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Labrador Shelf and Gulf of St. Lawrence Sea Ice Program, 1995-1998

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ABSTRACT

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For each winter from 1995 to 1998, ice beacons were deployed on landfast and mobile pack ice to measure ice and atmospheric properties. Four types of instruments were placed in the field: those that reported ice movement; those that measured ice pressure within floes, those that measured ice and air temperatures; and those that were equipped with anemometers to measure wind speed and direction and air temperature. Data were transmitted to satellites and relayed to the Bedford Institute of Oceanography for processing.

RÉSUMÉ

van der Baaren, A. and S. J. Prinsenberg. 2000. Labrador Shelf and Gulf of St. Lawrence Sea Ice Program, 1995-1998. *Can. Tech. Rep. Hydrogr. Ocean. Sci.* 207: vi + 213 p.

Chaque hiver de 1995 à 1998, des balises ont été déployées sur des glaces de rive et des glaces mobiles afin de mesurer les propriétés de la glace et les propriétés atmosphériques. Quatre types d’instruments ont été placés sur le terrain : ceux signalant les mouvements de la glace, ceux mesurant la pression de la glace dans les floes, ceux mesurant la température de la glace et de l’air, et ceux munis d’anémomètres pour mesurer la vitesse et la direction du vent ainsi que la température de l’air. Les données recueillies étaient transmises par satellite et acheminées jusqu’à l’Institut océanographique de Bedford en vue de leur traitement.

1 INTRODUCTION

Oil exploration, fisheries, and commercial shipping off the Labrador and Newfoundland coasts and in the Gulf of St. Lawrence have placed increasing demand on our ability to monitor and predict the properties and movement of the annual pack-ice. Placing satellite-tracked beacons on the ice is an economical and safe alternative to sea ice studies using expensive ship- and helicopter-based logistics. Satellites can track beacons and report data collected by various sensors mounted on the beacons. This type of ice monitoring was successfully used in field programs of 1993 and 1994 on the Newfoundland Shelf during which time atmospheric, ice, and oceanographic data were collected (Peterson, *et al*., 1995). The ice data included ice temperature and movement.

In 1995, the sea ice program continued to monitor the same ice data as in 1993 and 1994, but new to the program was the measurement of directional ice stress using an ice beacon developed at the Bedford Institute of Oceanography. The pressure sensor within the beacon measured either the ice pressure along a single axis or ice pressures along three axes. It is important to note that ice pressure within the pack ice primarily determines the success of navigation in ice infested areas. High ice pressure reduces ship maneuverability and increases the risk of ships and fixed platforms being damaged by pack ice.

This report presents satellite-tracked beacon data that were collected during four winter field programs, 1995 to 1998, on the Labrador Shelf and in the Gulf of St. Lawrence. In each of those years, data included ice pressure and stress, ice and air/water temperature, local wind, and ice floe location. Salinity and temperature data from CTD instrument casts below the ice were also collected while the ice beacons were being deployed, and floe thickness was measured through holes drilled in the pack-ice at each station. Since the CTD data and drilled ice thickness data augment the beacon data field programs, they are also presented. Before the complete data presentation in the appendices, there is a description of the field sites and of the instruments used to collect the measurements.

1.1 Study areas

One of the most distinct characteristics of the sea ice off Canada's East Coast is its dynamic movement in response to atmospheric and oceanic forcing. The predominant northwesterly winds and the strong southward flowing Labrador Current move locally formed ice and ice formed at higher latitudes rapidly southwards until the warm waters around the Grand Banks consume the ice. Although some of the advected ice enters the Gulf of St. Lawrence from the Labrador Shelf, most of the Gulf's ice is locally grown and less than 1 m thick. Under predominantly westerly winds, it moves from the Gulf to the Scotian Shelf where it melts in the warm water.

2 INSTRUMENTATION AND DATA COLLECTION

The satellite-tracked ice beacons, regardless of which sensors are mounted on them, all transmitted their data to satellites used by Service ARGOS. Service ARGOS provided position data for each beacon computed from the Doppler shift of the beacon transmissions to their satellites. The transmissions were received for about ten minutes on about ten satellite passes per day (Peterson, *et al*., 1995). Five kinds of satellite-tracked beacons provided ice property data, positional data, and atmospheric data:

1. ice pressure beacons transmitted hourly ice pressure data
2. Global Positioning System (GPS) beacons transmitted hourly beacon locations
3. a temperature staff transmitted ice temperatures at selected depths either hourly or per satellite pass
4. an atmospheric ice beacon transmitted hourly air and surface ice temperatures, air pressure, and wind speed and directions; the 6 most recent data were transmitted per satellite pass
5. a basic ice beacon provided position data once per satellite pass which is less regular than the GPS beacon data

In addition, *in situ*, ice/water property measurements and ice thickness measurements were made at each field station.

Transport to and from the field sites for deployment of the beacons was by helicopter.

2.1 Ice pressure beacons

The ice pressure beacon is a compact, expendable unit consisting of a battery pack/ARGOS transmitter module connected by cable to a sensor probe module. The unit has two sets of three plastic diaphragms, six diaphragms in total. The plastic diaphragms in each trio are 120° apart and both sets are combined into a single machined aluminum unit (Figure 2.1.1).

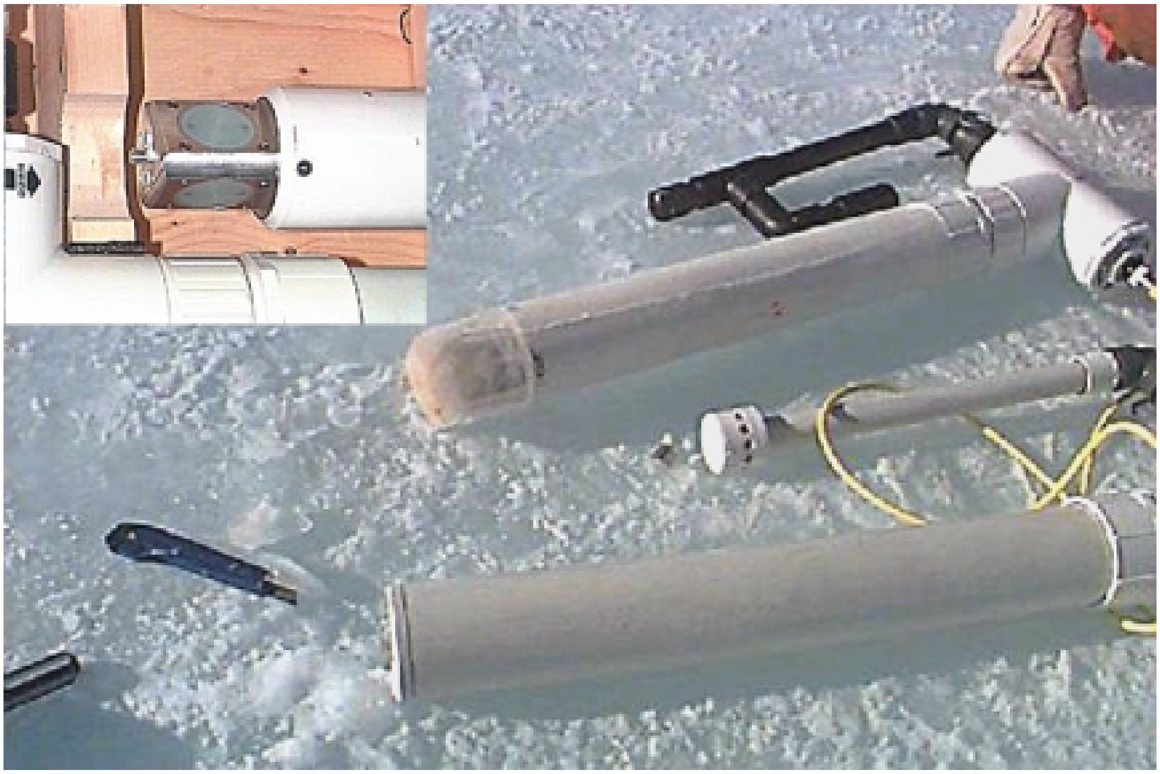

Figure 2.1.1 Ice pressure beacon with plastic diaphragms exposed (inset).

One set of diaphragms is exposed to the ice pressure while the other set is protected. By connecting the "active" diaphragm set to one port of a pressure transducer and the other "protected" set to the other port, the sensor is compensated for temperature variations in the ice/diaphragm/fluid assembly in addition to internal temperature compensation of the transducer itself. The three measured pressures are used to calculate major and minor principal ice stresses as well as their orientation. Before being deployed, the exposed diaphragms are frozen into a “popsicle”.

This improves the chances of a prompt freeze-in of the sensor probe. The unit is also checked for proper operation and satellite-link data recovery. The unit, along with a separate battery pack, is installed in two 10-cm diameter holes in the ice.

2.2 GPS location beacons

GPS location beacons, manufactured by METOCEAN Data Systems Ltd. and Seimac Ltd. of Dartmouth N. S., were deployed throughout the study regions to provide hourly positional information. Beacon electronic components are contained within a sealed, fiberglass shell and the instrument is deployed such that the bottom section sits in a shallow ice hole. The Seimac GPS beacons used in 1995-1997 weighed 65 lbs. and were 95 cm long with a narrow (10 cm in diameter) bottom section that housed the battery pack (Seimac Ltd., 1995). All beacons were designed to sink after the ice floe on which they were deployed, melted, or to quit transmitting after 3 months. The battery pack of the beacons was capable of powering the internal components for at least 60 days at –35°C and 90 days at temperatures averaging –20°C. ARGOS satellites received the eight most recent hourly positions upon each pass.

2.3 Atmospheric beacon

METOCEAN Data Systems, Ltd. of Dartmouth, N. S, manufactured the atmospheric beacon. The R. M. Young anemometer on the beacon computed a 10-minute average of wind speed and direction each hour at 2 m above the ice surface. Other sensors collected air temperature and air pressure. The beacon contained an ARGOS transmitter which transmitted the last six hourly atmospheric data to the ARGOS satellites. Only in 1997 was there an atmospheric beacon deployed; this was placed off the coast of Prince Edward Island in the Gulf of St. Lawrence.

2.4 Temperature staff beacon

The temperature staff is a data transmitter and a chain of thermisters spaced at selected intervals and combined into a single unit. All the thermisters had a resolution of 0.2°C. The battery pack inside the staff section is placed below the ice/air interface while the transmitter is above the interface.

2.5 Basic ARGOS location beacon

The “basic” beacon, built by METOCEAN Data Systems, Ltd. of Dartmouth, N. S., transmits a message containing the beacon’s reference number to the ARGOS satellite as it passes overhead (approximately every three hours). The satellite computes the location of the beacon upon each pass. This results in a series of latitudes and longitudes for that beacon which is less regular than the series obtained by the GPS beacons which store hourly GPS data internally.

2.6 CTD

Conductivity (salinity), temperature, and depth (CTD) data were collected near beacon deployment locations in 1996, 1997, and 1998 (Figure 7.3, Figure 7.5, and Figure 7.7) on the Labrador Shelf near Hamilton Bank. Scientists, who were dropped off on ice floes by helicopter, drilled holes through the ice and lowered the Seabird SBE-25 CTD probe to record water property data. The instrument’s descent was by free-fall (gravity) and a gasoline-powered winch raised it. The accuracy/resolution of the instrument sensors is 0.004/0.0003°C for temperature, 0.0003/0.00004 Siemens/m for conductivity, and 0.25%/0.015% for depth (m). The range for each of the sensors is 0 S/m to 7 S/m for conductivity, -5°C to 35°C for temperature, and 60 m to 1000 m for depth. For a depth range of 2000 m to 10500 m, the accuracy/resolution is 0.15%/0.015% (Seabird Electronics, 1991).

2.7 *in situ* measurements

At many of the field stations, ice holes were drilled and floe thickness was measured and recorded. Salinity of snow/ice, brine, and water was also measured using an AO-10419 hand-held refractometer that reads to approximately ±0.5 psu (Peterson, *et al.*, 1995).

3 DATA PROCESSING

3.1 Basic ARGOS location beacon data

The ice beacon identification numbers used by ARGOS for all years are tabulated in Tables 6.1 to 6.4. The types of beacons associated with each ID number and the deployment times are also given. Latitude and longitude data from ARGOS transmission headers were used to plot where the beacons were first deployed and to where they eventually traveled. These trajectory maps are given in Appendices A, B, and C for all the ice beacons deployed in 1996 through to 1998. Note that the 1995 ARGOS positions were not mapped since the beacons did not travel a great distance from their deployment locations that year; the reported ARGOS positions were very erratic.

3.2 Ice pressure beacon data

Pressure data from the uni-axial pressure sensors and air/ice temperature data measured by the pressure beacons were edited and plotted as time series. These graphs are given in Appendices D, E, F, and G, in Sections 11.2, 12.2, 13.2, and 14.2.

Pressure data from the tri-axial pressure beacon sensors were edited and major and minor principal ice stresses were computed from the data of the three sensors, p1, p2, and p3. The following equations were adapted from Hollister (1967) and were used to compute major/minor principal stresses (Prinsenberg, *et al.*, 1997):

$\sigma_1 = p + q$ major principal stress
$\sigma_2 = p - q$ minor principal stress

Where $p = [p_1 + p_2 + p_3]/3$, $q = \{2/9[(p_1 - p_2)^2 + (p_1 - p_3)^2 + (p_2 - p_3)^2]\}^{1/2}$

and $\tan(2\theta) = (p_1 - p_2)/[\sqrt{3}\,(p_3 - p)]$

θ is the angle, measured counterclockwise, between the major principal stress and the axis of p_1. The special computing function, "atan2", results in values of θ in the range, $[-\pi,\pi]$. In order to determine how the stress was applied within the ice, the context of the situation was taken into account. If winds were predominantly northwesterly, the assumption was that major pressure events would come from the north as long as the ice was restrained in some way at the south. θ was subtracted from the measured compass directions to find the direction in which the major principal stress acted relative to magnetic north:

measured compass direction - θ = direction of major principal stress relative to magnetic north

To find the direction of the stress relative to true north, magnetic declinations were computed and subtracted from the stress directions relative to magnetic north. The magnitude of the major and minor principal stresses are given in time series; stick plots show directions of the major principal stresses. These graphs are in Appendices E, F, and G, in Sections 12.2, 13.2, and 14.2. In 1997 the tri-axial pressure data needed a calibration correction to the compass values prior to computation of the major principal stress.

3.3 Atmospheric beacon data

Atmospheric data in 1997 were collected by beacon 4770. The data were put into an irregular time series where the ARGOS time stamp was used to construct the time channel. The wind vector had to be adjusted by 180°. The stick diagram of wind velocity is shown in Figure 13.5.1 in Appendix F.

3.4 Temperature staff beacon data

The air/water temperatures measured by the temperature staff's thermisters were edited and plotted. These temperature time series are shown in Appendices D, E, and G, in Sections 11.3, 12.3, and 14.3.

3.5 GPS location beacon data

Since the hourly GPS beacon data gave better resolution data than mere ARGOS positions, these data were edited for erroneous positions and then plotted in trajectory maps. Beacon positions are shown every six hours as points and dashed lines shows their entire routes. The plots for GPS beacons deployed for all four years are in four appendices, D – G, in the fourth section of each.

3.6 CTD

CTD data were averaged into 5-m bins and are presented in Appendices E, F, and G, in Sections 12.5, 13.4, and 14.5 in tabular and visual form. CTD header information gives the time and location of each cast. The downcast and upcast are shown for each station where available. Since ice crystals tended to contaminate the downcast data, the upcast is the most reliable. For some stations, salinity values are omitted at depths where temperatures are listed; these missing salinities are indications of erroneous conductivity samples.

4 SUMMARY

4.1 Ice drift

Beacons that were deployed in the Northumberland Strait and in the Gulf of St. Lawrence, north of Prince Edward Island, generally followed a mean eastward drift. In some cases the ice floes drifted out of the Gulf through Cabot Strait or ended up near the western Newfoundland coast northeast of their starting point.

In 1997, several beacons were placed west of Point North to measure ice convergence and ice pressure. One of these (beacon 972), traveled eastward around the point but the other six were unable to make it around. It is noted that the six that did not make it stopped functioning before the one that completed the circumnavigation.

Also in 1997, beacon 4770 was equipped with an anemometer and deployed west of Point North. It operated for four days, stopped transmitting, and then restarted itself after it had moved east of Point North in the Gulf of St. Lawrence. Its trajectory, east of Point North, closely followed the coastline after a short trip north. A regular time series of wind velocity components was constructed by interpolating the wind data into hourly values. The ARGOS reported positions were also interpolated into a regular hourly time series. Six-hourly mean wind speed values were computed and the beacon's drift speed over six hours was computed. When the two speeds were correlated using a complex correlation analysis, the turning angle was computed to be 14°, its gain to be 2%, and the wind was found to account for 38% of the variance in the ice motion. Similar gain and turning angles, but larger variances, are found for offshore pack ice conditions (Greenan, *et al.*, 1997).

After construction of Confederation Bridge was completed, beacons deployed in the vicinity of the bridge in 1998 tended to travel back and forth near/beneath the bridge due to tidal forcing, but generally tracking slowly eastward as expected (Figures 14.4.1 - 14.4.5).

Beacons deployed off the Labrador coast tended to drift southeasterly with the Labrador Current and the predominant northwesterly winds as expected (see also Peterson, 1990; Peterson, *et al.*, 1995; and Greenan, *et al.*, 1997).

4.2 Ice pressure

The difficulty in measuring ice pressure at the latitudes of this study is that the ice is not always thick or solid enough for meaningful pressures to be measured. The pressure sensor can be frozen into the ice at the time of deployment, but quickly be sitting in slush with sudden changes in climatic conditions. Then, no pressure can be detected. This was often the case and can be seen in the time series of some of the pressure sensors (*e. g*. Figures 12.2.3, 12.2.4, 13.2.2, 13.2.4, 13.2.5, and 13.2.6). The traces start out with a sharp spike indicating the freeze-in cycle but fall off quickly over a short time. The freezing point of the seawater is about –2°C and many of the ice temperature traces show values near this or above this when the pressure traces show little or no ice pressure.

When one of the sensors of the tri-axial set-up was unable to detect a pressure signal then a directed ice stress could not be confidently computed. This was the case in 1996 for beacons 1052 and 1055, in 1977 for beacon 1055, and in 1998 for beacons 1055 and 2362.

In 1995, the use of the uni-axial pressure sensor in landfast and pack-ice in Labrador lead to the development of the deployment method first freezing the sensor into an “ice popsicle” and then placing the frozen sensor unit into the drilled hole to completely freeze into the floe.

In 1996, the directed ice stress measured by beacon 1054 off Labrador was along a southwesterly axis (Figure 12.2.5). The pack ice itself traveled to the southeast (Figure 12.4.3). In 1997, beacons 976 and 1053 measured directed ice stresses along the same axis, northeast to southwest (Figures 13.2.4 and 13.2.5) while the pack ice traveled in a southeasterly direction (Figures 14.3.4 and 14.3.6). The offshore pack ice seemed to exert the mean northeast to southwest stress on the inshore ice pack.

In the Gulf of St. Lawrence the mean ice stress was directed southeasterly for beacon 1055 in 1997 (Figure 13.2.6). The pack ice was pushing the floes against the coast of Prince Edward Island on the western shores of Point North.

4.3 Ice thickness and salinity

In the Northumberland Strait and in the Gulf of St. Lawrence, within the ice sheet, ice salinities were generally in the range of 4-8 psu, at times reaching 15 psu. Surface ice and snow had salinities in the range of 0 psu to 2 psu. Ice thickness of undeformed, level ice ranged from 30 cm to over 1 m. In Labrador, salinity for surface ice and snow was occasionally higher (4.8 psu) since flushing of salt by melting snow had not occurred. Ice thickness in Labrador also ranged from 30 cm to over 1 m for undeformed, level ice.

4.4 Below-ice water properties

Surface seawater below the ice had salinities upwards of 30 psu or more in the Gulf of St. Lawrence. CTD casts over Hamilton Bank indicate a homogeneous surface layer with water temperature and salinity generally increasing at depth with occasional exceptions because of possible ice crystals in near-surface samples (*e. g.* Figure 12.5.4).

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6 TABLES

Table 6.1 Summary of 1995 ARGOS beacon data (Labrador)

TYPE OF BEACON	ID	DEPLOYMENT LOCATION	POWER-ON or DEPLOYMENT TIME (GMT)	SHUT-OFF or RECOVERY TIME (GMT)	DATA START (GMT)	DATA END (GMT)
pressure (uni-axial)	22191	pack-ice	88 15:10	94 15:18	88 10:50	94 13:40
sampling interval =	22192	landfast ice	61 16:20	88 20:45	66 3:25	88 13:50
12 min.	22193	landfast ice	61 16:30	88 20:45	66 3:25	88 06:48
		pack-ice	94 15:18	sank	94 14:12	115 17:13
temperature staff	02347	landfast ice	61 16:20	88 20:45	64 15:37	88 13:41
sampling interval =	02367	landfast ice	61 16:30	88 13:30	61 18:51	89 15:16
1 hr.		pack-ice	88 15:10	sank	91 15:21	99 14:47
GPS	10053	landfast ice	61 16:00	94 17:10	61 18:00	94 16:00
sampling interval =	10054	landfast ice	60 18:30	88 13:30	60 19:00	88 14:00
1 hr.		pack-ice C	88 15:10	sank	88 16:00	135 15:00
	21596	landfast ice	60 18:30	88 13:30	60 19:00	88 14:00
		pack-ice SE	88 16:00	sank	88 17:00	145 17:00
	21597	landfast ice	61 16:00	88 13:30	61 18:00	87 14:00
		pack-ice SW	88 16:00	sank	88 17:00	145 17:00
	21598	landfast ice	61 16:00	88 20:45	61 18:00	88 19:00
	21599	landfast ice	61 16:00	88 13:30	61 18:00	88 14:00
		pack-ice N	88 16:00	sank	88 16:00	145 08:00

NOTES:

- **Landfast ice site off Foxe Island** **54°34.32'N 57°13.57'W**
- **Offshore pack-ice site off Cape Harrison**
  - **C (center)** **54°51.42'N 57°27.82'W**
  - **SE corner was 1.4 Nmi from center**
  - **SW corner was 1.6 Nmi from center**
  - **N corner was 1.0 Nmi from center**
- **10053 was lost then found on day 94**
- **All GPS beacons were tested at Lake Melville from day 58 to day 60 before field deployment on the landfast ice.**
- **Beacons deployed on the offshore pack ice remained near the deployment site for approximately 47 days with very little movement.**

Table 6.2 Summary of 1996 ARGOS beacon data (Labrador (Lab) and Gulf of St. Lawrence (GSL))

TYPE OF BEACON	ID	DEPLOYMENT LOCATION	POWER-ON or DEPLOYMENT TIME (GMT)	SHUT-OFF or RECOVERY TIME (GMT)	DATA START (GMT)	DATA END (GMT)
pressure (uni-axial) sampling interval = 1 hr.	22192	station 1 Lab	71 19:00	sank	71 21:35	79 17:35
	22195	station 3 Lab	70 19:45	sank	70 20:45	96 10:45
	22196	station 6 Lab	73 19:30	sank	73 20:30	97 00:30
pressure (tri-axial) sampling interval = 1 hr.	01052	station 6 Lab	73 19:30	sank	73 20:30	102 08:30
	01054	station 3 Lab	70 19:45	sank	70 20:45	82 04:45
	01055	station 1 Lab	71 19:00	sank	71 21:35	79 17:35
basic beacon sampling interval = per ARGOS pass	00966	station 2 GSL	58 20:25	sank	58 20:51	93 15:55
	00969	station 3 GSL	59 14:30	sank	59 15:27	87 15:21
	00975	station 18.1 Lab	78 14:00	sank	78 15:25	123 17:14
	02362	station 15 GSL	65 13:30	sank	65 16:01	99 12:54
	02364	GSL	67	sank	67 17:19	87 13:52
	02365	CTD 5 Lab	79 13:50	sank	79 15:03	115 08:50
	11248	GSL	51	N/A	51 5:19	106 18:37
	11249	station 4 GSL	60 15:50	N/A	61 16:52	121 13:08
	11251	GSL	51	N/A	51 5:19	96 18:47
	11254	GSL	51	N/A	51 5:19	103 05:59
temperature staff sampling interval = 1 hr.	02347	station 1 Lab	71 20:00	N/A	71 22:50	79 15:17
GPS sampling interval = 1 hr.	21598	station 4 Lab	70 20:05	sank	70 21:00	100 18:00
	26366	station 7 Lab	73 20:29	sank	73 20:00	124 05:00
	26368	station 9 Lab	73 20:45	sank	73 21:00	89 21:00
	26370	station 8 Lab	73 20:45	sank	73 22:00	94 22:00
	26373	station 1 Lab	71 18:45	sank	71 20:00	85 18:00
	26374	station 6 Lab	73 19:30	sank	73 20:00	96 07:00
	26376	station 5 Lab	70 20:30	sank	70 21:00	96 20:00
	26377	station 11 GSL	61 15:29	sank	61 16:00	69 23:00
	26378	station 3 Lab	70 19:45	sank	70 20:00	82 06:00
	26379	station 2 Lab	70 19:08	sank	70 19:00	104 17:00
	26381	station 9 GSL	61 14:55	sank interpolated file*	61 15:00 62 00:00	88 11:00 88 00:00
	26382	station 5 GSL	60 16:10	sank	60 22:00	88 23:00
	26383	station 12 GSL	61 19:38	sank	61 20:00	88 08:00
	26384	station 10 GSL	61 15:14	sank interpolated file*	61 16:00 62 00:00	77 23:00 77 23:00
	26385	station 6 GSL	60 16:30	sank	60 18:00	82 23:00
	26386	station 8 GSL	60 20:00	sank	60 22:00	88 16:00
	26387	station 7 GSL	60 19:35	sank	60 22:00	88 13:00
	26388	station 16 GSL	65 16:00	sank	65 17:00	82 10:00

NOTES:

Gulf of St. Lawrence stations:

- **station 1**, west Northumberland Strait **45°22.52'N 64°14.37'W**
- **station 2**, 150 km N of Prince Edward Island **47°53.401'N 63°22.856'W**
- **station 3**, west Northumberland Strait **46°18.452'N 64°08.234'W**
- **station 4** **47°43.28'N 62°15.21'W**
- **station 5** **47°53.98'N 62°35.05'W**

- **station 6** **47°54.71'N** **62°51.45'W**
- **station 7** **48°09.0'N** **62°54.0'W**
- **station 8** **48°09.0'N** **62°35.0'W**
- **station 9** **47°54.0'N** **62°30.0'W**
- **station 10** **47°53.0'N** **62°36.0'W**
- **station 11** **47°50.0'N** **62°31.0'W**
- **station 12** **47°48.0'N** **62°35.0'W**
- **station 13**, 20 km W of Magdalen Islands **47°28.0'N** **62°05.0'W**
- **station 14**, area of Confederation Bridge **46°06.0'N** **63°39.0'W**
- **station 15**, west of Confederation Bridge **46°16.0'N** **63°48.0'W**
- **station 16**, area of Confederation Bridge **47°49.0'N** **62°20.0'W**
- **station 17**, area of Confederation Bridge **47°44.0'N** **61°52.0'W**
- **station 18**, north of Prince Edward Island **46°46.9'N** **63°22.9'W**
- **station 19**, offshore of Magdalen Islands **47°28.0'N** **61°54.0'W**

Labrador stations:

- **station 1**, landfast calibration line, Packs Harbour north of Huntingdon Island **53°51.67'N** **56°59.55'W**
- **station 2** **54°03.42'N** **55°27.27'W**
- **station 3** **54°03.58'N** **55°27.24'W**
- **station 4** **54°04.18'N** **55°28.88'W**
- **station 5** **54°04.32'N** **55°22.63'W**
- **station 6** **54°40.33'N** **56°20.04'W**
- **station 7** **54°42.97'N** **56°22.30'W**
- **station 8** **54°39.54'N** **56°12.66'W**
- **station 9** **54°37.27'N** **56°23.31'W**
- **Table Bay** **53° 28.24'N** **56° 25.40'W**
    - **Station 14.4**, black, landfast ice
    - **station 14.5**, bright, thin, landfast ice, 100 m NE of site
    - **station 14.6**, black, landfast ice 5 km NE of station 14.5
    - **station 14.7**, black, thin, landfast ice, 5 km NE of station 14.5
- **calibration line** **53°52.68'N** **56°59.51'W**
    - **station 15.8**, N of calibration line
    - **station 15.9**, NW of calibration line
- **station 15.10**, strand station, dull, landfast area **53°53.33'N** **56°09.85'W**
- E of Huntingdon Island **53°45.75N** **56°51.28'W**
    - **station 15.11**, dull, landfast area
    - **station 15.12**, bright band against thick ice
- **station 15.13**, 2nd calibration line E of Huntingdon Island, dull, landfast area **53°53.81'N** **53°44.73'W**
- **station 18.1**, off Spotted island **53°36.14'N** **55°33.84'W**
- **CTD station 1**, Hamilton Bank **54°08.84'N** **54°57.74'W**
- **CTD station 2**, Hamilton Bank **54°03.47'N** **55°05.91'W**
- **CTD station 3**, Hamilton Bank **53°59.90'N** **55°20.29'W**
- **CTD station 4**, 60 km off Grady Island **53°56.30'N** **55°36.97'W**
- **CTD station 5**, 40 km off Grady Island **53°53.03'N** **55°55.31'W**
- **CTD station 6**, 20 km off Grady Island **53°50.44'N** **56°08.27'W**

Table 6.3 Summary of 1997 ARGOS beacon data (Labrador (Lab) and Gulf of St. Lawrence (GSL))

TYPE OF BEACON	ID	DEPLOYMENT LOCATION	POWER-ON or DEPLOYMENT TIME (GMT)	SHUT-OFF or RECOVERY TIME (GMT)	DATA START (GMT)	DATA END (GMT)
pressure (uni-axial)	22192	station 25-1 GSL	56 19:20	71 sank	56 20:20	71 17:20
sampling interval =	02361	station 5-2 C Lab	64 18:25	sank	65 08:25	94 12:25
1 hr.	02362	station 5-1 C Lab	64 14:25	sank	65 02:25	68 00:25
pressure (tri-axial)	00976	station 5-2 C Lab	64 18:20	sank	65 07:20	78 09:20
sampling interval =	01053	station 5-1 C Lab	64 14:35	sank	65 01:35	67 23:35
1 hr.	01055	station 25-1 GSL station 12-1 GSL	56 19:20	71 removed	56 20:20	71 17:20
basic beacon	02363	station 17-2 GSL	76 22:15	unknown	79 23:18	120 10:11
sampling interval = per ARGOS pass	04765	GSL	70 13:20	unknown	70 13:27	79 13:31
atmospheric sampling interval = 1 hr.	04770	station 25-6 GSL	56 20:50	unknown	56 21:24	78 23:38
GPS	00968	station 21-2 GSL station 26-1 GSL	52 15:10 57 17:00	57 14:00 sank	52 14:00 57 20:00	57 14:00 65 23:00
sampling interval = 1 hr.	00970	station 25-3 GSL	56 19:20	sank	56 20:00	66 06:00
	00971	station 25-4 GSL	56 19:20	sank	56 21:00	72 17:00
	00972	station 20-1 GSL station 26-2 GSL	52 14:00 57 17:00	57 14:00 sank	52 15:00 57 21:00	57 14:00 72 07:00
	00973	station 25-2 GSL	56 19:20	sank	56 21:00	66 06:00
	00974	station 28-1 GSL	59 13:45	70 19:30	59 14:00	70 19:00
	05215	station 5-2 E Lab	64 17:40	sank	64 18:00	105 22:00
	05216	station 5-2 W Lab	64 17:35	sank	64 18:00	97 17:00
	05217	station 5-2 C Lab	64 17:15	sank	64 18:00	100 09:00
	05218	station 5-2 N Lab	64 17:50 interpolated file*	sank N/A	64 19:00 65 00:00	130 22:00 130 22:00
	10053	station 5-1 W Lab	64 13:30	sank	64 15:00	75 23:00
	26367	station 5-2 S Lab	64 18:00 interpolated file*	sank N/A	64 18:00 65 00:00	73 06:00 73 00:00
	26368	Lab (northern)	62 17:06	unknown	87 00:00	91 18:00
	26369	station 5-1 S Lab	64 14:30 interpolated file*	sank N/A	65 16:00 65 00:00	106 21:00 109 18:00
	26370	Gulf 3 GSL	55 16:00	sank	55 19:00	81 17:00
	26371	station 5-1 E Lab	64 15:00	sank	64 15:00	117 05:00
	26372	station 5-1 N Lab	64 14:30	sank	64 15:00	120 16:00
	26373	station 5-1 C Lab	64 15:10	sank	64 15:00	67 08:00
	26374	Gulf 1 GSL	55 16:00 interpolated file*	sank N/A	insufficient 56 00:00	insufficient 75 21:00
	26375	station 25-5 GSL	56 20:20 interpolated file*	57 20:10 N/A	57 13:00 57 07:00	64 18:00 64 18:00

TYPE OF BEACON	ID	DEPLOYMENT LOCATION	POWER-ON or DEPLOYMENT TIME (GMT)	SHUT-OFF or RECOVERY TIME (GMT)	DATA START (GMT)	DATA END (GMT)
GPS	26376	GSL	49 22:20	unknown	49 21:00	114 20:00
sampling interval = 1 hr.	26378	Lab (northern)	62 17:10	N/A N/A unknown	79 22:00 86 19:00 89 17:00	80 11:00 89 15:00 91 13:00
	26379	station 20-1 GSL Gulf 2 GSL	51 21:45 55 18:15	52 removed sank	52 01:00 55 18:00	52 13:00 72 20:00
	26380	station 25-1 GSL	56 18:20	57 removed	no data	no data
	26382	Lab (northern)	unknown unknown	unknown unknown	86 18:00 89 18:00	89 16:00 91 13:00
	26383	Lab (northern)	unknown	unknown	87 20:00	91 14:00
	26384	station 19-1 GSL	78 14:45 interpolated file*	unknown N/A	78 15:00 79 00:00	111 11:00 111 00:00
	26385	Gulf 5 GSL	77 20:55	unknown	77 21:00	91 22:00
	26386	Gulf 4 GSL	77 15:05	unknown	77 15:00	105 04:00
	26387	Lab (stationary)	unknown	unknown	49 20:00	107 13:00
	26388	Lab (northern)	unknown interpolated file*	unknown N/A	87 19:00 88 00:00	91 10:00 91 14:00

NOTES:

Gulf of St. Lawrence stations:

- **station 20-1**, Feb. 20, IOS test station **46°16.85'N 64°14.37'W**
- **station 21-2**, Feb. 21, DREP-N station
- **station 23-1**, Feb. 23, landfast ice Cape Gage **46°58.878'N 64°12.415'W**
- **Gulf 1**, station 24-1, Feb. 24 **46°50.0'N 62°00.0'W**
- **Gulf 2**, station 24-2, Feb. 24 **48°10.0'N 61°40.0'W**
- **Gulf 3**, station 24-3, Feb. 24 **47°30.0'N 63°00.0'W**
- **Gulf 4**, station 18-1, Mar. 18 **47°31.0'N 63°15.0'W**
- **Gulf 5**, station 18-2, Mar. 18 **48°06.4'N 62°09.3'W**
- **station 25-1**, Feb. 25, pressure station, center **46°56.65'N 64°17.37'W**
    - **station 26-1**, Feb. 26, pressure station, on the move **46°57.20'N 64°17.35'W**
    - **station 12-1**, Mar. 12, ice pressure beacons, on the move
  - **station 25-2**, W-GPS, 2.5 km west of center
  - **station 25-3**, N-GPS, 2.6 km north of center **46°59.43'N 64°17.13'W**
  - **station 25-4**, S-GPS, 2.7 km south of center
  - **station 25-5**, Feb. 25, E-GPS, 2.1 km east of center **46°58.87'N 64°14.42'W**
    - **station 26-2**, Feb. 26, E-GPS
- **station 25-6**, Feb. 25, atmospheric station on inshore landfast ice **46°55.77'N 64°12.19'W**
  - **station 11-2**, Mar. 11, atmospheric station on the move
- **Strait 1** **46°53.55'N 64°15.05'W**
  - station 28-1, Feb. 28, IOS acoustic station on landfast ice Cape Gage
  - station 11-1, Mar. 11, IOS acoustic station on the move
  - station 17-2, Mar. 17, west of Confederation Bridge
- **station 17-1**, Mar. 17, calibration lines, Point Prim
  - Mar. 17 **46°02.146'N 62°57.326'W**
  - Mar. 19 **46°02.149'N 62°57.316'W**
  - Mar. 23 **46°02.154'N 62°57.335'W**
- **station 19-1**, Mar. 19, ice rubble field **47°07.3'N 62°44.1'W**
  - Mar. 20 **46°57.0'N 62°38.9'W**

- Mar. 20 **46°56.0'N** **62°34.5'W**
- **station 19-2**, Mar. 19, Ainslie Lake, Cape Breton Island **46°10.0'N** **61°15.0'W**
- **station 21-1**, Mar. 21, pack-ice **46°40'N** **62°30'W**
- **station 22-1**, Mar. 22, Tracadie Bay **46°27.2'N** **62°48.9'W**
- **station 24-1**, Mar. 24, Tracadie Bay **46°26.2'N** **62°55.2'W**
- **station 25-1**, Mar. 25, calibration line, landfast ridge off Tracadie Bay **46°26.05'N** **62°5.36'W**

Labrador stations:

- **station 5-1,** center **54°06.27'N** **55°23.89'W**
    - **W-GPS**, 2.31 km west of center
    - **N-GPS**, 2.04 km north of center
    - **S-GPS**, 2.01 km south of center
    - **E-GPS**, 2.11 km east of center
- **station 5-2**, center **54°25.804'N** **55°59.051'W**
    - **W-GPS**, 2.1 km west of center
    - **N-GPS**, 2.1 km north of center
    - **S-GPS**, 2.21 km south of center
    - **E-GPS**, 2.1 km east of center
- **CTD 1** **54.1450°N** **54.8695°W**
- **CTD 2** **54.0811°N** **55.0935°W**
- **CTD 3** **54.0115°N** **55.3030°W**
- **CTD 4** **53.9668°N** **55.5706°W**
- **CTD 5** **53.8913°N** **55.8305°W**
- **CTD 6** **53.8593°N** **56.0278°W**
- **CTD 7** **53.8005°N** **56.2312°W**

Table 6.4 Summary of 1998 ARGOS beacon data (Labrador (Lab) and Gulf of St. Lawrence (GSL))

TYPE OF BEACON	ID	DEPLOYMENT LOCATION	POWER-ON or DEPLOYMENT TIME (GMT)	SHUT-OFF or RECOVERY TIME (GMT)	DATA START (GMT)	DATA END (GMT)
pressure (uni-axial) sampling interval = 1 hr.	00978	station 7.6 Lab	66 20:30	N/A	66 14:39	89 02:39
	01053	station 23.1 GSL	54 15:07	removed	54 16:07	83 15:07
	04768	station 7.1 Lab	66 17:00	N/A	no data	no data
	22191	station 22.2 GSL	53 15:45	N/A	59 13:45	74 17:45
pressure (tri-axial) sampling interval = 1 hr.	00977	station 7.1 Lab	66 17:00	N/A	66 18:00	83 13:00
	01055	station 22.2 GSL	53 15:45	N/A	53 17:45	74 18:45
	02362	station 7.6 Lab	66 20:30	N/A	66 22:30	89 00:30
	02364	station 23.1 GSL	53 15:07	removed	54 16:07	83 15:07
temperature chain sampling interval = 1 hr.	04764	station 7.6 Lab	66 20:30	N/A	67 00:28	89 02:24
GPS sampling interval = 1 hr.	00974	station 7.11 Lab	66	N/A	66 23:00	124 21:00
	02754	station 18.6 GSL	49 19:45	removed	49 19:00	55 19:00
	02755	station 18.4 GSL	49 19:20	sank	49 19:00	68 20:00
	02756	station 18.5 GSL	49 19:35	N/A	49 19:00	95 08:00
	02757	station 18.7 GSL	49 20:10	sank	no data	no data
	03121	station 22.5 GSL	53 17:00	sank	53 17:00	85 16:00
	03122	station 22.5 GSL	53 17:00	N/A	53 17:00	92 23:00
	03123	station 22.3 GSL	53 17:00	sank	53 17:00	57 00:00
	03124	station 22.2 GSL	53 15:45	N/A	53 15:00	100 12:00
	04457	station 23.4 GSL	54 18:44	sank	54 18:00	63 12:00
	04458	station 20.3 GSL	51 19:30	N/A	51 20:00	92 13:00
	04459	station 20.2 GSL	51 19:15	sank	51 20:00	73 20:00
	08537	station 7.3 Lab	66 19:00	N/A	66 19:00	117 17:00
	08538	station 7.5 Lab	66 19:20	N/A	66 20:00	89 22:00
	08539	station 7.2 Lab	66 18:50	N/A	66 18:00	117 00:00
	08540	station 7.6 Lab	66 20:30	sank	66 20:00	84 16:00
	08541	station 23.1 GSL	54 15:07	removed	54 15:00	83 14:00
	08542	station 23.3 GSL	54 15:29	removed	54 15:00	83 13:00
	08543	station 23.2 GSL	54 15:15	N/A	54 15:00	94 14:00
	08545	station 7.4 Lab	66 19:10	N/A	66 19:00	113 22:00
	08546	station 7.1 Lab	66 17:00	N/A	66 19:00	113 00:00
	10055	station 7.7 Lab	66 20:30	N/A	66 20:00	104 22:00
	10056	station 7.8 Lab	66 20:30	N/A	66 21:00	122 23:00
	10057	station 7.9 Lab	66 20:30	N/A	66 22:00	108 11:00
	10058	station 7.10 Lab	66 20:30	N/A	66 21:00	96 09:00
	26368	station 11.1 GSL	70	sank	71 12:00	81 14:00
	26378	station 11.2 GSL	70	N/A	71 12:00 82 19:00	82 16:00 94 20:00
	26380	station 14.1 GSL	73	N/A	no data	no data
	26381	station 21.1 GSL	52 15:30	N/A	52 15:00	100 19:00
	26382	station 11.3 GSL	70	N/A N/A	72 19:00 84 01:00	74 17:00 98 15:00
	26383	station 11.3 GSL	70	sank	70 20:00	81 19:00

NOTES:

Gulf of St. Lawrence stations:

- **station 17.1**, landfast ice off Cape Gage **46°53.85'N 64°14.87'W**
- **station 18.2**, pack-ice off Cape Gage **46°57.71'N 64°21.99'W**
- **station 18.3**, pack-ice off Cape Gage **46°57.39'N 64°24.63'W**
- **station 18.4**, pack-ice in Northumberland Strait, NW of Confederation Bridge **46°17.10'N 63°50.14'W**
- **station 18.5**, pack-ice in Northumberland Strait**,** SW of Confederation Bridge **46°14.5'N 63°53.00'W**
- **station 18.6**, pack-ice in Northumberland Strait, SE of Confederation Bridge **46°07.44'N 63°41.03'W**
- **station 18.7**, pack-ice in Northumberland Strait, NE of Confederation Bridge **46°10.54'N 63°38.77'W**
- **station 20.1**, calibration line in Hillsborough Bay **46°05.1'N 63°02.9'W**
    - **station 22.1**, calibration line on 53 at 14:30 GMT
    - **station 22.6**, calibration line on 53 at 20:00 GMT
- **station 20.2**, pack-ice in Northumberland Strait, NE of Confederation Bridge **46°07.95'N 63°35.04'W**
- **station 20.3**, pack-ice in Northumberland Strait, SE of Confederation Bridge **46°05.27'N 63°37.34'W**
- **station 21.1**, pack-ice off Cape Gage **46°59.14'N 64°36.53'W**
- **station 21.2**, pack-ice off N coast of PEI (temporary landfast ice) **46°27.5'N 62°56.4'W**
- **station 22.2**, ice pressure station 1 **46°41.47'N 64°30.92'W**
    - **station 22.3**, N corner of triangle **46°43.76'N 64°32.49'W**
    - **station 22.4**, SE corner of triangle **46°40.18'N 64°26.79'W**
    - **station 22.5**, SW corner of triangle **46°38.57'N 64°33.93'W**
- **station 23.1** ice pressure station 2 **46°29.46'N 64°23.13'W**
    - **station 23.2**, N corner of triangle **46°32.06'N 64°23.59'W**
    - **station 23.3**, SW corner of triangle **46°26.31'N 64°25.39'W**
    - **station 23.4**, SE corner of triangle **46°29.31'N 64°19.06'W**
- **station 11.1,** seal herd N of North Point
- **station 11.2**, seal herd N of North Point
- **station 11.3**, seal herd N of Summerside
- **station 14.1**, pancake ice rubble N of North Point
- **station 18.1**, calibration line SE of Point Egmont **46°19.91'N 64°04.5'W**

Labrador stations:

- **station 7.1**, southern pressure station, center **53°44.078'N 55°38.263'W**
    - **station 7.2**, NE GPS, 50°mag., 2.1 mi. from center
    - **station 7.3**, SE GPS, 140°mag., 2.2 mi. from center
    - **station 7.4**, SW GPS, 230°mag., 2.1 mi. from center
    - **station 7.5**, NW GPS, 320°mag., 2.2 mi. from center
- **station 7.6**, northern pressure station, center **54°44.20'N 56°25.0'W**
    - **station 7.7**, NW GPS, 320°mag., 2.1 mi. from center
    - **station 7.8**, SE GPS, 140°mag., 2.2 mi. from center
    - **station 7.9**, NE GPS, 50°mag., 2.1 mi. from center
    - **station 7.10**, SW GPS, 230°mag., 2.2 mi. from center
- **station 7.11**, ice drift station inshore of station 7.6 **54°06.0'N 56°36.0'W**
- **CTD 4**, Hamilton Bank, Mar. 6 **53°58.373'N 55°43.64'W**
- **CTD 5**, Hamilton Bank, Mar. 6 **53°54.02'N 55°51.87'W**
- **CTD 6**, Hamilton Bank, Mar. 6 **53°50.73'N 56°03.33'W**
- **CTD 7**, Hamilton Bank, Mar. 6 **53°48.44'N 56°11.55'W**
- **CTD 2479**, ice melt beacon, Hamilton Bank, Mar. 7 **53°42.73'N 55°40.317'W**

- **CTD 2374**, ice melt beacon, Hamilton Bank, Mar. 7 **54°09.16'N** **56°02.5'W**

7 FIGURES

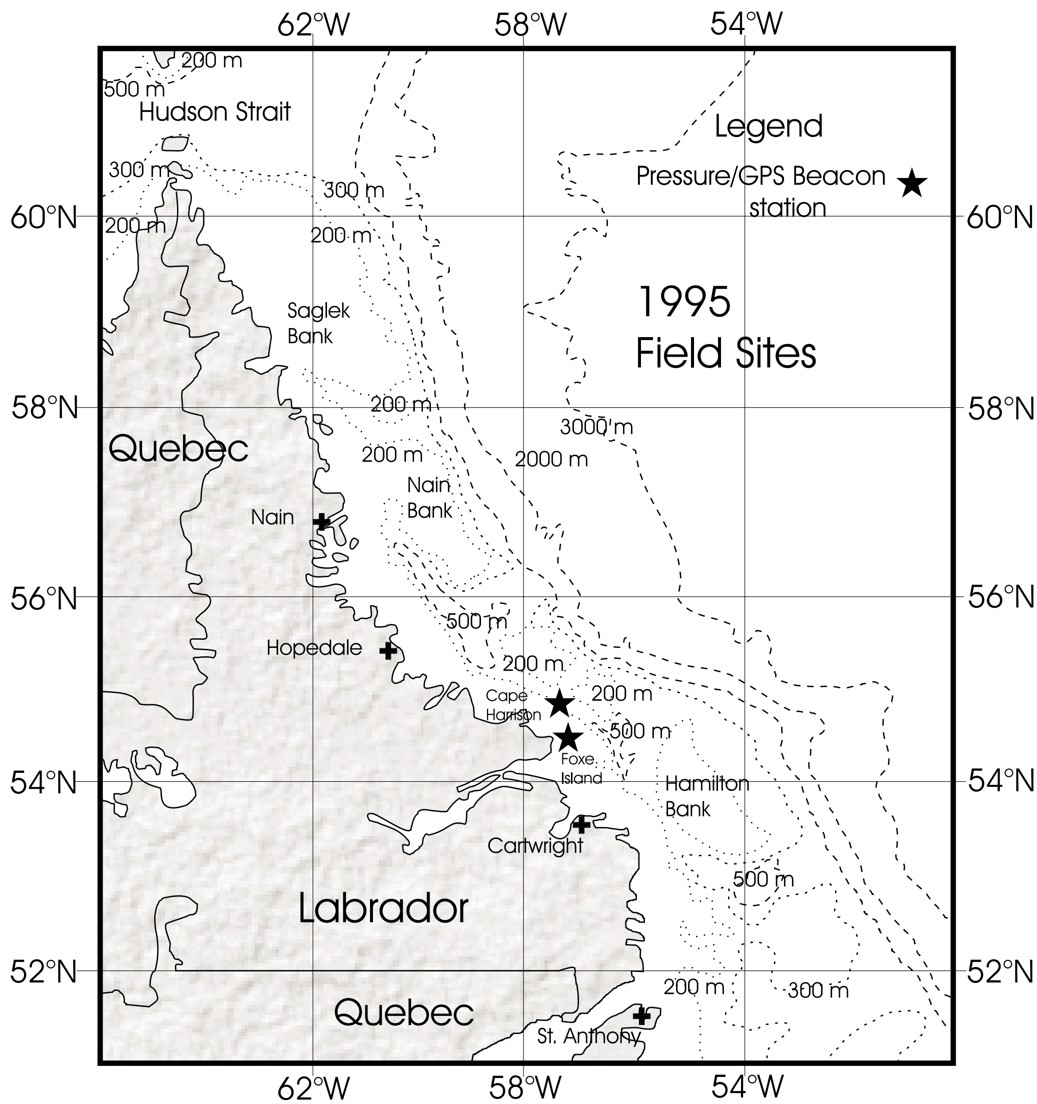

Figure 7.1 1995 Labrador station locations

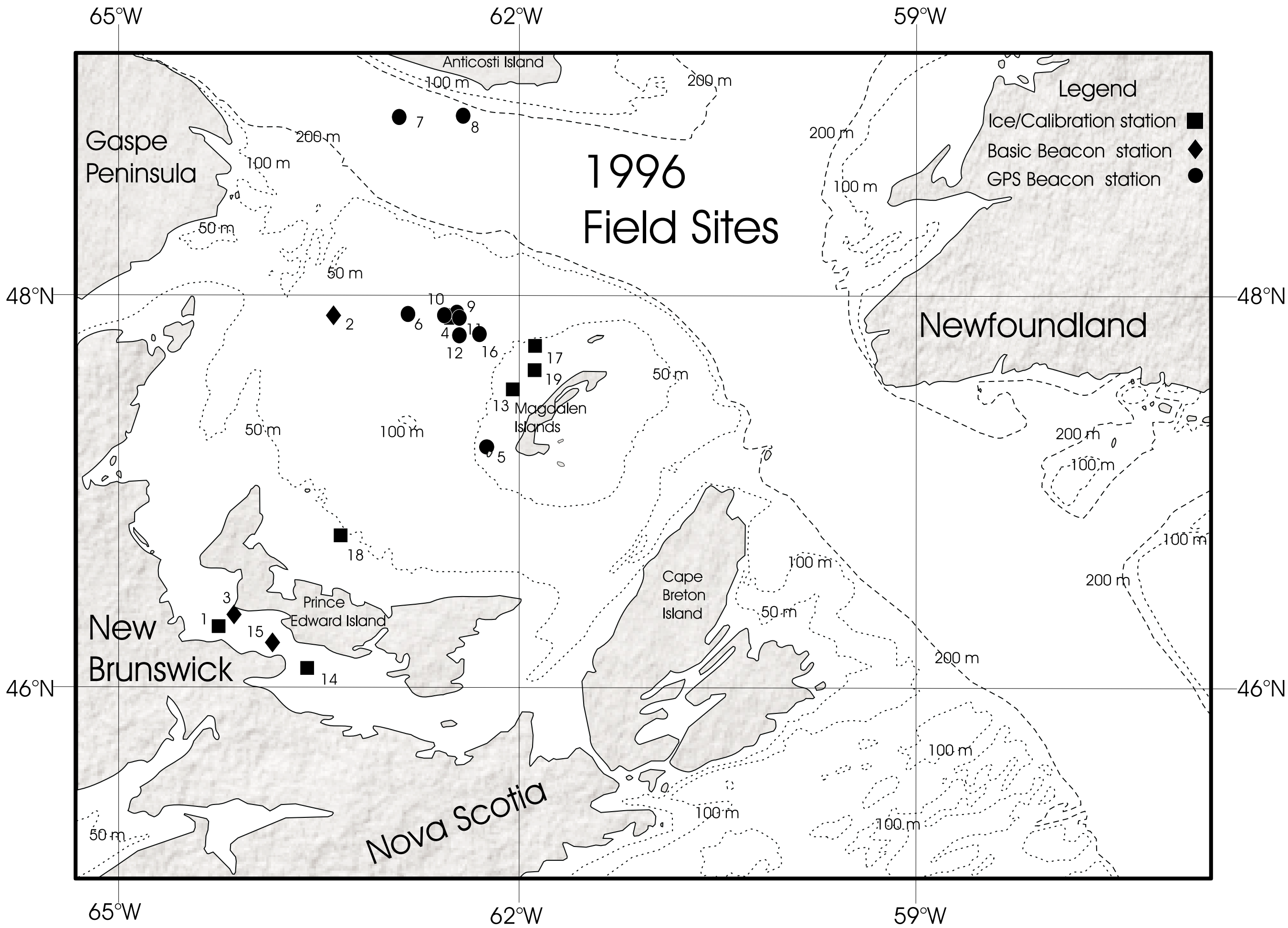

Figure 7.2 1996 Gulf of St. Lawrence station locations

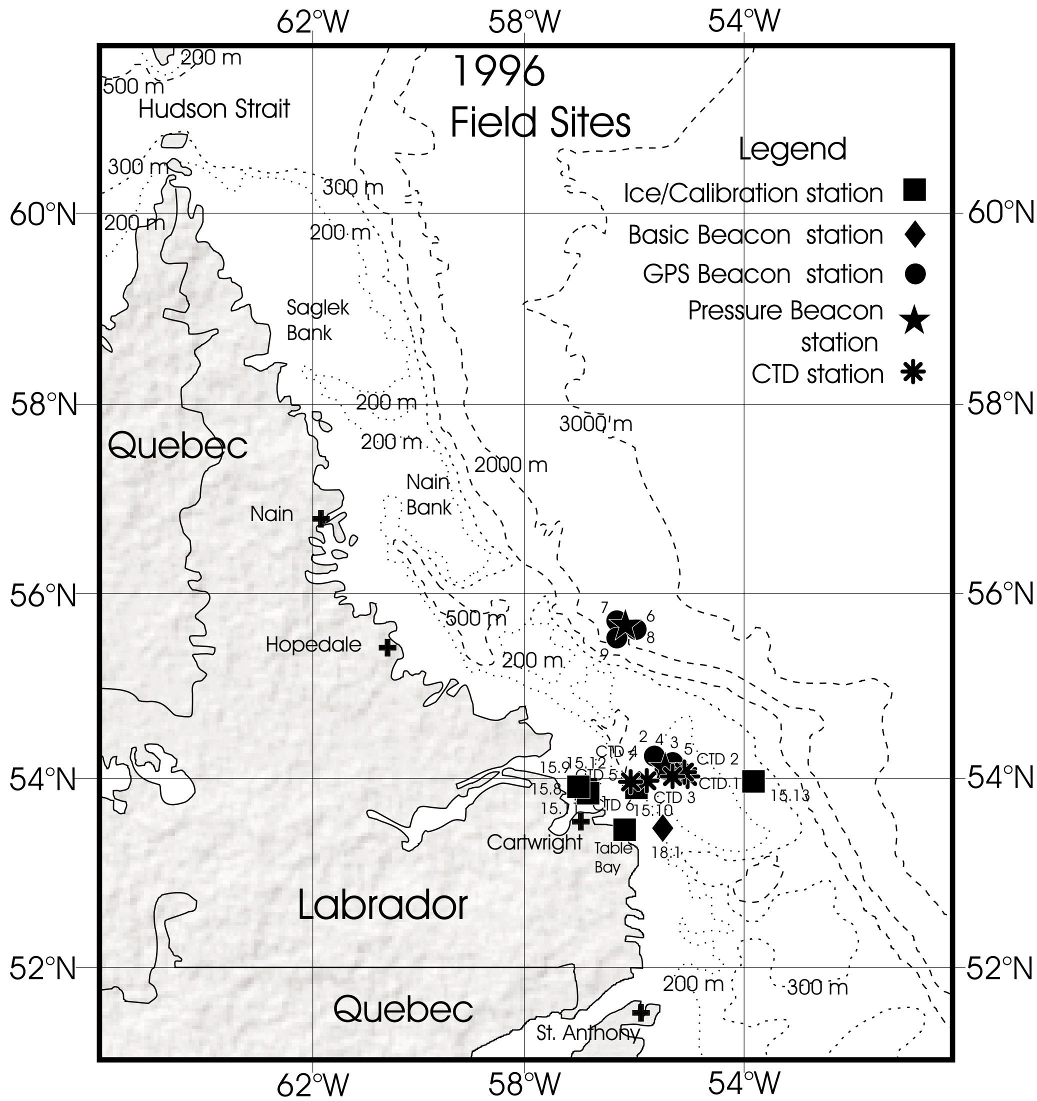

Figure 7.3 1996 Labrador station locations

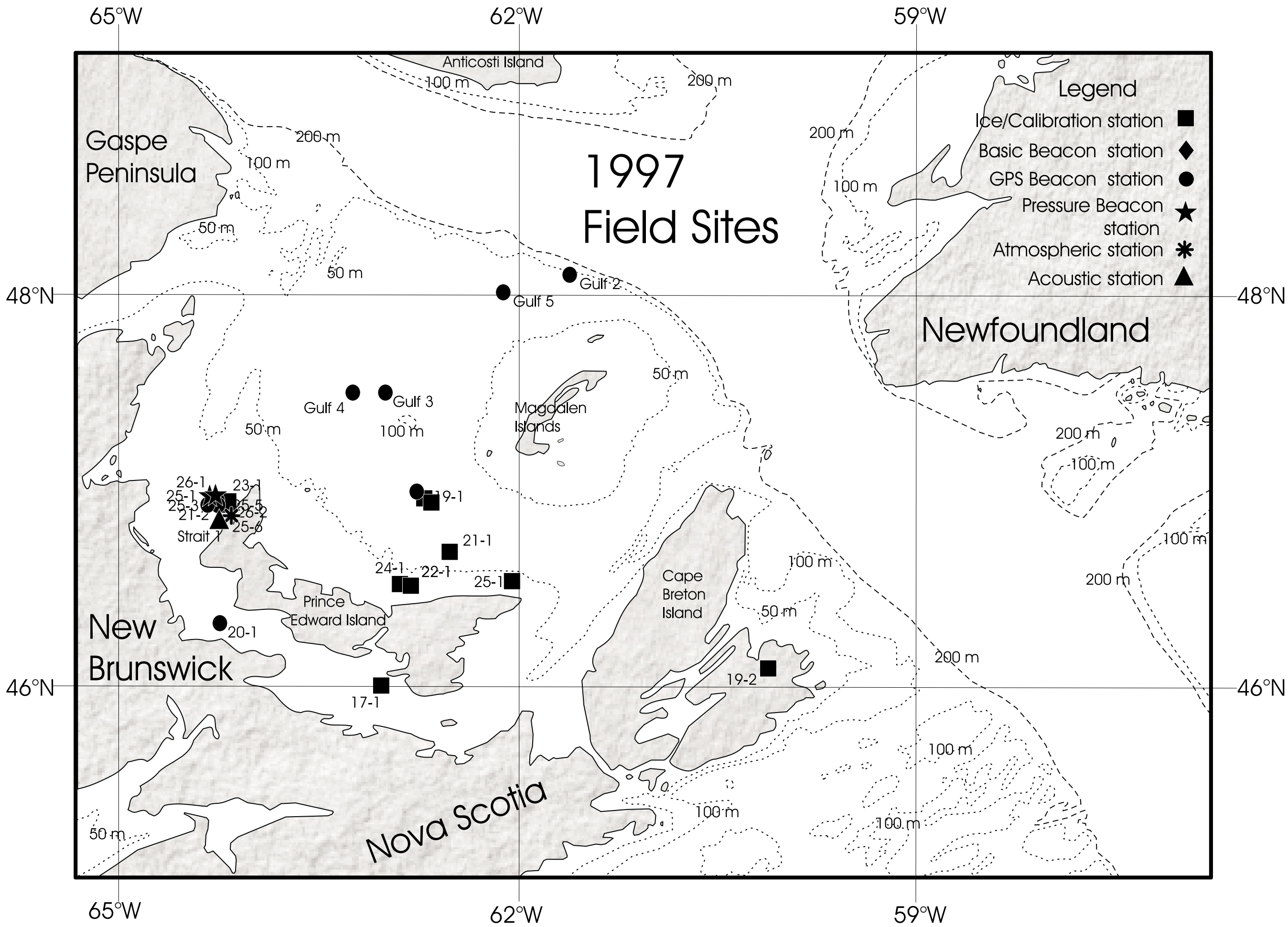

Figure 7.4 1997 Gulf of St. Lawrence station locations

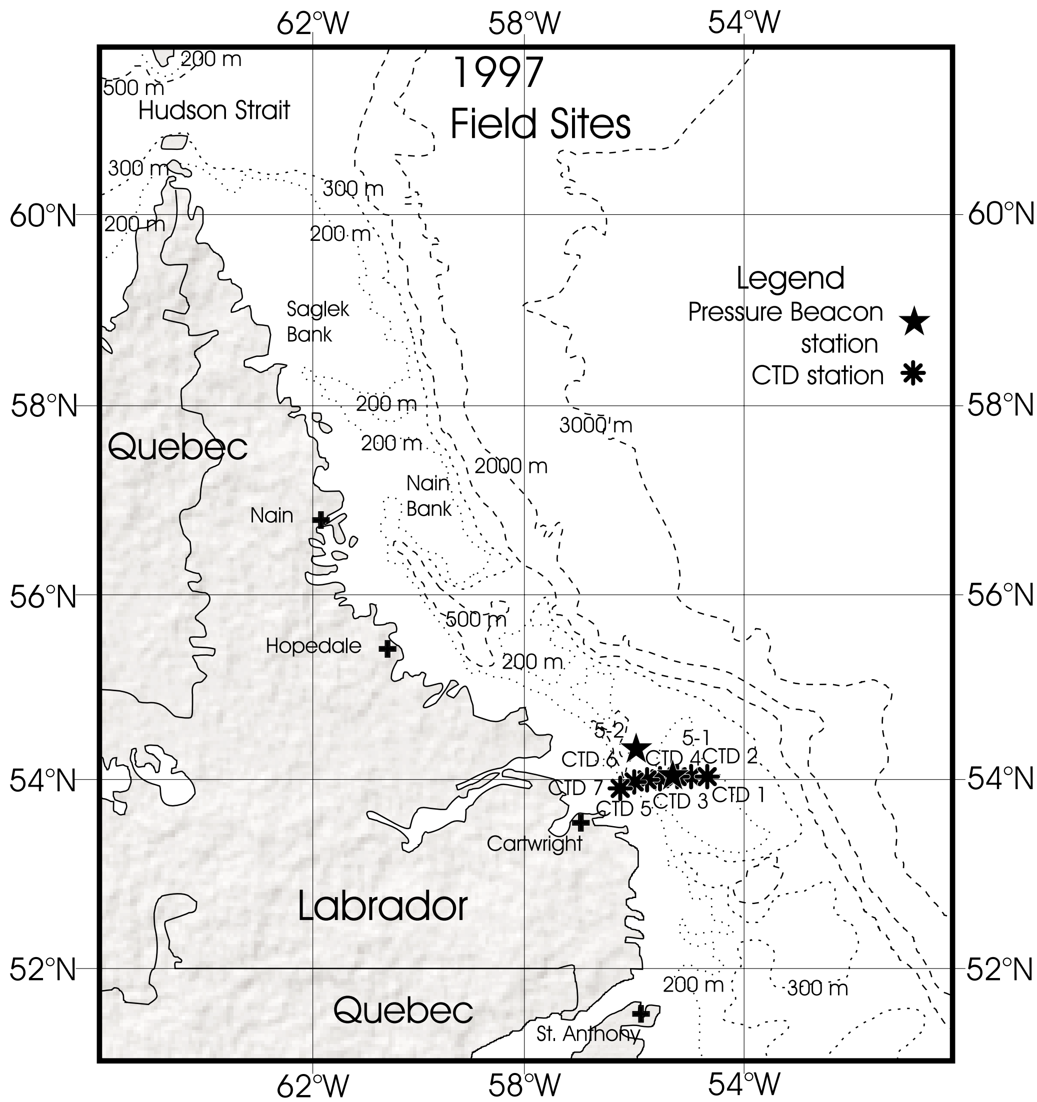

Figure 7.5 1997 Labrador station locations

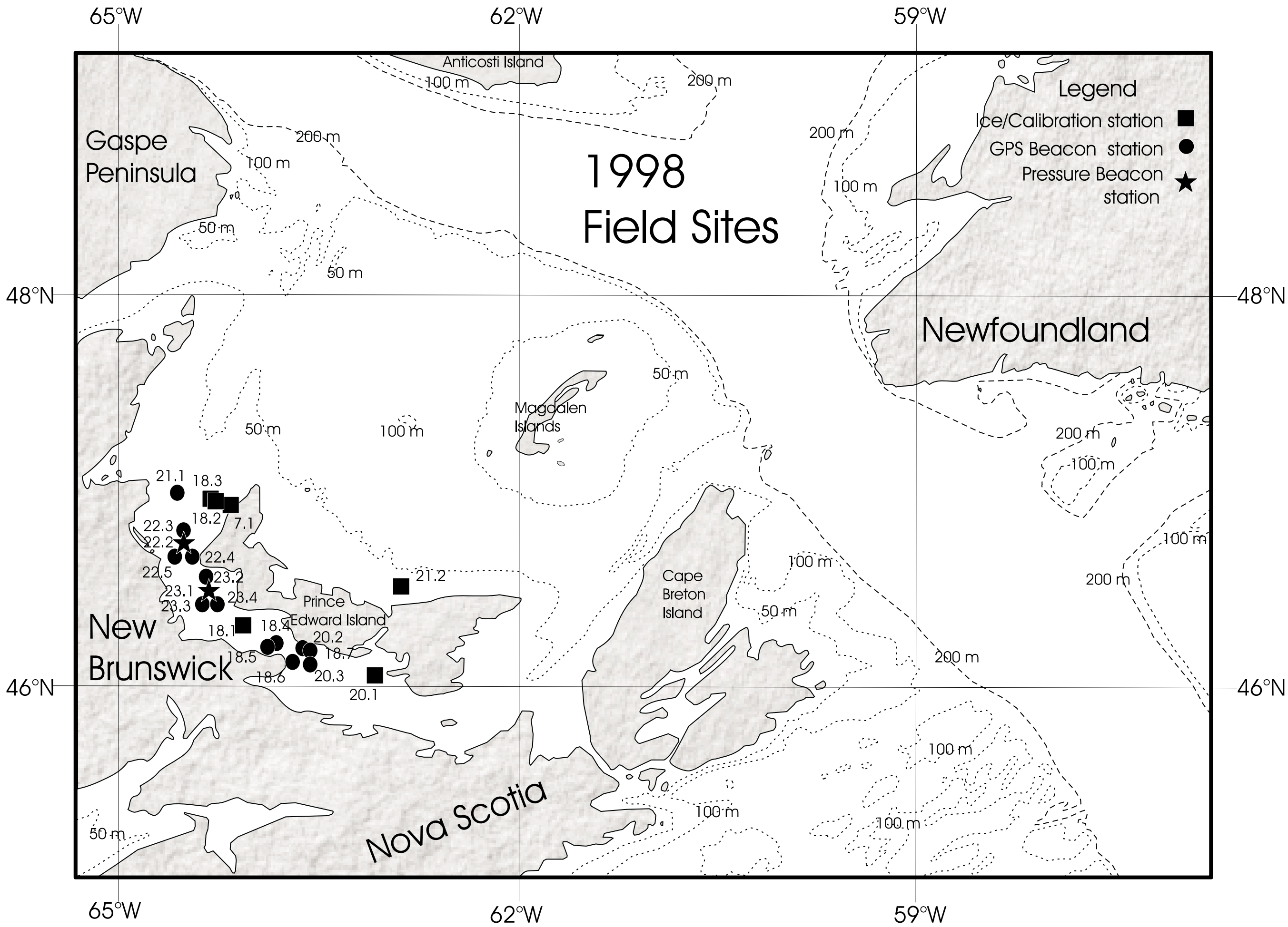

Figure 7.6 1998 Gulf of St. Lawrence station locations

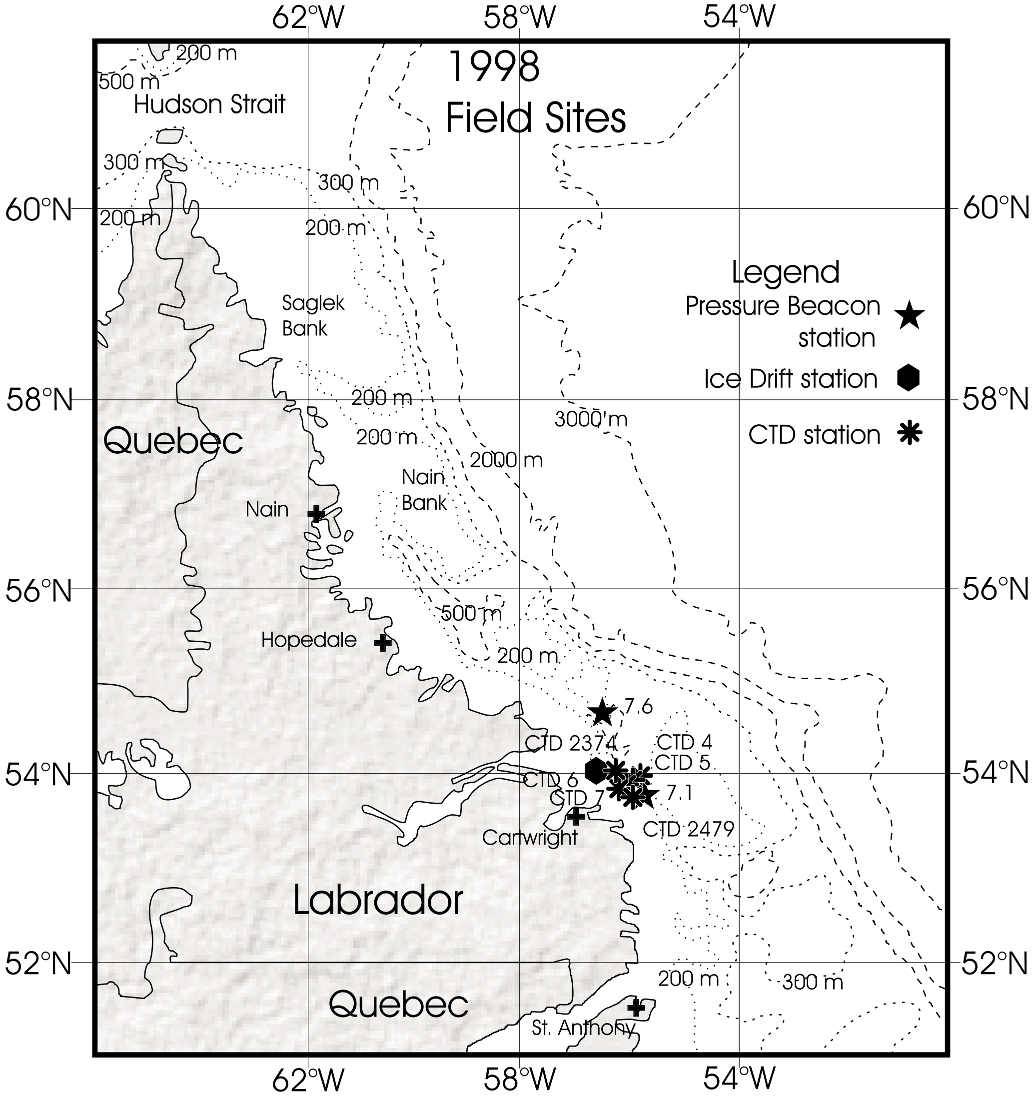

Figure 7.7 1998 Labrador station locations