Helicopterborne EM ice thickness surveys during SafeWin 2011 field campaign

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Introduction

The EU SafeWin project aims to improve the safety of winter navigation in the ice-covered Baltic Sea and other polar seas. It includes modeling and observational studies. As part of the latter, two winter field campaigns have been performed to provide data for the development and improvement of models and ship-in-ice studies, and for their validation. Ice thickness is one of the key parameters governing navigation in ice. Therefore, extensive ground-based, ship-borne, underwater, and airborne ice thickness surveys have been performed. This report summarizes the results of airborne electromagnetic (EM) ice thickness surveys undertaken during the second SafeWin winter field campaign in 2011, using a helicopter-towed EM Bird.

Surveys were flown during and after the RV Aranda sea ice cruise in the Sea and Bay of Bothnia, between March 2 and 7, 2011. Due to sever ice conditions, RV Aranda arrived late at her final destination in the Bay of Bothnia. Therefore, and due to further delays related to technical problems with the helicopter and contaminated fuel, surveys from the ship could only be performed on two days, before the ship had to return south. However, we decided to keep the EM Bird on land in Kokkola, and after some careful training by Alec Casey, Mikko Lensu was able to perform surveys on four more days.

In total, 11 flights were performed, covering large parts of the Bay of Bothnia, the Quarken, and the northern Sea of Bothnia (Figure 1). While some flights were designed to provide the best overview of the regional ice thickness distribution, several flights were performed over the buoy array in the region surrounding the ship, to observe thickness changes resulting from changes in ice deformation.

The University of Alberta participants in the 2011 sea ice cruise were Alec Casey, John Lobach, and Christian Haas.

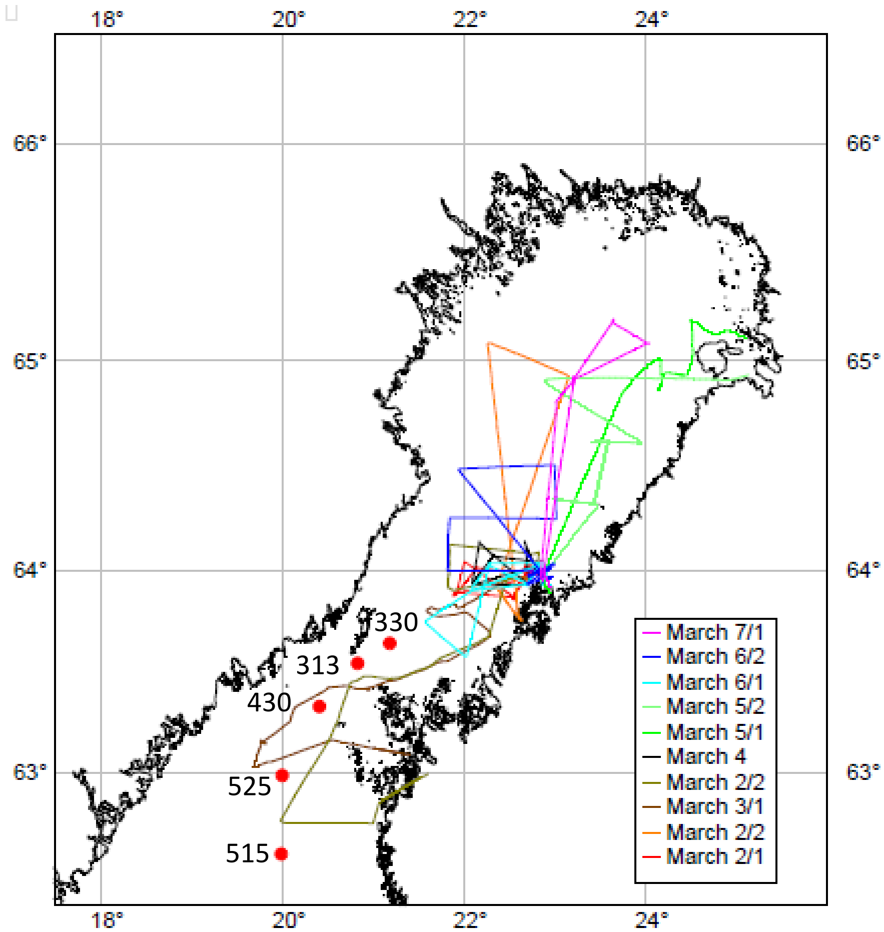


Figure 1: Overview of all EM ice thickness flights performed during SafeWin2011. Red circles show locations of CTD profiles and respective surface seawater conductivities in mS/m.

EM thickness sounding

An EM system consists of an assembly of coils for the transmission and reception of low-frequency EM fields, and a laser altimeter. The EM components are sensitive to the sensor's height above the conductive sea water surface, while the sensor's altitude above the ice or snow surface is determined with the laser altimeter. Over sea ice, the water surface coincides with the ice underside. Therefore, the difference of the height measurements of both components corresponds to the ice-plus-snow or total thickness.

We used a small, lightweight, helicopter-borne EM Bird, 3.5 m long and weighing 100 kg. It was suspended 20 m below the helicopter and towed at heights of 10 to 20 m above the ice surface. The EM bird operates at a frequency of 4.06 kHz, with a coil spacing of 2.7 m. The EM system is calibrated by means of internal calibration coils with a known response. EM sampling frequency is 10 Hz, corresponding to a measurement point spacing of approximately 3 to 4 m. Measurements are interrupted every 15 to 20 minutes by ascents to high altitude, to monitor electrical system drift. More information about the sensor and procedures can be found in Haas et al. (2009).

Comparison with drill-hole data shows that the EM derived ice thicknesses agree well within ±0.1 m over level ice. However, the accuracy is worse over ridges. Because the low-frequency EM field is diffusive, its strength represents the average thickness of an area of approximately 3.7 times the instruments altitude above the ice surface. Due to this “footprint”, the maximum ridge thickness can be underestimated by as much as 50% in the worst cases, depending on the geometry and consolidation of the ridge keel.

In the Baltic Sea, measurements are challenging due to the brackish nature of the sea water, with salinities of only around 5 ppt in the Sea of Bothnia and 3 ppt in the Bay of Bothnia, with a sharp salinity gradient in the Quarken region (see Figure 1). However, surveys have successfully been performed by a team from the Finish Geological Survey in the 1990s, and during the EU IRIS project between 2003 and 2005 (Haas, 2004), during PolIce in 2006, and during SafeWin2010. Note that with such low salinities/conductivities, the Quadrature component Q of the secondary EM field is larger than the Inphase I. Therefore, Q also has a better signal-to-noise ratio, and all thickness retrievals have been based on this component. This is different from measurements over ocean sea water, where the Inphase component is mostly used. Haas (2006) has shown that Quadrature measurements are less sensitive to the sea floor in shallow water.

The accuracy of the EM measurements is further compromised by the existence of shallow water and the formation of a freshwater layer under fast ice fed by river runoff from land. Haas (2006) has shown that ice thicknesses will be overestimated in brackish water shallower than 10 to 15 m, because currents are induced in the seafloor, which typically has a lower conductivity than the seawater. Similarly, the freshwater layer under the fast ice has negligible conductivity and cannot be distinguished from the ice. These two effects strongly influenced the results obtained during flights over fast ice, which resided near the coasts, most notably in the region around Hailuoto and along the shores west of Vasa, and east of the Quarken.

The data from the laser altimeter included in the bird can be used to retrieve the ice surface profile which can then be used to derive pressure ridge distributions. Surface heights have been obtained with the “Hibler Method” (Hibler, 1972) to remove the helicopter altitude variations inherent to the raw laser range measurements. These data have also been delivered to project participants.

Note that thicknesses have been obtained with a sampling frequency of 10 Hz, while the laser altimeter was operated with a sampling frequency of 100 Hz.

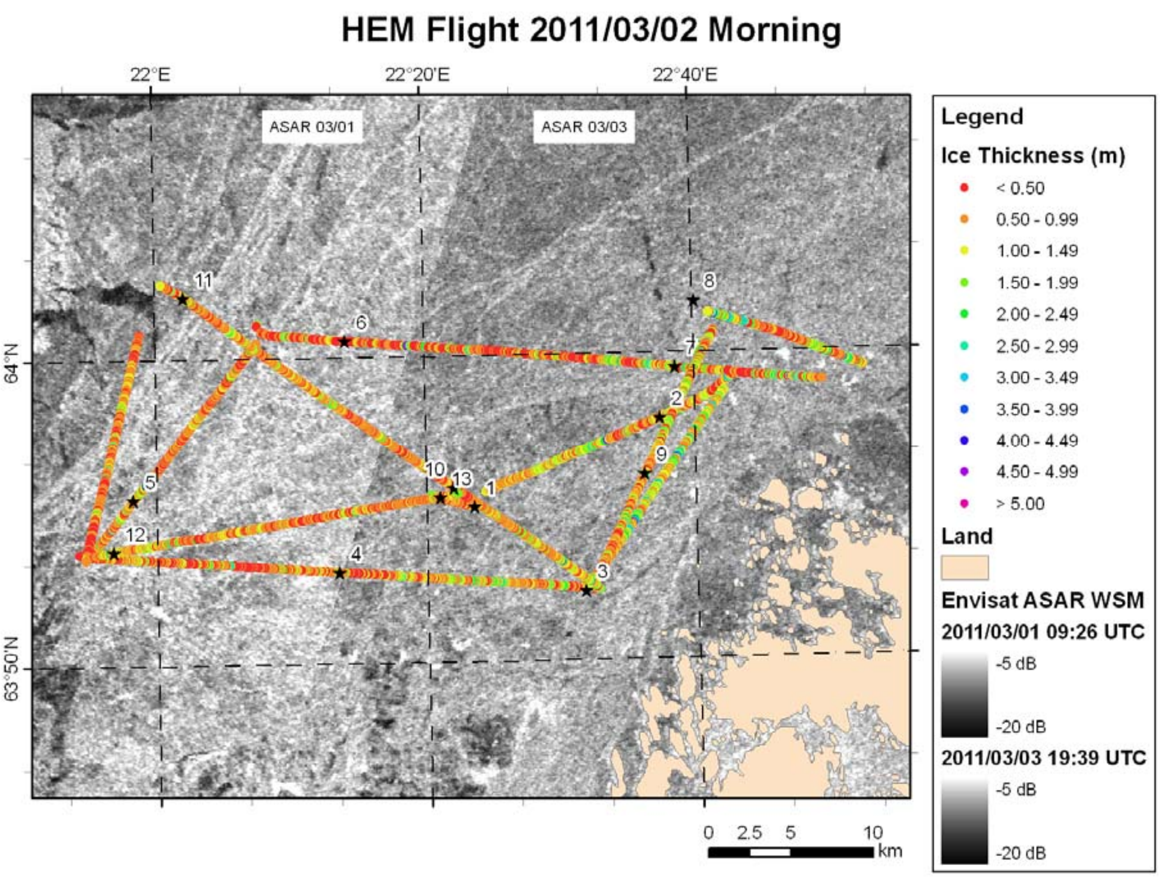
Results

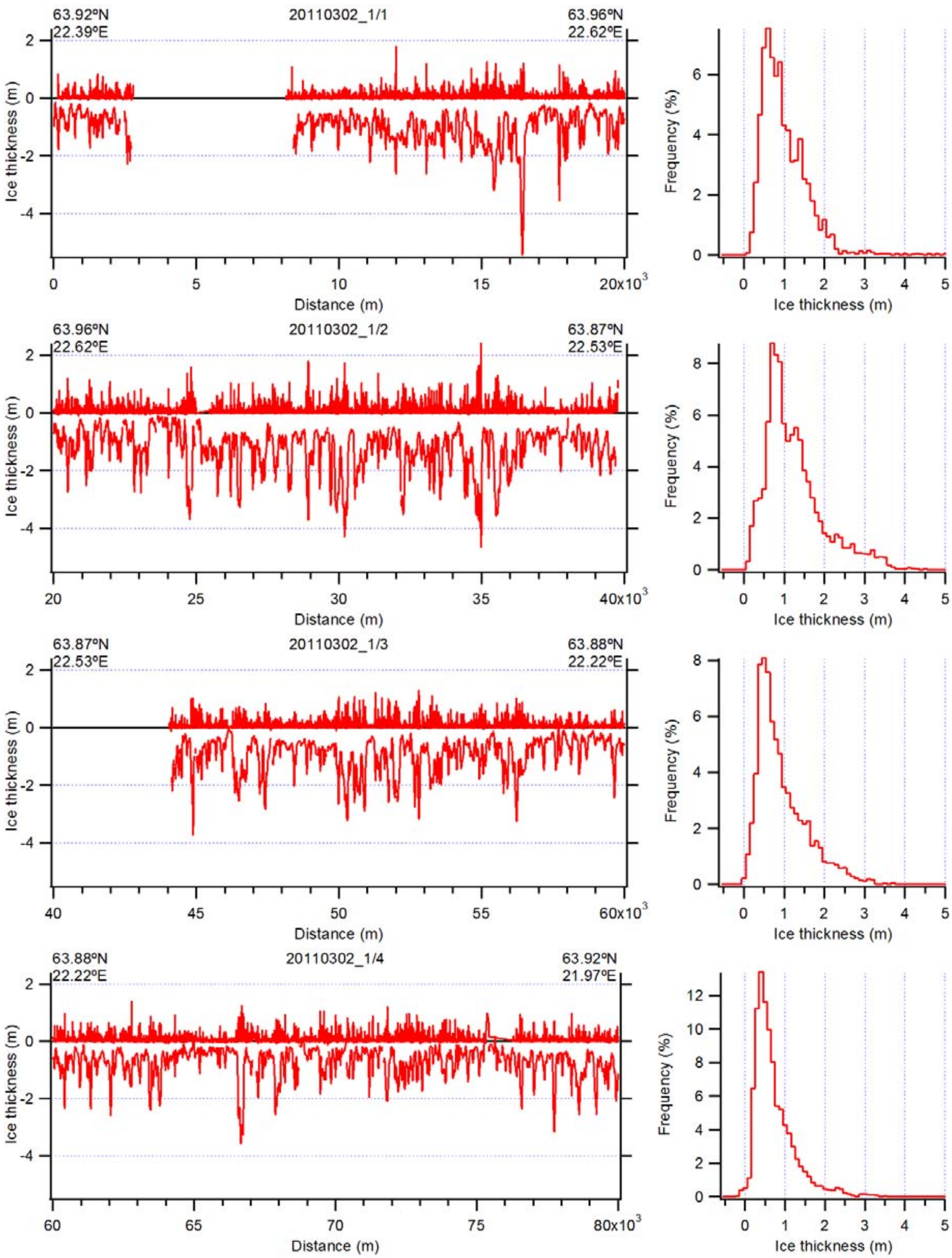
On the following pages, details of ice thicknesses along the flight tracks are given by means of profile plots of the corrected laser surface profiles and EM thickness profiles. Graphs show 20 km sections, with ice thickness plotted with negative sign to approximately resemble the draft profile. Data have been subdivided into 20 km sections for programming convenience only, and may therefore not best represent the involved flight tracks which were often characterized by many turns and curves. The users of the data can subsequently subdivide the data according to their own needs.

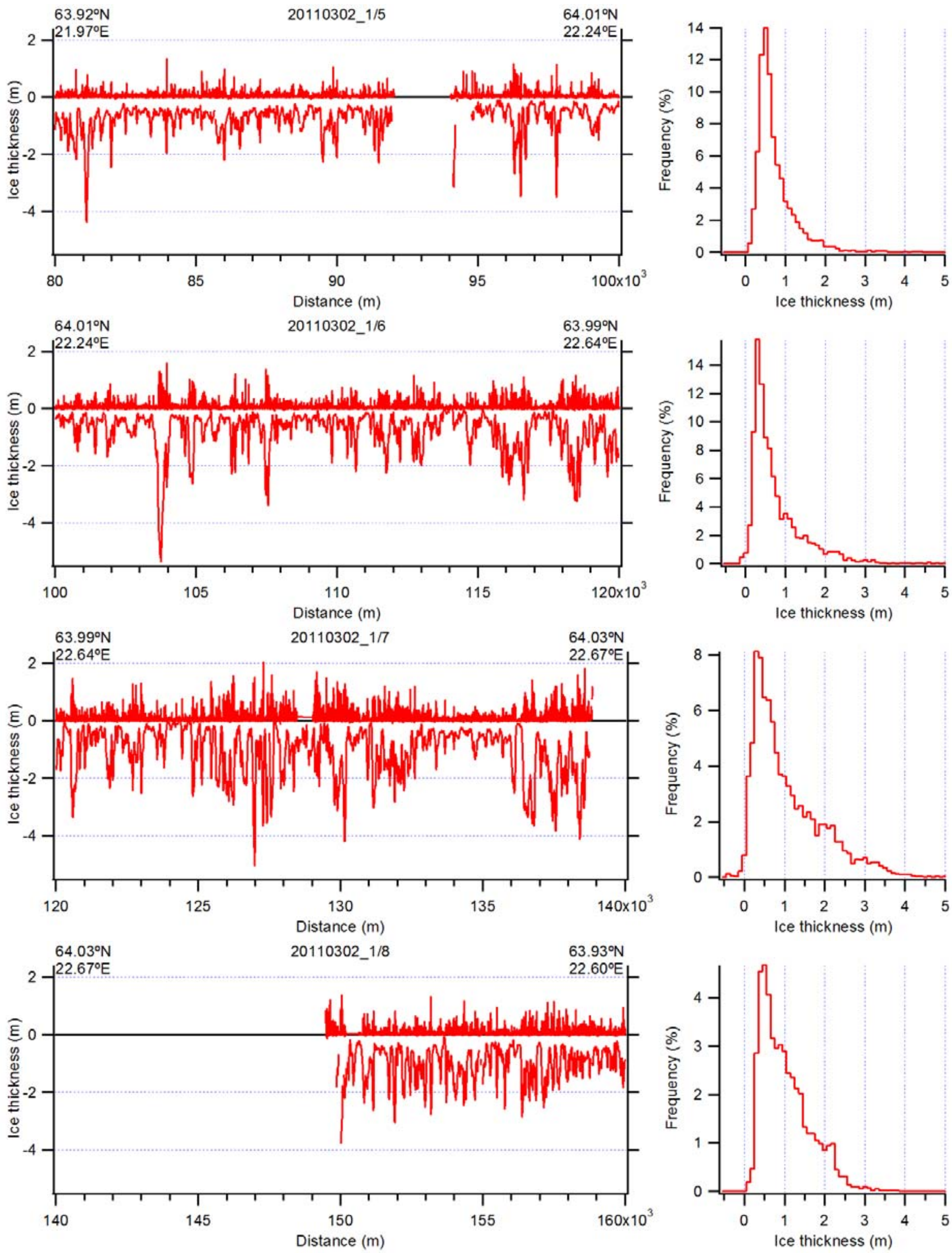
For each flight, a SAR image is shown for information about general ice conditions, with ice thicknesses overlaid. Subsequently, main results for 20 km sections are summarized in tables, profile figures, and histograms. Tables show the start and end position of each section, which are also displayed by the stars and associated segment number in the thickness maps.

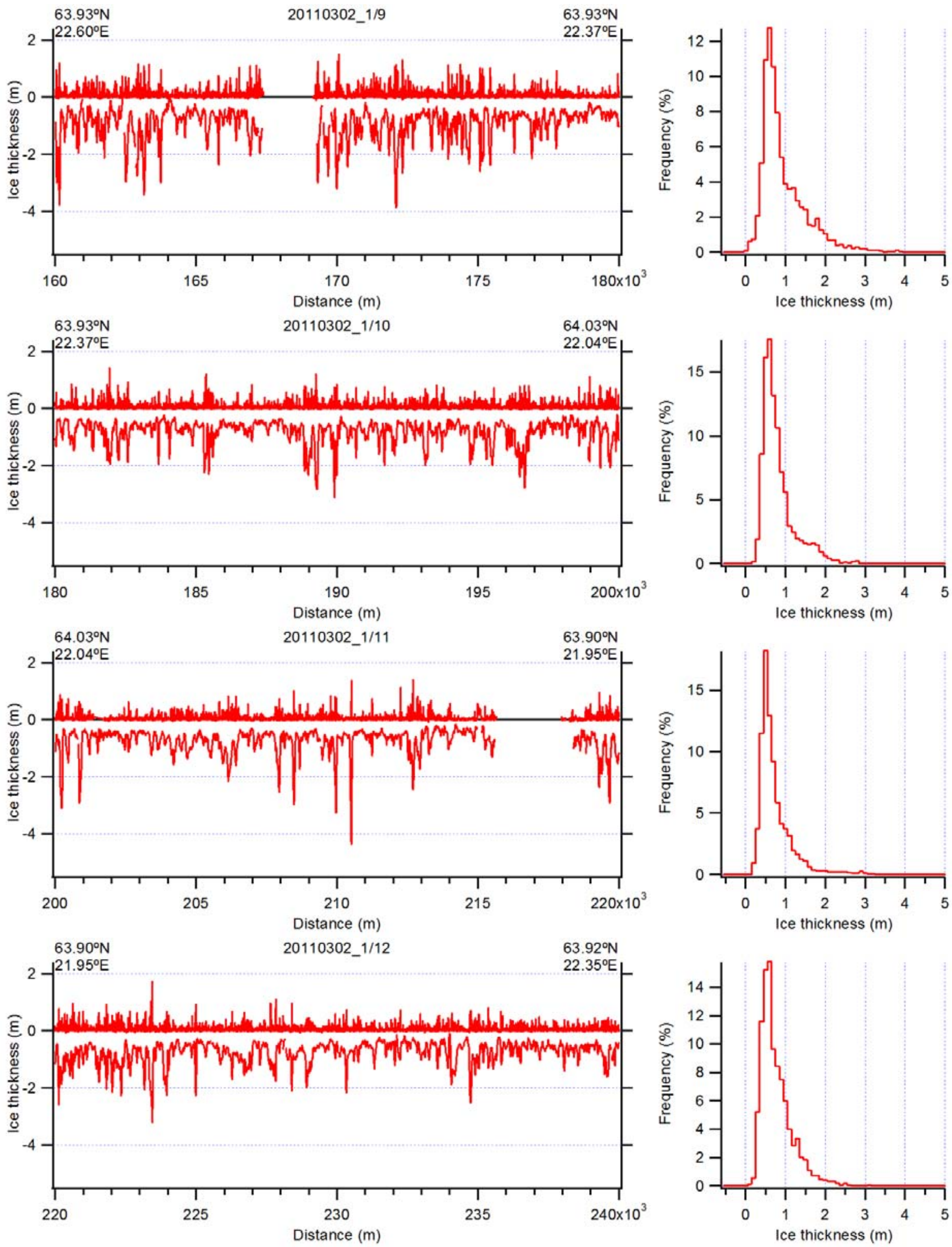
March 2, 2011, morning flight over buoy array

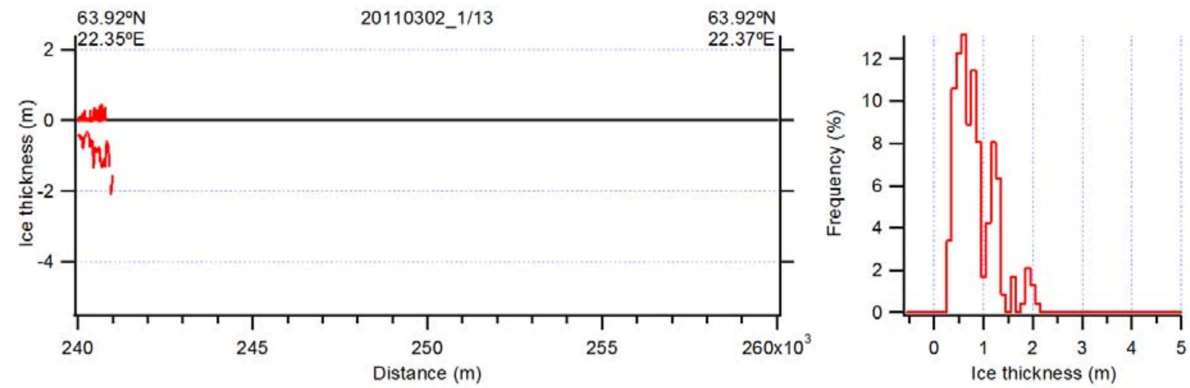
Segment No.	GPS time start (decimal hour)	GPS time end (decimal hour)	Mean thickness (m)	Standard deviation (m)	Modal thickness (m)
1	7.83017	7.96806	1.00417	0.585632	0.55
2	7.96806	8.32356	1.25393	0.733633	0.65
3	8.32356	8.48186	0.945975	0.611057	0.45
4	8.48186	8.67117	0.72974	0.511156	0.35
5	8.67117	8.80883	0.753142	0.508326	0.45
6	8.80883	8.93664	0.781615	0.700165	0.25
7	8.93664	9.17456	1.07741	0.855848	0.25
8	9.17456	9.3935	1.02192	0.602169	0.45
9	9.3935	9.54761	0.949472	0.567729	0.55
10	9.54761	9.68669	0.814186	0.416853	0.55
11	9.68669	9.86567	0.744964	0.454924	0.45
12	9.86567	9.98836	0.772241	0.392079	0.55
13	9.98836	9.99486	0.822701	0.387474	0.55




63.92ºN
22.39ºE
20110302_1/1
63.96ºN
22.62ºE
63.96ºN
22.62ºE
20110302_1/2
63.87ºN
22.53ºE
63.87ºN
22.53ºE
20110302_1/3
63.88ºN
22.22ºE
63.88ºN
22.22ºE
20110302_1/4
63.92ºN
21.97ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)

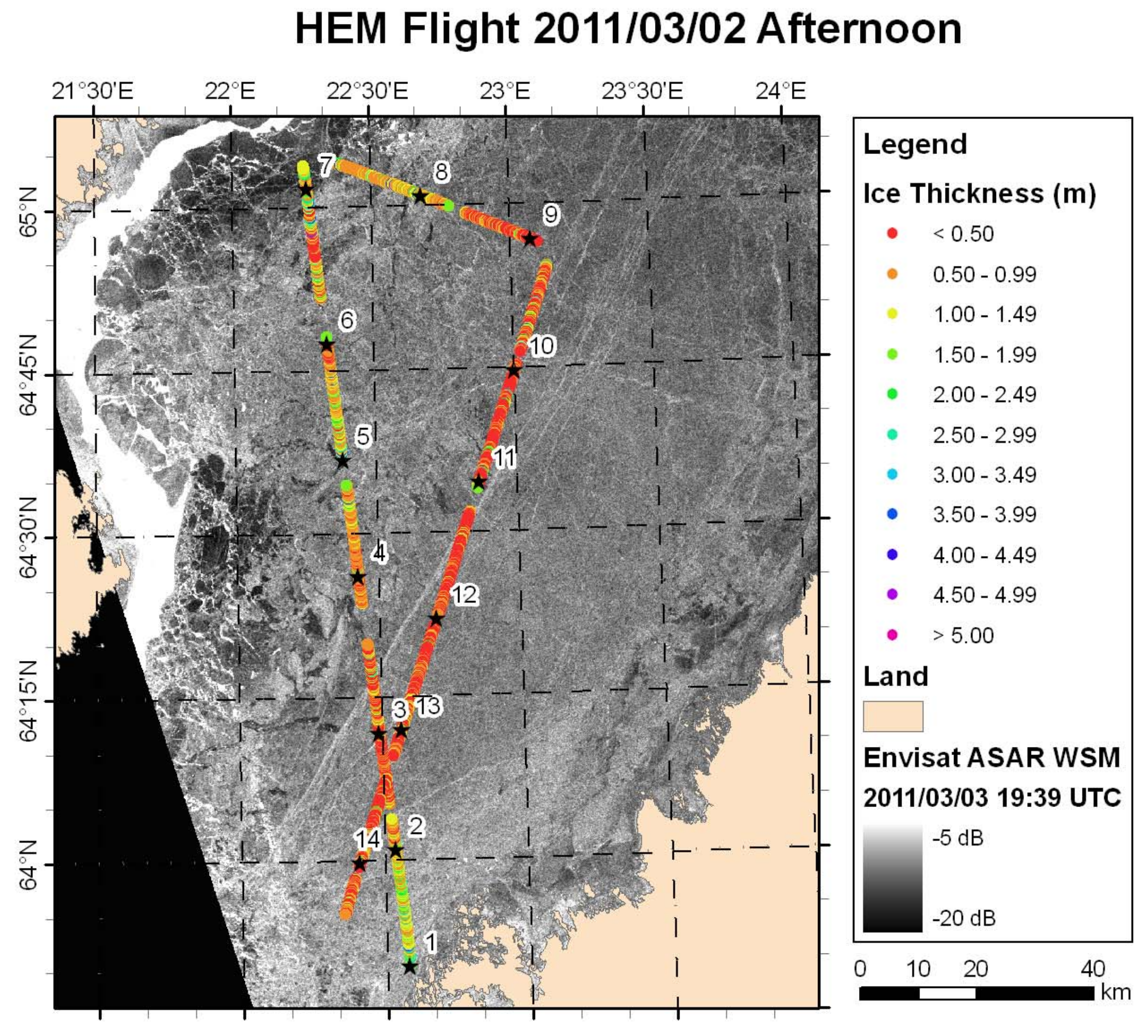

63.92ºN
21.97ºE
20110302_1/5
64.01ºN
22.24ºE
Ice thickness (m)
Distance (m)
100x10^3
Frequency (%)
Ice thickness (m)
64.01ºN
22.24ºE
20110302_1/6
63.99ºN
22.64ºE
120x10^3
63.99ºN
22.64ºE
20110302_1/7
64.03ºN
22.67ºE
140x10^3
64.03ºN
22.67ºE
20110302_1/8
63.93ºN
22.60ºE
160x10^3

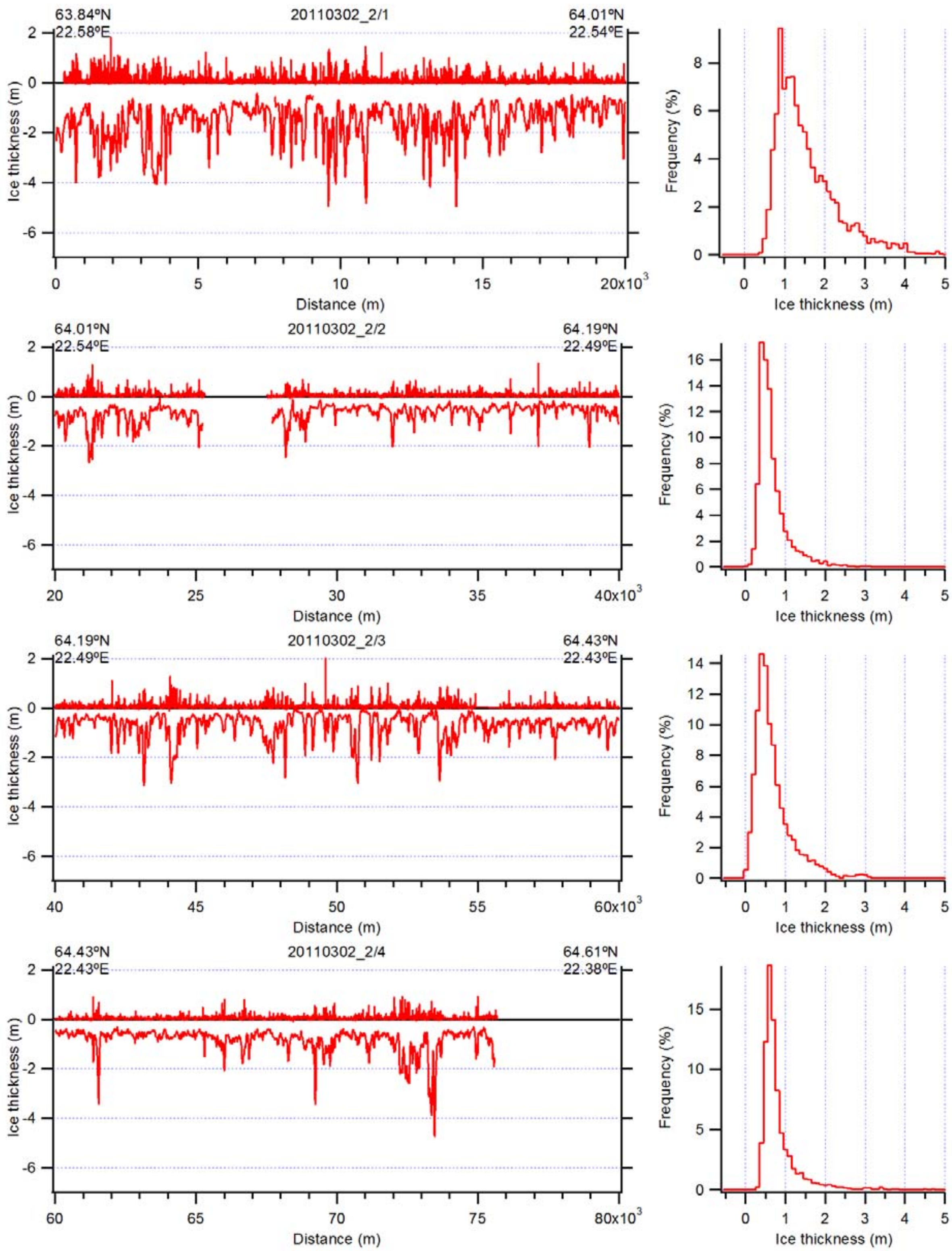

63.93ºN
22.60ºE
20110302_1/9
63.93ºN
22.37ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
63.93ºN
22.37ºE
20110302_1/10
64.03ºN
22.04ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
64.03ºN
22.04ºE
20110302_1/11
63.90ºN
21.95ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
63.90ºN
21.95ºE
20110302_1/12
63.92ºN
22.35ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)

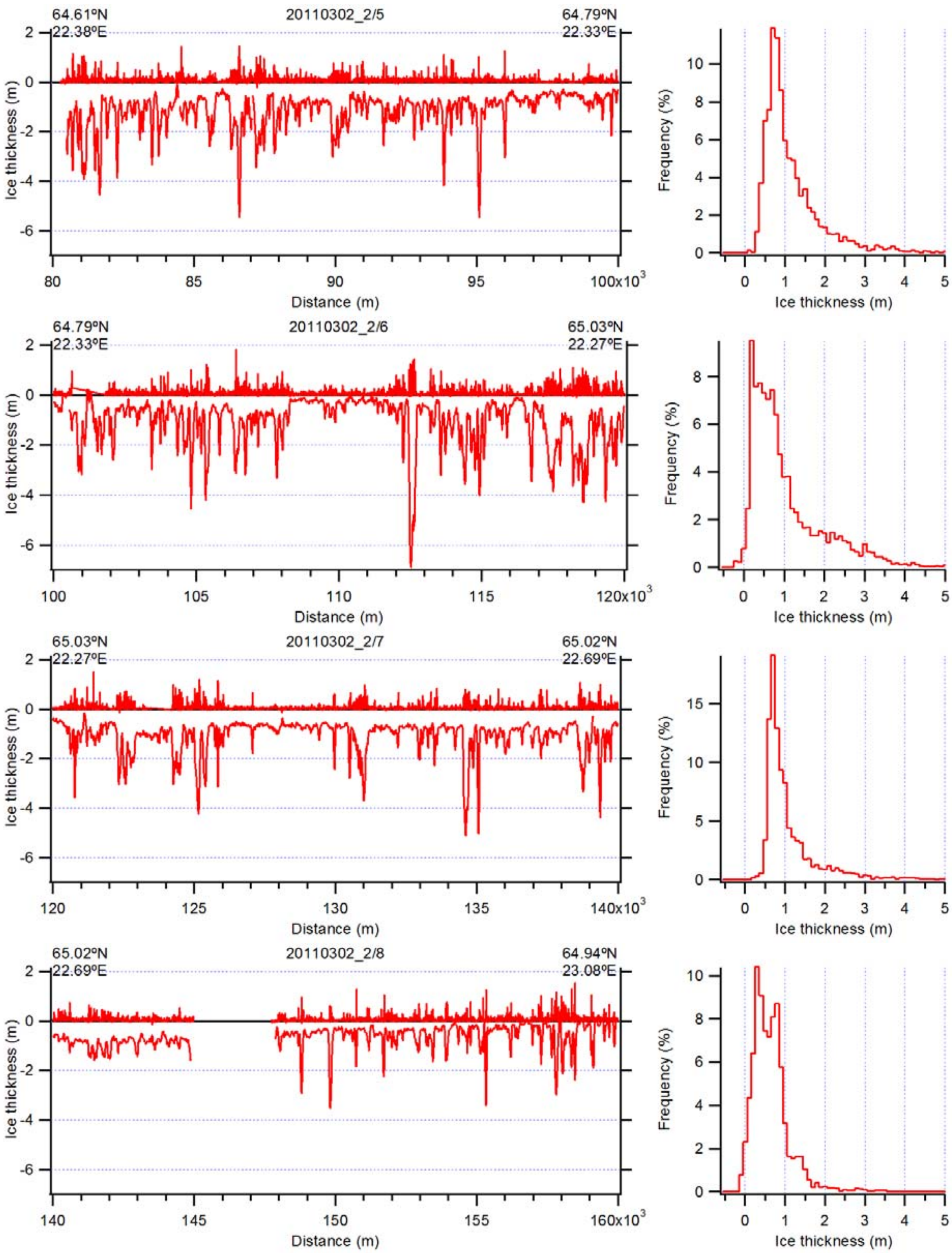

63.92ºN
22.35ºE
20110302_1/13
63.92ºN
22.37ºE
Ice thickness (m)
Distance (m)
240
245
250
255
260x10³
Frequency (%)
Ice thickness (m)

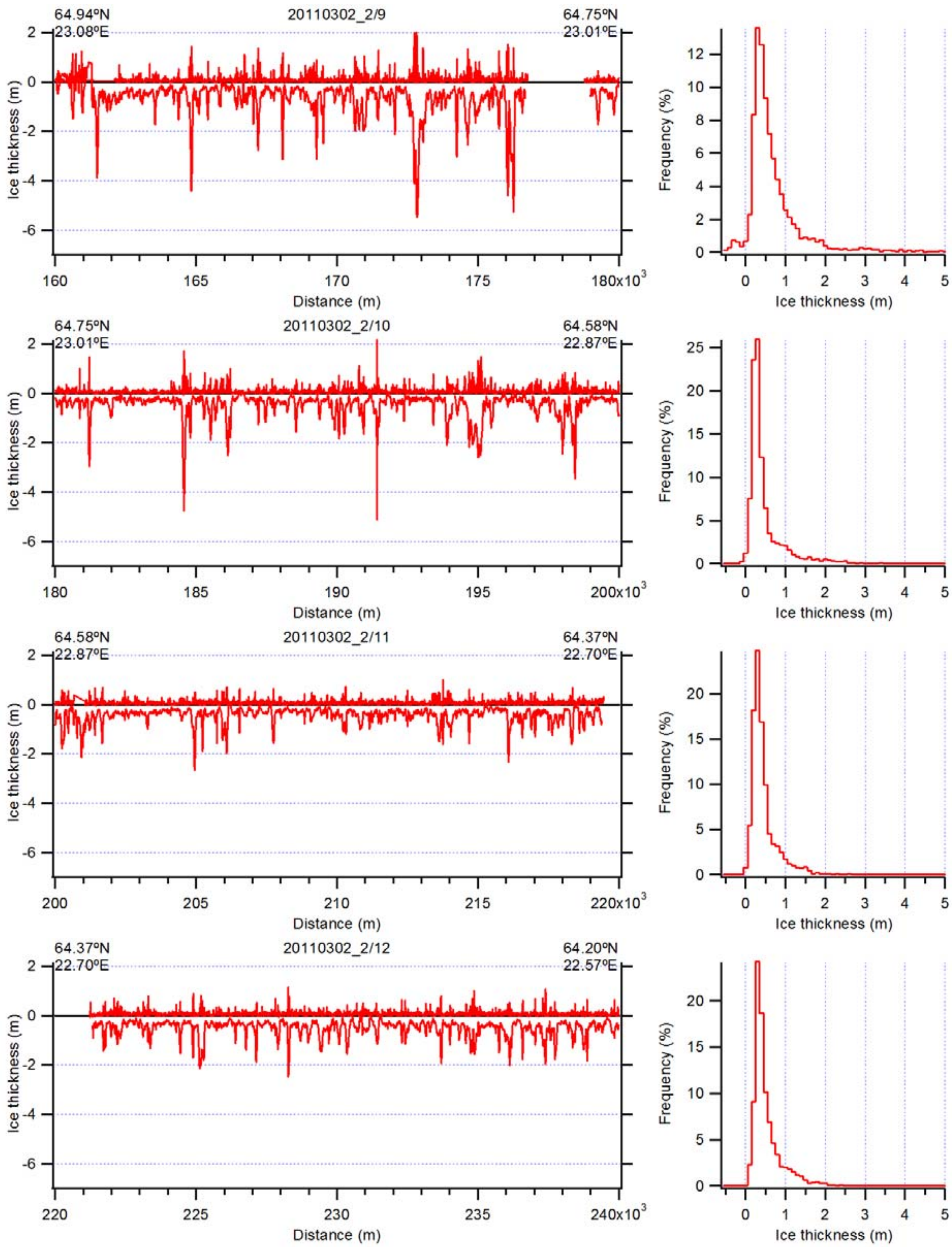
March 2, 2011, afternoon flight along CryoSat track to Norstroemsgrund (near Lulea)

Segment No.	GPS time start (decimal hour)	GPS time end (decimal hour)	Mean thickness (m)	Standard deviation (m)	Modal thickness (m)
1	11.84	11.9712	1.54929	0.76351	0.85
2	11.9712	12.0986	0.670421	0.380157	0.35
3	12.0986	12.2666	0.693321	0.488198	0.35
4	12.2666	12.3902	0.837055	0.501877	0.55
5	12.3902	12.5089	1.15589	0.742053	0.65
6	12.5089	12.6613	1.06348	0.972963	0.15
7	12.6613	12.8244	1.09337	0.693173	0.65
8	12.8244	12.9459	0.640959	0.470235	0.25
9	12.9459	13.1428	0.693338	0.731776	0.25
10	13.1428	13.294	0.484931	0.518387	0.25
11	13.294	13.4785	0.443548	0.323835	0.25
12	13.4785	13.6282	0.515981	0.345722	0.25
13	13.6282	13.8004	0.539426	0.417146	0.25
14	13.8004	13.8664	0.530731	0.369114	0.25

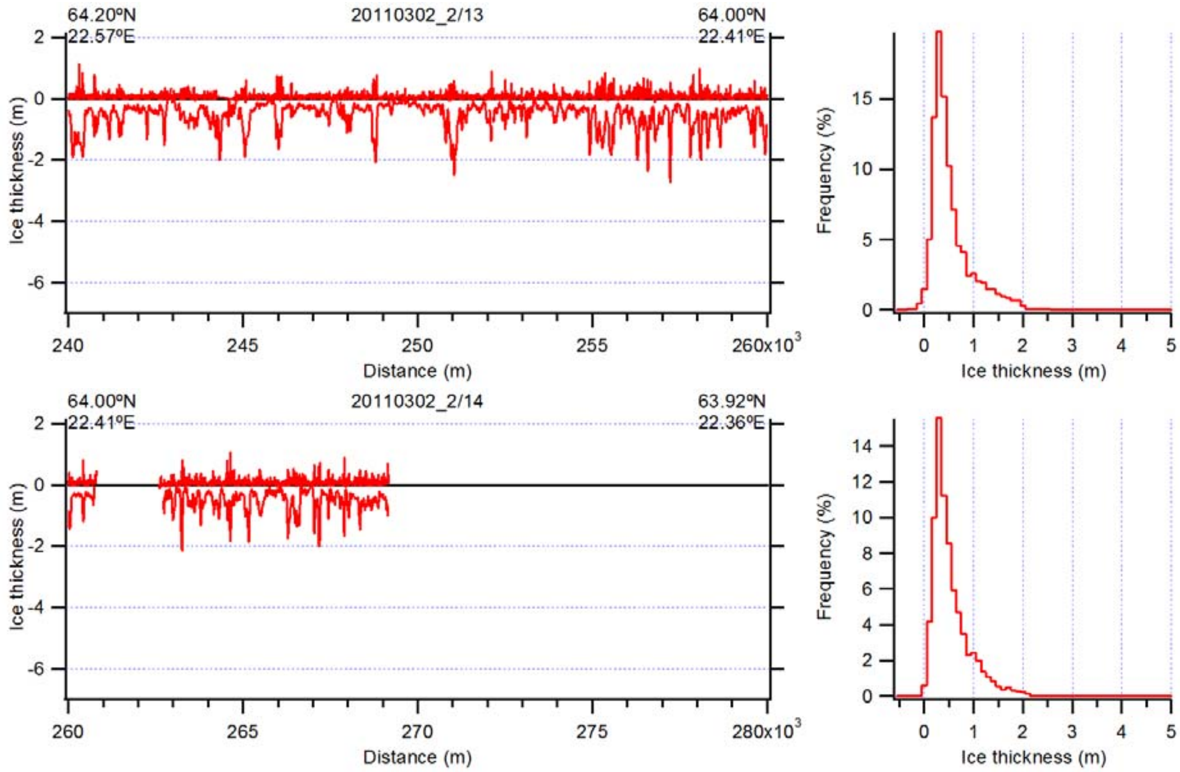

HEM Flight 2011/03/02 Afternoon
21°30'E
22°E
22°30'E
23°E
23°30'E
24°E
65°N
64°45'N
64°30'N
64°15'N
64°N
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Legend
Ice Thickness (m)
< 0.50
0.50 - 0.99
1.00 - 1.49
1.50 - 1.99
2.00 - 2.49
2.50 - 2.99
3.00 - 3.49
3.50 - 3.99
4.00 - 4.49
4.50 - 4.99
> 5.00
Land
Envisat ASAR WSM
2011/03/03 19:39 UTC
-5 dB
-20 dB
0 10 20 40
km


63.84ºN
22.58ºE
20110302_2/1
64.01ºN
22.54ºE
64.01ºN
22.54ºE
20110302_2/2
64.19ºN
22.49ºE
64.19ºN
22.49ºE
20110302_2/3
64.43ºN
22.43ºE
64.43ºN
22.43ºE
20110302_2/4
64.61ºN
22.38ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)


64.61ºN
22.38ºE
20110302_2/5
64.79ºN
22.33ºE
Ice thickness (m)
Distance (m)
100x10³
Frequency (%)
Ice thickness (m)
64.79ºN
22.33ºE
20110302_2/6
65.03ºN
22.27ºE
120x10³
65.03ºN
22.27ºE
20110302_2/7
65.02ºN
22.69ºE
140x10³
65.02ºN
22.69ºE
20110302_2/8
64.94ºN
23.08ºE
160x10³

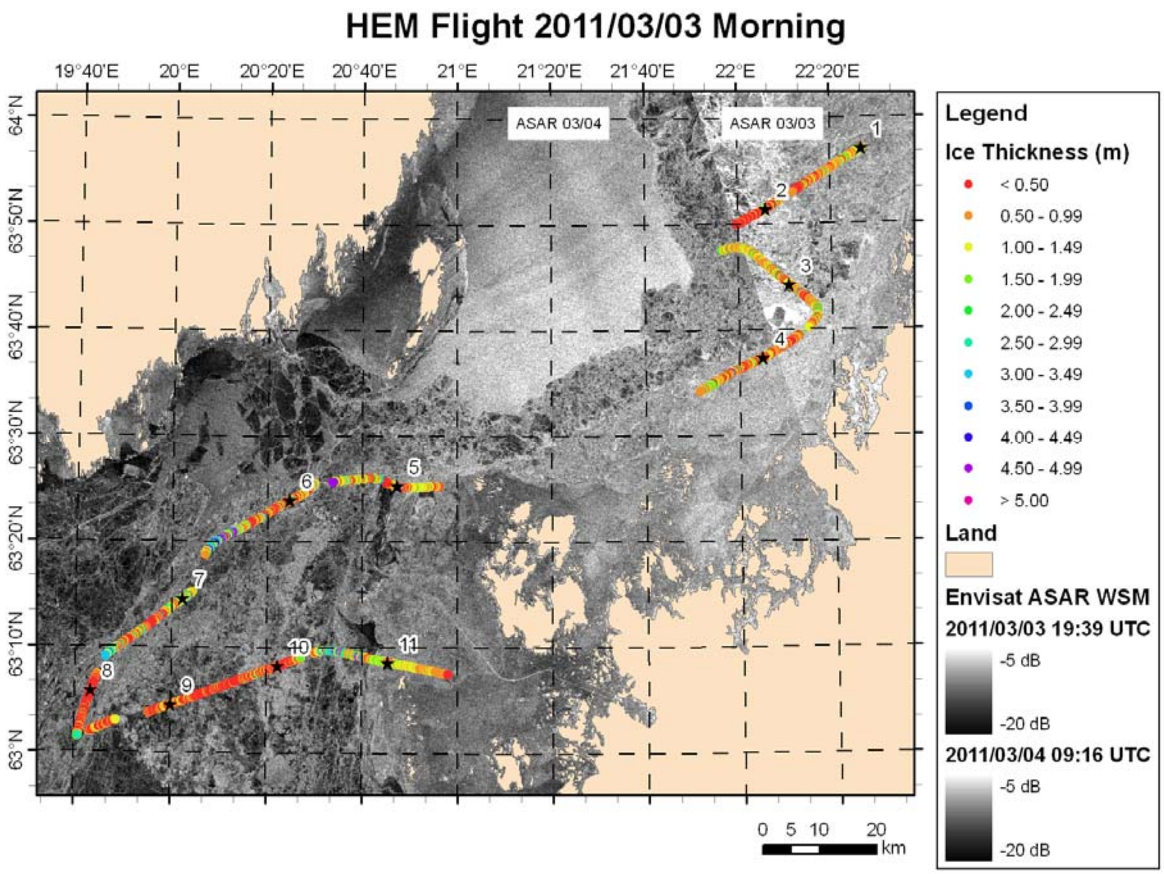


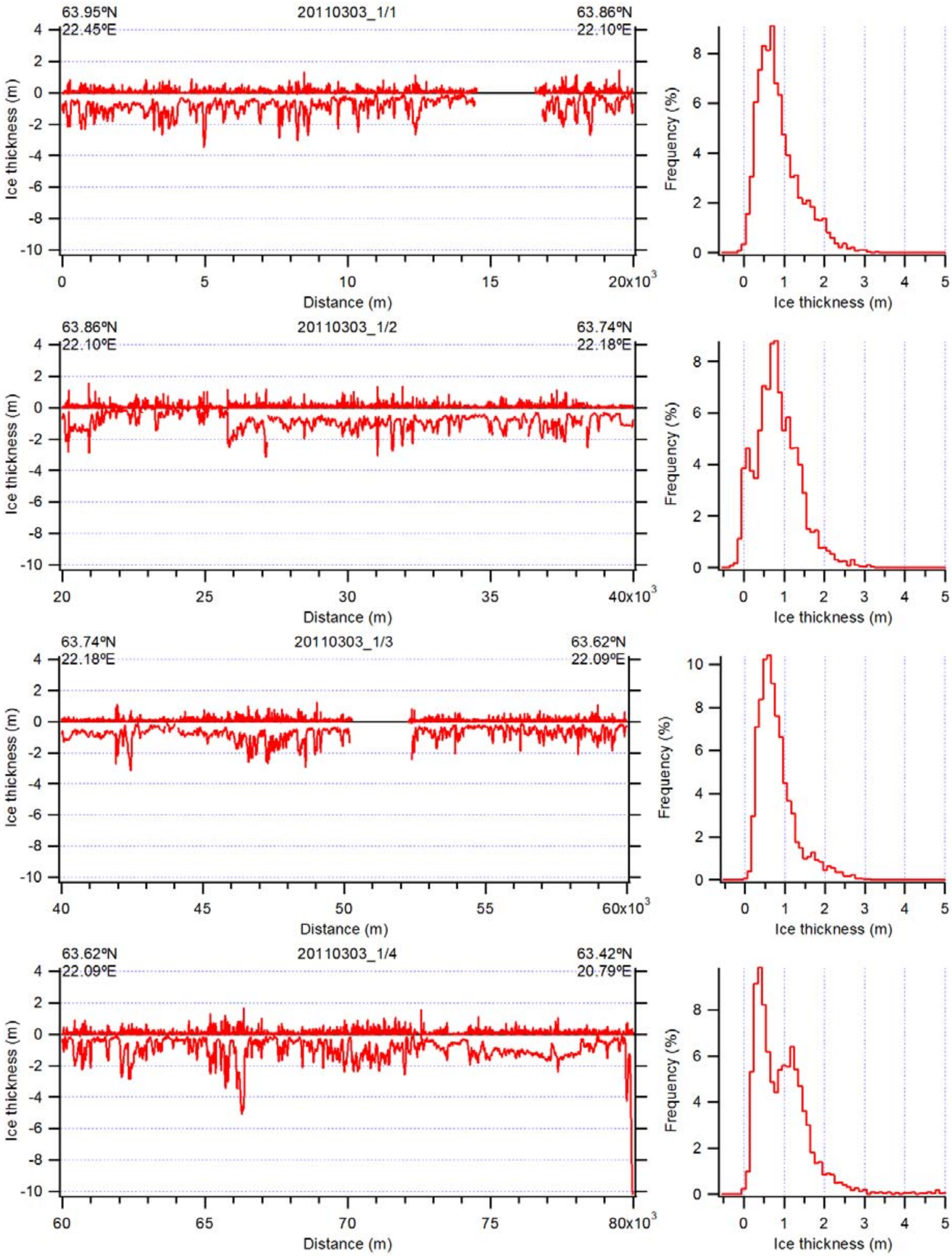
64.94ºN
23.08ºE
20110302_2/9
64.75ºN
23.01ºE
Ice thickness (m)
Distance (m)
160
165
170
175
180x10³
Frequency (%)
Ice thickness (m)
64.75ºN
23.01ºE
20110302_2/10
64.58ºN
22.87ºE
Ice thickness (m)
Distance (m)
180
185
190
195
200x10³
Frequency (%)
Ice thickness (m)
64.58ºN
22.87ºE
20110302_2/11
64.37ºN
22.70ºE
Ice thickness (m)
Distance (m)
200
205
210
215
220x10³
Frequency (%)
Ice thickness (m)
64.37ºN
22.70ºE
20110302_2/12
64.20ºN
22.57ºE
Ice thickness (m)
Distance (m)
220
225
230
235
240x10³
Frequency (%)
Ice thickness (m)


64.20ºN
22.57ºE
20110302_2/13
64.00ºN
22.41ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
64.00ºN
22.41ºE
20110302_2/14
63.92ºN
22.36ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)

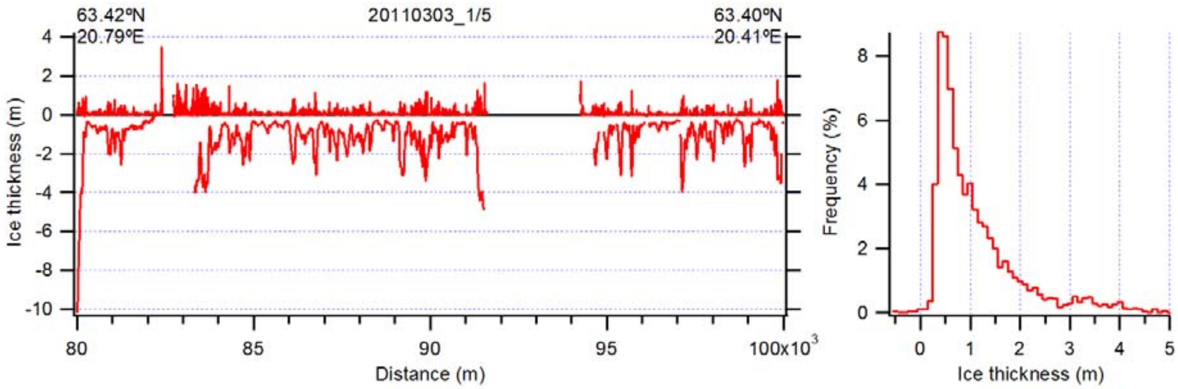
March 3, 2011, morning flight to Quarken and Vaasa

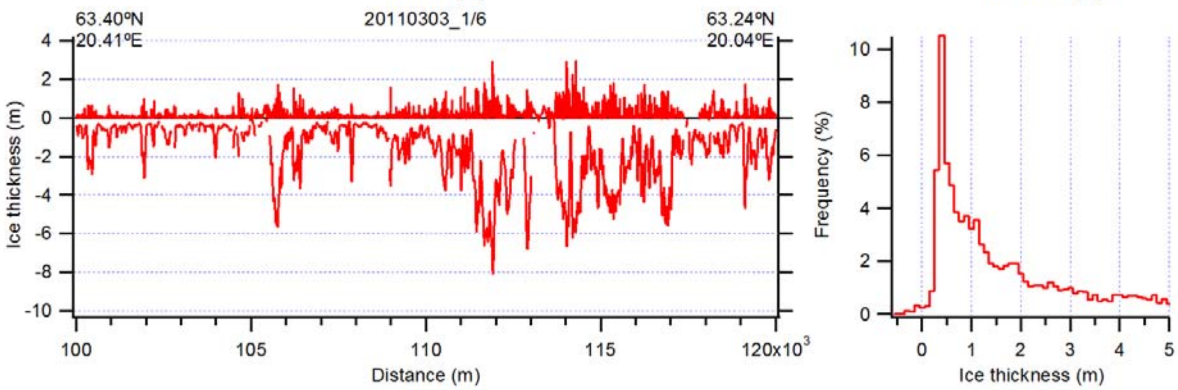
Segment No.	GPS time start (decimal hour)	GPS time end (decimal hour)	Mean thickness (m)	Standard deviation (m)	Modal thickness (m)
1	7.94969	8.10108	0.878215	0.538384	0.65
2	8.10108	8.50089	0.842745	0.540016	0.75
3	8.50089	8.64033	0.801694	0.478942	0.55
4	8.64033	9.17589	0.958471	0.662839	0.35
5	9.17589	9.32564	1.17302	1.10489	0.35
6	9.32564	9.50678	1.70396	1.5128	0.35
7	9.50678	9.73778	0.990693	0.873622	0.25
8	9.73778	9.91342	0.508956	0.382907	0.35
9	9.91342	10.0194	0.516246	0.401484	0.25
10	10.0194	10.1263	1.53589	1.20678	0.35
11	10.1263	10.1832	1.01268	0.337512	0.95

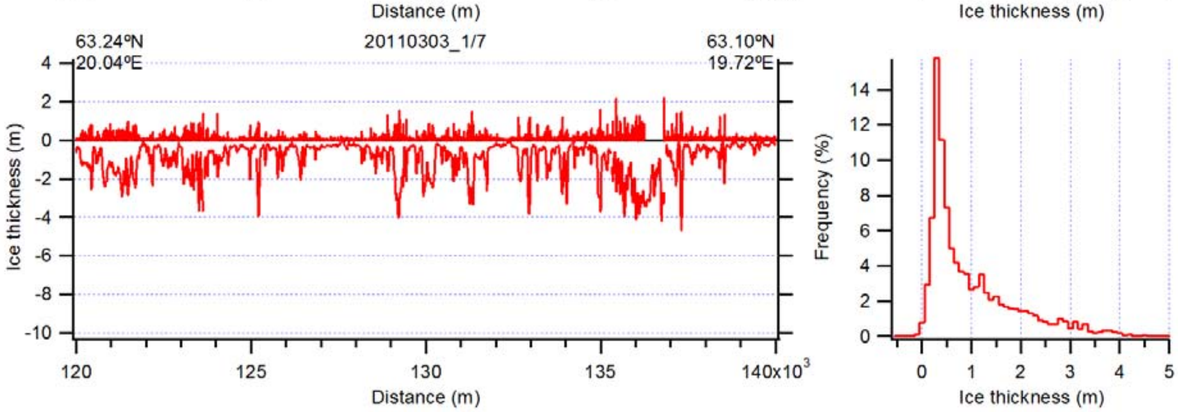


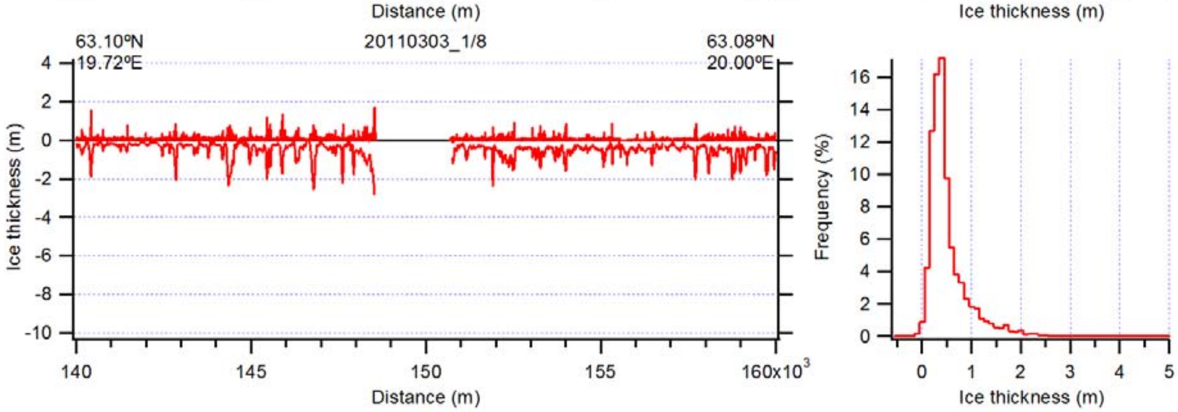


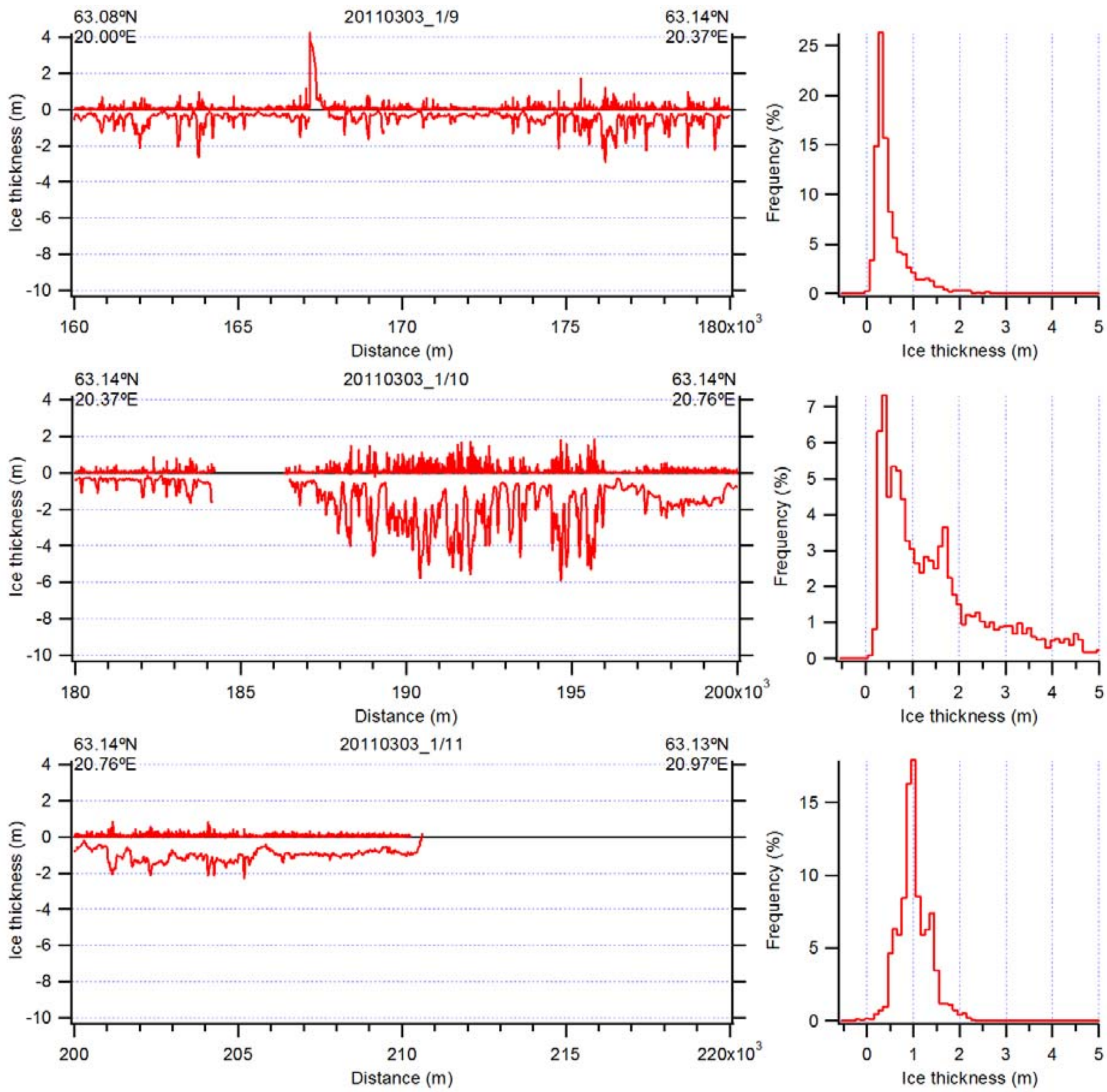
63.95ºN
22.45ºE
20110303_1/1
63.86ºN
22.10ºE
Ice thickness (m)
Distance (m)
20x10³
Frequency (%)
Ice thickness (m)
63.86ºN
22.10ºE
20110303_1/2
63.74ºN
22.18ºE
Ice thickness (m)
Distance (m)
40x10³
Frequency (%)
Ice thickness (m)
63.74ºN
22.18ºE
20110303_1/3
63.62ºN
22.09ºE
Ice thickness (m)
Distance (m)
60x10³
Frequency (%)
Ice thickness (m)
63.62ºN
22.09ºE
20110303_1/4
63.42ºN
20.79ºE
Ice thickness (m)
Distance (m)
80x10³
Frequency (%)
Ice thickness (m)


63.42ºN
20.79ºE
20110303_1/5
63.40ºN
20.41ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)


63.40ºN
20.41ºE
20110303_1/6
63.24ºN
20.04ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)

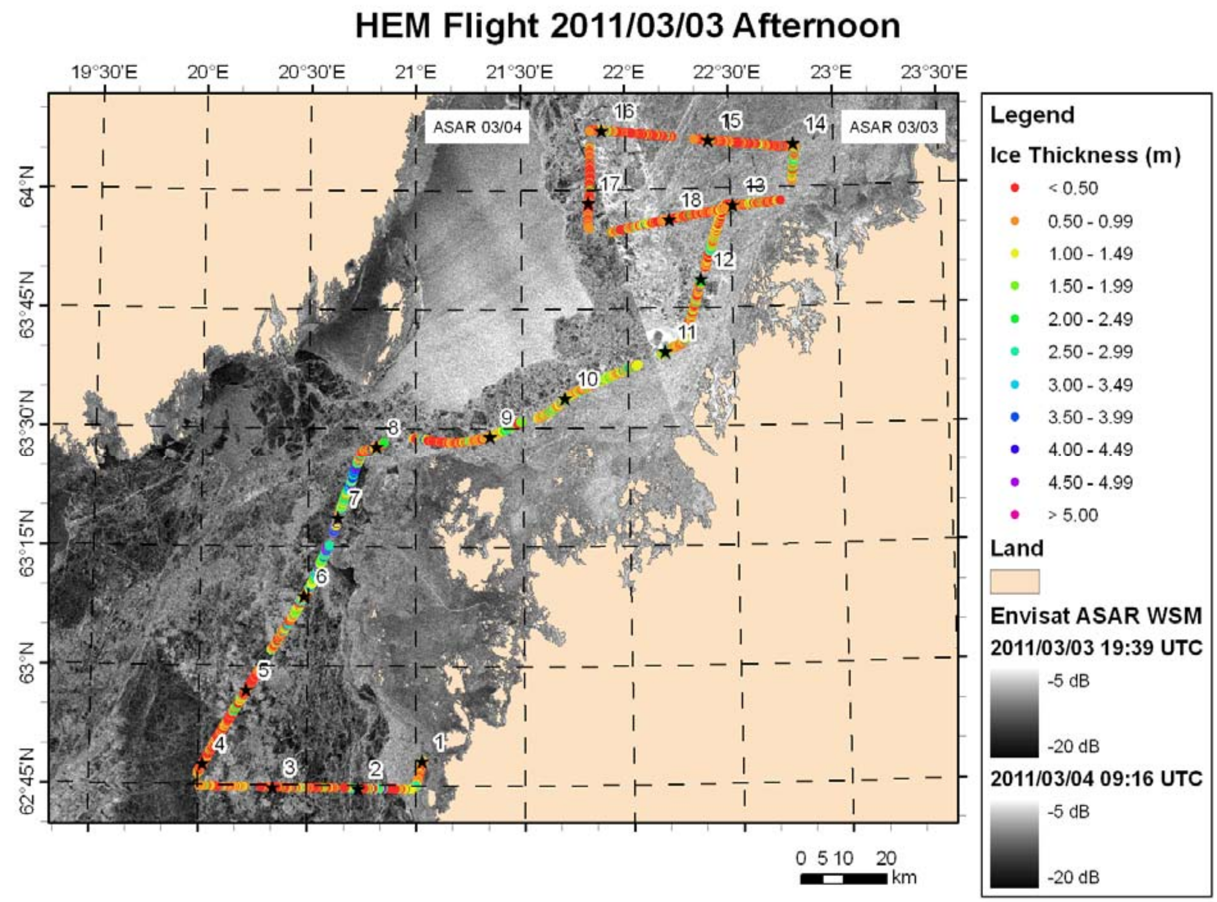

63.24ºN
20.04ºE
20110303_1/7
63.10ºN
19.72ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)

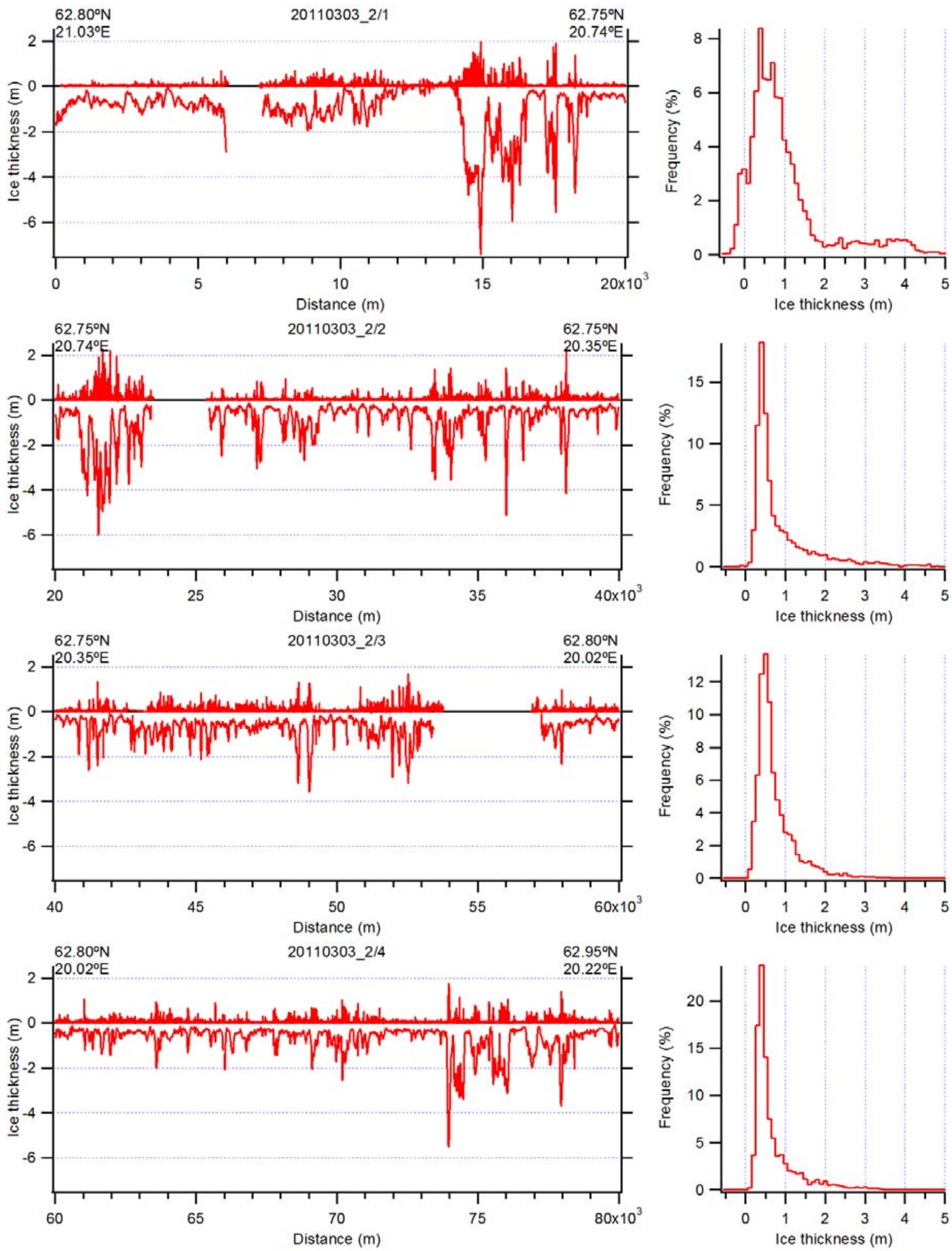

63.10ºN
19.72ºE
20110303_1/8
63.08ºN
20.00ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)

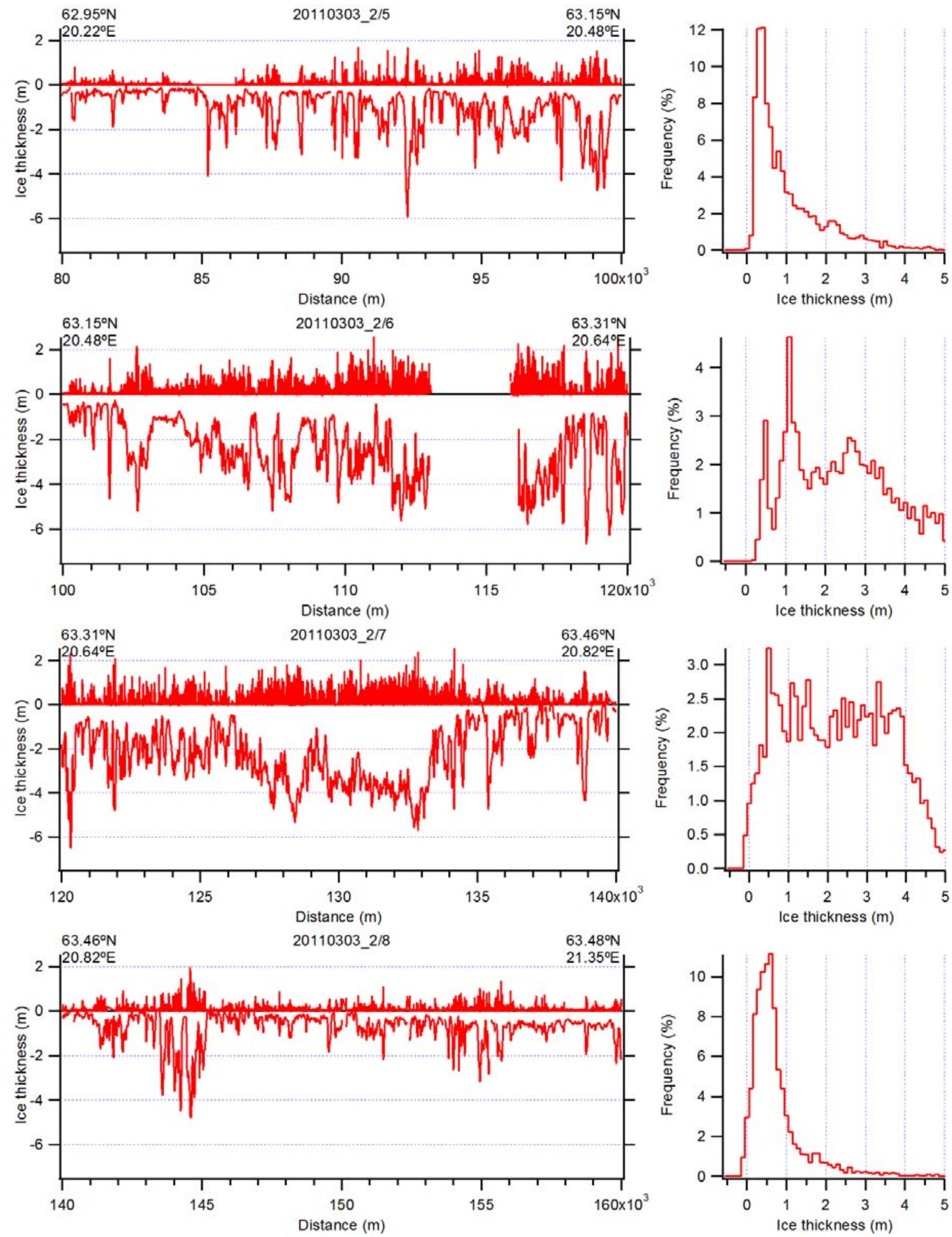

63.08ºN
20.00ºE
20110303_1/9
63.14ºN
20.37ºE
Ice thickness (m)
Distance (m)
180x10^3
Frequency (%)
Ice thickness (m)
63.14ºN
20.37ºE
20110303_1/10
63.14ºN
20.76ºE
Ice thickness (m)
Distance (m)
200x10^3
Frequency (%)
Ice thickness (m)
63.14ºN
20.76ºE
20110303_1/11
63.13ºN
20.97ºE
Ice thickness (m)
Distance (m)
220x10^3
Frequency (%)
Ice thickness (m)

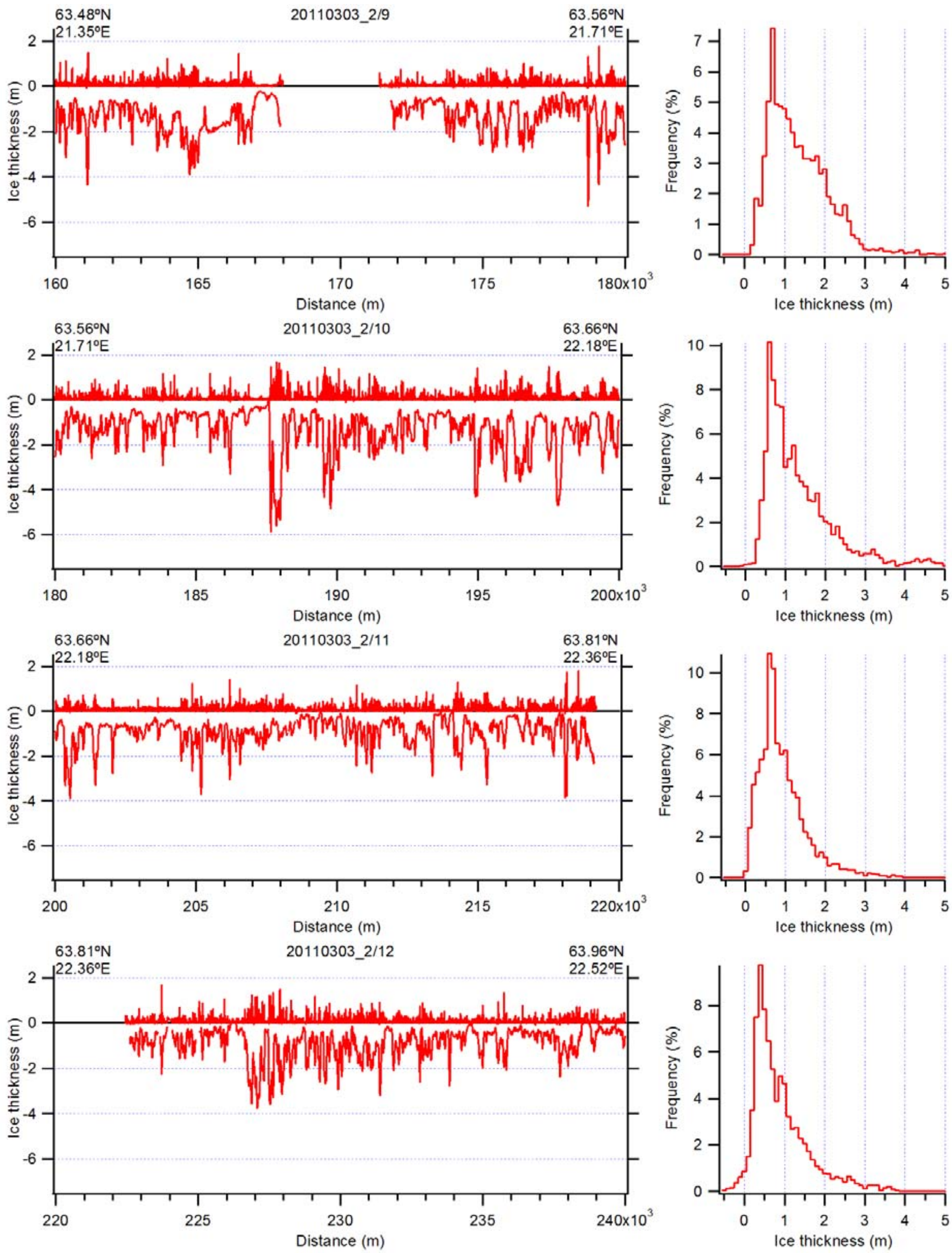
March 3, 2011, afternoon flight from Vaasa to Quarken and around ship

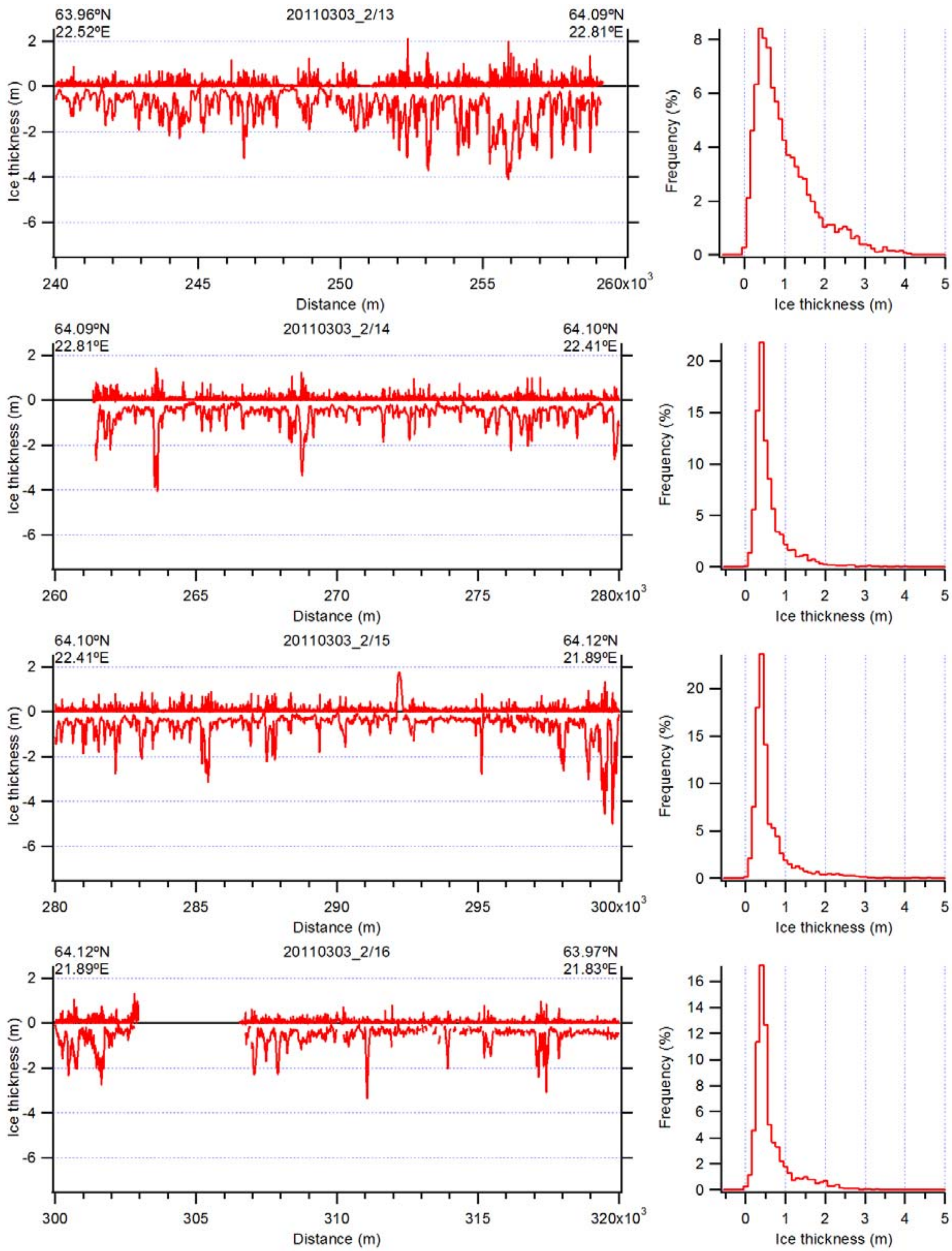
Segment No.	GPS time start (decimal hour)	GPS time end (decimal hour)	Mean thickness (m)	Standard deviation (m)	Modal thickness (m)
1	12.3331	12.4832	1.00715	1.06175	0.35
2	12.4832	12.6249	0.907134	0.866751	0.35
3	12.6249	12.7913	0.732366	0.491528	0.45
4	12.7913	12.9046	0.714105	0.611984	0.35
5	12.9046	13.0514	1.0324	0.917889	0.35
6	13.0514	13.1696	2.45523	1.33867	1.05
7	13.1696	13.2847	2.27896	1.3361	0.45
8	13.2847	13.4327	0.735604	0.684279	0.55
9	13.4327	13.5472	1.3358	0.718396	0.65
10	13.5472	13.6947	1.35625	0.912918	0.55
11	13.6947	13.82	0.924798	0.606295	0.55
12	13.82	13.9443	0.891894	0.683677	0.35
13	13.9443	14.102	1.01696	0.743778	0.35
14	14.102	14.2497	0.619878	0.485469	0.35
15	14.2497	14.426	0.635636	0.585778	0.35
16	14.426	14.5467	0.632583	0.481653	0.35
17	14.5467	14.69	0.69804	0.619429	0.35
18	14.69	14.7657	0.598028	0.359694	0.35

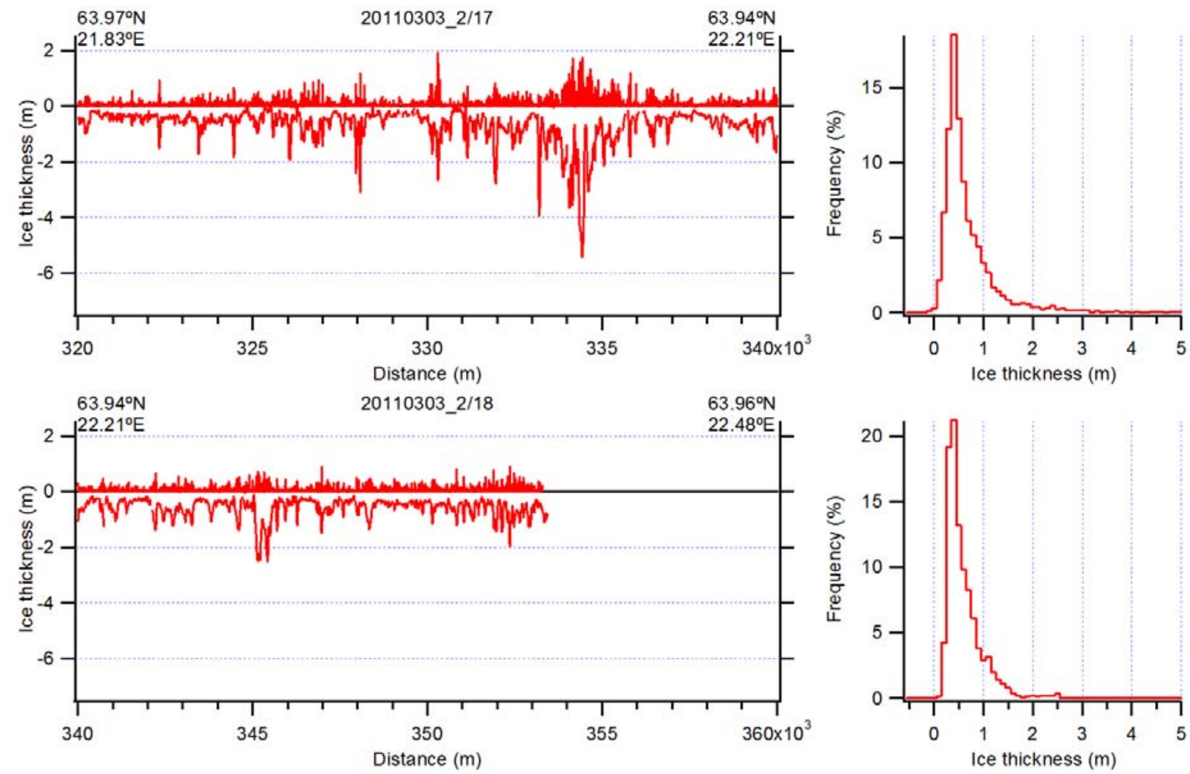

HEM Flight 2011/03/03 Afternoon
19°30'E
20°E
20°30'E
21°E
21°30'E
22°E
22°30'E
23°E
23°30'E
64°N
63°45'N
63°30'N
63°15'N
63°N
62°45'N
ASAR 03/04
ASAR 03/03
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
0 5 10 20
km
Legend
Ice Thickness (m)
< 0.50
0.50 - 0.99
1.00 - 1.49
1.50 - 1.99
2.00 - 2.49
2.50 - 2.99
3.00 - 3.49
3.50 - 3.99
4.00 - 4.49
4.50 - 4.99
> 5.00
Land
Envisat ASAR WSM
2011/03/03 19:39 UTC
-5 dB
-20 dB
2011/03/04 09:16 UTC
-5 dB
-20 dB


62.80ºN
21.03ºE
20110303_2/1
62.75ºN
20.74ºE
62.75ºN
20.74ºE
20110303_2/2
62.75ºN
20.35ºE
62.75ºN
20.35ºE
20110303_2/3
62.80ºN
20.02ºE
62.80ºN
20.02ºE
20110303_2/4
62.95ºN
20.22ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)


62.95ºN
20.22ºE
20110303_2/5
63.15ºN
20.48ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
63.15ºN
20.48ºE
20110303_2/6
63.31ºN
20.64ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
63.31ºN
20.64ºE
20110303_2/7
63.46ºN
20.82ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
63.46ºN
20.82ºE
20110303_2/8
63.48ºN
21.35ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)

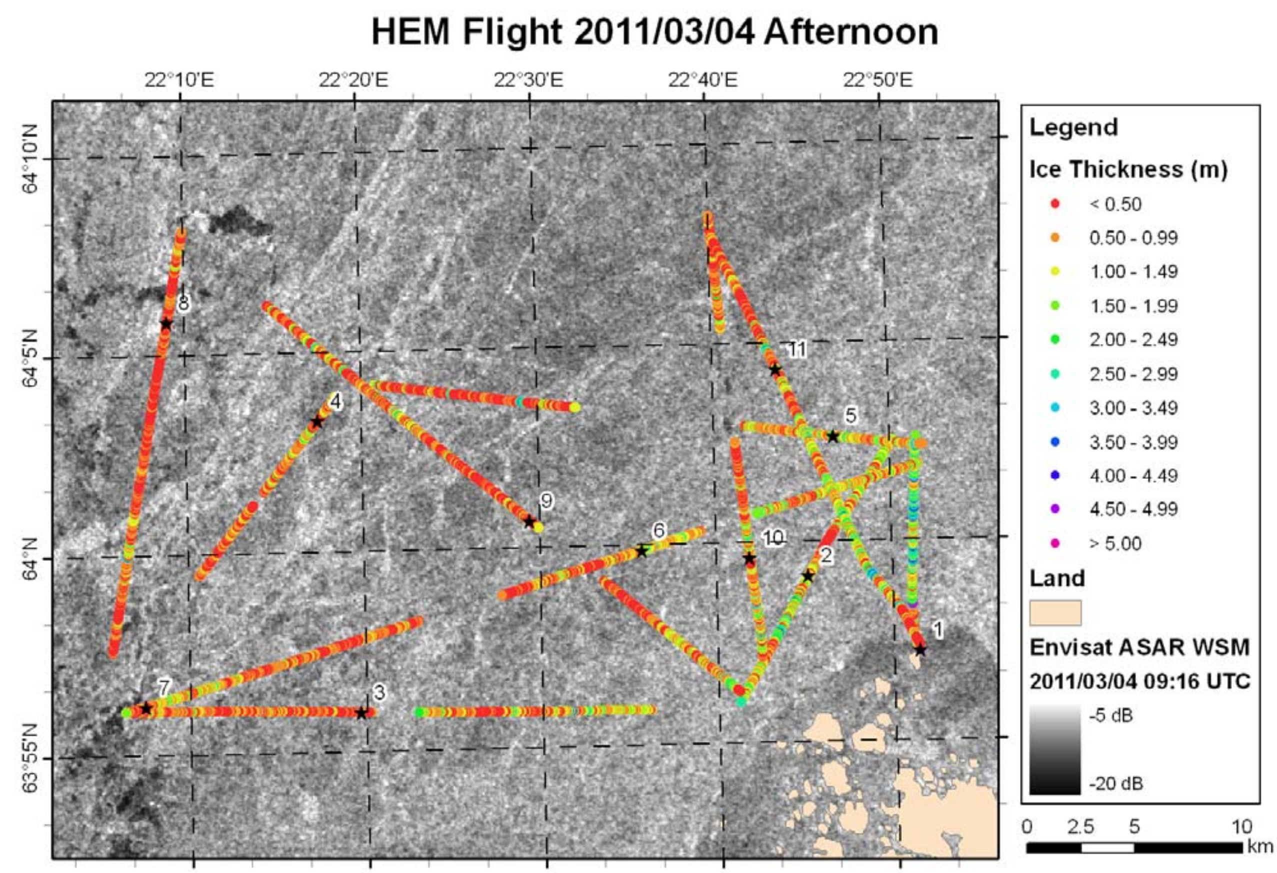

63.48ºN
21.35ºE
20110303_2/9
63.56ºN
21.71ºE
Ice thickness (m)
Distance (m)
180x10^3
Frequency (%)
Ice thickness (m)
63.56ºN
21.71ºE
20110303_2/10
63.66ºN
22.18ºE
Ice thickness (m)
Distance (m)
200x10^3
Frequency (%)
Ice thickness (m)
63.66ºN
22.18ºE
20110303_2/11
63.81ºN
22.36ºE
Ice thickness (m)
Distance (m)
220x10^3
Frequency (%)
Ice thickness (m)
63.81ºN
22.36ºE
20110303_2/12
63.96ºN
22.52ºE
Ice thickness (m)
Distance (m)
240x10^3
Frequency (%)
Ice thickness (m)

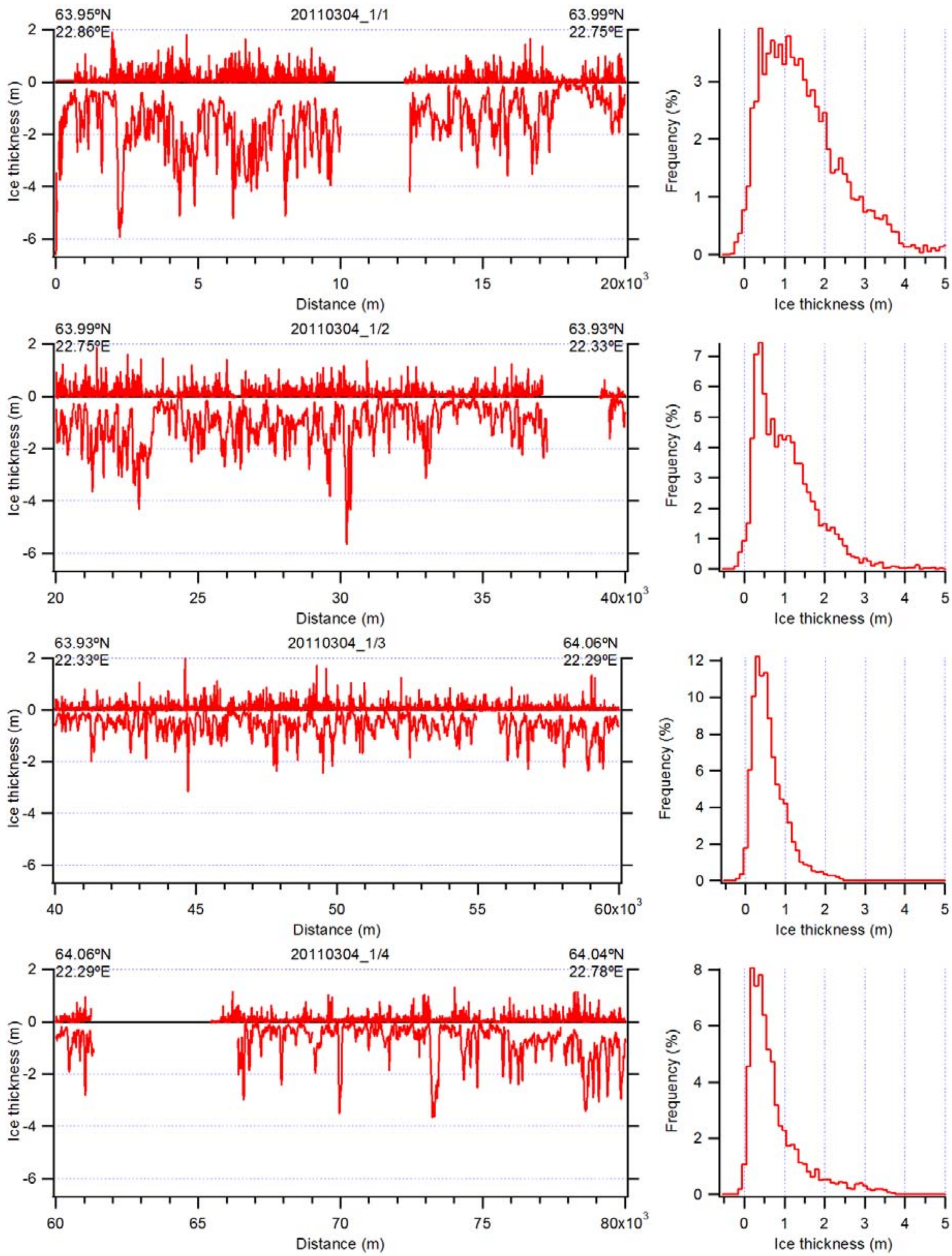

63.96ºN
22.52ºE
20110303_2/13
64.09ºN
22.81ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
64.09ºN
22.81ºE
20110303_2/14
64.10ºN
22.41ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
64.10ºN
22.41ºE
20110303_2/15
64.12ºN
21.89ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
64.12ºN
21.89ºE
20110303_2/16
63.97ºN
21.83ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)

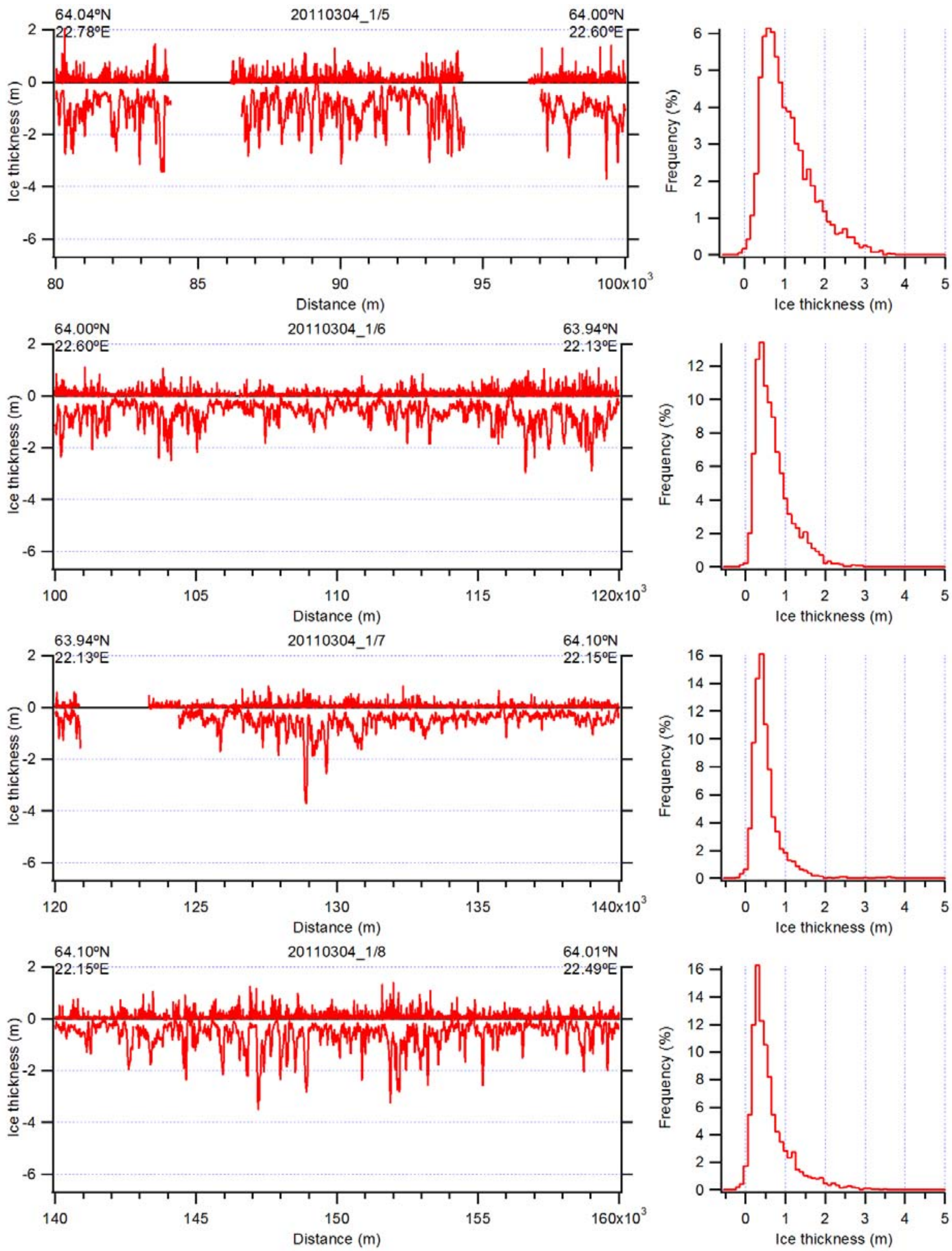

63.97ºN
21.83ºE
20110303_2/17
63.94ºN
22.21ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
63.94ºN
22.21ºE
20110303_2/18
63.96ºN
22.48ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)

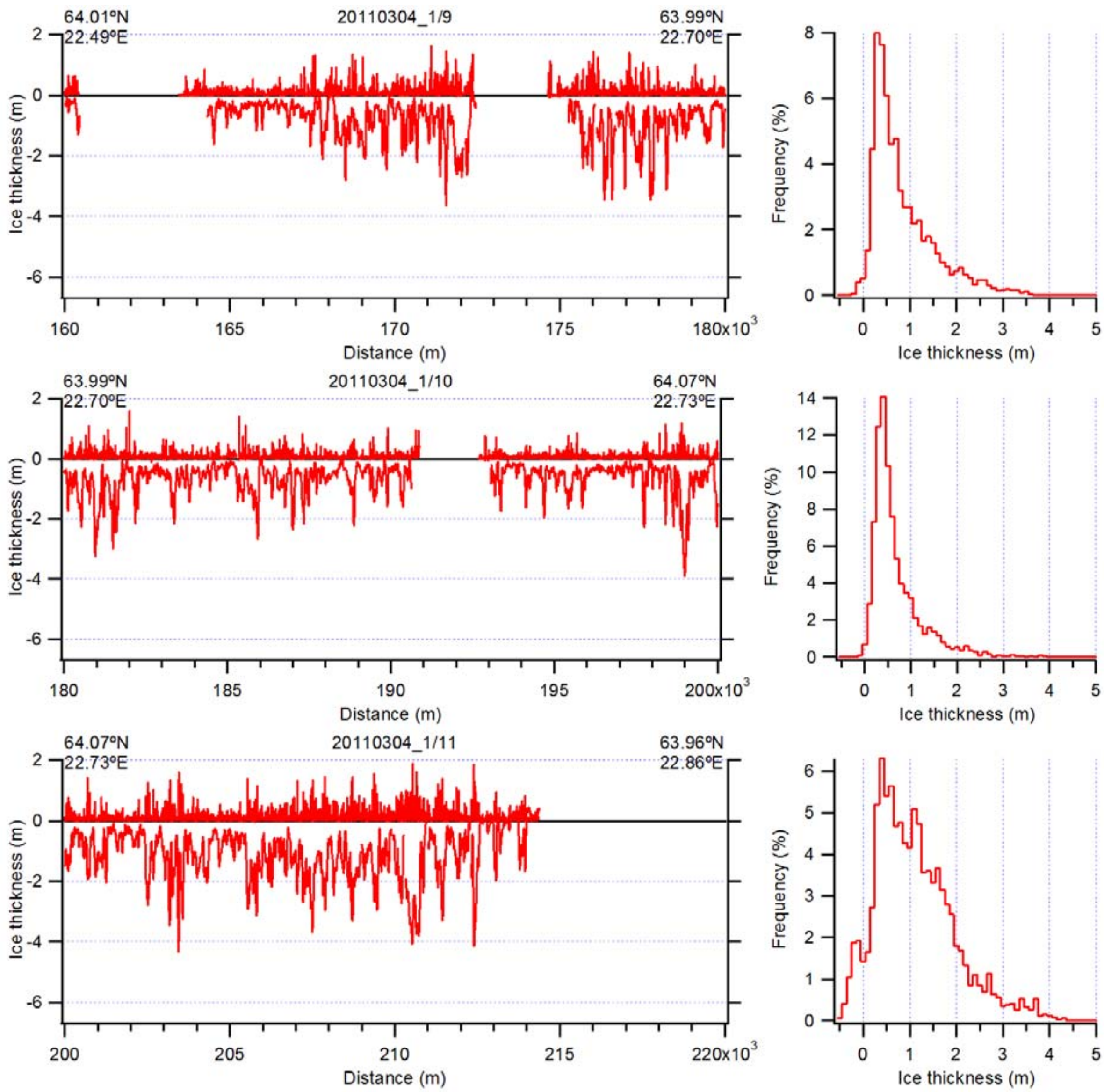
March 4, 2011, flight from Kokkola over buoy array

Segment No.	GPS time start (decimal hour)	GPS time end (decimal hour)	Mean thickness (m)	Standard deviation (m)	Modal thickness (m)
1	12.7245	12.8705	1.47959	1.02265	0.35
2	12.8705	13.0575	1.04786	0.763554	0.35
3	13.0575	13.2354	0.597935	0.429205	0.25
4	13.2354	13.3912	0.75604	0.687742	0.15
5	13.3912	13.535	1.06643	0.62554	0.55
6	13.535	13.7127	0.698682	0.449378	0.35
7	13.7127	13.8366	0.519371	0.396146	0.35
8	13.8366	13.9998	0.618507	0.522901	0.25
9	13.9998	14.1191	0.854957	0.668137	0.25
10	14.1191	14.2853	0.675388	0.539755	0.35
11	14.2853	14.3826	1.1138	0.842337	0.35




63.95ºN
22.86ºE
20110304_1/1
63.99ºN
22.75ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
63.99ºN
22.75ºE
20110304_1/2
63.93ºN
22.33ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
63.93ºN
22.33ºE
20110304_1/3
64.06ºN
22.29ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
64.06ºN
22.29ºE
20110304_1/4
64.04ºN
22.78ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)

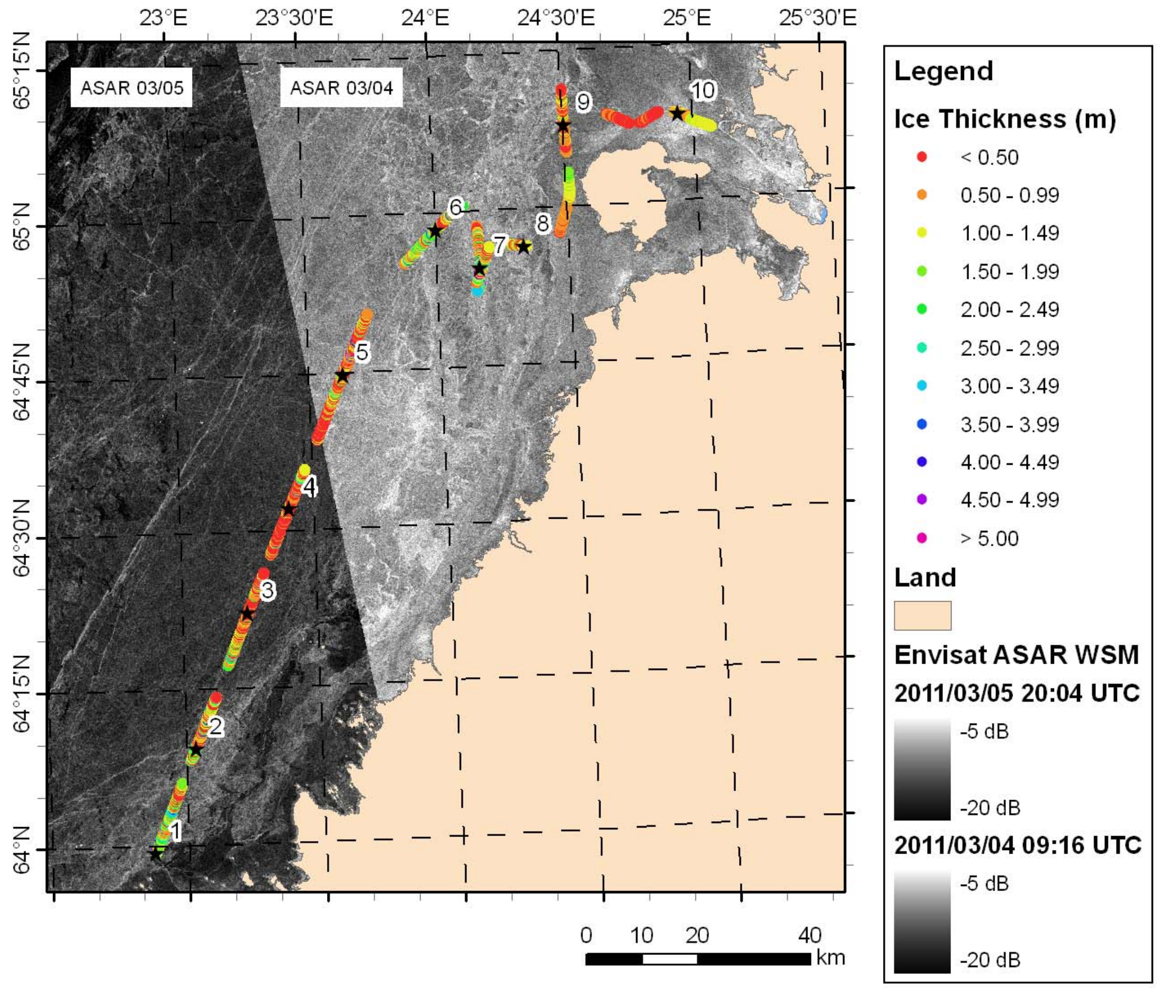

64.04ºN
22.78ºE
20110304_1/5
64.00ºN
22.60ºE
Ice thickness (m)
Distance (m)
100x10^3
Frequency (%)
Ice thickness (m)
64.00ºN
22.60ºE
20110304_1/6
63.94ºN
22.13ºE
Ice thickness (m)
Distance (m)
120x10^3
Frequency (%)
Ice thickness (m)
63.94ºN
22.13ºE
20110304_1/7
64.10ºN
22.15ºE
Ice thickness (m)
Distance (m)
140x10^3
Frequency (%)
Ice thickness (m)
64.10ºN
22.15ºE
20110304_1/8
64.01ºN
22.49ºE
Ice thickness (m)
Distance (m)
160x10^3
Frequency (%)
Ice thickness (m)

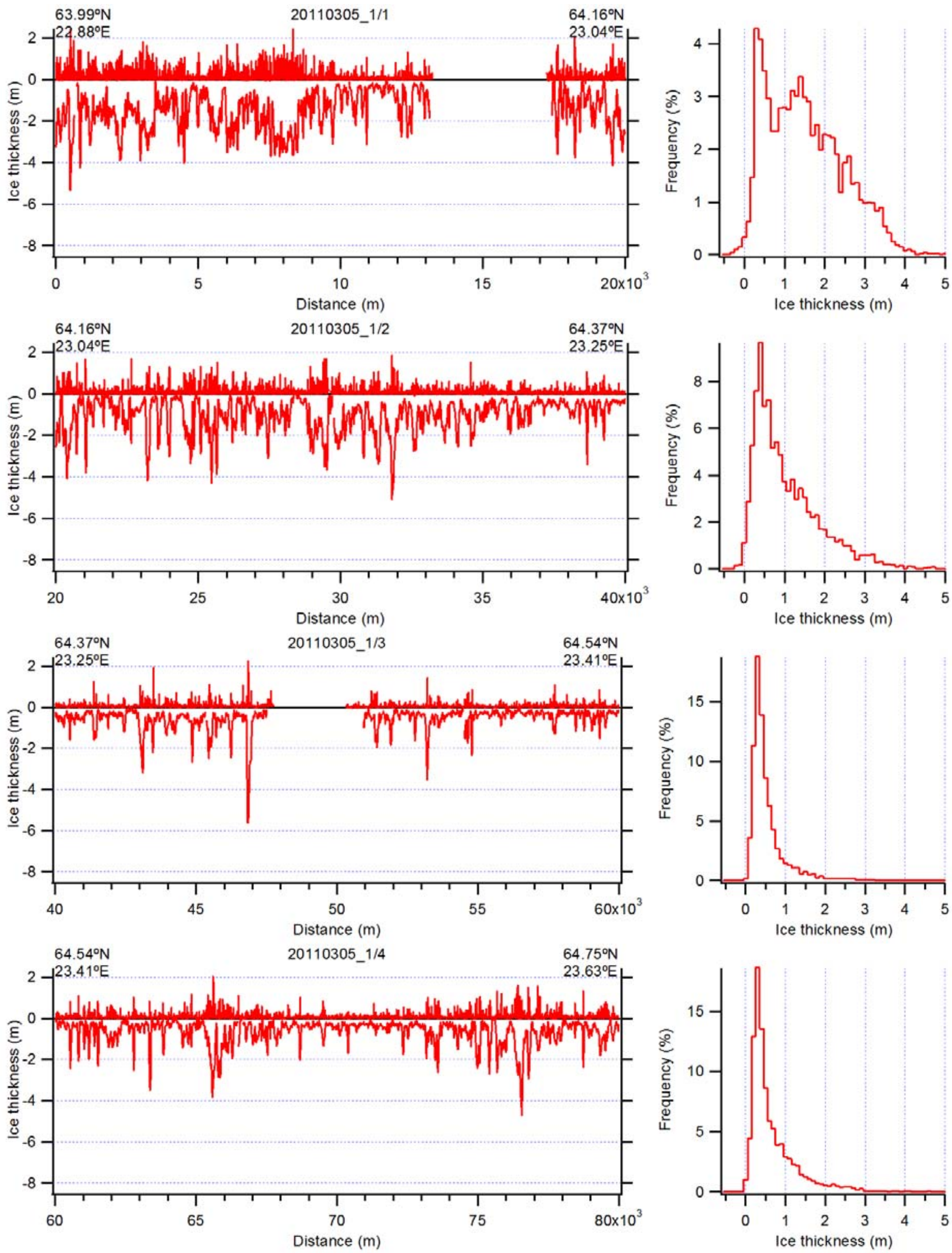

64.01ºN
22.49ºE
20110304_1/9
63.99ºN
22.70ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
63.99ºN
22.70ºE
20110304_1/10
64.07ºN
22.73ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
64.07ºN
22.73ºE
20110304_1/11
63.96ºN
22.86ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)

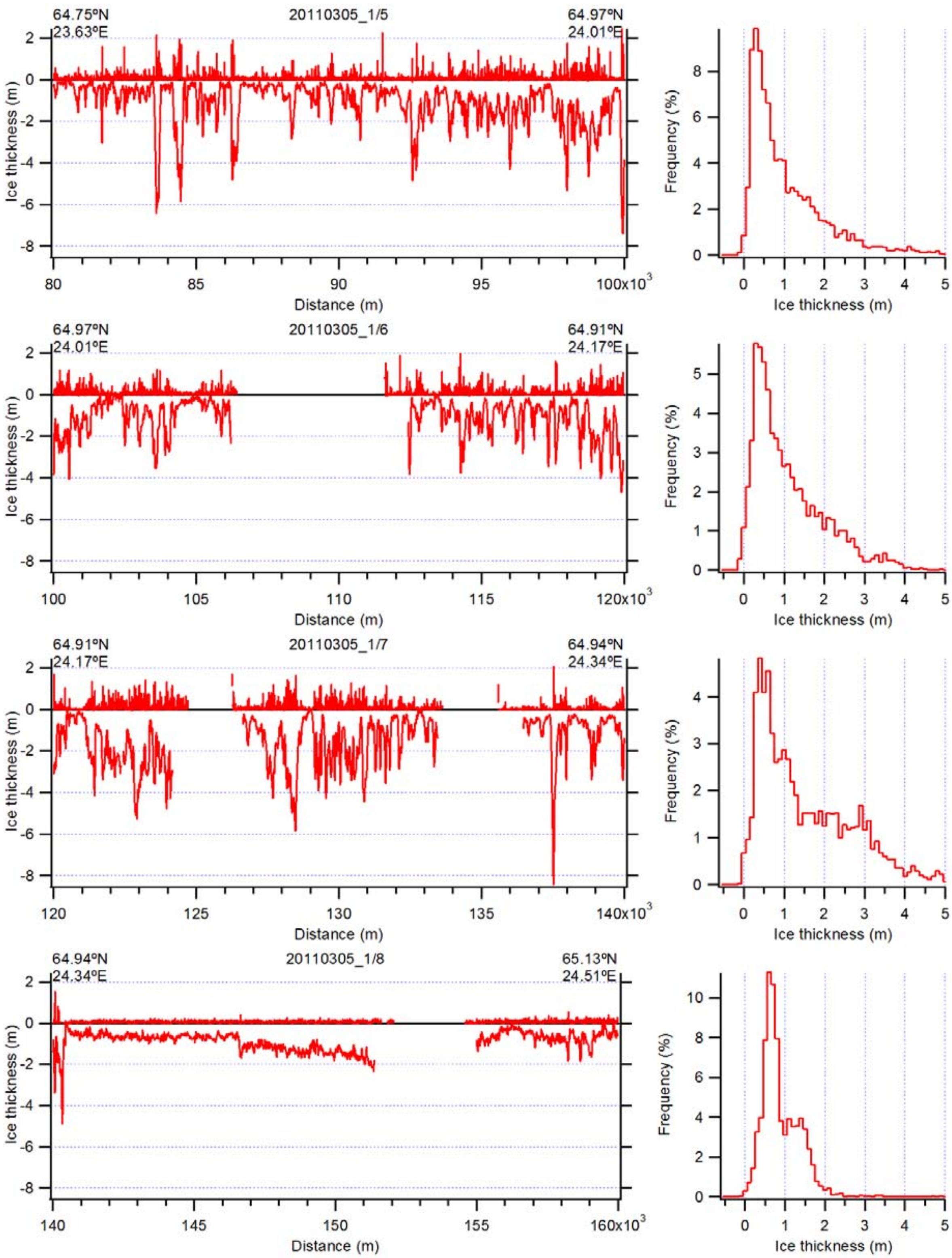
March 5, 2011, morning flight from Kokkola to Hailuoto and Oulu

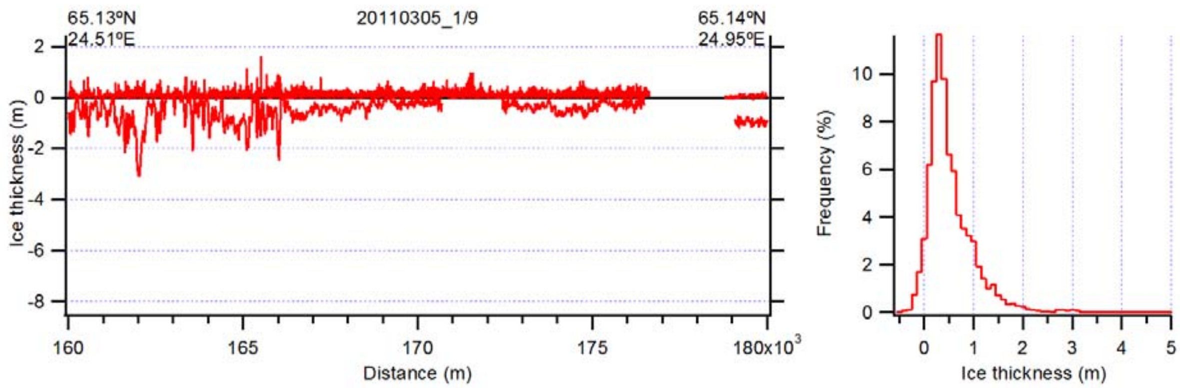
Segment No.	GPS time start (decimal hour)	GPS time end (decimal hour)	Mean thickness (m)	Standard deviation (m)	Modal thickness (m)
1	7.26917	7.40528	1.51329	0.941227	0.25
2	7.40528	7.57778	1.05925	0.825551	0.35
3	7.57778	7.70889	0.557953	0.541401	0.25
4	7.70889	7.87667	0.668171	0.60609	0.25
5	7.87667	8.07278	1.08491	1.00488	0.25
6	8.07278	8.18472	1.13843	0.96982	0.25
7	8.18472	8.31056	1.57343	1.21305	0.35
8	8.31056	8.51139	0.893944	0.486411	0.55
9	8.51139	8.72583	0.526387	0.458014	0.25
10	8.72583	8.76556	1.17705	0.305616	1.25

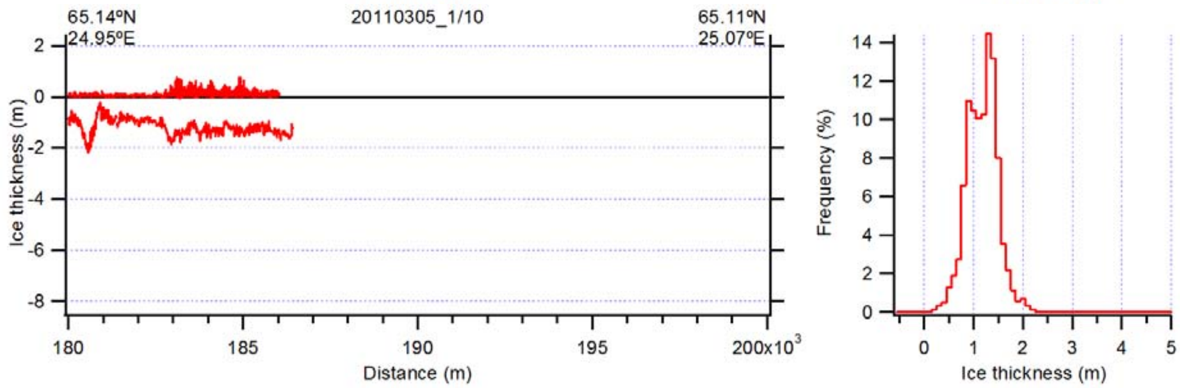
HEM Flight 2011/03/05 Morning




63.99ºN
22.88ºE
20110305_1/1
64.16ºN
23.04ºE
64.16ºN
23.04ºE
20110305_1/2
64.37ºN
23.25ºE
64.37ºN
23.25ºE
20110305_1/3
64.54ºN
23.41ºE
64.54ºN
23.41ºE
20110305_1/4
64.75ºN
23.63ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
20x10^3
40x10^3
60x10^3
80x10^3

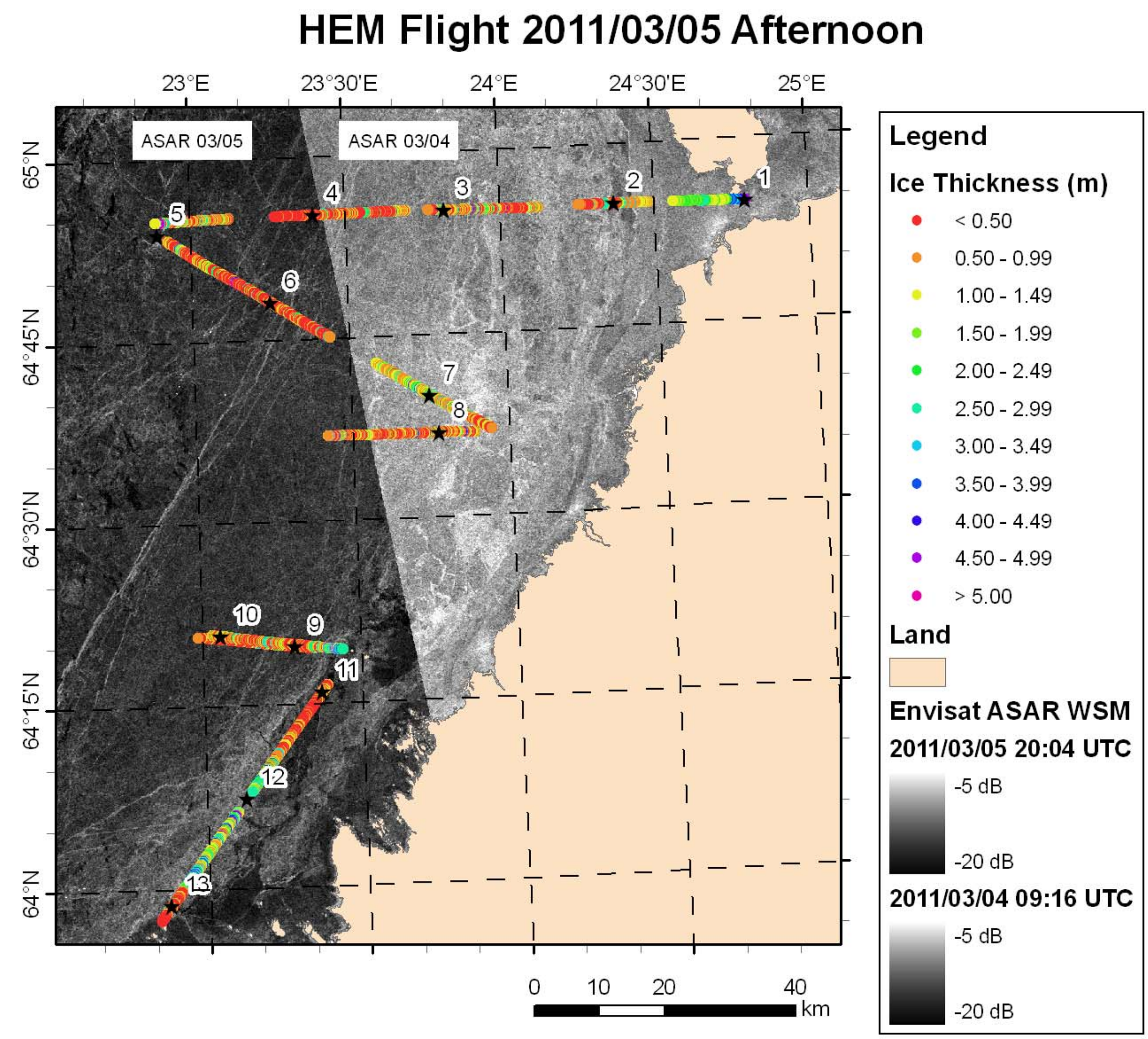

64.75ºN
23.63ºE
20110305_1/5
64.97ºN
24.01ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
64.97ºN
24.01ºE
20110305_1/6
64.91ºN
24.17ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
64.91ºN
24.17ºE
20110305_1/7
64.94ºN
24.34ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
64.94ºN
24.34ºE
20110305_1/8
65.13ºN
24.51ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)

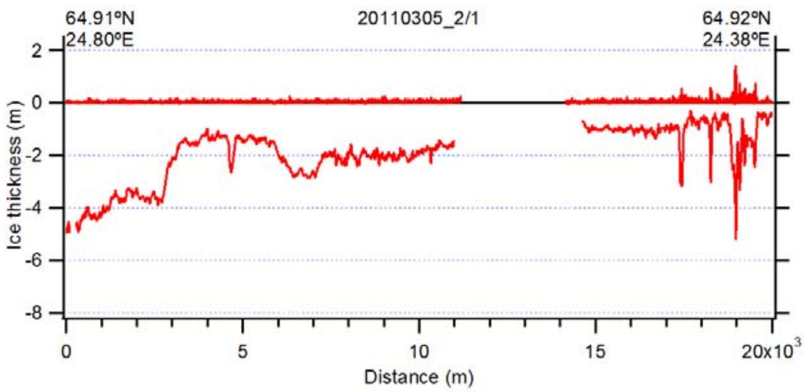

65.13ºN
24.51ºE
20110305_1/9
65.14ºN
24.95ºE
Ice thickness (m)
Distance (m)
180x10^3
Frequency (%)
Ice thickness (m)

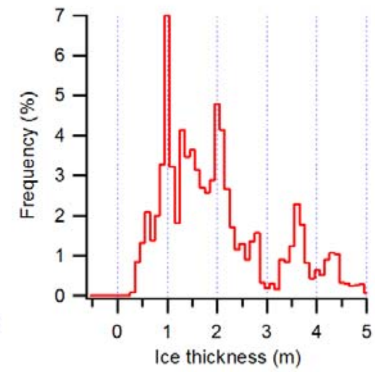

65.14ºN
24.95ºE
20110305_1/10
65.11ºN
25.07ºE
Ice thickness (m)
Distance (m)
200x10^3
Frequency (%)
Ice thickness (m)

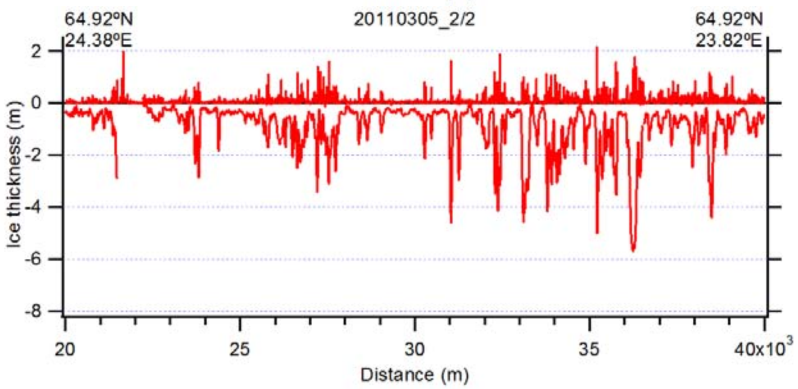
March 5, 2011, afternoon flight from Oulu to Kokkola, with some E-W transects

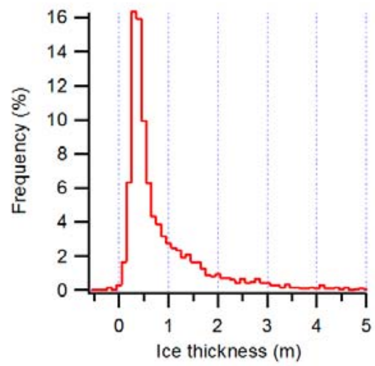
Segment No.	GPS time start (decimal hour)	GPS time end (decimal hour)	Mean thickness (m)	Standard deviation (m)	Modal thickness (m)
1	10.7903	10.9275	1.97397	1.06981	0.95
2	10.9275	11.1033	0.87866	0.880414	0.25
3	11.1033	11.2339	0.836501	0.829208	0.35
4	11.2339	11.4128	0.91015	1.10106	0.45
5	11.4128	11.5242	0.716061	0.749449	0.25
6	11.5242	11.68	0.937126	0.803869	0.05
7	11.68	11.8078	1.05202	0.840382	0.65
8	11.8078	12.3853	0.799631	0.752263	0.35
9	12.3853	12.5175	0.674726	0.62234	0.25
10	12.5175	12.6786	1.10435	1.11683	0.35
11	12.6786	12.8022	1.01062	0.921965	0.25
12	12.8022	12.9253	1.97646	1.20618	0.35
13	12.9253	12.9428	0.738846	0.884462	0.05

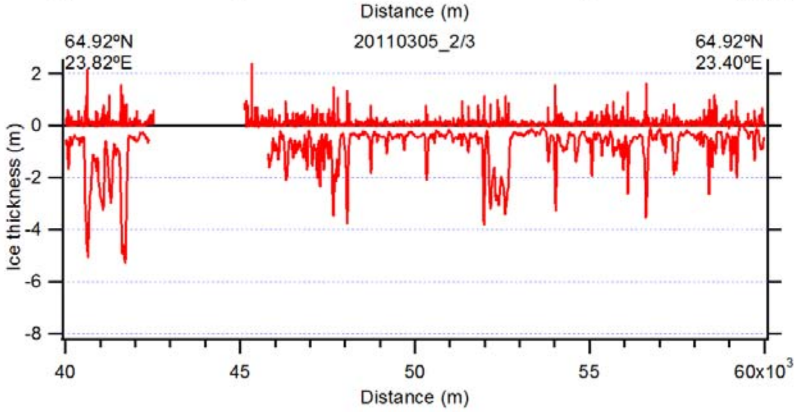

HEM Flight 2011/03/05 Afternoon
23°E
23°30'E
24°E
24°30'E
25°E
65°N
64°45'N
64°30'N
64°15'N
64°N
ASAR 03/05
ASAR 03/04
1
2
3
4
5
6
7
8
9
10
11
12
13
0
10
20
40
km
Legend
Ice Thickness (m)
< 0.50
0.50 - 0.99
1.00 - 1.49
1.50 - 1.99
2.00 - 2.49
2.50 - 2.99
3.00 - 3.49
3.50 - 3.99
4.00 - 4.49
4.50 - 4.99
> 5.00
Land
Envisat ASAR WSM
2011/03/05 20:04 UTC
-5 dB
-20 dB
2011/03/04 09:16 UTC
-5 dB
-20 dB

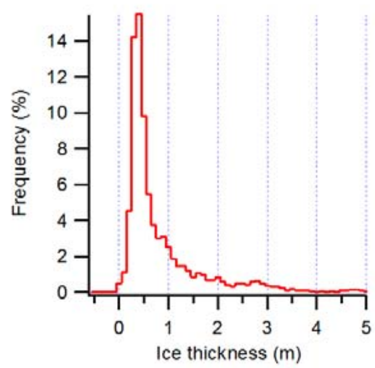

64.91ºN
24.80ºE
20110305_2/1
64.92ºN
24.38ºE
Ice thickness (m)
Distance (m)
20x10³

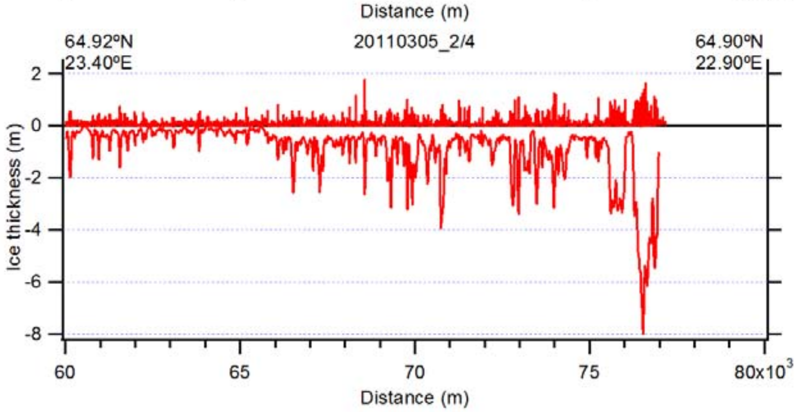

Frequency (%)
Ice thickness (m)

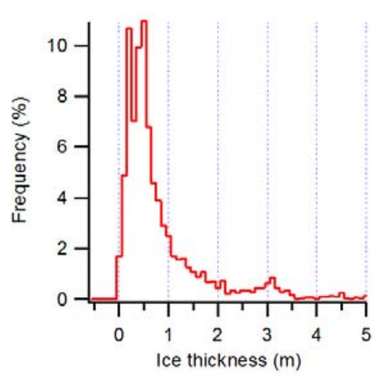

64.92ºN
24.38ºE
20110305_2/2
64.92ºN
23.82ºE
Ice thickness (m)
Distance (m)
40x10³

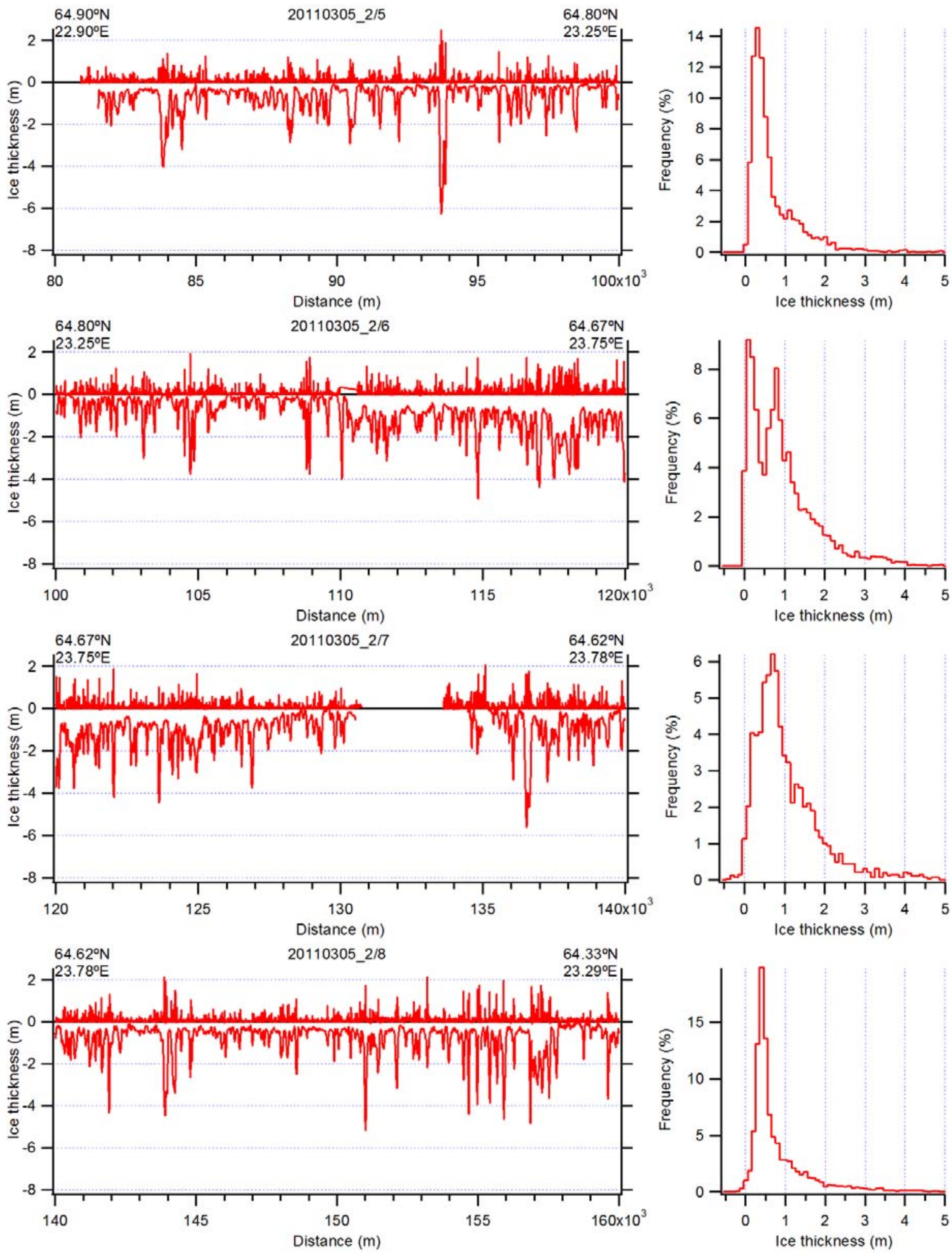

Frequency (%)
Ice thickness (m)

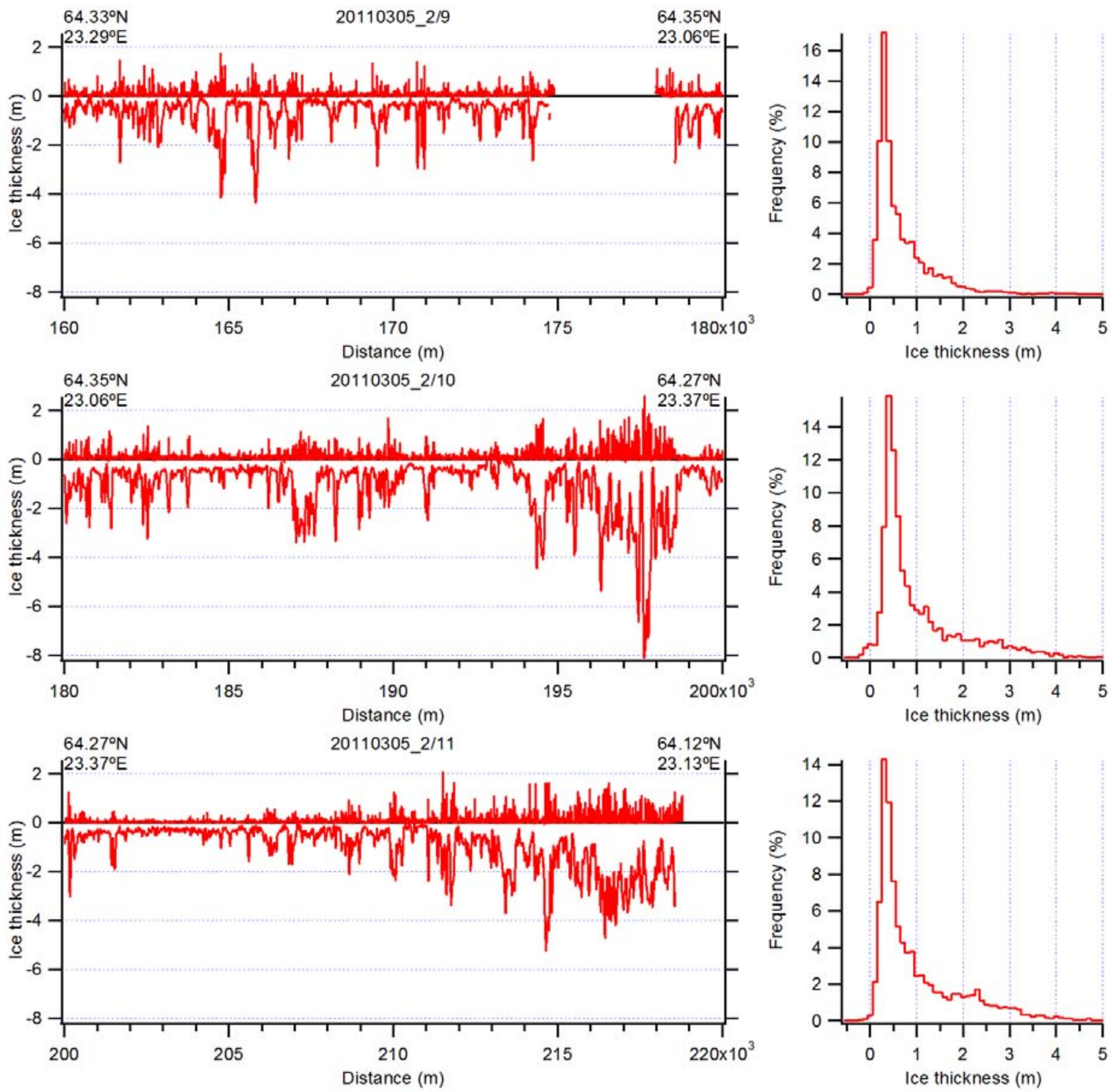

64.92ºN
23.82ºE
20110305_2/3
64.92ºN
23.40ºE
Ice thickness (m)
Distance (m)
60x10³

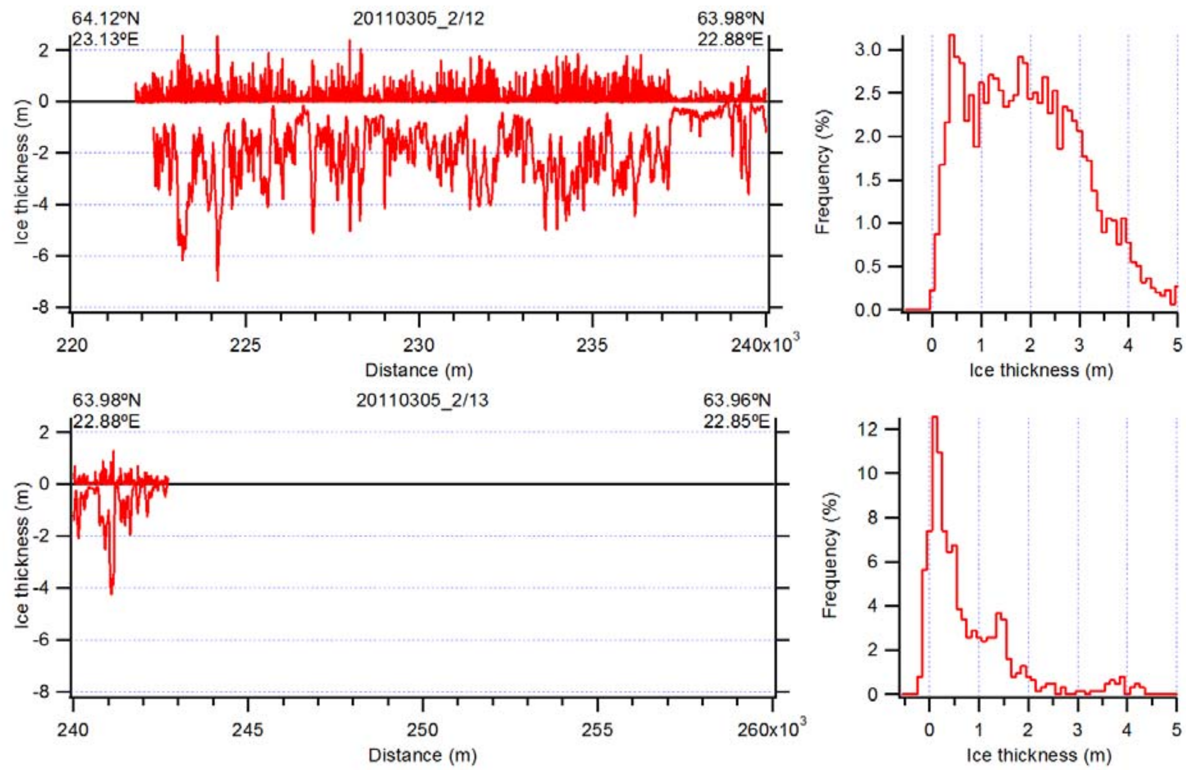

Frequency (%)
Ice thickness (m)


64.92ºN
23.40ºE
20110305_2/4
64.90ºN
22.90ºE
Ice thickness (m)
Distance (m)
80x10³


Frequency (%)
Ice thickness (m)

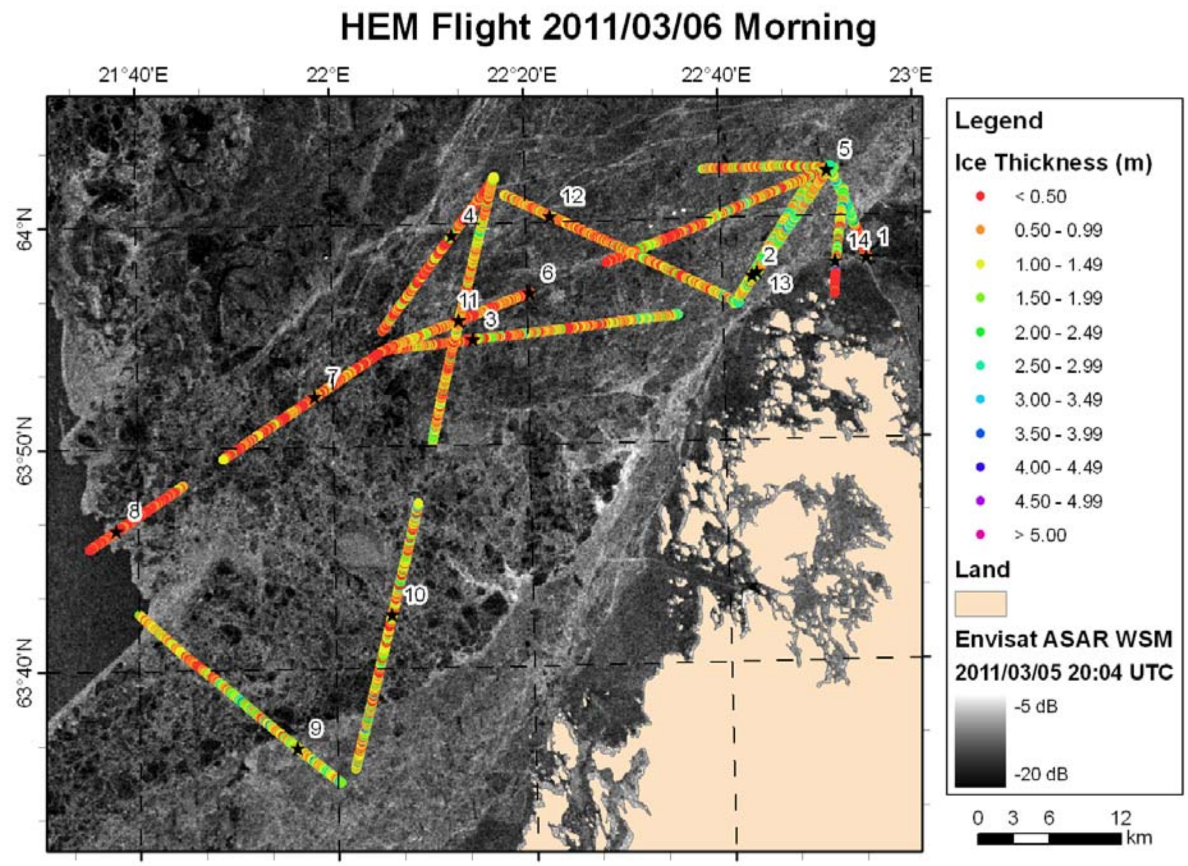

64.90ºN
22.90ºE
20110305_2/5
64.80ºN
23.25ºE
64.80ºN
23.25ºE
20110305_2/6
64.67ºN
23.75ºE
64.67ºN
23.75ºE
20110305_2/7
64.62ºN
23.78ºE
64.62ºN
23.78ºE
20110305_2/8
64.33ºN
23.29ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)

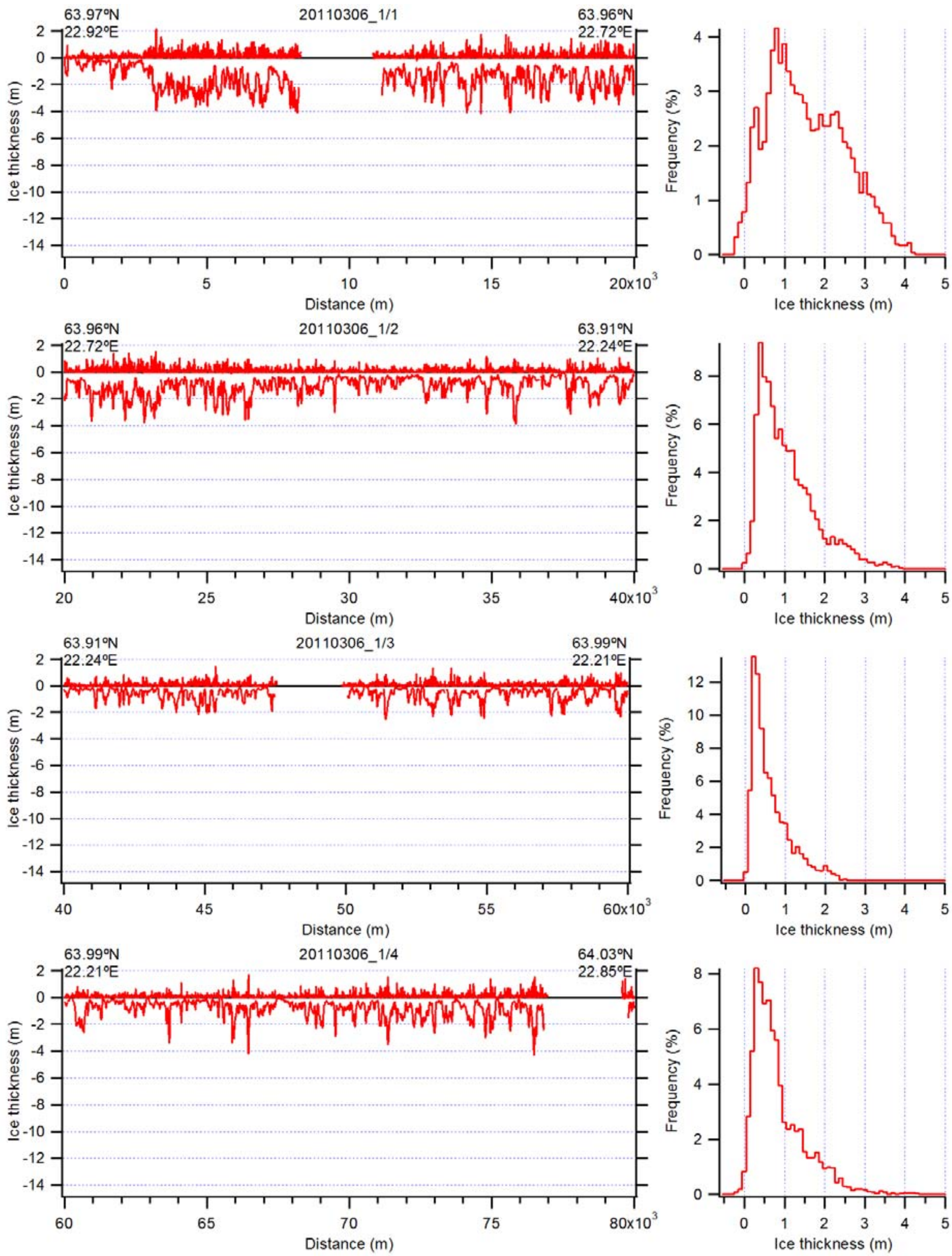

64.33ºN
23.29ºE
20110305_2/9
64.35ºN
23.06ºE
Ice thickness (m)
Distance (m)
180x10^3
Frequency (%)
Ice thickness (m)
64.35ºN
23.06ºE
20110305_2/10
64.27ºN
23.37ºE
Ice thickness (m)
Distance (m)
200x10^3
Frequency (%)
Ice thickness (m)
64.27ºN
23.37ºE
20110305_2/11
64.12ºN
23.13ºE
Ice thickness (m)
Distance (m)
220x10^3
Frequency (%)
Ice thickness (m)

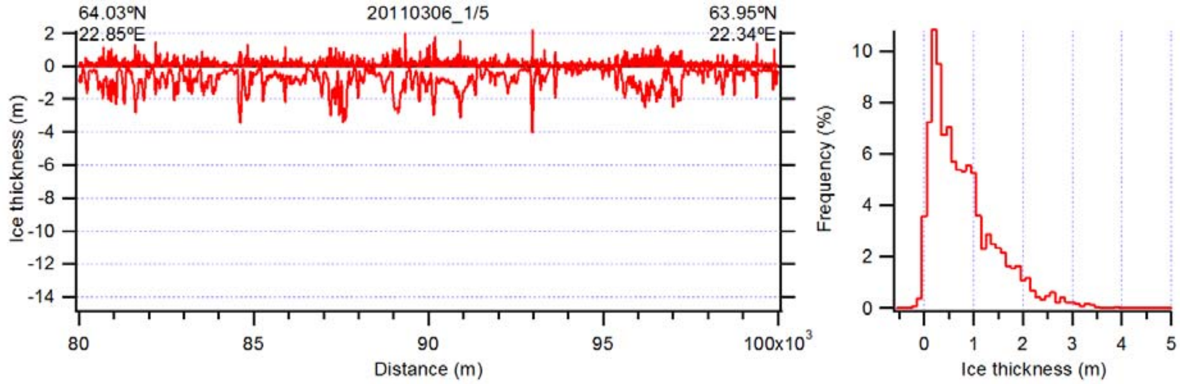

64.12ºN
23.13ºE
20110305_2/12
63.98ºN
22.88ºE
Ice thickness (m)
Distance (m)
240x10^3
Frequency (%)
Ice thickness (m)
63.98ºN
22.88ºE
20110305_2/13
63.96ºN
22.85ºE
Ice thickness (m)
Distance (m)
260x10^3
Frequency (%)
Ice thickness (m)

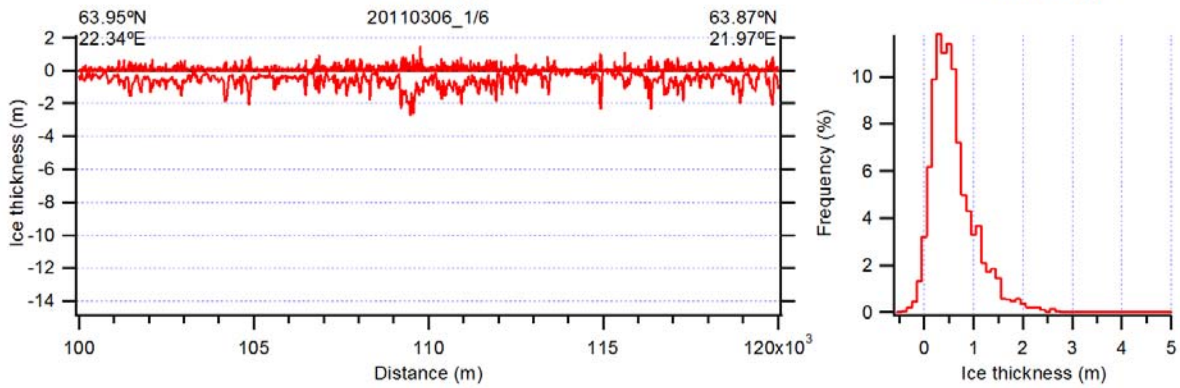
March 6, 2011, morning flight over buoy array

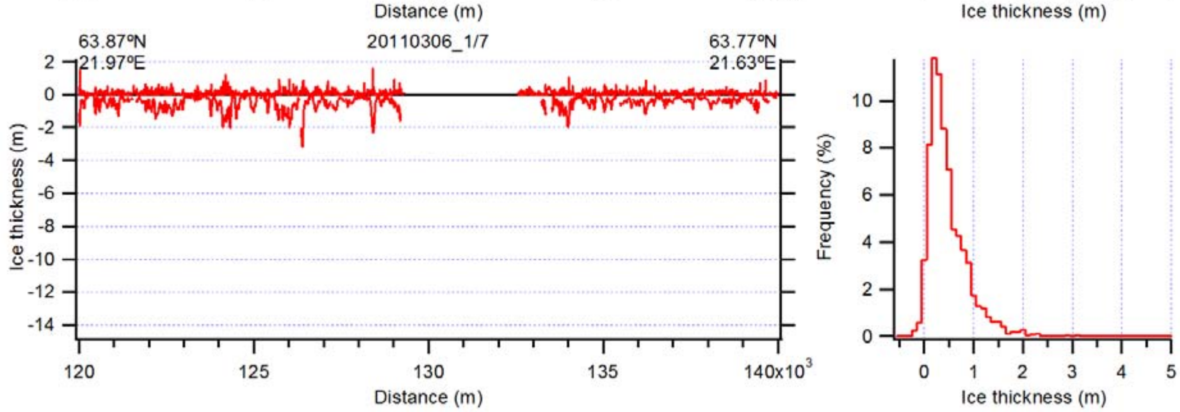
Segment No.	GPS time start (decimal hour)	GPS time end (decimal hour)	Mean thickness (m)	Standard deviation (m)	Modal thickness (m)
1	8.33025	8.46272	1.54787	0.940781	0.75
2	8.46272	8.62703	1.07361	0.704872	0.35
3	8.62703	8.75439	0.626819	0.487408	0.15
4	8.75439	8.9855	0.846579	0.645448	0.25
5	8.9855	9.15333	0.796076	0.660215	0.15
6	9.15333	9.27422	0.588078	0.443361	0.25
7	9.27422	9.39328	0.478223	0.401462	0.15
8	9.39328	9.55758	1.10094	0.71547	0.45
9	9.55758	9.69514	1.17591	0.811721	0.95
10	9.69514	9.87131	1.00189	0.712423	0.45
11	9.87131	10.0107	0.88014	0.512956	0.55
12	10.0107	10.1737	0.980628	0.685717	0.45
13	10.1737	10.3003	1.48674	0.81294	0.65
14	10.3003	10.3169	1.42797	2.35815	0.05

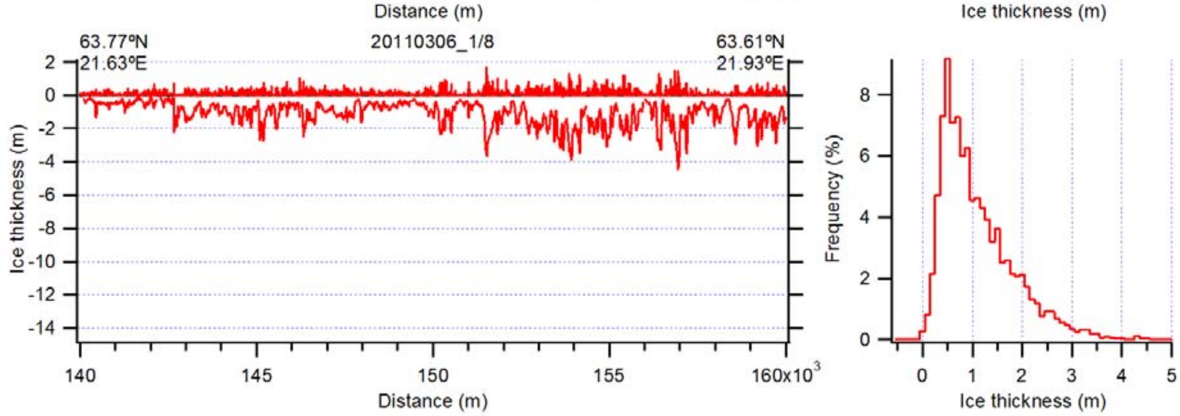

HEM Flight 2011/03/06 Morning
21°40'E
22°E
22°20'E
22°40'E
23°E
64°N
63°50'N
63°40'N
Legend
Ice Thickness (m)
< 0.50
0.50 - 0.99
1.00 - 1.49
1.50 - 1.99
2.00 - 2.49
2.50 - 2.99
3.00 - 3.49
3.50 - 3.99
4.00 - 4.49
4.50 - 4.99
> 5.00
Land
Envisat ASAR WSM
2011/03/05 20:04 UTC
-5 dB
-20 dB
0 3 6 12
km

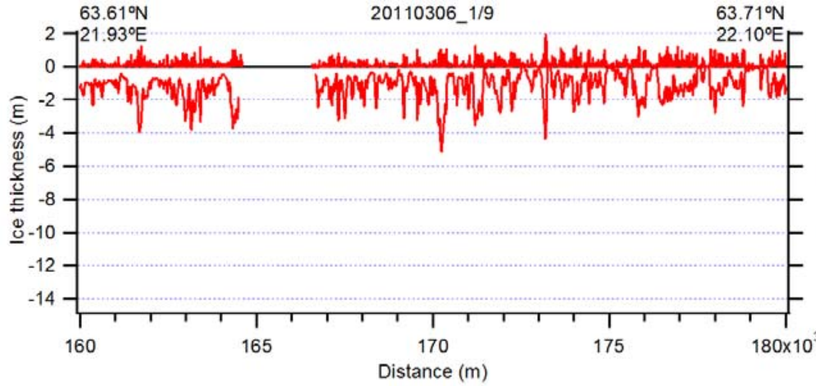

63.97ºN
22.92ºE
20110306_1/1
63.96ºN
22.72ºE
Ice thickness (m)
Distance (m)
20x10^3
Frequency (%)
Ice thickness (m)
63.96ºN
22.72ºE
20110306_1/2
63.91ºN
22.24ºE
Ice thickness (m)
Distance (m)
40x10^3
Frequency (%)
Ice thickness (m)
63.91ºN
22.24ºE
20110306_1/3
63.99ºN
22.21ºE
Ice thickness (m)
Distance (m)
60x10^3
Frequency (%)
Ice thickness (m)
63.99ºN
22.21ºE
20110306_1/4
64.03ºN
22.85ºE
Ice thickness (m)
Distance (m)
80x10^3
Frequency (%)
Ice thickness (m)

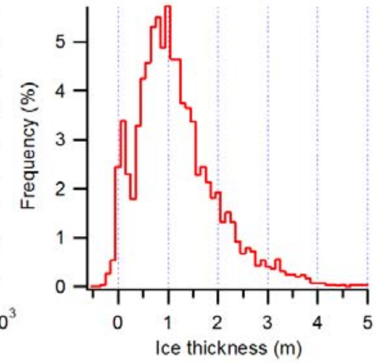

64.03ºN
22.85ºE
20110306_1/5
63.95ºN
22.34ºE
Ice thickness (m)
Distance (m)
80 85 90 95 100x10^3
Frequency (%)
Ice thickness (m)

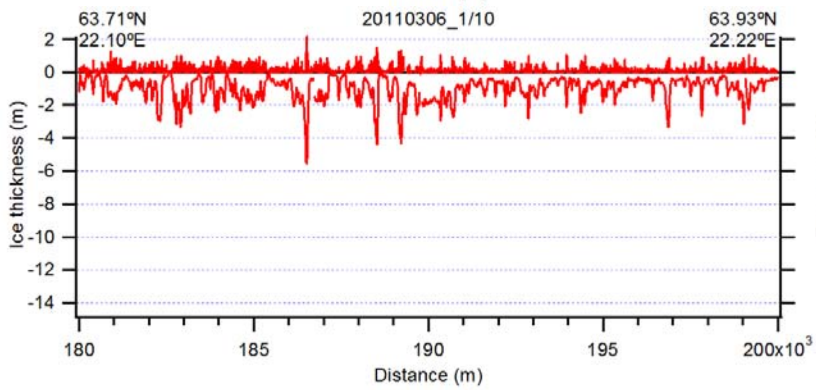

63.95ºN
22.34ºE
20110306_1/6
63.87ºN
21.97ºE
Ice thickness (m)
Distance (m)
100 105 110 115 120x10^3
Frequency (%)
Ice thickness (m)

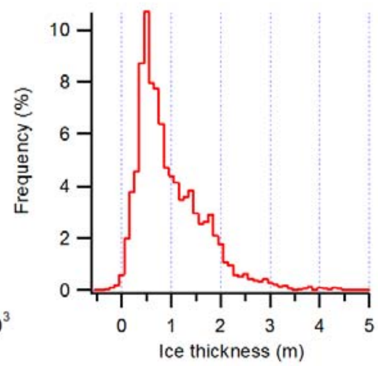

63.87ºN
21.97ºE
20110306_1/7
63.77ºN
21.63ºE
Ice thickness (m)
Distance (m)
120 125 130 135 140x10^3
Frequency (%)
Ice thickness (m)

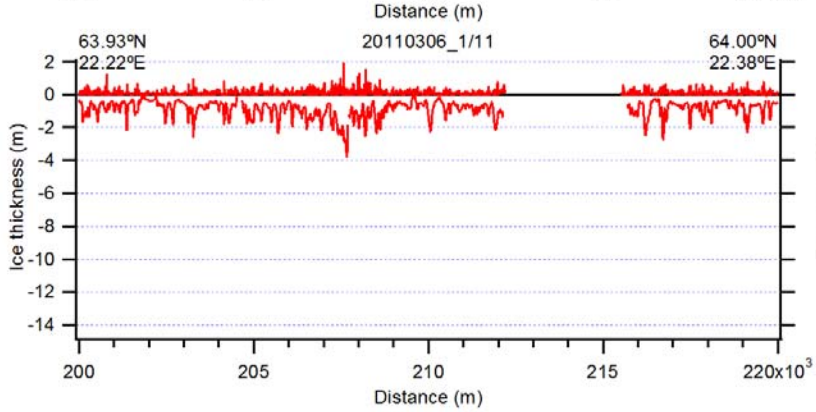

63.77ºN
21.63ºE
20110306_1/8
63.61ºN
21.93ºE
Ice thickness (m)
Distance (m)
140 145 150 155 160x10^3
Frequency (%)
Ice thickness (m)

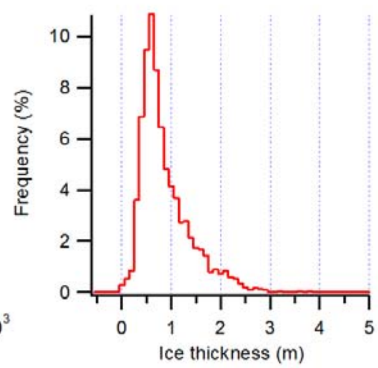

63.61ºN
21.93ºE
20110306_1/9
63.71ºN
22.10ºE
Ice thickness (m)
Distance (m)
160
165
170
175
180x10^3

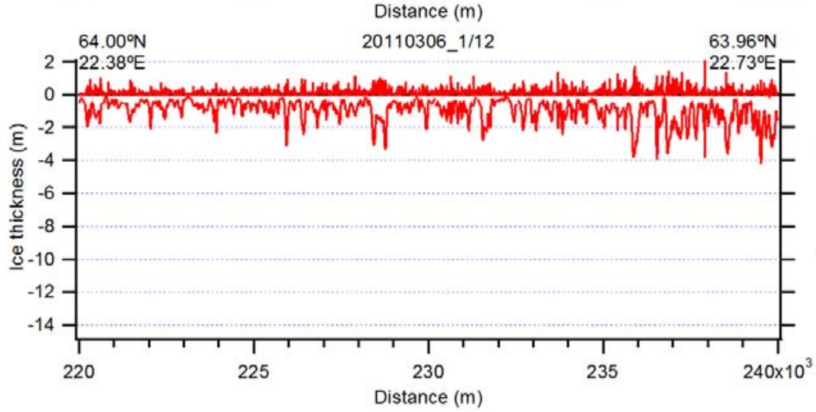

Frequency (%)
Ice thickness (m)

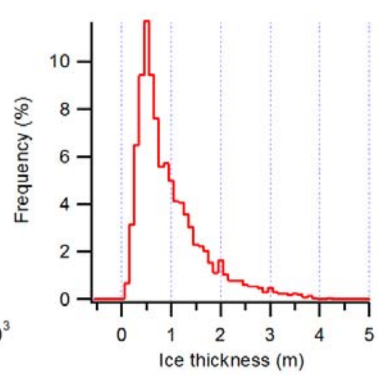

63.71ºN
22.10ºE
20110306_1/10
63.93ºN
22.22ºE
Ice thickness (m)
Distance (m)
180
185
190
195
200x10^3

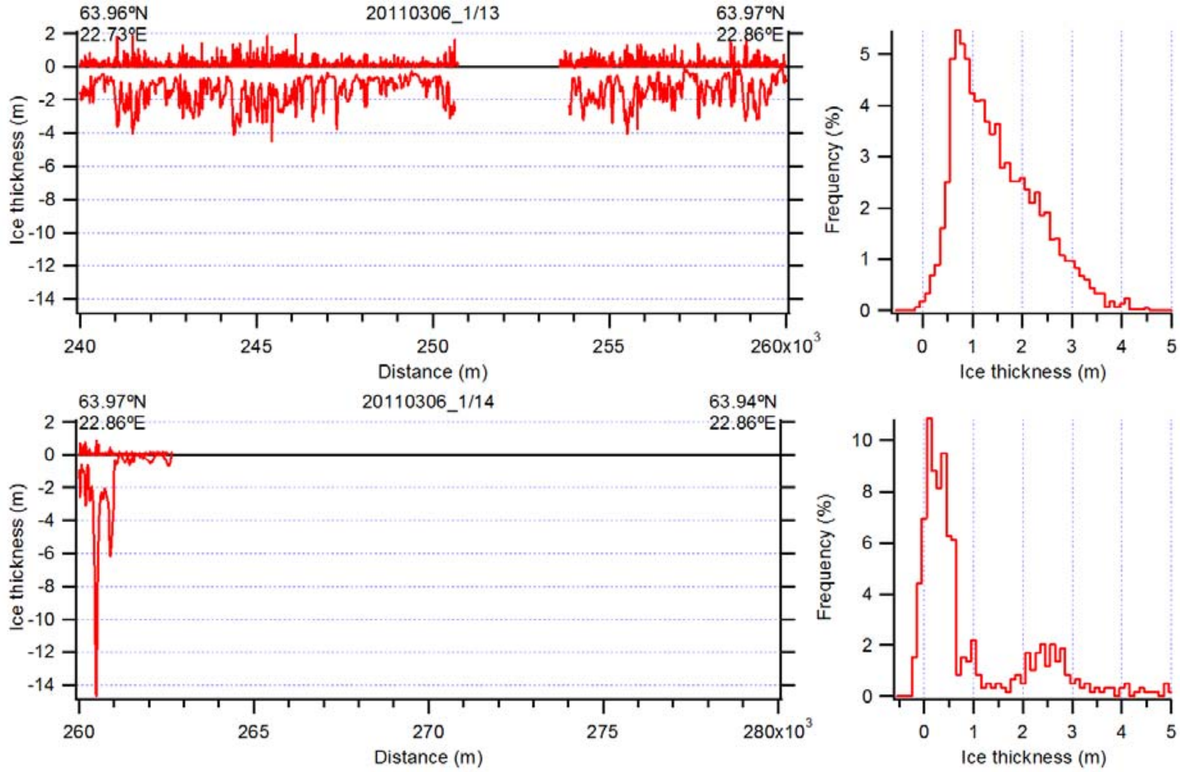

Frequency (%)
Ice thickness (m)


63.93ºN
22.22ºE
20110306_1/11
64.00ºN
22.38ºE
Ice thickness (m)
Distance (m)
200
205
210
215
220x10^3


Frequency (%)
Ice thickness (m)

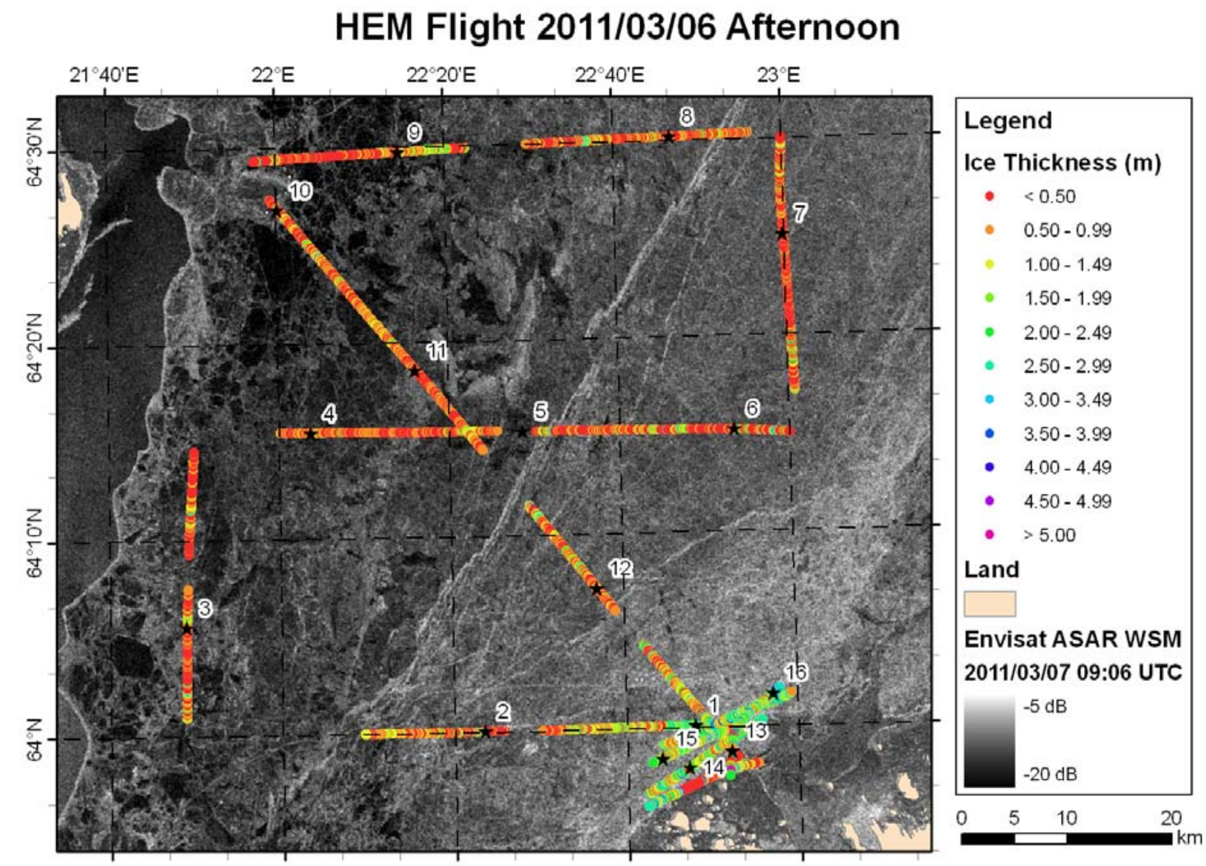

64.00ºN
22.38ºE
20110306_1/12
63.96ºN
22.73ºE
Ice thickness (m)
Distance (m)
220
225
230
235
240x10^3

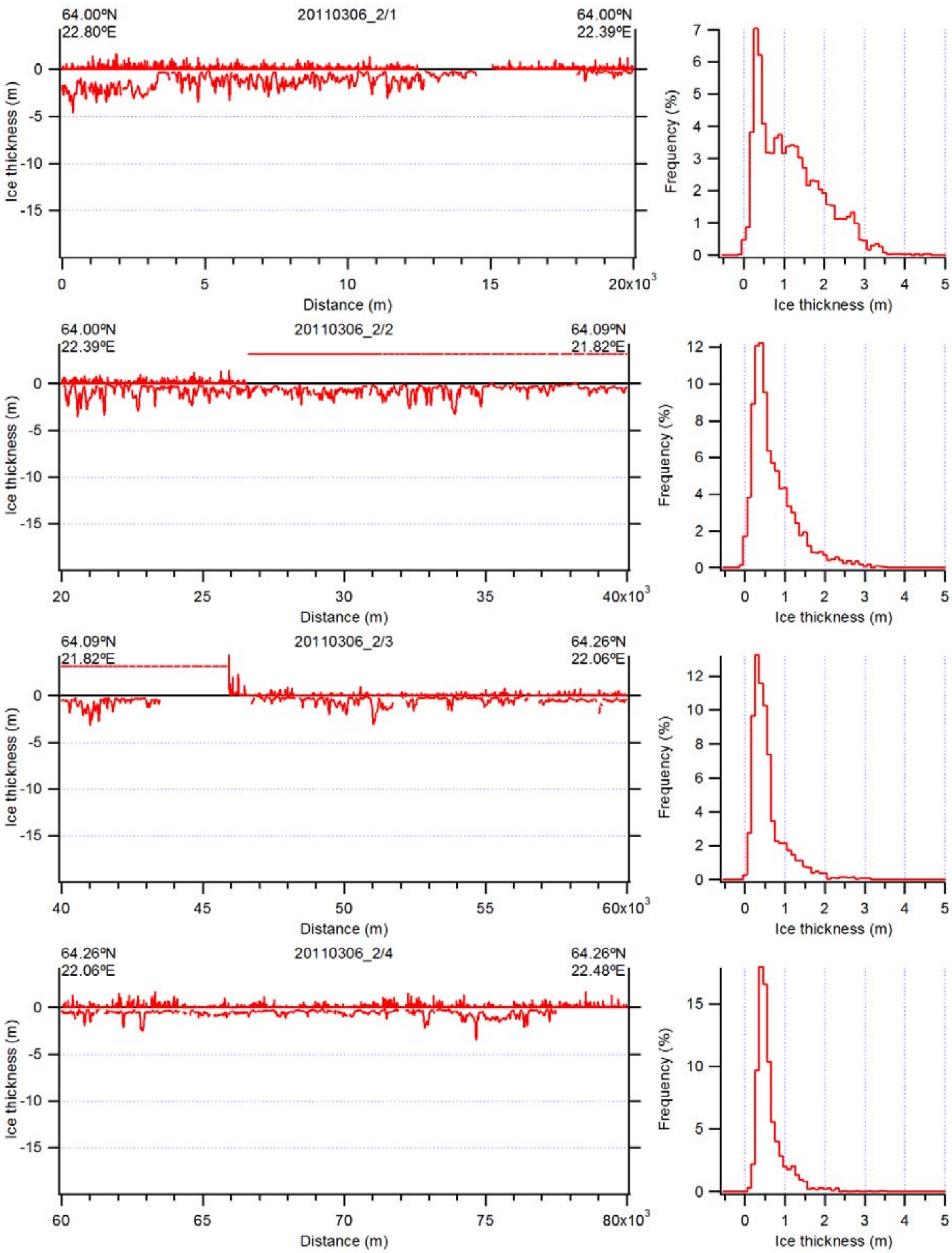

Frequency (%)
Ice thickness (m)

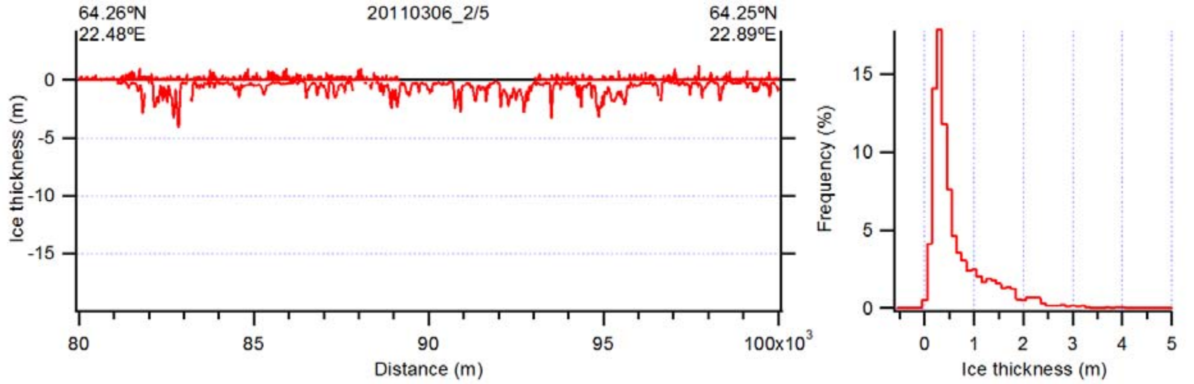

63.96ºN
22.73ºE
20110306_1/13
63.97ºN
22.86ºE
Ice thickness (m)
Distance (m)
260x10^3
Frequency (%)
Ice thickness (m)
63.97ºN
22.86ºE
20110306_1/14
63.94ºN
22.86ºE
Ice thickness (m)
Distance (m)
280x10^3
Frequency (%)
Ice thickness (m)

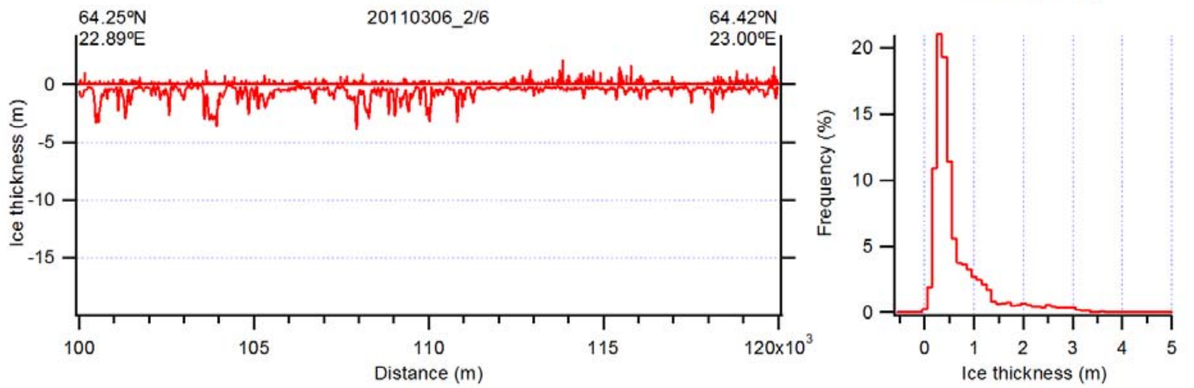
March 6, 2011, afternoon flight over southern Bay of Bothnia and coastal shear zones

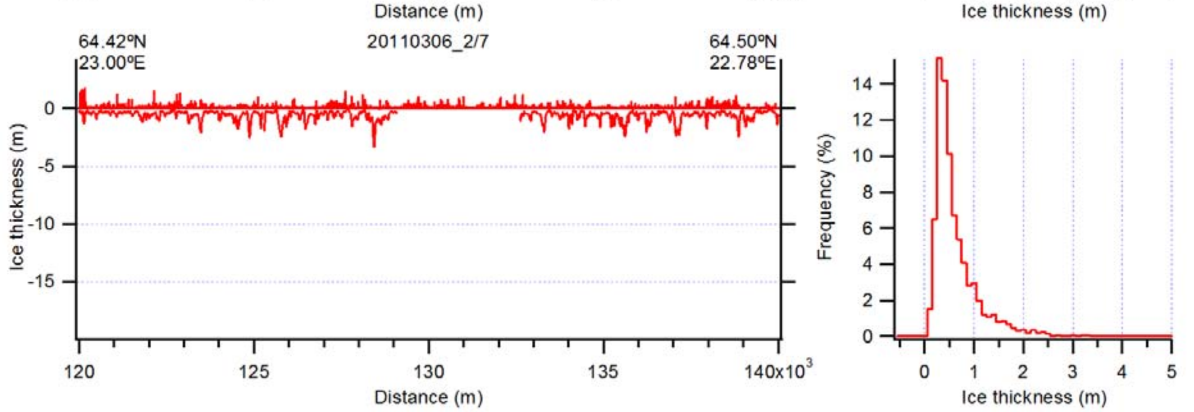
Segment No.	GPS time start (decimal hour)	GPS time end (decimal hour)	Mean thickness (m)	Standard deviation (m)	Modal thickness (m)
1	12.0689	12.1985	1.18674	0.807399	0.25
2	12.1985	12.4547	0.728698	0.577909	0.35
3	12.4547	12.6515	0.587908	0.459568	0.25
4	12.6515	12.778	0.622216	0.37603	0.35
5	12.778	12.8965	0.660589	0.598078	0.25
6	12.8965	13.0634	0.654955	0.595099	0.25
7	13.0634	13.2002	0.614676	0.435136	0.25
8	13.2002	13.3647	0.770585	0.628806	0.25
9	13.3647	13.4869	0.45445	0.373995	0.25
10	13.4869	13.5972	0.722787	0.468648	0.45
11	13.5972	13.7435	0.753186	0.580957	0.35
12	13.7435	13.8556	1.0627	0.789467	0.35
13	13.8556	14.0313	1.22687	1.18247	0.05
14	14.0313	14.1629	1.79459	0.846129	2.05
15	14.1629	14.2849	2.07216	0.965243	2.35
16	14.2849	14.3397	2.02928	1.83054	1.65

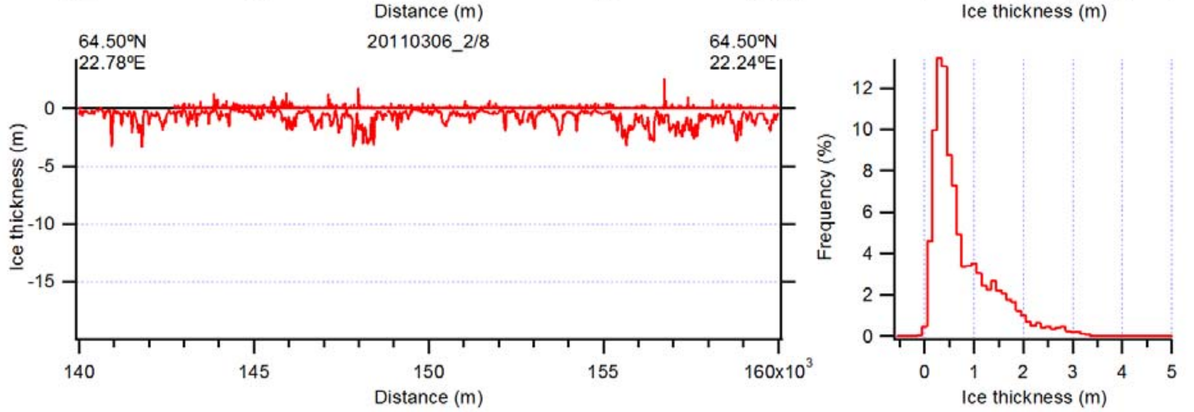

HEM Flight 2011/03/06 Afternoon
21°40'E
22°E
22°20'E
22°40'E
23°E
64°30'N
64°20'N
64°10'N
64°N
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Legend
Ice Thickness (m)
< 0.50
0.50 - 0.99
1.00 - 1.49
1.50 - 1.99
2.00 - 2.49
2.50 - 2.99
3.00 - 3.49
3.50 - 3.99
4.00 - 4.49
4.50 - 4.99
> 5.00
Land
Envisat ASAR WSM
2011/03/07 09:06 UTC
-5 dB
-20 dB
0 5 10 20
km

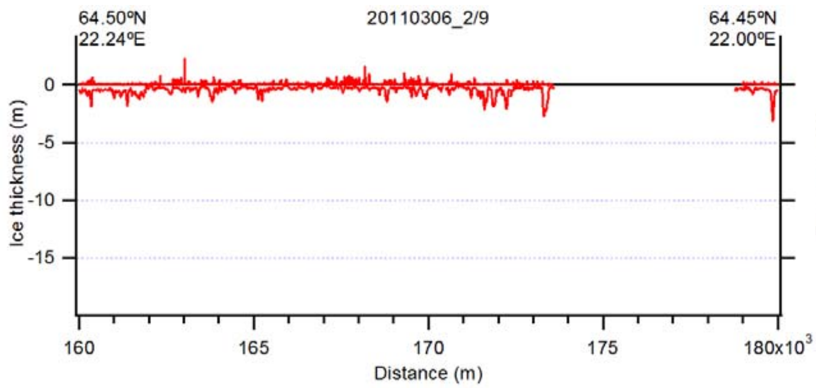

64.00ºN
22.80ºE
20110306_2/1
64.00ºN
22.39ºE
Ice thickness (m)
Distance (m)
20x10^3
Frequency (%)
Ice thickness (m)
64.00ºN
22.39ºE
20110306_2/2
64.09ºN
21.82ºE
40x10^3
64.09ºN
21.82ºE
20110306_2/3
64.26ºN
22.06ºE
60x10^3
64.26ºN
22.06ºE
20110306_2/4
64.26ºN
22.48ºE
80x10^3

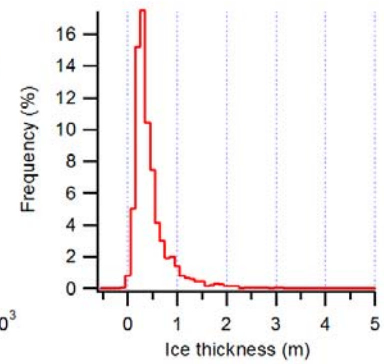

64.26ºN
22.48ºE
20110306_2/5
64.25ºN
22.89ºE
Ice thickness (m)
Distance (m)
100x10^3
Frequency (%)
Ice thickness (m)

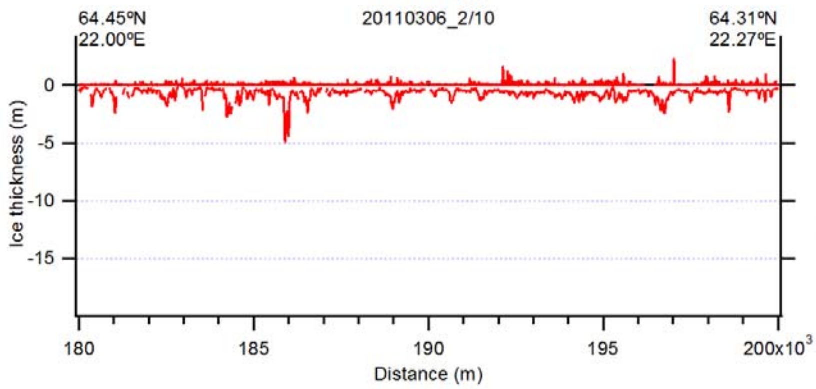

64.25ºN
22.89ºE
20110306_2/6
64.42ºN
23.00ºE
Ice thickness (m)
Distance (m)
120x10^3
Frequency (%)
Ice thickness (m)

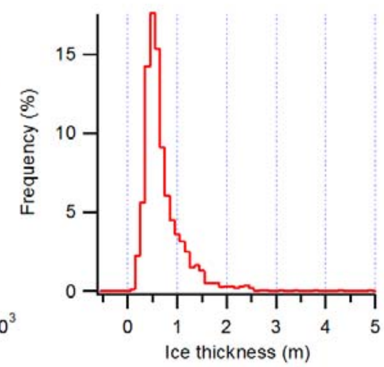

64.42ºN
23.00ºE
20110306_2/7
64.50ºN
22.78ºE
Ice thickness (m)
Distance (m)
140x10^3
Frequency (%)
Ice thickness (m)

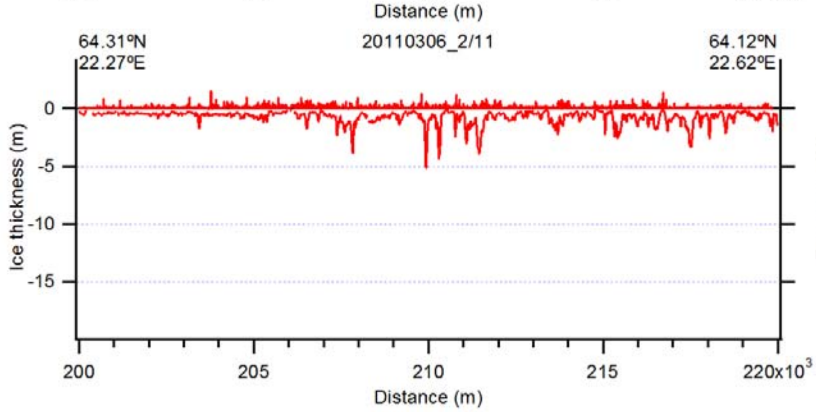

64.50ºN
22.78ºE
20110306_2/8
64.50ºN
22.24ºE
Ice thickness (m)
Distance (m)
160x10^3
Frequency (%)
Ice thickness (m)

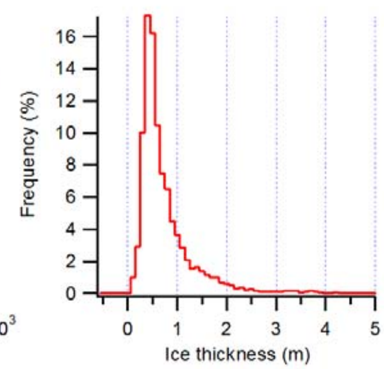

64.50ºN
22.24ºE
20110306_2/9
64.45ºN
22.00ºE
Ice thickness (m)
Distance (m)
180x10³

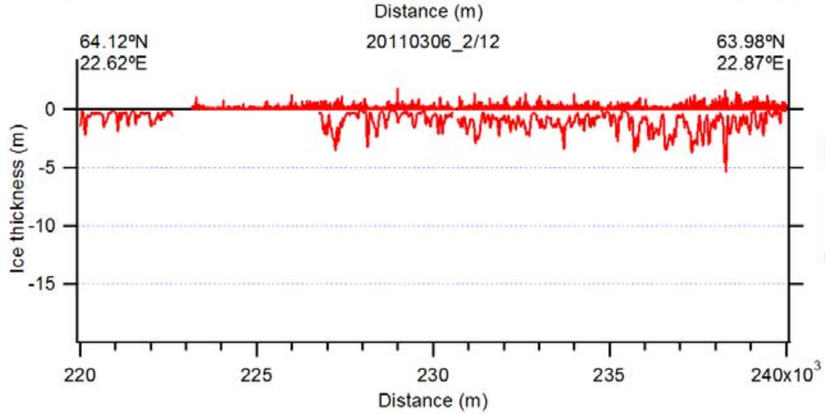

Frequency (%)
Ice thickness (m)

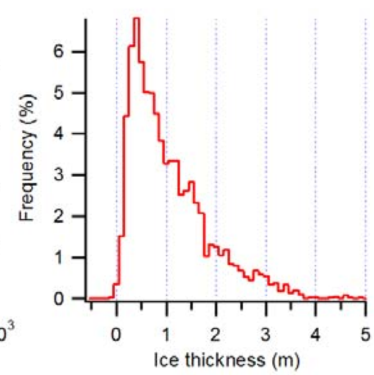

64.45ºN
22.00ºE
20110306_2/10
64.31ºN
22.27ºE
Ice thickness (m)
Distance (m)
200x10³

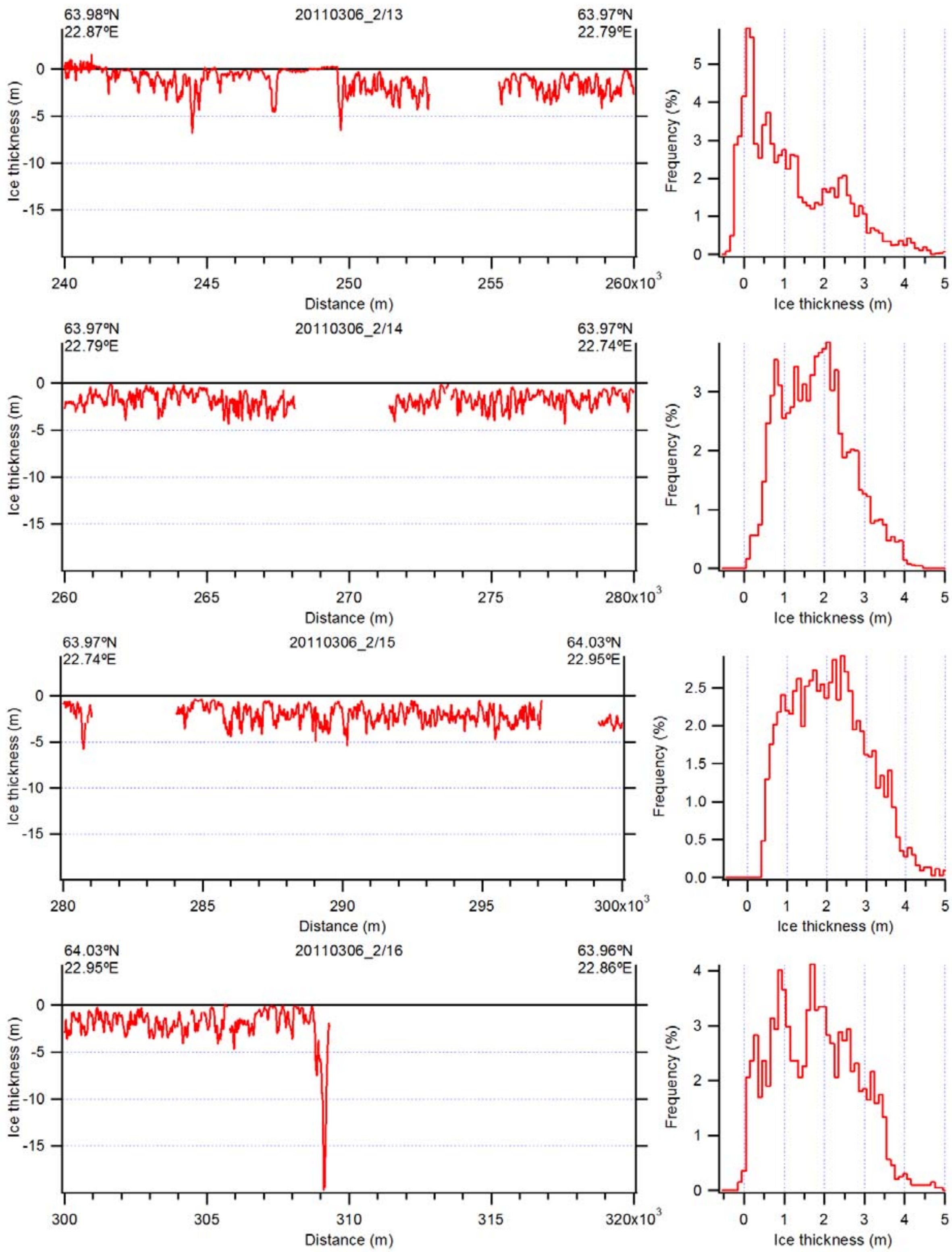

Frequency (%)
Ice thickness (m)


64.31ºN
22.27ºE
20110306_2/11
64.12ºN
22.62ºE
Ice thickness (m)
Distance (m)
220x10³


Frequency (%)
Ice thickness (m)

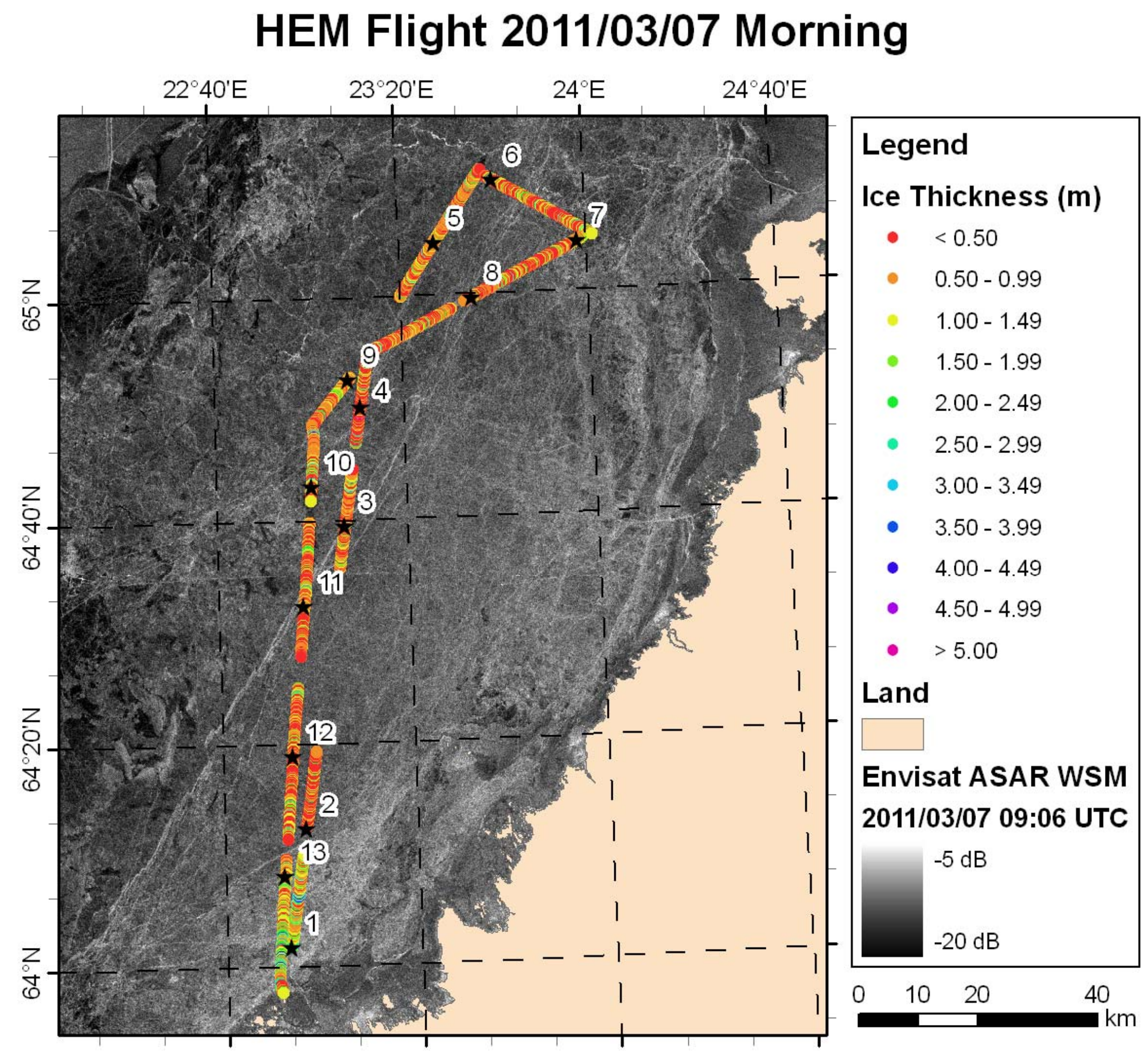

64.12ºN
22.62ºE
20110306_2/12
63.98ºN
22.87ºE
Ice thickness (m)
Distance (m)
240x10³

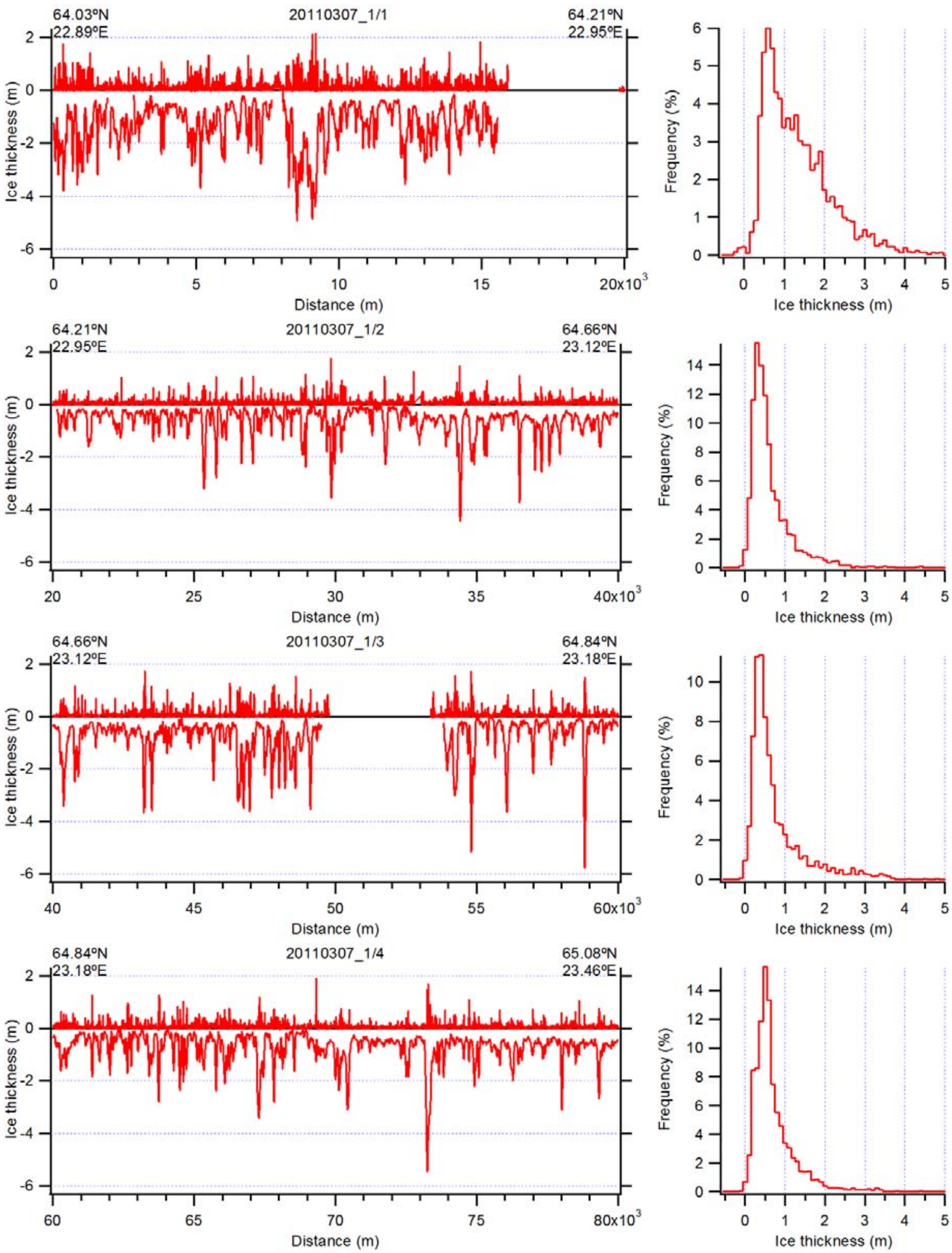

Frequency (%)
Ice thickness (m)

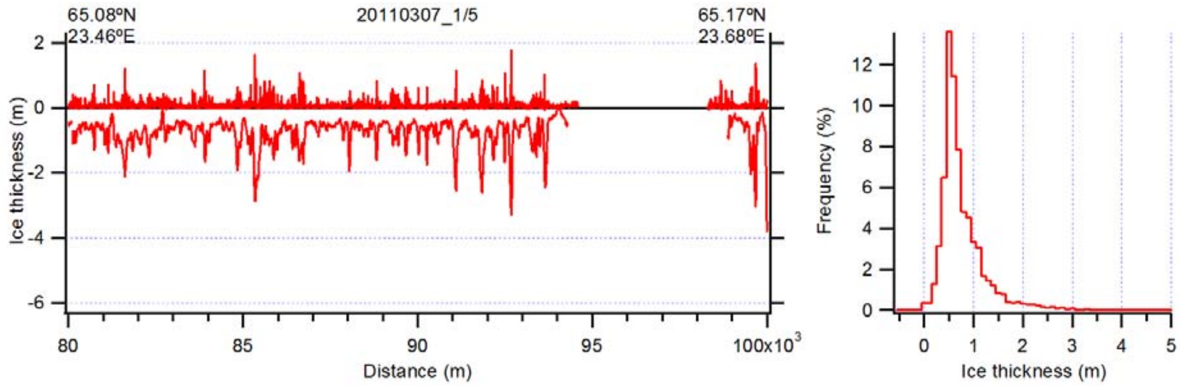

63.98ºN
22.87ºE
20110306_2/13
63.97ºN
22.79ºE
Ice thickness (m)
Distance (m)
260x10^3
Frequency (%)
Ice thickness (m)
63.97ºN
22.79ºE
20110306_2/14
63.97ºN
22.74ºE
Ice thickness (m)
Distance (m)
280x10^3
Frequency (%)
Ice thickness (m)
63.97ºN
22.74ºE
20110306_2/15
64.03ºN
22.95ºE
Ice thickness (m)
Distance (m)
300x10^3
Frequency (%)
Ice thickness (m)
64.03ºN
22.95ºE
20110306_2/16
63.96ºN
22.86ºE
Ice thickness (m)
Distance (m)
320x10^3
Frequency (%)
Ice thickness (m)

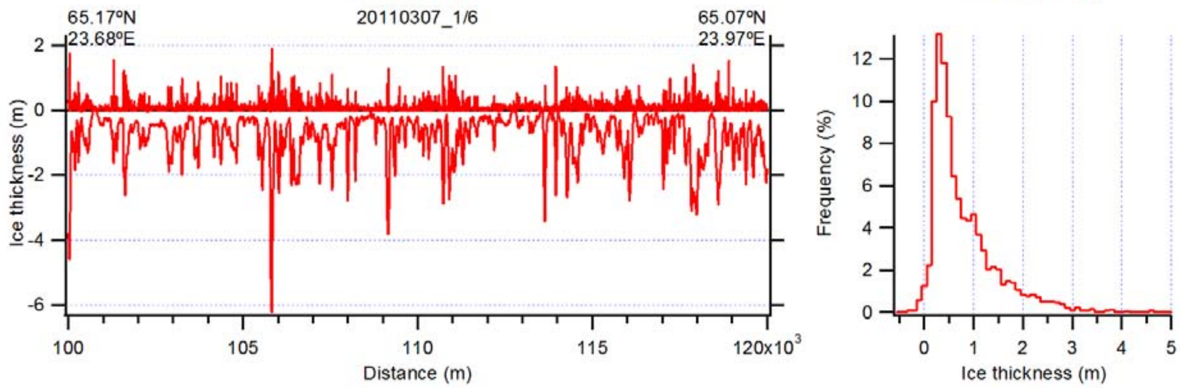
March 7, 2011, morning flight over central Bay of Bothnia

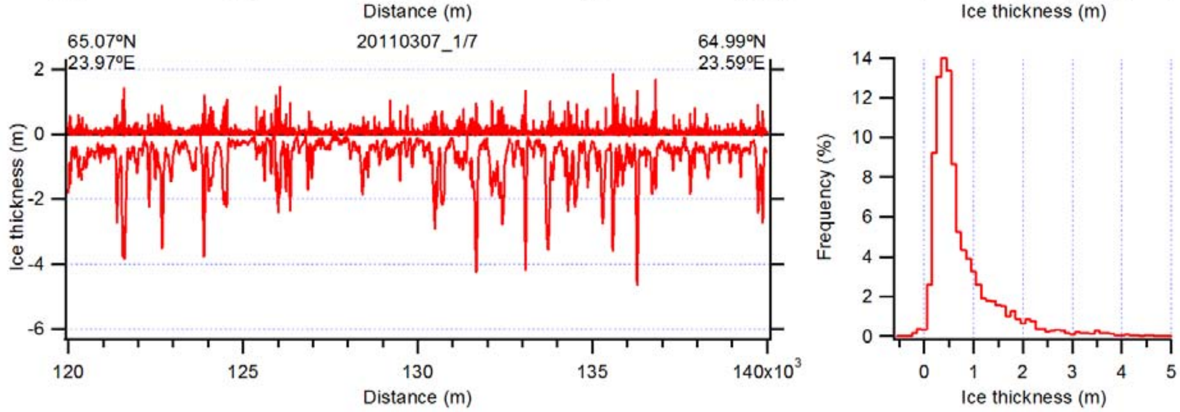
Segment No.	GPS time start (decimal hour)	GPS time end (decimal hour)	Mean thickness (m)	Standard deviation (m)	Modal thickness (m)
1	7.17511	7.28856	1.34112	0.834975	0.55
2	7.28856	7.56911	0.630183	0.544878	0.25
3	7.56911	7.68636	0.787656	0.765866	0.35
4	7.68636	7.92986	0.721712	0.577949	0.45
5	7.92986	8.05031	0.759116	0.438292	0.45
6	8.05031	8.20539	0.803024	0.703275	0.25
7	8.20539	8.35731	0.754058	0.668631	0.35
8	8.35731	8.54964	0.726709	0.50171	0.45
9	8.54964	8.69033	0.909156	0.655873	0.45
10	8.69033	8.82306	0.776276	0.560871	0.35
11	8.82306	8.99264	0.692795	0.445525	0.35
12	8.99264	9.1295	0.753833	0.64807	0.25
13	9.1295	9.26303	1.34703	0.903804	0.85

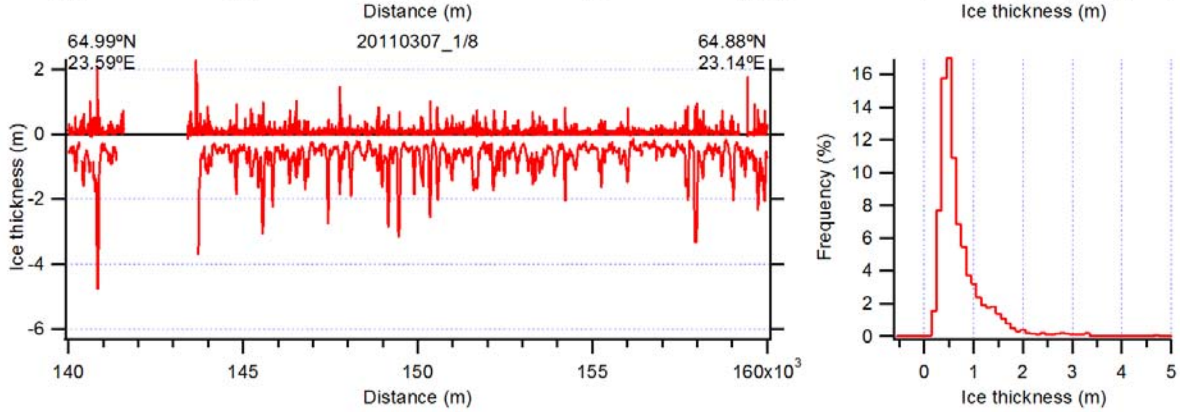

HEM Flight 2011/03/07 Morning
22°40'E
23°20'E
24°E
24°40'E
65°N
64°40'N
64°20'N
64°N
1
2
3
4
5
6
7
8
9
10
11
12
13
Legend
Ice Thickness (m)
< 0.50
0.50 - 0.99
1.00 - 1.49
1.50 - 1.99
2.00 - 2.49
2.50 - 2.99
3.00 - 3.49
3.50 - 3.99
4.00 - 4.49
4.50 - 4.99
> 5.00
Land
Envisat ASAR WSM
2011/03/07 09:06 UTC
-5 dB
-20 dB
0 10 20 40
km

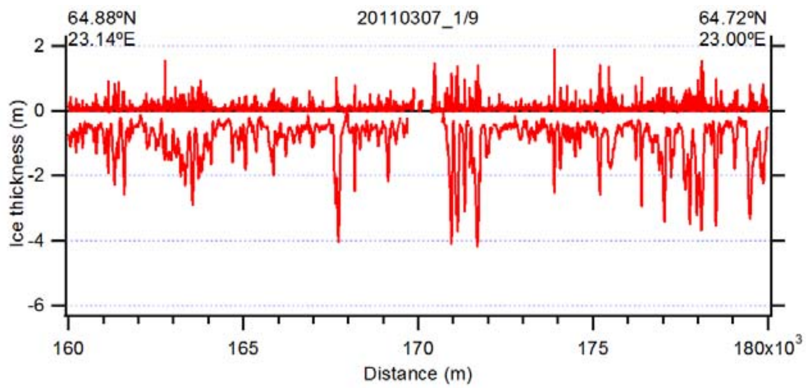

64.03ºN
22.89ºE
20110307_1/1
64.21ºN
22.95ºE
Ice thickness (m)
Distance (m)
20x10^3
Frequency (%)
Ice thickness (m)
64.21ºN
22.95ºE
20110307_1/2
64.66ºN
23.12ºE
Ice thickness (m)
Distance (m)
40x10^3
Frequency (%)
Ice thickness (m)
64.66ºN
23.12ºE
20110307_1/3
64.84ºN
23.18ºE
Ice thickness (m)
Distance (m)
60x10^3
Frequency (%)
Ice thickness (m)
64.84ºN
23.18ºE
20110307_1/4
65.08ºN
23.46ºE
Ice thickness (m)
Distance (m)
80x10^3
Frequency (%)
Ice thickness (m)

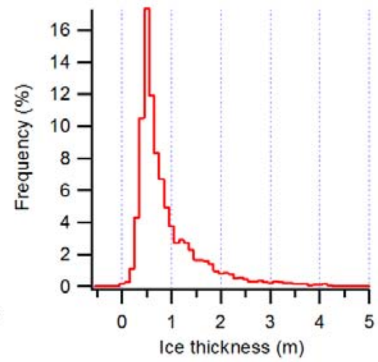

65.08ºN
23.46ºE
20110307_1/5
65.17ºN
23.68ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)

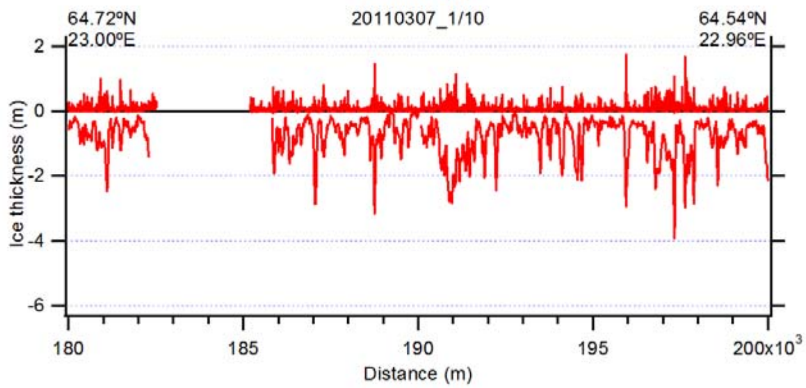

65.17ºN
23.68ºE
20110307_1/6
65.07ºN
23.97ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)

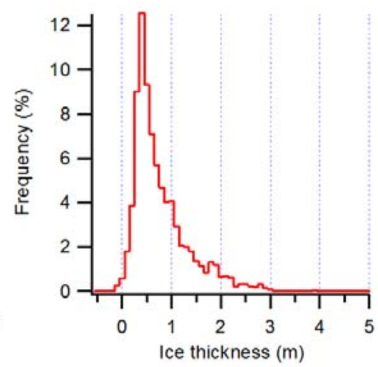

65.07ºN
23.97ºE
20110307_1/7
64.99ºN
23.59ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)

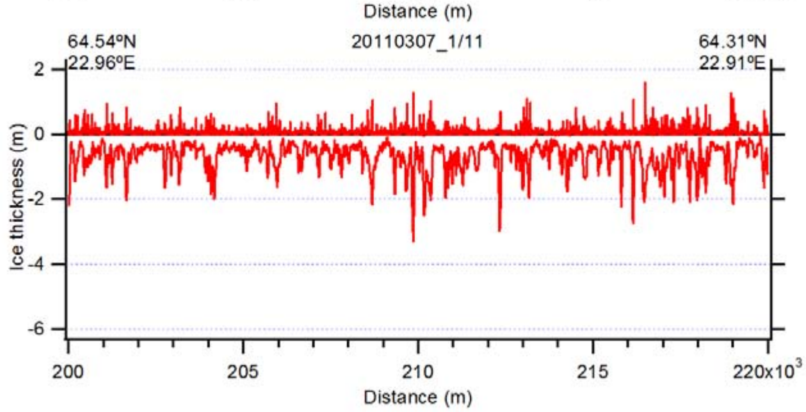

64.99ºN
23.59ºE
20110307_1/8
64.88ºN
23.14ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)

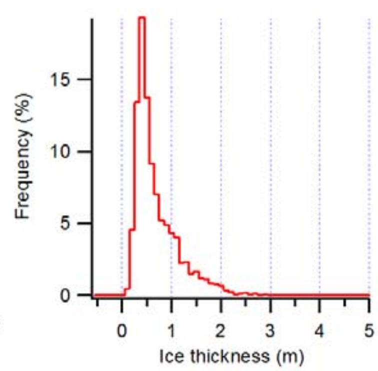

64.88ºN
23.14ºE
20110307_1/9
64.72ºN
23.00ºE
Ice thickness (m)
Distance (m)
180x10^3

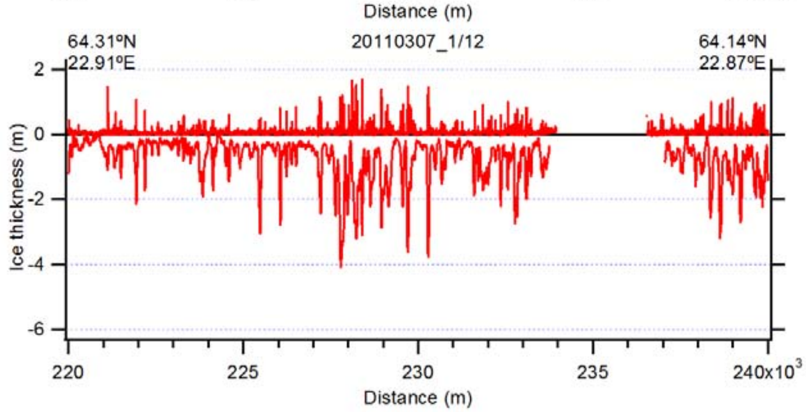

Frequency (%)
Ice thickness (m)

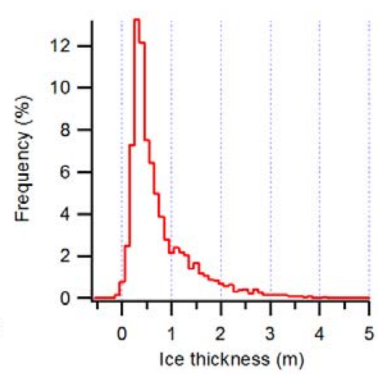

64.72ºN
23.00ºE
20110307_1/10
64.54ºN
22.96ºE
Ice thickness (m)
Distance (m)
200x10^3

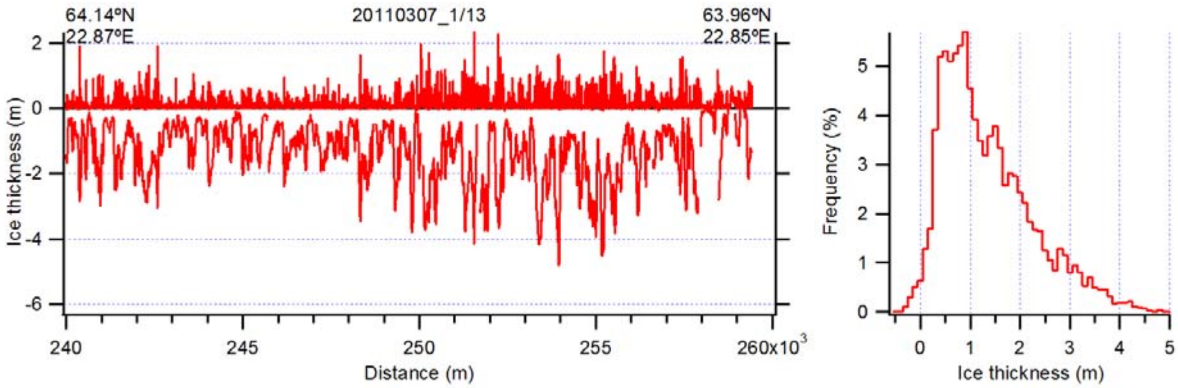

Frequency (%)
Ice thickness (m)


64.54ºN
22.96ºE
20110307_1/11
64.31ºN
22.91ºE
Ice thickness (m)
Distance (m)
220x10^3


Frequency (%)
Ice thickness (m)

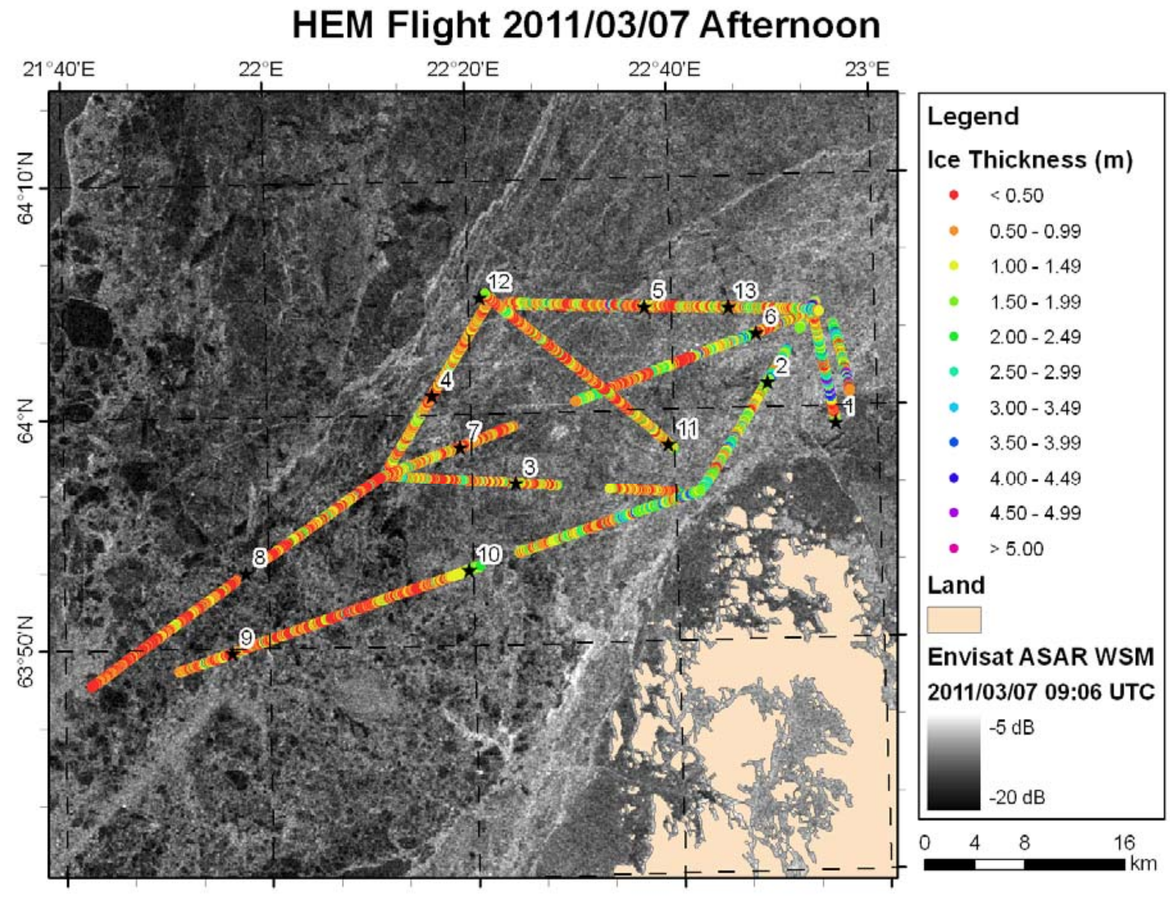

64.31ºN
22.91ºE
20110307_1/12
64.14ºN
22.87ºE
Ice thickness (m)
Distance (m)
240x10^3

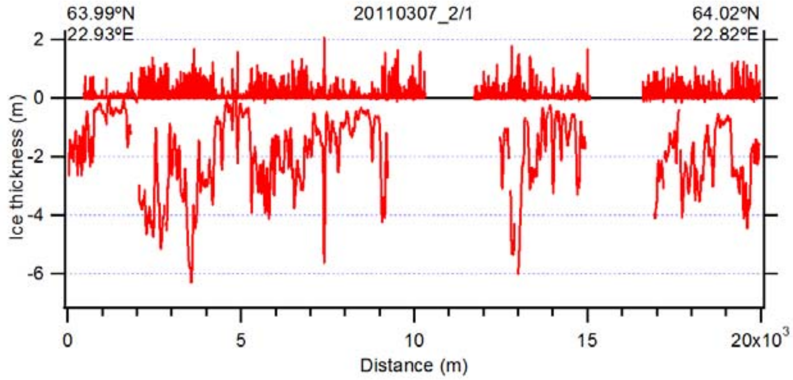

Frequency (%)
Ice thickness (m)

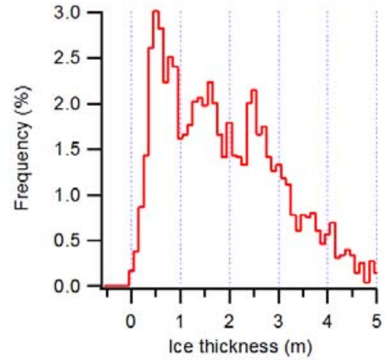

64.14ºN
22.87ºE
20110307_1/13
63.96ºN
22.85ºE
Ice thickness (m)
Distance (m)
260x10^3
Frequency (%)
Ice thickness (m)

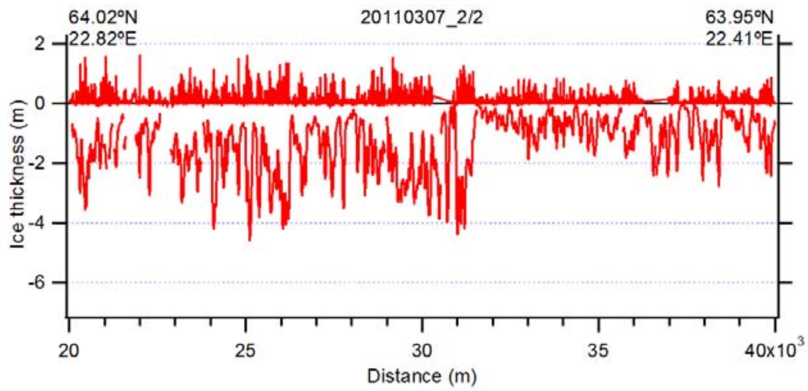
March 7, 2011, afternoon flight over buoy array

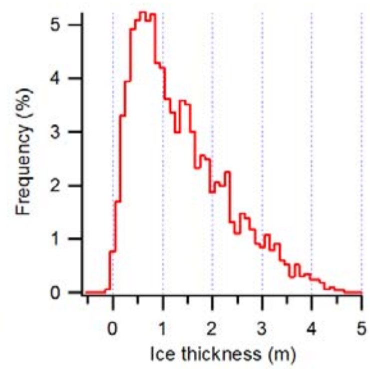
Segment No.	GPS time start (decimal hour)	GPS time end (decimal hour)	Mean thickness (m)	Standard deviation (m)	Modal thickness (m)
1	11.6206	11.7549	1.92664	1.23931	0.45
2	11.7549	11.9634	1.35738	0.933025	0.55
3	11.9634	12.0949	0.963042	0.69929	0.65
4	12.0949	12.2778	0.904907	0.779198	0.35
5	12.2778	12.4083	1.0816	0.930007	0.35
6	12.4083	12.5866	1.12396	0.895962	0.25
7	12.5866	12.7392	0.754121	0.603222	0.15
8	12.7392	12.9273	0.611447	0.412237	0.35
9	12.9273	13.039	0.707041	0.571078	0.25
10	13.039	13.1799	1.57918	1.0146	0.35
11	13.1799	13.3122	0.764926	0.544028	0.35
12	13.3122	13.4292	1.00843	0.830904	0.35
13	13.4292	13.5214	1.68647	1.23233	0.45

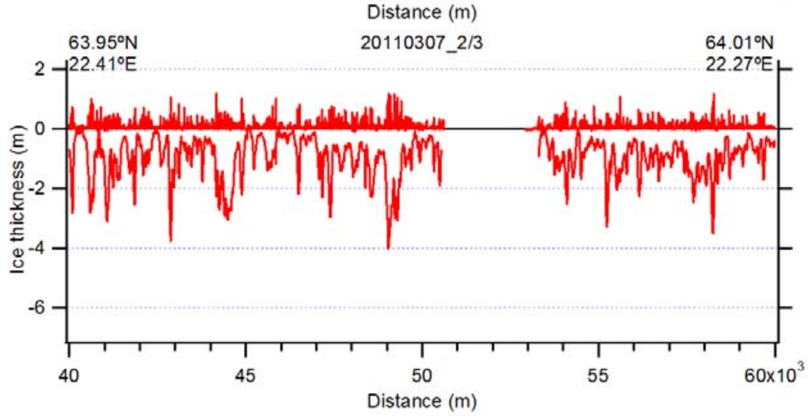

HEM Flight 2011/03/07 Afternoon
21°40'E
22°E
22°20'E
22°40'E
23°E
64°10'N
64°N
63°50'N
12
5
13
6
2
1
4
7
3
11
8
10
9
Legend
Ice Thickness (m)
< 0.50
0.50 - 0.99
1.00 - 1.49
1.50 - 1.99
2.00 - 2.49
2.50 - 2.99
3.00 - 3.49
3.50 - 3.99
4.00 - 4.49
4.50 - 4.99
> 5.00
Land
Envisat ASAR WSM
2011/03/07 09:06 UTC
-5 dB
-20 dB
0 4 8 16
km

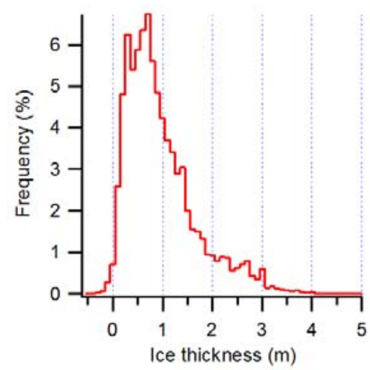

63.99ºN
22.93ºE
20110307_2/1
64.02ºN
22.82ºE
Ice thickness (m)
Distance (m)
20x10^3

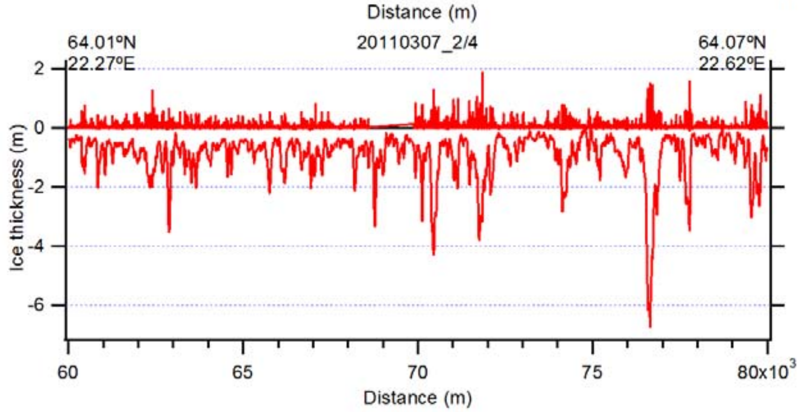

Frequency (%)
Ice thickness (m)

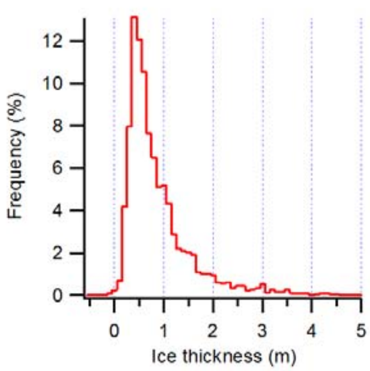

64.02ºN
22.82ºE
20110307_2/2
63.95ºN
22.41ºE
Ice thickness (m)
Distance (m)
40x10^3

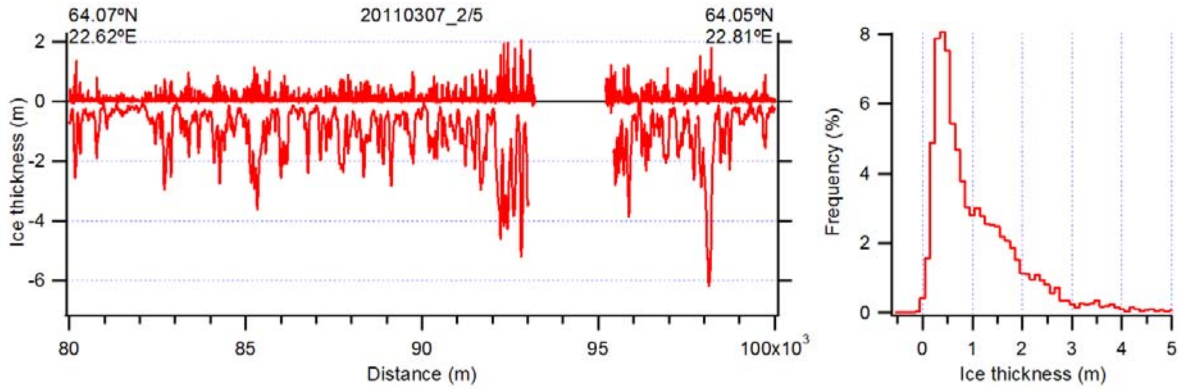

Frequency (%)
Ice thickness (m)

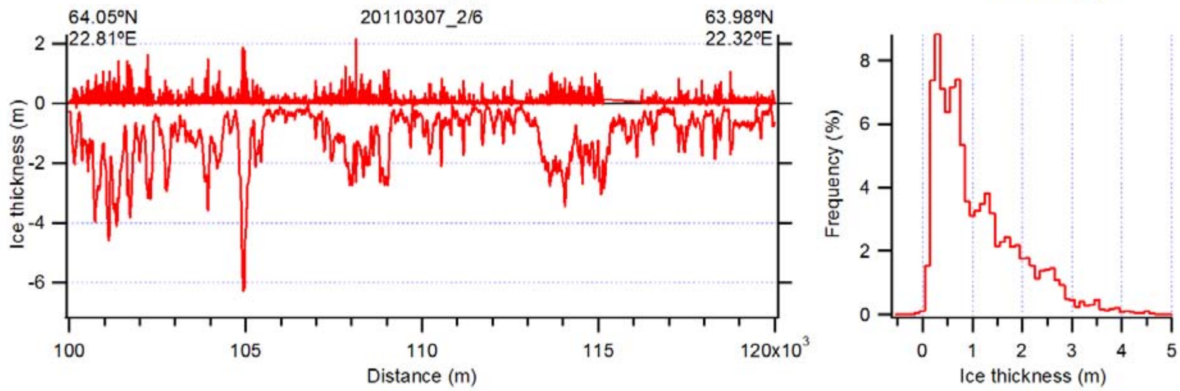

63.95ºN
22.41ºE
20110307_2/3
64.01ºN
22.27ºE
Ice thickness (m)
Distance (m)
60x10^3

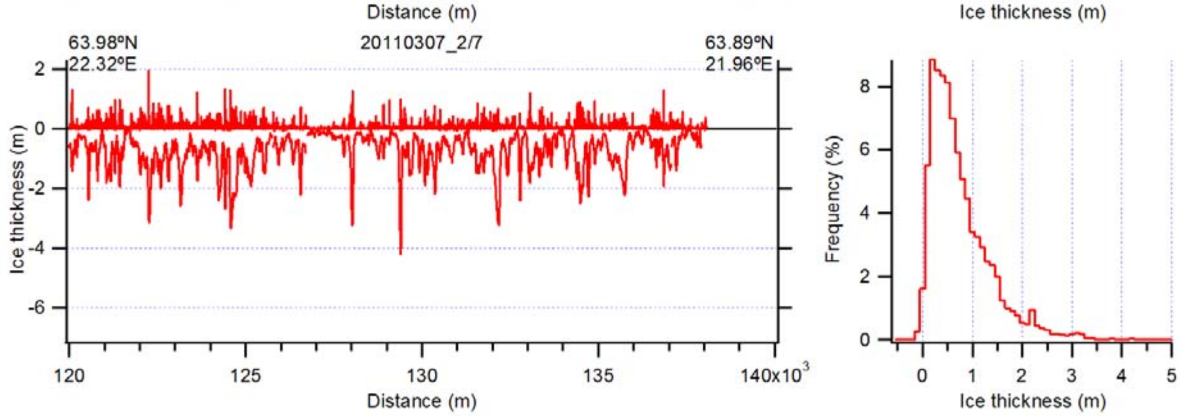

Frequency (%)
Ice thickness (m)

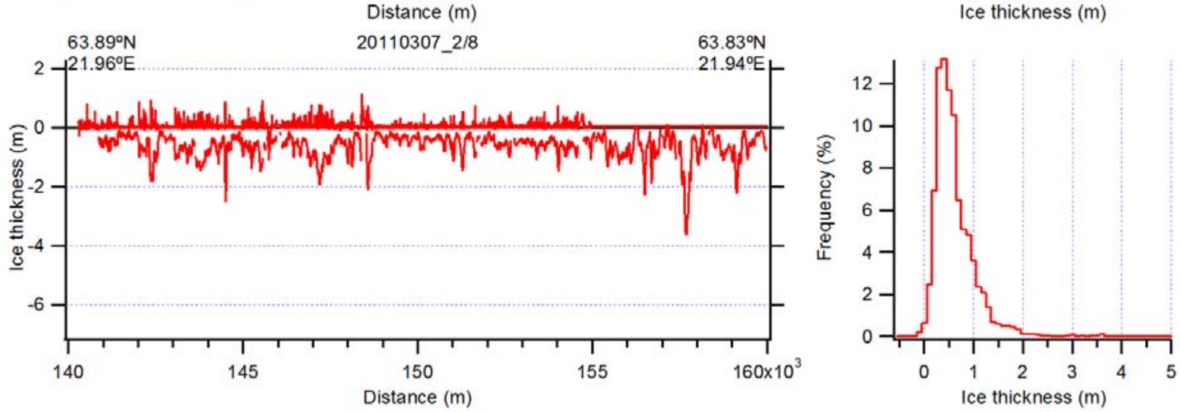

64.01ºN
22.27ºE
20110307_2/4
64.07ºN
22.62ºE
Ice thickness (m)
Distance (m)
80x10^3

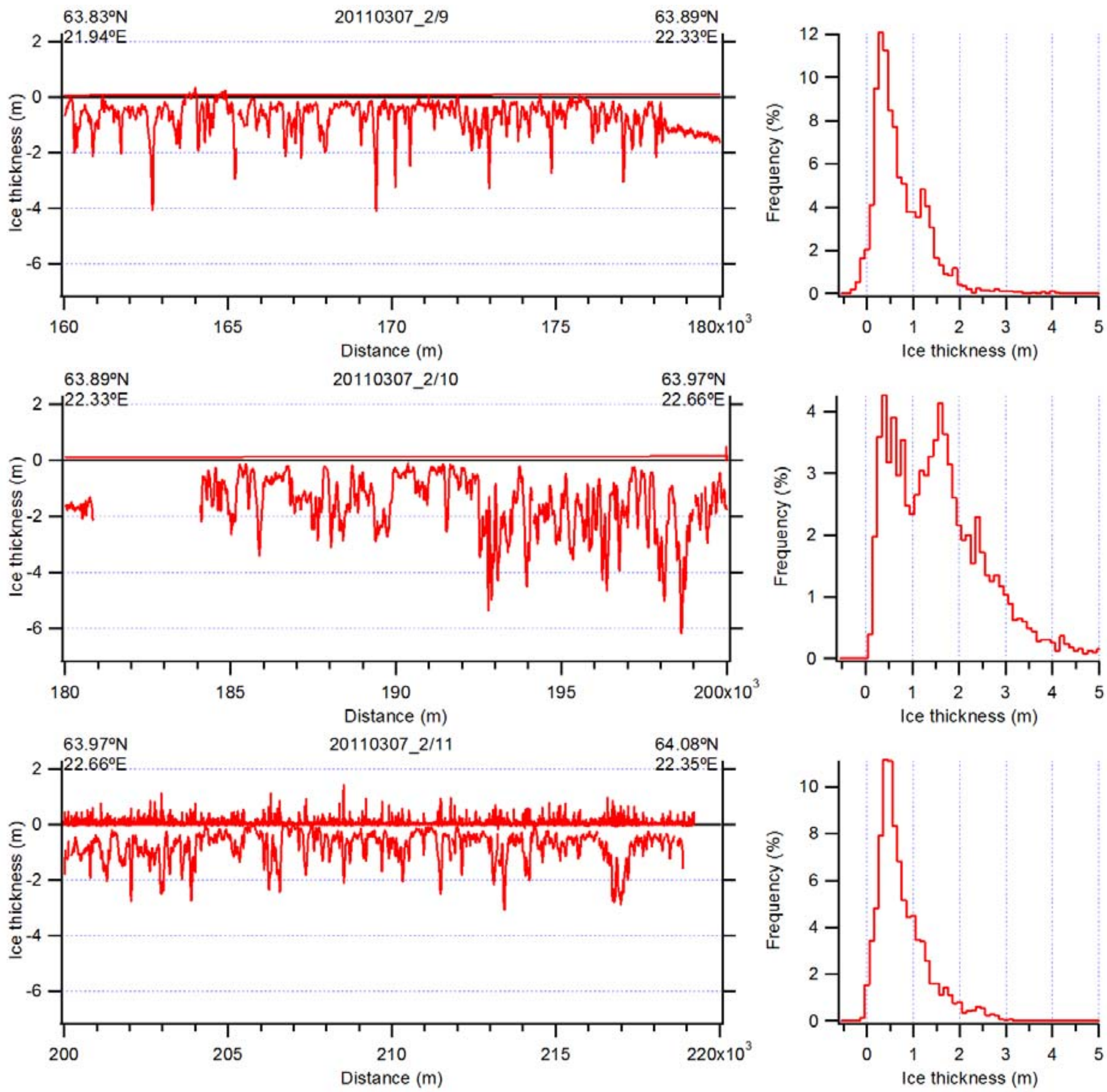

Frequency (%)
Ice thickness (m)

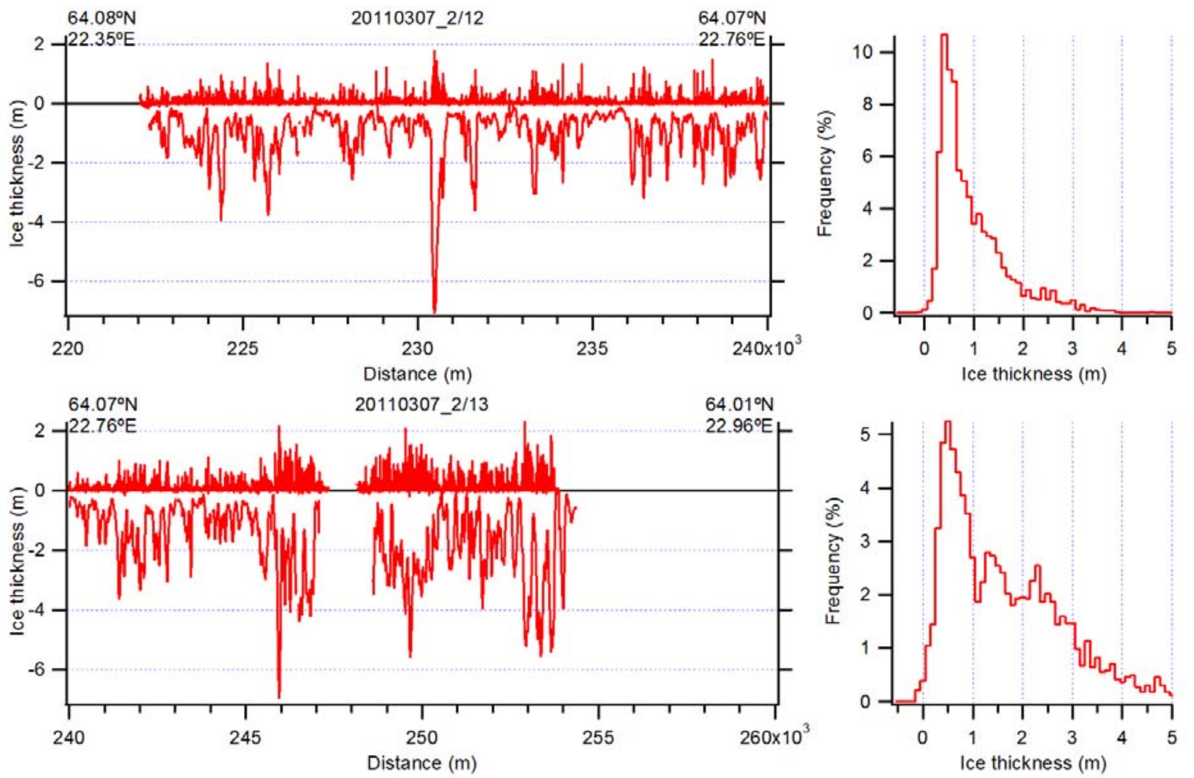

64.07ºN
22.62ºE
20110307_2/5
64.05ºN
22.81ºE
Ice thickness (m)
Distance (m)
100x10³
Frequency (%)
Ice thickness (m)


64.05ºN
22.81ºE
20110307_2/6
63.98ºN
22.32ºE
Ice thickness (m)
Distance (m)
120x10³
Frequency (%)
Ice thickness (m)


63.98ºN
22.32ºE
20110307_2/7
63.89ºN
21.96ºE
Ice thickness (m)
Distance (m)
140x10³
Frequency (%)
Ice thickness (m)


63.89ºN
21.96ºE
20110307_2/8
63.83ºN
21.94ºE
Ice thickness (m)
Distance (m)
160x10³
Frequency (%)
Ice thickness (m)


63.83ºN
21.94ºE
20110307_2/9
63.89ºN
22.33ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
63.89ºN
22.33ºE
20110307_2/10
63.97ºN
22.66ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)
63.97ºN
22.66ºE
20110307_2/11
64.08ºN
22.35ºE
Ice thickness (m)
Distance (m)
Frequency (%)
Ice thickness (m)


64.08ºN
22.35ºE
20110307_2/12
64.07ºN
22.76ºE
Ice thickness (m)
Distance (m)
240x10^3
Frequency (%)
Ice thickness (m)
64.07ºN
22.76ºE
20110307_2/13
64.01ºN
22.96ºE
Ice thickness (m)
Distance (m)
260x10^3
Frequency (%)
Ice thickness (m)

File formats

All thickness and surface roughness (ridging) data obtained during the SafeWIn 2011 flights have been provided as ASCII tables in two different files. Columns in each file represent the following variables:

1. *allfinal.dat files:

These two files include the complete ice thickness data obtained during each flight. Data have been obtained with a sampling frequency of 10 Hz. They contain the following 10 columns:

Year
Month
Day
GPS time (seconds of day)
Fid number (measurement index)
Latitude (Degrees)
Longitude (Degrees)
Distance along flight track (m)
Ice thickness (m)
Bird height (m)

2. *.fb files:

These files include the processed laser data, with the helicopter height variation removed following Hibler (1972), i.e. data represent surface roughness. For technical reasons, there is one file each for measurements obtained between successive ascents of the EM Bird. Data were acquired with a sampling frequency of 100 Hz. The Fid number can be used to synchronize the laser and EM data. The *.fb files contain the following 6 columns:

Fid number (measurement index)
Latitude (Degrees)
Longitude (Degrees)
GPS time (decimal hours)
Distance along flight track (m)
Surface height (m).

References

Haas, C. (2004). Airborne EM sea-ice thickness profiling over brackish Baltic sea water, Proceedings of the 17th international IAHR symposium on ice, June 21-25, 2004, St. Petersburg, Russia, All-Russian Research Institute of Hydraulic Engineering (VNIIG), Saint Petersburg, Russia,2,12-17.

Haas, C. (2006). Airborne electromagnetic sea ice thickness sounding in shallow, brackish water environments of the Caspian and Baltic Seas, Proceedings of OMAE2006 25th International Conference on Offshore Mechanics and Arctic Engineering, June 4-9, 2006, Hamburg, Germany, 6pp.

Haas, C., Lobach, J., Hendricks, S., Rabenstein, L., Pfaffling, A. (2009). Helicopter-borne measurements of sea ice thickness, using a small and lightweight, digital EM system, Journal of Applied Geophysics, 67(3), 234-241., doi:10.1016/j.jappgeo.2008.05.005.

Hibler W.D.III (1972). Removal of Aircraft Altitude Variation from Laser Profiles of the Arctic ice pack, J.Geophys. Res. Vol. 77, No. 36, 7190-7195.