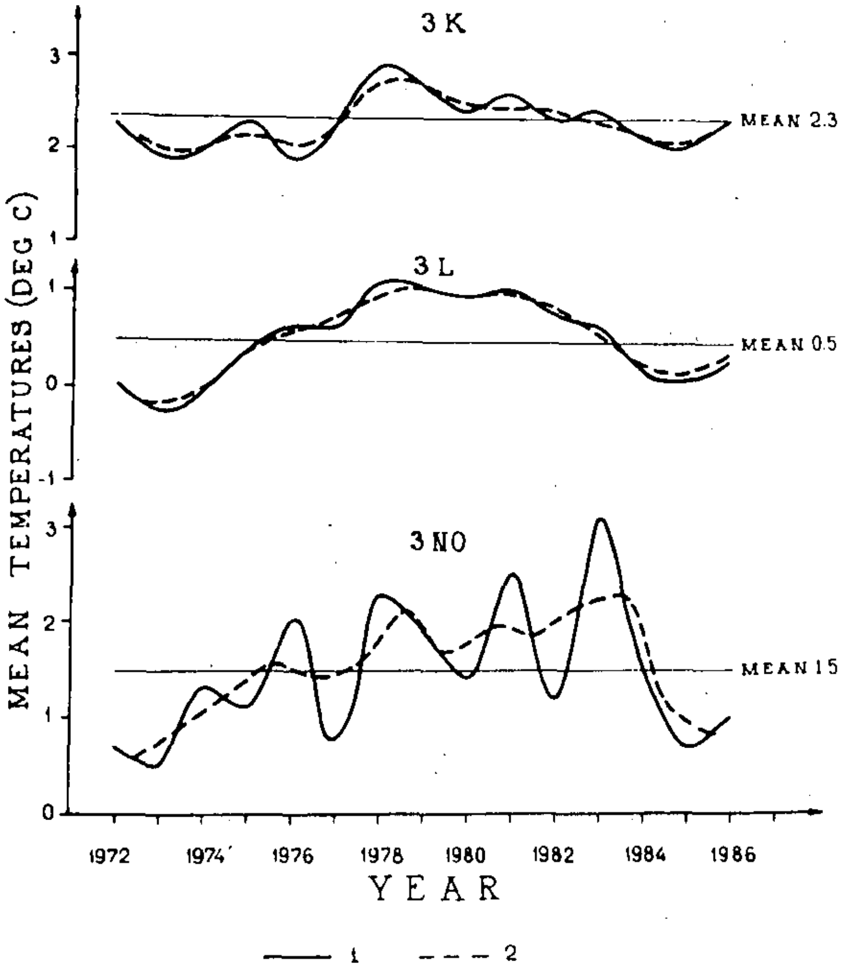

Fig.8 Characteristics of long-term water temperature variability in bottom layer on the Newfoundland shelf over the spring-summer period 1972-1986.
1 - temperature(°C), averaged in NAFO Divisions;
2 - temperature(°C), smoothed by means of step-by-step pair averaging;
straight line - long-term temperature normals(°C) averaged in NAFO Divisions.

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