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Airborne Electromagnetic Sea Ice Sounding Measurements During 1997 Gulf of St. Lawrence Field Program

by

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Abstract

Holladay, J.S. and S.J. Prinsenberg, 1999. Airborne Electromagnetic Sea Ice Sounding Measurements during 1997 Gulf of St. Lawrence Field Program. Can. Contract. Rep. Hydrogr. Ocean Sci. 52: vi + 45p.

The principal focus of the 1997 Gulf of St. Lawrence airborne field program was on testing and evaluation of the Coast Guard Electromagnetic Ice Sounder and snow radar sensors. The bird had been completely rebuilt following an accident during the 1996 field program in Labrador, and required re-calibration and further adjustment before it was ready for routine service. A small number of flights were executed to support other field data acquisition activities, including one long offshore survey traverse in the Southern Gulf and another in the Northumberland Strait, as well as profiling of a ridge site just north of Tracadie Bay. A total of approximately 100km of data were acquired during these offshore flights.

Laser altimeter glitches present in the 1997 raw data were removed in post-processing for this report, eliminating virtually all laser-induced spikes in ice thickness. The data were also re-calibrated based on repeated runs over surface measurement lines and re-inverted for this report, because the calibration performed in the field was incorrectly executed. The real-time results obtained during the field program had been underestimated by about 0.15 m due to this error. The corrected calibration yields mean snow-plus-ice thicknesses which agree with mean surface measurements within 0.02 m, well within the system's nominal level-ice accuracy of 0.05 m and the 0.06 m standard deviation of the surface data.

Résumé

Holladay, J.S. and S.J. Prinsenberg, 1999. Airborne Electromagnetic Sea Ice Sounding Measurements during 1997 Gulf of St. Lawrence Field Program. Can. Contract. Rep. Hydrogr. Ocean Sci. 52: vi + 45p.

Le programme d'observation aéroporté des glaces du golfe du Saint-Laurent 1997 était axé essentiellement sur les essais et l'évaluation du système de détection des glaces électromagnétique et des détecteurs radars de neige de la Garde côtière. La torpille de détection avait été complètement reconstruite à la suite d'un accident survenu au cours des opérations sur le terrain de 1996 au Labrador, qui a nécessité une vérification de l'étalonnage et des ajustements avant qu'elle puisse être utilisée de nouveau. On a effectué un nombre restreint de vols pour soutenir d'autres activités d'acquisition de données sur le terrain, y compris un long trajet d'acquisition de données extracôtier dans la partie sud du golfe et un autre au-dessus du détroit de Northumberland, ainsi qu'une mission de profilage d'une crête située juste au nord de la baie de Tracadie. En tout, environ 100 km de données ont été saisies dans le cadre de ces vols extracôtiers.

Des erreurs engendrées par l'altimètre laser et relevées dans les données brutes de 1997 ont été enlevées au cours du post-traitement avant la préparation de ce rapport, ce qui a permis d'éliminer presque tous les pics produits par le laser dans les données sur l'épaisseur des glaces. Les données ont également fait l'objet d'une vérification d'étalonnage en fonction de nouveaux sondages effectués au-dessus des lignes de surface, et elles ont été inversées de nouveau aux fins du présent rapport, puisque l'étalonnage effectué sur le terrain a été mal exécuté. Les données en temps réel saisies dans le cadre des opérations sur le terrain avaient donné lieu à une sous-estimation de 0,15 m en raison de cette erreur d'étalonnage. Les données corrigées indiquent que l'écart entre l'épaisseur de la neige et de la glace observée et les mesures à la surface est inférieur à 0,02 m, un écart qui se situe bien à l'intérieur de l'exactitude nominale du système pour les glaces uniformes, qui est de 0,05 m, et de l'écart-type de 0,06 m par rapport aux données saisies à la surface.

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1 Introduction

The 1997 Gulf of St. Lawrence field program began on March 17 and continued to March 27. This was the first field test of the airborne Electromagnetic Ice Sounder (EIS) sensor bird, also known as the ice probe, which had been severely damaged when it was dropped from a helicopter off Labrador during the 1996 field program (Moucha *et al*, 1998). An additional factor was the inclusion of a 500 MHz snow thickness radar transceiver, which had been tested during the 1992 St. Anthony field program (Holladay, 1995), had been upgraded and installed inside the bird. The bird's software and hardware had been altered after the bird was repaired in order to facilitate the real-time acquisition of snow depths while performing EIS profiling. The snow radar program has been described in Lalumiere (1998) and will not be addressed directly in this report.

Airborne EIS measurements were obtained over the Northumberland Strait and southern Gulf during a series of flights by CCG helicopter CG353. Surface activities, including GPS/ARGOS beacon emplacement and retrieval, preparation of marked lines for test and calibration purposes, and sampling for ice salinity were conducted using other CCG helicopters.

The methodology used during this program was based on procedures developed during field work and data analysis for programs in 1994, 1995 and 1996, as described in Holladay and Moucha, (1998), Holladay *et al*, (1998), and Moucha *et al*, (1998).

The Canadian Coast Guard airborne Electromagnetic Ice Sounder used during this field program was described in Holladay *et al*, (1998). It was towed beneath a Coast Guard MBB B0105 helicopter, CG353, piloted by Ron Moores.

This was the last BIO field program conducted with the assistance of Aerodat Inc. In late November 1997, Aerodat was placed in receivership, and was declared bankrupt in May, 1998.

This report begins with a summary of field personnel and operations, describes the 1997 EIS data set, and concludes with an assessment of system performance and calibration.

2 Field Program

Objectives

The 1997 field program had the following objectives:

1. Test and evaluate the EM sensor bird repairs performed since the 1996 accident.
2. Test and evaluate the snow radar sensor installed within the EM sensor bird.
3. Provide ice thickness data for other BIO field programs in the Gulf where possible.
4. Provide further training in EIS operation for Coast Guard and CIS personnel.

As can be seen from the above list of objectives, the principal activity during 1997 was test and evaluation rather than the acquisition of large EIS data sets.

Personnel:

Aerodat Inc.

- RZM Robert Z. Moucha (contractor to Aerodat)
- JL James Lee (EM engineer)
- LL Louis Lalumiere (Snow radar project leader)
- JY Jim Yee (software engineer, primarily snow radar support)
- SP Santanu Paul (software engineer, snow radar support)

Bedford Institute of Oceanography

- SP Simon Prinsenberg (Principal Investigator)
- GF George Fowler (Ice Pressure engineer)

Canadian Coast Guard

- AM André Maillet (Ice operations chief)
- RM Clifford Sadler (pilot)
- IH Ian Henderson (Charlottetown helicopter engineer)

Daily EIS Field Activity Summary

Monday, 17 March

Weather: Clear, -5°C, wind 19 km/hr SW

EM Flight Files: none

Travelled from Toronto to Charlottetown

Tuesday, 18 March

Weather: Clear, -6 °C, wind15 km/hr NW

EM Flight Files: none

Initial set-up and debugging. Bird had not been flown since repairs completed.

Wednesday, 19 March

Weather: Clear, -9 °C, wind 18 km/hr SW

EM Flight Files: none

System debug continued.

Thursday, 20 March

Weather: Clear, -9 °C, wind 9 km/hr SW

EM Flight Files: 92

Initial series of test flights, including FLT092 calibration flight with EM, navigation operational. Extra wires were added to tow cable for snow radar tests in afternoon.

Friday, 21 March

Weather: Overcast, -4 °C, snow

EM Flight Files: 96-97

96: Point Prim test lines

97: Surveyed to floe in Gulf where test line had been set up.

Bird was damaged, apparently by static discharge in snow shower, during ferry (FLT098) at end of mission. Damage occurred to snow radar as well as EM.

Saturday, 22 March

Weather: Clear, -11 °C, wind 6 km/hr NW

EM Flight Files: none

Assessed damage to bird. Wiring changed for snow radar tests. Bird used for snow radar test flights. No EM flights.

Sunday, 23 March

Weather: Clear, -8 °C, wind 15 km/hr NW

EM Flight Files: test flights only.

Bird repairs. Test flights with EM and snow radar, then radar only.

Monday, 24 March

Weather: Clear, -10 °C, wind 19 km/hr W

EM Flight Files:

EM repairs. New laser altimeter spike rejection code added to bird program (not successful).

Tuesday, 25 March

Weather: Clear, -10 °C, wind 19 km/hr W

EM Flight Files: 14

Separate EM and radar test flights, including EM over calibration lines and over Tracadie Bay offshore ridge line.

Wednesday, 26 March

Weather: Clear, -8 °C, wind 15 km/hr W

EM Flight Files: 15 (abort)

Test EM over Point Prim line, FLT015, good real-time results but system improperly shut down, with loss of raw data file.

Thursday, 27 March

Weather: Snow/rain, 0 °C, wind SW

EM Flight Files: 16-17

FLT016: Short file over Point Prim site

FLT017: More passes over Point Prim site, then offshore in Strait.

3 Flight Summary

1997 flights are summarised in Table 3.1. The flights are listed by their file number and by the date of collection. A brief description for each flight file and the operator identification by initials for the flight are included. Files which were used for test purposes, snow radar acquisition, or were aborted, and which therefore could not be used for profile and map preparation are not listed. Statistical summary files for these flights may be found in Appendix B.

The snow radar transceiver was installed in the bird for all flights. This affected the bird's calibration substantially, as confirmed during analysis of the 1998 field results, which were obtained after the radar unit had been removed.

Errors in the interface software for the Optech Alpha laser altimeter, which replaced the IBEO PS100E destroyed during the 1996 bird drop, were responsible for severe spiking in bird altitude measurements and hence in estimated ice thickness when flown over open water, particularly small patches of water with smooth surfaces. This effect was caused by poor signal return due to specular reflection of the laser beam from the water surface.

The altimeter appeared to perform accurately and reliably in all other respects. An unsuccessful attempt to correct the laser interface software was made by Jim Yee on March 24. However, the problem was not solved until the 1998 field program, when James Lee was able to analyse and correct the problem. De-spiking techniques developed during the 1998 field program have been applied in post-processing to eliminate the effects of these spikes.

For flights from 21 March through 25 March, external signal cables were attached on the tow cable for radar data acquisition. These generated increased EIS noise levels and, when connected to radar data acquisition electronics in the helicopter, generated spurious EM anomalies which, in many cases, compromised EM data acquisition. Flight lines whose data were contaminated by these effects were not included in the table below.

Table 3.1: 1997 Flight Summary

FLT #	Date	Comments	Operator	Re-baseline
92	20-Mar-97	Calibration flight.	JL	N
96	21-Mar-97	Calibration test flight. Bird calibration revised.	AM,JL	N
97	21-Mar-97	Includes run over Tracadie Bay ridge site	JL	Y
14	25-Mar-97	Survey flt from Magdalens. Includes Tracadie Bay line	AM	N
16	27-Mar-98	Two passes over calibration line	AM	N
17	27-Mar-97	Test over cal lines, survey down Strait to Bedeque Bay	AM	N

4 Calibration

Flights executed before March 23 used the bird calibration factors set up after reconstruction of the bird. The calibration factors used in this case had been obtained during the "Resolute Final" calibration during 1995, and continued to be used until the bird was damaged in 1996. It was expected that the bird's calibration would change as a result of the reconstruction and due to the presence of the snow radar unit. These factors were as follows:

Pre-set factors: (0.9790 + 0.0177i) (0.9270 + 0.3193I) (1.2501 + 0.5689i)

The 1997 system calibration was computed and installed by Jim Yee on March 21, using data from FLT092 over the calibration line near Point Prim in Hillsborough Bay, near Charlottetown. The surface measurements provided by one of the authors (Prinsenberg) are listed below. The full set of surface measurement data for the 1997 program are summarised in Appendix A.

Table 4.1: Surface measurements for Point Prim 1997 calibration line

Distance (m)	Ice (cm)	Snow (cm)	S+I (cm)	Bag #	Water Depth (m)
-400	----	----	----	----	----
-325	68-230+	----	----	----	----
-300	----	----	----	----	----
-110	38	12-18	50-56	----	5.2
-65	36	12-18	48-54	Lead-in	4.8
-40	37	12-18	49-55	----	4.6
0	36	16-18	52-54	1	4.4
20	36	14-16	50-52	2	4.1
40	36	14-15	50-51	3	3.8
60	38	15-18	53-56	4	3.6
80	35	10-12	45-47	5	3.4
100	35	08-10	43-45	6	3.4
120	33	10-14	43-47	7	3.6
140	38	08-18	46-56	8	3.6
160	37	12-14	49-51	9	3.5
+30	37	18-20	55-57	----	3.9
+63	38	12-18	50-63	----	3.8
+80/+110	55	0	55-64	Edge of pan	3.8
+120	35	12-16	47-51	----	3.9

The first set of ground-truth calibration factors used for FLT096-97 on March 21, were computed using properly measured airborne and surface data. However, an *incorrect snow plus ice thickness* was used during the calculation (0.35 m ice thickness compared to 0.50 m surface-measured snow plus ice). The calibration factors computed using this incorrect thickness were considerably too large in amplitude (about 4%) as a result. These factors were:

PEI_97_JY Factors: (+1.0315 + 0.0194i) (0.9806 + 0.3300i) (1.3076 + 0.5778i)

Use of these factors for F96-97 resulted in a considerable underestimation (typically about 0.15 m) of snow-plus-ice thickness for the affected real-time results.

Another calibration revision was evidently computed and used for real-time acquisition during FLT014, and further changes were made for FLT016 and FLT017. The adjustments required for each of these changes in calibration, all of which perpetuated the original error of neglecting the snow thickness during the calibration calculation, are given in Table 4.2 below. These were computed during post-processing using DFO program PCCalQW.

Table 4.2: Incremental calibration factors for 1997 flights

Flight files	F1 real	F1 imag	F2 real	F2 imag	F3 real	F3 imag
FLT092	1.02465	-0.00161	1.02112	0.00280	1.00789	-0.00014
FLT096	0.95918	0.00184	0.96780	-0.00030	0.96810	-0.01138
FLT014	0.96729	-0.00433	0.96515	-0.00429	0.96771	-0.00926
FLT016	0.96566	0.00784	0.96526	0.00905	0.96028	0.00095
FLT017	0.96048	-0.00966	0.97022	-0.00585	0.97535	-0.00893

Examination of this table indicates that the principal corrections made after FLT92 lay in the imaginary parts of the calibration factors, corresponding to changes in the phase of the EM response ranging from about 0.3 mrad to almost 10 mrad. Small adjustments of the EM phase primarily affect the estimated bulk ice conductivity, but can have significant effects on ice thickness for substantial thicknesses of ice (> 2 m). It is not known why so many changes were made to the calibration factors during this field program. Some were likely intended to correct for possible calibration changes caused by repairs or modifications of the EM or snow radar hardware. Others may have been attempts to obtain a better match between the real-time thicknesses and surface measurements. All of these attempts were compromised by an incorrect understanding of the calibration process. Use of the new calibration utility reduces the risk of arithmetic errors, but neglecting substantial snow thicknesses as was done in this case would still result in erroneous factors.

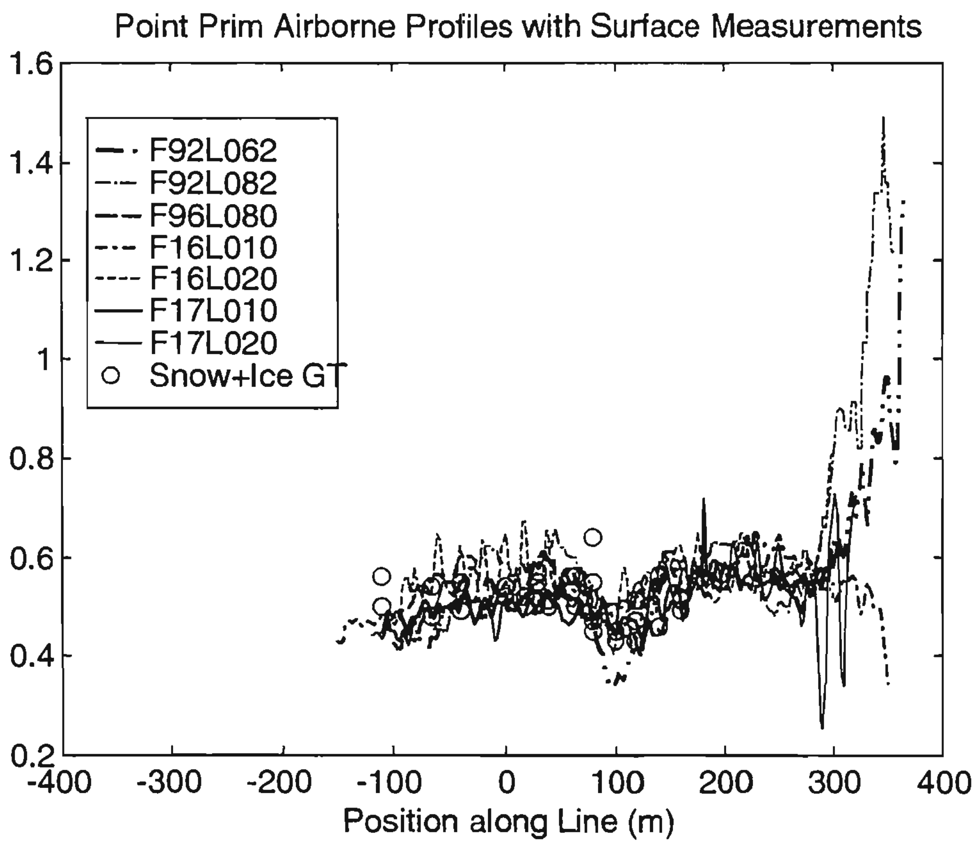


Figure 4.1: EIS profiles over Point Prim calibration line, plotted with surface snow plus ice thickness measurements.

Changes in the amplitude of these calibration factors after FLT96 are consistent within 0.7%, 0.5% and 1.5% of amplitude at 30, 90 and 150 kHz. These differences can be put into perspective. For a sensor at an 15m altitude over 1m ice, a difference of 1% in the amplitude of the calibration factors at both frequencies (30 and 90 kH) corresponds to a difference of about 5.2 cm in snow-plus-ice thickness and 2.6 mS/m in ice conductivity.

The mean amplitude range of 0.6% for 30 and 90 kHz thus corresponds to small systematic errors of about 3.1 cm in snow-plus-ice thickness, assuming that there was no actual change as a function of time in the snow plus ice thickness along the marked line.

The incremental factors as listed above were used to adjust the calibrations of the relevant flight files before they were re-inverted for presentation with this report.

When profiles over the Point Prim calibration line were extracted for the re-calibrated and re-inverted flights, they were found to exhibit good coherence and agreement with the surface measurements, as may be seen in Figure 4.1 above. The mean thickness along the length of the line is 0.51 ± .06 m (1σ), compared to the surface measurement mean of 0.052 ± .06 (1σ). A small variation in ice thickness with position along the line is visible in all of these profiles. Some profiles are noticeably noisier than others, particularly those from the earlier flights in which extra cables were attached to the tow cable for radar experiments. The strong and less-coherent variations in estimated thickness to the right of the figure are due to the bird being lifted rapidly out of its normal survey height at the end of the line. Under such conditions, noise or drift effects which would were small or negligible along the line are rapidly magnified as the EM signal reflected from the water surface drops off with sensor height.

5 Processing

The first step in processing of the 1997 field data set was to adjust for incorrect system calibrations, as discussed in the preceding section.

When this had been completed, the files were conditioned and re-inverted using the standard utilities.

The data were then inverted using the same frequencies and model set-up used for post-processing inversion of the 1996 data set, *i.e.*

- Frequencies used were 30 kHz, 90 kHz, in-phase and in-quadrature;
- Ice conductivity initial value 0.02 S/m, with range 0.001 to 0.1 S/m;
- Sea water conductivity 2.5 S/m (fixed);
- Ice thickness initial value 0.35 m, with range 0.01 and 10 m;

As will be seen below, some of these model and inversion control parameters would benefit from adjustment. However, it was considered preferable for the purposes of this report to maintain consistency in the model parameters from year to year to prevent the introduction of spurious systematic changes into this series of ice thickness data sets.

When inversion was complete, the flight files were processed in Matlab. to remove spikes due to laser dropouts using the raw laser data. The de-spiked data were then used to generate standard plot profiles and map output using the Matlab. mapping utilities. The statistical summaries, flight path and profile maps for each flight are listed in Appendices B, C and D.

6 Tracadie Bay Validation Line

A floe northeast of Tracadie Bay was marked and drilled, then profiled with EIS on March 25. Surface measurements obtained by Prinsenberg for this line are given in **Table 6.1** below:

Table 6.1: Surface measurements on Tracadie Bay marked floe

Distance (m)	Ice (cm)	snow (cm)	Distance (m)	Ice (cm)	snow (cm)
2.5	-----	20	-2.5	----	40
5	220+	10	-5	190	20
10	230+	0	-10	75	10
15	122	0	-15	50	5
20	118	0	-20	65	10
25	85	0	-25	65	7
30	65	0	-30	74	2
35	70	0	-35	52	1
40	50	0	-40	75	2
45	40	0	-45	45	5
50	91	0	-50	65	10
55	205	0	-55	55	10
60	50	0	-60	72	10
65	44	0	-65	60	5
70	60	0	-70	55	0
75	65	0	-75	60	0
			-80	55	0
80/110	flat (65)	0	-80/-125	flat (55)	0
110	2m ridge		-125	2m ridge	

The lack of flight path imagery makes direct mapping of the ground truth to the airborne data difficult. However, this was accomplished to first order by the following procedure:

1. Identify common features (*e.g.* a particular pattern of ridges)
2. Use these features to register the different airborne passes together
3. Register the ground truth data to the airborne passes using stretching (effectively just average velocity changes) and translation of the airborne data.

This process was aided by the use of a manual fiducial marker triggered by the operator as the system was flown over the site. Such marks are most effective when made at both ends of the marked line, which was not done in this case.

Two airborne profiles over the Tracadie Bay line are given in Figure 6.1 below. The mean snow plus ice thickness for the two sets of EIS results was 1.37 ± .78 m. The surface measurements had a mean of 1.39 ± 0.79m (both error estimates are 1σ). The close match between the airborne and surface results is probably fortuitous in this case, given the large range in thicknesses encountered and the method used for registration, but is certainly gratifying. The "blocky" character of the profiles on the left side of the figure appears to be due to the high ice conductivity of that feature, considerably more than the 0.1 S/m upper limit allowed during the inversion. This type of behaviour is typical of situations where the inverted model is prevented from matching some important property of the actual ice situation by artificial constraints such as parameter limits.

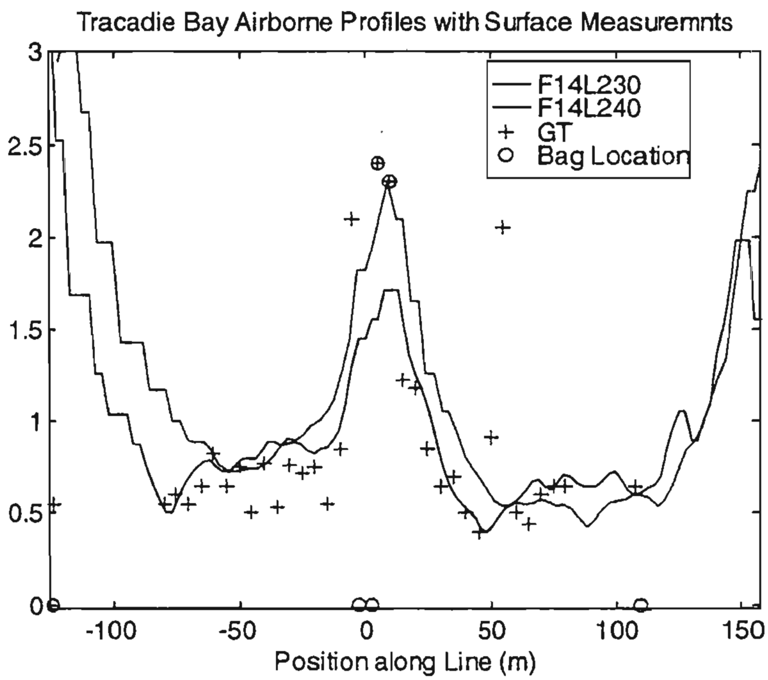


Figure 6.1: Two EIS profiles with surface measurements at Tracadie Bay site.

Surface measurements over the central ridge are matched more accurately by the second pass (L240), which was flown at a lower altitude and may have passed over a more substantial section of the ridge sail than did the first pass L230. It certainly appears that the flight paths for the two passes diverged on the left side of the figure, where substantially different thicknesses were encountered. The narrow ridge near +50 m was not detected by the EM, possibly because it was so narrow. It is interesting to note that this ridge was not clearly detected by the high-pass-filtered laser altimeter. These observations suggest that it was a highly localised (*i.e.* a 3D rather than 2D) feature.

Summary

The 1997 Gulf of St. Lawrence airborne field program was primarily focused on testing and evaluation of the Coast Guard Electromagnetic Ice Sounder and snow radar sensors. Support of other field data acquisition activities was a secondary objective.

The system was set up and debugged in conjunction with work on the snow radar sensor. After a setback caused by a static discharge event during the ferry flight back from a survey mission, the sensor bird was further tested and executed some offshore survey work, as well as profiling of a ridge site just north of Tracadie Bay.

Laser altimeter glitches present in the 1997 data. An unsuccessful attempt was made to correct these during the field program, but a satisfactory solution was not achieved until the 1998 field program. Post-processing correction software was used to correct the data presented in this report, eliminating virtually all laser-induced spikes in ice thickness.

The calibration performed in the field was incorrect, in that it used only part of the total snow-plus-ice thickness (ice thickness only) measured at the Point Prim calibration site. As a result, the real-time results obtained during the field program were low by about 15 cm. The data presented in this report have been corrected for this effect and re-inverted. The corrected calibration yields mean snow-plus-ice thicknesses which agree with mean surface measurements within 0.02 m, well within the system's nominal level-ice accuracy of 0.05 m and the 0.06 m standard deviation of the surface data.

Acknowledgements

The authors gratefully acknowledge the efforts of Coast Guard personnel in Charlottetown, particularly Ron Moores and Ian Henderson. André Maillet provided Coast Guard liaison and participated in the airborne and surface data acquisition. The EM field team comprised James Lee and Jim Yee, working in concert with the snow radar team headed by Louis Lalumiere. Rob Moucha wrote and supported the some portions of the DFO field processing software package and processed much of the data presented in this report. Support for this project was provided by the Panel on Energy Research and Development and by the Canadian Coast Guard.

References

Holladay, J.S. and R.Z. Moucha, 1998. Electromagnetic/laser ice thickness data from the Labrador Shelf, 1994, Can. Contract. Rep. Hydrogr. Ocean Sci. 49, v + 340pp.

Holladay, J.S., R.Z. Moucha and S. Prinsenberg, 1998, Airborne Electromagnetic Sea Ice Sounding Measurements During SIMMS'95, Can. Contract. Rep. Hydrogr. Ocean Sci.50, vii + 179.

Lalumiere, L.A., 1998, Implementation of a prototype real-time snow thickness radar, Can. Contr. Rep. Hydrogr. Ocean Sci. 48, v + 81pp.

Moucha R.Z, J.S. Holladay and S.J. Prinsenberg, 1998, Airborne Electromagnetic Sea Ice Sounder Measurements During RADARSAT Validation Project 1996. Can. Contract. Rep. Hydrogr. Ocean Sci., 51, vii + 349.

Appendix A: Surface Measurements

GULF STATION DATA (1997)

A: February 20 to March 12

Station 20-1 IOS-test station Clearing, -8°C
15kmph NW wind

Lat. 46° 16.85N
Long. 63° 44.38W

-Ice/snow salinity profile
-MetOcean beacon #26379 deployed at 17.45

Bag#	Depth(cm)	Salinity (ppt)
15	snow (8cm)	2.0
16	slush (2cm)	16.0
24	5	3.0
18	10	7.0
21	15	6.0
22	20	8.0
17	30	10.0

Saturday, 21 February

-Seimac beacon #0972 deployed at 10:00
-removed MetOcean beacon

Sunday, 23 February

-7.1meters of water
-43cm of ice; 18cm of hard snow flooded with 5cm of water

Monday, 24 February

-Salinities	-hard snow	1ppt
	-slush	6ppt
	-bottom slush	14ppt
	-slush water	56ppt
	-surface water	32ppt

Station 21-2 DREP-N station Overcast/snow, -2°C
15kmph SW wind

-Seimac beacon #0968 deployed at 10:10

Station 23-1 land-fast ice Cape Gage clear, -8°C
10kmph W wind

Lat. 46° 58.878N
Long. 64° 12.415W

-Placed 2 marker bags
-11.7m of water

Station 24-1 Gulf#1 Clear, -10°C
8kmph W wind

Lat. 46° 50.0N
Long. 62° 00.0W

-Beacon #26374 (12:00), 68m of water
-34cm of ice, large 1.5kmx1.5km floe
-17cm of snow flooded to 5cm depth
-slush layer 15 ppt

Station 24-2 Gulf#2 Clear, -10°C
8kmph W wind

Lat. 48° 10.0N
Long. 61° 40.0W

-Beacon #26379 (14:15), 121m of water
-30cm of ice, large 2kmx2km floe
-17cm of snow flooded to 4cm depth
-slush layer 15 ppt; snow 2ppt

Station 24-3 Gulf#3 Clear, -10°C
8kmph W wind

Lat. 47° 30.0N
Long. 63° 00.0W

-Beacon #26370 (15:20), 57m of water
-32cm of ice, large 2kmx2km floe
-11-20cm of snow flooded/frozen to 1cm depth
-surface ice 13 ppt, frozen slush layer 14 ppt, snow 2ppt

Station 25-1 | Pressure Station | Clear, -15°C
10kmph W wind

Lat. 46° 56.65
Long. 64° 17.37

-600mx400m floe, 4cm of new slush snow on top of old flooded snow/ice layer
-67-68cm of ice; pan of old surface snow layer (15cm) refrozen as ice
-surface ice 14ppt, bottom of slush 60ppt and surface slush 48ppt
-GPS beacon 26380 (14:15)
-Pressure beacon 1055 (14:20)
-Pressure beacon 22192 (14:29)

Station 25-2 | W-GPS Station | Clear, -15°C
10kmph W wind

-2.5kmiles west of pressure station
-500mx500m large floe, 1cm of new snow on top of old flooded snow/ice layer
-51cm of ice; pan of old surface snow layer (15cm) refrozen as ice
-GPS beacon 0973

Station 25-3 | N-GPS Station | Clear, -15°C
10kmph W wind

-2.6kmiles north of pressure station
-500mx500m large floe, 1cm of new snow on top of old flooded snow/ice layer
-47/43/62cm of ice; pan of old surface snow layer (15cm) refrozen as ice
-GPS beacon 0970 at 46° 59.43N; 64° 17.13W

Station 25-4 | S-GPS Station | Clear, -15°C
10kmph W wind

-2.7kmiles south of pressure station
-500mx500m large floe, 15cm of snow on top
-43/38cm of ice
-GPS beacon 0971

Station 25-5 | E-GPS Station | Clear, -15°C
10kmph W wind

-2.1kmiles east of pressure station
-500mx500m large floe, 4cm of new snow on top of old flooded snow/ice layer
-57/58cm of ice; pan of old surface snow layer (15cm) refrozen as ice
-GPS beacon 26375 (15:20)

Station 25-6 — Weather Station — Clear, -15°C, 10kmph W wind

Lat. 46° 55.77
Long. 64° 12.19

-land-fast ice; 35cm new slush/snow
-50-105cm of ice
-Atmospheric beacon 04770 (15:50)

Station 26-1 — Pressure Station — Cloudy, -16°C, 9kmph SW wind

Lat. 46° 57.20
Long. 64° 17.35

-replaced GPS beacon 26380 with 0968 (16:00)
-floe split in half, beacons 20m inshore of lead (10m)
-revisited Pressure Station February 28 (third time)
-lead edges not changed, 15m from pressure beacons still parallel to shore
-2-3cm of new snow, beacons solid frozen in the ice

Station 26-2 — E-GPS station — Cloudy, -16°C, 9kmph SW wind

Lat. 46° 58.87
Long. 64° 14.42

-400mx400m large floe
-50cm of ice; 15cm of snow
-GPS beacon 0972 (16.10)
-GPS beacon 26375 not relocated

Station 28-1 — IOS Acoustic Station — Clear, -8°C, 5kmph N wind

Lat. 46° 53.55 N
Long. 64° 15.05W

-Land-fast station off Cape Gage (ARGOS # 4998/ 16.48 volts)
-GPS-ARGOS beacon 0974(12:05)
-58m of ice; 30cm of snow
-snow flooded to 3cm; 16.9 and 16.6m depth of water
-three pairs of marker bags

B: March 10 to March 13

Tuesday, 11 March — Cloudy, -5C, 5kmph N wind

Station 11-1 — Acoustic/ARGOS station

-Heard beacon in morning but could not reach it over large shore lead and fog
-Locate acoustic/ARGOS beacon with range finder in afternoon.
-New snow acumulated to 1/2m, weight of snow flooded bottom half of snow.
-Inside box water had frozen wires and box into surface ice broke box open and removed beacon (10:30)
-removed GPS beacon which was only 2m from floe edge

Station 11-2 — Atmospheric beacon

-second try to locate beacon after it was not found in morning
-located beacon visually from ARGOS location (17:30)
-not located by range finder, ice/water in antenna
-middle of large floe (similar to size broken off the land-fast ice
-snow to top of beacon container.

Wednesday, 12 March — cloudy, -10C, 15kmph N wind

Station 12-1 — Ice pressure beacons

-located beacons with range finder in thick fog
-removed both pressure beacons, ridge had formed 1/2m from beacons
-GPS beacon not found would be in middle of ridge
-took salinity samples along both pressure beacons, dry ice to 40cm
-15cm of dry new snow

beacon #1055 (4m from ridge)

bag #	depth cm	salinity ppt
16	5	2
8	15	5
6	25	6
5	30	6
4	40	8

beacon #22192 (1/2m from ridge)

bag #	depth cm	salinity ppt
3	5	5
2	20	5
1	30	6
32	40	8

C: March 17 to March 25

Station 17-1	Calibration lines (Point Prim)	Clear, -5°C 19kmph SW winds

March 17 -Thick ice are inshore (fast ice)
-east end 3.8m and west end 3.6m water depths
-west end ends into a shoal, stranded ice

March 19 -Mean calibration line (35cm area)
-Water depth 3 holes 3.2, 3.4 and 3.2 m
-Ice thickness: 34, 35 and 35.5 cm

March 23 -8C, clear 15kmph NW wind

-Changed line length to 160m
-Put in cross line of 160m at centre bag

Bag #	Distance(m)	ice (cm)	depth(m)	Snow drifts (cm)
---	-400	major ridge		
---	-325	first ridge		72/68/200/220/230
---	-300	minor ridge to north of line		
---	-110	38	5.2	18/16/12
L	-65	36	4.8	18/16/12
---	-40	37	4.6	18/14/12
1	0	36	4.4	18/16
2	20	36	4.1	14/15/16
3	40	36	3.8	14/14/15
4	60	38	3.6	15/18/16
5	80	35	3.4	10/12/12
6	100	35	3.4	08/10/08
7	120	33	3.6	10/12/14
8	140	38	3.6	12/08/18
9	160	37	3.5	12/12/14
---	+30	37	3.9	20/20/18
---	+63	38	3.8	12/14/18
FR	+80/+110	64/60/55	4.1/4.2/3.8	00/00/00
---	+120	35	3.9	12/16/14

Lat.	46 02.146	46 02.149	46 02.154
Long.	62 57.326	62 57.316	62 57.335

March 20 -9C, clear 9kmph SW winds
-35cm of ice at both ends and middle
-profiled by probe at 11:30
-salinity samples at centre of line

Bag #	depth (cm)	salinity ppt
6	2	6
10	8	6
3	12	6
8	18	6
4	25	12
--	water	30

Station 17-2 Strait Stn#1 Clear, -5°C
10kmph SW wind

Lat. 46° 53.55 N
Long. 64° 15.05W

-MetOcean location beacon #2363 (17:15)
-Medium floe 400mx400m
-thicker than 1m, snow layer frozen

Station 18-1 Gulf #4 Clear, -6°C
15kmph NW wind

Lat. 47° 31.0N
Long. 63° 15.0W

-Deployed GPS-ARGOS beacon #26386 (11:05)
-500x500m floe 38/40cm thick
-Southwestern edge of heavier pack ice

Station 18-2 Gulf #5 Clear/Cloudy, -6°C
15kmph NW wind

Lat. 48° 06.4N
Long. 62° 09.3W

-Deployed GPS-ARGOS beacon #26385 (16:55)
-2x2km large floe 40/44cm thick
-Northern edge of heavier pack ice

Station 19-1 Pancake/rubble Clear, -9°C
18kmph SW wind

Lat. 47° 07.3N
Long. 62° 44.1W

-Deployed GPS-ARGOS beacon #26384 (10:45)
-1 mile inside grey ice N/S pancake ice rubble field
-Landed at two places, 4 holes thicker than 2m
-largest flat pan 5mx5m, refrozen rubble no snow

March 20 -9C, clear and 9kmph SW wind

-Lat. 46° 57.0N
-Long. 62° 38.9W
-40, 45, 40 and 46 cm of ice
-2-3 m floes hard/straight edges

March 20 -9C, clear and 9kmph SW wind

-Lat. 46° 56.0N
-Long. 62° 34.5W
-1.5+, 1.5+ and 1.5m of ice
-5-6m floes (pans)

Width of field: from Lat. 46° 57.56N Long. 62° 40.0W
to Lat. 46° 53.7N Long. 62° 35.1W

Station 19-2 Ainslie Lake Clear, -9°C

Lat. 46° 10.0N
Long. 61° 15.0W
-Fresh water lake on Cape Breton Island
Ice thickness: 62/63cm, snow drifts 0 to 30cm

Station 21-1 pack ice overcast/snowing
-4°C, 11kmph SE wind

Lat. 46° 40N
Long. 62° 30W
-First large floe in pack ice; 75m line out in N/S direction and 75m south of ridge

-Distance(m)	0	5	15	25	35	45	55	65	75
-Thickness(cm)	86	92	>160	105	100	135	60	60	92

Station 22-1	Tracadie Bay (land-fast ice)	Clear, -11°C 6kmph NW wind
March 22	Lat. 46° 27.2N Long. 62° 48.9W	
	-Land-fast ice along North shore of PEI -60cm of ice, floe with ridge -11m of water	
March 24	Lat. 46° 26.2N Long. 62° 55.2W	Clear, -10°C 19kmph W wind
Station 24-1	Tracadie Bay (snow dune)	-10°C, clear 19kmph W wind

distance(m)	snow(cm)	distance(m)	snow(cm)	
60	0	-120	0	ice
55	0	-100	15	dune
50	0	-80	5	ice
45	0	-70	8	ice
40	2	-60	10	ice
35	2	-50	5	ice
30	0	-40	14	dune
25	2	-30	15	dune
20	0	-20	5	dune
15	0	-10	5	dune
10	0	00	0	ridge
9	10			
8	10			
7	15			
6	20			
5	20			
4	25			
3	20			
2	15			
1	13			
00	ridge			

Station 25-1 — Land-fast ridge (off Tracadie Bay) — -8°C, clear, 15W wind

-calibration line/ridge off Tracadie Bay, 11m of water
-Lat. 46° 26.05N, Long. 62° 5.36W
-NW-SE line with 1.5m sail area ridge perpendicular to line
-ridge separating two pans each 100m+ in size
-distances positive to SE from centre ridge

Distance (m)	Ice (cm)	snow (cm)	Distance (m)	Ice (cm)	snow (cm)
2.5	-----	20	2.5	----	40
5	220+	10	-5	190	20
10	230+	0	-10	75	10
15	122	0	-15	50	5
20	118	0	-20	65	10
25	85	0	-25	65	7
30	65	0	-30	74	2
35	70	0	-35	52	1
40	50	0	-40	75	2
45	40	0	-45	45	5
50	91	0	-50	65	10
55	205	0	-55	55	10
60	50	0	-60	72	10
65	44	0	-65	60	5
70	60	0	-70	55	0
75	65	0	-75	60	0
			-80	55	0
80/110	flat (65)	0	-80/-125	flat (55)	0
110	2m ridge		-125	2m ridge	

Ice salinities at 20m from centre ridge	bag #	depth(cm)	salinity (ppt)
	30	2	2
	31	8	6
	29	15	5
	2	24	5
	5	30	8
	1	33	8
	32	40	8

Appendix B: Statistical Summary Tables

DATE: MAR20 FLIGHT #: 92 Total Length: 42.055 km

Line Number	Start FID	End FID	Start Lat. (deg. N)	Start Long. (deg. W)	End Lat. (deg. N)	End Long. (deg. W)	# of Smpls ICE	Length of Line/Seg. (km)	Ice Thickness Mean (m)	Ice Thickness Stdv. (m)	Avg Sample Spacing (s)	Avg Sample Spacing (m)
10010	71537700	71569200	46.1871	-63.0435	46.1937	-63.0477	309	0.808	8.18	3.197		
Total	71537700	71569200	46.1871	-63.0435	46.1937	-63.0477	311	0.808	8.18	3.197	0.10	2.56
10020	71593400	71659200	46.1936	-63.0540	46.1777	-63.0546	652	1.916	1.87	2.511		
Total	71593400	71659200	46.1936	-63.0540	46.1777	-63.0546	654	1.916	1.87	2.511	0.10	2.91
10030	71901600	71958300	46.1276	-63.1013	46.1441	-63.1113	83	2.000	0.66	1.627		
	71958300	72002400	46.1441	-63.1113	46.1580	-63.1187	71	1.657	0.23	0.043		
Total	71901600	72002400	46.1276	-63.1013	46.1580	-63.1187	220	3.657	0.46	1.211	0.10	3.72
10040	72136100	72209300	46.1820	-63.1122	46.1642	-63.1124	380	2.002	0.62	0.255		
	72209300	72281800	46.1642	-63.1124	46.1467	-63.1075	123	2.000	0.26	0.109		
	72281800	72349900	46.1467	-63.1075	46.1302	-63.0982	284	2.000	0.58	0.201		
	72349900	72357400	46.1302	-63.0982	46.1284	-63.0969	76	0.221	0.48	0.156		
Total	72136100	72357400	46.1820	-63.1122	46.1284	-63.0969	992	6.223	0.55	0.247	0.10	2.88
10050	72569600	72620600	46.0611	-63.0514	46.0466	-63.0368	450	2.013	1.83	0.958		
	72620600	72673000	46.0466	-63.0368	46.0407	-63.0127	496	1.989	1.74	0.529		
	72673000	72694800	46.0407	-63.0127	46.0390	-63.0031	210	0.773	1.12	0.387		
Total	72569600	72694800	46.0611	-63.0514	46.0390	-63.0031	1154	4.775	1.66	0.756	0.11	4.14
10060	72731800	72800400	46.0384	-62.9884	46.0343	-62.9639	661	2.003	0.85	0.492		
	72800400	72875700	46.0343	-62.9639	46.0343	-62.9494	733	2.000	0.61	0.533		
	72875700	72909800	46.0343	-62.9494	46.0381	-62.9610	342	0.996	0.61	0.215		
Total	72731800	72909800	46.0384	-62.9884	46.0381	-62.9610	1744	4.998	0.70	0.484	0.10	2.82
10070	72988200	73037400	46.0366	-62.9455	46.0422	-62.9616	493	1.429	0.93	0.312		
Total	72988200	73037400	46.0366	-62.9455	46.0422	-62.9616	493	1.429	0.93	0.312	0.10	2.90
10080	73197600	73275800	46.0390	-62.9811	46.0314	-62.9580	783	2.002	0.75	0.502		
	73275800	73353100	46.0314	-62.9580	46.0345	-62.9510	759	1.999	0.39	0.318		
	73353100	73382400	46.0345	-62.9510	46.0380	-62.9615	294	0.903	0.64	0.237		
Total	73197600	73382400	46.0390	-62.9811	46.0380	-62.9615	1838	4.904	0.59	0.431	0.10	2.65
10090	73444600	73514400	46.0343	-62.9483	46.0394	-62.9621	668	1.799	0.96	0.629		
Total	73444600	73514400	46.0343	-62.9483	46.0394	-62.9621	668	1.799	0.96	0.629	0.10	2.69
10100	73573400	73637600	46.0239	-62.9632	46.0396	-62.9541	614	2.003	0.57	0.231		
	73637600	73648400	46.0396	-62.9541	46.0427	-62.9530	102	0.367	0.87	0.167		
Total	73573400	73648400	46.0239	-62.9632	46.0427	-62.9530	723	2.369	0.62	0.245	0.10	3.15
10110	73862400	73913600	46.1073	-62.9793	46.1214	-62.9952	513	2.004	0.93	0.176		
	73913600	73960600	46.1214	-62.9952	46.1349	-63.0120	471	1.997	0.89	0.110		
	73960600	74007400	46.1349	-63.0120	46.1497	-63.0265	457	2.001	0.94	0.140		
	74007400	74052400	46.1497	-63.0265	46.1643	-63.0416	451	2.001	0.83	0.064		
	74052400	74084400	46.1643	-63.0416	46.1724	-63.0512	244	1.175	0.54	0.299		
Total	73862400	74084400	46.1073	-62.9793	46.1724	-63.0512	2132	9.177	0.86	0.202	0.10	4.30

DATE: MAR21 FLIGHT #: 96   Total Length: 35.768 km

Line Number	Start FID	End FID	Start Lat. (deg. N)	Start Long. (deg. W)	End Lat. (deg. N)	End Long. (deg. W)	# of Smpls ICE	Length of Line/Seg. (km)	Ice Thickness Mean (m)	Ice Thickness Stdv. (m)	Avg Sample Spacing (s)	Avg Sample Spacing (m)
10010	71773800	71836300	46.0185	-62.9415	46.0313	-62.9592	583	2.000	0.61	0.335		
	71836300	71859400	46.0313	-62.9592	46.0352	-62.9680	201	0.815	0.57	0.340		
Total	71773800	71859400	46.0185	-62.9415	46.0352	-62.9680	799	2.815	0.60	0.337	0.10	3.34
10020	71968800	72037800	46.0201	-62.9421	46.0320	-62.9610	665	2.002	0.41	0.240		
	72037800	72062400	46.0320	-62.9610	46.0358	-62.9699	208	0.818	0.62	0.356		
Total	71968800	72062400	46.0201	-62.9421	46.0358	-62.9699	886	2.819	0.46	0.287	0.10	3.01
10030	72206700	72283300	46.0206	-62.9332	46.0335	-62.9502	700	2.001	1.02	0.493		
	72283300	72320400	46.0335	-62.9502	46.0379	-62.9610	372	0.997	0.52	0.191		
Total	72206700	72320400	46.0206	-62.9332	46.0379	-62.9610	1071	2.998	0.85	0.477	0.11	2.80
10040	72428800	72507500	46.0279	-62.9341	46.0367	-62.9560	780	2.002	0.46	0.090		
	72507500	72546400	46.0367	-62.9560	46.0416	-62.9680	364	1.086	1.16	0.628		
Total	72428800	72546400	46.0279	-62.9341	46.0416	-62.9680	1143	3.088	0.68	0.489	0.10	2.70
10050	72716500	72789200	46.0302	-62.9292	46.0401	-62.9499	728	2.000	0.95	0.208		
	72789200	72810400	46.0401	-62.9499	46.0417	-62.9564	213	0.547	0.75	0.134		
Total	72716500	72810400	46.0302	-62.9292	46.0417	-62.9564	940	2.547	0.90	0.210	0.10	2.71
10060	72924500	73004000	46.0280	-62.9292	46.0378	-62.9493	786	2.001	1.12	0.208		
	73004000	73015400	46.0378	-62.9493	46.0385	-62.9526	115	0.269	0.86	0.208		
Total	72924500	73015400	46.0280	-62.9292	46.0385	-62.9526	900	2.270	1.09	0.225	0.10	2.52
10070	73197500	73278400	46.0237	-62.9238	46.0323	-62.9460	810	2.001	0.69	0.251		
	73278400	73327400	46.0323	-62.9460	46.0368	-62.9590	484	1.131	0.47	0.085		
Total	73197500	73327400	46.0237	-62.9238	46.0368	-62.9590	1293	3.132	0.61	0.233	0.10	2.42
10080	73553500	73629000	46.0342	-62.9365	46.0413	-62.9569	736	1.799	1.01	0.342		
Total	73553500	73629000	46.0342	-62.9365	46.0413	-62.9569	738	1.799	1.01	0.342	0.10	2.42
10090	73871000	73945500	46.1020	-63.0144	46.1121	-63.0354	737	2.002	0.64	0.143		
	73945500	74026100	46.1121	-63.0354	46.1211	-63.0574	799	1.999	0.67	0.164		
	74026100	74099100	46.1211	-63.0574	46.1307	-63.0790	723	2.000	1.47	0.835		
	74099100	74163100	46.1307	-63.0790	46.1429	-63.0978	620	2.003	1.35	0.590		
	74163100	74192400	46.1429	-63.0978	46.1493	-63.1045	232	0.891	0.95	0.489		
Total	73871000	74192400	46.1020	-63.0144	46.1493	-63.1045	3122	8.894	1.01	0.629	0.10	2.79
10100	74280000	74337600	46.1763	-63.1142	46.1934	-63.1216	426	2.001	0.59	0.260		
	74337600	74396200	46.1934	-63.1216	46.2104	-63.1258	433	2.000	0.35	0.208		
	74396200	74433400	46.2104	-63.1258	46.2212	-63.1165	373	1.405	0.65	0.062		
Total	74280000	74433400	46.1763	-63.1142	46.2212	-63.1165	1298	5.406	0.52	0.239	0.10	3.52

DATE: MAR21 FLIGHT #: 97 Total Length: 1.820 km

Line Number	Start FID	End FID	Start Lat. (deg. N)	Start Long. (deg. W)	End Lat. (deg. N)	End Long. (deg. W)	# of Smpls ICE	Length of Line/Seg. (km)	Ice Thickness Mean (m)	Ice Thickness Stdv. (m)	Avg Sample Spacing (s)	Avg Sample Spacing (m)
10110	78648600	78692400	46.7554	-62.5778	46.7668	-62.5609	376	1.820	0.91	0.378		
Total	78648600	78692400	46.7554	-62.5778	46.7668	-62.5609	390	1.820	0.91	0.378	0.10	4.15

DATE: MAR25 FLIGHT #: 14 Total Length: 41.844 km

Line Number	Start FID	End FID	Start Lat. (deg. N)	Start Long. (deg. W)	End Lat. (deg. N)	End Long. (deg. W)	# of Smpls ICE	Length of Line/Seg. (km)	Ice Thickness Mean (m)	Ice Thickness Stdv. (m)	Avg Sample Spacing (s)	Avg Sample Spacing (m)
10080	70391500	70460700	47.1952	-62.0325	47.1824	-62.0481	666	2.001	1.18	0.359		
	70460700	70510600	47.1824	-62.0481	47.1652	-62.0553	403	2.002	0.97	0.398		
	70510600	70562800	47.1652	-62.0553	47.1512	-62.0713	418	1.998	0.61	0.134		
	70562800	70614400	47.1512	-62.0713	47.1375	-62.0883	469	2.000	0.60	0.202		
	70614400	70664300	47.1375	-62.0883	47.1238	-62.1052	428	2.002	0.49	0.131		
	70664300	70713000	47.1238	-62.1052	47.1110	-62.1234	419	1.999	0.48	0.245		
	70713000	70760500	47.1110	-62.1234	47.0971	-62.1401	346	1.999	0.40	0.215		
	70760500	70808100	47.0971	-62.1401	47.0840	-62.1579	388	2.000	0.36	0.176		
	70808100	70856400	47.0840	-62.1579	47.0710	-62.1760	442	2.000	0.29	0.177		
	70856400	70904800	47.0710	-62.1760	47.0582	-62.1942	374	2.001	0.28	0.072		
	70904800	70953800	47.0582	-62.1942	47.0453	-62.2123	433	1.998	0.34	0.107		
	70953800	71002400	47.0453	-62.2123	47.0312	-62.2282	437	2.001	0.24	0.068		
	71002400	71051800	47.0312	-62.2282	47.0193	-62.2476	406	1.998	0.26	0.070		
	71051800	71102100	47.0193	-62.2476	47.0070	-62.2666	437	2.000	0.23	0.044		
	71102100	71153500	47.0070	-62.2666	46.9950	-62.2860	371	2.002	0.24	0.046		
	71153500	71204900	46.9950	-62.2860	46.9828	-62.3050	333	1.998	0.26	0.049		
	71204900	71229400	46.9828	-62.3050	46.9764	-62.3132	228	0.949	0.18	0.093		
Total	70391500	71229400	47.1952	-62.0325	46.9764	-62.3132	7264	32.950	0.47	0.355	0.10	3.94
10160	71906500	71953900	46.7659	-62.5723	46.7515	-62.5879	164	2.003	0.22	0.111		
	71953900	72004700	46.7515	-62.5879	46.7371	-62.6041	150	2.030	0.23	0.125		
	72004700	72051400	46.7371	-62.6041	46.7240	-62.6211	152	1.959	0.27	0.124		
Total	71906500	72051400	46.7659	-62.5723	46.7240	-62.6211	559	5.993	0.24	0.121	0.11	4.39
10230	73225900	73284400	46.4332	-62.9168	46.4363	-62.9373	431	1.654	1.24	0.770		
Total	73225900	73284400	46.4332	-62.9168	46.4363	-62.9373	465	1.654	1.24	0.770	0.10	2.82
10240	73394400	73437400	46.4340	-62.9148	46.4354	-62.9306	380	1.247	1.48	0.763		
Total	73394400	73437400	46.4340	-62.9148	46.4354	-62.9306	392	1.247	1.48	0.763	0.10	2.89

DATE: MAR27 FLIGHT #: 16 Total Length: 6.512 km

Line Number	Start FID	End FID	Start Lat. (deg. N)	Start Long. (deg. W)	End Lat. (deg. N)	End Long. (deg. W)	# of Smpls ICE	Length of Line/Seg. (km)	Ice Thickness Mean (m)	Ice Thickness Stdv. (m)	Avg Sample Spacing (s)	Avg Sample Spacing (m)
10010	59578000	59639600	46.0224	-62.9179	46.0306	-62.9406	484	2.003	0.86	0.255		
	59639600	59690400	46.0306	-62.9406	46.0375	-62.9597	418	1.684	0.50	0.087		
Total	59578000	59690400	46.0224	-62.9179	46.0375	-62.9597	950	3.687	0.69	0.267	0.10	3.28
10020	59842100	59906900	46.0263	-62.9312	46.0352	-62.9534	608	2.002	0.53	0.091		
	59906900	59933400	46.0352	-62.9534	46.0386	-62.9628	233	0.823	0.80	0.351		
Total	59842100	59933400	46.0263	-62.9312	46.0386	-62.9628	858	2.825	0.60	0.234	0.10	3.09

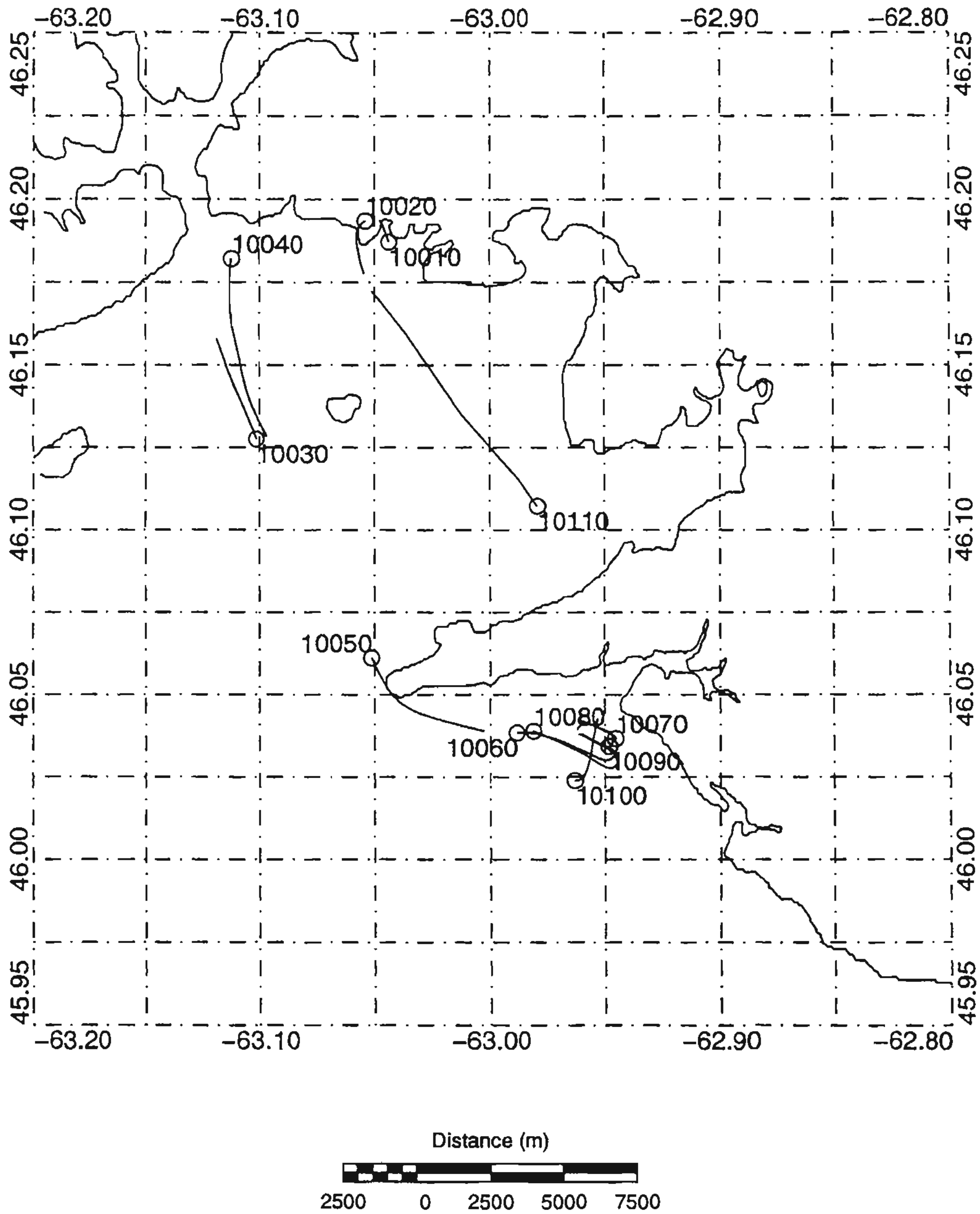
DATE: MAR27 FLIGHT #: 17 Total Length: 63.910 km

Line Number	Start FID	End FID	Start		End		# of Smpls ICE	Length of Line/Seg. (km)	Ice Thickness		Avg Sample Spacing	
			Lat. (deg. N)	Long. (deg. W)	Lat. (deg. N)	Long. (deg. W)			Mean (m)	Stdv. (m)	(s)	(m)
10010	70771100	70821600	46.0081	-62.9021	46.0203	-62.9210	358	2.000	1.06	0.305		
	70821600	70873600	46.0203	-62.9210	46.0310	-62.9415	430	2.000	0.69	0.223		
	70873600	70928200	46.0310	-62.9415	46.0389	-62.9645	353	2.001	0.64	0.310		
	70928200	70934400	46.0389	-62.9645	46.0397	-62.9673	63	0.236	0.93	0.279		
Total	70771100	70934400	46.0081	-62.9021	46.0397	-62.9673	1274	6.237	0.80	0.333	0.10	3.82
10020	71089100	71139700	46.0249	-62.9292	46.0340	-62.9512	405	2.003	0.54	0.116		
	71139700	71159400	46.0340	-62.9512	46.0372	-62.9603	160	0.797	0.57	0.139		
Total	71089100	71159400	46.0249	-62.9292	46.0372	-62.9603	588	2.800	0.55	0.124	0.10	3.98
10030	71337400	71388500	46.0022	-62.9421	46.0168	-62.9561	403	2.000	1.57	0.749		
	71388500	71436200	46.0168	-62.9561	46.0297	-62.9731	361	2.000	1.38	0.745		
	71436200	71484000	46.0297	-62.9731	46.0361	-62.9972	279	2.003	1.15	0.367		
	71484000	71530100	46.0361	-62.9972	46.0412	-63.0218	367	1.997	1.32	0.429		
	71530100	71577400	46.0412	-63.0218	46.0473	-63.0460	297	2.002	1.44	0.402		
	71577400	71622600	46.0473	-63.0460	46.0561	-63.0684	227	1.998	1.61	0.966		
	71622600	71668600	46.0561	-63.0684	46.0645	-63.0912	293	2.003	1.68	0.424		
	71668600	71714300	46.0645	-63.0912	46.0729	-63.1139	325	1.998	1.65	0.437		
	71714300	71758900	46.0729	-63.1139	46.0793	-63.1379	359	2.000	1.61	0.401		
	71758900	71805500	46.0793	-63.1379	46.0861	-63.1617	303	2.000	1.26	0.352		
	71805500	71822300	46.0861	-63.1617	46.0886	-63.1698	140	0.694	1.26	0.501		
Total	71337400	71822300	46.0022	-62.9421	46.0886	-63.1698	3624	20.696	1.46	0.580	0.10	4.31
10040	72162800	72209900	46.1319	-63.3416	46.1371	-63.3662	224	2.004	1.57	1.342		
	72209900	72259400	46.1371	-63.3662	46.1415	-63.3912	233	1.998	1.51	0.478		
	72259400	72305200	46.1415	-63.3912	46.1461	-63.4162	206	2.003	1.24	0.404		
	72305200	72352200	46.1461	-63.4162	46.1535	-63.4396	182	2.001	0.98	0.431		
	72352200	72399800	46.1535	-63.4396	46.1609	-63.4630	283	1.996	0.86	0.178		
	72399800	72446400	46.1609	-63.4630	46.1672	-63.4871	158	2.001	0.75	0.242		
	72446400	72491400	46.1672	-63.4871	46.1735	-63.5113	143	2.001	0.91	0.418		
	72491400	72494900	46.1735	-63.5113	46.1740	-63.5131	20	0.154	1.31	1.562		
Total	72162800	72494900	46.1319	-63.3416	46.1740	-63.5131	1679	14.157	1.14	0.697	0.11	4.56
10050	72920700	72968900	46.2512	-63.7158	46.2638	-63.7341	483	2.004	1.99	1.131		
	72968900	73013000	46.2638	-63.7341	46.2762	-63.7528	421	1.996	1.61	0.448		
	73013000	73057300	46.2762	-63.7528	46.2886	-63.7715	423	2.003	1.48	0.295		
	73057300	73086000	46.2886	-63.7715	46.2967	-63.7834	156	1.290	1.38	0.326		
Total	72920700	73086000	46.2512	-63.7158	46.2967	-63.7834	1500	7.294	1.67	0.749	0.10	4.54
10080	73350100	73395500	46.3057	-63.8676	46.3211	-63.8548	349	2.002	1.03	0.731		
	73395500	73437600	46.3211	-63.8548	46.3372	-63.8437	299	1.999	1.71	0.715		
	73437600	73481000	46.3372	-63.8437	46.3547	-63.8388	428	2.002	1.70	0.490		
	73481000	73522900	46.3547	-63.8388	46.3710	-63.8286	420	2.000	1.58	0.146		
	73522900	73563500	46.3710	-63.8286	46.3822	-63.8104	393	1.999	0.90	0.392		
	73563500	73600700	46.3822	-63.8104	46.3842	-63.7846	338	2.001	0.80	0.066		
	73600700	73614400	46.3842	-63.7846	46.3847	-63.7753	138	0.723	0.79	0.128		
Total	73350100	73614400	46.3057	-63.8676	46.3847	-63.7753	2412	12.726	1.26	0.608	0.10	4.85

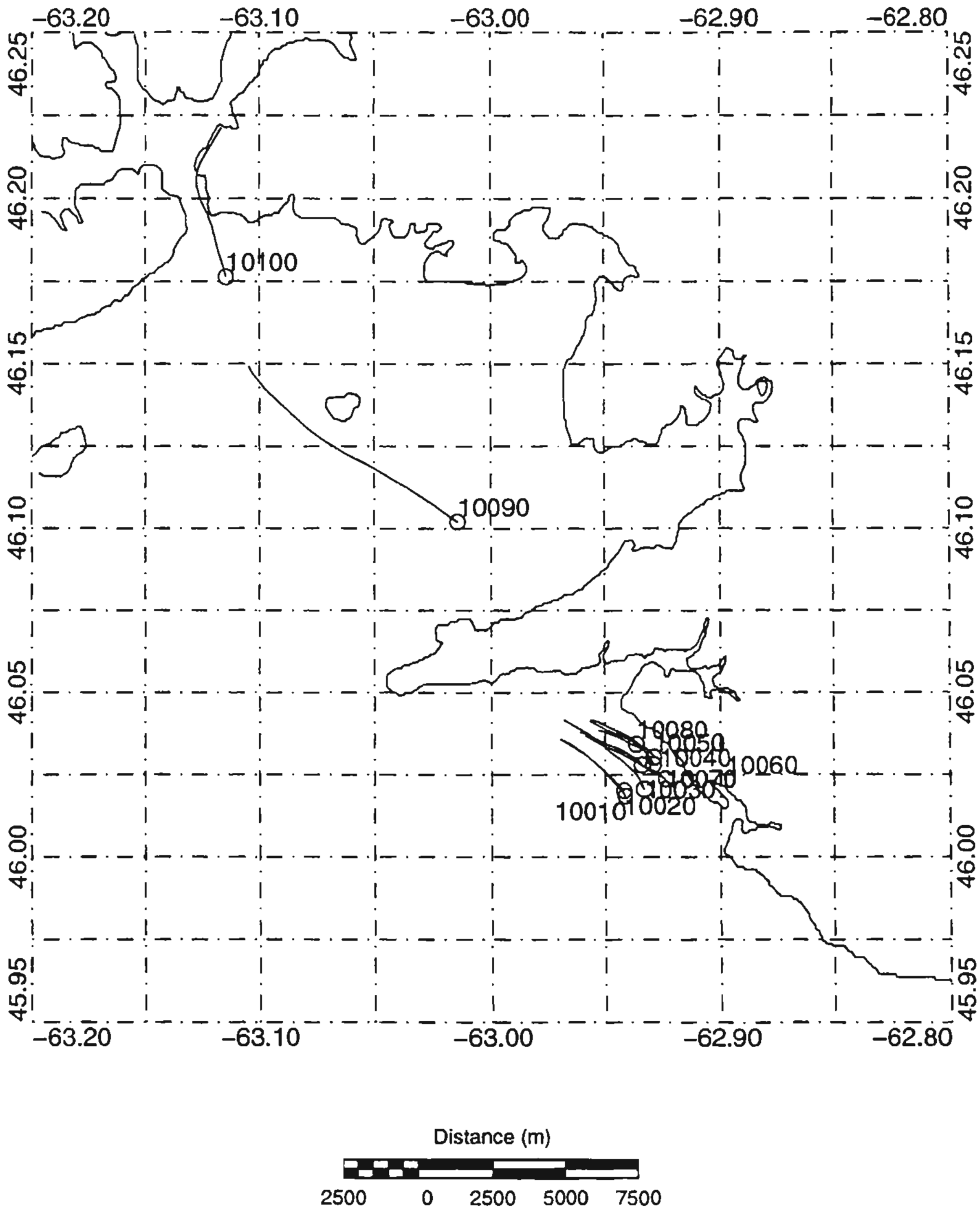
Grand Total Length 191.909 km.

Appendix C: Flight Path Maps

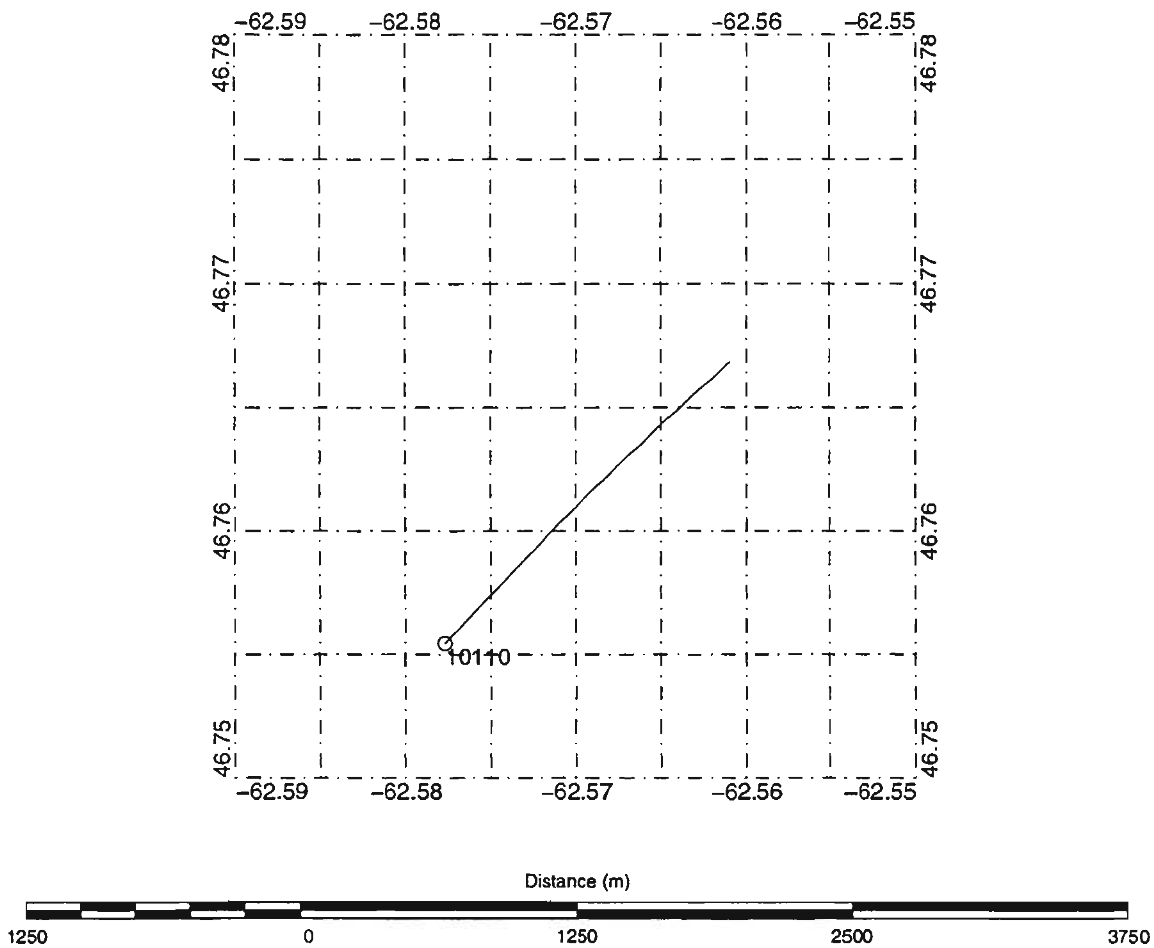
MARCH 20, 1997 FLIGHT 92
Lambert Conic Proj., Center Long.: −63.05, Lat1 49.00, Lat2 77.00
Map Scale 1:250000



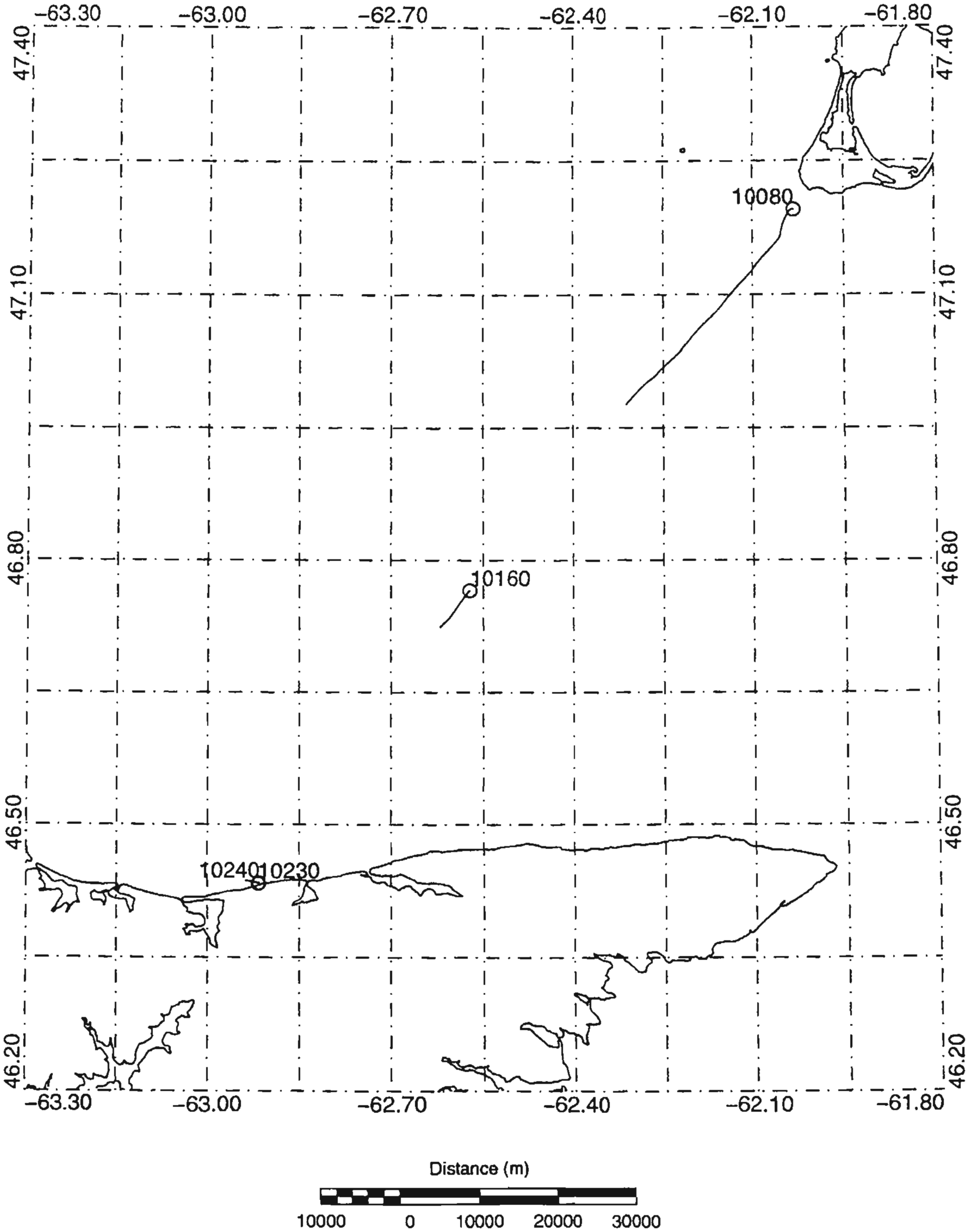
MARCH 21, 1997 FLIGHT 96
Lambert Conic Proj., Center Long.: −63.00, Lat1 49.00, Lat2 77.00
Map Scale 1:250000



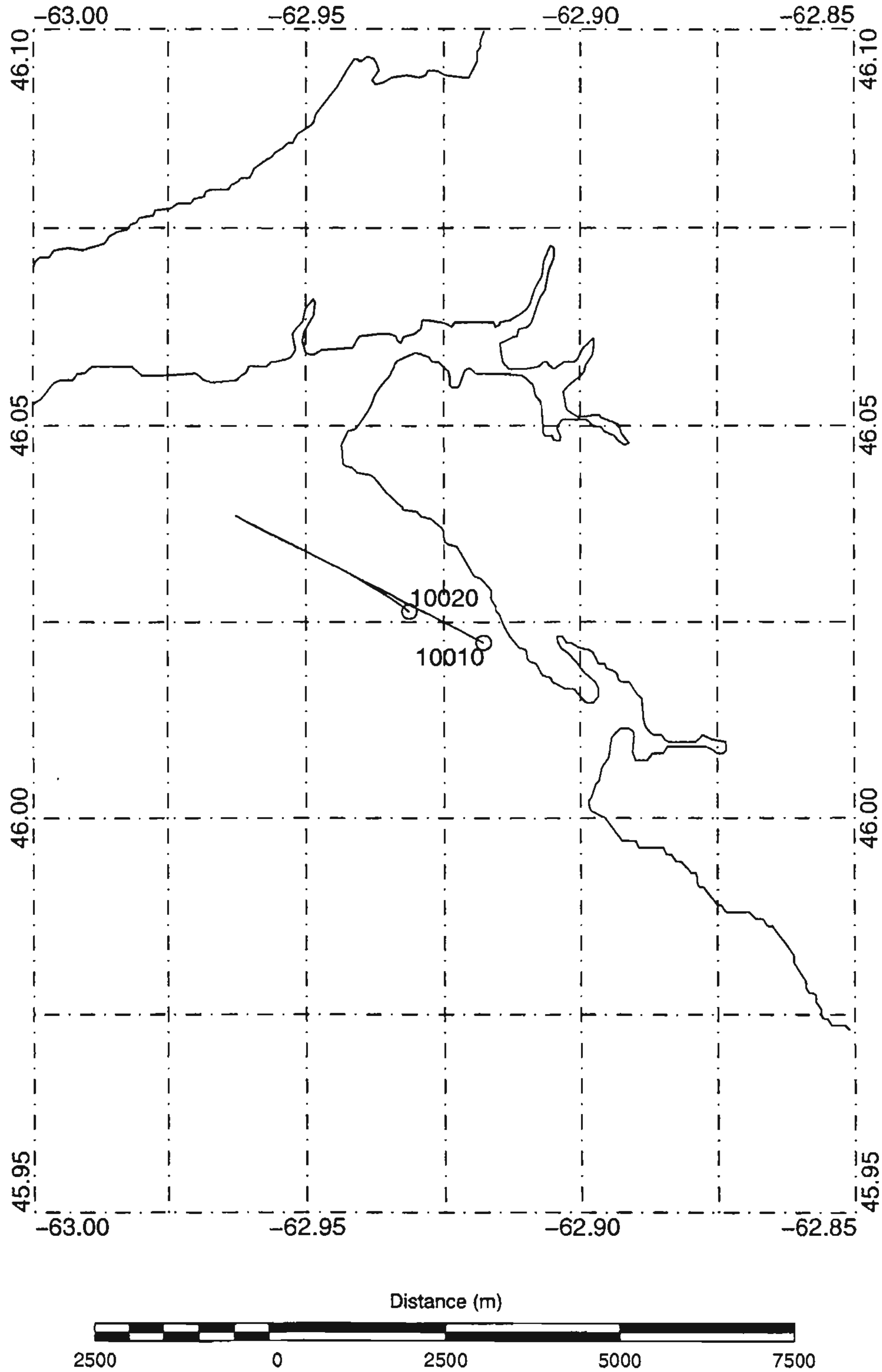
MARCH 21, 1997 FLIGHT 97
Lambert Conic Proj., Center Long.: -62.57, Lat1 49.00, Lat2 77.00
Map Scale 1:30000



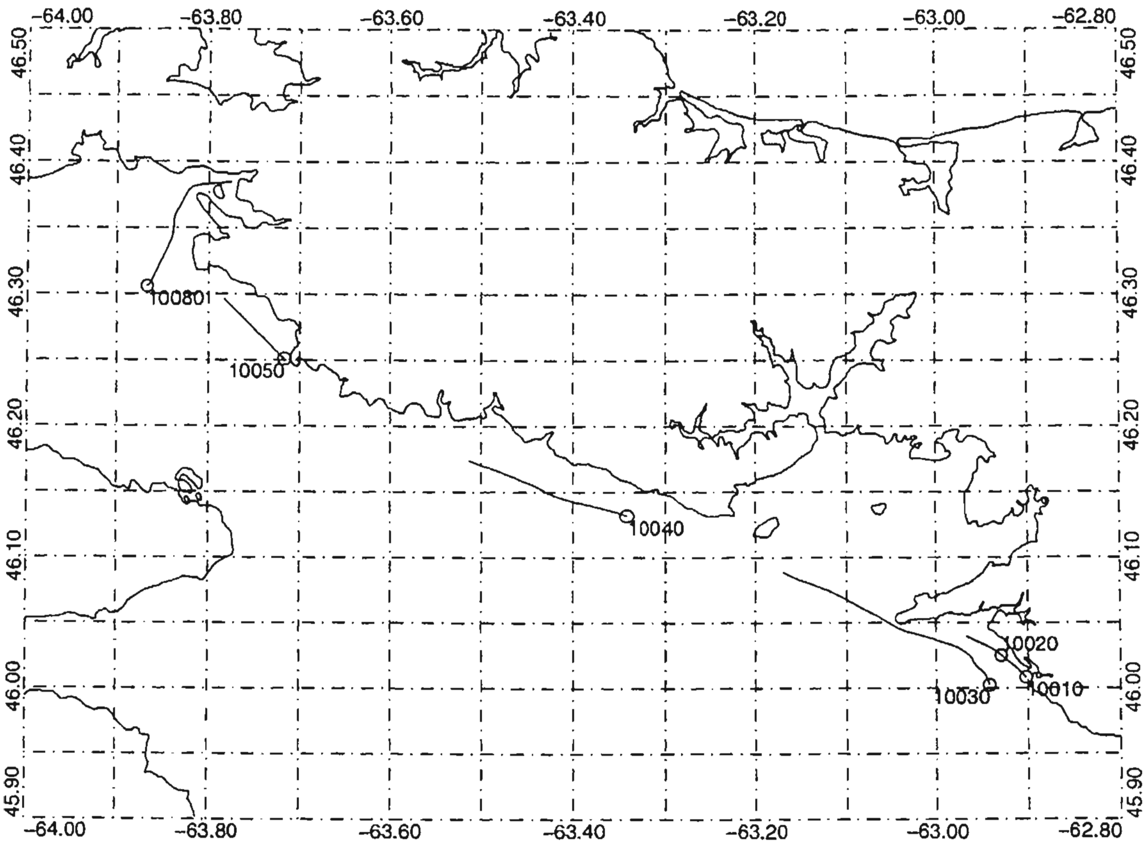
MARCH 25, 1997 FLIGHT 14
Lambert Conic Proj., Center Long.: -62.50, Lat1 49.00, Lat2 77.00
Map Scale 1:800000

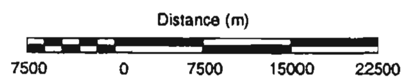


MARCH 27, 1997 FLIGHT 16
Lambert Conic Proj., Center Long.: -62.95, Lat1 49.00, Lat2 77.00
Map Scale 1:100000



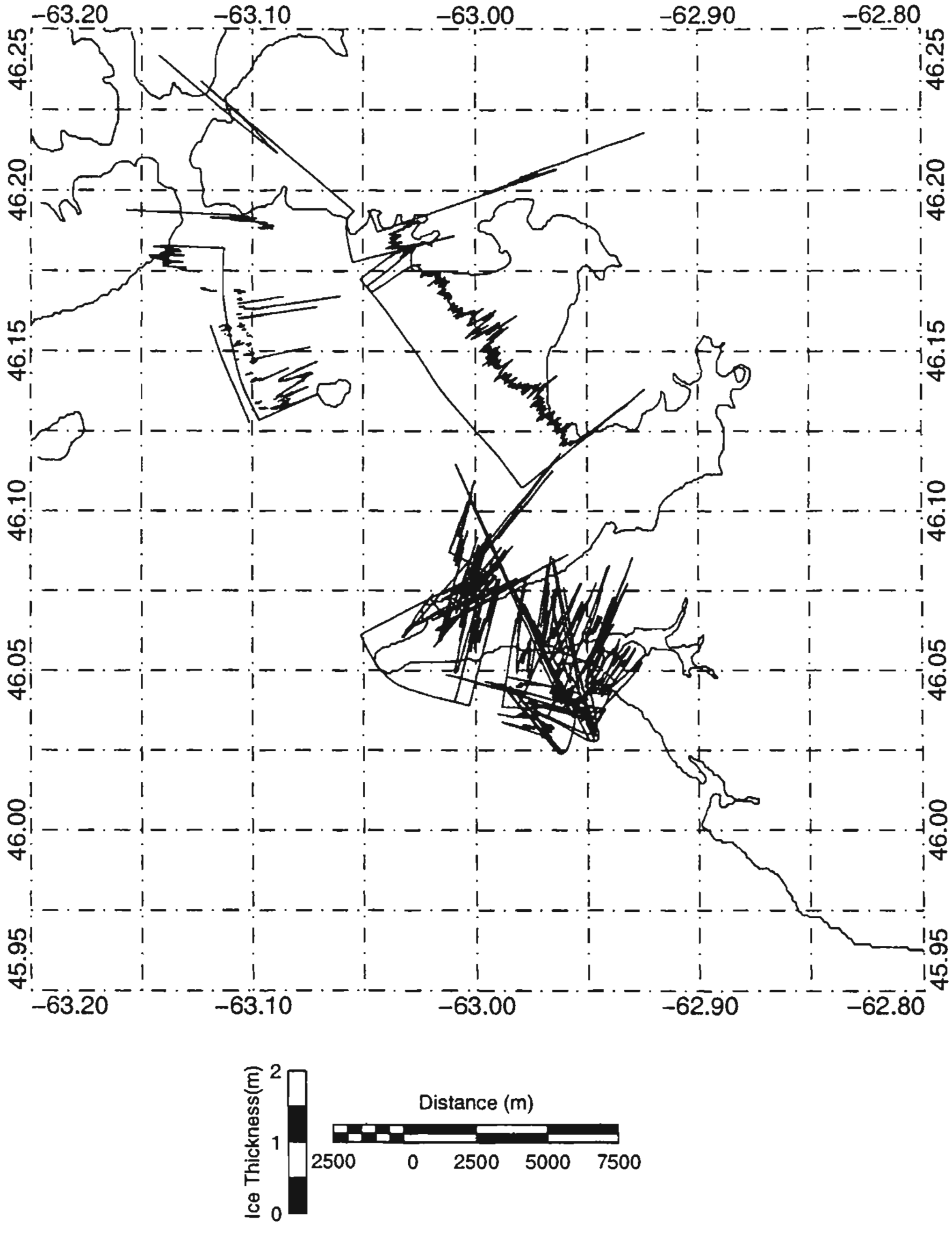
MARCH 27, 1997 FLIGHT 17
Lambert Conic Proj., Center Long.: -63.40, Lat1 49.00, Lat2 77.00
Map Scale 1:500000



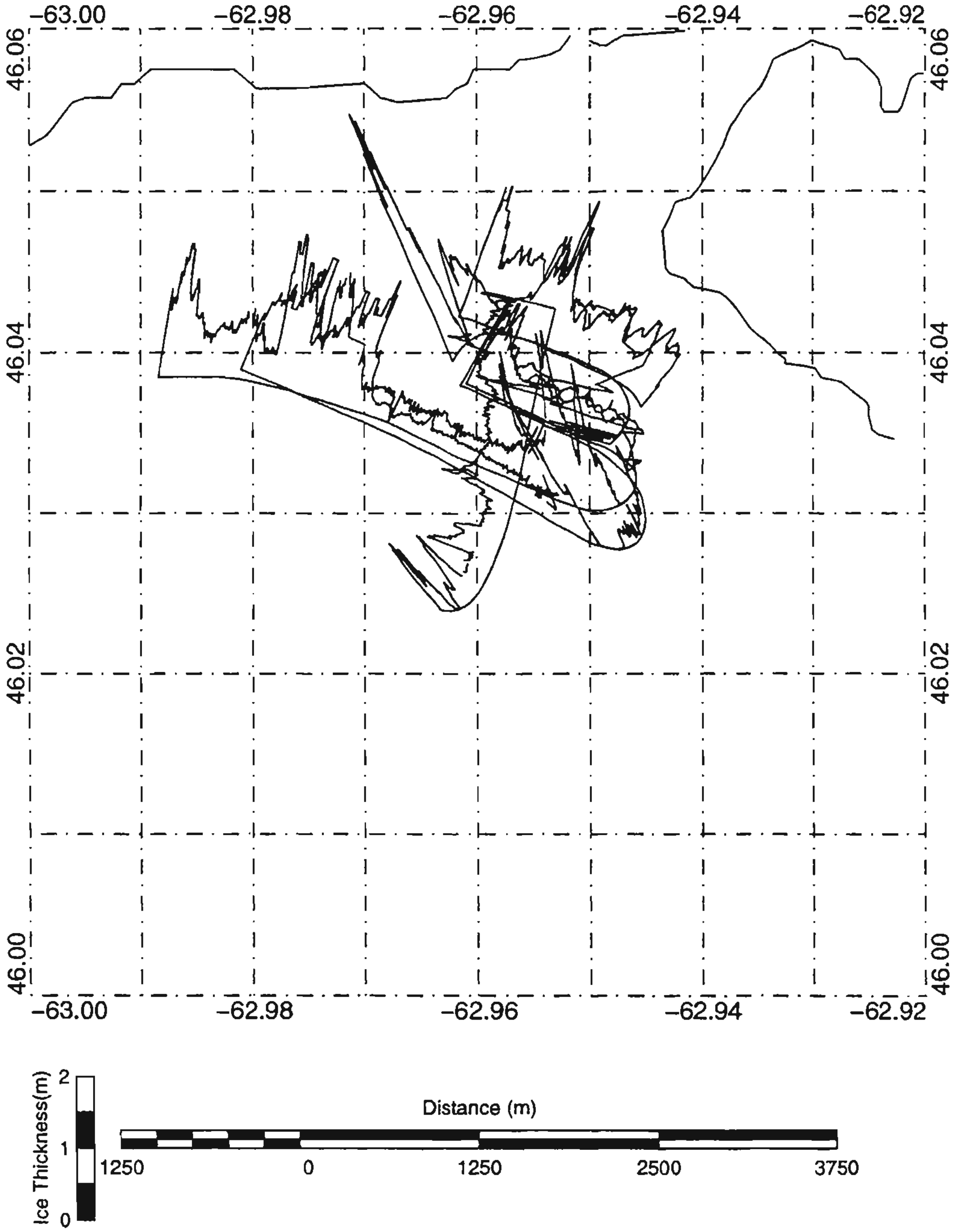


Appendix D: Profile Maps

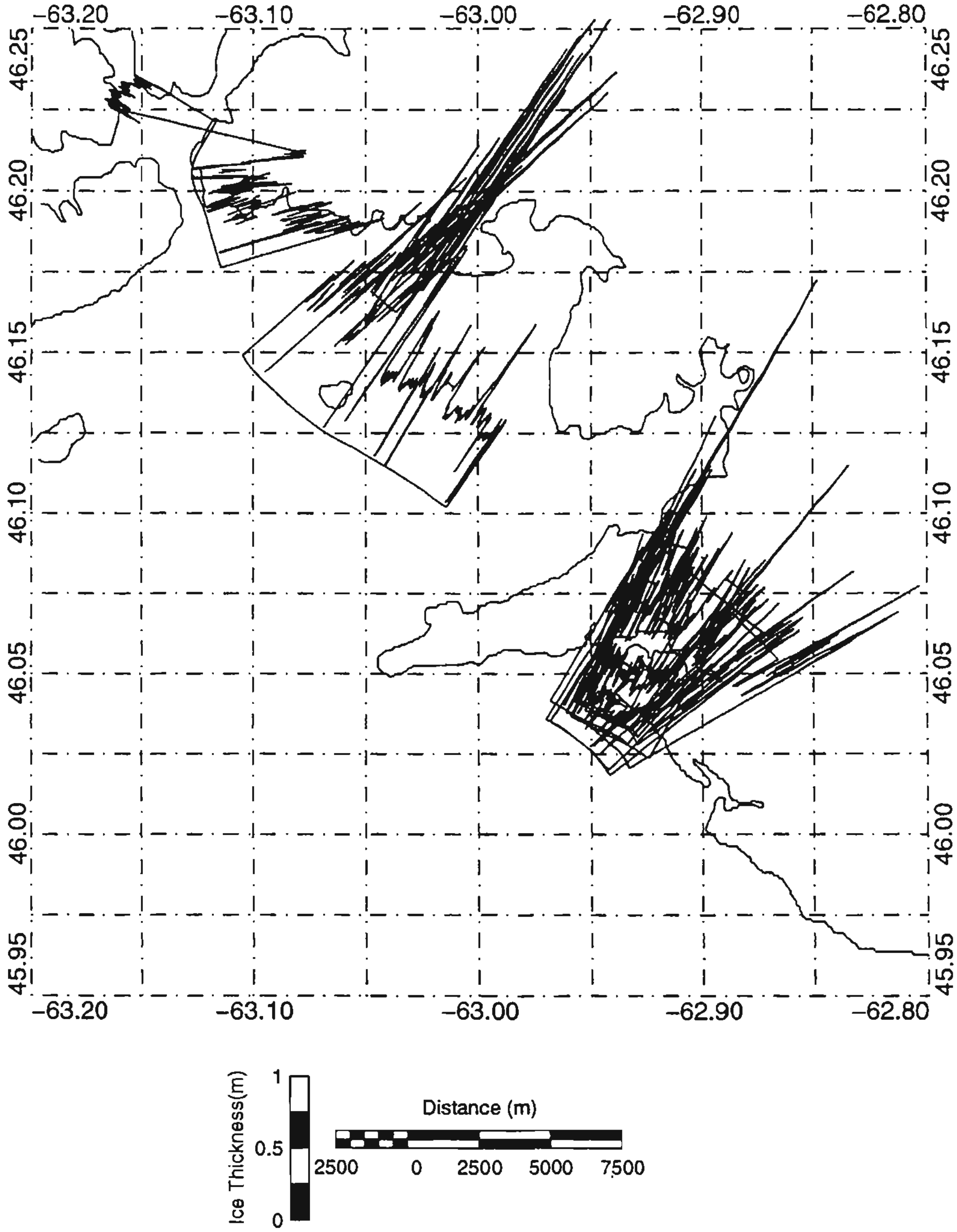
MARCH 20, 1997 FLIGHT 92
Lambert Conic Proj., Center Long.: –63.05, Lat1 49.00, Lat2 77.00
Ice Thickness 1 cm/1 m,Map Scale 1:250000



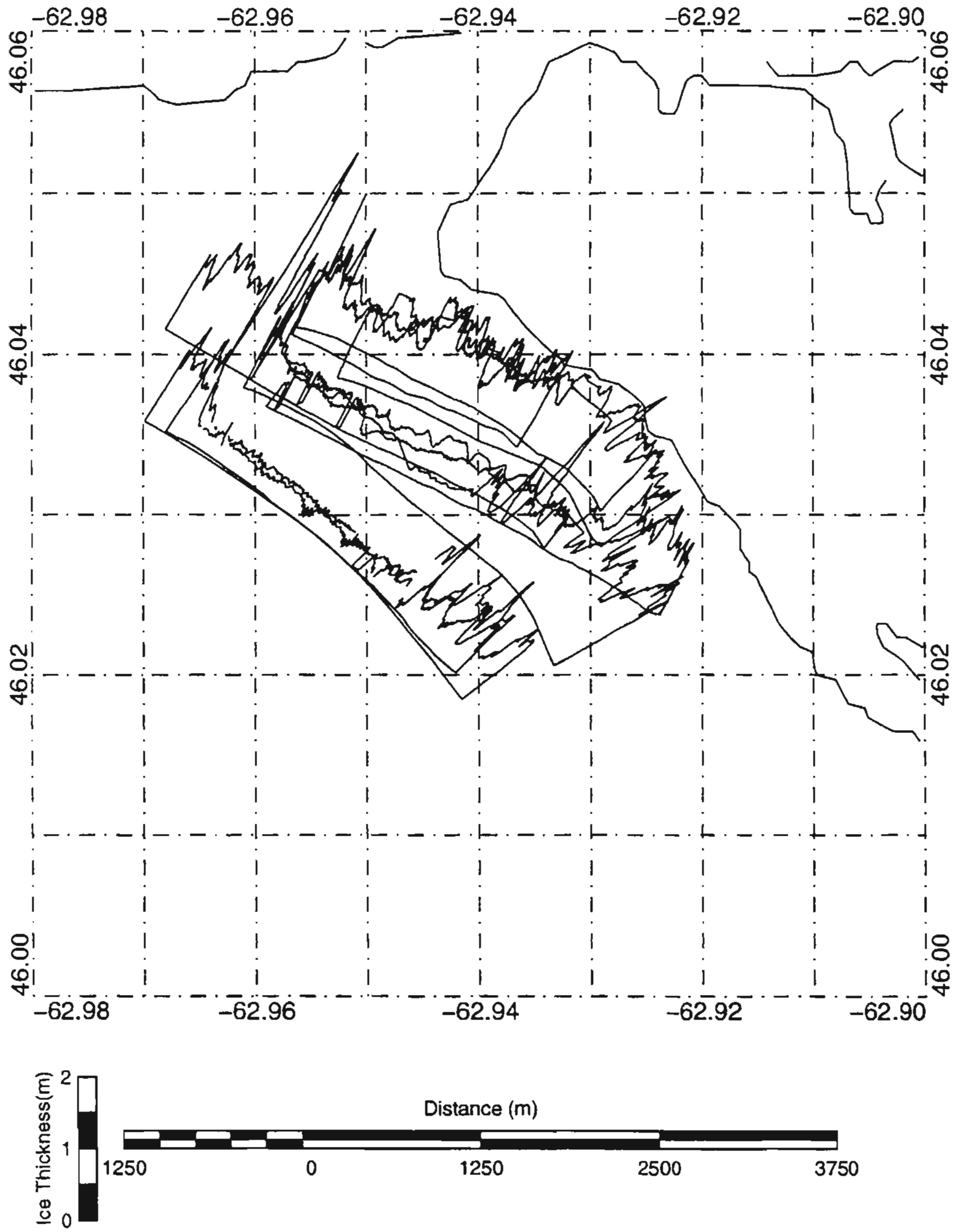
MARCH 20, 1997 FLIGHT 92, Lines: 10060 – 10100
Lambert Conic Proj., Center Long.: –62.97, Lat1 49.00, Lat2 77.00
Ice Thickness 1 cm/1 m, Map Scale 1:50000



MARCH 21, 1997 FLIGHT 96
Lambert Conic Proj., Center Long.: −63.00, Lat1 49.00, Lat2 77.00
Ice Thickness 1 cm/0.5 m,Map Scale 1:250000



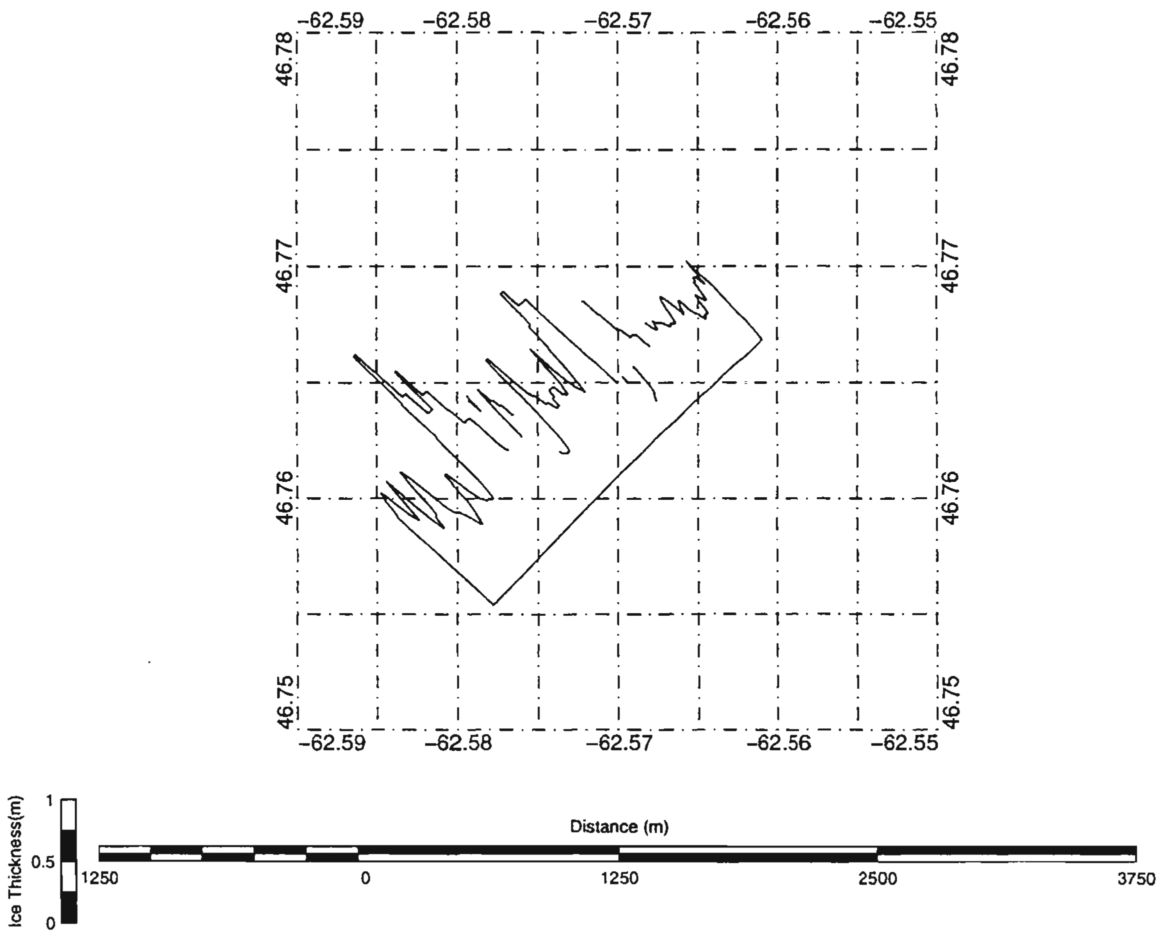
MARCH 21, 1997 FLIGHT 96, Lines: 10010 - 10080
Lambert Conic Proj., Center Long.: -62.95, Lat1 49.00, Lat2 77.00
Ice Thickness 1 cm/1 m,Map Scale 1:50000



MARCH 21, 1997 FLIGHT 97

Lambert Conic Proj., Center Long.: -62.60, Lat1 49.00, Lat2 77.00

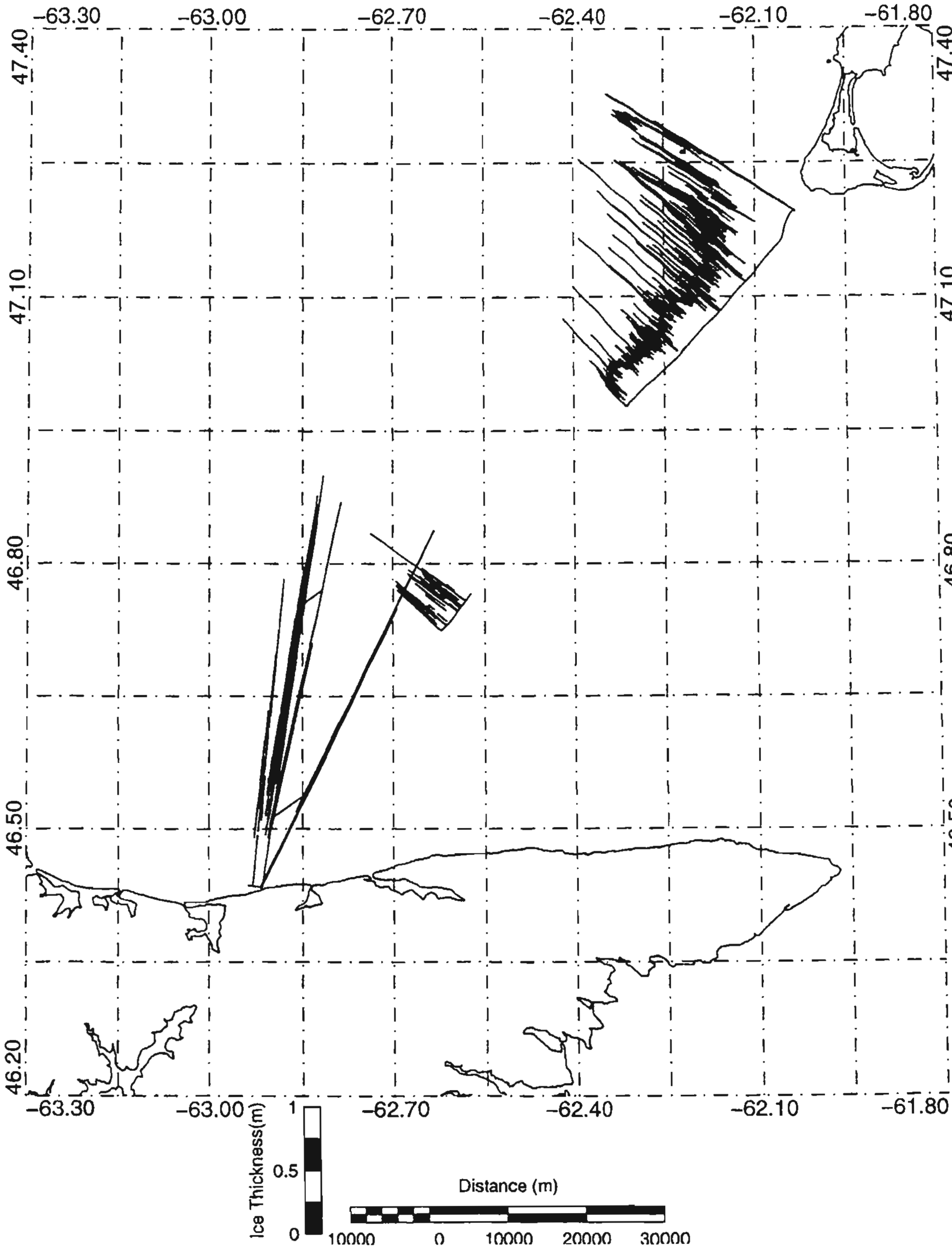
Ice Thickness 1 cm/0.5 m,Map Scale 1:30000



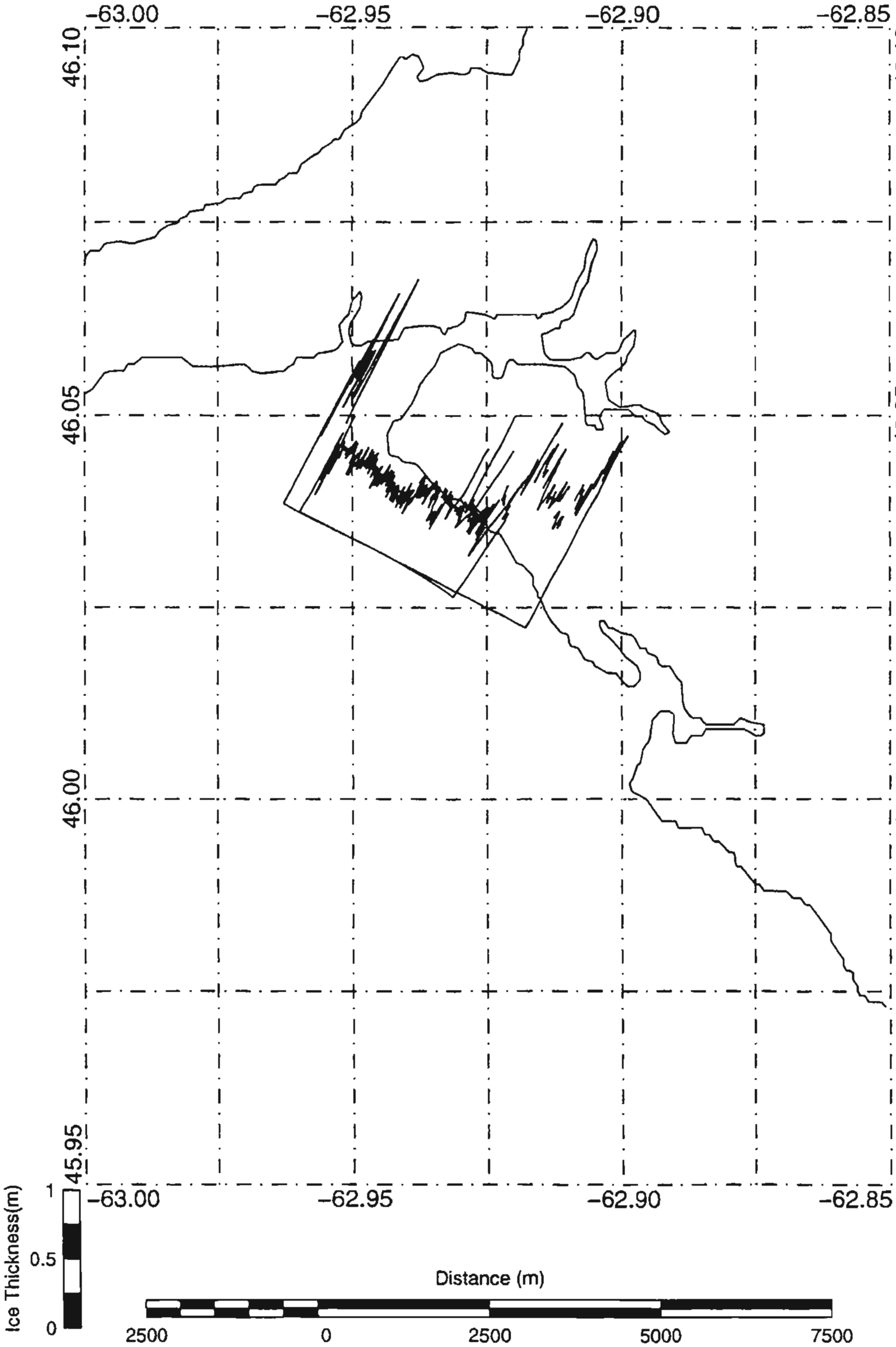
MARCH 25, 1997 FLIGHT 14

Lambert Conic Proj., Center Long.: -62.50, Lat1 49.00, Lat2 77.00

Ice Thickness 1 cm/0.5 m,Map Scale 1:800000



MARCH 27, 1997 FLIGHT 16
Lambert Conic Proj., Center Long.: –62.90, Lat1 49.00, Lat2 77.00
Ice Thickness 1 cm/0.5 m,Map Scale 1:100000



MARCH 27, 1997 FLIGHT 17
Lambert Conic Proj., Center Long.: -63.40, Lat1 49.00, Lat2 77.00
Ice Thickness 1 cm/1 m, Map Scale 1:500000