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The Cold Intermediate Layer on the Labrador and Northeast Newfoundland Shelves, 1978-1986

by

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1. Introduction

The purpose of this document is to present a preliminary examination of the oceanographic conditions in NAFO areas 2J3KL for the years 1978-1986 with particular emphasis on the 1984-86 period. The data which we shall discuss include hydrographic sections from Hamilton Bank and the Northeast Newfoundland Shelf, the Station 27 observations, temperature data from moored instruments on Hamilton Bank and the areal coverage of ice south of 55°N. First, however, we would like to present a brief review of the ocean temperature distribution over the Labrador and Newfoundland shelf.

Templeman (1975) presented the average summer temperature sections (Fig. 1.1) for Hamilton Bank, Cape Bonavista and 47° N corresponding to fishing areas 2J, 3KL and 3L respectively. A major oceanographic feature of these areas is a subsurface layer of cold water which we shall call the Cold Intermediate Layer (CIL). We shall tentatively define the boundaries of the CIL by the 0°C isotherm. Figure 1.1 shows that, in the region, the CIL has a characteristic thickness of 100-200 m, extends 200-300 km offshore and has minimum summer temperatures of -1.0 to -1.5°C. Figure 1.2 shows the plots of monthly averaged temperature versus depth for the inner and outer halves of the Northeast Newfoundland Shelf which is bounded by the 1000 m isobath. A 200 m thick layer of below zero water develops in February in the inshore half of the shelf. A minimum core temperature of about -1.5°C at 75 m is reached in April while, at the same time, a seasonal thermocline is developing at the surface. By November sub-zero temperatures have disappeared. The offshore half of the shelf follows the same pattern but with some quantitative differences, namely, the CIL is about one half as thick, minimum core temperature of -0.7°C occurs in June and sub-zero temperatures generally do not persist past August.

In Fig. 1.3 and 1.4 we show the mean monthly temperature distributions across Hamilton Bank and along the Bonavista Section based on all available but not all existing bottle, BT, XBT and CTD data archived by MEDS. The monthly time series of the area of water with T < 0°C is shown in Fig. 1.5. The Hamilton Bank sections run from June-November only, as there were not sufficient data to establish mean conditions for the other months. The intermediate layer appears to be most extensive and coldest in June and July with large areas of water less than -1.0°C. The temperature of the CIL increases through the summer and fall with a corresponding decrease of the area of water with T < 0°C until it finally disappears in November.

The Bonavista Sections (Fig. 1.4, 1.5) cover the period April-November. In April, the water column from 0-150 m is less than 0°C. The coldest water, less than -1.0°C, is confined to the coast. Near the bottom, temperatures range from about 2-4°C. The development of a warm surface layer has begun in May and continues to increase in temperature until September. The CIL (Fig. 1.5) shows a gradual decrease in area from May-June to November similar to the decline on Hamilton Bank. Bottom temperatures remain between 2-3°C during this period. The CIL's average temperature continues to increase until November when minima are just below 0°C.

Keeley (1981) has compiled the mean monthly temperature sections along 47°N. The best overall coverage is in July and August when the CIL has areas of 39.7 and 34.6 km^2 respectively. There is significantly more water below -1°C in August.

We shall now discuss the temperature data for the 1978-86 period starting generally in the north and moving southward.

2. Hydrographic Sections

a) Hamilton Bank Section

Temperature sections from summertime hydrographic surveys conducted by Bedford Institute are shown in Fig. 2.1 for Hamilton Bank for 1980 and 1983-1986. The area of the CIL from these surveys is plotted in Fig. 2.2a along with transects taken by the Northwest Atlantic Fisheries Center (NAFC) from 1984-86 in the same general area but not over the same track. Both surveys show extensive areas (36 to 46 km^2) of below zero water in 1984 and 1985. In fact, a large fraction of the water was less than -1.5°C for those years. The temperature of the CIL was below normal and its area was above normal compared to the long term mean conditions (Fig. 1.3 and 1.5). Conditions improved in 1986 with a decrease of the area of the CIL to 23-30 km^2 and a near total disappearance of water less than -1.5°C.

b) White Bay Section

The NAFC conducted hydrographic surveys along the White Bay Section in August 1984-1986. The area (Fig. 2.2b) of the CIL for each of these transects shows the same behaviour as the Hamilton Bank sections, namely, large in 1984 and 1985 (70-77 km^2) relative to 1986 (56 km^2). Water below -1.5°C was a major constituent of the CIL in 1984-1985 but was present in only minor amounts in 1986.

c) Bonavista Section

Summertime temperature sections which highlight the CIL and were collected by the NAFC from 1978-86 (1980 missing) are presented in Fig. 2.3. The area of the CIL (Fig. 2.2c) shows a general increase for the 1978-84 period when it reached a maximum of 48 km^2. It dropped to about 40 km^2 in 1985 followed by a further decrease to about 22 km^2 in 1986. Extensive areas of water with temperatures less than -1.5°C were present in 1984 while, in 1985, the proportion of this very cold water was reduced. In 1986, only small areas of such water were present. Comparison of the 1984 and 1985 sections to the long term mean (Fig. 1.4) indicates the CIL temperatures were below normal.

d) 47° North Section

Summertime temperature sections collected by the NAFC and highlighting the CIL are shown in Fig. 2.4 for the period 1978-1986. Figure 2.2d shows that from 1982-1986 the area of the CIL decreased very slightly from 39 km^2 to 36 km^2. This is in contrast to the other three sections just described which showed marked decreases in area in 1986. Temperatures over the Grand Bank were below normal and similar from year to year for the 1982-1985 period (Akenhead, 1986). In 1986, the temperatures in this section were not significantly different from the previous four years.

3. Oceanographic Time Series

a) Station 27

Figure 3.1 shows the monthly temperature anomalies for Station 27 at 0, 50, 100 and 150 m. The period 1983-1986 was characterized by below normal temperatures particularly at the deeper levels. Table 3.1 shows the annual anomalies of temperature for the four depths, from 1984 to 1986. Temperatures in 1984 and 1985 were well below normal with conditions generally improving in 1986 but, overall, still remaining slightly below normal. The positive monthly temperature anomalies that did occur in 1986 at Station 27 generally were evident between the late spring and early fall. Towards the end of the year negative anomalies returned at all levels.

Figure 3.2 shows the integrated (0-175) monthly temperature anomalies for Station 27 (see also Fig. 2.2 f,g). A period of below normal temperatures is evident in 1984, 1985 and early 1986. By mid-1986, the anomalies have become positive and persist until the end of the year. Overall 1984 had the coldest annual temperature (0-175 m) in 40 years, 1985 was third coldest and 1986 ranked sixteenth.

TABLE 3.1

Annual Temperature Anomalies at Station 27

	0 m	50 m	100 m	150 m
1984	-.42	-.61	-.34	-.26
1985	-.79	-.56	-.51	-.48
1986	-.18	.10	-.13	-.11

b) Hamilton Bank

The time series of monthly temperature anomalies (mean T = -.0.63°C) from a current meter at 200m depth on the western side of Hamilton Bank is shown in Fig. 3.3 for the period 1978-1986. The period from October 1978 to October 1980 was warmer than average by 0.54°C whereas the period from Dec. 1982 - November 1985 was colder than average by 0.5°C. There was a change to positive anomalies in December 1985, continuing to August 1986 with an average anomaly over this period of 0.32°C.

The annual temperature anomalies are plotted in Fig. 2.2e and show an apparent (and expected) inverse relationship with the time series of CIL area at Hamilton Bank, White Bay and Bonavista. There is also a positive correlation evident with the two Station 27 time series (Fig. 2.2 f,g).

c) Ice Extent

In Fig. 3.4 we show the time series (1963-1986) of monthly anomalies in the area of ice south of 55° N compiled from maps prepared by the Atmospheric Environment Service. It is apparent that 1983-1985 were years of above normal ice coverage. On the other hand, 1986 appears to be a transition year, beginning with an above normal ice extent and changing in May to below normal coverage. The average monthly anomalies of ice extent based on the Jan. - June monthly anomalies are shown in Fig. 2.2h for 1978 to 1986. The ice season beginning in December 1986 started with above normal coverage.

4. Results

a) Intercomparison of Oceanographic Time Series

Figure 4.1 shows scatter plots of the monthly temperature anomalies at Hamilton Bank (200 m) with those at 0, 50, 100 and 150 m at Station 27. The zero lag correlation for Hamilton Bank versus Station 27, 150 is 0.67, decreasing monotonically for Hamilton Bank lagging Station 27 and oscillating between 0.6 and 0.75 for Hamilton Bank leading Station 27 by up to 23 months. This is indicative of a generally north to south advection. Correlations were lower for Hamilton Bank (200 m) and the other depths at Station 27.

Fig. 4.2 shows scatter plots of the monthly temperature anomalies at 4 depths at Station 27. At zero lag the correlations are 0.41 (100-150 m), 0.31 (100-50 m) and 0.14 (100-0 m) for 40 years of data. This suggests small vertical scales of variability and/or significant phase differences with depth. A cross-spectral analysis of these obsevations is planned to attempt to sort out these difficulties.

In Fig. 4.3 we show the scatter plots of ice coverage with the 200 m Hamilton Bank and Station 27 temperature anomalies. There appears to be negative correlations between the ice coverage and all of the temperature series.

b) Intercomparison of Section Parameters

Finally, a correlation table (Table 1) is shown for all variables plotted in Fig. 2.2. Of the 21 possible correlations, 18 were significant at the 95% level, that is, the variables are generally highly correlated with one another. The average magnitude of the correlation coefficients is 0.77 disregarding the number of points in each record. Ice extent is best correlated with the six other variables with an average correlation ($\bar{r}$) of 0.86, followed by the Bonavista Section CIL area ($\bar{r}$ = 0.83), the 200m Hamilton Bank temperature ($\bar{r}$ = 0.82), the 0-175 m, Station 27, May to September temperature anomaly ($\bar{r}$ = 0.80), the Hamilton Bank CIL area ($\bar{r}$ = 0.79), the 0-175 m, Station 27 annual temperature anomaly ($\bar{r}$ = 0.76) and finally the 47^{o}N CIL area ($\bar{r}$ = 0.58). There is little to chose between these variables except for the 47^{o}N Section which appears to be the least related to the other six on the basis of this simplified analysis.

5. Summary and Discussion

Table 2 presents a summary for the period 1984-86 of most of the variables discussed here with their rank relative to the longest time series assembled to this point. The CIL appears to have had nearly its greatest extent in 1984 over all three sections. In 1985, conditions were not too different from those in 1984, whereas, 1986 appeared to have 2 areas below normal (i.e. the CIL area was smaller than average) for 2 sections and above normal for the third. The temperature time series indicate that 1984 and 1985 were exceptionally cold years. In 1986, temperatures were closer to but perhaps slightly below normal. Ice cover was greatest for 1984-1985 and near normal for 1986.

The other point that deserves reiteration is the indication from Section 6 that the oceanography of the area appears to be varying in a coherent fashion with perhaps the one exception being the 47°N Section. This may be because large areas of the 47°N Section are quite shallow and are insulated from direct effects of the Labrador Current. The temperature distribution for this Section may have a stronger locally generated component with a smaller contribution from advection. This merits additional investigation.

References

Akenhead, S. 1986. The decline of summer subsurface temperatures on the Grand Bank, 1978-1985. NAFO SCR Doc 86/25.

Drinkwater, K. and R. Trites. 1986. Overview of environmental conditions in the Northwest Atlantic in 1985. NAFO SCR Doc. 86/72.

Keeley, J.R. 1981. Mean conditions of potential temperature and salinity along the Flemish Cap Section. Fisheries and Oceans, Tech. Rep. 9, Ottawa, Canada, 148 pp.

Templeman, W. 1975. Comparison of temperatures in July-August hydrographic sections of eastern Newfoundland area in 1972 and 1973 with those from 1951 to 1971. ICNAF Special Publication 10, p. 17-39.

TABLE 1

Correlation of Annual Anomalies for Variables Plotted in Fig. 2.2

	Area CIL HB	B	47	T(200 HB)	Sta. 27 0-175 Annual	May-Sept	Ice
HB		0.85	0.47*	-0.75*	-0.87	-0.78	0.997
B	4		0.63	-0.94	-0.76	-0.93	0.87
47	5	8		-0.84	-0.38*	-0.53	0.61
T(200 HB)	4	7	7		0.72	0.76	-0.91
Sta. 27 Annual	5	8	9	8		0.92	-0.89
Sta. 27 M-S	5	8	9	8	9		-0.86
Ice	5	8	9	8	9		

*not significant at the 95% level

TABLE 2

Summary Table of Oceanographic Conditions 1984-1986

a) CIL Area (km^2)	Number of Years Data	1984	Rank*	1985	Rank	1986	Rank
Hamilton Bank	5	44.3	2	45.9	1	30.5	4
Bonavista	8	48.2	1	39.4	2	21.7	7
47°N	9	37.2	3	35.2	5	35.5	4

*From greatest area to least

b) Annual Temperature Anomaly (°C)	Number of Years Data	1984	Rank*	1985	Rank	1986	Rank
Hamilton Bank (200 m)	8	-.54	1	-.35	3	.35	4
Sta. 27 0-175 m	40	-.55	1	-.51	3	.03	16
0	40	-.42	12	-.79	5	-.18	19
50	40	-.61	2	-.56	9	.10	17
100	40	-.34	4	-.51	2	-.13	6
150	40	-.26	6	-.48	1	-.11	12

*From coldest to warmest

c) Ice Cover Anomaly Monthly Average (km^2) (Jan.-June)	Number of Years Data	1984	Rank*	1985	Rank	1986	Rank
	23	106,000	2*	118,000	1	700	9

*From greatest to least

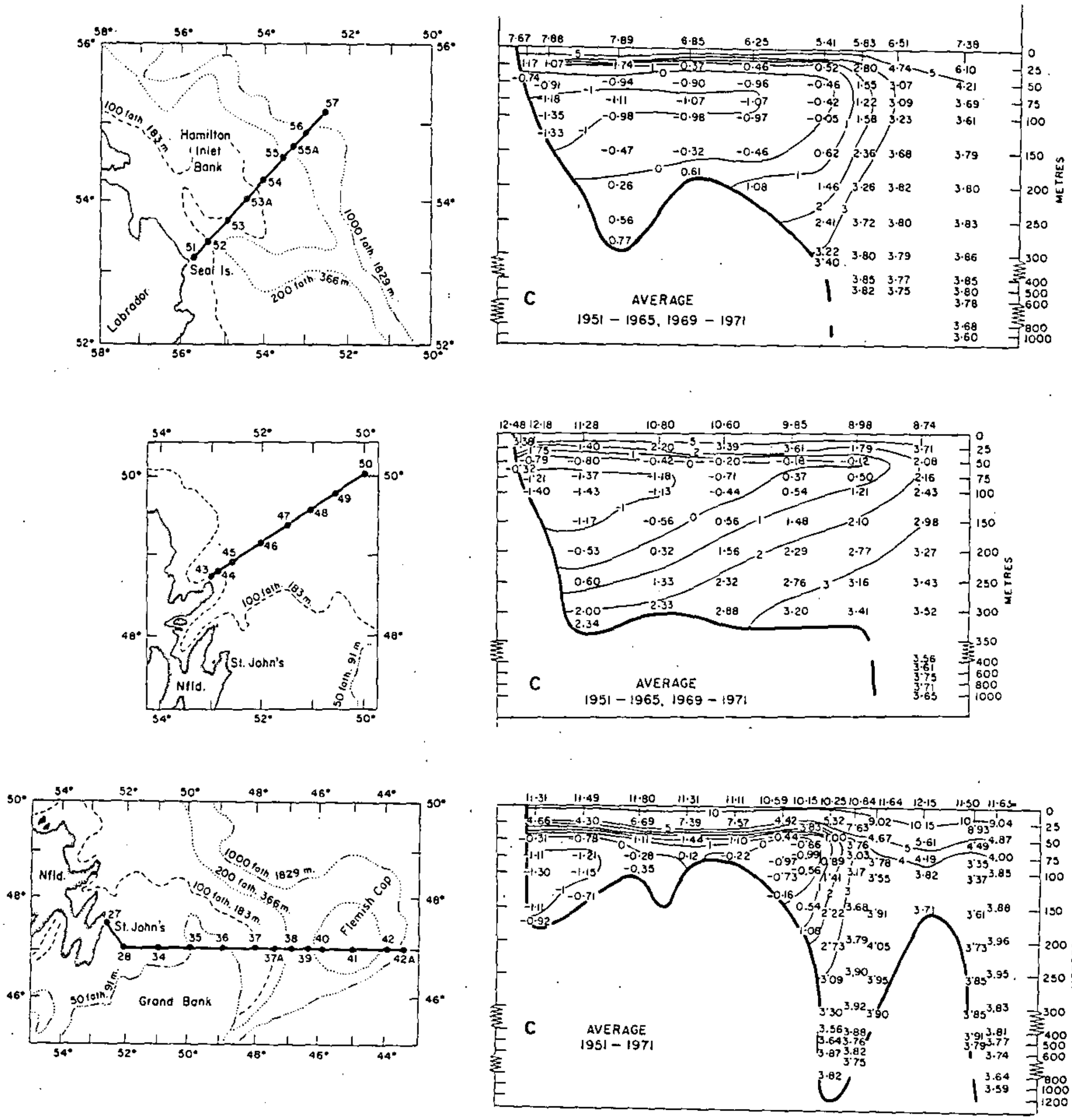


Fig. 1.1 Mean temperatures sections from Hamilton Bank, Bonavista and 47°N for summer (Templeman, 1975).

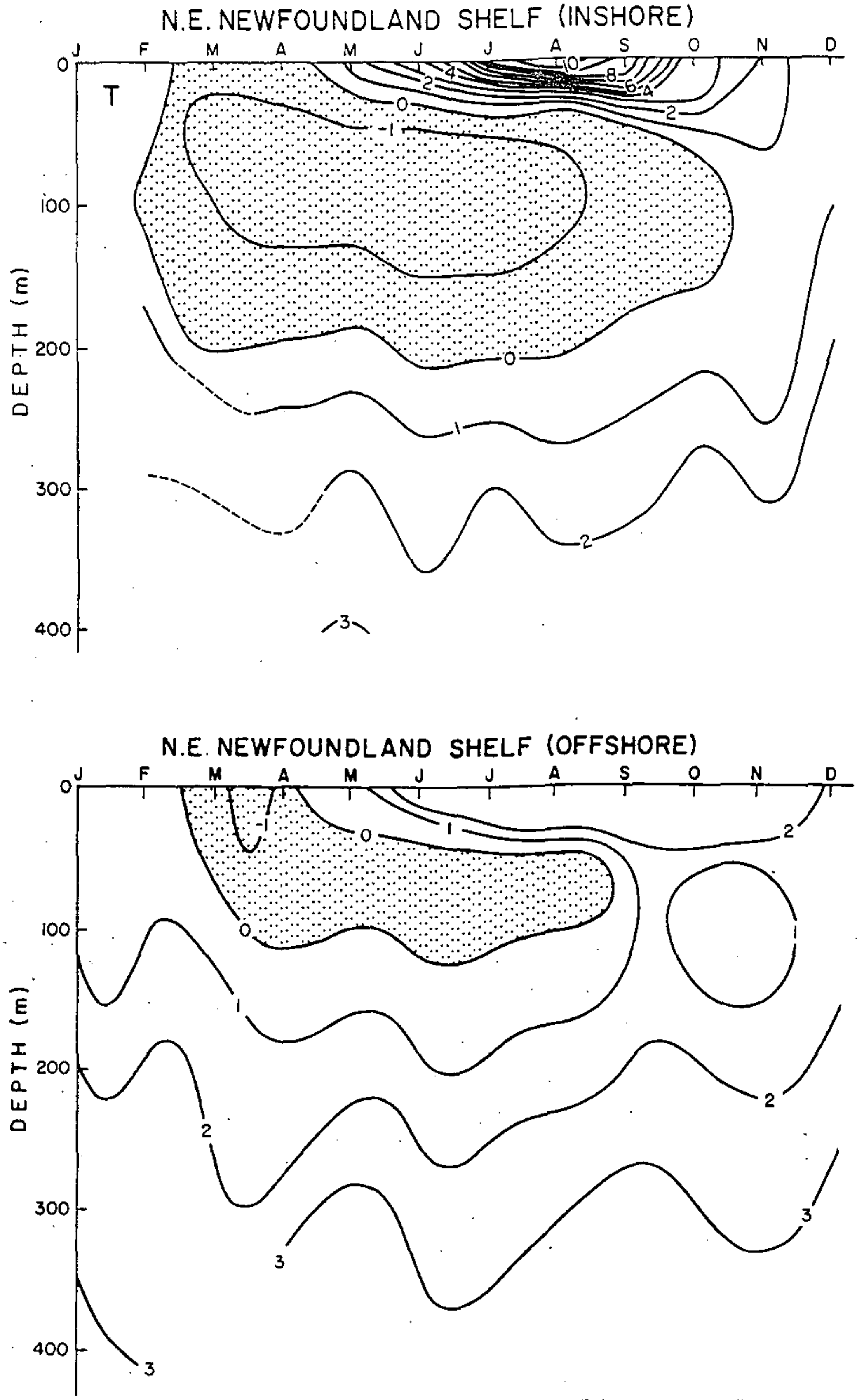
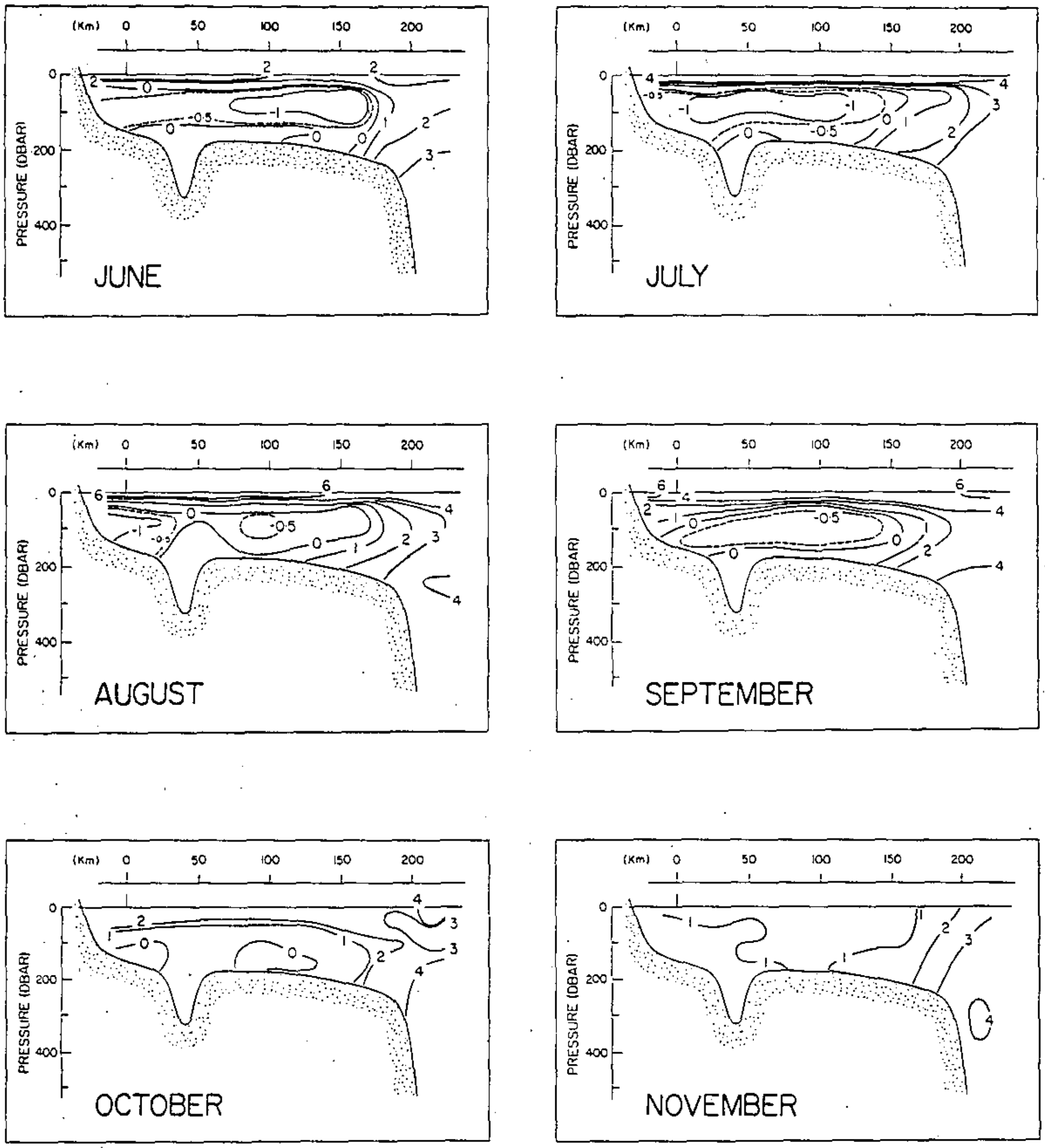


Fig. 1.2 Time series of temperature versus depth based on an analysis of archived bottle data (1910-1982) by Drinkwater and Trites (1986) for the inshore and offshore halves of the Northeast Newfoundland Shelf.



· HAMILTON BANK ·
(MEAN) TEMPERATURE PROFILE

Fig. 1.3 Monthly mean temperature sections for Hamilton Bank for June-November based on the MEDS bottle, XBT, BT and CTD data archive.

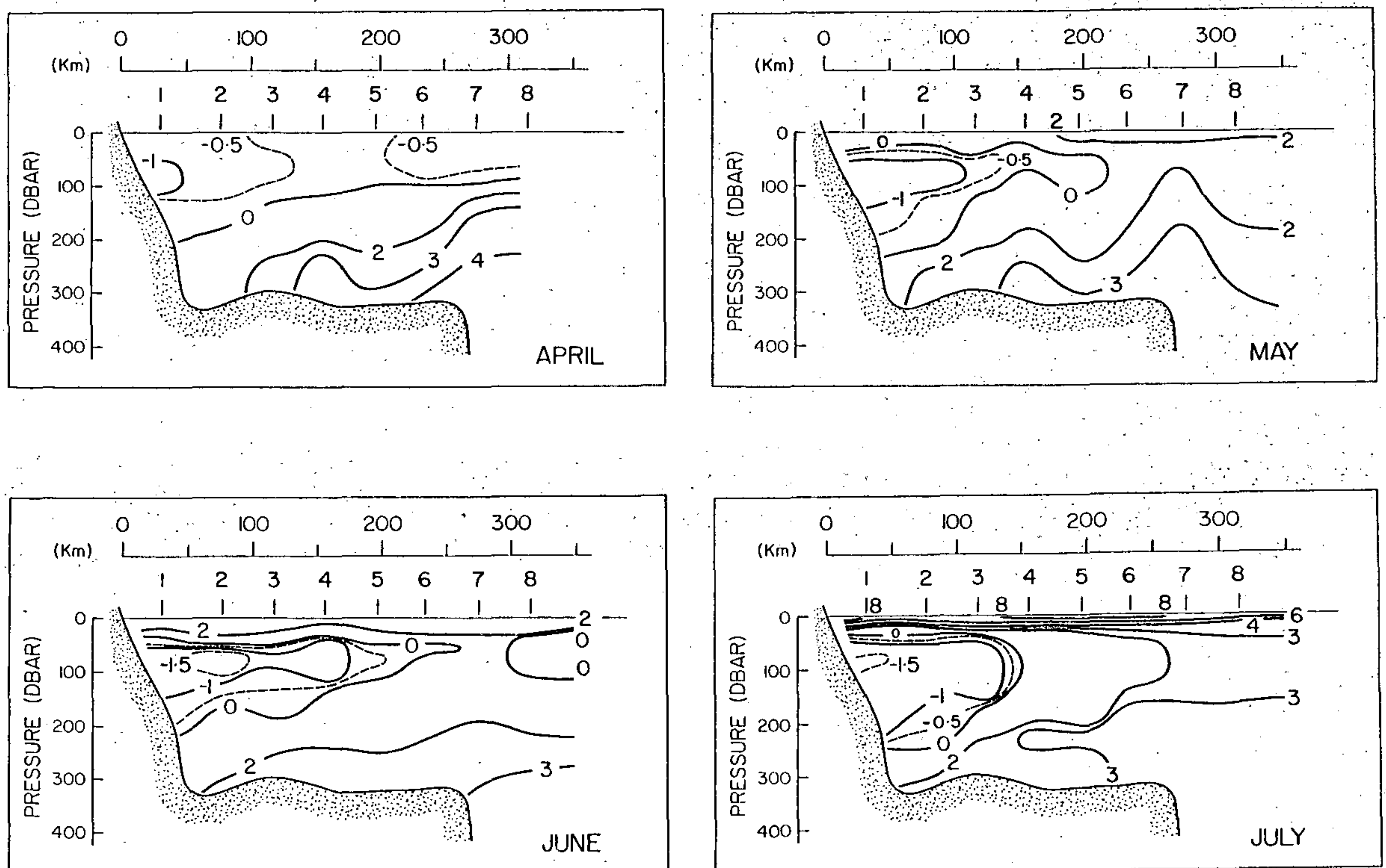


Fig. 1.4 Monthly mean temperature sections for Bonavista for April-November based on the MEDS bottle, XBT, BT and CTD data archive.

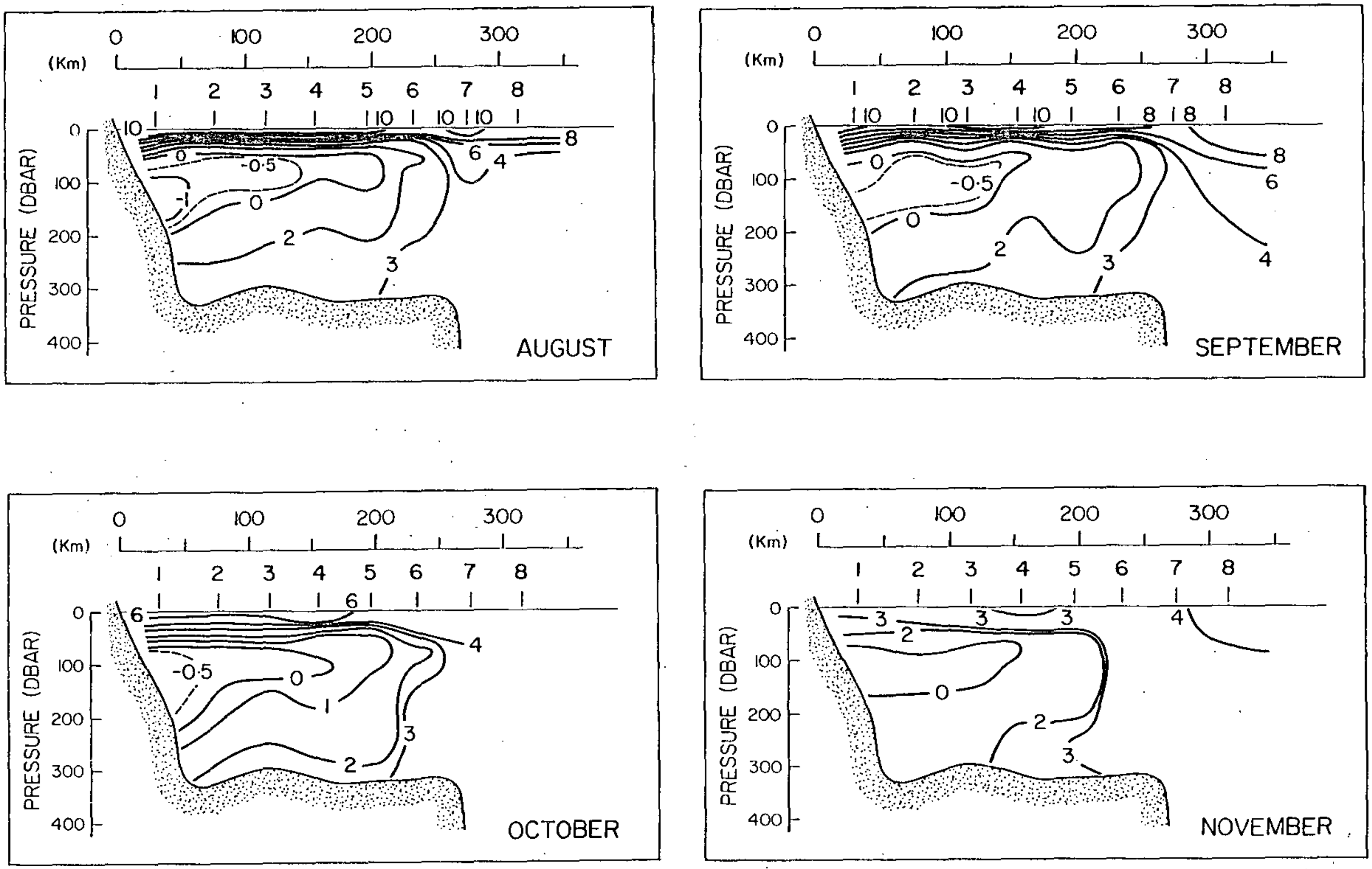


Fig. 1.4 Continued.

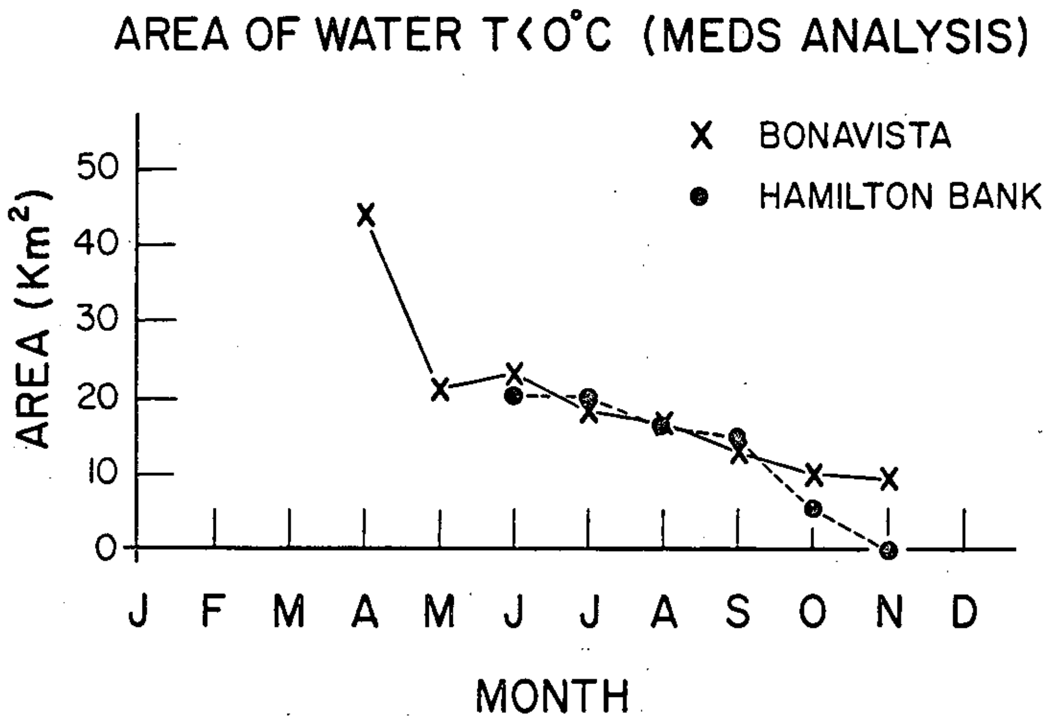
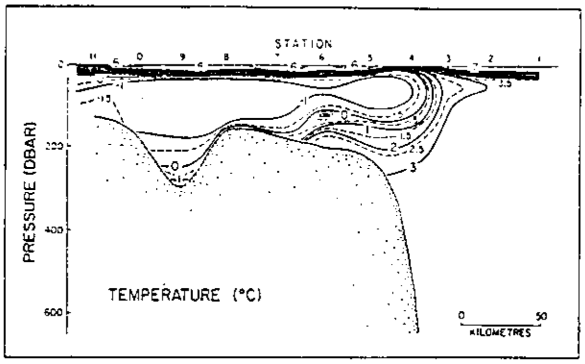
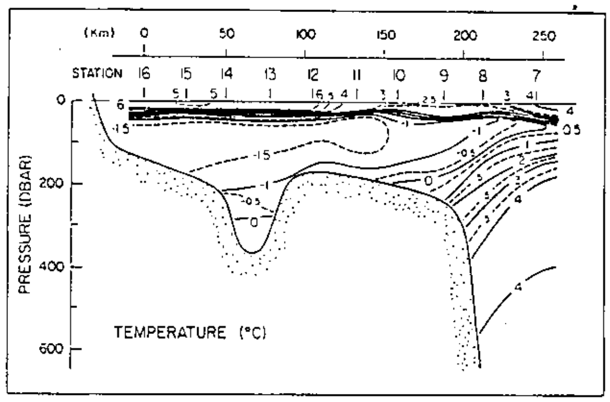


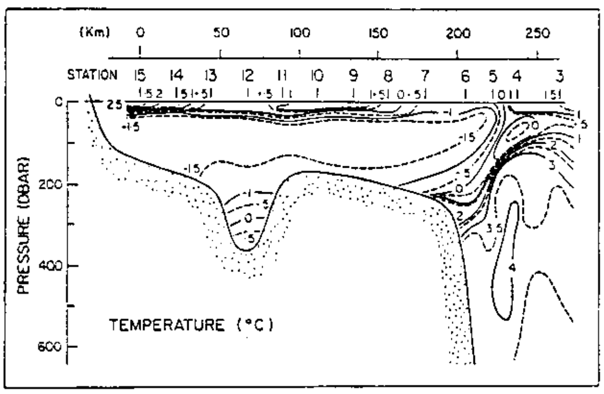
Fig. 1.5 Area of water with T < 0°C for the Hamilton Bank and Bonavista sections.



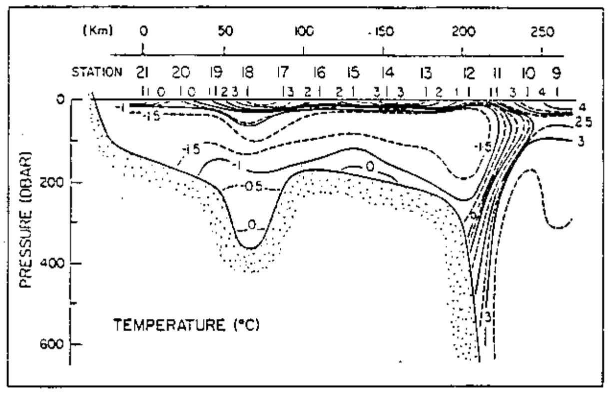
HAMILTON BANK (July 14-25 1980)



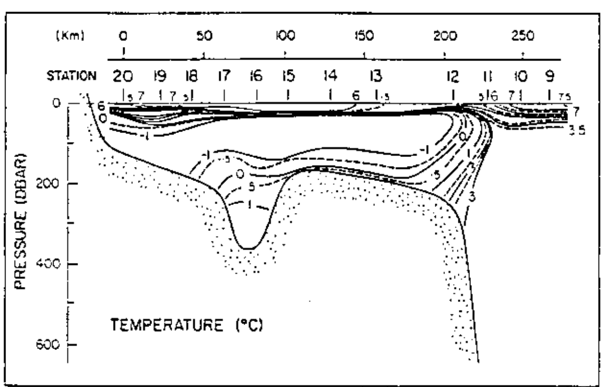
HAMILTON BANK (Jul.28-Aug.6 1983)



HAMILTON BANK (Jun.22-Jul.6 1984)



HAMILTON BANK (Jun.30-Jul.13 1985)



HAMILTON BANK (Jul.24-Aug.7 1986)

Fig. 2.1 Temperature sections from Hamilton Bank.

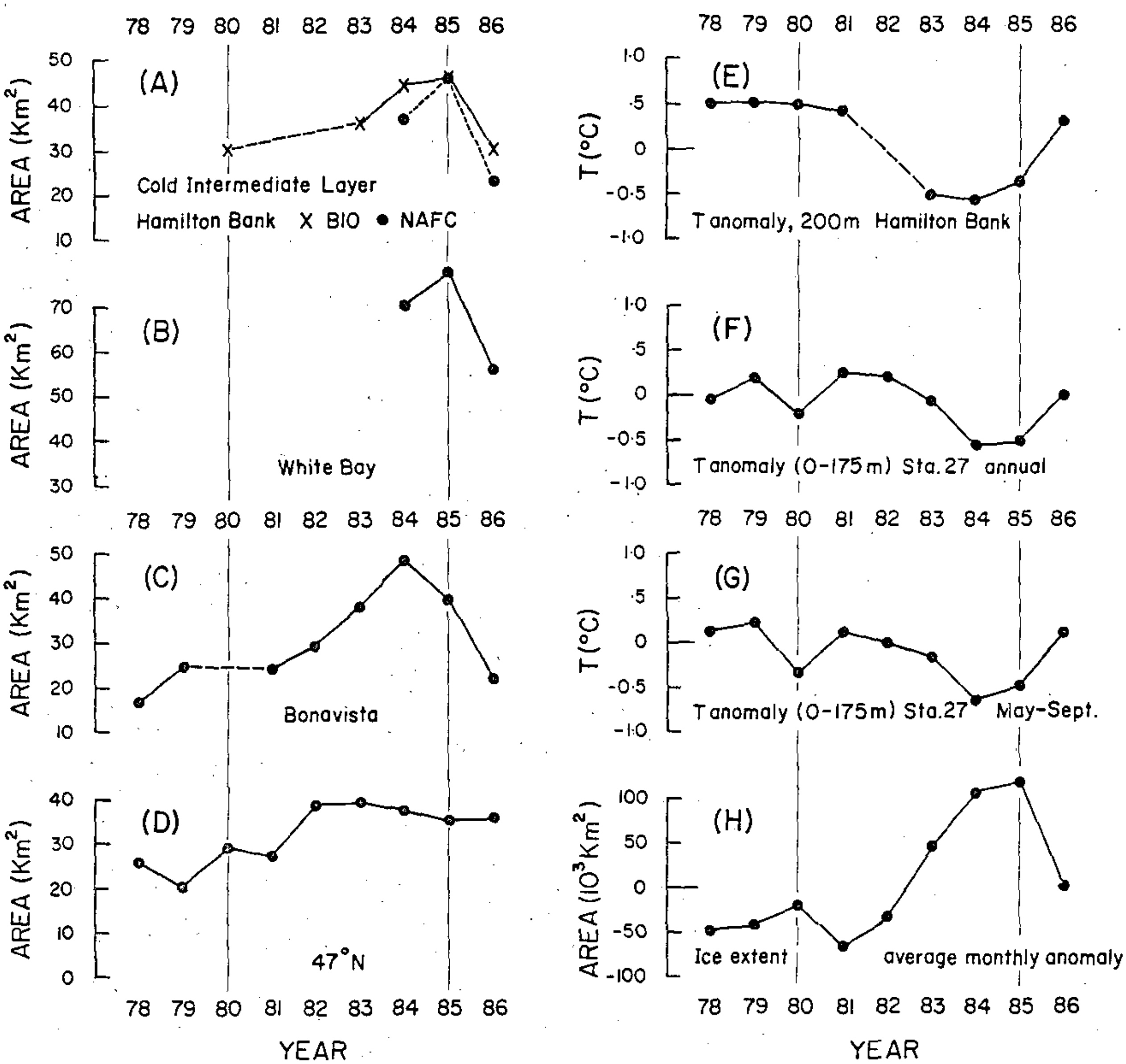


Fig. 2.2 a) Area of CIL, Hamilton Bank; b) Area of CIL, White Bay; c) Area of CIL, Bonavista; d) Area of CIL, 47°N; e) Annual temperature anomaly, 0-175 m, Sta. 27; f) May-Sept. temperautre anomaly, 0-175 m, Sta. 27; g) Annual temperature anomaly, 200 m, Hamilton Bank; h) Ice extent average monthly anomaly based on January-June observations.

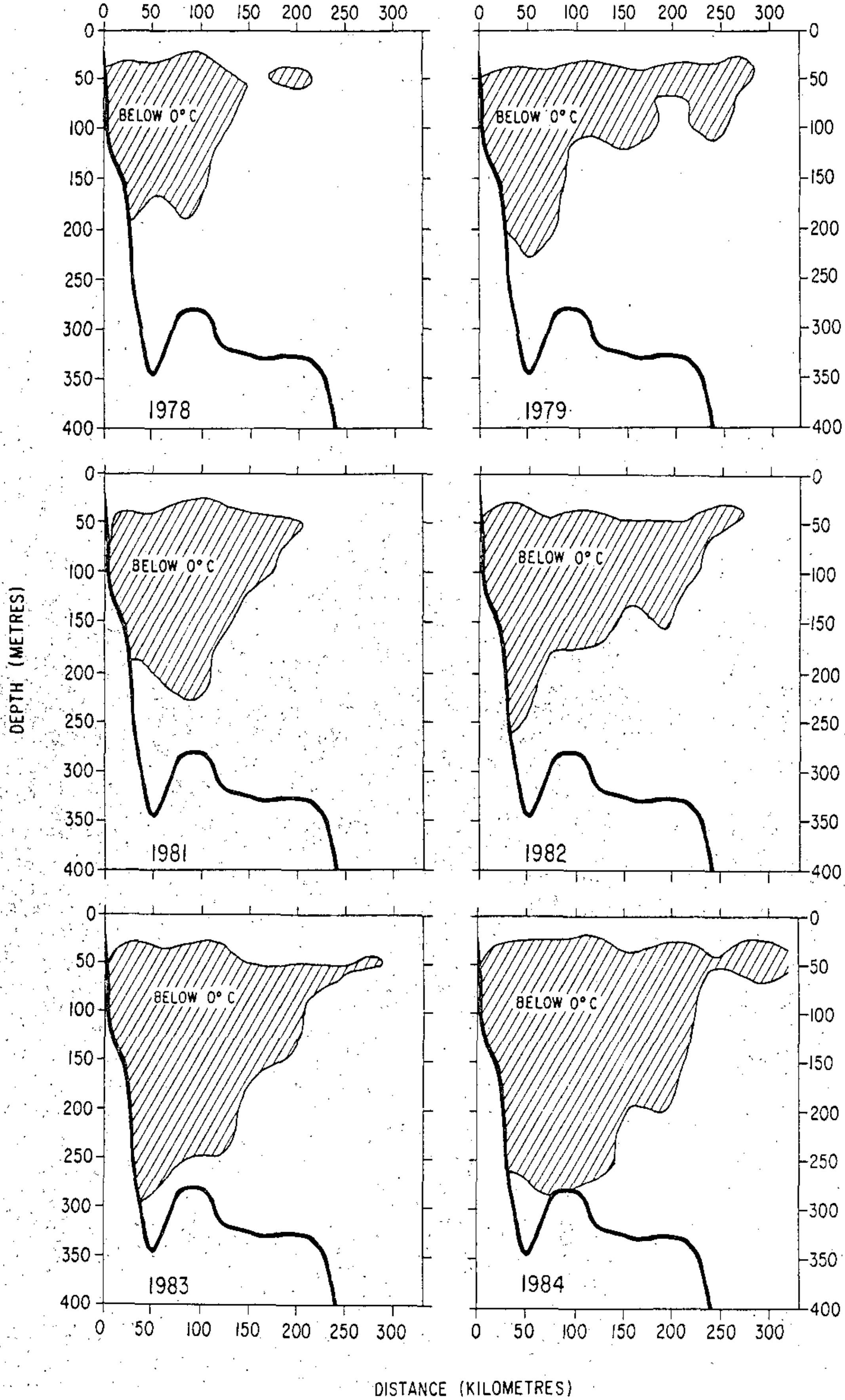


Fig. 2.3 Extent of the CIL off Cape Bonavista

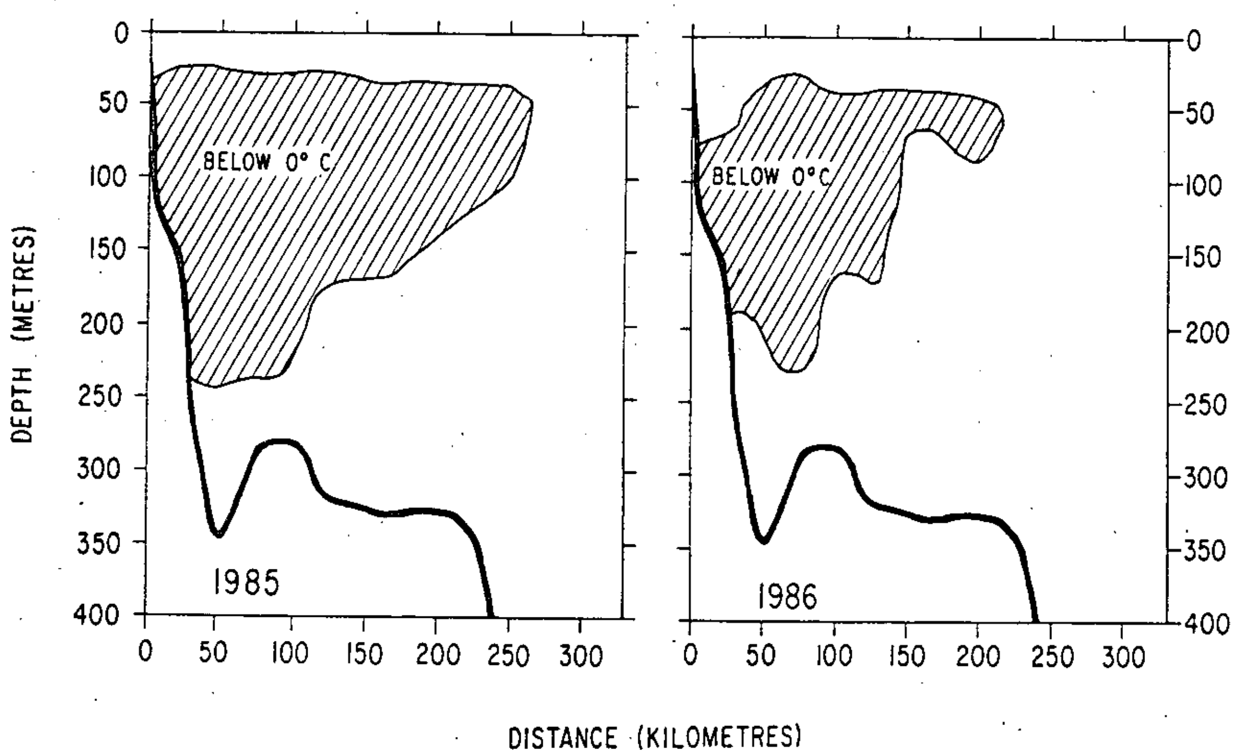


Fig. 2.3 Continued.

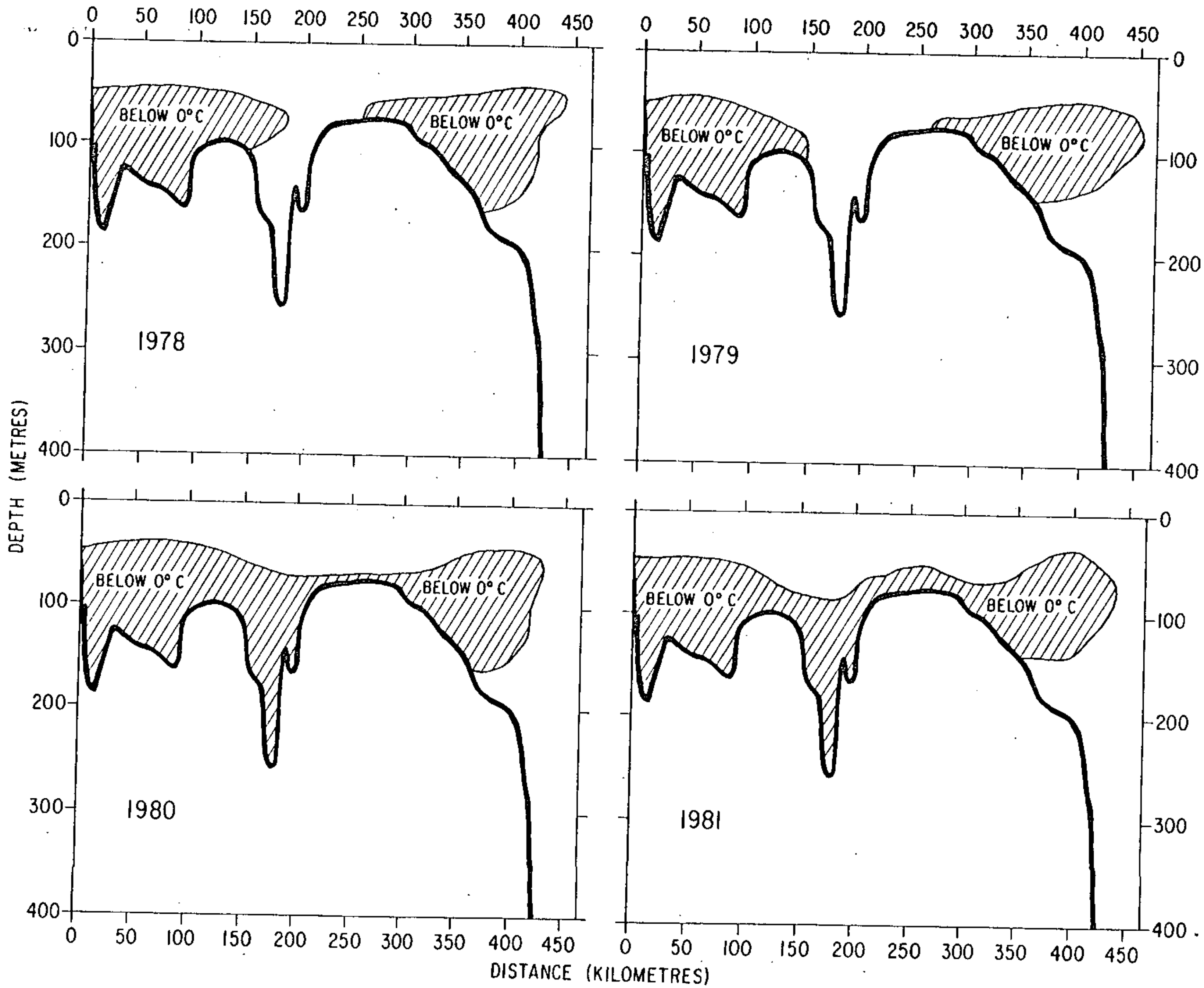


Fig. 2.4 Extent of the CIL along 47°N.

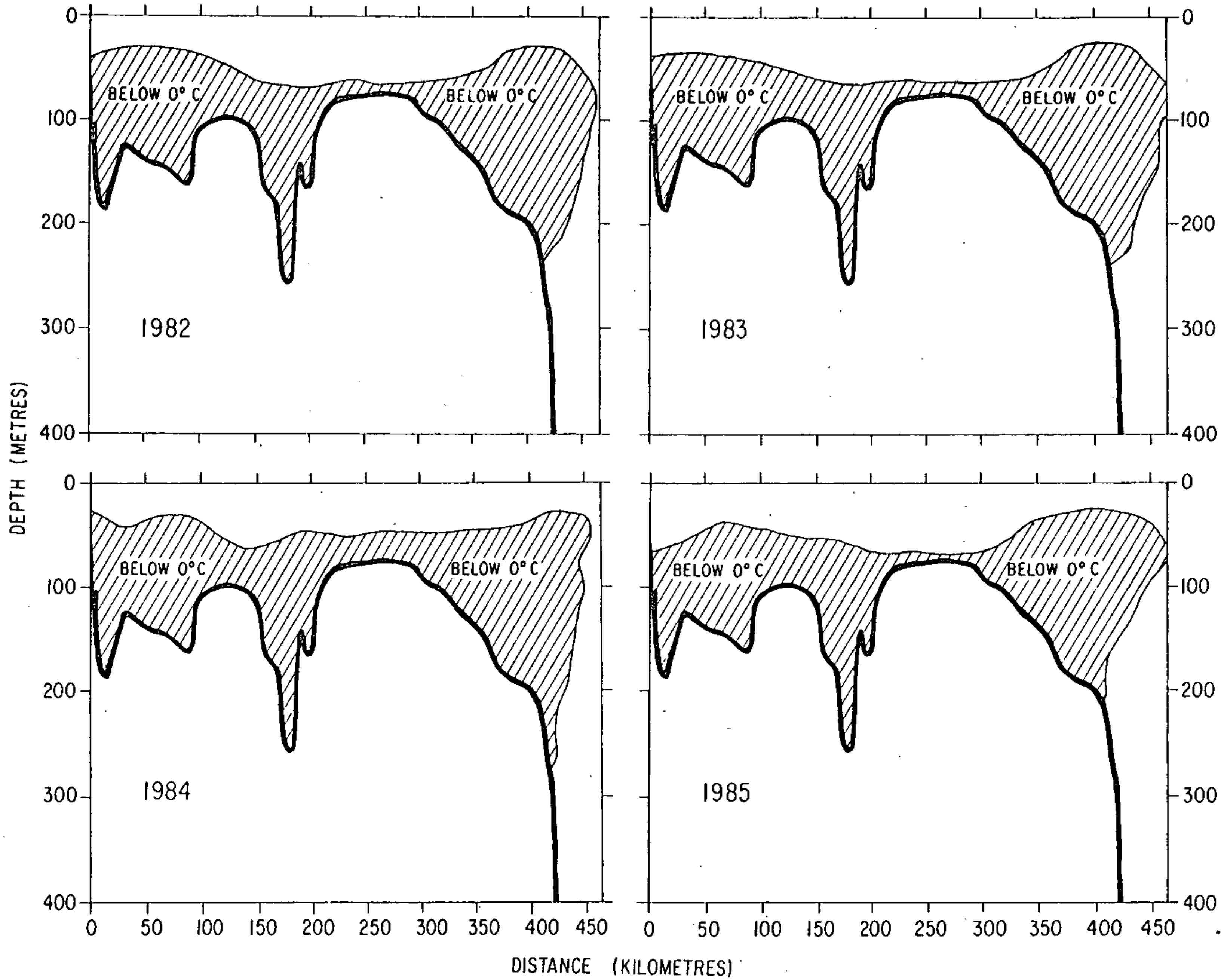


Fig. 2.4 Extent of the CIL along 47°N.

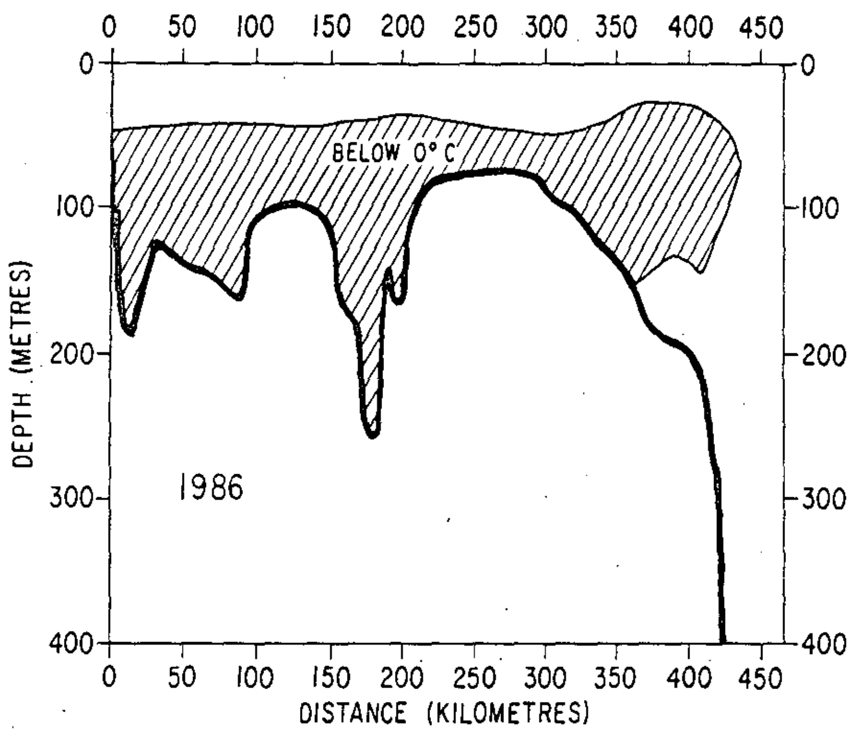


Fig. 2.4 Extent of the CIL along 47°N.

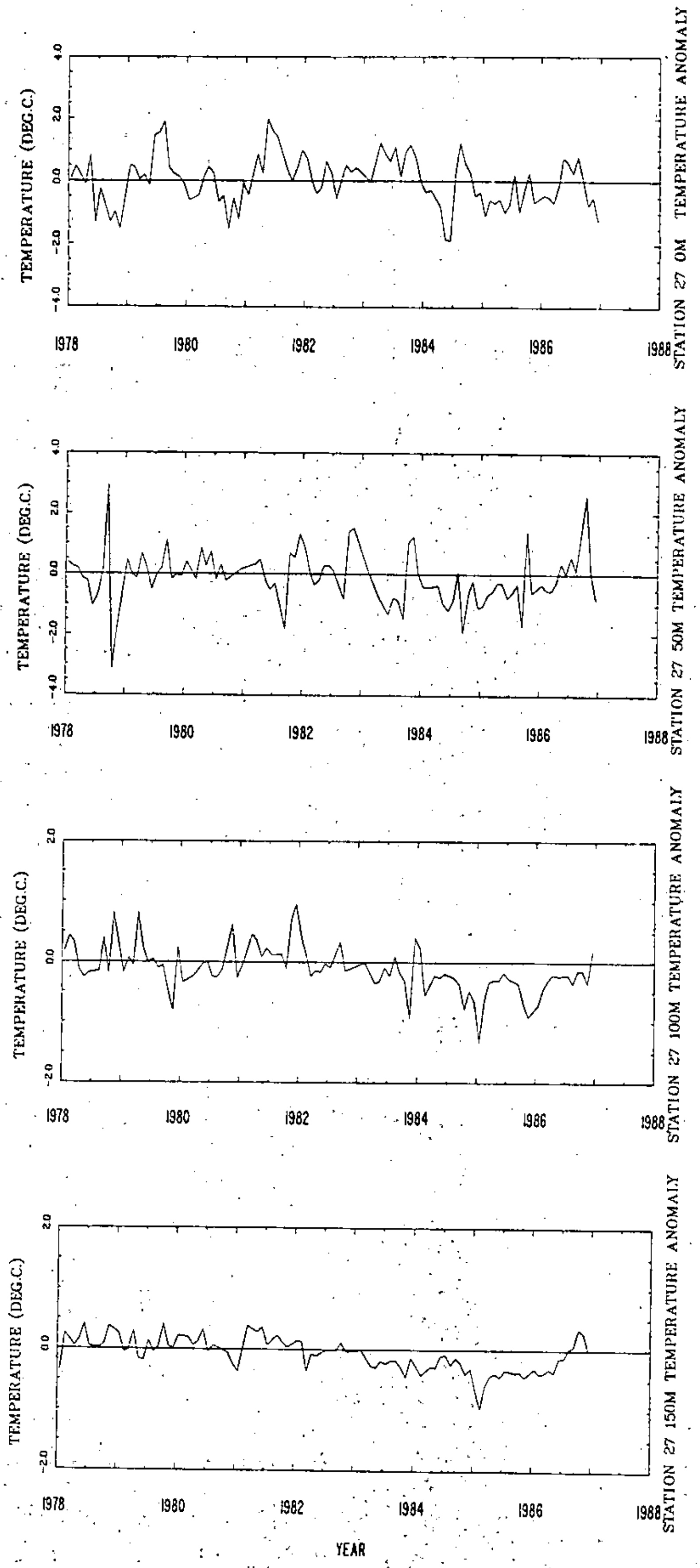


Fig. 3.1 Monthly temperature anomalies for Sta. 27 at 0, 50, 100 and 150 m.

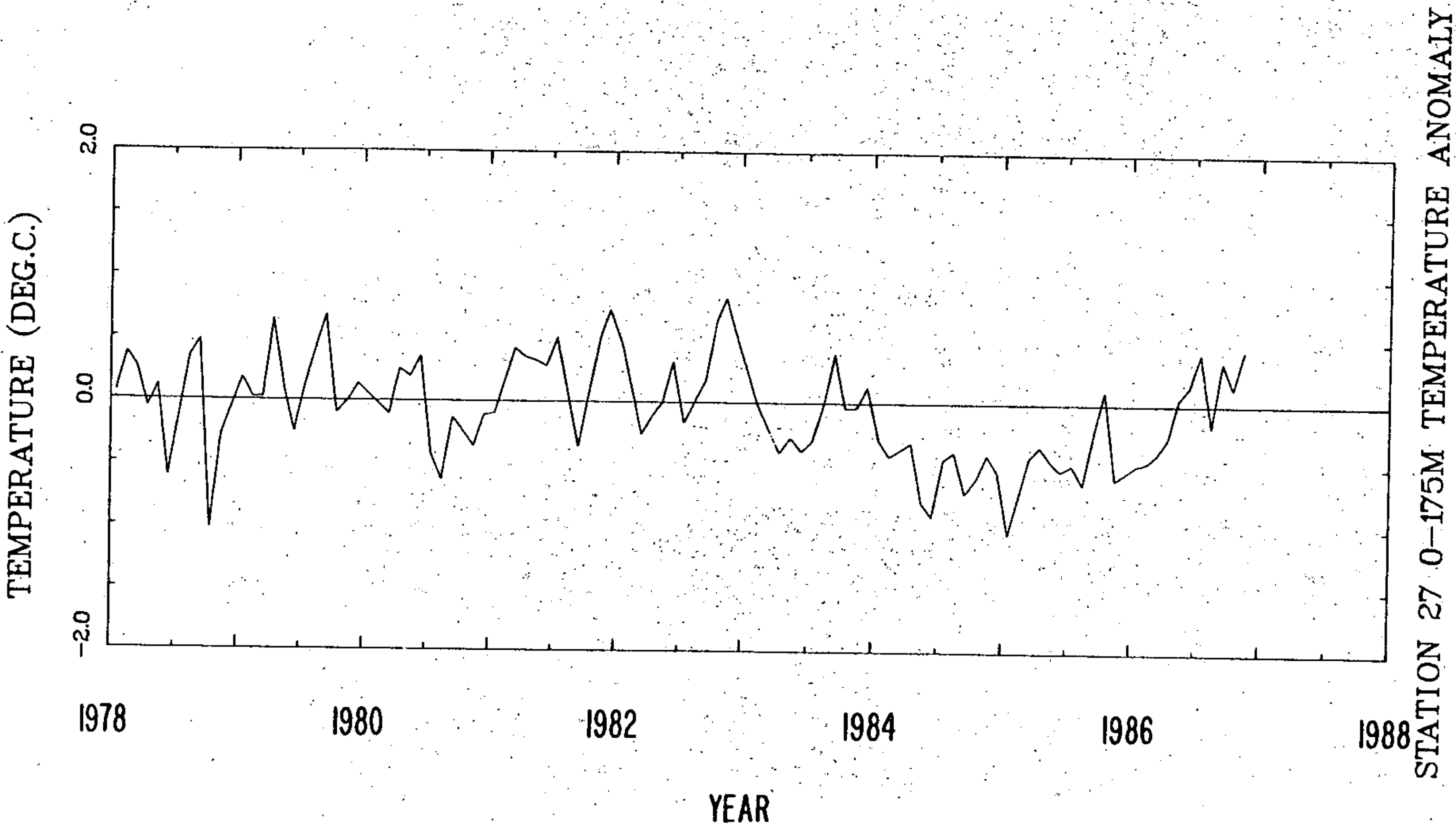


Fig. 3.2 Monthly temperature anomalies for Sta. 27 averaged over 0-175 m.

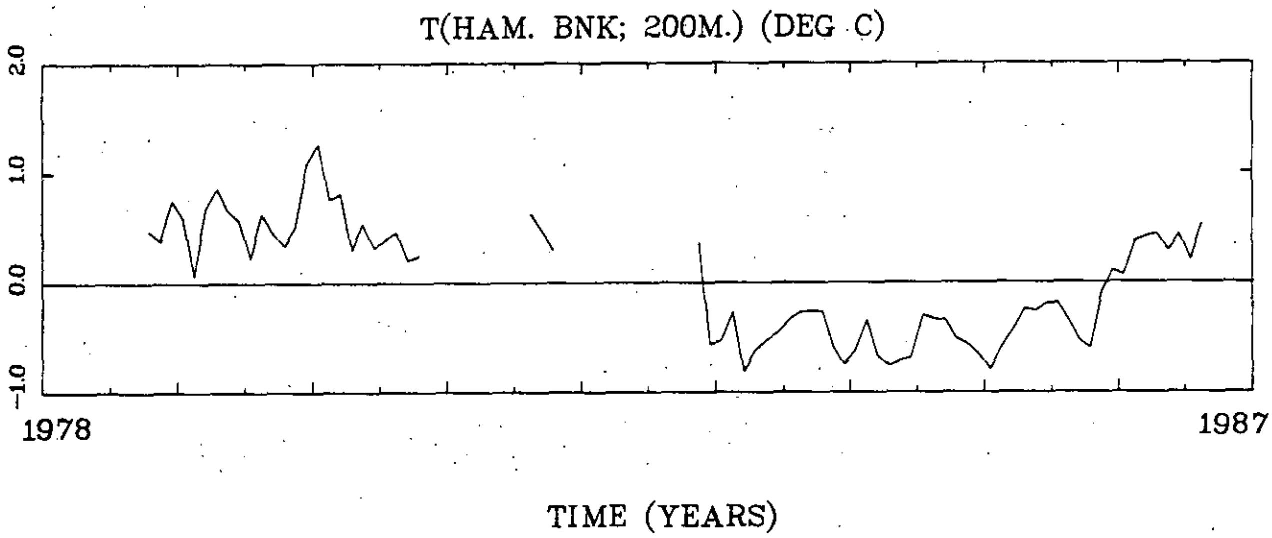


Fig. 3.3 Monthly temperature anomalies from a current meter at 200 m on Hamilton Bank.

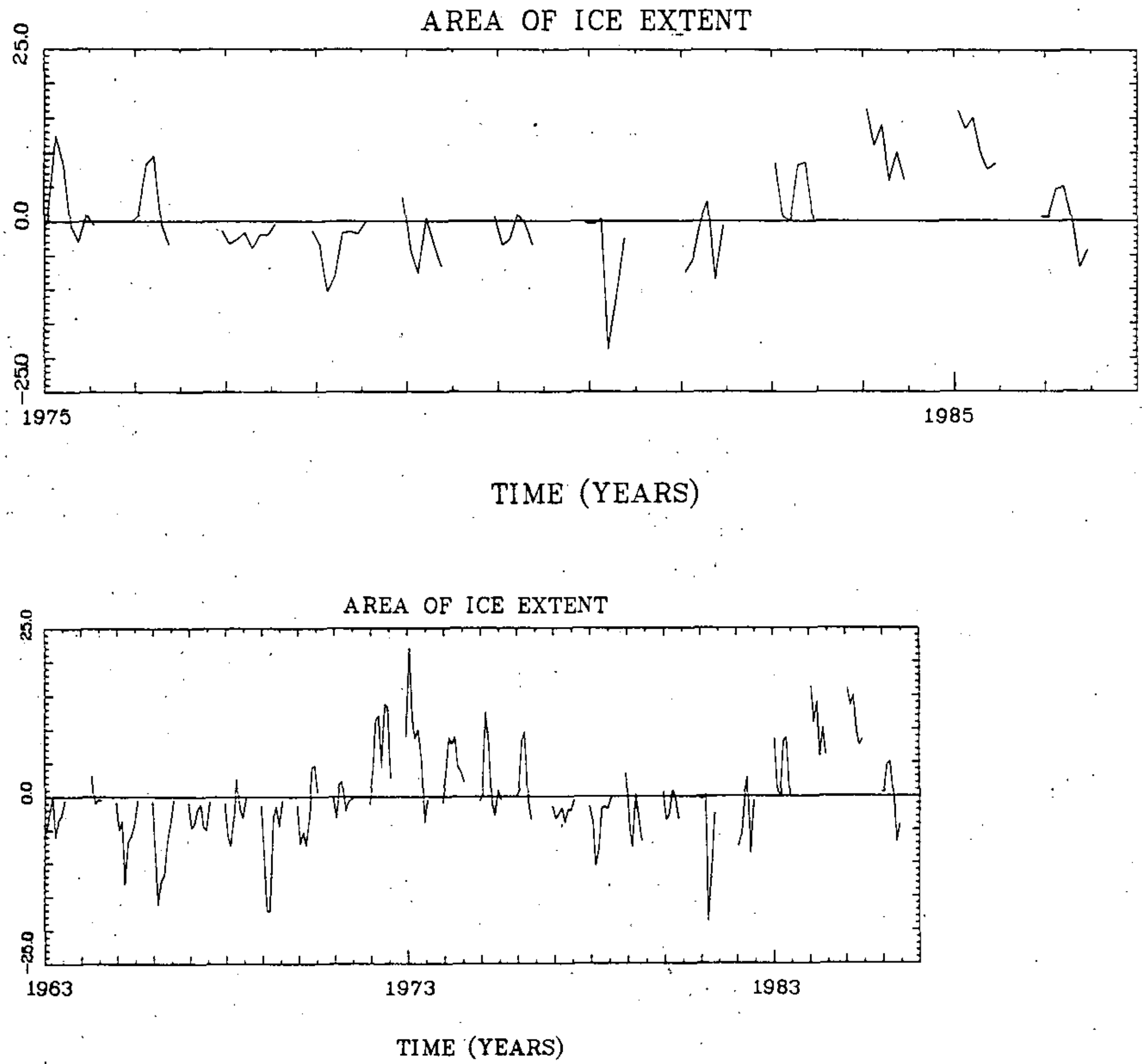
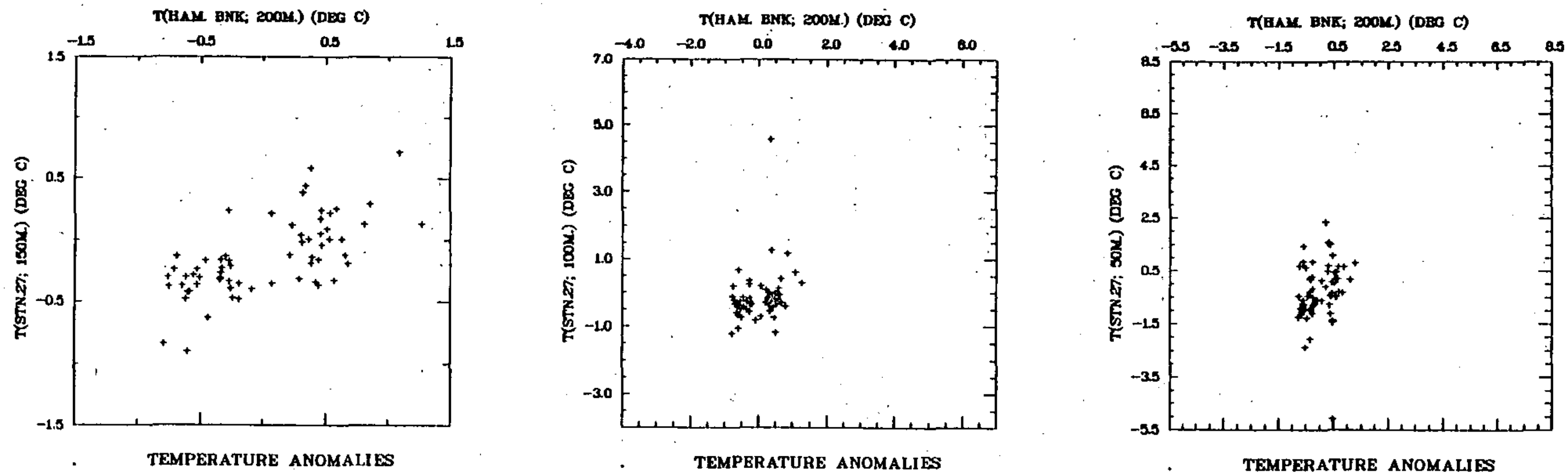


Fig. 3.4 Monthly anomalies of ice area in units of $10^4/km^2$.



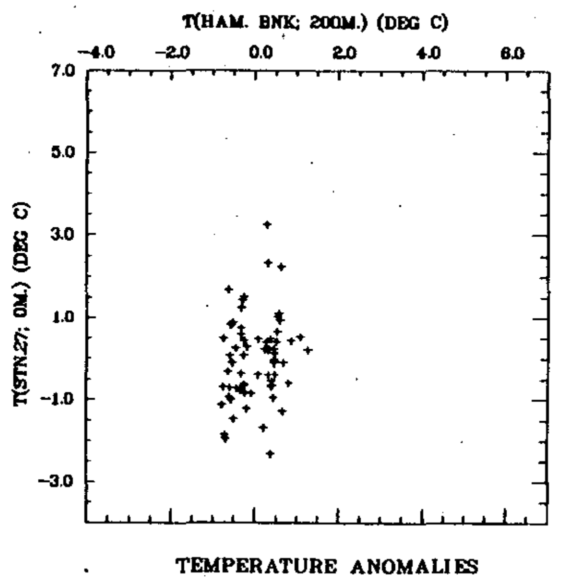


Fig. 4.1 Scatter plots of monthly temperature anomaly at 200 m Hamilton Bank versus Sta. 27 and 0, 50, 100 and 150 m.

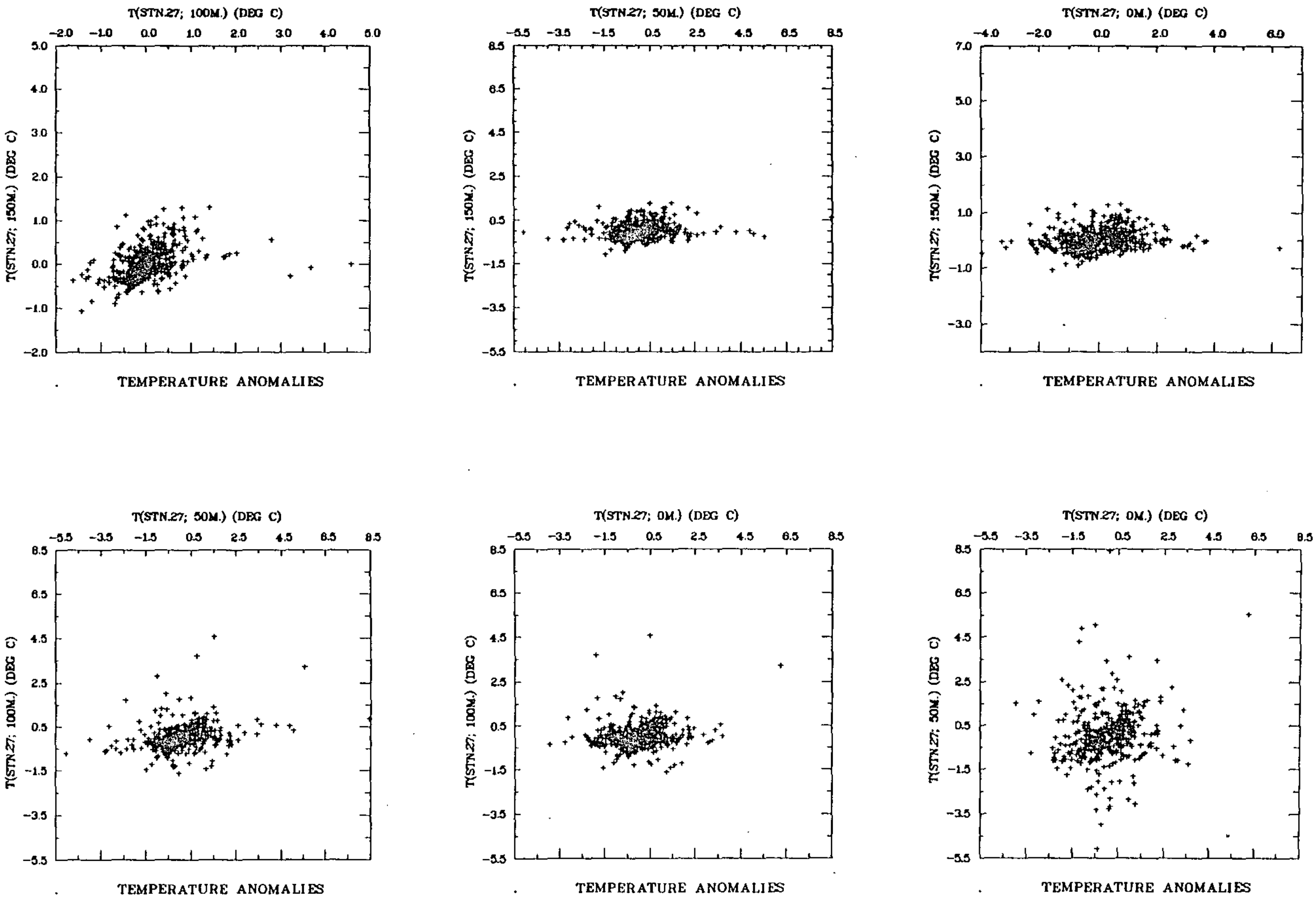


Fig. 4.2 Scatter plots of monthly temperature anomalies between all paris at Sta. 27 0, 50, 100 and 150 m.

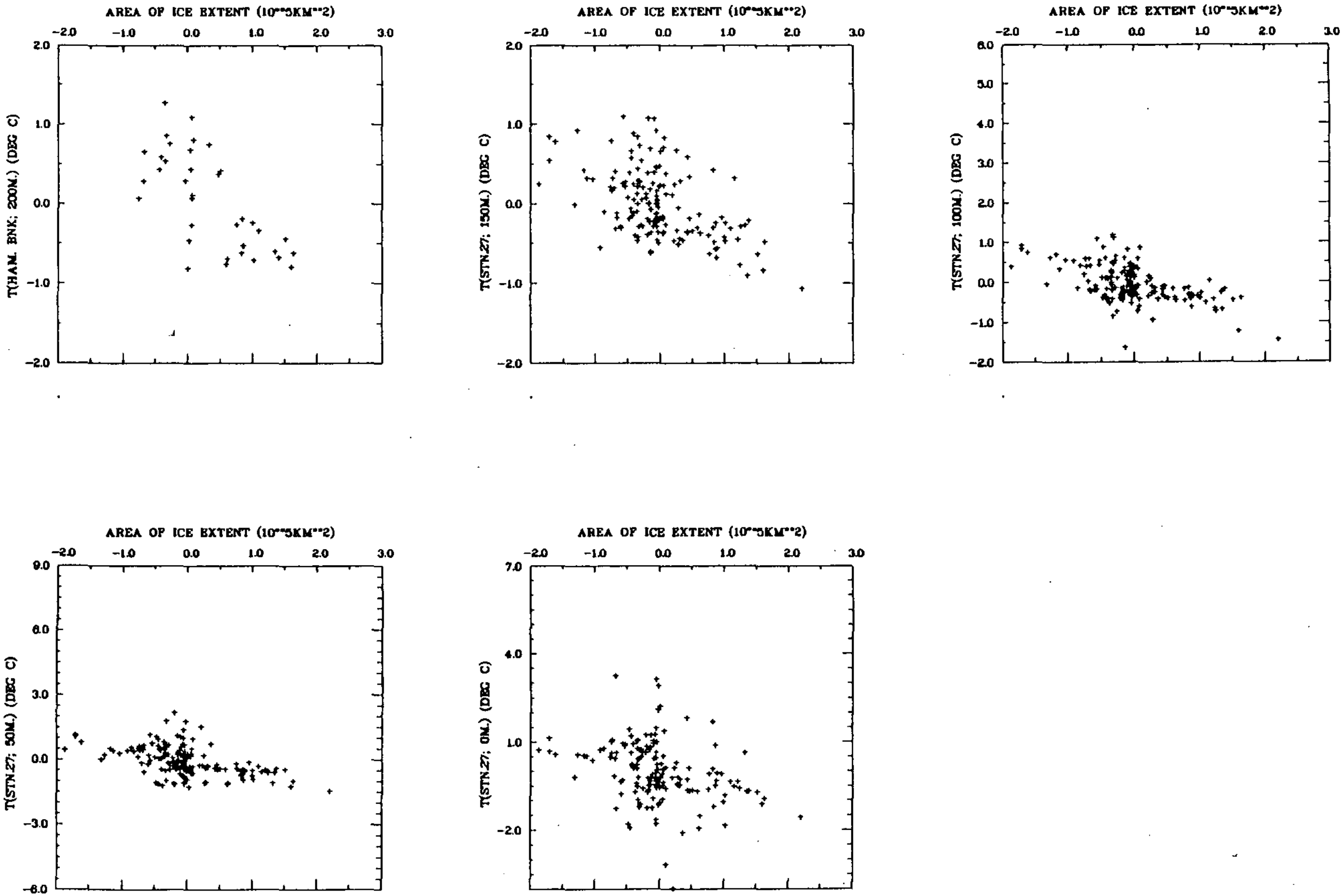


Fig. 4.3 Scatter plots of ice coverage with the monthly temperature anomalies at 200 m Hamilton Bank and at 0, 50, 100 and 150 m at Sta. 27.