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NEWFOUNDLAND SHELF SEA ICE PROGRAM, 1993 AND 1994

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ABSTRACT

Peterson, I.K., S.J. Prinsenberg and G.A. Fowler. 1995. Newfoundland Shelf Sea Ice Program, 1993 and 1994. Can. Tech. Rep. Hydrogr. Ocean. Sci. 167:vi + 129 p.

Twenty-three ice beacons, deployed on land-fast and mobile pack ice off the coast of Labrador and Newfoundland, were used to collect atmospheric, ice and oceanographic data during the winters of 1992-1993 and 1993-1994. The data were telemetered via satellite and used to study variations in sea ice properties in response to atmospheric and oceanographic conditions. This manuscript presents ice beacon, CTD and ice thickness data collected in the 1993 and 1994 winter surveys, as well as a preliminary analysis of the meteorological and ice conditions in 1993 and 1994.

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Vingt-trois balises des glaces ont été déployées sur la banquise côtière et la banquise pour la collecte de données atmosphériques, glacielles et océanographiques au large de la côte du Labrador et de Terre-Neuve pendant les hivers de 1992-1993 et 1993-1994. Les données ont été transmises par télémétrie par satellite et utilisées pour l'etude de variations des propriétés de la glace de mer en réponse aux conditions atmosphériques et océanographiques. Ce rapport présente les données provenant des balises des glaces, CTP et épaisseurs de glace pour le relevé des hivers 1993 et 1994, ainsi qu'une analyse préliminaire des conditions meteorologiques et de glace pour les hivers 1993 et 1994.

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1.0 INTRODUCTION

The seasonal pack ice along the eastern Canadian seaboard poses a threat to safe operations at sea associated with hydrocarbon exploration, shipping and fishing. Sea ice programs of the Bedford Institute of Oceanography in Dartmouth, N.S. study the seasonal variability of the movement and extent of the pack ice along the Labrador and Newfoundland coasts to help in the safe management of offshore resources. Advection of ice by wind and ocean currents from the northern Labrador Shelf and Davis Strait is the major source of ice over the Northeast Newfoundland Shelf. This ice is thicker and takes longer to decay than the thinner locally-formed ice along the southern Labrador and Newfoundland Shelves. The southernmost extent of the pack ice is determined by a balance between the volume of ice advected southwards and the rate at which the ice is melted locally due to oceanic and atmospheric heat fluxes.

In recent years, field programs have collected ice, oceanic and atmospheric data to aid in the understanding of the processes controlling the movement and extent of the pack ice. Six ice beacons in February 1993 and 13 beacons in February-March 1994 were deployed on drifting ice off the Labrador coast. Two beacons were deployed on land-fast ice near Wolf Island in March 1993, and anemometer beacons were deployed on Wolf Island in March 1993 and on Grady Island in February 1994. After a description of the field programs and instrumentation, this manuscript presents the ice beacon, CTD and ice thickness data collected during the program. Anomalies of ice extent and air temperature for 1992/93 and 1993/94 are also presented. The data collected by the program are shown in detail in the Appendices.

2.0 INSTRUMENTATION

2.1 ICE BEACONS

Five types of ice beacons, four designed and manufactured by Metocean Data Systems Ltd. of Dartmouth, N.S. and one by Seimac Ltd. were deployed in 1993 and 1994. The beacons had a variety of sensor packages (Table 1), and the data were telemetered via the Argos satellite system. The position of each ice beacon is computed by Service Argos from the measured Doppler shift of the beacon transmissions, which are received for about 10 minutes on about 10 passes per day. The accuracy and resolution of the sensors of the beacons are

listed in Table 2. Only the beacons deployed on the islands and landfast ice were recovered after the surveys; those deployed on the mobile pack ice by helicopter drifted freely with the pack ice until the floes on which they were deployed melted.

The main function of nine of the beacons was to collect position data from which ice drift rates were calculated. The two beacons built by Siemac provided position data only, while seven of the Metocean beacons were Compact Meteorological Ice Beacons (CMIB) which also report barometric pressure, air temperature, and ice surface temperature. They have battery packs designed to operate for about 3 months.

Five beacons were equipped with R.M. Young anemometers positioned at a height of 2 m above the ice surface. The beacons compute a ten-minute average of wind speed and direction once per hour and transmit these ten-minute averages for each of the previous six hours, along with the barometric pressure and air temperature. Three of the beacons were deployed on the offshore pack ice, while one was deployed on Wolf Island in 1993 and one on Grady Island in 1994 as part of another study.

Three types of ice beacons provided temperature profiles in air, ice and water. Two used the basic CMIB as a data transmitter and as a platform to collect barometric pressure, and air and hull temperature. The first of these is the Small Ice Monitoring Platform (SIMP). It consists of the transmitter (CMIB) and a rigid temperature staff frozen into the ice through an augered ice hole. Seventeen ice/water thermistors are spaced 10 cm apart below the ice surface. The top seven thermistors have a resolution of 0.2°C, and the bottom ten thermistors have a resolution of 0.1°C. The ice staff containing the thermistors is connected to the transmitter by an electrical cable. Two beacons of this type were deployed in 1993 and three in 1994.

The second beacon type using the CMIB as a data transmitter was a temperature chain ice beacon designed to measure temperature profiles down to 100 m in the water column. The flexible temperature chain was attached to a 2 m semi-rigid top section which was frozen into the ice through an augered ice hole. Ice and surface water temperatures were collected by six temperature sensors spaced at 5, 20, 35, 50, 65 and 80 cm below the snow/ice interface. The flexible chain consisted of a 1.0 cm diameter cable along which

temperature sensors were potted at 2, 3, 5, 10, 20, 30, 45, 60, 80 and 100 m below the snow/ice interface. A pressure sensor, mounted above the 50 lb ballast weight at the bottom of the chain, collected pressure data. The pressure data are used to determine the chain's wire angle from which the average current shear between the ice cover and the ocean surface layer can be obtained from mooring models (Hamilton, 1989). One of these beacons was deployed in 1993.

The third beacon type measuring temperature profiles in ice and water was similar to the SIMP, however the data transmitter and temperature staff were joined in one unit. The ice staff consisted of 24 ice/water thermistors spaced 5 cm apart, all with a resolution of 0.2°C. The battery pack inside the staff section was below the ice/air interface, while the transmitter was above the interface. Two beacons of this type were deployed in 1994.

2.2 TEMPERATURE-SALINITY INSTRUMENTATION

Temperature and salinity profiles were collected through augered ice holes at the sites where ice beacons were deployed, when time and weather permitted. The profiles were taken with a self-recording Seabird SBE-25 CTD probe. The CTD probe was lowered through augered ice holes by a cable fastened to a portable winch which was driven by the same auger gasoline engine used to drill the CTD ice holes. The accuracy/resolution of the sensors of the Seabird CTD are .004/.0003°C for temperature, .01/.005 psu for salinity and .25%/.015% for pressure.

Salinity samples of the ice were obtained from ice chips collected at various depths of the ice cover by the 4-inch hand-auger. The chips were stored and melted in standard sea water sample bottles. Salinity values were determined in the field with an AO-10419 hand-held refractometer which could be read to ±.5 psu. To check the accuracy of refractometer-determined values, salinity values of the samples were also determined by Guildline Autosal salinometer at the Bedford Institute of Oceanography.

3.0 STUDY AREA AND FIELD PROGRAM

The field programs deployed a total of 19 satellite-tracked ice beacons

on the pack ice off the coast of Labrador and Newfoundland in order to study the response of ice drift and distribution to wind stress, air temperature and ocean currents. A detailed field schedule is given in Appendix A. For safety, two helicopters were used during the field trips. One helicopter carried up to eight ice beacons, while the second carried the augers, CTD system and the equipment for collecting ice salinity samples and ice thickness measurements. Helicopters were chartered from Universal Helicopter Ltd. and Canadian Helicopter Ltd.; both companies have helicopters stationed in Goose Bay.

On February 16, 1993, six ice beacons were deployed using two helicopters on drifting pack ice off the Wolf Islands, a group of islands east of Cartwright at 53° 40.0'N, 56° 00.00'W. The ice chart for February 16 (Fig. 1) showed the ice cover extending south over northern Grand Bank and east to about the 1000 m isobath, the median position of the eastern ice edge. The chart indicated that the six beacons deployed on February 16 were on pack ice with a concentration of $9^{+}/10$ and a maximum thickness of 70-120 cm. On the way out from the Wolf Islands, a Small Ice Monitoring Platform (SIMP) was deployed at the inner site, an anemometer beacon at the middle site, and a Compact Meteorological Ice Beacon (CMIB) at the outer site. On the return trip from the ENE of Wolf Is., another CMIB was deployed at the middle site, and a SIMP at the inner site. On March 1, a CMIB and a position-only beacon were deployed on landfast ice near the Wolf Islands, and on March 7, an anemometer beacon was deployed on North Wolf Island as part of another study.

In 1994, two SIMPs measuring ice temperature profiles were deployed by helicopter on February 23 in land-fast ice off Grady Island (20 km northwest of the Wolf Islands), and an anemometer beacon was deployed on February 24 on Grady Island as part of another study. Between March 3 and March 9, eleven ice beacons were deployed on drifting pack ice off Cartwright. The ice chart for March 6 (Fig. 2) showed the ice cover extending south over northern Grand Bank and east past the 1000 m isobath. The chart indicated that the eleven beacons deployed between March 3 and 9 were on pack ice with a concentration of $9^{+}/10$ and a maximum thickness of over 120 cm. A CMIB was deployed on drifting pack ice on March 3, two CMIBs and an anemometer beacon were deployed on March 4, a SIMP and a CMIB were deployed on March 6, a SIMP and a position-only beacon were deployed on March 7, and a SIMP, an anemometer beacon and a CMIB were deployed on March 9.

4.0 1992/1993 AND 1993/1994 AIR TEMPERATURE AND ICE COVER ANOMALIES

As in the winters of 1990/91 and 1991/92, below-normal air temperatures (Table 3) and above-normal ice extent were experienced along the Canadian east coast during the winter (Jan-Mar) of 1992/93 and 1993/94 (AES, 1994). Of the four years, 1992/93 experienced the coldest winter air temperatures. However for the April to June period (when each year the southern ice edge retreats northward), air temperatures were below normal in 1991-1993, but were above normal in 1994.

The anomalies of ice cover extent relative to the 1963-1988 mean were above normal in 1992/93 and 1993/94, as they were in the previous two years (Fig. 3). Of the four years, the highest anomalies were in 1992/93 for the northernmost latitude band (53-55°N). The ice retreated earlier than normal in 1994, reflecting the air temperature anomaly.

5.0 ICE BEACON DATA

5.1 ICE BEACON TRAJECTORIES

The start and end times of the period over which the ice beacons operated on the ice are shown in Table 1. The operating period ranged from 6 to 64 days, with a mean of 43 days for the beacons on the drifting pack ice. The anemometer beacon on Grady Island operated for 93 days with 51 days of good wind data.

After removing spikes from the position data, six-hourly values were computed using linear interpolation. The trajectories of the beacons for the two years, based on these 6-hourly positions, are plotted in Figures 8 and 9. The trajectories of individual beacons are shown in Appendix B, with the positions marked at 1800 GMT each day and labelled every 10 days. The beacons deployed in February 1993 followed a cohesive drift pattern southward and parallel to the coast, and finally drifted onto the Grand Banks where the ice melted in mid-April (Fig. 4). The beacons deployed in March 1994 also drifted southwards initially along the Labrador coast, but then moved southeastward over the Northeast Newfoundland Shelf (Fig. 5). Four of the beacons eventually became entrained in the offshore branch of the Labrador Current.

Note that all the beacons eventually moved offshore; none moved southwards between the Grand Bank and the Newfoundland coast.

Daily mean velocity components were calculated from beacon positions using 2100 GMT as start and end times. For each beacon, Table 6 lists the mean velocity components, mean speed and direction travelled as well as minimum and maximum daily speeds over the period the beacons tracked the offshore pack ice. Beacons generally drifted at 10-20 cm/sec towards the south or southeast. Daily speeds were as high as 87 cm/sec or 75 km for a single day.

5.2 ICE BEACON ENVIRONMENTAL DATA

In addition to position data, the beacons collected data from the ocean, ice cover and atmosphere. The sensors on the various ice beacons are listed in Table 1, with the sensor resolutions and accuracies shown in Table 2.

All the data except wind data were processed as follows. For each pass, the median value for each parameter was computed and obvious spikes were removed. Most of the data are plotted in Appendix C. Hourly ice and water temperatures were computed using linear interpolation and used to derive daily mean profiles. Two examples of air temperature and ice and water temperature profiles are shown in Fig. 6: from beacon #974 in 1993 and #973 in 1994. Data from the other SIMPs are shown in Appendix C. Daily mean ice and water temperature profiles are plotted as solid lines every two days relative to -1.8°C lines which are dotted, and one day represents 1°C. Beacon #974 was deployed on day 47 of 1993, and the underlying ice melted on day 102 when the temperature of the underlying water rose above the freezing point of seawater (-1.8°C). Beacon #973 on the other hand was deployed later in the season (day 66 of 1994) and the underlying ice melted on day 121 when it was warmest at the surface and was warmer than the underlying water.

The two ice temperature profile ice beacons (SIMPs) deployed in 1993 (#970 and #974) operated for 61 and 55 days respectively until the ice on which they were placed melted; the ice/water thermistors for #970 failed after 52 days. The landfast ice on which the two SIMPs were deployed in February 1994 broke away, and #2367 was recovered after seven days of operation; however the ice staff had been sheared off and the thermistors below 40 cm had

failed about a day earlier. Beacon #2368 failed after 6 days of operation when it was probably crushed. The three SIMPs deployed in March 1994 (#971, #972 and #973) operated for 52, 18 and 55 days respectively; #972 was likely crushed, and the ice under the other two beacons probably melted. In 1993, the ice beacon with a thermistor chain (#10058) operated for 22 days; however there were only 13 days of air temperature data and six days of ice/water temperature data.

In 1993, the anemometer beacon on Wolf Island (#8668) operated for 22 days when it was recovered. The beacon on drifting ice (#4757) operated for 21 days when it may have been crushed. In 1994, the anemometer beacon on Grady Island (#4769) operated for 121 days when it was recovered; there are 65 days of good wind data. The anemometer beacons on drifting ice (#8664 and #8668) operated for 51 and 56 days respectively when the ice on which they were placed melted. For each anemometer beacon, the hourly wind data were sorted using the internal clock time. For each hour, the record having the largest number of repeats was selected. Missing values were filled using linear interpolation. Three-hourly mean wind components for beacon #8664 are shown as stick plots in Fig. 7 along with the three-hourly drift velocities; plots for the other anemometer beacons are in Appendix C. The plots show a high correlation between the wind and beacon drift.

5.3 ICE AND WATER TEMPERATURE/SALINITY DATA

In 1993, CTD profiles (Appendix E) were collected at the six ice beacon deployment sites, however only five were successful. Ice salinity samples were collected at three of the sites. In 1994, three CTD profiles were done on February 24, and six were done on March 8 along a transect across Hamilton Bank (Appendix E). Snow and ice salinity samples were collected at the ice beacon deployment sites on March 4, 6, 7 and 9.

The CTD data were averaged in 0.5 dbar bins, and are shown as plots in Appendix E for both the downcasts (solid lines) and upcasts (dashed lines). Freezing temperatures, also shown, were calculated as a function of salinity and pressure using the equations of Fujino et al (1974). The CTD data listed at intervals of 5 dbar (Appendix E) are from the upcast.

In February 1993, the CTD profiles showed that the depth of the

homogeneous surface mixed layer (at the freezing point) was 120-150 m at the inner stations (Table 5). At the outer station (Sta. 9303) it was only 70 m, below which the temperature increased to -0.1°C at 145 m. In February 1994, all three of the CTD profiles showed that the depth of the surface mixed layer extended to the bottom of the profile (160, 150 and 80 m). In March 1994, the mixed layer extended to the bottom of the profile (80 m) at the inner station. Moving offshore, the depth of the mixed layer decreased from 145 m at station #5 to 65 m at station #1. Below the surface layer, the temperature increased to -0.2°C at station #1.

Ice salinities ranged from 7 to 28 ppt in 1993, and from 6 to 27 ppt in 1994. Snow salinities were 3 to 37 ppt, and a slush layer was found at two of the inshore sites with a salinity of 35 ppt. The high ice salinity values probably represent refrozen slush layers formed after snow depressed the ice surface and flooding occurred.

6.0 CONCLUSION

Below normal air temperatures and above normal ice coverage occurred during the winters of 1992/1993 and 1993/1994 over the Labrador and NE Newfoundland shelves. However, spring air temperatures were above normal in 1994, and the ice retreated earlier than normal.

During the winters of 1993 and 1994, the Bedford Institute of Oceanography deployed a total of 23 satellite-tracked ice beacons off the Labrador coast, 19 on drifting pack ice and four on landfast ice. Several different types of ice beacons were used, all of which telemetered their environmental data via the Argos satellite system and provided position data. The beacons generally drifted from 10 to 20 cm/sec towards the south or southeast.

Temperature and salinity profiles of the water column beneath the ice cover were collected at five of the beacon deployment sites in 1993, at three sites in February 1994, and at six sites along a transect out to Hamilton Bank in March 1994. At the nearshore sites, there was a homogeneous layer of water at the freezing point down to the bottom the profiles, while at the offshore sites, the surface mixed layer was 65-70 m thick.

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Table 1. Start and end times in calendar days, types and sensors (x) for ice beacons on both land-fast and drifting ice. The times represent the times when the beacons were transmitting on the ice; in some cases, the sensors did not work over the whole period.

Year	Beacon ID	Type*	Year Day Start	Year Day End	Sensors: Bar. P.	Air T.	Hull T.	Ice T.	Wind
1993	974	SIMP	47	102	x	x	x	x	-
1993	4757	Anem.	47	68	x	x	-	-	x
1993	967	CMIB	47	111	x	x	x	-	-
1993	968	CMIB	47	108	x	x	x	-	-
1993	10058	T.C.	47	69	x	x	x	x	-
1993	970	SIMP	47	108	x	x	x	x	-
1993	2342	Loc.	60	88	-	-	-	-	-
1993	969	CMIB	60	88	x	x	x	-	-
1993	8668	Anem.	66	88	x	x	-	-	x
1994	2367	SIMP	54	61	x	x	x	x	-
1994	2368	SIMP	54	60	x	x	x	x	-
1994	4769	Anem.	55	176	x	x	-	-	x
1994	977	CMIB	62	113	x	x	x	-	-
1994	976	CMIB	63	119	x	x	x	-	-
1994	965	CMIB	63	119	x	x	x	-	-
1994	8668	Anem.	63	119	x	x	-	-	x
1994	971	SIMP	65	117	x	x	x	x	-
1994	978	CMIB	65	120	x	x	x	-	-
1994	973	SIMP	66	121	x	x	x	x	-
1994	2342	Loc.	66	115	-	-	-	-	-
1994	972	SIMP	68	86	x	x	x	x	-
1994	8664	Anem.	68	119	x	x	-	-	x
1994	979	CMIB	68	80	x	x	x	-	-

* Anem. = Anemometer beacon
CMIB = Compact Meteorological Ice Beacon
Loc. = Location beacon
SIMP = Small Ice Monitoring Platform
T.C. = Temperature Chain Beacon

Table 2. Accuracy and resolution of ice beacon data parameters.

Data parameters	Accuracy	Resolution
Latitude	0.2 km	0.1 km
Longitude	0.2 km	0.1 km
Barometric pressure	1.5 mb	0.15 mb
Air temperature	1.0°C	0.3°C
Hull temperature	1.0°C	0.2°C
Ice temperature	1.0°C	0.2°C
Water temperatures	1.0°C	0.1°C
Wind: speed (<10 m/s)	1.0 m/s	0.48 m/s
speed (>10 m/s)	10%	10%
Wind direction	5°	<1°

Table 3. Air temperature anomalies for stations along the Canadan east coast from the Climatic Perspectives published monthly by AES (1994).

	AREA	Baffin Bay	Davis Strait	Hudson Strait	Labrador S. Coast	Newfoundland NE. Coast	
	Station	Clyde	C. Dyer	Iqaluit	Cartwright	St. John's	
1992	October	1.0	2.5	2.1	0.6	-1.3	
	November	-3.1	-4.0	-5.4	-2.9	-3.7	
	December	-1.9	-2.5	-3.9	-2.6	-1.5	
1993	January	-6.0	-6.5	-5.9	-3.7	-3.3	
	February	-5.4	-6.0	-8.7	-6.4	-1.7	
	March	-5.3	-5.0	-4.5	-4.9	-1.3	
	April	-2.3	-4.0	-4.7	-0.2	0.8	
	May	-0.2	-0.9	-0.9	-0.6	0.1	
	June	-0.1	0.4	0.4	-1.7	-1.7	
	July	0.2	-0.8	-1.4	-3.1	-3.1	
1993	October	0.6	1.0	1.1	-0.3	-1.0	
	November	-8.0	-6.0	-3.9	-2.5	-1.4	
	December	-2.8	-3.5	-4.3	0.5	1.3	
1994	January	-3.5	-1.0	-0.8	-4.1	-1.7	
	February	-0.9	-1.0	-1.2	-5.7	-5.0	
	March	-3.8	-3.6	-3.4	-1.8	-0.2	
	April	1.1	1.0	0.9	-0.9	1.2	
	May	2.3	1.0	0.4	-0.4	0.4	
	June	0.9	0.4	0.2	0.5	0.5	
	July	0.6	0.0	-0.3	0.8	1.3	
							Area
	Jan.-Mar.94	-2.7	-1.9	-1.7	-3.9	-2.3	-2.5
	Apr.-Jun.94	1.4	0.8	0.5	-0.3	0.7	0.6
							Area
	Jan.-Mar.93	-5.6	-5.8	-6.3	-5.0	-2.1	-5.0
	Apr.-Jun.93	-0.9	-1.5	-1.8	-0.8	-0.3	-1.0
							Area
	Jan.-Mar.92	-4.1	-2.3	-4.1	-3.5	-2.7	-3.3
	Apr.-Jun.92	-2.5	-3.5	-4.3	-1.4	-0.4	-2.4
							Area
	Jan.-Mar.91	-2.2	-2.9	-3.1	-2.7	-1.6	-2.5
	Apr.-Jun.91	1.4	-1.1	-1.5	-2.4	-1.2	-1.0

Table 4. Mean and standard deviation of velocity components, vector mean speed and direction, minimum and maximum daily speed and number of days for the ice beacons deployed on drifting pack ice (i.e. those in Cartwright Harbour are omitted). U and V are the velocity components, such that positive U is toward the east, and positive V is toward the north.

Beacon ID	$\overline{U}$ cm/s	s.d.(U) cm/s	$\overline{V}$ cm/s	s.d.(V) cm/s	Speed cm/s	Dir. °T	Min Sp. cm/s	Max Sp. cm/s	Days
1993									
00967	9.0	14.2	-12.9	18.0	15.7	145.	3.4	61.3	64
00968	5.9	14.0	-13.0	17.3	14.3	156.	3.0	61.0	61
00970	7.8	14.3	-12.8	17.3	15.0	149.	0.5	63.5	61
00974	8.5	16.1	-16.0	17.2	18.1	152.	0.1	62.9	52
04757	0.3	8.0	-16.0	20.9	16.0	179.	2.9	61.1	20
10058	0.9	8.6	-19.2	21.6	19.2	177.	1.8	64.7	21
1994									
00965	5.8	10.5	-8.7	17.6	10.5	147.	2.9	62.6	56
00971	10.4	13.1	-14.3	19.4	17.7	144.	2.9	70.6	52
00972	-1.7	7.9	0.3	10.4	1.8	-80.	1.6	24.7	14
00973	6.5	11.7	-10.0	20.9	11.9	147.	1.5	67.8	54
00976	0.1	0.7	-0.1	1.0	0.2	157.	0.0	6.3	55
00977	6.1	11.2	-11.9	16.4	13.4	153.	3.5	55.4	50
00978	12.4	18.5	-14.7	21.9	19.3	140.	4.0	87.4	55
00979	-2.5	8.8	-0.8	12.3	2.6	253.	1.0	25.5	10
02342	10.5	11.7	-9.8	19.9	14.3	133.	5.0	62.3	47
02367	10.4	18.5	-12.0	28.9	15.9	139.	0.1	82.2	6
02368	3.9	10.6	-0.4	5.8	3.9	95.	0.1	24.9	5
08664	12.6	14.1	-16.0	20.9	20.4	142.	3.4	85.6	51
08668	3.6	9.0	-10.2	15.9	10.9	161.	0.1	67.2	56

Table 5. Salinity-Temperature profile data for 1993 and 1994.

Stn #	File #	Temperature		Salinity		Depth (m)	
		down	up	down	up	mixed l.	profile
9301	PRIN9301	yes	yes	yes	yes	120	125
9302	PRIN9302	yes	yes	yes	yes	120	195
9303	PRIN9303	yes	yes	yes	yes	70	145
9305	PRIN9305	yes	yes	yes	yes	80	100
9306	PRIN9306	yes	yes	yes	yes	150	170
9400	SIM09400	yes	yes	no	no	160	160
9402	SIM09402	yes	yes	no	no	145	145
9403	SIM09403	yes	yes	no	no	80	80
1	SIM19403	yes	yes	>20m	<80m	65	165
2	SIM19402	yes	yes	yes	yes	80	145
3	SIM19401	yes	yes	yes	yes	105	150
4	SIM19404	yes	yes	yes	yes	100	145
5	SIM19405	yes	yes	>20m	yes	145	165
6	SIM19406	yes	yes	yes	yes	70	70

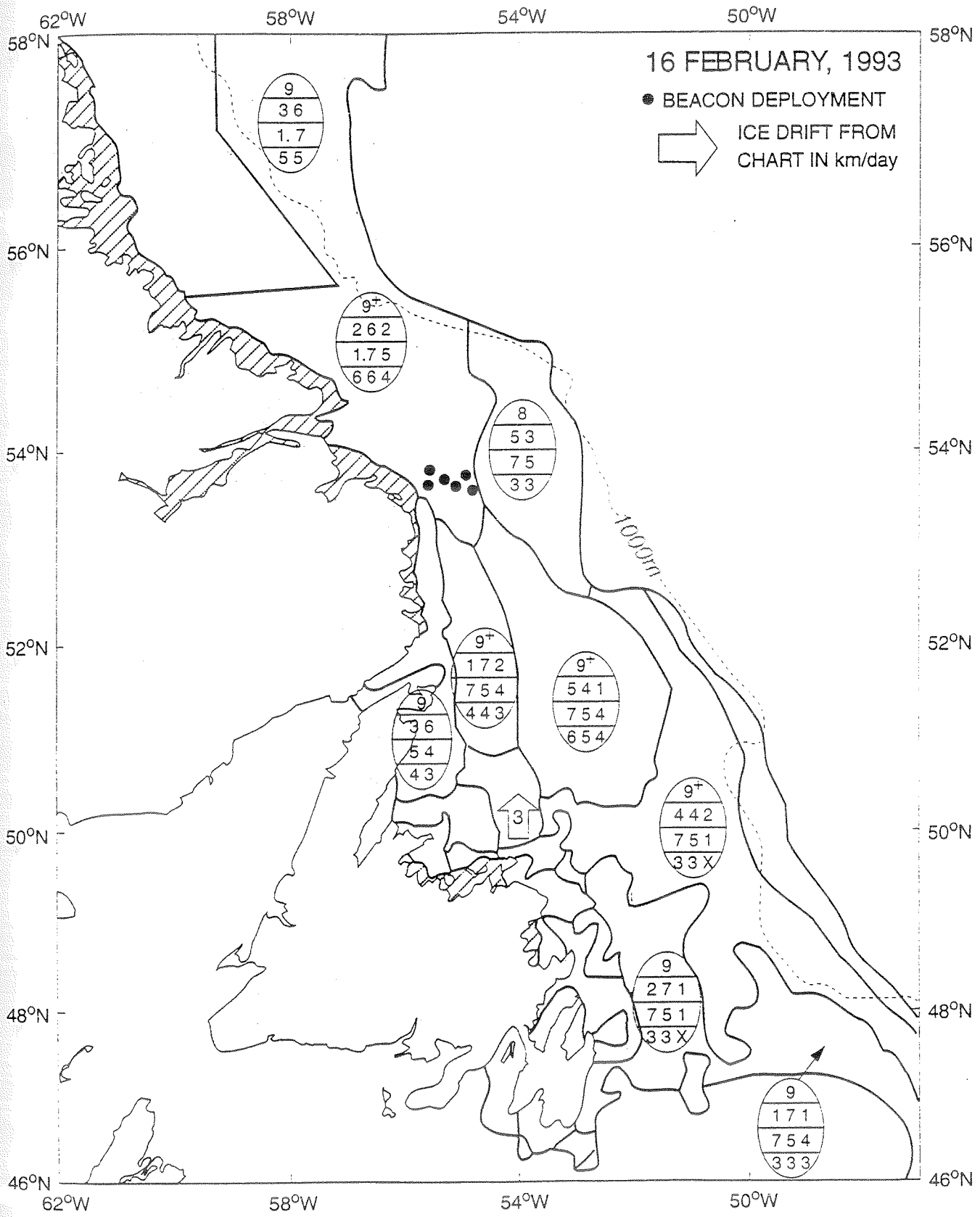


Fig. 1. Ice chart of February 16, 1993, showing the locations of the beacons deployed on February 16. Hatched areas nearshore represent land-fast ice.

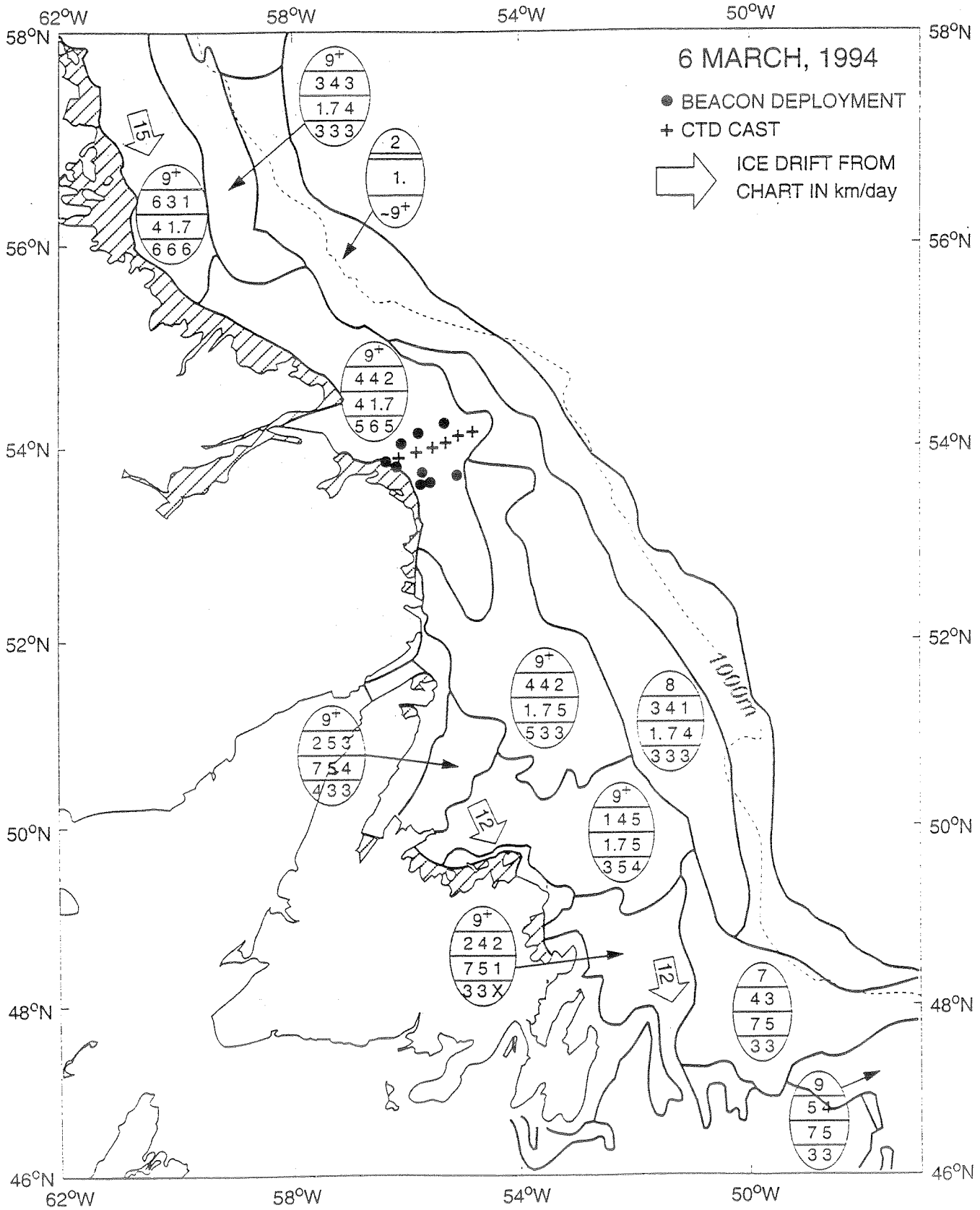


Fig. 2. Ice chart of March 6, 1994, showing the locations of the beacons deployed on March 3 to 9, and the CTD stations on March 8. Hatched areas nearshore represent land-fast ice.

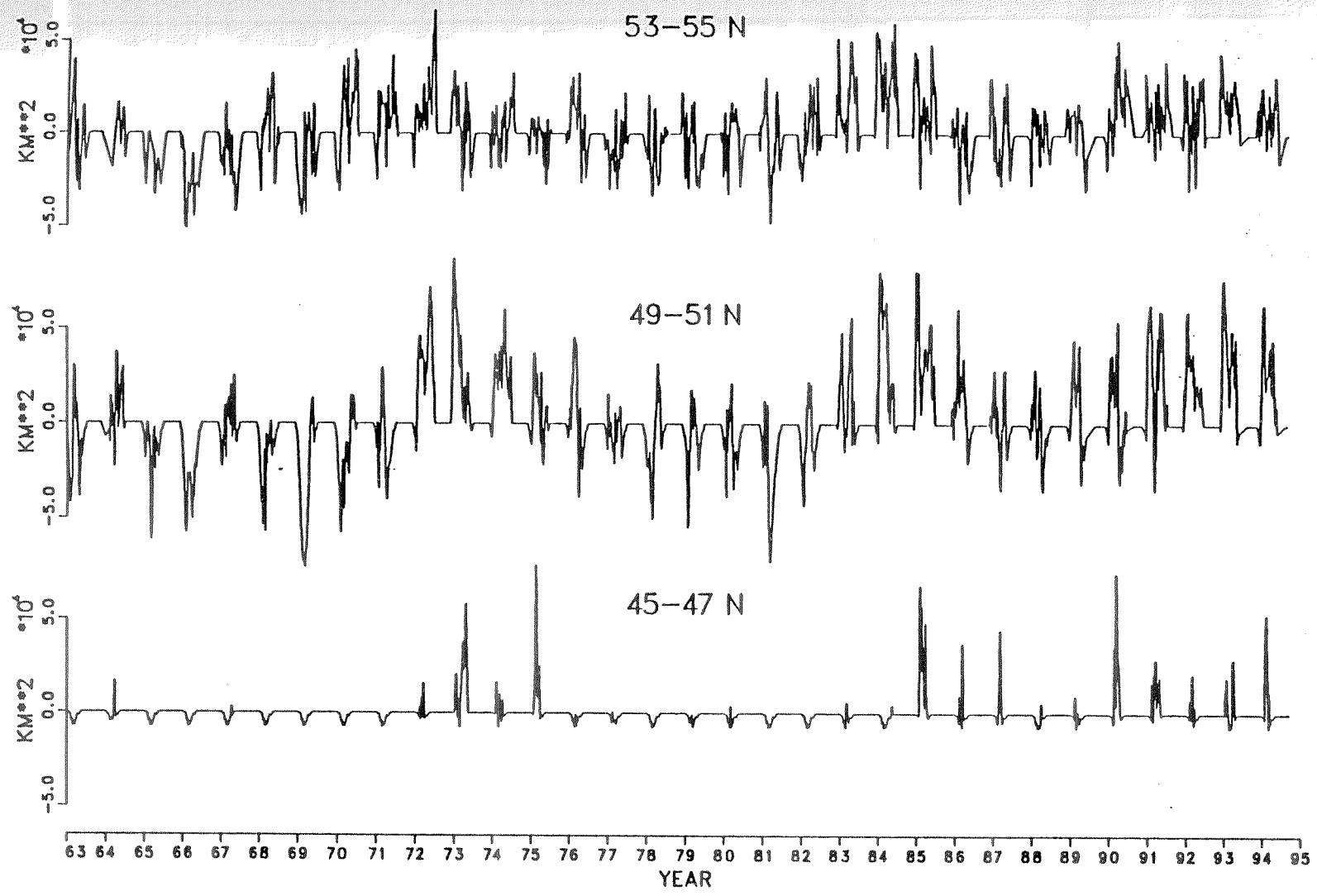


Fig. 3. Seasonal ice cover anomalies in $10^4 km^2$ (weekly values) for three areas along the Labrador/Newfoundland coast: Hamilton Bank area from 53 to 55°N, NE Newfoundland shelf from 49 to 51°N and S Grand Bank from 45 to 47°N.

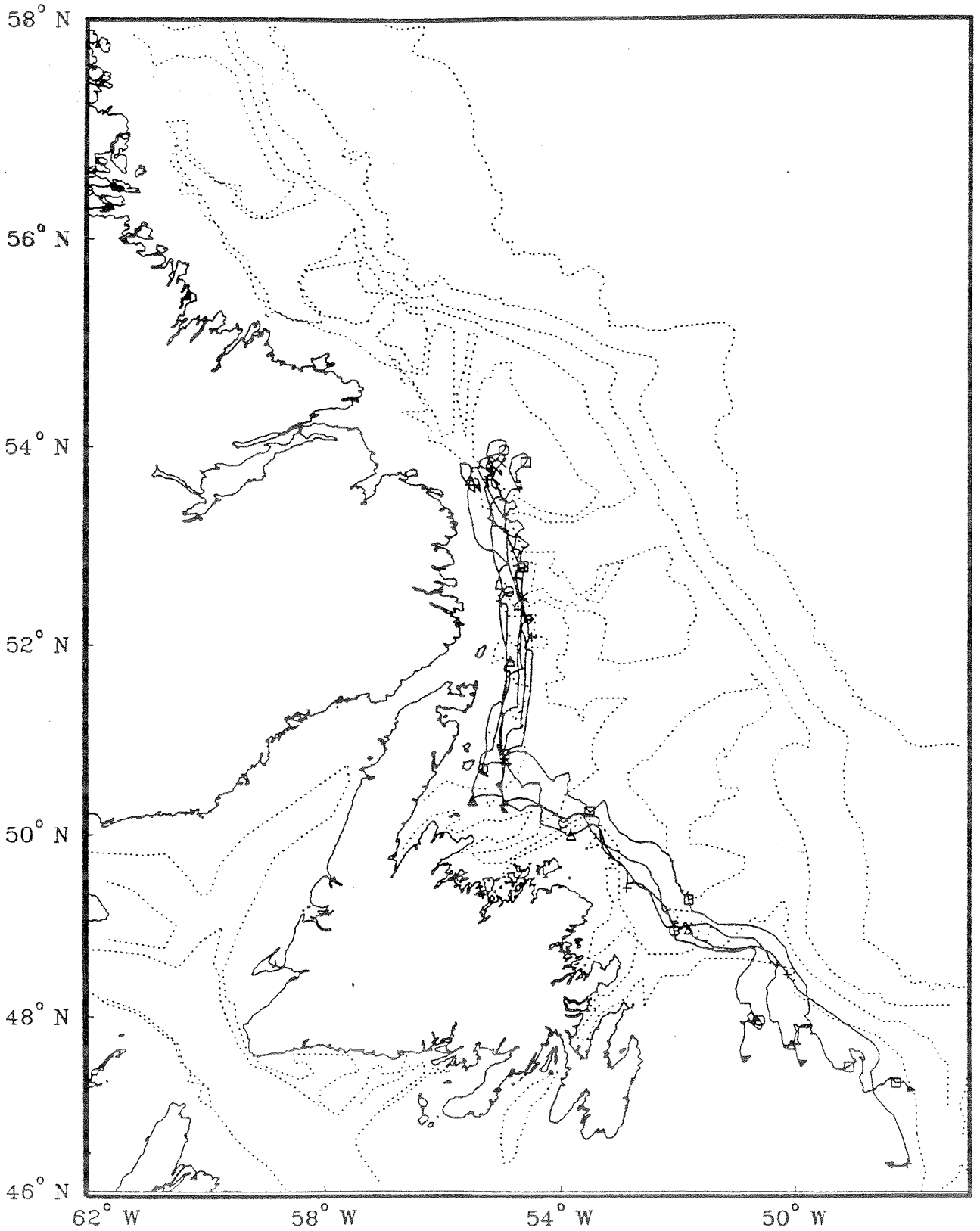


Fig. 4. Trajectories of ice beacons deployed on February 16, 1993, with positions marked every 10 days.

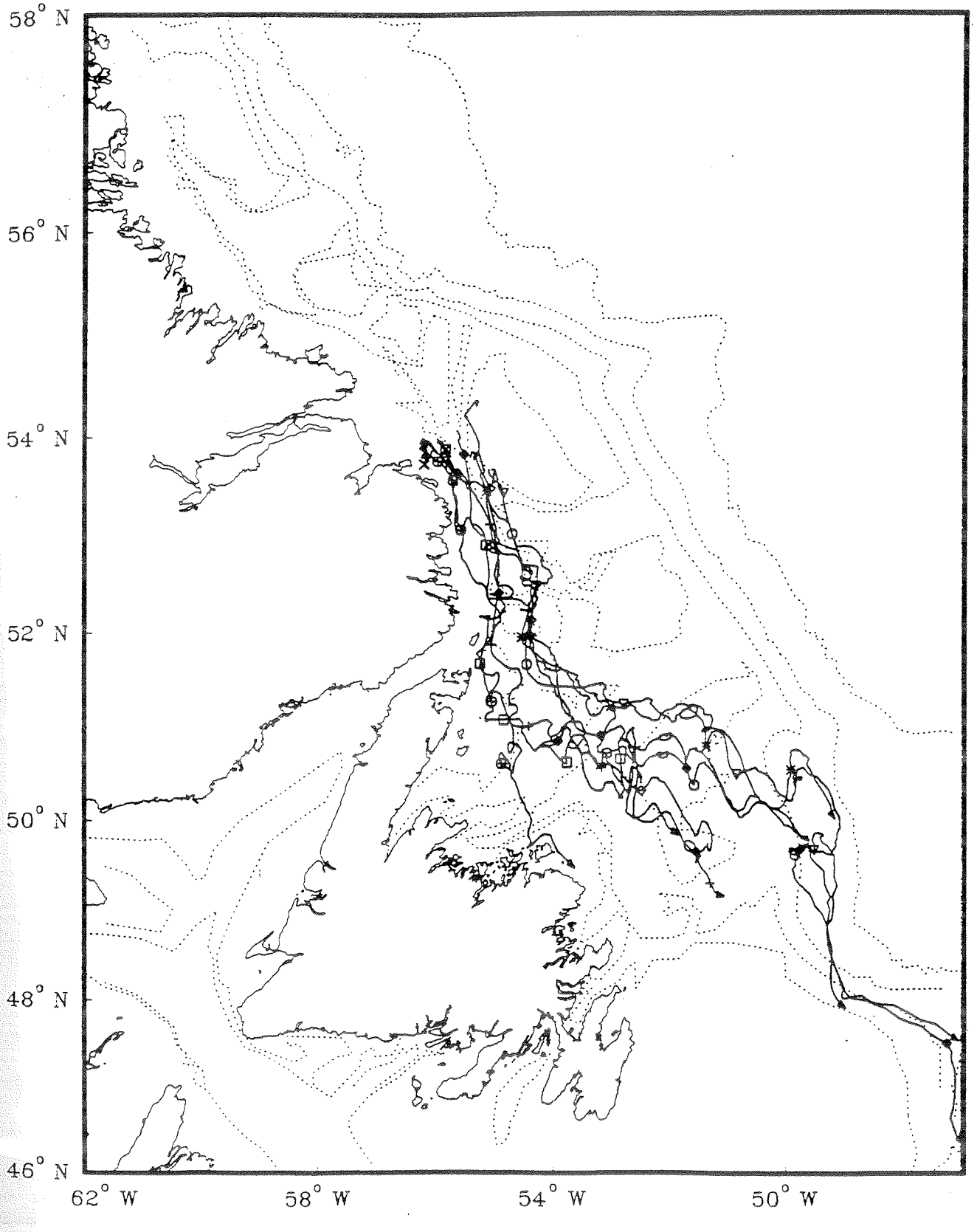


Fig. 5. Trajectories of ice beacons deployed on March 6 to 9, 1994, with positions marked every 10 days.

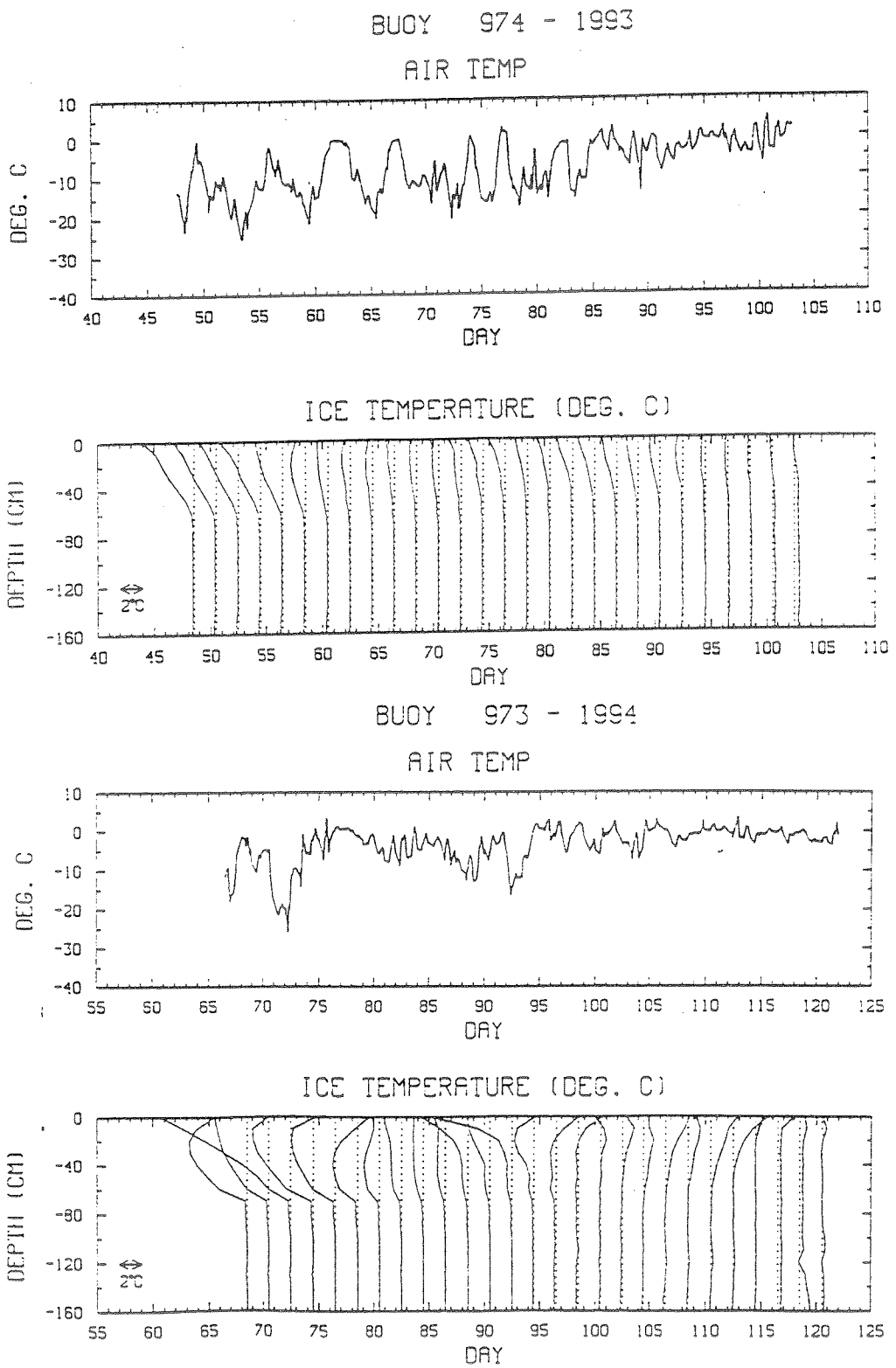


Fig. 6. Air temperature and ice/water temperature profiles from ice beacons #974 and #973, which were deployed on drifting ice off Cartwright on February 16, 1993 and March 7, 1994 respectively. Daily mean temperatures at each depth are plotted every 2 days. Dotted vertical lines represent freezing points (-1.8°C) for the profiles, and 1 day=1°C in temperature.

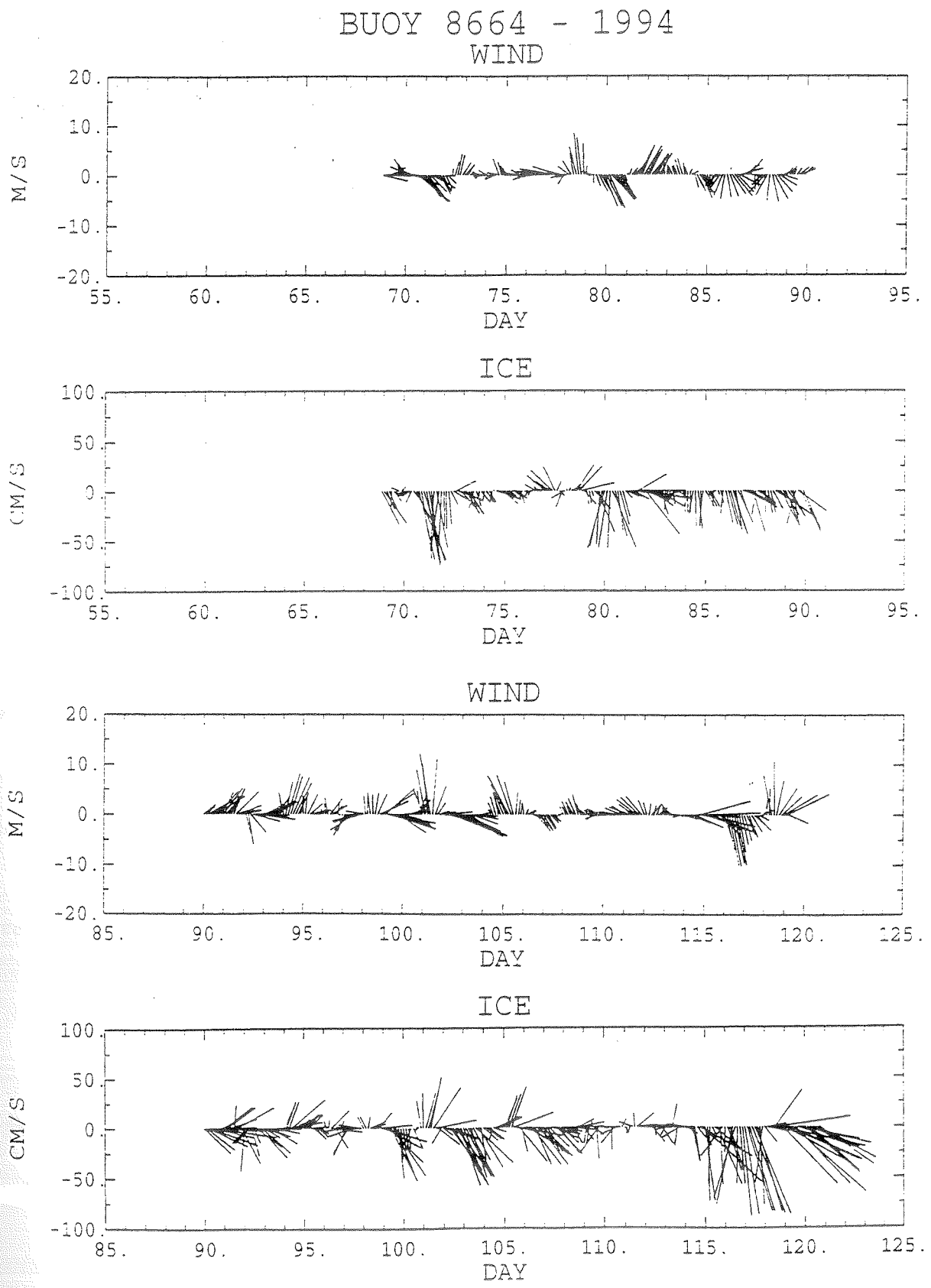


Fig. 7. Stick plots of wind and ice velocity (3-hourly) from beacon #8664 in 1994, while drifting from Hamilton Bank (day 70) to the northern flank of Grand Bank (day 105).

APPENDIX A: FIELD PROGRAM SCHEDULE

1993

February 13
- -G. Fowler, B. Beanlands, M. Scotney and S. Prinsenberg arrived at 1600 in Goose Bay.
- -Prepared beacons and CTD for deployment trip.
- -#969 only transmitting on DX setting of Telonics.
- -#4757 at first was not reporting.

February 14
- -Snowing, -8°C and winds from NE at 15kmph.
- -No flying.

February 15
- -Clearing, -10°C and winds from N at 10kmph.
- -Two Universal Helicopters, pilots R. Moores and D. Dobbin.
- -Located ice pressure sensors off White Bear Islands.
- -Overnight at Cartwright.

February 16
- -Clear, -15°C and winds from N at 15kmph.

Stn #9301
- -20km east of Wolf Island.
- -Temperature staff beacon #974.
- -CTD, ice salinity samples and sounded depth 175m.

Stn #9302
- -40km east of Wolf Island.
- -Anemometer beacon #4757.
- -Telonics responded but no numbers.
- -CTD done, sounded depth 200m.

Stn #9303
- -60km east of Wolf Island.
- -Location beacon #967.
- -CTD done, sounded depth 150m.

Stn #9304
- -60km east of northeast of Wolf Island.
- -Location beacon #968.
- -CTD done,sounded depth 180m.
- -Helicopter leaking oil.

Stn #9305
- -40km east of northeast of Wolf Island.
- -Temperature chain beacon #10058.
- -CTD, ice salinity samples, sounded depth 115m.
- -Helicopter repair done.

Stn #9306
- -20km east of Wolf Island.
- -Temperature staff beacon #970.
- -CTD, ice salinity samples, sounded depth 175m.

- -Back at Cartwright 1430.
- -One helicopter grounded, returning with CTD equipment and M. Scotney to Goose Bay.
- -Second helicopter recovered ice pressure sensors, overnight at Rigolet.

February 17 -Flew back from Rigolet.
-Packed equipment and returned to Halifax.

March 1 -30°C winds 15 kmph from Northwest.
G. Fowler and B. Beamlands deployed ice pressure sensors in land fast ice off Wolf Island's chain.
One Universal helicopter was used, pilot D. Dobblin.

Stn P93-4: Lat: 53° 40.97 N
Long: 55° 57.99 W

95cm of ice 10cm of snow and 0cm of freeboard.
Depth of water 74m at four places.
Seimac Ice beacon #2342 deployed 5m NE of sensors.
Sensors started at 1700 GMT on Logger #1.
-#167 facing West of Northwest
-#166 facing North
-#162 facing East of Northeast

Stn P93-5: 95cm of ice 50cm of snow and -8cm of freeboard.
Depth of water 74m at four places.
MetOcean Ice Beacon #969 deployed 5m NE of sensors.
Sensors started at 1812 GMT on Logger #4.
-#171 facing West of Northwest
-#168 facing North
-#169 facing East of Northeast

March 7 -12°C winds 5 kmph from South and snowing.
Stn P93-4 and P93-5 visited by S. Prinsenberg and M. Scotney.
Anemometer beacon #8668 placed on North Wolf Island.
Ice thicknesses: 97, 101, 98 and 99cm.
Snow depths: 35, 23, 30 and 38cm.
Freeboard: -4, +1, +2 and +1cm.

March 29 -8°C winds 15kmph from Northwest.
GF and SP to Wolf Islands to recover beacons.
Left Goose Bay 07:00, done at Wolf Islands at 12:00.
Ice thicknesses: 105, 103 and 105cm.
Snow depths: 75, 30 and 45cm.
Freeboard: -4, 0 and -3cm.

1994

Wednesday, February 23, 1994 -25°C, clear NW winds at 25mph

SP, GF, BB and BW to Cartwright at 08:55
MS and CT by LabAir to Cartwright at 08:40
Canadian Helicopter C-GMHS, poppout floats, Mike
Canadian Helicopter C-FNYQ, large floats, Wayne Massie
At Wolf Island 11:15, no site here/ open water
At Grady Island 12:15, north of Island
52° 49.3 North Longitude; 056° 25.18 West Latitude
Winds up to 40mph from North
Sent FNYQ back to Cartwright 12:30, it went offshore at 15:00

Between 12:15 and 15:15
Set out eastern North-South line: 25m spacing stakes #1 to #12
Set out western North-South line: 25m spacing stakes #24 to #18
Set out East-West line: 25m spacing stakes #6, #13 to #18
Snow and ice thicknesses at all stakes
Deployed Temperature Staffs #2367 and #2368 (15:00)

Thursday, February 24, 1994 -20°C, clear NW winds at 25mph

Off at 08:00 but C-FNYQ has troubles at fuel depot
Delayed until 09:00; at Grady Island at 09:15
C-FNYQ dropped extra gear off on way to pack ice (09:45)

Between 09:15 and 14:30
Ice pressure sensors at stake #1 in at 12:00
Ice pressure sensors at stake #24 in at 13:15
NRC pressure sensors at stake #1 in at 14:15
Six ice salinity samples each at stake #1 and #24
Back to Cartwright to pick up beacons; weather forecast bad.
MS and CT back from pack ice, pack ice breaking up 3 CTDs done

Station#	Latitude	Longitude	Ice thickness	File name
9400	53 56.87N	55 35.48W	91cm	sim09400
9402	53 53.04N	55 51.19W	71cm	sim09402
9403	53 51.01N	56 03.11W	42cm	sim09403

Sent second helicopter back to Goose with MS and BW
Between 15:45 and 17:15. Wayne now pilot of C-GMHS.
Deployed 5 GPS beacons: ARGOS #10055 at stake #1
(16:30) ARGOS #21599 at stake #6
ARGOS #21597 at stake #12
ARGOS #21598 at stake #18
ARGOS #21596 at stake #24
GPS beacon at stake #1 (large) needed to be taped up.
Deployed 2 beacons on Grady Island:
(16:55) Atmospheric ARGOS #4769
GPS location ARGOS #10056
Salinities determined, packed and readied CM
Note: beacon numbers and ARGOS numbers differ.

Monday February 28, 1994 -11°C, overcast winds at 35 from 270

Weather day, no flying all staying in Goose Bay.

Tuesday March 1, 1994 -10°C, winds at 30 from 270

Left Goose Bay at 13:45 after weather cleared.
Pilots: Wayne Massie (Canadian H.) and Jerry Nutall (Universal H.)
Arrived at Cartwright Hotel at 15:15, winds at 20 from 290.
Put out calibration line 10 bags at 25m spacing.

Wednesday March 2, 1994 -20°C, clear no wind.

Left at 8:30 to Indian Tickle (reflectors drifted off),
on to Stoney Arm (Stn. 2.1) and to Wolf and Grady Islands.
No responses on Telonics for ice pressure and GPS stations.
Received latest positions of pressure stations from BIO at hotel.

-20°C, clear 10mph NW winds

Left at 13:40 for last position of GPS beacon 10053, 72 nm away.
Used ARGOS range finder in helicopter to track it down (1/2 hour).
Took until 16:30 to take instrumentation out of the ice.
One set of sensors found at 52 46.69N, 055 33.15W (Stn. 2.4).
Floe (15x15m) just big enough to land on beside the pressure sensors.
Ice staff was 1/2m from edge and bottom probably sheared off.

Thursday, 3 March, 1994 -10°C, clear light NW winds

Test flight of EM bird around Cartwright.
MS, MM and CS sampled off Grady and Wolf Island (Stns. 3.1 and 3.2).

-7°C,overcast no wind

Afternoon: long flight to pack ice, off by 13:30 from fuel depot.
From Grady magnetic east to middle of ERS-1 swath 54 10.14N, 55 24.12W,
then turn 45° to N towards and past a large iceberg.
Landed north of iceberg at 54 16.24 55 21.78W.
Small floe 35x15m (Stn. 3.3). Obtained snow and ice thicknesses.
Deployed location beacon #977 at 15:05, returned at Cartwright (16:00).

Friday, 4 March, 1994 -12°C, light southerly wind

Morning both helicopters off at 08:25 from fuel depot.
Large composite floe North of Wolf Island 53 44.75N, 56 09.91W.
Salinity samples (4) and beacon #976 deployed at 09:15.

Southwards to a large floe south of Wolf Island.
Composite floe made of pancake ice 3/4m diameter
Beacon 965 deployed at 10:30, 53 33.29N, 55 45.58W.
Ice thickness and salinity samples taken.
Back to Cartwright (11:30) via Black Tickle.

Afternoon, weather starting to close in.
Only float helicopter out to RDI location (53 50.7N, 56 3.15W).
Deployed Atmospheric beacon #8668 at 14:15.
Large composite floe made up of pancake ice.
Snowing on way back winds from East.

Saturday, 5 March, 1994 -12°C, blizzard

Weather day, winds east turning to northeast in morning.
Dug out beacons after blizzard.

Sunday, 6 March, 1994 -25°C, clear light NW wind

Off from fuel depot to Wolf Island by 09:30.
Thin ice all the way to Cunningham Island.
Landed on large composite floes 2x2km SW of Wolf Islands.
Deployed beacon on flat 30x30m pan of large composite floe.
Stn. 6.1, temperature staff #971 on at 10:30, 53 41.26N 055 42.37W.
MS took core and EM bird came over and landed 10:54.

Continued east, landed on large composite floe 4x4km (Stn. 6.2).
Deployed beacon 978 at 11:30, 53 41.00N 055 07.00W.
West to Roundhill Island, seals on ice, 10.3nm out of Roundhill Isl.
Round Hill Island is at 53 26.0N, 055 36.5W.
Back to Cartwright (12:50) via Black Tickle.

Afternoon SP/MM/WM 15:00, still -22°C and light NW winds.
Stn. 6.4: 53 29.32N, 056 02.90W, MM did ice core (Stoney Arm).
Medium reflector at Stn. 6.4, small reflector to NW and large reflector at 53 29.44N, 056 03.60W. Deep snow 30-40cm.
Rocky Bay: Stn. 6.5. Large reflector at 53 29.88N, 055 58.70W.
Snow/ slush and ice salinity (21cm of ice). Very flat ice, no ridges.

Monday 7 March, 1994 -18°C, clear light NW wind

Long flight south via Wolf Islands.
Table Bay (west of Cunningham Isl.) frozen over with flat young ice.
Landed near Spotted Islands (09:30) on a large floe.
Stn. 7.1: 53 29.90N, 55 40.47W.
Deployed temperature staff 973, ice and snow samples taken.
Ice blocks in the area are 35cm thick floe may be rafted to 2x35cm.
Continued south to large thin ice area.
Landed on thick floe within the thin ice area.
Stn. 7.2: 50x50m floe, 53 02.66N, 055 38.37W.
Stopped on way back to look at standard rubble height between floes.
Stn. 7.3: 53 13.26N, 055 38.60W. Sal. #64660 (14ppt) of 5cm thick ice.
Stopped in Rocky Bay (reflector) to take salinity samples and ice core.
MS/CT arrived with 3nd helicopter (Pilot: Jim Myra, Universal H.).
Dumped pressure data, mercury sensors may not have logged.

Tuesday 8 March, 1994 -9°C, partly overcast, 10mph SE winds

CT and MS off at 08:10 for CTD and ice melt beacon deployment.
Off to Rocky Bay and Porcupine Bay for ice cores and salinity samples.
East offshore to deploy beacon near iceberg.
Beacon 2342 deployed at 11:45. Stn. 8.3: 53 45.55 055 26.44.
On to Cartwright, saw a stranded iceberg with upstream rubble field and long wake to Wolf Isl. at 53 44.01N, 56 06.28W (11:55).
Six CTD stations done by MS with other helicopter.

Time	Stn#	Distance	Latitude	Longitude	Depth*	Ice thickness	File name
14:55Z	1	103 km	54 09.05N	54 52.83W	174(175)m	---	sim19403
14:20Z	2	87.2km	54 05.02N	55 05.92W	154(152)m	---	sim19402
13:55Z	3	75.9km	54 01.50N	55 14.76W	157(140)m	32cm	sim19401
11:45Z	4	55.1km	53 58.62N	55 33.40W	150+(233)m	64cm	sim19404
16:40Z	5	45.4km	53 56.21N	55 41.72W	175+(180)m	143cm	sim19405
16:20Z	6	16 km	53 50.10N	56 06.57W	83(75)m	97cm	sim19406

*Sounding depth (depth from map in brackets)

No flying in afternoon due to snow.
CTD equipment packed and shipped home along with current meter and mooring boxes.

Wednesday 9 March, 1994 -9°C, snowing, 10mph NE winds.

No flying in morning, packing and shipping gear.
2 boxes to Universal, one bundle of 3 beacons and red box to BIO.

Clearing by 13:30. Off to Grady Island and out along 90° magnetic.
Planned end point was 45nm from Grady.
Landed near lead at 15nm from end on large composite floe.
Largest pan was 35x25 and 107cm thick, 53 58.62, 056 04.63.
Deployed temperature staff #972 at 14:45 (Stn. 9.1).

Continued offshore, landed on large composite floe near large lead.
Pan 50x50m, 54 05.63N, 55 48.89W. Rafted blocks 50-75cm. Stn. 9.2.
Floe 175-200cm thick, deployed atmospheric beacon #8664 at 15:20.

Distance to Cartwright from Stn. 9.2 is 52nm.
On way back landed near an iceberg at Stn. 9.3: 53 59.79N, 056 04.28.
No cracks in ice cover around berg, 100% ice cover.
Deployed location beacon #979 at 15:45.
Too late and windy to fly back to Goose Bay.

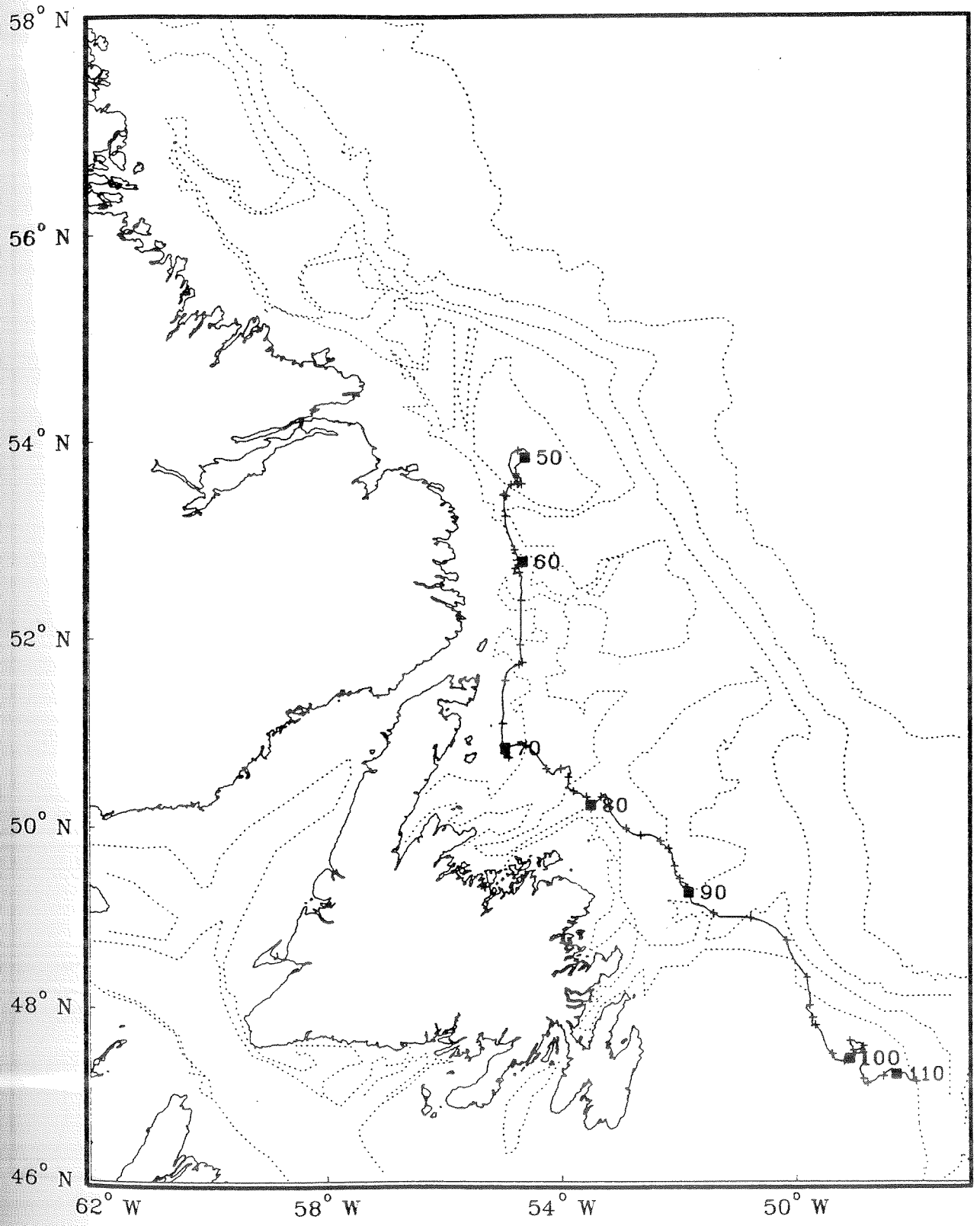
APPENDIX B: ICE BEACON TRAJECTORIES

Trajectories of the ice beacons deployed on drifting pack ice in 1993 and 1994, with positions at 1800 hours GMT marked every day, and labelled every 10 days. The end time below reflect either when the beacon failed, or when the ice beneath the beacon melted.

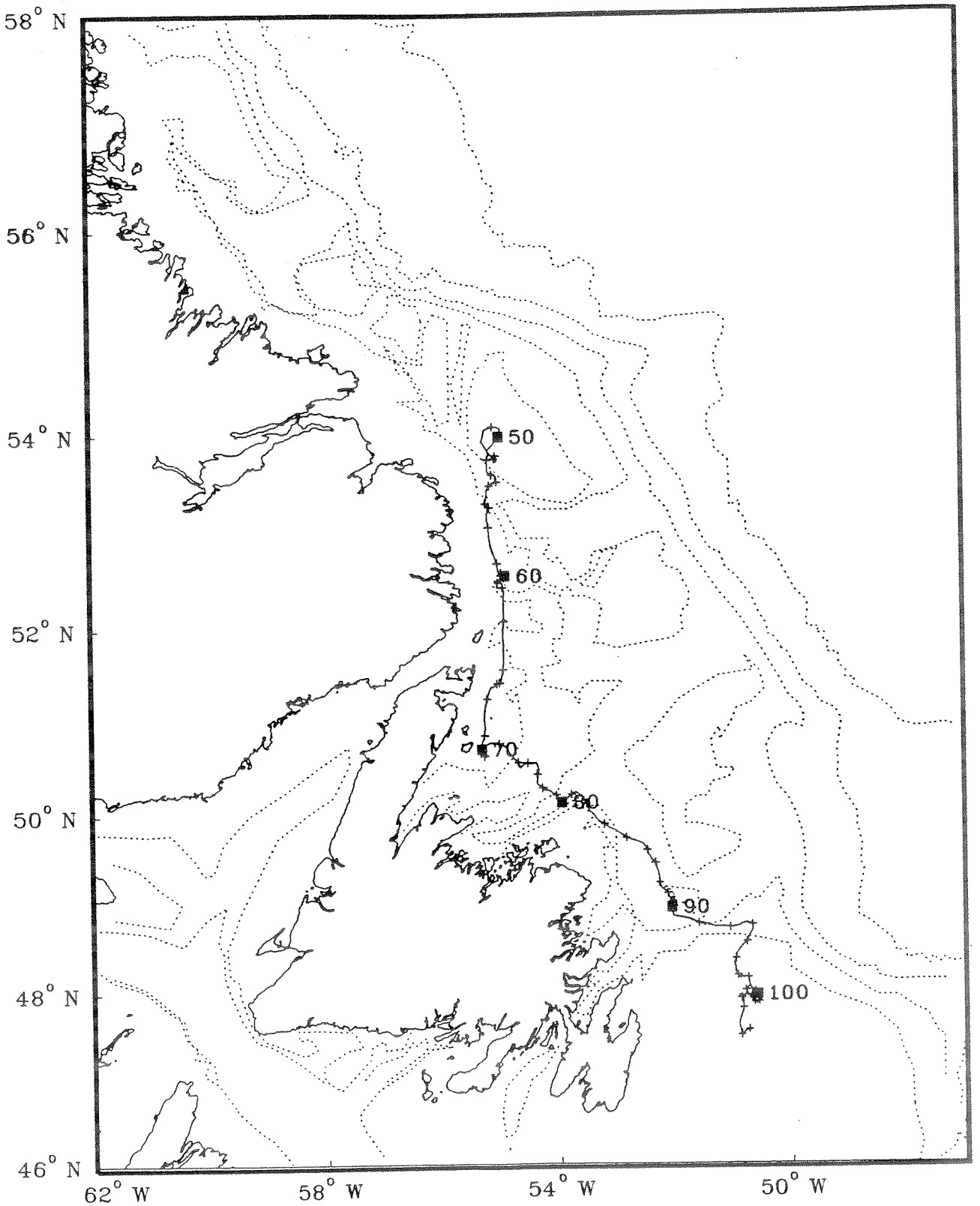
Year	Beacon ID #	Start Time*	End Time*	Type
1993	967	47	111	Location (CMIB)
	968	47	108	Location (CMIB)
	970	47	108	Ice Staff (SIMP)
	974	47	102	Ice Staff (SIMP)
	4757	47	68	Anememometer
	10058	47	69	Temp. Chain
1994	965	63	119	Location (CMIB)
	971	65	117	Ice staff (SIMP)
	972	68	86	Ice Staff (SIMP)
	973	66	121	Ice Staff (SIMP)
	977	62	113	Location (CMIB)
	978	65	120	Location (CMIB)
	979	68	80	Location (CMIB)
	2342	66	115	Location
	2367	54	61	Ice Staff (SIMP)
	8664	68	119	Anememometer
	8668	63	119	Anememometer

* times in calendar days.

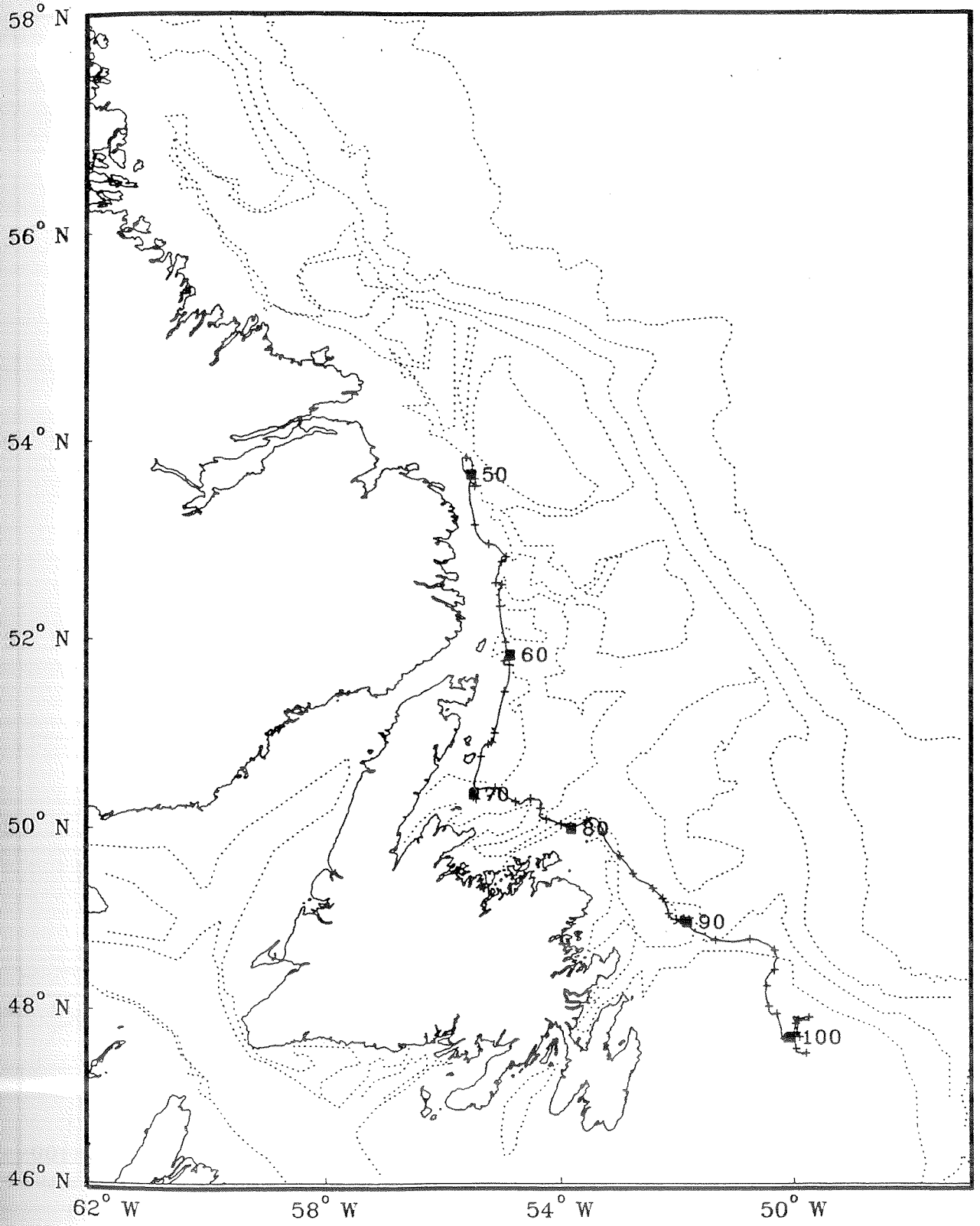
BUOY 967 – 1993



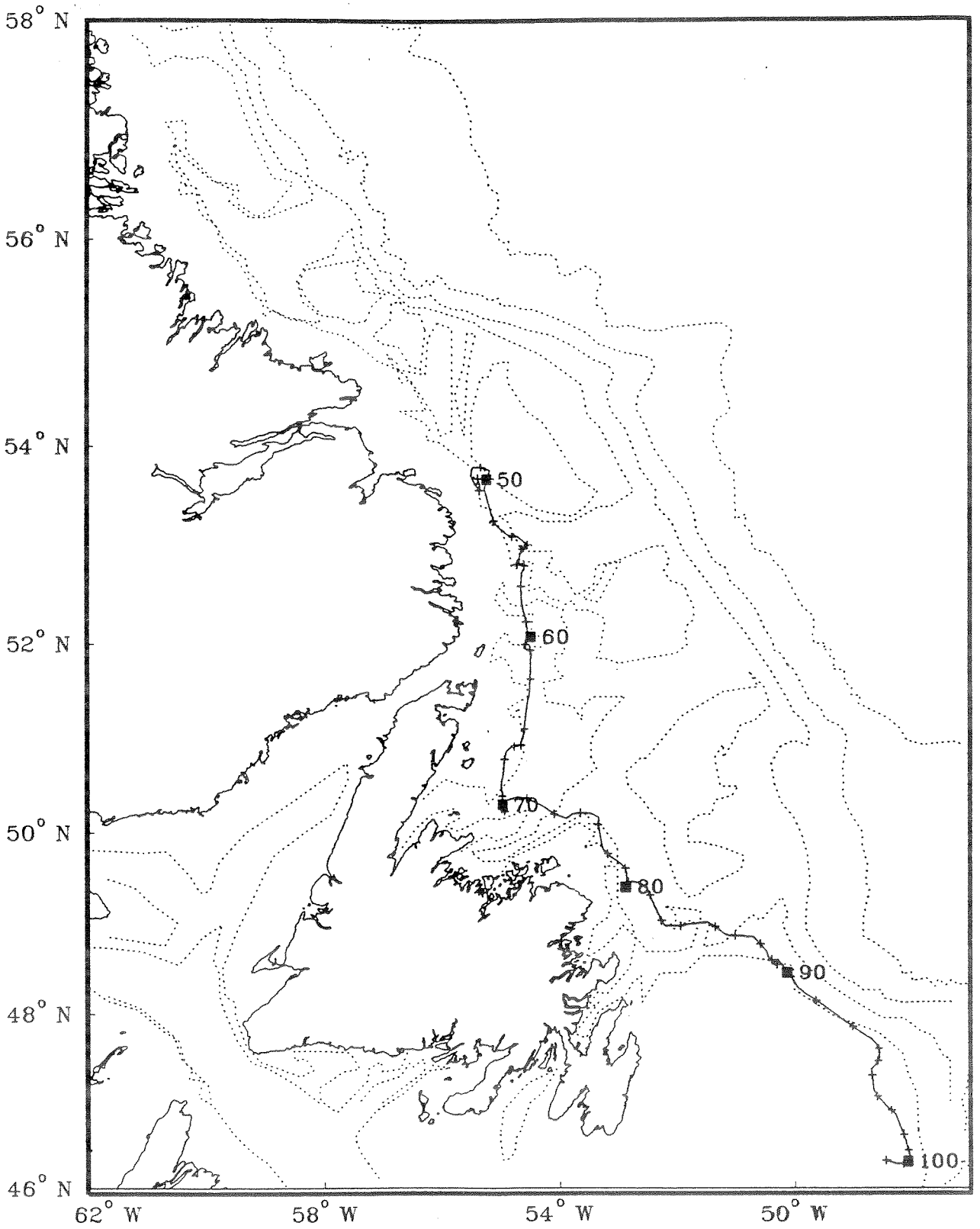
BUOY 968 – 1993



BUOY 970 – 1993



BUOY 974 – 1993



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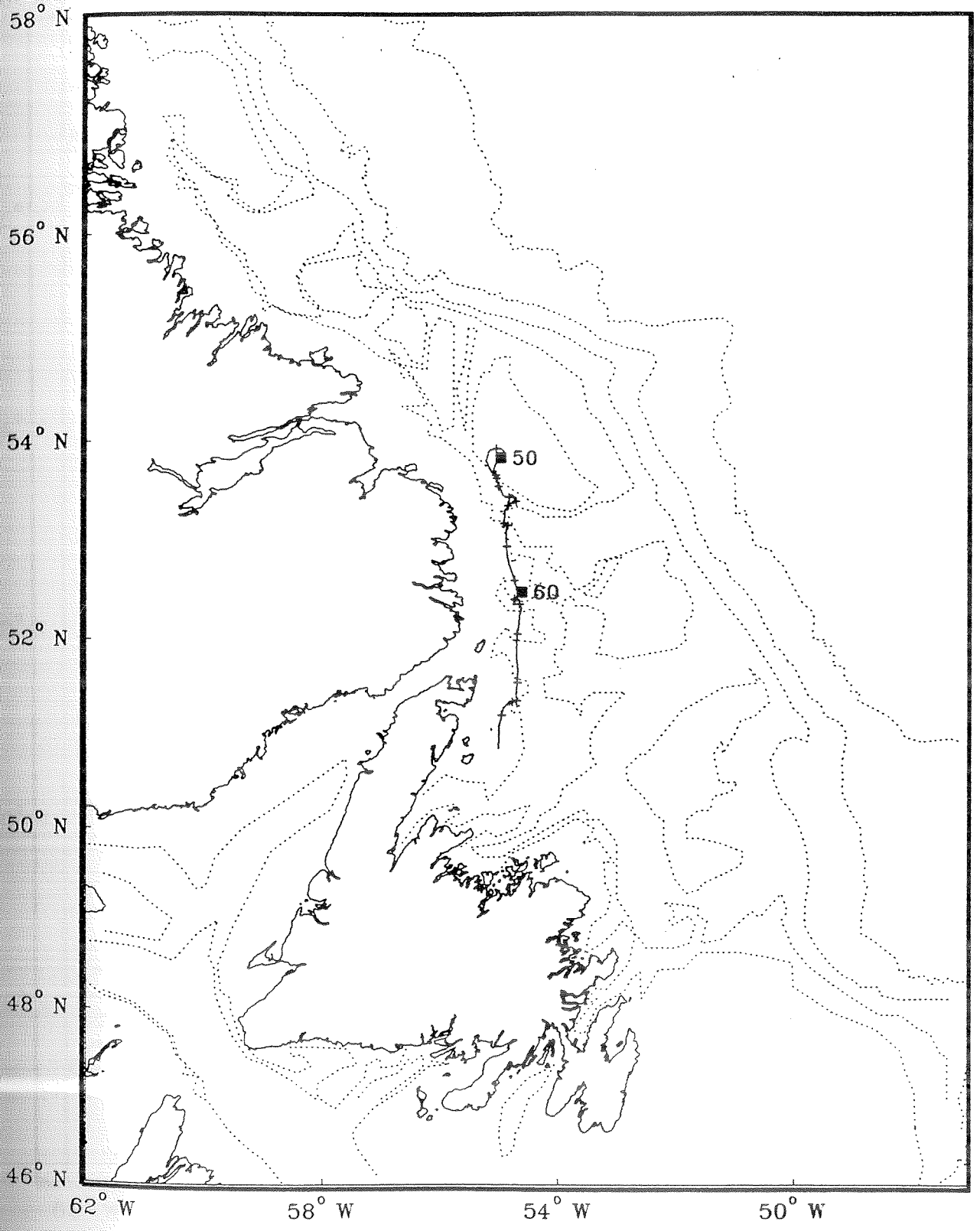
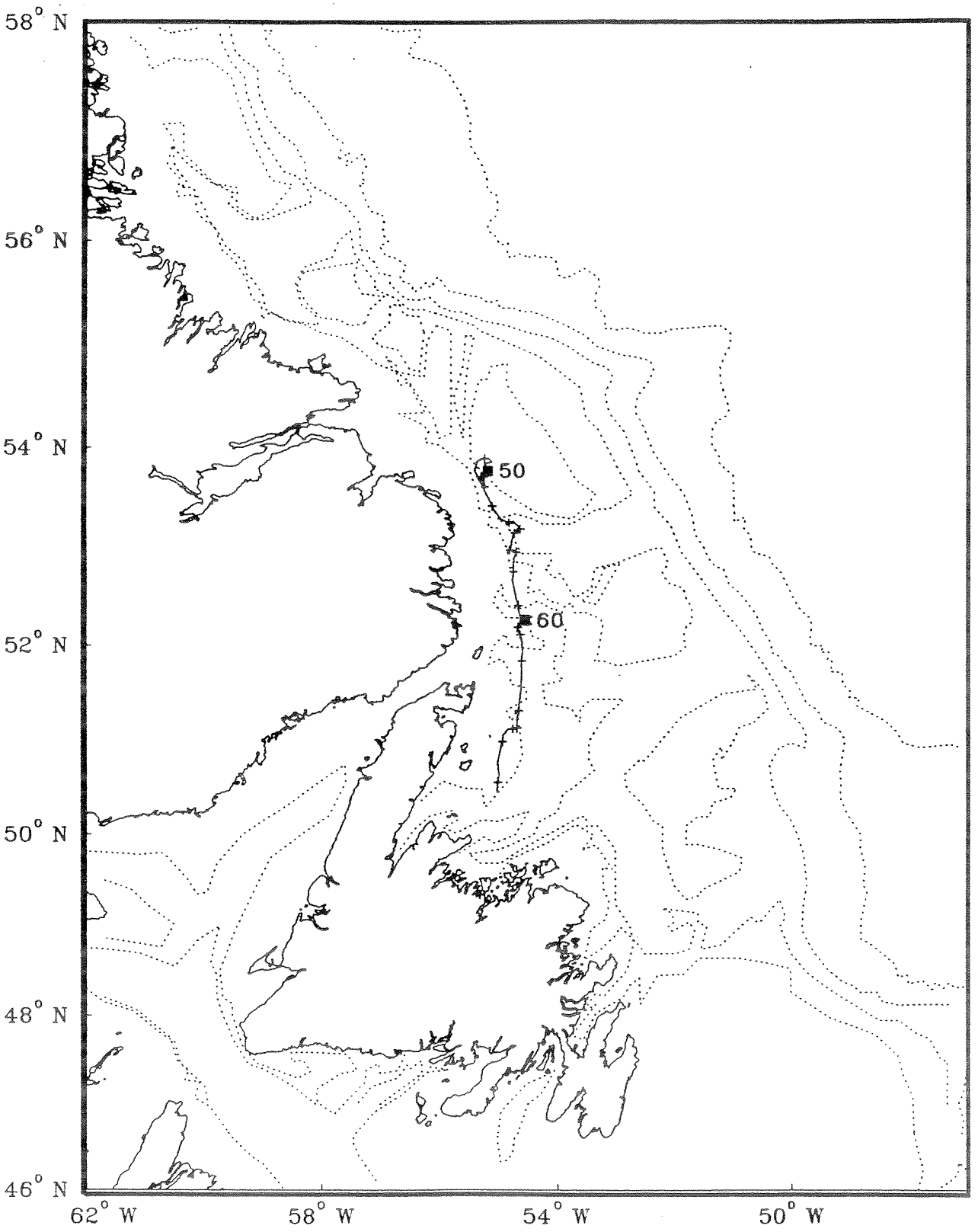
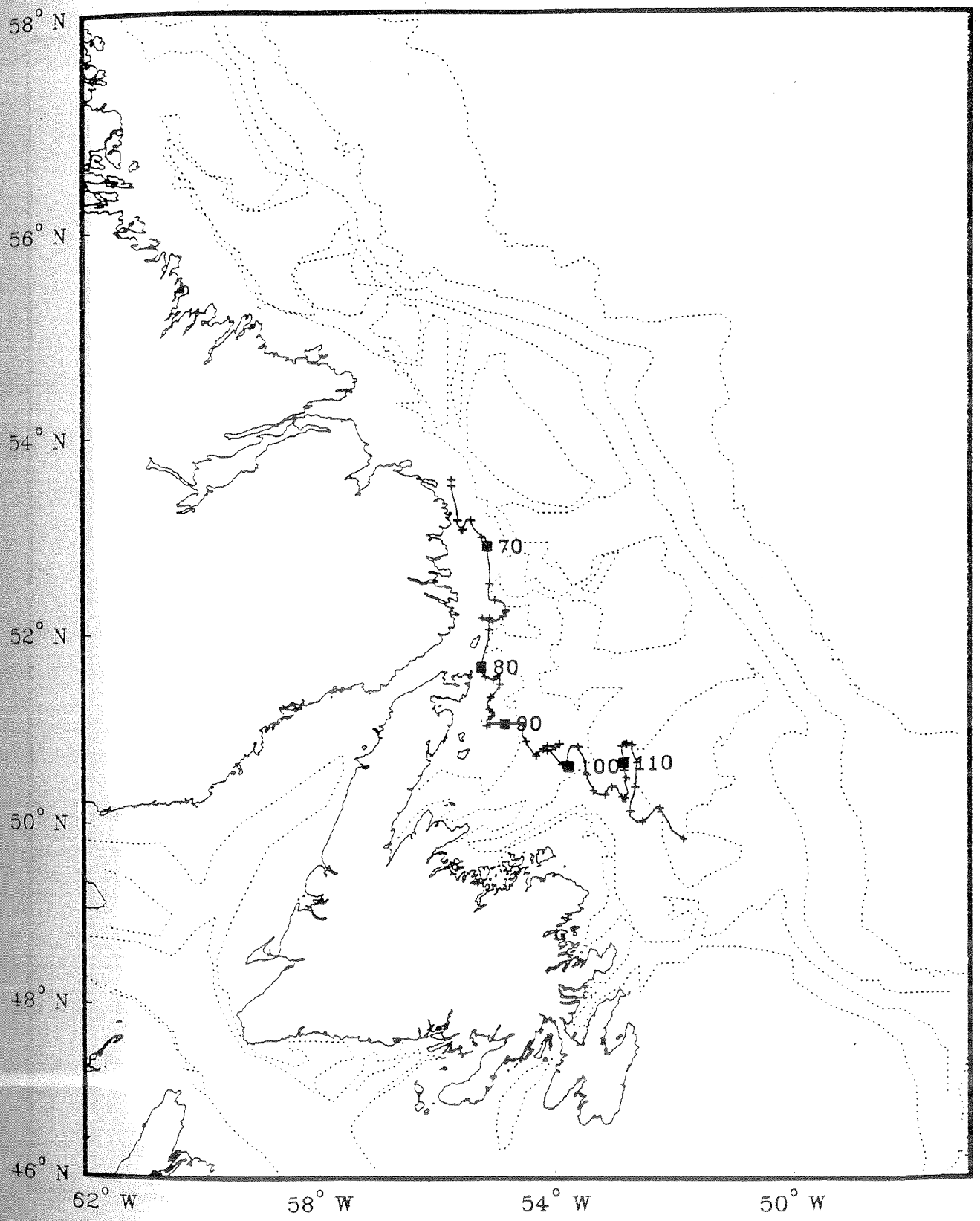


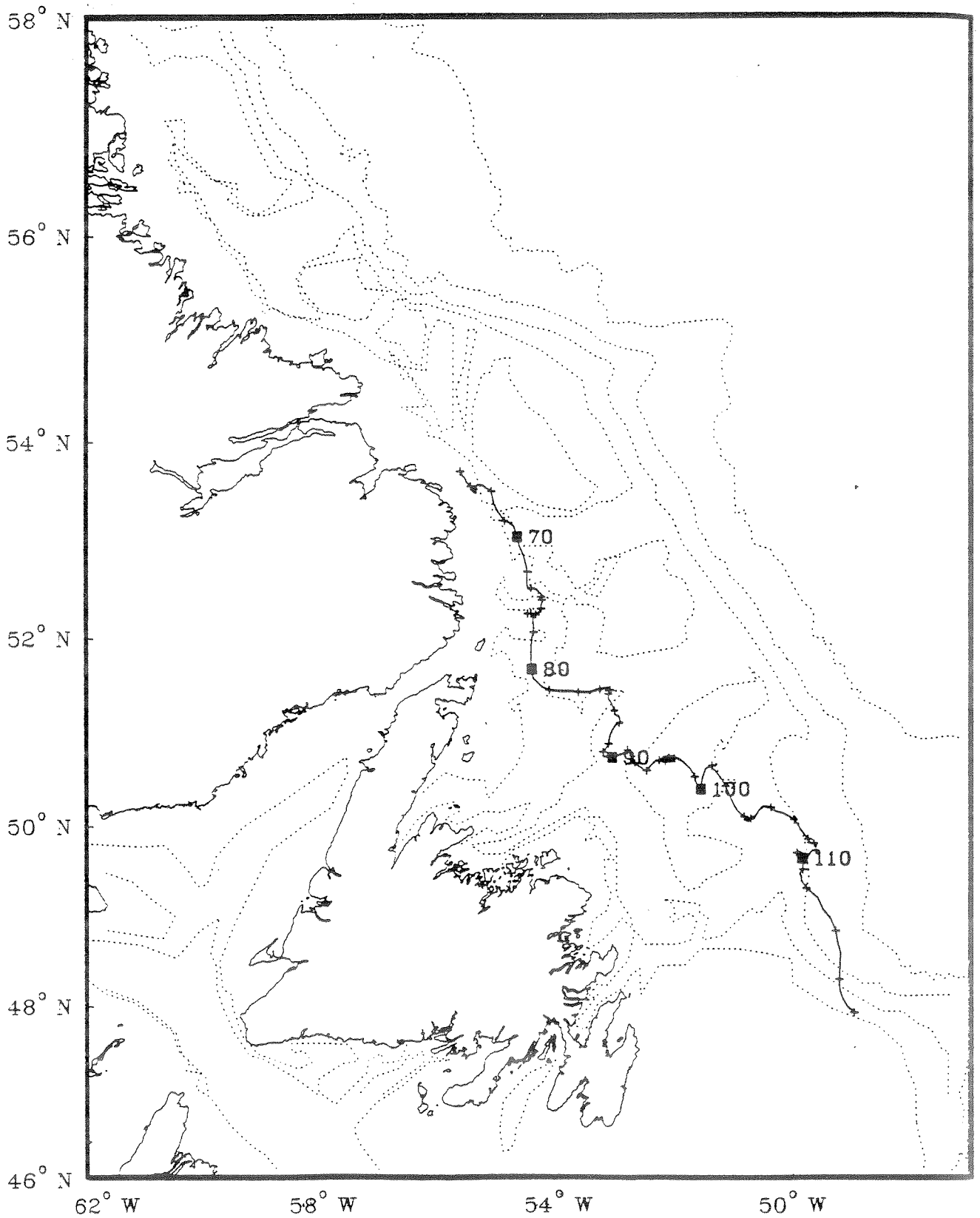
BUOY 10058 – 1993



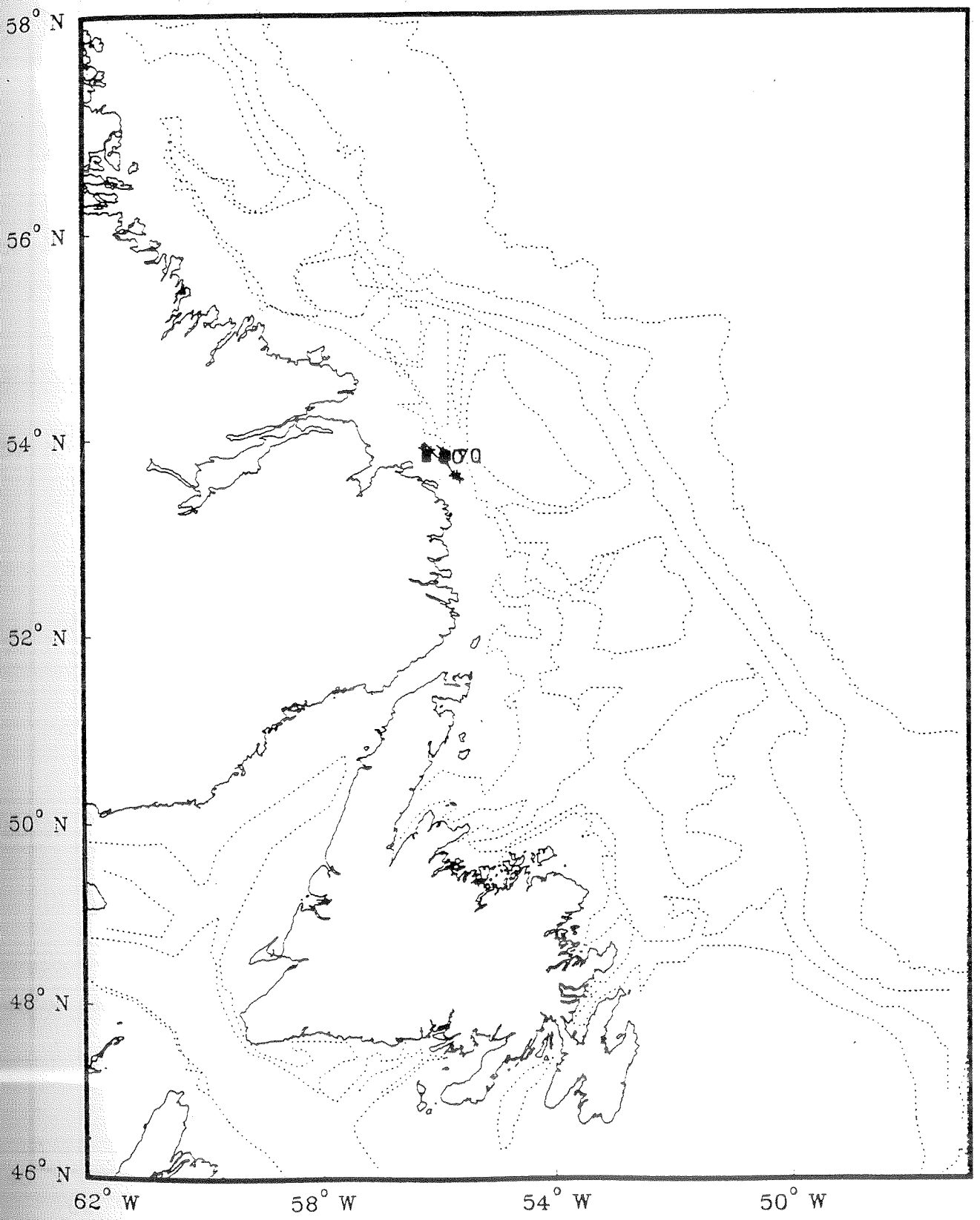
BUOY 965 – 1994



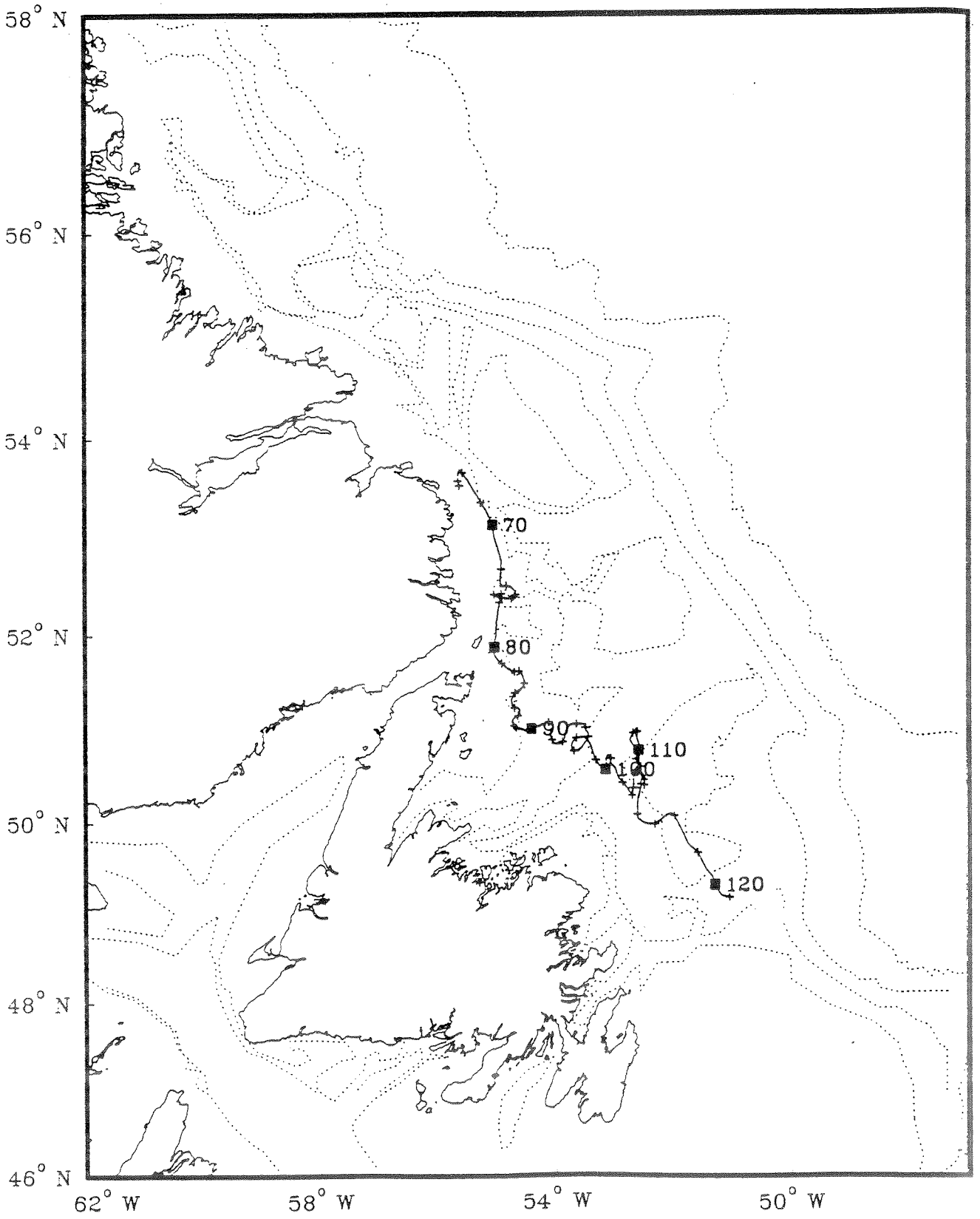
BUOY 971 – 1994



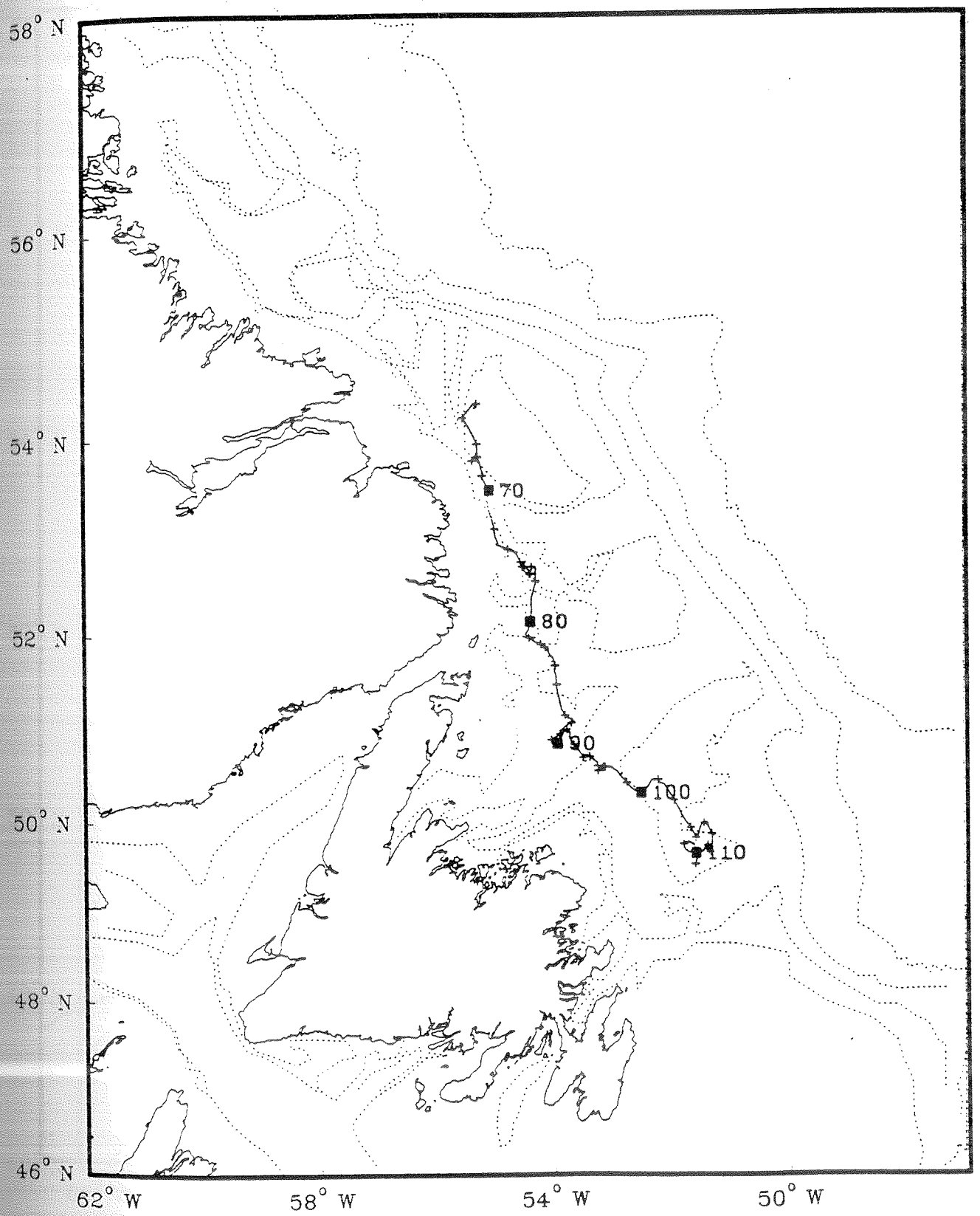
BUOY 972 – 1994



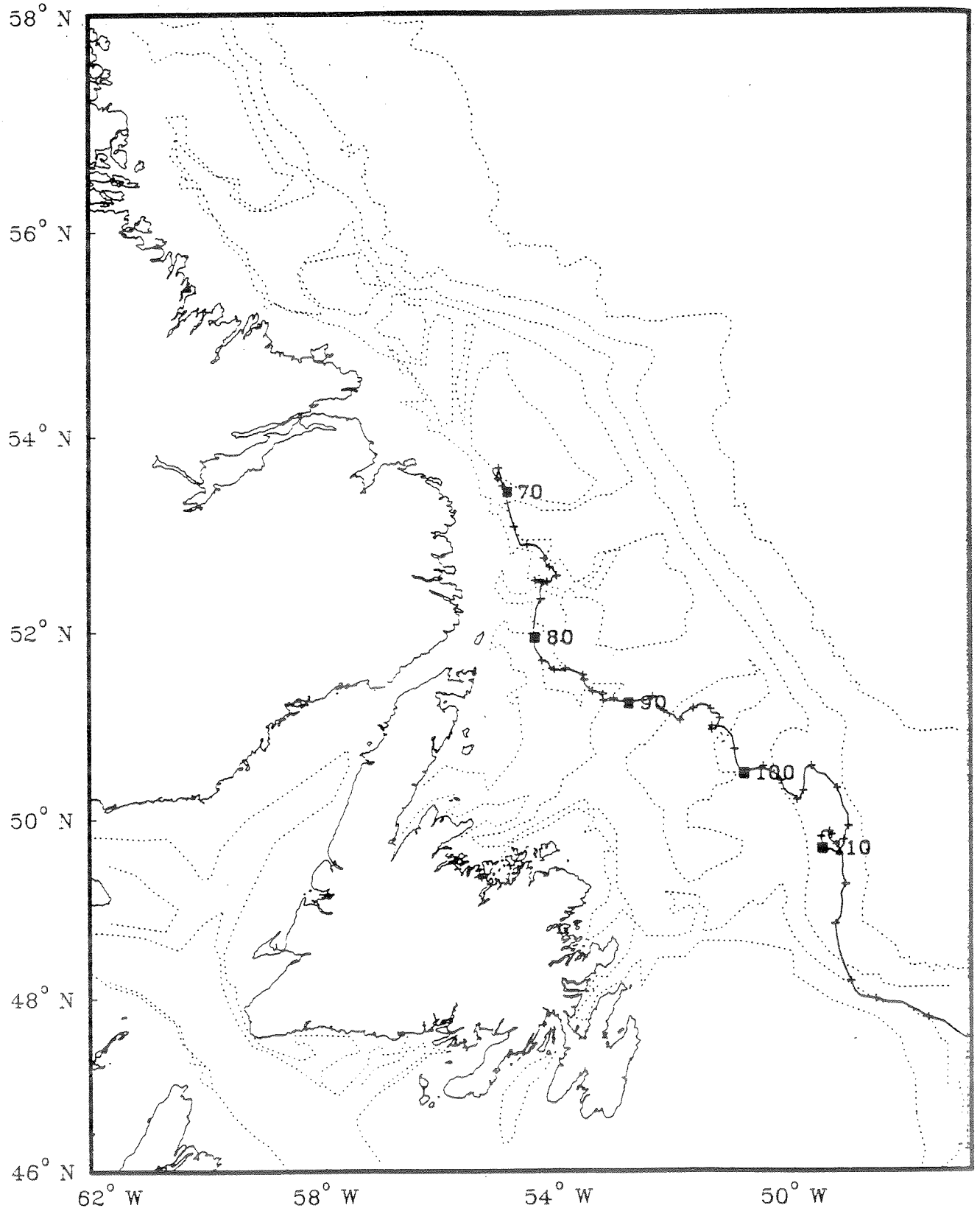
BUOY 973 – 1994



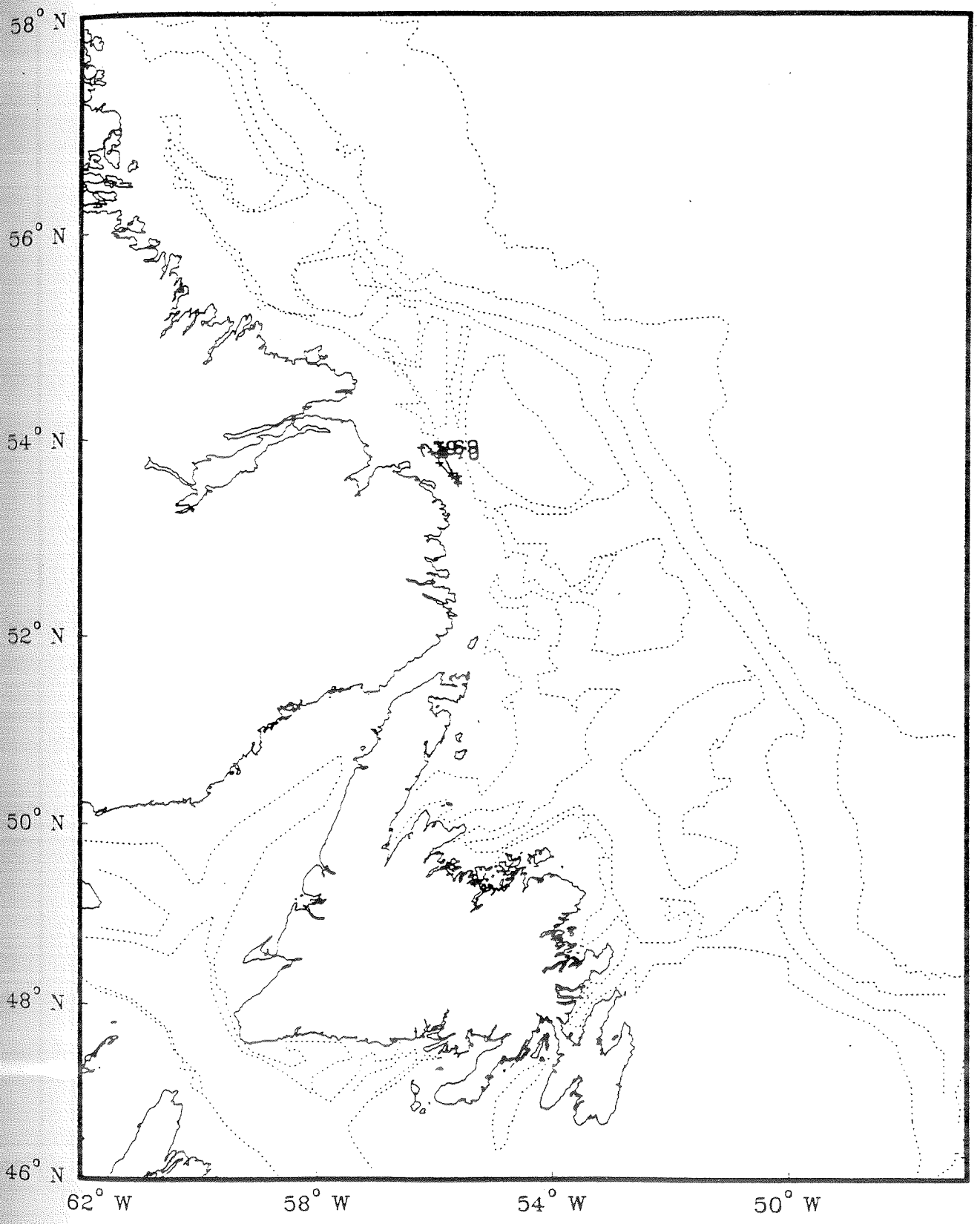
BUOY 977 – 1994



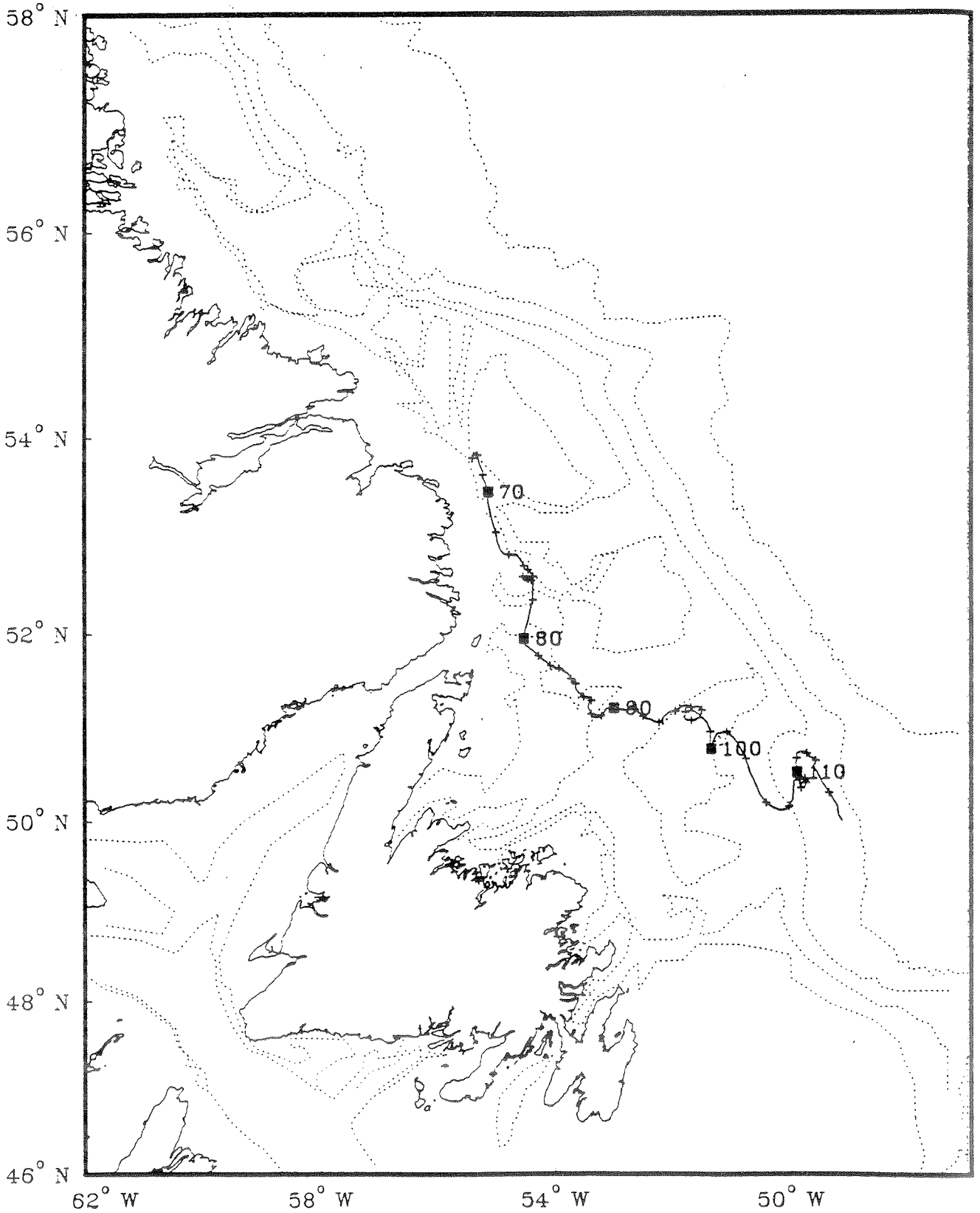
BUOY 978 – 1994



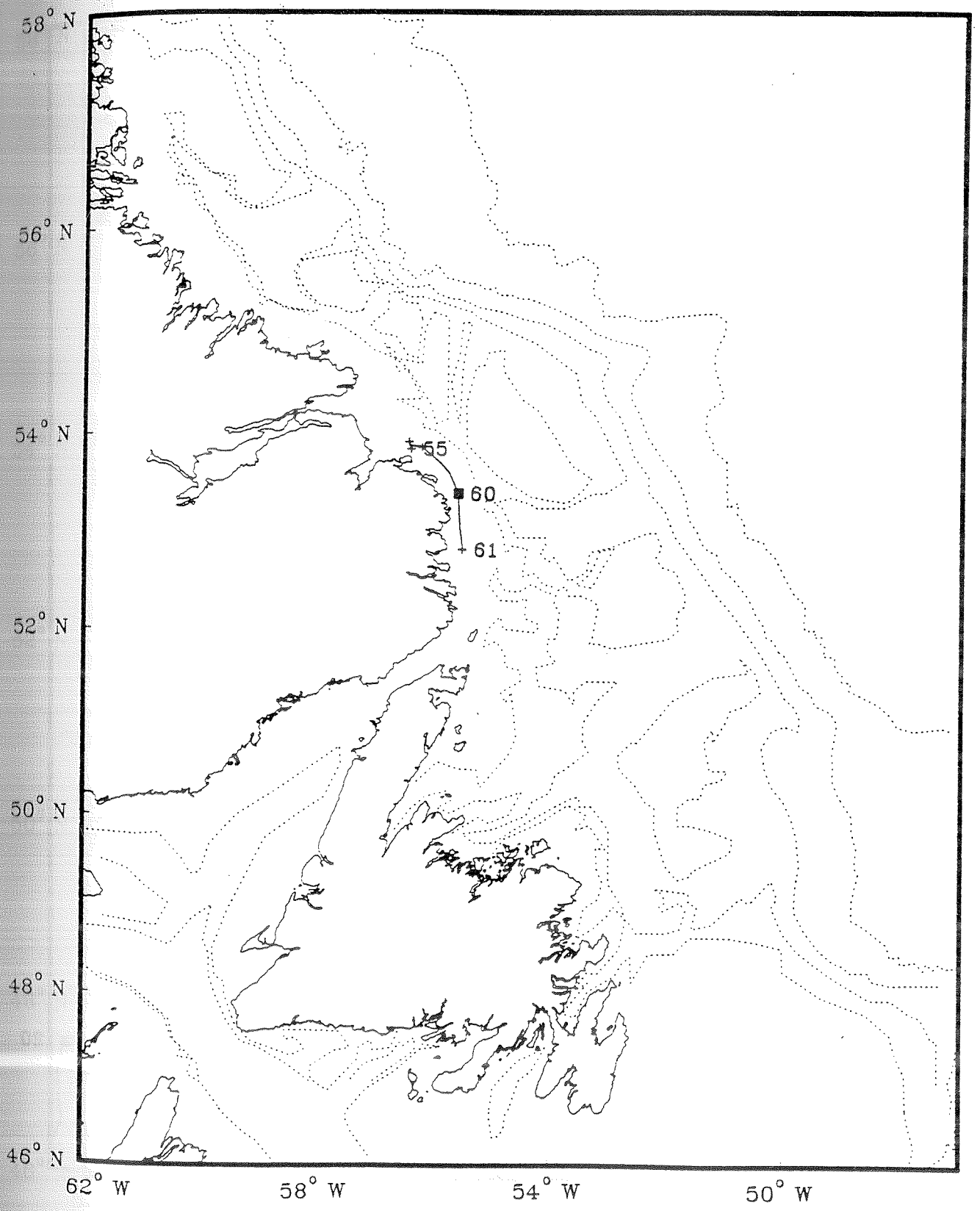
BUOY 979 – 1994



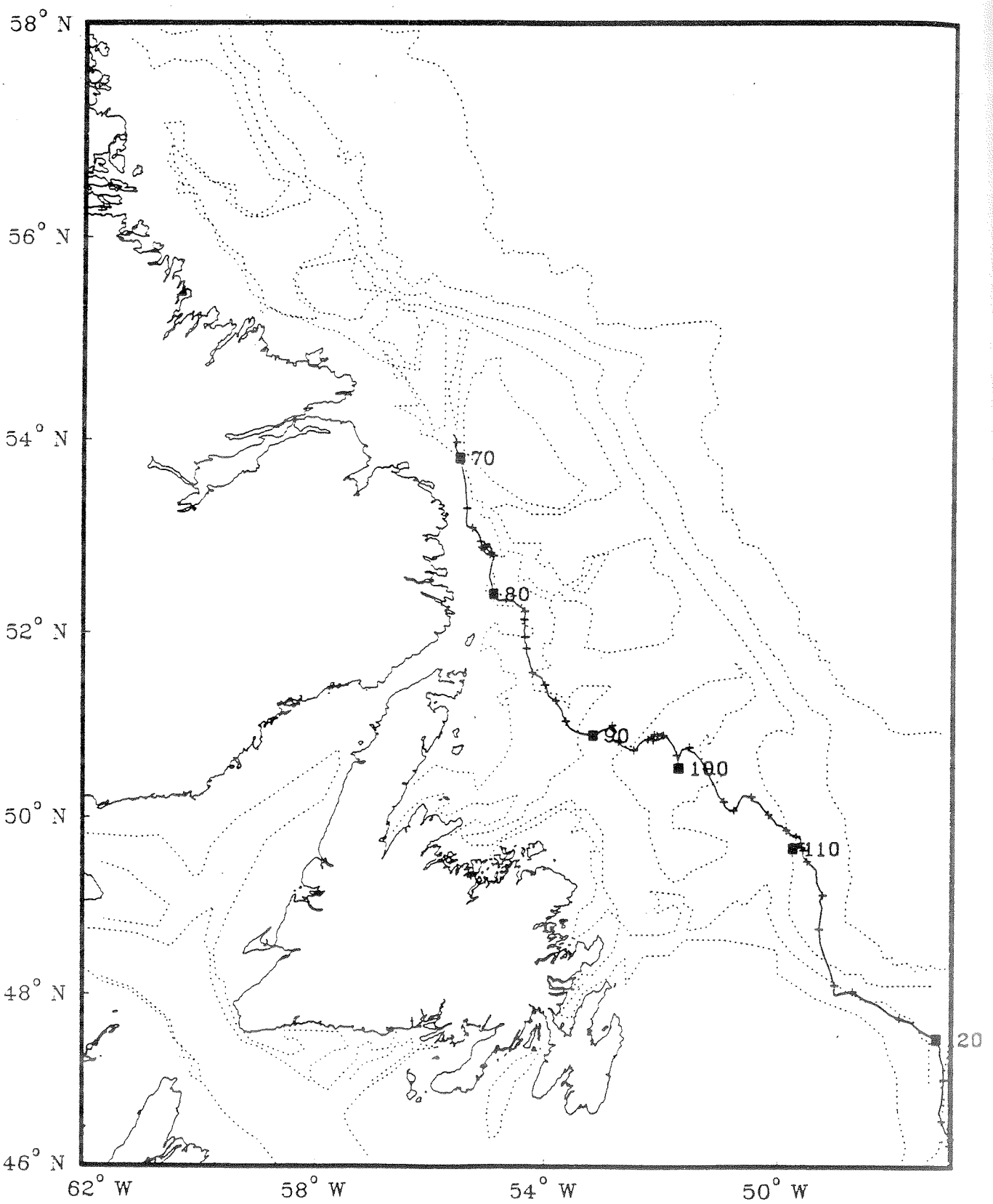
BUOY 2342 – 1994



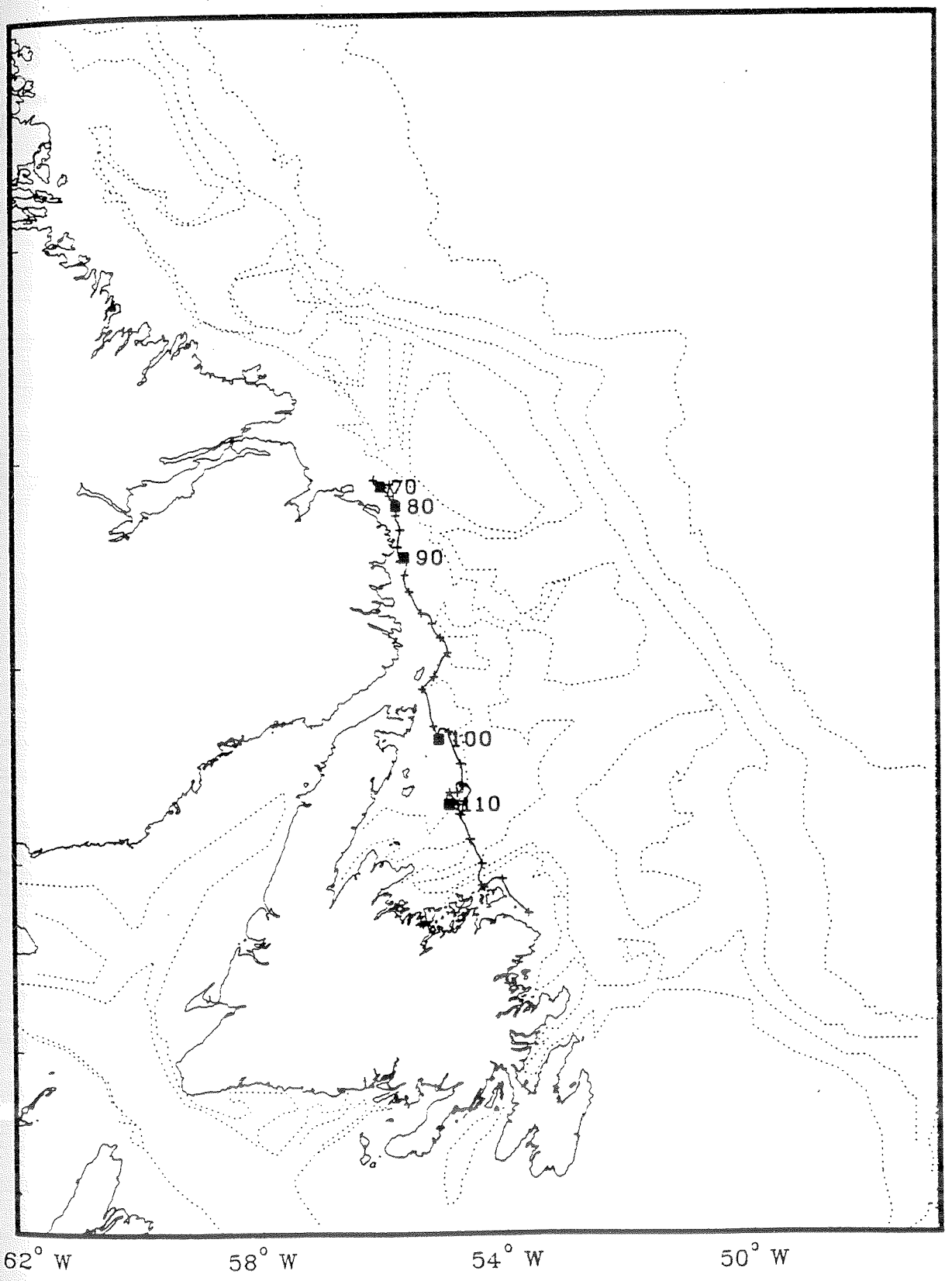
BUOY 2367 – 1994



BUOY 8664 – 1994



BUOY 8668 – 1994

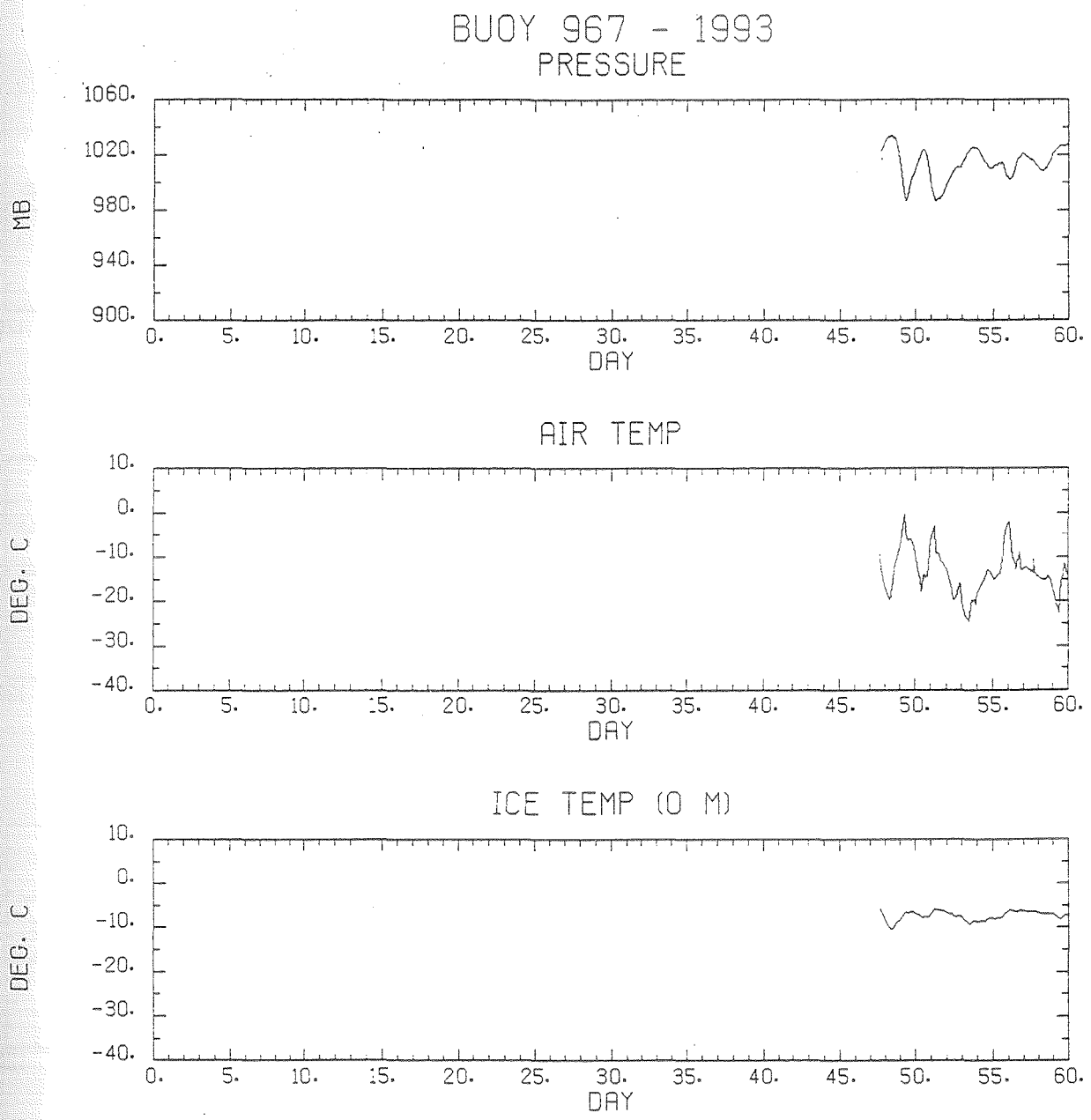


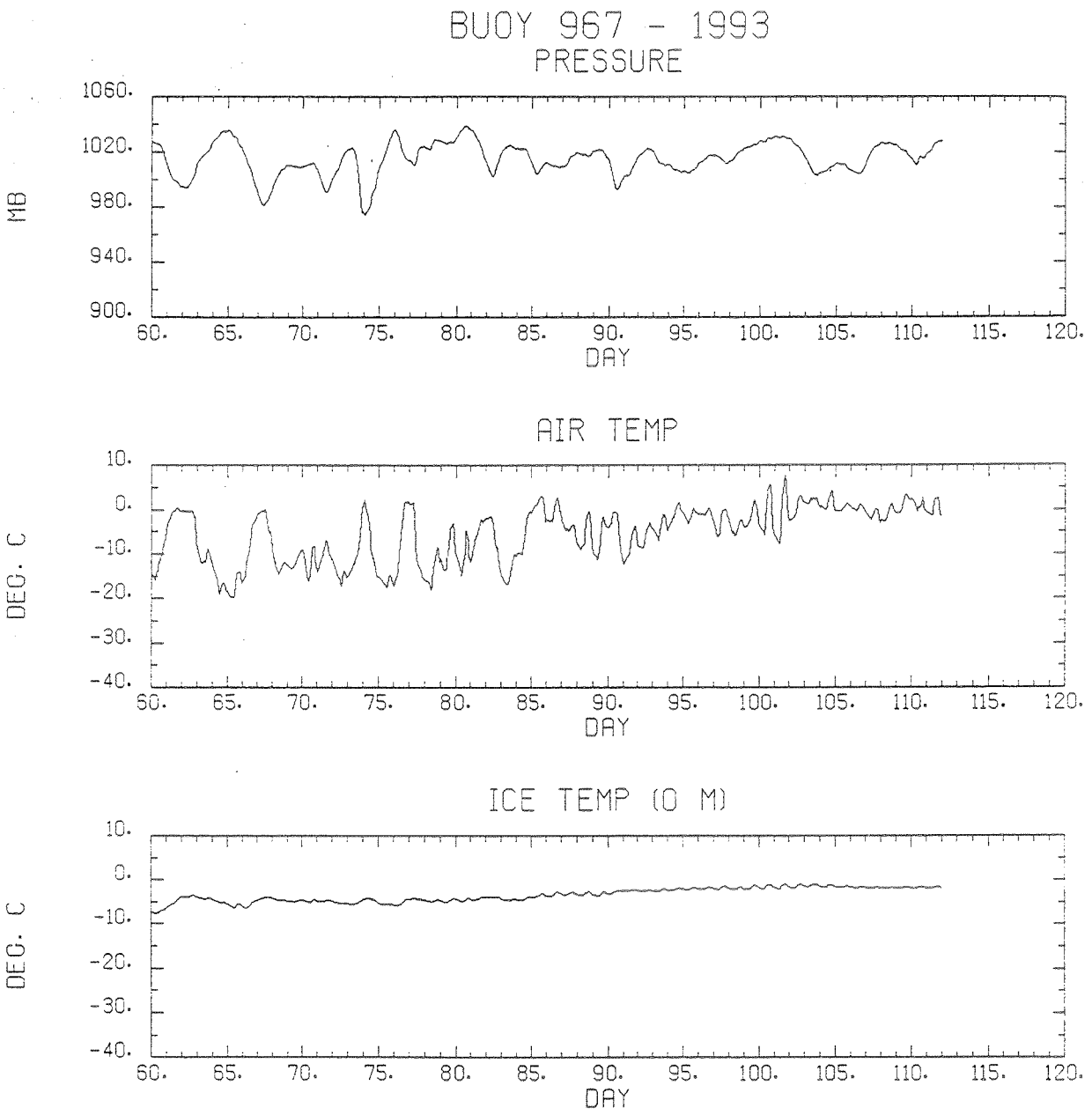
APPENDIX C: ICE BEACON ENVIRONMENTAL DATA

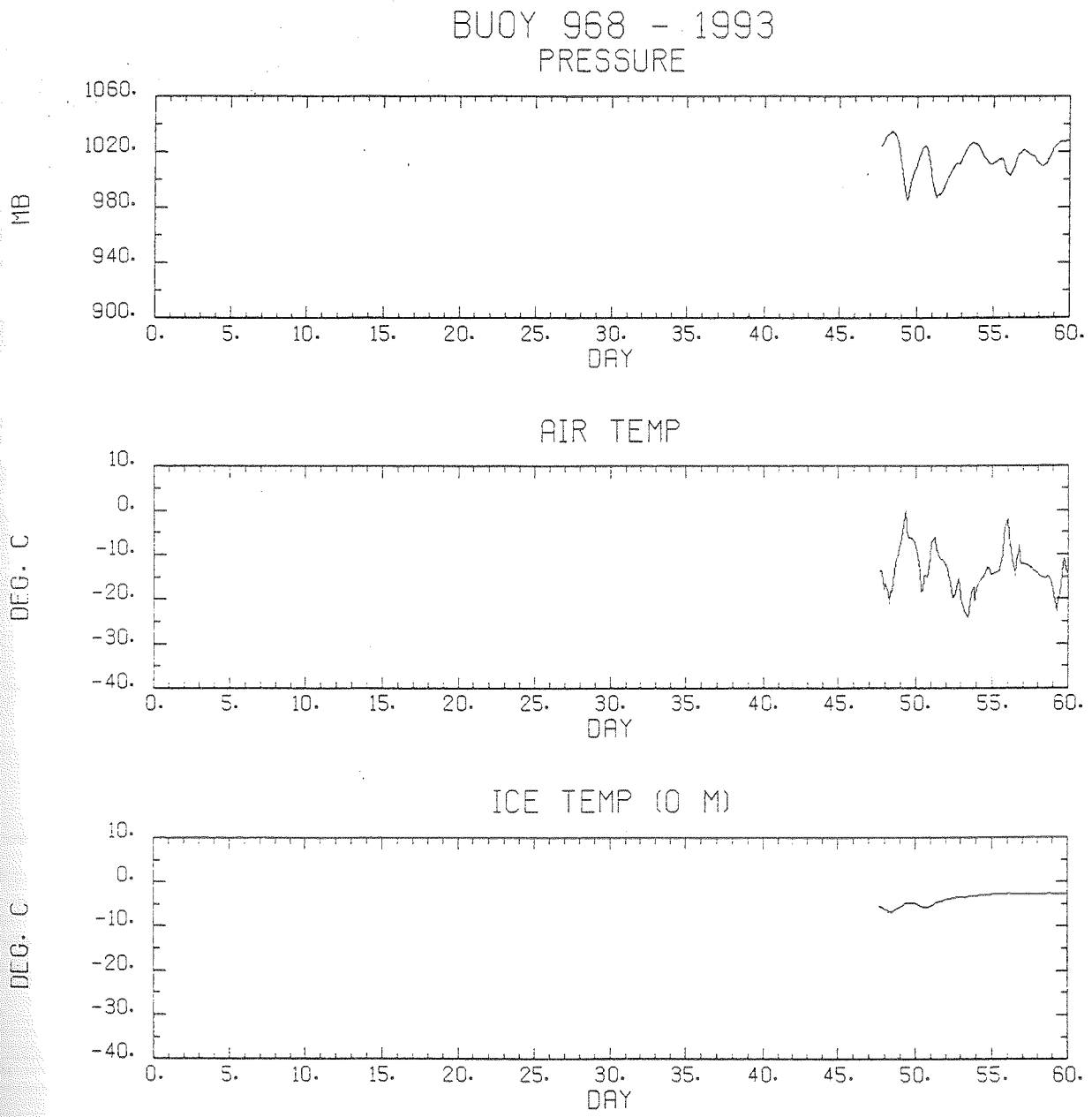
Time series plots of the environmental data collected by the beacons deployed on the mobile pack ice and the land-fast ice in Cartwright harbour.

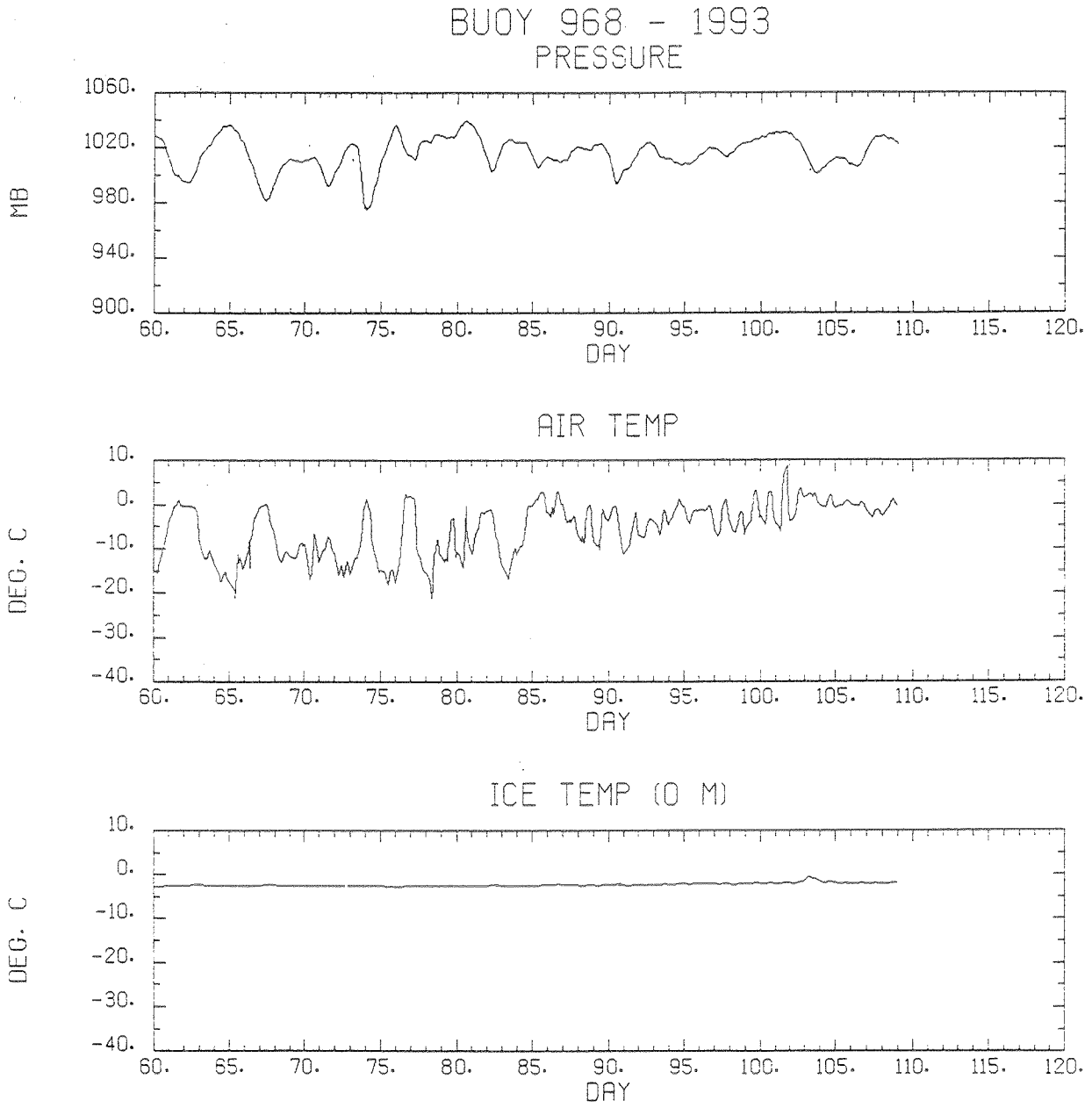
Year	Beacon ID #	Start Time*	End Time*	Type	Location
1993	967	47	111	Location (CMIB)	Pack ice
	968	47	108	Location (CMIB)	Pack ice
	969	60	88	Location (CMIB)	Near Wolf Is.
	970	47	108	Ice staff (SIMP)	Pack ice
	974	47	102	Ice staff (SIMP)	Pack ice
	4757	47	68	Anemometer	Pack ice
	8668	66	88	Anemometer	On North Wolf Is.
	10058	47	69	Temp. Chain	Pack ice
1994	965	63	119	Location (CMIB)	Pack ice
	971	47	108	Ice staff (SIMP)	Pack ice
	972	47	108	Ice staff (SIMP)	Pack ice
	973	66	121	Ice staff (SIMP)	Pack ice
	976	63	119	Location (CMIB)	Pack ice
	977	62	113	Location (CMIB)	Pack ice
	978	65	120	Location (CMIB)	Pack ice
	979	68	80	Location (CMIB)	Pack ice
	2367	54	61	Ice staff (SIMP)	Pack ice
	2368	54	60	Ice staff (SIMP)	Pack ice
	4769	55	176	Anemometer	On Grady Is.
	8664	68	119	Anemometer	Pack ice
	8668	63	119	Anemometer	Pack ice

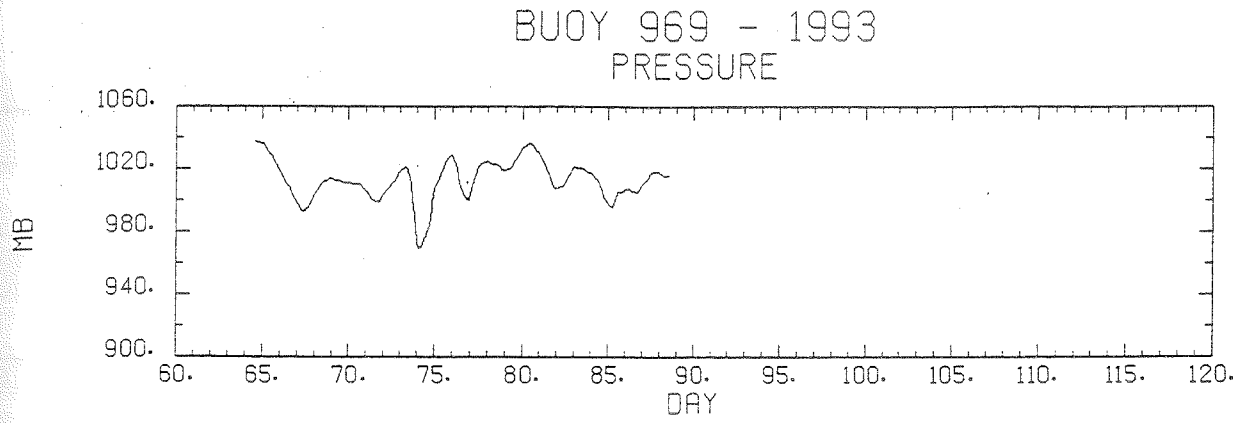
* times in 1992 calendar days.

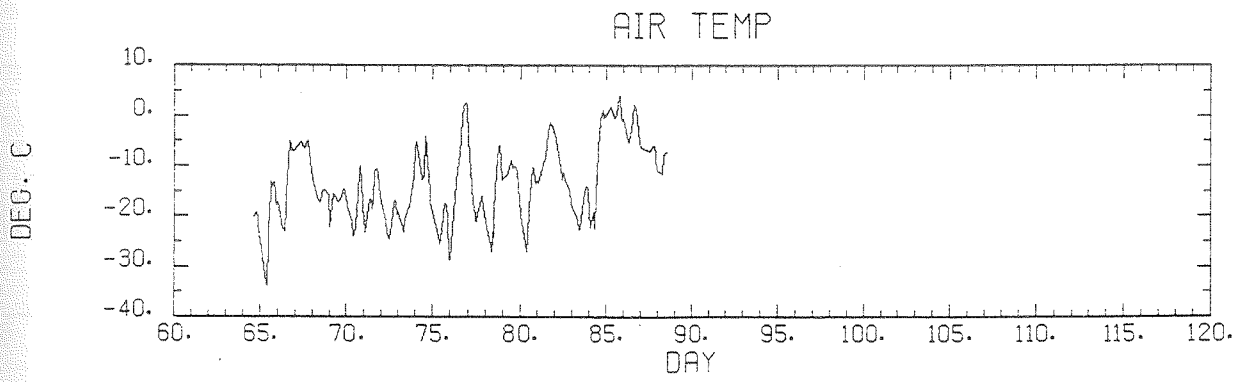

BUOY 967 - 1993
PRESSURE
MB
1060.
1020.
980.
940.
900.
0. 5. 10. 15. 20. 25. 30. 35. 40. 45. 50. 55. 60.
DAY
AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
0. 5. 10. 15. 20. 25. 30. 35. 40. 45. 50. 55. 60.
DAY
ICE TEMP (0 M)
DEG. C
10.
0.
-10.
-20.
-30.
-40.
0. 5. 10. 15. 20. 25. 30. 35. 40. 45. 50. 55. 60.
DAY

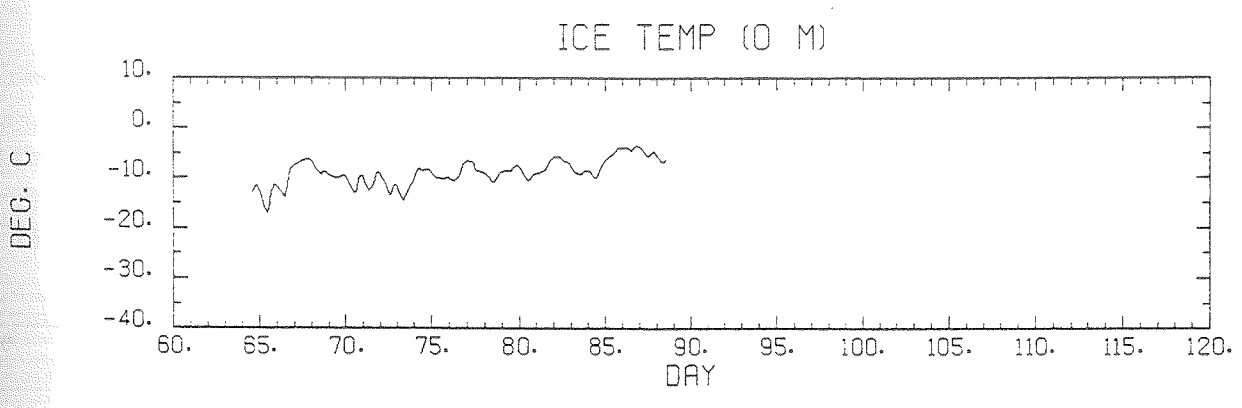

BUOY 967 - 1993
PRESSURE
MB
1060.
1020.
980.
940.
900.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY
AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY
ICE TEMP (0 M)
DEG. C
10.
0.
-10.
-20.
-30.
-40.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY

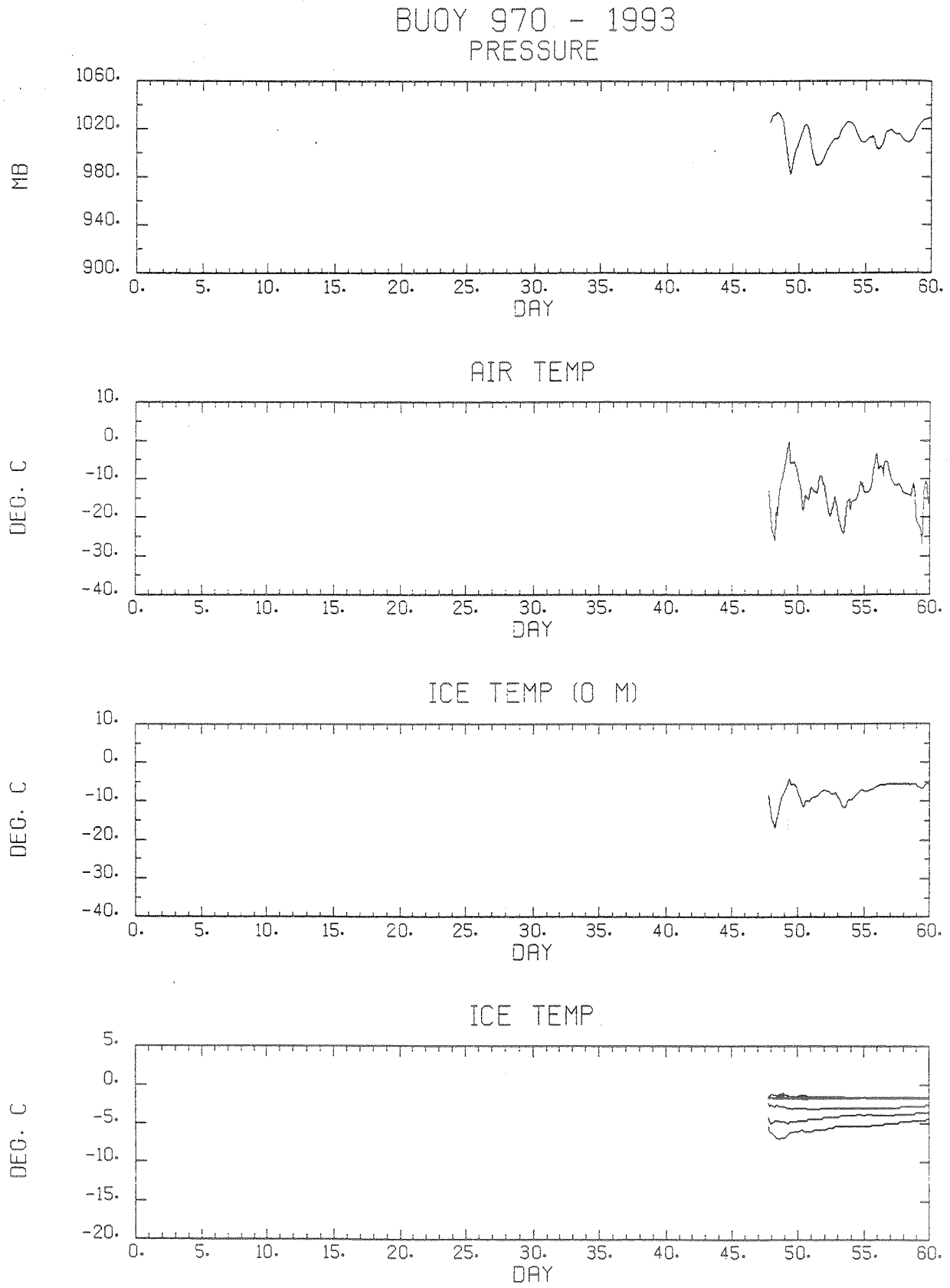

BUOY 968 - 1993
PRESSURE
MB
1060.
1020.
980.
940.
900.
0. 5. 10. 15. 20. 25. 30. 35. 40. 45. 50. 55. 60.
DAY
AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
0. 5. 10. 15. 20. 25. 30. 35. 40. 45. 50. 55. 60.
DAY
ICE TEMP (0 M)
DEG. C
10.
0.
-10.
-20.
-30.
-40.
0. 5. 10. 15. 20. 25. 30. 35. 40. 45. 50. 55. 60.
DAY


BUOY 968 - 1993
PRESSURE
MB
1060.
1020.
980.
940.
900.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY
AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY
ICE TEMP (0 M)
DEG. C
10.
0.
-10.
-20.
-30.
-40.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY


BUOY 969 - 1993
PRESSURE
MB
1060.
1020.
980.
940.
900.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY

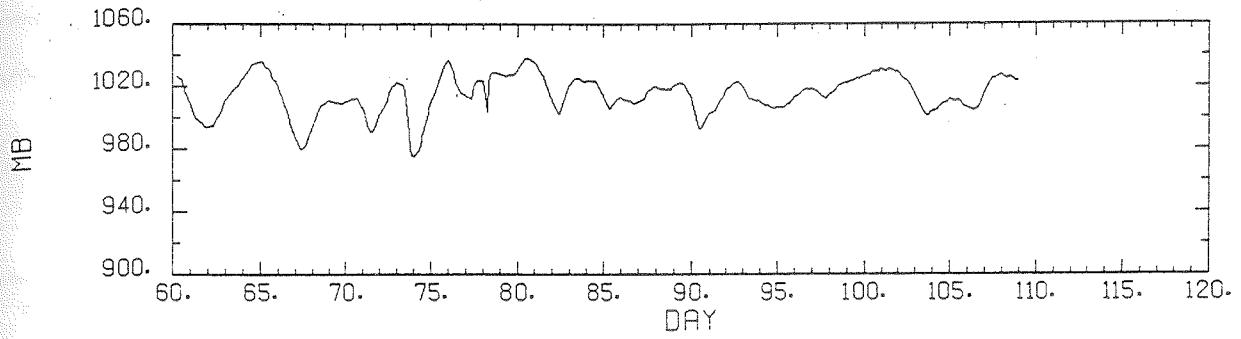

AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY


ICE TEMP (0 M)
DEG. C
10.
0.
-10.
-20.
-30.
-40.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY

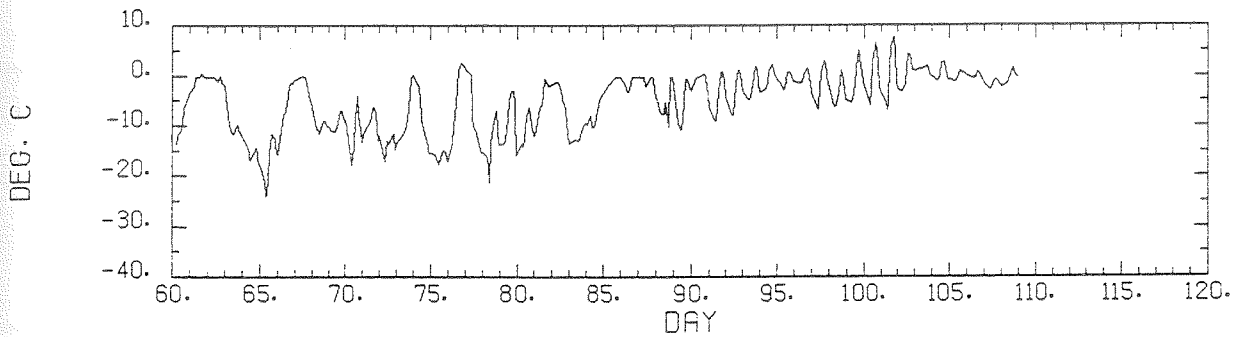

BUOY 970 - 1993
PRESSURE
MB
1060.
1020.
980.
940.
900.
0. 5. 10. 15. 20. 25. 30. 35. 40. 45. 50. 55. 60.
DAY
AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
0. 5. 10. 15. 20. 25. 30. 35. 40. 45. 50. 55. 60.
DAY
ICE TEMP (0 M)
DEG. C
10.
0.
-10.
-20.
-30.
-40.
0. 5. 10. 15. 20. 25. 30. 35. 40. 45. 50. 55. 60.
DAY
ICE TEMP
DEG. C
5.
0.
-5.
-10.
-15.
-20.
0. 5. 10. 15. 20. 25. 30. 35. 40. 45. 50. 55. 60.
DAY

BUOY 970 - 1993

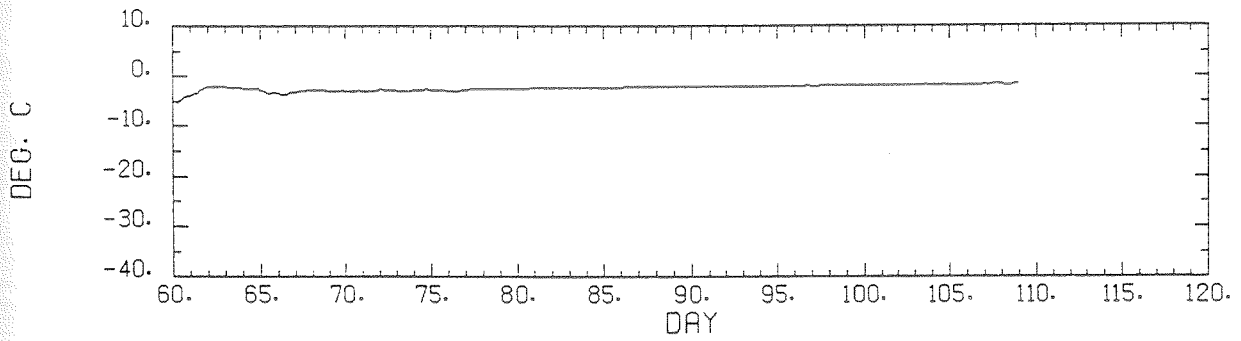
PRESSURE



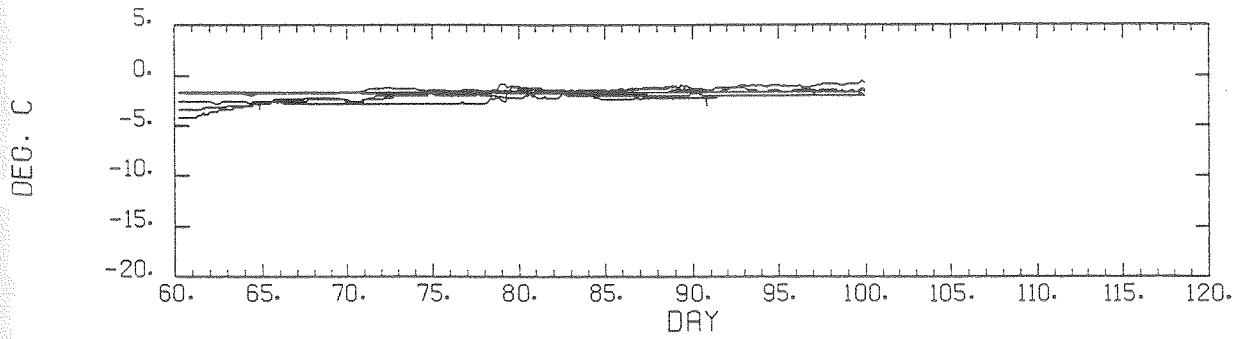
AIR TEMP

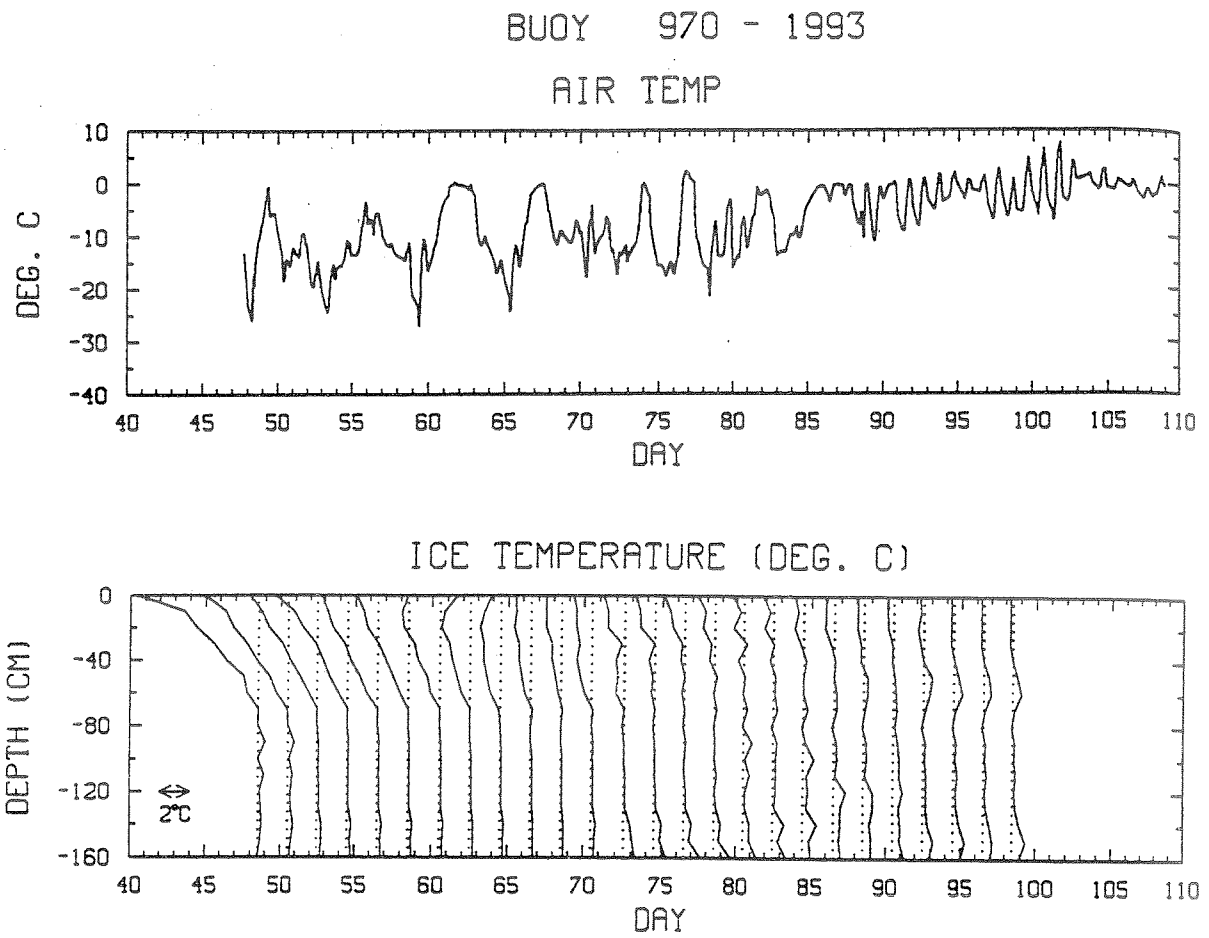


ICE TEMP (0 M)



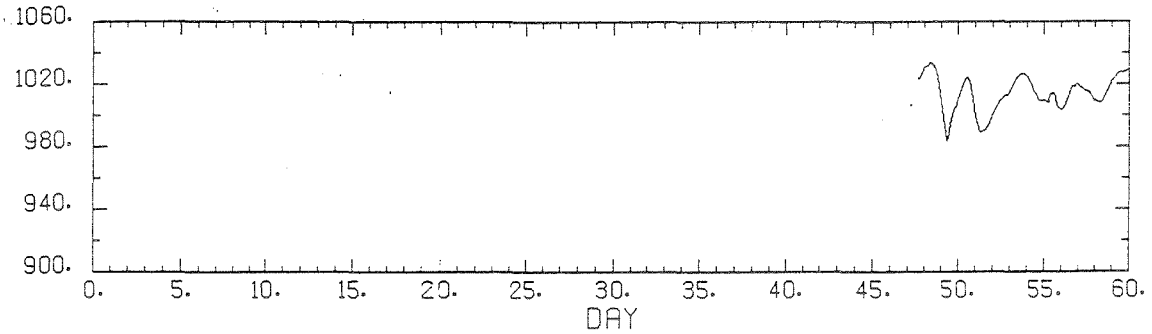
ICE TEMP



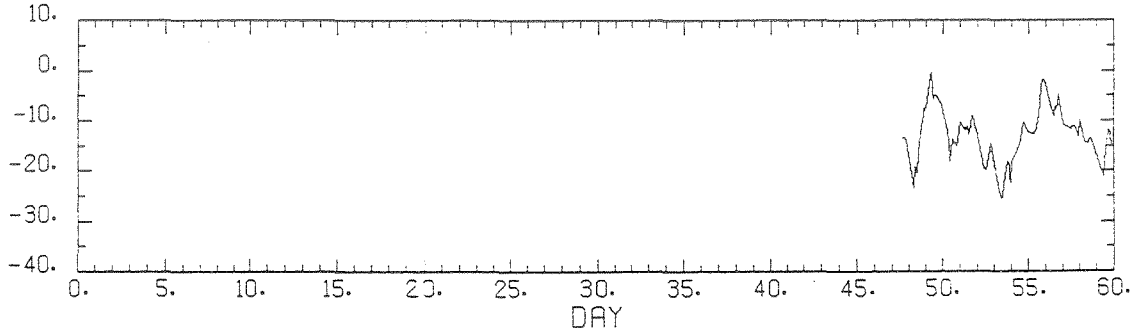

BUOY 970 - 1993
AIR TEMP
DEG. C
10
0
-10
-20
-30
-40
40 45 50 55 60 65 70 75 80 85 90 95 100 105 110
DAY
ICE TEMPERATURE (DEG. C)
DEPTH (CM)
0
-40
-80
-120
-160
2°C
40 45 50 55 60 65 70 75 80 85 90 95 100 105 110
DAY

BUOY 974 - 1993

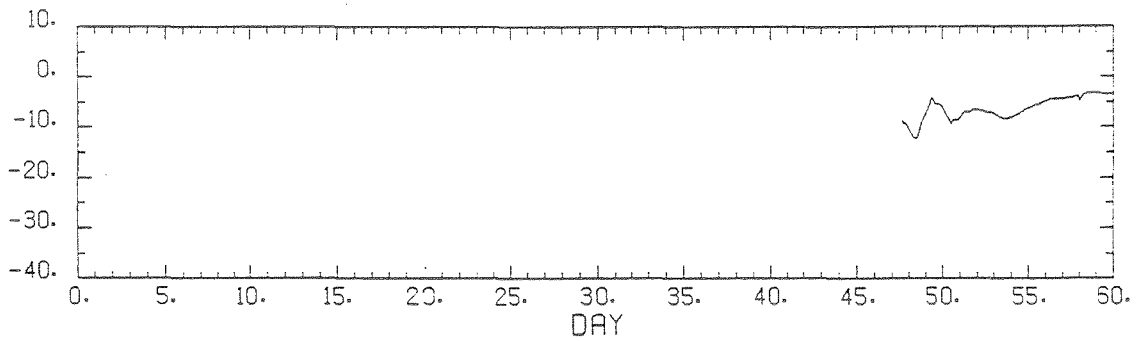
PRESSURE



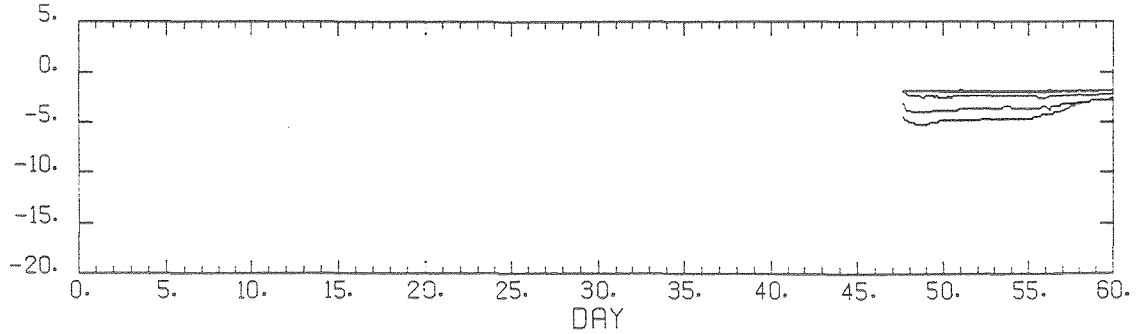
AIR TEMP

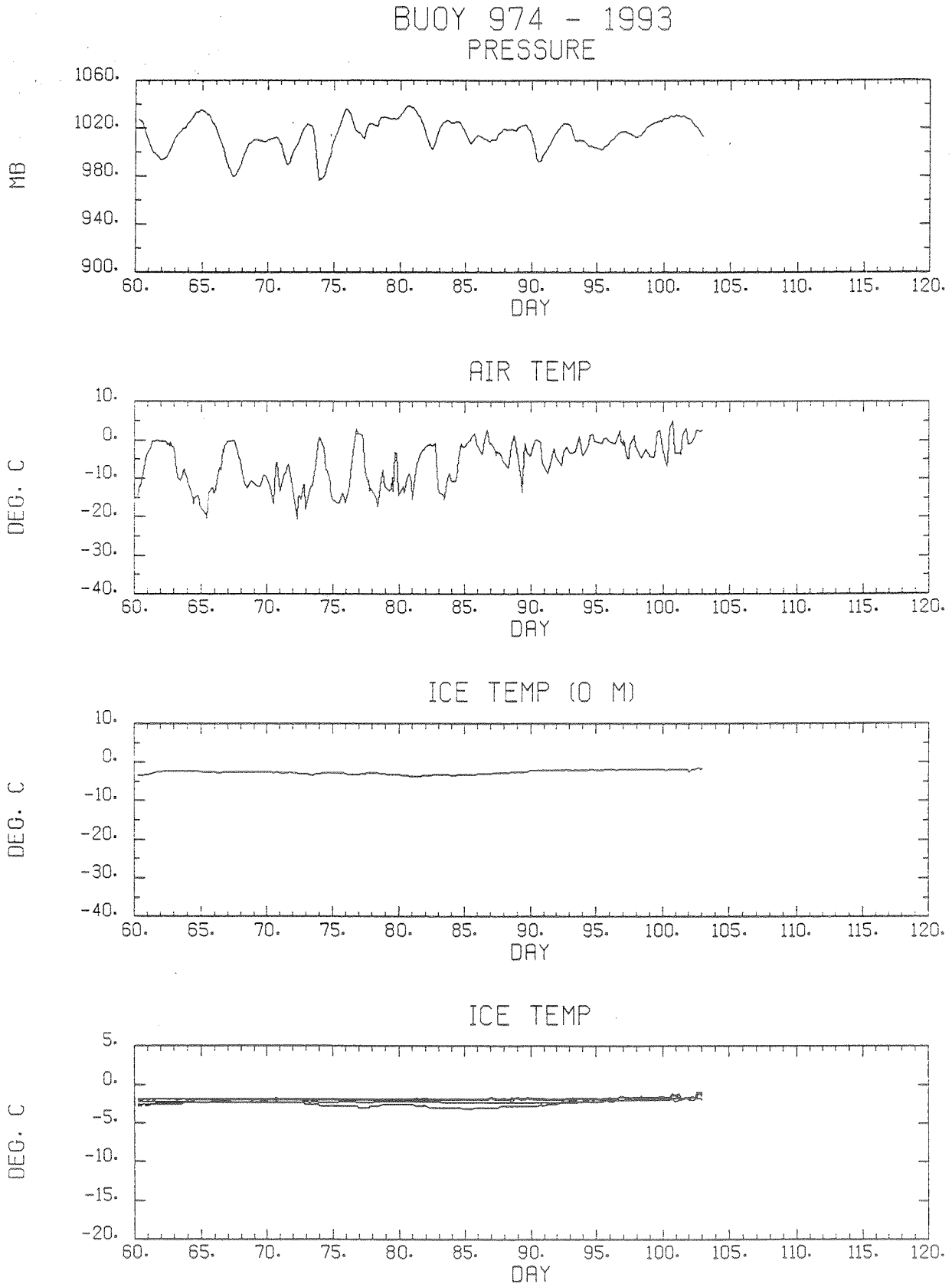


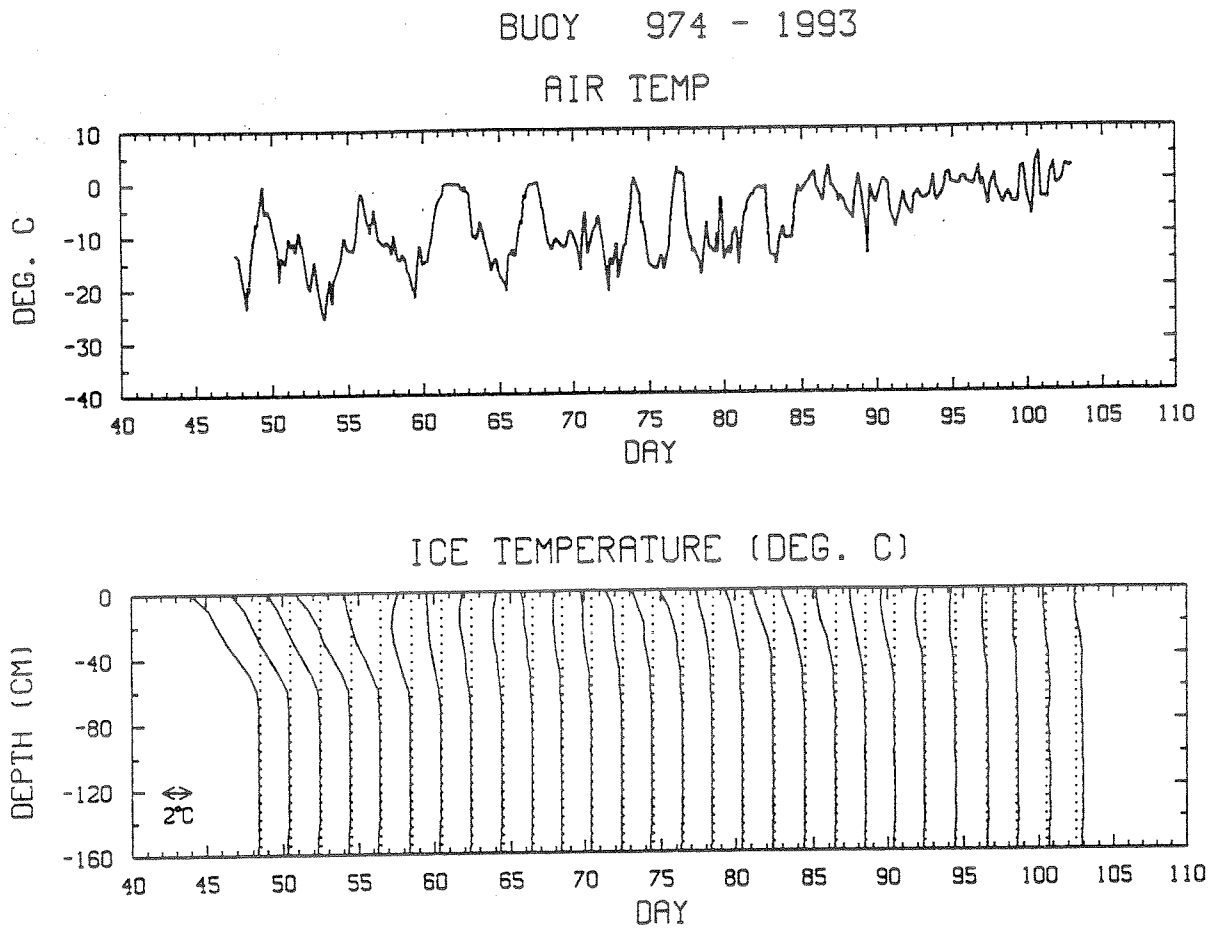
ICE TEMP (0 M)

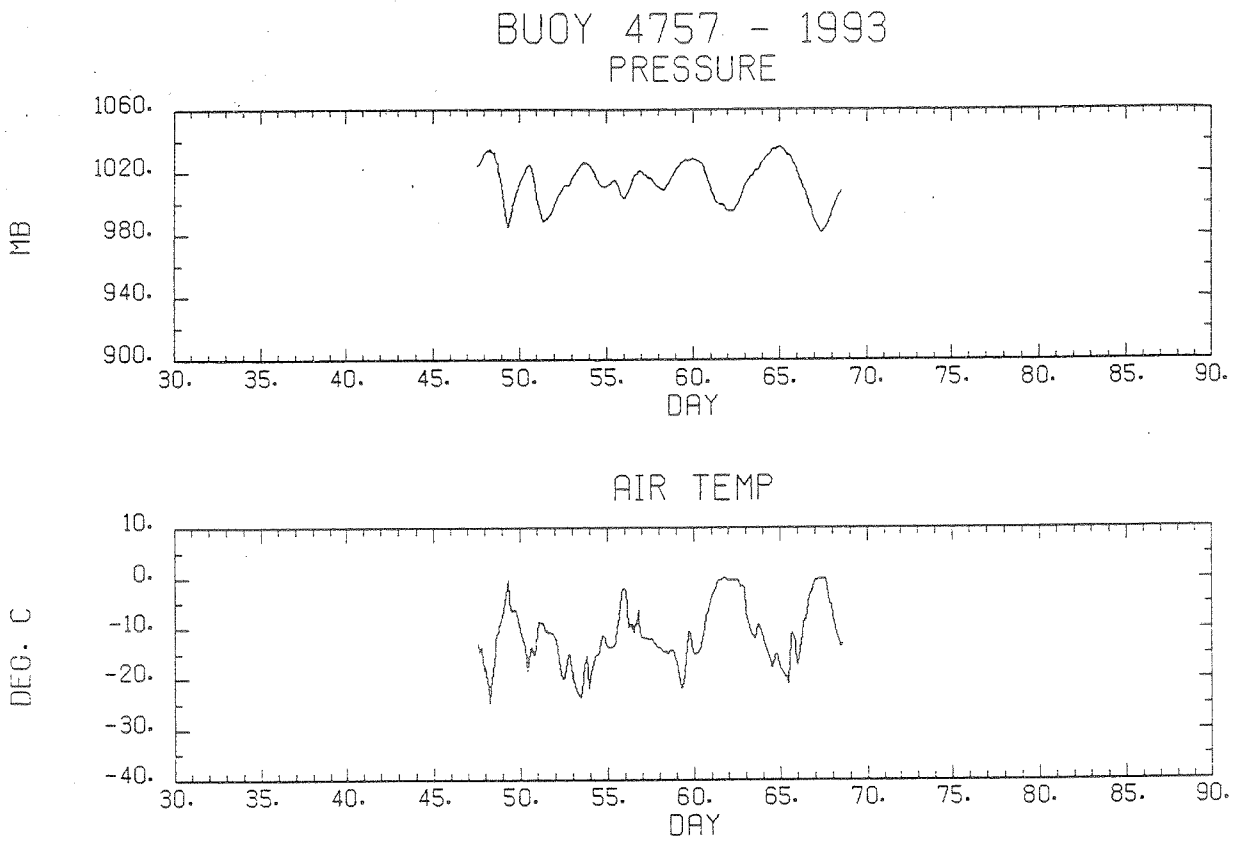


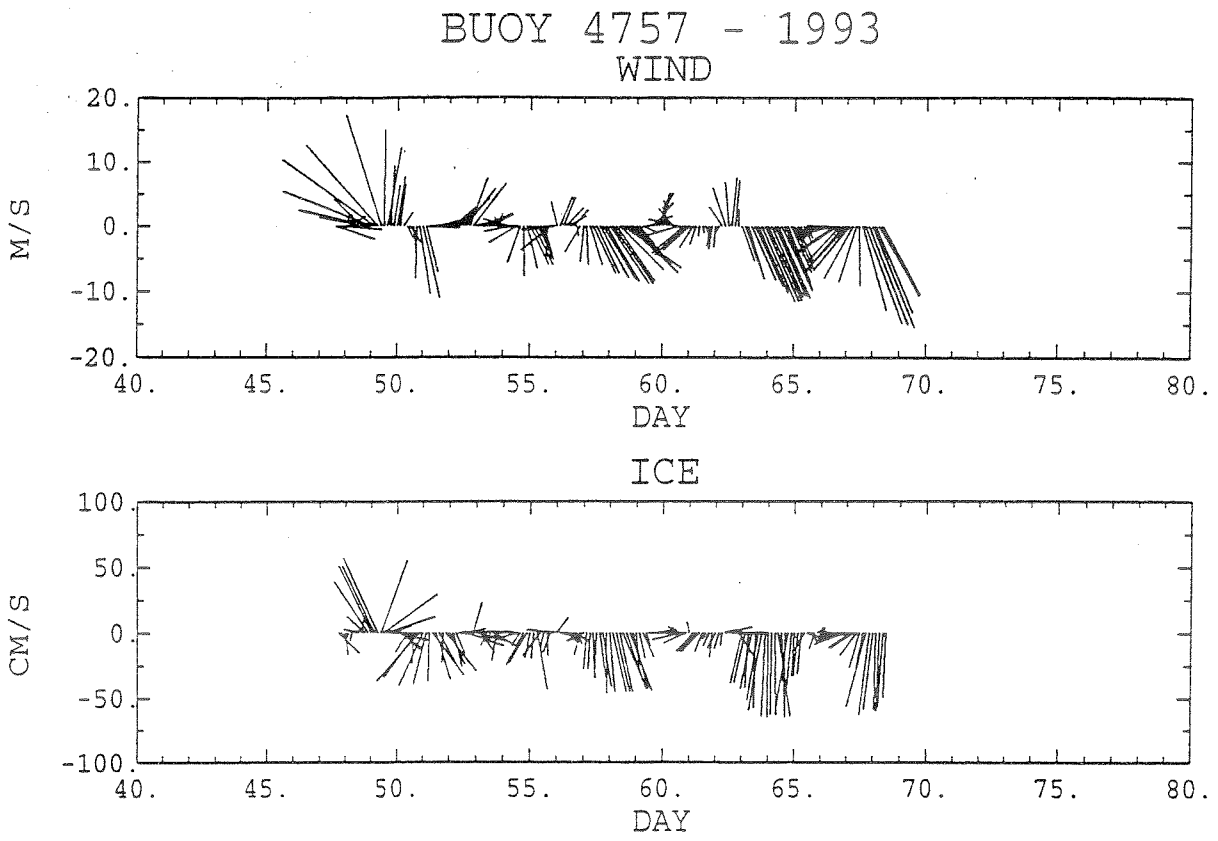
ICE TEMP

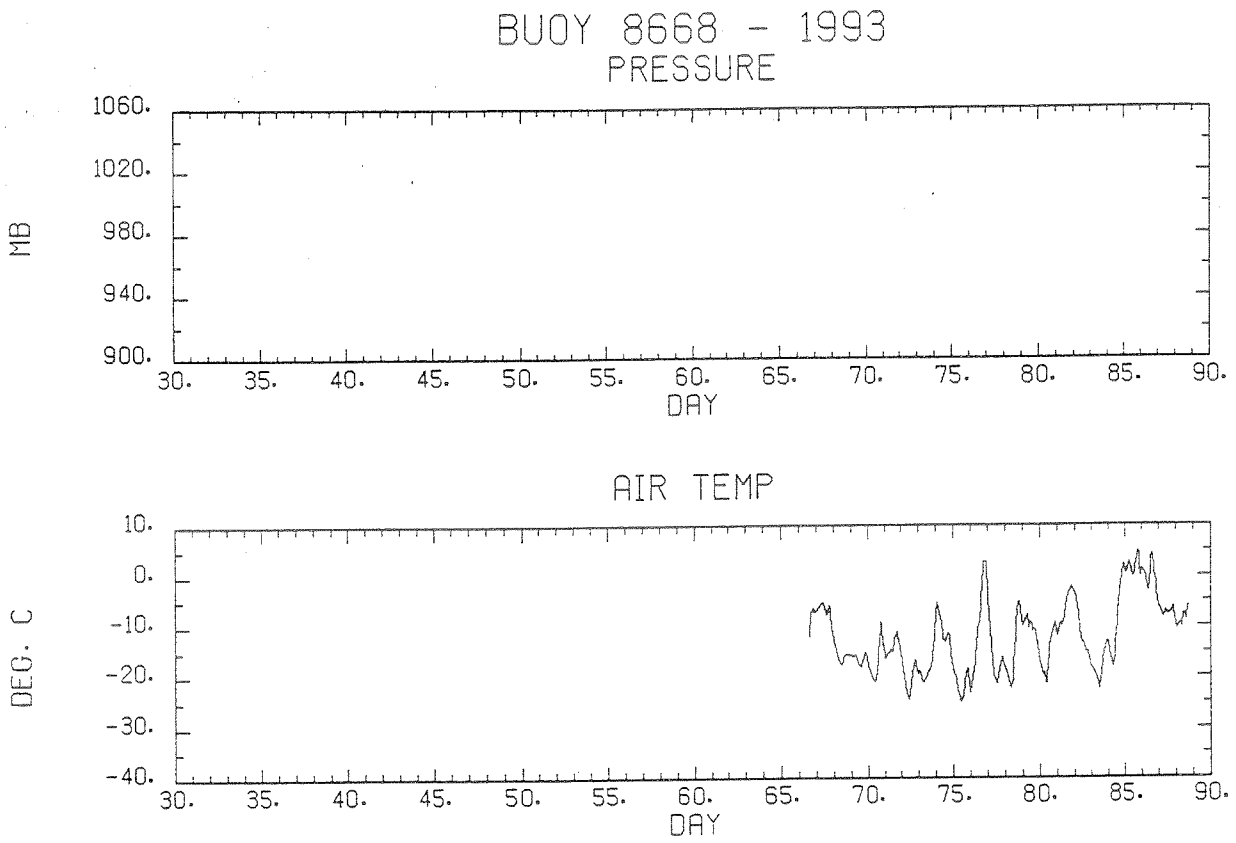


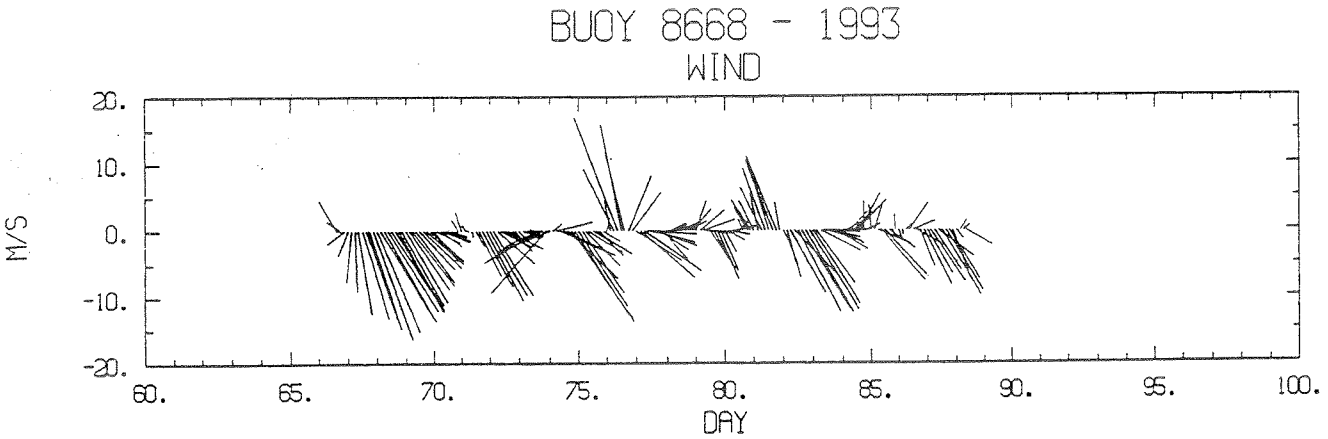

BUOY 974 - 1993
PRESSURE
MB
1060.
1020.
980.
940.
900.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY
AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY
ICE TEMP (0 M)
DEG. C
10.
0.
-10.
-20.
-30.
-40.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY
ICE TEMP
DEG. C
5.
0.
-5.
-10.
-15.
-20.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY

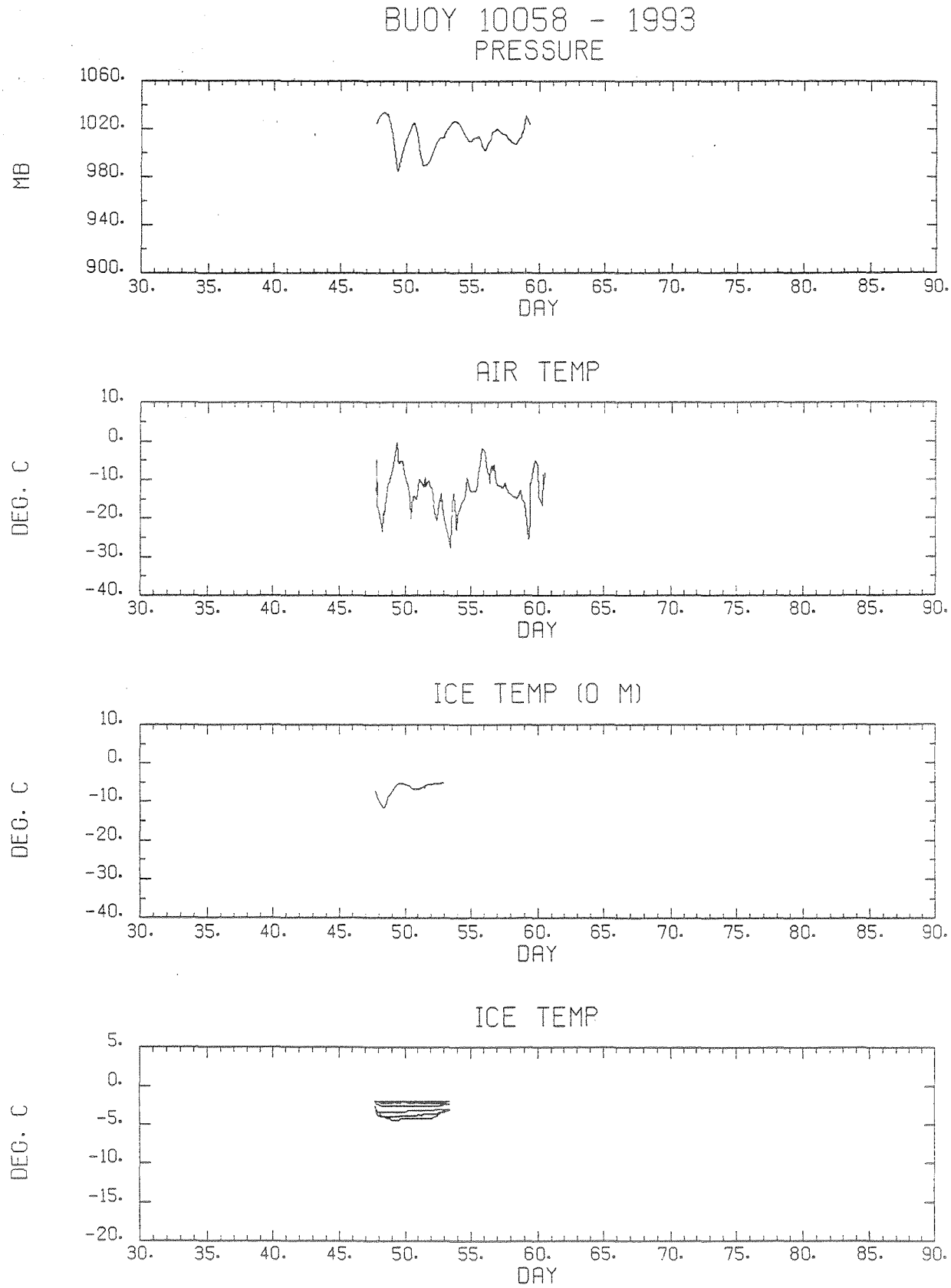

BUOY 974 - 1993
AIR TEMP
DEG. C
10
0
-10
-20
-30
-40
40 45 50 55 60 65 70 75 80 85 90 95 100 105 110
DAY
ICE TEMPERATURE (DEG. C)
DEPTH (CM)
0
-40
-80
-120
-160
2°C
40 45 50 55 60 65 70 75 80 85 90 95 100 105 110
DAY

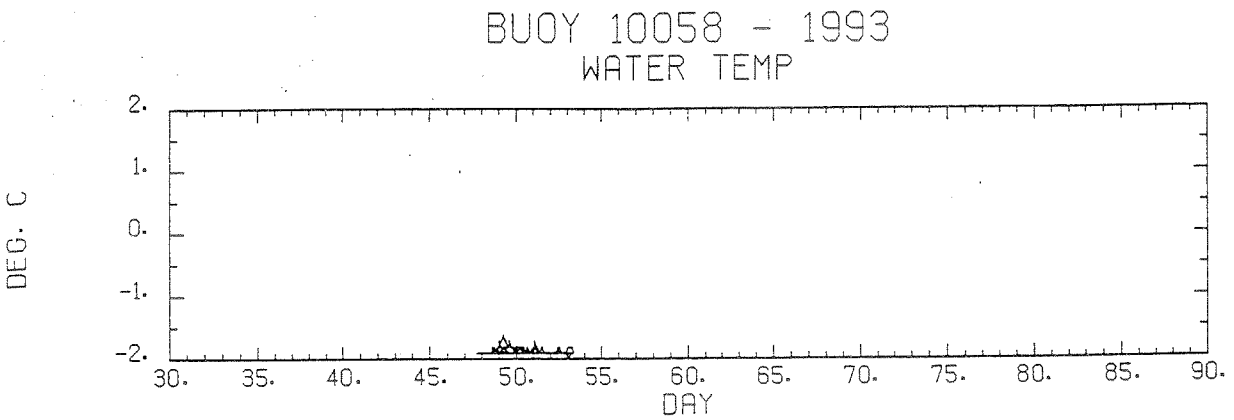

BUOY 4757 - 1993
PRESSURE
MB
1060.
1020.
980.
940.
900.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.
DAY
AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.
DAY

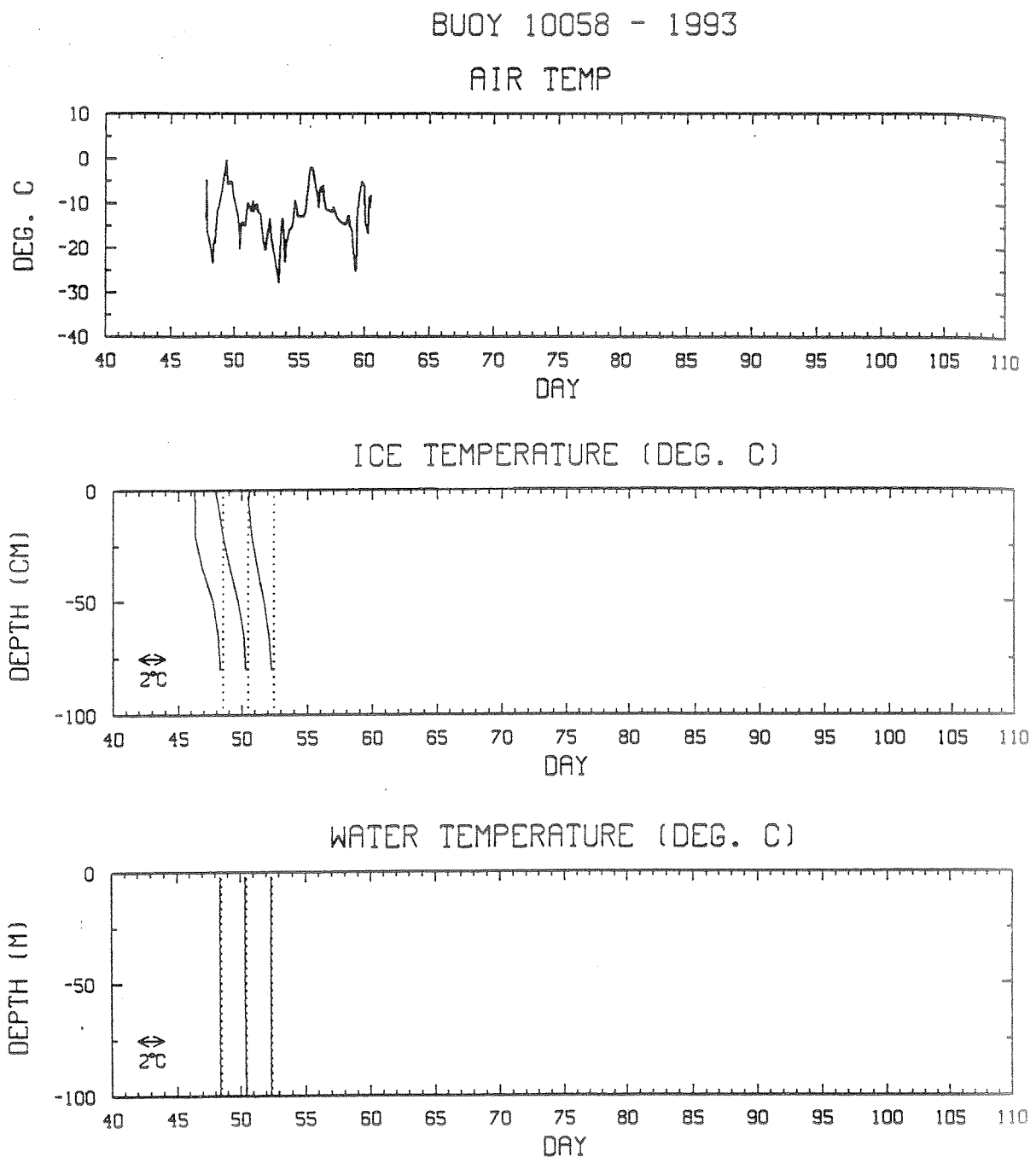

BUOY 4757 - 1993
WIND
M/S
20.
10.
0.
-10.
-20.
40.
45.
50.
55.
60.
65.
70.
75.
80.
DAY
ICE
CM/S
100.
50.
0.
-50.
-100.
40.
45.
50.
55.
60.
65.
70.
75.
80.
DAY


BUOY 8668 - 1993
PRESSURE
MB
1060.
1020.
980.
940.
900.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.
DAY
AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.
DAY

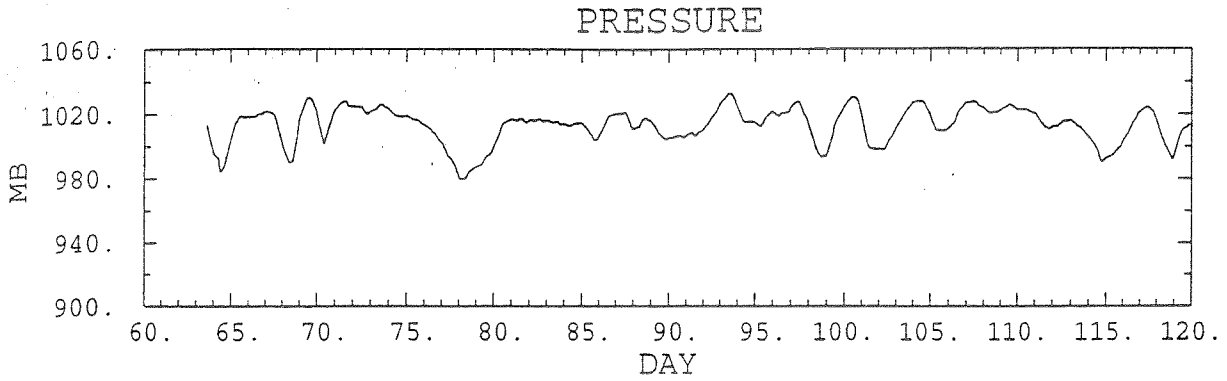

BUOY 8668 - 1993
WIND
M/S
20.
10.
0.
-10.
-20.
60.
65.
70.
75.
80.
85.
90.
95.
100.
DAY

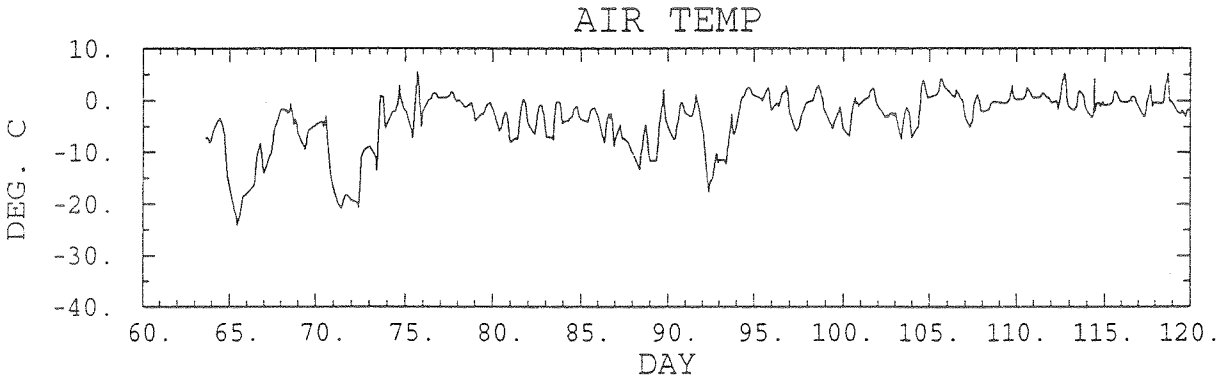

BUOY 10058 - 1993
PRESSURE
MB
1060.
1020.
980.
940.
900.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.
DAY
AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.
DAY
ICE TEMP (0 M)
DEG. C
10.
0.
-10.
-20.
-30.
-40.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.
DAY
ICE TEMP
DEG. C
5.
0.
-5.
-10.
-15.
-20.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.
DAY

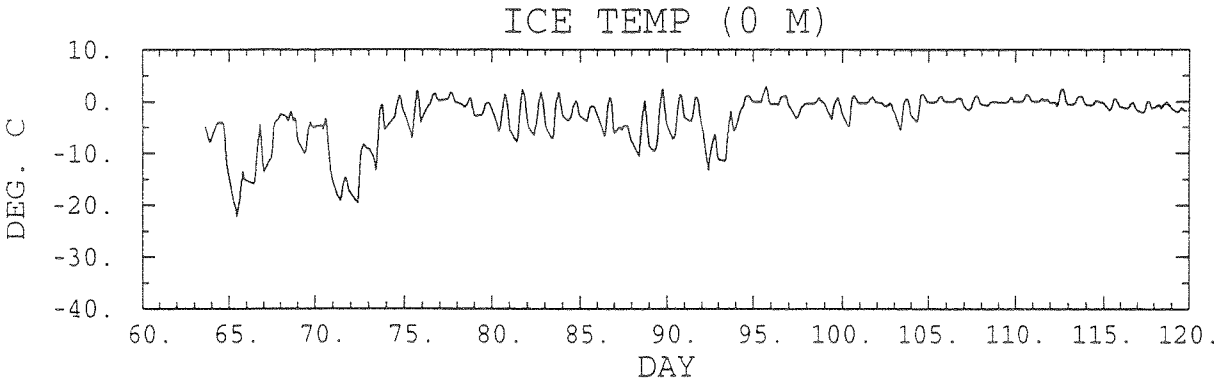

BUOY 10058 - 1993
WATER TEMP
DEG. C
2.
1.
0.
-1.
-2.
30.
35.
40.
45.
50.
55.
60.
65.
70.
75.
80.
85.
90.
DAY


BUOY 10058 - 1993
AIR TEMP
DEG. C
10
0
-10
-20
-30
-40
40 45 50 55 60 65 70 75 80 85 90 95 100 105 110
DAY
ICE TEMPERATURE (DEG. C)
DEPTH (CM)
0
-50
-100
2°C
40 45 50 55 60 65 70 75 80 85 90 95 100 105 110
DAY
WATER TEMPERATURE (DEG. C)
DEPTH (M)
0
-50
-100
2°C
40 45 50 55 60 65 70 75 80 85 90 95 100 105 110
DAY

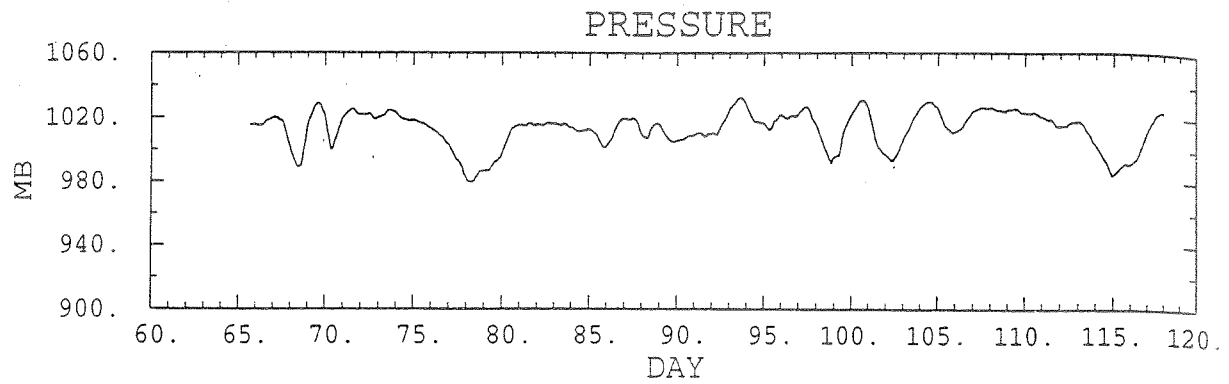
BUOY 965 - 1994

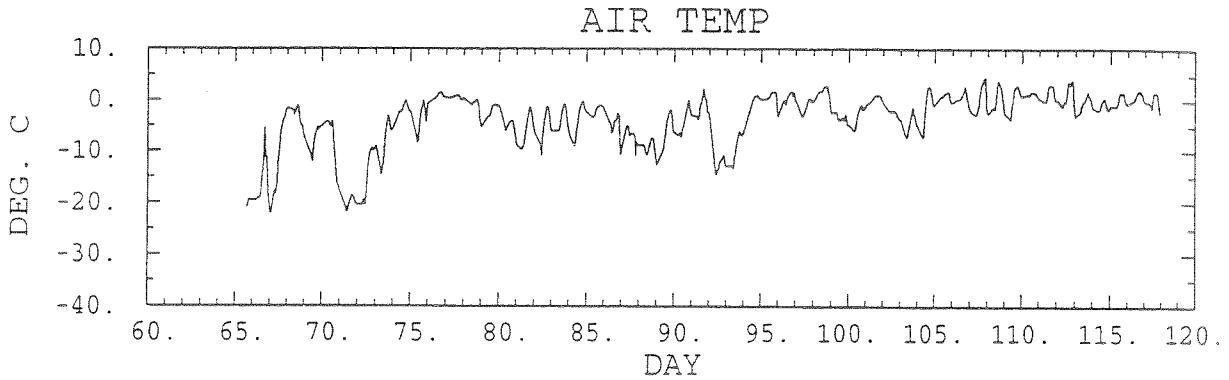


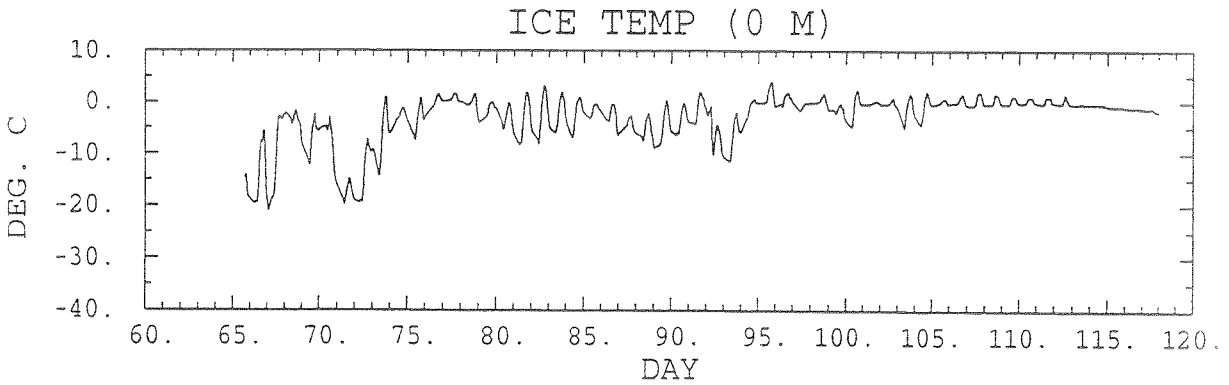


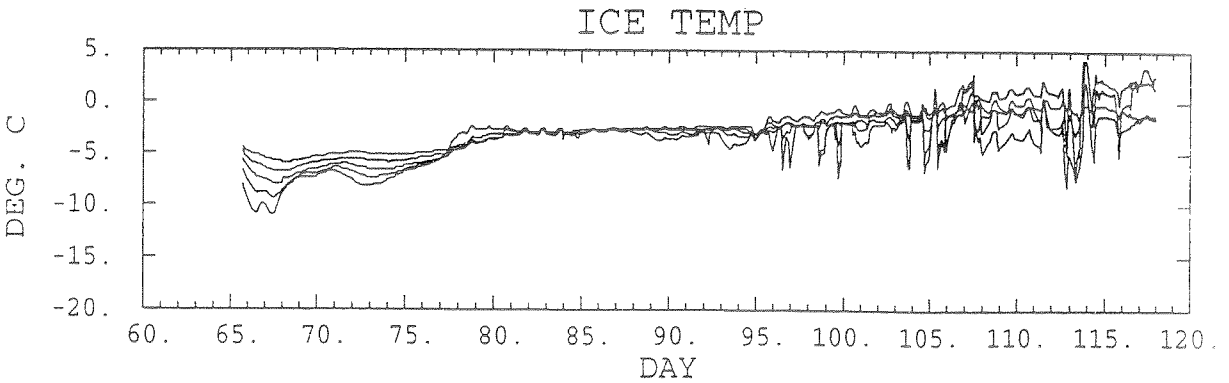


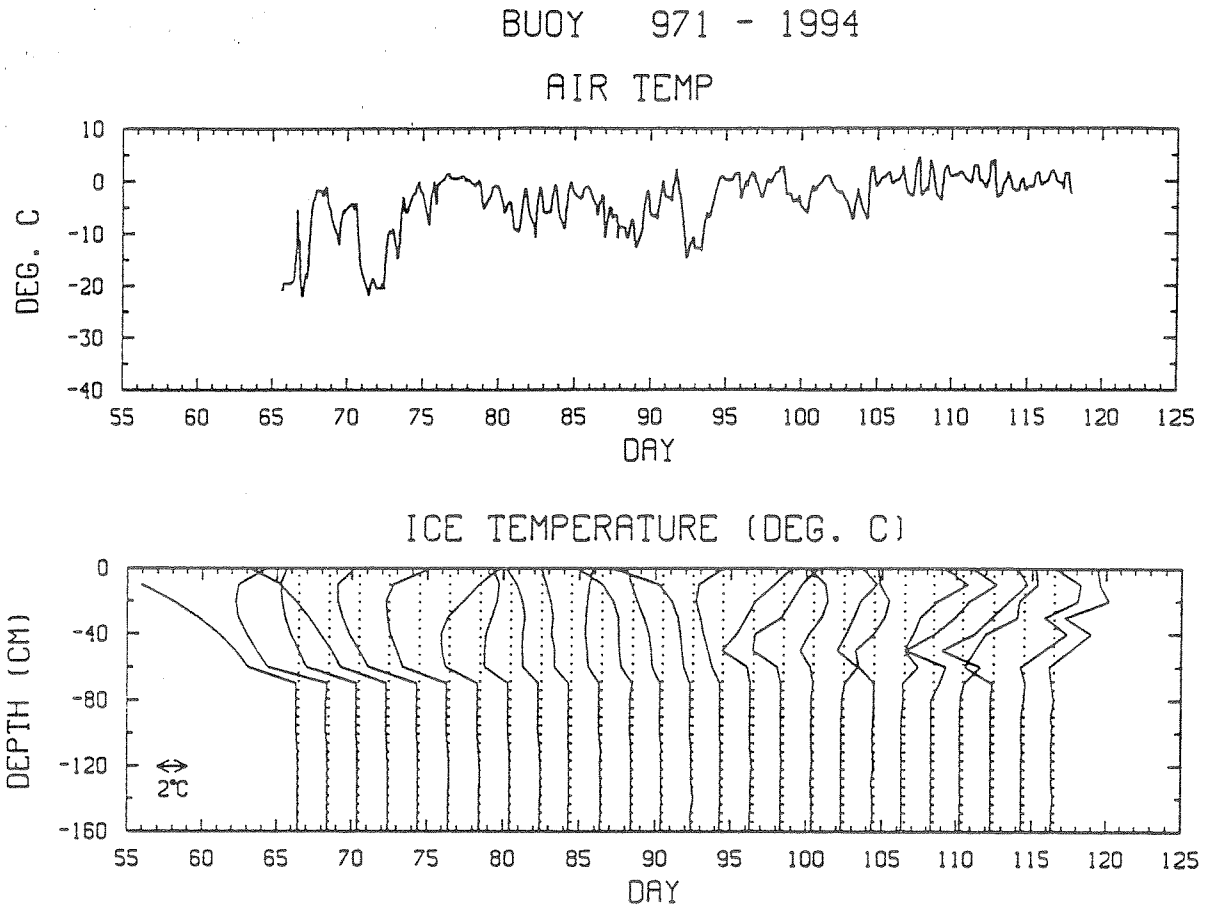
BUOY 971 - 1994

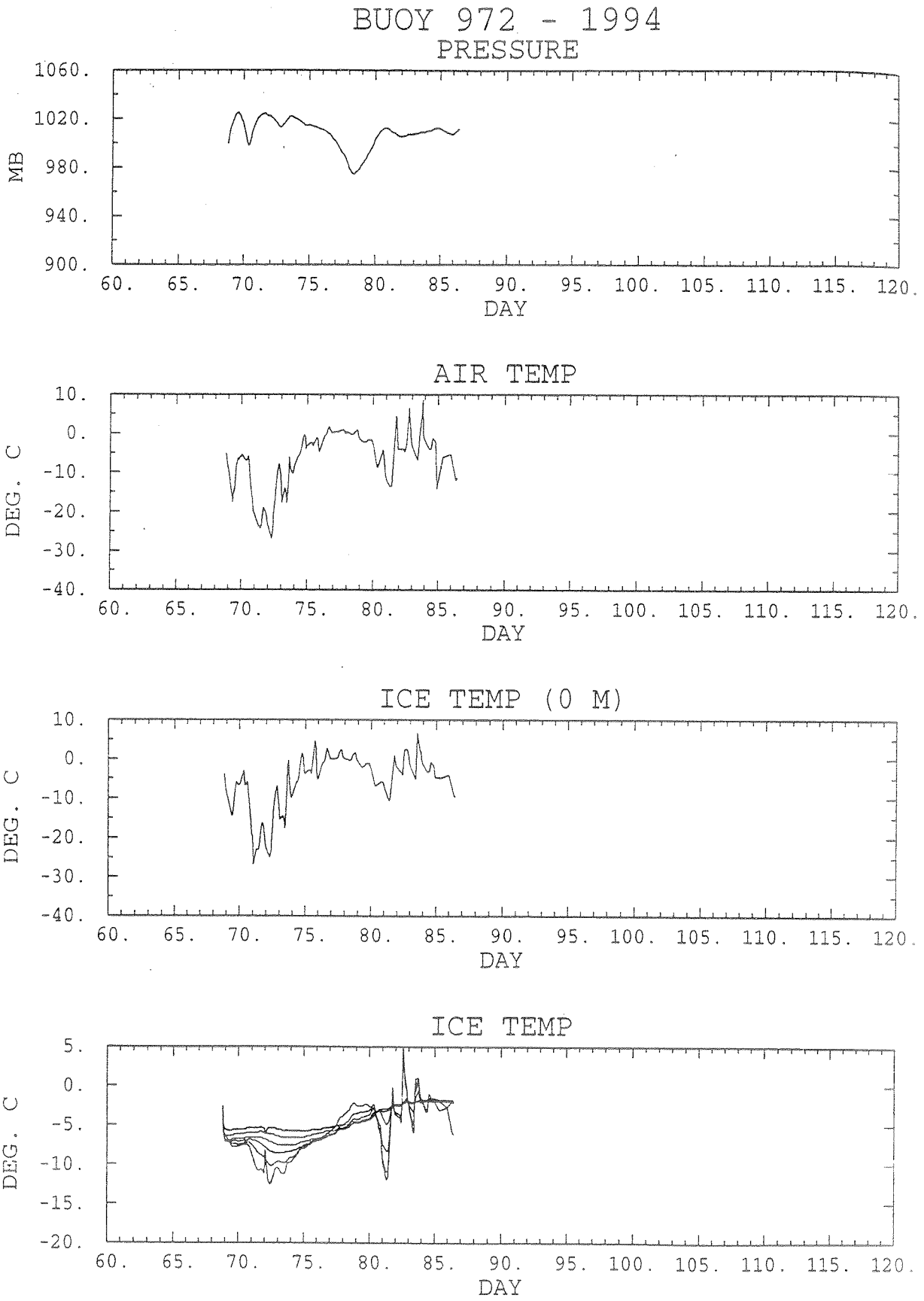


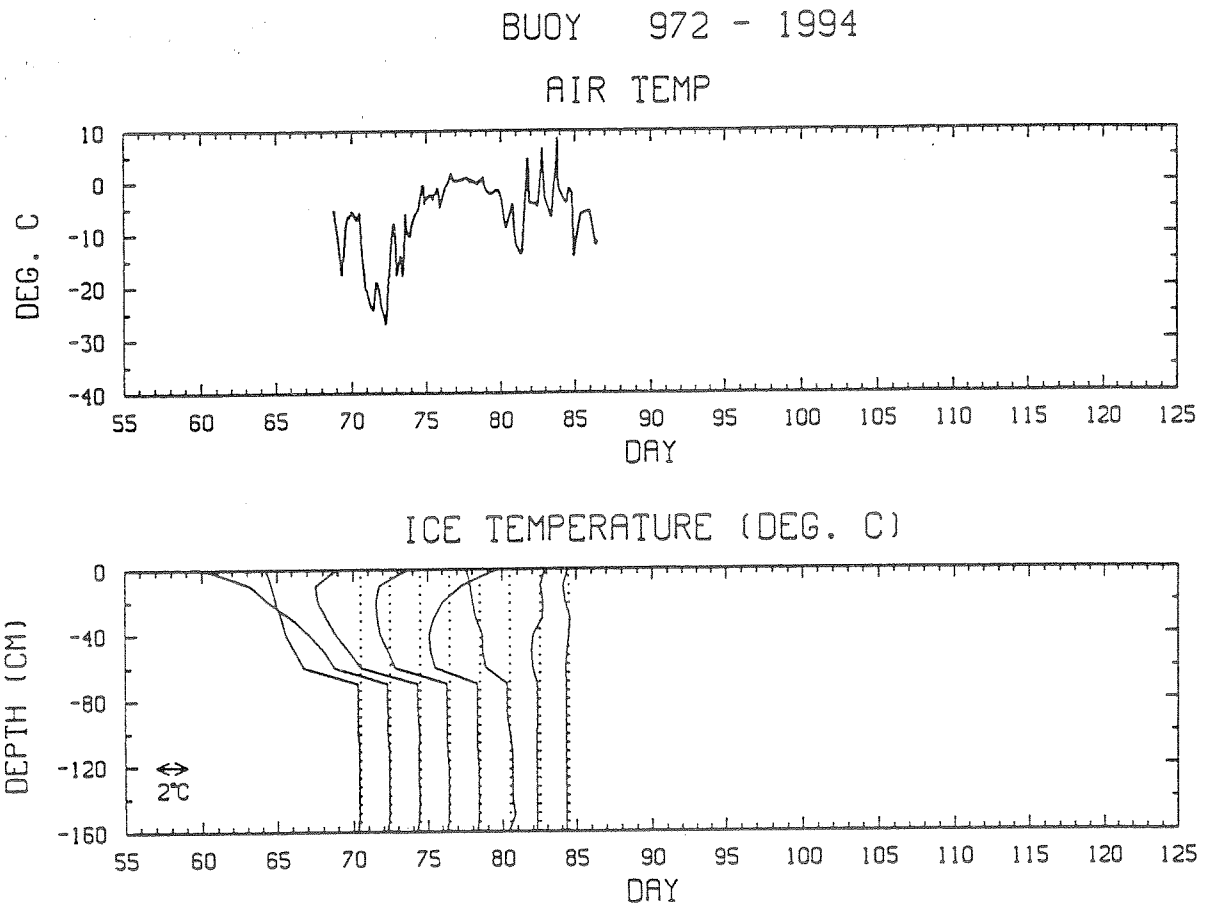


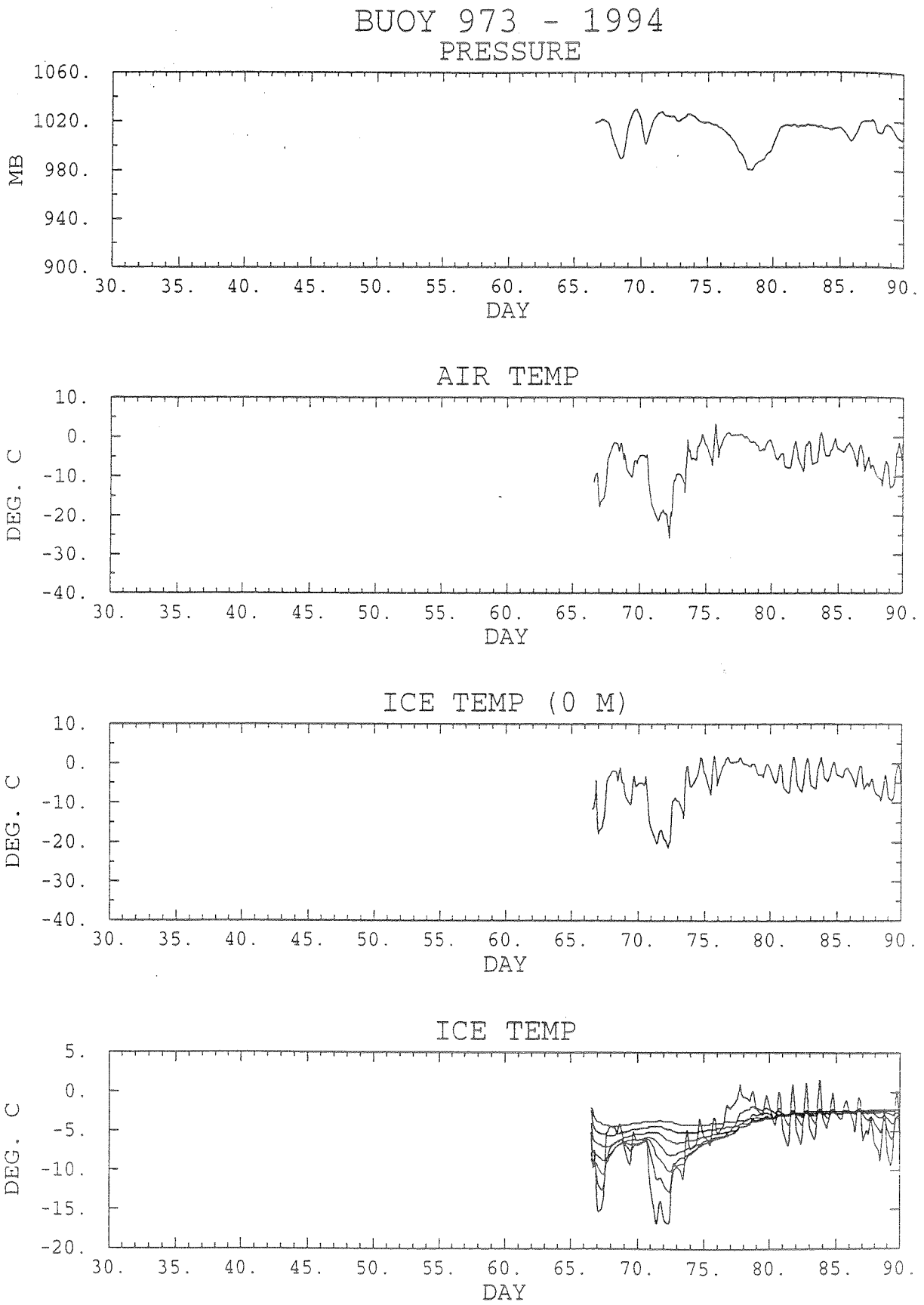




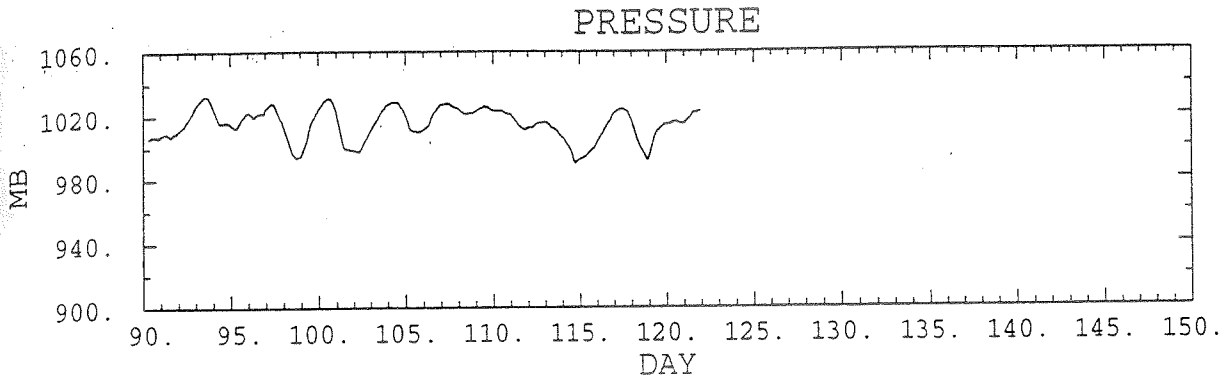

BUOY 971 - 1994
AIR TEMP
DEG. C
10
0
-10
-20
-30
-40
55 60 65 70 75 80 85 90 95 100 105 110 115 120 125
DAY
ICE TEMPERATURE (DEG. C)
DEPTH (CM)
0
-40
-80
-120
-160
2°C
55 60 65 70 75 80 85 90 95 100 105 110 115 120 125
DAY

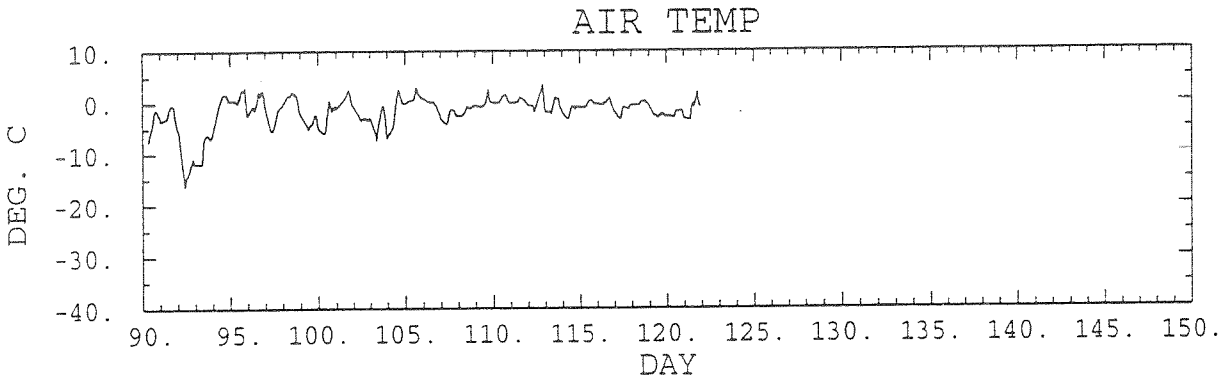

BUOY 972 - 1994
PRESSURE
MB
1060.
1020.
980.
940.
900.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY
AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY
ICE TEMP (0 M)
DEG. C
10.
0.
-10.
-20.
-30.
-40.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY
ICE TEMP
DEG. C
5.
0.
-5.
-10.
-15.
-20.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY

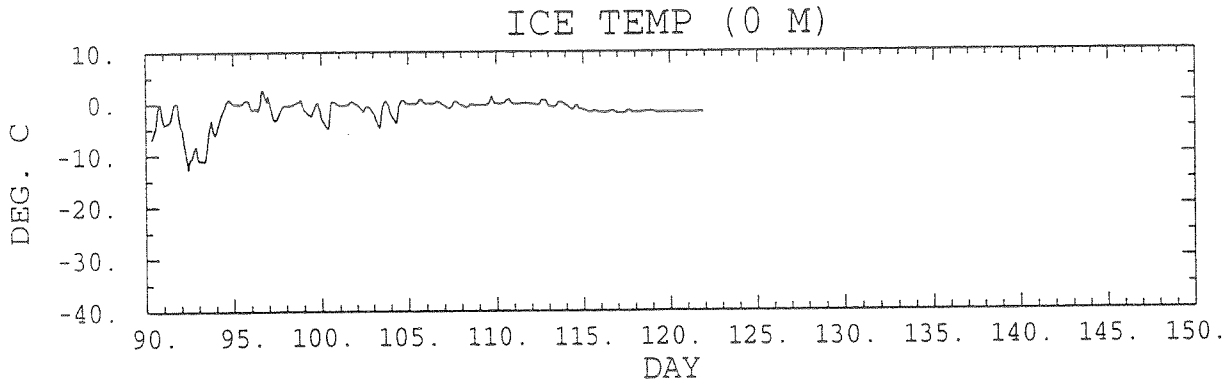

BUOY 972 - 1994
AIR TEMP
DEG. C
10
0
-10
-20
-30
-40
55 60 65 70 75 80 85 90 95 100 105 110 115 120 125
DAY
ICE TEMPERATURE (DEG. C)
DEPTH (CM)
0
-40
-80
-120
-160
2°C
55 60 65 70 75 80 85 90 95 100 105 110 115 120 125
DAY

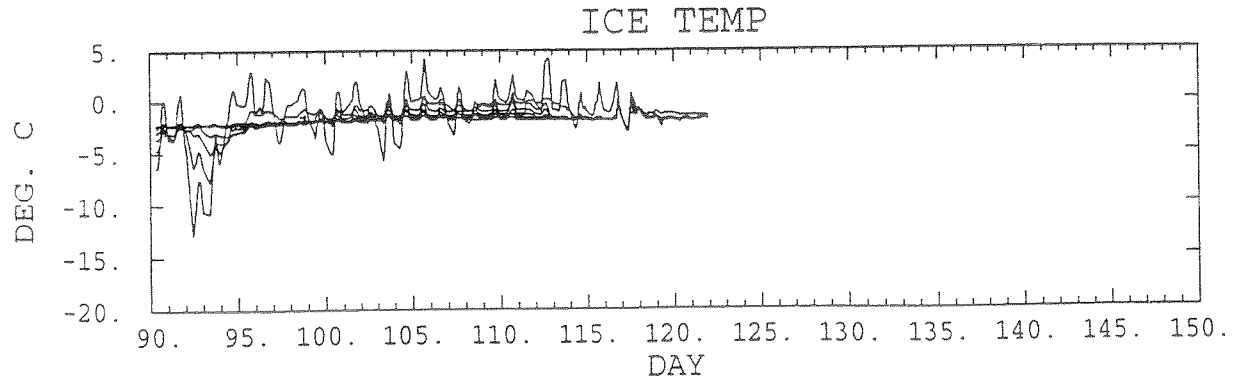

BUOY 973 - 1994
PRESSURE
MB
1060.
1020.
980.
940.
900.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.
DAY
AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.
DAY
ICE TEMP (0 M)
DEG. C
10.
0.
-10.
-20.
-30.
-40.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.
DAY
ICE TEMP
DEG. C
5.
0.
-5.
-10.
-15.
-20.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.
DAY

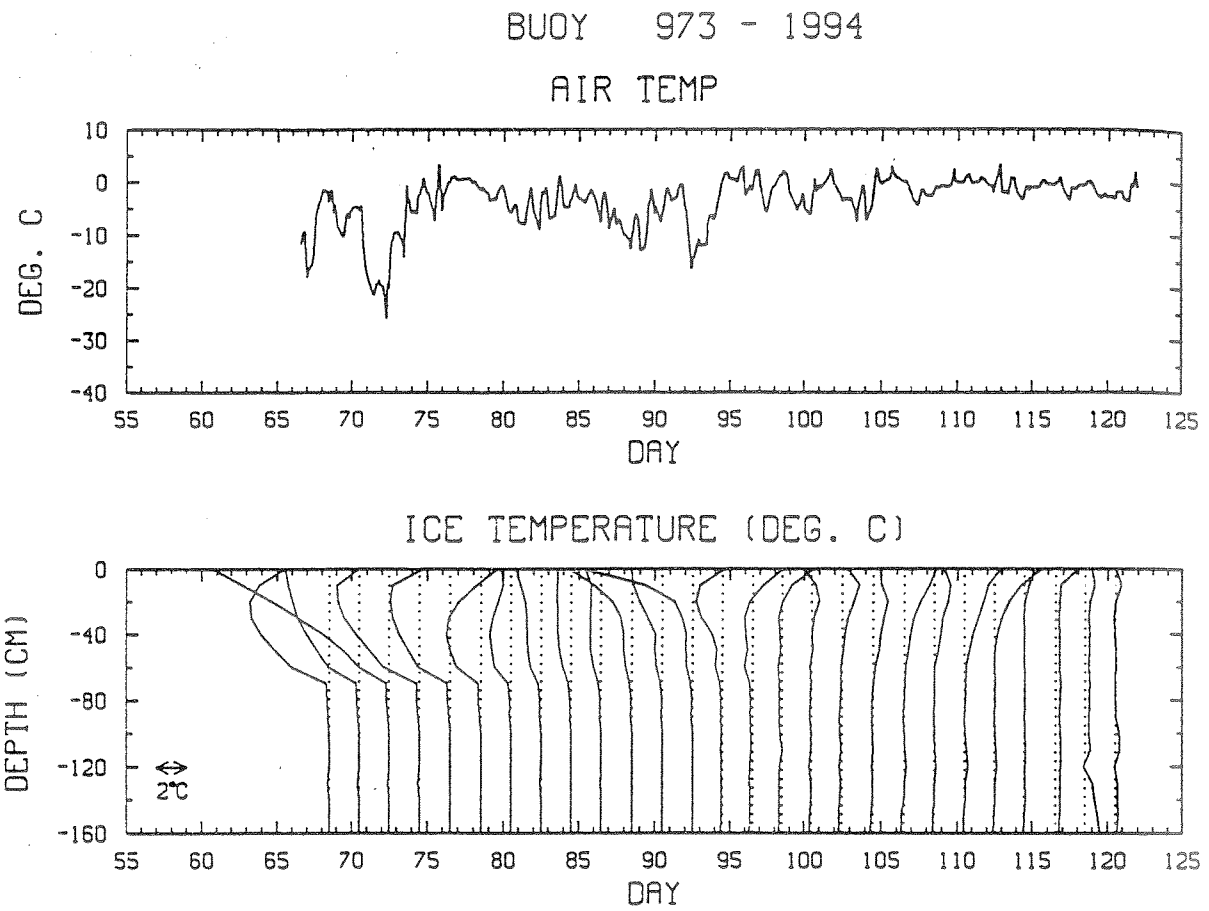
BUOY 973 - 1994



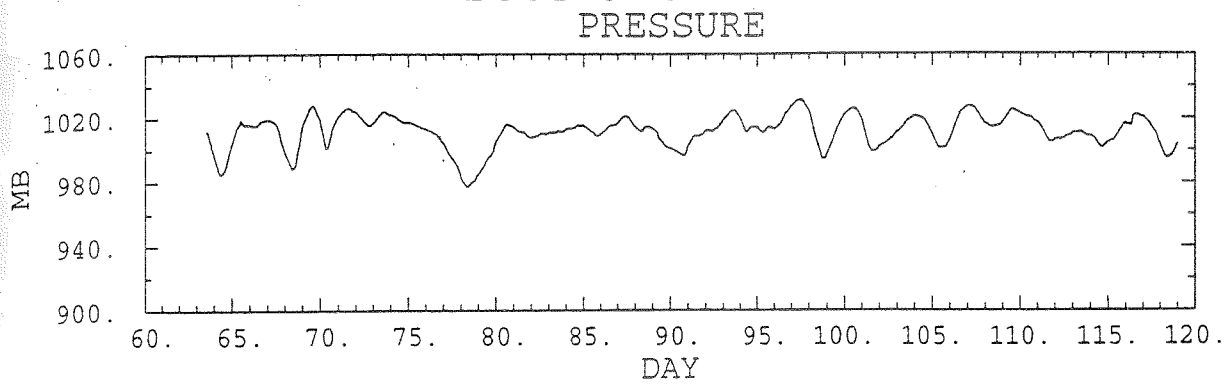


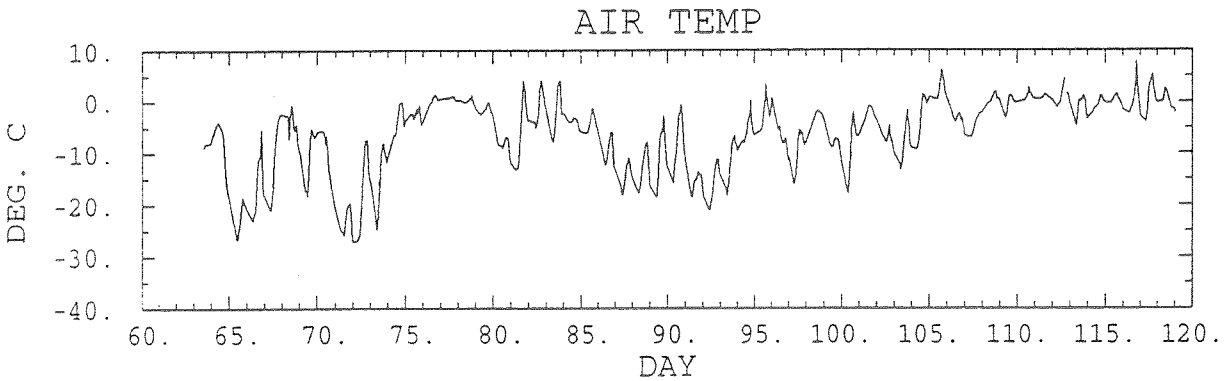


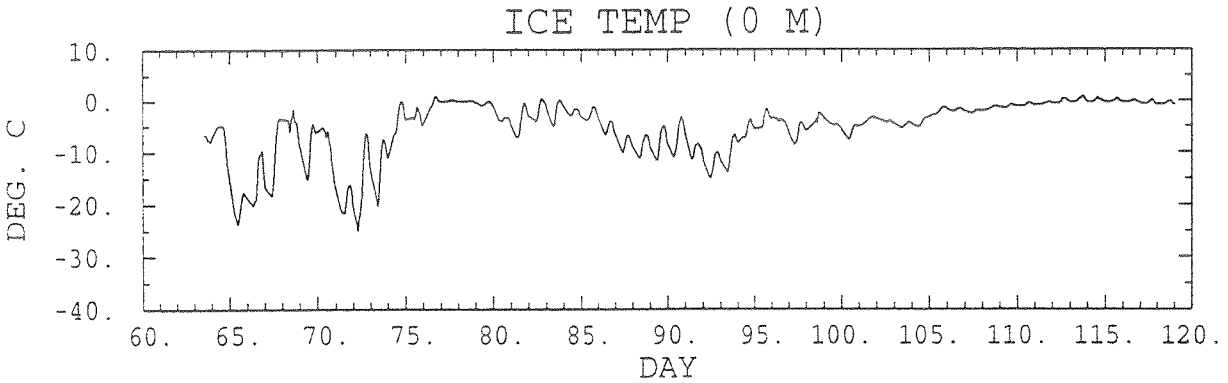


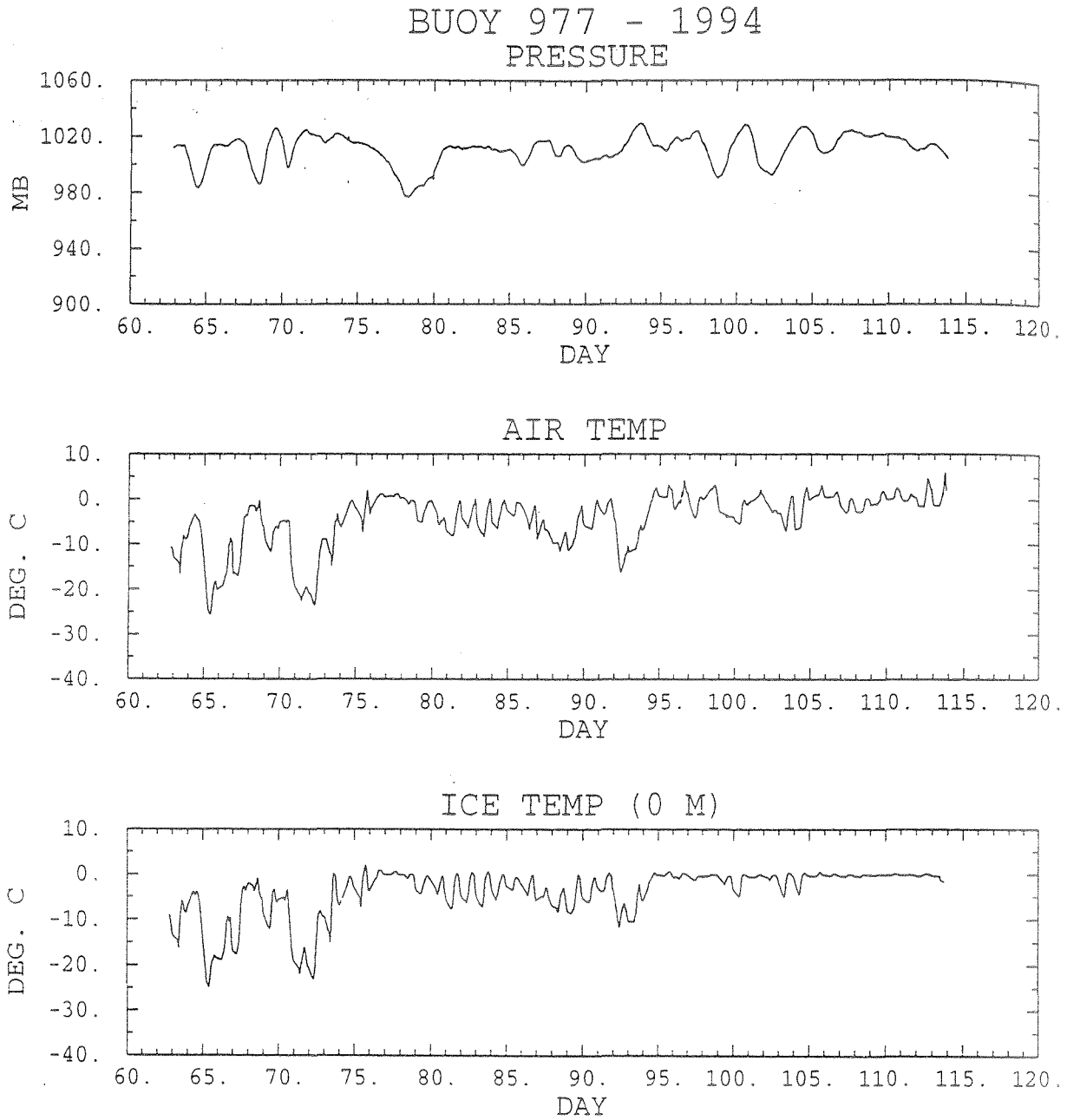

BUOY 973 - 1994
AIR TEMP
DEG. C
10
0
-10
-20
-30
-40
55 60 65 70 75 80 85 90 95 100 105 110 115 120 125
DAY
ICE TEMPERATURE (DEG. C)
DEPTH (CM)
0
-40
-80
-120
-160
2°C
55 60 65 70 75 80 85 90 95 100 105 110 115 120 125
DAY

BUOY 976 - 1994

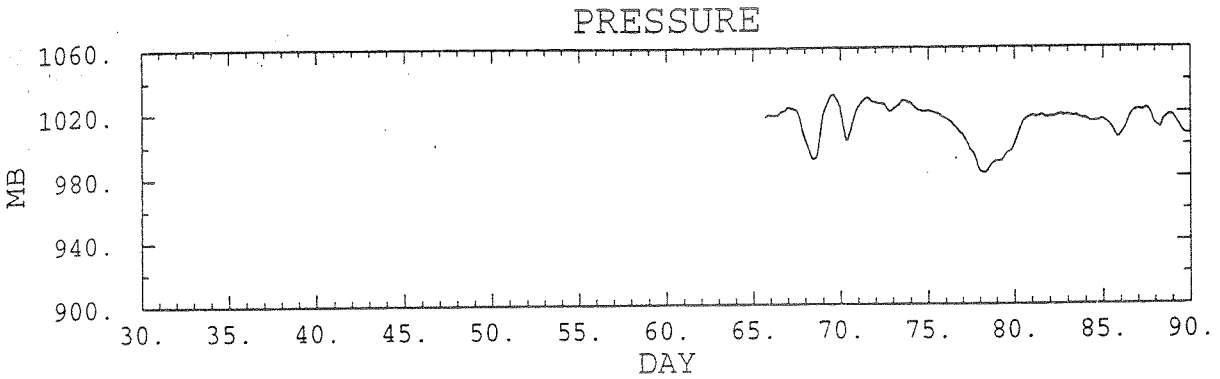


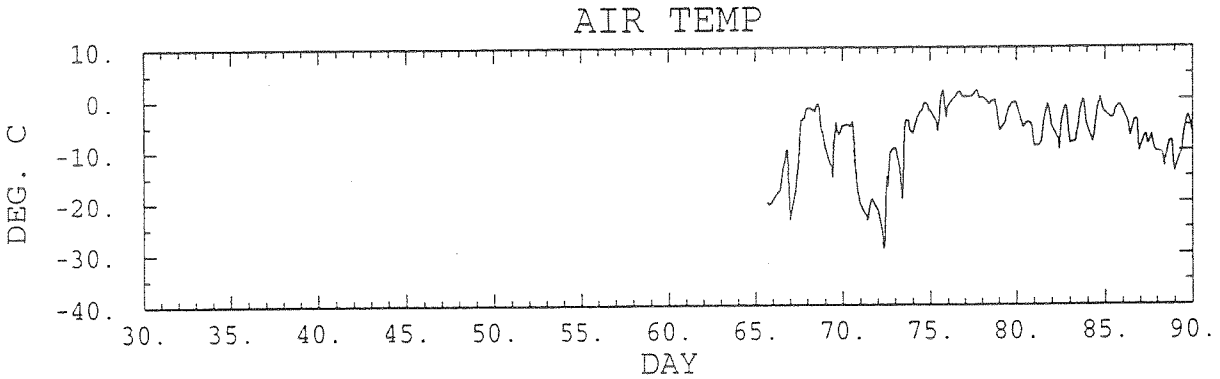


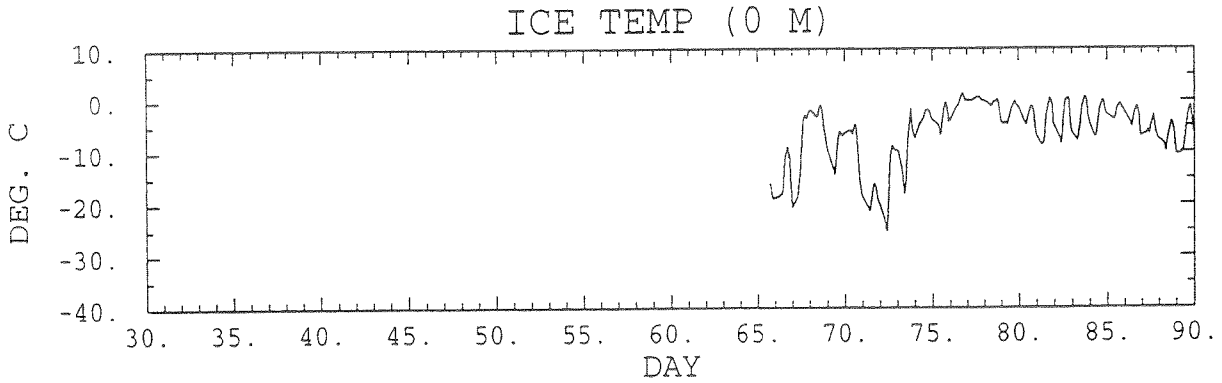


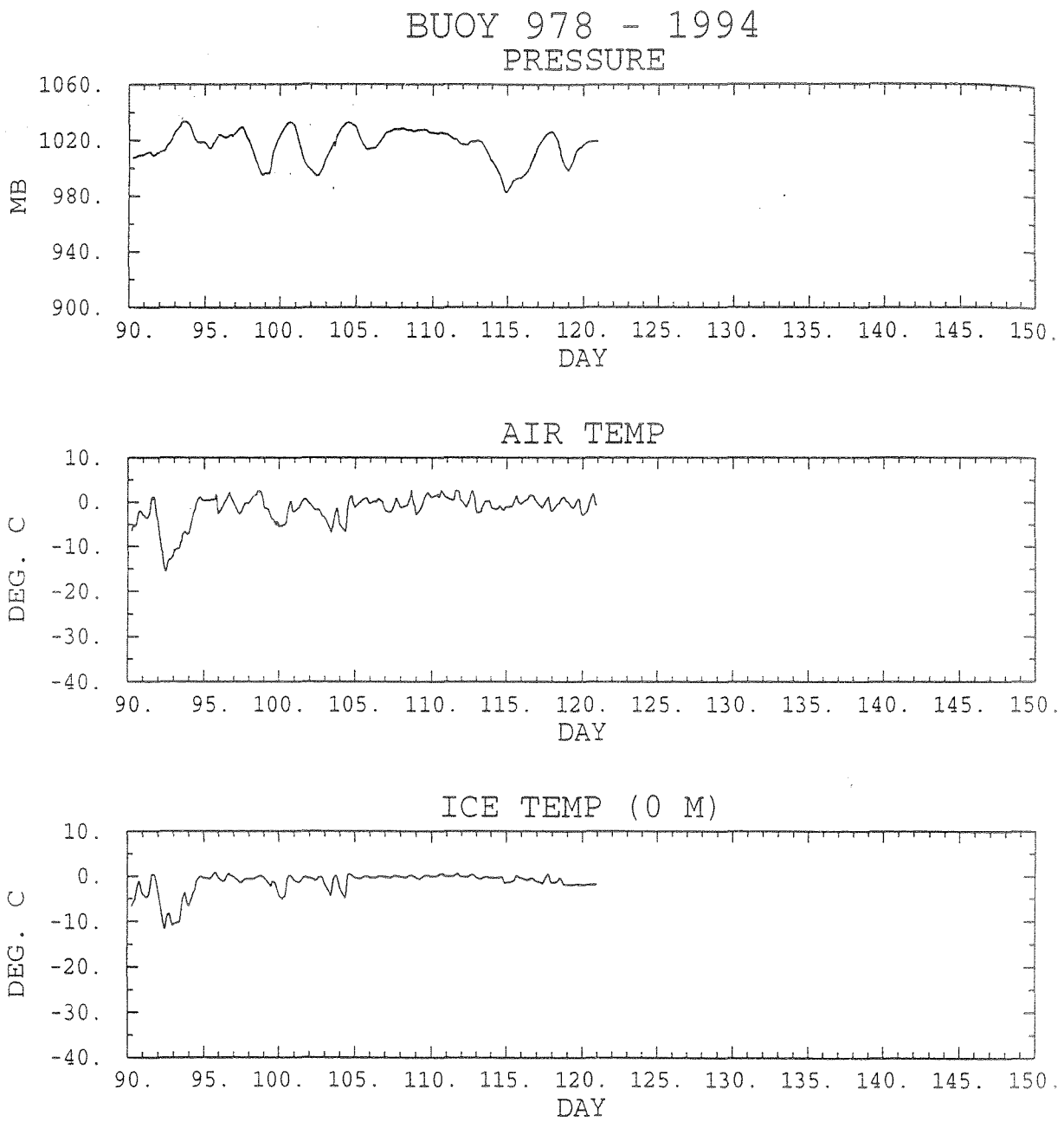

BUOY 977 - 1994
PRESSURE
MB
1060.
1020.
980.
940.
900.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY
AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY
ICE TEMP (0 M)
DEG. C
10.
0.
-10.
-20.
-30.
-40.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY

BUOY 978 - 1994

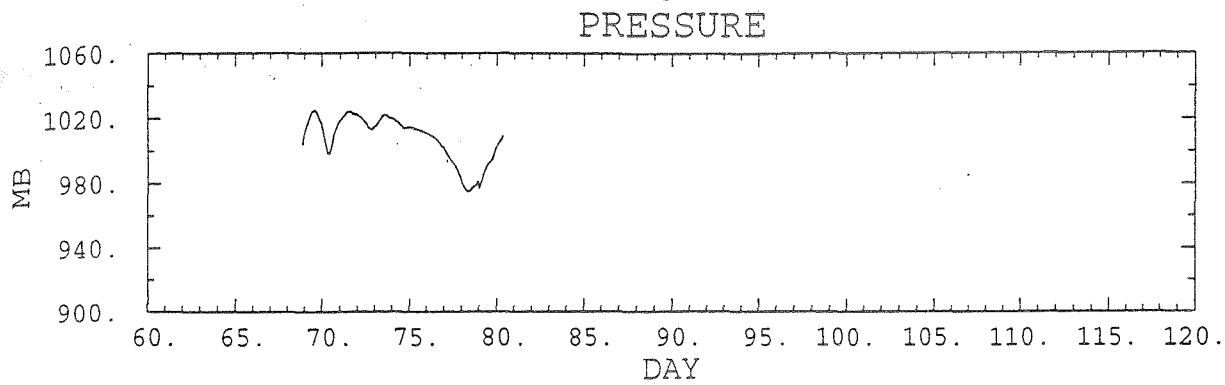


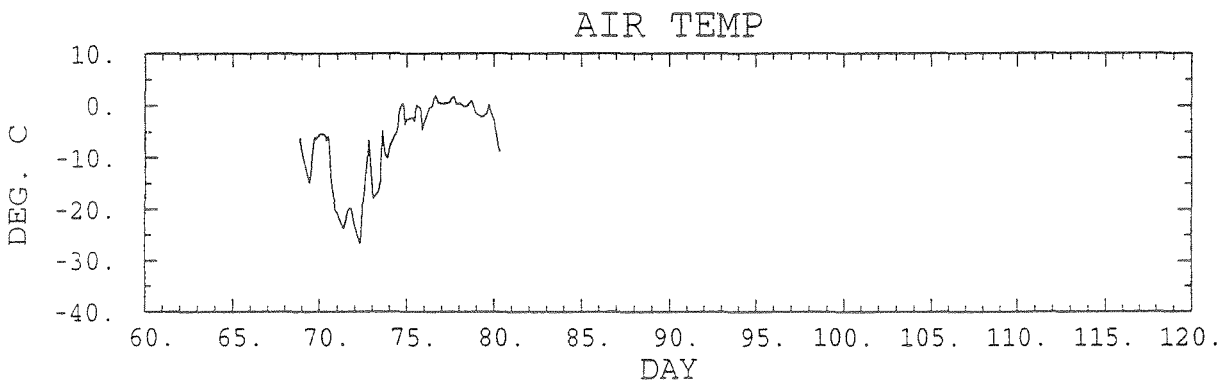


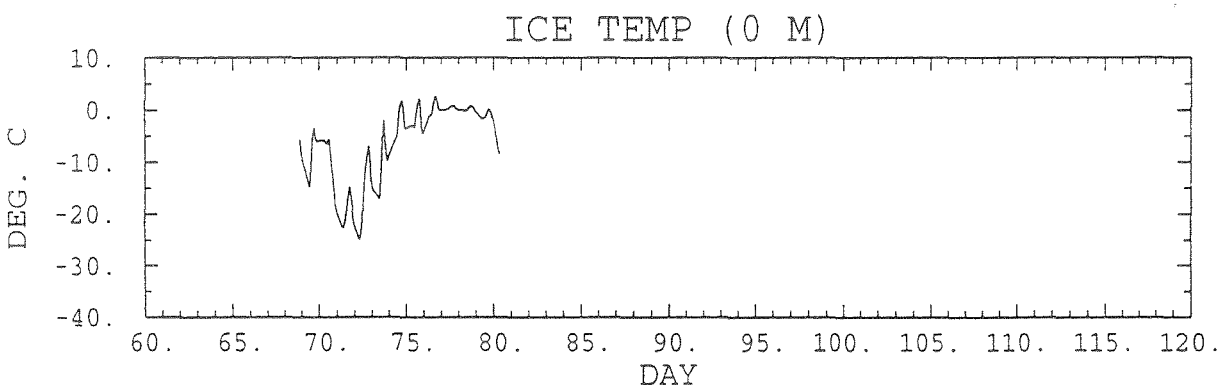


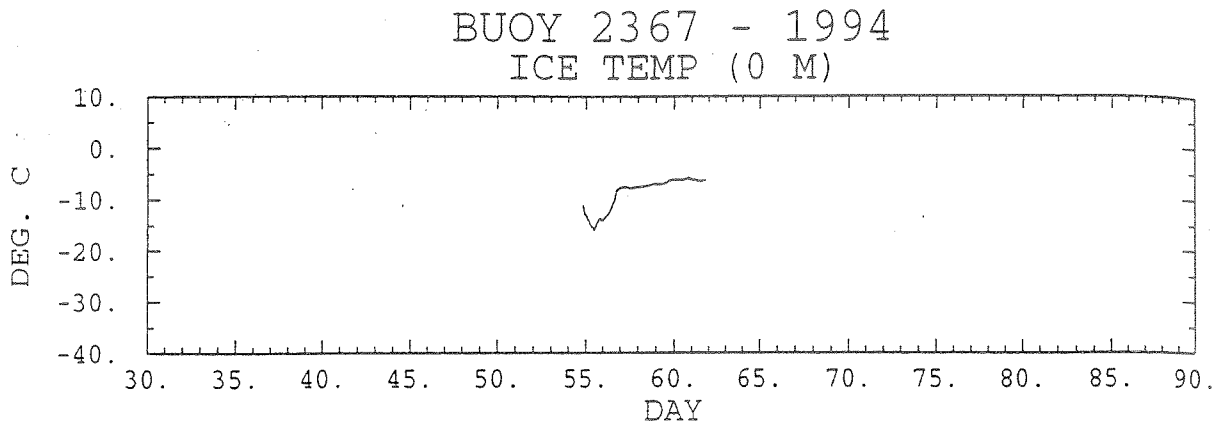

BUOY 978 - 1994
PRESSURE
MB
1060.
1020.
980.
940.
900.
90. 95. 100. 105. 110. 115. 120. 125. 130. 135. 140. 145. 150.
DAY
AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
90. 95. 100. 105. 110. 115. 120. 125. 130. 135. 140. 145. 150.
DAY
ICE TEMP (0 M)
DEG. C
10.
0.
-10.
-20.
-30.
-40.
90. 95. 100. 105. 110. 115. 120. 125. 130. 135. 140. 145. 150.
DAY

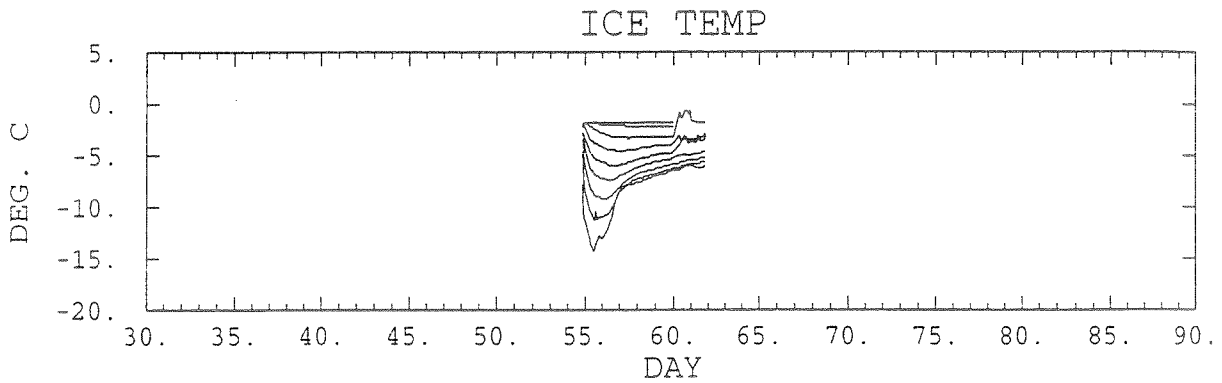
BUOY 979 - 1994

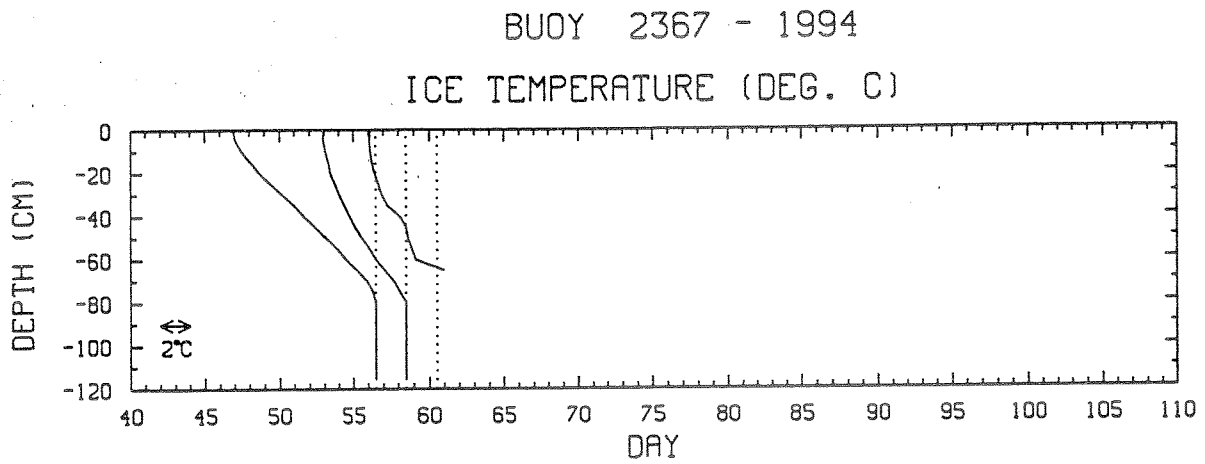


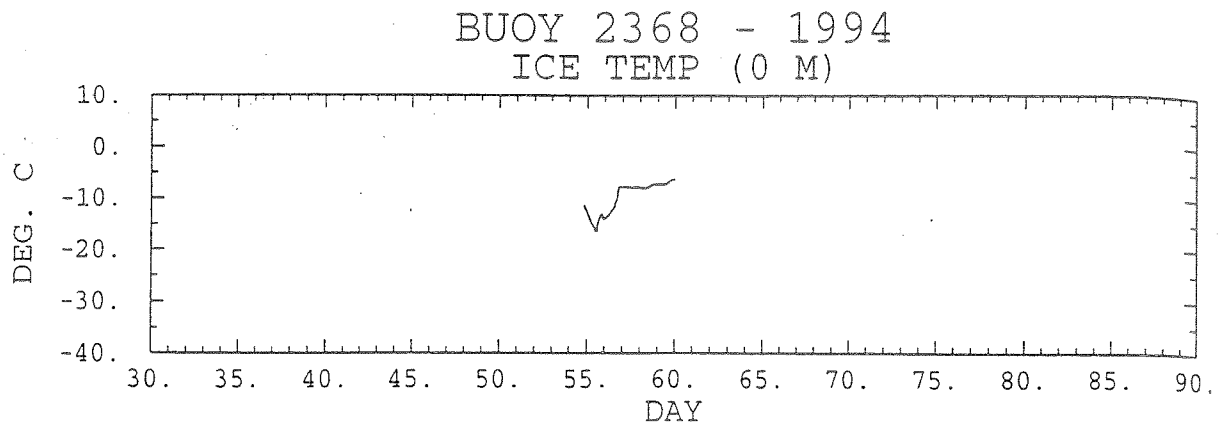


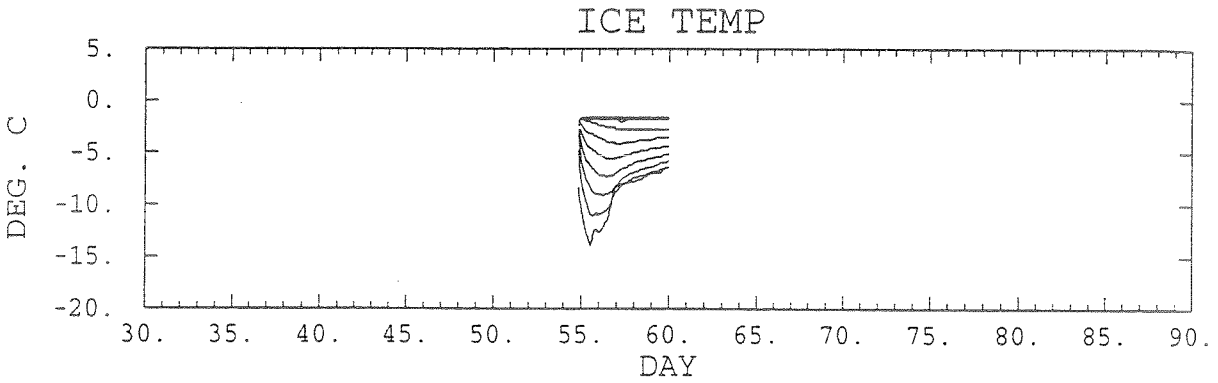


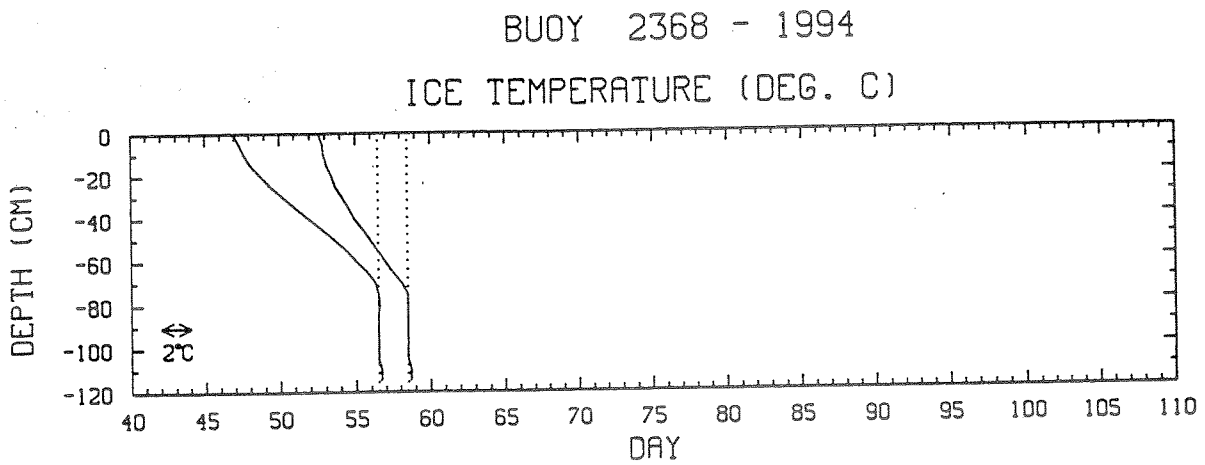

BUOY 2367 - 1994
ICE TEMP (0 M)
DEG. C
10.
0.
-10.
-20.
-30.
-40.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.
DAY

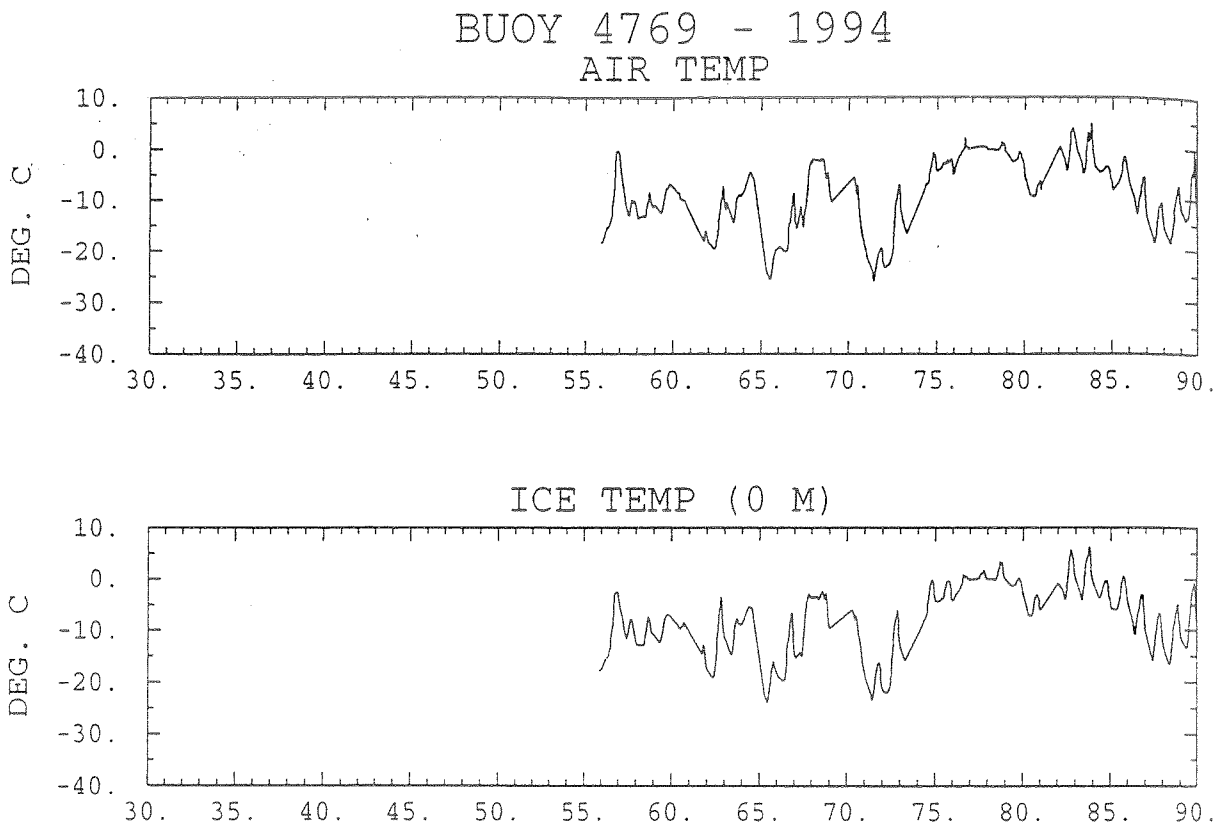

ICE TEMP
DEG. C
5.
0.
-5.
-10.
-15.
-20.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.
DAY

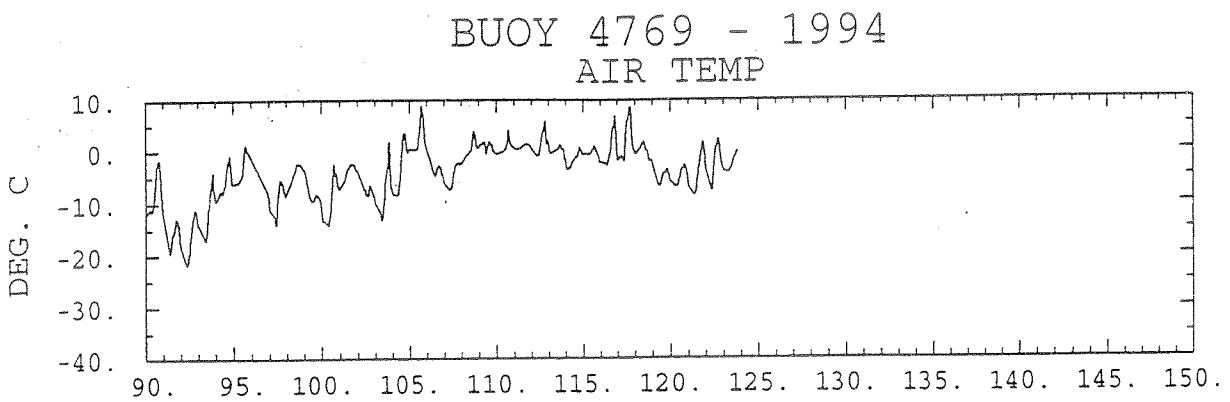

BUOY 2367 - 1994
ICE TEMPERATURE (DEG. C)
DEPTH (CM)
0
-20
-40
-60
-80
-100
-120
2°C
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
DAY

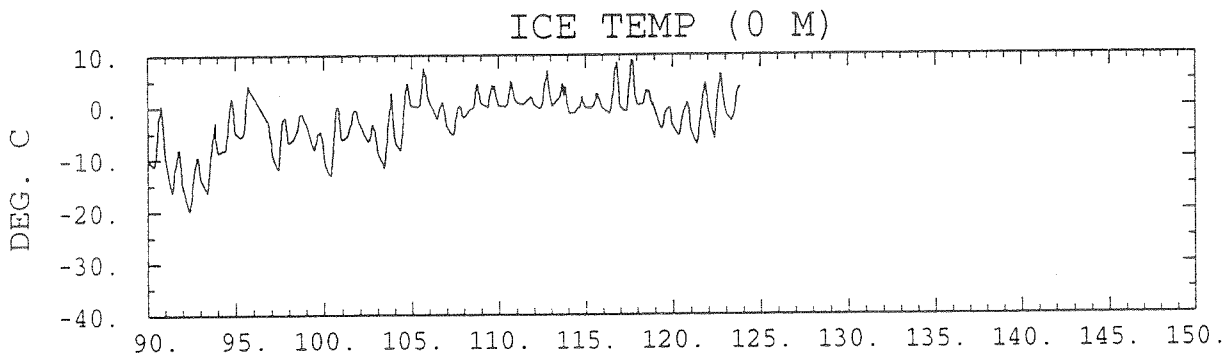

BUOY 2368 - 1994
ICE TEMP (0 M)
DEG. C
10.
0.
-10.
-20.
-30.
-40.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.
DAY


ICE TEMP
DEG. C
5.
0.
-5.
-10.
-15.
-20.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.
DAY

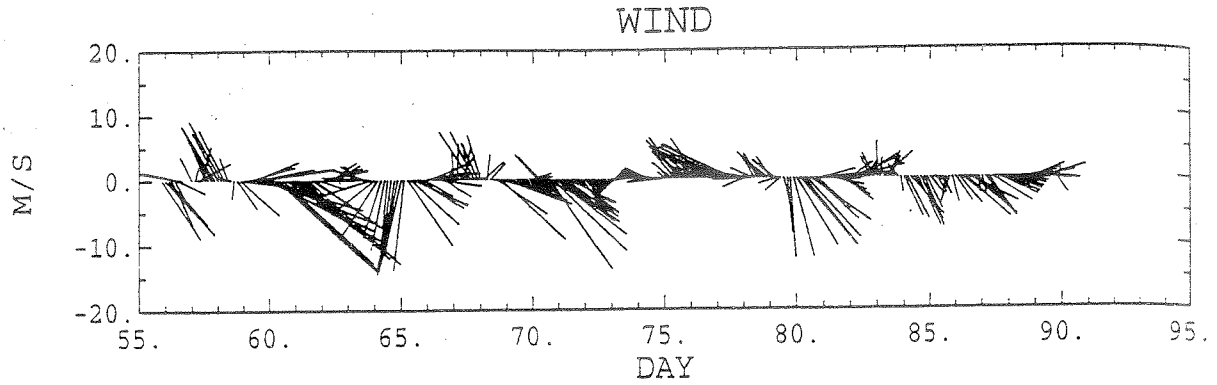

BUOY 2368 - 1994
ICE TEMPERATURE (DEG. C)
DEPTH (CM)
0
-20
-40
-60
-80
-100
-120
2°C
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
DAY

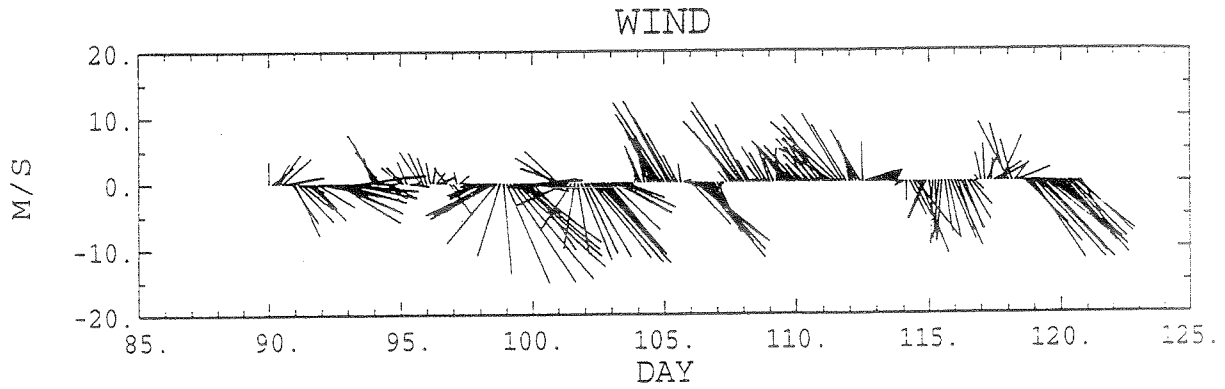

BUOY 4769 - 1994
AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.
ICE TEMP (0 M)
DEG. C
10.
0.
-10.
-20.
-30.
-40.
30. 35. 40. 45. 50. 55. 60. 65. 70. 75. 80. 85. 90.

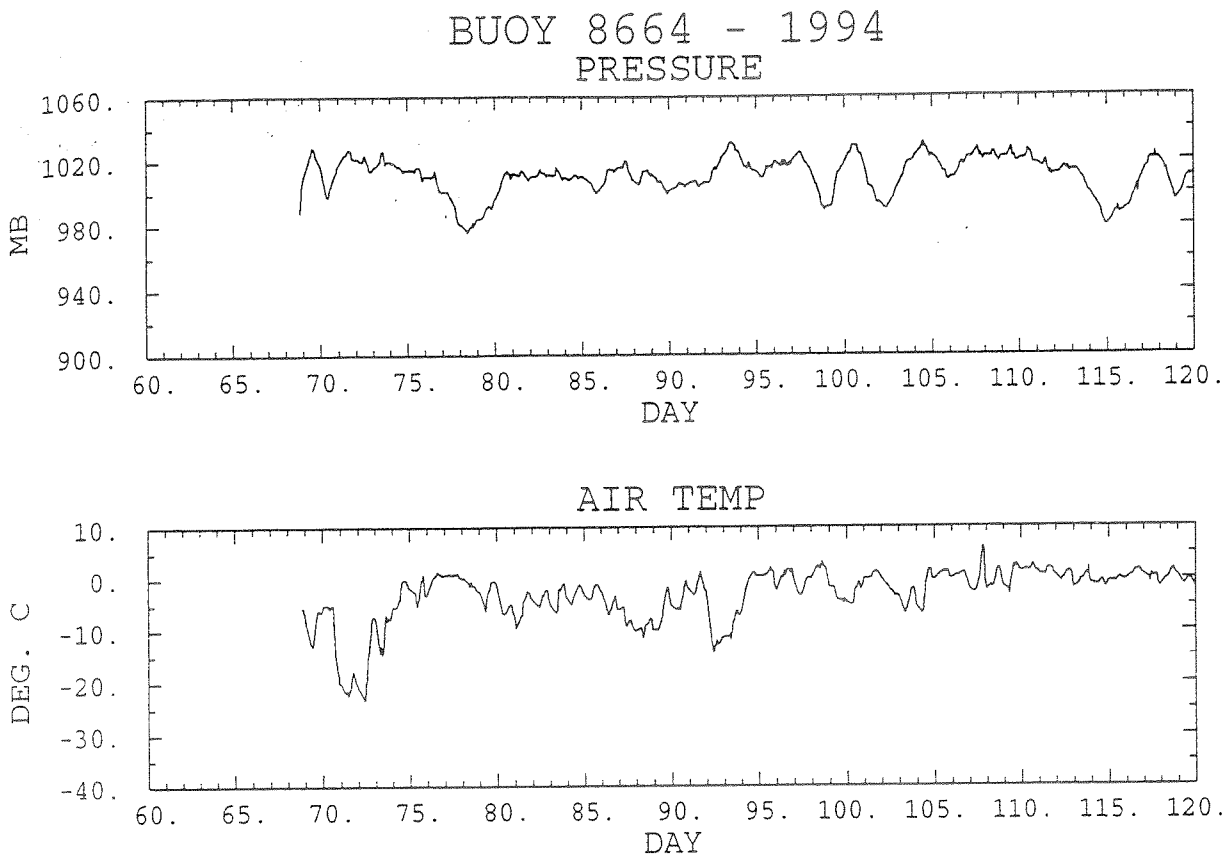

BUOY 4769 - 1994
AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
90. 95. 100. 105. 110. 115. 120. 125. 130. 135. 140. 145. 150.

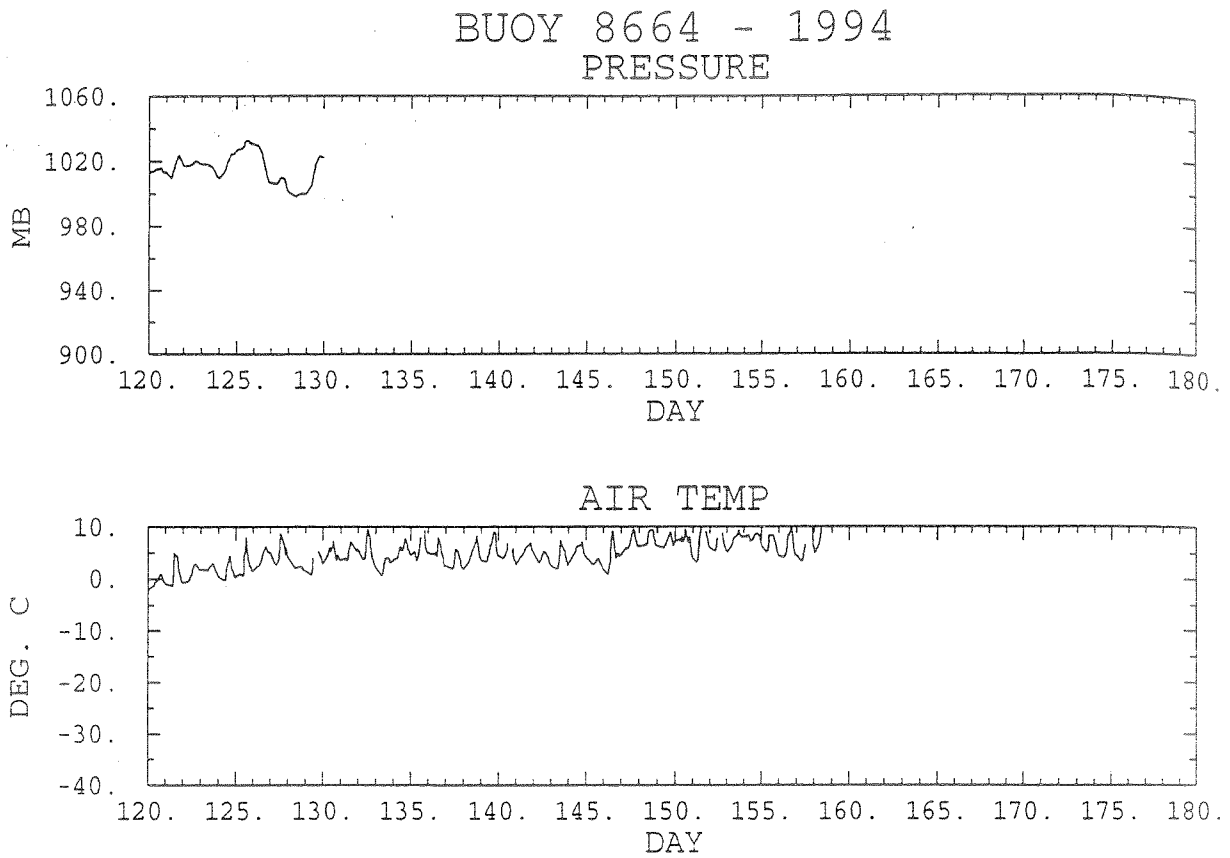

ICE TEMP (0 M)
DEG. C
10.
0.
-10.
-20.
-30.
-40.
90. 95. 100. 105. 110. 115. 120. 125. 130. 135. 140. 145. 150.

BUOY 4769 - 1994

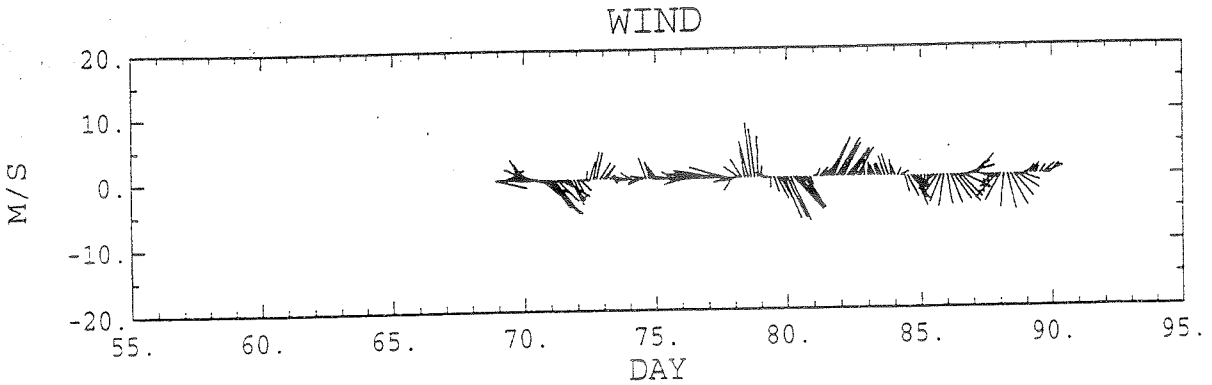


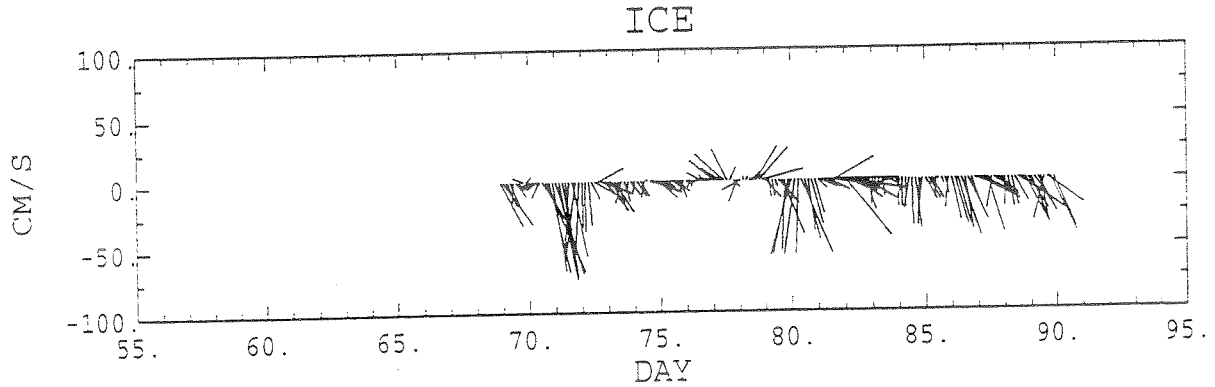


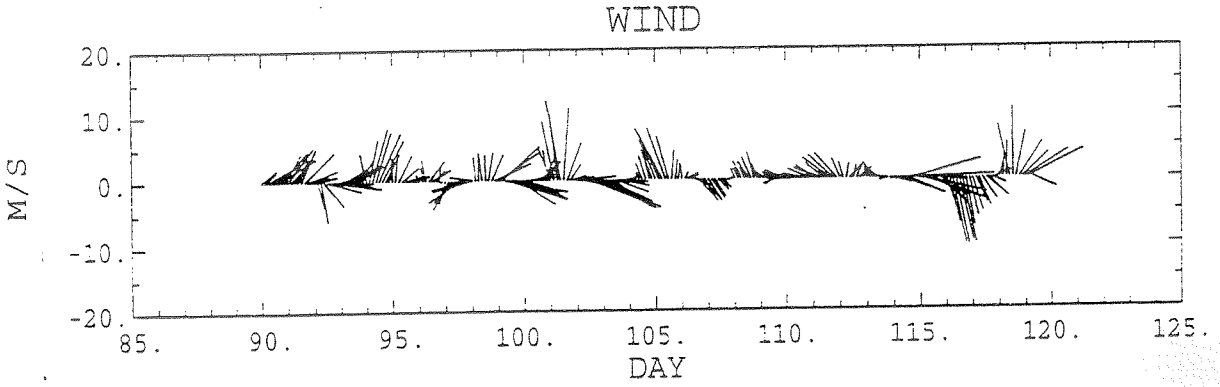

BUOY 8664 - 1994
PRESSURE
MB
1060.
1020.
980.
940.
900.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY
AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY

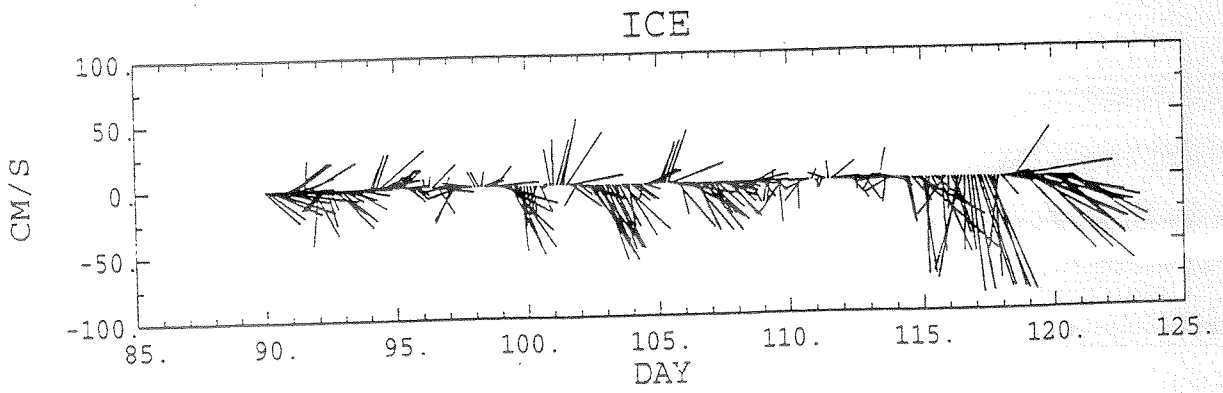

BUOY 8664 - 1994
PRESSURE
1060.
1020.
980.
940.
900.
MB
120. 125. 130. 135. 140. 145. 150. 155. 160. 165. 170. 175. 180.
DAY
AIR TEMP
10.
0.
-10.
-20.
-30.
-40.
DEG. C
120. 125. 130. 135. 140. 145. 150. 155. 160. 165. 170. 175. 180.
DAY

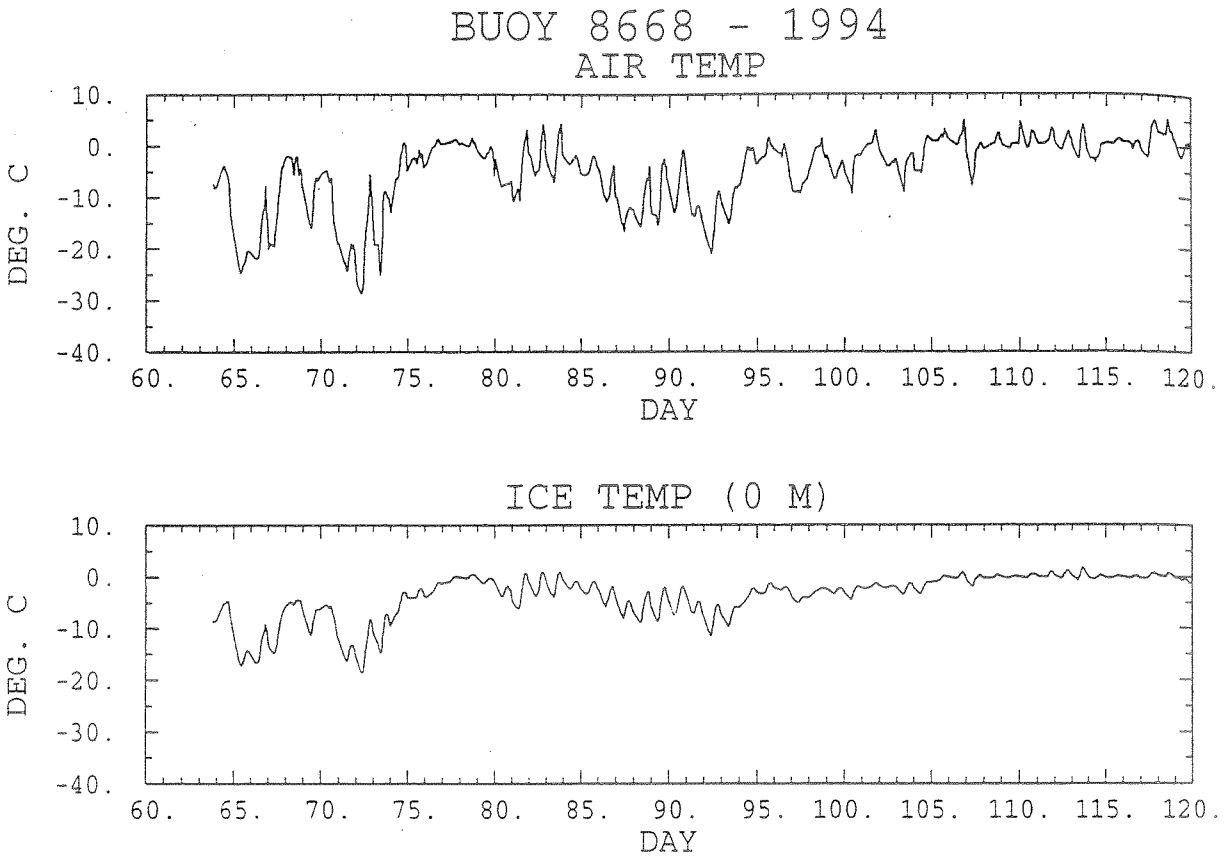
BUOY 8664 - 1994



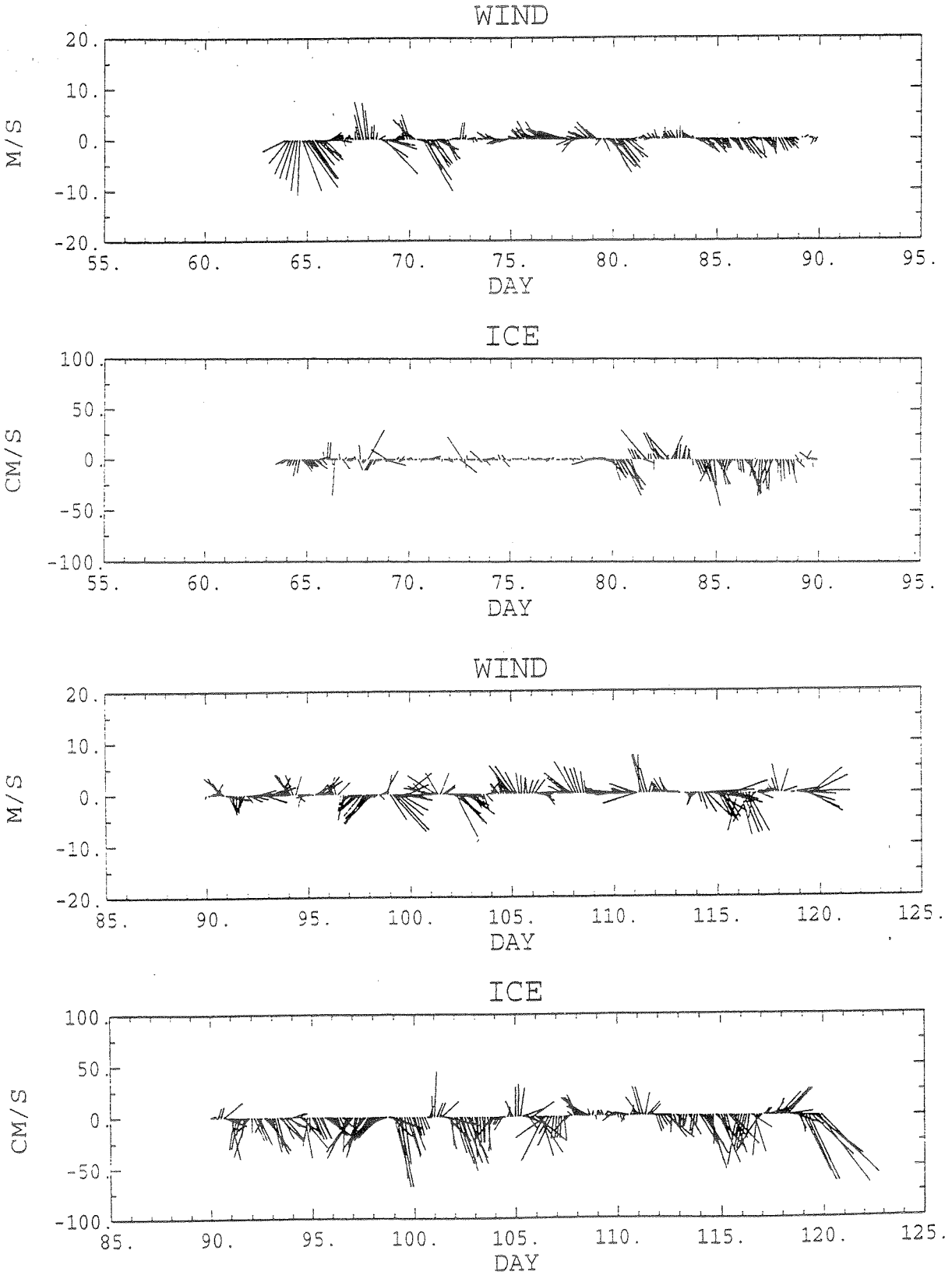







BUOY 8668 - 1994
AIR TEMP
DEG. C
10.
0.
-10.
-20.
-30.
-40.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY
ICE TEMP (0 M)
DEG. C
10.
0.
-10.
-20.
-30.
-40.
60. 65. 70. 75. 80. 85. 90. 95. 100. 105. 110. 115. 120.
DAY

BUOY 8668 - 1994



APPENDIX D: ICE AND SURFACE WATER SALINITY SAMPLES

1993

Stn. 9301

Location: 20km east of Wolf Island
Temperature Staff #974

Lat. 53° 46.0N
Long. 55° 25.0W

Date: February 16, 1993
Time: Day 47, 1345 GMT
Depth: 175m

Ice: 55cm
Snow: 17cm
Floe: 2.0kmx1.5km
Conc. 9/10

Sample#	Depth cm	Bottle#	Salinity
9301.01	5 - 10	20765	8.0
9301.02	20 - 25	20749	9.0
9301.03	30 - 35	78757	14.0

Stn. 9302

Location: 40km east of Wolf Island
Anemometer beacon #4757

Lat. 53° 42.0N
Long. 55° 05.0W

Date: February 16, 1993
Time: Day 47, 1415 GMT
Depth: 200+m

Ice: 65cm
Snow: 17cm
Floe: 3.0kmx3.0km
Conc. 9/10

Stn. 9303

Location: 60km east of Wolf Island
Location Beacon #967

Lat. 53° 38.0N
Long. 54° 45.0W

Date: February 16, 1993
Time: Day 47, 1405 GMT
Depth: 150m

Ice: 65cm
Snow: 18cm
Floe: 2.0kmx2.0km
Conc. 9/10
Rafted to: 88cm

Stn. 9304

Location: 60km ENE of Wolf Island
Location Beacon #968

Lat. 53° 48.5N
Long. 54° 59.9W

Date: February 16, 1993
Time: Day 47, 1530 GMT
Depth: 180m

Ice: 55cm
Snow: 17cm
Floe: 5.0kmx5.0km
Conc. 9/10

Stn. 9305

Location: 40km ENE of Wolf Island
Temperature Chain #10058

Lat. 53° 44.0N
Long. 55° 16.0W

Date: February 16, 1993
Time: Day 47, 1700 GMT
Depth: 115m

Ice: 55cm
Snow: 22cm
Floe: 3.0kmx3.0km
Conc. 9/10

Sample#	Depth cm	Bottle#	Salinity
9305.01	5 - 10	10854	28.0
9305.02	15 - 20	05120	10.0
9305.03	25 - 30	02748	7.0
9305.04	35 - 40	02047	13.0

Stn. 9306

Location: 20km east of Wolf Island
Temperature Staff #970

Lat. 53° 42.6N
Long. 55° 28.2W

Date: February 16, 1993
Time: Day 47, 1740 GMT
Depth: 175m

Ice: 65cm
Snow: 21cm
Floe: 2.0kmx2.0km
Conc. 9/10

Sample#	Depth cm	Bottle#	Salinity
9306.01	5 - 10	78759	10.0
9306.02	20 - 25	78757	8.0
9306.03	35 - 40	20751	14.0

1994

Station 1.1

Calibration Line off Black Head, Cartwright
(spacing 25m, Tuesday 1 March, 1994)

Stn #	Ice cm	Snow cm	Free board cm	Snow +Ice cm	
11	78	17	1	95	3 bags
	--	30	-	--	
12	68	25	0	93	
	--	20	-	--	
13	62	24	0	86	
	--	24	-	--	
14	62	32	-6	94	
	--	22	-	--	
15	74	9	0	83	
	--	18	-	--	
16	86	27	2	113	
	--	20	-	--	
17	66	32	-1	98	
	--	22	-	--	
18	84	20	2	104	
	--	17	-	--	
19	72	30	-1	102	
	--	20	-	--	
20	72	25	0	97	2 bags

Station 2.1

Landfast ice (Stoney Arm)
Large flat ice cover inside a bay.
Snow floaded ice: salty froozen slush layer of 6cm.

Date:	March 2, 1994	Latitude:	53 29.56N
Time:	09:05 EST	Longitude:	056 02.56W
Wind:	Light NW	Temp:	-20°C/clear
Depth:	14.3m		

Stn #	Ice cm	Snow cm	Free board cm	Snow +Ice cm
1	70	25	-7	95
2	72	22-28	-6	97
3	72	20-30	-4	97

refroozen slush layer of 6cm (14ppt)
Surface crust layer of 1cm (0ppt)

Station 3.3

Calibration Floe Pack Ice
Small floe in rough ridged ice
North of iceberg/ARGOS beacon #977

Date:	March 3, 1994	Latitude:	54 16.24N
Time:	15:00 EST	Longitude:	055 21.78W
Wind:	Calm	Temp:	-8°C/overcast

Stn #	Ice cm	Snow cm	Free board cm	Snow +Ice cm
1	104	6	16	110
2	104	2	12	106
3	+++	2	12	+++
4	102	2	10	104
5	63*	2	6	65*

* rafted with 8cm of slush between rafts
floe 15x35m, ridge blocks 45-50cm/one large block 95cm
Slush layer between floes 64ppt

Station 4.1

Calibration Floe Pack Ice

Flat large floe made of pancake ice
North of Wolf Island/Argos Beacon 976

Date:	March 4, 1994	Latitude:	53 44.75N
Time:	09:15 EST	Longitude:	056 09.91W
Wind:	5kmph/180	Temp:	-12°C/overcast

Stn #	Ice cm	Snow cm	Free board cm	Snow +Ice cm	
1	35	4	1	39	black bag
	35	5	1	40	small ridge
2	49	4	3	53	
	49	3	3	52	
3	47	5	2	53	
	42	4	2	46	
4	94	4	4	98	orange bag (rafted)

Stn. seperated by 25m plus in between samples.
(line SE-NW, sampled by Ice Probe at 09:45)

Snow and ice salinities

Between Stn 2 and 3 (ARGOS beacon #976)

bottle #	depth (cm)	Salinity ppt
64659	Snow	13.0
64652	5	8.0
64660	25	6.0
64665	45	10.0

Station 4.2

Calibration Floe Pack Ice

Flat large floe made of pancake ice
South of Wolf Island/Argos Beacon 965

Date:	March 4, 1994	Latitude:	53 33.29N
Time:	10:30 EST	Longitude:	055 45.58W
Wind:	Calm	Temp:	-12°C/clouds to SW

Stn #	Ice cm	Snow cm	Free board cm	Snow +Ice cm
1	56	5	3	60
2	57	7	4	64
3	56	5	3	61

Stns. near helicopter

Snow and ice salinities

near ARGOS beacon #965

bottle #	depth (cm)	Salinity ppt
64658	1	16.0
64667	15	8.0
64656	35	8.0

Station 4.3

Black Tickle thin ice station

Flat rafted floe, SE of one-day old ice
SW of black Tickle

Date:	March 4, 1994	Latitude:	53 25.73N
Time:	11:30 EST	Longitude:	055 44.60W
Wind:	Calm	Temp:	-12°C/clouds SE

Stn #	Ice cm	Snow cm	Free board cm	Snow +Ice cm
1	57	4	8	61
2	56	4	8	60
3	52*	4	8	56*

* rafted, 8cm slush between rafted layers
Stns. near helicopter (floe 30x30m)
Thin ice 9cm/black and 16cm/grey
Large area to NE and inbay to East bordering landfast ice

Salinities Stn. 4.3

Thin black ice: surface (auger) and 20x20cm pancake

bottle #	depth (cm)	Salinity ppt
64657	auger	16.0
64655	pancake	17.0

Station 6.1

15km east of Wolf Island.

Large composite floe.

Date:	March 6, 1994	Latitude:	53 41.26N
Time:	10:30 EST	Longitude:	055 42.37W
Wind:	5mph NW	Temp:	-25°C/clear

Stn #	Ice cm	Snow cm	Free board cm	Snow +Ice cm
1	103	6	7	110

2	103	5	6	109
3	107	6	7	114

Salinities Stn. 6.1

bottle #	depth (cm)	Salinity ppt
64659	snow	3.0
64658	2	13.0
64652	25	9.0
64655	45	8.0
64656	65	10.0

Station 6.3

Black Tickle: south of thin ice area.

Date:	March 6, 1994	Latitude:	53 25.79N
Time:	12:50 EST	Longitude:	055 45.18W
Wind:	5mph NW	Temp:	-25°C/clear

bottle #	depth (cm)	Salinity ppt
64657	snow	3.0
64666	slush	35.0
64663	ice	14.0

Station 6.5

Rocky Bay: Reflector on large thin ice area.
(second visit March 7, afternoon)

Date:	March 6, 1994	Latitude:	53 29.88N
Time:	17:20 EST	Longitude:	055 58.70W
Wind:	5mph NW	Temp:	-25°C/clear

bottle #	depth (cm)	Salinity ppt
64667	0-2snow	37.0
64665	2-4slush	35.0
64660	5	9.0?

64644*	1	12.0
64645*	10	6.0?

Ice 21cm thick and 1cm of freeboard.
* done March 7

Station 7.1

5km SE off Spotted Island

Large composite floe

Date:	March 7, 1994	Latitude:	53 29.90N
Time:	09:30 EST	Longitude:	055 40.47W
Wind:	calm	Temp:	-18°C/clear

Stn #	Ice cm	Snow cm	Free board cm	Snow +Ice cm
1	75	2	7	77
2	76	2	8	78
3	77	2	8	79

Temperature staff beacon #973.

Salinities Stn. 7.1

bottle #	depth (cm)	Salinity ppt	
64650	snow	6.0	
64658	1	16.0	
64659	10	15.0	
64649	20	10.0	
64666	30	23.0	(rafted slush layer?)
64667	45	14.0	

Station 7.2

Start of large thin area, 40km south of Roundhill Island.

Date:	March 7, 1994	Latitude:	53 02.66N
Time:	10:30 EST	Longitude:	055 38.37W
Wind:	calm	Temp:	-18°C/clear

bottle #	depth (cm)	Salinity ppt
64652	frost*	82.0
64657	pancake	20.0
64663	5	20.0

10-12cm of ice.

Station 8.1

Brighter part of Rocky Bay on ERS-1 image.

Date:	March 8, 1994	Latitude:	53 29.98N
Time:	09:50 EST	Longitude:	055 56.26W
Wind:	Calm	Temp:	-9°C/clear

bottle #	depth (cm)	Salinity ppt
64647	soft snow	36.0
64654	hard snow	35.0
64655	2	9.0
64658	10	10.0
64651	20	5.0

30cm of ice but 20cm of slush wind pushed it downwind.
Hard snow in 1m waves 9cm amplitude filled with 5cm of soft snow.

Station 8.2

Porcupine Bay, a bay facing southeast.

Date:	March 8, 1994	Latitude:	
Time:	10:10 EST	Longitude:	
Wind:	SW 10-15mph	Temp:	-9°C/clear

Stn #	Ice cm	Snow cm	Free board cm	Snow +Ice cm
1	15	5	0	20
2	16	6	0	22
3	15	5	0	20

bottle #	depth (cm)	Salinity ppt

64649	snow	33.0
64666	5	7.0

Station 9.1

Northeast of Grady Island

Date:	March 9, 1994	Latitude:	53 58.62
Time:	14:30 EST	Longitude:	056 04.63
Wind:	NW 10-15mph	Temp:	-9°C/overcast

Stn #	Ice cm	Snow cm	Free board cm	Snow +Ice cm
1	107	2	10	127
2	107	2	10	127
3	107	2	10	127

bottle #	depth (cm)	Salinity ppt
64644	snow	3.0
64657	5	12.0
64646	25	21.0
64661	35	26.0
64648	55	27.0
64665	80	12.0

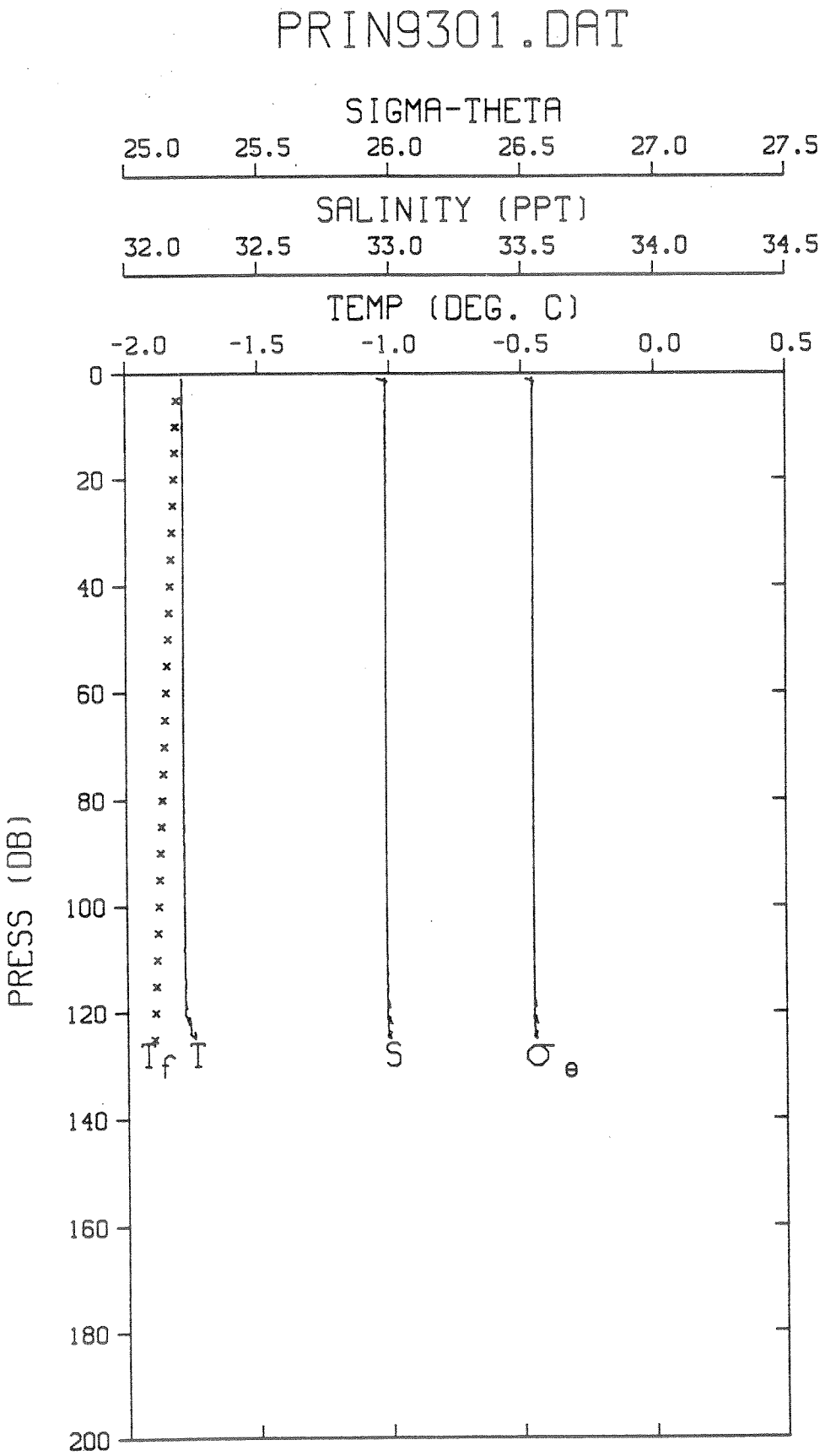
APPENDIX E: TEMPERATURE AND SALINITY DATA

Plots and listings of Seabird CTD data (pressure, temperature, salinity and density (σ_θ)). In the plots, T_f represents the freezing point at in situ pressure.

Year	Sta. #	Date	Site	Beacon #	File #	Latitude	Longitude
1993	9301	Feb. 16	inner	974	prin9301	53 46.00N	55 25.00W
	9302	Feb. 16	middle	4757	prin9302	53 42.00N	55 05.00W
	9303	Feb. 16	outer	967	prin9303	53 38.00N	54 45.00W
	9305	Feb. 16	middle	10058	prin9305	53 44.00N	55 16.00W
	9306	Feb. 16	inner	970	prin9306	53 42.46N	55 28.21W
1994	9400	Feb. 24	outer		sim09400	53 56.87N	55 35.48W
	9402	Feb. 24	middle		sim09402	53 53.04N	55 51.19W
	9403	Feb. 24	inner		sim09403	53 51.01N	56 03.11W
	1	Mar. 8	103 km		sim19403	54 09.05N	54 52.83W
	2	Mar. 8	87 km		sim19402	54 05.02N	55 05.92W
	3	Mar. 8	76 km		sim19401	54 01.50N	55 14.76W
	4	Mar. 8	55 km		sim19404	53 58.62N	55 33.40W
	5	Mar. 8	45 km		sim19405	53 56.21N	55 41.72W
	6	Mar. 8	16 km		sim19406	53 50.10N	56 06.57W

raw data file = prin9301.dat

decibars	temp	salinity	sigmatheta
5	-1.7861	32.9839	26.5414
10	-1.7848	32.9828	26.5405
15	-1.7848	32.9829	26.5406
20	-1.7839	32.9824	26.5401
25	-1.7839	32.9823	26.5401
30	-1.7837	32.9824	26.5401
35	-1.7840	32.9828	26.5404
40	-1.7839	32.9825	26.5402
45	-1.7837	32.9823	26.5400
50	-1.7837	32.9821	26.5399
55	-1.7839	32.9826	26.5403
60	-1.7838	32.9824	26.5401
65	-1.7837	32.9829	26.5406
70	-1.7835	32.9825	26.5402
75	-1.7834	32.9828	26.5405
80	-1.7833	32.9828	26.5404
85	-1.7831	32.9822	26.5400
90	-1.7832	32.9827	26.5404
95	-1.7832	32.9827	26.5403
100	-1.7831	32.9827	26.5404
105	-1.7829	32.9821	26.5399
110	-1.7824	32.9820	26.5398
115	-1.7824	32.9838	26.5413
120	-1.7818	32.9830	26.5406
125	-1.7436	32.9980	26.5519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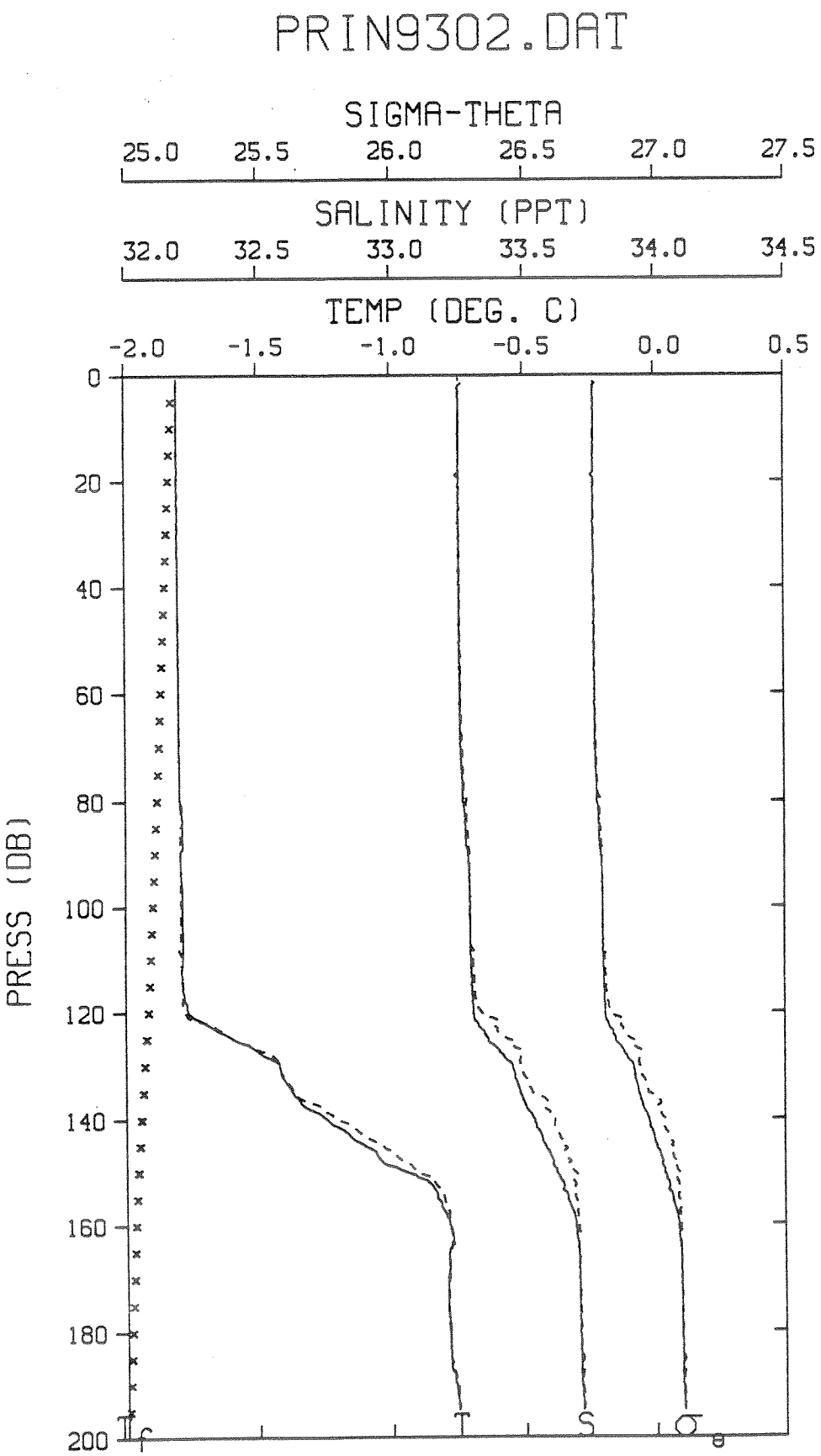
25.5
26.0
26.5
27.0
27.5
SALINITY (PPT)
32.0
32.5
33.0
33.5
34.0
34.5
TEMP (DEG. C)
-2.0
-1.5
-1.0
-0.5
0.0
0.5
PRESS (DB)
0
20
40
60
80
100
120
140
160
180
200
T_f
T
S
σ_θ

raw data file = prin9302.dat

decibars	temp	salinity	sigmatheta
5	-1.8035	33.2608	26.7669
10	-1.8027	33.2609	26.7670
15	-1.8021	33.2607	26.7668
20	-1.8021	33.2607	26.7668
25	-1.8018	33.2607	26.7668
30	-1.8019	33.2607	26.7668
35	-1.8018	33.2609	26.7670
40	-1.8014	33.2615	26.7674
45	-1.8011	33.2615	26.7674
50	-1.8008	33.2617	26.7676
55	-1.7997	33.2627	26.7684
60	-1.7988	33.2638	26.7692
65	-1.7982	33.2645	26.7698
70	-1.7981	33.2653	26.7705
75	-1.7974	33.2701	26.7743
80	-1.7956	33.2712	26.7752
85	-1.7865	33.2826	26.7843
90	-1.7936	33.2913	26.7915
95	-1.7911	33.2957	26.7950
100	-1.7863	33.2981	26.7969
105	-1.7843	33.2994	26.7979
110	-1.7854	33.3008	26.7991
115	-1.7867	33.3044	26.8020
120	-1.7653	33.3093	26.8055
125	-1.5987	33.3649	26.8465
130	-1.4190	33.4557	26.9153
135	-1.3695	33.4833	26.9363
140	-1.2396	33.5356	26.9746
145	-1.0987	33.5783	27.0047
150	-0.9428	33.6187	27.0319
155	-0.8277	33.6625	27.0632
160	-0.7819	33.6903	27.0839
165	-0.7846	33.7011	27.0927
170	-0.7899	33.7015	27.0933
175	-0.7896	33.7034	27.0948
180	-0.7853	33.7039	27.0950
185	-0.7813	33.7067	27.0972
190	-0.7620	33.7088	27.0981
195	-0.7523	33.7147	27.1025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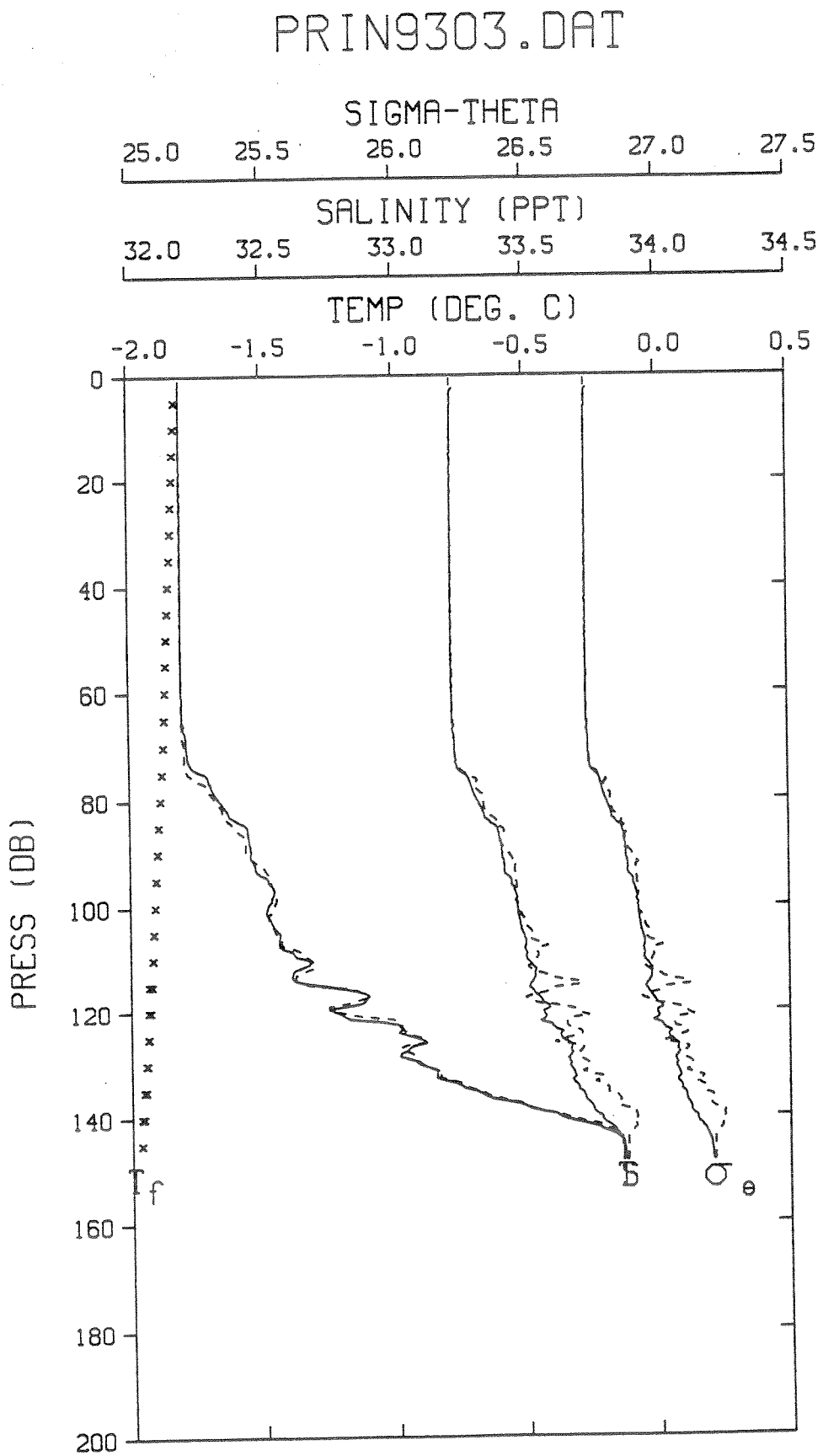
SIGMA-THETA
25.0 25.5 26.0 26.5 27.0 27.5
SALINITY (PPT)
32.0 32.5 33.0 33.5 34.0 34.5
TEMP (DEG. C)
-2.0 -1.5 -1.0 -0.5 0.0 0.5
PRESS (DB)
0 20 40 60 80 100 120 140 160 180 200
Tc
T
S
σθ

raw data file = prin9303.dat

decibars	temp	salinity	sigmatheta
5	-1.8046	33.2256	26.7383
10	-1.8045	33.2239	26.7370
15	-1.8041	33.2231	26.7363
20	-1.8040	33.2225	26.7358
25	-1.8039	33.2226	26.7358
30	-1.8036	33.2226	26.7358
35	-1.8038	33.2226	26.7358
40	-1.8040	33.2229	26.7361
45	-1.8036	33.2226	26.7358
50	-1.8031	33.2224	26.7357
55	-1.8029	33.2231	26.7363
60	-1.8026	33.2235	26.7366
65	-1.8006	33.2240	26.7370
70	-1.7864	33.2319	26.7430
75	-1.7187	33.2632	26.7669
80	-1.6665	33.3147	26.8075
85	-1.5602	33.3875	26.8639
90	-1.5452	33.4111	26.8826
95	-1.4785	33.4448	26.9082
100	-1.4807	33.4680	26.9270
105	-1.4340	33.4876	26.9416
110	-1.3328	33.5014	26.9498
115	-1.2712	33.5133	26.9576
120	-1.2329	33.5643	26.9977
125	-0.9245	33.6288	27.0394
130	-0.9049	33.6674	27.0700
135	-0.6984	33.6978	27.0866
140	-0.3744	33.7865	27.1446
145	-0.1384	33.8671	27.1987


PRIN9303.DAT
SIGMA-THETA
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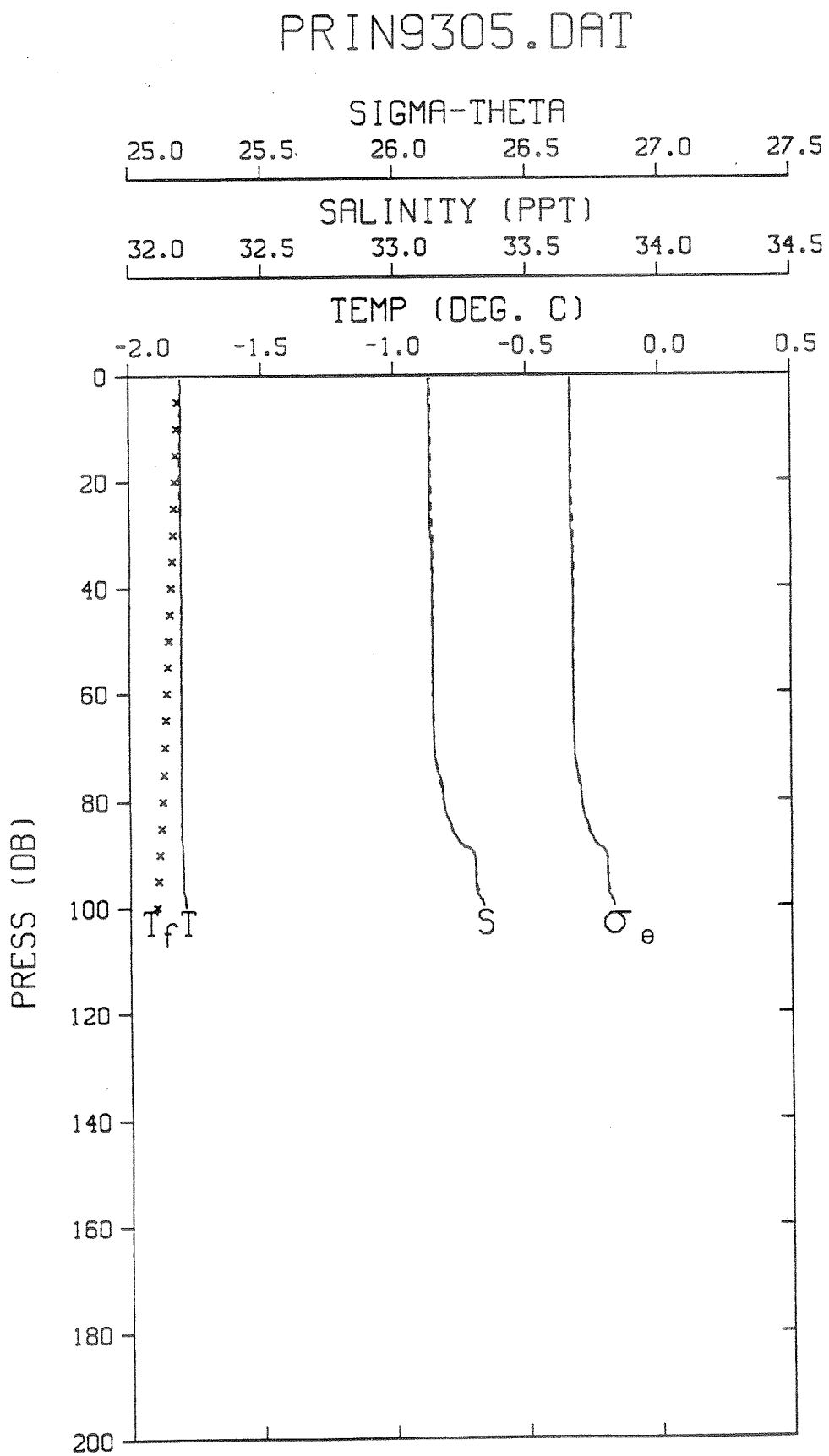
25.5
26.0
26.5
27.0
27.5
SALINITY (PPT)
32.0
32.5
33.0
33.5
34.0
34.5
TEMP (DEG. C)
-2.0
-1.5
-1.0
-0.5
0.0
0.5
PRESS (DB)
0
20
40
60
80
100
120
140
160
180
200
Tf
θb
θe

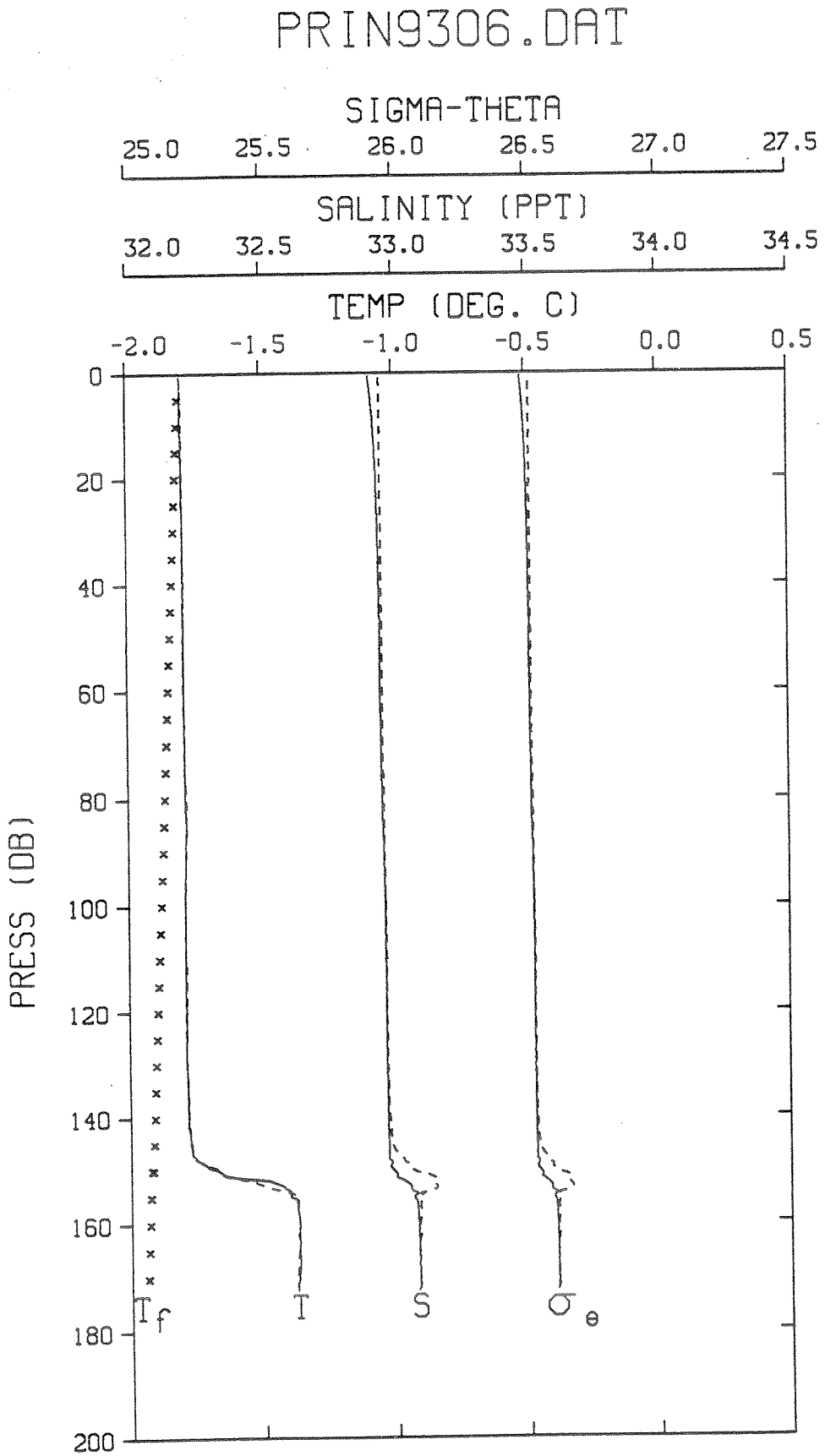
raw data file = prin9305.dat

decibars	temp	salinity	sigmatheta
5	-1.8041	33.1333	26.6632
10	-1.8041	33.1345	26.6642
15	-1.8047	33.1348	26.6645
20	-1.8049	33.1344	26.6642
25	-1.8057	33.1349	26.6646
30	-1.8070	33.1357	26.6652
35	-1.8045	33.1416	26.6700
40	-1.8041	33.1429	26.6711
45	-1.8036	33.1434	26.6715
50	-1.8034	33.1442	26.6722
55	-1.8035	33.1456	26.6732
60	-1.8035	33.1460	26.6736
65	-1.8036	33.1478	26.6751
70	-1.8037	33.1508	26.6775
75	-1.8041	33.1656	26.6896
80	-1.8047	33.1840	26.7046
85	-1.8061	33.2128	26.7279
90	-1.8016	33.2971	26.7964
95	-1.7991	33.3028	26.8010
100	-1.7887	33.3343	26.8264


PRIN9305.DAT
SIGMA-THETA
25.0
25.5
26.0
26.5
27.0
27.5
SALINITY (PPT)
32.0
32.5
33.0
33.5
34.0
34.5
TEMP (DEG. C)
-2.0
-1.5
-1.0
-0.5
0.0
0.5
PRESS (DB)
0
20
40
60
80
100
120
140
160
180
200
T_f
T
S
σ_θ

raw data file = prin9306.dat

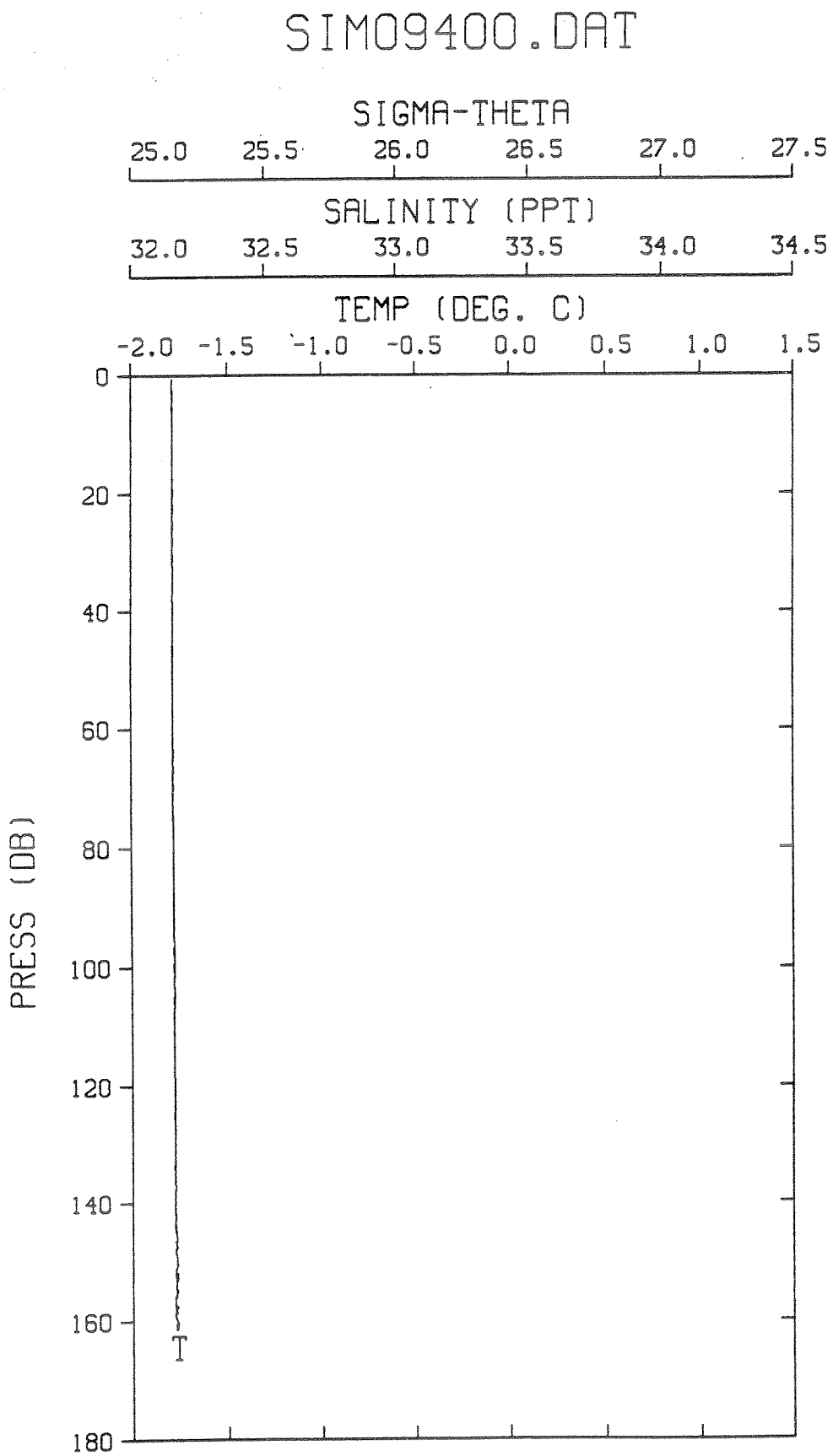
decibars	temp	salinity	sigmatheta
5	-1.7952	32.9550	26.5181
10	-1.7923	32.9560	26.5188
15	-1.7918	32.9563	26.5191
20	-1.7909	32.9560	26.5188
25	-1.7910	32.9563	26.5190
30	-1.7903	32.9570	26.5196
35	-1.7901	32.9575	26.5200
40	-1.7901	32.9583	26.5207
45	-1.7904	32.9587	26.5210
50	-1.7907	32.9590	26.5213
55	-1.7901	32.9587	26.5210
60	-1.7894	32.9586	26.5209
65	-1.7893	32.9588	26.5211
70	-1.7891	32.9591	26.5213
75	-1.7876	32.9591	26.5213
80	-1.7819	32.9618	26.5233
85	-1.7823	32.9623	26.5238
90	-1.7851	32.9623	26.5238
95	-1.7861	32.9630	26.5244
100	-1.7882	32.9639	26.5252
105	-1.7885	32.9641	26.5254
110	-1.7877	32.9644	26.5256
115	-1.7880	32.9653	26.5264
120	-1.7852	32.9654	26.5263
125	-1.7871	32.9662	26.5270
130	-1.7875	32.9663	26.5272
135	-1.7842	32.9674	26.5280
140	-1.7833	32.9677	26.5282
145	-1.7757	32.9695	26.5295
150	-1.6744	32.9831	26.5382
155	-1.4025	33.0631	26.5962
160	-1.3698	33.0773	26.6067
165	-1.3724	33.0809	26.6097
170	-1.3740	33.0820	26.6107


PRIN9306.DAT
SIGMA-THETA
25.0
25.5
26.0
26.5
27.0
27.5
SALINITY (PPT)
32.0
32.5
33.0
33.5
34.0
34.5
TEMP (DEG. C)
-2.0
-1.5
-1.0
-0.5
0.0
0.5
PRESS (DB)
0
20
40
60
80
100
120
140
160
180
200
Tf
T
S
σθ

Station #9400 on February 24, 1994

Raw data file: simo9400.dat

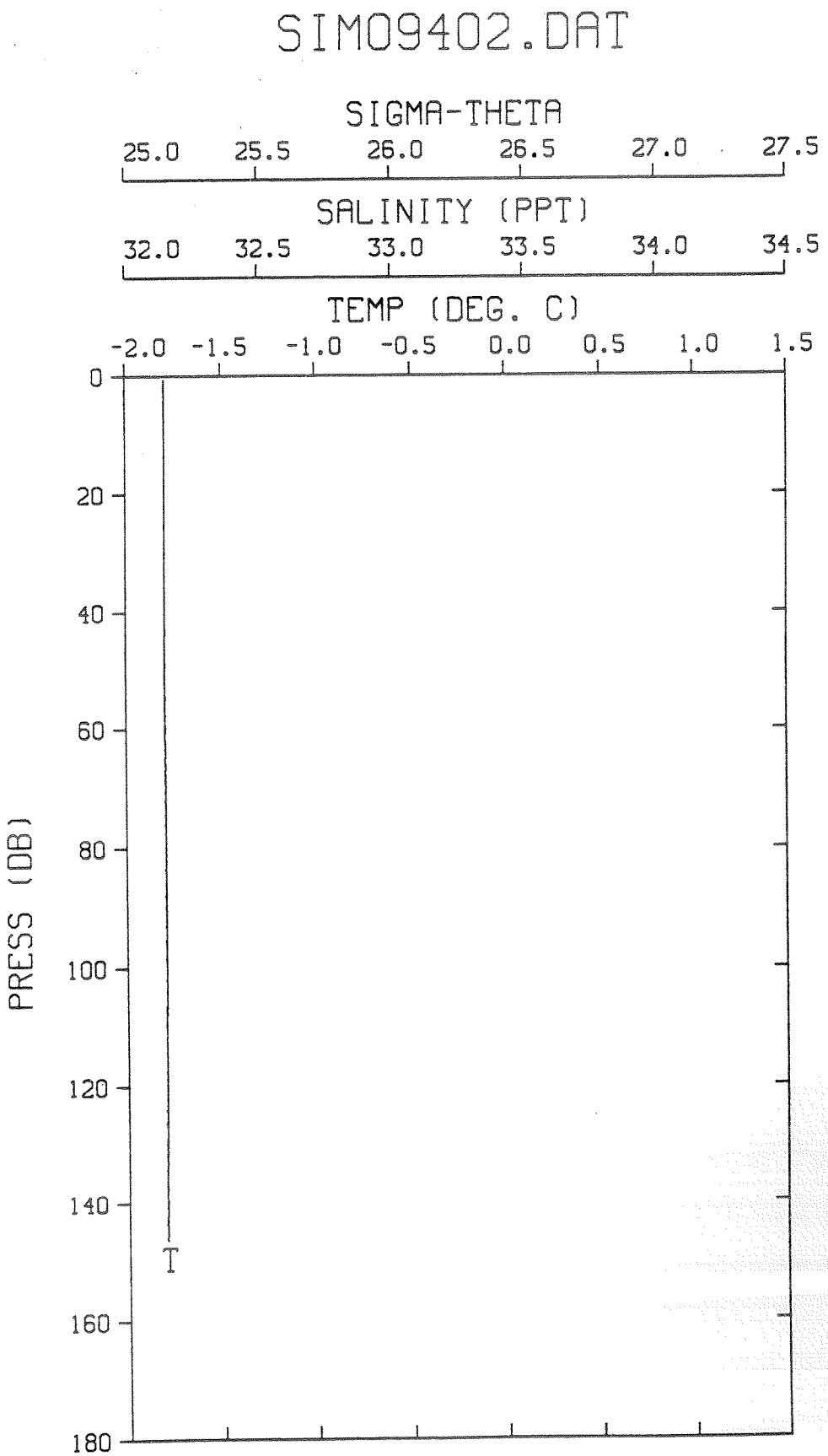
decibars	temp
5.	-1.7846
10.	-1.7845
15.	-1.7840
20.	-1.7836
25.	-1.7823
30.	-1.7823
35.	-1.7819
40.	-1.7825
45.	-1.7827
50.	-1.7824
55.	-1.7827
60.	-1.7823
65.	-1.7805
70.	-1.7803
75.	-1.7810
80.	-1.7807
85.	-1.7800
90.	-1.7786
95.	-1.7803
100.	-1.7794
105.	-1.7792
110.	-1.7790
115.	-1.7785
120.	-1.7775
125.	-1.7782
130.	-1.7781
135.	-1.7775
140.	-1.7775
145.	-1.7730
150.	-1.7668
155.	-1.7661
160.	-1.7615


SIM09400.DAT
SIGMA-THETA
25.0 25.5 26.0 26.5 27.0 27.5
SALINITY (PPT)
32.0 32.5 33.0 33.5 34.0 34.5
TEMP (DEG. C)
-2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5
PRESS (DB)
0 20 40 60 80 100 120 140 160 180

Station #9402 on February 24, 1994

Raw data file: simo9402.dat

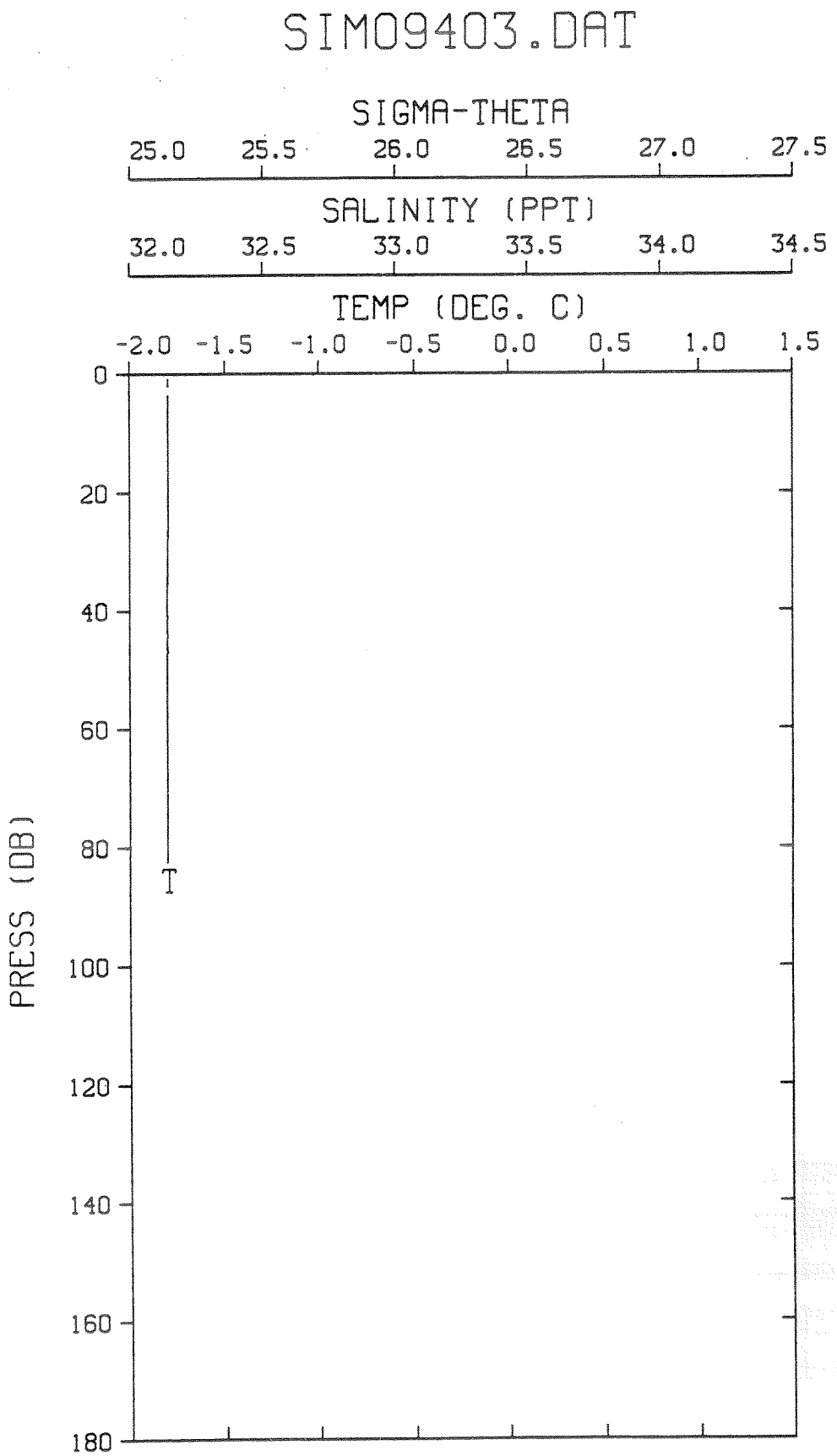
decibars	temp
5.	-1.7935
10.	-1.7932
15.	-1.7934
20.	-1.7933
25.	-1.7932
30.	-1.7932
35.	-1.7929
40.	-1.7932
45.	-1.7926
50.	-1.7928
55.	-1.7925
60.	-1.7926
65.	-1.7927
70.	-1.7926
75.	-1.7925
80.	-1.7924
85.	-1.7921
90.	-1.7927
95.	-1.7925
100.	-1.7924
105.	-1.7925
110.	-1.7934
115.	-1.7936
120.	-1.7943
125.	-1.7956
130.	-1.7958
135.	-1.7958
140.	-1.7960
145.	-1.7957


SIM09402.DAT
SIGMA-THETA
25.0 25.5 26.0 26.5 27.0 27.5
SALINITY (PPT)
32.0 32.5 33.0 33.5 34.0 34.5
TEMP (DEG. C)
-2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5
PRESS (DB)
0 20 40 60 80 100 120 140 160 180
T

Station #9403 on February 24, 1994

Raw data file: simo9403.dat

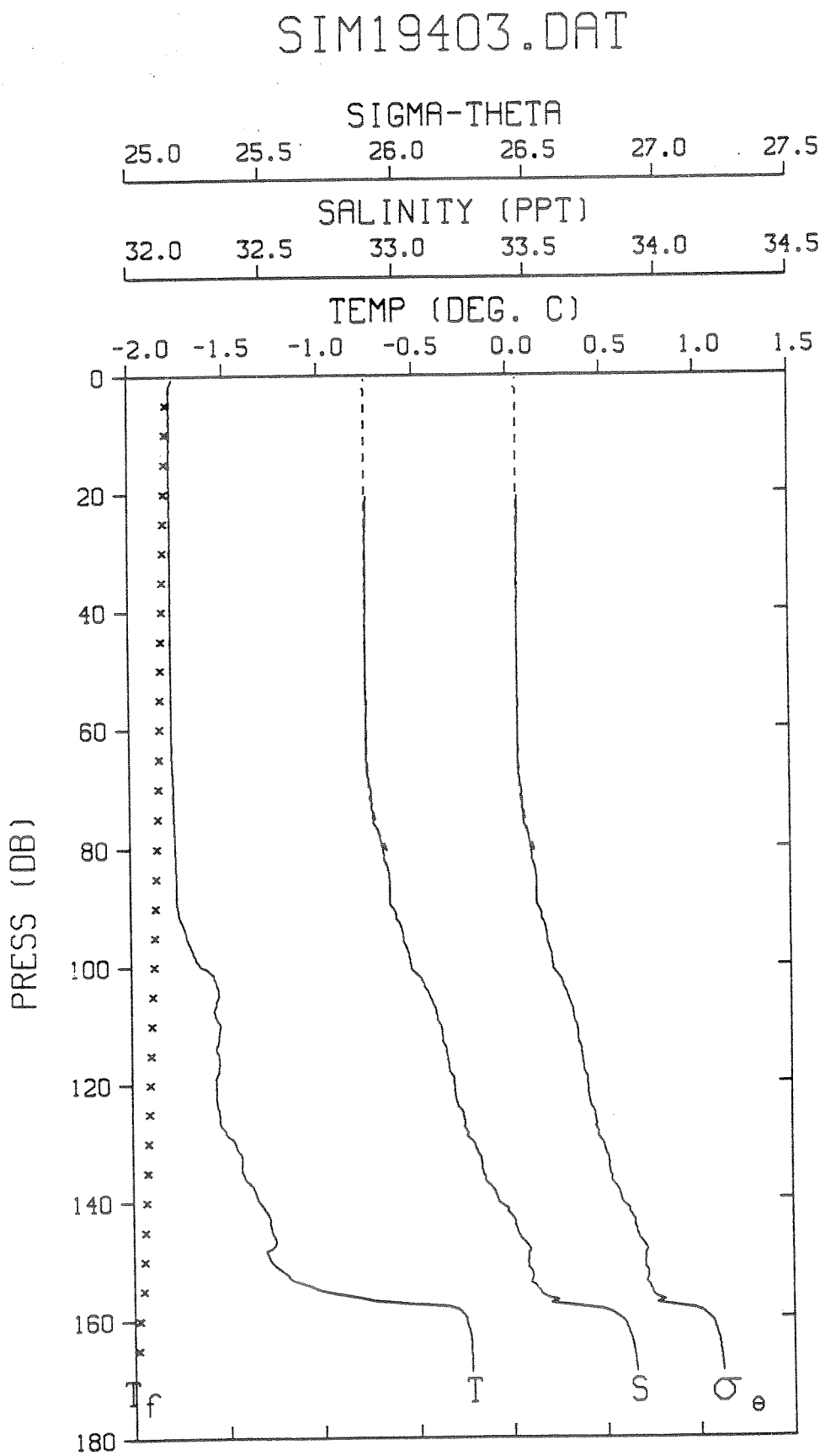
decibars	temp
5.	-1.7967
10.	-1.7969
15.	-1.7968
20.	-1.7971
25.	-1.7985
30.	-1.8005
35.	-1.8017
40.	-1.8018
45.	-1.8025
50.	-1.8027
55.	-1.8027
60.	-1.8026
65.	-1.8026
70.	-1.8023
75.	-1.8022
80.	-1.8022


SIM09403.DAT
SIGMA-THETA
25.0 25.5 26.0 26.5 27.0 27.5
SALINITY (PPT)
32.0 32.5 33.0 33.5 34.0 34.5
TEMP (DEG. C)
-2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5
PRESS (DB)
0 20 40 60 80 100 120 140 160 180

Station #1 on March 8, 1994

Raw data file: sim19403.dat

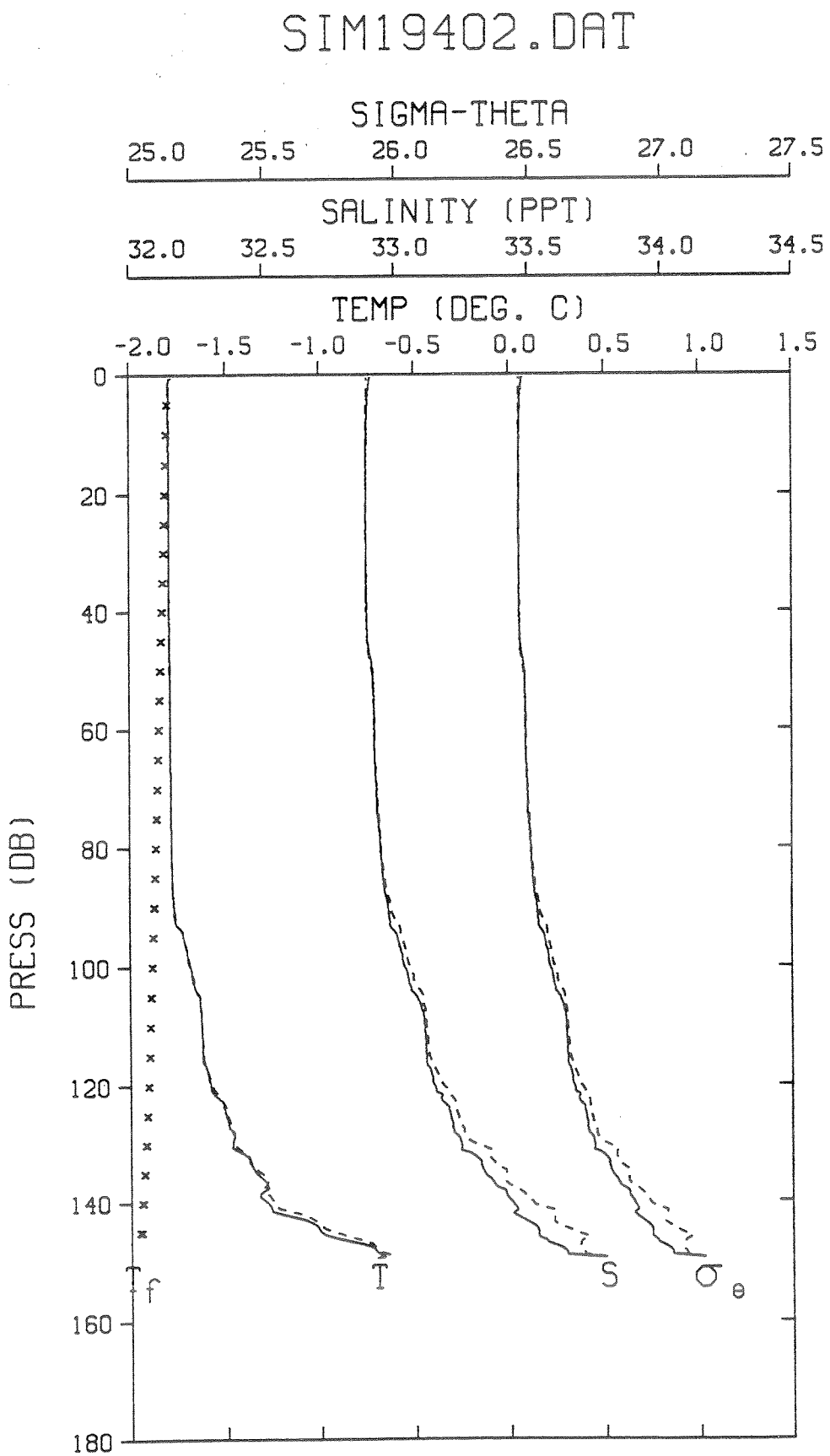
decibars	temp	salinity	sigmatheta
5.	-1.7844	32.8908	26.4656
10.	-1.7838	32.8904	26.4654
15.	-1.7842	32.8907	26.4655
20.	-1.7840	32.8907	26.4656
25.	-1.7836	32.8904	26.4654
30.	-1.7837	32.8907	26.4656
35.	-1.7833	32.8906	26.4655
40.	-1.7832	32.8912	26.4660
45.	-1.7825	32.8909	26.4658
50.	-1.7820	32.8914	26.4662
55.	-1.7814	32.8913	26.4660
60.	-1.7815	32.8919	26.4665
65.	-1.7798	32.8938	26.4681
70.	-1.7769	32.8995	26.4726
75.	-1.7722	32.9211	26.4901
80.	-1.7667	32.9620	26.5232
85.	-1.7628	32.9728	26.5319
90.	-1.7562	32.9815	26.5388
95.	-1.7118	33.0227	26.5713
100.	-1.6388	33.0531	26.5942
105.	-1.5414	33.1228	26.6484
110.	-1.5342	33.1670	26.6841
115.	-1.5435	33.1904	26.7033
120.	-1.5583	33.2161	26.7246
125.	-1.5423	33.2486	26.7506
130.	-1.4600	33.2858	26.7786
135.	-1.4239	33.3201	26.8054
140.	-1.3361	33.3768	26.8488
145.	-1.2707	33.4484	26.9050
150.	-1.2800	33.4900	26.9390
155.	-1.0324	33.5222	26.9569
160.	-0.2469	33.8390	27.1812
165.	-0.2230	33.8883	27.2199


SIM19403.DAT
SIGMA-THETA
25.0 25.5 26.0 26.5 27.0 27.5
SALINITY (PPT)
32.0 32.5 33.0 33.5 34.0 34.5
TEMP (DEG. C)
-2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5
PRESS (DB)
0 20 40 60 80 100 120 140 160 180
Tf
T
S
σθ

Station #2 on March 8, 1994

Raw data file: sim19402.dat

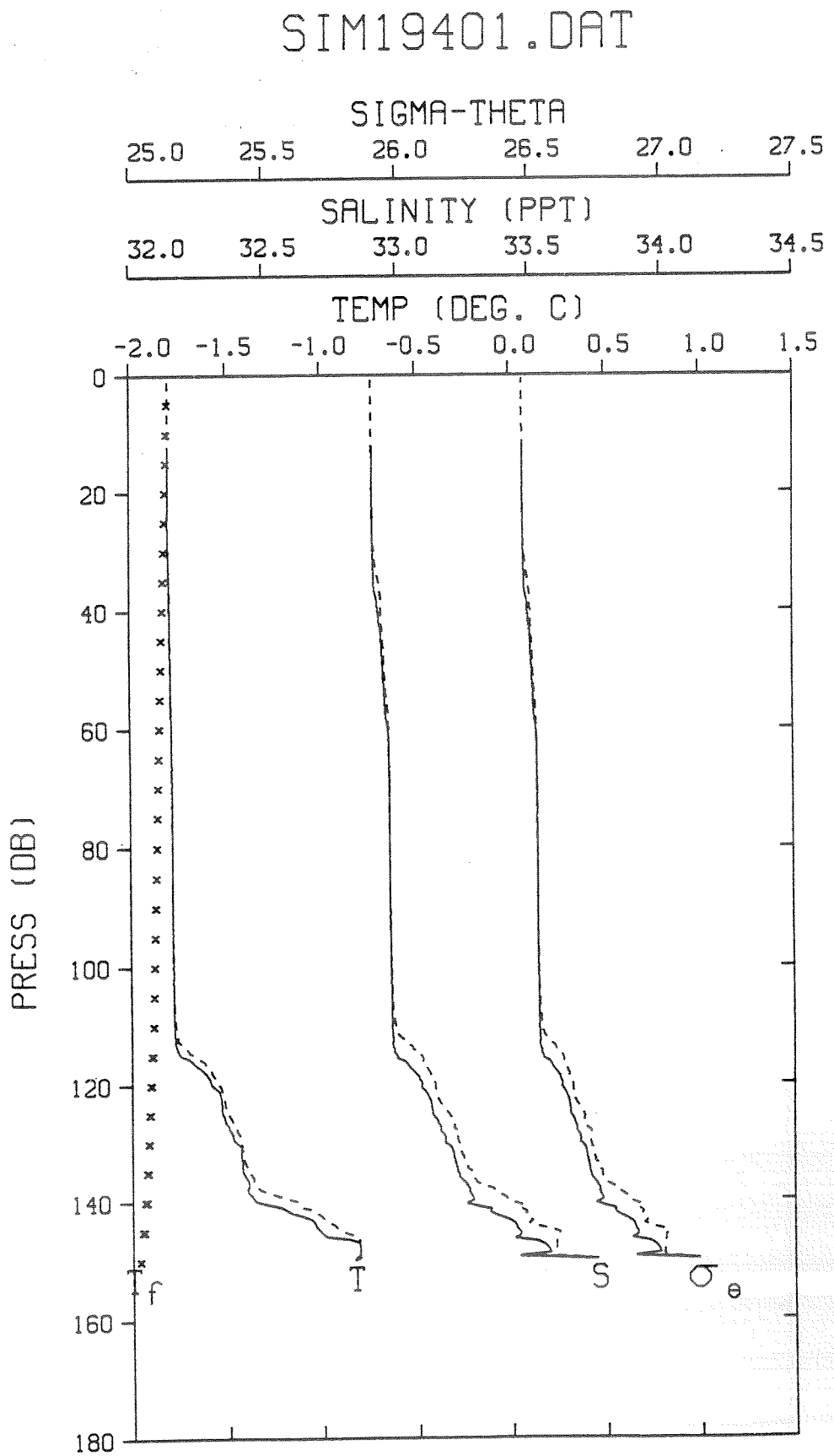
decibars	temp	salinity	sigmatheta
5.	-1.7957	32.8933	26.4680
10.	-1.7953	32.8930	26.4677
15.	-1.7954	32.8934	26.4680
20.	-1.7946	32.8930	26.4677
25.	-1.7948	32.8934	26.4680
30.	-1.7944	32.8932	26.4679
35.	-1.7934	32.8937	26.4683
40.	-1.7934	32.8949	26.4692
45.	-1.7923	32.8972	26.4711
50.	-1.7902	32.9137	26.4844
55.	-1.7890	32.9209	26.4903
60.	-1.7881	32.9237	26.4925
65.	-1.7876	32.9252	26.4937
70.	-1.7867	32.9315	26.4988
75.	-1.7846	32.9398	26.5056
80.	-1.7826	32.9469	26.5113
85.	-1.7787	32.9590	26.5210
90.	-1.7700	32.9824	26.5398
95.	-1.7206	33.0236	26.5722
100.	-1.6883	33.0555	26.5974
105.	-1.6379	33.1030	26.6347
110.	-1.6269	33.1171	26.6459
115.	-1.6199	33.1284	26.6549
120.	-1.5726	33.1826	26.6977
125.	-1.4937	33.2344	26.7377
130.	-1.4570	33.3031	26.7925
135.	-1.3097	33.4140	26.8782
140.	-1.2435	33.5107	26.9545
145.	-0.9354	33.6606	27.0656


SIM19402.DAT
SIGMA-THETA
25.0 25.5 26.0 26.5 27.0 27.5
SALINITY (PPT)
32.0 32.5 33.0 33.5 34.0 34.5
TEMP (DEG. C)
-2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5
PRESS (DB)
0 20 40 60 80 100 120 140 160 180
Tf
T
S
σθ

Station #3 on March 8, 1994

Raw data file: sim19401.dat

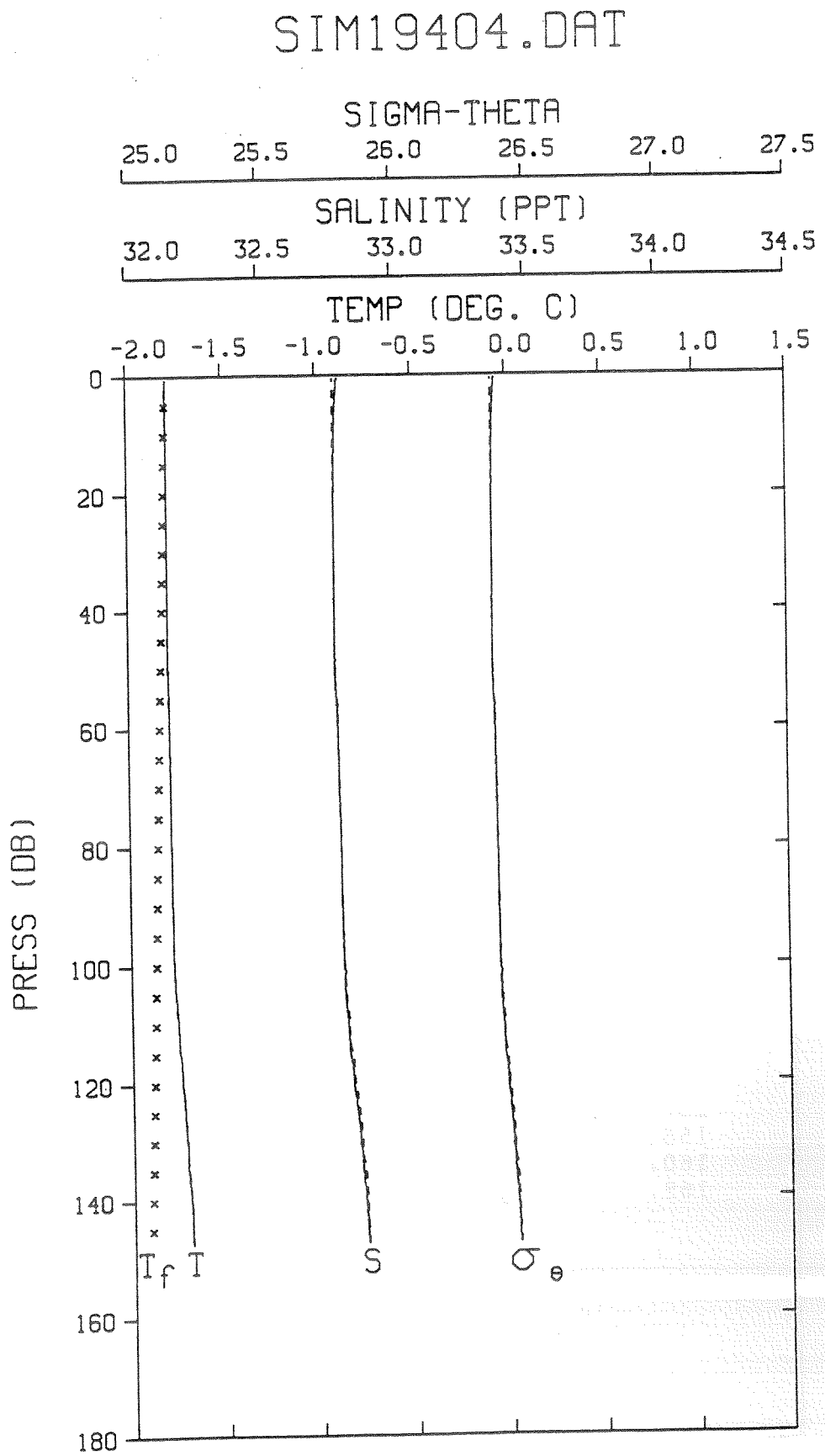
decibars	temp	salinity	sigmatheta
5.	-1.8002	32.9069	26.4791
10.	-1.8009	32.9077	26.4798
15.	-1.8012	32.9087	26.4806
20.	-1.8013	32.9095	26.4813
25.	-1.8013	32.9102	26.4818
30.	-1.7990	32.9173	26.4875
35.	-1.7930	32.9338	26.5008
40.	-1.7911	32.9435	26.5086
45.	-1.7905	32.9488	26.5129
50.	-1.7892	32.9550	26.5180
55.	-1.7873	32.9630	26.5245
60.	-1.7857	32.9691	26.5294
65.	-1.7850	32.9709	26.5308
70.	-1.7843	32.9713	26.5311
75.	-1.7839	32.9714	26.5312
80.	-1.7834	32.9716	26.5314
85.	-1.7833	32.9720	26.5317
90.	-1.7824	32.9730	26.5324
95.	-1.7818	32.9740	26.5333
100.	-1.7798	32.9751	26.5341
105.	-1.7785	32.9792	26.5374
110.	-1.7700	32.9906	26.5465
115.	-1.6665	33.0864	26.6219
120.	-1.5429	33.1414	26.6635
125.	-1.4944	33.1920	26.7033
130.	-1.4258	33.2286	26.7312
135.	-1.3833	33.2797	26.7714
140.	-1.1389	33.4114	26.8707
145.	-0.8996	33.5820	27.0006
150.	-0.8328	33.7551	27.1383


SIM19401.DAT
SIGMA-THETA
25.0 25.5 26.0 26.5 27.0 27.5
SALINITY (PPT)
32.0 32.5 33.0 33.5 34.0 34.5
TEMP (DEG. C)
-2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5
PRESS (DB)
0 20 40 60 80 100 120 140 160 180
Tf
T
S
σθ

Station #4 on March 8, 1994

Raw data file: sim19404.dat

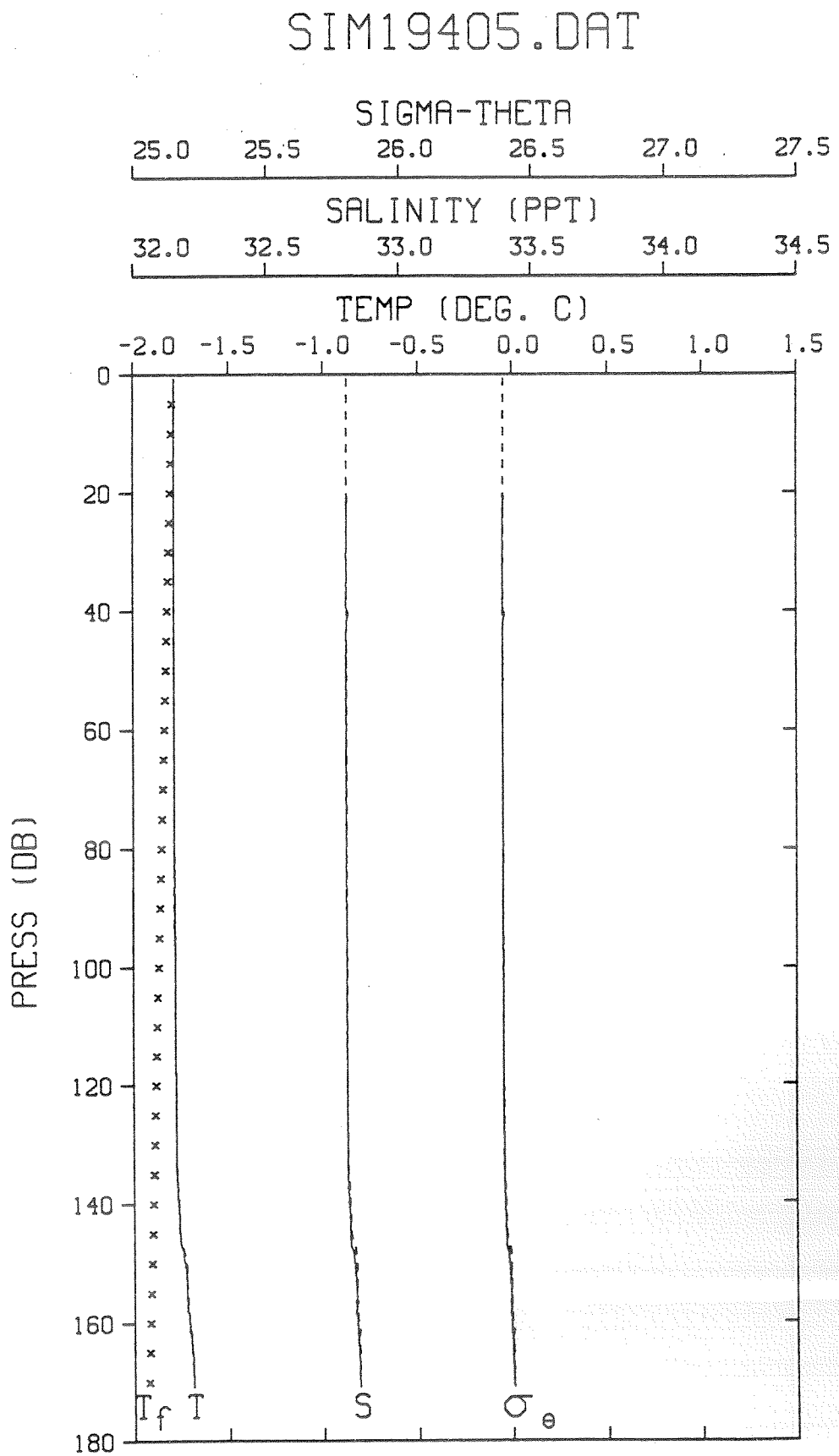
decibars	temp	salinity	sigmatheta
5.	-1.7926	32.7808	26.3764
10.	-1.7922	32.7803	26.3761
15.	-1.7920	32.7802	26.3759
20.	-1.7924	32.7809	26.3764
25.	-1.7919	32.7805	26.3762
30.	-1.7914	32.7802	26.3759
35.	-1.7913	32.7804	26.3760
40.	-1.7910	32.7805	26.3761
45.	-1.7910	32.7808	26.3764
50.	-1.7907	32.7820	26.3773
55.	-1.7887	32.7870	26.3814
60.	-1.7851	32.7913	26.3849
65.	-1.7848	32.7929	26.3861
70.	-1.7837	32.7952	26.3880
75.	-1.7822	32.7961	26.3886
80.	-1.7815	32.7983	26.3904
85.	-1.7802	32.8001	26.3918
90.	-1.7779	32.8009	26.3925
95.	-1.7770	32.8027	26.3939
100.	-1.7741	32.8050	26.3957
105.	-1.7674	32.8108	26.4003
110.	-1.7559	32.8188	26.4065
115.	-1.7490	32.8314	26.4166
120.	-1.7375	32.8396	26.4230
125.	-1.7262	32.8536	26.4341
130.	-1.7152	32.8630	26.4416
135.	-1.7098	32.8724	26.4491
140.	-1.6971	32.8799	26.4549
145.	-1.6948	32.8841	26.4583


SIM19404.DAT
SIGMA-THETA
25.0 25.5 26.0 26.5 27.0 27.5
SALINITY (PPT)
32.0 32.5 33.0 33.5 34.0 34.5
TEMP (DEG. C)
-2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5
PRESS (DB)
0 20 40 60 80 100 120 140 160 180
T_f T
S
σ_θ

Station #5 on March 8, 1994

Raw data file: sim19405.dat

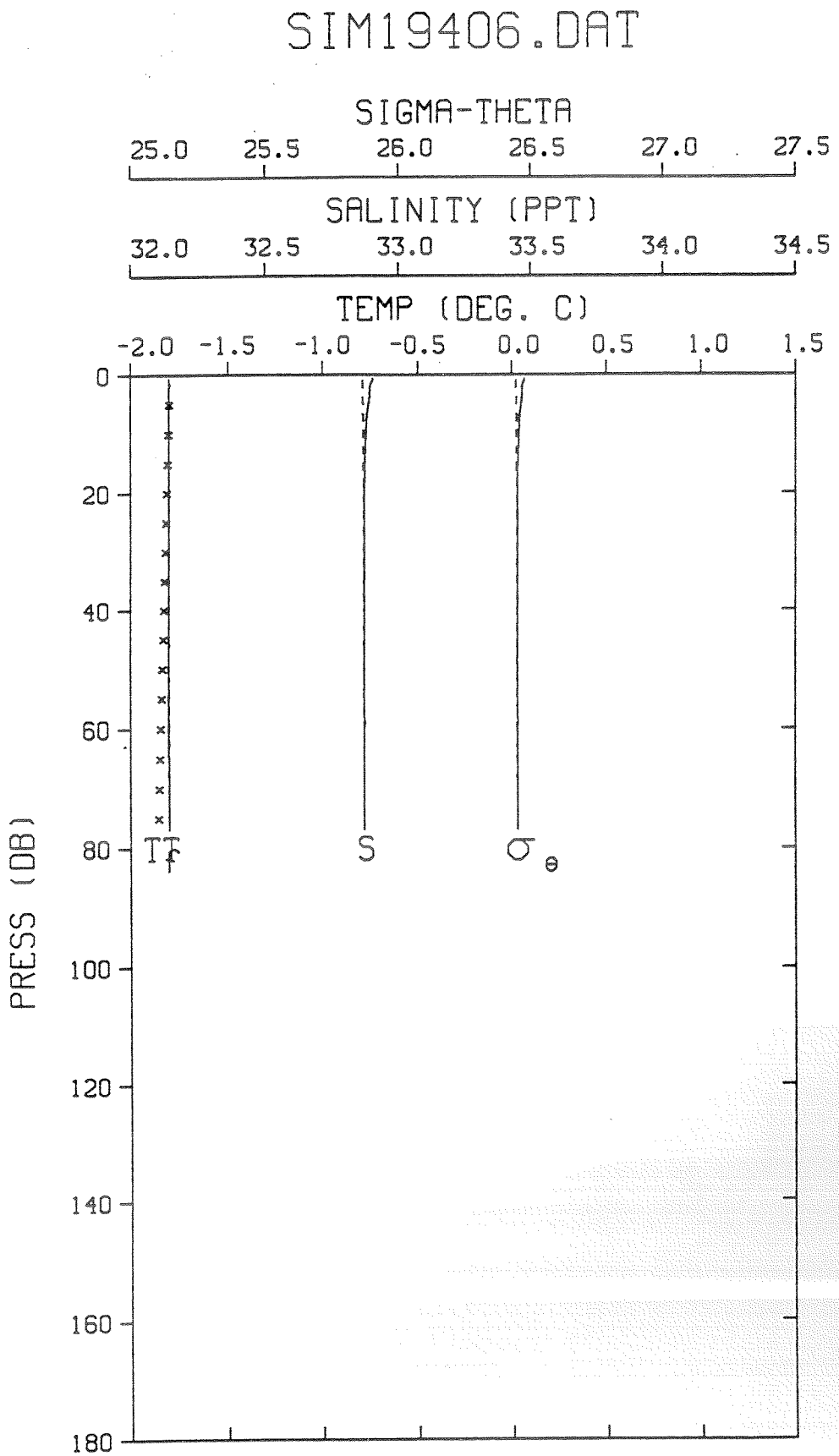
decibars	temp	salinity	sigmatheta
5.	-1.7890	32.8053	26.3963
10.	-1.7889	32.8054	26.3963
15.	-1.7888	32.8054	26.3963
20.	-1.7889	32.8055	26.3964
25.	-1.7891	32.8056	26.3965
30.	-1.7886	32.8055	26.3963
35.	-1.7891	32.8048	26.3958
40.	-1.7887	32.8044	26.3955
45.	-1.7888	32.8048	26.3959
50.	-1.7886	32.8051	26.3961
55.	-1.7885	32.8043	26.3954
60.	-1.7889	32.8048	26.3959
65.	-1.7883	32.8044	26.3956
70.	-1.7885	32.8047	26.3957
75.	-1.7887	32.8048	26.3958
80.	-1.7876	32.8053	26.3963
85.	-1.7872	32.8048	26.3958
90.	-1.7871	32.8042	26.3953
95.	-1.7864	32.8061	26.3969
100.	-1.7832	32.8066	26.3972
105.	-1.7823	32.8065	26.3971
110.	-1.7825	32.8070	26.3976
115.	-1.7824	32.8075	26.3979
120.	-1.7808	32.8075	26.3979
125.	-1.7801	32.8081	26.3984
130.	-1.7793	32.8090	26.3991
135.	-1.7774	32.8104	26.4002
140.	-1.7673	32.8158	26.4043
145.	-1.7623	32.8197	26.4074
150.	-1.7306	32.8400	26.4232
155.	-1.7235	32.8408	26.4238
160.	-1.7141	32.8444	26.4264
165.	-1.6995	32.8510	26.4314


SIM19405.DAT
SIGMA-THETA
25.0 25.5 26.0 26.5 27.0 27.5
SALINITY (PPT)
32.0 32.5 33.0 33.5 34.0 34.5
TEMP (DEG. C)
-2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5
PRESS (DB)
0 20 40 60 80 100 120 140 160 180
T_f T S σ_θ

Station #6 on March 8, 1994

Raw data file: sim19406.dat

decibars	temp	salinity	sigmatheta
5.	-1.8025	32.8669	26.4467
10.	-1.8026	32.8679	26.4475
15.	-1.8022	32.8686	26.4480
20.	-1.8021	32.8692	26.4485
25.	-1.8020	32.8705	26.4496
30.	-1.8019	32.8704	26.4495
35.	-1.8017	32.8711	26.4500
40.	-1.8015	32.8707	26.4497
45.	-1.8018	32.8714	26.4502
50.	-1.8016	32.8712	26.4501
55.	-1.8013	32.8712	26.4501
60.	-1.8010	32.8712	26.4501
65.	-1.8010	32.8715	26.4503
70.	-1.8003	32.8720	26.4507


SIM19406.DAT
SIGMA-THETA
25.0 25.5 26.0 26.5 27.0 27.5
SALINITY (PPT)
32.0 32.5 33.0 33.5 34.0 34.5
TEMP (DEG. C)
-2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5
PRESS (DB)
0 20 40 60 80 100 120 140 160 180
T
S
σθ