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Technical Support for the 2014 SMOSice Campaign in SE Svalbard

SMOSice 2014 Data Acquisition Report

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1 Introduction

The ESA SMOSice study (Contract number: 4000101476/10/NL/CT) has demonstrated for the first time the potential to retrieve sea ice thickness from SMOS data. It was therefore the aim of the 2014 SMOSice campaign to improve the SMOS sea-ice thickness retrieval algorithm by assembling a comprehensive data set of high resolution L-Band radiometer data, auxiliary sea ice conditions and sea-ice thickness validation data. The surveys were centered on newly formed thin sea ice regimes in the Barents Sea south-east of the Svalbard in spring 2014.

The objectives for the analysis of the campaign data are the assessment of biases and uncertainties of the low resolution L-Band brightness temperatures of SMOS with high resolution information and the validation and optimization of sea-ice thickness retrieval algorithms with coincident direct measurements of sea-ice thickness. It was therefore the goal of the SMOSice 2014 field campaign to collect the following datasets:

1. High resolution, polarized L-Band brightness temperatures at different incident angles to assess spatial variability
2. Estimations of snow-depth to estimate the effect of the snow layer on brightness temperatures
3. Independent sea-ice thickness measurements for the validation of retrieval algorithms.
4. Auxiliary datasets as input for retrieval algorithms and characterization of surface properties (surface temperature, longwave and shortwave radiative fluxes and freeboard/surface roughness)

To obtain coincident datasets of these parameters, two sensor platforms were used. The polar research aircraft “Polar-5” of the Alfred Wegener Institute operated from the airport in Longyearbyen, Spitsbergen and a helicopter surveyed the sea ice from the Norwegian research vessel Lance. The voyage of RV Lance was funded and organized by the University of Hamburg in the framework of the German Ice Route Optimization Project (IRO-2), lead by the Hamburg Ship Model Basin (HSVA) and funded by the German Federal Ministry for Economic Affairs and Energy (BMWi).

The combination and coordination of the two sensor platforms at different flight levels allowed the acquisition of a unique datasets consisting of coincident measurements of all relevant parameters for thin-ice thickness retrieval with SMOS. Polar-5 was equipped with EMIRAD-2, an airborne L-Band radiometer from DTU-Space, a radar system dedicated for snow depth estimation, a linear-swath type laser scanner, infrared pyrometer to estimate sea ice surface temperatures and radiation sensors. The helicopter towed an EM-Bird, operated by personnel of the Norwegian Polar Institute (NPI), to measure the sum of ice and snow thickness.

In addition to the data acquisition for SMOS thin ice thickness validation and retrieval algorithm improvement, the opportunity was used to survey sea ice along a CryoSat-2 ground track. The data shall be used to investigate future data fusion techniques of SMOS and CryoSat-2 sea-ice thickness data products.

Figure 1: Left: Polar-5 research aircraft at the airport in Longyearbyen, Spitsbergen, Right: RV Lance with Survey Helicopter

Table 1: Overview of observables during the 2014 SMOSice field campaign

Platform	Sensor	Observable
Polar-5	EMIRAD-2	L-Band brightness temperatures • horizontal and vertical polarizations • Nadir and higher incidence angles
Lance Helicopter	Airborne EM (EM-Bird)	Sea-Ice Thickness
Polar-5	Airborne Laserscanner	Freeboard, Surface Roughness
Polar-5	Airbone Snow Radar	Snow Depth (experimental)
Polar-5	KT19	Surface Temperature
Polar-5	Pyrgeometer/Pyranometer	Up/Downwelling longwave/shortwave radiation
Polar-5	Photo Camera	Visual impression of sea-ice conditions
Lance	Ship EM	Sea-Ice Thickness (data courtesy of IRO-2 project, L. Kaleschke)

The purpose of this document is the description of the airborne surveys and the collected datasets of the 2014 SMOSice field campaign. The documented is therefore structured in the following parts:

1. Summary of operation
2. Description of instrumentation
3. Processing steps
4. Data inventory
5. Technical data information
6. Conclusion

1.1 Summary of operations

Table 2: Activities of 2014 SMOSice field campaign

Date	Activity	Flight Objective	Flight ID
17.03.2014	Start of RV Lance cruise		
19.03.2014	Helicopter Science Flight	Science Flight	20149319_f1
20.03.2014	Helicopter Science Flight	Science Flight	20149320_f2
	Helicopter Science Flight	Science Flight	20149320_f3
21.03.2014	LYR Team Arrival		
22.03.2014	Polar-5 Integration		
	Helicopter Science Flight	Science Flight	20140322_f4
	Helicopter Science Flight	Science Flight	20140322_f5
23.03.2014	Polar-5 Science Flight	Instrument verification	20140323_01
	Helicopter Science Flight	Science Flight	20140323_f6
24.03.2014	Polar-5 Science Flight	Polar-5 – Helicopter	20140324_01
	Helicopter Science Flight	Helicopter – Polar-5	20140324_f7
25.03.2014	Weather Day		
26.03.2014	Polar-5 Science Flight	Polar-5 – Helicopter	20140326_01
	Helicopter Science Flight	Helicopter – Polar-5	20140326_f8
	Polar-5 Science Flight	CryoSat-2 Track	20140326_02
27.03.2014	Weather Day		
28.03.2014	LYR Team Departure		
29.03.2014	End of RV Lance Cruise		

Table 2 lists the timeline of activities from the Polar-5 scientific team in Longyearbyen (LYR) and the helicopter survey from the cruise of R/V Lance.

1.2 Sea Ice Conditions

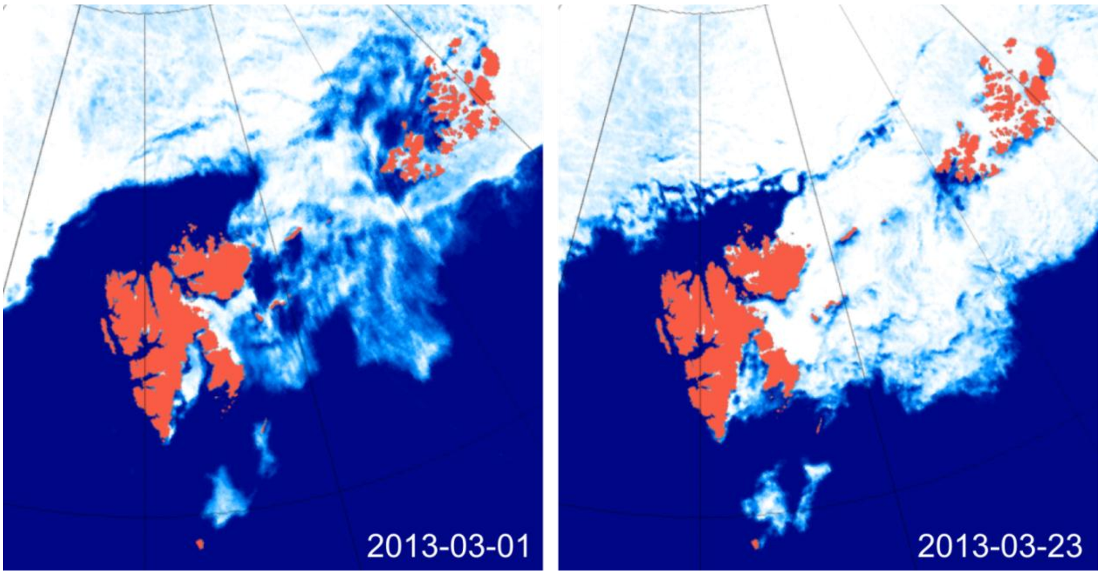


Figure 2: Sea Ice Concentration maps from 1. March (left) and 23. March (right). (Source: ZMAW: AMSR2/UHH-processing, AMSR2L1R data [JAXA])

The aircraft surveys took place in the period between the 23rd of March and the 26th of March. During this time almost the entire Storfjorden area and the region east of the Svalbard Archipelago was covered with sea ice. Sea-ice concentration maps from the University of Hamburg (Figure 2) show significantly lower ice concentrations in the Barents Sea region at beginning of March. This leads to the conclusion that most of the sea ice observed during the 2014 SMOSice campaign was locally formed in the week prior to the surveys.

1.3 Survey Layout

The layout of the survey waypoints were constrained by three factors:

a. Safety issues with the aircraft and helicopter operating in close distance and in comparable altitudes
b. Conflicting flight altitude requirements for data acquisition of the EMIRAD radiometer and the snow radar
c. Measurements of side-looking horn of the airborne L-Band radiometer EMIRAD would be negatively influenced by direct or reflected insolation

The surveys were there organized as repeated surveys in two different altitudes between two waypoints (Figure 3), where the helicopter followed Polar-5 on the second leg with lower airspeed. This approach sufficed the safety requirements a) and data acquisition at different altitudes b). Avoiding data acquisition of the side-looking horn required aircraft headings that did not result in a sun position of 55 to 145 degree in the aircraft (Figure 4). Since this requirements was depended on the local solar time during the survey, the sun position were computed for location and data of surveys and EMIRAD operated at one of the two legs where the side-looking horn pointed away from the sun direction.

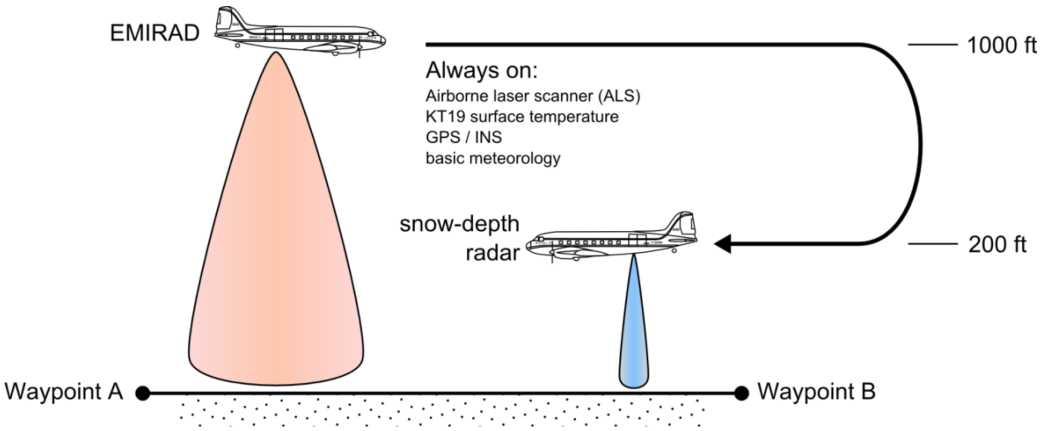


Figure 3: Organization of Polar-5 survey altitude. Every line was sampled twice in altitudes optimized for L-Band brightness temperatures (1000 ft) and lower altitude for snow radar estimations (200ft)

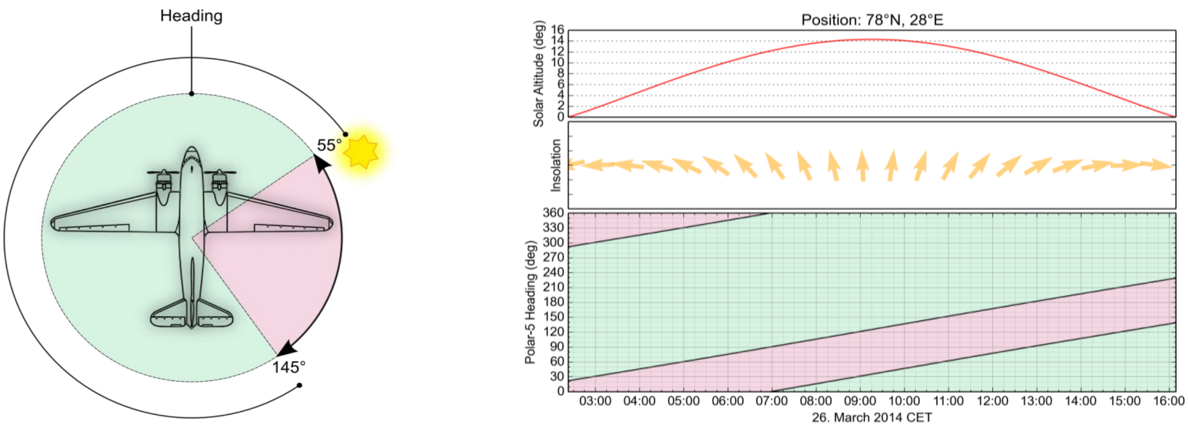


Figure 4: Insolation constrains for the operation of the side-looking horn of EMIRAD-2. No usable scientific data can be retrieved if the sun is oriented between 55 and 145 degree azimuth in the local aircraft reference frame

2 Instrumentation

This section summarizes the technical specifications of the instrumention used on both sensor platforms (Polar-5, helicopter)

2.1 EMIRAD

The EMIRAD-2 L-band radiometer system has been developed by DTU, and operated by DTU in a range of campaigns, known as the CoSMOS campaigns, in support of SMOS. It is a fully polarimetric (4 Stokes parameters) system with advanced RFI detection features (kurtosis and polarimetry). The system has operated successfully on different aircraft (Aero Commander and Skyvan) in Denmark, Norway, Finland, Germany, France, Spain, Australia), and 2013 it was operated on the AWI Basler BT-67 (Polar-6) in Antarctica for the DOMECAir campaign. The main features of the system are:

- Correlation radiometer with direct sampling
- Fully polarimetric (i.e. 4 Stokes parameters)
- Frequency: 1400.5 – 1426.5 MHz (-3 dB BW)
1392 - 1433 (-60 dB BW)
- Digital radiometer with 139.4 MHz sampling
- Digital I/Q demodulation and correlation for accurate estimation of 3rd and 4th Stokes
- Advanced analog filter for RFI suppression.
- Additional digital filter bank: 4 sub-bands.
- RFI flagging by kurtosis and polarimetry.
- Data integrated to 1 ms recorded on primary storage PC.
- “Fast data” pre-integrated to 14.4 μs. recorded on dedicated PC.
- Sensitivity: 0.1 K for 1 s. integration time
- Stability: better than 0.1 K over 15 min. before internal calibration.
- Calibration: internal load, noise diode, and Active Cold Load (ACL).
- 2 antennas - one nadir pointing, one side looking at 45 deg. incidence angle
- Antennas are Potter horns with 37.6 deg & 30.6 deg HPBW
- Nadir horn has 210 m footprint from 1000 ft flight altitude
- Tilted horn has 245 m by 320 m footprint, again from 1000 ft flight altitude.
- Each data package time stamped using GPS 1PPS signal with 100 ns accuracy.
- Minimum operating altitude: 250 m above terrain @ 140 knots
- Integrated with Embedded GPS/INS unit (EGI) for navigation and attitude date

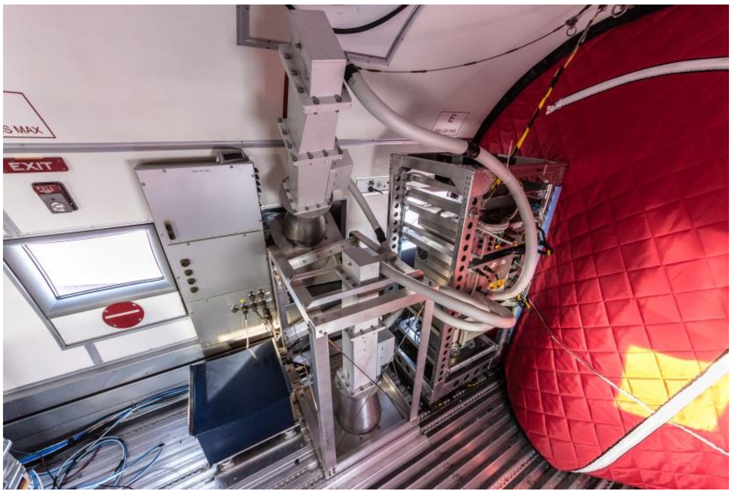


Figure 5: Installation of Nadir and Side-Looking EMIRAD-2 antennas in Polar-5

Further information about EMIRAD-2 is found in [Skou et al, 2006] and [Skou et al, 2010].

The installation and functionality of the radiometer system on-board the aircraft was tested during a test flight off Bremerhaven carried out February 19, 2014.

2.2 Airborne Laser Scanner

The laser scanner model used on the Polar-5 was a Riegl VQ-580. This scanner and similar models of Riegl laser scanner have been used on previous ESA sponsored campaigns, e.g. in the CryoVEx programme.

The scanner yield linear scans and operates in near infrared with an accuracy and precision of 25 mm over snow and ice. A swath angle of 60° and typically 300 measurements per scan lead to a point spacing in the order of centimeters at typical flight altitudes.

2.3 Snow Radar

The snow-radar used during the 2014 SMOSice field campaign was developed by the Technical University Hamburg-Harburg (TUHH) and has been optimized for low-level surveys to comply with the sea-ice thickness sensor (EM-Bird), which is optional for Polar-5.

The snow depth sensor has recently been tested over inland ice in Antarctica and has proven to work within its specifications; however this field campaign was the first application to sea ice targets.

AWI snow radar specifications:

Frequency Range	8 – 12 GHz
Transmit Power	35 dBm = 3,2 W
Theoretical Resolution	2,5 cm (vsnow = 200 m/µs)

Sample Time	20 ms
Sample Frequency	10 Hz
Antenna (Transmitter/Receiver) Gain	20 dB
Aircraft altitude Range	200 – 300 ft

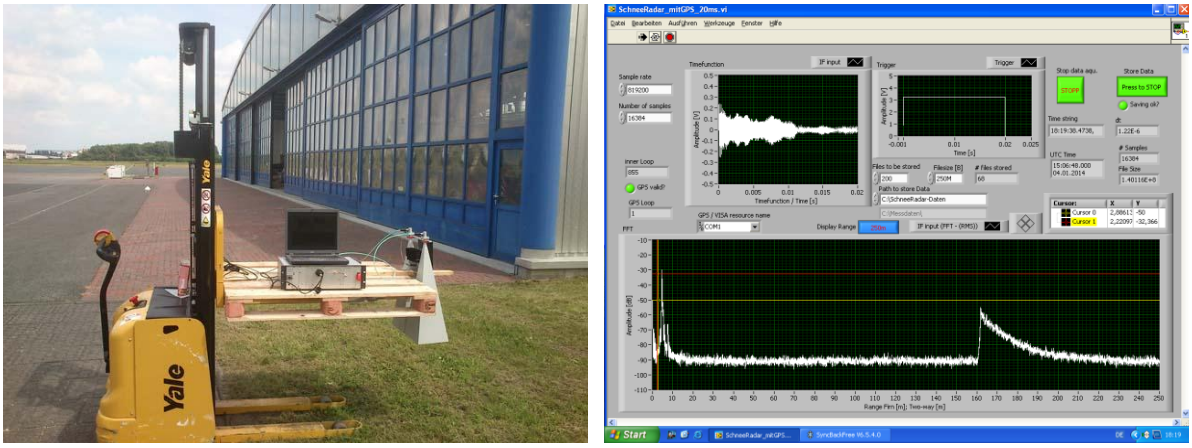


Figure 6:Components of snow-depth radar (horn antennas and data acquisition unit). (left) Test setup in Bremerhaven and first airborne data of the AWI sea-ice snow-radar over Antarctic firn (right)

2.4 Radiation and Surface Temperature

Polar-5 is equipped with two Kipp&Zonen pyrgeometers of type CGR 4 for measuring broadband hemispheric down- and upwelling thermal (longwave) radiation as well as with two Kipp&Zonen pyranometers of type CMP 22 for measuring broadband hemispheric down- and upwelling solar (shortwave) radiation.

Surface temperature is measured with a Heitronics Kt19.85 II at a rate of 10 Hz with an accuracy of 0.1°C (Manufacturer specifications).

2.5 Aerial Nadir Photography

Polar-5 is equipped with a nadir-mounted digital camera (Canon EOS 1D Mark III). Photos are taken every ten seconds over sea ice. Due to technical limitations of the internal data acquisition system, the internal timestamp of the camera is only available with full second resolution.

The nadir imagery is mostly used for documentary purposes and not processed to higher data levels, e.g. orthographically projected images. Therefore the images are not described any further in this document. However, 3573 photos are available at AWI upon request.

2.6 EM-Bird

The Eurocopter AS350 helicopter onboard R/V Lance was used to measure the sea ice thickness close to coincident with the measurements from the Polar-5 aircraft. A combined electromagnetic induction sounding and laser altimeter device, called EM-Bird or HEM, was towed on a 20 m cable under the helicopter. The EM-Bird was built by Ferra Dynamics Inc., Ontario, Canada, and it is operated by personnel of the Norwegian Polar Institute. The HEM system is operated at a height of approximately 15 m above the sea ice surface. With a nominal flying speed of 70 knots (36 m/s), the sea ice thickness is measured every 3 to 4 m within a footprint of about 50 m. The HEM system measures the ice thickness by making use of the difference in conductivity between sea ice and sea water. The distance between the HEM system and the snow or ice surface is measured by a Riegl LD90-3 laser altimeter. Therefore the HEM measures the combined ice and snow thickness called sea ice thickness henceforth. Uncertainties arise from swinging motion of the HEM sensor and assumptions made about the conductivity of the underlying sea water. On flat, homogenous sea ice the accuracy is better than 0.1 m [Haas et al., 2009].

Figure 7 : EM-Bird operation on the helicopter deck of R/V Lance (Photo: M. Drusch, ESA)

EM-Bird specifications:

Sensor	**Electromagnetics**	**Laser Altimeter**
Length 350 cm (nominal)	Transmitter Coil	Type Riegl LD90-3
Diameter 36.2cm (outside)	Frequency 4060 Hz ±10 Hz	Accuracy ± 15mm
Weight 100 kg nominal	Field Strength 78 watts	Sampling Frequency 100 Hz
Tow Cable Kevlar 20 m	Sampling Frequency 10 Hz	

3 Campaign Summary

This section gives an overview of all flights performed for the project; a detailed listing of recorded files is given in the Appendix.

3.1 Polar-5 Surveys

Bremerhaven EMIRAD calibration and certification flight

In preparation of the field campaign a test flight was performed in Bremerhaven, Germany on February 19th, 2014 with the aim of test mounting, calibration and certification of the EMIRAD-2 antennas on the Polar-5 aircraft. Flight track and acquired data events are given in Figure 8 and Table 3.

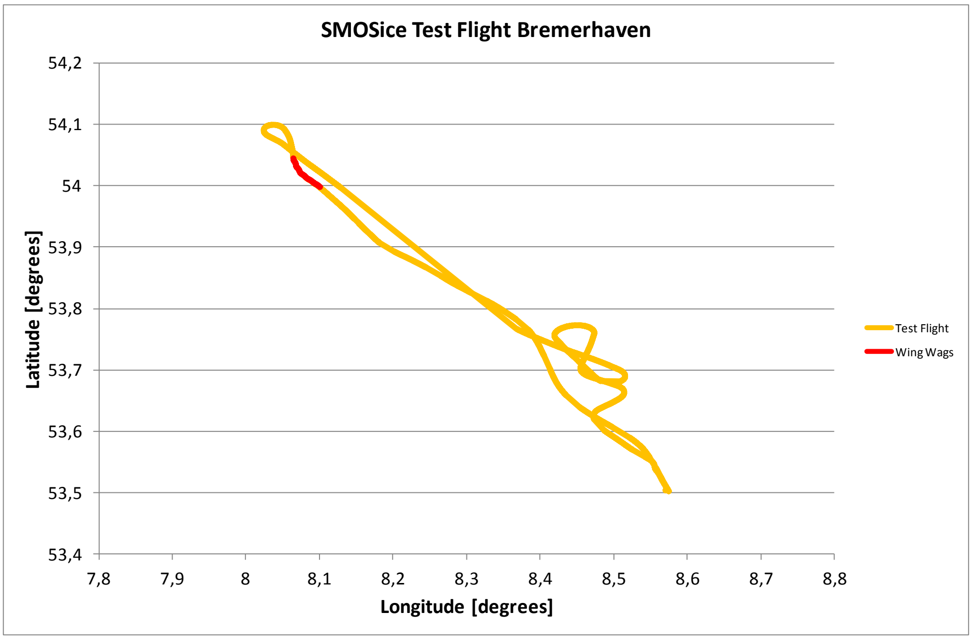


Figure 8: Flight track of the EMIRAD calibration and certification test flight in Bremerhaven, Geramyn on February 19, 2014

Table 3: Instrument calibration flight, Bremerhaven. Overview of EMIRAD-2 data

Date	Time (UTC)	Route	Special circumstances	Notes
20140219	15:25-15:53	BRV-Ocean	Transit	
20140219	15:55-15-59	Ocean nose and wing wags	Instrument validation manoeuvres	
20140219	16:00-16:38	Ocean-BRV	Transit, including other on-board instruments	

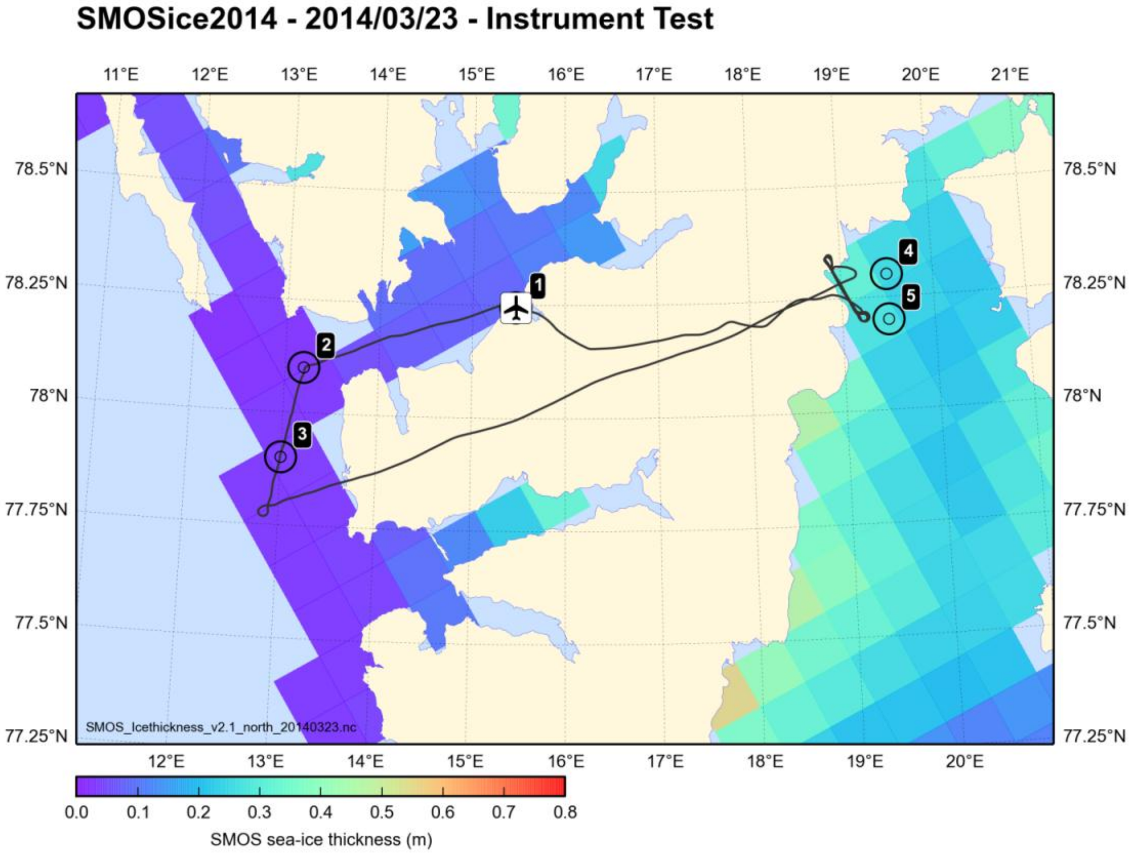


Figure 9: Overview of flight 20140323_01 (flight track and waypoints). Map background color shows SMOS sea-ice thickness product from University of Hamburg.

Flight 2010323_01

Purpose of the flight was a full instrument verification and calibration at the beginning of the field campaign. Main part of the flight were the calibration of EMIRAD-2 over open ocean between waypoints 2 and 3 and a performance test of the snow radar over deeper snow over the fast ice zone in Storfjorden between waypoints 4 and 5 (Figure 9).

Events

Time	Position	Event
2014-03-23 12:32:50.472	Lat= 78° 14,755' N Lon= 15° 30,128' E	taxi
2014-03-23 12:34:09.695	Lat= 78° 14,663' N Lon= 15° 29,811' E	Start
2014-03-23 12:34:30.757	Lat= 78° 14,735' N Lon= 15° 28,532' E	Takeoff
2014-03-23 12:34:37.992	Lat= 78° 14,781' N Lon= 15° 27,712' E	Deicing on
2014-03-23 12:37:21.404	Lat= 78° 13,809' N Lon= 15° 2,730' E	Rollerdoors open
2014-03-23 13:28:18.392	Lat= 78° 18,239' N Lon= 18° 55,908' E	Camera start
2014-03-23 13:52:22.621	Lat= 78° 14,151' N Lon= 19° 8,319' E	Camera stop
2014-03-23 14:06:23.095	Lat= 78° 9,820' N Lon= 16° 47,448' E	Rollerdoors closed
2014-03-23 14:19:04.845	Lat= 78° 14,756' N Lon= 15° 30,108' E	Park Position

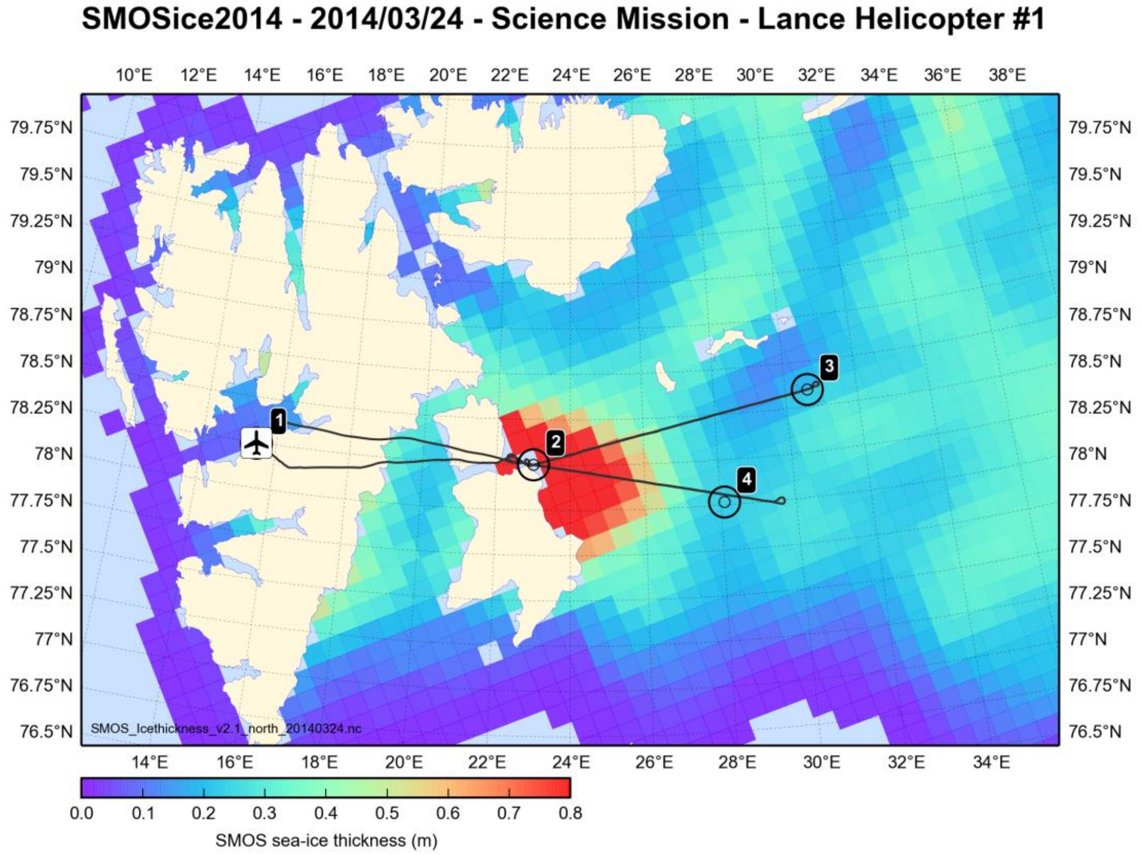


Figure 10: Overview of flight *20140324_01* (flight track and waypoints). Map background color shows SMOS sea-ice thickness product from University of Hamburg.

Flight 20140324_01

The survey on March 24, 2014 was the first science mission with coincident Polar-5 and helicopter surveys. The waypoints were chosen based on the SMOS sea-ice thickness product of the University of Hamburg, with two transects along the steepest gradients of SMOS sea-ice thickness. The Polar-5 track followed the waypoints (1 - 2 - 4 (Lance) - 2 - 3 - 2 - 1). After Polar-5 passed R/V Lance, the helicopter followed, leading to coincident data acquisition on leg 4- 2 and parts of leg 2- 3.

Events

Time	Position	Event
2014-03-24 09:20:23.913	Lat= 78° 14,757' N Lon= 15° 30,112' E	taxi
2014-03-24 09:25:14.165	Lat= 78° 14,766' N Lon= 15° 27,964' E	Takeoff
2014-03-24 09:25:21.946	Lat= 78° 14,820' N Lon= 15° 27,010' E	Deicing on
2014-03-24 09:29:31.702	Lat= 78° 20,598' N Lon= 15° 47,545' E	Rollerdoors open
2014-03-24 09:29:37.338	Lat= 78° 20,703' N Lon= 15° 48,559' E	KT19 on
2014-03-24 09:56:36.031	Lat= 78° 16,864' N Lon= 22° 4,901' E	Camera start
2014-03-24 12:53:08.291	Lat= 78° 17,266' N Lon= 22° 31,788' E	Camera stop
2014-03-24 12:59:00.119	Lat= 78° 15,146' N Lon= 21° 28,083' E	Rollerdoors closed
2014-03-24 13:32:21.523	Lat= 78° 14,645' N Lon= 15° 30,134' E	Touchdown
2014-03-24 13:32:35.788	Lat= 78° 14,709' N Lon= 15° 29,010' E	Deicing off
2014-03-24 13:36:02.185	Lat= 78° 14,755' N Lon= 15° 30,132' E	Park Position

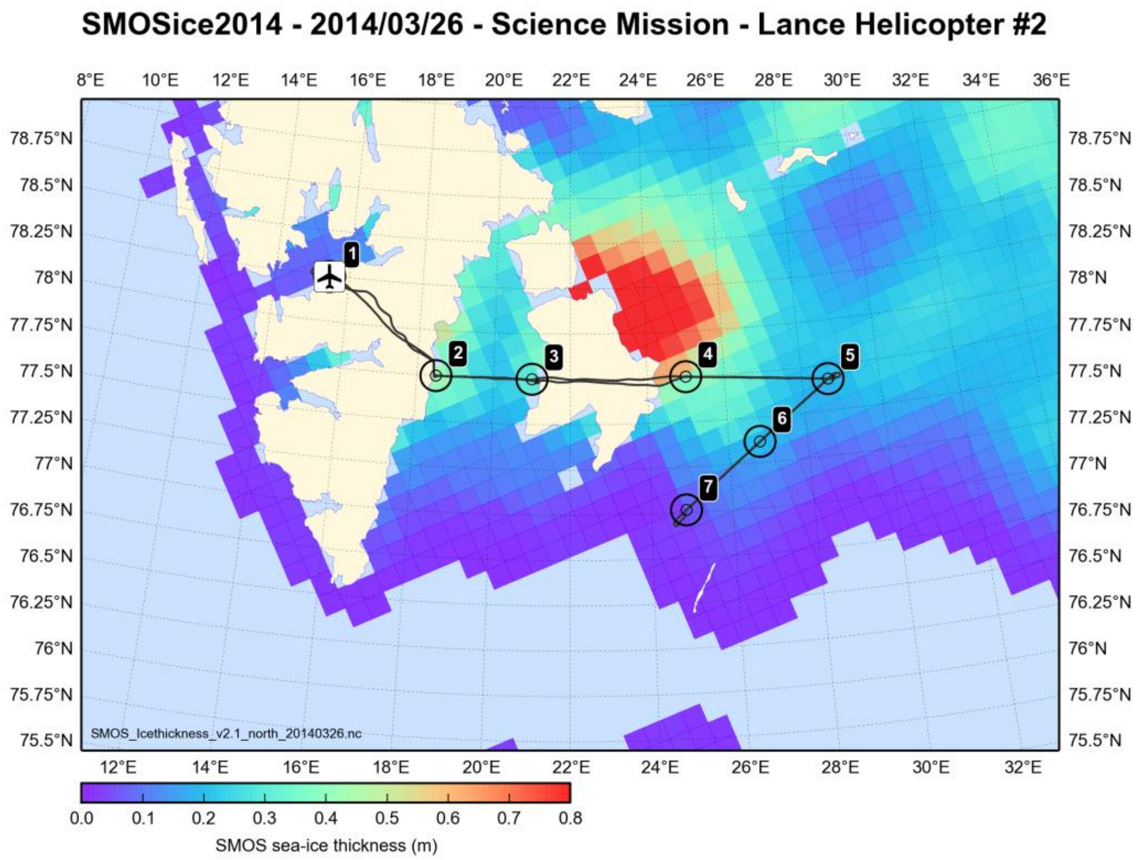


Figure 11:Overview of flight *20140326_01* (flight track and waypoints). Map background color shows SMOS sea-ice thickness product from University of Hamburg.

Flight 20140326_01

The survey on March 26, 2014 was the second joint Polar-5 Helicopter survey, following a similar approach then the first coincident flight. Survey areas were a zonal section of sea ice in Storfjorden at 77.75°N (WP 2 – 3) and a sea ice survey further south compared to the flight from March 24. Polar-5 met R/V Lance near WP 6 and the helicopter followed Polar-5 after the second flyby of Lance on the northbound leg of Polar-5 (WP 7 – 5). At the end of this flight calibration procedures were conducted for the laser scanner and snow radar over the runway and buildings of the airport of Longyearbyen.

Events

Time	Position	Event
2014-03-26 08:51:34.056	Lat= 78° 14,750' N Lon= 15° 29,899' E	taxi
2014-03-26 08:57:42.599	Lat= 78° 14,922' N Lon= 15° 25,181' E	Start
2014-03-26 08:57:56.581	Lat= 78° 14,902' N Lon= 15° 25,537' E	Deicing on
2014-03-26 08:58:12.597	Lat= 78° 14,830' N Lon= 15° 26,836' E	Takeoff
2014-03-26 09:19:51.166	Lat= 77° 46,668' N Lon= 18° 26,398' E	snowradar on
2014-03-26 09:21:22.097	Lat= 77° 44,993' N Lon= 18° 34,402' E	Camera start
2014-03-26 09:35:51.614	Lat= 77° 44,552' N Lon= 20° 57,898' E	snowradar & scanner off
2014-03-26 09:52:44.807	Lat= 77° 42,411' N Lon= 24° 14,481' E	snowradar & scanner on
2014-03-26 09:57:19.854	Lat= 77° 45,076' N Lon= 24° 59,889' E	WP4
2014-03-26 10:18:03.905	Lat= 77° 40,288' N Lon= 28° 43,930' E	WP5

2014-03-26 10:18:10.374	Lat= 77° 40,252' N Lon= 28° 44,971' E	Laserscanner ^ snowradar off
2014-03-26 10:21:27.993	Lat= 77° 38,878' N Lon= 28° 30,173' E	Laserscanner start
2014-03-26 10:34:27.397	Lat= 77° 20,415' N Lon= 26° 38,301' E	WP6
2014-03-26 10:47:14.890	Lat= 77° 0,778' N Lon= 24° 50,672' E	WP7
2014-03-26 10:48:14.153	Lat= 76° 58,577' N Lon= 24° 47,909' E	Laserscanner off
2014-03-26 10:51:31.538	Lat= 76° 58,317' N Lon= 24° 37,370' E	Laserscanner SNOWRADAR ON
2014-03-26 10:53:23.118	Lat= 77° 0,960' N Lon= 24° 51,339' E	WP7
2014-03-26 11:21:29.606	Lat= 77° 40,698' N Lon= 28° 41,561' E	WP5
2014-03-26 11:21:43.918	Lat= 77° 41,033' N Lon= 28° 43,614' E	snowradar & Laserscanner off
2014-03-26 11:24:17.303	Lat= 77° 40,567' N Lon= 28° 52,281' E	Laserscanner on
2014-03-26 11:45:20.242	Lat= 77° 44,966' N Lon= 24° 58,887' E	WP4
2014-03-26 12:08:02.710	Lat= 77° 44,953' N Lon= 20° 52,089' E	Scanner on
2014-03-26 12:20:46.916	Lat= 77° 45,021' N Lon= 18° 32,823' E	WP2
2014-03-26 12:20:59.242	Lat= 77° 45,044' N Lon= 18° 30,467' E	Scanner off
2014-03-26 12:38:48.399	Lat= 78° 14,078' N Lon= 15° 40,216' E	Scanner & snowradar on
2014-03-26 12:39:36.962	Lat= 78° 14,584' N Lon= 15° 31,280' E	runway start
2014-03-26 12:39:55.040	Lat= 78° 14,746' N Lon= 15° 28,275' E	runway stop
2014-03-26 12:40:19.351	Lat= 78° 14,979' N Lon= 15° 23,992' E	snowradar off
2014-03-26 12:50:47.327	Lat= 78° 17,959' N Lon= 15° 18,751' E	Rollerdoors closed
2014-03-26 12:57:33.454	Lat= 78° 14,741' N Lon= 15° 28,407' E	Touchdown
2014-03-26 12:57:43.345	Lat= 78° 14,713' N Lon= 15° 28,908' E	Deicing off
2014-03-26 12:59:56.059	Lat= 78° 14,753' N Lon= 15° 30,114' E	Park Position

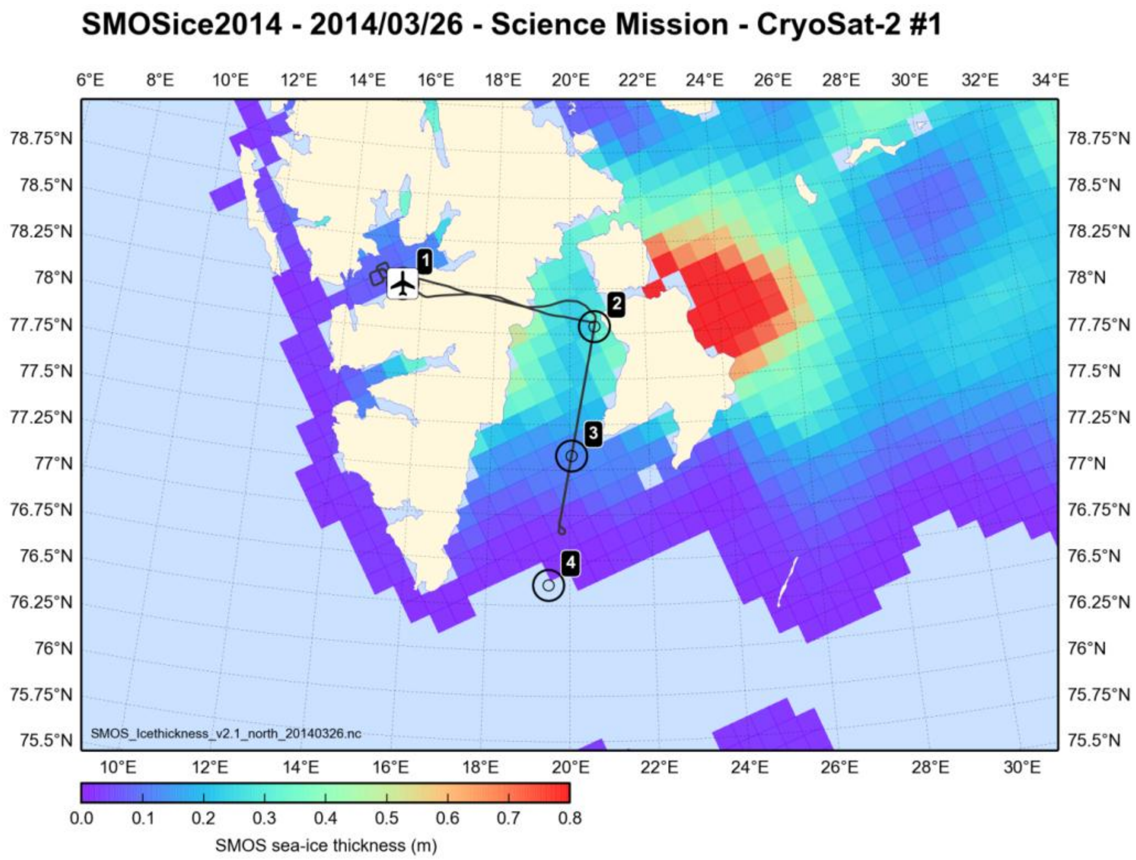


Figure 12: Overview of flight *20140326_01* (flight track and waypoints). Map background color shows SMOS sea-ice thickness product from University of Hamburg.

Flight 20140326_02

The second survey flight on March 26, 2014 was an opportunity mission with the goal of a CryoSat-2 underflight (Orbit-Nr. 21016). Data acquisition took place on the CryoSat-2 ground track between WP 2 and 4. WP 4 was already in open water and therefore the line ground track was not completed until WP 4.The clear-sky conditions in the beginning of the flight were used for calibration procedures of the radiation sensors (Radiation Box).

Events

Time	Position	Event
2014-03-26 14:29:42.964	Lat= 78° 14,753' N Lon= 15° 30,113' E	taxi
2014-03-26 14:35:04.739	Lat= 78° 14,810' N Lon= 15° 27,182' E	Takeoff
2014-03-26 14:35:16.583	Lat= 78° 14,727' N Lon= 15° 28,658' E	Deicing on
2014-03-26 14:40:03.181	Lat= 78° 17,704' N Lon= 15° 11,873' E	Radiation Box start leg 1
2014-03-26 14:41:14.959	Lat= 78° 16,203' N Lon= 14° 59,964' E	Radiation Box start leg 2
2014-03-26 14:41:58.302	Lat= 78° 16,494' N Lon= 14° 52,607' E	Radiation Box start leg 3
2014-03-26 14:43:01.815	Lat= 78° 18,419' N Lon= 14° 45,676' E	Radiation Box start leg 4
2014-03-26 14:43:48.064	Lat= 78° 19,829' N Lon= 14° 45,612' E	Radiation Box start leg 5
2014-03-26 14:44:54.921	Lat= 78° 20,977' N Lon= 14° 54,826' E	Radiation Box start leg 6
2014-03-26 14:45:28.780	Lat= 78° 20,750' N Lon= 14° 59,659' E	Radiation Box start leg 7
2014-03-26 14:46:35.789	Lat= 78° 18,633' N Lon= 15° 4,808' E	Radiation Box start leg 8
2014-03-26 14:48:46.394	Lat= 78° 18,818' N Lon= 14° 51,022' E	Radiation Box start leg 9

2014-03-26 14:49:51.642	Lat= 78° 17,638' N Lon= 14° 38,286' E	Radiation Box start leg 10
2014-03-26 14:50:32.578	Lat= 78° 16,342' N Lon= 14° 33,813' E	Radiation Box start leg 11
2014-03-26 14:51:43.966	Lat= 78° 13,932' N Lon= 14° 38,510' E	Radiation Box start leg 12
2014-03-26 14:52:27.903	Lat= 78° 13,452' N Lon= 14° 44,126' E	Radiation Box start leg 13
2014-03-26 14:53:34.053	Lat= 78° 14,522' N Lon= 14° 53,546' E	Radiation Box start leg 14
2014-03-26 14:55:13.288	Lat= 78° 17,584' N Lon= 14° 49,186' E	Radiation Box start leg 15
2014-03-26 15:26:21.668	Lat= 78° 4,642' N Lon= 20° 40,707' E	scanner and snow thickness on
2014-03-26 15:54:45.325	Lat= 76° 58,221' N Lon= 19° 44,927' E	END of leg 200ft
2014-03-26 16:27:28.015	Lat= 78° 2,553' N Lon= 20° 39,066' E	END of leg 1000ft
2014-03-26 16:28:43.431	Lat= 78° 4,168' N Lon= 20° 30,612' E	Camera stop
2014-03-26 16:37:34.001	Lat= 78° 9,207' N Lon= 18° 44,336' E	KT19 off, LD90 off
2014-03-26 16:45:06.910	Lat= 78° 12,327' N Lon= 17° 4,614' E	Rollerdoors closed
2014-03-26 16:57:06.696	Lat= 78° 14,812' N Lon= 15° 27,166' E	Touchdown
2014-03-26 16:57:34.243	Lat= 78° 14,700' N Lon= 15° 29,131' E	Deicing off
2014-03-26 16:59:09.576	Lat= 78° 14,757' N Lon= 15° 30,118' E	Park Position

3.2 Helicopter Surveys

In total eight EM-bird helicopter flights were performed from R/V Lance during the IRO-2 cruise between 19 and 26 March 2014. Figure 11 shows an overview of the flight patterns including the dates and the table below lists some more details. Two of the flights, on 24th and 26th March, were done in conjunction with the Polar-5 overflights and are presented in more detail.

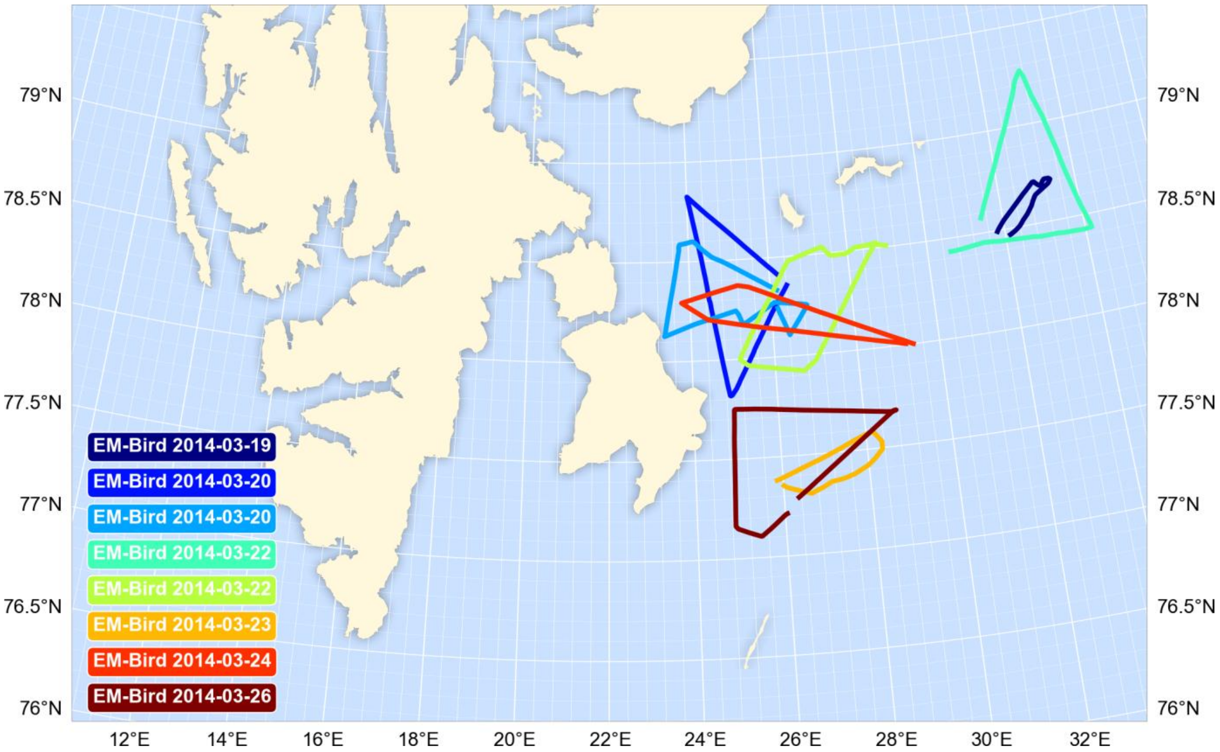


Figure 13: Location of EM-Bird surveys (flight tracks)

Table 1: List of EM-Bird flights during the IRO-2 cruise. Times are UTC.

Date	Start Time	Stop Time	Start lon/lat	Stop lon/lat	Comment
19/03/2014	14:50	15:42	31.90°/78.49°	31.75°/78.48°	
20/03/2014	08:52	11:03	26.40°/78.37°	26.45°/78.36°	CryoSat underflight
20/03/2014	14:23	16:28	26.28°/78.32°	26.16°/78.24°	CryoSat underflight
22/03/2014	08:32	10.52	31.13°/78.42°	30.55°/78.44°	
22/03/2014	13:51	15:55	29.14°/78.50°	28.69°/78.54°	
23/03/2014	12:45	13:56	25.73°/77.37°	26.03°/77.36°	
24/03/2014	10:39	13:16	29.32°/78.00°	29.37°/77.99°	With Polar-5
26/03/2014	11:06	13:17	26.30°/77.26°	26.05°/77.21°	With Polar-5

Flight 2014-03-24

The helicopter followed Polar-5 from R/V Lance in westward direction towards waypoint 2 (see Polar-5 surveys). Due to the distance the waypoint could not be reached but the helicopter diverged towards north and followed a part of the Polar-5 waypoint 2 to 3 transect. During the flight it was discovered that Flight Radio (123.5 MHz) caused massive interference for the EM-Bird. That led to degradation in quality and data loss of ice thickness data before about 11:05 UTC. Overall the flight was successful with extended ice thickness data acquisition.

The table below gives the flight notes taken during the 24/03/2014 survey.

Time (UTC)	CAL	Event
10:39:00		Start Engine
10:44:00		at 500'
	rec / cal / wait	extra rec & cal due to flight radio
10:48:32		at 130'
10:52:52		lead, mix, 50m
10:54:24		lead, mix, 200m, dir = 281 degrees
10:55:30	wait	at 500', delta = 5310 (unusually high)
10:57:17		at 130'
11:02:08		lead, frozen grey ice, 100m
11:04:35	wait	at 500' delta = 5367 (unusually high)
11:05:20	rec / cal / wait	delta = 5 post-calibration
11:07:00		at 130', dir 281degrees, -16c,
11:09:00		lead, frozen, 50m
11:10:29		lead, frozen, 1000m
11:13:13		lead, mix, 1500m
11:15:27		lead, frozen, 400m
11:17:13		lead, frozen, 50m
11:22:03	wait	at 500' - delta =323, flight radio TX -recal
11:24:00	rec / cal / wait	at 500'
11:26:08		at 130'
11:32:14		birds avoidance - up to 150' and down
11:41:00	wait	at 500', delta = 310
11:42:38		at 130'
11:46:13		lead, ow, 20m
11:48:52		high, alt = 150'
11:55:00		waypoint
11:55:40		at 400', delta = 550
	rec / cal / wait	
12:00:40		at 130'
12:01:50		GPS drop-out
12:02:20		at 500' - 2x restart due to SBC network error
12:06:11	rec / cal / wait	
12:08:00		at 130'
12:09:00		at 150' - bird avoidance, DIR = 75 degr
12:16:50		at 150' - pressure ridge
12:21:22		lead, frozen, 30m
12:23:00	wait	at 500', 50% fuel, delta = 181
	rec / cal / wait	
12:27:22		at 130', dir = 113degr, -18c
		no leads for 10 mins, snow 10-15cm
12:34:27		lead, frozen, 200m

12:37:40		lead, frozen grey ice, 300m
12:40:20		lead, mix, 700m
12:42:20	wait	at 500', delta = 166
12:43:58		at 130'
12:47:14		lead, frozen, 1000m
12:48:45		lead, mix, 800m
12:50:23		lead, mix 1000m
12:56:59		lead, mix, 100m
12:58:41		lead, frozen grey ice, 300m
12:59:08	wait	at 500' - delta = 320
	rec / cal / wait	
13:02:08		at 130'
13:02:47		lead, frozen, 300m - 30% fuel
13:12:17	wait	at 500' near Lance, delta = 78
13:16:00		landing
13:18:00		engine off

Flight 2014-03-26

The helicopter followed Polar-5 from R/V Lance (waypoint 6) in northeast direction towards waypoint 5 (see Polar-5 surveys). From there the helicopter followed Polar-5 for the largest part of the waypoint 5 to 4 transect. During the EM-Bird calibration at the end of the first record accidentally the flight radio was used again. That led to degradation in ice thickness data quality for the last part of that leg so this data had to be discarded. Overall the flight was successful with extended ice thickness data acquisition.
The table below gives the flight notes taken during the 26/03/2014 survey.

ID	Time (UTC)	CAL	Event
	11:00:00		Start Engine
	11:06:00		Life-off
	11:07:26	Rec / Cal / wait	at 500'
	11:09:24		Began measurements at 130', -12c
	11:12:42		Lead, frozen, 500m
	11:14:36		Lead, frozen, 350m
	11:16:30	wait	at 500'. delta = 113
	11:18:07		at 130'
	11:19:27		lead, mix (frozen and open water), 1000m
	11:25:39		lead, mix, 400m
	11:26:30		Rx VHF, no EMF disturbance visible
	11:27:26		Avoided birds - quick turns
	11:27:54		lead, OW, 400m
	11:29:18	wait/rec/cal	at 500', pilot used flight radio
	11:32:16		at 130', dir = 53, spd=72
	11:33:49		lead, ow, 350m
	11:35:28		lead, ow, 600m
	11:37:55		lead, ow, 200m
	11:40:02		lead, frozen, 400m, grey ice

11:41:25		lead, frozen, thin, 1000m+
11:42:20	wait	at 500', TX Lance VHF, delta = 127
11:44:45		at 130' - turn to waypoint 5
11:46:00		turn to waypoint 4
11:49:10		lead, ow, 30m
11:5x:xx		lead, grey ice, 1000m, time recorded wrong
11:59:12		lead, mix, 1500m
12:01:19	wait / rec / cal	at 500', delta = 324
12:04:21		at 130', DIR = 275 degrees
12:05:20		lead, ow, 30m
12:10:02		lead, mix, 2800m
12:12:19		lead, mix, 1600m
12:16:53		lead, ow, 50m
12:19:09	wait	at 500', TX VHF - delta = 120
12:21:17		at 130' , dir = 273, -13c
12:22:30		lead, frozen, 2500m, near Ryke Yse islands
12:26:21		Turn to waypoint 7, new dir = 182, spd 66kn
12:26:45		return to level flight at <130'
12:28:45		lead, frozen, grey ice, 3500m
12:35:23		lead, mix, 1400m, no snow
12:36:12	wait / rec/ cal	at 500', delta = 220
12:39:08		at 130'
12:46:30		lead, frozen, 1 cm snow, 800m
12:53:06	wait	at 500', delta = 77, TX VHF Lance
12:55:47		at 130', dir = 181, spd = 74kn
12:57:00		turn due to bad ice (swell, open ocean)
		new dir = 110 degrees
13:04:00		turn back on track
13:04:45		TX VHF Lance (at 110' ?)
13:07:44		lead, ow, 100m
13:08:00		ow, conc 5/10, pancakes
13:09:00		frozen pancakes, no snow, 3-4 km
13:11:00		thin ice, ow 2 km.
13:13:35	wait / rec off	at 500', delta = 147, near Lance
		power down bird
13:17:00		landing on deck
13:19:00		engine off

4 Data Calibration and Processing Status

This chapter gives an overview of calibration procedures of campaign data acquired by sensors onboard Polar-5 and the helicopter EM-Bird as well as potential future processing steps within the project.

4.1 EMIRAD

4.1.1 Calibration

The data set has been calibrated and corrected according to the procedure, illustrated in Figure 14.

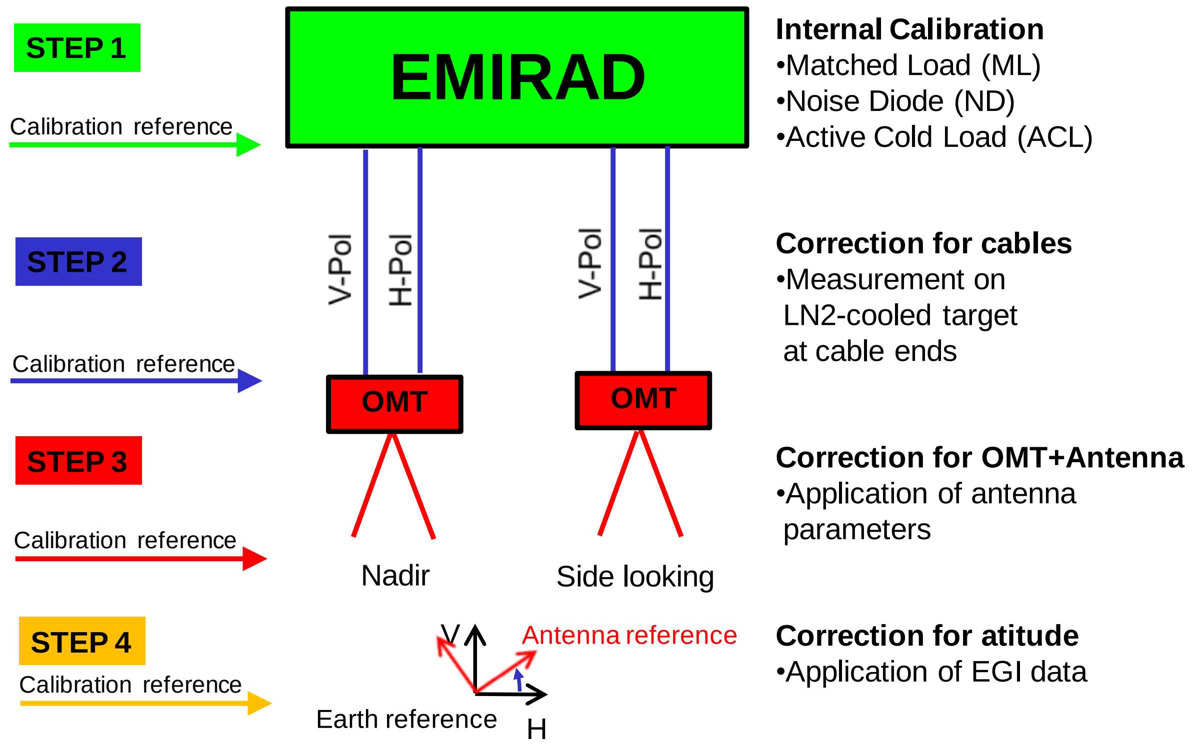


Figure 14: EMIRAD-2 processing procedure

The procedure includes the following steps:

1) Internal calibrations are used to characterise internal system gain and noise, including the effects of internal physical temperature variations.
2) LN2 measurements have been carried out during the campaign. These are used to characterise the losses in the antenna cables and validate the internal calibrations.
3) Laboratory measured (and field verified during Bremerhaven validation flight) characteristics of the EMIRAD-2 antennas and OMTs have been taken into account.

This is considered sufficient as these are robust passive components, which have remained installed in the aircraft from the validation flight until the campaign start. Measurements during nose and wing wags over ocean are used to validate the calibration, but any effect of actual installation on the antenna pattern has not been assessed.

4) The antenna frame rotation relative to Earth horizontal and vertical polarizations has been computed from EGI data, and the inverse rotation has been applied to the data in order to ensure polarization purity

4.1.2 Integration and RFI mitigation

Data have been integrated to 100 ms and 1 second integration times, which both provide oversampling with respect to antenna footprint size. Prior to temporal integration, the data set has been screened for RFI by evaluating kurtosis, polarimetric channels, and TB anomalies.

All data samples found to be affected by RFI have been removed from the data set. This, however, does not guarantee that the data samples still contained within the data set are indeed free from RFI.

A special RFI situation applies to the nadir looking horn, especially the horizontal channel. During the Svalbard validation flight, a 20 K offset relative to the nadir vertical channel and to modelled, expected brightness temperatures, was detected. RFI was suggested as a possible reason, but the source was not revealed until survey 3, where a camera was not switched on during the first open ocean sections of the flight, causing no offset to be present. When the camera was later turned on, the 20 K offset reappeared. The camera produces a continuous wave type of RFI, and hence it is not detectable through the kurtosis method, being rather insensitive to this kind of signals. The original polarimetric detection algorithm would discard around 95% of all data from the nadir horn, and hence the detection limits for the algorithm have been modified according to the magnitude of the offset for all data except survey 3. Still 10% - 30% of data samples are discarded, and during further data processing additional aspects will be investigated, e.g. the geographical distribution of RFI flagged data points. Finally, the nature of the 20 K offset will be further investigated in order to determine, if the offset may be considered stable enough to be removed through subtraction of a constant value.

4.2 Airborne Laser Scanner

The collected raw laser scanner data consists of the timestamp, range and shot angle of each laser shot. To create a digital elevation model, the geo-located elevations with respect to the WGS 84 reference ellipsoid have to be calculated. These elevations are obtained by subtracting the laser range from the aircraft GPS altitude, taking into account the

a) Location of the scanner and GPS antenna in the aircraft reference frame

b) Orientation of the scanner in the aircraft reference frame

c) Attitude of the aircraft recorded by the INS systems

d) Scan Angle of the individual laser shot

Except the orientation of the scanner in the aircraft reference frame, all factors are known or recorded during flight. To remove the bias on the elevations and geo-locations of each shot that is caused inaccurate scanner mounting angle in post-processing, a special calibration procedure was implemented during the campaign: A well-defined target, such as the airport buildings were overflown in different angles and altitude and the difference in the individual elevation models were minimized by iteratively improving the approximation of the mounting angle. This procedure was carried out over the airport in Longyearbyen at the end of the second flight on March 26, 2014.

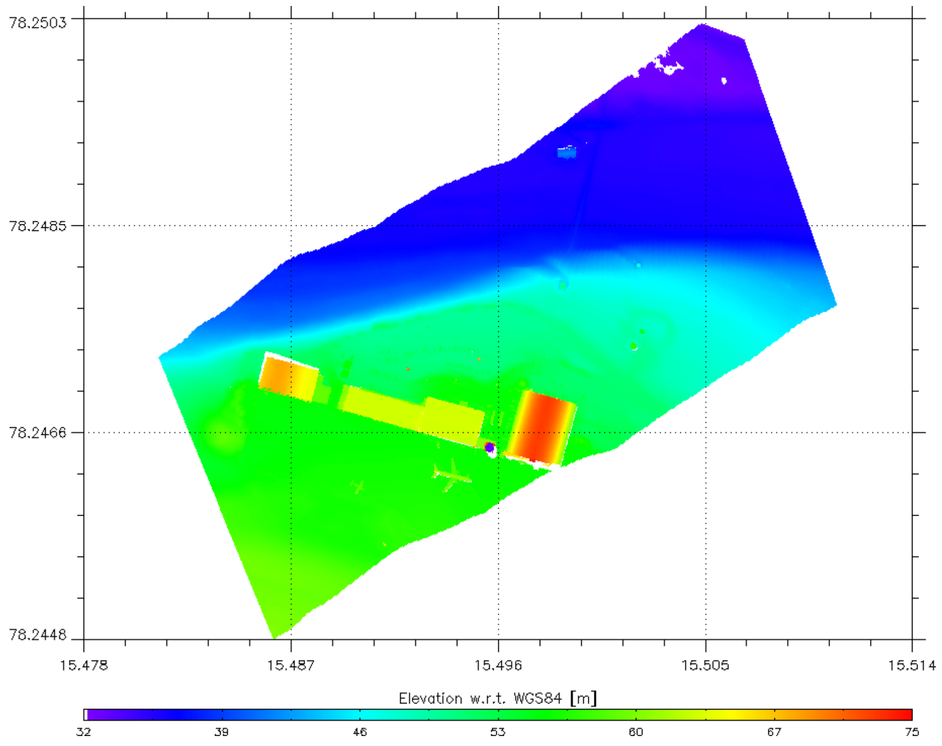


Figure 15: Digital Elevation Model obtained during a calibration cross-over at airport buildings in Longyearbyen

With the obtained mounting angles, the entire dataset is then reprocessed yielding ellipsoidal height for each laser shot. An example over sea ice is given in Figure 16.

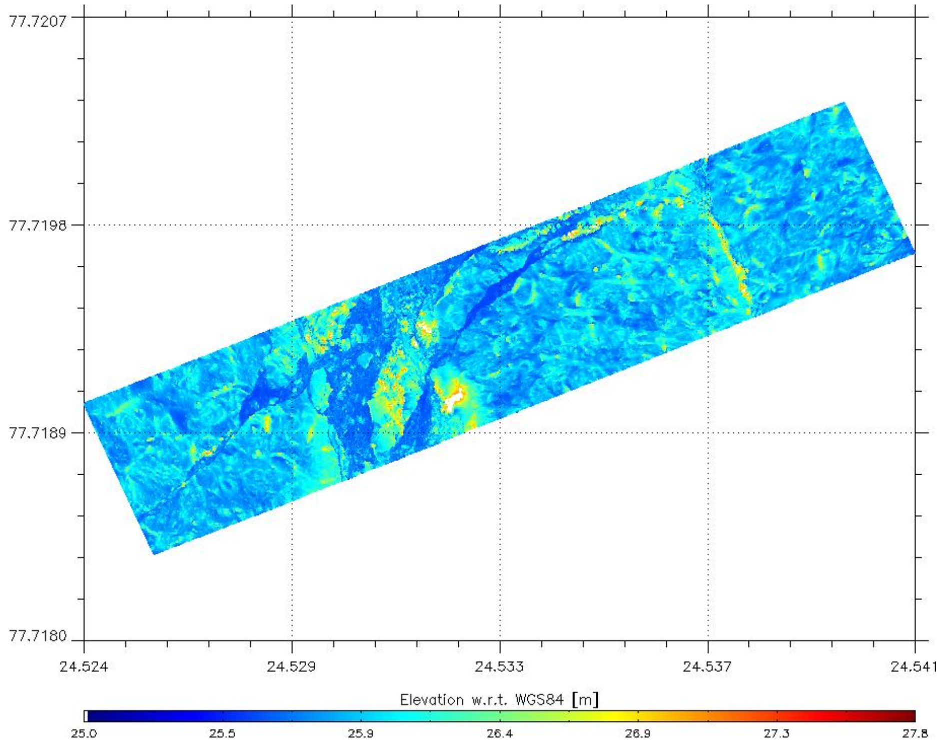


Figure 16 : Example of a digital elevation model over sea-ice

4.3 Snow Radar

The SMOSice 2014 field campaign was the first occasion where snow radar data of this particular radar system over snow on sea ice has been acquired. Though the technical functionality of the radar itself has been validated on numerous previous occasions, the analysis of retrieved radar echoes and their interaction with the snow layer does require substantial analysis work. A description of a geophysical product (snow depth) is therefore beyond the scope of this report and only a preliminary processing status with data characteristics is given here.

Figure 17 show a snapshot of snow radar data (10Hz telegram) of the controlling software during flight. Clear features in the radar two-way delay time is the main surface reflection between range bin 60 and 70. Clear signals not related to the return of the sea ice surface are can be seen

1. High signals at very small two-way delay times, probably associated with direct waves or general interference near the aircraft
2. A double reflection, most likely associated with radar – surface – wings – surface – radar travel path

Both signals are continuously observed during all flight, but can be safely discriminated from the geophysical surface returns.

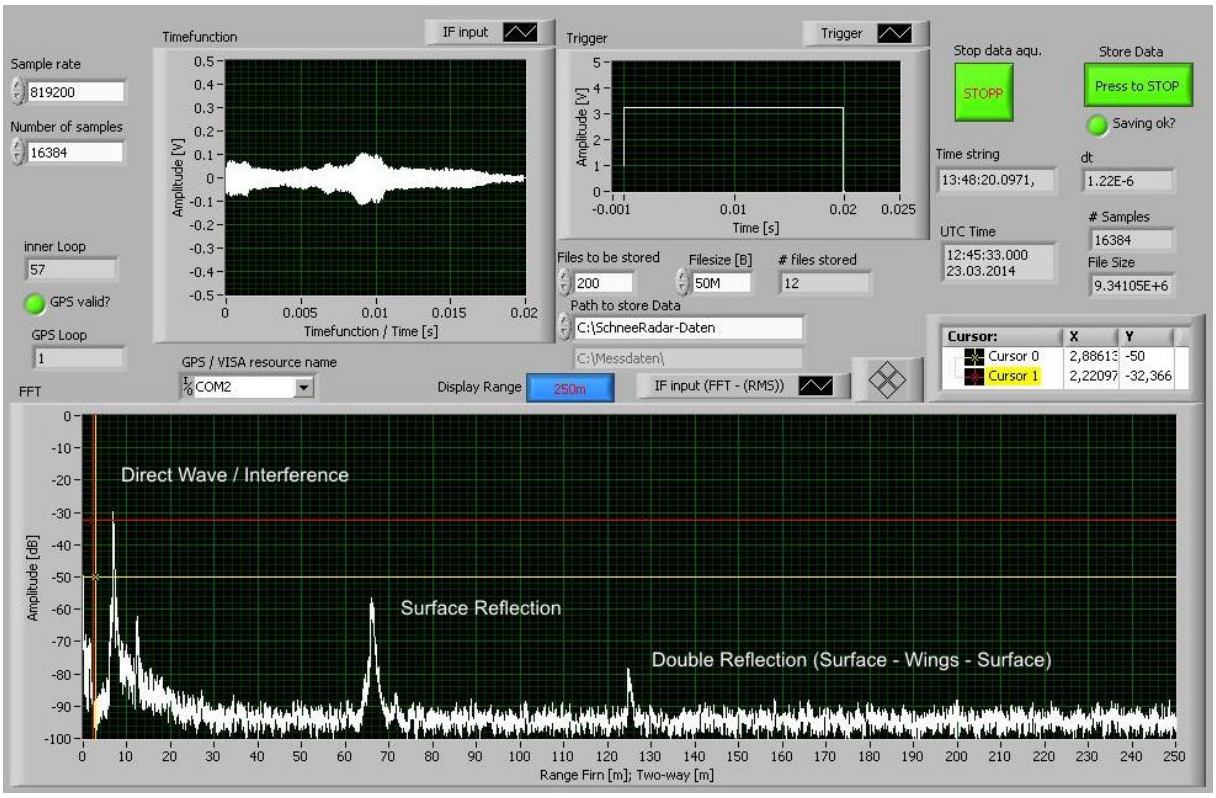


Figure 17: Screenshot of snow radar data on the inflight live telemetry control panel.

Another characteristic observed over open water is a saturation of the receiver signal waveforms and thus a scattering of signal noise throughout the entire radar range. This effect is visible in Figure 18 during intermittent periods of higher signal noise that has been observed while passing over leads. Though an unwanted feature of the radar data characteristics, which might be amended by hardware changes in the future, it can be used to constrain the location of leads for the laser scanner freeboard processing.

The translation of the radar range into snow depth requires a calibration of the radar data and a comparison with the freeboard from the laser scanner to obtain the dominant backscatter horizon for the 8-12 GHz radar data. The following steps will be undertaken until the end of the project:

1. Calibration of radar two-way bias by length of antenna cables and range offset to laser scanner by comparing radar and laser data over the runway of the airport Longyearbyen, Spitsbergen.
2. Data filtering and and geolocation of waveforms
3. Gridding of laser scanner data on to radar footprint
4. Comparison of radar and laser freeboard

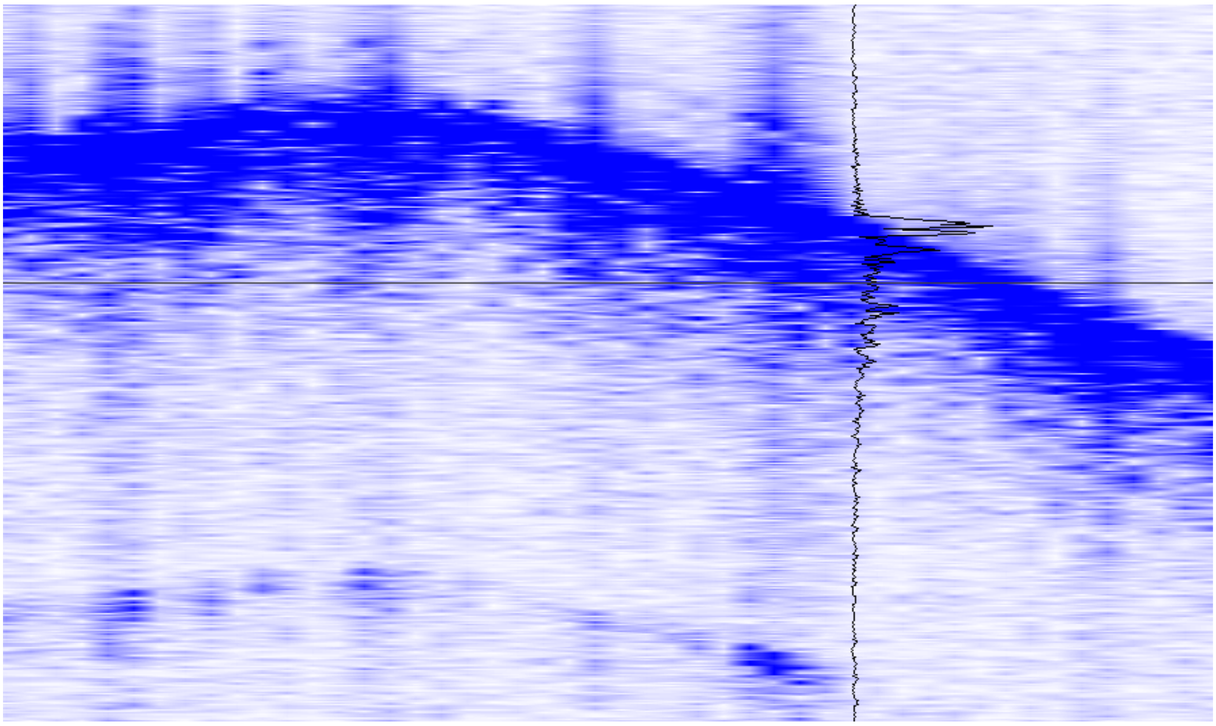


Figure 18 : Example of radar backscatter (color coded intensity) of several seconds of data with an example wave form (vertical black line). Repeated periods of higher intensity are specular reflections of saturated waveforms.

4.4 EM-Bird

The raw EM-Bird measurements are processed using scripts (IGOR Pro and C) mainly developed at AWI. The processing contains some manual steps to remove the instrument drift during the measurements and define the zero ice thickness level. To avoid bad data the processing routine automatically removes data outside minimum & maximum thresholds in laser height, and data that coincide with a change in heading (to avoid roll events on change of direction). Other small gaps in the data occur due to GPS dropout and to the laser on our EM-Bird failing over open water. The nominal sea ice thickness (snow plus ice thickness) uncertainty for a single measurement is 10 cm for level ice [Haas et al., 2009]. For ridges significant larger errors can occur. Averaged over the EMIRAD footprint size uncertainties of less than 10 cm can be assumed.

All EM-Bird data has been processed and sea ice thickness measurements with collocated GPS positions are available. Figure 15 shows an overview of EM-Bird ice thickness for all eight flights obtained during the IRO-2 cruise. Figure 16 shows the ice thickness histograms for the two EM-Bird flights coincident with the Polar-5 on 24th and 26th March 2014.

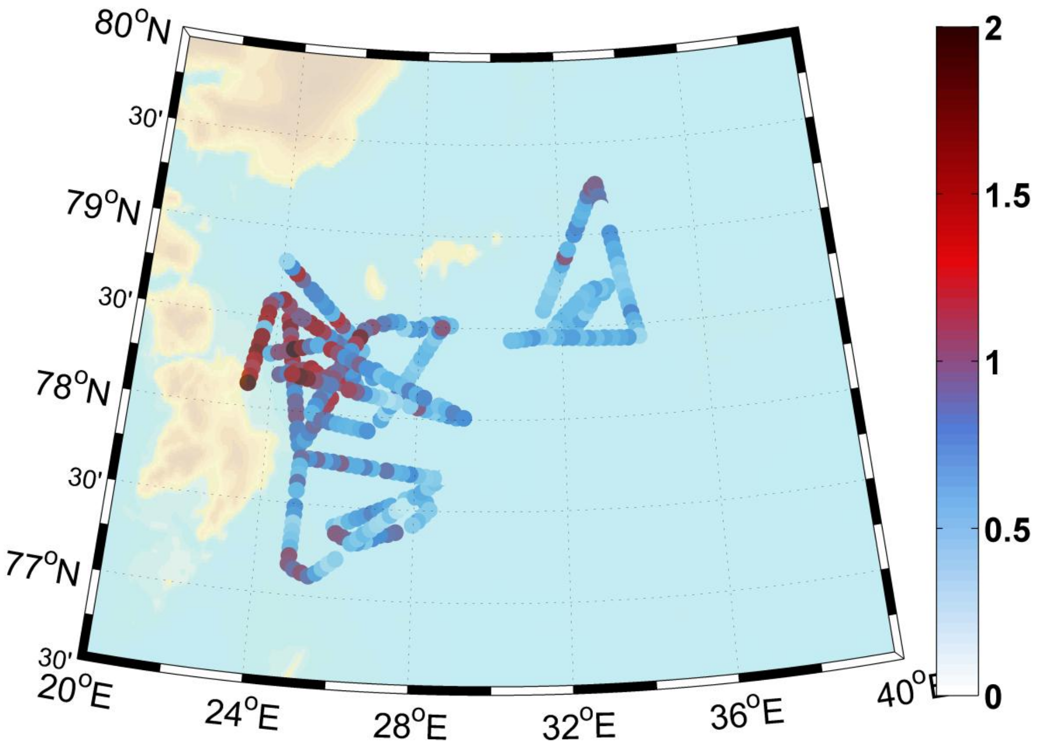


Figure 15: Overview of sea ice thickness obtained during eight EM-Bird flights. To identify the flights on 24th and 26th March coincident with the Polar-5 measurements please refer to Figure 11.

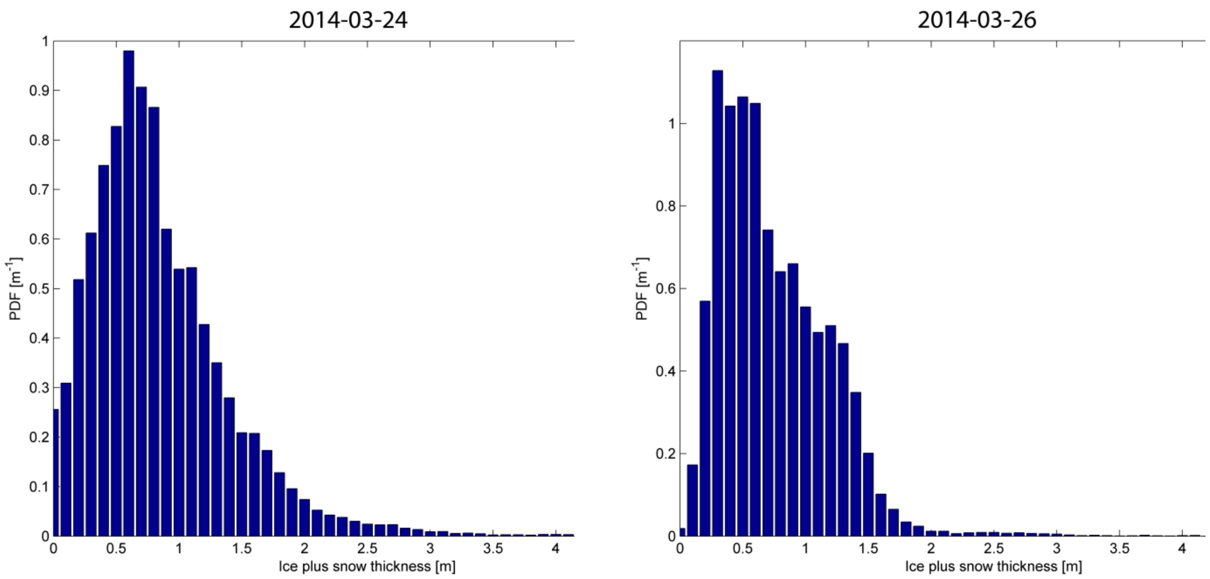


Figure 16: Sea ice thickness distributions (10 cm bins) for the two EM-Bird flights coincident with the Polar-5 measurements on 24th and 26th March 2014.

4.5 KT19

Polar-5 is equipped with a Heitronics radiation pyrometer of type KT19.85II. The digital output of the instrument is used as surface temperature, although measurements are performed under the assumption of a constant surface emissivity of 1.

4.6 Radiation Sensors

Raw data of the pyrgeometer and pyranometer are processed by applying calibrations of the sensitivity of the instruments. Calibrations are regularly performed at the Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center. To calculate longwave radiation flux densities, the body temperature of the pyrgeometers has to be taken into account additionally.

As the radiation sensors are mounted at the aircraft in a fixed position, shortwave irradiances are only calculated for clear-sky conditions. Data of the upward facing pyranometer, which receives direct solar radiation, is corrected for the misalignment of the instrument as well as the roll and pitch angles of the aircraft to derive downwelling hemispheric radiation flux densities for horizontal exposition of the sensor.

5 Technical Data Description

This section gives a technical description of the data files of the SMOSice 2014 campaign flight data.

5.1 EMIRAD

A list of the data files constituting the processed output of the EMIRAD-2 radiometer from the SMOSice Campaign March 2014 is given in the Appendix for each Survey (sections 8 through 11). There are separate files for the nadir and side looking antennas, separable by the file extensions. Both files contain both radiometer data and navigation data.

All data files are provided in four versions, representing 100 ms and 1 s integration times, and with/without correction for antenna frame rotation. Data file names are identical for the four cases, while folder names characterize the actual processing setup. Table 4 outlines the four combinations.

Table 4: SMOSice campaign EMIRAD-2 data processing versions

Folder name	Integration time	Correction for antenna frame rotation
Svalbard data - 1 s	1 s	Yes
Svalbard data - 100 ms	100 ms	Yes
Svalbard data - 1 s - no corrections	1 s	No
Svalbard data - 100 ms - no corrections	100 ms	No

In addition to the Polar-5 GPS and INS systems, EMIRAD-2 records its own navigational data. Table 5 gives an overview at which time EMIRAD-2 navigation data is available.

Table 5: Navigation data recorded from all flights.

Date	When (UTC)	Route	Special circumstances	Notes
20140323	12:27-12:46	LYR-Ocean		
20140323	12:48-12-53	Ocean nose and wing wags		
20140323	12:55-14:20	Ocean-LYR		
20140324	09:16-13:37	Survey 1		
20140326	08:46-13:01	Survey 2		
20140326	14:27-17:00	Survey 3		

5.1.1 Data format

Data is provided as ASCII files with 14 columns each. All data files follow the naming convention “`xxxhhmm0.zzz`” where

- `xxx` day of year
- `hh` Hour at start of measurement (UTC)
- `mm` Minute at start of measurement (UTC)
- `zzz` File type, which can be one of the following:
  - `e61` Calibrated data from nadir antenna
  - `e62` Calibrated data from side-looking antenna

The content of each column is given in Table 6.

Table 6: Contents of each column for file types e61 and e62.

Column	**Definition**
1	Measurement time, UTC [UNIX time] (http://en.wikipedia.org/wiki/Unix_time)
2	Vertical TB [Kelvin]
3	Horizontal TB [Kelvin]
4	3rd Stokes parameter [Kelvin]
5	4th Stokes parameter [Kelvin]
6	Aircraft position latitude [degrees]
7	Aircraft position longitude [degrees]
8	Aircraft altitude [m]
9	Aircraft roll [degrees, positive numbers correspond to right turn]
10	Aircraft pitch [degrees, positive numbers correspond to nose up]
11	Aircraft true heading, relative to Earth North [degrees, positive numbers = east, negative numbers = west]
12	Antenna incidence angle, antenna boresight in relation to nadir [degrees]
13	Antenna pointing angle, antenna boresight in relation to north [degrees, positive numbers = east, negative numbers = west]
14	Antenna rotation, antenna reference frame in relation to Earth reference frame [degrees]

5.2 Airborne Laser Scanner

The filename of the laser scanner data contains the start and stop time of the data file in UTC.

```
            Date         Start   Stop
ALS_L1B_YYYYMMDDTHHMMSS_HHMMSS
```

The laser scanner data is stored in big-endian binary format, containing a section for

a) File header
b) Time stamp of each scan line
c) Data containing for each line (× number of lines)
    a. Timestamp
    b. Latitude
    c. Longitude
    d. Elevation
    e. Amplitude
    f. Reflectance

The data is organized in scan lines and number of shots per scan line. The number of scan lines and data points per line is stored in the header.

Table 7: Description of ALS file header information

Field	Description	Unit	Size (Bytes)	Type
1	Header size	Byte	2	Byte
2	Nr of scan lines (Nsl)		4	Unsigned int32
3	Nr of shots per scan (Ns)		2	Unsigned int16
4	Bytes per scan line	Byte	2	Unsigned int16
5	Bytes timestamp information	Byte	8	Unsigned int64
6	Year (Start Time)		2	Unsigned int16
7	Month (Start Time)		1	Byte
8	Day (Start Time)		1	Byte
9	Start Time	Seconds of day	4	Unsigned int32
10	Stop Time	Seconds of day	5	Unsigned int32
11	Device Name (Scanner ID)		8	Char*8

The header is followed by the time stamp information of each side-ward scan line. This information is given as a convenience to select subsections of the data, without the need to read the entire data file first

Table 8: Description of ALS file timestamp information

Fields	Description	Unit	Size (Bytes)	Type
Nsl	Timestamp	Seconds of day	2 × Nsl	Unsigned int16

Last part of the ALS file is the data section. The data structure is stored for each scan and the scan records are repeated for the number of line scans.

Table 9: Description of ALS file data record (for each scan, repeated by number of scans)

Fields	Description	Unit	Size (Bytes)	Type
Ns	Timestamp	Seconds of day	8 × Ns	Float64
Ns	Latitude	Degree	8 × Ns	Float64
Ns	Longitude	Degree	8 × Ns	Float64
Ns	Elevation	Meter	8 × Ns	Float64
Ns	Amplitude		8 × Ns	Float64
Ns	Reflectance		8 × Ns	Float64

5.3 Snow Radar

The snow radar data raw data are given as ASCII files with one row for each shot. Time information for each shot is only given as the UTC time; the date of data acquisition is not registered in the files or in the filename. The date must therefore be obtained from the name of the folder that contains the snow radar raw files.

Several radar files exist per surveys, since the software generates a new data file if the old one reaches a file size limit of 50 Mb.

Column	Description	Unit
1	Timestamp	
2-16385	Amplitude (16384 samples per Shot)	db

Note: *Higher level data products (geolocated radar range) will be made available at the end of the project*.

5.4 KT19

The KT19 data is delivered in standard netCDF (Version 4) binary data format. The data files are self-descriptive and can be read with netCDF libraries available for all major programming languages and software tools.

More information: http://www.unidata.ucar.edu/software/netcdf/

The KT19 netcdf files contain the following datasets:

Timestamp	Seconds since Jan 01, 1970 00:00 UTC
Surface Temperature	Degree Celsius

5.5 Radiometer

The radiometer data is delivered in standard netCDF (Version 4) binary data format. The data files are self-descriptive and can be read with netCDF libraries available for all major programming languages and software tools.

More information: http://www.unidata.ucar.edu/software/netcdf/

The radiometer netcdf files contain the following datasets:

Timestamp	Seconds since Jan 01, 1970 00:00 UTC
Downwelling Radiation	W/m^2
Upwelling Radiation	W/m^2
Downwelling Radiation 20 sec moving average	W/m^2
Upwelling Radiation 20 sec moving average	W/m^2

5.6 EM-Bird

The EM-Bird data is delivered in tabulator separated ASCII columnar files.

Table 10 : Description of EM-Bird data files

Column	**Description**	**Unit**
1	Year	
2	Month	
3	Day	
4	Second of the day	
5	Record number	
6	Latitude	Decimal degree
7	Longitude	Decimal degree
8	Distance	Meter
9	Total Thickness	Meter
10	Laser Range	Meter

6 Conclusion

The data acquisition was a success, with almost flawless data acquisition of all sensors mounted on the aircraft, helicopter and ship. Four successful science missions within one week is a good result for typical weather and flying condition in Arctic spring. The main objective was reached with the two coordinated aircraft and helicopter flights over a variety of different thin-sea ice conditions. The underflight of a CryoSat-2 track extends the available sea-ice thickness validation data for CryoSat-2 to the thin ice regime, which can be used to study the synergy of CryoSat-2 and SMOS sea-ice thickness data sets.

For EMIRAD, the only reservation concerns data from the nadir looking horn at horizontal polarization during the first two survey flights, as RFI may have degraded data quality. As the two nadir channels are almost redundant, and as the offset is rather stable, hence possibly allowing for RFI removal, the impact of the RFI contamination is considered very limited.

The data processing of the snow radar is an ongoing and final retrieval algorithms for snow depth might not be achieved within the period of this project. However, with the SMOSice campaign the development of such a system on an aircraft, which is also able additionally able to hold a laser scanner and an EM-Bird was initiated with the SMOSice 2014 campaign.

In summary, the campaign yielded an unique data sets for thin ice-thickness retrieval, mostly due to the combination of three different sensor platform. The collected data will be one baseline dataset for future studies of satellite-based thin-ice thickness retrievals with L-Band radiometry.

7 References

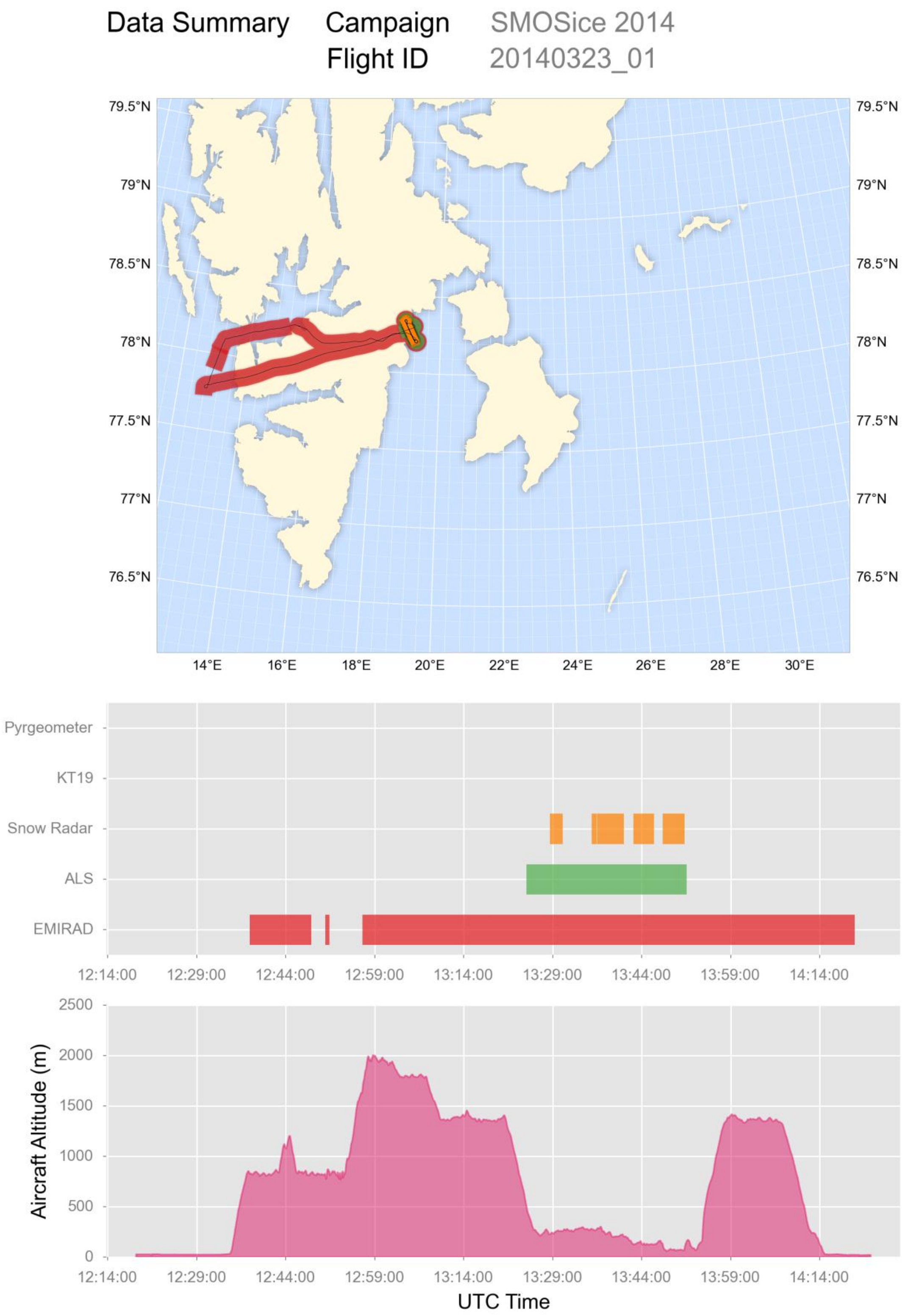
Haas, C., J. Lobach, S. Hendricks, L. Rabenstein and A. Pfaffling (2009): “Helicopter-borne measurements of sea ice thickness, using a small and lightweight, digital EM system”, Journal of Applied Geophysics, 67(3), 234-241, doi:10.1016/j.jappgeo.2008.05.005.

Skou, N., S. S. Søbjærg, J. Balling, and S. S. Kristensen: "A Second Generation L-band Digital Radiometer for Sea Salinity Campaigns", Proceedings of IGARSS'06, 4p., July 2006.

Skou, N., S. S. Søbjærg, J. Balling, S. S. Kristensen, and A. Kusk: "EMIRAD-2 and its use in the SMOS Cal/Val Campaign“, DTU Space, AR 502, pp. 1-59, June 2010.

Appendix

8 Flight Summary 20140323_01



EMIRAD Files

Filename	Start Time	Stop Time	Comment
08212260.e61	2014-03-23 12:37:55	2014-03-23 12:48:15	LYR-Ocean (Nadir)
08212260.e62	2014-03-23 12:37:55	2014-03-23 12:48:15	LYR-Ocean (Side)
08212480.e61	2014-03-23 12:50:38	2014-03-23 12:51:20	Ocean nose and wing wags (Nadir)
08212480.e62	2014-03-23 12:50:38	2014-03-23 12:51:20	Ocean nose and wing wags (Side)
08212550.e61	2014-03-23 12:56:54	2014-03-23 14:19:55	Ocean-LYR (Nadir)
08212550.e62	2014-03-23 12:56:54	2014-03-23 14:19:55	Ocean-LYR (Side)

ALS Files

Filename	Start Time	Stop Time	Comment
ALS_L1B_20140323T132435_135136	2014-03-23 13:24:35	2014-03-23 13:51:36	

Snow Radar Files

Filename	Start Time	Stop Time	Comment
SNOW124533.dat	2014-03-23 13:28:31	2014-03-23 13:29:31	
SNOW132932.dat	2014-03-23 13:29:32	2014-03-23 13:30:32	
SNOW133032.dat	2014-03-23 13:30:32	2014-03-23 13:30:40	
SNOW133534.dat	2014-03-23 13:35:34	2014-03-23 13:36:26	
SNOW133626.dat	2014-03-23 13:36:26	2014-03-23 13:37:55	
SNOW133755.dat	2014-03-23 13:37:55	2014-03-23 13:38:56	
SNOW133856.dat	2014-03-23 13:38:56	2014-03-23 13:39:56	
SNOW133957.dat	2014-03-23 13:39:57	2014-03-23 13:40:57	
SNOW134057.dat	2014-03-23 13:40:57	2014-03-23 13:40:59	
SNOW134237.dat	2014-03-23 13:42:37	2014-03-23 13:43:36	
SNOW134336.dat	2014-03-23 13:43:36	2014-03-23 13:44:37	
SNOW134437.dat	2014-03-23 13:44:37	2014-03-23 13:45:37	
SNOW134538.dat	2014-03-23 13:45:38	2014-03-23 13:46:04	
SNOW134733.dat	2014-03-23 13:47:33	2014-03-23 13:48:08	
SNOW134808.dat	2014-03-23 13:48:08	2014-03-23 13:49:09	
SNOW134909.dat	2014-03-23 13:49:10	2014-03-23 13:50:10	
SNOW135010.dat	2014-03-23 13:50:10	2014-03-23 13:51:11	
SNOW135111.dat	2014-03-23 13:51:11	2014-03-23 13:51:12	

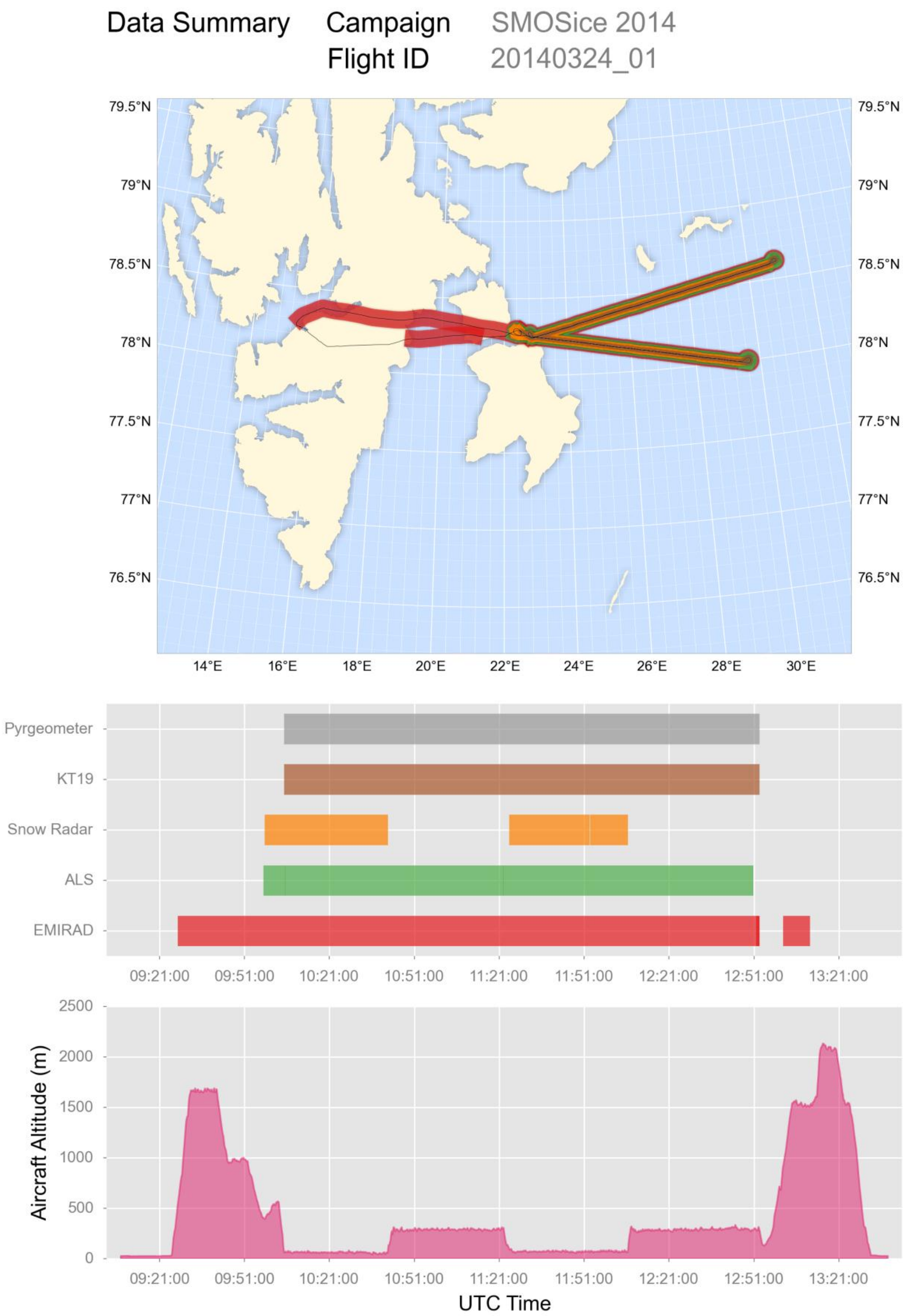
KT19 Files

none

Pyrgeometer Files

none

9 Flight Summary 20140324_01



EMIRAD Files

Filename	Start Time	Stop Time	Comment
08309150.e61	2014-03-24 09:27:28	2014-03-24 12:52:56	Primary data set (Nadir)
08309150.e62	2014-03-24 09:27:28	2014-03-24 12:52:56	Primary data set (Side)
08312510.e61	2014-03-24 12:51:46	2014-03-24 12:52:56	Wing wags over ice (Nadir)
08312510.e62	2014-03-24 12:51:46	2014-03-24 12:52:56	Wing wags over ice (Side)
08312590.e61	2014-03-24 13:01:14	2014-03-24 13:10:46	Transit (Nadir)
08312590.e62	2014-03-24 13:01:14	2014-03-24 13:10:46	Transit (Side)

ALS Files

Filename	Start Time	Stop Time	Comment
ALS_L1B_20140324T095739_100301	2014-03-24 09:57:39	2014-03-24 10:03:01	
ALS_L1B_20140324T100300_100523	2014-03-24 10:03:00	2014-03-24 10:05:23	
ALS_L1B_20140324T100521_104150	2014-03-24 10:05:21	2014-03-24 10:41:50	
ALS_L1B_20140324T104148_104429	2014-03-24 10:41:48	2014-03-24 10:44:29	
ALS_L1B_20140324T104428_112225	2014-03-24 10:44:28	2014-03-24 11:22:25	
ALS_L1B_20140324T112223_120647	2014-03-24 11:22:23	2014-03-24 12:06:47	
ALS_L1B_20140324T120645_120913	2014-03-24 12:06:45	2014-03-24 12:09:13	
ALS_L1B_20140324T120912_125047	2014-03-24 12:09:12	2014-03-24 12:50:47	Runway Calibration

Snow Radar Files

Filename	Start Time	Stop Time	Comment
SNOW092923.dat	2014-03-24 09:58:06	2014-03-24 09:59:07	
SNOW095907.dat	2014-03-24 09:59:07	2014-03-24 10:00:08	
SNOW100008.dat	2014-03-24 10:00:08	2014-03-24 10:01:08	
SNOW100108.dat	2014-03-24 10:01:08	2014-03-24 10:02:09	
SNOW100209.dat	2014-03-24 10:02:09	2014-03-24 10:03:09	
SNOW100309.dat	2014-03-24 10:03:09	2014-03-24 10:04:10	
SNOW100410.dat	2014-03-24 10:04:11	2014-03-24 10:05:11	
SNOW100511.dat	2014-03-24 10:05:12	2014-03-24 10:06:12	
SNOW100612.dat	2014-03-24 10:06:12	2014-03-24 10:07:13	
SNOW100713.dat	2014-03-24 10:07:13	2014-03-24 10:08:13	
SNOW100813.dat	2014-03-24 10:08:14	2014-03-24 10:09:14	
SNOW100914.dat	2014-03-24 10:09:15	2014-03-24 10:10:16	
SNOW101016.dat	2014-03-24 10:10:16	2014-03-24 10:11:16	
SNOW101116.dat	2014-03-24 10:11:17	2014-03-24 10:12:17	
SNOW101217.dat	2014-03-24 10:12:17	2014-03-24 10:13:18	
SNOW101318.dat	2014-03-24 10:13:18	2014-03-24 10:14:18	
SNOW101418.dat	2014-03-24 10:14:18	2014-03-24 10:15:19	
SNOW101519.dat	2014-03-24 10:15:19	2014-03-24 10:16:19	
SNOW101620.dat	2014-03-24 10:16:20	2014-03-24 10:17:20	
SNOW101720.dat	2014-03-24 10:17:20	2014-03-24 10:18:21	
SNOW101821.dat	2014-03-24 10:18:21	2014-03-24 10:19:24	
SNOW101925.dat	2014-03-24 10:19:25	2014-03-24 10:20:25	
SNOW102025.dat	2014-03-24 10:20:25	2014-03-24 10:21:26	
SNOW102126.dat	2014-03-24 10:21:26	2014-03-24 10:22:26	
SNOW102226.dat	2014-03-24 10:22:27	2014-03-24 10:23:27	
SNOW102327.dat	2014-03-24 10:23:27	2014-03-24 10:24:34	
SNOW102434.dat	2014-03-24 10:24:34	2014-03-24 10:25:35	
SNOW102535.dat	2014-03-24 10:25:35	2014-03-24 10:26:36	
SNOW102636.dat	2014-03-24 10:26:36	2014-03-24 10:27:36	
SNOW102736.dat	2014-03-24 10:27:36	2014-03-24 10:28:37	
SNOW102837.dat	2014-03-24 10:28:37	2014-03-24 10:29:38	
SNOW102938.dat	2014-03-24 10:29:38	2014-03-24 10:30:38	
SNOW103038.dat	2014-03-24 10:30:38	2014-03-24 10:31:40	
SNOW103140.dat	2014-03-24 10:31:40	2014-03-24 10:32:41	
SNOW103242.dat	2014-03-24 10:32:42	2014-03-24 10:33:42	
SNOW103342.dat	2014-03-24 10:33:42	2014-03-24 10:34:43	
SNOW103443.dat	2014-03-24 10:34:43	2014-03-24 10:35:44	
SNOW103544.dat	2014-03-24 10:35:44	2014-03-24 10:36:44	

SNOW103644.dat	2014-03-24 10:36:44	2014-03-24 10:37:45	
SNOW103745.dat	2014-03-24 10:37:45	2014-03-24 10:38:46	
SNOW103846.dat	2014-03-24 10:38:46	2014-03-24 10:39:48	
SNOW103948.dat	2014-03-24 10:39:48	2014-03-24 10:40:49	
SNOW104049.dat	2014-03-24 10:40:49	2014-03-24 10:41:38	
SNOW112435.dat	2014-03-24 11:24:30	2014-03-24 11:24:42	
SNOW112442.dat	2014-03-24 11:24:42	2014-03-24 11:25:43	
SNOW112543.dat	2014-03-24 11:25:43	2014-03-24 11:26:44	
SNOW112644.dat	2014-03-24 11:26:44	2014-03-24 11:27:45	
SNOW112745.dat	2014-03-24 11:27:45	2014-03-24 11:28:45	
SNOW112846.dat	2014-03-24 11:28:46	2014-03-24 11:29:46	
SNOW112947.dat	2014-03-24 11:29:47	2014-03-24 11:30:47	
SNOW113047.dat	2014-03-24 11:30:47	2014-03-24 11:31:48	
SNOW113148.dat	2014-03-24 11:31:48	2014-03-24 11:32:49	
SNOW113249.dat	2014-03-24 11:32:49	2014-03-24 11:33:50	
SNOW113350.dat	2014-03-24 11:33:50	2014-03-24 11:34:50	
SNOW113451.dat	2014-03-24 11:34:51	2014-03-24 11:35:52	
SNOW113552.dat	2014-03-24 11:35:52	2014-03-24 11:36:52	
SNOW113652.dat	2014-03-24 11:36:53	2014-03-24 11:37:53	
SNOW113753.dat	2014-03-24 11:37:53	2014-03-24 11:38:54	
SNOW113854.dat	2014-03-24 11:38:54	2014-03-24 11:39:55	
SNOW113955.dat	2014-03-24 11:39:55	2014-03-24 11:40:56	
SNOW114056.dat	2014-03-24 11:40:56	2014-03-24 11:41:56	
SNOW114157.dat	2014-03-24 11:41:57	2014-03-24 11:42:57	
SNOW114257.dat	2014-03-24 11:42:57	2014-03-24 11:43:58	
SNOW114358.dat	2014-03-24 11:43:58	2014-03-24 11:44:59	
SNOW114459.dat	2014-03-24 11:44:59	2014-03-24 11:46:00	
SNOW114600.dat	2014-03-24 11:46:00	2014-03-24 11:47:00	
SNOW114701.dat	2014-03-24 11:47:01	2014-03-24 11:48:01	
SNOW114801.dat	2014-03-24 11:48:01	2014-03-24 11:49:02	
SNOW114902.dat	2014-03-24 11:49:02	2014-03-24 11:50:03	
SNOW115003.dat	2014-03-24 11:50:03	2014-03-24 11:51:04	
SNOW115104.dat	2014-03-24 11:51:04	2014-03-24 11:52:04	
SNOW115204.dat	2014-03-24 11:52:05	2014-03-24 11:53:05	
SNOW115305.dat	2014-03-24 11:53:05	2014-03-24 11:54:06	
SNOW115406.dat	2014-03-24 11:54:06	2014-03-24 11:55:07	
SNOW115507.dat	2014-03-24 11:55:07	2014-03-24 11:56:08	
SNOW115608.dat	2014-03-24 11:56:08	2014-03-24 11:57:08	
SNOW115708.dat	2014-03-24 11:57:09	2014-03-24 11:58:09	
SNOW115809.dat	2014-03-24 11:58:09	2014-03-24 11:59:10	
SNOW115910.dat	2014-03-24 11:59:10	2014-03-24 12:00:11	
SNOW120011.dat	2014-03-24 12:00:11	2014-03-24 12:01:12	
SNOW120112.dat	2014-03-24 12:01:12	2014-03-24 12:02:12	
SNOW120212.dat	2014-03-24 12:02:13	2014-03-24 12:03:13	
SNOW120313.dat	2014-03-24 12:03:13	2014-03-24 12:04:14	
SNOW120414.dat	2014-03-24 12:04:14	2014-03-24 12:05:15	
SNOW120515.dat	2014-03-24 12:05:15	2014-03-24 12:06:16	
SNOW120616.dat	2014-03-24 12:06:16	2014-03-24 12:06:27	

KT19 Files

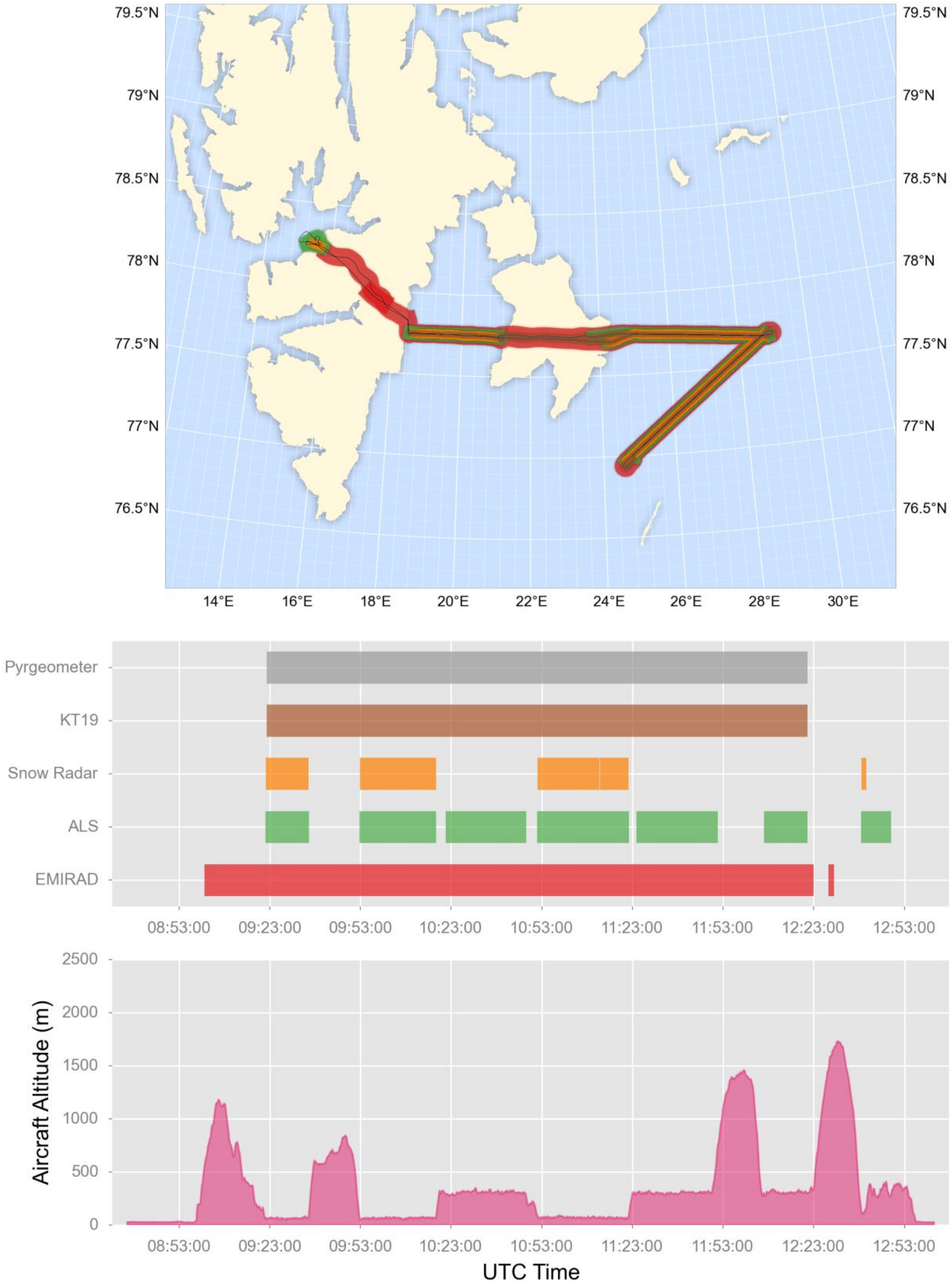
Filename	Start Time	Stop Time	Comment
2014032402_KT19.nc	2014-03-24 10:05:00	2014-03-24 12:52:59	

Pyrgeometer

Filename	Start Time	Stop Time	Comment
2014032402_pyrgeometer.nc	2014-03-24 10:05:00	2014-03-24 12:52:59	

10 Flight Summary 20140326_01

Data Summary	Campaign	SMOSice 2014
	Flight ID	20140326_01



EMIRAD Files

Filename	Start Time	Stop Time	Comment
08508460.e61	2014-03-26 09:01:24	2014-03-26 12:22:58	Primary data set (Nadir)
08508460.e62	2014-03-26 09:01:24	2014-03-26 12:22:58	Primary data set (Side)
08512260.e61	2014-03-26 12:27:49	2014-03-26 12:29:47	Transit (Nadir)
08512260.e62	2014-03-26 12:27:49	2014-03-26 12:29:47	Transit (Side)

ALS Files

Filename	Start Time	Stop Time	Comment
ALS_L1B_20140326T092131_093601	2014-03-26 09:21:31	2014-03-26 09:36:01	
ALS_L1B_20140326T095241_101806	2014-03-26 09:52:41	2014-03-26 10:18:06	
ALS_L1B_20140326T102117_104749	2014-03-26 10:21:17	2014-03-26 10:47:49	
ALS_L1B_20140326T105129_112151	2014-03-26 10:51:29	2014-03-26 11:21:51	
ALS_L1B_20140326T112415_115116	2014-03-26 11:24:15	2014-03-26 11:51:16	
ALS_L1B_20140326T120632_122057	2014-03-26 12:06:32	2014-03-26 12:20:57	
ALS_L1B_20140326T123840_124038	2014-03-26 12:38:40	2014-03-26 12:40:38	
ALS_L1B_20140326T124037_124207	2014-03-26 12:40:37	2014-03-26 12:42:07	
ALS_L1B_20140326T124205_124452	2014-03-26 12:42:05	2014-03-26 12:44:52	

Snow Radar Files

Filename	Start Time	Stop Time	Comment
SNOW084306.dat	2014-03-26 09:21:40	2014-03-26 09:22:40	
SNOW092240.dat	2014-03-26 09:22:40	2014-03-26 09:23:41	
SNOW092341.dat	2014-03-26 09:23:41	2014-03-26 09:24:41	
SNOW092441.dat	2014-03-26 09:24:41	2014-03-26 09:25:42	
SNOW092542.dat	2014-03-26 09:25:42	2014-03-26 09:26:42	
SNOW092642.dat	2014-03-26 09:26:42	2014-03-26 09:27:43	
SNOW092743.dat	2014-03-26 09:27:43	2014-03-26 09:28:43	
SNOW092844.dat	2014-03-26 09:28:44	2014-03-26 09:29:44	
SNOW092944.dat	2014-03-26 09:29:44	2014-03-26 09:30:45	
SNOW093045.dat	2014-03-26 09:30:45	2014-03-26 09:31:45	
SNOW093145.dat	2014-03-26 09:31:45	2014-03-26 09:32:46	
SNOW093246.dat	2014-03-26 09:32:46	2014-03-26 09:33:46	
SNOW093346.dat	2014-03-26 09:33:46	2014-03-26 09:34:47	
SNOW093447.dat	2014-03-26 09:34:47	2014-03-26 09:35:47	
SNOW093547.dat	2014-03-26 09:35:47	2014-03-26 09:35:51	
SNOW095249.dat	2014-03-26 09:52:49	2014-03-26 09:53:46	
SNOW095346.dat	2014-03-26 09:53:46	2014-03-26 09:54:47	
SNOW095447.dat	2014-03-26 09:54:47	2014-03-26 09:55:47	
SNOW095548.dat	2014-03-26 09:55:48	2014-03-26 09:56:48	
SNOW095648.dat	2014-03-26 09:56:48	2014-03-26 09:57:49	
SNOW095749.dat	2014-03-26 09:57:49	2014-03-26 09:58:50	
SNOW095850.dat	2014-03-26 09:58:50	2014-03-26 09:59:50	
SNOW095950.dat	2014-03-26 09:59:50	2014-03-26 10:00:51	
SNOW100051.dat	2014-03-26 10:00:51	2014-03-26 10:01:52	
SNOW100152.dat	2014-03-26 10:01:52	2014-03-26 10:02:52	
SNOW100252.dat	2014-03-26 10:02:52	2014-03-26 10:03:53	
SNOW100353.dat	2014-03-26 10:03:53	2014-03-26 10:04:54	
SNOW100454.dat	2014-03-26 10:04:54	2014-03-26 10:05:54	
SNOW100554.dat	2014-03-26 10:05:55	2014-03-26 10:06:55	
SNOW100655.dat	2014-03-26 10:06:55	2014-03-26 10:07:56	
SNOW100756.dat	2014-03-26 10:07:56	2014-03-26 10:08:57	
SNOW100857.dat	2014-03-26 10:08:57	2014-03-26 10:09:58	
SNOW100958.dat	2014-03-26 10:09:58	2014-03-26 10:10:58	
SNOW101058.dat	2014-03-26 10:10:59	2014-03-26 10:11:59	
SNOW101159.dat	2014-03-26 10:11:59	2014-03-26 10:13:00	
SNOW101300.dat	2014-03-26 10:13:00	2014-03-26 10:14:01	
SNOW101401.dat	2014-03-26 10:14:01	2014-03-26 10:15:01	
SNOW101501.dat	2014-03-26 10:15:01	2014-03-26 10:16:02	
SNOW101602.dat	2014-03-26 10:16:02	2014-03-26 10:17:03	

SNOW101703.dat	2014-03-26 10:17:03	2014-03-26 10:17:58	
SNOW105134.dat	2014-03-26 10:51:34	2014-03-26 10:51:52	
SNOW105152.dat	2014-03-26 10:51:52	2014-03-26 10:52:52	
SNOW105253.dat	2014-03-26 10:52:53	2014-03-26 10:53:53	
SNOW105353.dat	2014-03-26 10:53:53	2014-03-26 10:54:54	
SNOW105454.dat	2014-03-26 10:54:54	2014-03-26 10:55:55	
SNOW105555.dat	2014-03-26 10:55:55	2014-03-26 10:56:56	
SNOW105656.dat	2014-03-26 10:56:56	2014-03-26 10:57:57	
SNOW105757.dat	2014-03-26 10:57:57	2014-03-26 10:58:57	
SNOW105857.dat	2014-03-26 10:58:58	2014-03-26 10:59:58	
SNOW105958.dat	2014-03-26 10:59:58	2014-03-26 11:00:59	
SNOW110059.dat	2014-03-26 11:00:59	2014-03-26 11:02:00	
SNOW110200.dat	2014-03-26 11:02:00	2014-03-26 11:03:01	
SNOW110301.dat	2014-03-26 11:03:01	2014-03-26 11:04:01	
SNOW110402.dat	2014-03-26 11:04:02	2014-03-26 11:05:02	
SNOW110502.dat	2014-03-26 11:05:03	2014-03-26 11:06:03	
SNOW110603.dat	2014-03-26 11:06:03	2014-03-26 11:07:04	
SNOW110704.dat	2014-03-26 11:07:04	2014-03-26 11:08:05	
SNOW110805.dat	2014-03-26 11:08:05	2014-03-26 11:09:06	
SNOW110906.dat	2014-03-26 11:09:06	2014-03-26 11:10:06	
SNOW111007.dat	2014-03-26 11:10:07	2014-03-26 11:11:07	
SNOW111107.dat	2014-03-26 11:11:08	2014-03-26 11:12:08	
SNOW111208.dat	2014-03-26 11:12:08	2014-03-26 11:13:09	
SNOW111309.dat	2014-03-26 11:13:09	2014-03-26 11:14:10	
SNOW111410.dat	2014-03-26 11:14:10	2014-03-26 11:15:11	
SNOW111511.dat	2014-03-26 11:15:11	2014-03-26 11:16:11	
SNOW111612.dat	2014-03-26 11:16:12	2014-03-26 11:17:12	
SNOW111712.dat	2014-03-26 11:17:13	2014-03-26 11:18:13	
SNOW111813.dat	2014-03-26 11:18:13	2014-03-26 11:19:14	
SNOW111914.dat	2014-03-26 11:19:14	2014-03-26 11:20:15	
SNOW112015.dat	2014-03-26 11:20:15	2014-03-26 11:21:16	
SNOW112116.dat	2014-03-26 11:21:16	2014-03-26 11:21:40	
SNOW123848.dat	2014-03-26 12:38:48	2014-03-26 12:39:25	
SNOW123925.dat	2014-03-26 12:39:25	2014-03-26 12:40:19	

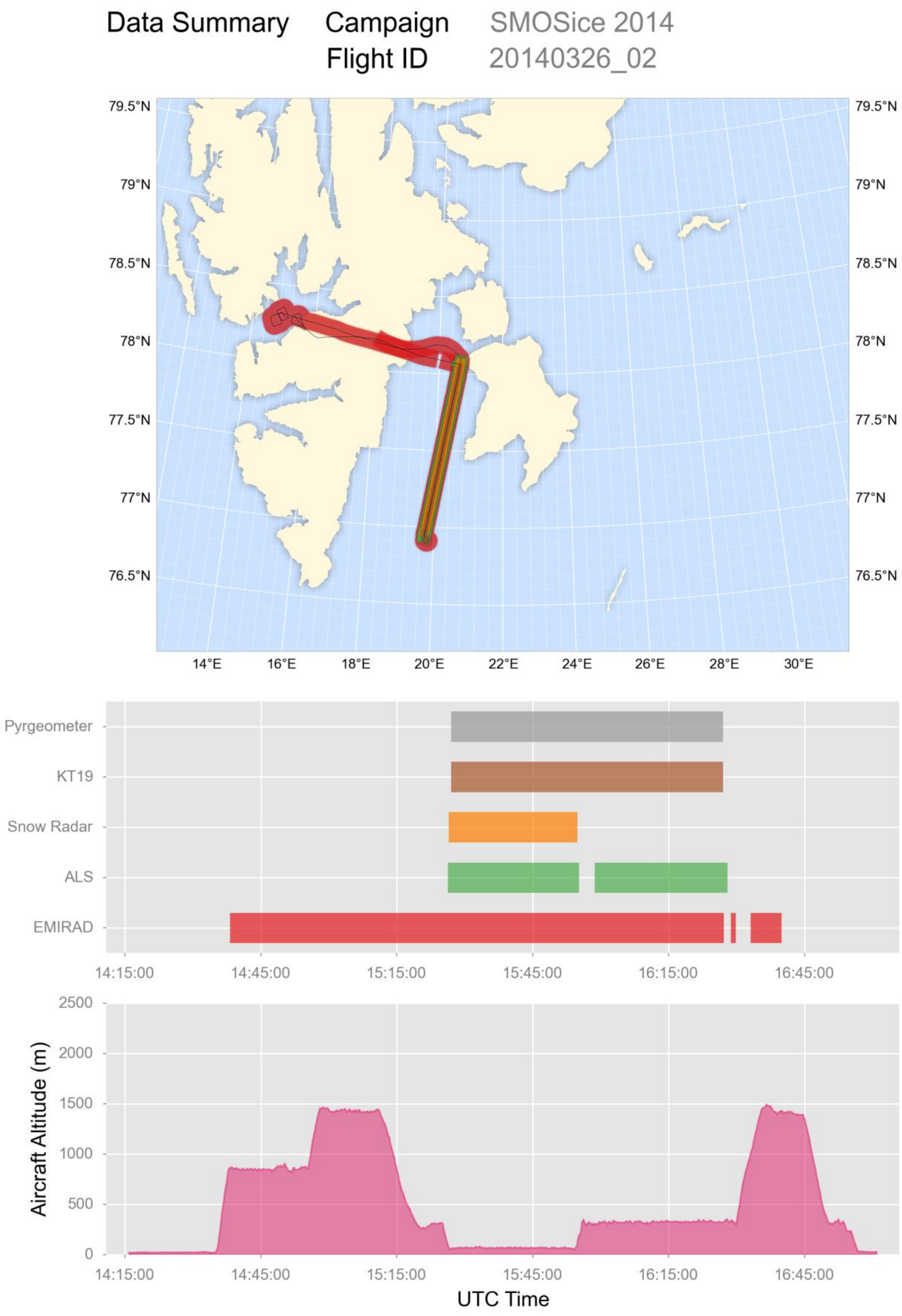
KT19 Files

Filename	Start Time	Stop Time	Comment
2014032603_KT19.nc	2014-03-26 09:22:00	2014-03-26 12:20:59	

Pyrgeometer Files

Filename	Start Time	Stop Time	Comment
2014032603_pyrgeometer.nc	2014-03-26 09:22:00	2014-03-26 12:20:59	

11 Flight Summary 20140326_02



EMIRAD Files

Filename	Start Time	Stop Time	Comment
08514260.e61	2014-03-26 14:38:12	2014-03-26 16 16:27:08	Primary data set (Nadir)
08514260.e62	2014-03-26 14:38:12	2014-03-26 16 16:27:08	Primary data set (Side)
08516280.e61	2014-03-26 16:28:42	2014-03-26 16 16:29:46	Wing wags over ice (Nadir)
08516280.e62	2014-03-26 16:28:42	2014-03-26 16 16:29:46	Wing wags over ice (Side)
08516320.e61	2014-03-26 16:33:03	2014-03-26 16 16:39:54	Transit (Nadir)
08516320.e62	2014-03-26 16:33:03	2014-03-26 16 16:39:54	Transit (Side)

ALS Files

Filename	Start Time	Stop Time	Comment
ALS_L1B_20140326T152618_155513	2014-03-26 15:26:18	2014-03-26 15:55:13	South-bound leg (200 ft)
ALS_L1B_20140326T155838_162800	2014-03-26 15:58:38	2014-03-26 16:28:00	North-bound leg (1000 ft)

Snow Radar Files

Filename	Start Time	Stop Time	Comment
SNOW142256.dat	2014-03-26 15:26:24	2014-03-26 15:27:25	
SNOW152725.dat	2014-03-26 15:27:25	2014-03-26 15:28:26	
SNOW152826.dat	2014-03-26 15:28:26	2014-03-26 15:29:26	
SNOW152926.dat	2014-03-26 15:29:27	2014-03-26 15:30:27	
SNOW153027.dat	2014-03-26 15:30:27	2014-03-26 15:31:28	
SNOW153128.dat	2014-03-26 15:31:28	2014-03-26 15:32:29	
SNOW153229.dat	2014-03-26 15:32:29	2014-03-26 15:33:30	
SNOW153330.dat	2014-03-26 15:33:30	2014-03-26 15:34:31	
SNOW153431.dat	2014-03-26 15:34:31	2014-03-26 15:35:32	
SNOW153532.dat	2014-03-26 15:35:32	2014-03-26 15:36:33	
SNOW153633.dat	2014-03-26 15:36:33	2014-03-26 15:37:33	
SNOW153734.dat	2014-03-26 15:37:34	2014-03-26 15:38:34	
SNOW153834.dat	2014-03-26 15:38:34	2014-03-26 15:39:35	
SNOW153935.dat	2014-03-26 15:39:35	2014-03-26 15:40:36	
SNOW154036.dat	2014-03-26 15:40:36	2014-03-26 15:41:37	
SNOW154137.dat	2014-03-26 15:41:37	2014-03-26 15:42:38	
SNOW154238.dat	2014-03-26 15:42:38	2014-03-26 15:43:39	
SNOW154339.dat	2014-03-26 15:43:39	2014-03-26 15:44:40	
SNOW154440.dat	2014-03-26 15:44:40	2014-03-26 15:45:41	
SNOW154541.dat	2014-03-26 15:45:41	2014-03-26 15:46:41	
SNOW154642.dat	2014-03-26 15:46:42	2014-03-26 15:47:42	
SNOW154742.dat	2014-03-26 15:47:42	2014-03-26 15:48:43	
SNOW154843.dat	2014-03-26 15:48:43	2014-03-26 15:49:44	
SNOW154944.dat	2014-03-26 15:49:44	2014-03-26 15:50:45	
SNOW155045.dat	2014-03-26 15:50:45	2014-03-26 15:51:46	
SNOW155146.dat	2014-03-26 15:51:46	2014-03-26 15:52:46	
SNOW155246.dat	2014-03-26 15:52:47	2014-03-26 15:53:47	
SNOW155348.dat	2014-03-26 15:53:48	2014-03-26 15:54:48	

KT19 Files

Filename	Start Time	Stop Time	Comment
2014032604_KT19.nc	2014-03-26 15:27:00	2014-03-26 16:26:59	

Pyrgeometer Files

Filename	Start Time	Stop Time	Comment
2014032604_pyrgeometer.nc	2014-03-26 15:27:00	2014-03-26 16:26:59	

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