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OVERVIEW OF THE ENVIRONMENTAL CONDITIONS IN THE GULF OF ST. LAWRENCE IN 1993

by

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ABSTRACT

We present an overview of the environmental conditions in the Gulf of St. Lawrence for the period between October 1992 and September 1993. The relevant meteorological conditions (air temperatures, heights of the 100 and 50 kPa surfaces, and precipitations) over eastern Canada are described. A select set of oceanogaphic observations (freshwater discharges, ice conditions and August-September water temperatures) for 1991, 1992 and 1993 is presented. The 1993 observations are compared to the long-term mean conditions presented by Petrie (1990), and the year to year (1991 to 1993) variability is discussed. We find that the winter of 1993 was among the 9% coldest winters since 1895, that the intermediate layer (30 to 100 m) waters were as much as 1.60°C colder than the long-term average, but that the Gulf waters have been, on average, slowly warming up between 1991 and 1993.

RÉSUMÉ

Le présent document contient un survol des conditions environnementales qui régnaient dans le golfe du Saint-Laurent d'octobre 1992 à septembre 1993, incluant les conditions météorologiques pertinentes (températures de l'air, hauteur des niveaux de 100 et de 50 kPa et précipitations) qu'a connues l'est du Canada pendant cette période ainsi qu'un ensemble d'observations océanographiques (écoulements d'eau douce, conditions de glace et températures de l'eau en août et septembre) pour 1991, 1992 et 1993. On compare les observations réalisées en 1993 aux conditions moyennes à long terme présentées par Petrie (1990), en traitant de la variabilité d'une année à l'autre (de 1991 à 1993). On en arrive à la conclusion que l'hiver 1993 a été parmi les 9 % d'hivers les plus froids depuis 1895, que la température de la couche d'eau intermédiaire (de 30 à 100 m) était inférieure à la moyenne à long terme, l'écart atteignant jusqu'à 1,60 °C, mais qu'en moyenne les eaux du Golfe se sont réchauffées lentement entre 1991 et 1993.

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1. INTRODUCTION

This report provides an overview of the environmental conditions in the Gulf of St. Lawrence for the period between October 1992 and September 1993. The review is based on the *Perspectives Climatiques* published monthly by the Atmospheric Environment Service of Canada (see references), on the weekly charts of sea ice observations from Ice Central of Environment Canada, and on the profiling data (CTD/STD) gathered by the personnel of the Gulf, Scotia-Fundy and Québec Regions of the Department of Fisheries and Oceans (Fig. 1). Where possible, the environmental conditions are compared to the 30-year base period (long-term means) from 1951 to 1980, in accordance with the convention of the World Meteorological Organization, the recommandation of the Northwest Atlantic Fisheries Organization (NAFO), and to the eleven previous NAFO yearly reports on the state of the environment in the Northwest Atlantic (see for example Drinkwater 1993, and Drinkwater et al. 1992). The Atmospheric Environment Service has now published the climatic means for the years 1961-1990 and will, in the next few months, use this new period as their long-term mean in the *Perspectives Climatiques*. In this report, we used the 1961-1990 period only for the river discharge data. Next year, we plan to use the 1961-1990 period as our long-term mean for all the observations.

2. METEOROLOGICAL CONDITIONS

2.1 Air temperatures

The Atmospheric Environment Service of Canada publishes the monthly mean air temperature anomalies for Canada in the *Perspectives Climatiques*. The anomalies are calculated relative to the 30-year mean 1951-1980. Over the Gulf of St. Lawrence (Fig. 2), negative anomalies persisted from October 1992 to March 1993, inclusively. The coldest anomalies (-6° C) occurred, as in 1992, in February from the west coast of Newfoundland to Baffin Island but extended further south than in 1992 (see Fig. 1 of Drinkwater 1993), reaching Baie des Chaleurs. The temperatures rose slightly above normal in April and May, fell below the long-term mean in June and July, to rise above the mean in August and September. The seasonally-averaged anomalies (Fig. 3) were systematically below average from September 1992 to September 1993. Even if the coldest anomalies (-8° C) of the last three years over the Gulf of St. Lawrence occurred in January 1991 on the southern Labrador coast (Drinkwater et al. 1992), the winter of 1993 was the coldest in the past three years. In the Atlantic provinces, the winter of 1993 was among the 9% coldest winters since 1895 (Service Atmosphérique du Canada 1993, February issue). In eastern Canada, the summer of 1993 was also colder than the long-term average but was warmer than the summers of 1991 and 1992. It is worthwhile to note that, for the whole country, the summer of 1992 was the 13th coldest summer since 1895, while the summer of 1993 was the 23rd warmest summer since 1895.

The southern extension of the cold air masses can also be seen in the monthly anomalies from six coastal stations (Fig. 4): Iqualuit, Cartwight, Sept-Iles, Stephenville, Charlottetown and Iles-de-la-Madeleine. The anomalies for February 1993 are larger than those for February 1991 and 1992 at Iqualuit, Cartwright and Iles-de-la-Madeleine (compare with Fig. 3 of Drinkwater 1993). The anomalies were as large as 6°C at Sept-Iles and Stephenville, and 5°C at Charlottetown. The anomalies at Iles-de-la-Madeleine may seem low, but they were calculated from daytime observations only and relative to the 1984-1993 base period, since the meteorological station was moved in 1983.

2.2 Precipitations

On the Atlantic coast and in the Great Lakes region (St. Lawrence's watershed), the precipitations were above average in the fall of 1992, the winter of 1992-1993 and the spring of 1993 (Fig. 5). This above average precipitation was caused by numerous travelling storms: thunderstorms in the fall, snowstorms in the winter and tropical storms (related to El Niño) in the spring. The summer of 1993 was also very wet: the north shore of the St. Lawrence River, the Gulf of St. Lawrence and southern Newfoundland received 50% more precipitation than the 1951-1980 average.

2.3 Sea surface air pressures

Large scale daily mean heights of the 100 kPa pressure surface (approximatively the sea-surface) were averaged for us by A. Caillet of the Atmospheric Environment Service of Canada (Canadian Climatic Center). The few missing days were replaced by the forecast for that day. The 100 kPa heights and 100 kPa height anomalies are presented in Figure 6. As expected, the seasonal pressure pattern over the North Atlantic is dominated by the combination of the Icelandic Low, between Greenland and Iceland, and the Bermuda-Azores High, between Florida and North Africa (Thompson and Hazen, 1983). Fall includes September 1992 to November 1992, winter covers December 1992 to February 1993, spring includes March 1993 to May 1993 and summer covers June 1993 to August 1993.

Besides a stronger Bermuda-Azores High than average, the situation over the North Atlantic (and the Gulf of St. Lawrence), in the fall of 1992, follows the long-term average. What the mean anomalies do not show is the regular alternance of cold arctic and warm air masses over most of Canada from September to November. In the winter of 1992-1993, the Bermuda-Azores High moved over the Algerian coast, while the Icelandic Low expanded and deepened, moving slightly westward but mostly northeastward to lie over the Barents Sea, with a secondary minimum over the Norwegian Sea. This configuration promotes strong northwesterly winds over the Labrador Sea and the Gulf of St. Lawrence. The situation was more or less back to normal in the spring: the Icelandic Low and the Bermuda-Azores High were back to their long-term mean position. A small positive anomaly over the Gulf of St. Lawrence brought stronger than average westerly winds. In the summer, the Bermuda-Azores High moved to the middle of the North Atlantic. This pattern would have brought southwesterly winds.

2.4 Upper atmosphere air pressures

Monthly heights and anomalies of height of the 50 kPa pressure surface (approximately 5 km above the earth's surface) over the northern hemisphere are published in the *Revue mensuelle des Perspectives Climatiques* (not shown). Of interest here, are the 50 kPa anomalies (Fig. 7), averaged for the summer of 1993 (June to August). The above average (50%) amount of precipitation in the summer of 1993 is related to a change in the high altitude circulation pattern which forced humid tropical air northward from the southern California coastal areas and the Gulf of Mexico to join the general circulation to the north. We can see on Figure 7 that this period is dominated by two anomalies: a negative anomaly (-4 dam) over the northwest United States and a positive anomaly over Québec (+6 dam). They caused a strengthening of the high (+5 dam) over the Pacific and of the low (-5 dam) over the North Atlantic (near Newfoundland): the high generally found over the Pacific moved over land. This circulation pattern brought an increase in the precipitations over the Atlantic coast and the Great Lakes region, and is also responsible for the floods in the Missisipi Valley.

3. SEA ICE OBSERVATIONS

Ice Central of Environment Canada in Ottawa produces weekly charts which provide information on the location and concentration of sea ice in the Gulf of St. Lawrence. These charts are based on plane surveys and ship-based observations, and may be compared with the long-term median, maximum and minimum positions of the ice edge for the years 1962 to 1987, published by Côté (1989). A study of the interannual variability of sea ice cover in the Gulf of St. Lawrence from 1963 to 1990 can also be found in Déry (1992). On Figure 8, the dashed line denotes the 1962-87 maximum extent of sea ice, the dotted line denotes the 1962-87 median, and the solid line indicates the 1993 ice edge, using the same notation as Drinkwater (1993). Note that the dates for the historical ice edge positions of Côté (1989) are all three days earlier than the dates for the 1993 sea ice maps.

Sea ice first appeared on December 14 in the St. Lawrence Estuary, and in a narrow band along most of the coastline in the northern and western parts of the Gulf. Most of this ice had melted on December 21, but reformed on December 28 and then started quickly expanding. On January 4 and February 1, Figure 8 shows that the ice edge laid between the median and maximum positions everywhere in the Gulf. Throughout the period of February 8 to March 22, ice exiting from the Gulf of St. Lawrence through Cabot Strait drifted towards the southwest and reached Nova Scotia's eastern shore. The maximum westward extension of the ice cover, a few tens of kilometers west of Halifax beyond the historical maximum, occurred on March 1 following the extremely cold month of February. After a short retreat, ice reappeared on Nova Scotia's eastern shore from April 5 to April 26. Meanwhile, the St. Lawrence Estuary had become almost completely ice free by March 29, and some ice lingered on the Magdalen Shallows and in the northeast Gulf throughout the month of April. The last presence of sea ice was reported on May 10 in the southwestern Gulf, and on June 14 in the northeast Gulf near the Strait of Belle Isle.

4. OCEANOGRAPHIC OBSERVATIONS

4.1 Freshwater discharge

The monthly freshwater discharge of the St. Lawrence Estuary is presented in Figure 9 where the different components of RIVSUM (St. Lawrence, Outaouais and Saguenay Rivers) are plotted separately and where the Carillon curve is offset by +2000 $m^3 s^{-1}$ for clarity. The long-term means were calculated using the period 1961-1990 (1962-1990 for Carillon). While the Outaouais (April) and Saguenay (May) 1993 peak discharges were slightly above average and below average respectively, the Cornwall discharge was systematically above average from August 1992 to September 1993. Even if the 1993 discharge values are preliminary, the May and June 1993 values are 2500 $m^3 s^{-1}$ (32%) above average. This higher discharge is probably related to the higher than average precipitations in the Great Lakes region for the 1992-1993 period.

4.2 Water temperatures and salinities

A meteorological buoy has been moored in the northwest Gulf of St. Lawrence (see Figure 1 for location) by the Atmospheric Environment Service of Canada, in collaboration with the Department of Fisheries and Oceans and the Canadian Coast Guard. This buoy has been operational for the last three navigation seasons (April to November 1991, 1992 and 1993). The monthly averaged air and water temperatures from this buoy are presented in Figure 10. The monthly means were obtained by averaging the hourly observations. The air and water temperatures both reflect the climatic variations over the past three years: 1992 was the coldest year since a long time (coldest month of July of the century in Ontario) while the summer of 1993 was warmer than in the previous years. We also note that, in the summer of 1993, the air and water temperatures were much closer to each other than in the previous two years.

All the available CTD profiles gathered in water deeper than 200 m, in a box of 1° latitude by 1° of longitude centered on the meteorological buoy, were averaged and are presented in Figure 11. Sixteen profiles were available for 1991, six for 1992 and seven for 1993; all the observations were obtained between August 28 and September 15 of each year. We note that the surface layer (0-40 m) was colder in 1992 (coldest year) and fresher in 1993 (wettest year). We also note that the water between 60 and 240 m was slightly colder and fresher in 1991. At 120 m, for example, the water was 0.6°C colder and 0.25 psu fresher in 1991 than in 1992 and 1993. The water below 250 m was slightly colder in 1992 and 1993 than in 1991.

In order to prepare an overview of the oceanographic conditions in the Gulf of St. Lawrence, we gathered all of the available (by opposition to existing) CTD observations for the summers of 1991 (197 casts), 1992 (189 casts) and 1993 (387 casts). The profiles were quality-controlled and standardized. They were sorted by Petrie boxes (Petrie 1990) and averaged by layer (0-30 m, 30-100 m, 100-200 m, 200-300 m, and > 300 m) to enable us to compare the 1993 observations to the monthly mean temperatures and salinities computed by Petrie (1990) for the Gulf of St. Lawrence. There are seventeen original Petrie boxes. We added an eighteenth box to cover the Baie des Chaleurs area. This ensemble of eighteen boxes will hereafter be called the "Petrie boxes". They are shown in Figure 1. The names of the boxes and the number of profiles in each box are given in Table 1. In this report, we will concentrate on the 1993 observations, obtained during the Needler's yearly groundfish stock assesment fall surveys: between August 18 and September 9 in the northern Gulf (DFO: Québec Region survey) and between September 10 and 25 in the southern Gulf (DFO: Gulf Region survey). In 1991 and 1992, the northern Gulf groundfish stock assesment surveys were from August 25 to September 16 and from August 11 to September 1, respectively. The reader must consider these observations with care; more data is needed for a systematic interannual study. We are now gathering all the historical data for such a study.

The next four figures (Figures 12, 13, 14 and 15) present the average temperature in each of the first four layers in 1993: 0-30 m, 30-100 m, 100-200 m and 200-300 m. For each layer and each Petrie box, a mean value was computed; the mean values were then contoured. These mean temperatures, together with Petrie's September mean temperatures, are given in Table 2. For the sake of completeness, the mean salinities in each layer are given in Table 3. The mean temperatures for 1991 and 1992, averaged by layer, are given in Table 4. In the 30 to 100 m layer, the coldest temperatures in 1993 were found in the Laurentian Channel (boxes 9 and 10), near the Belle Isle Strait (box 3) and in the Northwest Magdalen Shallows (box 12). The coldest waters in the 100 to 200 m layer were found in the northeastern Gulf (boxes 4 and 5). In the 200 to 300 m layer, the warmest waters were found in Cabot Strait (boxes 1 and 2), indicating the intrusion of warmer (and saltier) Atlantic waters.

Figures 16 to 19 present the deviation, in each of the first four layers, from the long-term September averages computed by Petrie (1990). Petrie's mean values are given at standard depths (0, 10, 20, 30, 50, 75, 100, 125, 150, 175, 200, 225, 250, 275, 300 and 400 meters); we averaged the September means by layer. Because seasonal changes of temperature were not taken into account at this stage of our analyses, the reader should be extremely careful in interpreting Figure 16 and, to a lesser extent, Figure 17. However, let us mention here that in the 30 to 100m layer, the coldest waters were found in the Laurentian Channel (boxes 9 and 10), where the average temperatures in 1993 (-0.17°C and -0.06°C, respectively) are more than 1°C colder than the long-term averages (1.10°C and 1.55°C, respectively); the largest anomalies were found near the Belle Isle Strait (boxes 3 and 4) where the temperatures were more than 2.2°C lower than the long-term average. The 100 to 200 m layer was colder than average everywhere, except in Cabot Strait West (box 1). A very strong positive anomaly was also seen in the Cabot Strait area in the 200 to 300m layer (Figure 19).

The next four figures illustrate the year to year variations in the 100 to 200 m and 200 to 300 m layers. Figures 20 and 22 present the differences between 1993 and 1992 (1993 minus 1992), while Figures 21 and 23 present the differences between 1992 and 1991 (1992 minus 1991). We see that the Gulf deep waters (> 100 m) were generally warmer in 1993 than in 1992, and were also slightly warmer in 1992 than in 1991, although the differences are often so small that they may not be significant. Table 5 presents a "bulk" picture of the interannual variability over the last three years. From it, we can see that, even if the Gulf waters in the 30 to 200 m layers were much colder in 1991, 1992 and 1993 than the long-term average, they are slowly warming up: the cooling must have happened before or in 1991. These results confirm the recent cooling episode referred to in D'Amours (1993). Based on the decadal changes presented in Bugden (1991; see his Figure 5), we suggest that the cooling observed in the 200 to 300 m layer (see Table 5) must have started after 1989, since his 200 to 300 m mean temperatures for 1988 and 1989 are greater than 5.5°C. More data and a more careful study are clearly needed, especially in the deep layer of the Laurentian Trough and in the Magdalen Shallows. Our choice of layers (30-100 m and 100-200 m) is probably not adequate for a careful study of the variability in the Magdalen Shallows; we plan to refine it next year.

4.3 Cold intermediate layer (CIL)

The cold intermediate layer (CIL) of the Gulf of St. Lawrence is a cold (up to -1°C or -2°C) and salty (31.5 to 33 psu) layer that can extend from about 30 m to 125 m. It is defined here as waters with temperature less than 0°C. During winter, the surface layer disappears and the cold layer extends to the surface. Therefore, the CIL is largely produced by *in situ* winter cooling, but a fraction of its volume, about 35% according to Petrie et al. (1988), comes from the Labrador shelf waters entering the Gulf through the Strait of Belle-Isle. This cold layer can be found all over the Gulf of St. Lawrence and the Lower St. Lawrence Estuary, up to the Head of the Laurentian Trough.

Maps of the thickness of the cold intermediate layer for August-September 1991, 1992 and 1993 are presented in Figures 24, 25 and 26, respectively. The maximum thickness is found, every year, near the Strait of Belle-Isle (Petrie boxes 3, 4 and 5). It is thicker in the Laurentian Channel (boxes 9 and 10) than in the Cabot Strait, and the thickness decreases towards the Head of the Laurentian Trough. In general, the thickness of the layer has systematically decreased since 1991. This decrease in thickness of the CIL of the Gulf of St. Lawrence over the past three years is consistent with the decrease in area of the CIL observed on the Labrador and Newfoundland shelves (Drinkwater 1993). The average temperature of the CIL (not shown) presents a different behaviour. The western part of the system (boxes 5, 6, 7 and 8: Estuary and western Gulf) has slowly warmed up since 1991, while the eastern parts (boxes 1, 2, 3 and 4: the Cabot and Belle-Isle Straits) cooled down. The temperature of the CIL in the central portion of the Gulf (boxes 9 and 10: between Anticosti Island and the Magdalen Shallows) remained unchanged (within about 0.04°C). We have to be careful about the interpretation of the data because the differences are often small and may not be significant. Further studies are needed.

5. SUMMARY

The extremely cold winter of 1992-1993 resulted in extensive ice formation in the Gulf.

The areal extent of sea ice was systematically larger than the median extent (1962-1987) and close to the maximum extent recorded. Although the temperature of the Gulf as a whole has been slowly increasing over the past three years, temperatures 2°C colder than the long-term average were observed in the Belle Isle Strait area in 1993. The higher than average precipitations in the Great Lakes and Gulf regions caused a 30% increase in the freshwater discharge at Cornwall and a slight decrease in the surface salinities in the Gulf (not shown). An "in depth" analysis of the historical interannual variability of physical properties in the Gulf of St. Lawrence is overdue. To do that, we need long time series (ie: a permanent monitoring program) and a better monthly coverage of the Gulf. The data exist but are dispersed. We urge everyone to send their historical data to MEDS (Marine Environment Data Service), in Ottawa, or to us (c.o. B. Pelchat) at the Maurice Lamontagne Institute.

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The meteorological buoy data were made available to us by Roger Gauthier of the Environment Service of Canada (Scientific Services Division, in Ville St-Laurent, Québec). Alain Caillet of the Atmospheric Environment Service of Canada (Canadian Climatic Center, in Downsview, Ontario) graciously computed and prepared the 100 kPa heights and anomalies of height maps. The river discharge data were made available to us by Roger Couture of the Services Hydriques du Gouvernement du Québec. Thanks to everyone.

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TABLE 1

The eighteen boxes used in this study. The first seventeen are the original Petrie boxes. This ensemble of boxes or areas will be called "Petrie boxes". The first column gives the box number, the second column the box name, the last three columns give the number of CTD profiles available for August-September 1991, 1992 and 1993. The latitudes and longitudes of the corners of the boxes are given in Petrie (1990).

Box #	Name	1991	1992	1993
1	Cabot Strait West	8	4	19
2	Cabot Strait East	14	15	20
3	Esquiman Channel, NFLD	41	34	40
4	Esquiman Channel, Québec	26	27	32
5	Jacques Cartier Passage	25	26	27
6	Northwest Gulf	31	22	15
7	Estuary	9	13	12
8	Gaspé	13	17	26
9	Laurentian Channel Anticosti	17	15	17
10	Laurentian Channel Central	13	16	17
11	Shediac Valley	--	--	19
12	Northwest Magdalen Shallows	--	--	39
13	Northeast Magdalen Shallows	--	--	15
14	Northumberland Strait West	--	--	10
15	Southern Magdalen Shallows	--	--	33
16	Cape Breton Channel	--	--	22
17	Northumberland Strait East	--	--	16
18	Baie des Chaleurs	--	--	8
	TOTAL	197	189	387

TABLE 2

Mean temperatures (in °C) in each of the Petrie boxes, averaged by layer. For each of the layers, the first column (AVR) presents the September means computed from Petrie (1990) and the second column gives the August-September 1993 values. For the layer deeper than 300 m, an asterisk identifies a Petrie box for which only the 300 m value was available.

Box #	0 - 30 m		30 - 100 m		100 - 200 m		200 - 300 m		> 300 m	
	AVR	1993	AVR	1993	AVR	1993	AVR	1993	AVR	1993
1	11.45	12.49	2.81	1.17	2.76	3.41	4.36	6.20	4.29	5.35
2	9.54	13.05	2.76	0.37	2.75	2.39	5.28	5.83	5.53	5.59
3	10.25	11.12	2.18	-0.05	3.14	1.89	5.58	4.82	5.98*	5.41
4	9.31	10.84	2.75	0.11	2.40	1.65	5.17	5.03	--	--
5	7.92	10.20	1.32	0.08	1.77	1.29	4.35	4.90	--	5.30
6	6.23	8.61	1.24	0.25	2.66	2.38	4.37	4.67	4.80*	5.02
7	4.67	7.26	1.70	1.13	2.92	2.21	4.34	4.27	4.39*	4.64
8	8.27	9.14	1.94	0.88	2.42	1.87	4.41	4.44	4.81*	5.00
9	8.01	10.16	1.10	-0.17	1.76	1.79	4.51	4.90	5.27*	5.30
10	9.84	11.32	1.55	-0.06	2.80	1.79	5.02	4.71	5.31*	5.12
11	10.26	10.17	2.89	0.39	1.53	--	--	--	--	--
12	9.90	10.80	1.49	-0.02	1.11	--	--	--	--	--
13	10.49	12.10	1.88	--	--	--	--	--	--	--
14	12.50	11.74	--	--	--	--	--	--	--	--
15	11.24	13.07	2.72	--	--	--	--	--	--	--
16	11.80	13.55	2.43	1.76	2.38	--	--	--	--	--
17	14.32	14.65	5.89	--	--	--	--	--	--	--
18	--	9.49	--	1.25	--	--	--	--	--	--

TABLE 3

Mean salinity (in psu) in each of the Petrie boxes, averaged by layer. For each of the layers, the first column (AVR) presents the September means computed from Petrie (1990) and the second column gives the August-September 1993 values. For the layer deeper than 300 m, an asterisk identifies a Petrie box for which only the 300 m value was available.

Box #	0 - 30 m		30 - 100 m		100 - 200 m		200 - 300 m		> 300 m	
	AVR	1993	AVR	1993	AVR	1993	AVR	1993	AVR	1993
1	30.37	30.57	31.96	32.22	33.36	33.59	34.17	34.57	34.54	34.78
2	31.49	30.77	32.30	31.98	33.44	33.30	34.42	34.55	34.63	34.81
3	31.10	30.66	32.20	31.95	33.34	33.17	34.09	34.31	34.25*	34.57
4	31.01	30.62	31.89	31.86	32.92	33.15	33.65	34.40	--	--
5	31.07	30.40	32.11	31.98	33.03	33.13	33.75	34.38	--	34.73
6	30.75	29.77	32.31	32.54	33.57	33.80	34.32	34.64	34.57*	34.81
7	29.63	28.28	32.11	32.15	33.71	33.79	34.33	34.51	34.44*	34.65
8	29.75	28.88	31.19	31.97	33.18	33.51	34.09	34.50	34.55*	34.78
9	30.92	30.55	32.14	32.14	33.08	33.30	34.14	34.41	34.60*	34.77
10	30.13	29.80	31.98	32.06	33.47	33.30	34.23	34.39	34.57*	34.73
11	29.21	28.53	31.48	31.92	32.80	--	--	--	--	--
12	29.66	28.95	31.57	31.93	--	--	--	--	--	--
13	30.06	29.39	31.40	--	--	--	--	--	--	--
14	28.59	28.02	--	--	--	--	--	--	--	--
15	29.03	28.25	30.75	--	--	--	--	--	--	--
16	29.37	28.87	31.66	31.66	33.01	--	--	--	--	--
17	28.61	28.37	30.00	--	--	--	--	--	--	--
18	--	28.25	--	31.15	--	--	--	--	--	--

TABLE 4

Mean temperatures (in °C) in each Petrie box in August-September 1991 and 1992, averaged by layer.

Box #	0 - 30 m		30 - 100 m		100 - 200 m		200 - 300 m		> 300 m	
	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992
1	13.29	11.88	1.21	0.89	1.50	2.13	4.61	5.06	5.15	5.07
2	12.59	12.09	0.71	0.59	1.13	1.57	4.37	4.71	5.22	5.13
3	10.20	11.34	-0.01	-0.06	1.25	1.19	4.63	4.60	5.15	5.10
4	8.45	9.81	-0.08	-0.39	0.99	1.21	4.59	--	4.97	--
5	8.80	9.11	-0.43	-0.11	0.66	1.04	4.55	4.63	5.18	5.15
6	6.55	8.61	0.08	0.53	1.77	2.07	4.64	4.50	5.19	5.06
7	5.04	6.84	0.52	0.79	1.68	2.23	4.13	4.18	4.75	4.69
8	8.73	7.31	0.24	-0.02	1.65	1.67	4.58	4.39	5.18	4.99
9	9.98	12.20	-0.28	-0.06	1.40	1.23	4.61	4.57	5.22	5.12
10	11.06	11.76	-0.12	-0.04	1.47	1.81	4.58	4.65	5.20	5.04
11	--	--	--	--	--	--	--	--	--	--
12	--	--	--	--	--	--	--	--	--	--
13	--	--	--	--	--	--	--	--	--	--
14	--	--	--	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--	--	--	--
16	--	--	--	--	--	--	--	--	--	--
17	--	--	--	--	--	--	--	--	--	--
18	--	--	--	--	--	--	--	--	--	--

TABLE 5

Mean temperatures (in °C) in each layer, averaged over Petrie boxes 1 to 10 (ie: the northern Gulf and Cabot Strait), in August-September 1991, 1992 and 1993. The last two columns present the long-term September averages (computed from the data in Petrie (1990)) and the 1993 anomalies (4th column minus 5th column), respectively.

Layer	1991	1992	1993	Petrie	1993-Petrie
0 - 30 m	9.47	10.10	10.42	8.55	1.87
30 - 100 m	0.18	0.21	0.34	1.94	-1.60
100 - 200 m	1.35	1.61	2.07	2.54	-0.47
200 - 300 m	4.53	4.59	4.98	4.82	0.16
> 300 m	5.12	5.04	5.19	5.05	0.14

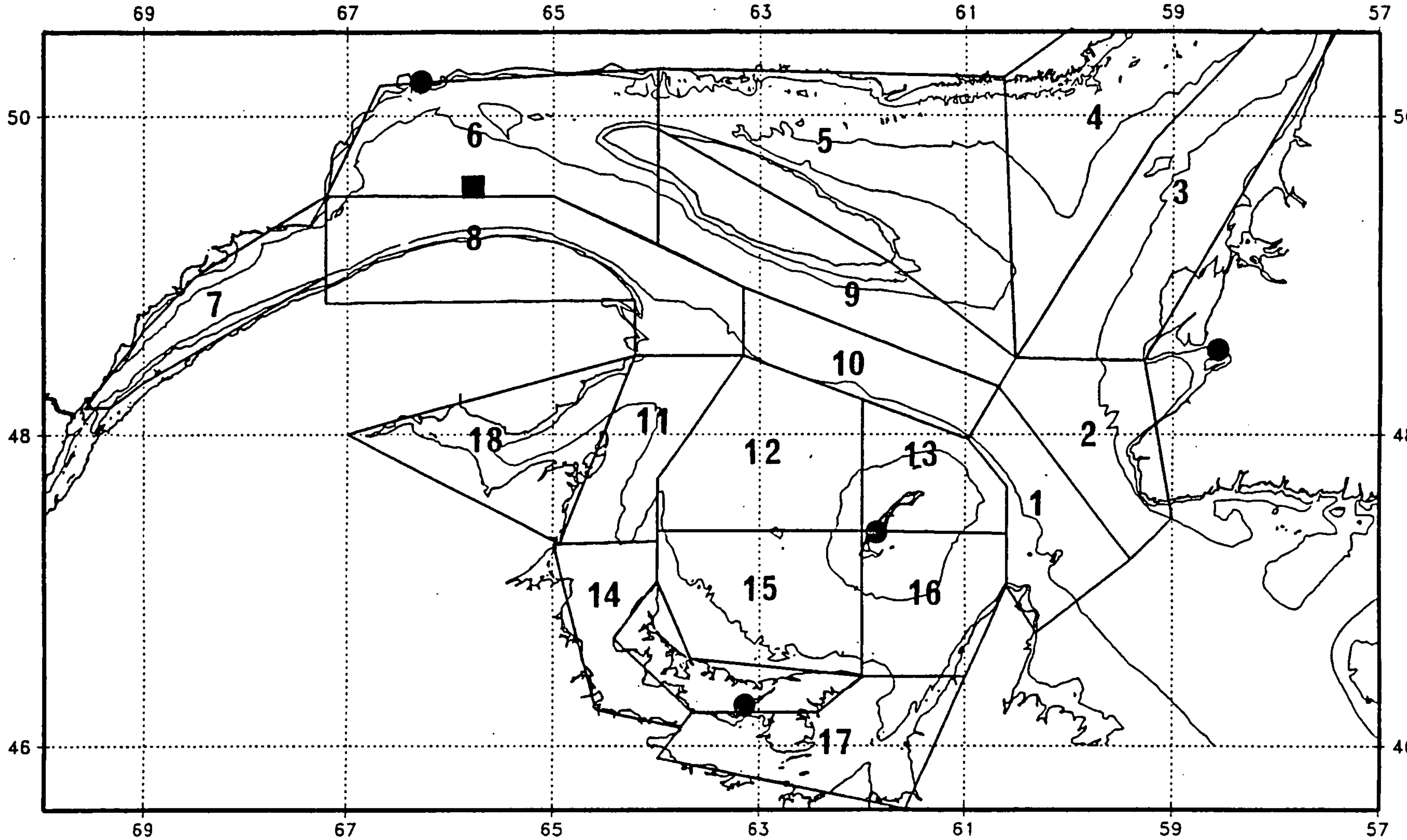


Figure 1a: Map of the Gulf of St. Lawrence (with the 50 m and 200 m isobaths) showing Petrie's (1990) boxes, the meteorological coastal stations (black circles) and the position of the meteorological buoy (black square).

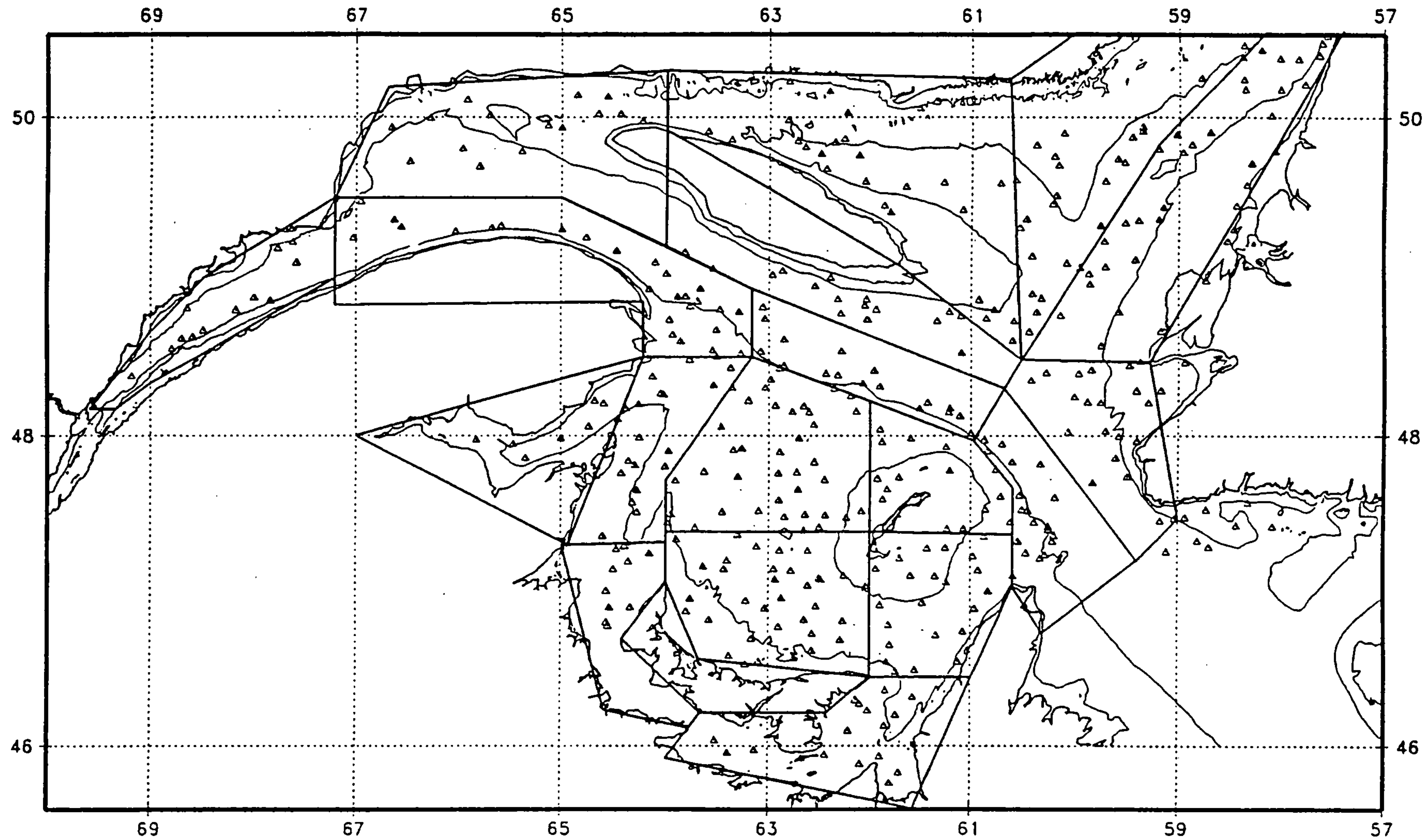


Figure 1b: Map of the Gulf of St. Lawrence (with the 50 m and 200 m isobaths) showing the location of the 1993 CTD casts (triangles).

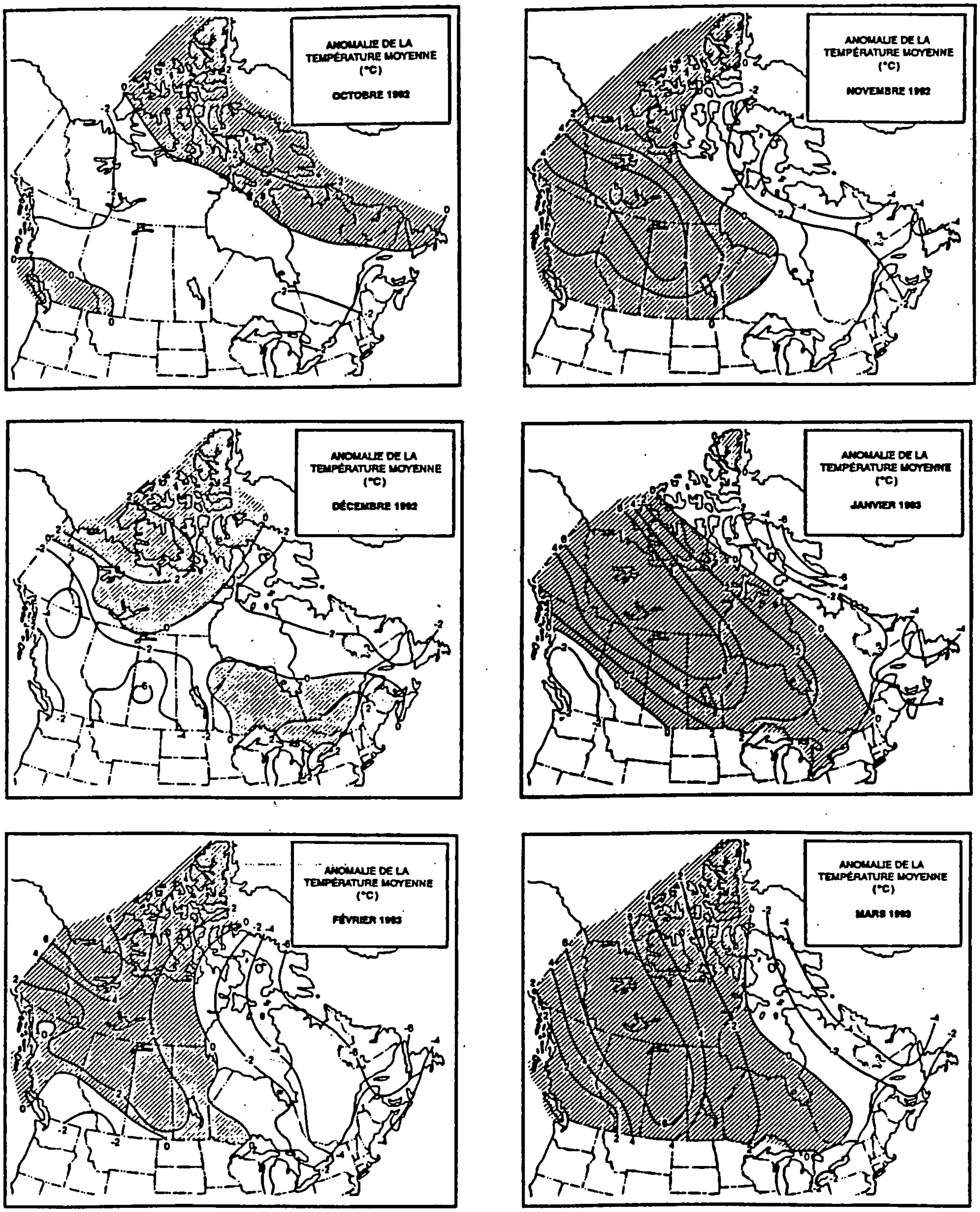


Figure 2: Monthly air temperature anomalies (°C) over Canada from October 1992 to September 1993. Shaded areas are positive anomalies. (From *Perspectives Climatiques*, Vols 14 and 15).

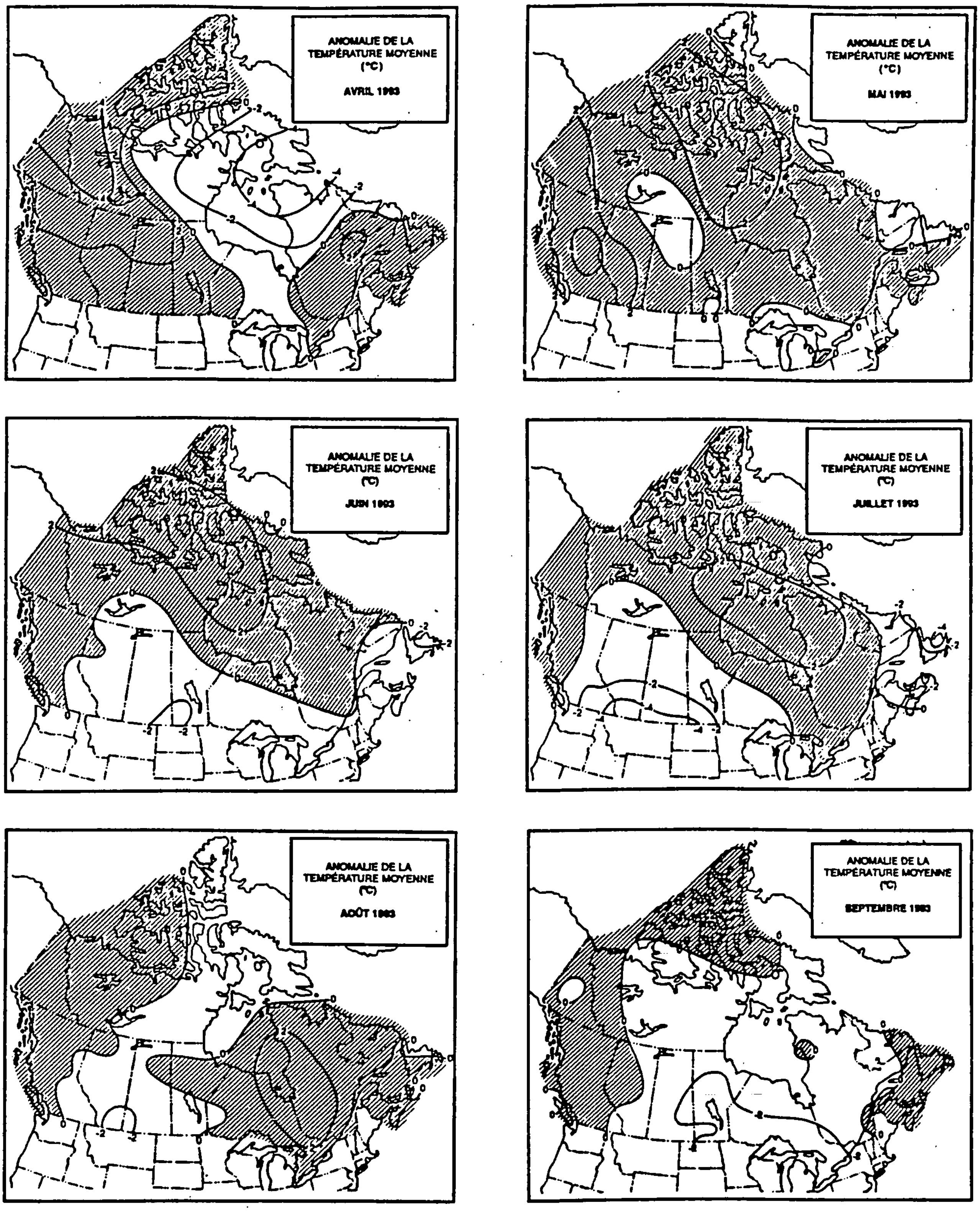


Figure 2: (Concluded)

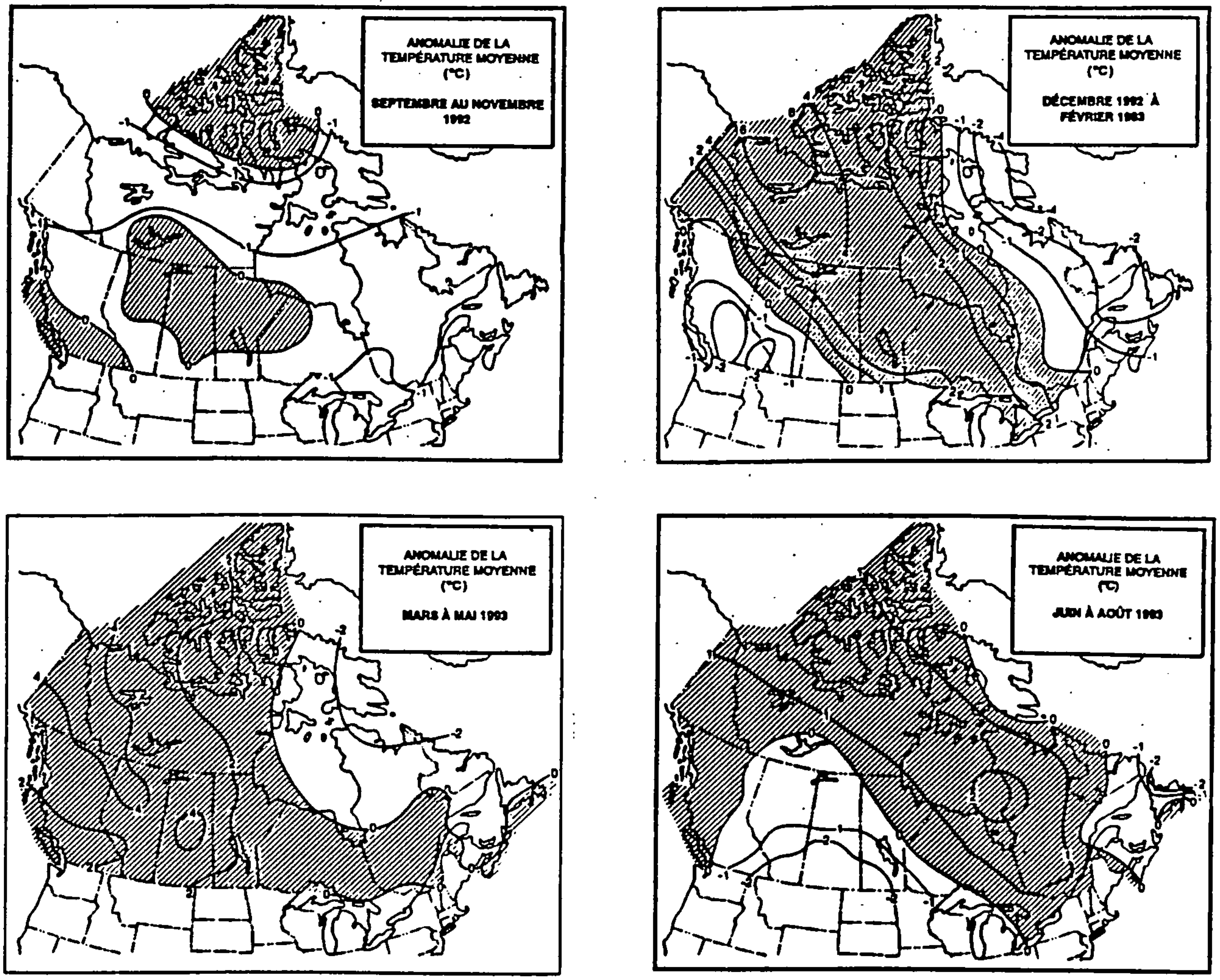


Figure 3: Seasonal air temperature anomalies (°C) over Canada from September 1992 to August 1993. Shaded areas are positive anomalies. (From *Perspectives Climatiques*, Vols 14 and 15).

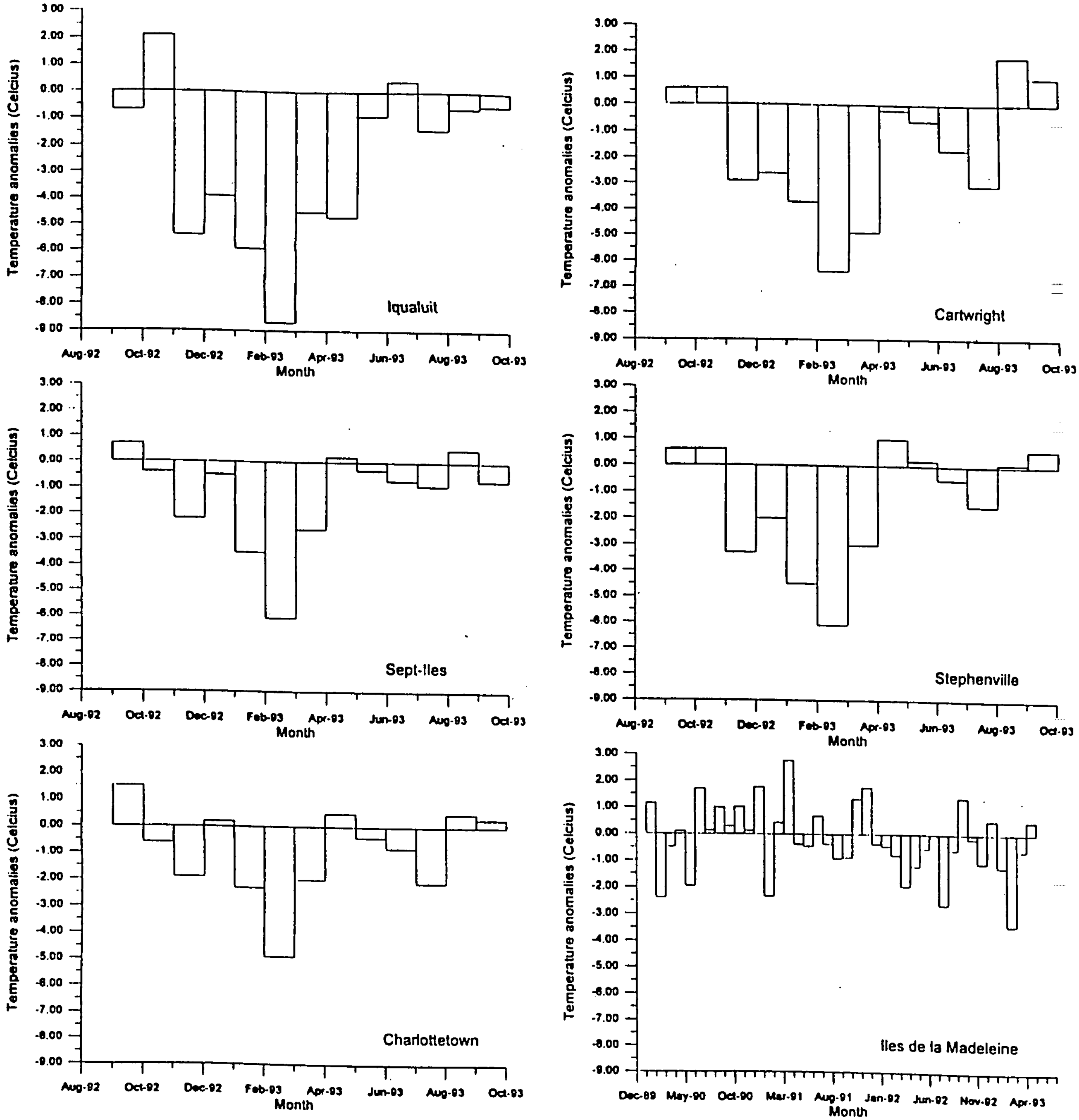


Figure 4: Monthly air temperature anomalies (°C) for six coastal stations from September 1992 to September 1993. The stations around the Gulf of St. Lawrence are Sept-Iles (Québec), Stephenville (Newfoundland), Charlottetown (Prince Edward Island) and Iles-de-la-Madeleine (Québec). The stations of Iqualuit (Northwest Territories) and Cartwright (Labrador) are also shown for comparison. Note that the anomalies at Iles-de-la-Madeleine are from January 1990 to April 1993, and from daytime observations only. Since this last meteorological station was recently moved (1983), the anomalies were calculated relative to 1984-1993 base period.

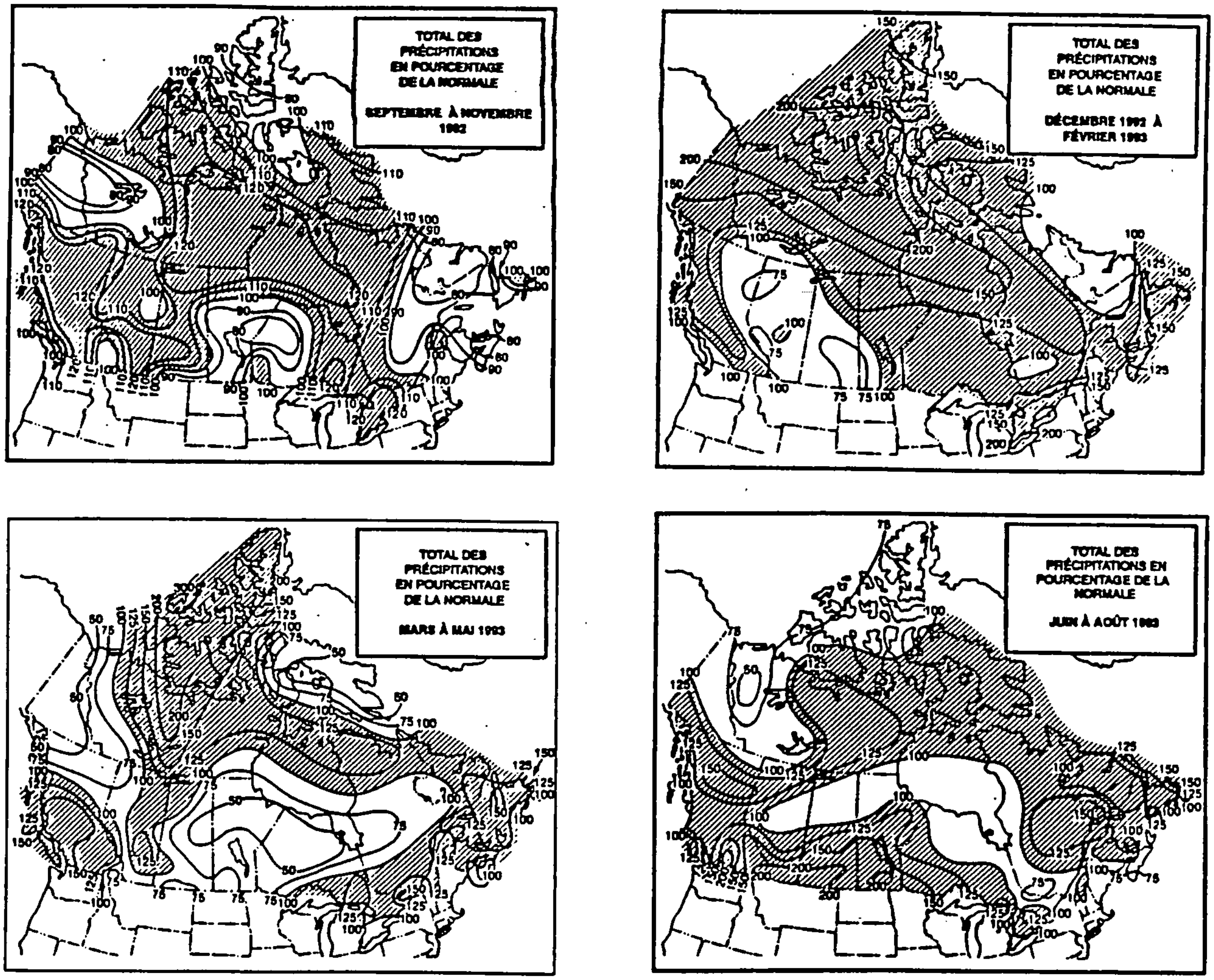


Figure 5: Seasonal amount of precipitation over Canada from September 1992 to October 1993, expressed as a percentage of the long-term average (1951-1980).

01 SEP 92 - 30 NOV 92

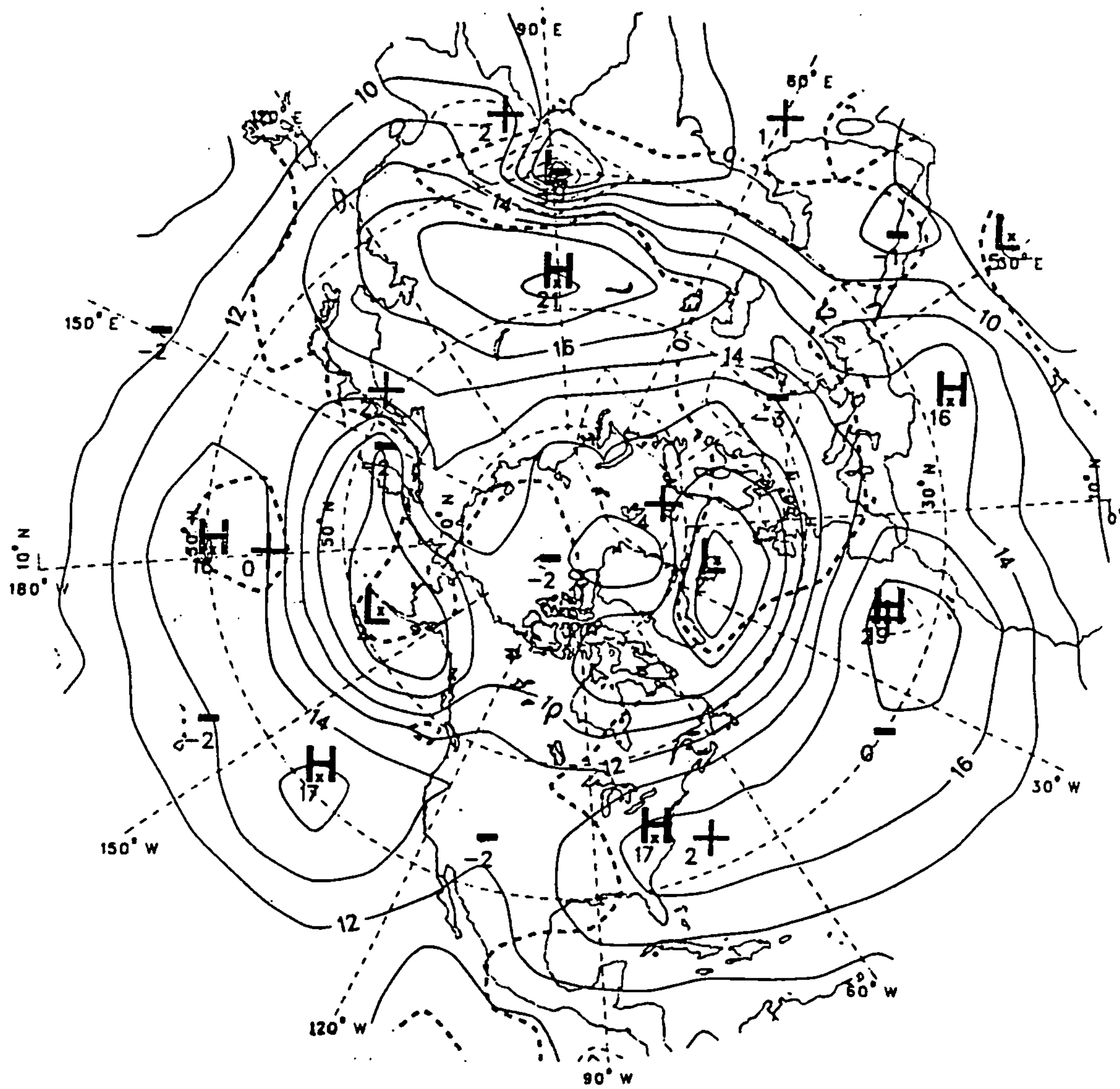


Figure 6: Seasonal average heights and anomalies of height relative to the 1951-1980 means (in decameters: dam) of the 100 kPa air pressure surface (approximatively the sea-surface) over the northern hemisphere from September 1992 to August 1993. The maps were graciously prepared by Alain Caillet of AES (Canadian Climatic Center), by averaging the daily pressure maps. The few missing days were replaced by the forecast for that day. The solid lines are the 100 kPa heights, the dashed lines are the 100 kPa height anomalies; the double-dashed (=) is the zero anomaly isoline. The contour interval is 2 dam.

01 DEC 92 – 28 FEB 93

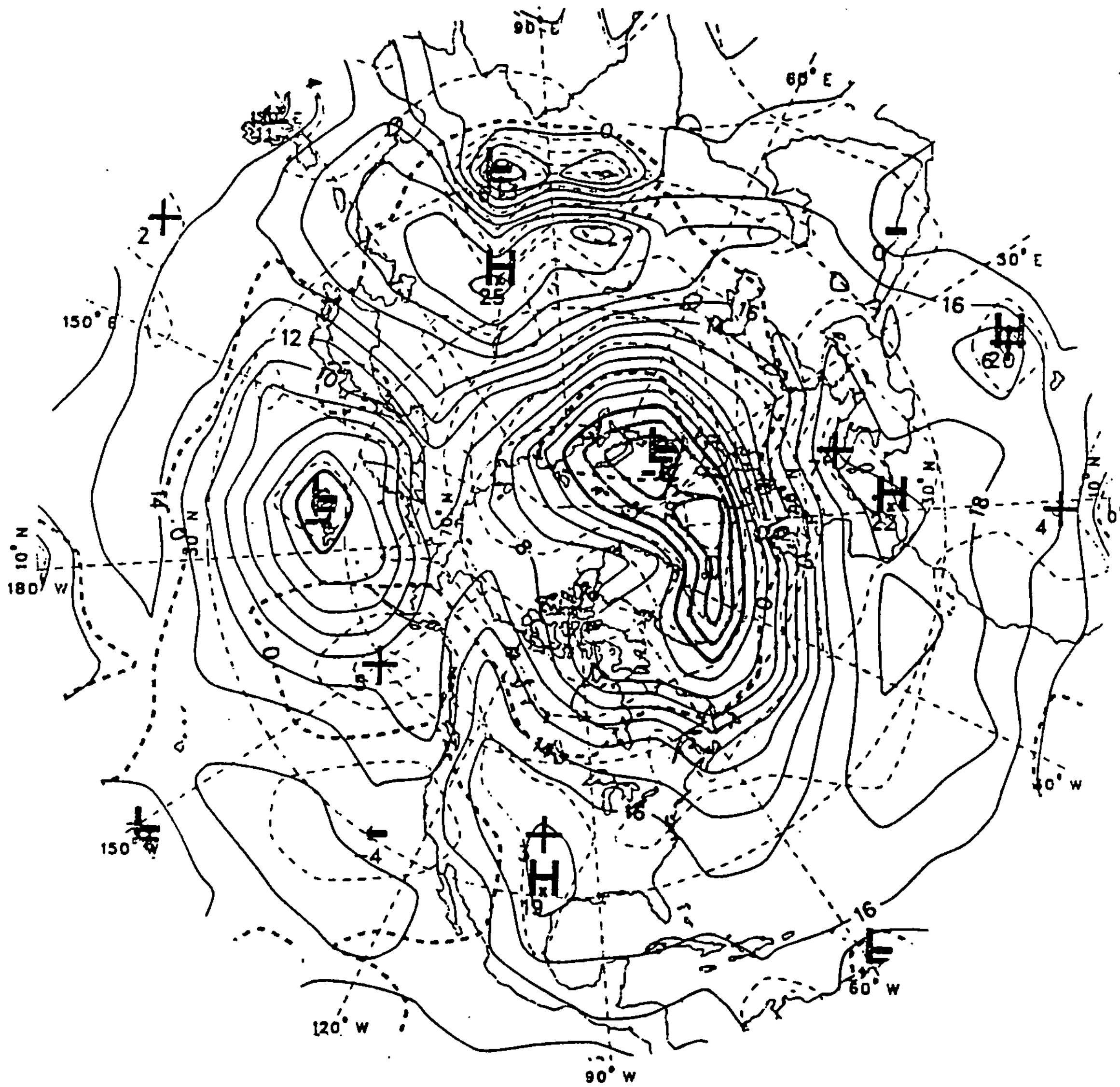


Figure 6: (Continued)

01 MAR 93 – 31 MAY 93

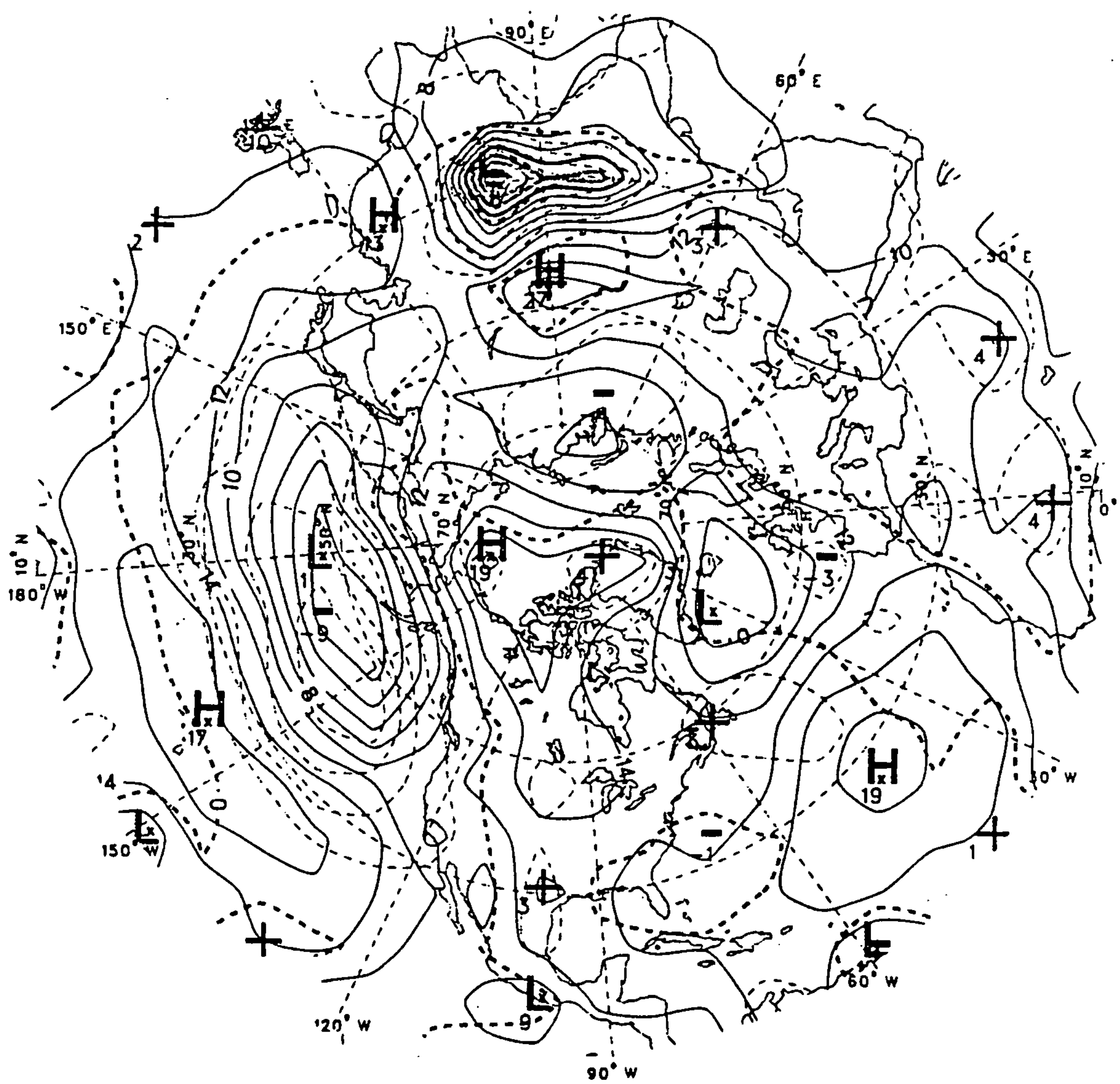


Figure 6: (Continued)

01 JUN 93 – 31 AUG 93

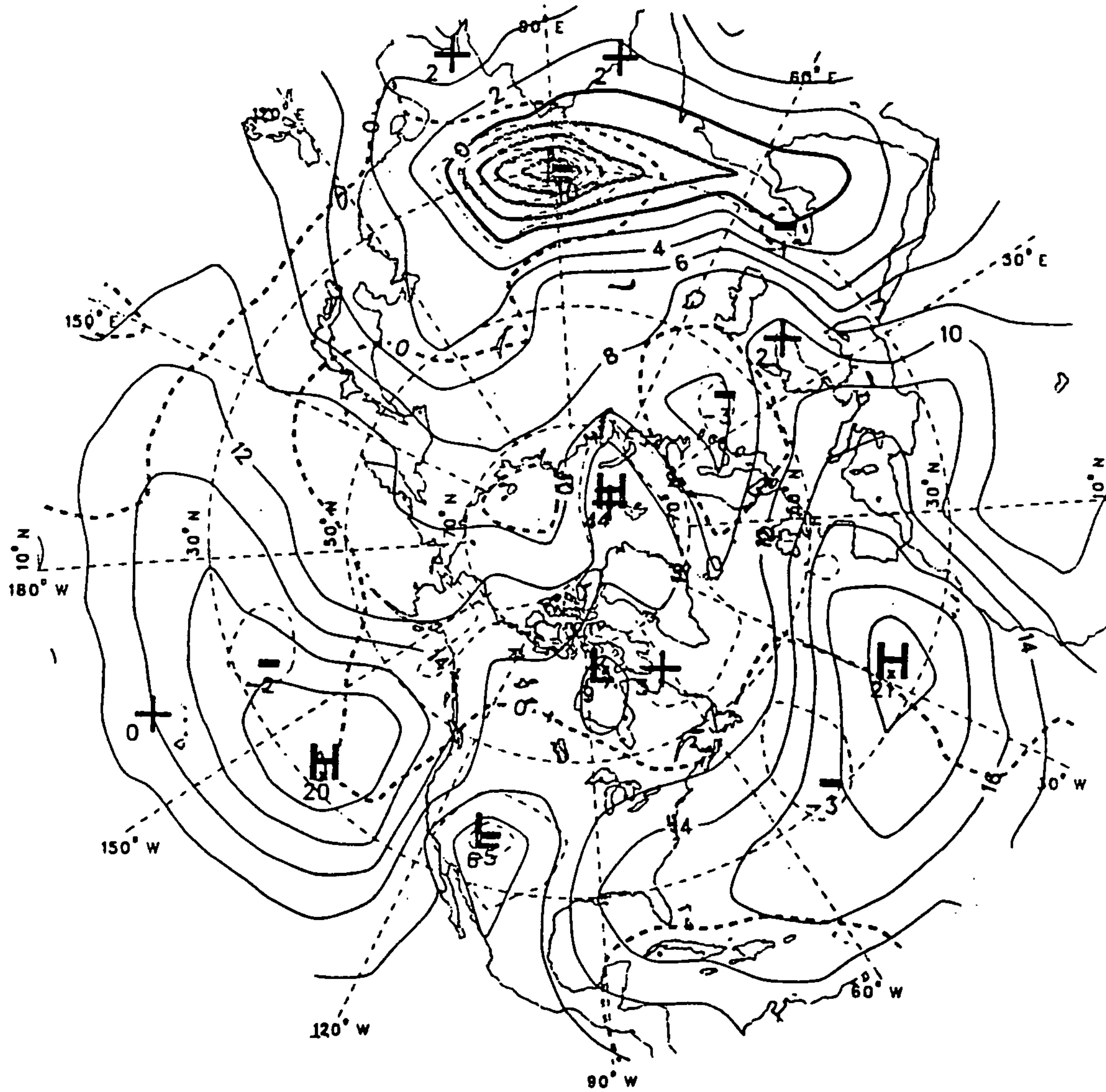
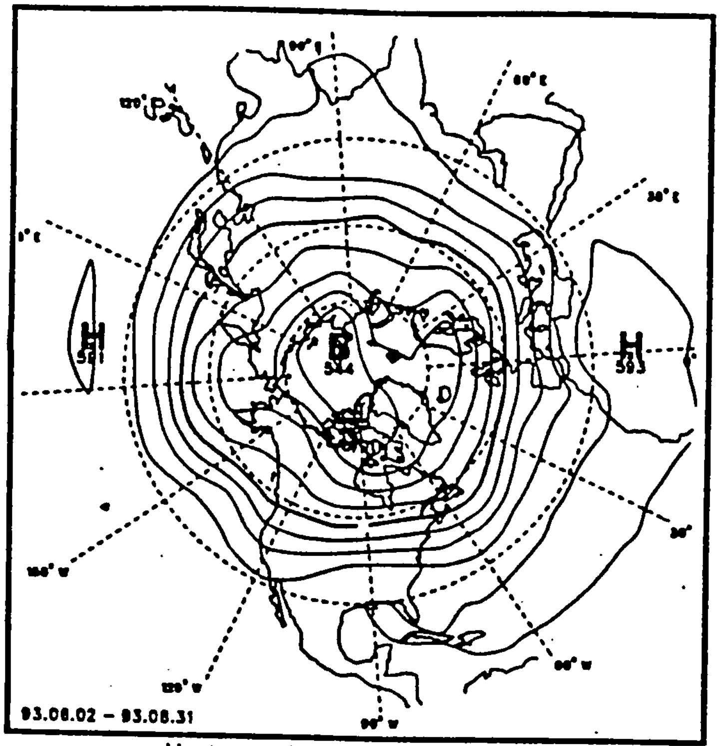
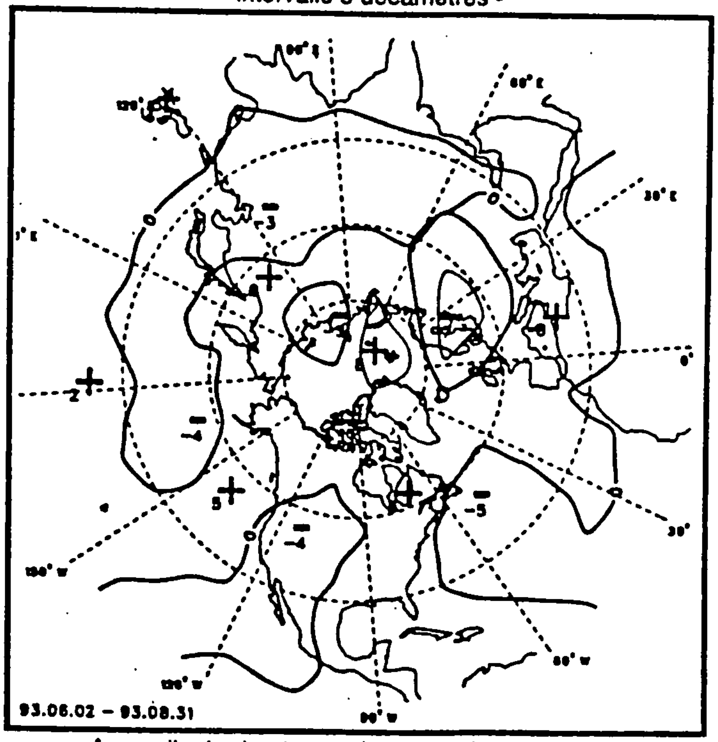


Figure 6 (Concluded)



Hauteurs géopotentielles moyennes
- intervalle 5 décamètres -



Anomalie des hauteurs géopotentielles moyennes
- intervalle 5 décamètres -

Figure 7: Seasonal average heights and anomalies of height (in decameters: dam) over the northern hemisphere relative to the 1951-1980 means of the 50 kPa surface (approximatively 5 km above the earth's surface) averaged over the summer of 1993 (June to August). (From *Perspectives Climatiques*, Vol. 15).

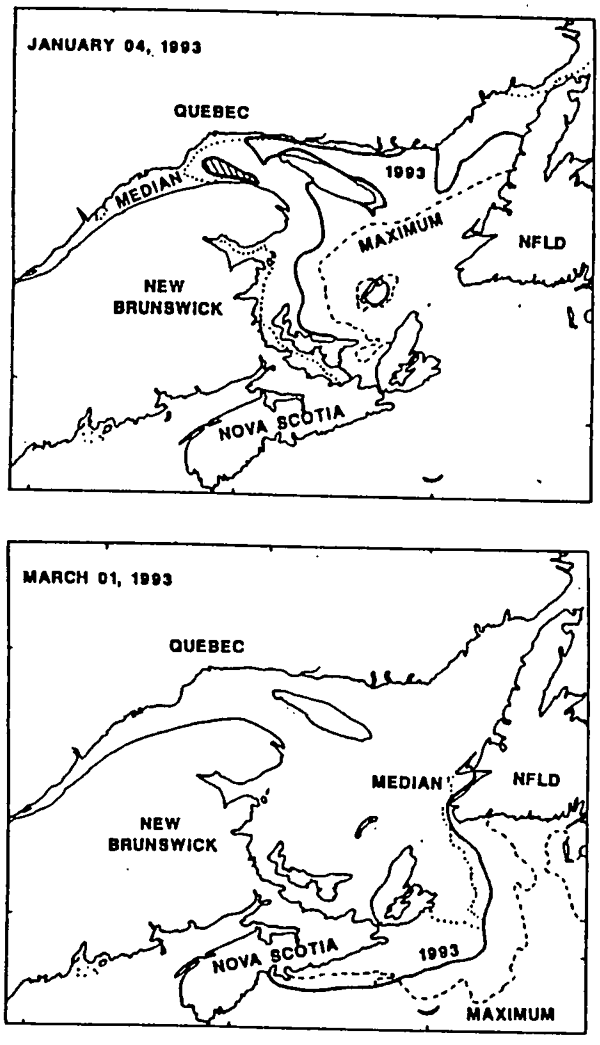


Figure 8: The location of the ice edge together with the historical (1962-1987) median and maximum positions in the Gulf of St. Lawrence between January and April 1993. Hatched areas indicate ice free waters when there could be a danger of confusion.

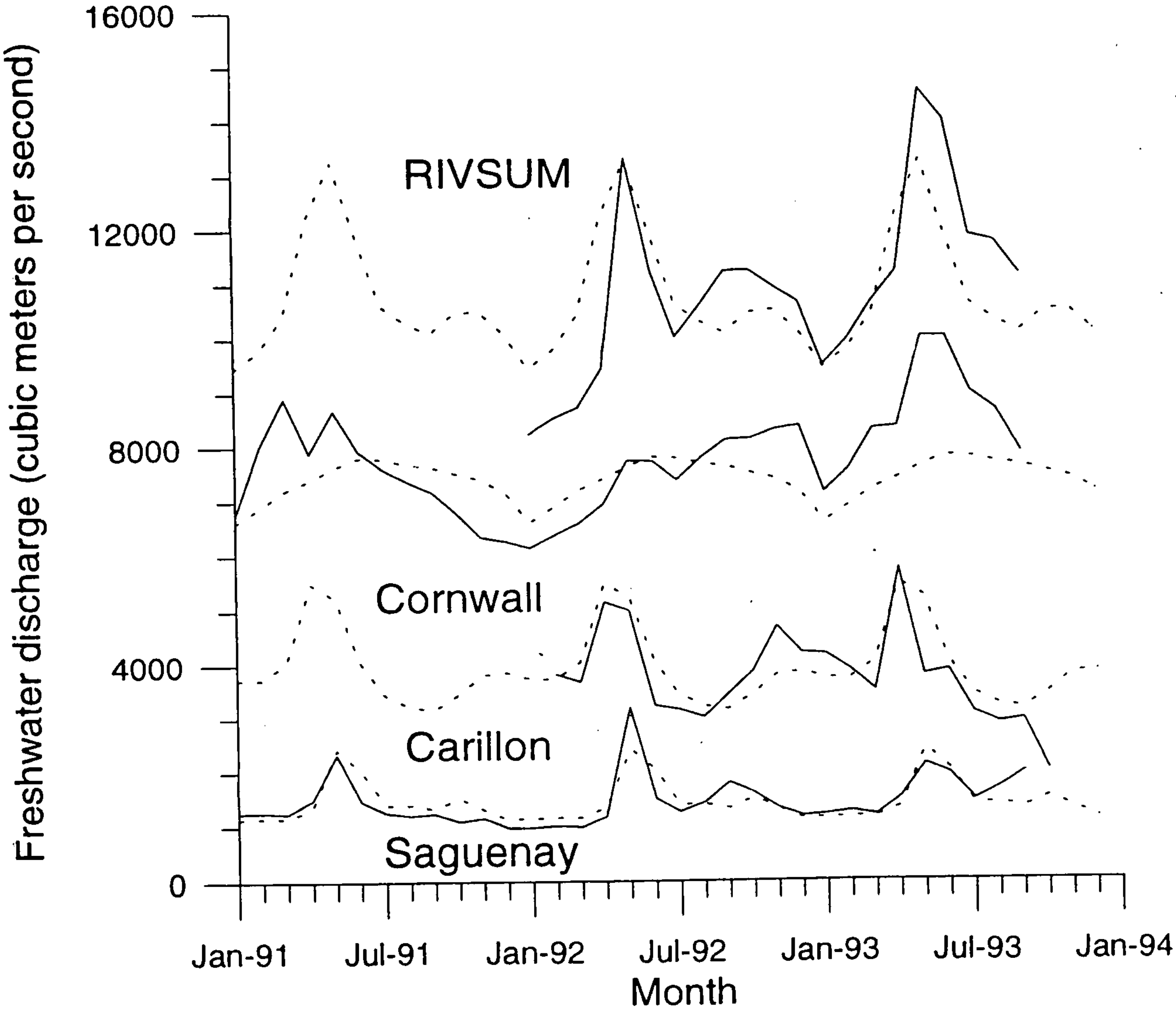


Figure 9: Monthly freshwater discharge from the St. Lawrence (Cornwall), the Outaouais (Carillon) and the Saguenay (Isle Maligne) Rivers. The dotted line represents the monthly mean discharges averaged over the period 1961-1990; these monthly values are repeated three times. The solid line is the monthly mean discharges from January 1991 to December 1993; the 1993 values are preliminary values. The Carillon curve is offset by +2000 $m^3 s^{-1}$ for clarity. RIVSUM is defined as the sum of the three river discharges.

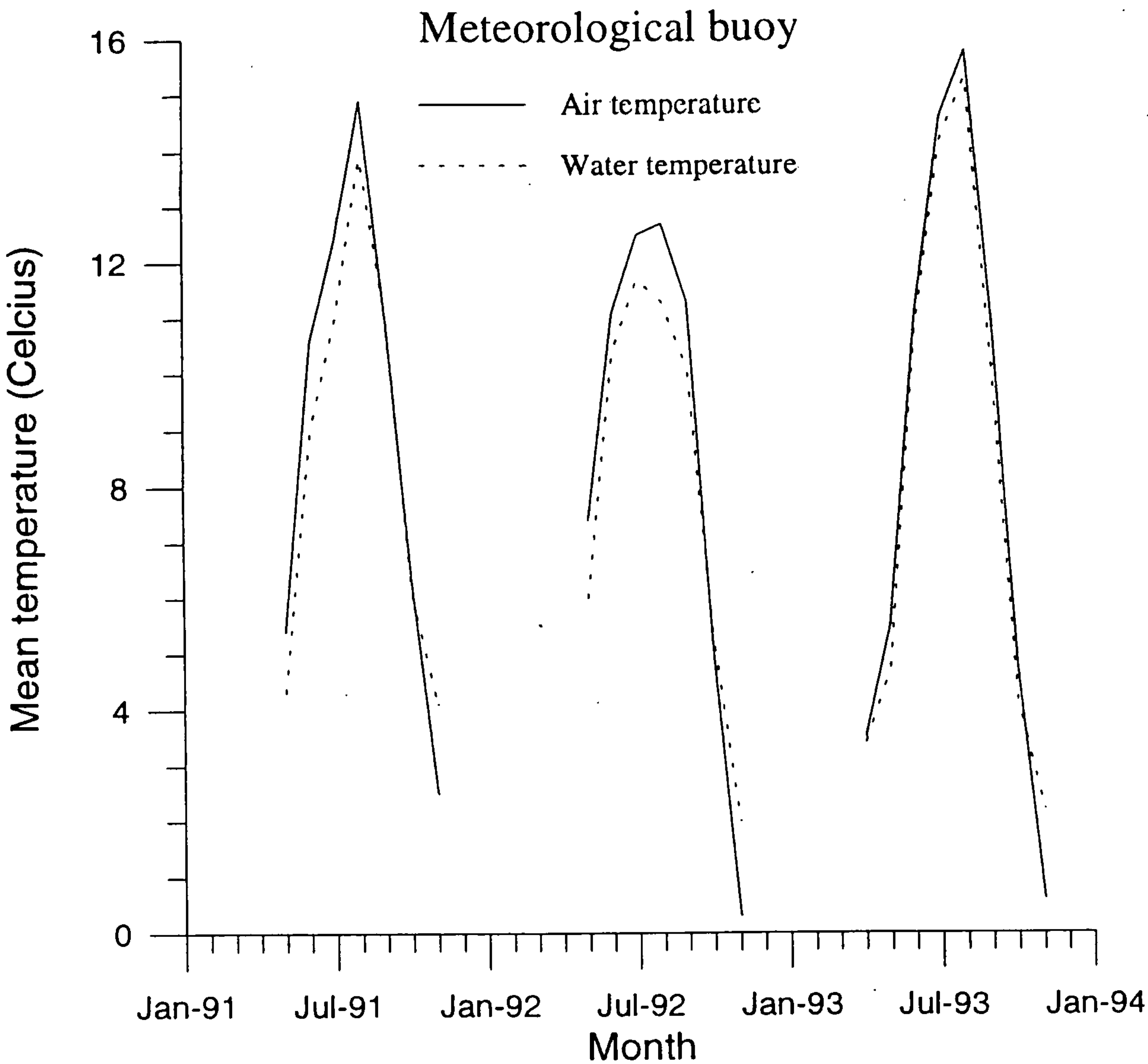
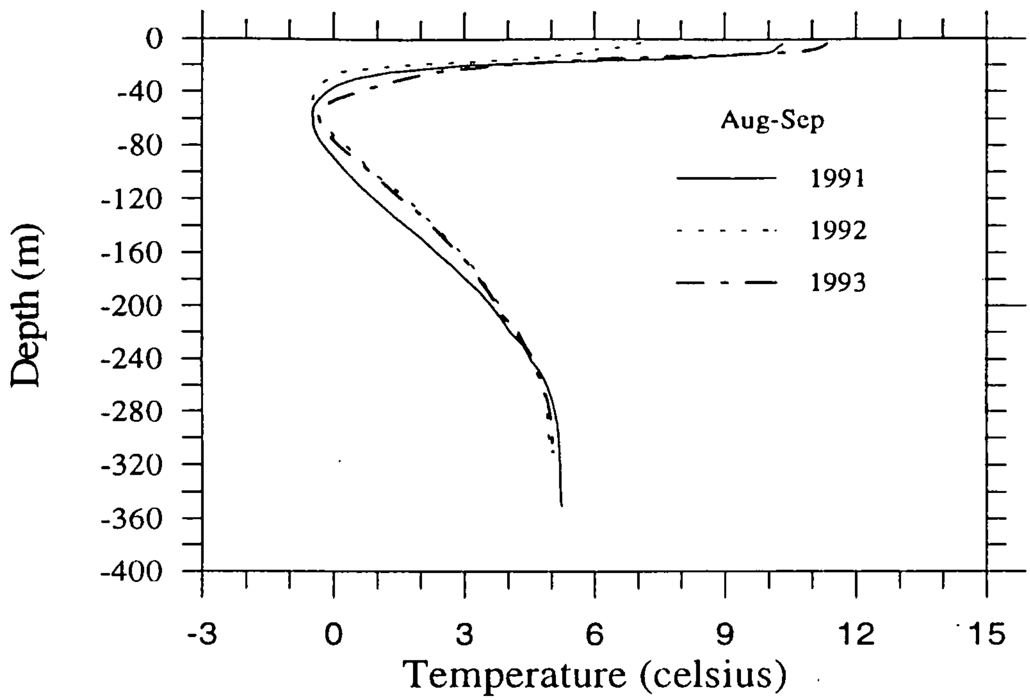


Figure 10: Monthly mean temperatures at the meteorological buoy (see Fig. 3.1, for location). The solid line is the air temperature while the dotted line is the water temperature. The monthly means were obtained by simply averaging the hourly observations.



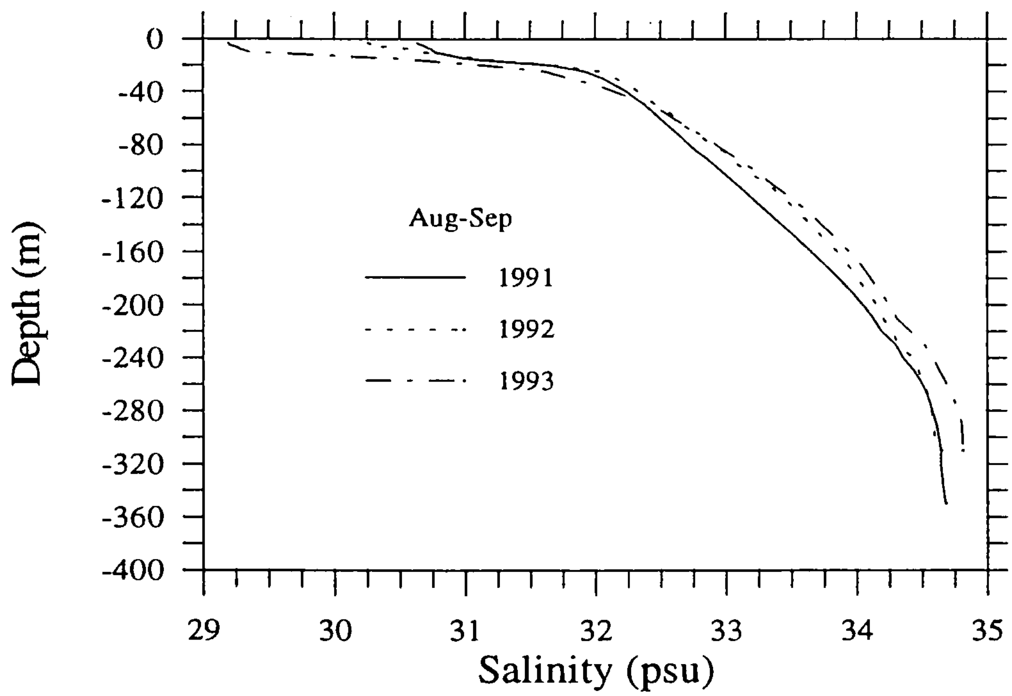


Figure 11: Average temperature and salinity profiles in the vicinity of the meteorological buoy for 1991, 1992 and 1993. All the profiles gathered in water deeper than 200 meters, in a box of one degree of latitude by one degree of longitude centered on the meteorological buoy , were simply averaged. Sixteen profiles were available for 1991, six for 1992 and seven for 1993.

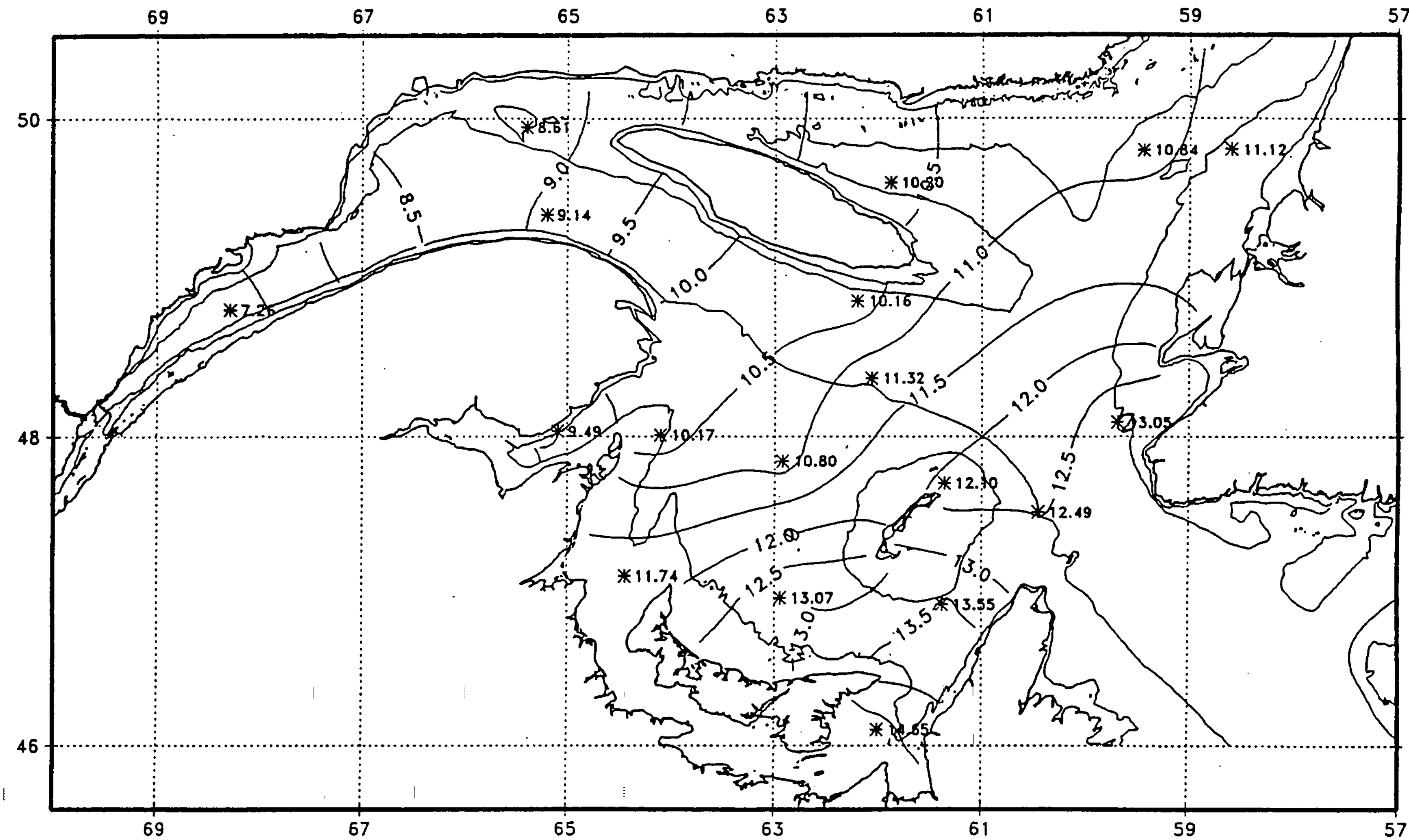


Figure 12: Average temperature (in °C) in the 0 to 30 m layer, in August-September 1993.

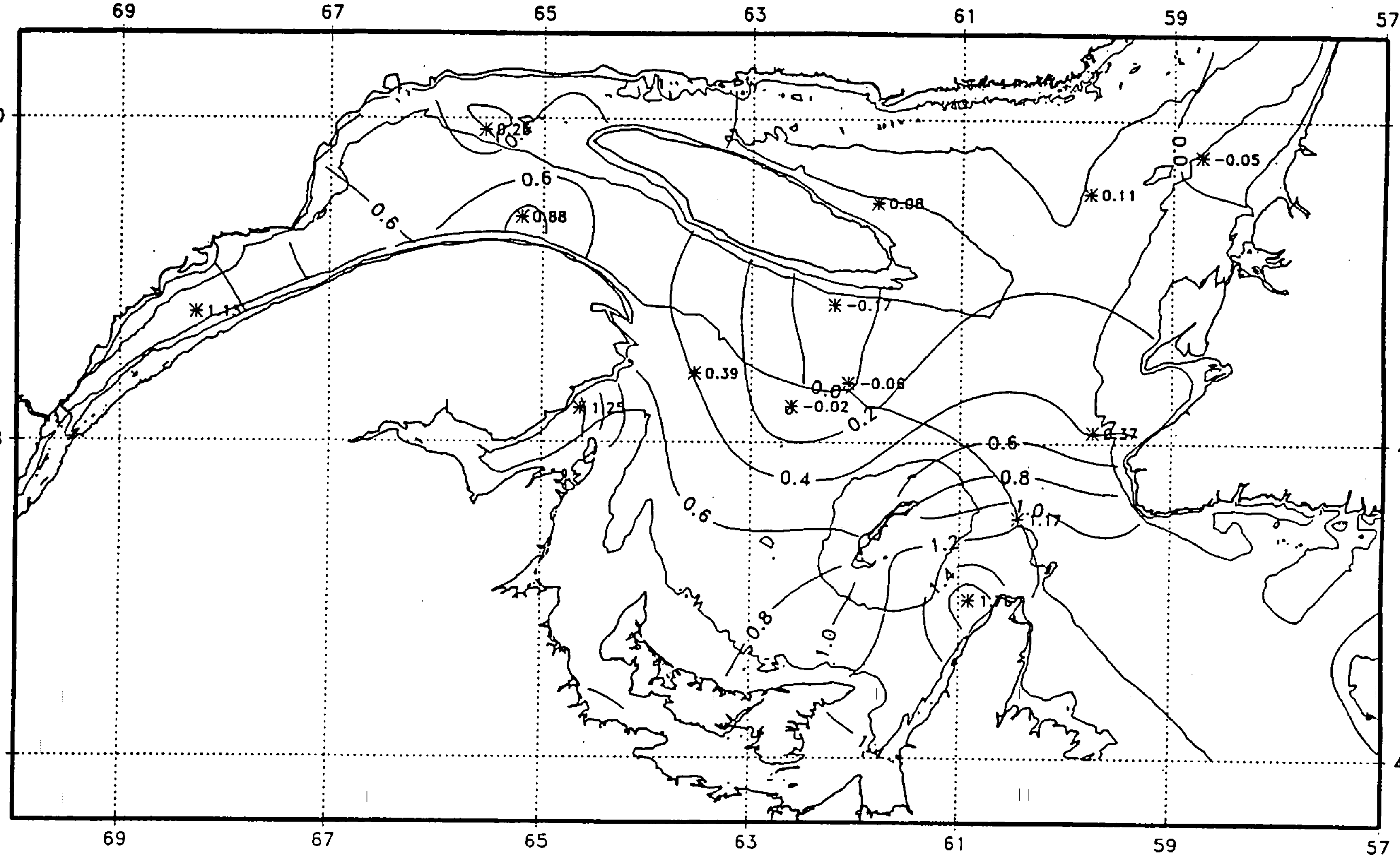


Figure 13: Average temperature (in °C) in the 30 to 100 m layer, in August-September 1993.

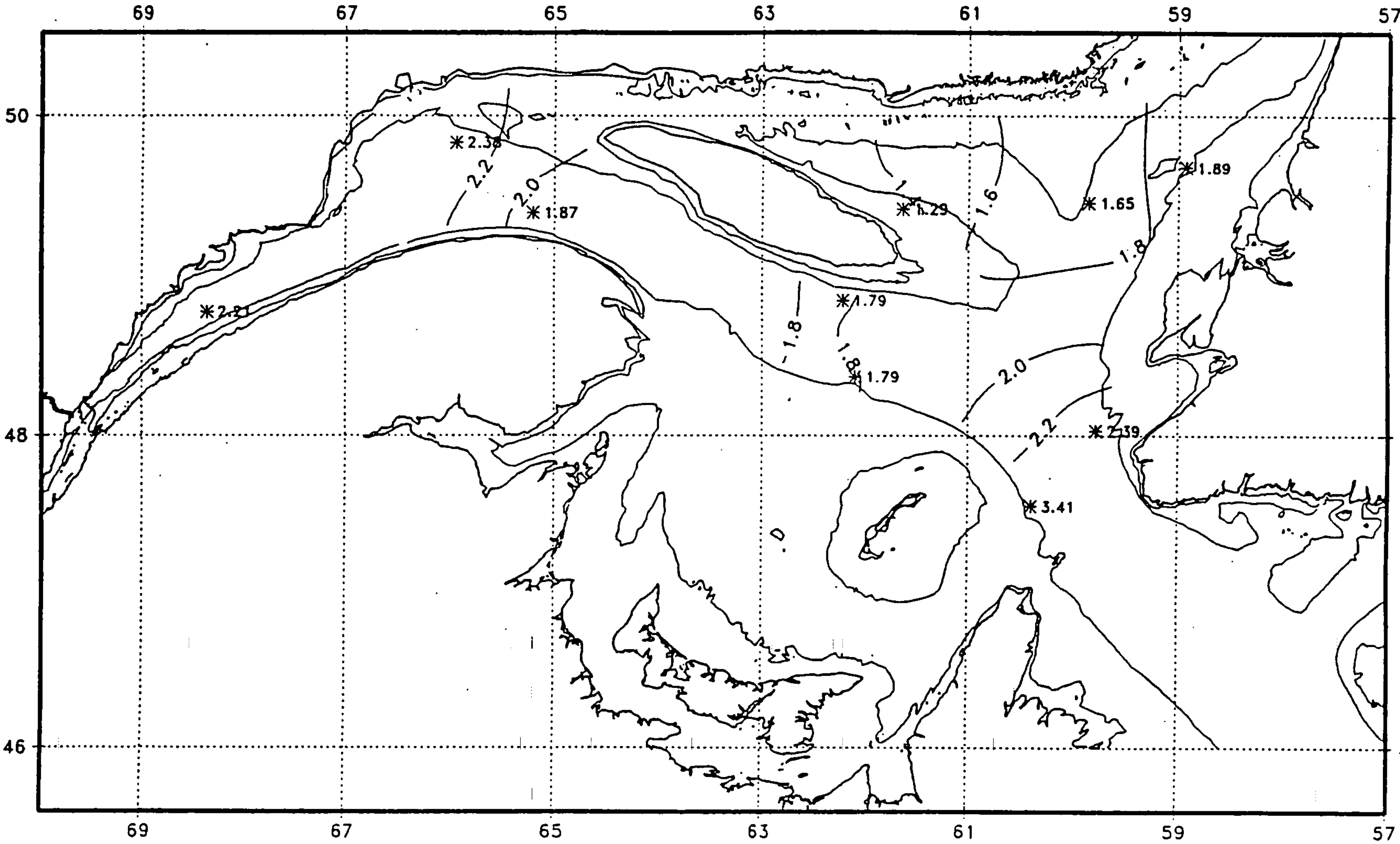


Figure 14: Average temperature (in °C) in the 100 to 200 m layer, in August-September 1993.

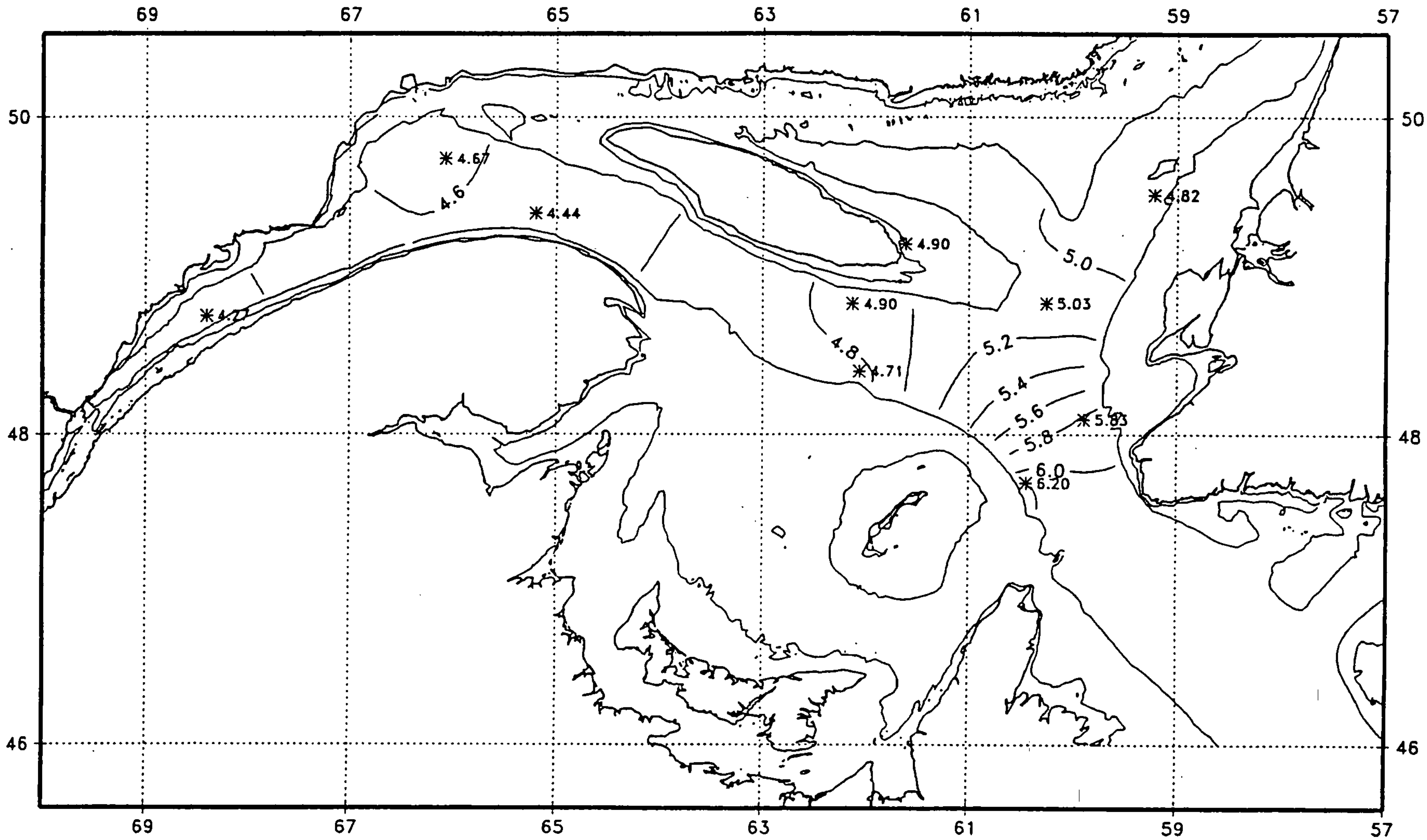


Figure 15: Average temperature (in °C) in the 200 to 300 m layer, in August-September 1993.

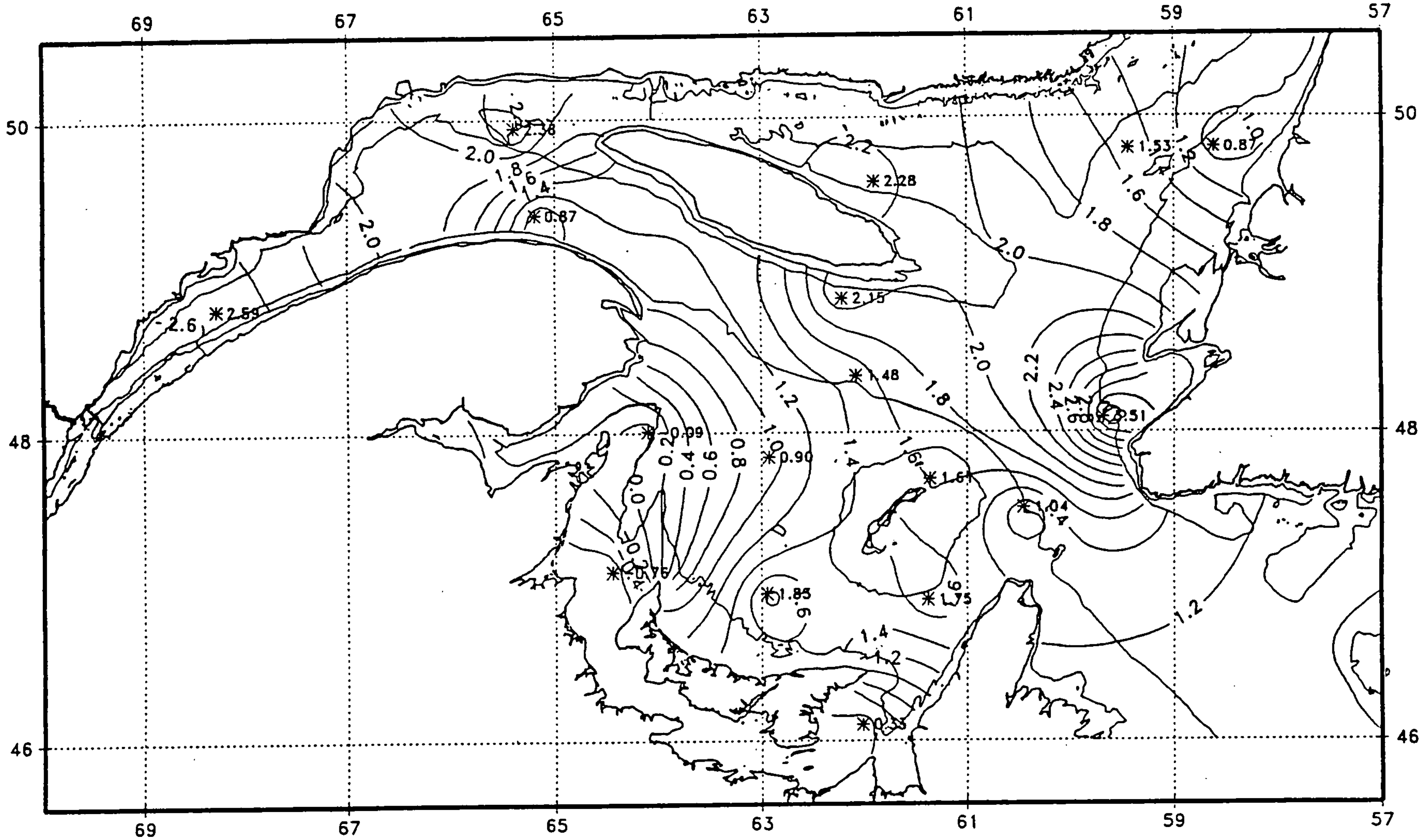


Figure 16: Temperature anomalies (in °C) in the 0 to 30 m layer, in August-September 1993, with respect to Petrie's (1990) long-term means (1993 minus Petrie).

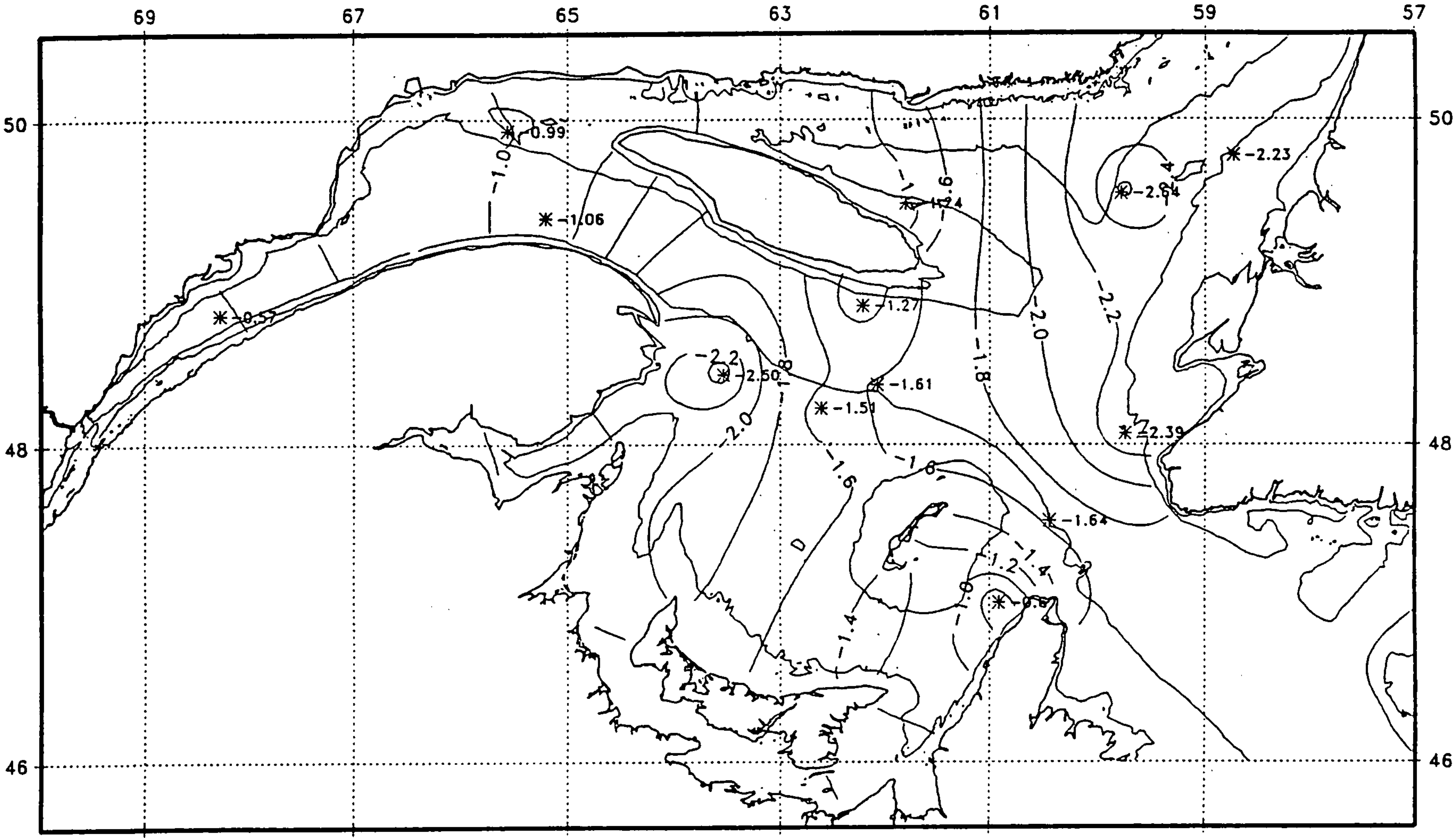


Figure 17: Temperature anomalies (in °C) in the 30 to 100 m layer, in August-September 1993, with respect to Petrie's (1990) long-term means (1993 minus Petrie).

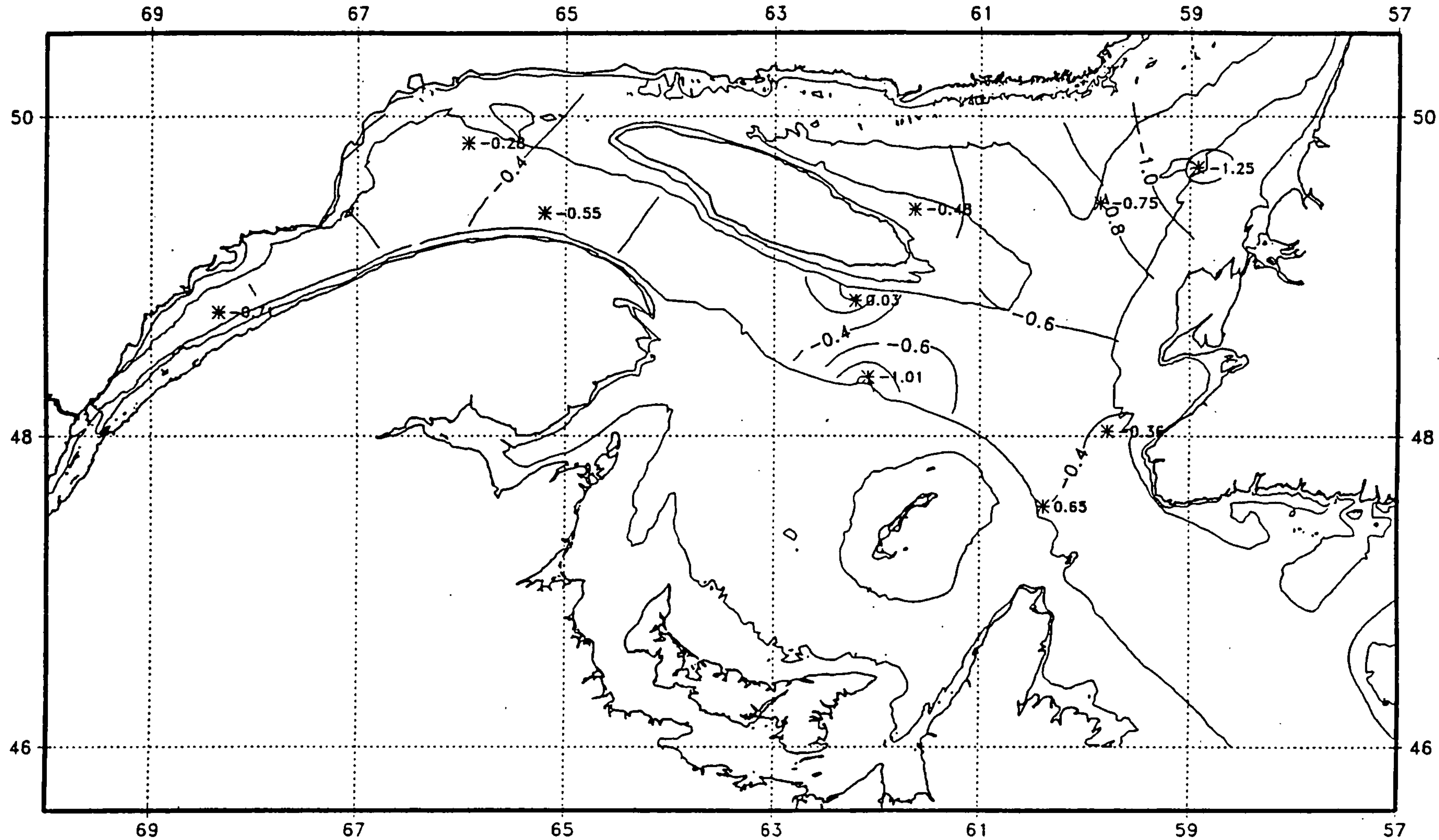


Figure 18: Temperature anomalies (in °C) in the 100 to 200 m layer, in August-September 1993, with respect to Petrie's (1990) long-term means (1993 minus Petrie).

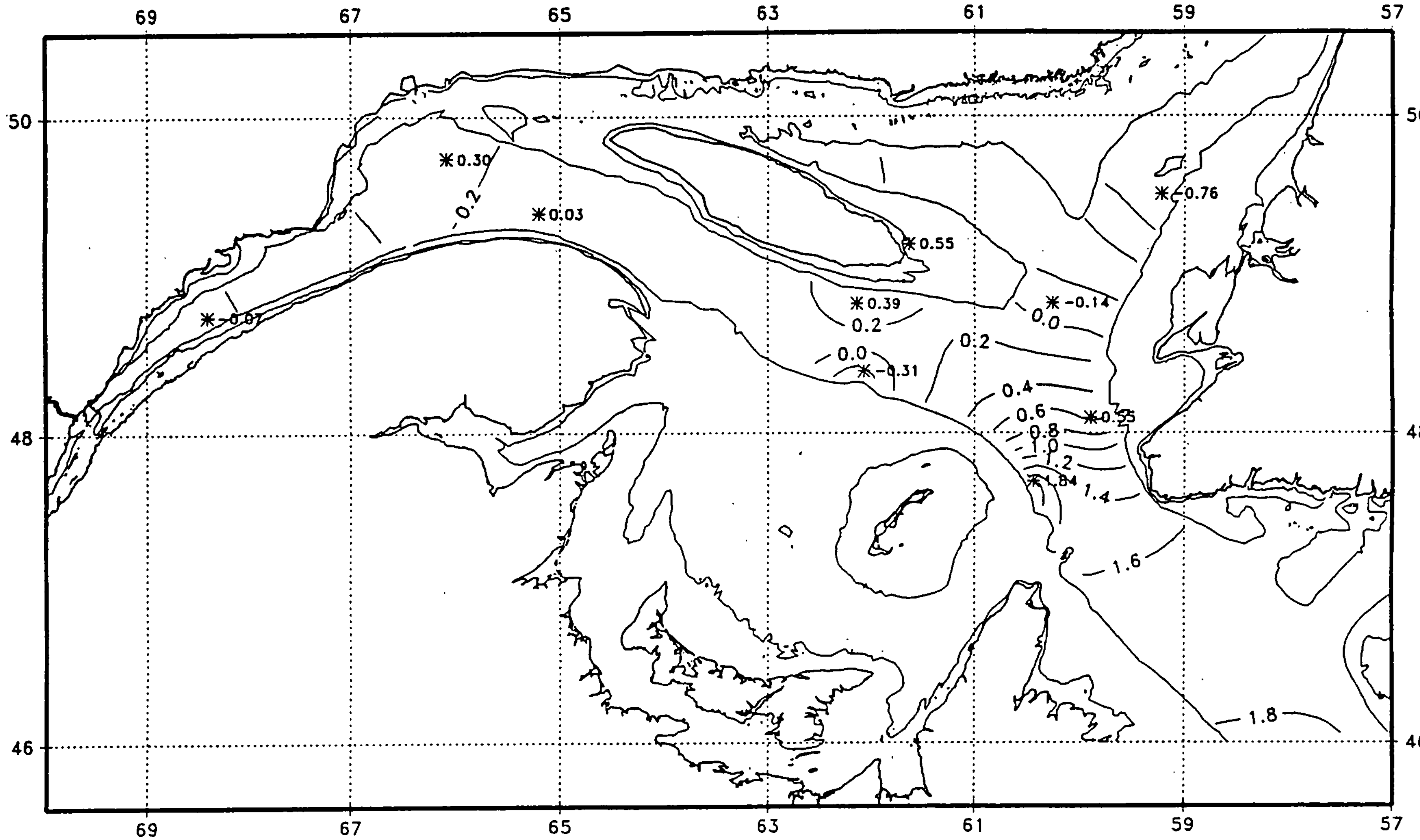


Figure 19: Temperature anomalies (in °C) in the 200 to 300 m layer, in August-September 1993, with respect to Petrie's (1990) long-term means (1993 minus Petrie).

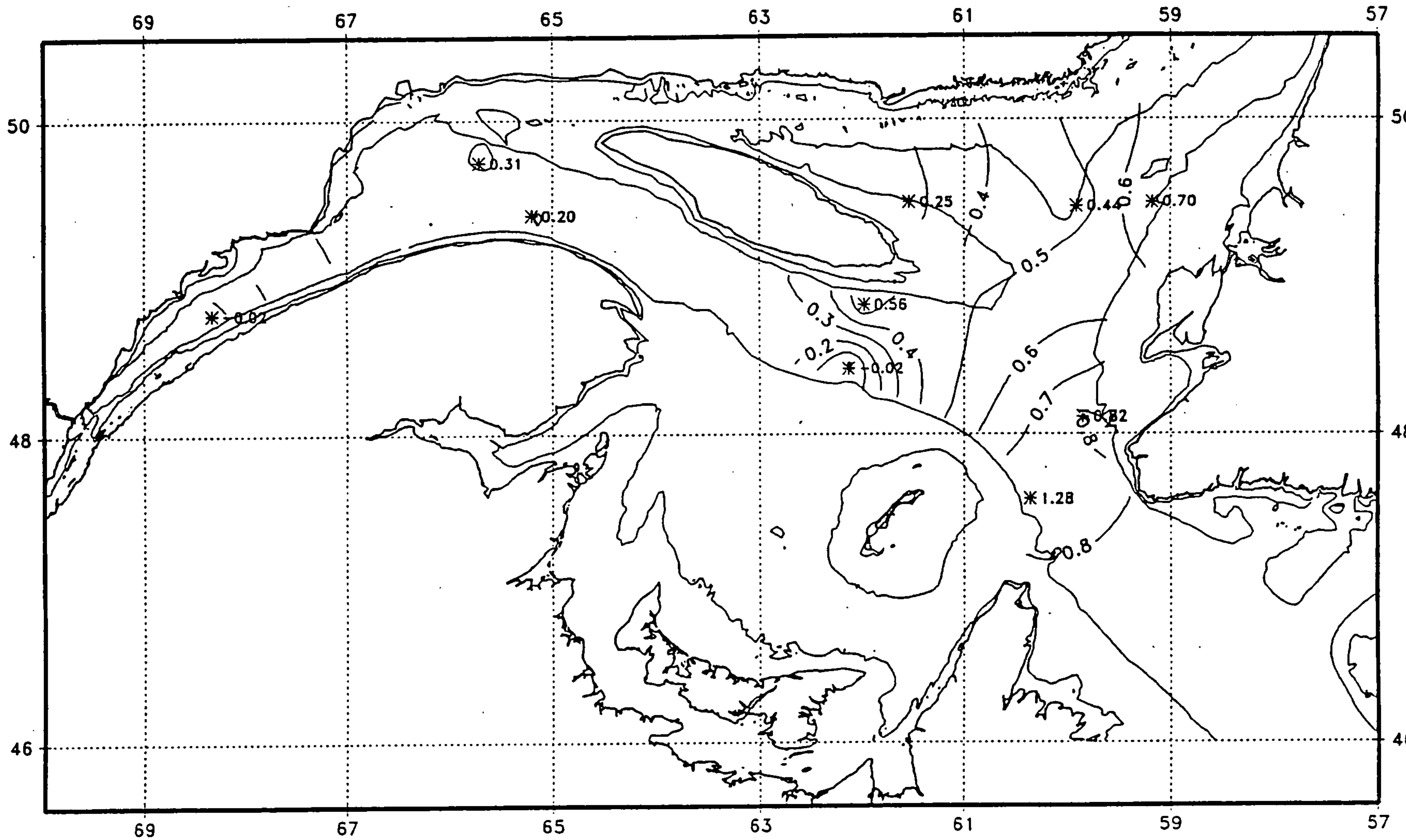


Figure 20: Differences (in °C) in the temperature of the 100 to 200 m layer between 1993 and 1992 (1993 minus 1992).

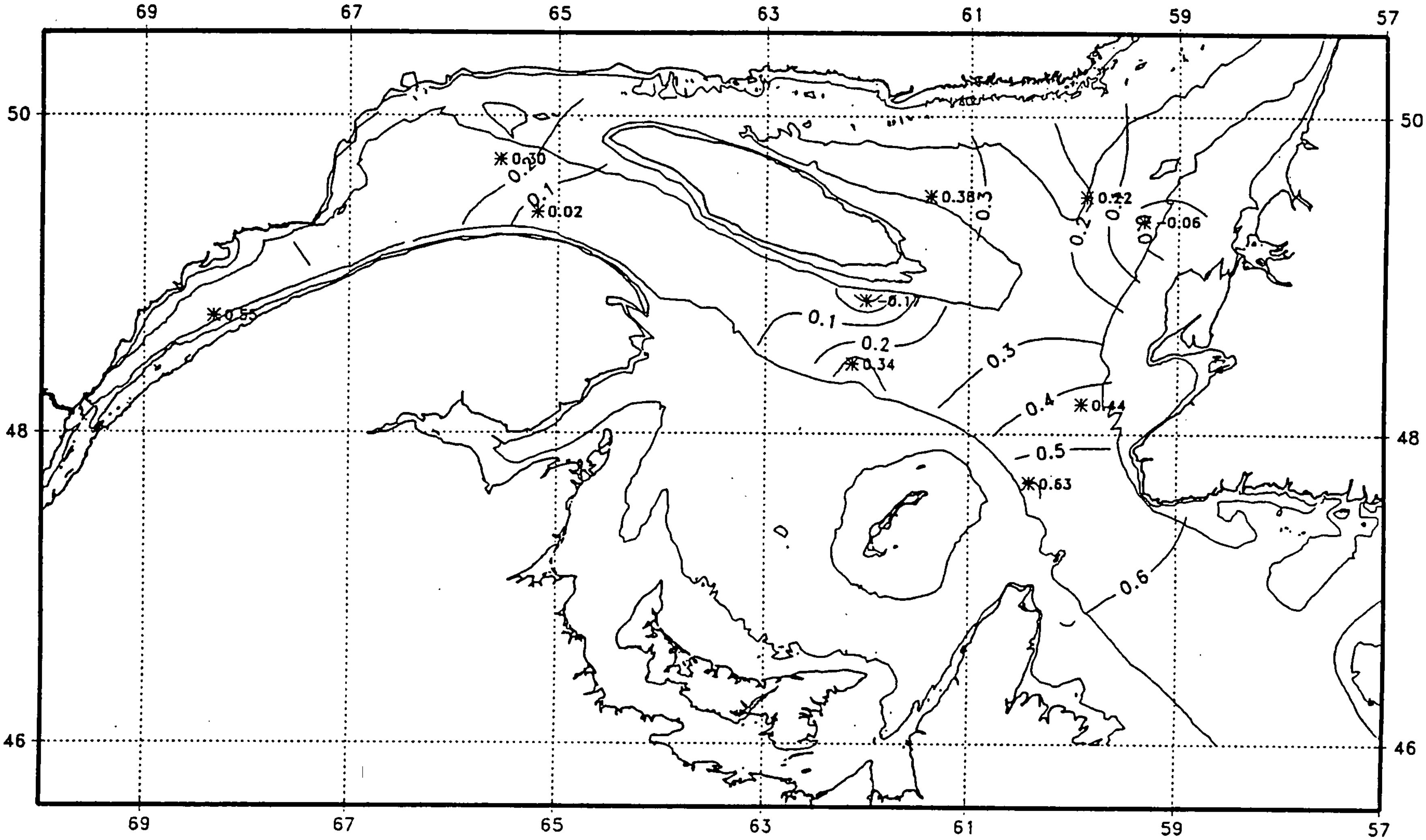


Figure 21: Differences (in °C) in the temperature of the 100 to 200 m layer between 1992 and 1991 (1992 minus 1991).

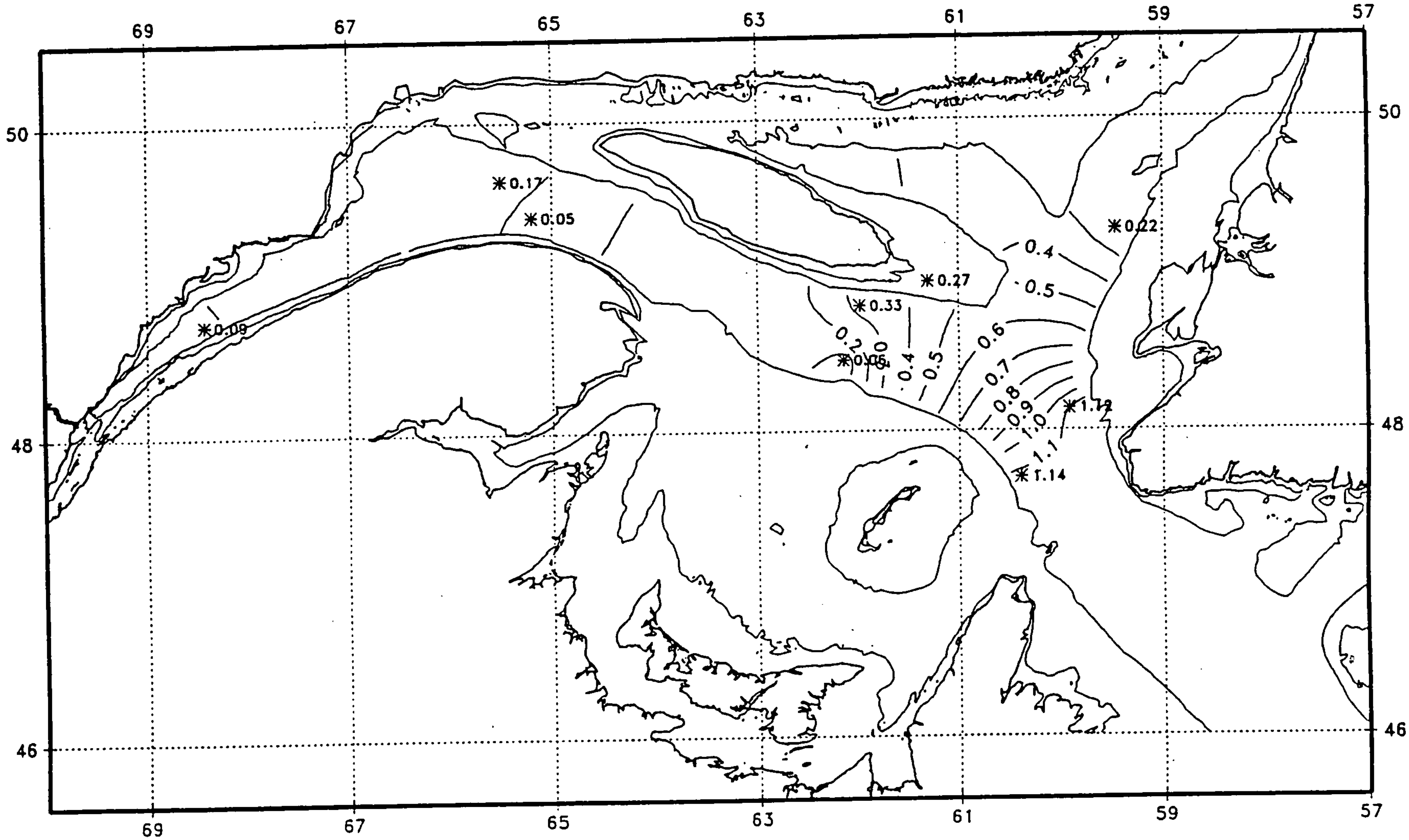


Figure 22: Differences (in °C) in the temperature of the 200 to 300 m layer between 1993 and 1992 (1993 minus 1992).

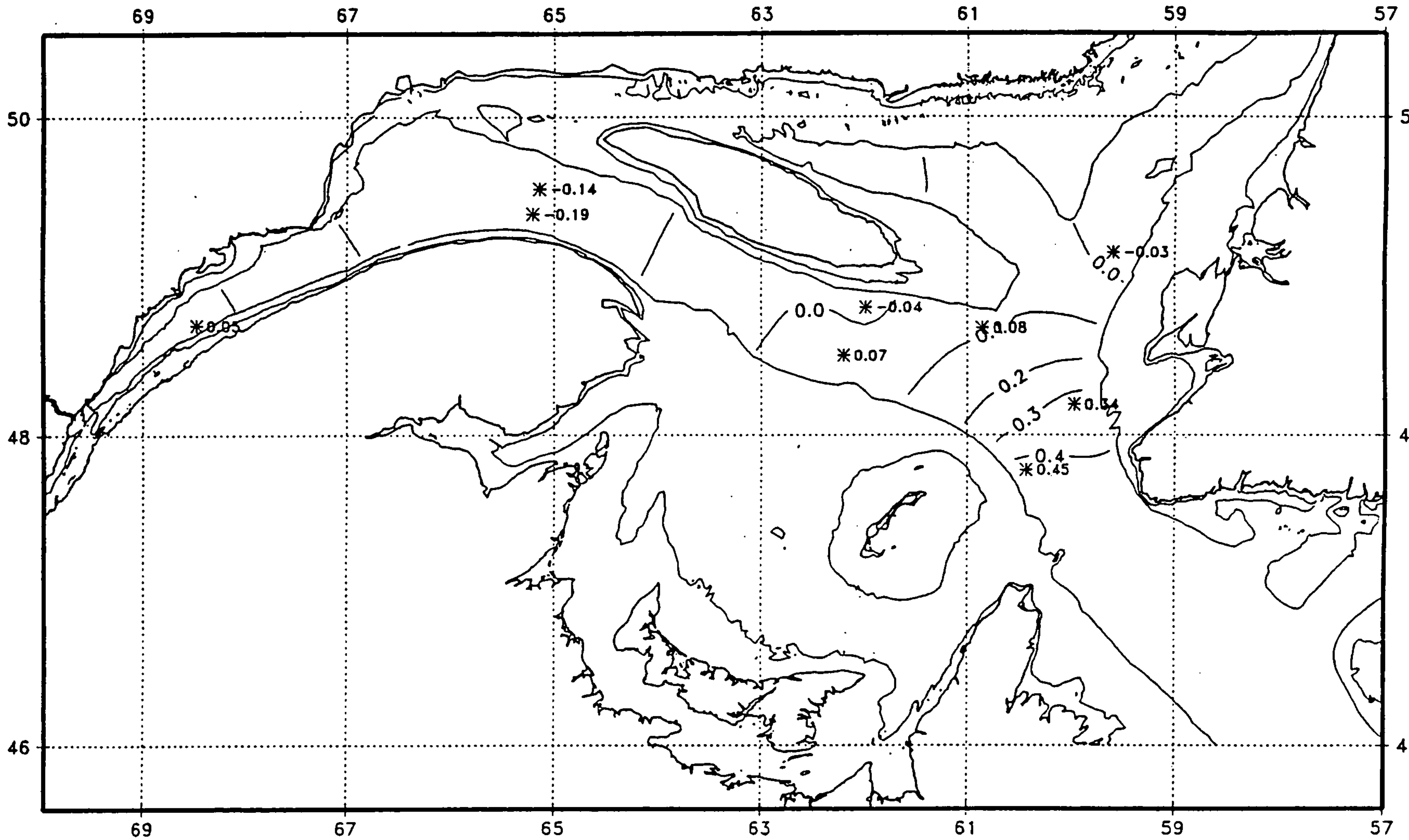


Figure 23: Differences (in °C) in the temperature of the 200 to 300 m layer between 1992 and 1991 (1992 minus 1991).

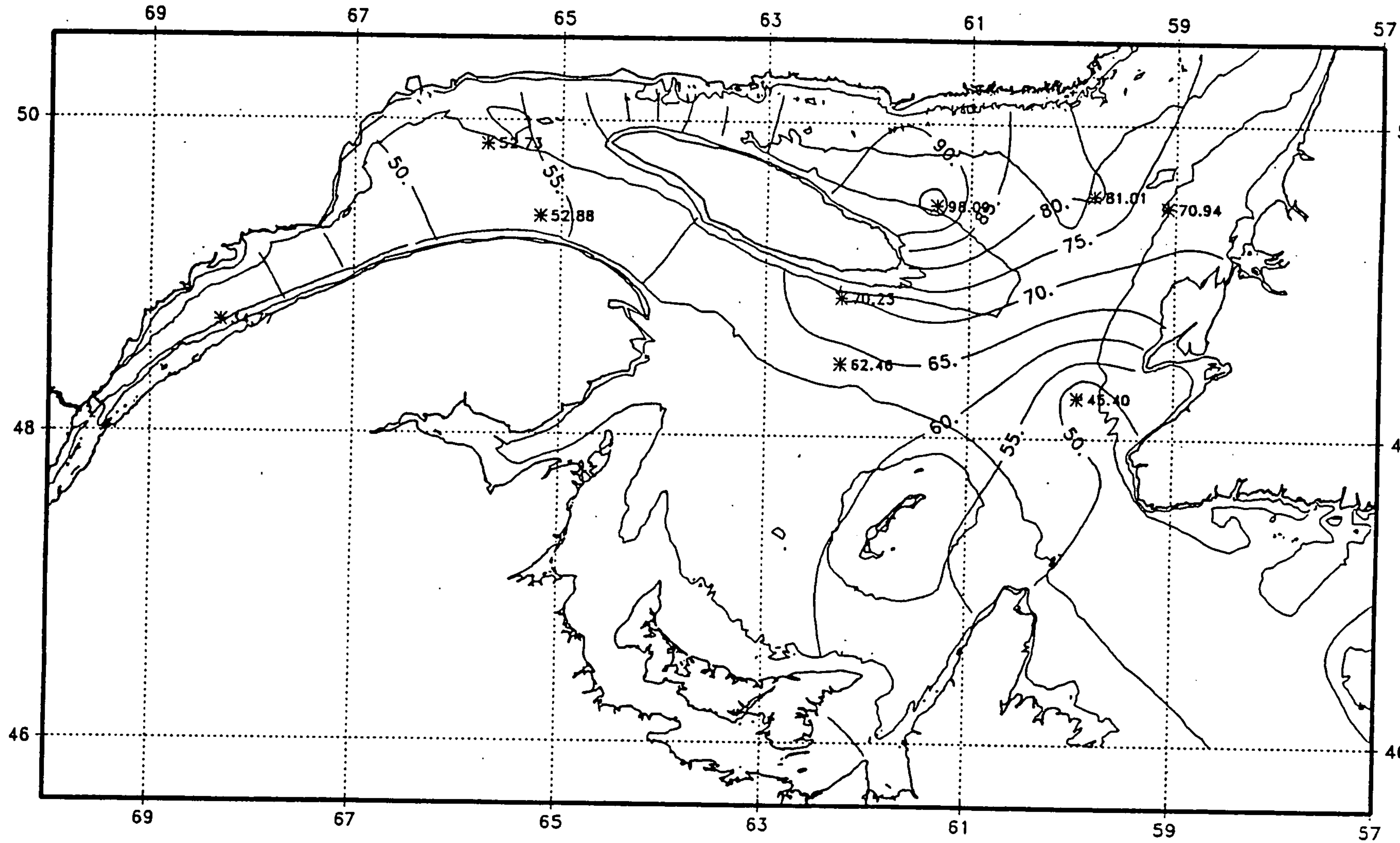


Figure 24: Thickness (in meters) of the cold intermediate layer (CIL) of the Gulf of St. Lawrence in August-September 1991. The CIL is defined as the intermediate layer with waters colder than 0°C.

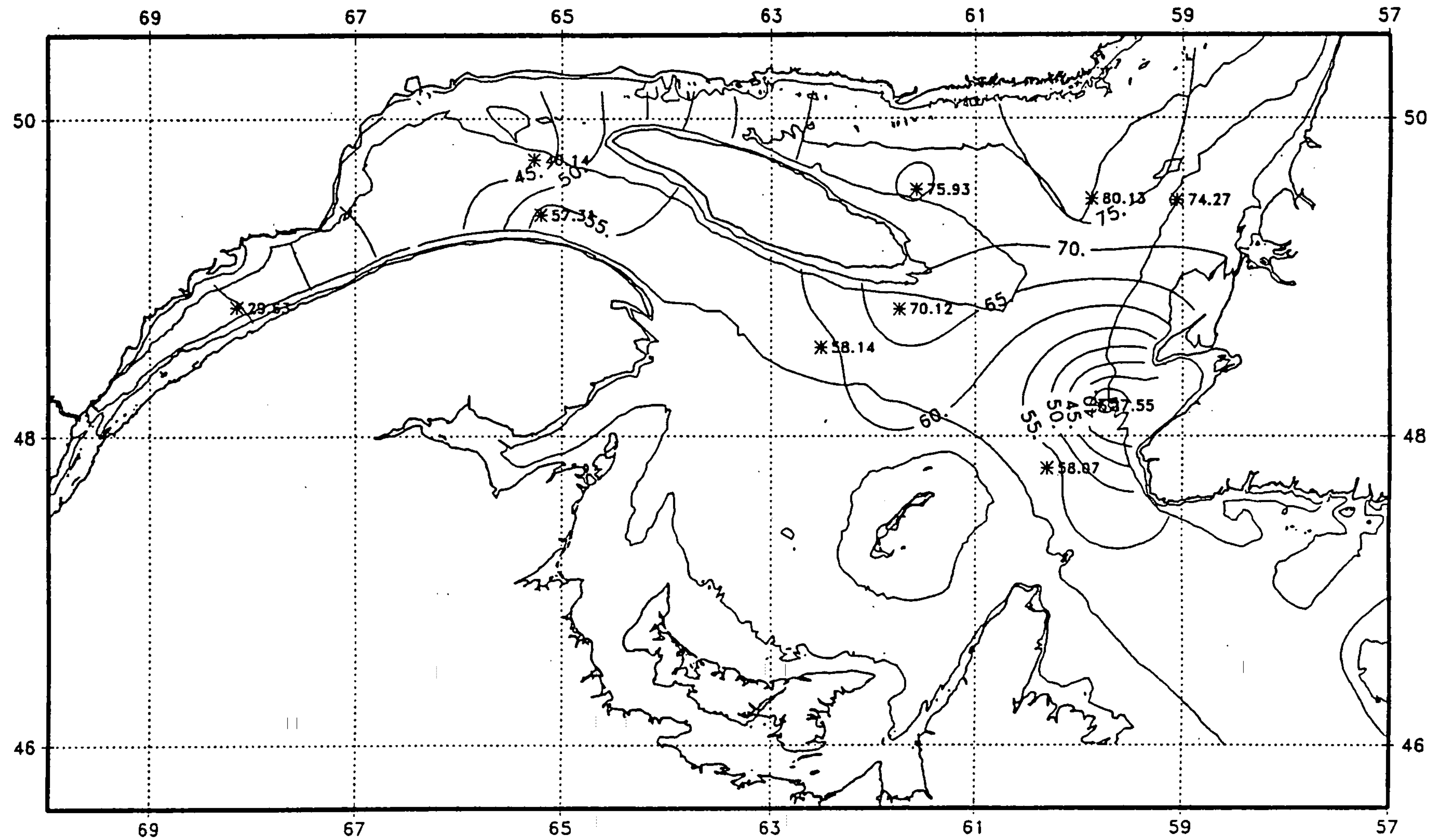


Figure 25: Thickness (in meters) of the cold intermediate layer (CIL) of the Gulf of St. Lawrence in August-September 1992. The CIL is defined as the intermediate layer with waters colder than 0°C.

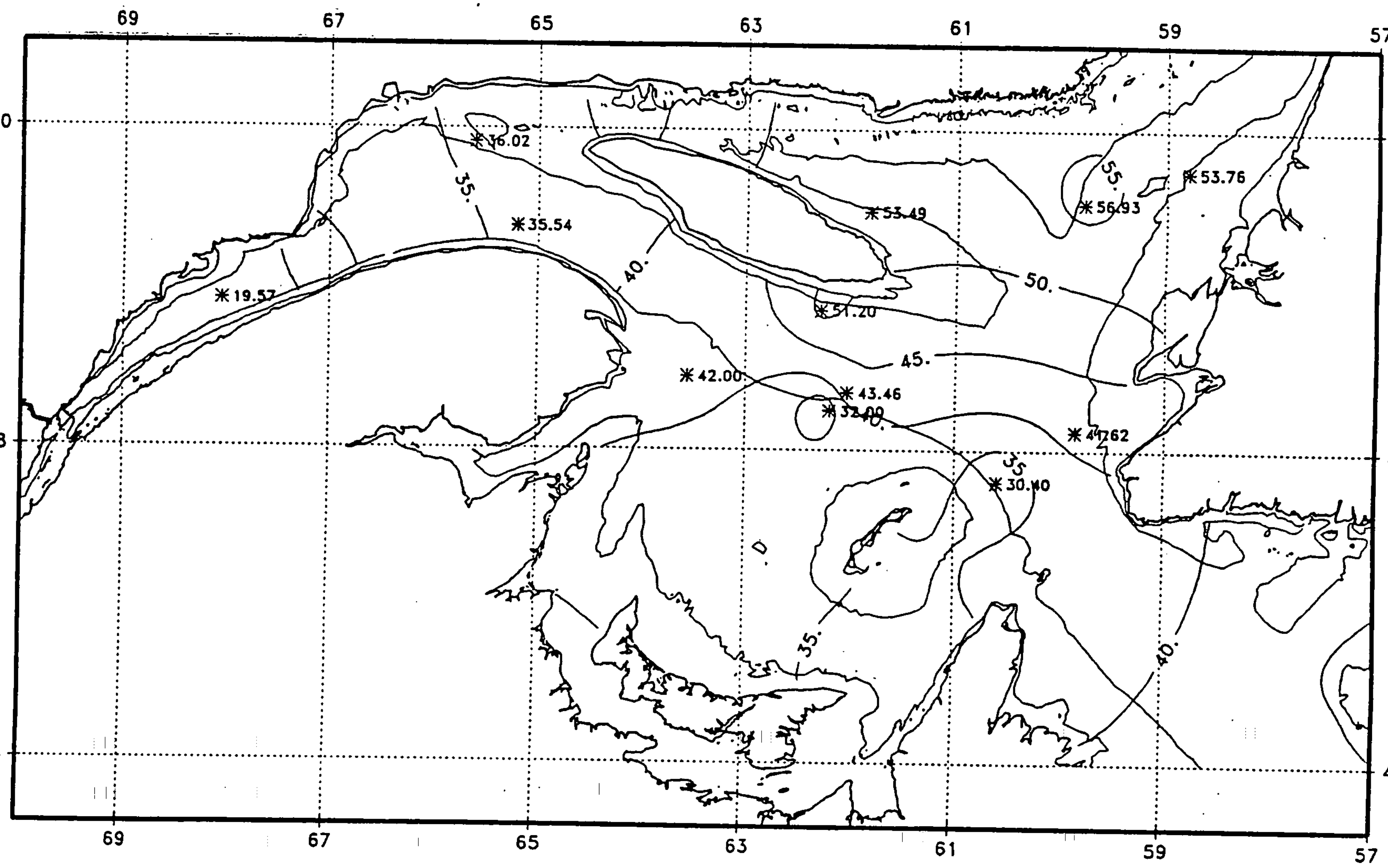


Figure 26: Thickness (in meters) of the cold intermediate layer (CIL) of the Gulf of St. Lawrence in August-September 1993. The CIL is defined as the intermediate layer with waters colder than 0°C.