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Oceanographic Conditions during the Annual Fall Groundfish Survey in NAFO Divisions 2J3KL

by

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ABSTRACT

Analysis of the water temperature data collected during the annual fall groundfish survey in NAFO divisions 2J3KL indicates that the surface temperature over the entire area was between 1.0 to 2.0 °C below the long-term mean during the month of November 1992 and about 1.0 to 3.0 °C below the 1991 values for the same time period. The horizontal temperature field at the 100 m depth shows a much more extensive CIL over the northeast Newfoundland shelf in both 1991 and 1992 compared to the long-term mean. Off Cape Bonavista the cross-sectional area of the fall CIL was slightly below the 1980-1990 mean in 1991 and slightly greater in 1992 with a much colder upper layer compared to 1991.

At station 27 temperature anomalies were slightly positive in the upper layer in 1991 and slightly negative in 1992 and strongly negative in both years at mid-depths. At the bottom the fall temperature anomaly was approximately -0.5 °C in 1991 but had warmed to -0.2 °C in 1992.

The analysis of the fall data also shows bottom temperatures were up to -1.0 °C below normal (based on a 1980 to 1990 mean) over the Grand Banks and the northeast Newfoundland shelf in 1992. The negative temperature anomalies were mainly restricted to division 3L in 1991 with maximum amplitudes of about -1.0 °C. Analysis of bottom temperature time series since 1977 by strata show negative anomalies during 1984/85 and 1991/92 for some but not all strata.

In general the strong negative temperature anomalies experienced during the spring and summer of 1991 had moderated by the fall of 1991 over most areas. In 1992 the spring and summer water temperatures were near normal but large negative anomalies had returned by the fall of 1992.

RÉSUMÉ

L'analyse des données sur les températures de l'eau recueillies durant la campagne automnale annuelle d'évaluation des stocks de poisson de fond dans les divisions 2J3KL de l'OPANO révèle que la température de surface dans toute la région était de 1,0 à 2,0 °C sous la moyenne à long terme en novembre 1992 et de 1,0 à 3 °C sous les températures de 1991 pour la même période. À une profondeur de 100 m au nord-est de la plate-forme de Terre-Neuve, le champ de température horizontal dénotait, en 1991 et en 1992, une couche froide intermédiaire (CFI) beaucoup plus grande que la moyenne à long terme. La température d'une coupe transversale de la CFI au large du cap Bonavista était légèrement inférieure à la moyenne de 1980-1990 en 1991 et légèrement supérieur à cette moyenne en 1992, année où la couche supérieure était beaucoup plus froide qu'en 1991.

À la station 27, les anomalies de température de la couche supérieure étaient légèrement positives en 1991 et légèrement négatives en 1992. Elles étaient très fortement négatives à mi-profondeur en 1991 et en 1992. Au fond, l'anomalie de température automnale était d'environ -0,5 °C en 1991, mais remontait à -0,2 °C en 1992.

L'analyse des données d'automne révèle aussi qu'en 1992 les températures de fond étaient inférieures à la normale (jusqu'à -1,0 °C sous celle-ci) sur les Grands Bancs et dans le nord-est de la plate-forme de Terre-Neuve, cela par rapport à la moyenne de 1980-1990. Les anomalies de température négatives étaient surtout limitées à la division 3L en 1991. Leur amplitude maximale était d'environ -1,0 °C. L'analyse de la série chronologique des températures du fond par couche depuis 1977 dénote des anomalies négatives en 1984-1985 et en 1991-1992 dans certaines des couches.

En général, les fortes anomalies de température négatives enregistrées au printemps et en été 1991 se sont atténuées en automne de la même année dans la plupart des régions. En 1992, toutefois, les températures de l'eau étaient proches de la normale au printemps et en automne, mais ont connu de grandes anomalies négatives en automne.

INTRODUCTION

The very cold air temperatures experienced during the winter of 1990 and 1991 resulted in abnormal ice coverage during the spring of 1991. This gave rise to large negative temperature anomalies during late spring and summer (Drinkwater et.al., 1992. Narayanan et. al., 1992). By the fall of 1991 water temperatures had returned to near normal conditions over most of the area and by the spring of 1992 water temperatures were again at near normal levels. The cold air temperatures (up to -6.0 °C below normal, Findly, 1992) experienced over Atlantic Canada during late spring and summer of 1992 again may have contributed to large negative temperature anomalies over most of the water column by November 1992.

This paper presents an overview of the environmental conditions in the Northwest Atlantic based on temperature data collected mainly from the annual fall groundfish surveys in NAFO divisions 2J3KL since 1980. Data from other sources as well as all available historical data for the area are included in the analysis. The horizontal, vertical and bottom temperature field for the fall of (late October to mid-December) 1991 and 1992 are compared to the long-term, and the 1980 to 1990 means.

DATA SOURCES AND ANALYSIS

Water temperature data for NAFO divisions 2J3KL are available from archives at the Marine Environmental Data Service (MEDS) in Ottawa and the Northwest Atlantic Fisheries Center (NAFC) in St. John's Newfoundland. During the fall period since 1977 (in division 2J), and since 1981 (in divisions 2J3KL) the bulk of these data were collected during the stratified random groundfish surveys using XBTs. Since the fall of 1989 most of the water temperatures were measured using trawl-mounted Seabird 19 CTD systems. The extraction of the bottom temperature has also changed from a single measurement at the bottom of the XBT trace (usually at the end of the tow) to a 10 to 20 minute horizontal average along the center portion of the tow. The temperature measurements made during the deployment of the trawl are used together with other available data to determine the temperature field over the water column.

Horizontal maps of the average temperature at standard depths are produced from all available data from 1910 to 1990 for a particular month over a region of interest. The actual isotherms are then derived from unweighted averages of all temperature profiles within a square grid with spacing of 0.25 degrees. The data were then quality controlled and linearly interpolated to the standard depth of interest. No attempts were made to adjust the data for possible temporal or spatial aliasing arising from this averaging procedure. Some temporal aliasing is probably present in the analysis given the wide time interval over which the fall survey is conducted plus the fact that this is a period when rapid cooling of the upper water column is taking place.

Horizontal bottom temperature maps were produced by taking all near-bottom temperature values for the annual fall groundfish survey in NAFO divisions 2J3KL. For this purpose all data collected on several groundfish cruises from late October to mid December are assumed to be representative of the mean fall temperature. The average bottom temperature maps were generated by averaging all data within a stratum for the period 1980 to 1990 inclusive, yearly anomalies were then determined from this average. Time series of temperature and anomalies were produced from 1977 to 1992 for selected strata. Again data from all groundfish trawl sets within a particular stratum were averaged for each year.

Vertical cross-sections of the temperature structure were contoured by taking all observations within 40 minutes of latitude of the standard NAFO Bonavista transect between the middle of October and the middle of December. The observations were then assumed to lie on a line joining the endpoints of the standard transect. The data were then interpolated to 5.0 m depths intervals and averaged into 5.0 km bins along the line. Again the data were not adjusted to account for spatial or temporal aliasing.

HORIZONTAL TEMPERATURE FIELD

Figure 1a shows the mean surface temperature field for November derived from all available data as described above. The mean surface temperature range from 1 to 3 °C shoreward off the shelf break in NAFO divisions 2J3K and from 3 to 6 °C in division 3L (isotherms are -1,0,1,2,4,6 etc °C, bathymetry lines are 300 and 1000 m). Figure 1b and 1c shows the surface temperature determined from all available data for November 1991 and 1992. The surface temperature in November 1991 ranged from approximately 1 to 4 °C in 2J3K and from 4 to 8 °C in 3L, somewhat higher the average. In November 1992 the surface temperature ranged from 1 to 2 °C in 2J3K and from 2 to 4 °C in 3L, about 1 to 4 °C below the 1991 values and 1 to 2 °C below normal.

Figure 2a to 2c shows the November average and the 1991 and 1992 temperature at a depth of 100.0 m, about at the center of the cold intermediate layer (CIL). On average 0.0 °C water covers the entire Grand Banks and part of the northeast Newfoundland shelf. In 1991 and 1992 0.0 °C water was much more extensive over the northeast Newfoundland shelf with the largest anomaly of about -1.0 to -2.0 °C in 1992. This is in contrast to the near normal upper layer temperature in 1991.

VERTICAL TEMPERATURE FIELD

A dominant feature of the temperature structure along the east coast off Newfoundland on the continental shelves is the cold intermediate layer (CIL) (Petrie et. al., 1988). The CIL is most apparent in the summer when spring ice melt and seasonal heating has increased the stratification in the upper layers to a point when heat transfer to the lower layers is inhibited. The result is a cold layer of water with temperatures ranging from -1.5 to 0.0 °C sandwiched between the warm upper layer and warmer water near the bottom.

Figure 3a shows the average temperature transect off Cape Bonavista during the approximate time period of the annual fall groundfish survey from 1981 to 1990. This transect spans the northern section of NAFO division 3L and the southern portion of division 3K. The seasonal warm upper layer has not completely cooled down, so the summer-like structure of the cold intermediate layer is still present with an average cross-sectional area of about 23.5 km^2. The temperature structure across the northeast Newfoundland shelf in the bottom layer is very similar to summer conditions. For example the anchor position of the 2.0 °C isotherm is situated at about 125 km offshore and the 3.0 °C isotherm is located near the edge of the shelf, about the same as the average summer positions. Figures 3b and 3c show the temperature and its anomaly along the Bonavista transect for the fall of 1991 and 1992. The temperature anomaly is based on a fall mean from 1981 to 1990. The cross-sectional areas of cold intermediate water less than 0.0 °C are about 22 and 27 km^2 respectively. A much colder surface layer in 1992 compared to 1991 and the mean is shown. The largest anomaly (-0.5 to -2.0 °C) occurred during 1992 at water depths less than 50 m. The 1981 to 1992 time series of CIL area for the summer (July-August) and fall (late October to mid-December) is shown in Fig. 4. The fall CIL area shows similar trends as in the summer, however the average area has decreased from 33.0 km^2 during the summer to 23.5 km^2 in the fall as a result of summer heating and vertical mixing over the water column.

STATION 27 TIME SERIES

Time series of the vertical temperature structure and anomaly at station 27 off St. John's for the fall of 1991 and 1992 are shown in Fig. 5a and 5b. The anomalies are calculated from the mean of all data collected on the station since 1946. The position of this station is such that the cold water (< 0.0 °C) that forms the CIL is present year around in water depths from about 100 m to the bottom. Hence this time series is invaluable in monitoring the variability in the seasonal upper layer as well as the core of the

CIL, however it does not show the full vertical extent of the CIL over the continental shelf. A significant portion of the interannual variance in the temperature at station 27 is accounted for by the wind and local air temperature (Petrie et. al., 1992). They were able to predict, using regression analysis of water on air temperature from 1963 to 1986, the water temperatures at station 27 for the period 1987 to 1992 with reasonable agreement with observed values.

The 1991 time series show upper layer temperatures ranging from 2 to 7 °C during the annual fall survey with temperature anomalies slightly above average. The time series also show a cooling rate in the upper layer of approximately 0.1 °C/day from mid-October to mid-December. At depths greater than 60 to 80 m the temperature remained below 0.0 °C with negative anomalies ranging from -0.5 to -2.0 °C in 1991. The 1992 data show slightly lower upper layer temperatures than in 1991 for the same time period while again at deeper depths the temperature remained below 0.0 °C with negative anomalies up to -1.0 °C until early December when the anomalies were positive. The average bottom (175.0 m) temperature anomaly from October to December was about -0.5 °C in 1991 and had warmed to -0.2 °C in 1992.

A comparison of figures 3 and 5 show some differences in the magnitude of the temperature anomaly during the fall of 1991 at station 27 and the Bonavista transect. For example, at depths below 50 m at station 27 the average anomaly over the fall period is about -1.0 to -2.0 °C while in the inshore regions of the Bonavista transect the anomaly is about -0.5 °C in deep water. Some of these differences may be accounted for by the difference in the averaging interval from which the anomaly was calculated, 1981 to 1990 for Bonavista and 1946 to 1992 for station 27.

BOTTOM TEMPERATURES

Figure 6 shows a location map of the 1992 annual groundfish survey in divisions 2J3KL. This survey begin in 1977 in 2J, 1978 in 2J3k and in 1981 over 2J3KL. The average (1980-1990) bottom temperature corresponding to these surveys is shown in Fig. 7a. The average bottom temperature over the northeast Newfoundland shelf (2J3K) ranged from 0.0 inshore, to 4.0 °C offshore at the shelf break. The average temperature over most of the Grand Banks varied from -1.0 to 0.0 °C and to 4.0 °C at the shelf break. In general the isotherms follow the bathymetry exhibiting east-west gradients over most of the northeast shelf. Figs 7b to 7n show bottom temperature and anomaly maps from 1980 to 1990. In general bottom temperatures were at or above the mean during 1981/82 and from 1986 to 1989 and below average from 1983 to 1985 and from 1990 to 1992, over most on the 2J3KL area. The years 1984 and 1986 were the two extremes with anomalies up to -1.0 °C in 1984 and up to 1.0 °C in 1986 over most of the northeast Newfoundland shelf.

The percentage area of water less than -1.0 °C over the Grand

Banks in 1992 was less than in 1991 but still significantly larger than the 1980-1990 mean. In 1991 the temperature was about average over the northeast shelf while over the northern Grand Banks (3L) the anomaly ranged from -0.25 to -1.0 °C. In 1992 the temperature anomaly ranged from -0.25 to -0.75 °C over the northeast shelf and from -0.25 to -1.0 °C over the Grand Banks.

Figure 8a shows the boundaries of all strata defined in NAFO divisions 3LNO (Doubleday, 1981). Listed in table 1 and highlighted in Fig. 8a are selected strata for which time series of the bottom temperatures are examined in each division. Strata are selected from inshore off to the shelf break spanning all depth ranges for each division. As described earlier bottom temperatures for all sets in each stratum are averaged for each year.

Time series plots of average bottom temperature and anomaly for each year (for the fall survey) for the selected strata in division 3L since 1981 are shown in Figs 8b and c. The temperatures range from -1.0 to 4.0 °C over water depths from 93 to 549 m. The time series show a consistent negative anomaly from about 1983 to 1986 with maximum amplitude of about -1.2 °C. A negative anomaly starting in 1990 (with maximum amplitude of about -1.5 °C) extended over most of the shallow portion of the Grand Banks. Offshore of stratum 390 in deeper water the anomaly was positive reaching a maximum of 1.0 °C.

Figures 9a to c show the location of and average bottom temperatures and anomalies for selected strata in NAFO division 3K. The temperature ranged from 0.5 to 4.0 °C over water depths of 200 to 1000 m. A negative anomaly existed over most of the area in 1984/85 and again in 1992 reaching a maximum of -1.2 °C. The positive anomaly in the deeper waters of division 3L is not apparent in division 3K. Similarly Figs. 10a to c show location and average bottom temperature for the selected strata spanning all depth intervals in division 2J. Again there are significant negative anomalies during 1984/85 and again in 1992 ranging from 0.0 to -1.0 °C. Temperatures generally range from -1.0 to 4.0 ° in water depths of 100 to 1000 m.

In general the time series plots of the average bottom temperature data within a particular stratum, with a few exceptions, show a high degree of variability from one year to the next. For example the time series for stratum 341 near the edge of the Avalon Channel shows only weak anomalies during 1984/85 and 1991/92 unlike most other strata in 3L. No attempt was made to examine individual data points within each stratum for each year. It is expected that there may be high variations in the data due to strong temperature gradients over depth intervals up to 400 m for some strata.

SUMMARY

The analysis presented in this paper shows a large upper layer temperature anomaly in the fall of 1992 and near normal values in 1991. This together with below normal air temperatures (-6 to -10 below the mean in early February, Climate Perspectives 1993) during the winter of 1992/93 had resulted in near record ice coverage (south of 46 N latitude) by early February 1993. The strong negative temperature anomalies experienced during the spring and summer of 1991 had disappeared by the fall of 1991 over most areas. The cross-sectional area of the CIL across the northeast shelf was less than the 1981-1990 mean in 1991 and slightly greater in 1992. In addition the upper layer along the transect was significantly colder in 1992 compared to 1991 and the long-term mean.

At station 27 temperature anomalies were slightly positive in the upper layer in 1991 and slightly negative in 1992 and strongly negative in both years at mid-depths except towards the end of the fall survey. The analysis show some differences in the anomalies seen near shore at Cape Bonavista and at station 27. This may be due to differences in the temporal averaging or the spatial separation in the two locations (about 150 km).

Bottom temperatures anomalies were restricted to the southern areas of NAFO division 3L in the fall of 1991 but appeared to be more wide spread in the fall of 1992. Analysis of bottom temperature time series data by strata show negative anomalies during 1984/85 and 1991/92 for some but not all strata. Variations in the set positions within the strata together with temporal aliasing between years makes a more detailed analysis of the data necessary.

ACKNOWLEDGEMENTS

I would like to thank D. Senciall for computer software support and D. Foote for data processing and technical assistance in the preparation of this document. I would also like to thank the groundfish scientists at the NAFC for collecting and providing much of the data contained in this analysis.

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Div #	Stratum #	Depth Interval(M)	Div #	Stratum #	Depth Interval(M)
2J	205	101-200	3K	645	401-500
	206	101-200		646	501-750
	213	201-300		647	751-1000
	222	301-400	3L	341	93-185
	223	401-500		350	57-92
	224	501-750		363	57-92
	236	751-1000		372	57-92
3K	620	201-300		384	57-92
	625	301-400		390	93-185
	631	401-500		391	184-275
	630	301-400		392	276-366
	634	201-300		729	367-549
	633	301-400			

Table #1 : Analysis of various Strata in NAFO Divisions 2J and 3KL.

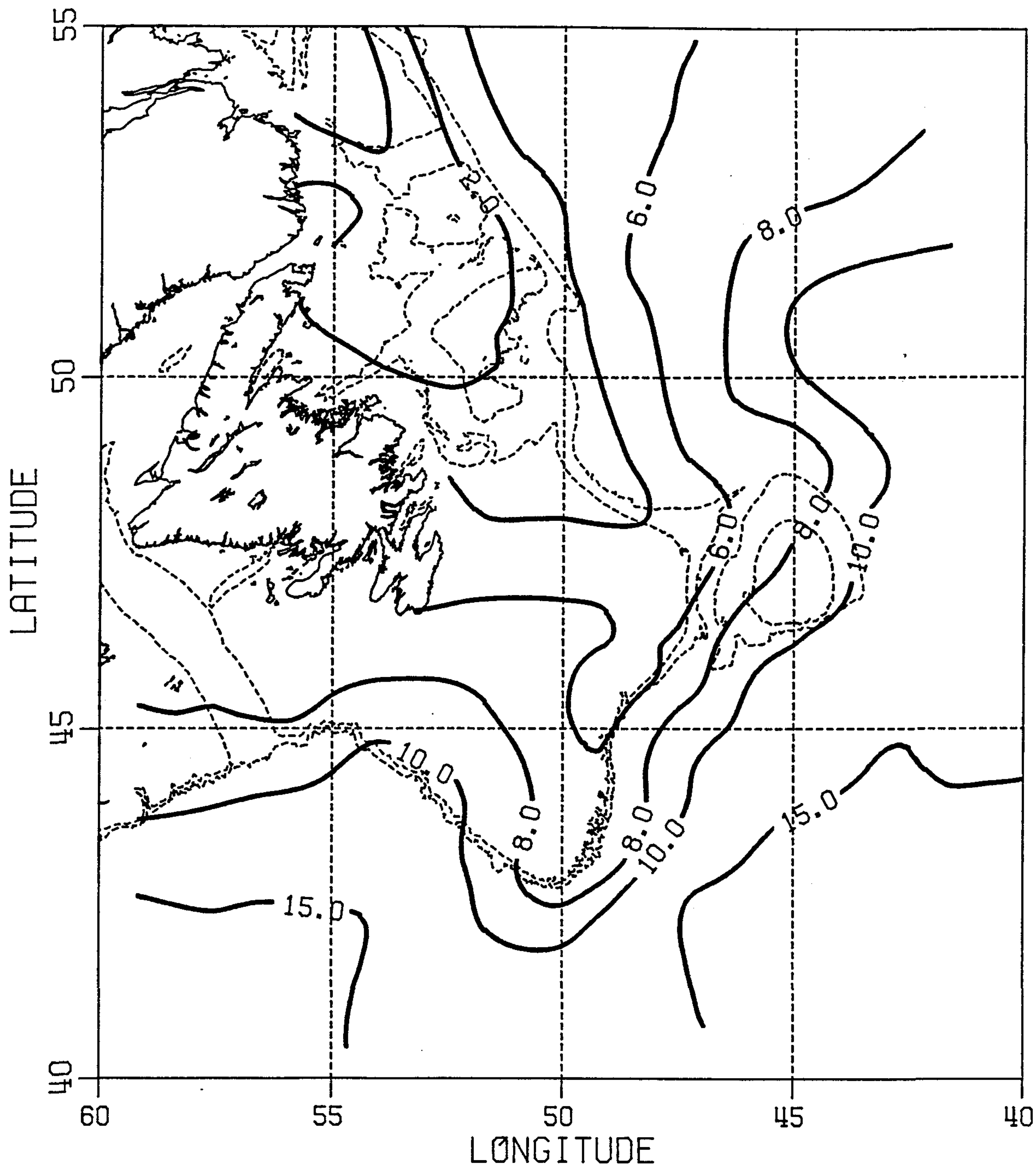


Fig. 1a. The average surface temperature for November, from all available data.

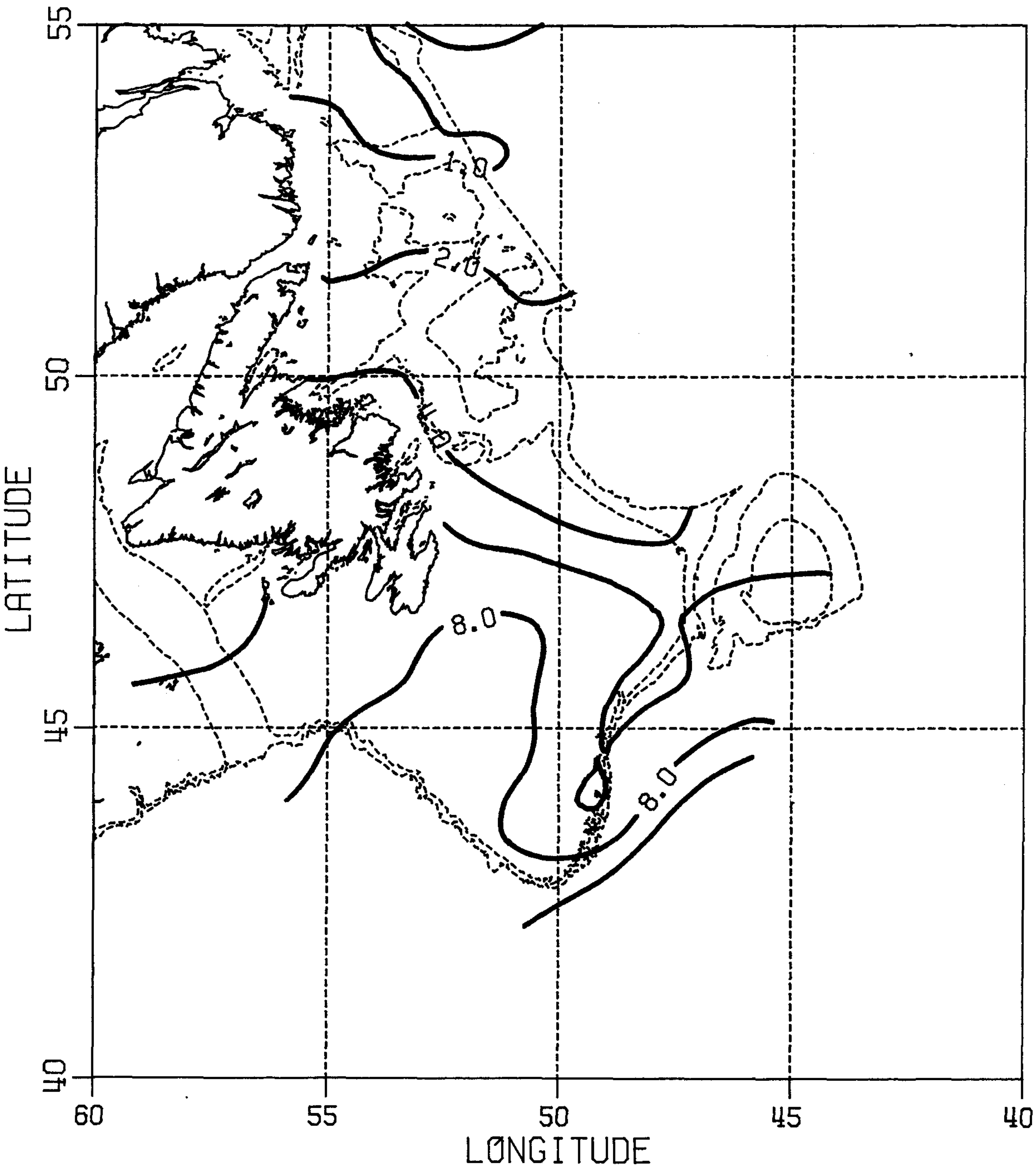


Fig. 1b. The surface temperature for November 1991, from all available data.

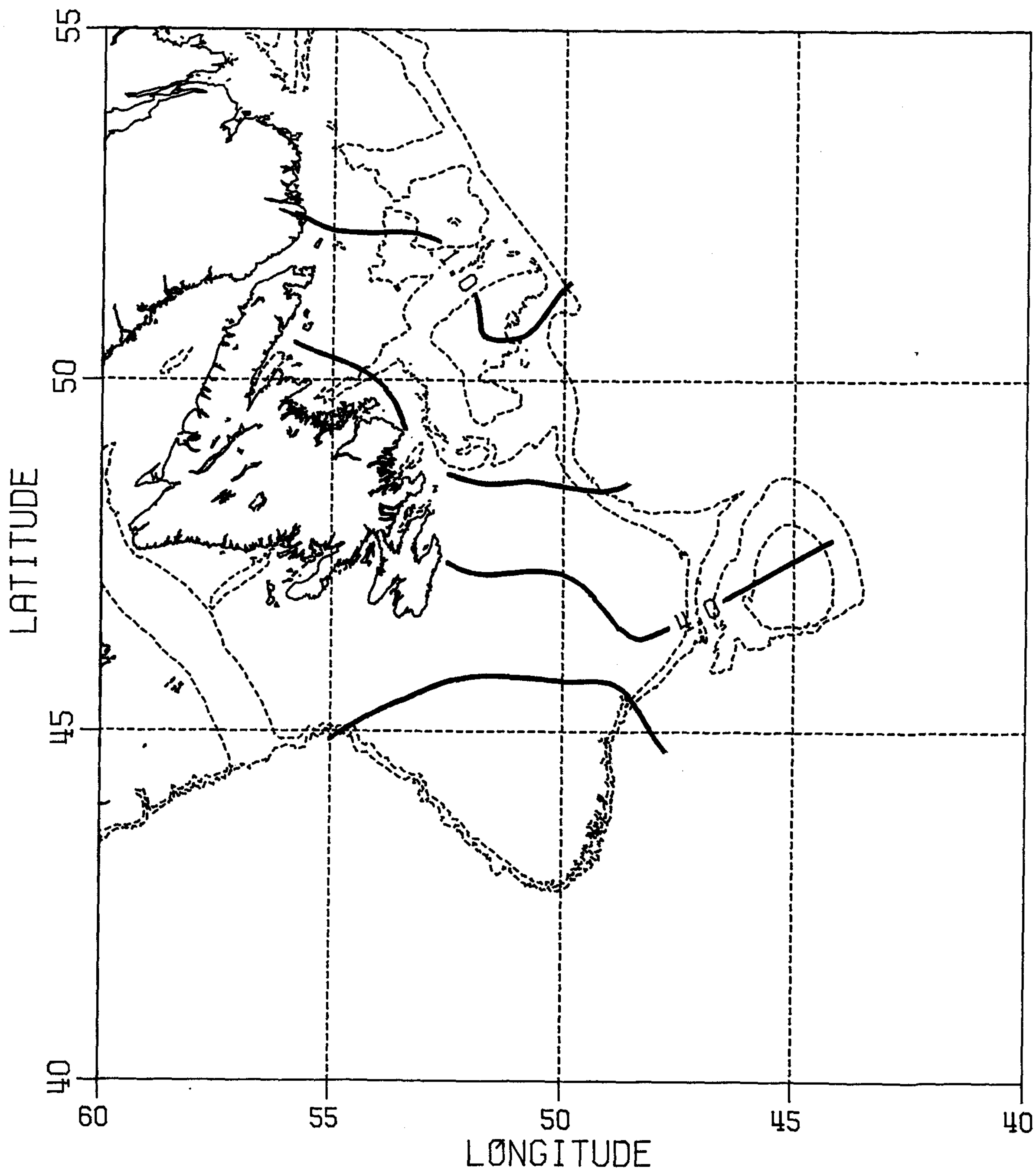


Fig. 1c. The surface temperature for November 1992, from all available data.

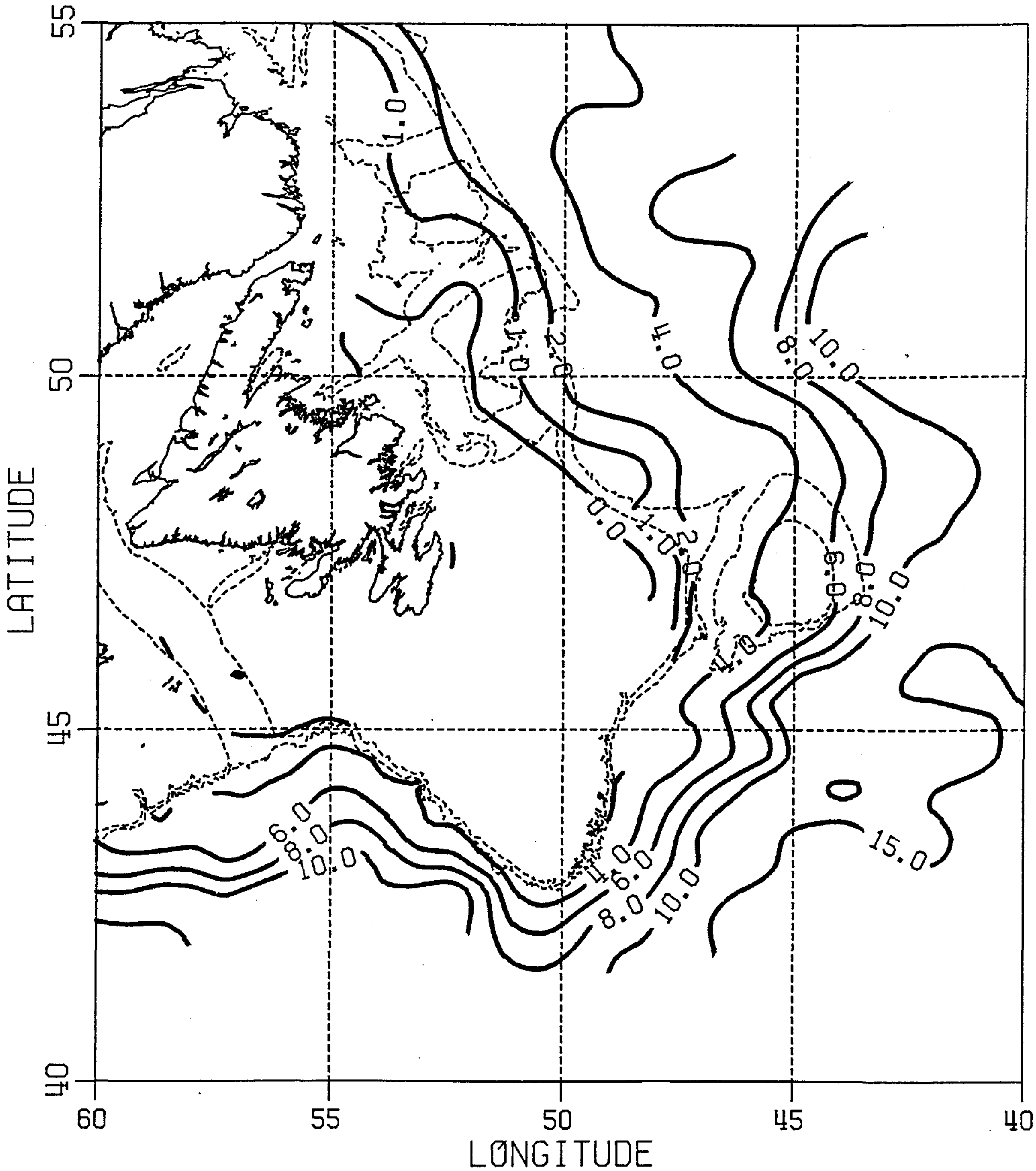


Fig. 2a. The average temperature at 100 m for November, from all available data.

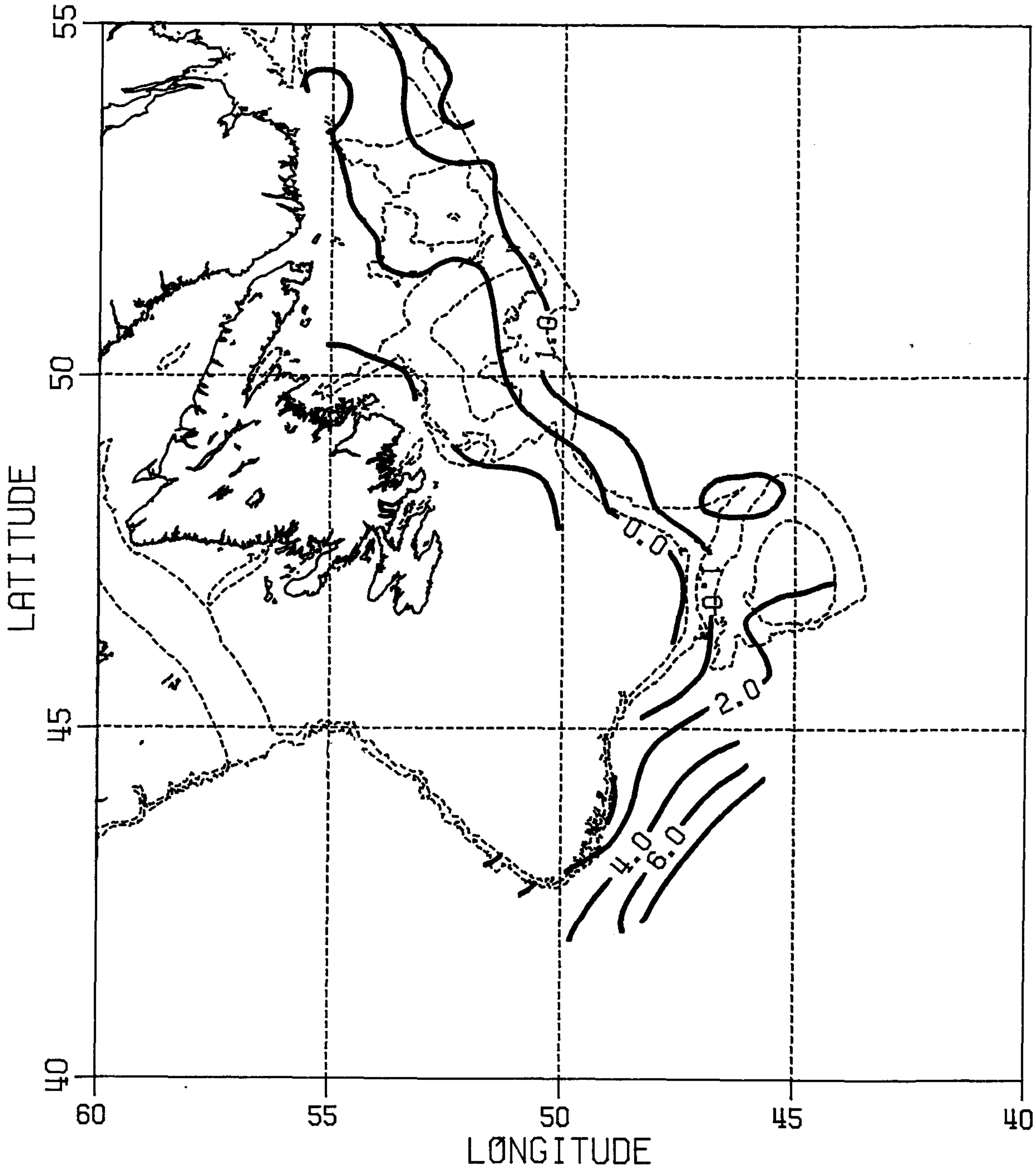


Fig. 2b. Temperature at 100 m depth for November 1991, from all available data for the month.

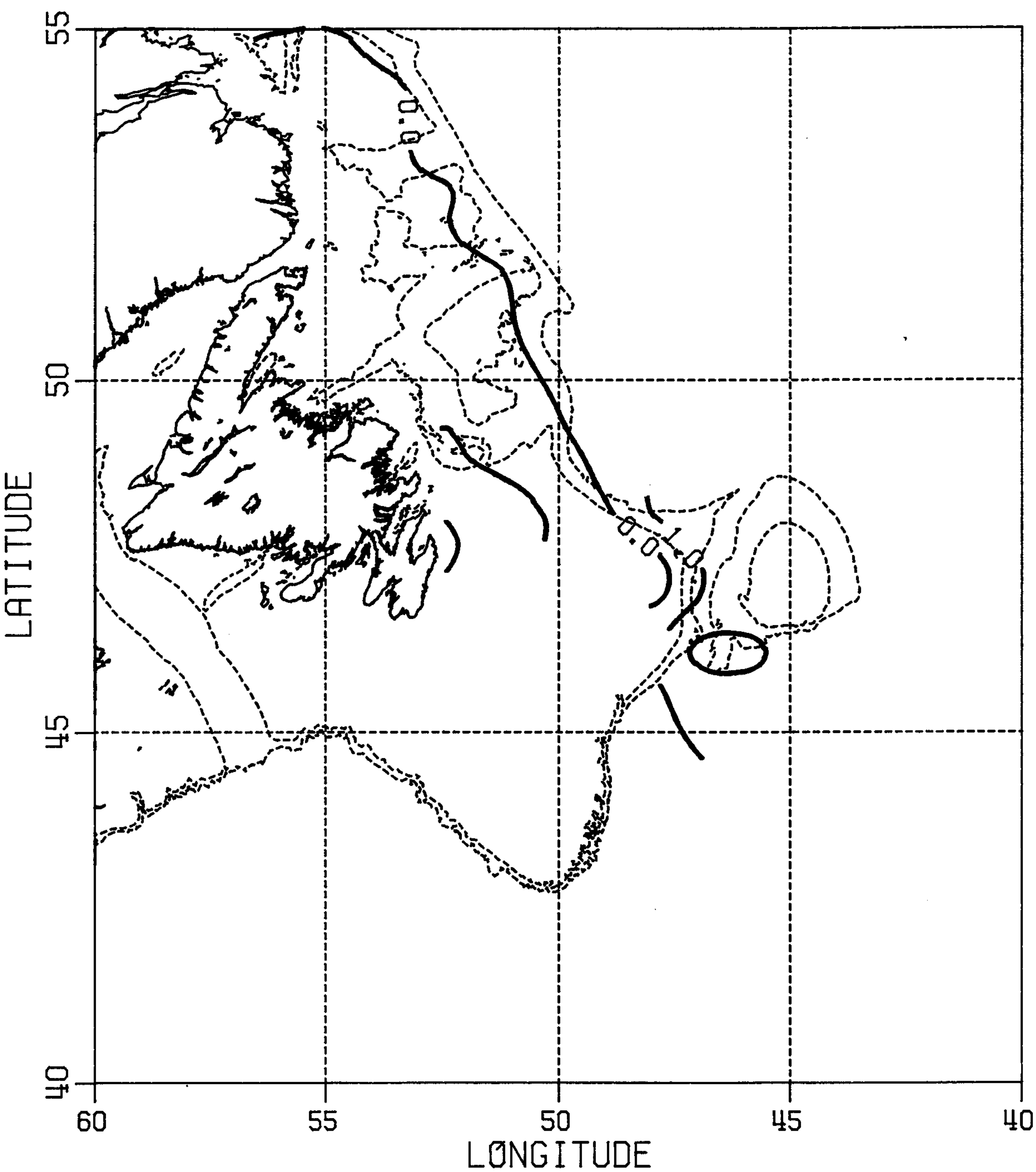


Fig. 2c. Temperature at 100 m depth for November 1992, from all available data for the month.

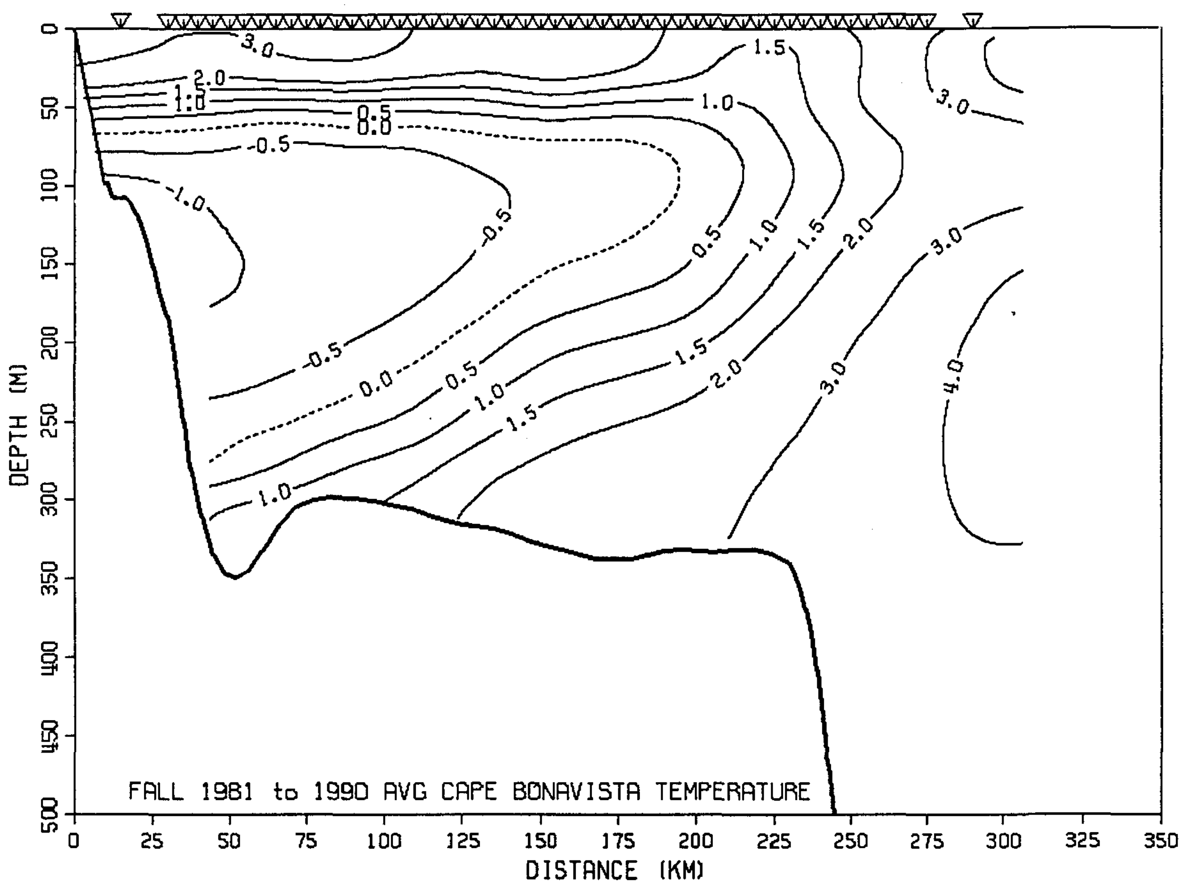


Fig. 3a. The 1981 to 1990 fall average temperature for the Cape Bonavista transect.

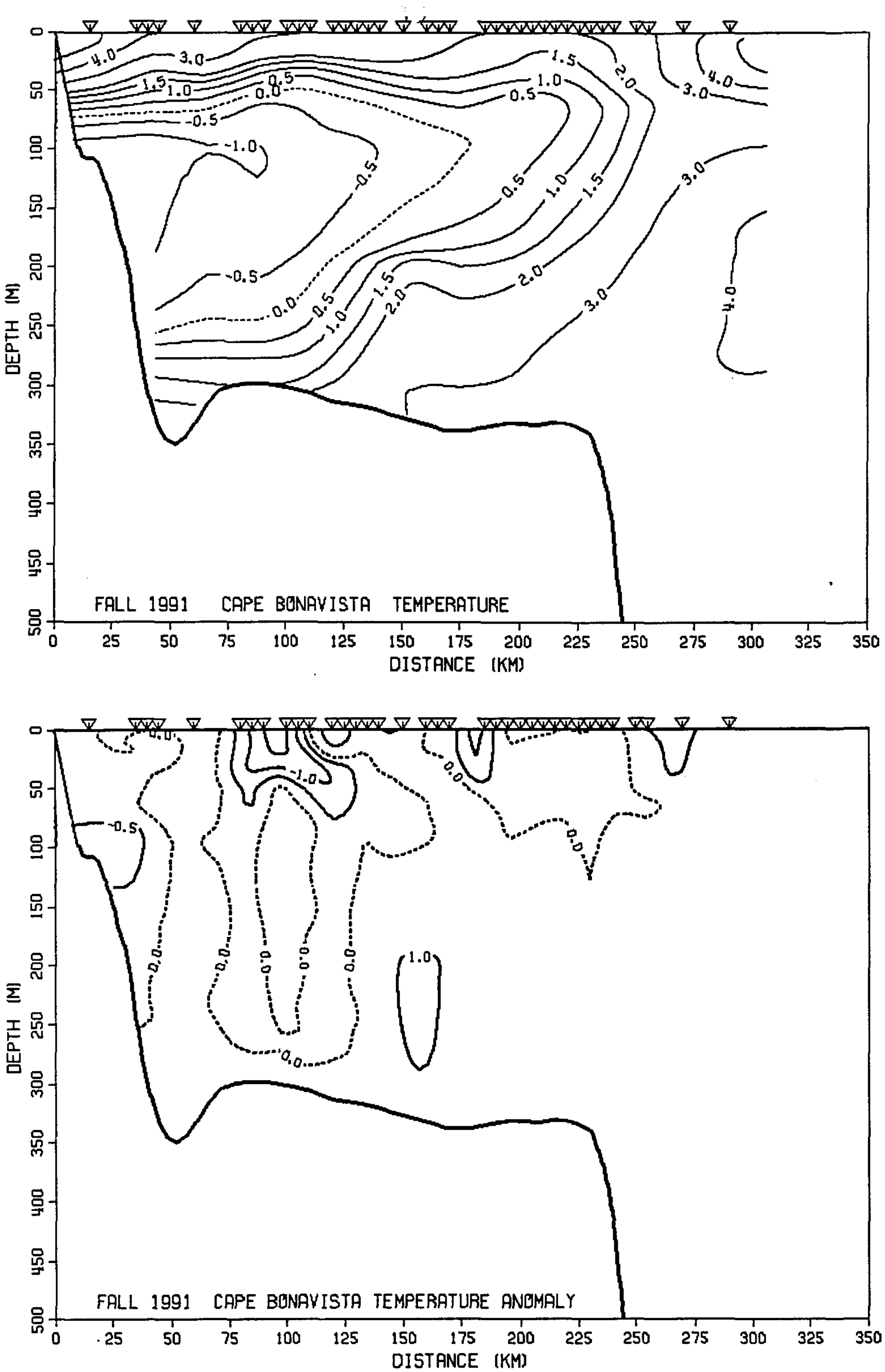
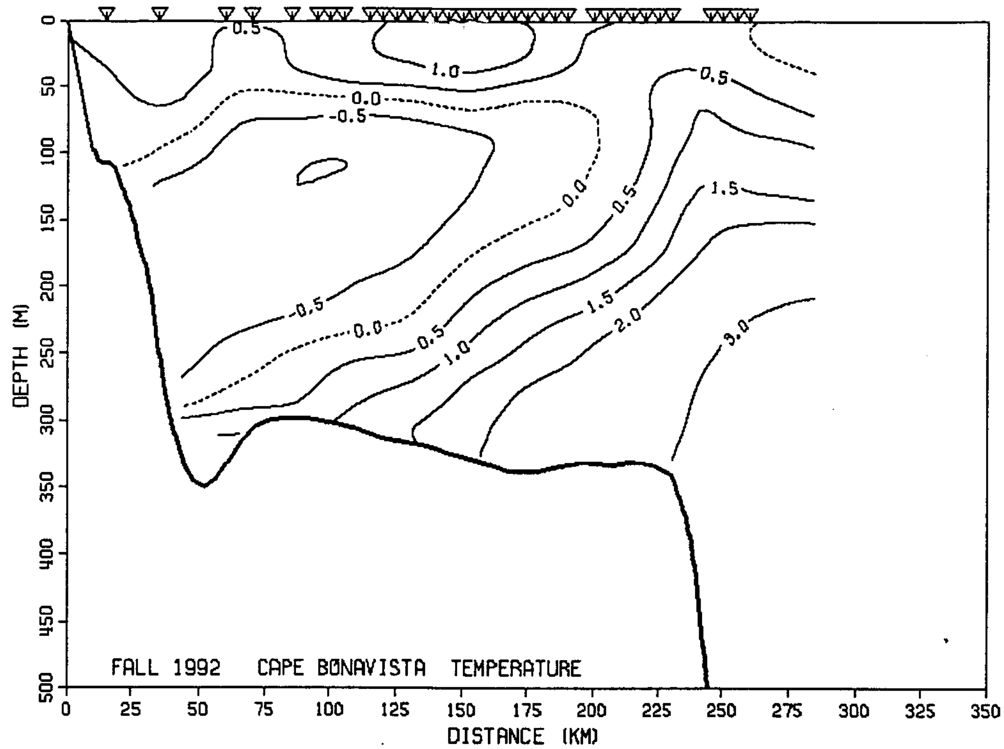


Fig. 3b. The 1991 fall temperature and anomaly for the Cape Bonavista transect.



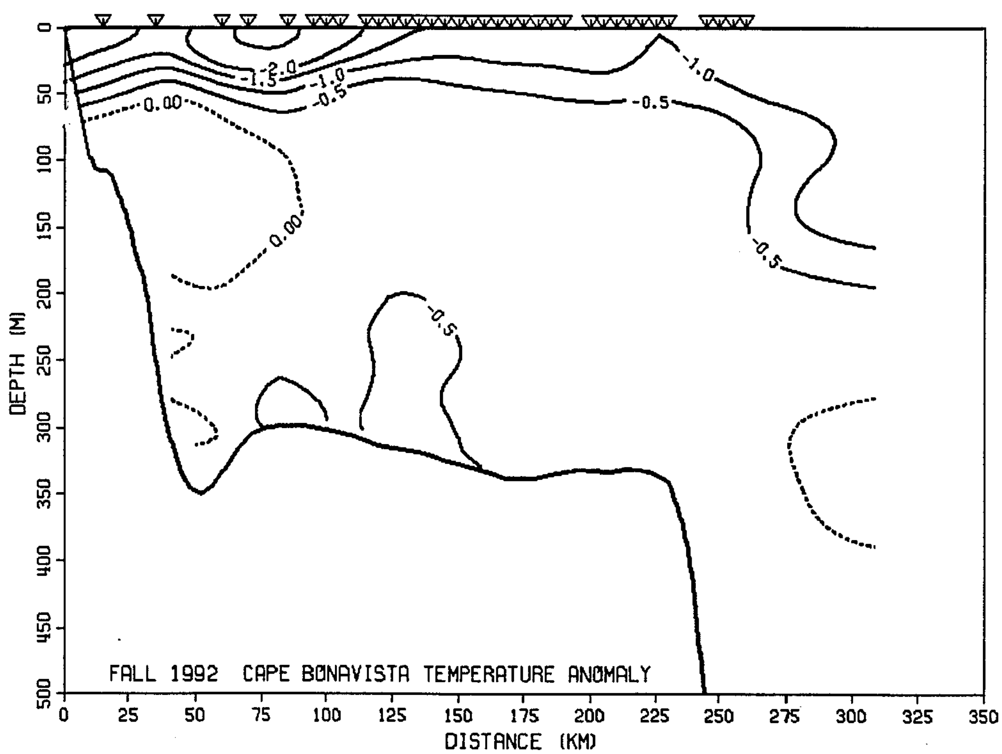


Fig. 3c. The 1992 fall temperature and anomaly for the Cape Bonavista transect.

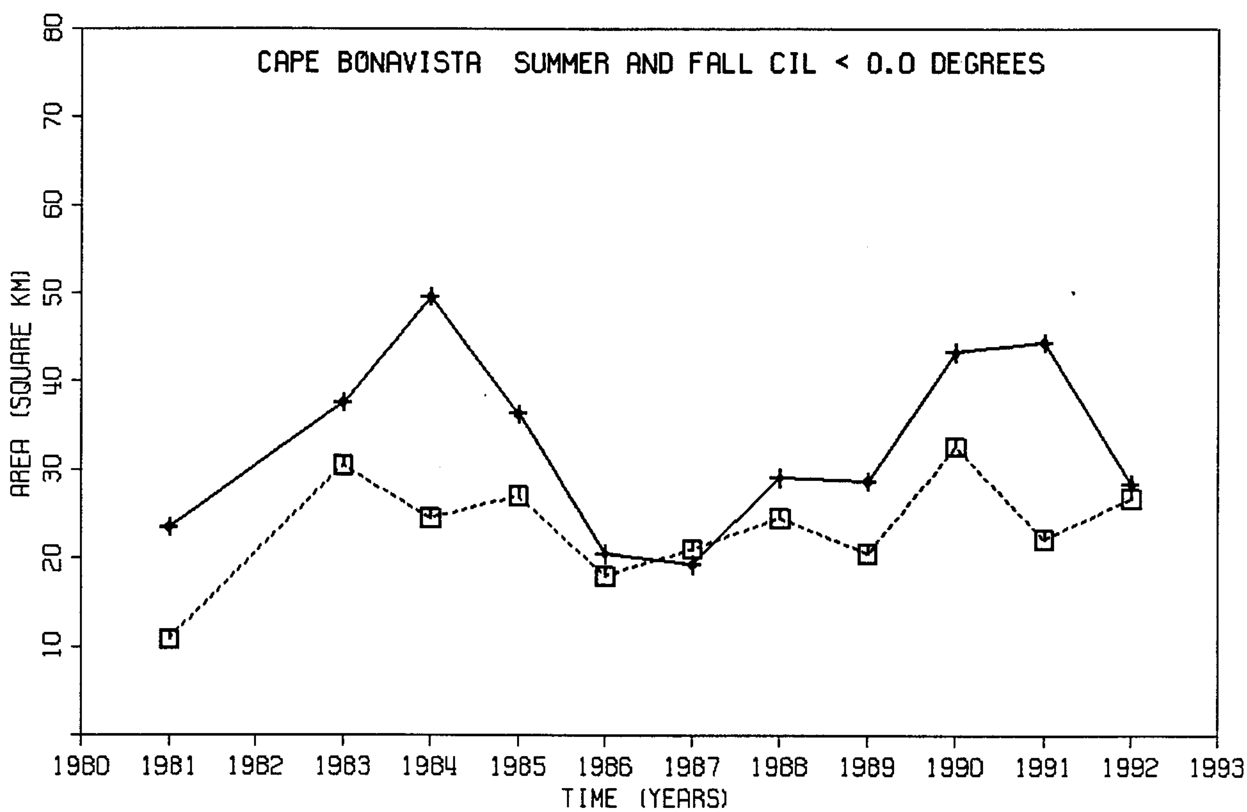


Fig. 4. Time series of CIL cross sectional area less than 0.0 degrees C during summer (solid line) and fall (dashed line) for the Cape Bonavista transect.

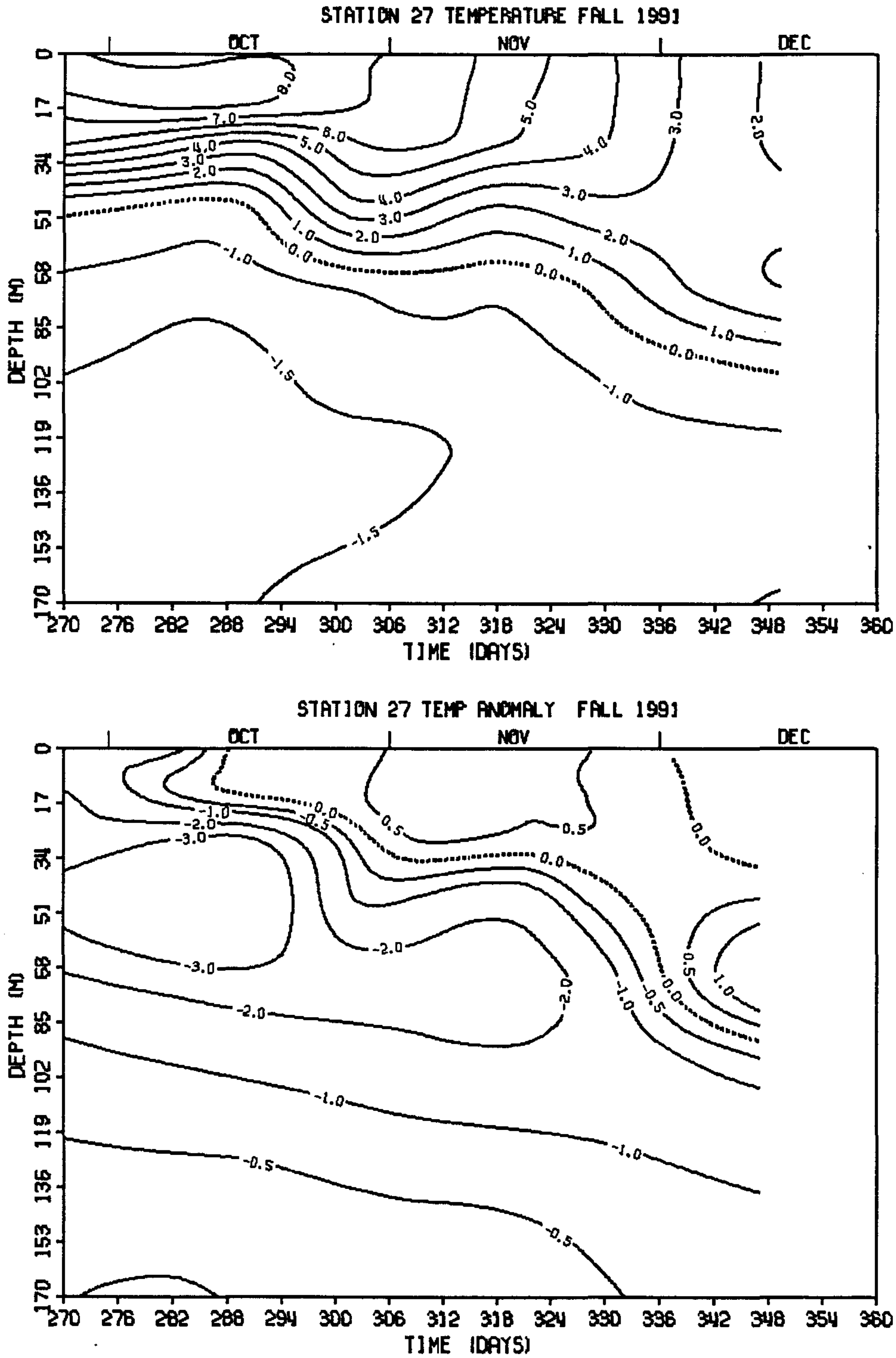


Fig. 5a. Time series of temperature and anomaly versus depth at station 27 for the fall of 1991.

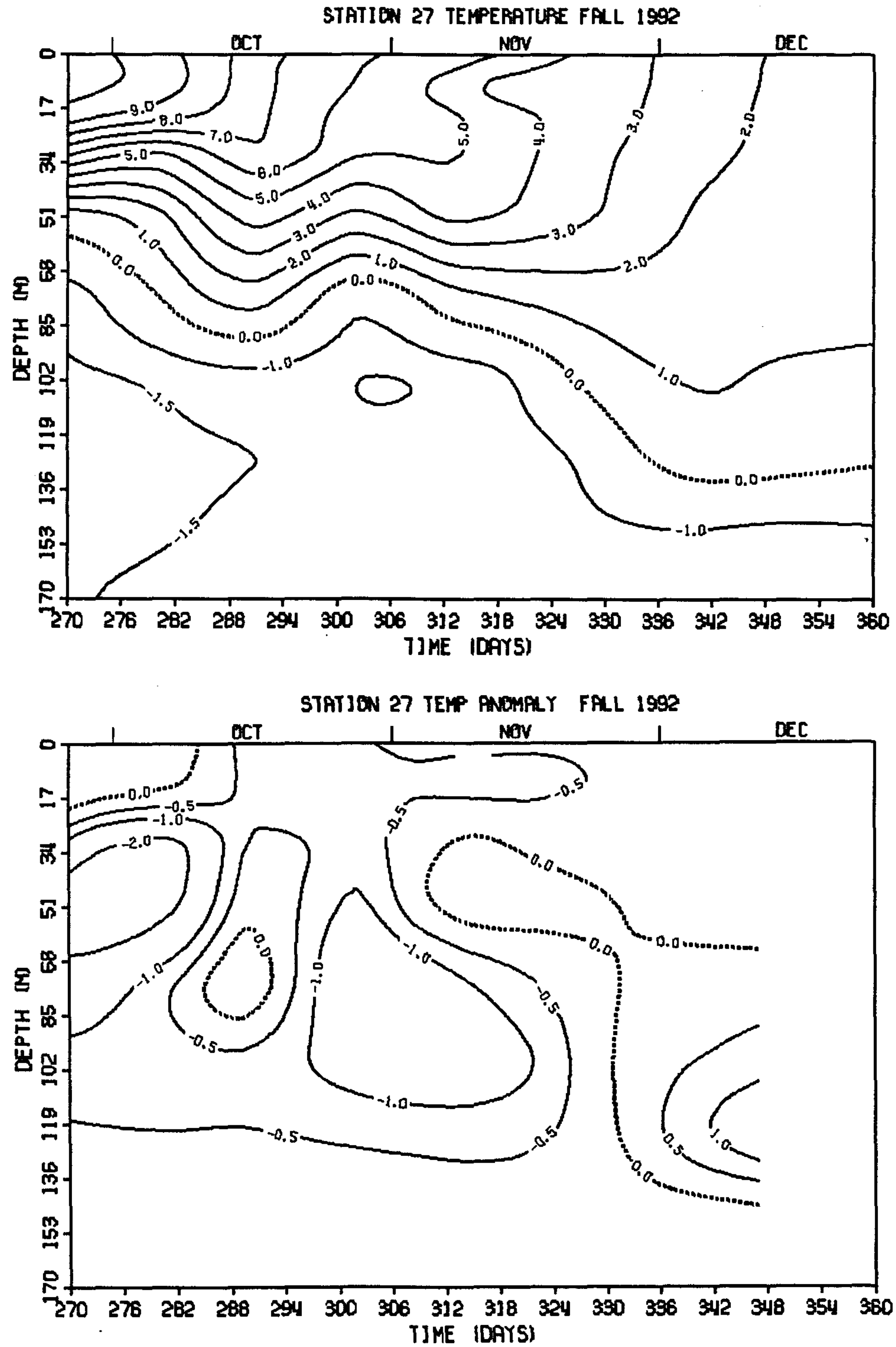


Fig. 5b. Time series of temperature and anomaly versus depth at station 27 for the fall of 1992.

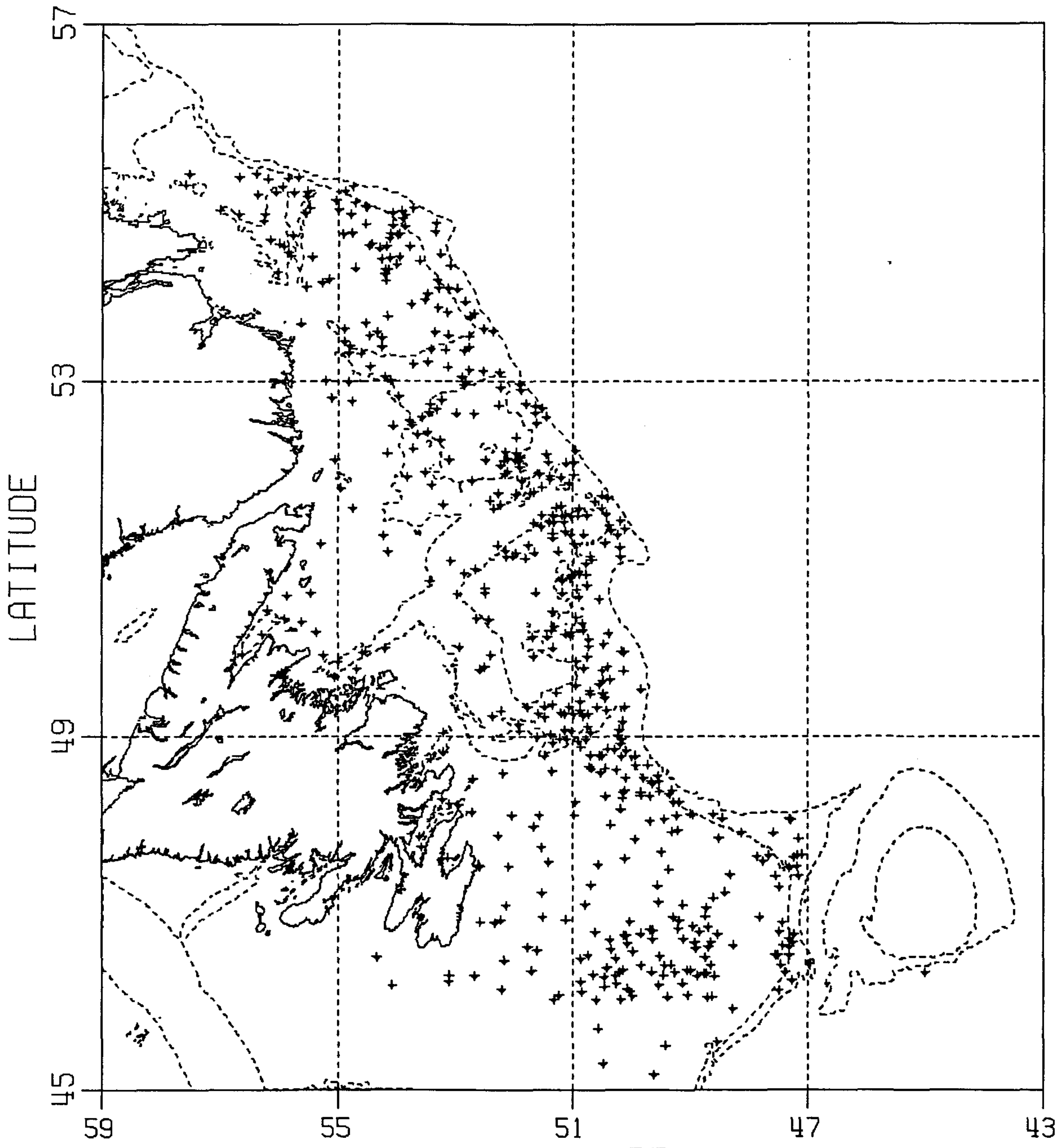


Fig. 6. Location map showing set positions during the 1992 annual fall groundfish survey.

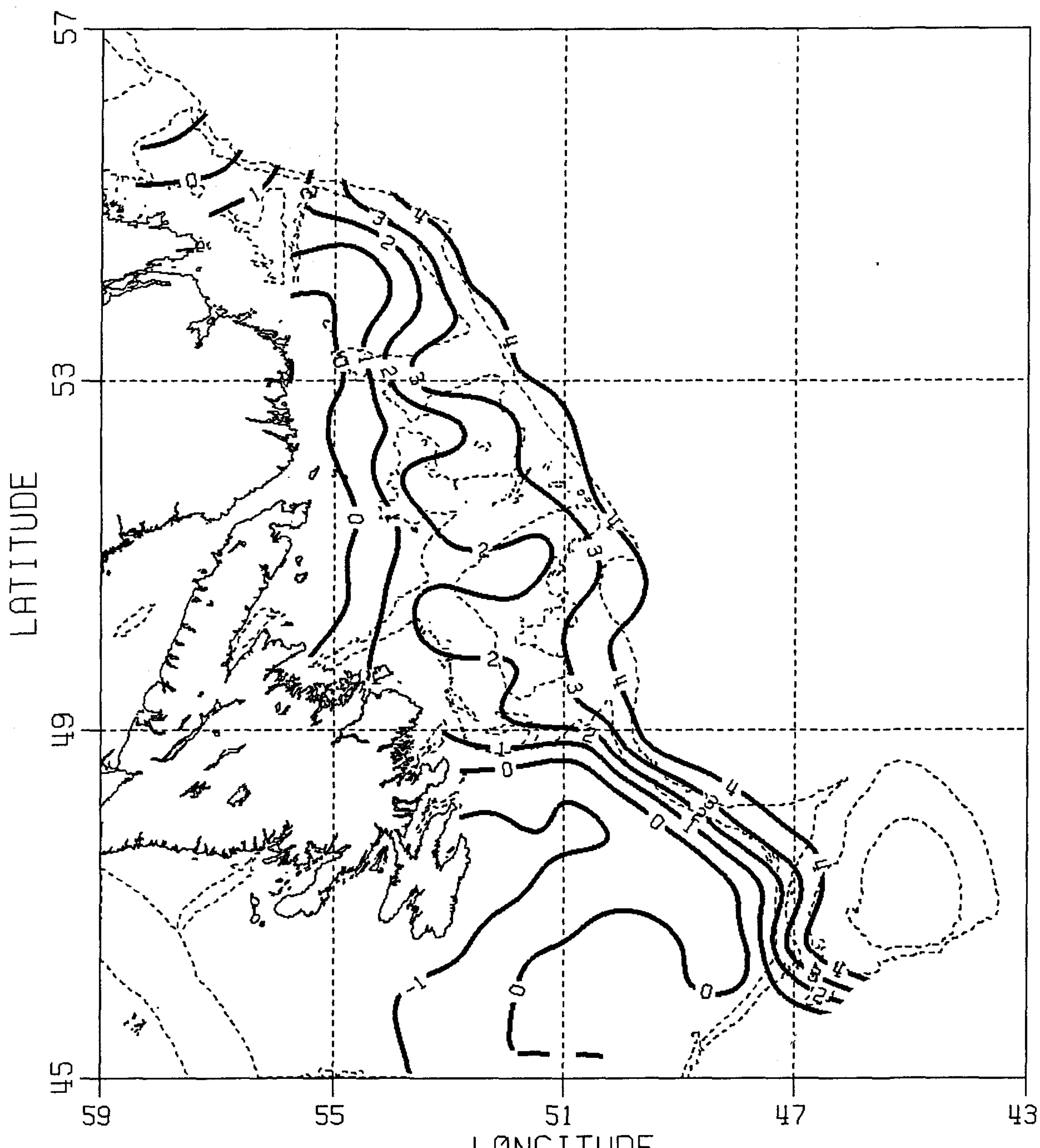


Fig. 7a. The 1980 to 1990 average fall bottom temperature.

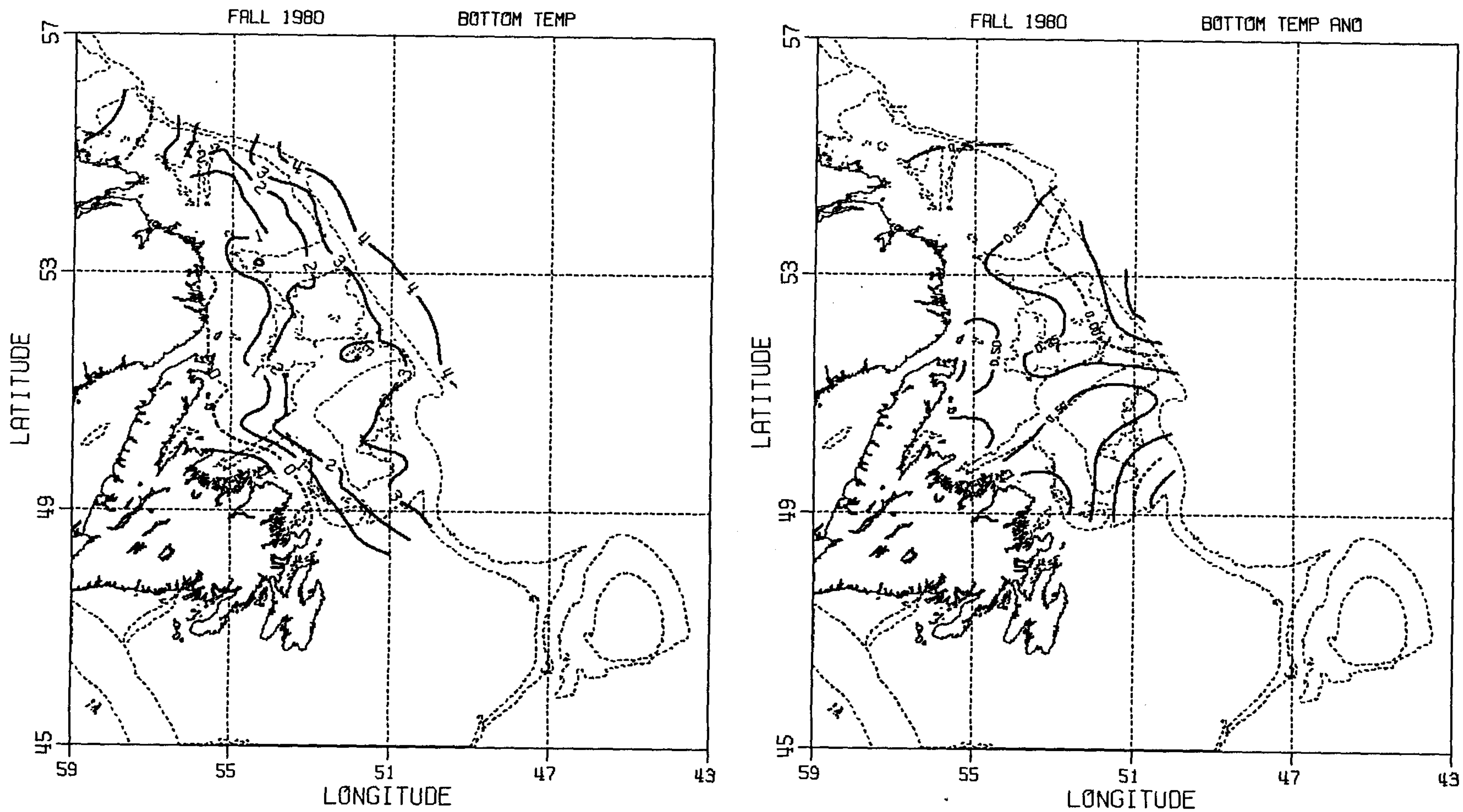


Fig. 7b. 1980 fall bottom temperatures and anomaly.

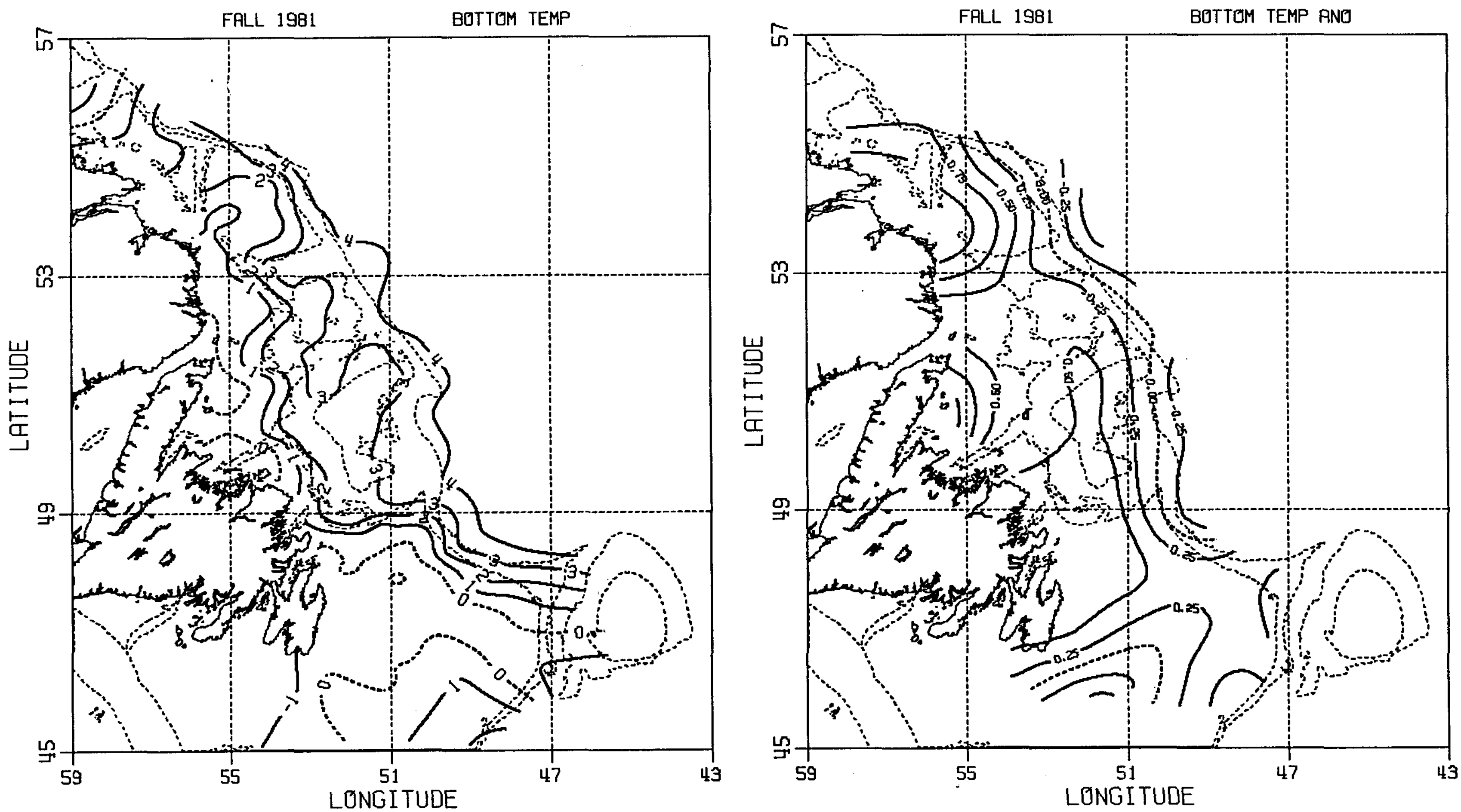


Fig. 7c. 1981 fall bottom temperatures and anomaly.

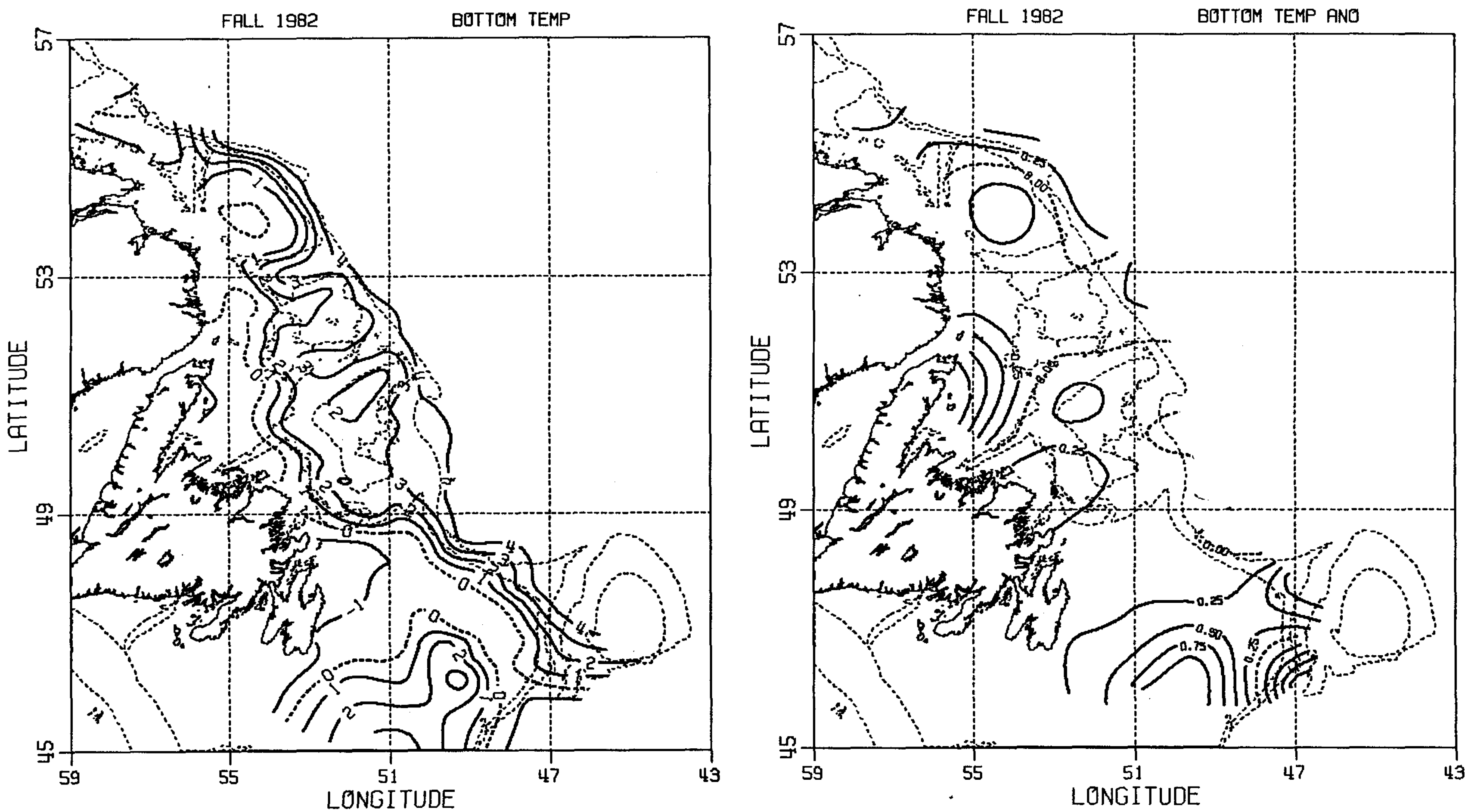


Fig. 7d. 1982 fall bottom temperature and anomaly.

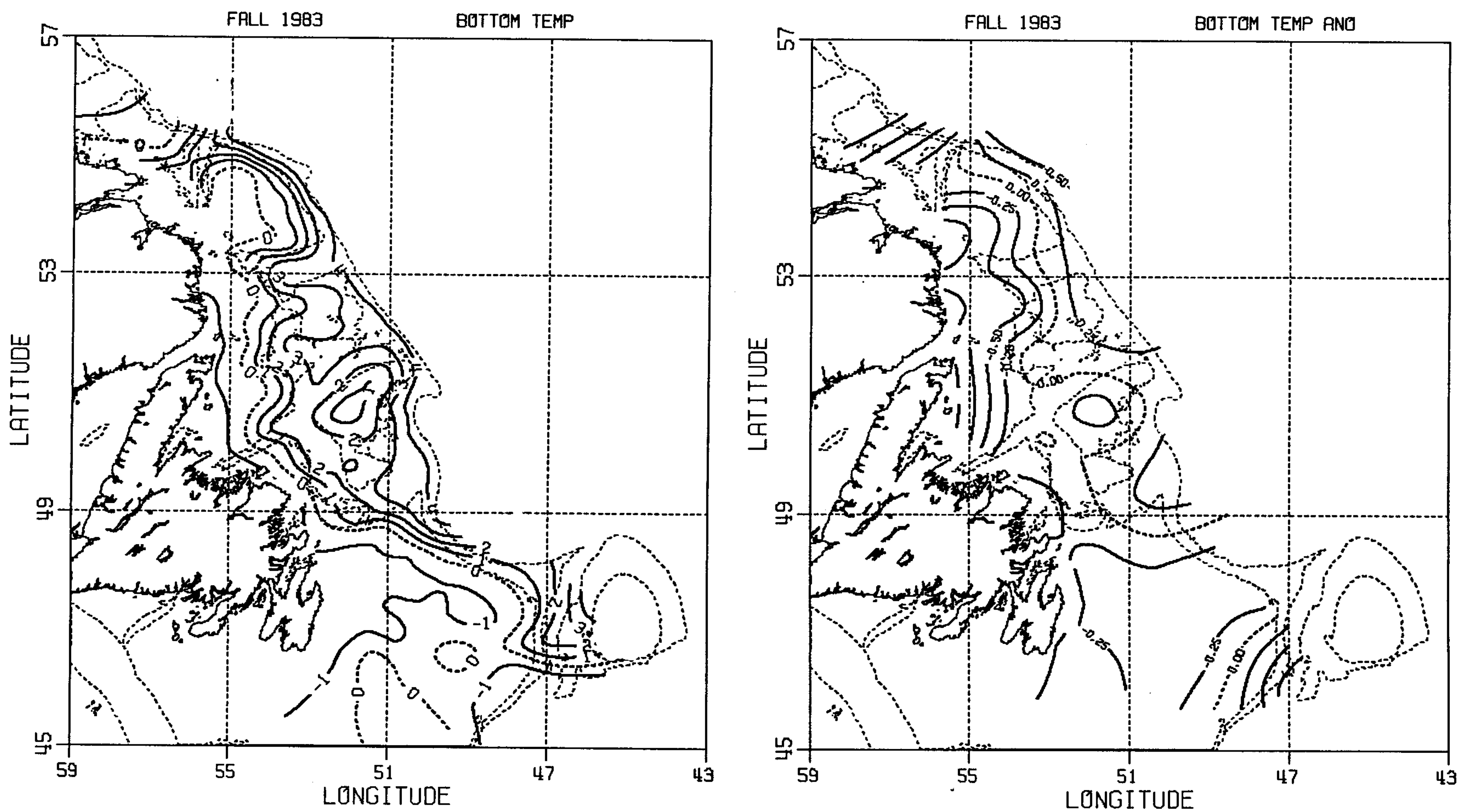


Fig. 7e. 1983 fall bottom temperature and anomaly.

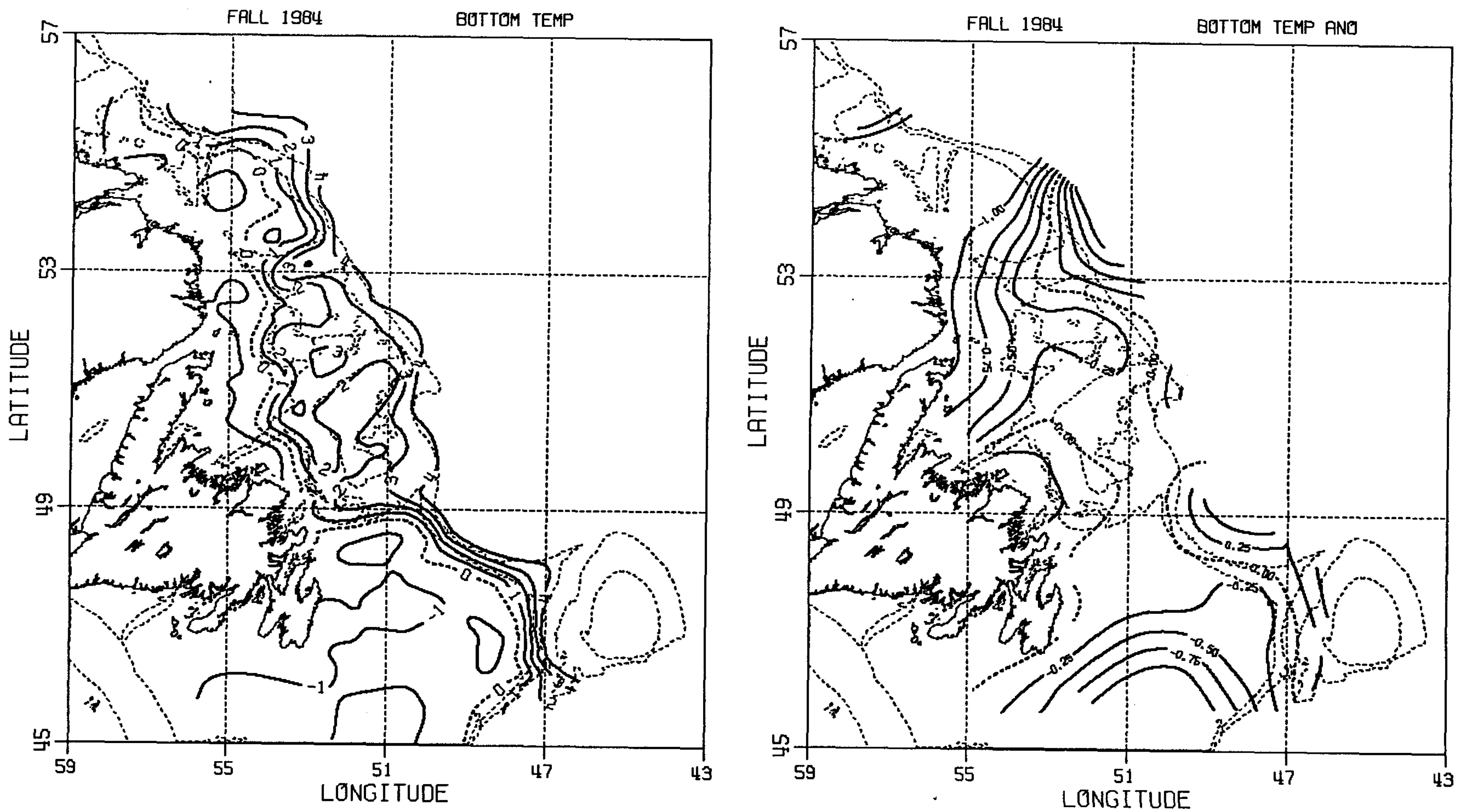


Fig. 7f. 1984 fall bottom temperature and anomaly.

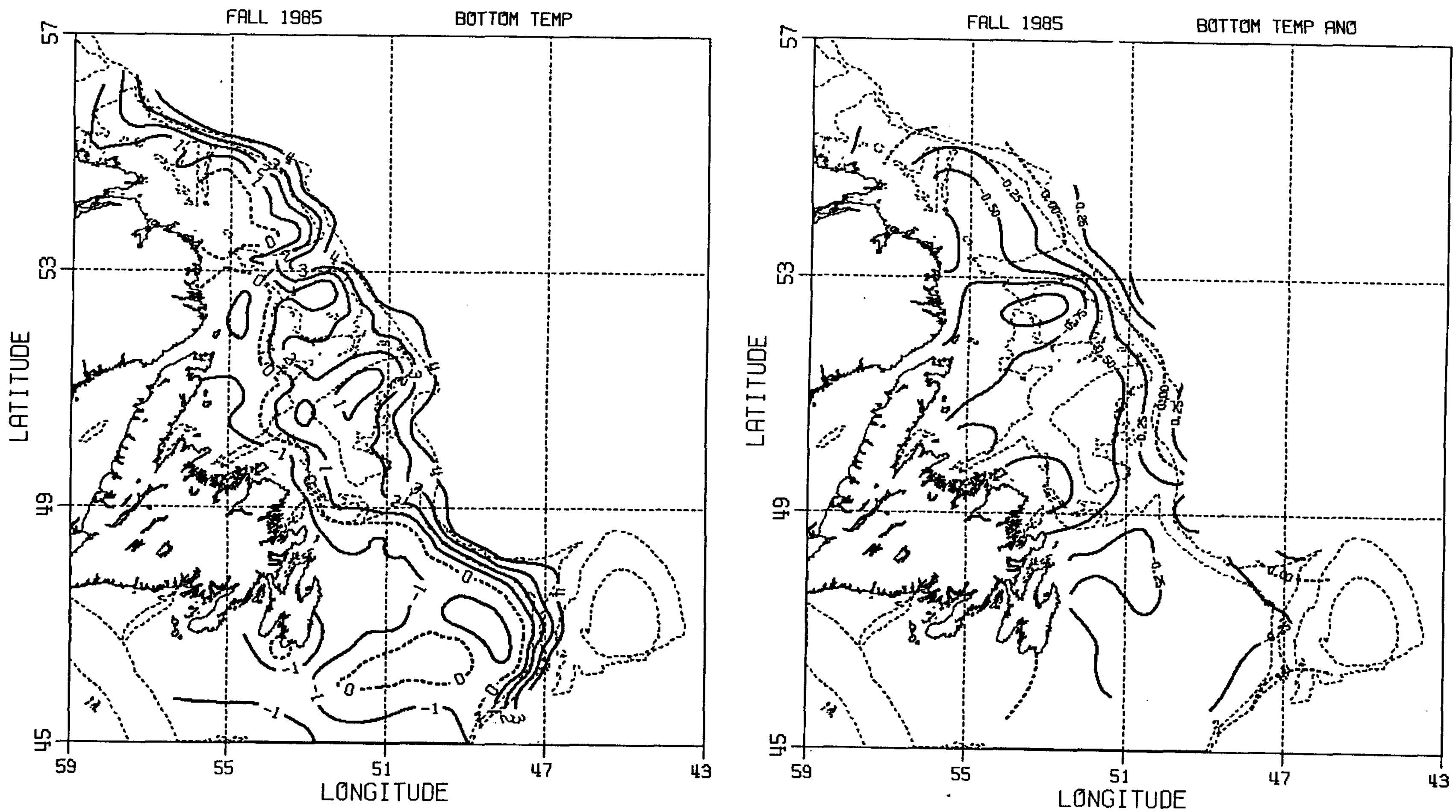


Fig. 7g. 1985 fall bottom temperature and anomaly.

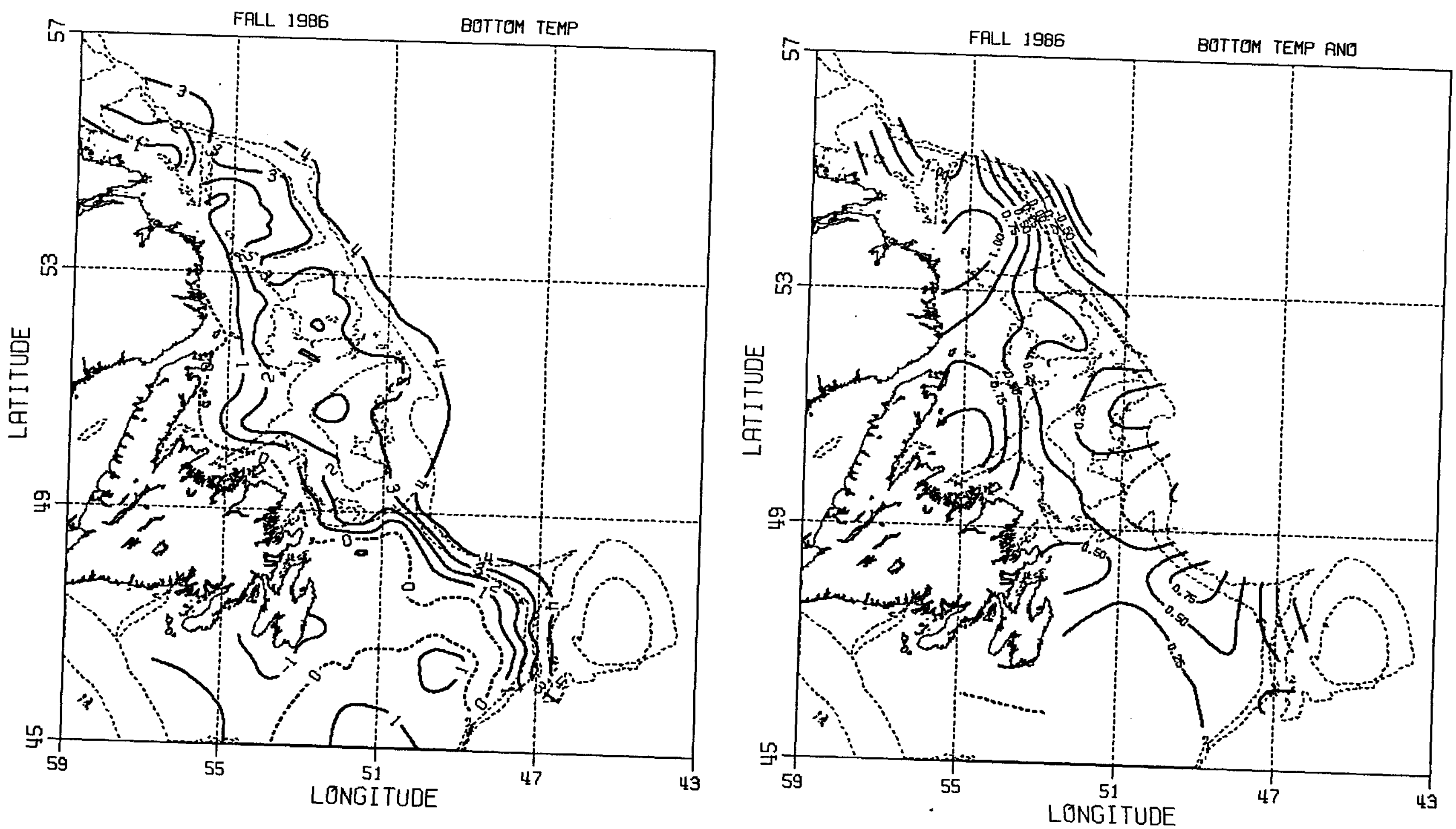


Fig. 7h. 1986 fall bottom temperature and anomaly.

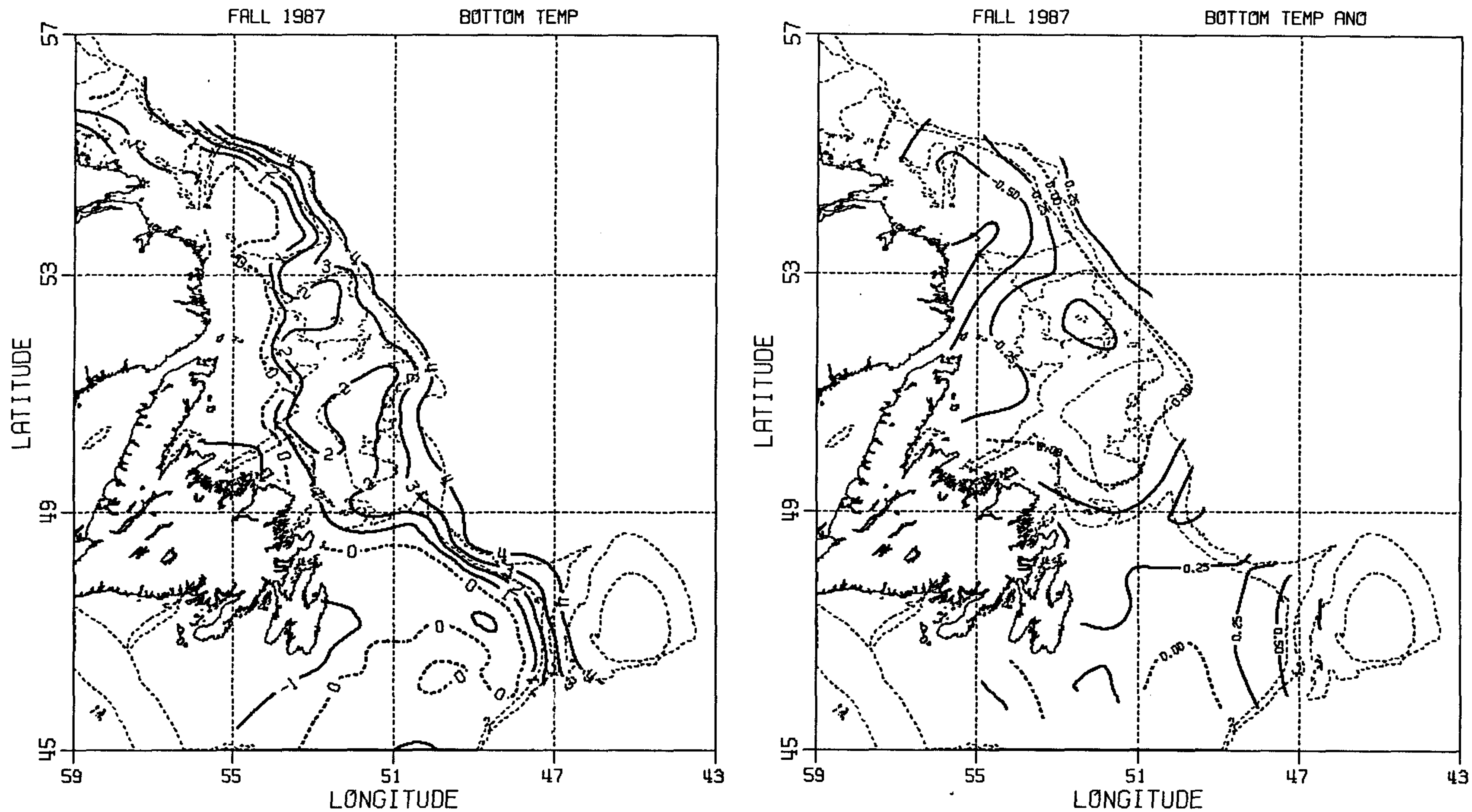


Fig. 7i. 1987 fall bottom temperature and anomaly.

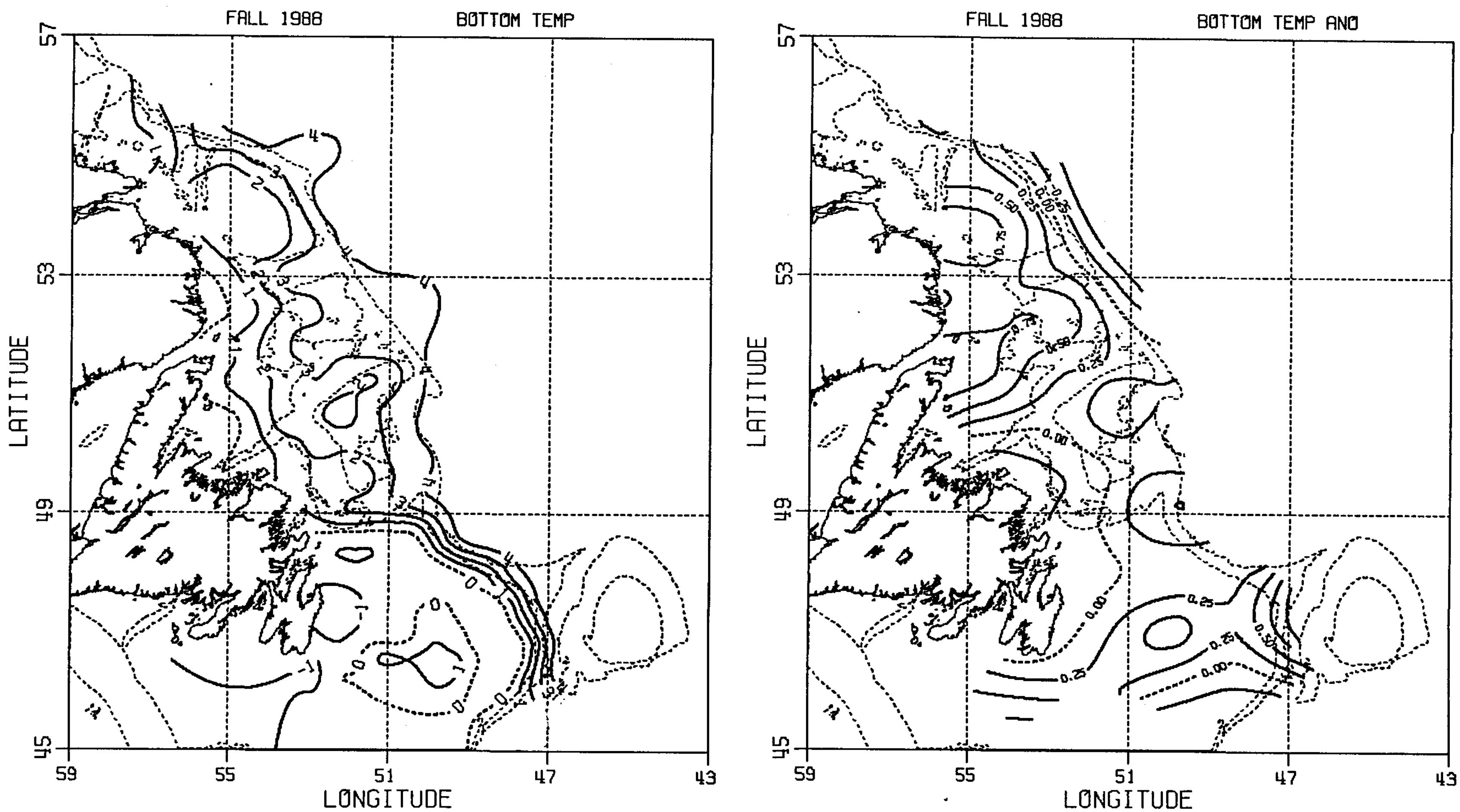


Fig. 7j. 1988 fall bottom temperature and anomaly.

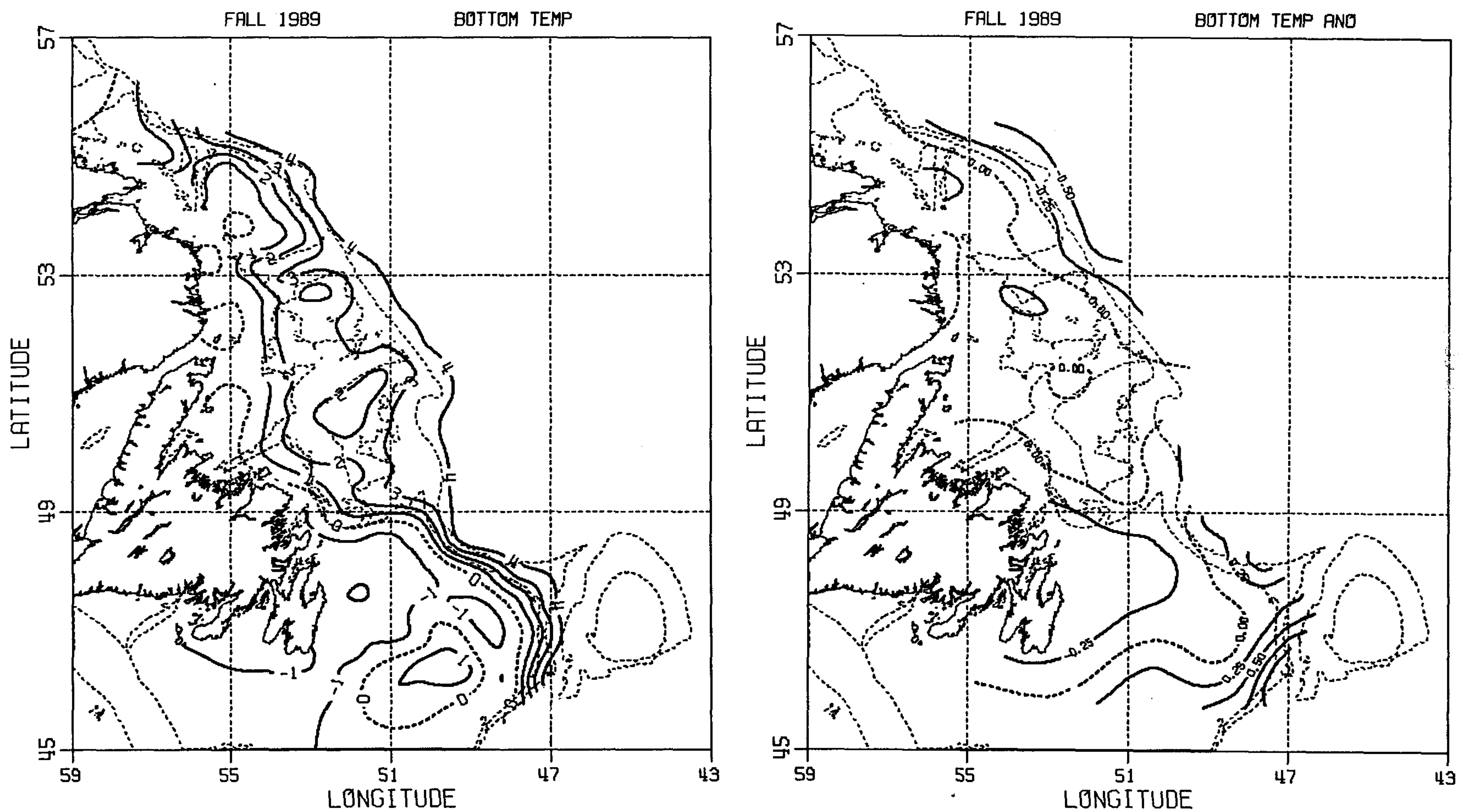


Fig. 7k. 1989 fall bottom temperature and anomaly.

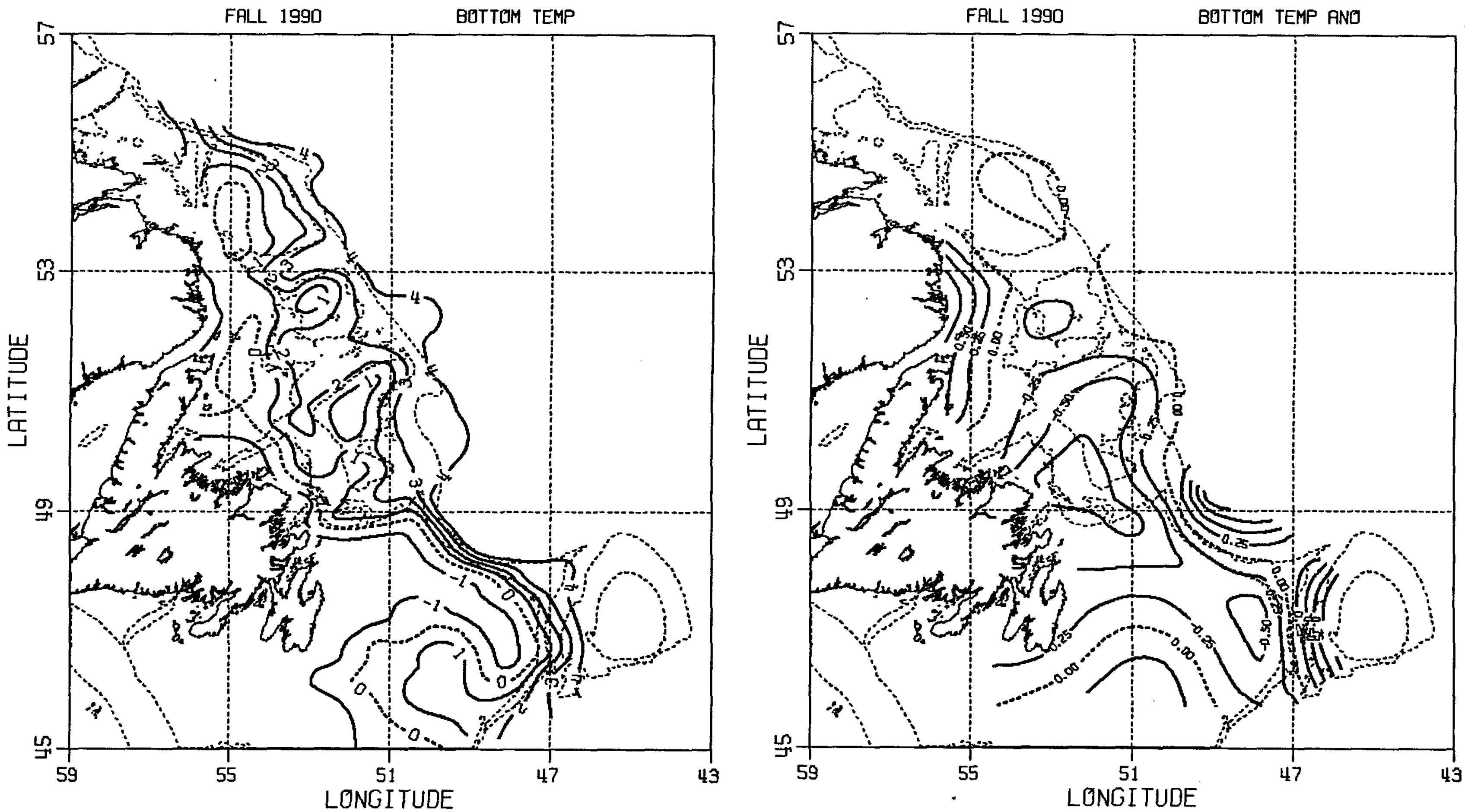


Fig. 71. 1990 fall bottom temperature and anomaly.

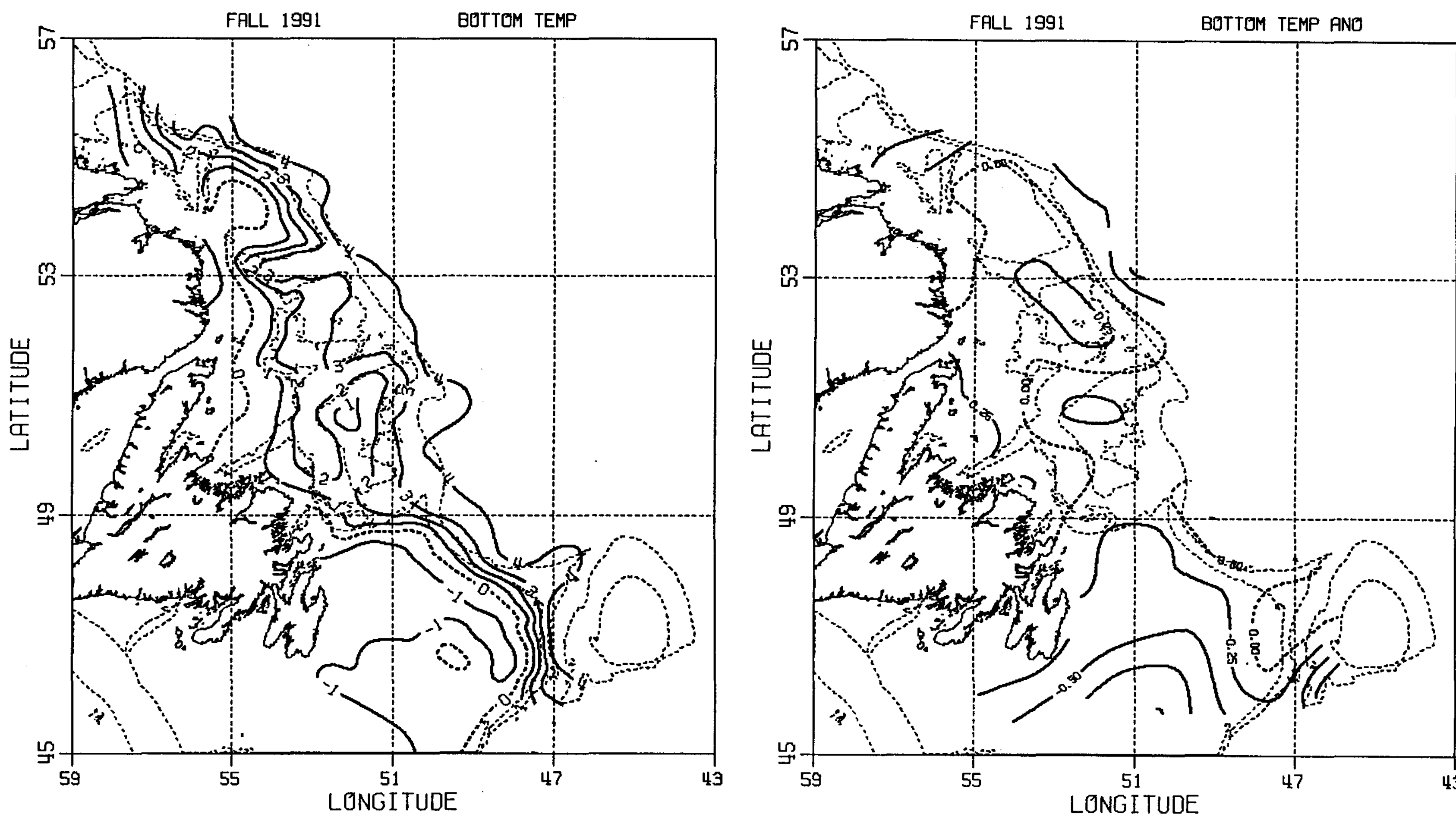


Fig. 7m. 1991 fall bottom temperature and anomaly.

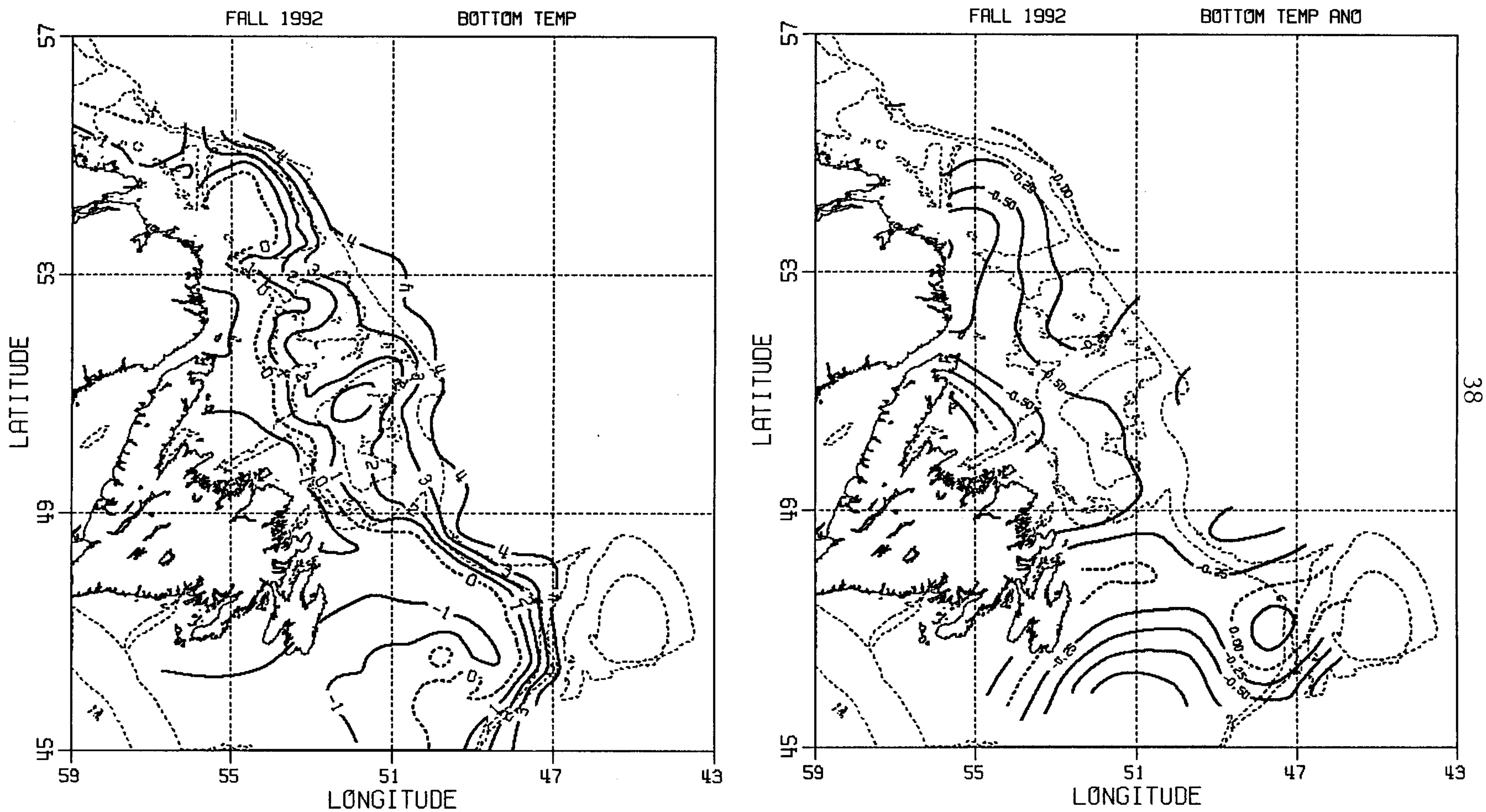


Fig. 7n. 1992 fall bottom temperature and anomaly.

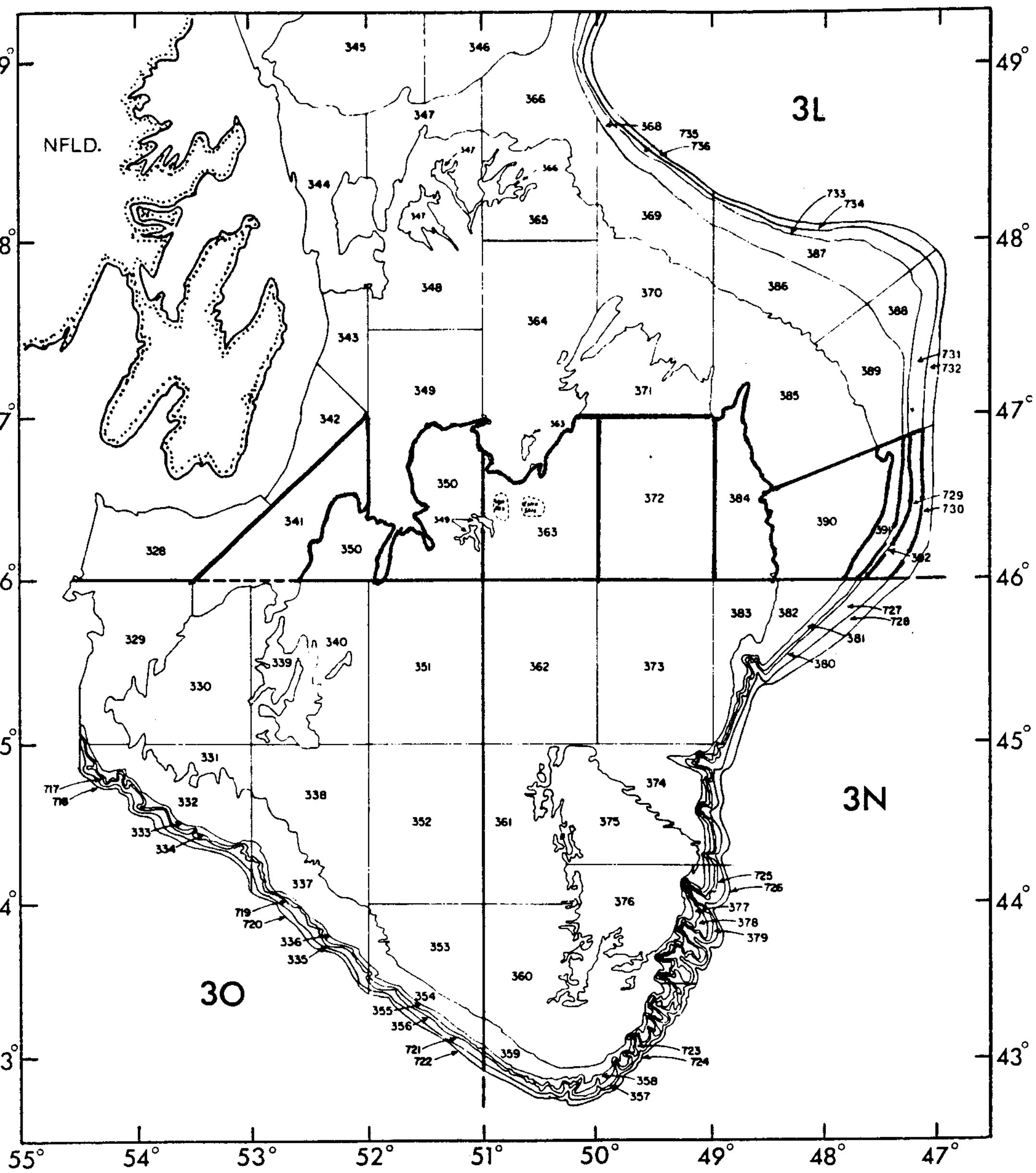


Fig. 8a. Strata in NAFO Division 3KNO

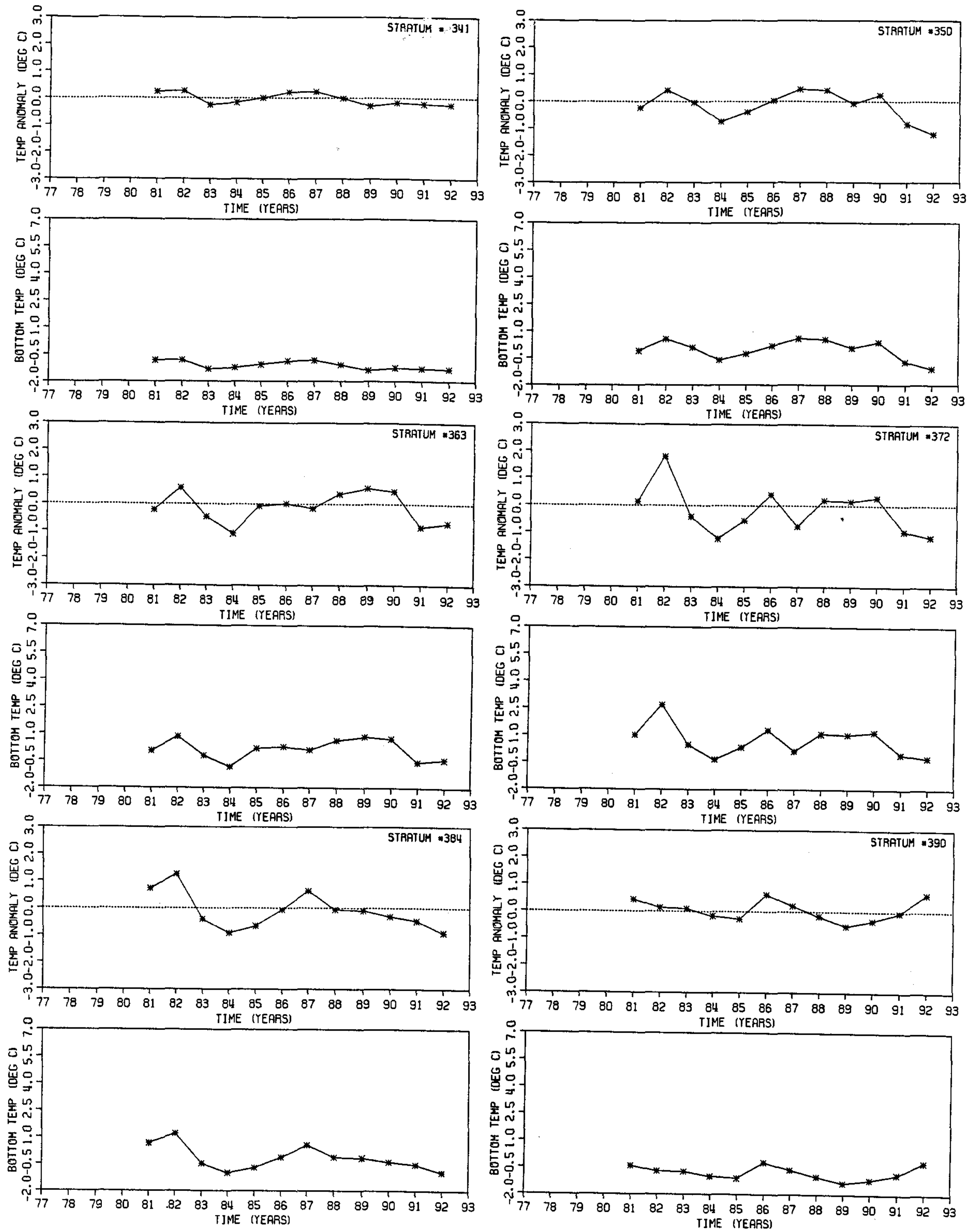


Fig. 8b. Time series of bottom temperatures for selected strata (Table 1) in NAFO Division 3L.

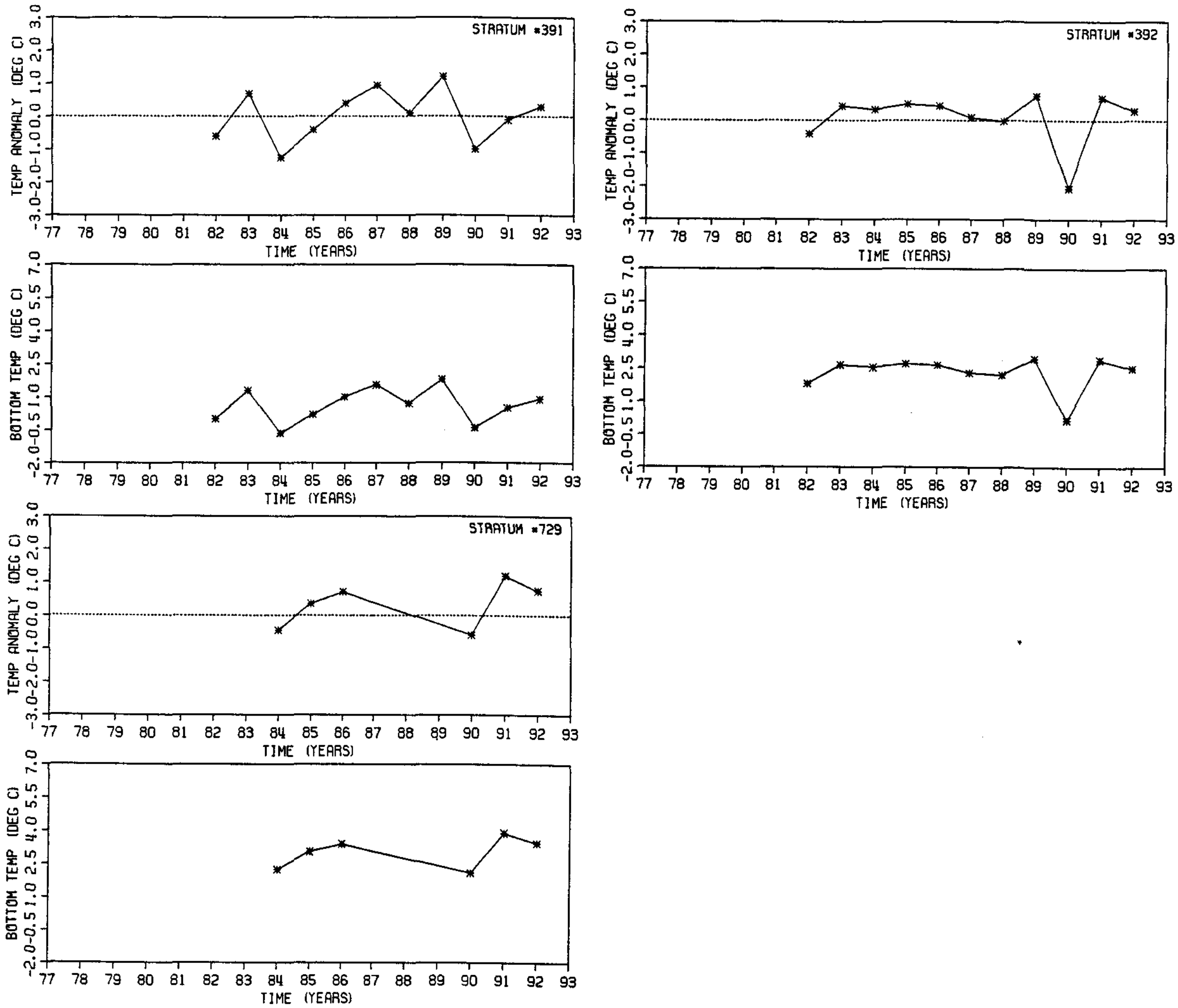


Fig. 8c. Time series of bottom temperatures for selected strata (Table 1) in NAFO Division 3L.

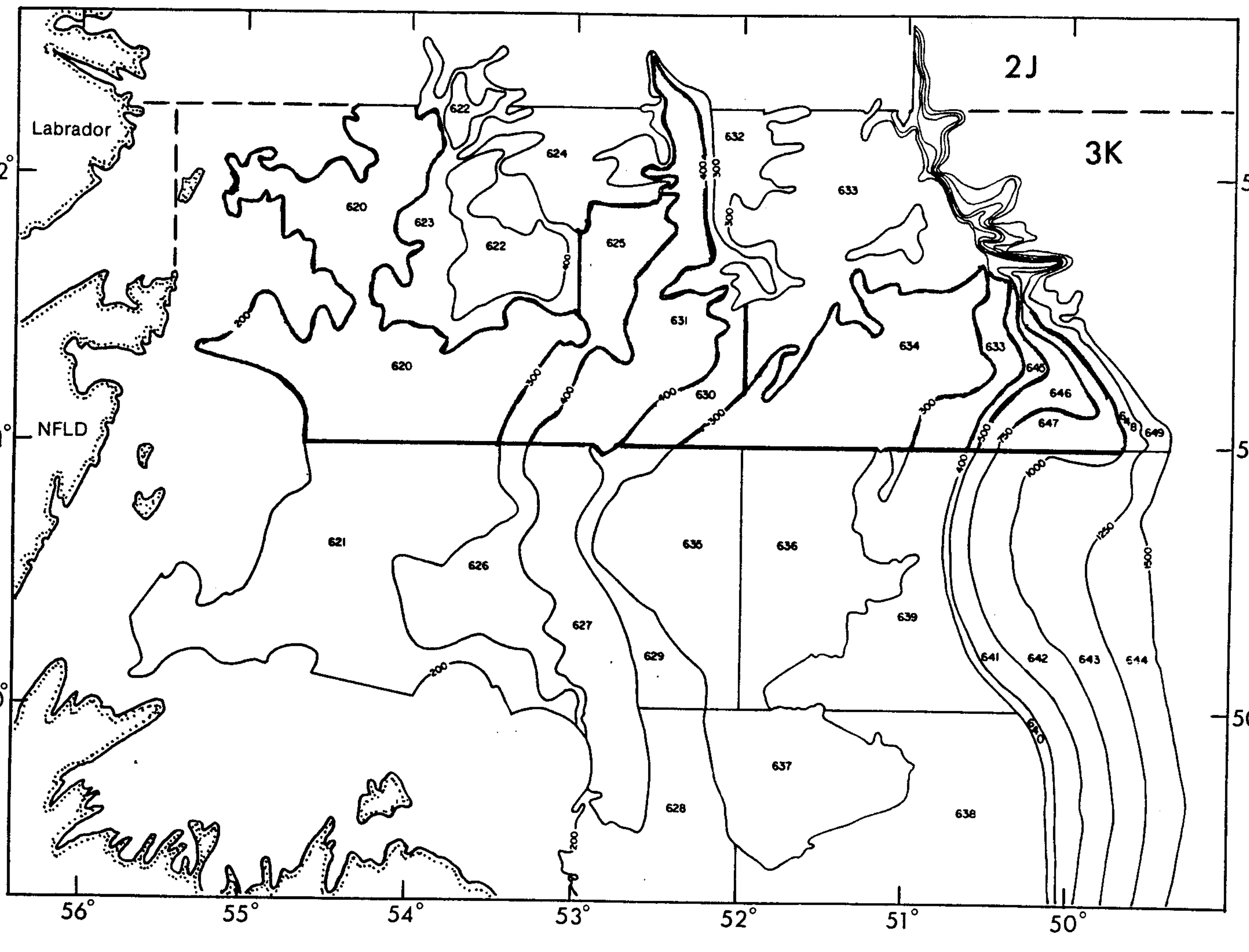


Fig. 9a. Strata in NAFO Division 3K.

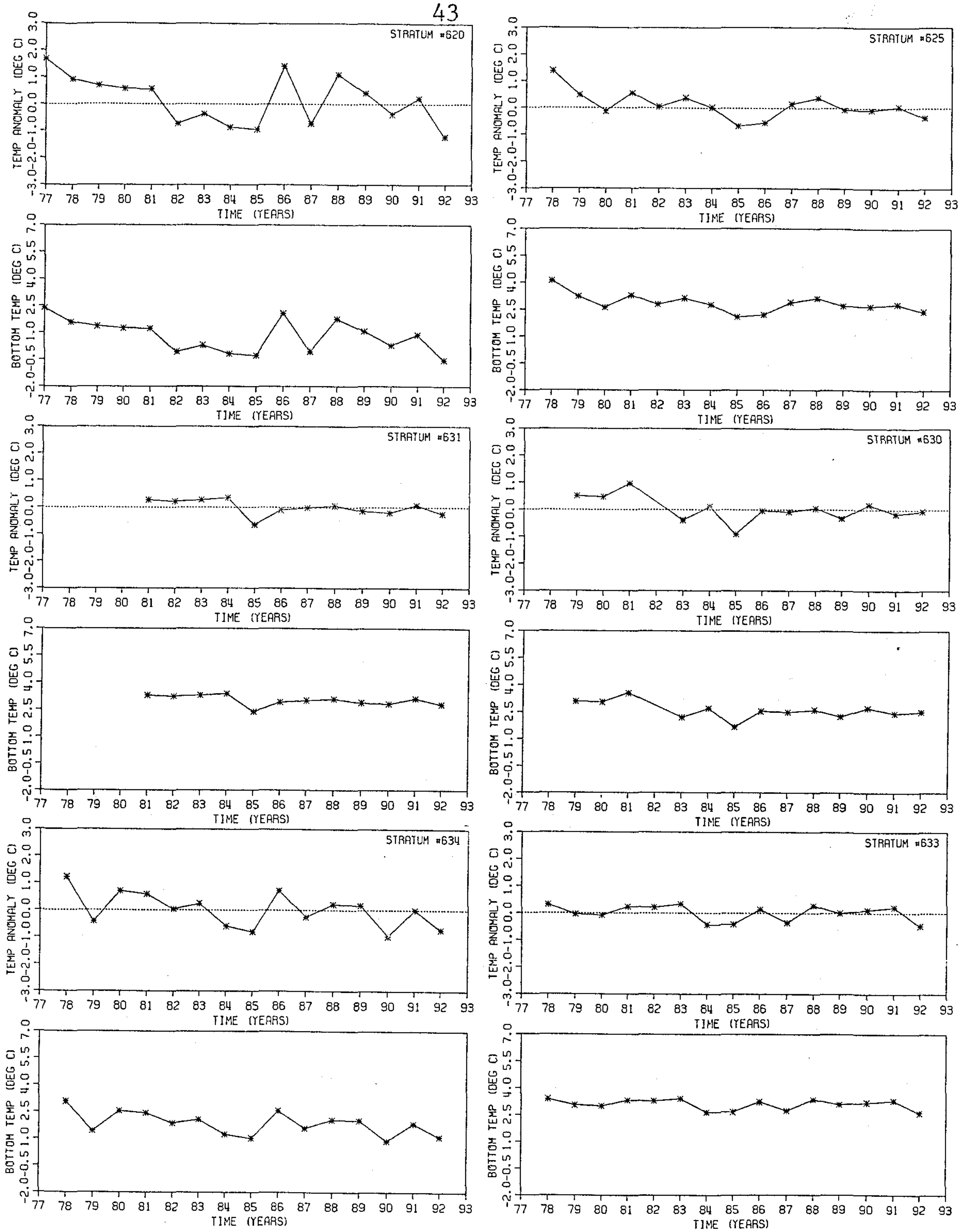


Fig. 9b. Time series of bottom temperatures for selected strata (Table 1) in NAFO Division 3K.

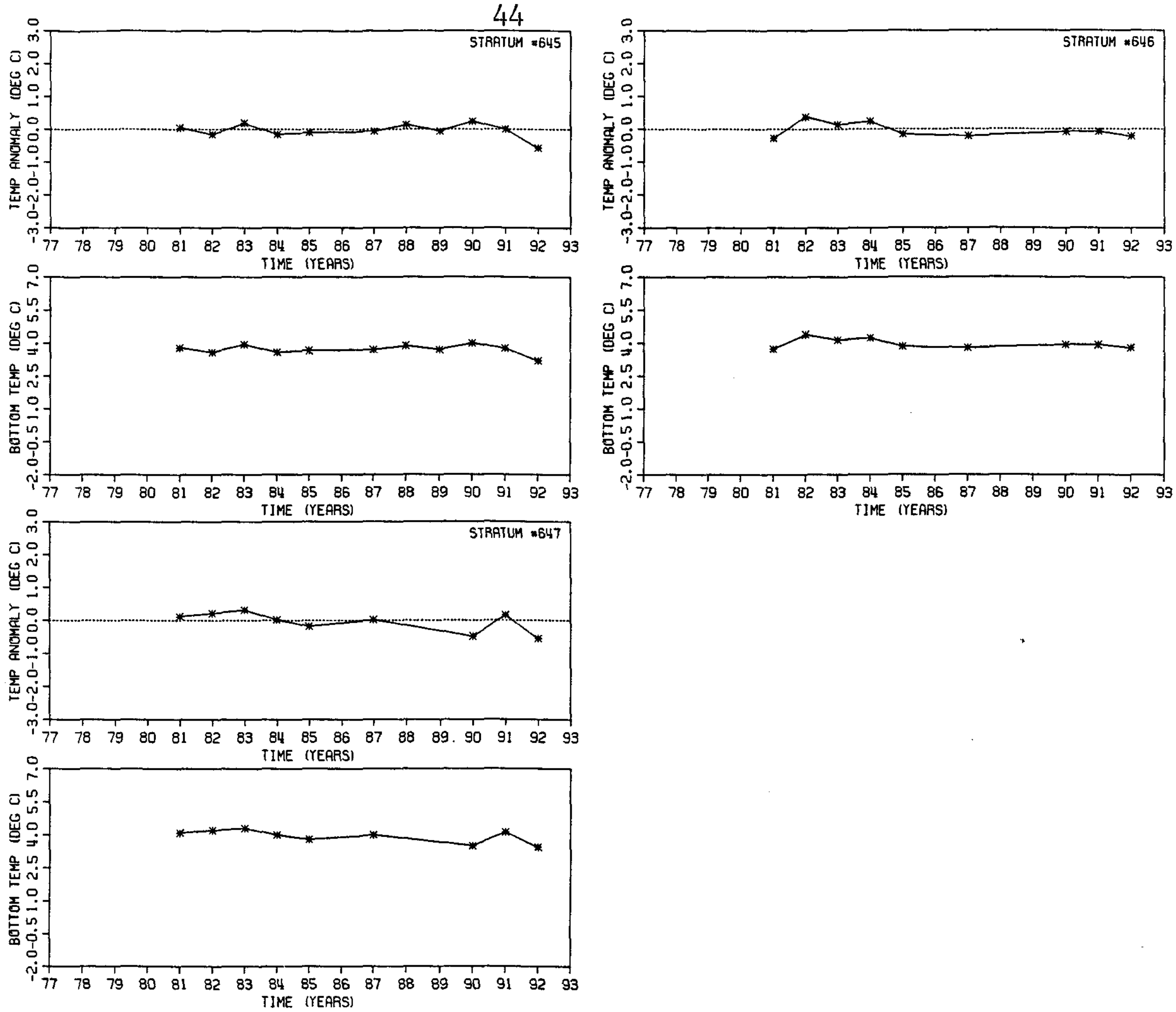


Fig. 9c. Time series of bottom temperatures for selected strata (Table 1) in NAFO Division 3K.

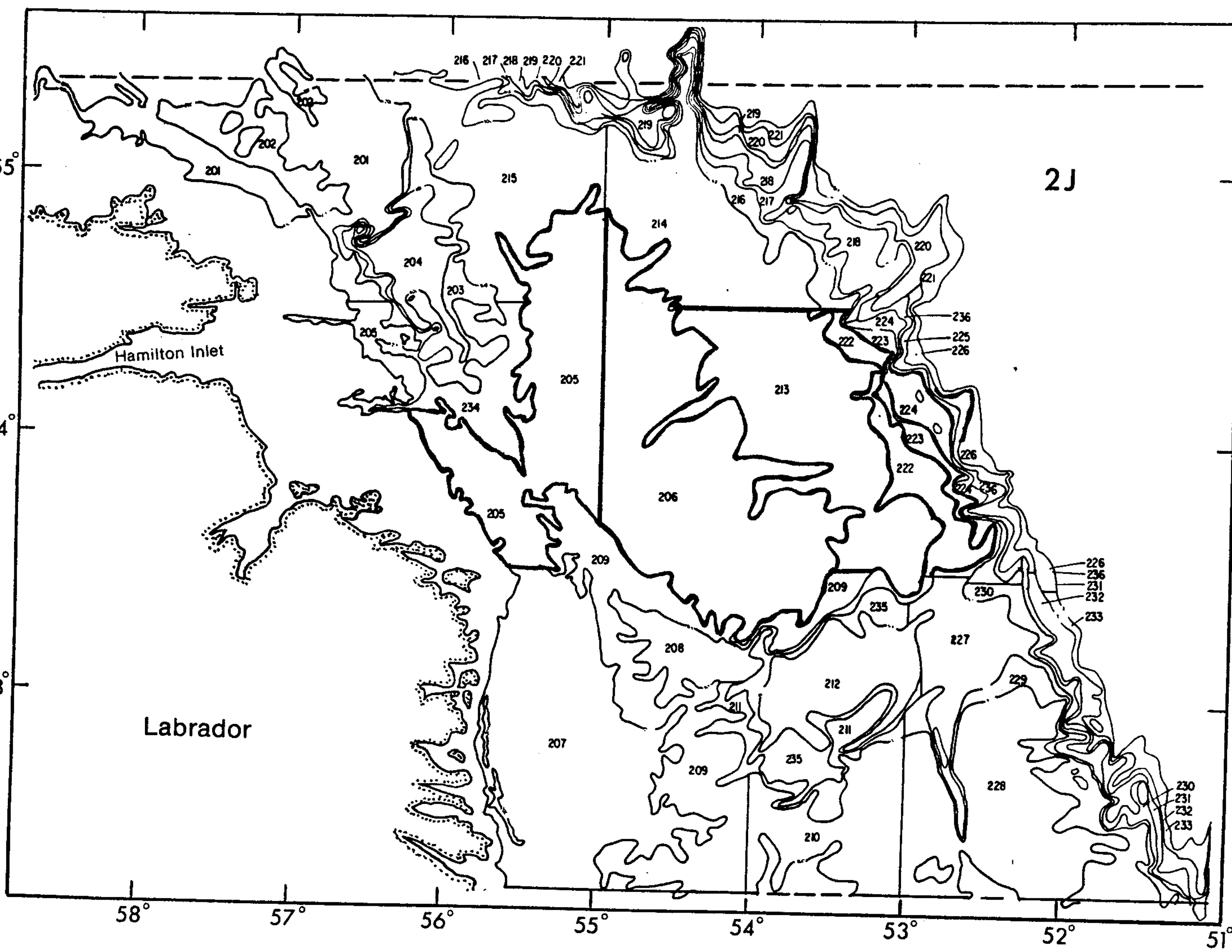


Fig. 10a. Strata in NAFO Division 2J.

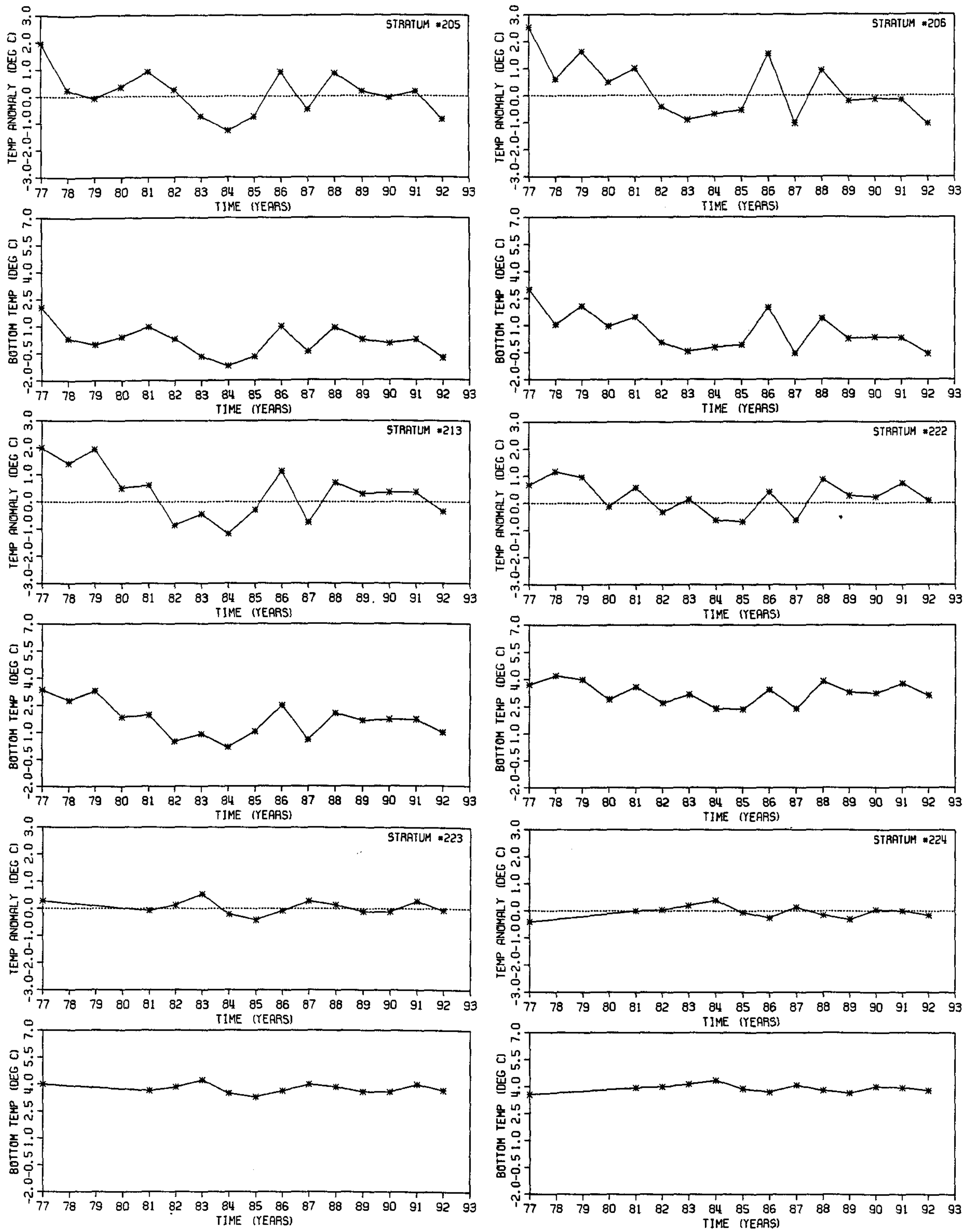


Fig. 10b Time series of bottom temperatures for selected strata (Table 1) in NAFO Division 2J.

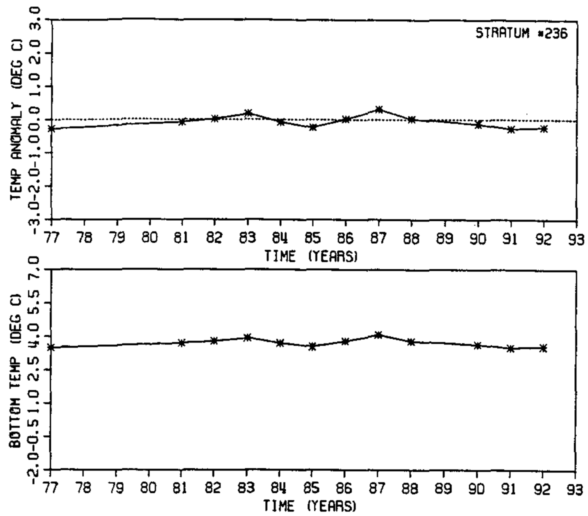


Fig. 10c. Time series of bottom temperatures in strata 236, NAFO Division 2J.