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ESA CryoVEx/EU ICE-ARC 2016

Airborne field campaign with ASIRAS radar, and laser scanner measurements

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1. Introduction

The 2016 airborne campaign was partly an ESA CryoSat-2 Validation EXperiment (CryoVEx) campaign and partly a EU FP7 project ICE-ARC. As the same aircraft and instrument installation were used for both campaigns this report includes both the CryoVEx and ICE-ARC campaign data. Below is given an overview of which data belongs to which project. This report is part of ICE-ARC deliverable 1.62. The mobilization costs were shared equally between the projects.

The ESA CryoSat-2 Validation Experiment (CryoVEx) 2016 was primarily carried out to follow up on a recommendation given within ESA CryoVal Land Ice project (2014-2015), where it was found that the traditional under-flights of the Cryosat-2 satellite were inadequate. This is primarily due to uncertainties in the radar-echo location (POCA) due to topography. To account for this effect, the 2016 ESA-CryoVEx airborne campaign was aimed at flying dense grids of parallel lines at Austfonna ice cap along CryoSat-2 ground tracks, to cover a broad range of possible POCA locations from different re-trackers (CryoVal-LI D4).

The ICE-ARC campaign was mainly used to the opportunity was used to repeat some sea ice flights out of Station Nord, which partly had failed in 2015 due to problems with the ALS logging system. The opportunity was taken to make the first Sentinel-3A under-flight over sea ice in Fram Strait.

This report outlines the airborne field operations conducted during April 4-16, 2016, with the ESA airborne Ku-band interferometric radar (ASIRAS), coincident airborne laser scanner (ALS) and vertical photography. The airborne campaign was coordinated by National Space Institute, Technical University of Denmark (DTU Space) using a Twin Otter (reg. TF-POF) chartered from Norlandair, Iceland.

1.1 The primary objectives achieved during the campaign

- Land ice validation of CryoSat-2 – Austfonna ice cap, Svalbard to follow up on ESA CryoVal-LI recommendations (ESA CryoVEX).
- First Sentinel-3 underflights over sea ice in Fram Strait (EU FP7 ICE-ARC).
- Monitoring sea ice thickness north of Greenland and Fram Strait, repeat lines (EU FP7 ICE-ARC).
- Overflight of upward looking sonars moored in Fram Strait to support CryoSat-2 sea ice freeboard-to-thickness conversion (EU FP7 ICE-ARC).
- Repeated flights from earlier campaigns, to monitor the interaction between the ice shelf and the buttressing sea-ice in the Nioghalvfjerdsfjorden glacier complex (EU FP7 ICE-ARC).

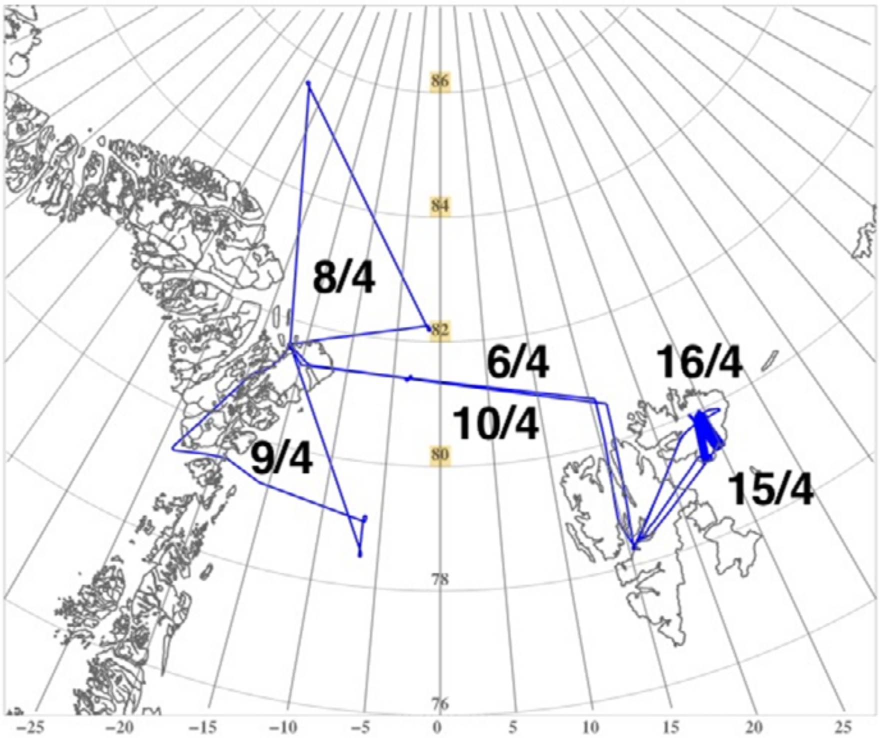


Figure 1 Overview of the flight tracks (blue lines) from the CryoVEx/ICE-ARC 2016 airborne campaign. Dates of the respective flights are marked next to the flight lines.

2. Summary of operation

The CryoVEx/ICE-ARc 2016 airborne campaign was conducted in the period April 4-16, 2016. An overview of the ground tracks of the airborne campaign is presented in Figure 1. The campaign was based out of Station Nord (STN), Northeast Greenland, and Longyearbyen (LYR), Svalbard, Norway.

A Norlandair Twin Otter (reg: TF-POF), which is the same aircraft as used throughout previous CryoVEx campaigns, was chartered for the entire campaign. The instrument certification for the aircraft was obtained in 2006 (Hvidegaard and Stenseng, 2006). The flight altitude is typically 300 m agl, limited by the range of the laser scanner, and the nominal ground speed is 135 knots. The aircraft is equipped with an extra ferry tank permitting longer flights (5-6 hrs), and an autopilot for better navigation accuracy. In good conditions the across-track accuracy is down to a few meters using a custom-made navigation system connected to geodetic GPS receivers. Due to shared logistics of the Twin Otter with Danish company Polar Logistics Group ApS (POLOG), the installation and de-installation of the ASIRAS radar and laser scanner (ALS) took place in Luftransport AS hangar in LYR and was performed by DTU Space personnel.

As the first part of the campaign was aimed at measuring sea ice in the proximity of the Station Nord, North-East Greenland the ferry flight was used to seek the opportunity of the first under-flight of ESA Sentinel-3A SAR altimeter only 51 days after the launch. At Station Nord the weather conditions proved optimal for aerial surveying, despite low temperatures (down to -35^{o}C). The low temperatures resulted in long start-up time for the ALS as fog was frozen on the inside of the instrument window during take-off, preventing the laser to penetrate through the window, see Section 4. Despite the difficulties with the start-up of the scanner, all planned sea-ice flights north of Greenland and in the Fram Strait were surveyed between April 6 and April 10. Unfortunately a planned coincident flight with NASA Operation IceBridge (OIB) was not performed due to unexpected aircraft maintenance of the OIB aircraft. A more detailed description of the flights is given in Section 6.

During the second part of the campaign, the weather presented itself more challenging with Austfonna ice cap covered in low clouds. This together with strong winds postponed the survey flights at Austfonna to the very last days of operations. On April 15 and 16, two dense grids were flown along two CryoSat-2 tracks, during two long flights.

The airborne team consisted of Henriette Skourup (HSK), Louise Sandberg Sørensen (SLSS), and Sebastian B. Simonsen (SSIM). Calibration flights of the instruments over buildings and runways were performed whenever possible. The CryoVEx/ICE-ARC 2016 campaign ended on April 16 where the equipment was uninstalled in Longyearbyen. An overview of the flights is found in Table 1. A day-to-day overview is given in Section 2.1 and operator logs and plots of flight tracks are provided in Appendix B.

The CryoVEx/ICE-ARC 2016 campaign was a success and the scientific community now has another unique collection of measurements to analyze as an extension to the data time series from the previous campaigns.

Table 1 Overview of CryoVEx/ICE-ARC 2016 flights.

Date	DOY	Flight	Track	Take off UTC	Landing UTC	Airborne	Airborne accumulated [dd:hh:mm]	Survey operator
April 5, 2016	96		Test flight LYR	14:47	15:16	00:29	00:00:29	HSK/SSIM
April 6, 2016	97	a	Test flight LYR	09:55	10:14	00:19	00:00:48	HSK/SSIM
April 6, 2016	97	b	LYR - S3 (orbit 712) - STN	14:03	17:24	03:21	00:04:09	HSK/SSIM
April 8, 2016	99		STN-F1-F2-STN	11:26	16:28	05:02	00:09:11	HSK/SSIM
April 9, 2016	100		STN-ULS-STN	11:03	15:38	04:35	00:13:46	HSK/SSIM
April 10, 2016	101		STN- S3 (orbit 769) -LYR	15:04	18:27	03:23	00:17:09	HSK/SSIM
April 15, 2016	106		LYR - CS2 (orbit 32066) - LYR	08:28	14:08	05:40	00:22:49	SLSS/SSIM
April 16, 2016	107		LYR - CS2 (orbit 31971) - LYR	08:28	14:02	05:34	01:04:23	SLSS/SSIM
Total							28h 23min	

1.2 Day to day

The airborne part of CryoVEx/ICE-ARC 2016 progressed as follows:

April 3: Scientists HSK and SSIM CPH to LYR

April 4-5: Installation of equipment and test flight over the fjord together with overflight of calibration building. The ASIRAS PC2 was not operational and had to be bypassed with the help of RST.

April 6: Local test flight in LYR with runway overflight. The flight was successful with ASIRAS only running on PC1. Second flight on route STN following Sentinel-3A orbit 712.

April 7: Low clouds in the area around STN, no flights.

April 8: Triangle flight north of Station Nord (STN-F1-F2-STN). Cold morning (-34°C), caused the scanner to freeze and had to be heated before the flight to make it operational. The weather was excellent for the survey.

April 9: Flight to 79-glacier and moored upward looking sonars in Fram Strait. Slightly warmer this morning, but still problems with ALS condensation, due to cold temperatures.
SLSS from Copenhagen to LYR.

April 10: Second Sentinel-3A under flight (orbit 769) on route STN to LYR. Planned CS-2 under flight (orbit 31841) was cancelled, due to low clouds in the area north of Svalbard.

April 11-14: HSK from LYR to Copenhagen.
Windy and cloudy conditions at Austfonna, no survey.

April 15: First Austfonna flight. Despite persistent cloudy conditions at the ice cap a survey of parallel lines of the CS2 orbit 32066, which will pass Austfonna on April 26,

	were possible. The planned tracks had to be shortened due to clouds on the north side of the ice cap.
April 16:	Second Austfonna flight. Again cloudy condition at Austfonna, but it was possible to conduct a survey around the CS2 orbit 31971, which will pass Austfonna on April 19. After the survey the equipment was un-mounted and packed for shipping.
April 17:	SLSS and SSIM LYR to Copenhagen.

3. Hardware installation

The installation of the ASIRAS system was identical to the setup used throughout the previous CryoVEx campaigns (see e.g. Hvidegaard et al (2016), Skourup et al (2013a, 2013b)). To support the ASIRAS system a Novatel GPS DL-V3 was kindly loaned from the Alfred Wegener Institute (AWI). The ALS equipment was of type Riegl LMS Q-240i-60. To prevent malfunction of the ALS during the extreme low temperatures (-25^{o}C and below) in the first part of the campaign, the ALS was wrapped with external heater pads. In addition, an external heater fan as well as an electrical heater, were installed in the instrument bay in the rear baggage compartment of the aircraft, see Figure 6. An older version of the ALS Riegl (LMS Q-140i) was carried along as backup unit.

In addition, three geodetic dual-frequency GPS receivers were mounted for precise aircraft positioning. The receivers (AIR1, AIR2 and AIR3) were connected to two separate GPS antennas ("front" and "rear") through antenna beam splitters. The GPS antennas are permanently installed on TF-POF. Receiver types, antenna information, as well as logging rates for the GPS receivers are given below:

- AIR1 Receiver type Javad Delta front antenna logging rate 1 Hz
- AIR2 Receiver type Javad Delta rear antenna logging rate 2 Hz
- AIR3 Receiver type Javad Delta front antenna logging rate 1 Hz

The higher logging rate for AIR2 was chosen to obtain a higher precision for the on-board navigation system. Offsets between GPS antennas and ASIRAS/ALS are given in Table 2.

To record the attitude (pitch, roll and heading) of the aircraft, two inertial navigation systems (INS) were used. The primary unit is a medium grade INS of type Honeywell H-764G. This unit collects data both in a free-inertial and a GPS-aided mode at 50 Hz. Specified accuracy levels in roll and pitch are better than 0.1^{o}, and usual accuracy is higher than this. A backup INS is provided by an OXTS Inertial+2 integrated GPS-INS unit, with a nominal similar accuracy as the H-764G. The Honeywell INS was connected to the front GPS antenna. During most of the campaign the OxTS used dual antenna setup with the rear GPS antenna as primary antenna.

To collect visual imagery of the surfaces surveyed during the sea ice flights, two cameras were mounted next to the ALS in the rear baggage compartment of the aircraft, see Figure 6. The cameras were a GoPro photo/video camera in time lapse mode (to limit the data volume) and a uEye webcam as backup system. Both collect nadir looking images.

The setup of the instruments in the aircraft is shown in Figure 2 and pictures of the various instruments are shown in Figure 3-7.

Table 2 : The dx, dy and dz offsets for the lever arm form the GPS antennas to the origin of the laser scanner, and to the back center of the ASIRAS antenna (see arrow Figure 2).

To laser scanner	**dx (m)**	**dy (m)**	**Dz (m)**
- from AIR1/AIR3 (front)	- 3.70	+ 0.52	+ 1.58
- from AIR2/AIR4 (rear)	+ 0.00	- 0.35	+ 1.42
To ASIRAS antenna	**dx (m)**	**dy (m)**	**dz (m)**
- from AIR1/AIR3 (front)	-3.37	+0.47	+2.005
- from AIR2/AIR4 (rear)	+0.33	-0.40	+1.845

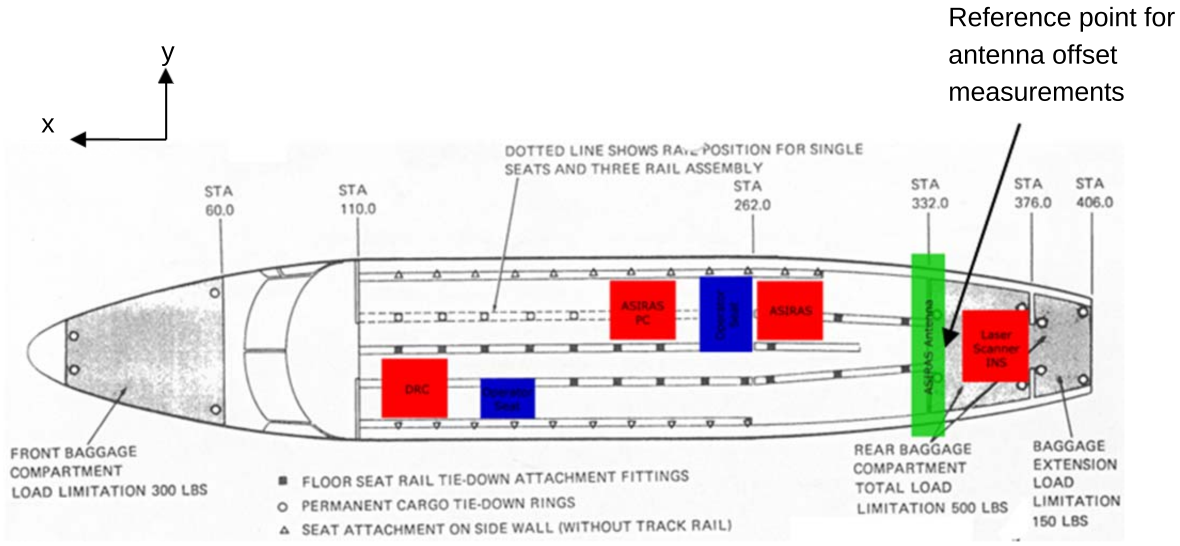


Figure 2 Overview of instrument setup in the TF-POF Twin Otter aircraft.

Figure 3 ASIRAS antenna.

Figure 4 View of cabin in aircraft; Rack with ASIRAS PC's (front right), rack for ALS, GPS and INS (rear left). Spare fuel tank for extra airborne time (front left) Photo: SSIM.

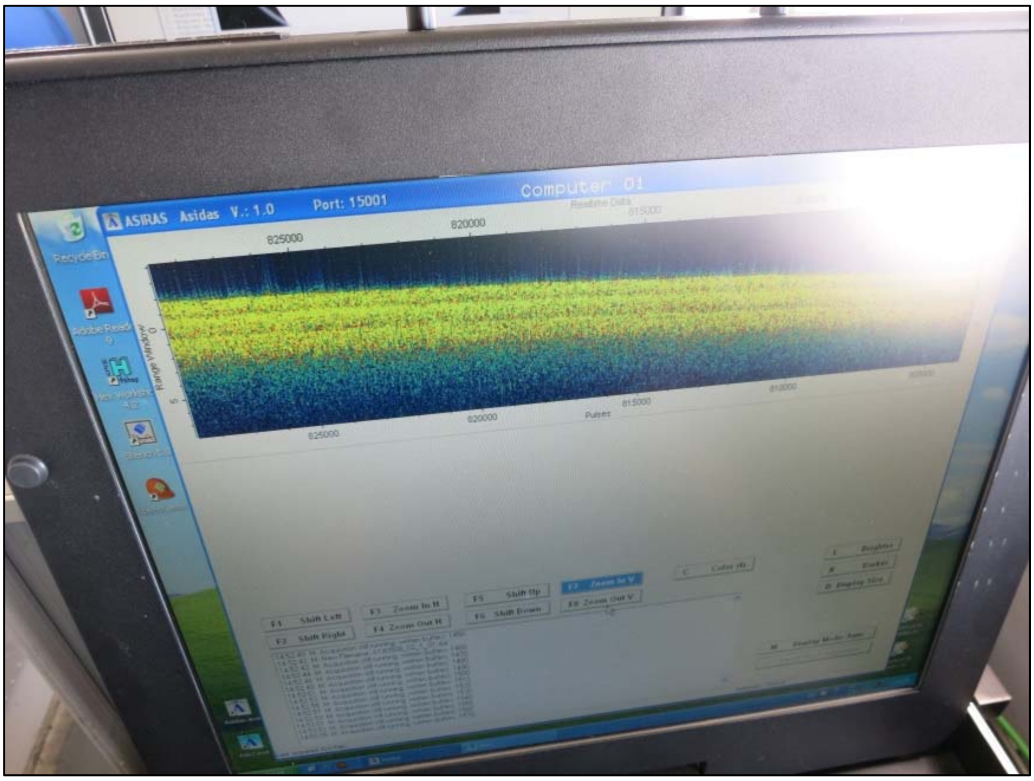


Figure 5 Snapshot of ASIRAS operation display over land ice.

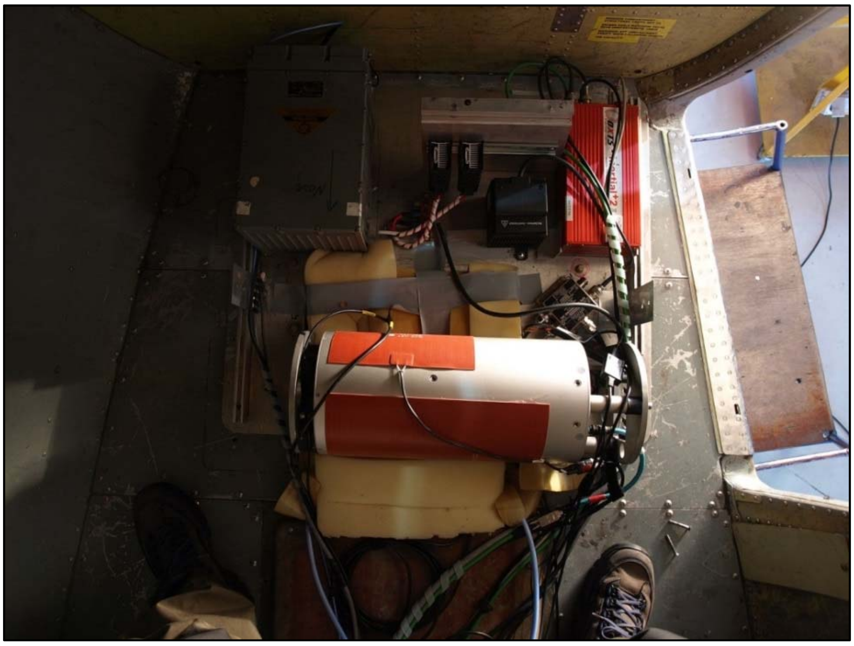


Figure 6 Instrument bay in rear baggage compartment of the aircraft. In front laser scanner RIEGL LMS Q-240i with heater pads (grey/orange instrument). H-764G INS (grey box) and OXTS INS (red box) in the back. Between the two INS instruments are mounted two external heaters.

Figure 7 : Photo taken from below through hole in aircraft; visible instruments are laser scanner (purple windows) and nadir looking cameras (left).

4. Overview of acquired data

Data from the various instruments were acquired where feasible, considering the limited height range of the ALS system and the weather. An overview of all acquired data is listed in Table 3.

All the ASIRAS data were acquired in Low Altitude Mode (LAM) with low along-track resolution (LAMa). This allows flight at an altitude of 300 m, which is within the operational range of the ALS system and a relative low data volume of about 28 GB per hour. A total of 604 TB raw ASIRAS data were collected during the CryoVEx/ICE-ARC 2016 campaign. The data were stored on hard discs as ASIRAS level 0 raw data in the modified compressed format (Cullen, 2010). The ASIRAS system performed well during the campaign only using PC1, due to a malfunction of PC2 detected during the first test flight in Longyearbyen.

In general, the ALS worked well. At low temperatures (below -25^{o}C) encountered at Station Nord, icing of the instrument window during take-off and steep climbs/descends prevented the laser to see through the instrument window. Partly blocking of the laser signals was apparent for the first hour of operation resulting in no surface return or a narrow scan width. Slow climbs during take-off reduced the icing on the scanner window. The actual loss of data was limited since most of the flights included some ferry flight to the designated survey areas. To circumvent the laser to lock on the frozen instrument window, the ALS was switched to measure the “last laser pulse”. The data volume obtained by the ALS is about 250-300 MB per hour, which is a relative small amount, when compared to the ASIRAS data volume. During the campaign a total of 7.6 GB ALS data were acquired.

The airborne GPS units logged data internally in the receivers (AIR1, AIR2 and AIR3) during flight, which were downloaded upon landing on laptop PCs. The Novatel GPS was dedicated to support ASIRAS and was not part of the logging system. GPS files were recovered for all receivers at all flights. The GPS reference stations listed in Table 3 are described in further detail in Section 5.1.

Both INS systems logged continuously throughout the campaign and no problems were observed with the systems.

Vertical photography was collected during sea ice flights. Pictures were acquired every 2 seconds for most flights by nadir-looking photography. Due to problems with the data system running the uEye webcam, this camera was only used on the first flight from LYR to STN. The GoPro camera recorded nadir-photography from the remaining sea ice flights.

All data are stored on external hard discs, as well as the DTU Space servers with tape backup system.

Table 3: Overview of data.

Date	DOY	AIR1	AIR2	AIR3	EGI H-764G	INS OxTS	ALS	ASIRAS	GPS REF1	GPS REF2	uEye	GoPro	Log	Remarks
05-04-2016	96	X	X	X	X	X	X	-	X	-	-	-	X	Test fight LYR
06-04-2016	97a	X	X	X	X	X	X	LAM	X	-	-	-	X	Test fight LYR
06-04-2016	97b	X	X	X	X	X	X	LAMa	-	-	X	-	X	LYR-S3-STN
08-04-2016	99	X	X	X	X	X	X[1]	LAMa	X[2]	-	-	X	X	STN-F1-F2-STN
09-04-2016	100	X	X	X	X	X	X[1]	LAMa	X	-	-	X	X	STN-ULS-STN
10-04-2016	101	X	X	X	X	X	X[1]	LAMa	-	-	-	X[3]	X	STN-S3-LYR
15-04-2016	106	X	X	X	X	X	X	LAMa	X	-	-	-		LYR-CS2-LYR
16-04-2016	107	X	X	X	X	X	X	LAMa		-	-	-		LYR-CS2-LYR

[1] Icing of the scanner window during take-off and steep climbs/descends
[2] The cold conditions made the GPS run out of battery 16:24, but the TF-POF landed at STN 16:28
[3] The GoPro image-file G0017431.jpg was corrupted

5. Processing

The data processing is divided between DTU Space and AWI. ASIRAS data is processed by AWI using GPS and INS data supplied by DTU Space. GPS differential positioning together with combined INS-GPS integration is done by DTU Space followed by processing of laser distance measurement into elevation above a reference ellipsoid. This is supplemented by geo-reference of the images taken along the flights, see Section x.x.

1.3 GPS data processing

The exact position of the aircraft is found from kinematic solutions of the GPS data obtained by the GPS receivers installed in the aircraft, see Section 3. Two methods can be used for post-processing of GPS data, kinematic differential (DIF) processing and precise point positioning (PPP). Whereas the first method uses information from base stations in the processing procedure, the PPP method is only based on precise information of satellite clock and orbit errors.

The GPS base stations used as reference stations for differential post processing of the GPS data are listed in Table 4. A Javad Maxor Receiver with internal antenna and logging rate 1 Hz was used as base station. The base station was mounted on DTU Space small tripods (vertical height 12 cm). However, the reference points were generally not marked.

The positions of the base stations are determined using the online GPS processing services AUSPOS (http://www.ga.gov.au/earth-monitoring/geodesy/auspos-online-gps-processing-service.html) offered by Geoscience Australia. The service calculates the position of the reference stations in the ITRF 2008 reference system using data from the closest permanent GPS stations with a position accuracy of about 2 cm. This accuracy is available even in the Arctic with long distances to the closest permanent stations. The coordinates of all the reference stations used during CryoVEx/ICE-ARC 2016 are found in Appendix C.

Table 4: Overview of CryoVEx/ICE-ARC 2016 GPS reference stations

Name	Site	Site description
STN1	Station Nord	On snow field between building 9 and runway*
LYR1	Longyearbyen	Next to parking lot outside airport for test-flights/Airport next to apron for Austfonna flights

*The usual spot near fuel pump was not used due to fuel-lift (operation northern Falcon)

The GPS processing were performed with Waypoint GrafNav (version 8.30) by use of precise IGS orbit and clock files and correction for ionospheric and tropospheric errors. For each flight several solutions are made using different combinations of GPS reference stations and aircraft receivers. The best solution for each flight is selected according to Table 5 and used in the further processing, and the statistically basis for the selection of the preferred GPS-solution are listed in Appendix C.

1.4 Inertial Navigation System

The position and attitude information (pitch, roll and heading) recovered from the raw Honeywell (H-764G) and the Oxford Inertial 2+ (OxTS) INS data at 10 Hz, are merged with the GPS solutions by draping the INS derived positions onto the GPS solutions. The draping is done by modeling the function, found in the equation below, by a low pass smoothed correction curve, which is added to the INS.

$$\varepsilon(t) = P_{GPS}(t) - P_{INS}(t)$$

This way a smooth GPS-INS solution is obtained, which can be used for geolocation of laser and camera observations. The selected INS solutions are listed in Table 5. As seen, all solutions are based on input from the Honeywell instrument, avoiding solutions based on the OxTS INS, which has degraded accuracy during acceleration, which includes turns and rapid changes of altitude (Skourup et al., 2012).

The best solutions of both GPS and INS data based on Table 5, is packed as binary files in the special ESA file format, see Appendix G 1.26 and 1.27. An overview of the final GPS and INS files is also listed in Table 6 with file name convention according to Appendix G.

Table 5 List of best combination of GPS and INS data

Date	DOY	GPS rover	GPS Ref.	GPS Pro.	INS	GPS-file	Combined GPS-INS file
05-04-16	96	AIR2	STN1	DIF	H-764G	GPS_R_20160405T144559_151837_0001.DBL	INS_20160405T144536_151754_0001.DBL
06-04-16	97a	AIR2	No	PPP	H-764G	GPS_R_20160406T093656_101927_0001.DBL	INS_20160406T093718_101756_0001.DBL
06-04-16	97b	AIR2	No	PPP	H-764G	GPS_R_20160406T134950_172958_0001.DBL	INS_20160406T135146_172748_0001.DBL
08-04-16	99	AIR2	No	PPP	H-764G	GPS_R_20160408T110941_163200_0001.DBL	INS_20160408T110936_163110_0001.DBL
09-04-16	100	AIR2	No	PPP	H-764G	GPS_R_20160409T104614_154300_0001.DBL	INS_20160409T104612_154203_0001.DBL
10-04-16	101	AIR2	No	PPP	H-764G	GPS_R_20160410T144015_183129_0001.DBL	INS_20160410T144227_183013_0001.DBL
15-04-16	106	AIR2	LYR1	DIF	H-764G	GPS_R_20160415T081412_140915_0001.DBL	INS_20160415T081348_140759_0001.DBL
16-04-16	107	AIR2	No	PPP	H-764G	GPS_R_20160416T081752_140236_0001.DBL	INS_20160416T081724_140300_0001.DBL

1.5 Airborne Laser Scanner (ALS)

The laser scanner operates with wavelength 904 nm. The pulse repetition frequency is 10,000 Hz and the ALS scans 40 lines per second, thus the data rate is 251 pulses per line. This corresponds to a horizontal resolution of 0.7 m x 0.7 m at a flight height of 300 m and a ground speed of 250 kph. The across-track swath width is roughly equal to the flight height, and the vertical accuracy is in the order of 10 cm depending primarily on uncertainties in the kinematic GPS-solutions. The raw logged files with start /stop times are listed in Appendix D.

Calibration

The calibration of the misalignment angles between ALS and INS can be estimated by analyzing crossovers of a ground segment. The calibration is further assisted by successive overflights from different directions of the same building, where the position of the corners is known with high precision from GPS measurements. These dedicated calibration maneuvers over building have been carried out twice during the 2016 campaign:

- 05-04-2016 DOY 096 Akureyri
- 08-04-2016 DOY 099 Station Nord

Figure 8: Map of Akureyri airport with building used for calibration marked by red circle. The corners of a building close to the Norlandair hangar and the runway were surveyed by geodetic GPS to be included in the calibration of the ALS and ASIRAS. The scanner image is shown in appendix D.

The ALS data has been routinely processed and the calibration angles for each flight based on the calibration flights together with inspection of cross-overs and overflights of relative flat surfaces can be found in Appendix D Table 10.

Laser scanner outlier detection and removal

No major problems were encountered with the instruments. Due to the problems with moisture on the inside of the ALS (see Chapter 4), some of the flights of the first part of the campaign have reduced scan width down to about 100m. The largest effects were obtained during the first 30-45 minutes of the survey flights until the external and internal heaters had melted the ice. For most of the flights this effect of icing of the scanner window was reduced by setting the instrument to the TS1 mode, that detects the last return pulse. The outlier removal was done by manual inspection of all data-files, after the data was filtered for clouds and echoes from the instrument window.

Cross-over statistics

The ALS is in general of high quality with a standard deviation of cross-over differences of less than 10 cm. As a part of the processing routine, crossover statistics are derived for all repeated overflight within an hour of the first overflight. This derived statistics is shown in Appendix D Section 1.22. The quality of these crossover statistics varies depending on surface type, incidence angle and level of processing. The statistics provided in Appendix D is based on raw scanner data before outlier editing, therefore the results summarized in XX

Table 6 XO statistics, see the full distributions in Appendix D 1.22

DOY	XO number of the day	Mean (m)	Std. Dev (m)	Min (m)	Max (m)
096	0	-0.008	0.079	-0.3	0.29
	3	-0.007	0.071	-0.24	0.23
	5	-0.058	0.053	-0.37	0.12
	6	-0.043	0.056	-0.29	0.14
	7	-0.052	0.048	-0.42	0.34
	9	-0.007	0.071	-0.24	0.23
097a	0	0.020	0.086	-0.34	0.47
	1	0.001	0.131	-0.42	0.35
	2	0.024	0.086	-0.34	0.47
0.97b	No suitable XO’s during the sea ice flight				
099	1	0.001	0.086	-0.4	0.4
	3	-0.021	0.080	-0.98	0.75
100	No suitable XO’s during the sea ice flight				
101	No suitable XO’s during the sea ice flight				
106	1	0.103	0.068	-0.17	0.34
	3	-0.030	0.054	-0.30	0.19
	5	0.014	0.088	-0.46	0.46
	7	0.011	0.084	-0.44	0.44
	8	0.012	0.084	-0.44	0.44
	9	0.016	0.066	-0.61	0.72
	10	0.010	0.084	-0.44	0.44
	11	0.016	0.066	-0.61	0.72
107	0	0.004	0.058	-0.23	0.28
	1	-0.004	0.054	-0.27	0.24

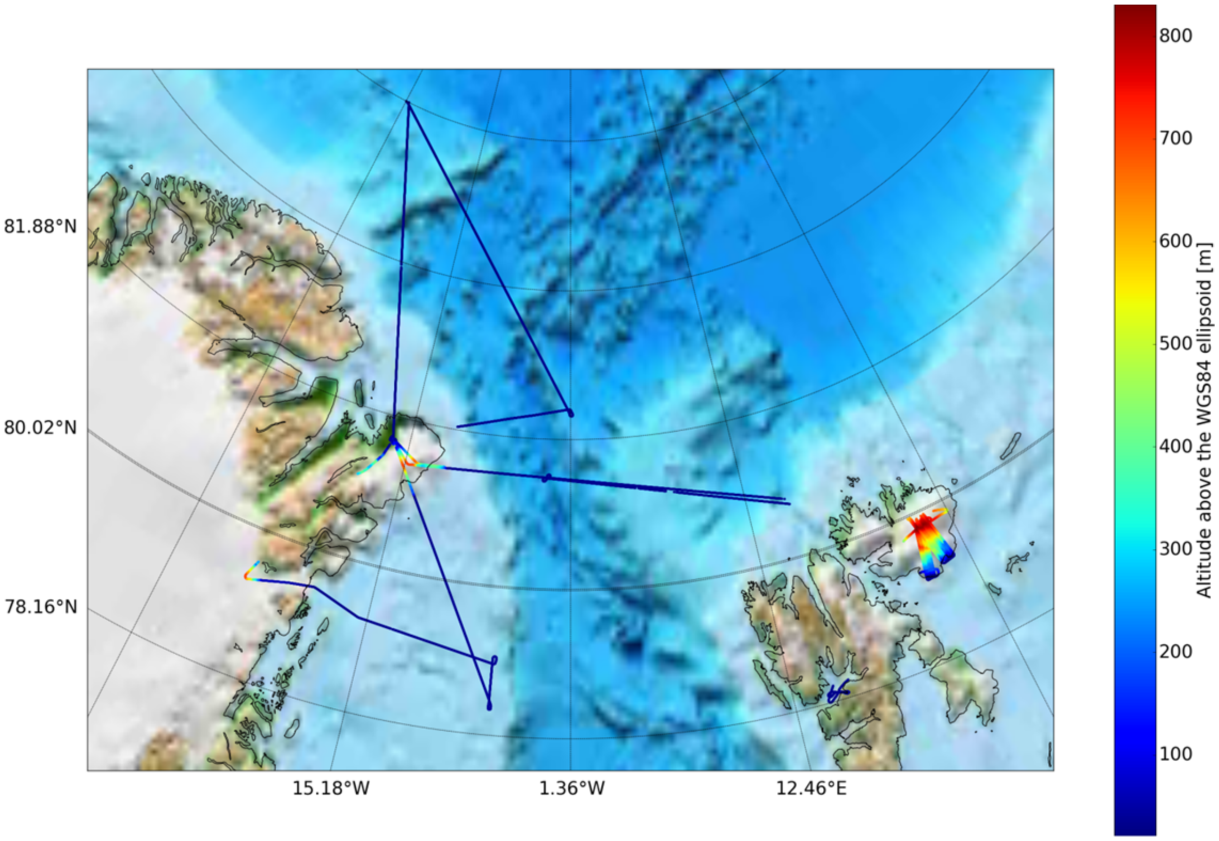


Figure 1 Mission overview of the ALS data, all recorded heights is given as geo-located point-clouds in respect to the WGS-84 reference ellipsoid.

Final processed data

Processed data comes as geo-located point clouds, in lines of width 200-300 m at full resolution 1mx1m, in format time, latitude, longitude, heights given with respect to WGS-84 reference ellipsoid. The data is packed in binary data files in the special ESA format, see Appendix 1.28. An overview of the processed data is given in Figure XX together with Appendix E.

Table 7 Data files available for the processed ALS data, the full summery can be found Appendix D.

Date	DOY	Final file:	File size (MB)
05-04-2016	96	ALS_20160405T145633_151543.sbi	47
06-04-2016	97a	ALS_20160406T095732_101041.sbi	21.9
06-04-2016	97b	ALS_20160406T150445_155400.sbi	261
		ALS_20160406T155415_155415.sbi	0.03
		ALS_20160406T155509_162442.sbi	214
		ALS_20160406T165822_172147.sbi	145
08-04-2016	99	ALS_20160408T114748_124032.sbi	185
		ALS_20160408T124054_133656.sbi	396
		ALS_20160408T133728_142503.sbi	383
		ALS_20160408T142809_142821.sbi	1.63
		ALS_20160408T142913_152138.sbi	425
		ALS_20160408T152228_162601.sbi	515
09-04-2016	100	ALS_20160409T110529_112058.sbi	17.8
		ALS_20160409T120200_130138.sbi	383

		ALS_20160409T130205_135633.sbi	419
		ALS_20160409T135655_144340.sbi	352
		ALS_20160409T144405_153402.sbi	381
10-04-2016	101	ALS_20160410T150554_155910.sbi	148
		ALS_20160410T155928_165925.sbi	382
		ALS_20160410T165950_172837.sbi	182
15-04-2016	106	ALS_20160415T092600_100137.sbi	127
		ALS_20160415T100230_105729.sbi	298
		ALS_20160415T105914_115327.sbi	324
		ALS_20160415T115359_124947.sbi	326
		ALS_20160415T125136_131820.sbi	163
		ALS_20160415T135400_140445.sbi	26.8
16-04-2016	107	ALS_20160416T092330_102336.sbi	314
		ALS_20160416T102602_111552.sbi	303
		ALS_20160416T111630_120958.sbi	328
		ALS_20160416T121301_131316.sbi	365

1.6 ASIRAS

The ASIRAS radar operates at 13.5 GHz with footprint size 10 m across-track and 3 m along-track at a standard flight height of 300 m. An overview of the acquired ASIRAS log-files together with start/stop times, range window and number of pulses are listed in Appendix 4.

CryoVEx 2016 ASIRAS processing results

The ASIRAS radar operates at 13.5 GHz with footprint size 3 m along-track and 10 m across-track in Low Altitude mode with low resolution (LAM-A) at a standard flight height of 300 m. The ASIRAS processing of the raw (level 0) data files is analogous to the concepts already presented in Helm et al. (2006), using ESA's processor version ASIRAS_04_03.
The processed ASIRAS data is delivered as a level-1b in the ESA binary format see Cullen (2009). The product includes full waveforms information (see example in Figure 6), and an estimate of the re-tracked height w.r.t. WGS-84 reference ellipsoid using a simple Offset Center of Gravity (OCOG) re-tracker. The re-tracker is not optimal for sea ice applications, but gives a quick estimate of heights. To obtain absolute surface heights from ASIRAS an offset needs to be applied to account for internal delays in cables and electronics. As the offset is dependent on the choice of re-tracker it has not been applied in the ASIRAS Level 1b processing. The offset is estimated by comparing ASIRAS surface heights to surface heights obtained by ALS over a surface, where both the radar and the laser are known to reflect at the same surface. Such measurements are typically obtained by overflights of runways.

Also information about roll angles are given as it is common to remove roll angles above/below a certain threshold (±1.5°) due to waveform blurring

Runway over flights and comparison with ALS-DEM

During the campaign runway overflights was performed at:

- 06-04-2016 DOY 97 Longyearbyen
- 08-04-2016 DOY 99 Station Nord
- 15-04-2016 DOY 106 Longyearbyen

Figure 13a shows the laser scanner elevation model of the Alert runway including the ASIRAS profile (black line). Gaps in the line represent areas where the roll angles are larger than 1.5°. This data was excluded from the analysis. In figure 13b the comparison of the Alert overpass with the ALS-DEM is shown. The black line in the upper panel shows the ALS elevation, whereas the dark gray line shows the ASIRAS elevation. The light gray line shows the roll angle. A difference of 3.80 +/- 0.24 between the elevations is determined with the OCOG retracker. The lower left panel shows the variation of the difference around the median value. Statistics of this variation is shown in the histogram. This offset was not applied in the final ASIRAS level_1b processing as it is dependent on the choise of re-tracker, thus a runway calibration should be carried out for each re-tracker used. Table 7 lists the successful runway overflights and the calibration results. Unfortunately coincident ASIRASand ALS data are only obtained for runway calibration in three cases, from March 23 and 26 and April 28.

NO corner reflector overflights …

1.7 Vertical images

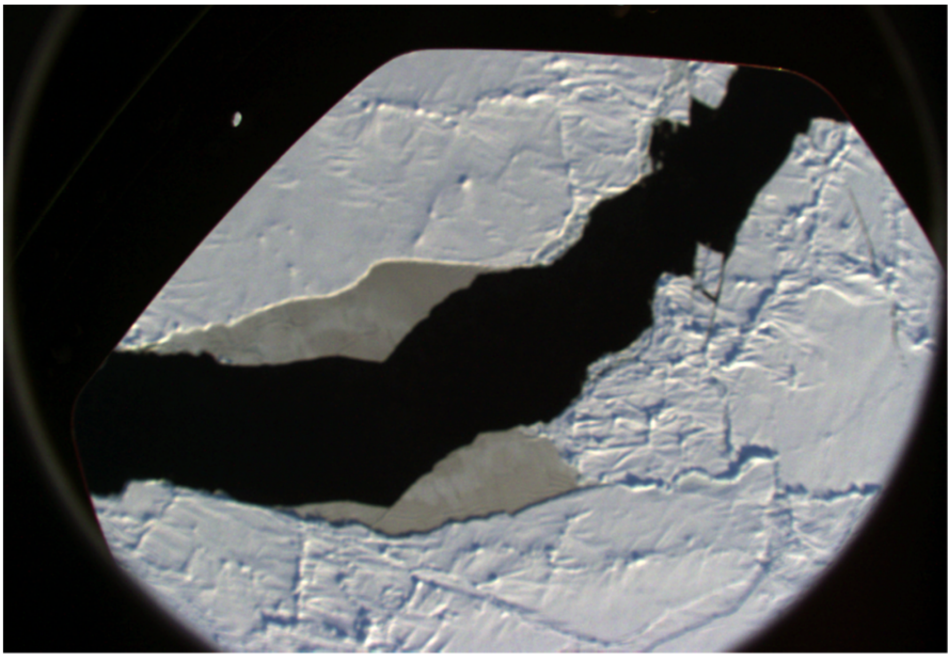
To complement the analysis of ALS and ASIRAS data over sea ice high-resolution images are collected along the flights.

Two nadir-looking cameras were mounted next to the ALS instrument in the rear baggage compartment, see Figure 10. On the right, a GoPro camera in time lapse mode collected photos at a 2 second interval. Next to this a backup uEye webcam was installed also acquiring images at 2 second interval but with slightly lower resolution. Both cameras were remote controlled and time tagged using the internal PC/camera clock. By combining the time-tag of the images with GPS data the images can be geo-referenced along the flight lines. An overview of the properties of the cameras is given in Table 5 and examples are shown in Figure 11.

Table 5: Overview of camera types and settings.

Camera type	View	Interval (sec)	Resolution (pixels)	Image size (MB)
uEye	Nadir-looking	2	1280x1024	~5
GoPro	Nadir-looking	2	2592x1944	~1.6

Figure 9: Camera installation of nadir-looking cameras for CryoVEx 2016; uEye (left) and GoPro (right).



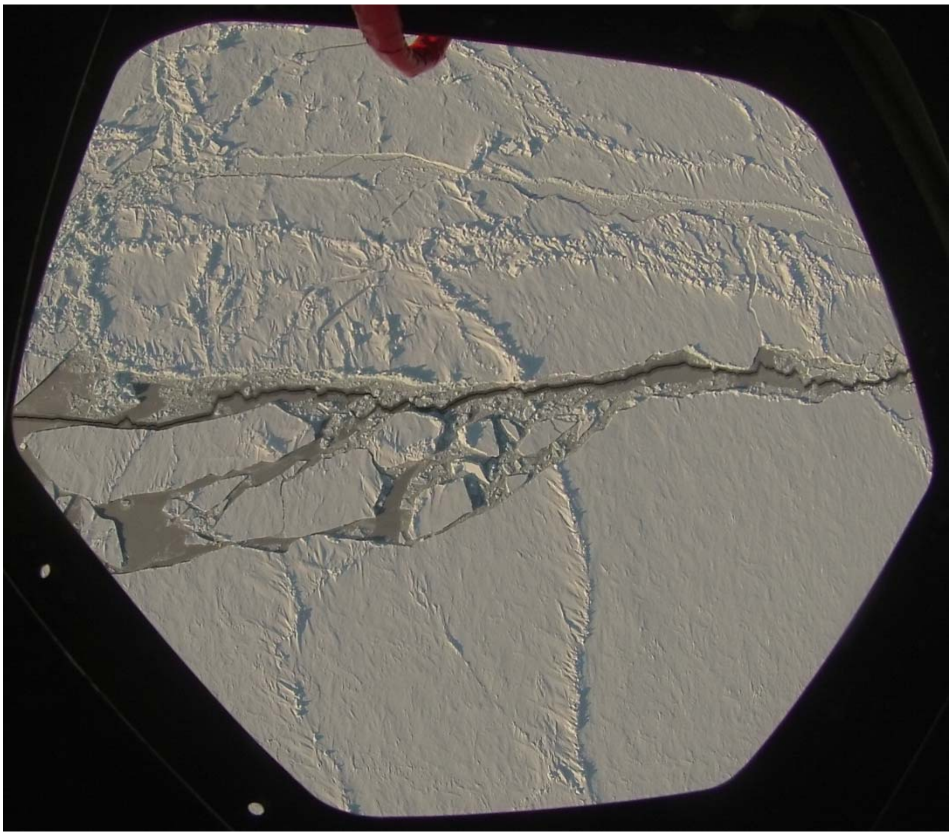


Figure 10: Examples of nadir-looking images.(Upper) uEye image (lower) GoPro.

6. Calibration and validation sites

1.8 Land ice

The primary flights during CryoVEx 2016 airborne campaign were the flights at Austfonna ice cap, see below. As an opportunity, the Nioghalvfjerdsfjorden glacier system was re-flown from EU ICE-ARC 2015 airborne campaign, together with measurements of the local ice cap Flade Isblink (FIB) near Station Nord.

1.9 Austfonna

The Austfonna ice cap (Figure 12) was flown on April 15 and 16, 2016. The flight lines were prepared to form a dense grid of parallel lines to cover the total POCA area along selected CS-2 orbits. The two closest (in time) CS-2 orbits were orbit 31971 and 32066 with passage dates on April 19 and April 26, respectively. Two approaches were tested with line spacings of 1 and 2 km, respectively. In addition, an East-West oriented line (Eton East) was re-flown from previous campaigns. The preliminary surface elevations shown in Figure 13 were presented at the ESA Living Planet Symposium by Davidson and Parrinello (2016) and Sørensen et al. (2016). It is seen that the length of the lines were limited towards north; this was a consequence of low clouds in this area of the ice cap.

Unfortunately, it was not possible to coordinate the flights directly with the Norwegian ground team, as they were based on the western most part of the ice cap. However, daily contact by iridium phone with the ground team prior to flights has been invaluable to receive updates on weather conditions.

The grid flown at Austfonna, where aimed at making the best possible reference surface for validation of Cryosat-2, and where designed in close collaboration with the ESA CryoVal-Land-Ice team members. An inter-comparison with ESA Baseline C L2 data and the obtained ALS measurements are shown in Figure 11.

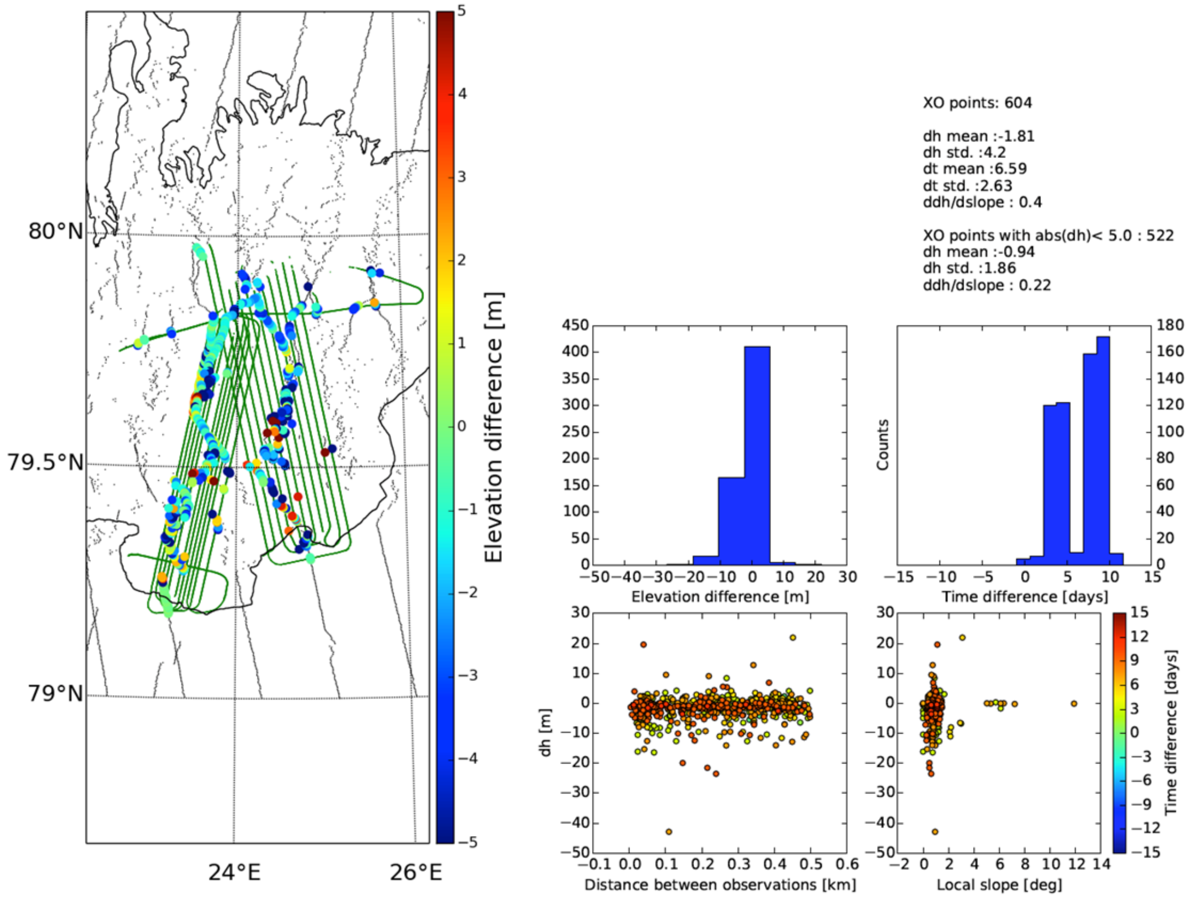


Figure 11 Inter-comparison of ESA Cryosat-2 L2 data and the ALS data obtained in April 2016

1.10 Sea ice

As an opportunity Sentinel-3A (S3A) under-flight over sea ice in Fram Strait was acquired on April 6 along orbit 712. The satellite passed above the aircraft 16:30 UTC at position 81° 24.43'N and 04° 50.03'W. At the passage time only ASIRAS was recording, due to low thick clouds, which appeared on the track 5 minutes before the satellite passage. This direct under-flight of the S3A over sea ice is to our knowledge the first done for this satellite.

On transit flight STN-LYR, April 10, a planned CryoSat-2 under-flight (orbit 31841) was cancelled due to low clouds in the area north of Svalbard, and instead a second S3A under-flight was prioritized. The flight followed S3A ground track orbit 769 with passage time of the satellite at 16:27 UTC at position 81° 20.24'N 01° 07.00'E. The weather for this flight was excellent and we only encountered low clouds when approaching Svalbard.

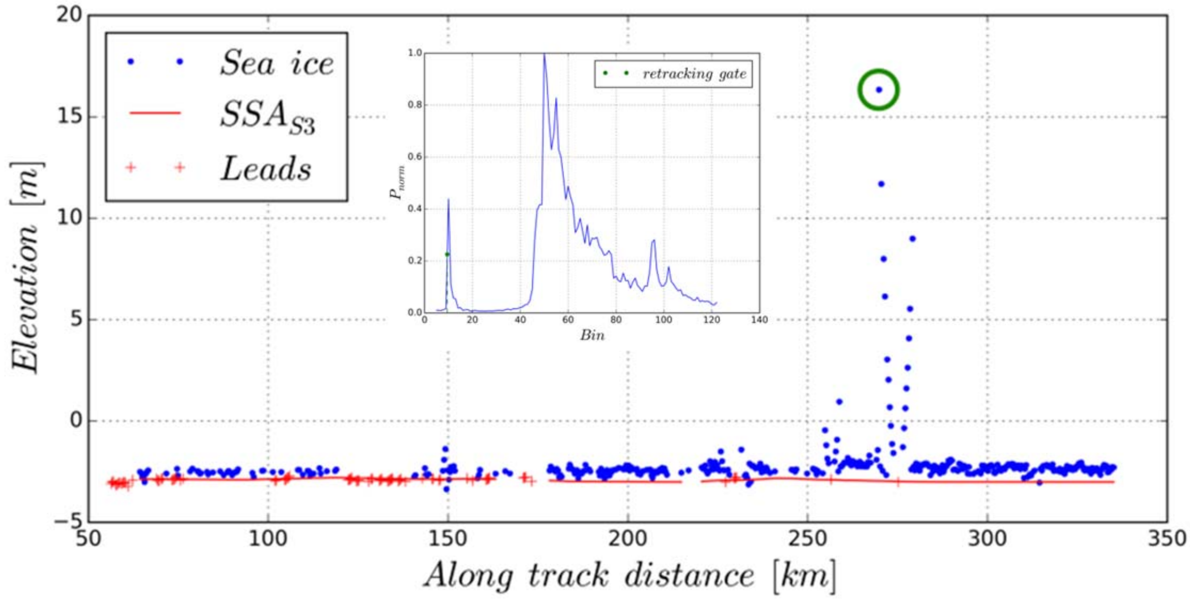
ESA has confirmed that S3A operated in SAR-mode on April 6 and provided the respective level 1b products (i.e. waveforms) so that a first comparison with ALS results could be performed. On the flight on April 10 S3A was switched to Low resolution mode (LRM). A preliminary inter-comparison study of S3A and ALS data from underflight on April 6 was presented at AGU fall meeting 2016 by Di Bella et al. (2016). A short update of the presentation is given below. The S3A waveforms have been classified using their pulse peakiness as being generated by reflections from sea ice or leads. While sea ice waveforms have been retracked using a threshold algorithm (TFMRA50%), lead elevations are estimated using a Gaussian retracker.

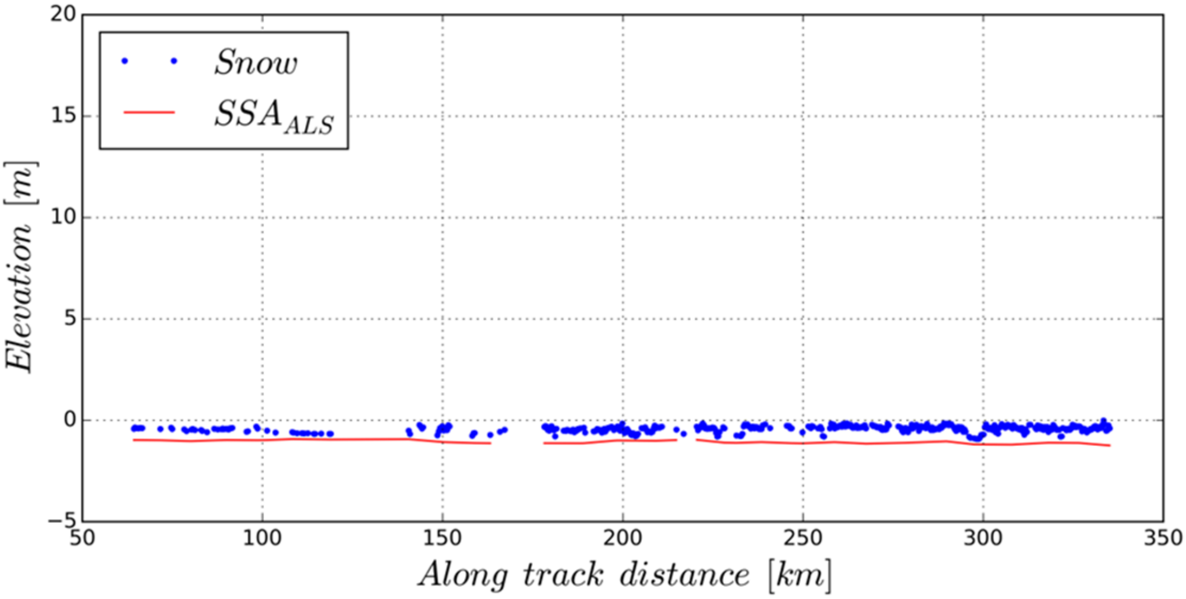
Elevation profiles from S3A and ALS can be observed in figure 1, where the blue dots in the upper plot show the sea ice elevations retrieved processing S3A data, while those in the bottom plot show the snow elevations obtained from ALS measurements. Both elevations have been detrended using the DTU15 mean sea surface (MSS). The red solid lines in the plots represent the sea surface anomalies (SSA), which have been determined by interpolating lead elevations along track.

Comparing the two profiles, an average bias of a couple of meters can be observed between S3A and ALS elevations. This is due to the geophysical corrections not being available for S3A measurements at the time when the processing was performed.

Additionally, the upper plot shows a series of extremely high elevations, up to 18 m, estimated by S3A around 275 km along track which is not observed in the bottom plot. The cause for these extreme elevations has been investigated by analyzing one of the waveforms, corresponding to the circled point in the upper plot of figure 1. Figure 2 shows that the TFMRA50% algorithm retracks the half-power point of the first peak around bin number 10 (green dot) instead of the main one around bin number 45. This kind of waveforms is not unusual in sea-ice-covered areas and might be associated with an ice floe inside the satellite footprint. In this case, however, ALS was not able to detect the ice floe, possibly due to its smaller footprint. In fact, while S3A coverage extends up to 1.6 km across track, ALS only covers 0.3 km in the same direction.

Overall, a fairly good agreement between S3A and ALS elevations has been found, especially taking into account that, in the common situation of snow-covered sea ice, the radar on board of S3A measures the height of a surface within the snowpack whereas ALS measures the height of the snow-air interface.




Snow
SSA_{ALS}
Elevation [m]
Along track distance [km]
20
15
10
5
0
−5
50
100
150
200
250
300
350

6.2.2 Triangle flight north of Station Nord

The triangle flight (STN-F1-F2-STN), has been flown repeatedly since 2003, and with a single beam laser in 1998. The primary aim of the 2016 flight was to get continuation in the data set, as there were problems with retrieval of ALS measurements during a similar flight flown within the EU ICE-ARC 2015 campaign.

The first part of the flight STN-F1 was originally planned as a coincident flight with NASA's Operation IceBridge (OIB) P-3 aircraft equipped with multiple sensors for sea ice and snow retrievals, where especially the snow depth radar is valuable for snow depth information to support estimation of ASIRAS penetration depths. Unfortunately this coincident flight was canceled due to unexpected aircraft maintenance of the OIB aircraft.

An example of the distribution of ALS freeboard heights from repeated flight tracks (2003-2016) of the sea ice north of Greenland (81-87°N), was presented at the ESA Living Planet Symposium by S. M. Hvidegaard et al. (2016), and is shown in Figure 14. The data set is unique and covers 13 years of observations – from April or May. The freeboard heights are retrieved from ALS by selecting the lowest values in the track data as described in Hvidegaard et al. (2002). The dotted lines mark datasets not covering the full flight line. Data from various campaigns show an overall thinning of the sea ice with large inter-annual changes overlaid.

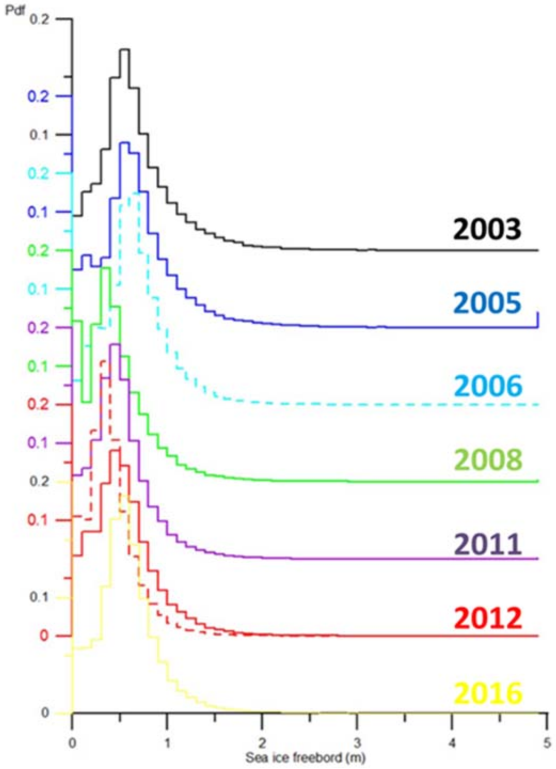


Figure 14: Sea ice freeboard heights from repeated flights north of Station Nord 2003 – 2016.

6.2.3 Upward looking sonars

Norwegian Polar Institute (NPI) maintains an array of upward looking sonar moorings located in the Fram Strait measuring the sea ice draft continuously in time. One of these buoys F14 at position 78 48.87N, 06 30.03W was overflown on April 9, along a straight N/S line to account for sea ice drift, see star in Figure 1. Similar over-flights have been collected in April 2012, 2014, 2015.

The airborne laser and radar measures, the sea ice freeboard (Hvidegaard and Forsberg (2002)), as is the case for CryoSat-2. Where the laser reflects on the top of the snow layer, the radar penetrates partly into the snow layer, depending on the snow conditions (Gerland et al. (2013), Hendricks et al. (2010), Willatt et al. (2011)). Thus, a combination of the airborne measurements complements the ULS measurements from below the ice to give an estimate of the thicknesses of the sea ice. These combined data sets are unique, and can be used to validate the sea ice freeboard to thickness conversion in a very dynamic sea ice area, to support CryoSat-2 sea ice thickness estimates. The data from the ULS have not yet been studied as there always is a lack in the availability of the buoy data, as these needs to be physically removed to download data.

Figure 15: Large scale snow drift pattern on sea ice, Fram Strait, April 2016.

7. Conclusion

The CryoVEx 2016/ICE-ARC airborne campaign has been a success. In general, the weather was good in Greenland, which allowed data acquisition from all planned flights, and partially good in Svalbard allowing 2 out of 3 planned flights to be carried out.

The instruments worked without any major problems and the data is of high quality based on cross-over analysis and runway overflights. ASIRAS was only operating by the use of PC1, which is possible in LAM-mode, due to a mal-function of PC2. Due to low temperatures (down to -35oC) at Station Nord, parts of the ALS data acquisition was limited due to icing of fog on the inside of the scanner window, primarily encountered during take-off and steep descends (e.g. down the Nioghalvfjerdsfjorden glacier). This partly prevented the laser to penetrate through the window, for the first hour of flight, resulting in no surface return or a narrow scan width. Slow climbs during take-off reduced the icing on the scanner window. The actual loss of data was limited since most of the flights included some ferry flight to the designated survey areas. Pre-processed ALS data show good results, and first results were already presented at ESA Living Planet May 9-13, 2016, in Prague, Czech Republic

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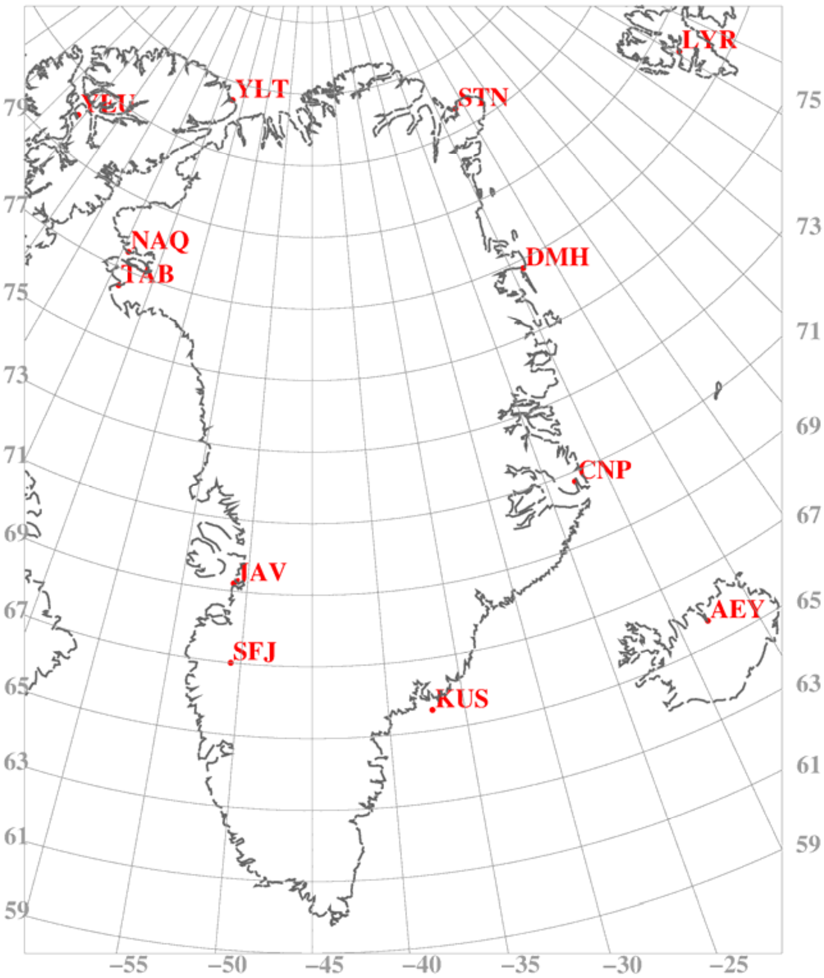
APPENDIX

Appendix A. Airport codes

IATA		Location	Land	Latitude	Longitude
AEY		Akureyri	Iceland	65.659994	-18.072703
CNP		Constable Pynt	Greenland	70.7444	-22.6482
n/a	DMH	Danmarkshavn	Greenland	76.7704	-18.6581
JAV		Ilulissat	Greenland	69.217	-51.083
KUS		Kulusuk	Greenland	65.573611	-37.123611
LYR		Longyearbyen	Norway	78.2456	15.4991
NAQ		Qaanaaq	Greenland	77.50	-69.25
n/a	STN	Station Nord	Greenland	81.5971	-16.6569
SFJ		Kangerlussuaq	Greenland	67.006	-50.703
THU		Thule AB	Greenland	76.53	-68.71
YEU		Eureka	Canada	79.994444	-85.811944
YLT		CFS Alert	Canada	82.500	-62.325



Appendix B. Operator logs

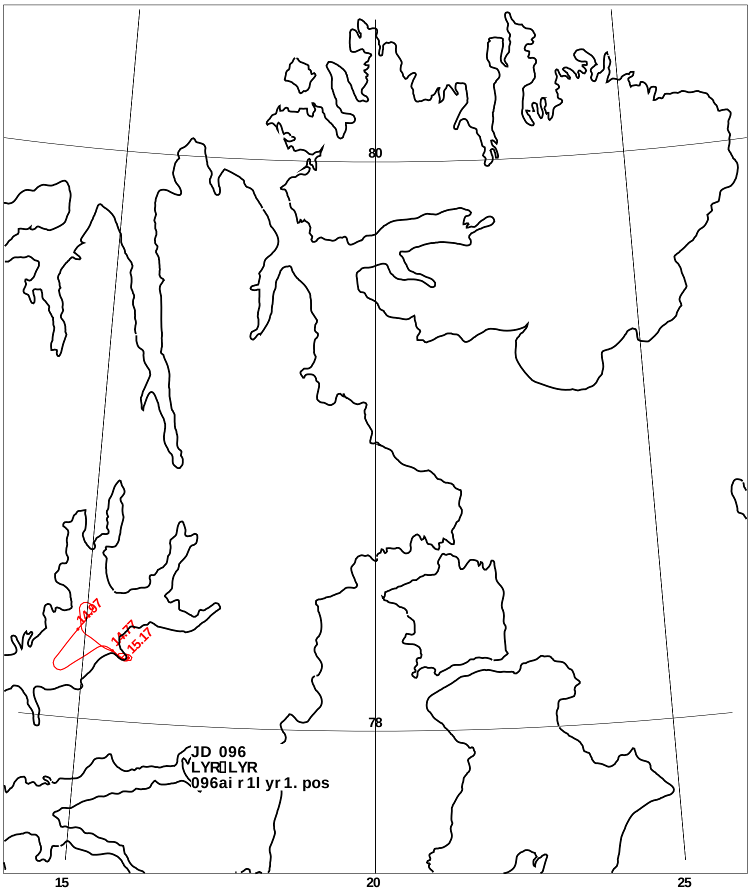
1.11 DOY 96, April 5, 2016: Test flight LYR (fjord and building) (hsk/ssim)

ALS-log:

14:45	Ready to Start
14:48	Take-off ? for overflight of fjord and building.
15:09	Building S -> N
15:11	Building W-> E
15:15	Building E -> W, On ground.

ASIRAS-log:

14:46	Taxi for test flight
14:47	Take-off
15:02	PC2 not working



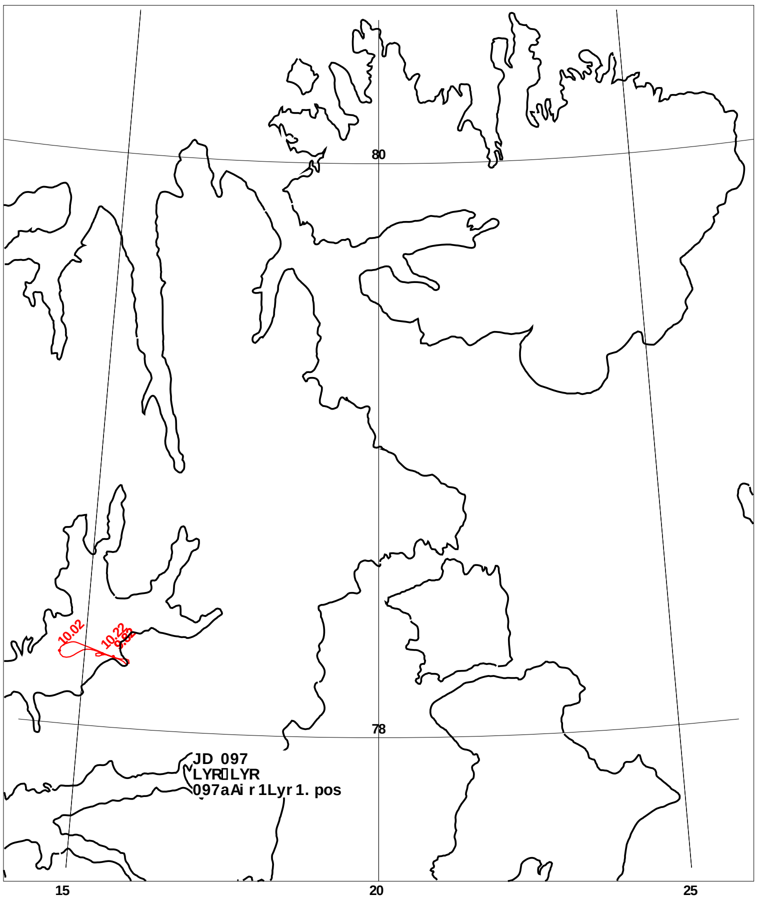
1.12 DOY 97, April 6, 2016: a) Test flight 2 LYR (fjord and runway) (hsk/ssim)

ALS-log:

09:53	Taxi
09:55	Take off
09:57:30	New scanner file, Asiras ok, Going for runway overflight at ~300 meters.
10:05	1st pass
10:09	2nd pass
10:10	close scanner file
10:14	On ground

ASIRAS-log:

09:39	Ready for ASIRAS test
09:53	Taxi
09:55	Take off
09:57	ASIRAS started and running new rec.
10:04	1st pass Event 0
10:06	turn for second pass
10:07	2nd pass of runway Event 1
10:08	stopped rec.
10:09	PC1 off
10:14	On ground



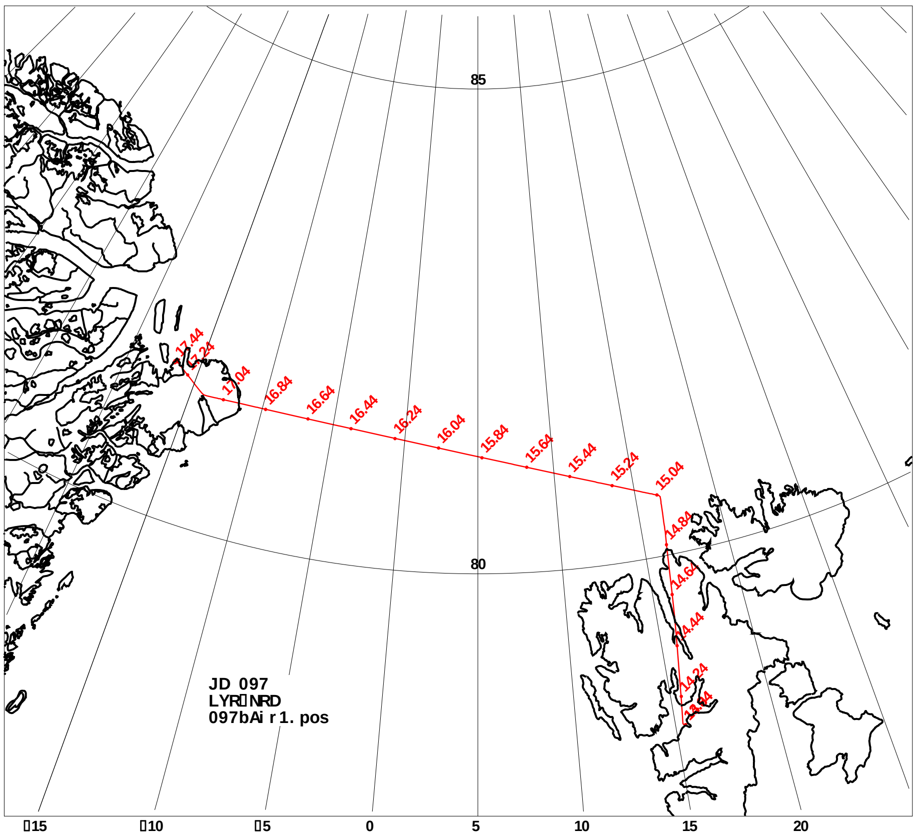
1.13 DOY 97, April 6, 2016: b) LYR – S3 – STN (hsk/ssim)

ALS-log:

hh:mm Taxi
hh:mm Take-off
14:20 Ops. Normal
14:31 uEye started
14:35:57 uEye stopped
14:37:20 uEye started
14:38:40 uEye stopped
14:39:20 uEye started
14:40 uEye started new exp. Setting
14:57:15 uEye started new exp. Setting
15:04:45 Started new scanner file 097_150445.2dd
15:08 Ops. On S3A-S3B little clouds
15:27:50 uEye started new exp. Setting
15:32 at s3b
15:38:00 uEye started new exp. Setting
15:47 Ops. Low clouds but returne on als
15:48 Ops. No clouds
15:51 uEye started new exp. Setting
15:55:10 new scanner file. Wrong sync in 097_155430.2dd, new flie 097_155510.2dd
16:03 At s3c
16:14 Ops. Normal
16:23 Ops. Ground fog
16:24 lost echo on scanner
16:27 Echo from clouds
16:29 Climbed 100ft
16:30 Sentinel-3 pass at N 81 24.43, W 04 50.03
16:31 Scanner stopped
16:32 Climbed 100ft
16:33 Climbed 100ft
16:34 at s3d
16:35 uEye stopped
16:43 new scanner file, but logging not started due to clouds
16:56:30 new scanner file for the survey of FIB
16:59 Echo from FIB
17:06 At s3e
17:16 done with FIB
17:18 first overflight and turn
17:21 second overflight
17:24 On ground STN

ASIRAS-log:

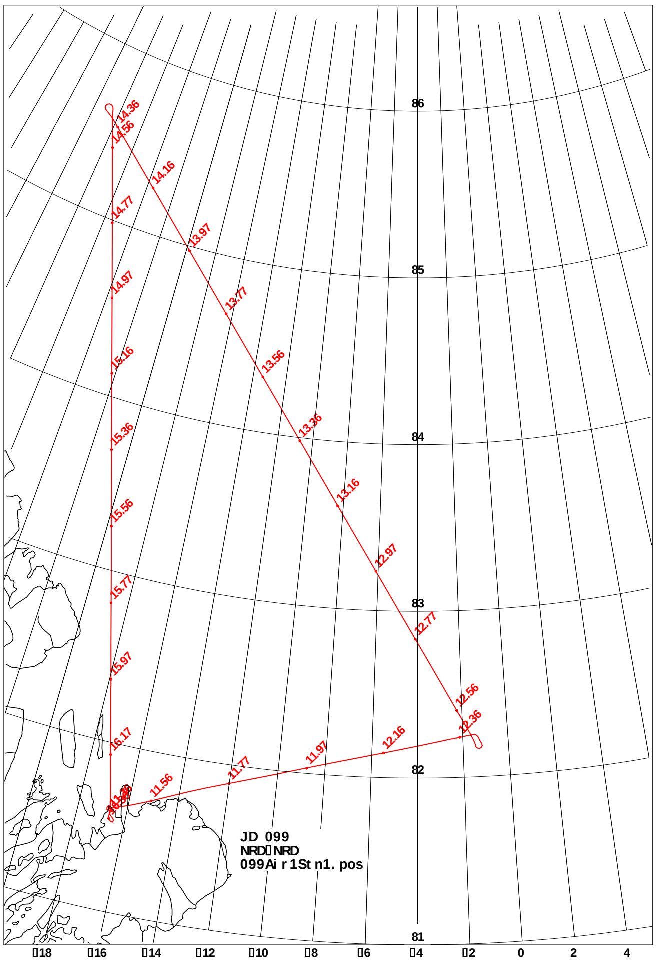
14:59 ASIRAS turn on
15:02 cal file A160406_
15:06 started rec.
15:41 clouds no als
16:00 New file 02_1_00
16:20 Low thin layer
16:23 lost als signal
16:27 Climbed 100ft above clouds
16:30 Climbed 100ft above clouds
16:33 Climbed to 420
16:37 Climbed to 480
16:37 uEye stopped
16:44 tested cloud base but had to climb to 540
16:54 New file 03
17:15 stop rec and calb.



1.14 DOY 99, April 8, 2016: STN-F1-F2-STN) (hsk/ssim)

ALS-log:

Before take-off (~-30 deg laser cold had to heat it, the laser is set to last pulse
11:22 Taxi
11:26 Take-off
11:28 Lost scanner echo during the climb, icing on internal window.
11:45 Scanner slowly warming, weak echo
11:47:50 New scanner file, Weak echo about only half the width.
11:52 Lost echo on scanner clouds
11:53 echo back
11:55 uEYE cannot be started
12:00 GoPro on
12:11 Ops. Normal good survey conditions the scanner is getting better.
12:23 At F1 and turn for teardrop
12:29 At f1
12:30 Scanner looks better, now about 150m scan
12:40:55 New scanner file (good scanner echo)
13:37:30 New scanner file, notification about sync error
14:23 at F2 and turn for teardrop. Resync. Scanner
14:27:40 New scanner file, no data
14:28:10 New scanner file, file stopped to fast, might have the xo of the teardrop
14:29:15 New scanner file, just after the crossing at f2, missing the XO
15:22:30 New scanner file, the fille 099_152200.2dd not started, the right file is 099_152230.2dd
16:03 Fast ice started about 15 min/38 nm out of STN
16:18 1st pass of rwy
16:22 2nd pass of rwy
16:25 crossing the rwy
16:26 stop scanner file
16:28 On ground STN



ASIRAS-log:

11:32 Startup ASIRAS
11:34 New ASIRAS File 00
12:21 F1
12:22 New ASIRAS File 01
13:16 Big ice islands
13:26 New ASIRAS File 02
14:22 F2
14:22 New ASIRAS File 03
15:20 New ASIRAS File 04
16:01 Ok conditions for work on the ice with snowmobile.
16:07 New ASIRAS File 05
16:16 Rwy overflight STN, 1 pass, event 1
16:20 Rwy overflight STN, 2 pass, event 1
16:27 On ground

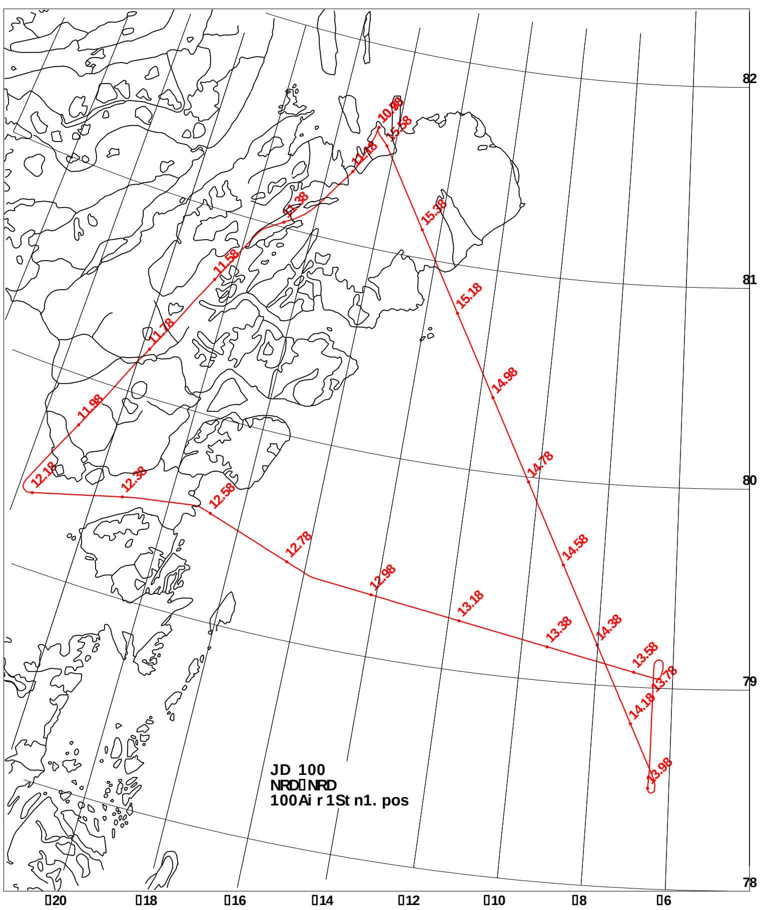
1.15 DOY 100, April 9, 2016: STN-79Glac-TOB-ULS-STN (hsk/ssim)

ALS-log:

10:43	GoPro started
10:58	Taxi
11:03	Take-off
11:05:30	New scanner file (using last pulse)
11:07	losing scanner echo, weak signal
11:16	Weak echo, flying high
11:20:00	Logging stopped
12:02:00	New scanner file, weak signal high altitude ice on mirror, only half return.
12:06	scanner ok
12:07	turn for G9
12:18	weak return from half the scanner, icing??
12:23	At G8
12:29	Scanner ok, the icing on the mirror correlates to the change in altitude
12:31	At the front of 79glacier
12:32	At G7
12:49	at TOB
13:02:05	New scanner file
13:37	ULN15 and tune left to tear drop
13:43	at ULN 16
13:50	at UL14
13:55	at ULS16 and turn for teardrop
13:56:55	New scanner file
14:03	at ULS15
14:19	XO of line TOB-ULN15
14:44:05	New scanner file, called 100_1444405.2dd
15:17	front of FIB
15:34	Scanner stopped
15:38	On ground STN

ASIRAS-log:

11:03	Take-off at STN
11:07	Turned on ASIRAS and cal.
11:57	Started record
11:59	Ice edge
12:08	WP G1 79glacier
~12:30	At glacier front
12:53	New file 01
12:56	Fast ice / Drifting ice edge
13:35	ULSN15 -> ULSN16
13:48	ULSF14, event 1, Prevailing wind NE 45deg right of flight direction
13:55	ULS S16
13:56	New ASIRAS File 02
14:58	New ASIRAS file 03
15:15	Flade isblink
15:30	Shut down ASIRAS



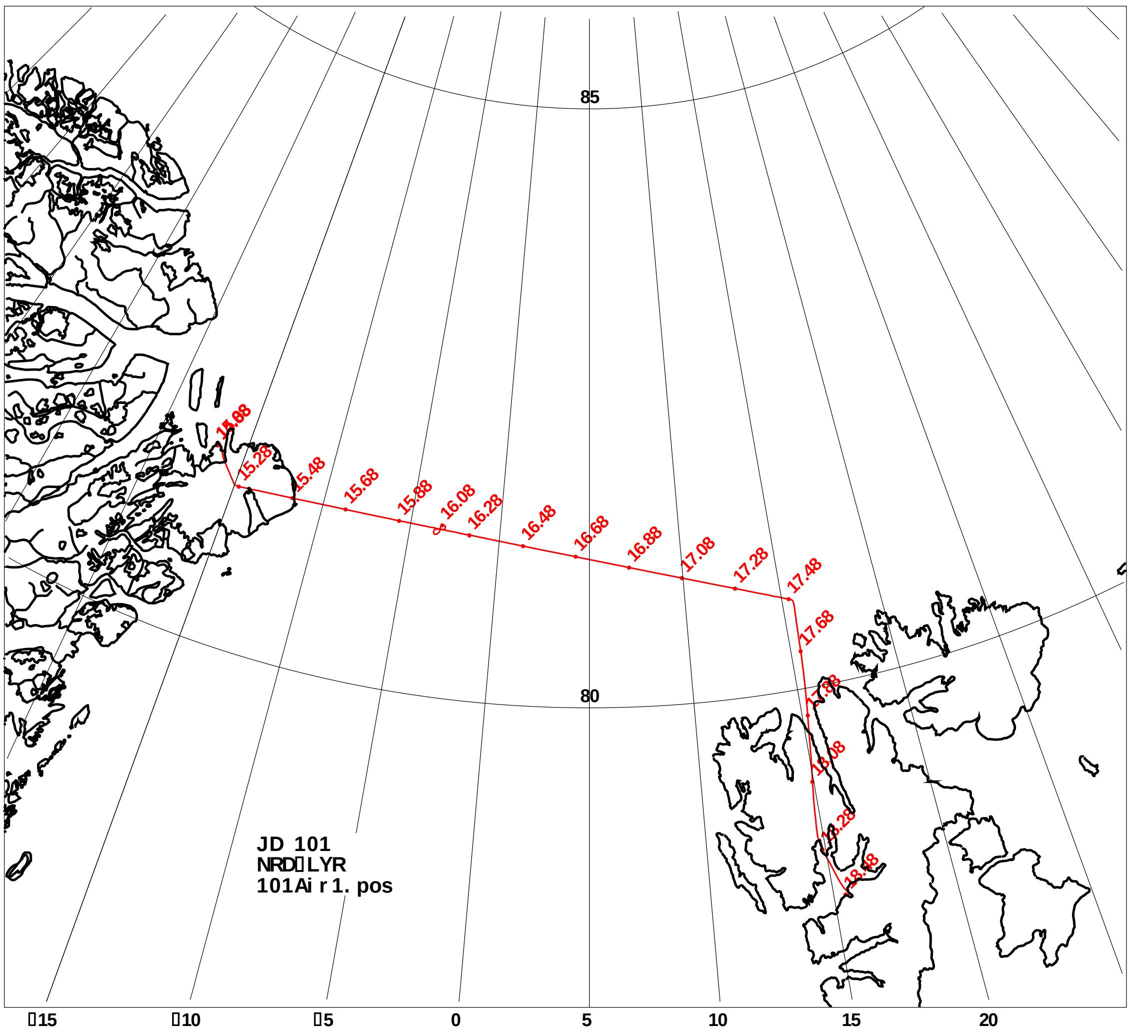
1.16 DOY 101, April 10, 2016: STN-S3A 769 – LYR (hsk/ssim)

ALS-Log:

14:21 GoPro turn on
15:01 Taxi-off
15:05:55 New scanner file, scanner set to last pulse
15:08 icing in scanner only half the scan
15:15 At S3F
15:17 Strong winds at FIB, drifting snow. Almost no scanner echo
15:23 Echo back only half width
15:29 off FIB
15:30 scanner width increasing
15:47 at S3G
15:59:30 New scanner file
16:02 teardrop right
16:05 XO of track
16:09 Back on track and XO of XO
16:27 S3 passing, at 81 20.24N 01 07.00 E
16:58 At S3I
16:59:50 New scanner file
17:22 Low clouds, ok echo
17:28 Break line and heading for LYR, about 3 min from S3J
17:28 Stopping Scanner
17:41 GoPro stopped
18:27 On Ground LYR

ASIRAS-log:

15:07 Turned on ASIRAS and Cal
15:08 Started log 00
16:00 New ASIRAS file 01 , Tear drop
16:27 S3A passage time
17:00 New ASIRAS file 02
17:26 Stop file and cal
18:28 Landed, On ground LYR.



1.17 DOY 106, April 15, 2016: LYR-Austfonna-LYR (ssim / slss)

ALS-log:

08:27 Taxi
08:29 Take off
09:23 Reached Austfonna. Cloudy.
09:26 New scanner file 106_092600.2dd

09:26-09:46 Many clouds in the area. When flying along the crossing (W-E) line only very little LiDAR could be collected. It was decided to try a different CS track. Aim for CS26.

09:46 Free of clouds on CS26N- CS26S. But Northern part of the planned tracks are completely cloud covered.
10:02 New scanner file 106_100230.2dd
10:04 At L11s26
10:19 Break line due to clouds
10:22 On track R5n26-R5s26
10:41 On track L9s26- L9n26

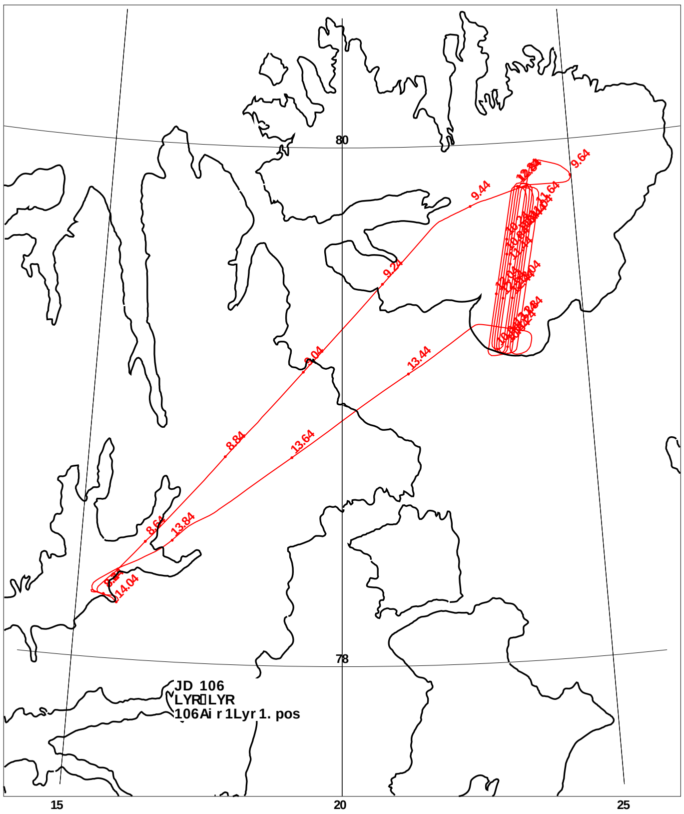
ASIRAS-log:
08:28 Take off
08:43 Cal
09:15 Cal
09:17 Started ASIRAS file 00_1_00
09:18 At 720 m alt.
09:24 At 300 m alt.
09:29 Low clouds
09:37 Changing plans for flight due to clouds. Going for the CS2 pass at the 26 of April
09:40 At new line
09:50 ops. Normal
10:00 turn and start/stop file 01_1_00, then started file 02_1_00
10:01 Northbound line
10:17 Turn
10:36 next line
10:39 on line and ice
10:55 turn
10:55 new file 03_1_00
11:03 turn clouds
11:32 turn end of line
11:51 turn and new file 04_1_00
12:11 turn clouds at the north dome of Austfonna
12:14 on line southbound
12:30 end of line
12:34 on line north

10:58 New scanner file 106_105800.2dd
11:00 On track R9s26- R9n26
11:18 On track R5s26- R5n26
11:37 On track R13n26- R13s26
11:54 New scanner file 106_115400.2dd

No more planned tracks as WPs. Decide to densify grid to 1km spacing. The following lines were flown as 1000m west of other tracks.

11:57 Start of track : 1000m west of L11 ('L13')
12:15 Start of track : 1000m west of R5 ('R3')
12:33 Start of track : 1000m west of L5 ('L3')
12:51 New scanner file 106_125130.2dd
12:53 Start of track : 1000m west of L9 ('L7')
13:10-13:18 Crossing all lines
13:54 New scanner file 106_135400.2dd two runway overflights
14:08 Landing

12:47 turn for south bound
12:48 new file *05*_1_00
12:50 on line south
13:06 turn left for cross of all lines
13:15 end of grid xo
13:16 stop record
13:53 started asiras for runway overflight, new file 06_1_00
13:57 1st pass event 0
14:01 2nd pass event 1
14:03 stopped
14:03 cal



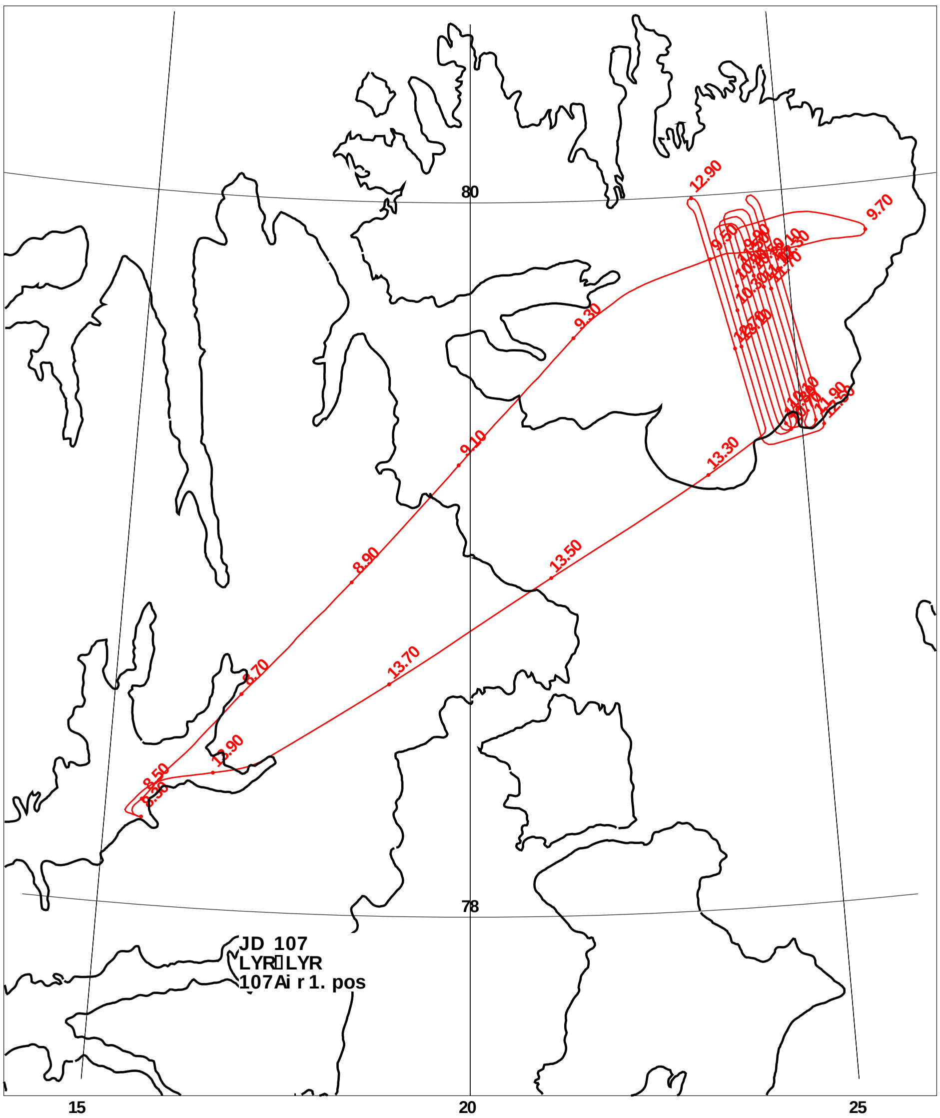
1.18 DOY 107, April 16, 2016. LYR-Austfonna-LYR (ssim / slss)

ALS-log:

08:24	Taxi
08:26	Take off
09:22	At ETON1. Cloudy.
09:23	New scanner file: 107_092330.2dd. No clouds.
09:47	Clouds. We will have to skip the northern-most part of all tracks.
09:50	On track CS19n-CS19s
10:09	On track L13s19- L13n19
10:23	Break off line
10:25	New scanner file: 107_102500.2dd
10:27	On track R5n19- R5s19
10:43	On track L9s19- L9n19
10:59	Break off line
11:01	On track R9n19- R9s19
11:15	Break off line
11:16	New scanner file: 107_111630.2dd
12:11	New scanner file: 107_121100.2dd
12:13-	Without WPs: on tracks 'R21n19-R21s19' followed by 'L21s19-L21n19'
1402	Landing

ASIRAS-log:

08:26	Take-off
09:04	cal
09:09	cal
09:10	Record without return, altitude?
09:14	rec stop
09:16	cal
09:17	start new file 01_1_00
09:39	turn for grid around CS2 April 19
09:50	at CS2 line
10:04	turn at coast
10:07	on line northbound
10:22	new file 02_1_00
11:14	turn new file 03_1_00
12:08	turn new file 04_1_00
13:10	turn and end of rec
13:10	cal and closing down



Appendix C. GPS Processing

1.19 Airborne rovers

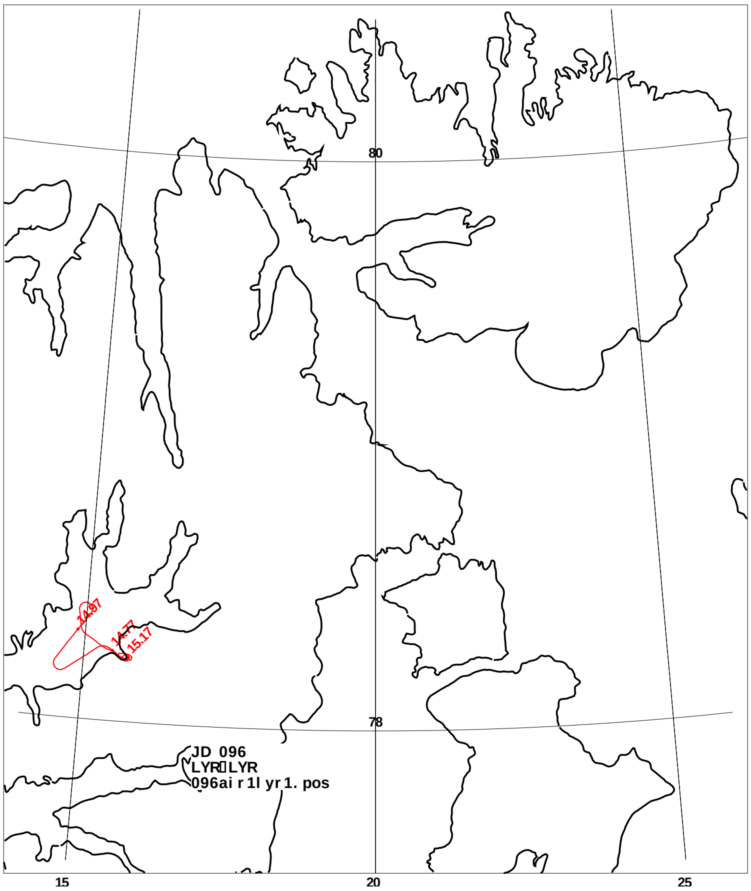
All GPS processing have been done in GrafNav8.30. Table [] provide the raw and processed files, and the statistics given by GrafNav8.30. Based on the provided statistics and the plotted SD of the elevation a preferred GPS solution is found. The preferred solution is indicated with green in the table below.

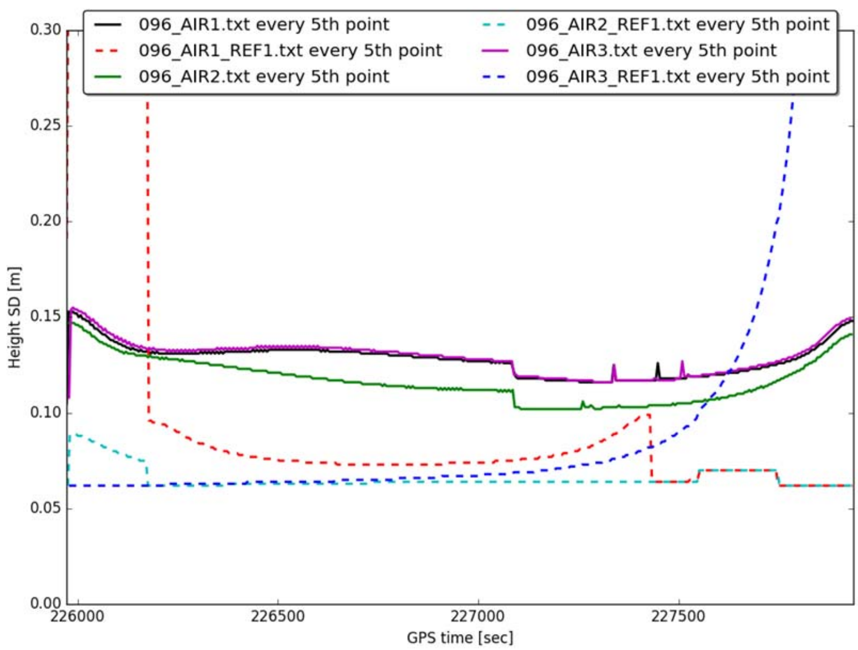
Date	DOY	Position Standard Deviation Percentages	AIR1 PPP		AIR1 Diff name		AIR2 PPP		AIR2 Diff		AIR3 PPP		AIR3 Diff		Quality Number Percentages
05-04-2016	96	Name	096_AIR1.txt		096_AIR1_REF1.txt		096_AIR2.txt		096_AIR2_REF1.txt		096_AIR3.txt		096_AIR3_REF1.txt		Name
		0.00 - 0.10 m:	0.0 %	0.0 %	25.7 %	12.2 %	0.0 %	0.0 %	100.0 %	79.8 %	0.0 %	0.0 %	100.0 %	96.9 %	Q1
		0.10 - 0.30 m:	100.0 %	91.3 %	64.0 %	68.8 %	100.0 %	100.0 %	0.0 %	20.1 %	100.0 %	89.9 %	0.0 %	3.0 %	Q2
		0.30 - 1.00 m:	0.0 %	8.7 %	10.3 %	11.1 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	10.1 %	0.0 %	0.0 %	Q3
		1.00 - 5.00 m:	0.0 %	0.0 %	0.0 %	7.5 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.1 %	Q4
		5.00 m + over:	0.0 %	0.0 %	0.0 %	0.4 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	Q5
		Accumulated gaps [sec]	0	0.0 %	0	0.0 %	0	0.0 %	0	0.0 %	0	0.0 %	0	0.0 %	Q6
06-04-2016	97a	Name	097a_AIR1		097a_AIR1_REF1.txt		097a_AIR2.txt		097a_AIR2_REF1.txt		097a_AIR3.txt		097a_AIR3_REF1.txt		Name
		0.00 - 0.10 m:	0.0 %	0.0 %	59.3 %	22.4 %	0.0 %	0.0 %	87.5 %	0.0 %	0.0 %	0.0 %	87.2 %	0.0 %	Q1
		0.10 - 0.30 m:	100.0 %	100.0 %	40.7 %	64.7 %	98.9 %	98.6 %	12.5 %	100.0 %	99.3 %	99.2 %	12.8 %	99.6 %	Q2
		0.30 - 1.00 m:	0.0 %	0.0 %	0.0 %	10.5 %	0.2 %	0.3 %	0.0 %	0.0 %	0.1 %	0.1 %	0.0 %	0.4 %	Q3
		1.00 - 5.00 m:	0.0 %	0.0 %	0.0 %	2.3 %	0.8 %	0.2 %	0.0 %	0.0 %	0.3 %	0.1 %	0.0 %	0.0 %	Q4
		5.00 m + over:	0.0 %	0.0 %	0.0 %	0.1 %	0.1 %	0.1 %	0.0 %	0.0 %	0.2 %	0.1 %	0.0 %	0.0 %	Q5
		Accumulated gaps [sec]	22	0.0 %	0	0.0 %	201	0.8 %	0	0.0 %	29	0.5 %	0	0.0 %	Q6
06-04-2016	97b	Name	097b_AIR1.txt		No Ref.		097b_AIR2.txt		No Ref.		097b_AIR3.txt		No Ref.		Name
		0.00 - 0.10 m:	19.3 %	0.0 %			21.7 %	0.0 %			19.3 %	0.0 %			Q1
		0.10 - 0.30 m:	80.6 %	100.0 %			78.2 %	100.0 %			80.7 %	99.9 %			Q2
		0.30 - 1.00 m:	0.0 %	0.0 %			0.0 %	0.0 %			0.0 %	0.0 %			Q3
		1.00 - 5.00 m:	0.0 %	0.0 %			0.0 %	0.0 %			0.0 %	0.0 %			Q4
		5.00 m + over:	0.0 %	0.0 %			0.0 %	0.0 %			0.1 %	0.0 %			Q5
		Accumulated gaps [sec]	15	0.0 %			0	0.0 %			0	0.1 %			Q6
08-04-2016	99	Name	099_AIR1.txt		099_AIR1_STN1.txt		099_AIR2.txt		099_AIR2_STN1.txt		099_AIR3.txt		099_AIR3_STN1.txt		Name
		0.00 - 0.10 m:	8.4 %	0.0 %	20.6 %	0.0 %	12.5 %	0.0 %	39.0 %	58.8 %	7.8 %	0.0 %	29.8 %	0.0 %	Q1
		0.10 - 0.30 m:	91.6 %	100.0 %	79.4 %	88.0 %	87.5 %	100.0 %	61.0 %	37.6 %	92.2 %	100.0 %	70.2 %	98.0 %	Q2
		0.30 - 1.00 m:	0.0 %	0.0 %	0.0 %	10.1 %	0.0 %	0.0 %	0.0 %	3.5 %	0.0 %	0.0 %	0.0 %	2.0 %	Q3
		1.00 - 5.00 m:	0.0 %	0.0 %	0.0 %	1.8 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	Q4
		5.00 m + over:	0.0 %	0.0 %	0.0 %	0.1 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	Q5
		Accumulated gaps [sec]	13	0.0 %		0.0 %	15	0.0 %		0.0 %	6	0.0 %		0.0 %	Q6
09-04-2016	100	Name	100_AIR1.txt		100_AIR1_STN1.txt		100_AIR2.txt		100_AIR2_STN1.txt		100_AIR3.txt		100_AIR3_STN1.txt		Name
		0.00 - 0.10 m:	21.2 %	0.0 %	21.8 %	0.0 %	22.4 %	0.0 %	33.7 %	1.8 %	21.2 %	0.0 %	31.7 %	0.0 %	Q1
		0.10 - 0.30 m:	78.8 %	100.0 %	77.1 %	85.9 %	77.5 %	99.9 %	66.3 %	88.8 %	78.8 %	99.9 %	68.2 %	94.0 %	Q2
		0.30 - 1.00 m:	0.0 %	0.0 %	1.1 %	9.1 %	0.0 %	0.0 %	0.0 %	8.5 %	0.0 %	0.0 %	0.0 %	5.9 %	Q3
		1.00 - 5.00 m:	0.0 %	0.0 %	0.0 %	4.2 %	0.0 %	0.0 %	0.0 %	0.8 %	0.0 %	0.0 %	0.1 %	0.1 %	Q4
		5.00 m + over:	0.0 %	0.0 %	0.0 %	0.8 %	0.1 %	0.0 %	0.0 %	0.0 %	0.1 %	0.0 %	0.0 %	0.0 %	Q5
		Accumulated gaps [sec]	18	0.0 %	0	0.0 %	0	0.1 %	0	0.0 %	6	0.1 %	0	0.0 %	Q6
10-04-2016	101	Name	101_AIR1.txt		No Ref.		101_AIR2.txt		No Ref.		101_AIR3.txt		No Ref.		Name
		0.00 - 0.10 m:	17.0 %	0.0 %			17.0 %	0.0 %			17.0 %	0.0 %			Q1
		0.10 - 0.30 m:	83.0 %	99.7 %			83.0 %	99.7 %			83.0 %	99.7 %			Q2
		0.30 - 1.00 m:	0.0 %	0.3 %			0.0 %	0.3 %			0.0 %	0.3 %			Q3
		1.00 - 5.00 m:	0.0 %	0.0 %			0.0 %	0.0 %			0.0 %	0.0 %			Q4

		5.00 m + over:	0.0 %	0.0 %			0.0 %	0.0 %			0.0 %	0.0 %			Q5
		Accumulated gaps [sec]	18	0.0 %			13	0.0 %			15	0.0 %			Q6
15-04-2016	106	Name	106_AIR1.txt		106_AIR1_LYR1.txt		106_AIR2.txt		106_AIR2_LYR1.txt		106_AIR3.txt		106_AIR3_LYR1.txt		Name
		0.00 - 0.10 m:	12.1 %	0.0 %	22.8 %	2.4 %	12.5 %	0.0 %	60.8 %	0.0 %	12.2 %	0.0 %	52.7 %	0.0 %	Q1
		0.10 - 0.30 m:	87.9 %	100.0 %	77.2 %	87.5 %	87.5 %	100.0 %	39.2 %	95.4 %	87.8 %	100.0 %	47.3 %	93.8 %	Q2
		0.30 - 1.00 m:	0.0 %	0.0 %	0.0 %	7.9 %	0.0 %	0.0 %	0.0 %	3.8 %	0.0 %	0.0 %	0.0 %	5.4 %	Q3
		1.00 - 5.00 m:	0.0 %	0.0 %	0.0 %	2.1 %	0.0 %	0.0 %	0.0 %	0.7 %	0.0 %	0.0 %	0.0 %	0.8 %	Q4
		5.00 m + over:	0.0 %	0.0 %	0.0 %	0.1 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	Q5
		Accumulated gaps [sec]	107	0.0 %	0	0.0 %	48	0.0 %	0	0.0 %	79	0.0 %	0	0.0 %	Q6
16-04-2016	107	Name	107_AIR1.txt		107_AIR1_LYR1.txt		107_AIR2.txt		107_AIR2_LYR1.txt		107_AIR3.txt		107_AIR3_LYR1.txt		Name
		0.00 - 0.10 m:	12.0 %	0.0 %	11.4 %	2.2 %	12.3 %	0.0 %	39.0 %	0.0 %	12.0 %	0.0 %	29.4 %	0.1 %	Q1
		0.10 - 0.30 m:	88.0 %	100.0 %	88.6 %	83.6 %	87.7 %	100.0 %	61.0 %	89.6 %	88.0 %	100.0 %	70.6 %	91.2 %	Q2
		0.30 - 1.00 m:	0.0 %	0.0 %	0.0 %	8.3 %	0.0 %	0.0 %	0.0 %	9.4 %	0.0 %	0.0 %	0.0 %	6.8 %	Q3
		1.00 - 5.00 m:	0.0 %	0.0 %	0.0 %	5.0 %	0.0 %	0.0 %	0.0 %	1.0 %	0.0 %	0.0 %	0.0 %	1.7 %	Q4
		5.00 m + over:	0.0 %	0.0 %	0.0 %	0.9 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.3 %	Q5
		Accumulated gaps [sec]	38	0.0 %	0	0.0 %	31	0.0 %	0	0.0 %	42	0.0 %	0	0.0 %	Q6
Date	**DOY**	**Position Standard Deviation Percentages**	**AIR1 PPP**		**AIR1 Diff name**		**AIR2 PPP**		**AIR2 Diff**		**AIR3 PPP**		**AIR3 Diff**		**Quality Number Percentages**

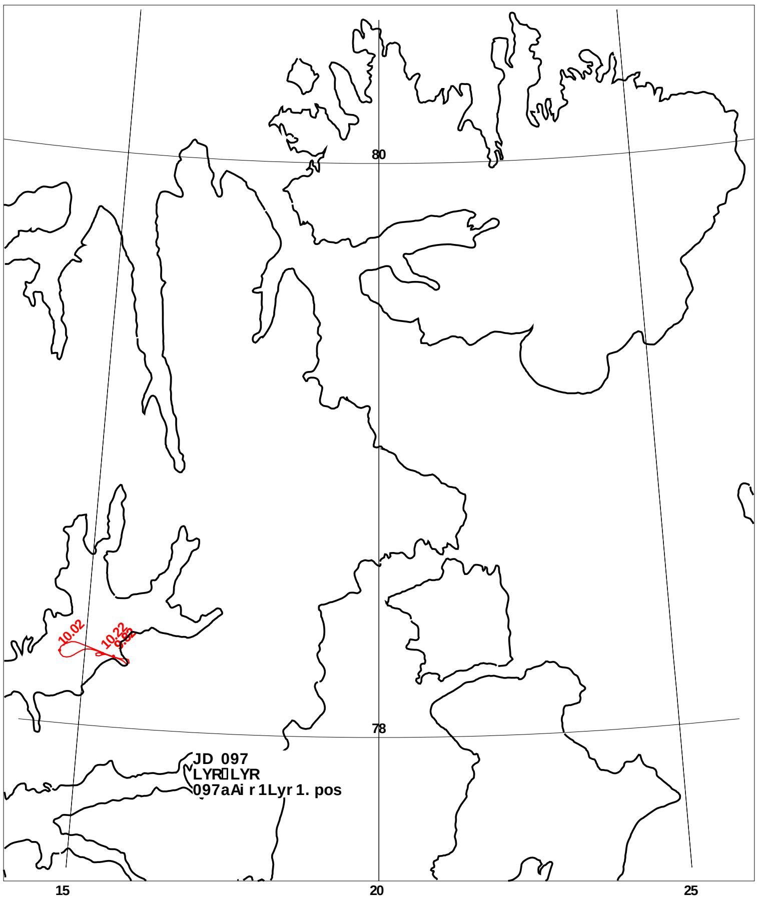
Table 1 Statistics for the GPS processing. Green indicate the preferred solution.

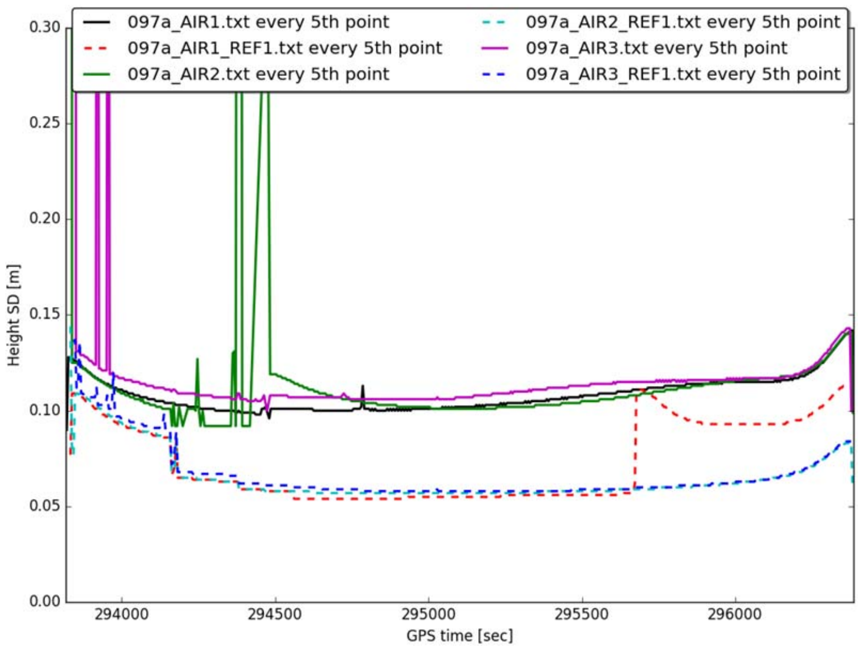
DOY 96


80
78
15
20
25
JD 096
LYR LYR
096air1lyr1.pos
14.97
14.77
15.17

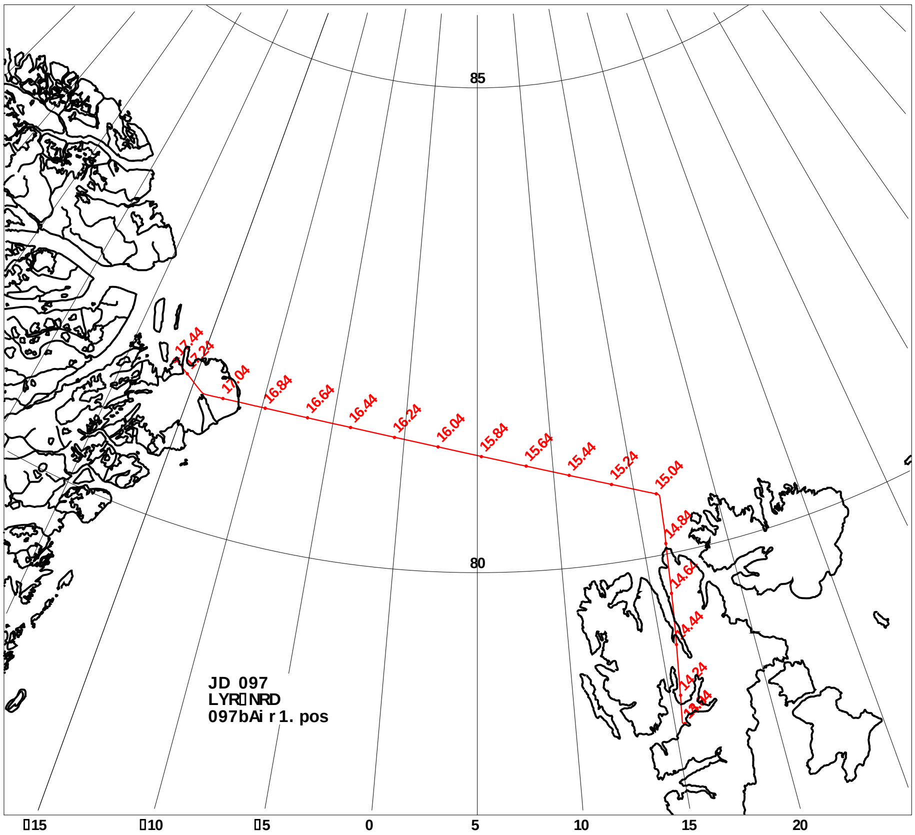

096_AIR1.txt every 5th point
096_AIR1_REF1.txt every 5th point
096_AIR2.txt every 5th point
096_AIR2_REF1.txt every 5th point
096_AIR3.txt every 5th point
096_AIR3_REF1.txt every 5th point
Height SD [m]
0.30
0.25
0.20
0.15
0.10
0.05
0.00
226000
226500
227000
227500
GPS time [sec]

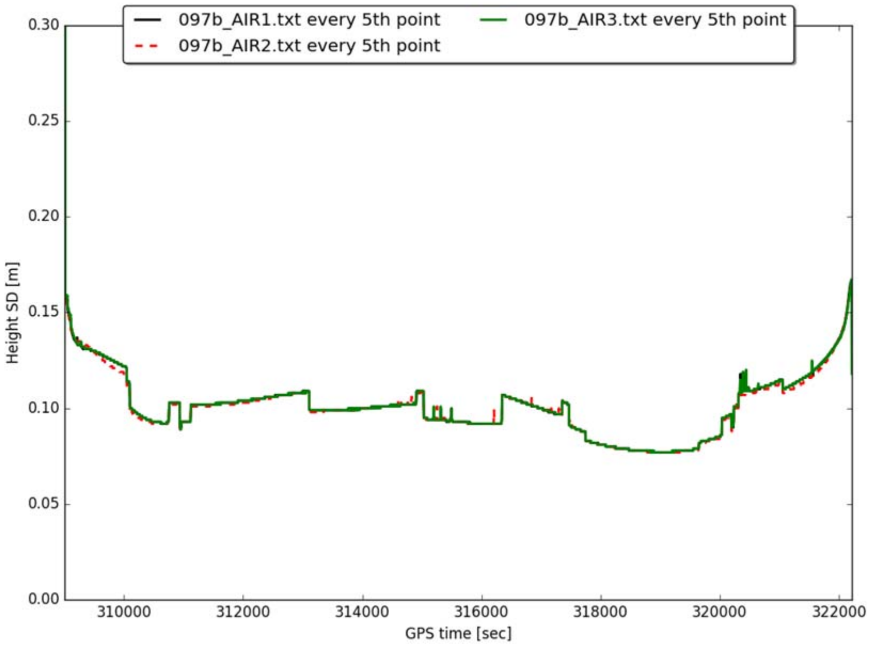
DOY 97a


80
78
JD 097
LYR LYR
097aAi r 1Lyr 1. pos
15
20
25

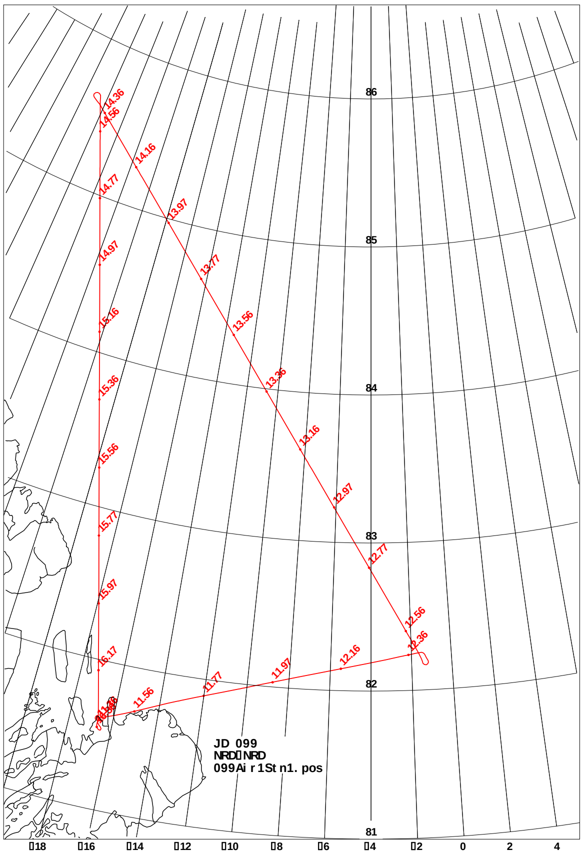

097a_AIR1.txt every 5th point
097a_AIR1_REF1.txt every 5th point
097a_AIR2.txt every 5th point
097a_AIR2_REF1.txt every 5th point
097a_AIR3.txt every 5th point
097a_AIR3_REF1.txt every 5th point
Height SD [m]
0.30
0.25
0.20
0.15
0.10
0.05
0.00
294000
294500
295000
295500
296000
GPS time [sec]

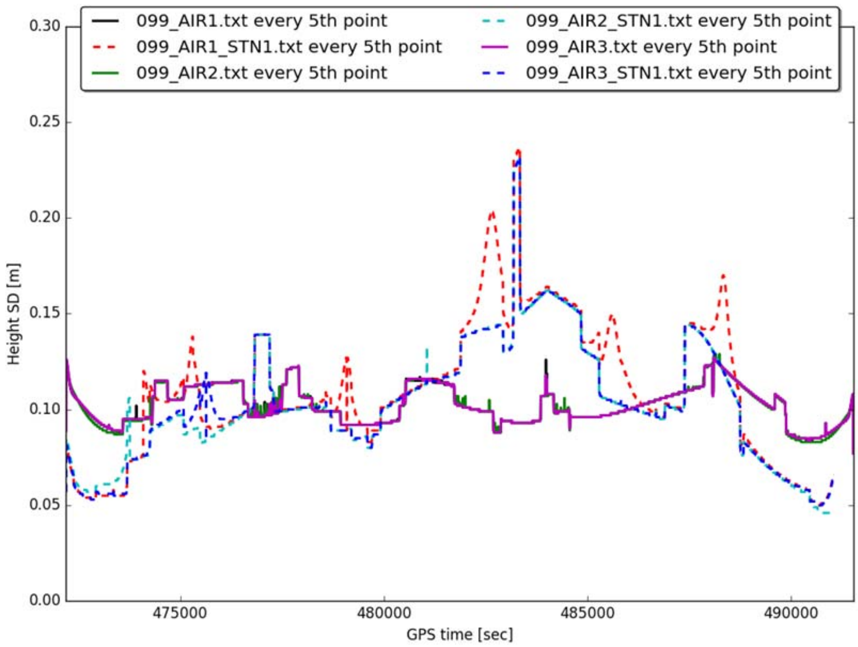
DOY 97b


85
80
JD 097
LYR‑NRD
097bAi r 1. pos
17.44
17.24
17.04
16.84
16.64
16.44
16.24
16.04
15.84
15.64
15.44
15.24
15.04
14.84
14.64
14.44
14.24
14.04
‑15
‑10
‑5
0
5
10
15
20

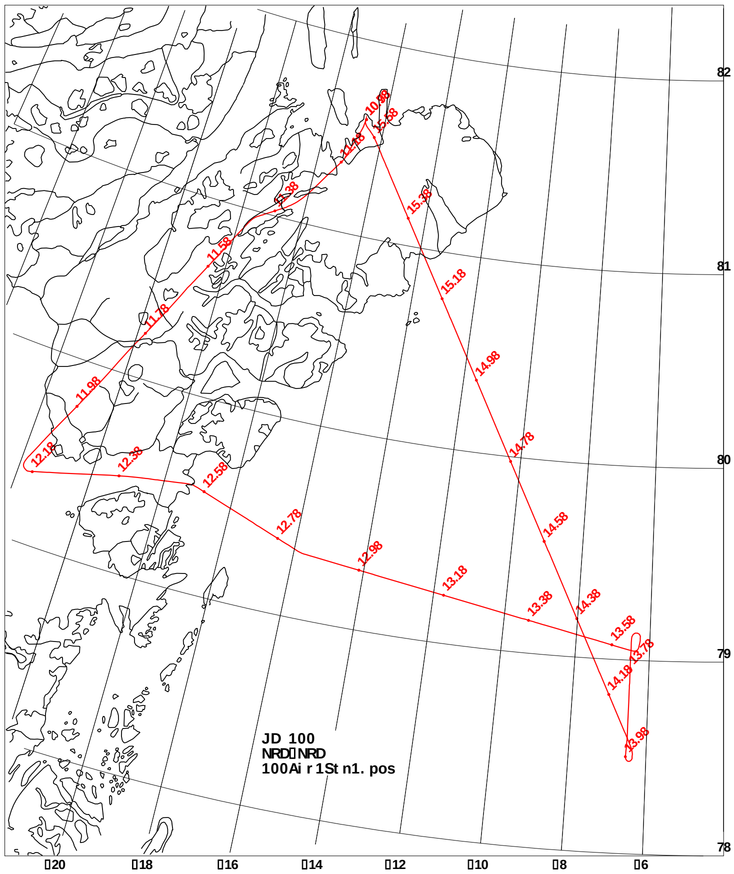

097b_AIR1.txt every 5th point
097b_AIR2.txt every 5th point
097b_AIR3.txt every 5th point
Height SD [m]
GPS time [sec]
0.30
0.25
0.20
0.15
0.10
0.05
0.00
310000
312000
314000
316000
318000
320000
322000

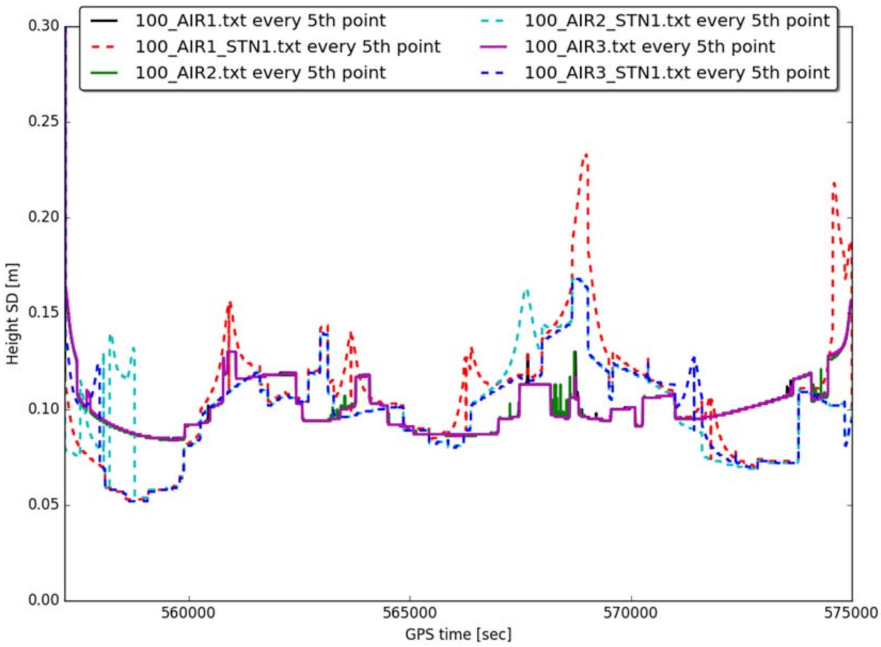
DOY 99



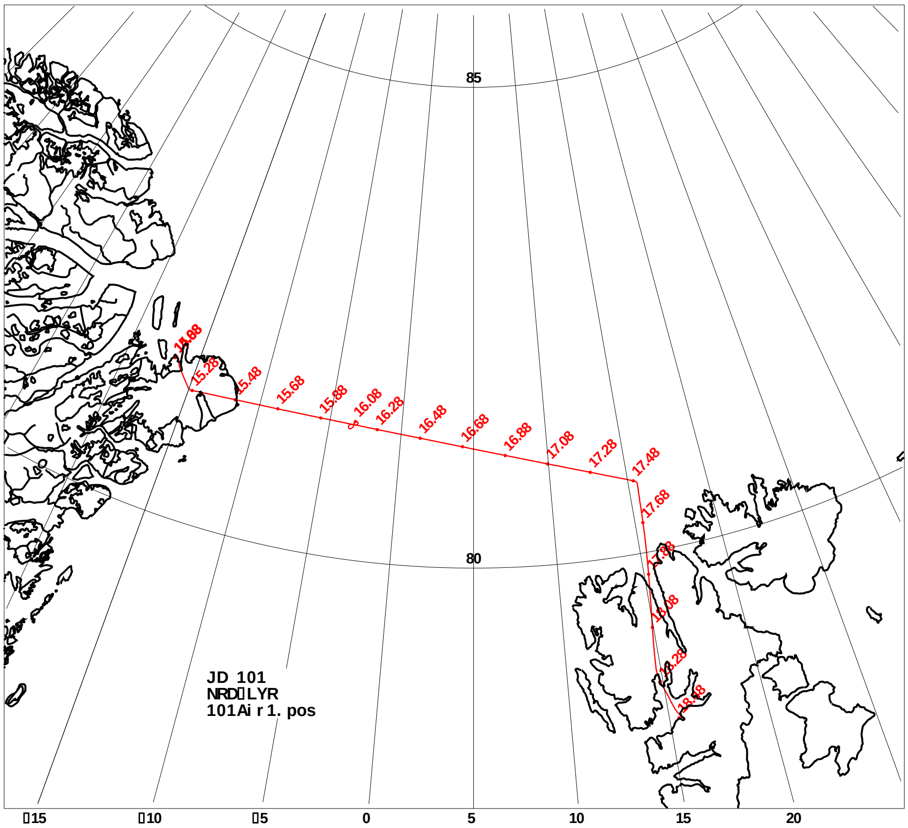

099_AIR1.txt every 5th point
099_AIR1_STN1.txt every 5th point
099_AIR2.txt every 5th point
099_AIR2_STN1.txt every 5th point
099_AIR3.txt every 5th point
099_AIR3_STN1.txt every 5th point
Height SD [m]
GPS time [sec]
0.00
0.05
0.10
0.15
0.20
0.25
0.30
475000
480000
485000
490000

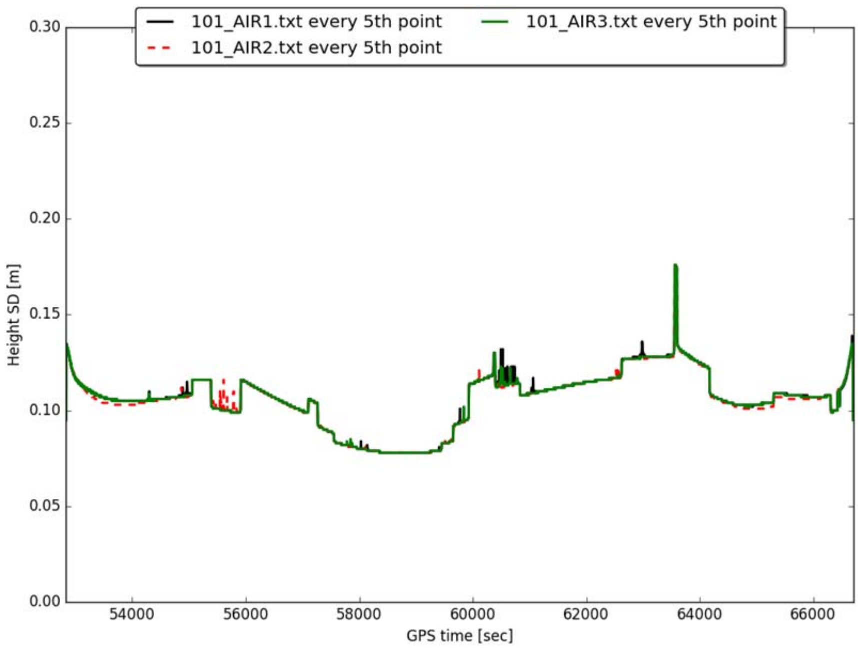
DOY 100


JD 100
NRD NRD
100Air1Stn1.pos
82
81
80
79
78

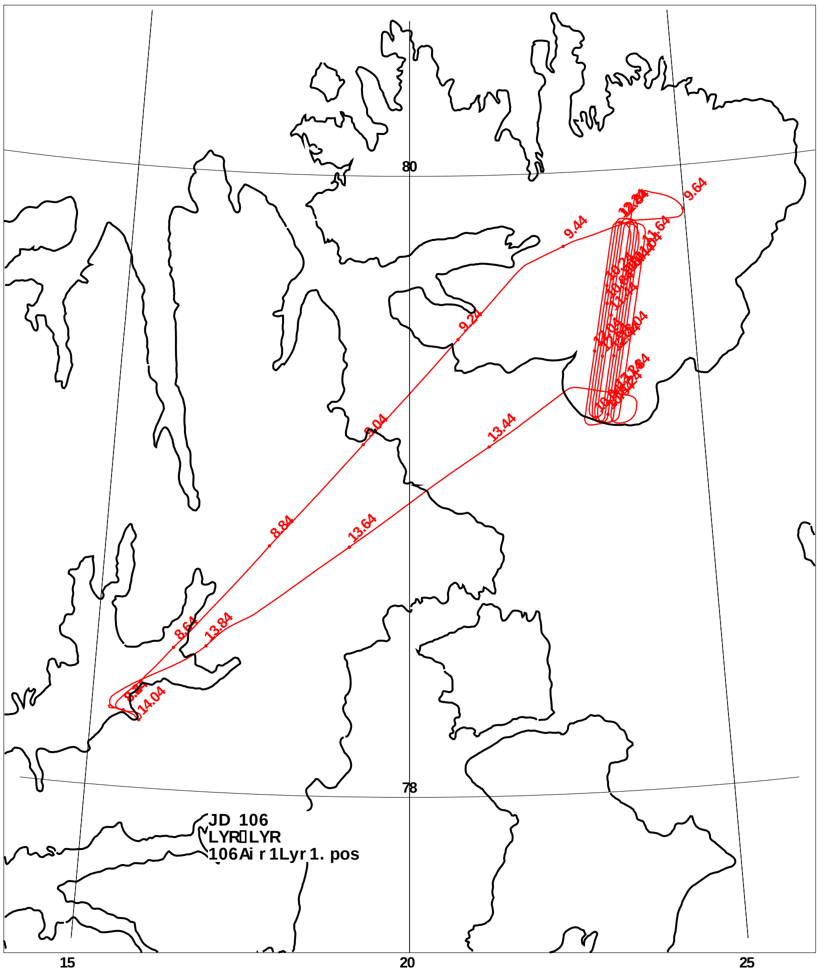

100_AIR1.txt every 5th point
100_AIR1_STN1.txt every 5th point
100_AIR2.txt every 5th point
100_AIR2_STN1.txt every 5th point
100_AIR3.txt every 5th point
100_AIR3_STN1.txt every 5th point
Height SD [m]
GPS time [sec]

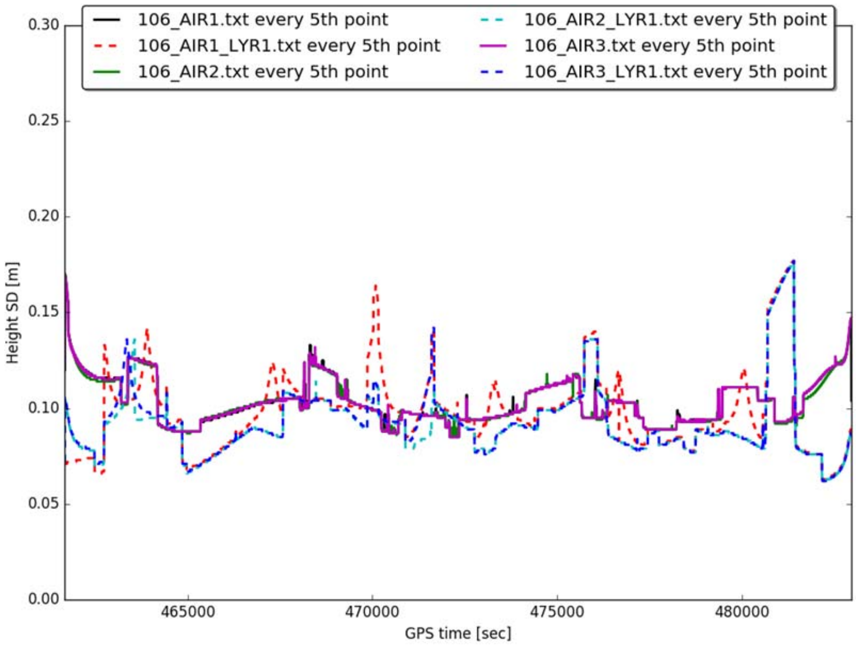
DOY 101


85
80
JD 101
NRD LYR
101Air1.pos
15
10
5
0
5
10
15
20
15.28
15.48
15.68
15.88
16.08
16.28
16.48
16.68
16.88
17.08
17.28
17.48
17.68

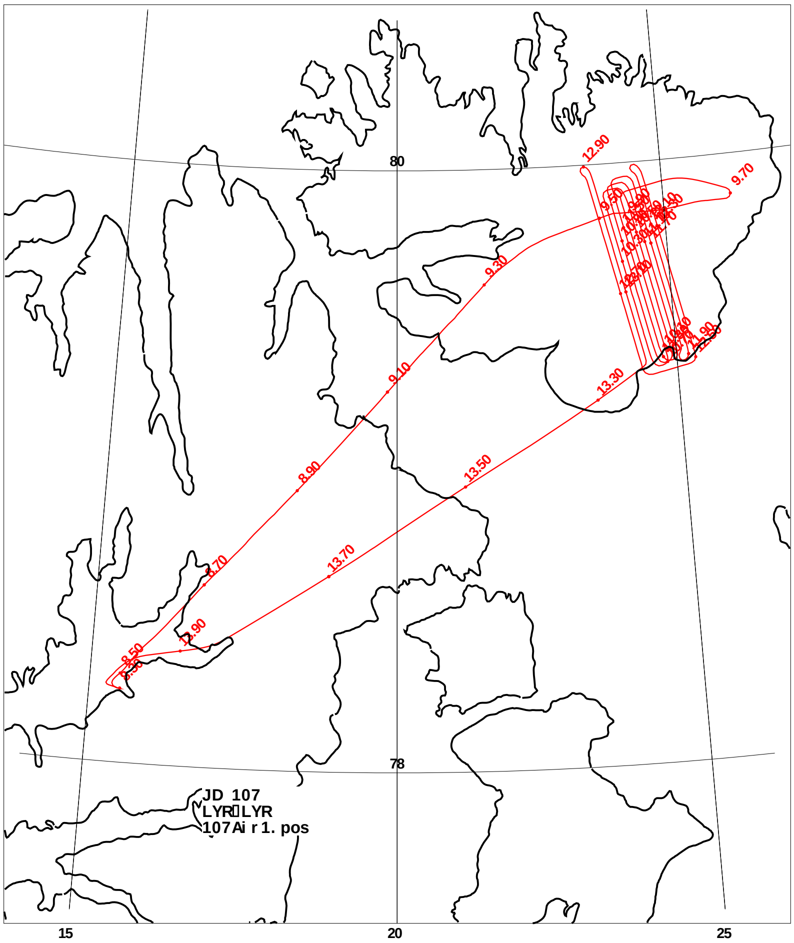

101_AIR1.txt every 5th point
101_AIR2.txt every 5th point
101_AIR3.txt every 5th point
Height SD [m]
GPS time [sec]
0.00
0.05
0.10
0.15
0.20
0.25
0.30
54000
56000
58000
60000
62000
64000
66000

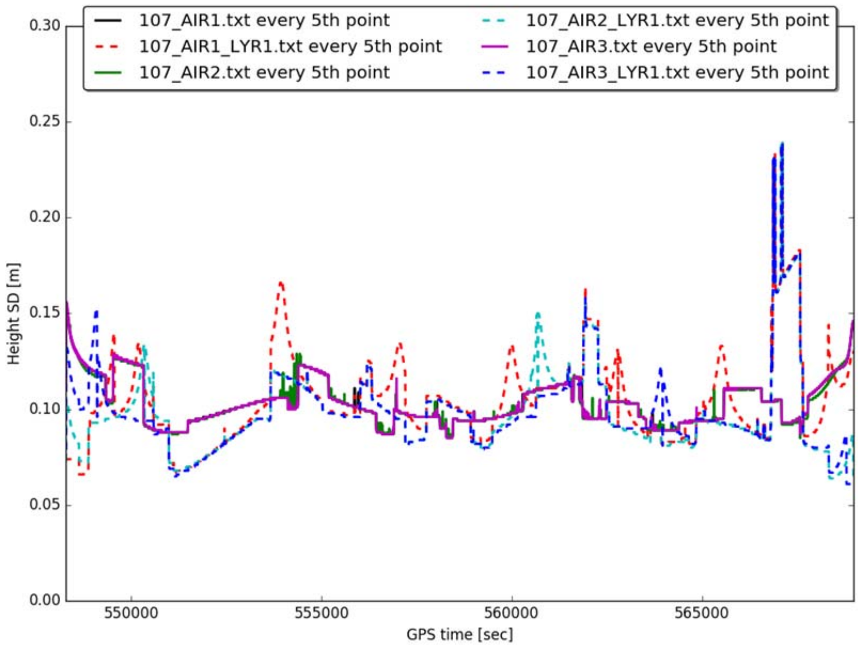
DOY 106


80
78
15
20
25
9.64
9.44
9.24
9.04
8.84
8.64
13.44
13.64
13.84
14.04
JD 106
LYR LYR
106Air1Lyr1.pos


106_AIR1.txt every 5th point
106_AIR1_LYR1.txt every 5th point
106_AIR2.txt every 5th point
106_AIR2_LYR1.txt every 5th point
106_AIR3.txt every 5th point
106_AIR3_LYR1.txt every 5th point
Height SD [m]
GPS time [sec]
0.00
0.05
0.10
0.15
0.20
0.25
0.30
465000
470000
475000
480000

DOY 107


80
78
15
20
25
JD 107
LYR LYR
107Air1.pos
12.90
9.70
9.30
9.10
8.90
8.70
8.50
13.30
13.50
13.70
12.90


107_AIR1.txt every 5th point
107_AIR1_LYR1.txt every 5th point
107_AIR2.txt every 5th point
107_AIR2_LYR1.txt every 5th point
107_AIR3.txt every 5th point
107_AIR3_LYR1.txt every 5th point
Height SD [m]
0.00
0.05
0.10
0.15
0.20
0.25
0.30
550000
555000
560000
565000
GPS time [sec]

1.20 Reference stations

All processing of reference stations are done by the online services at http://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/auspos.

Date	DOY	Reference	Latitude (DMS)	Longitude (DMS)	Ellipsoidal Height (m)
05-04-2017	096	LYR	78 14 51.54631	15 29 31.23559	50.197
06-04-2017	097a	LYR	78 14 51.55234	15 29 31.31248	50.237
08-04-2017	099	STN	81 36 02.38057	-16 39 42.25359	66.266
09-04-2017	100	STN	81 35 46.52426	-16 39 28.76166	62.020
15-04-2017	106	LYR	78 14 46.55145	15 30 09.01729	54.429
16-04-2017	107	LYR	78 14 46.56476	-15 30 08.95578	54.412

Appendix D. Overview of acquired ALS data

Table 8 Overview of acquired raw ALS data files

DOY	File name	Start (dechr)	Stop (dechr)	Comments
96	96_145700.2dd	14.9450665	15.26464	
97	097_095730.2dd	9.9585528	10.17761	
	097_150445.2dd	15.0793013	15.76766	
	097_155430.2dd	15.9043684		Wrong start of file, timing not correct. File terminated
	097_155510.2dd	15.9192798	16.52252	
	097_164430.2dd			Logging not start due to clouds.
	097_165630.2dd	16.9418363	17.36307	
99	099_114750.2dd	11.7967171	12.48510	Ice on mirror, only half of the lines with return
	099_124055.2dd	12.6818639	13.37027	
	099_133730.2dd	13.6246450	14.31308	
	099_142740.2dd			Empty file, wrong start
	099_142810.2dd	14.4692318	14.47255	Operator error, closed working scanning
	099_142915.2dd	14.4874478	15.17588	
	099_152200.2dd			Empty file, wrong start
	099_152230.2dd	15.3749566	16.06341	
100	100_110530.2dd	11.0915498	11.35013	
	100_120200.2dd	12.0334605	12.72182	
	100_130205.2dd	13.0348671	13.72329	
	100_135655.2dd	13.9487053	14.63712	
	100_1444405.2dd	14.7348652	15.42329	File is started 144405
101	101_150555.2dd	15.0985238	15.78693	
	101_155930.2dd	15.9913675	16.67981	
	101_165950.2dd	16.9973501	17.47713	
106	106_092600.2dd	9.4333946	10.02698	Clouds half way
	106_100230.2dd	10.0417738	10.73011	
	106_105800.2dd	10.9667781	11.65510	
	106_115400.2dd	11.8998171	12.58814	
	106_125130.2dd	12.8584490	13.30773	
	106_135400.2dd	13.9000600	14.07921	LYR runway overflight
107	107_092330.2dd	9.3917884	10.08011	
	107_102500.2dd	10.4167771	11.10509	
	107_111630.2dd	11.2751218	11.96344	
	107_121100.2dd	12.1834562	12.87178	

1.21 Building overflights

Both in LYR and STN buildings have been overflown to assist the calibration of the ALS-system.

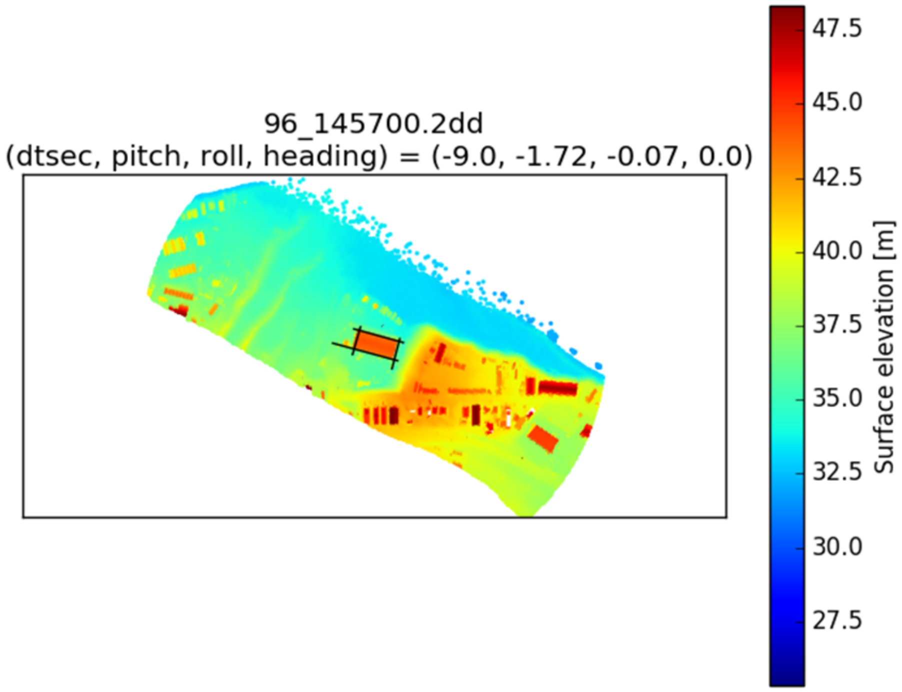


Figure 2: Building overflight in LYR. The black lines indicate the in-situ measurements of the building.

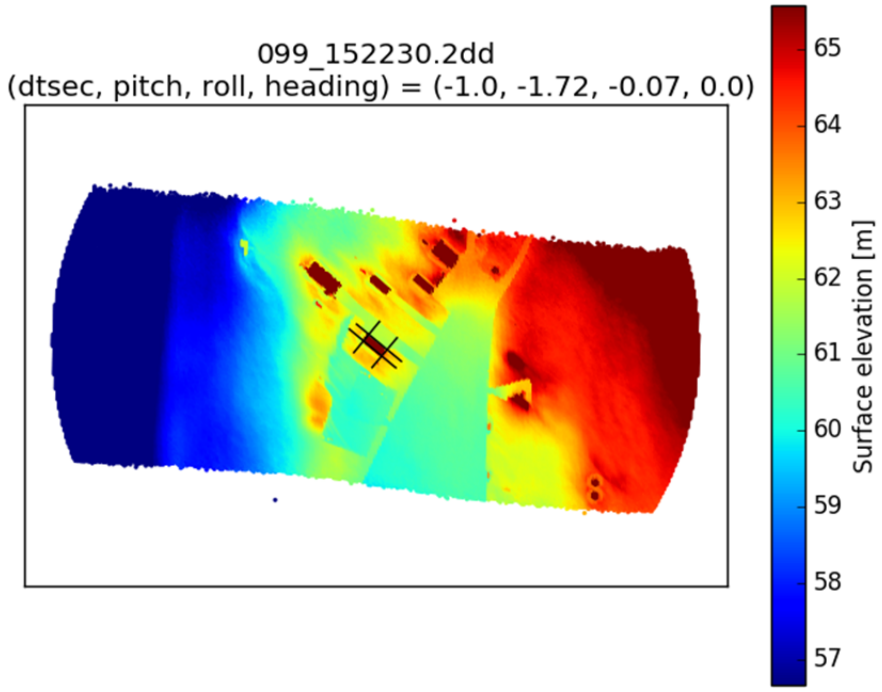
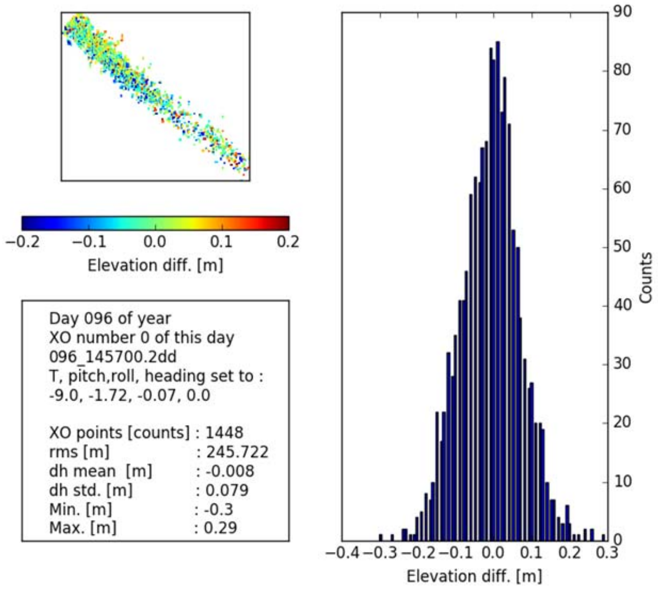


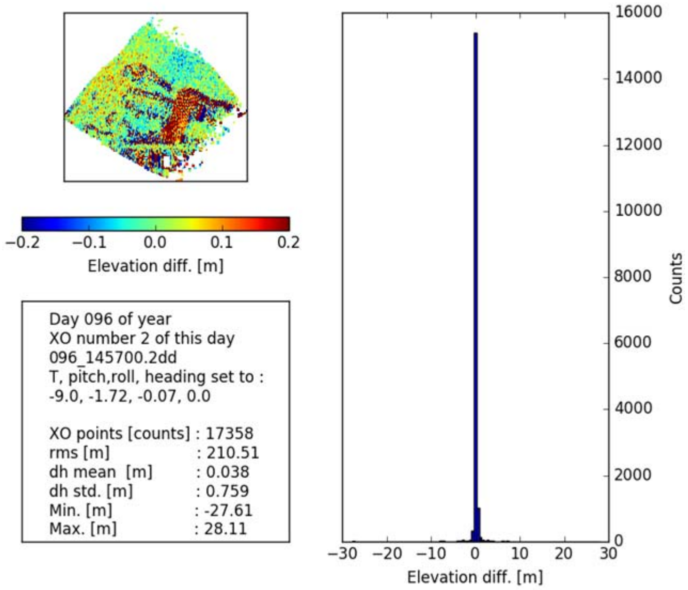
Figure 3 : Building overflight at STN. The black lines indicate the in-situ measurements of the building.

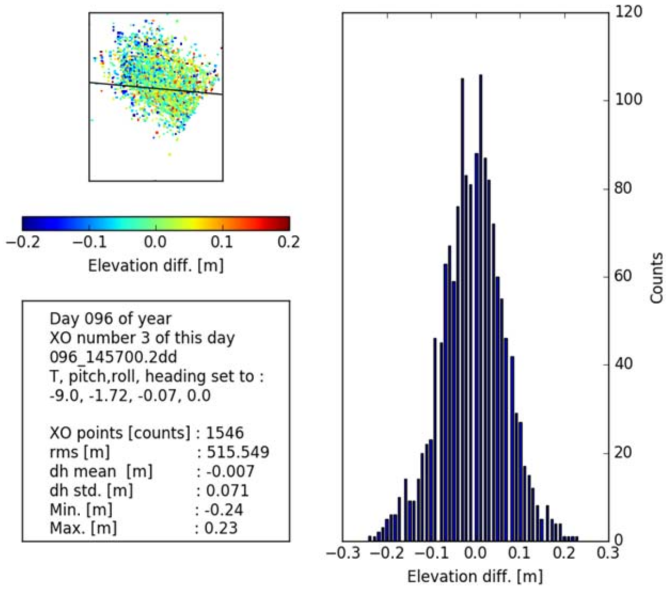
1.22 Crossover statistics for the ALS

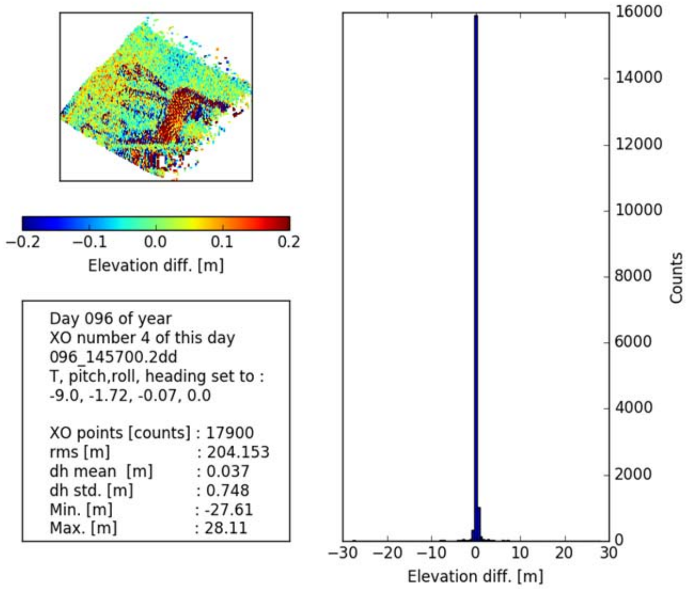
In the following is the full statistics of preformed crossovers within one-hour segments for the ALS surveys. The RMS given for the following is not corrected for outliers, such as clouds or reflections from the instrument window.

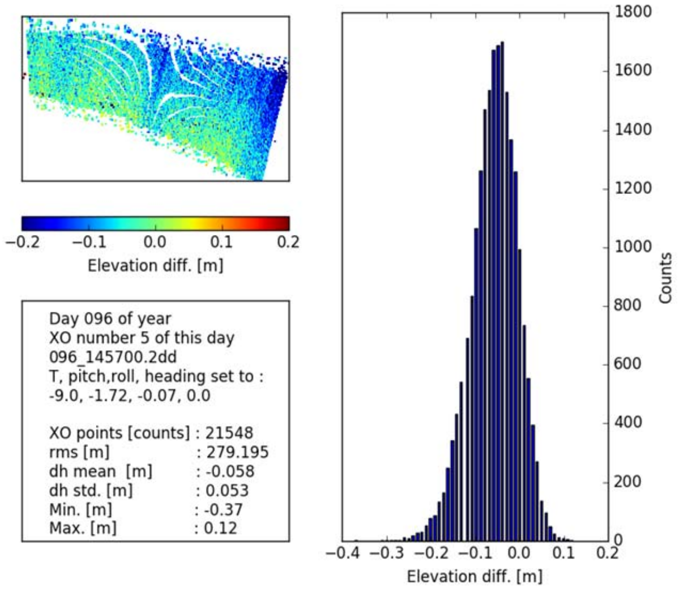
DOY 096

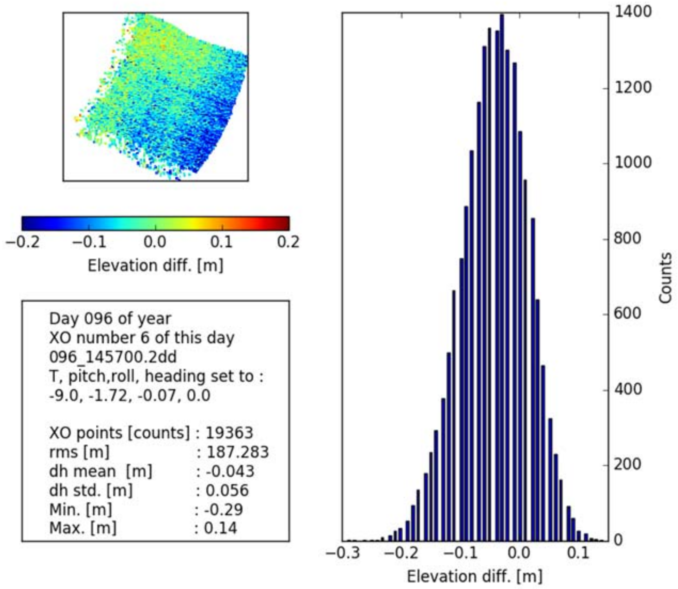


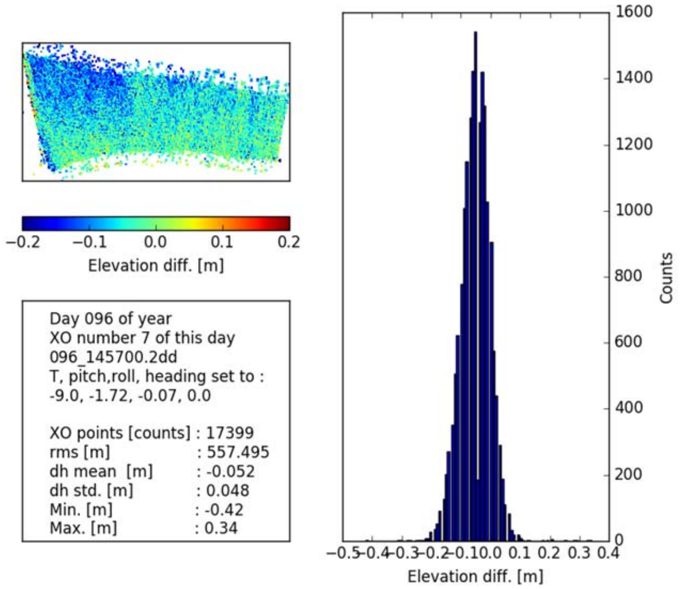


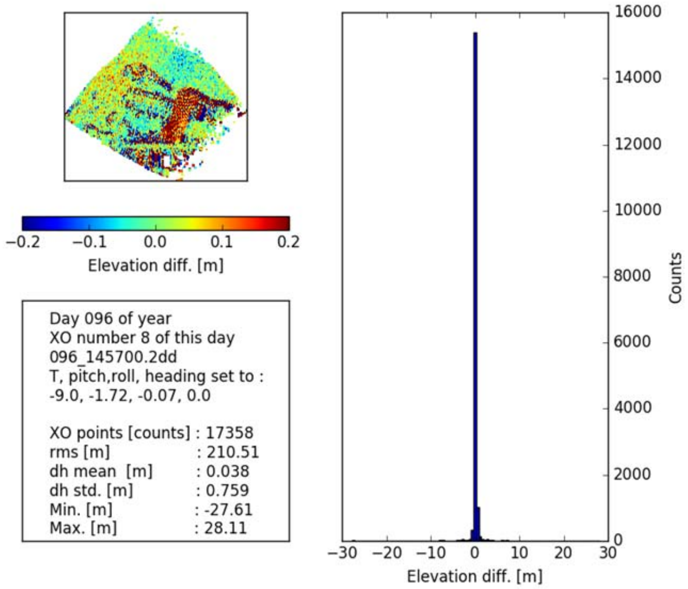

−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 096 of year
XO number 3 of this day
096_145700.2dd
T, pitch,roll, heading set to :
-9.0, -1.72, -0.07, 0.0
XO points [counts] : 1546
rms [m] : 515.549
dh mean [m] : -0.007
dh std. [m] : 0.071
Min. [m] : -0.24
Max. [m] : 0.23
Counts
Elevation diff. [m]

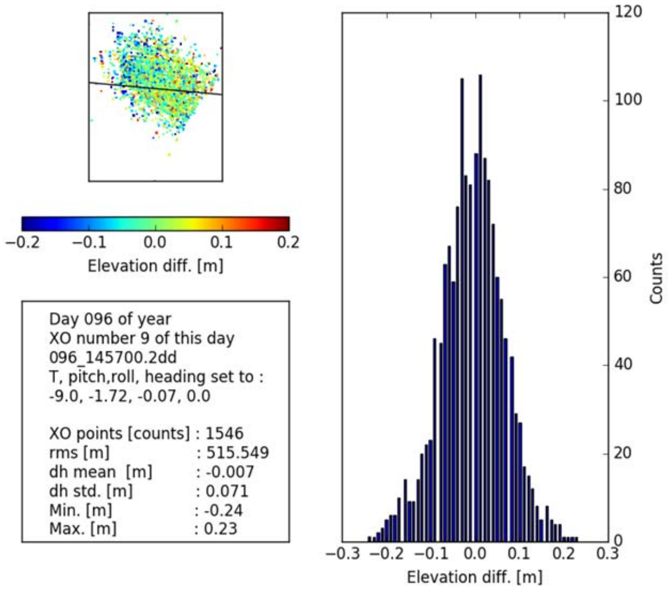

−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 096 of year
XO number 4 of this day
096_145700.2dd
T, pitch,roll, heading set to :
-9.0, -1.72, -0.07, 0.0
XO points [counts] : 17900
rms [m] : 204.153
dh mean [m] : 0.037
dh std. [m] : 0.748
Min. [m] : -27.61
Max. [m] : 28.11
Counts
Elevation diff. [m]

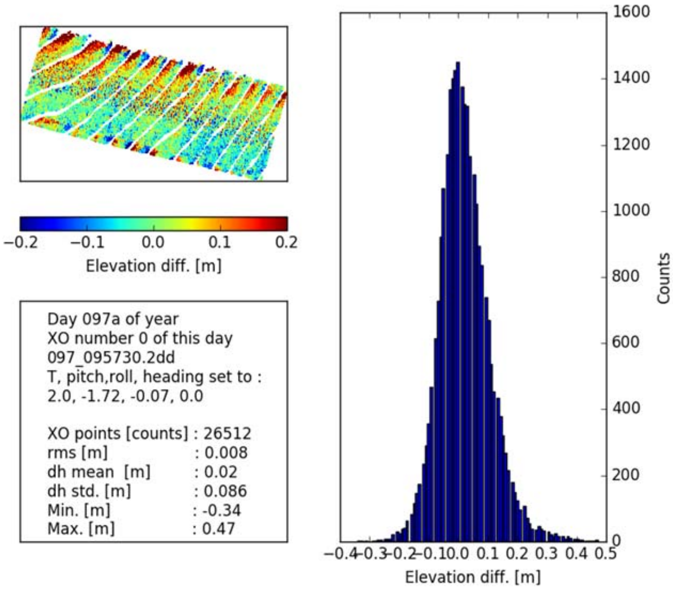

−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 096 of year
XO number 5 of this day
096_145700.2dd
T, pitch,roll, heading set to :
-9.0, -1.72, -0.07, 0.0
XO points [counts] : 21548
rms [m] : 279.195
dh mean [m] : -0.058
dh std. [m] : 0.053
Min. [m] : -0.37
Max. [m] : 0.12
1800 1600 1400 1200 1000 800 600 400 200 0
Counts
−0.4 −0.3 −0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]


−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 096 of year
XO number 6 of this day
096_145700.2dd
T, pitch,roll, heading set to :
-9.0, -1.72, -0.07, 0.0
XO points [counts] : 19363
rms [m] : 187.283
dh mean [m] : -0.043
dh std. [m] : 0.056
Min. [m] : -0.29
Max. [m] : 0.14
1400 1200 1000 800 600 400 200 0
Counts
−0.3 −0.2 −0.1 0.0 0.1
Elevation diff. [m]

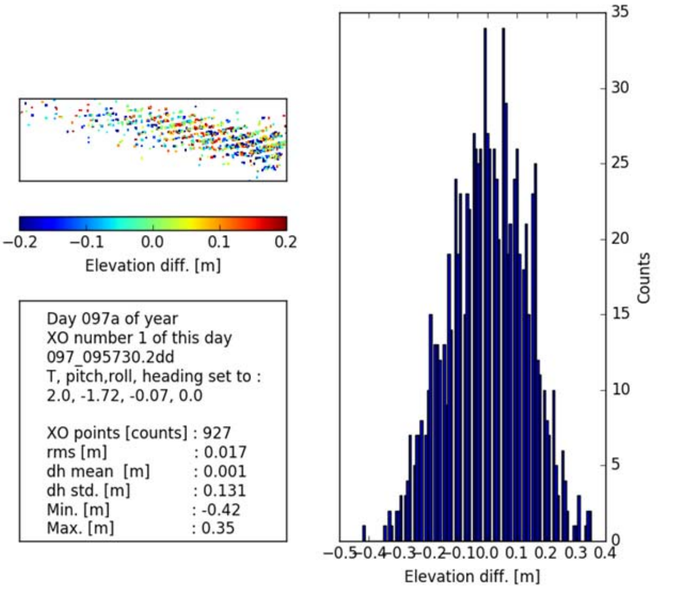

−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 096 of year
XO number 7 of this day
096_145700.2dd
T, pitch,roll, heading set to :
-9.0, -1.72, -0.07, 0.0
XO points [counts] : 17399
rms [m] : 557.495
dh mean [m] : -0.052
dh std. [m] : 0.048
Min. [m] : -0.42
Max. [m] : 0.34
Counts
0 200 400 600 800 1000 1200 1400 1600
−0.5 −0.4 −0.3 −0.2 −0.1 0.0 0.1 0.2 0.3 0.4
Elevation diff. [m]

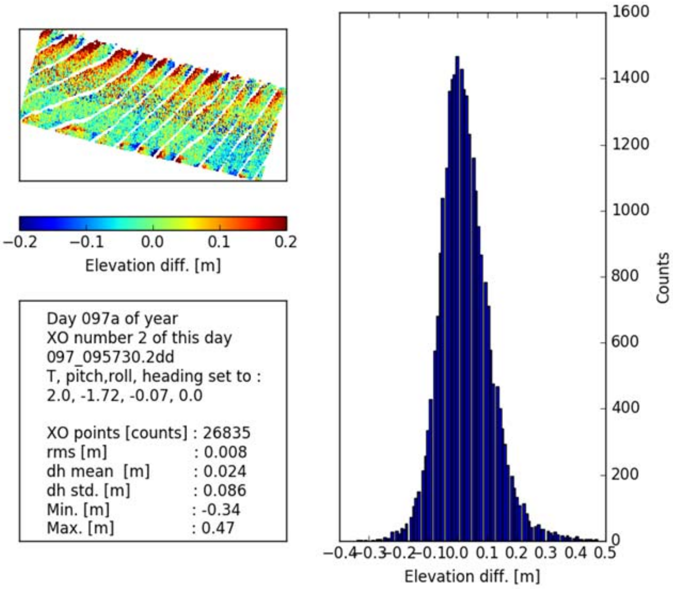

−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 096 of year
XO number 8 of this day
096_145700.2dd
T, pitch,roll, heading set to :
-9.0, -1.72, -0.07, 0.0
XO points [counts] : 17358
rms [m] : 210.51
dh mean [m] : 0.038
dh std. [m] : 0.759
Min. [m] : -27.61
Max. [m] : 28.11
Counts
0 2000 4000 6000 8000 10000 12000 14000 16000
−30 −20 −10 0 10 20 30
Elevation diff. [m]


−0.2
−0.1
0.0
0.1
0.2
Elevation diff. [m]
Day 096 of year
XO number 9 of this day
096_145700.2dd
T, pitch,roll, heading set to :
-9.0, -1.72, -0.07, 0.0
XO points [counts] : 1546
rms [m] : 515.549
dh mean [m] : -0.007
dh std. [m] : 0.071
Min. [m] : -0.24
Max. [m] : 0.23
Counts
−0.3 −0.2 −0.1 0.0 0.1 0.2 0.3
Elevation diff. [m]

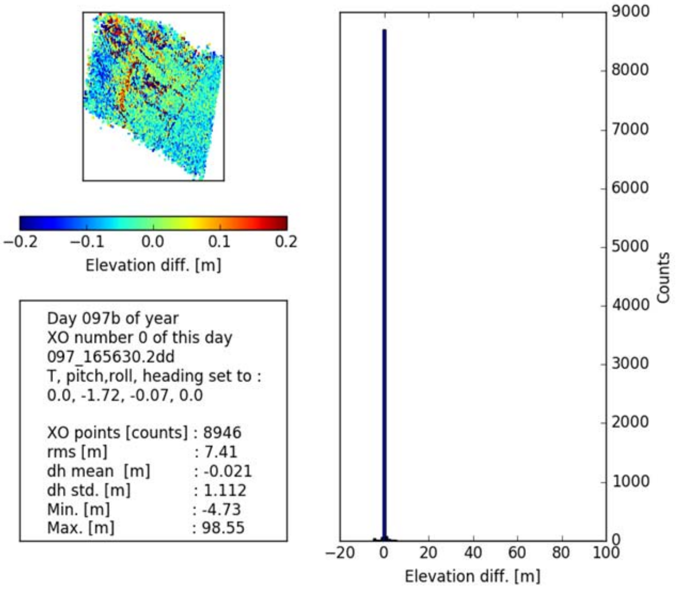

−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 097a of year
XO number 0 of this day
097_095730.2dd
T, pitch,roll, heading set to :
2.0, -1.72, -0.07, 0.0
XO points [counts] : 26512
rms [m] : 0.008
dh mean [m] : 0.02
dh std. [m] : 0.086
Min. [m] : -0.34
Max. [m] : 0.47
1600
1400
1200
1000
800
600
400
200
0
Counts
−0.4 −0.3 −0.2 −0.1 0.0 0.1 0.2 0.3 0.4 0.5
Elevation diff. [m]

DOY 097a

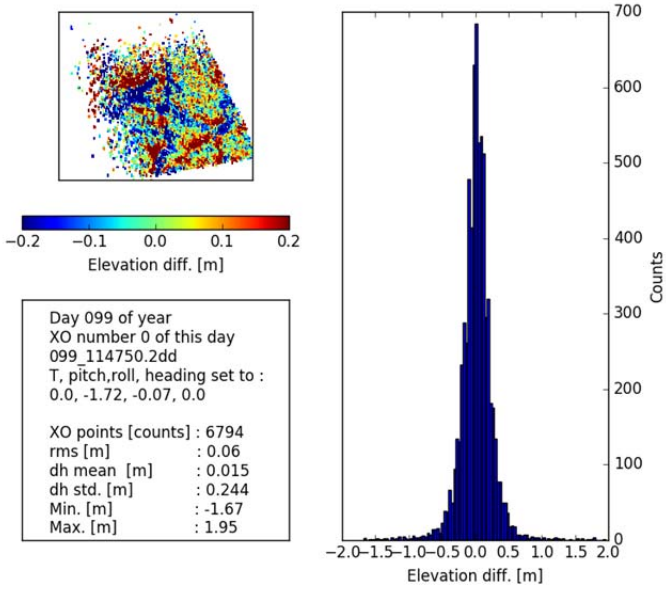

−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 097a of year
XO number 1 of this day
097_095730.2dd
T, pitch,roll, heading set to :
2.0, -1.72, -0.07, 0.0
XO points [counts] : 927
rms [m] : 0.017
dh mean [m] : 0.001
dh std. [m] : 0.131
Min. [m] : -0.42
Max. [m] : 0.35
Counts
0 5 10 15 20 25 30 35
−0.5 −0.4 −0.3 −0.2 −0.1 0.0 0.1 0.2 0.3 0.4
Elevation diff. [m]

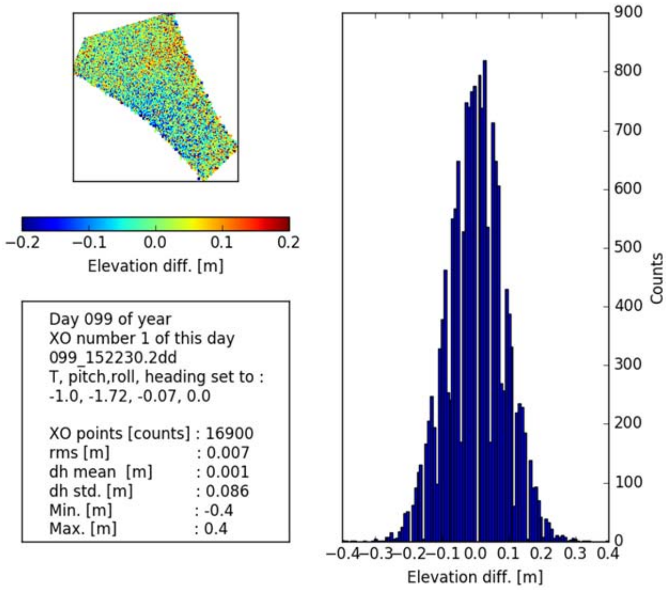

−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 097a of year
XO number 2 of this day
097_095730.2dd
T, pitch,roll, heading set to :
2.0, -1.72, -0.07, 0.0
XO points [counts] : 26835
rms [m] : 0.008
dh mean [m] : 0.024
dh std. [m] : 0.086
Min. [m] : -0.34
Max. [m] : 0.47
Counts
0 200 400 600 800 1000 1200 1400 1600
−0.4 −0.3 −0.2 −0.1 0.0 0.1 0.2 0.3 0.4 0.5
Elevation diff. [m]

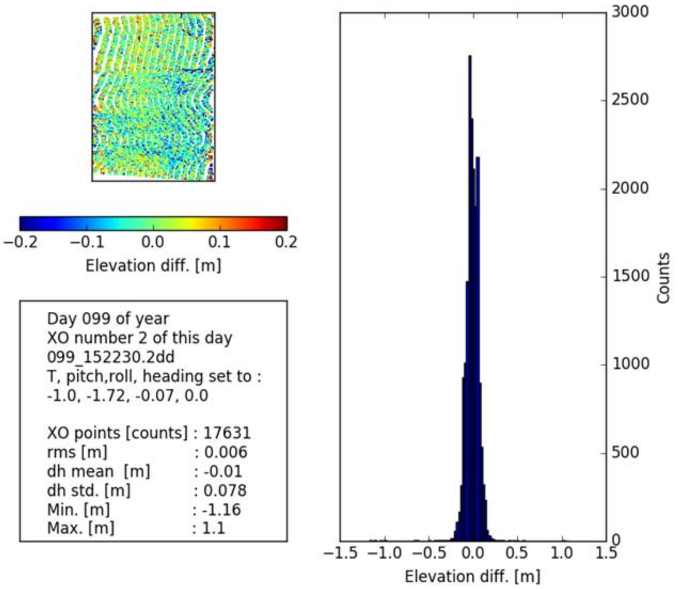
DOY 097b

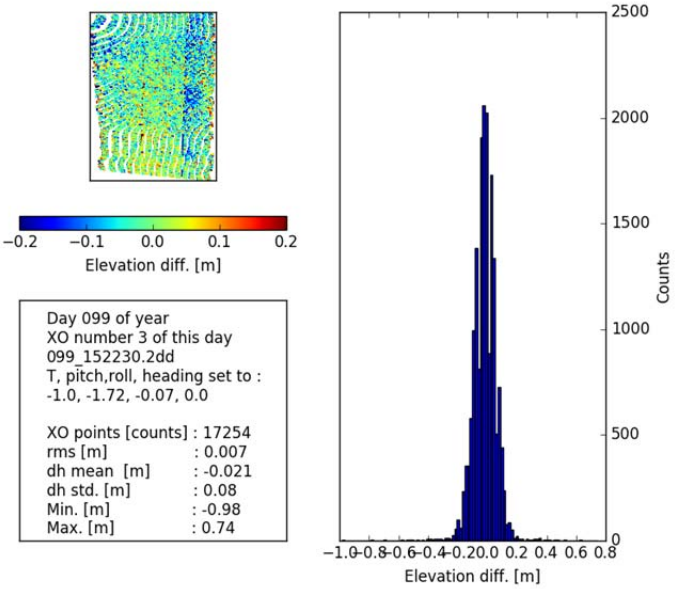

−0.2
−0.1
0.0
0.1
0.2
Elevation diff. [m]
Day 097b of year
XO number 0 of this day
097_165630.2dd
T, pitch,roll, heading set to :
0.0, -1.72, -0.07, 0.0
XO points [counts] : 8946
rms [m] : 7.41
dh mean [m] : -0.021
dh std. [m] : 1.112
Min. [m] : -4.73
Max. [m] : 98.55
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Counts
−20
0
20
40
60
80
100
Elevation diff. [m]

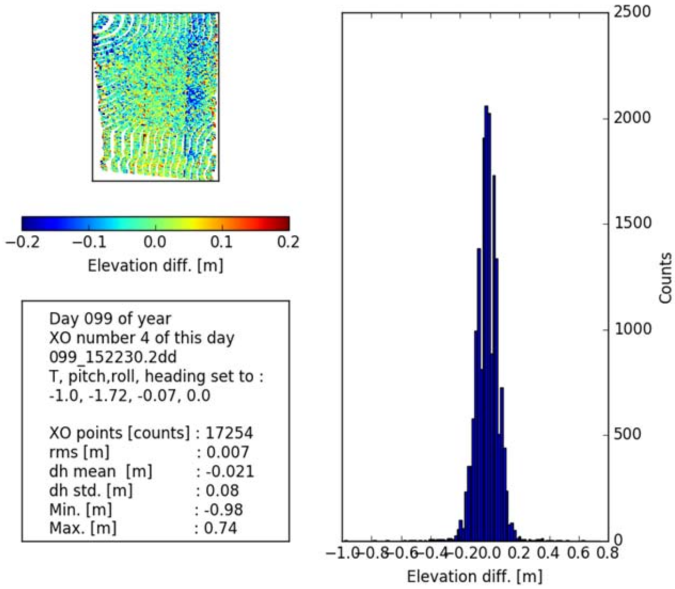
DOY 099

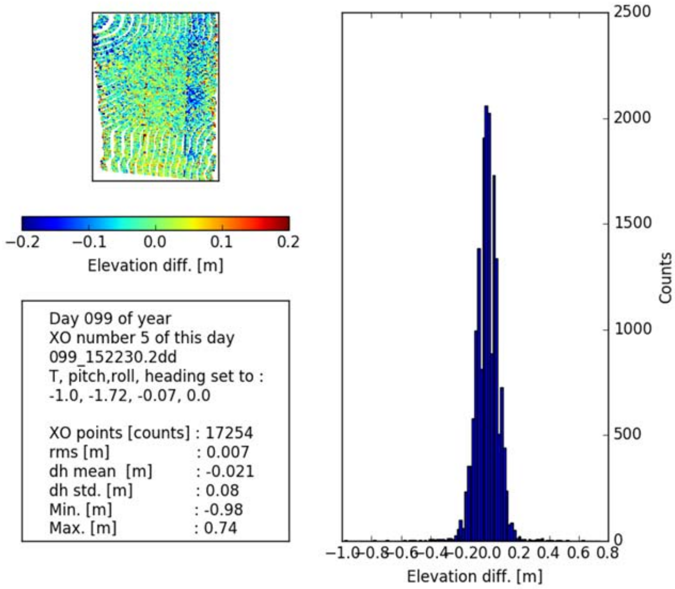

−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 099 of year
XO number 0 of this day
099_114750.2dd
T, pitch,roll, heading set to :
0.0, -1.72, -0.07, 0.0
XO points [counts] : 6794
rms [m] : 0.06
dh mean [m] : 0.015
dh std. [m] : 0.244
Min. [m] : -1.67
Max. [m] : 1.95
Counts
0 100 200 300 400 500 600 700
−2.0 −1.5 −1.0 −0.5 0.0 0.5 1.0 1.5 2.0
Elevation diff. [m]


−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 099 of year
XO number 1 of this day
099_152230.2dd
T, pitch,roll, heading set to :
-1.0, -1.72, -0.07, 0.0
XO points [counts] : 16900
rms [m] : 0.007
dh mean [m] : 0.001
dh std. [m] : 0.086
Min. [m] : -0.4
Max. [m] : 0.4
Counts
0 100 200 300 400 500 600 700 800 900
−0.4 −0.3 −0.2 −0.1 0.0 0.1 0.2 0.3 0.4
Elevation diff. [m]

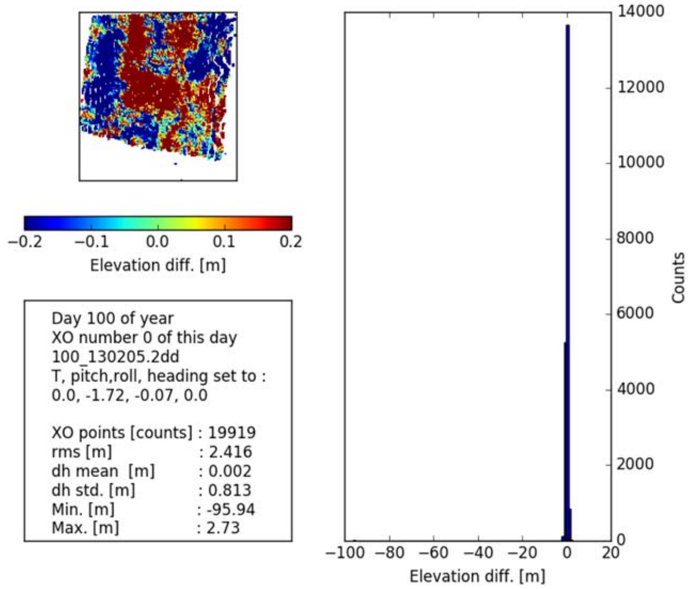

−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 099 of year
XO number 2 of this day
099_152230.2dd
T, pitch,roll, heading set to :
-1.0, -1.72, -0.07, 0.0
XO points [counts] : 17631
rms [m] : 0.006
dh mean [m] : -0.01
dh std. [m] : 0.078
Min. [m] : -1.16
Max. [m] : 1.1
3000
2500
2000
1500
1000
500
0
Counts
−1.5 −1.0 −0.5 0.0 0.5 1.0 1.5
Elevation diff. [m]


−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 099 of year
XO number 3 of this day
099_152230.2dd
T, pitch,roll, heading set to :
-1.0, -1.72, -0.07, 0.0
XO points [counts] : 17254
rms [m] : 0.007
dh mean [m] : -0.021
dh std. [m] : 0.08
Min. [m] : -0.98
Max. [m] : 0.74
2500
2000
1500
1000
500
0
Counts
−1.0 −0.8 −0.6 −0.4 −0.2 0.0 0.2 0.4 0.6 0.8
Elevation diff. [m]

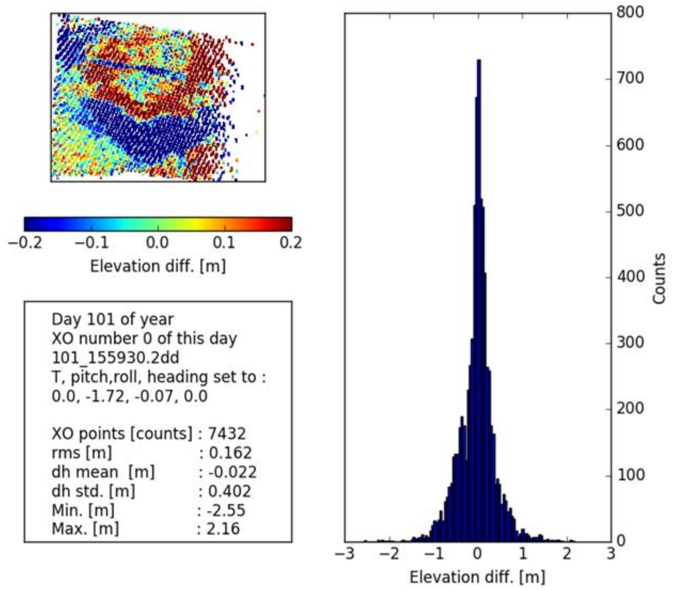

−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 099 of year
XO number 4 of this day
099_152230.2dd
T, pitch,roll, heading set to :
-1.0, -1.72, -0.07, 0.0
XO points [counts] : 17254
rms [m] : 0.007
dh mean [m] : -0.021
dh std. [m] : 0.08
Min. [m] : -0.98
Max. [m] : 0.74
Counts
Elevation diff. [m]

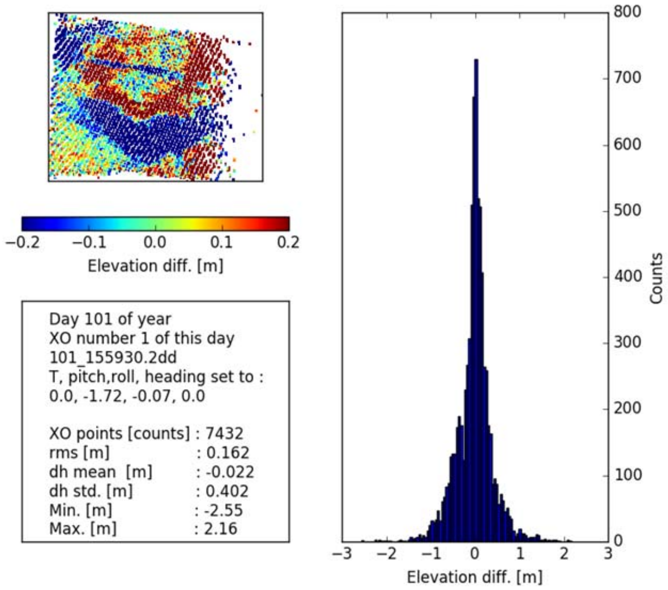

−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 099 of year
XO number 5 of this day
099_152230.2dd
T, pitch,roll, heading set to :
-1.0, -1.72, -0.07, 0.0
XO points [counts] : 17254
rms [m] : 0.007
dh mean [m] : -0.021
dh std. [m] : 0.08
Min. [m] : -0.98
Max. [m] : 0.74
Counts
Elevation diff. [m]

DOY 100

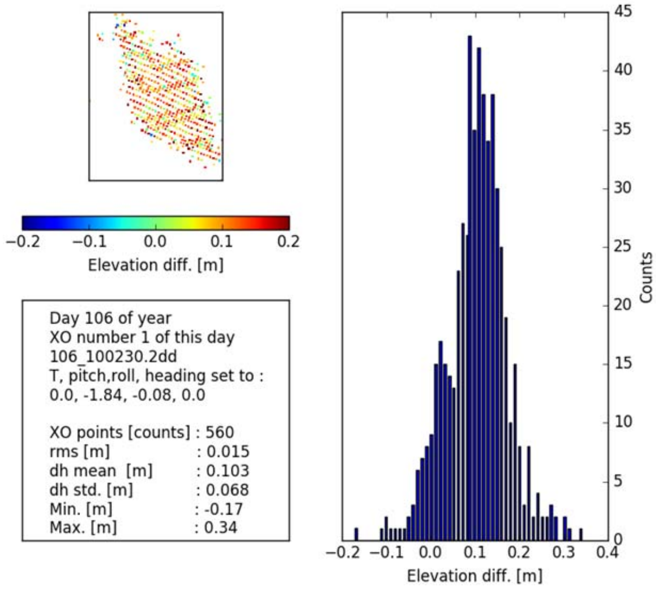


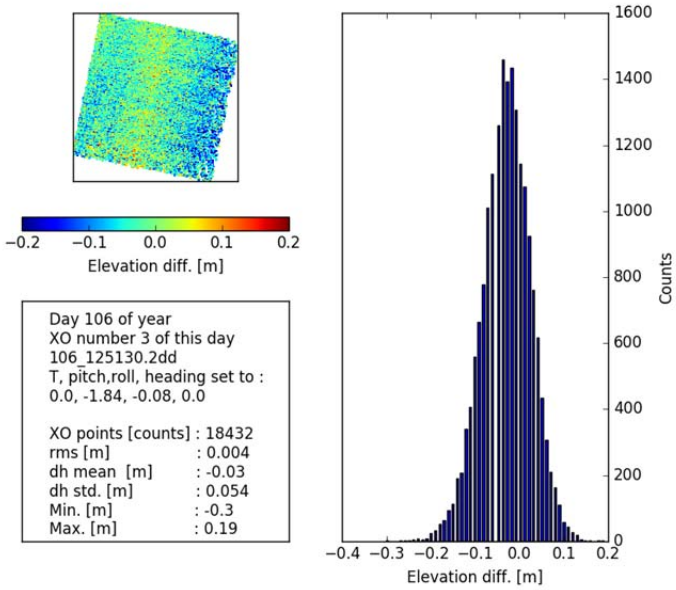
DOY 101

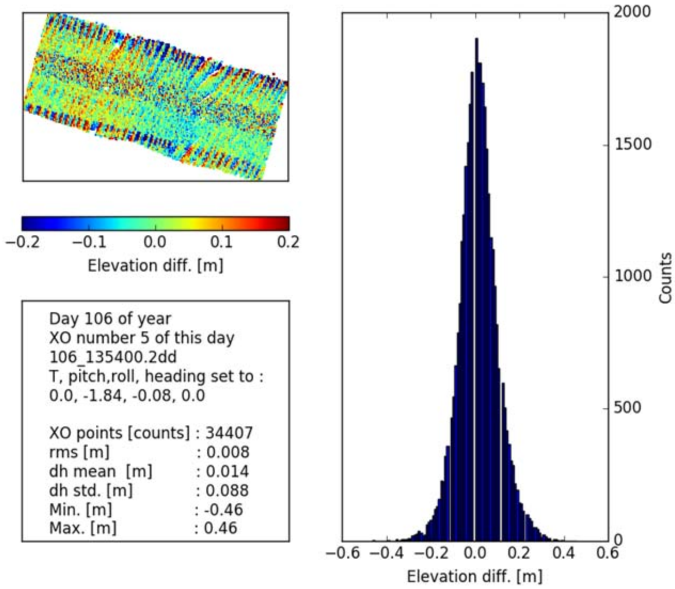


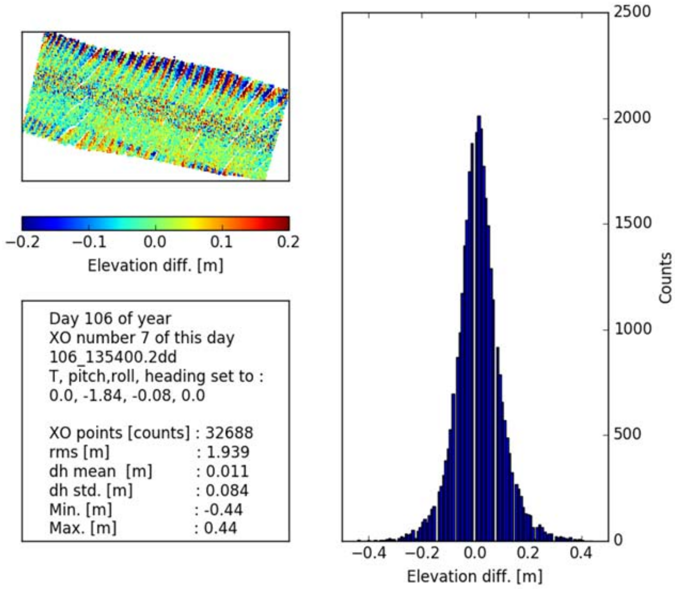

−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 101 of year
XO number 1 of this day
101_155930.2dd
T, pitch,roll, heading set to :
0.0, -1.72, -0.07, 0.0
XO points [counts] : 7432
rms [m] : 0.162
dh mean [m] : -0.022
dh std. [m] : 0.402
Min. [m] : -2.55
Max. [m] : 2.16
Counts
0 100 200 300 400 500 600 700 800
−3 −2 −1 0 1 2 3
Elevation diff. [m]

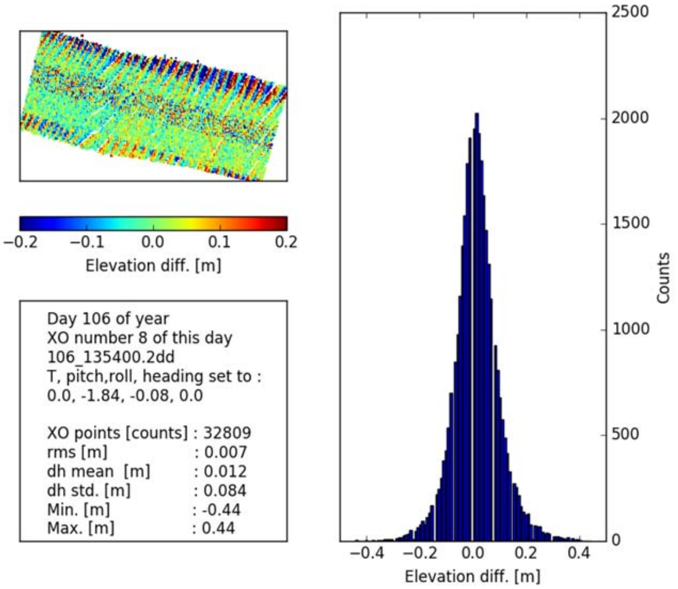
DOY 106

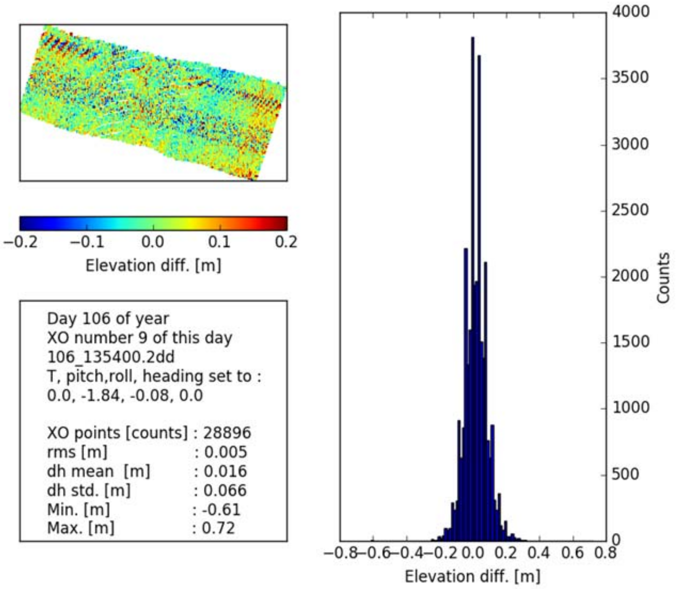

Elevation diff. [m]
Day 106 of year
XO number 1 of this day
106_100230.2dd
T, pitch,roll, heading set to :
0.0, -1.84, -0.08, 0.0
XO points [counts] : 560
rms [m] : 0.015
dh mean [m] : 0.103
dh std. [m] : 0.068
Min. [m] : -0.17
Max. [m] : 0.34
Counts
Elevation diff. [m]

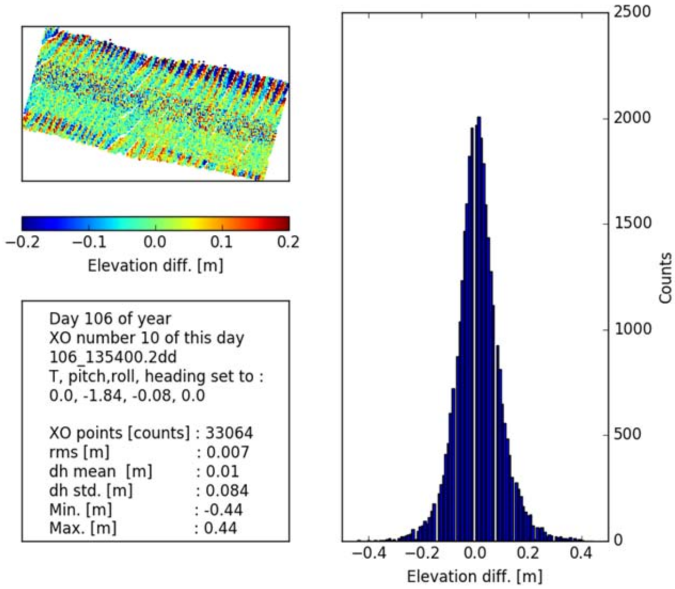

Elevation diff. [m]
Day 106 of year
XO number 3 of this day
106_125130.2dd
T, pitch,roll, heading set to :
0.0, -1.84, -0.08, 0.0
XO points [counts] : 18432
rms [m] : 0.004
dh mean [m] : -0.03
dh std. [m] : 0.054
Min. [m] : -0.3
Max. [m] : 0.19
Counts
Elevation diff. [m]

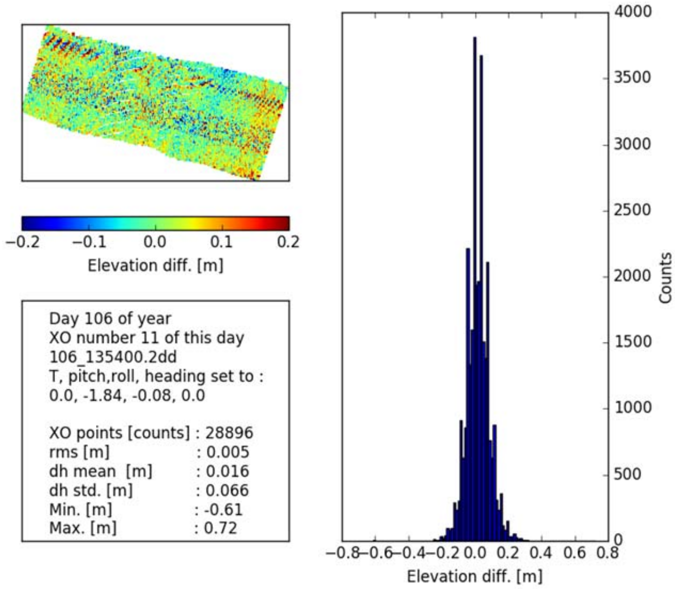

−0.2
−0.1
0.0
0.1
0.2
Elevation diff. [m]
Day 106 of year
XO number 5 of this day
106_135400.2dd
T, pitch,roll, heading set to :
0.0, -1.84, -0.08, 0.0
XO points [counts] : 34407
rms [m] : 0.008
dh mean [m] : 0.014
dh std. [m] : 0.088
Min. [m] : -0.46
Max. [m] : 0.46
2000
1500
1000
500
0
Counts
−0.6 −0.4 −0.2 0.0 0.2 0.4 0.6
Elevation diff. [m]


−0.2
−0.1
0.0
0.1
0.2
Elevation diff. [m]
Day 106 of year
XO number 7 of this day
106_135400.2dd
T, pitch,roll, heading set to :
0.0, -1.84, -0.08, 0.0
XO points [counts] : 32688
rms [m] : 1.939
dh mean [m] : 0.011
dh std. [m] : 0.084
Min. [m] : -0.44
Max. [m] : 0.44
2500
2000
1500
1000
500
0
Counts
−0.4 −0.2 0.0 0.2 0.4
Elevation diff. [m]

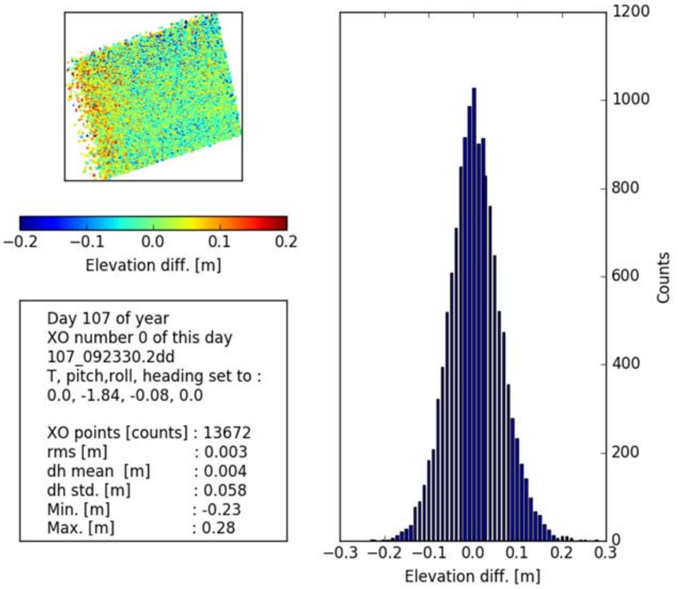

−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 106 of year
XO number 8 of this day
106_135400.2dd
T, pitch,roll, heading set to :
0.0, -1.84, -0.08, 0.0
XO points [counts] : 32809
rms [m] : 0.007
dh mean [m] : 0.012
dh std. [m] : 0.084
Min. [m] : -0.44
Max. [m] : 0.44
Counts
Elevation diff. [m]

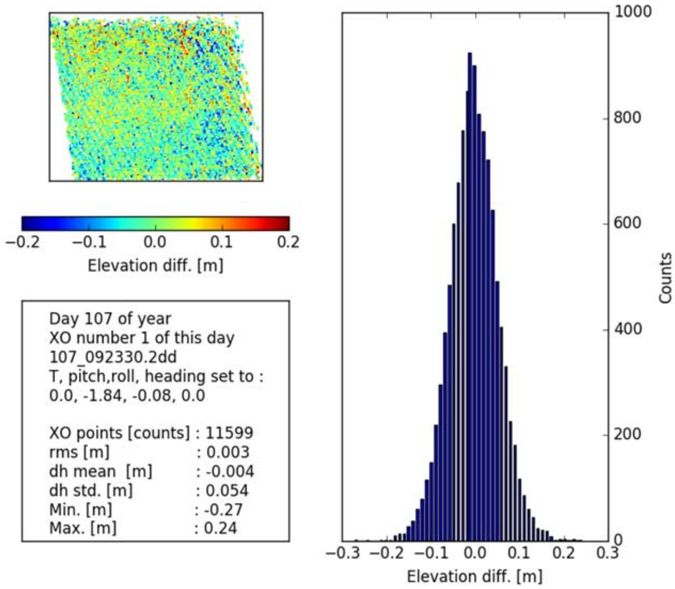

−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 106 of year
XO number 9 of this day
106_135400.2dd
T, pitch,roll, heading set to :
0.0, -1.84, -0.08, 0.0
XO points [counts] : 28896
rms [m] : 0.005
dh mean [m] : 0.016
dh std. [m] : 0.066
Min. [m] : -0.61
Max. [m] : 0.72
Counts
Elevation diff. [m]

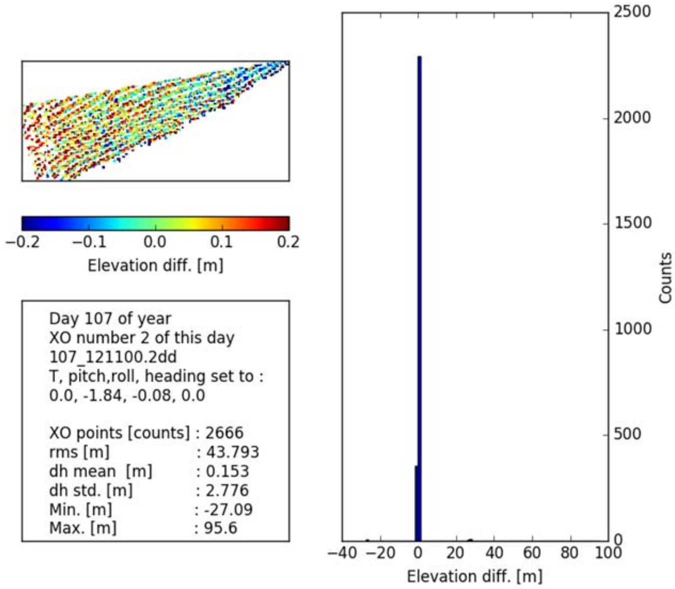

−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 106 of year
XO number 10 of this day
106_135400.2dd
T, pitch,roll, heading set to :
0.0, -1.84, -0.08, 0.0
XO points [counts] : 33064
rms [m] : 0.007
dh mean [m] : 0.01
dh std. [m] : 0.084
Min. [m] : -0.44
Max. [m] : 0.44
Counts
Elevation diff. [m]


−0.2 −0.1 0.0 0.1 0.2
Elevation diff. [m]
Day 106 of year
XO number 11 of this day
106_135400.2dd
T, pitch,roll, heading set to :
0.0, -1.84, -0.08, 0.0
XO points [counts] : 28896
rms [m] : 0.005
dh mean [m] : 0.016
dh std. [m] : 0.066
Min. [m] : -0.61
Max. [m] : 0.72
Counts
Elevation diff. [m]

DOY 107


−0.2
−0.1
0.0
0.1
0.2
Elevation diff. [m]
Day 107 of year
XO number 0 of this day
107_092330.2dd
T, pitch,roll, heading set to :
0.0, -1.84, -0.08, 0.0
XO points [counts] : 13672
rms [m] : 0.003
dh mean [m] : 0.004
dh std. [m] : 0.058
Min. [m] : -0.23
Max. [m] : 0.28
1200
1000
800
600
400
200
0
Counts
−0.3 −0.2 −0.1 0.0 0.1 0.2 0.3
Elevation diff. [m]





1.23 Calibration of the ALS-measurements.

All crossovers and building overflights have been evaluated and the calibration angles are listed in the table 9 below.

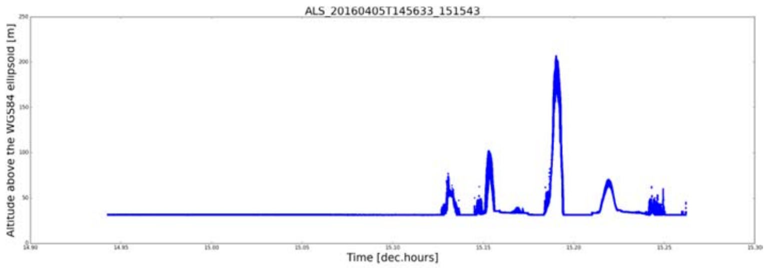
Table 10 Information of the calibrated ALS files.

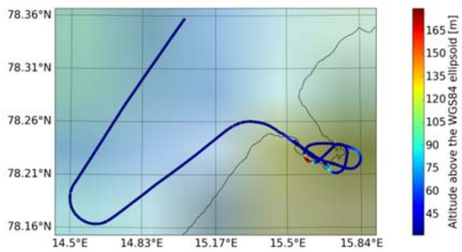
Date	DOY	Preffered GPS solution	EGI file name	Scanner file	Delta time (sec)	Calibration angles (Pitch, Roll, Yaw)	Note	Final file:	File size (MB)
05-04-2016	96	096_AIR2_REF1.p	EGI-160405-142328.ddk	96_145700.2dd	-9	(-1.72, -0.07, 0.)	Calibration building	ALS_20160405T145633_151543.sbi (096_145700_filt.scn)	47
06-04-2016	97a	097a_AIR2_REF1.p	EGI-160406-093029.ddk	097_095730.2dd	2.	(-1.72, -0.07, 0.)	A bad XO, but the previous calibration angles is found to be a good solution to the XO	ALS_20160406T095732_101041.sbi (097a_095730_filt.scn)	21.9
06-04-2016	97b	097b_AIR2.p	EGI-160406-134457.ddk	097_150445.2dd	0	(-1.72, -0.07, 0.)		ALS_20160406T150445_155400.sbi (097b_150445_flit_flit.scn)	261
				097_155430.2dd	0			ALS_20160406T155415_155415.sbi (097b_155430_flit.scn)	0.03
				097_155510.2dd	0			ALS_20160406T155509_162442.sbi (097b_155510_flit_filt.scn)	214
				097_165630.2dd	0			ALS_20160406T165822_172147.sbi (097b_165630_flit_filt.scn)	145
08-04-2016	99	099_AIR2.p	EGI-160408-110039.ddk	099_114750.2dd	0	(-1.72, -0.07, 0.)		ALS_20160408T114748_124032.sbi (099_114750_filt_filt.scn)	185
				099_124055.2dd	0			ALS_20160408T124054_133656.sbi (099_124055_filt_filt.scn)	396
				099_133730.2dd	0			ALS_20160408T133728_142503.sbi (099_133730_filt.scn)	383
				099_142810.2dd	0			ALS_20160408T142809_142821.sbi (099_142810_filt.scn)	1.63
				099_142915.2dd	-1			ALS_20160408T142913_152138.sbi (099_142915_filt.scn)	425
				099_152230.2dd	-1		Calbibation building	ALS_20160408T152228_162601.sbi (099_152230_filt_filt.scn)	515
09-04-2016	100	100_AIR2.p	EGI-160409-103647.ddk	100_110530.2dd	0	(-1.72, -0.07, 0.)	The 2 XO which have been performed was above sea ice visula inspection confirmed the anglse from previous flights	ALS_20160409T110529_112058.sbi (100_110530_filt_filt.scn)	17.8
				100_120200.2dd	0			ALS_20160409T120200_130138.sbi (100_120200_filt_filt.scn)	383
				100_130205.2dd	0			ALS_20160409T130205_135633.sbi (100_130205_filt.scn)	419
				100_135655.2dd	0			ALS_20160409T135655_144340.sbi (100_135655_filt.scn)	352
				100_144405.2dd	0			ALS_20160409T144405_153402.sbi (100_144405_filt.scn)	381
10-04-2016	101	101_AIR2.p	EGI-160410-143530.ddk	101_150555.2dd	0	(-1.72, -0.07, 0.)		ALS_20160410T150554_155910.sbi (101_150555_filt.scn)	148
				101_155930.2dd	0			ALS_20160410T155928_165925.sbi (101_155930_filt.scn)	382
				101_165950.2dd	0			ALS_20160410T165950_172837.sbi (101_165950_filt.scn)	182
15-04-2016	106	106_AIR2_LYR1.p	EGI-160415-080413.ddk	106_092600.2dd	0	(-1.84, -0.08, 0.)		ALS_20160415T092600_100137.sbi (106_92600_filt.scn)	127
				106_100230.2dd	0			ALS_20160415T100230_105729.sbi (106_100230_filt.scn)	298
				106_105800.2dd	0			ALS_20160415T105914_115327.sbi (106_105800_filt.scn)	324

				106_115400.2dd	0			ALS_20160415T115359_124947.sbi (106_115400_filt_filt.scn)	326
				106_125130.2dd	0			ALS_20160415T125136_131820.sbi (106_125130_filt.scn)	163
				106_135400.2dd	0			ALS_20160415T135400_140445.sbi (106_135400_filt.scn)	26.8
16-04-2016	107	107_AIR2.p	EGI-160416-080631.ddk	107_092330.2dd	0	(-1.84, -0.08, 0.)		ALS_20160416T092330_102336.sbi (107_92330_filt_filt.scn)	314
				107_102500.2dd	0			ALS_20160416T102602_111552.sbi (107_102500_filt_filt.scn)	303
				107_111630.2dd	0			ALS_20160416T111630_120958.sbi (107_111630_filt.scn)	328
				107_121100.2dd	0			ALS_20160416T121301_131316.sbi (107_121100_filt.scn)	365

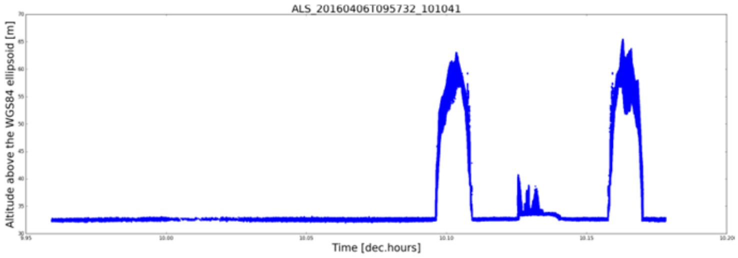
1.24 Overview plots of the individual data files.

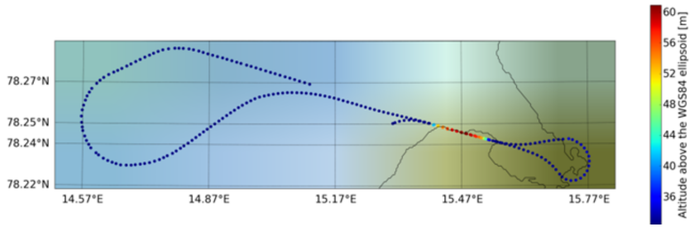
Day 096



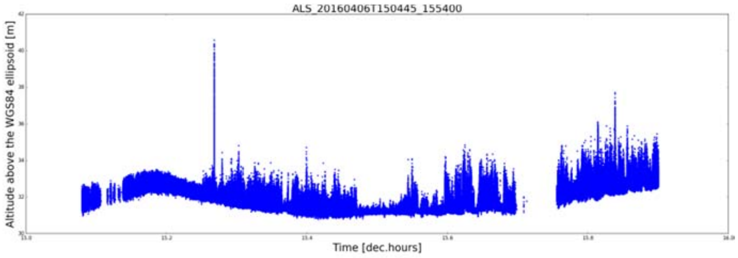


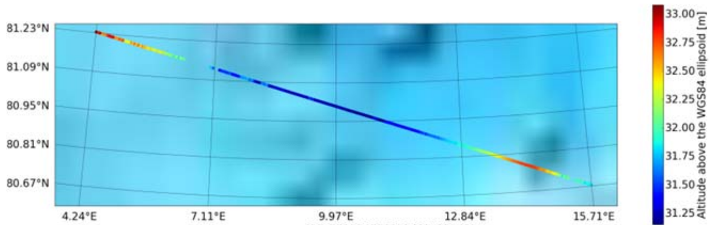
Day 097a

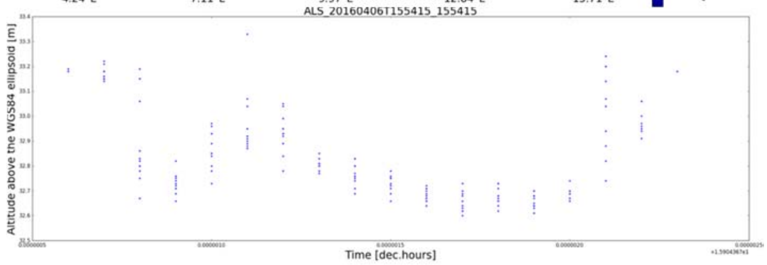


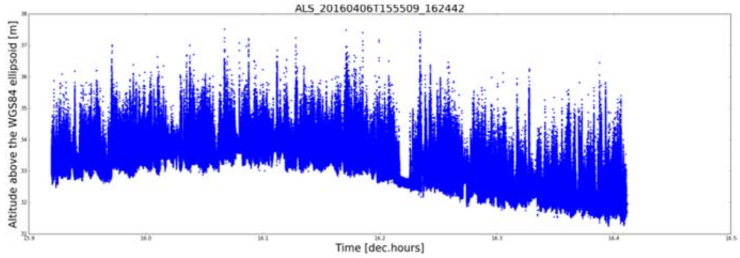


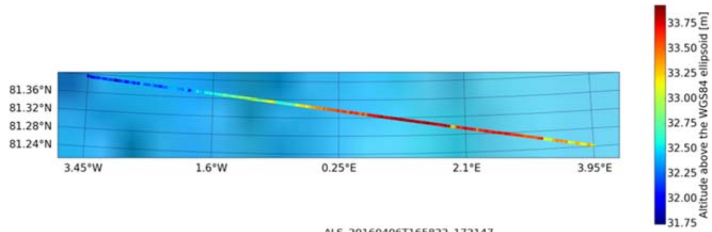
Day 097b

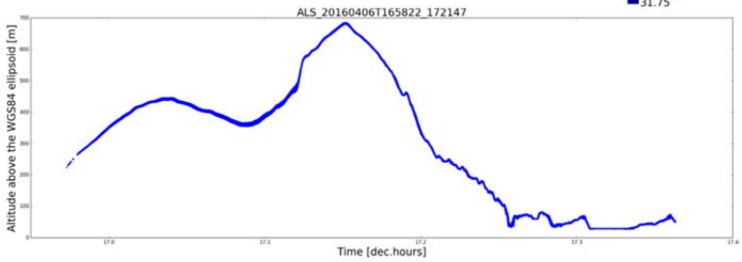


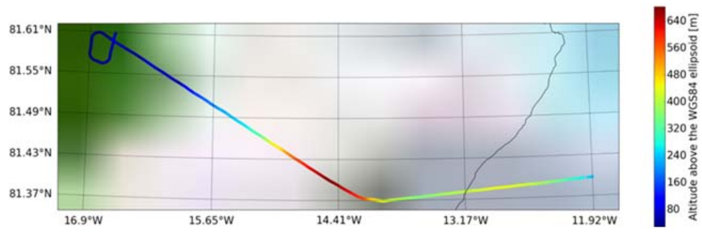




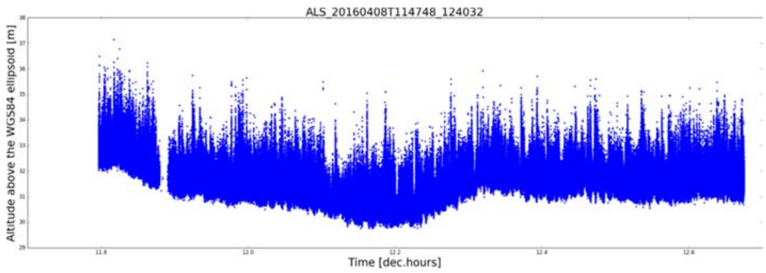

ALS_20160406T155509_162442
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

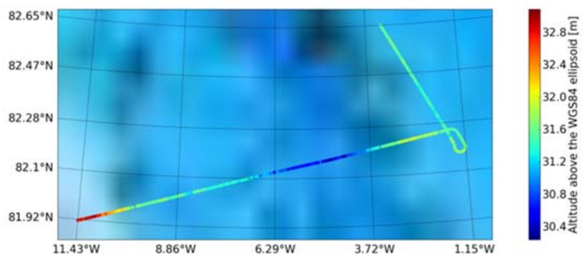

81.36°N
81.32°N
81.28°N
81.24°N
3.45°W
1.6°W
0.25°E
2.1°E
3.95°E
33.75
33.50
33.25
33.00
32.75
32.50
32.25
32.00
31.75
Altitude above the WGS84 ellipsoid [m]

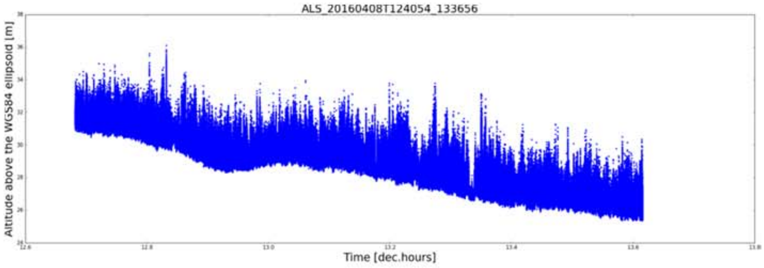

ALS_20160406T165822_172147
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

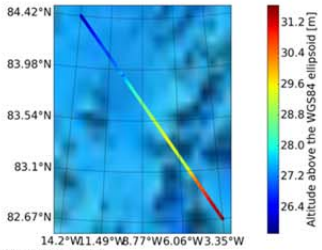

81.61°N
81.55°N
81.49°N
81.43°N
81.37°N
16.9°W
15.65°W
14.41°W
13.17°W
11.92°W
640
560
480
400
320
240
160
80
Altitude above the WGS84 ellipsoid [m]

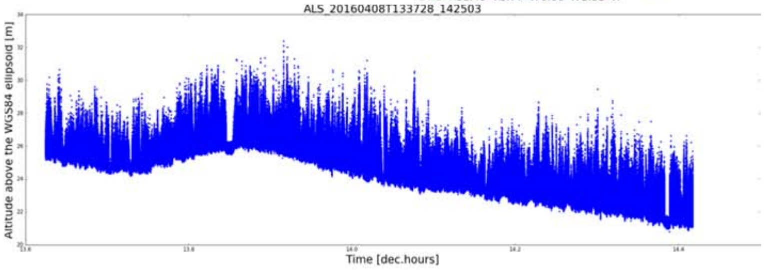
Day 099

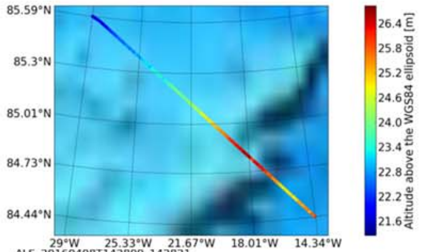

ALS_20160408T114748_124032
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

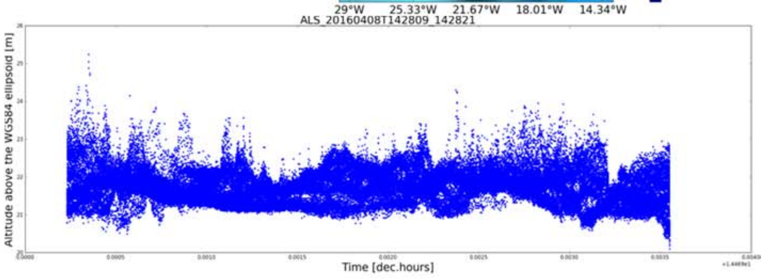

82.65°N
82.47°N
82.28°N
82.1°N
81.92°N
11.43°W
8.86°W
6.29°W
3.72°W
1.15°W
32.8
32.4
32.0
31.6
31.2
30.8
30.4
Altitude above the WGS84 ellipsoid [m]


ALS_20160408T124054_133656
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

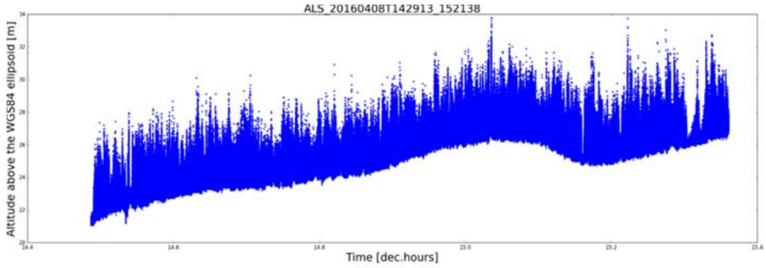

84.42°N
83.98°N
83.54°N
83.1°N
82.67°N
14.2°W11.49°W8.77°W6.06°W3.35°W
31.2
30.4
29.6
28.8
28.0
27.2
26.4
Altitude above the WGS84 ellipsoid [m]

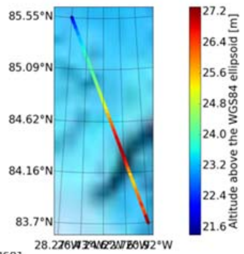

ALS_20160408T133728_142503
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

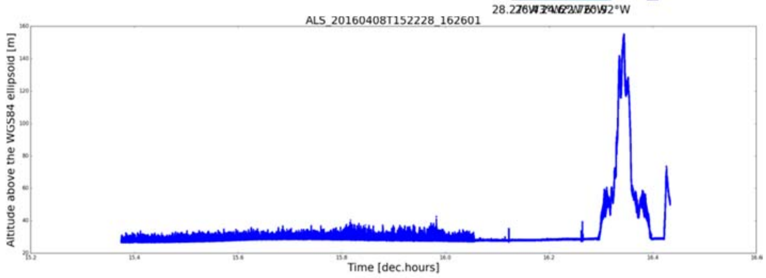

85.59°N
85.3°N
85.01°N
84.73°N
84.44°N
29°W
25.33°W
21.67°W
18.01°W
14.34°W
26.4
25.8
25.2
24.6
24.0
23.4
22.8
22.2
21.6
Altitude above the WGS84 ellipsoid [m]

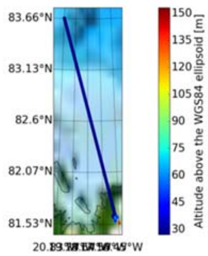

ALS_20160408T142809_142821
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]


This scanner file is to short ot make time average

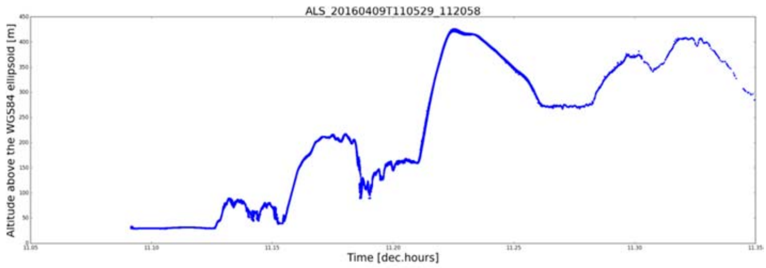

ALS_20160408T142913_152138
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

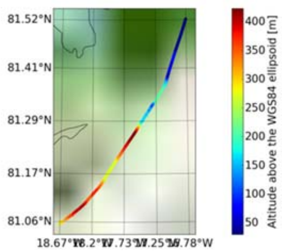

85.55°N
85.09°N
84.62°N
84.16°N
83.7°N
27.2
26.4
25.6
24.8
24.0
23.2
22.4
21.6
Altitude above the WGS84 ellipsoid [m]

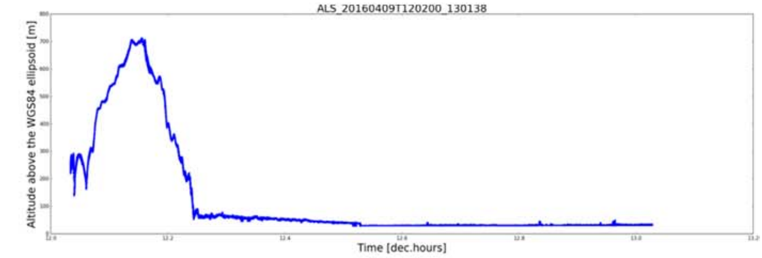

ALS_20160408T152228_162601
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

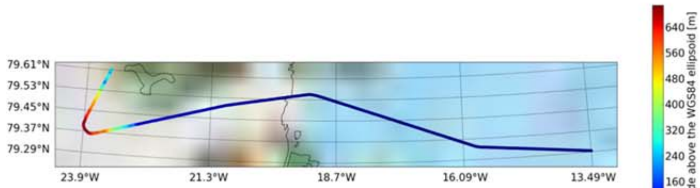

83.66°N
83.13°N
82.6°N
82.07°N
81.53°N
150
135
120
105
90
75
60
45
30
Altitude above the WGS84 ellipsoid [m]

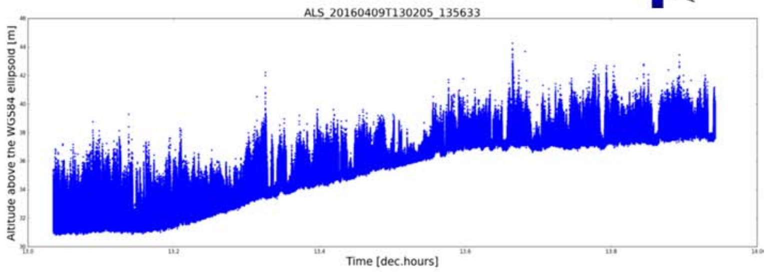
Day 100

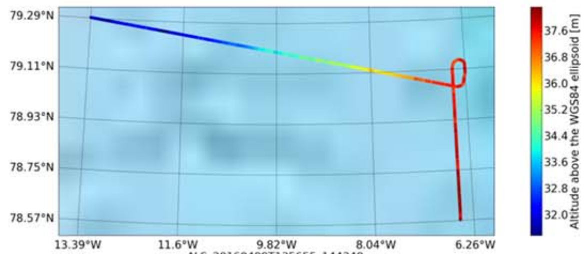

ALS_20160409T110529_112058
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

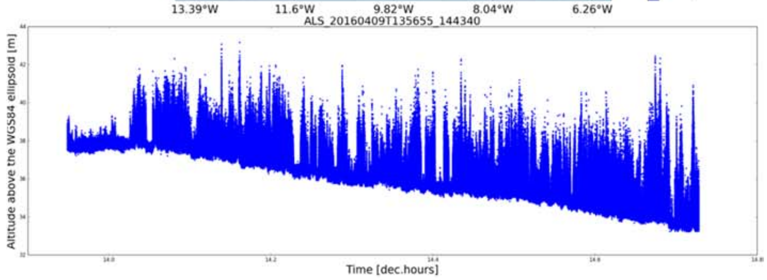

81.52°N
81.41°N
81.29°N
81.17°N
81.06°N
400
350
300
250
200
150
100
50
Altitude above the WGS84 ellipsoid [m]

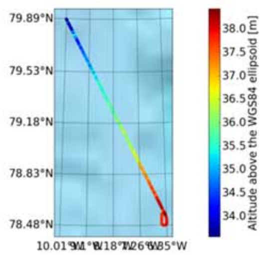

ALS_20160409T120200_130138
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

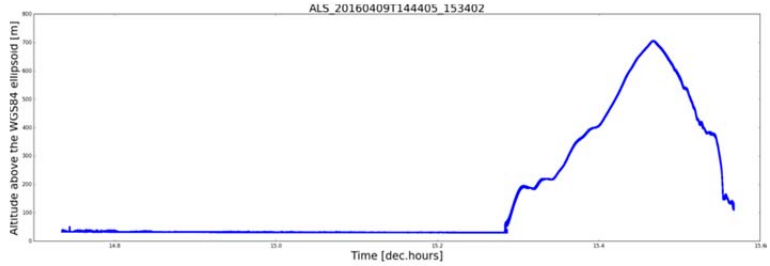

79.61°N
79.53°N
79.45°N
79.37°N
79.29°N
23.9°W
21.3°W
18.7°W
16.09°W
13.49°W
640
560
480
400
320
240
160
80
Altitude above the WGS84 ellipsoid [m]

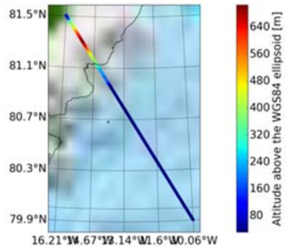

ALS_20160409T130205_135633
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]


79.29°N
79.11°N
78.93°N
78.75°N
78.57°N
13.39°W
11.6°W
9.82°W
8.04°W
6.26°W
37.6
36.8
36.0
35.2
34.4
33.6
32.8
32.0
Altitude above the WGS84 ellipsoid [m]

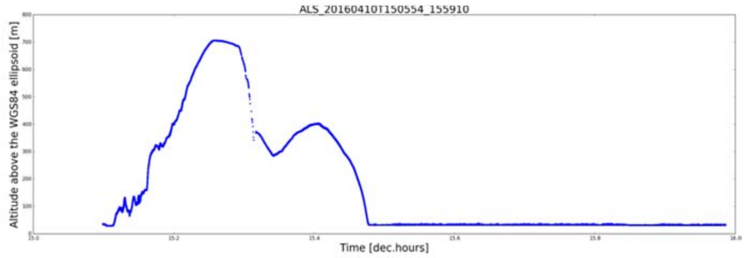

ALS_20160409T135655_144340
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

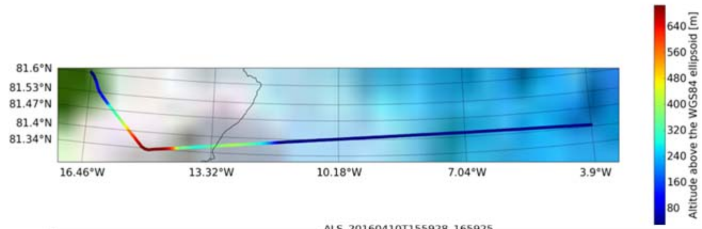

79.89°N
79.53°N
79.18°N
78.83°N
78.48°N
38.0
37.5
37.0
36.5
36.0
35.5
35.0
34.5
34.0
Altitude above the WGS84 ellipsoid [m]

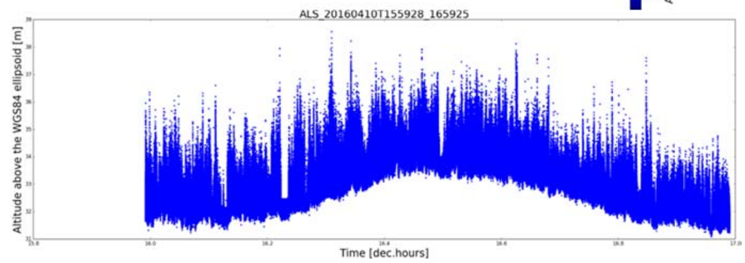

ALS_20160409T144405_153402
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

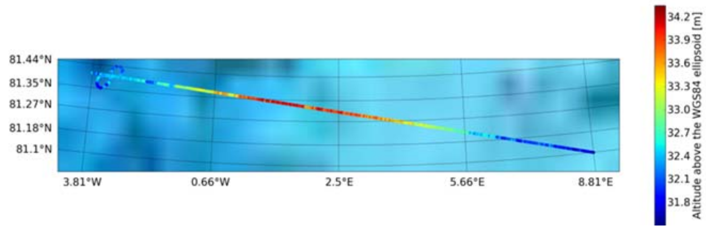

81.5°N
81.1°N
80.7°N
80.3°N
79.9°N
640
560
480
400
320
240
160
80
Altitude above the WGS84 ellipsoid [m]

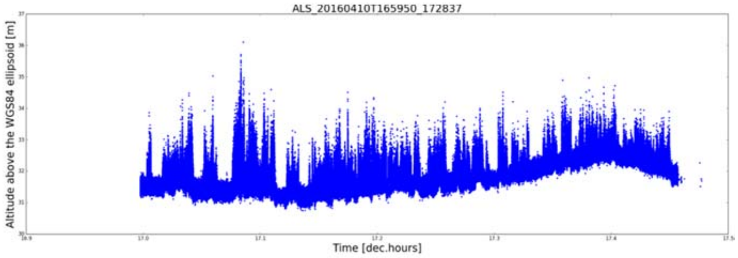
Day 101

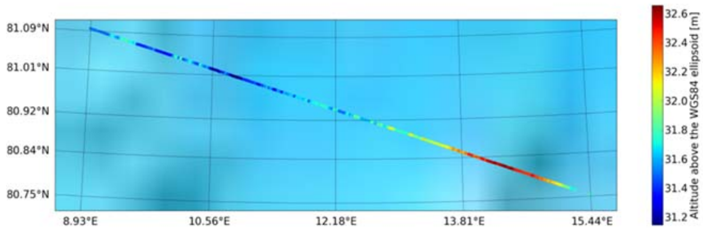

ALS_20160410T150554_155910
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]


81.6°N
81.53°N
81.47°N
81.4°N
81.34°N
16.46°W
13.32°W
10.18°W
7.04°W
3.9°W
640
560
480
400
320
240
160
80
Altitude above the WGS84 ellipsoid [m]

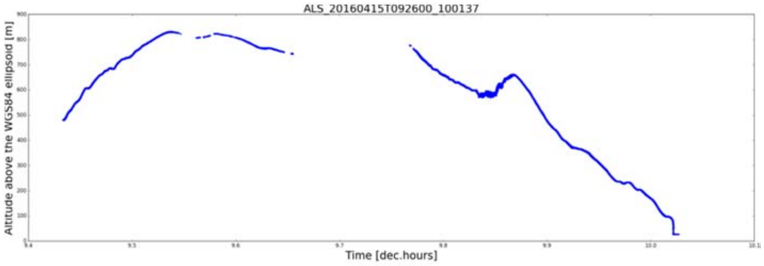

ALS_20160410T155928_165925
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

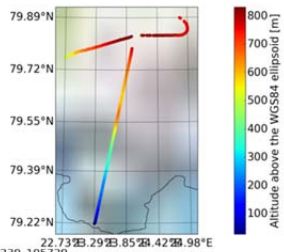

81.44°N
81.35°N
81.27°N
81.18°N
81.1°N
3.81°W
0.66°W
2.5°E
5.66°E
8.81°E
34.2
33.9
33.6
33.3
33.0
32.7
32.4
32.1
31.8
Altitude above the WGS84 ellipsoid [m]

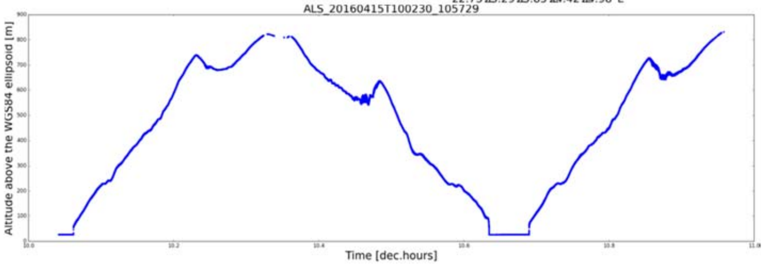

ALS_20160410T165950_172837
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

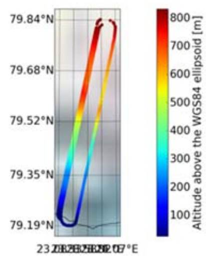

81.09°N
81.01°N
80.92°N
80.84°N
80.75°N
8.93°E
10.56°E
12.18°E
13.81°E
15.44°E
32.6
32.4
32.2
32.0
31.8
31.6
31.4
31.2
Altitude above the WGS84 ellipsoid [m]

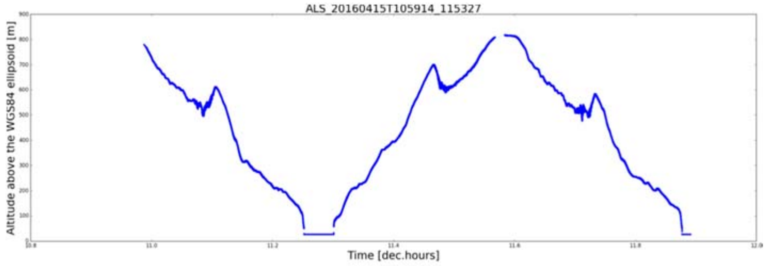
Day 106

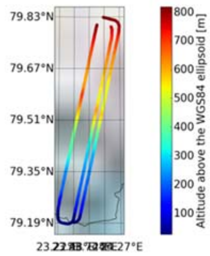

ALS_20160415T092600_100137
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

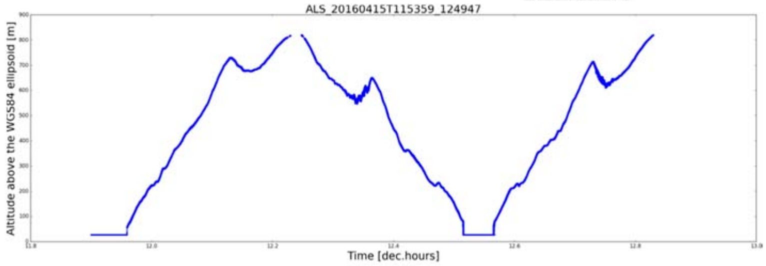

79.89°N
79.72°N
79.55°N
79.39°N
79.22°N
800
700
600
500
400
300
200
100
Altitude above the WGS84 ellipsoid [m]

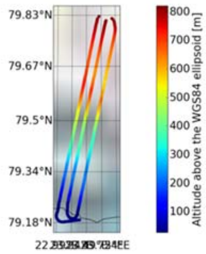

ALS_20160415T100230_105729
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

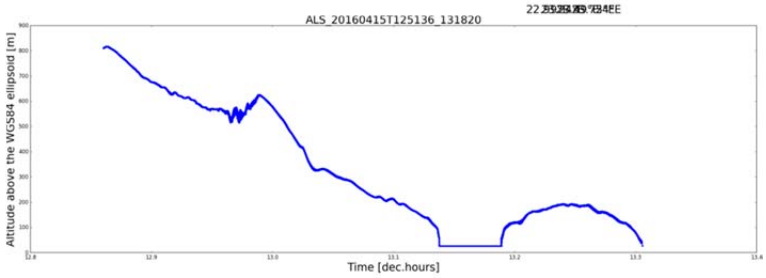

79.84°N
79.68°N
79.52°N
79.35°N
79.19°N
800
700
600
500
400
300
200
100
Altitude above the WGS84 ellipsoid [m]

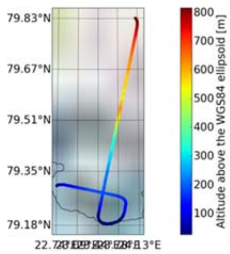

ALS_20160415T105914_115327
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

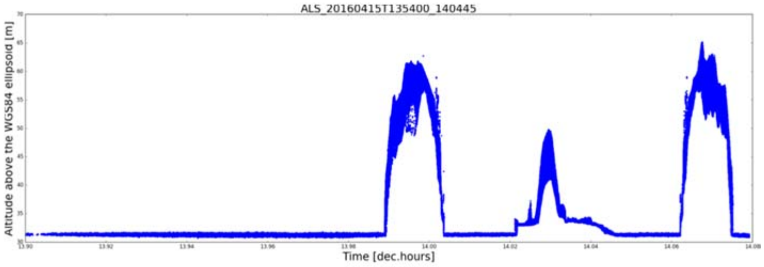

79.83°N
79.67°N
79.51°N
79.35°N
79.19°N
800
700
600
500
400
300
200
100
Altitude above the WGS84 ellipsoid [m]

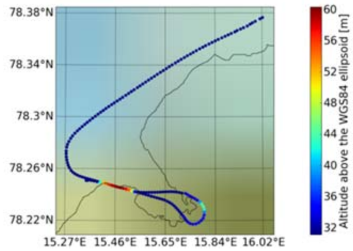

ALS_20160415T115359_124947
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]


79.83°N
79.67°N
79.5°N
79.34°N
79.18°N
800
700
600
500
400
300
200
100
Altitude above the WGS84 ellipsoid [m]

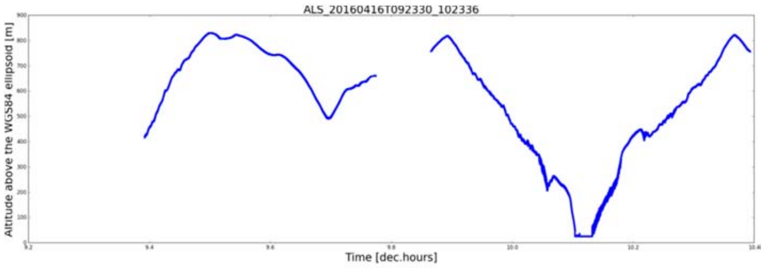

ALS_20160415T125136_131820
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

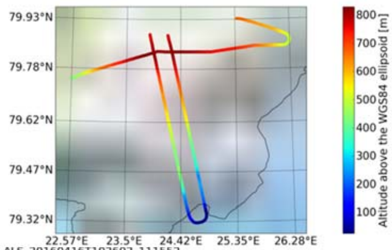

79.83°N
79.67°N
79.51°N
79.35°N
79.18°N
800
700
600
500
400
300
200
100
Altitude above the WGS84 ellipsoid [m]

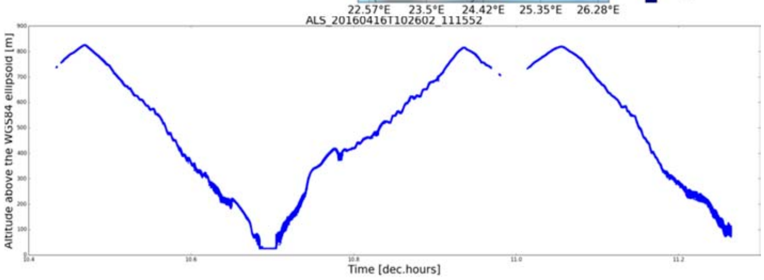

ALS_20160415T135400_140445
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

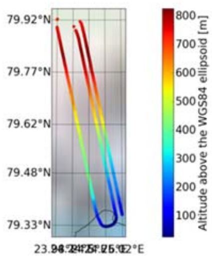

78.38°N
78.34°N
78.3°N
78.26°N
78.22°N
15.27°E 15.46°E 15.65°E 15.84°E 16.02°E
60
56
52
48
44
40
36
32
Altitude above the WGS84 ellipsoid [m]

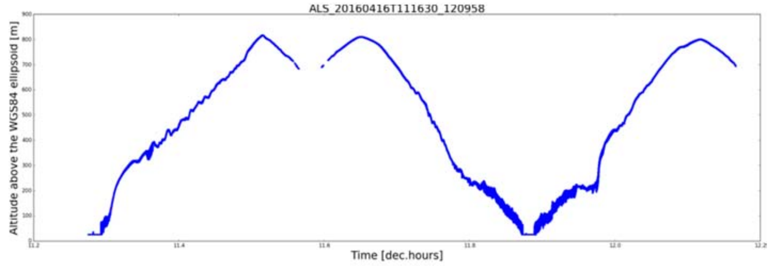
Day 107

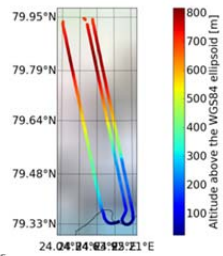

ALS_20160416T092330_102336
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]

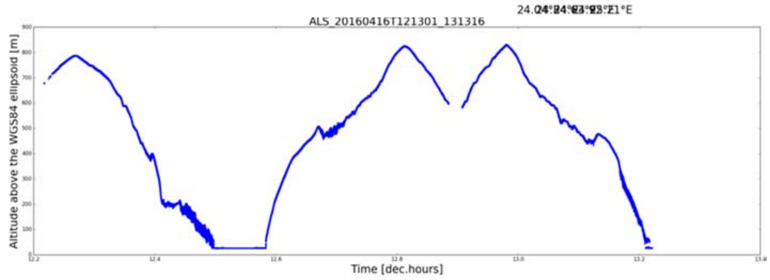

79.93°N
79.78°N
79.62°N
79.47°N
79.32°N
22.57°E 23.5°E 24.42°E 25.35°E 26.28°E
800
700
600
500
400
300
200
100
Altitude above the WGS84 ellipsoid [m]

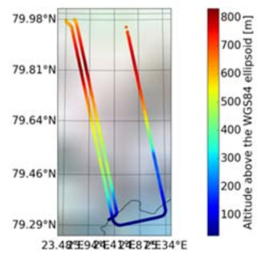

ALS_20160416T102602_111552
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]


79.92°N
79.77°N
79.62°N
79.48°N
79.33°N
800
700
600
500
400
300
200
100
Altitude above the WGS84 ellipsoid [m]


ALS_20160416T111630_120958
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]


79.95°N
79.79°N
79.64°N
79.48°N
79.33°N
800
700
600
500
400
300
200
100
Altitude above the WGS84 ellipsoid [m]


ALS_20160416T121301_131316
Altitude above the WGS84 ellipsoid [m]
Time [dec.hours]


79.98°N
79.81°N
79.64°N
79.46°N
79.29°N
800
700
600
500
400
300
200
100
Altitude above the WGS84 ellipsoid [m]

Appendix E. Overveiw of acquired ASIRAS log-files

Date	File name	Start time (UTC)	End time (UTC)	Range window (m)	# Pulses
05-04-2016	A160405_00.log	Problems with PC2		360.00	153199
	A160405_01.log			360.00	34866
06-04-2016	A160406_00.log	09:58:14	10:10:23	360.00	1822490
	A160406_01.log	15:07:43	16:01:40	90.00	8092449
	A160406_02.log	16:01:45	16:56:18	90.00	8182446
	A160406_03.log	16:56:22	17:16:34	90.00	3029980
08-04-2016	A160408_00.log	11:36:07	12:23:54	90.00	7167456
	A160408_01.log	12:23:59	13:28:40	90.00	9702442
	A160408_02.log	13:28:44	14:23:37	90.00	8232450
	A160408_03.log	14:23:41	15:22:34	90.00	8832446
	A160408_04.log	15:22:37	16:09:31	90.00	7034957
	A160408_05.log	16:09:34	16:23:19	90.00	2062487
09-04-2016	A160409_00.log	11:59:16	12:55:17	90.00	8402446
	A160409_01.log	12:55:21	13:58:32	90.00	9477436
	A160409_02.log	13:58:36	15:00:13	90.00	9242438
	A160409_03.log	15:00:16	15:32:27	90.00	4827467
10-04-2016	A160410_00.log	15:09:59	16:02:10	90.00	7827451
	A160410_01.log	16:02:14	17:00:19	90.00	8712443
	A160410_02.log	17:00:22	17:27:52	90.00	4124973
15-04-2016	A160415_00.log	09:18:57	10:01:31	90.00	6384958
	A160415_01.log	10:01:37	10:01:46	90.00	22500
	A160415_02.log	10:01:59	10:57:27	90.00	8319944
	A160415_03.log	10:57:30	11:52:58	90.00	8319943
	A160415_04.log	11:53:01	12:50:50	90.00	8672442
	A160415_05.log	12:50:53	13:18:20	90.00	4117473
	A160415_06.log	13:55:09	14:04:39	90.00	1424991
16-04-2016	A160416_00.log	09:12:34	09:16:25	90.00	577497
	A160416_01.log	09:19:17	10:24:03	90.00	9714935
	A160416_02.log	10:24:07	11:16:13	90.00	7814948
	A160416_03.log	11:16:18	12:10:47	90.00	8172445
	A160416_04.log	12:10:50	13:12:33	90.00	9257437

Appendix F. ESA File name convention ESA data format

In general, the filename contains a shortcut for the instrument and the start and stop time of the data file.

ASIRAS:
AS30AXX_ASIWL1BNNNN_SSSSSSSSSSSSSSS_PPPPPPPPPPPPPPP_0001.DBL

AS30AXX	ASIRAS (AS30), AXX number of data log
ASIWL1BNNNN	Level 1B data (L1B) processor version (NNNN)
SSSSSSSSSSSSSSS	Start time given as YYYYMMDDTHHMMSS
PPPPPPPPPPPPPPP	Stop time given as YYYYMMDDTHHMMSS

GPS
GPS_ANT_VER_SSSSSSSSSSSSSSS-PPPPPP_0001.DAT

ANT	GPS antenna R for rear, and F for front
VER	Version
SSSSSSSSSSSSSSS	Start time given as YYYYMMDDTHHMMSS
PPPPPP	Stop time given as HHMMSS

Inertial Navigation System (INS)
INS_ SSSSSSSSSSSSSSS-PPPPPP_0001.DAT

SSSSSSSSSSSSSSS	Start time given as YYYYMMDDTHHMMSS
PPPPPP	Stop time given as HHMMSS

Airborne laser scanner (ALS) full resolution
ALS_L1B_ SSSSSSSSSSSSSSS-PPPPPP.DAT

L1B	Level 1B data
SSSSSSSSSSSSSSS	Start time given as YYYYMMDDTHHMMSS
PPPPPP	Stop time given as HHMMSS

AEM data files
HEM_CMPID_SSSSSSSSSSSSSSS_PPPPPPPPPPPPPPP.dat

CMPID	Contains campaign name (3 letters + 2 digits of year), The id for the CryoVEx 2011 field campaign is given by CRV11.
SSSSSSSSSSSSSSS	Start time given as YYYYMMDDTHHMMSS
PPPPPPPPPPPPPPP	Stop time given as YYYYMMDDTHHMMSS

Appendix G. ESA data format

The following appendix has been adapted from Stenseng et al (2007). The format description for core products is taken from the "ASIRAS, product Description, Issue: 2.6.1" by Cullen (2010) and the users should refer to this document for detailed information. The definition of the types used in the binary files can be found in Table 15.

Table 11: Definition of binary types used in the description of the file format

Type	Description	Size [Bytes]
uc	Unsigned character	1
sc	Signed character	1
us	Unsigned short integer	2
ss	Signed short integer	2
ul	Unsigned long integer	4
sl	Signed long integer	4
ull	Unsigned long long integer	8
sll	Signed long long integer	8
d	Double precision floating	8
f	Single precision floating	4
[n]	Array length n	

1.25 ASIRAS L1b

Processed L1b ASIRAS data is delivered in binary, big endian format as described by Cullen (2010) and Tables 16, 17 and 18.

The L1b product consists of two elements.

1. An ASCII header consisting of a main product header (MPH), a specific product header (SPH), and the data set descriptors (DSDs).
2. A binary, big endian measurement data set (MDS).

Table 12: ASIRAS main product header (MPH) format

Field #	Description	Units	Bytes	Format
	Product Identification Information			
#01	PRODUCT=	keyword	8	8*uc
	quotation mark (")		1	uc
	Product File Name		62	uc
	quotation mark (")		1	uc
	newline character	terminator	1	uc
#02	PROC_STAGE=	keyword	11	11*uc
	Processing stage code:		1	uc
	N = Near-Real Time			
	T = Test			
	O = OFF Line (Systematic)			

	R = Reprocessing			
	L = Long Term Archive			
	newline character	terminator	1	uc
#03	REF_DOC=	keyword	8	8*uc
	quotation mark (")		1	uc
	Reference DFCB Document		23	23*uc
	describing the product			
	quotation mark (")		1	uc
	newline character	terminator	1	uc
#04	Spare		40	40*uc
	newline character	terminator	1	uc
	Data Processing Information			
#05	ACQUISITION_STATION=	keyword	20	20*uc
	quotation mark (")		1	uc
	Acquisition Station ID		20	Kiruna
	Filled by blanks			
	quotation mark (")		1	uc
	newline character	terminator	1	uc
#06	PROC_CENTER=	keyword	12	12*uc
	quotation mark (")		1	uc
	Processing Center ID code		6	PDS
	quotation mark (")		1	uc
	newline character	terminator	1	uc
#07	PROC_TIME=	keyword	10	10*uc
	quotation mark (")		1	uc
	Processing Time	UTC	27	dd-MMM-yyyy
	(Product Generation Time)			hh:mm:ss.uuuuuu
	quotation mark (")		1	uc
	newline character	terminator	1	uc
#08	SOFTWARE_VER=	Keyword	13	13*uc
	quotation mark (")		1	uc
	Processor name, up to 8 characters, and		14	14*uc
	software version number followed by			ProcessorName/VV.rr
	trailer blanks if any.			
	If not used set to blanks			
	quotation mark (")		1	uc
	newline character	terminator	1	uc
#09	Spare (blank characters)		40	40*uc
	newline character	terminator	1	uc
	Information on Time of Data			
#10	SENSING_START=	keyword	14	14*uc
	quotation mark (")		1	uc
	UTC start time of data sensing. This is	UTC	27	dd-MMM-yyyy

	the UTC start time of the Input Level 0			hh:mm:ss.uuuuuu
	Product.			
	If not used set to 27 blanks			
	quotation mark (")		1	uc
	newline character	terminator	1	uc
#11	SENSING_STOP=	keyword	13	13*uc
	quotation mark (")		1	uc
	UTC stop time of data sensing. This is	UTC	27	dd-MMM-yyyy
	the UTC stop time of the Input Level 0			hh:mm:ss.uuuuuu
	Product.			
	If not used set to 27 blanks			
	quotation mark (")		1	uc
	newline character	terminator	1	uc
#12	Spare (blank characters)		40	40*uc
	newline character	terminator	1	uc
	Orbit Information			
#13	PHASE=	keyword	6	6*uc
	Phase Code:		1	
	phase letter (A, B, \...)			uc
	If not used set to X			
	newline character	terminator	1	uc
#14	CYCLE=	keyword	6	6*uc
	Cycle number.		4	%+04d
	If not used set to +000			
	newline character	terminator	1	uc
#15	REL_ORBIT=	keyword	10	10*uc
	Relative Orbit Number at sensing start		6	%+06d
	time. If not used set to +00000			
	newline character	terminator	1	uc
#16	ABS_ORBIT=	keyword	10	10*uc
	Absolute Orbit Number at sensing start		6	%+06d
	time. If not used set to +00000			
	newline character	terminator	1	uc
#17	STATE_VECTOR_TIME=	keyword	18	18*uc
	quotation mark (")		1	uc
	UTC state vector time	UTC	27	dd-MMM-yyyy
	It is filled properly in case of usage of			hh:mm:ss.uuuuuu
	FOS Predicted Orbit information			
	otherwise it shall be set to 27 blanks			
	quotation mark (")		1	uc
	newline character	terminator	1	uc
#18	DELTA_UT1=	keyword	10	10*uc
	Universal Time Correction:	s	8	%+08.6f
	DUT1 = UT1 - UTC			

	Not used for ASIRAS. It shall be set to			
	+.000000			
	<s>	units	3	3*uc
	newline character	terminator	1	uc
#19	X_POSITION=	keyword	11	11*uc
	X position in Earth Fixed Reference.	m	12	%+012.3f
	If not used set to +0000000.000			
	<m>	units	3	3*uc
	newline character	terminator	1	uc
#20	Y_POSITION=	keyword	11	11*uc
	Y position in Earth Fixed Reference.	m	12	%+012.3f
	If not used set to +0000000.000			
	<m>	units	3	3*uc
	newline character	terminator	1	uc
#21	Z_POSITION=	keyword	11	11*uc
	Z position in Earth Fixed Reference.	m	12	%+012.3f
	If not used set to +0000000.000			
	<m>	units	3	3*uc
	newline character	terminator	1	uc
#22	X_VELOCITY=	keyword	11	11*uc
	X velocity in Earth Fixed Reference.	m/s	12	%+012.6f
	If not used set to +0000.000000			
	<m/s>	units	5	5*uc
	newline character	terminator	1	uc
#23	Y_VELOCITY=	keyword	11	11*uc
	Y velocity in Earth Fixed Reference.	m/s	12	%+012.6f
	If not used set to +0000.000000			
	<m/s>	units	5	5*uc
	newline character	terminator	1	uc
#24	Z_VELOCITY=	keyword	11	11*uc
	Z velocity in Earth Fixed Reference.	m/s	12	%+012.6f
	If not used set to +0000.000000			
	<m/s>	units	5	5*uc
	newline character	terminator	1	uc
#25	VECTOR_SOURCE=	keyword	14	14*uc
	quotation mark (")		1	uc
	Source of Orbit State Vector Record		2	2*uc
	FP = FOS predicted			
	DN = DORIS Level 0 navigator			
	DP = DORIS precise orbit			
	FR = FOS Restituted			
	DI = DORIS Preliminary			
	quotation mark (")		1	uc
	newline character	terminator	1	uc
#26	Spare (blank characters)		40	40*uc

	newline character	terminator	1	uc
	SBT to UTC conversion information			
#27	UTC_SBT_TIME=	Keyword	13	13*uc
	quotation mark (")		1	uc
	Not used and set to 27 blanks		27	27*uc
	quotation mark (")		1	uc
	newline character	Terminator	1	uc
#28	SAT_BINARY_TIME=	Keyword	16	16*uc
	Satellite Binary Time		11	+0000000000
	Not used for ASIRAS/Cryosat and it shall be			
	to zeros			
	newline character	Terminator	1	uc
#29	CLOCK_STEP =	Keyword	11	11*uc
	Clock Step		11	+0000000000
	Not used for ASIRAS/Cryosat and it shall be			
	to zeros			
	<ps>	Units	4	4*uc
	newline character	Terminator	1	uc
#30	Spare (blank characters)		32	32*uc
	newline character	Terminator	1	uc
	Leap Second Information			
#31	LEAP_UTC=	Keyword	9	9*uc
	quotation mark (")		1	uc
	UTC Time of the occurrence of the leap	UTC	27	dd-MMM-yyyy
	second.			hh:mm:ss.uuuuuu
	If a leap second occurred in the product			
	window the field is set by a devoted			
	function in the CFI			
	EXPLORER_ORBIT library (see			
	[EXPL_ORB-SUM] for details),			
	otherwise it is set to 27 blanks. It			
	corresponds to the time after the Leap			
	Second occurrence (i.e. midnight of the			
	day after the leap second)			
	quotation mark (")		1	uc
	newline character	terminator	1	uc
#32	LEAP_SIGN=	Keyword	10	10*uc
	Leap second sign	S	4	%+04d
	If a leap second occurred in the product			
	window the field is set to the expected			
	value by a devoted function in the CFI			
	EXPLORER_ORBIT library (see			
	[EXPL_ORB-SUM] for details),			
	otherwise it is set to +000.			
	newline character	terminator	1	uc

#33	LEAP_ERR=	keyword	9	9*uc
	Leap second error flag.		1	uc
	This field is always set to 0 considering			
	that CRYOSAT products have true UTC			
	times.			
	newline character	terminator	1	uc
#34	Spare (blank characters)		40	40*uc
	newline character	terminator	1	uc
	Product Confidence Data Information			
#35	PRODUCT_ERR=	keyword	12	12*uc
	Product Error Flag set to 1 if errors have		1	uc
	been reported in the product			
	newline character	terminator	1	uc
	Product Size Information			
#36	TOT_SIZE=	keyword	9	9*uc
	Total size of the product	bytes	21	%+021d
	<bytes>	units	7	7*uc
	newline character	terminator	1	uc
#37	SPH_SIZE=	keyword	9	9*uc
	Length of the SPH	bytes	11	%+011d
	<bytes>	units	7	7*uc
	newline character	terminator	1	uc
#38	NUM_DSD=	keyword	8	8*uc
	Number of Data Set Descriptors,		11	%+011d
	including spares and all other types of			
	DSDs			
	newline character	terminator	1	uc
#39	DSD_SIZE=	keyword	9	9*uc
	Length of each DSD	bytes	11	%+011d
	<bytes>	units	7	7*uc
	newline character	terminator	1	uc
#40	NUM_DATA_SETS=	keyword	14	14*uc
	Number of attached Data Sets (note that		11	%+011d
	not all the DSDs have a DS attached)			
	newline character	terminator	1	uc
#41	CRC=	keyword	4	4*uc
	Cyclic Redundancy Code computed as		6	%+06d
	overall value of all records of the			
	Measurement Data Set. If not computed			
	it shall be set to -00001			
	newline character	terminator	1	uc
#42	Spare (blank characters)		29	29*uc
	newline character	terminator	1	uc
Total				**1247**

Table 13: ASIRAS specific product header (SPH) format

Field #	Description	Units	Bytes	Format
	Product description and identification			
#1	SPH_DESCRIPTOR=	keyword	15	15*uc
	quotation mark (")		1	uc
	ASCII string describing the product		28	28*uc
	Set to			
	ASI_SAR_1B SPECIFIC HEADER			
	quotation mark (")		1	uc
	newline character	terminator	1	uc
	Product Time information			
#2	START_RECORD_TAI_TIME=	keyword	22	22*uc
	quotation mark (")		1	uc
	TAI of the first record in the Main	TAI	27	dd-MMM-yyyy
	MDS of this product			hh:mm:ss.uuuuuu
	quotation mark (")		1	uc
	newline character	terminator	1	uc
#3	STOP_RECORD_TAI_TIME=	keyword	21	21*uc
	quotation mark (")		1	uc
	TAI of the last record in in the Main	TAI	27	dd-MMM-yyyy
	MDS of this product			hh:mm:ss.uuuuuu
	quotation mark (")		1	uc
	newline character	terminator	1	uc
	Product Orbit Information			
#4	ABS_ORBIT_START=	keyword	16	16*uc
	Absolute Orbit Number at Product Start		6	%06d
	Time			
	newline character	terminator	1	uc
#5	REL_TIME_ASC_NODE_START=	Keyword	24	24*uc
	Relative time since crossing ascending	s	11	%011.6f
	node time relative to start time of data			
	sensing			
	<s>	units	3	3*uc
	newline character	terminator	1	uc
#6	ABS_ORBIT_STOP=	keyword	15	15*uc
	Absolute Orbit Number		6	%06d
	at Product Stop Time			
	newline character	terminator	1	uc
#7	REL_TIME_ASC_NODE_STOP=	Keyword	23	23*uc
	Relative time since crossing ascending	s	11	%011.6f
	node time relative to stop time of data			
	sensing			
	<s>	units	3	3*uc
	newline character	terminator	1	uc

#8	EQUATOR_CROSS_TIME_UTC=	Keyword	23	23*uc
	quotation mark (")		1	uc
	Time of Equator crossing at the	UTC	27	dd-MMM-yyyy
	ascending node of the sensing start time			hh:mm:ss.uuuuuu
	quotation mark (")		1	uc
	newline character	terminator	1	uc
#9	EQUATOR_CROSS_LONG=	Keyword	19	19*uc
	Longitude of Equator Crossing at the	s	11	%+011d
	ascending node of the sensing start time			
	(positive East, 0 = Greenwich) referred			
	to WGS84			
	<10-6degE>	units	10	10*uc
	newline character	terminator	1	uc
#10	ASCENDING_FLAG=	keyword	15	15*uc
	Orbit Orientation at the sensing start time		1	uc
	A= Ascending			
	D= Descending			
	newline character	terminator	1	uc
	Product Location Information			
#11	START_LAT=	keyword	10	10*uc
	WGS84 latitude of the first record in the	[10-6 deg]	11	%+011d
	Main MDS (positive north)			
	<10-6degN>	units	10	10*uc
	newline character	terminator	1	uc
#12	START_LONG=	keyword	11	11*uc
	WGS84 longitude of the first record in	[10-6 deg]	11	%+011d
	the Main MDS (positive East, 0 =			
	Greenwich)			
	<10-6degE>	units	10	10*uc
	newline character	terminator	1	uc
#13	STOP_LAT=	keyword	9	9*uc
	WGS84 latitude of the last record in	[10-6 deg]	11	%+011d
	the Main MDS (positive north)			
	<10-6degN>	units	10	10*uc
	newline character	terminator	1	uc
#14	STOP_LONG	keyword	10	10*uc
	WGS84 longitude of the last record in	[10-6 deg]	11	%+011d
	the Main MDS (positive East,			
	0 = Greenwich)			
	<10-6degE>	units	10	10*uc
	newline character	terminator	1	uc
#15	Spare (blank characters)		50	50*uc
	newline character	terminator	1	uc
	Level 0 Quality information			
#16	L0_PROC_FLAG=	keyword	13	13*uc

	Processing errors significance flag		1	uc
	(1 or 0).			
	1 if the percentage of SIRAL packets			
	free of processing errors is less than the			
	acceptable threshold			
	newline character	terminator	1	uc
#17	L0_PROCESSING_QUALITY=	keyword	22	22*uc
	Percentage of quality checks successfully	[10-2%]	6	%+06d
	passed during the SP processing (max			
	allowed +10000)			
	<10-2%>	units	7	7*uc
	newline character	terminator	1	uc
#18	L0_PROC_THRESH=	keyword	15	15*uc
	Minimum acceptable percentage of	[10-2%]	6	%+06d
	quality threshold that must be passed			
	during SP processing (max allowed			
	+10000)			
	<10-2%>	units	7	7*uc
	newline character	terminator	1	uc
#19	L0_GAPS_FLAG=	keyword	13	13*uc
	Gaps significance flag (1 or 0).		1	uc
	1 if gaps (either caused by extraction or			
	alignment failures) were detected during			
	the SP processing			
	newline character	terminator	1	uc
#20	L0_GAPS_NUM=	keyword	12	12*uc
	Number of gaps detected during the SP		8	%+08d
	processing (no gaps indicated as			
	+0000000)			
	newline character	terminator	1	uc
#21	Spare (blank characters)	ascii	50	50*uc
	newline character	terminator	1	uc
	ASIRAS Instrument Configuration			
#22	ASI_OP_MODE=	keyword	12	12*uc
	quotation mark (")		1	uc
	ASIRAS Operative Mode:		10	10*uc
	HAM			
	LAM			
	(strings shorter than 10 are filled in with			
	blanks)			
	quotation mark (")		1	uc
	newline character	terminator	1	uc
#23	ASI_CONFIGURATION=	keyword	18	17*uc
	quotation mark (")		1	uc
	SIRAL Configuration:		7	7*uc

	RX_1			
	RX_2			
	BOTH			
	UNKNOWN			
	(strings shorter than 7 are filled in with			
	blanks)			
	quotation mark (")		1	uc
	newline character	terminator	1	uc
	Surface Statistics			
#24	OPEN_OCEAN_PERCENT=	keyword	19	19*uc
	Percentage of records detected on open	[10-2%]	6	%+06d
	ocean or semi-enclosed seas			
	<10-2%>	units	7	7*uc
	newline character	terminator	1	uc
#25	CLOSE_SEA_PERCENT=	keyword	18	18*uc
	Percentage of records detected on closed	[10-2%]	6	%+06d
	seas or inland lakes			
	<10-2%>	units	7	7*uc
	newline character	terminator	1	uc
#26	CONTINENT_ICE_PERCENT=	keyword	22	22*uc
	Percentage of records detected on	[10-2%]	6	%+06d
	continental ice			
	<10-2%>	units	7	7*uc
	newline character	terminator	1	Uc
#27	LAND_PERCENT Keyword 13 13*uc			
	Percentage of records detected on land	[10-2%]	6	%+06d
	<10-2%>	units	7	7*uc
	newline character	terminator	1	uc
#28	Spare (blank characters)	ascii	50	50*uc
	newline character	terminator	1	uc
	Level 1 Processing information			
#29	L1B_PROD_STATUS=	keyword	16	16*uc
	Complete/Incomplete Product		1	uc
	Completion Flag (0 or 1).			
	1 if the Product as a duration shorter than			
	the input Level 0			
	newline character	terminator	1	uc
#30	L1B_PROC_FLAG=	keyword	14	14*uc
	Processing errors significance flag (1 or 0).		1	uc
	1 if the percentage of DSR free of			
	processing errors is less than the			
	acceptable threshold			
	newline character	terminator	1	uc
#31	L1B_PROCESSING_QUALITY=	keyword	23	23*uc
	Percentage of quality checks successfully	[10-2%]	6	%+06d

	passed during Level 1B processing (max			
	allowed +10000)			
	<10-2%>	units	7	7*uc
	newline character	terminator	1	uc
#32	L1B_PROC_THRESH=	keyword	16	16*uc
	Minimum acceptable percentage of	[10-2%]	6	%+06d
	quality threshold that must be passed			
	during Level 1B processing (max			
	allowed +10000)			
	<10-2%>	units	7	7*uc
	newline character	terminator	1	uc
#33	Spare (blank characters)	ascii	50	50*uc
	newline character	terminator	1	uc
Total				**1112**

Table 14: ASIRAS data set descriptors (DSD) format

Field #N	Description	Units	Bytes	Format
	DSD Section			
#N.1	DS_vvvvvvvvvvvvvvvv	keyword	8	8*uc
	quotation mark (")		1	uc
	Name describing the Data Set		28	28*uc
	quotation mark (")		1	uc
	newline character	terminator	1	uc
#N.2	DS_TYPE=	keyword	8	8*uc
	Type of Data Set. It can be:		1	uc
	M = Measurement			
	R = Reference			
	newline character	terminator	1	uc
	External Product Reference			
	External Product Reference			
#N.3	FILENAME=	keyword	9	9*uc
	quotation mark (")		1	uc
	Name of the Reference File.		62	62*uc
	Used if DS_TYPE is set to R. It is left			
	trailer blanks. The file name includes			
	If not used it is set to 62 blanks.			
	quotation mark (")		1	uc
	newline character	terminator	1	uc
	Position and site of DS			
	Position and size of DS			
#N.4	DS_OFFSET=	keyword	10	10*uc
	Length in bytes of MPH + SPH	bytes	21	%+021d
	DS size of previous Data Set (if any).			

	<bytes>	units	7	7*uc
	newline character	terminator	1	uc
#N.5	DS_SIZE=	keyword	8	8*uc
	Length in bytes of the attached	bytes	21	%+021d
	Used if DS_TYPE is set to M			
	If not used set to 0			
	<bytes>	units	7	7*uc
	newline character	terminator	1	uc
	Number and length of DSRs			
	Number and length of DSRs			
#N.6	NUM_DSR=	keyword	8	8*uc
	Number of Data Set Records		11	%+011d
	newline character	terminator	1	uc
#N.7	DSR_SIZE=	keyword	9	9*uc
	Length in bytes of the Data Set	bytes	11	%+011d
	If not used set to +0			
	If variable set to -1			
	<bytes>	units	7	7*uc
	newline character	terminator	1	uc
#N.8	Spare	ascii	32	32*uc
	newline character	terminator	1	uc
Total				**280**

The MDS can be further divided into five parts as described below:

1. Time and Orbit Group (20 blocks per record)
2. Measurements Group (20 blocks per record)
3. Corrections Group (one block per record)(Zeroed for ASIRAS)
4. Average waveforms Group (one block per record)(Zeroed for ASIRAS)
5. Waveform Group (20 blocks per record)

Table 15: ASIRAS measurement data set (MDS) format

Identifier	Description	Units	Type	Size [Bytes]
	Time & Orbit Group Repeated 20 times			
1	Days	TAI	sl	4
2	Seconds		ul	4
3	Microseconds		ul	4
4	Spare		sl	4
5	Spare		us	2
6	Spare		us	2

7	Instrument Config		ul	4
8	Burst Counter		ul	4
9	Geodetic latitude of ASIRAS	10^{-7} Deg	sl	4
10	Longitude of ASIRAS centre	10^{-7} Deg	sl	4
11	WGS-84 ellipsoidal altitude	10^{-3} m	sl	4
12	Altitude rate determined	10^{-6} m/s	sl	4
13	Velocity [x,y,z], described	10^{-3} m/s	sl	3*4
14	Real antenna beam	10^{-6} m	sl	3*4
15	Interferometer baseline	10^{-6} m	sl	3*4
16	Measurement Confident		ul	4
	Measurements Group Repeated 20 times			
17	Window delay	10-12 s	sll	8
18	Spare		sl	4
19	OCOG width	Range bins*100	sl	4
20	OCOG or threshold	10^{-3} m	sl	4
21	Surface elevation derived	10^{-3} m	sl	4
22	AGC Channel 1	dB/100	sl	4
23	AGC Channel 2	dB/100	sl	4
24	Total fixed gain Ch1	dB/100	sl	4
25	Total fixed gain Ch2	dB/100	sl	4
26	Transmit Power	10^{-6} Watts	sl	4
27	Doppler range correction	10^{-3} m	sl	4
28	Instrument range	10^{-3} m	sl	4
29	Instrument range	10^{-3} m	sl	4
30	Spare		sl	4
31	Spare		sl	4
32	Internal phase correction	10^{-6} rad	sl	4
33	External phase correction	10^{-6} rad	sl	4
34	Noise power	dB/100	sl	4
35	Roll	10^{-3} Deg	ss	2
36	Pitch	10^{-3} Deg	ss	2
37	Yaw	10^{-3} Deg	ss	2
38	Spare		ss	2
39	Heading	10^{-3} Deg	sl	4
40	Standard deviation of roll	10^{-4} Deg	us	2
41	Standard deviation of pitch	10^{-4} Deg	us	2
42	Standard deviation of yaw	10^{-4} Deg	us	2
	Corrections Group Once per record			
	Empty for ASIRAS			
43	Spare		uc	64*1
	Average pulse-width limited Waveform group Once per record			
	Empty for ASIRAS			
44	Spare		uc	8236*1
	Multilooked Waveform Group Repeated 20 times			

45	Multi-looked Power Echo.	Counts (0-65535)	us	4096*2
46	Linear scale factor, A		sl	4
47	Power of 2 scale factor,B		sl	4
48	Number of multilooked		us	2
49	Flags		us	2
50	Beam behaviour		us	50*2
Total				**177940**

Processed ASIRAS profiles

The following recorded data are available for the ASIRAS radar system.

Day of Year	File	Size [KB]
096		

Following plots show all processed ASIRAS profiles. Each profile are plotted twice, and are shown next to each other using either the OCOG (left) or the TSRA (right) re-tracker. Each profile plot consists of four parts:

1. Header composed of daily profile number and the date and a sub-header with the filename.
2. Geographical plot of the profile (diamond indicates the start of the profile).
3. Rough indication of the heights as determined with the OCOG or TSRA retracker plotted versus time of day in seconds.
4. Info box with date, start and stop times in hour, minute, seconds, and in square brackets seconds of the day, acquisition mode etc.

It should be emphasized that the surface height determined by the OCOG retracker is a rough estimate and not a true height.

1.26 GPS

Processed DGPS data is delivered in binary, big endian format with each record formated as described by Cullen (2010) and Table 20.

Identifier	Description	Unit	Type	Size [Bytes]
1	Days (MJD)	UTC	sl	4
2	Seconds		ul	4
3	Microseconds		ul	4
4	Latitude	10^{-7} deg	sl	4
5	Longitude	10^{-7} deg	sl	4
6	Geodetic ellipsoidal height (WGS-84)	m	d	8
7	Spare_7	N/A	d	8
8	Spare_8	N/A	d	8
9	Spare_9	N/A	d	8
10	Spare_10	N/A	d	8
Total				**72**

Processed GPS data in ESA format

The following files are provided in the ESA GPS format.

Day of Year	File	Size [KB]
096	GPS_R_20160405T144559_151837_0001.DBL	115
097a	GPS_R_20160406T093656_101927_0001.DBL	150
097b	GPS_R_20160406T134950_172958_0001.DBL	775
099	GPS_R_20160408T110941_163200_0001.DBL	1133
100	GPS_R_20160409T104614_154300_0001.DBL	1044
101	GPS_R_20160410T144015_183129_0001.DBL	813
106	GPS_R_20160415T081412_140915_0001.DBL	1249
107	GPS_R_20160416T081752_140236_0001.DBL	1211

1.27 INS

Processed INS data is delivered in binary, big endian format with each record formatted as described by Cullen (2010) and Table 21.

Identifier	Description	Unit	Type	Size [Bytes]
1	Days (MJD)	UTC	sl	4
2	Seconds		sl	4
3	Microseconds		sl	4
4	Latitude (WGS-84)	Deg	d	8
5	Longitude	Deg	d	8
6	Ground speed	Kts	d	8
7	True Track	Deg	d	8
8	True Heading	Deg	d	8
9	Wind Speed	Kts	d	8
10	Wind Direction	Deg	d	8
11	Magnetic Heading	Deg	d	8
12	Pitch	Deg	d	8
13	Roll	Deg	d	8
14	Pitch Rate	deg/s	d	8
15	Roll Rate	deg/s	d	8
16	Yaw Rate	deg/s	d	8
17	Body longitudinal Acceleration	G	d	8
18	Body lateral Acceleration	G	d	8
19	Body normal acceleration	G	d	8
20	Vertical Acceleration in G	G	d	8
21	Velocity Inertial Vertical	ft/min	d	8
22	Velocity North-South	Kts	d	8
23	Velocity East-west	Kts	d	8
Total				**172**

Processed INS data in ESA format

The following files are provided in the ESA INS format.

Table 16 Files available

Day of Year	File	Size [KB]
096	INS_20160405T144536_151754_0001.DBL	3257
097a	INS_20160406T093718_101756_0001.DBL	4096
097b	INS_20160406T135146_172748_0001.DBL	21774
099	INS_20160408T110936_163110_0001.DBL	32411
100	INS_20160409T104612_154203_0001.DBL	29820
101	INS_20160410T144227_183013_0001.DBL	22958
106	INS_20160415T081348_140759_0001.DBL	35701
107	INS_20160416T081724_140300_0001.DBL	34836

1.28 Laser scanner (ALS)

Processed ALS data is delivered in binary, little endian format with each record formatted as described in Table 22. Note that time is in decimal hours since the beginning of the day with respect to UTC time.

Table 17: ALS file format

Identifier	Description	Unit	Type	Size [Bytes]
Header				
1	Header Size	bytes	uc	1
2	Number of scan lines, N_{als_scan}	lines	ul	4
3	Number of data points per line, N_{als_dppl}	points	uc	1
4	Bytes per line, N_{als_bbl}	bytes	us	2
5	Bytes sec line	bytes	ull	8
6	Year of acquisition	UTC	us	2
7	Month of acquisition	UTC	uc	1
8	Day of acquisition	UTC	uc	1
9	Acquisition Start time (Seconds of day)	UTC	ul	4
10	Acquisition Stop time (Seconds of day)	UTC	ul	4
11	Device name		uc	8
Total				**36**
Time stamp array				
1	Array of time stamps for each scan line	UTC	ul	$4*N_{als\_scan}$
Total				**$4*N_{als\_scan}$**
DEM Record Repeated N_{als_scan} times				
1	Array of time stamps for each point	UTC	d	$8*N_{als\_dppl}$
2	Array of latitudes for each point	degrees	d	$8*N_{als\_dppl}$
3	Array of longitudes for each point	degrees	d	$8*N_{als\_dppl}$
2	Array of ellipsoidal heights for each point	meter	d	$8*N_{als\_dppl}$
Total				**N_{als_bbl}**

Processed ALS data in ESA format

Day of Year	File	Size [KB]
096		

1.29 Vertical Camera

Approximate time and position of the vertical camera when a picture is taken is delivered in windows ASCII format as described in Table 24 and all individual pictures are in JPEG format. Each ASCII line gives the filename, time and position for the named picture. If no DGPS data is available, the time and position is replaced with the string “No position available”.

Table 18: Position file format for vertical images

Identifier	Description	Unit
1	JPEG filename	
2	Decimal hours	hour
3	Latitude (WGS-84)	deg
4	Longitude	deg
5	Geodetic ellipsoidal height	m
6	Newline characters "\r \n"	

Time-tagged and geo-located images

The following time-tagged and geo-located images are available from the GoPro camera, used for the sea ice flights April 8th -10th.

ASCII file	Date of acquisition	File name of zipped images	File size (MB)
PIX_GoPro_20160408.pos	08-04-2016	PIX_GoPro_20160408T120032-123330.zip	1,869
		PIX_GoPro_20160408T123333-130648.zip	1,947
		PIX_GoPro_20160408T130651-134006.zip	2,043
		PIX_GoPro_20160408T134009-141324.zip	2,005
		PIX_GoPro_20160408T141327-144642.zip	2,072
		PIX_GoPro_20160408T144645-151959.zip	2,186
		PIX_GoPro_20160408T152003-155120.zip	1,694
		PIX_GoPro_20160408T155123-162438.zip	1,644
		PIX_GoPro_20160408T162441-163039.zip	283
PIX_GoPro_20160409.pos	09-04-2016	PIX_GoPro_20160409T105911-111632.zip	882
		PIX_GoPro_20160409T111635-114951.zip	1,795
		PIX_GoPro_20160409T114954-122309.zip	1,874
		PIX_GoPro_20160409T122312-125627.zip	1,728
		PIX_GoPro_20160409T125630-132945.zip	2,082
		PIX_GoPro_20160409T132948-140303.zip	1,808
		PIX_GoPro_20160409T140306-143621.zip	1,962
		PIX_GoPro_20160409T143624-145642.zip	1,314
		PIX_GoPro_20160409T145644-153000.zip	1,857
		PIX_GoPro_20160409T153002-154142.zip	619
PIX_GoPro_20160410.pos	10-04-2016	PIX_GoPro_20160410T150324-152858.zip	1,289
		PIX_GoPro_20160410T152859-160216.zip	1,964

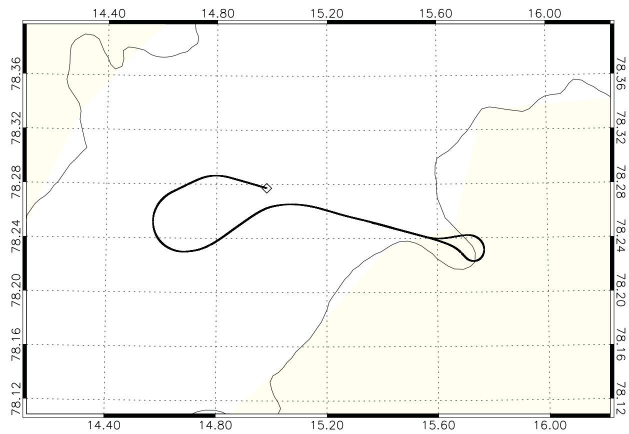
	PIX_GoPro_20160410T160217-160439.zip	137
	PIX_GoPro_20160410T163535-170852.zip	1,816
	PIX_GoPro_20160410T170853-173826.zip	1,437

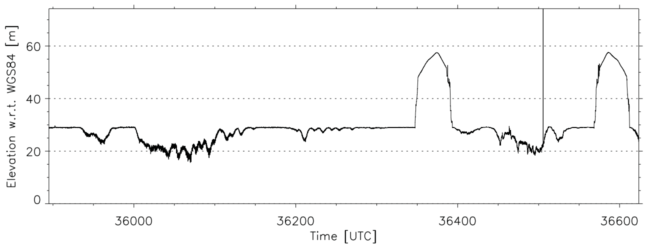
Images are also available from the uEye camera, for the first flight April 6th, see table below. None of the cameras were used during the second part of the campaign on the Austfonna ice cap in Svalbard.

ASCII file	Date of acquisition	File name of zipped images	File size (MB)
PIX_uEye_20160406.pos	06-04-2016	PIX_uEye_20160406T143114-145959.zip	1,075
		PIX_uEye_20160406T150000-155959.zip	1,820
		PIX_uEye_20160406T160000-163600.zip	2,244

A160406_00

AS60A00_ASIWL1B040320160406T095814_20160406T101023_0001.DBL

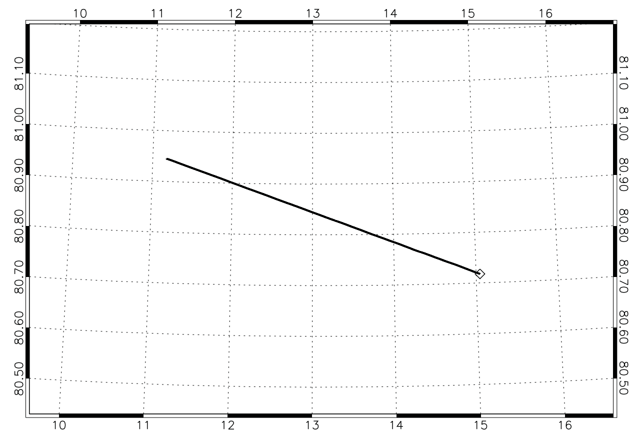


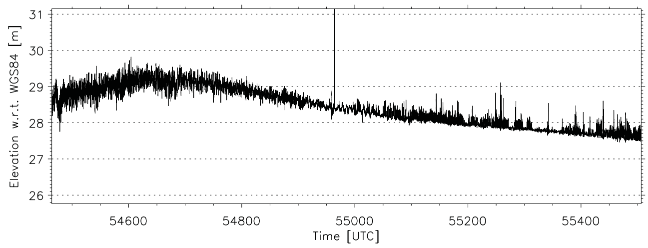


Date	2016-04-06	**Instrument Mode**	Adv. Low Altitude
Start Time	09:58:15 (35895)	**Aircraft**	BAS Twin Otter
Stop Time	10:10:23 (36623)	**Retracker**	OCOG
Distance	52.485 km	**INS Resolution**	50 Hz
Duration	00 h 12 m 09 s	**Processor Version**	0403

A160406_01

AS60A01_ASIWL1B040320160406T150743_20160406T160140_0001.DBL

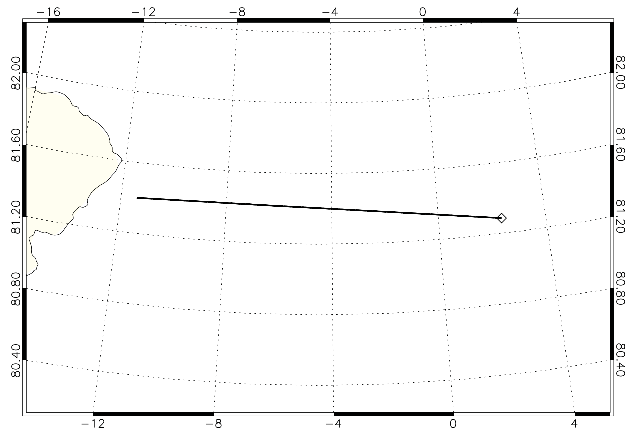


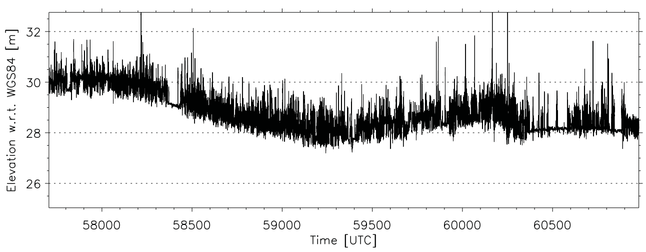


Date	2016-04-06	**Instrument Mode**	Adv. Low Altitude
Start Time	15:07:44 (54464)	**Aircraft**	BAS Twin Otter
Stop Time	15:25:06 (55506)	**Retracker**	OCOG
Distance	73.097 km	**INS Resolution**	50 Hz
Duration	00 h 17 m 23 s	**Processor Version**	0403

A160406_02

AS60A02_ASIWL1B040320160406T160145_20160406T165618_0001.DBL

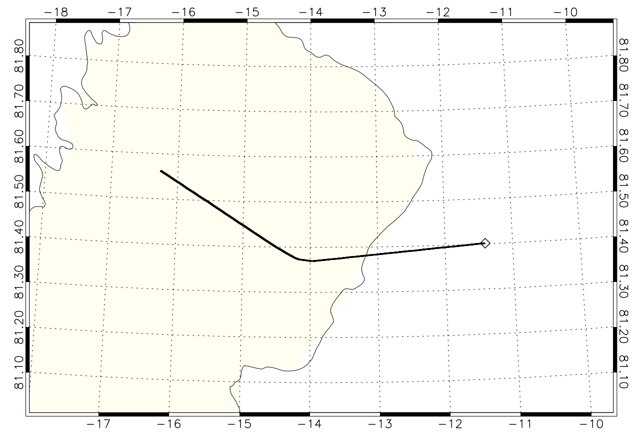


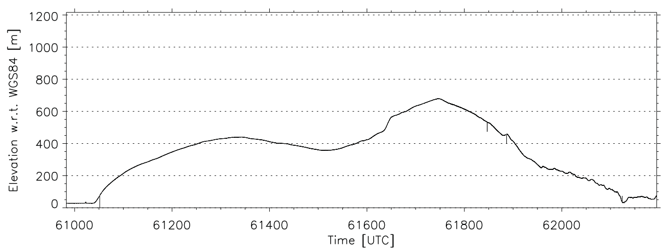


Date	2016-04-06	**Instrument Mode**	Adv. Low Altitude
Start Time	16:01:46 (57706)	**Aircraft**	BAS Twin Otter
Stop Time	16:56:18 (60978)	**Retracker**	OCOG
Distance	230.027 km	**INS Resolution**	50 Hz
Duration	00 h 54 m 32 s	**Processor Version**	0403

A160406_03

AS60A03_ASIWL1B040320160406T165622_20160406T171634_0001.DBL

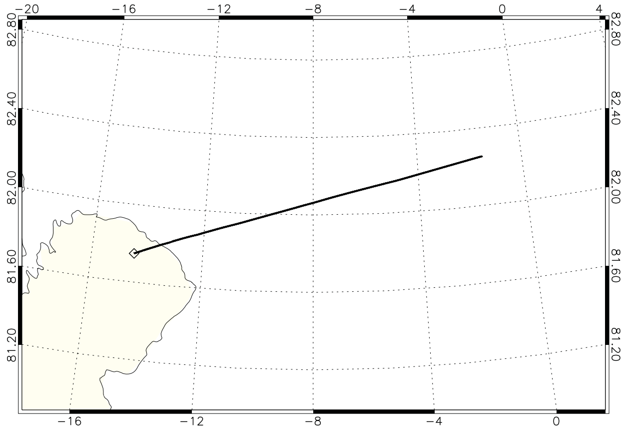


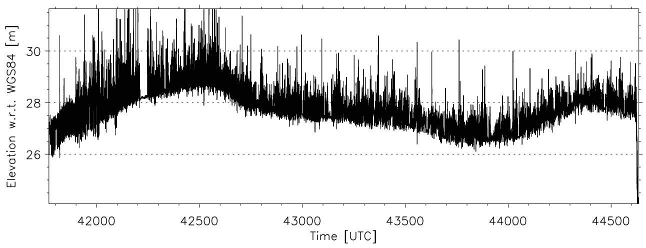


Date	2016-04-06	**Instrument Mode**	Adv. Low Altitude
Start Time	16:56:23 (60983)	**Aircraft**	BAS Twin Otter
Stop Time	17:16:34 (62194)	**Retracker**	OCOG
Distance	86.816 km	**INS Resolution**	50 Hz
Duration	00 h 20 m 12 s	**Processor Version**	0403

A160408_00

AS60A00_ASIWL1B040320160408T113607_20160408T122354_0001.DBL

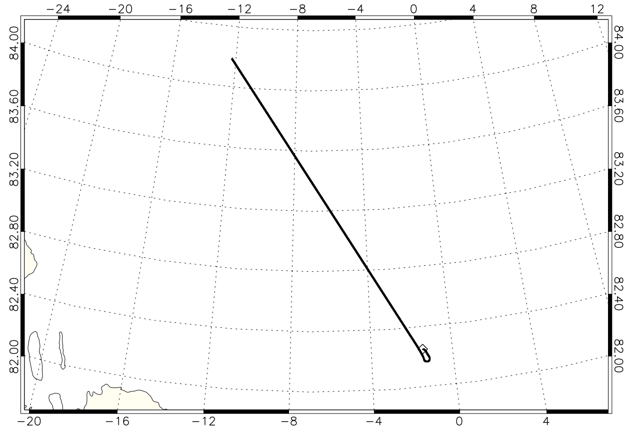


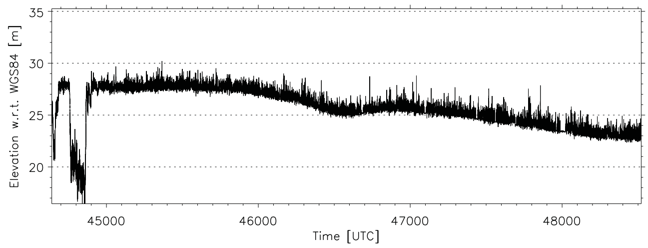


Date	2016-04-08	**Instrument Mode**	Adv. Low Altitude
Start Time	11:36:08 (41768)	**Aircraft**	BAS Twin Otter
Stop Time	12:23:54 (44634)	**Retracker**	OCOG
Distance	208.234 km	**INS Resolution**	50 Hz
Duration	00 h 47 m 47 s	**Processor Version**	0403

A160408_01

AS60A01_ASIWL1B040320160408T122359_20160408T132840_0001.DBL

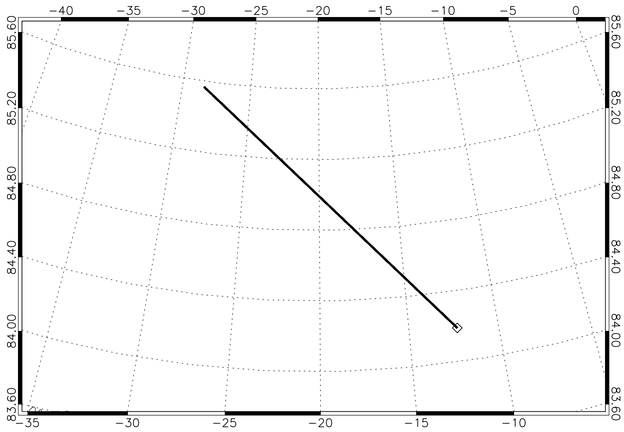


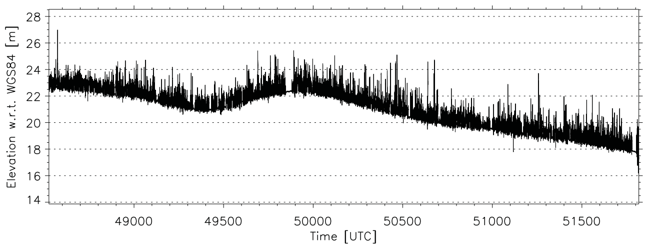


Date	2016-04-08	**Instrument Mode**	Adv. Low Altitude
Start Time	12:24:00 (44640)	**Aircraft**	BAS Twin Otter
Stop Time	13:28:40 (48520)	**Retracker**	OCOG
Distance	279.094 km	**INS Resolution**	50 Hz
Duration	01 h 04 m 41 s	**Processor Version**	0403

A160408_02

AS60A02_ASIWL1B040320160408T132844_20160408T142337_0001.DBL

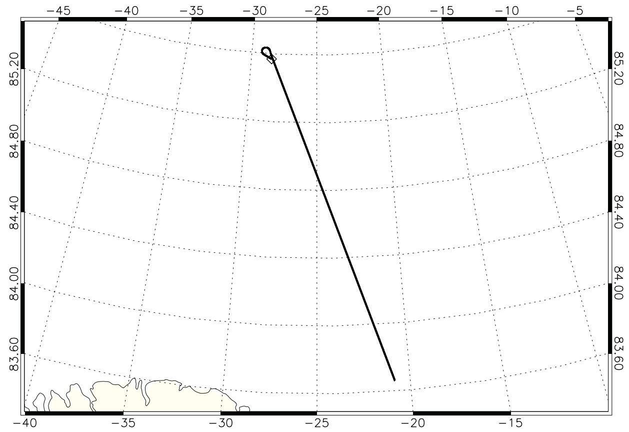


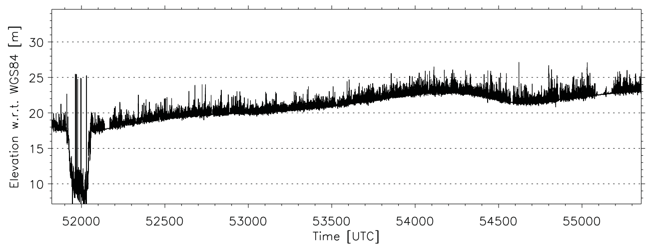


Date	2016-04-08	**Instrument Mode**	Adv. Low Altitude
Start Time	13:28:45 (48525)	**Aircraft**	BAS Twin Otter
Stop Time	14:23:37 (51817)	**Retracker**	OCOG
Distance	220.286 km	**INS Resolution**	50 Hz
Duration	00 h 54 m 53 s	**Processor Version**	0403

A160408_03

AS60A03_ASIWL1B040320160408T142341_20160408T152234_0001.DBL

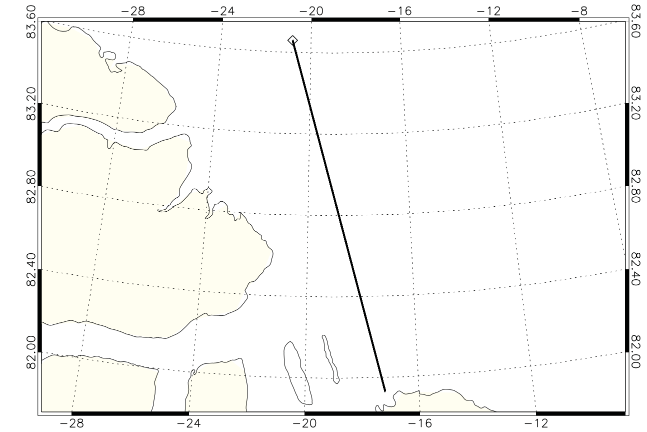


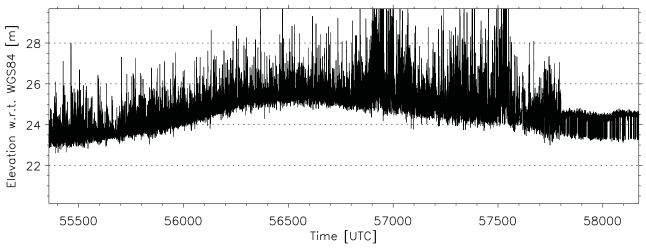


Date	2016-04-08	**Instrument Mode**	Adv. Low Altitude
Start Time	14:23:42 (51822)	**Aircraft**	BAS Twin Otter
Stop Time	15:22:34 (55354)	**Retracker**	OCOG
Distance	247.773 km	**INS Resolution**	50 Hz
Duration	00 h 58 m 53 s	**Processor Version**	0403

A160408_04

AS6OA04_ASIWL1B040320160408T152237_20160408T160931_0001.DBL

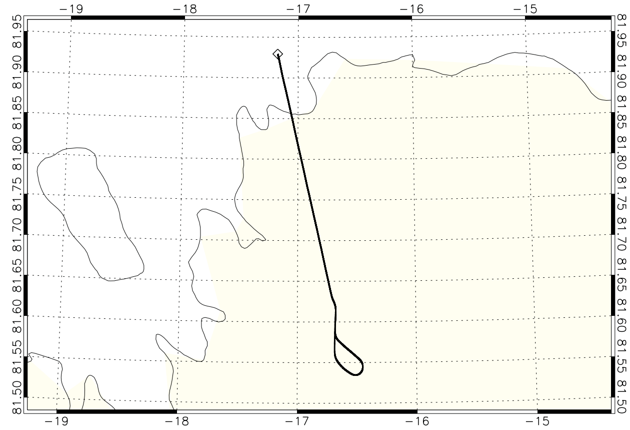


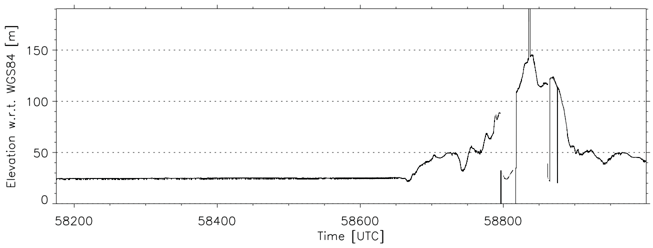


Date	2016-04-08	**Instrument Mode**	Adv. Low Altitude
Start Time	15:22:38 (55358)	**Aircraft**	BAS Twin Otter
Stop Time	16:09:31 (58171)	**Retracker**	OCOG
Distance	198.448 km	**INS Resolution**	50 Hz
Duration	00 h 46 m 54 s	**Processor Version**	0403

A160408_05

AS6OA05_ASIWL1B040320160408T160934_20160408T162319_0001.DBL

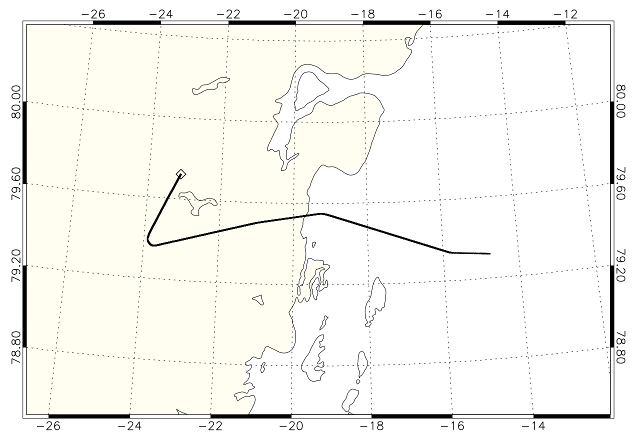


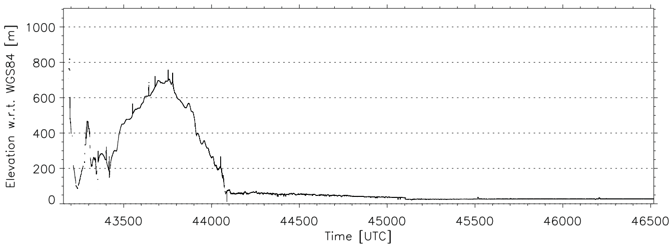


Date	2016-04-08	**Instrument Mode**	Adv. Low Altitude
Start Time	16:09:35 (58175)	**Aircraft**	BAS Twin Otter
Stop Time	16:23:19 (58999)	**Retracker**	OCOG
Distance	57.053 km	**INS Resolution**	50 Hz
Duration	00 h 13 m 45 s	**Processor Version**	0403

A160409_00

AS6OA00_ASIWL1B040320160409T115916_20160409T125517_0001.DBL

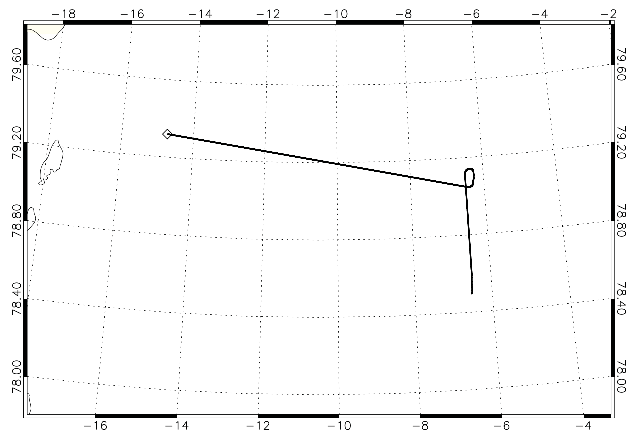


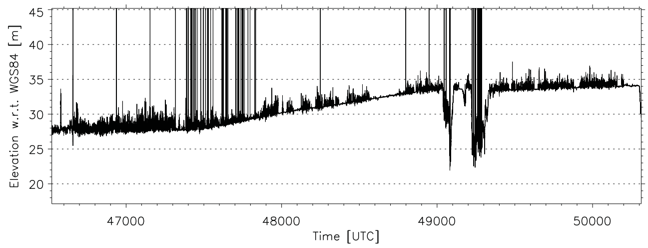


Date	2016-04-09	**Instrument Mode**	Adv. Low Altitude
Start Time	11:59:17 (43157)	**Aircraft**	BAS Twin Otter
Stop Time	12:55:17 (46517)	**Retracker**	OCOG
Distance	234.627 km	**INS Resolution**	50 Hz
Duration	00 h 56 m 01 s	**Processor Version**	0403

A160409_01

AS6OA01_ASIWL1B040320160409T125521_20160409T135832_0001.DBL

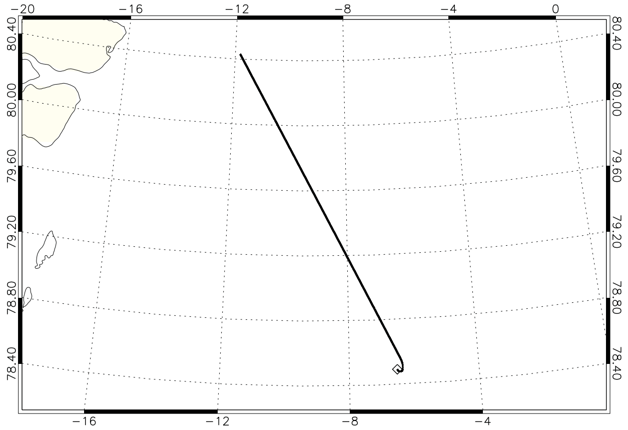


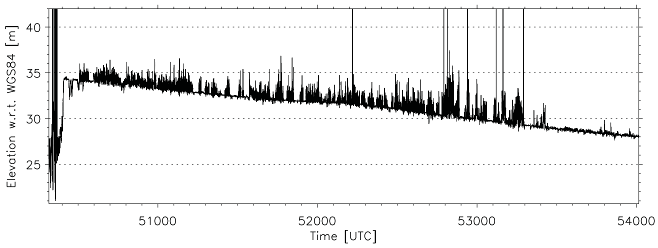


Date	2016-04-09	**Instrument Mode**	Adv. Low Altitude
Start Time	12:55:22 (46522)	**Aircraft**	BAS Twin Otter
Stop Time	13:58:32 (50312)	**Retracker**	OCOG
Distance	262.899 km	**INS Resolution**	50 Hz
Duration	01 h 03 m 11 s	**Processor Version**	0403

A160409_02

AS60A02_ASIWL1B040320160409T135836_20160409T150013_0001.DBL

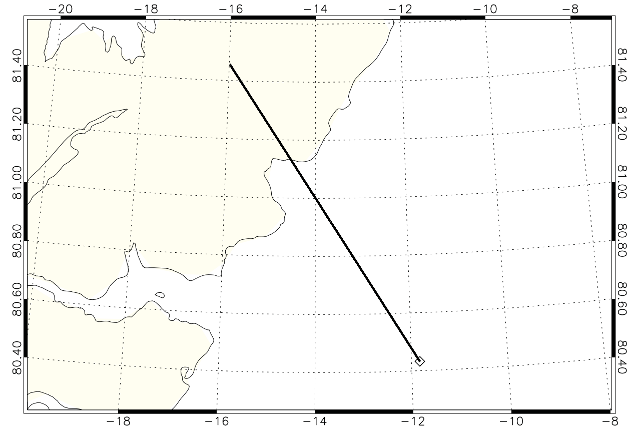


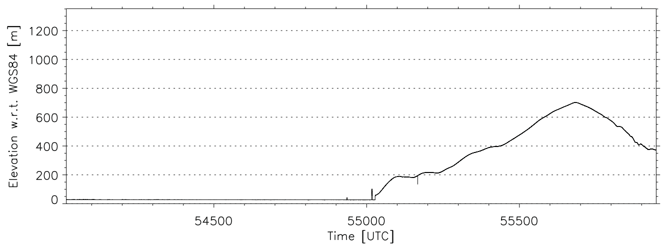


Date	2016-04-09	**Instrument Mode**	Adv. Low Altitude
Start Time	13:58:37 (50317)	**Aircraft**	BAS Twin Otter
Stop Time	15:00:13 (54013)	**Retracker**	OCOG
Distance	247.859 km	**INS Resolution**	50 Hz
Duration	01 h 01 m 37 s	**Processor Version**	0403

A160409_03

AS60A03_ASIWL1B040320160409T150016_20160409T153227_0001.DBL

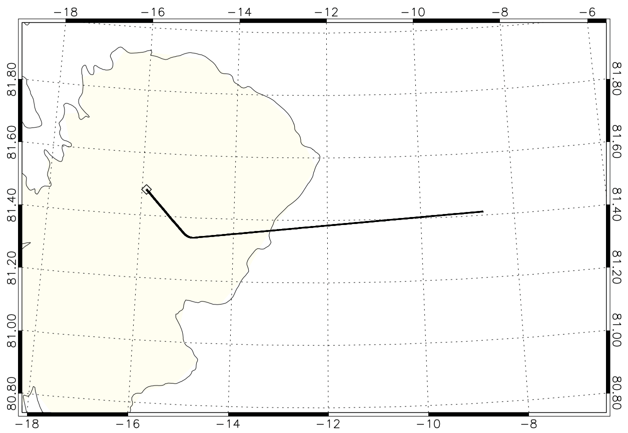


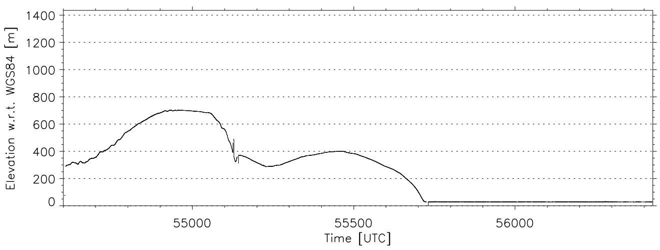


Date	2016-04-09	**Instrument Mode**	Adv. Low Altitude
Start Time	15:00:17 (54017)	**Aircraft**	BAS Twin Otter
Stop Time	15:32:27 (55947)	**Retracker**	OCOG
Distance	134.927 km	**INS Resolution**	50 Hz
Duration	00 h 32 m 11 s	**Processor Version**	0403

A160410_00

AS60A00_ASIWL1B040320160410T150959_20160410T160210_0001.DBL

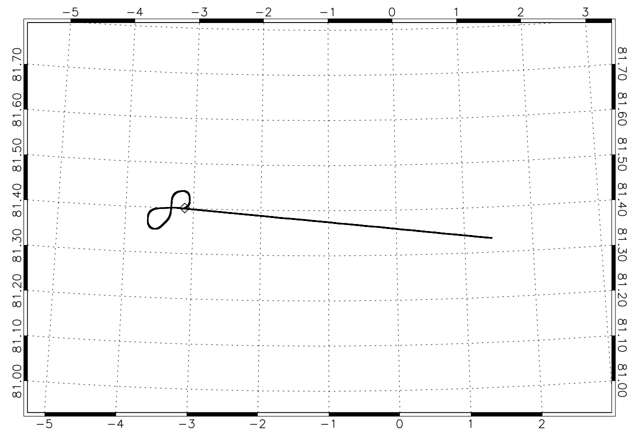


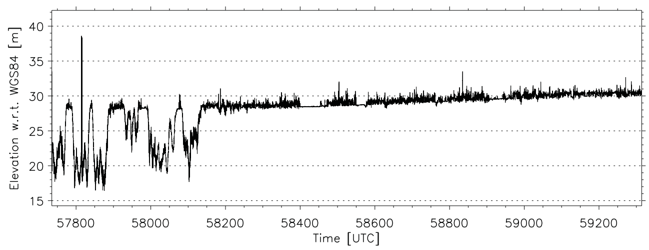


Date	2016-04-10	**Instrument Mode**	Adv. Low Altitude
Start Time	15:10:00 (54600)	**Aircraft**	BAS Twin Otter
Stop Time	15:40:26 (56426)	**Retracker**	OCOG
Distance	128.039 km	**INS Resolution**	50 Hz
Duration	00 h 30 m 27 s	**Processor Version**	0403

A160410_01

AS60A01_ASIWL1B040320160410T160214_20160410T170019_0001.DBL

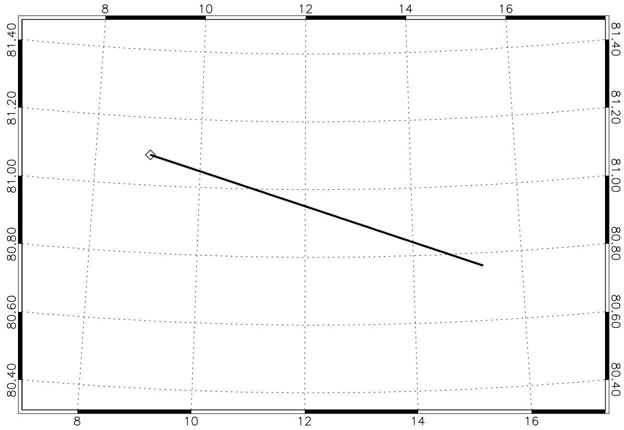


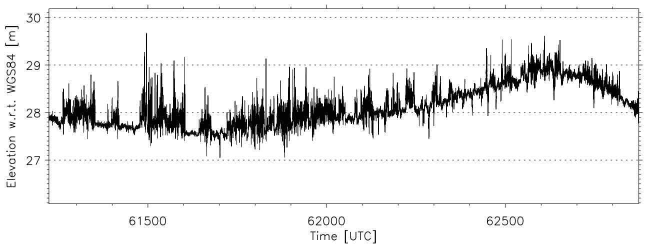


Date	2016-04-10	**Instrument Mode**	Adv. Low Altitude
Start Time	16:02:15 (57735)	**Aircraft**	BAS Twin Otter
Stop Time	16:28:34 (59314)	**Retracker**	OCOG
Distance	108.942 km	**INS Resolution**	50 Hz
Duration	00 h 26 m 19 s	**Processor Version**	0403

A160410_02

AS60A02_ASIWL1B040320160410T170022_20160410T172752_0001.DBL

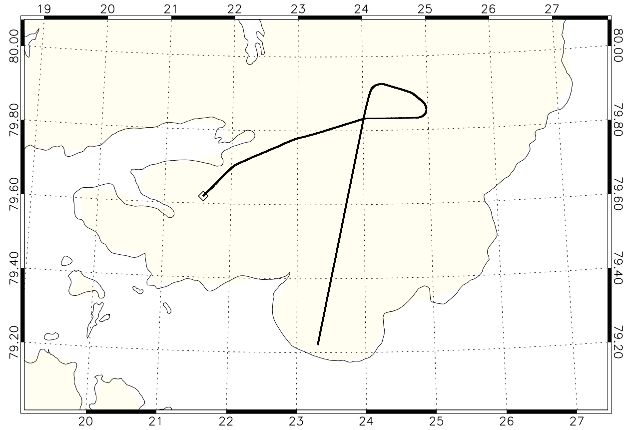


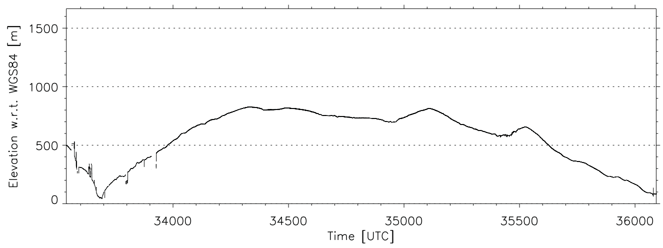


Date	2016-04-10	**Instrument Mode**	Adv. Low Altitude
Start Time	17:00:23 (61223)	**Aircraft**	BAS Twin Otter
Stop Time	17:27:53 (62873)	**Retracker**	OCOG
Distance	115.119 km	**INS Resolution**	50 Hz
Duration	00 h 27 m 30 s	**Processor Version**	0403

A160415_00

AS60A00_ASIWL1B040320160415T091857_20160415T100131_0001.DBL

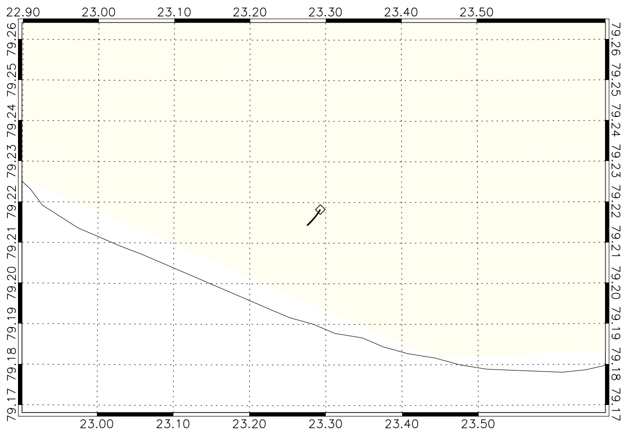


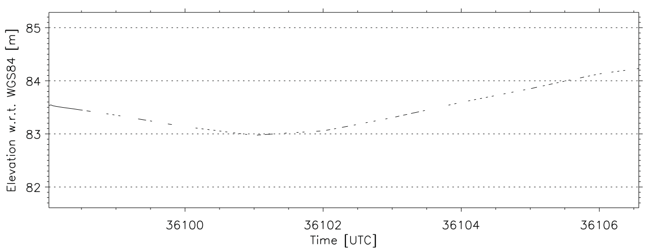


Date	2016-04-15	**Instrument Mode**	Adv. Low Altitude
Start Time	09:18:58 (33538)	**Aircraft**	BAS Twin Otter
Stop Time	10:01:31 (36091)	**Retracker**	OCOG
Distance	173.228 km	**INS Resolution**	50 Hz
Duration	00 h 42 m 34 s	**Processor Version**	0403

A160415_01

AS60A01_ASIWL1B040320160415T100137_20160415T100146_0001.DBL

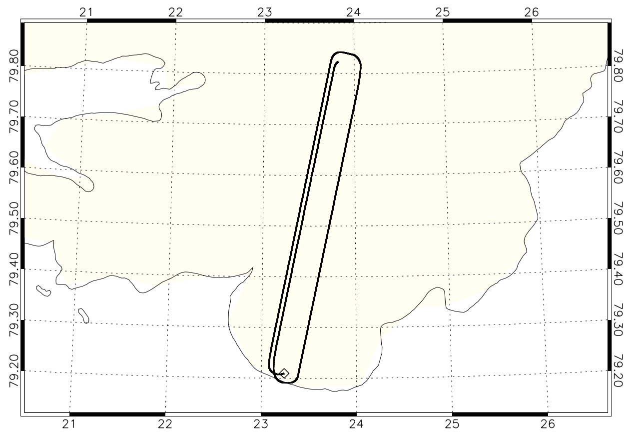


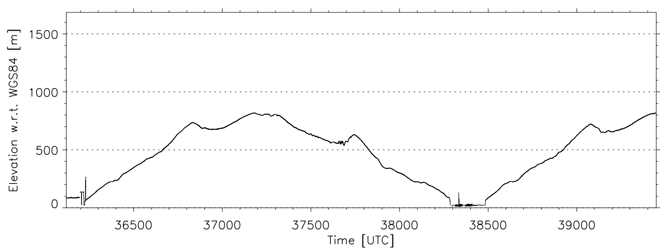


Date	2016-04-15	**Instrument Mode**	Adv. Low Altitude
Start Time	10:01:38 (36098)	**Aircraft**	BAS Twin Otter
Stop Time	10:01:46 (36106)	**Retracker**	OCOG
Distance	0.571 km	**INS Resolution**	50 Hz
Duration	00 h 00 m 09 s	**Processor Version**	0403

A160415_02

AS60A02_ASIWL1B040320160415T100159_20160415T105727_0001.DBL

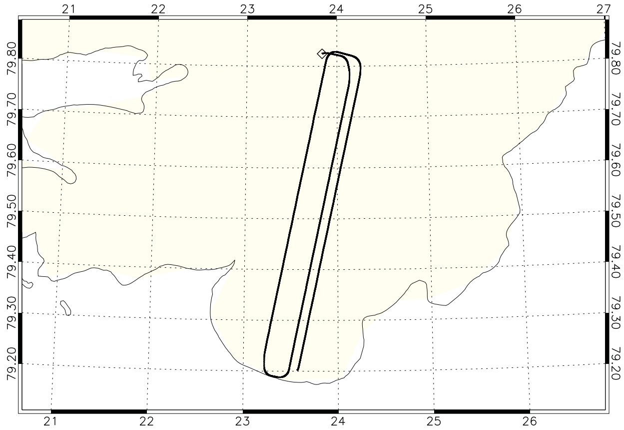


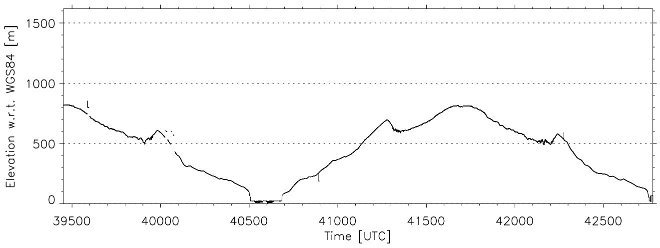


Date	2016-04-15	**Instrument Mode**	Adv. Low Altitude
Start Time	10:02:00 (36120)	**Aircraft**	BAS Twin Otter
Stop Time	10:57:27 (39447)	**Retracker**	OCOG
Distance	227.709 km	**INS Resolution**	50 Hz
Duration	00 h 55 m 28 s	**Processor Version**	0403

A160415_03

AS60A03_ASIWL1B040320160415T105730_20160415T115258_0001.DBL

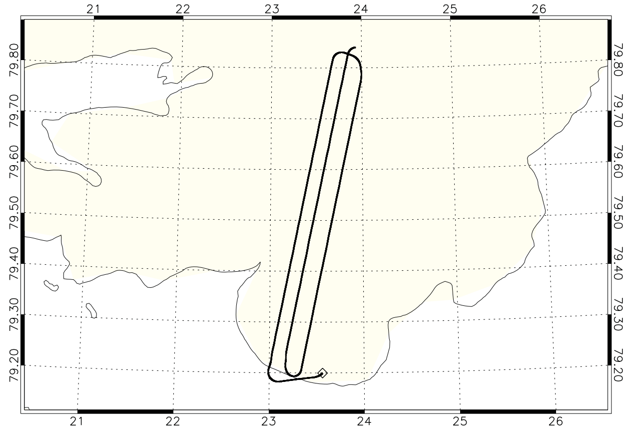


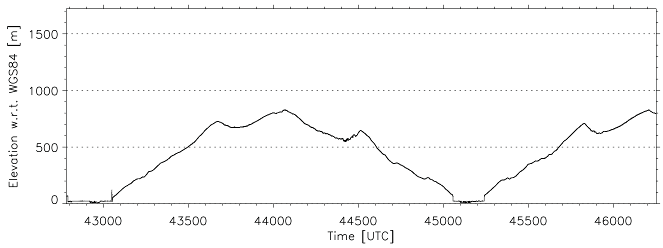


Date	2016-04-15	**Instrument Mode**	Adv. Low Altitude
Start Time	10:57:31 (39451)	**Aircraft**	BAS Twin Otter
Stop Time	11:52:58 (42778)	**Retracker**	OCOG
Distance	228.628 km	**INS Resolution**	50 Hz
Duration	00 h 55 m 27 s	**Processor Version**	0403

A160415_04

AS60A04_ASIWL1B040320160415T115301_20160415T125050_0001.DBL

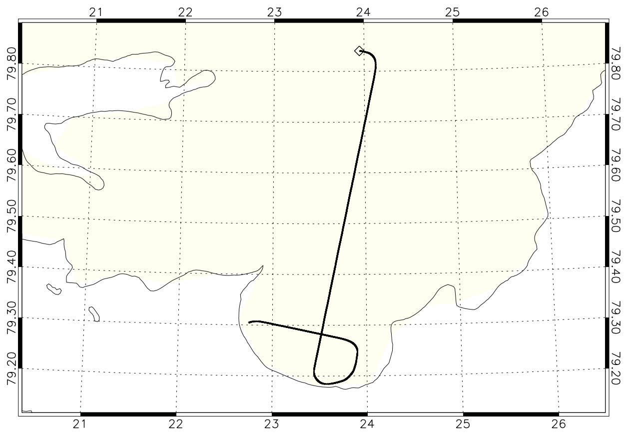


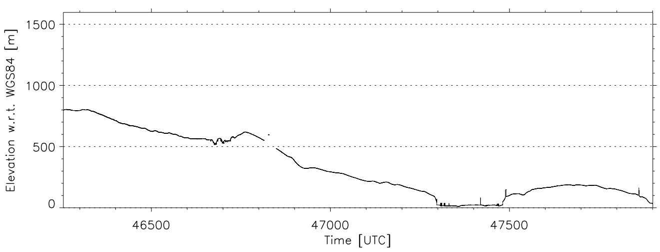


Date	2016-04-15	**Instrument Mode**	Adv. Low Altitude
Start Time	11:53:02 (42782)	**Aircraft**	BAS Twin Otter
Stop Time	12:50:51 (46251)	**Retracker**	OCOG
Distance	236.755 km	**INS Resolution**	50 Hz
Duration	00 h 57 m 49 s	**Processor Version**	0403

A160415_05

AS60A05_ASIWL1B040320160415T125053_20160415T131820_0001.DBL

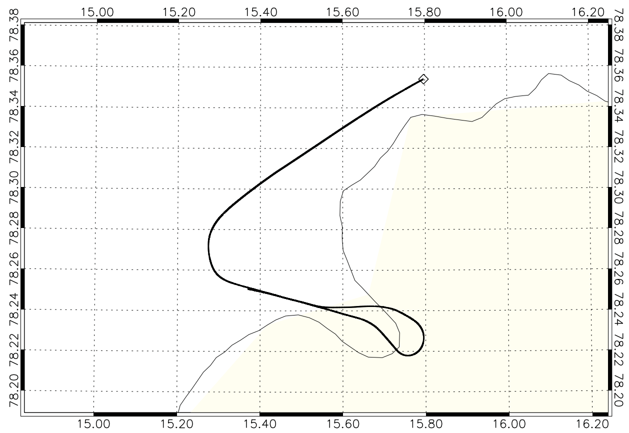


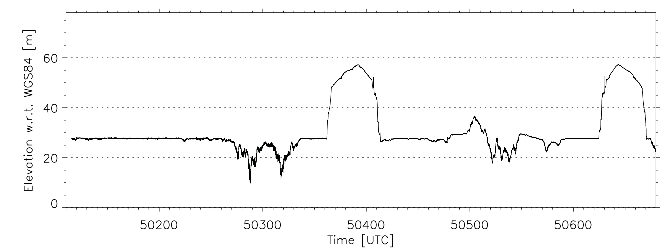


Date	2016-04-15	**Instrument Mode**	Adv. Low Altitude
Start Time	12:50:54 (46254)	**Aircraft**	BAS Twin Otter
Stop Time	13:18:20 (47900)	**Retracker**	OCOG
Distance	115.035 km	**INS Resolution**	50 Hz
Duration	00 h 27 m 26 s	**Processor Version**	0403

A160415_06

AS60A06_ASIWL1B040320160415T135509_20160415T140439_0001.DBL

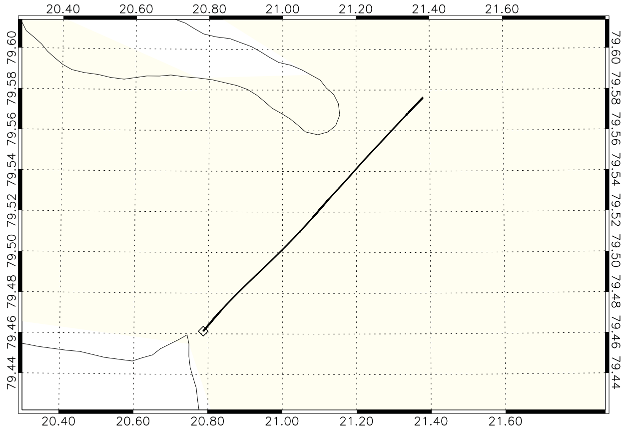


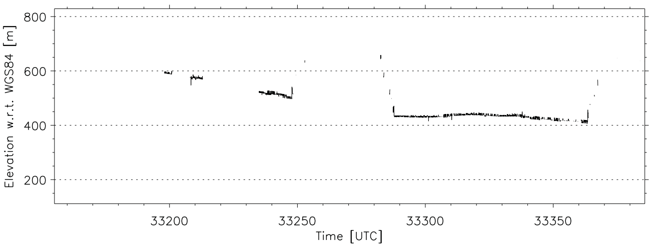


Date	2016-04-15	**Instrument Mode**	Adv. Low Altitude
Start Time	13:55:10 (50110)	**Aircraft**	BAS Twin Otter
Stop Time	14:04:39 (50679)	**Retracker**	OCOG
Distance	40.563 km	**INS Resolution**	50 Hz
Duration	00 h 09 m 30 s	**Processor Version**	0403

A160416_00

AS60A00_ASIWL1B040320160416T091234_20160416T091625_0001.DBL

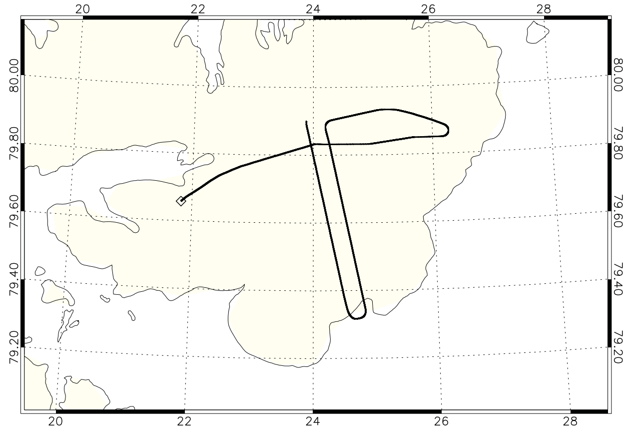


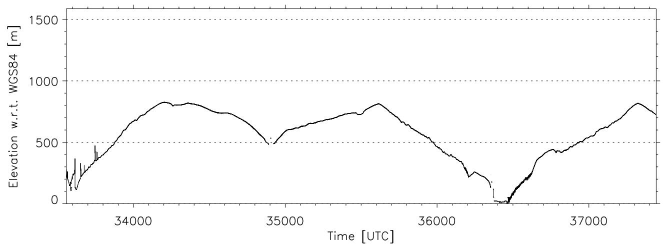


Date	2016-04-16	Instrument Mode	Adv. Low Altitude
Start Time	09:12:35 (33155)	Aircraft	BAS Twin Otter
Stop Time	09:16:25 (33385)	Retracker	OCOG
Distance	17.585 km	INS Resolution	50 Hz
Duration	00 h 03 m 51 s	Processor Version	0403

A160416_01

AS60A01_ASIWL1B040320160416T091917_20160416T102403_0001.DBL

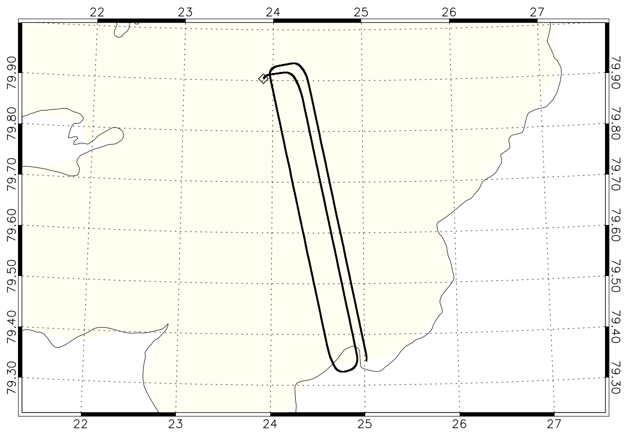


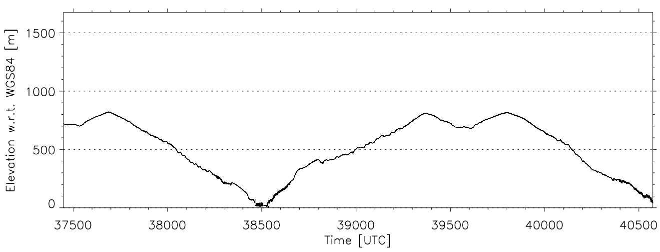


Date	2016-04-16	Instrument Mode	Adv. Low Altitude
Start Time	09:19:18 (33558)	Aircraft	BAS Twin Otter
Stop Time	10:24:03 (37443)	Retracker	OCOG
Distance	271.271 km	INS Resolution	50 Hz
Duration	01 h 04 m 45 s	Processor Version	0403

A160416_02

AS60A02_ASIWL1B040320160416T102407_20160416T111613_0001.DBL

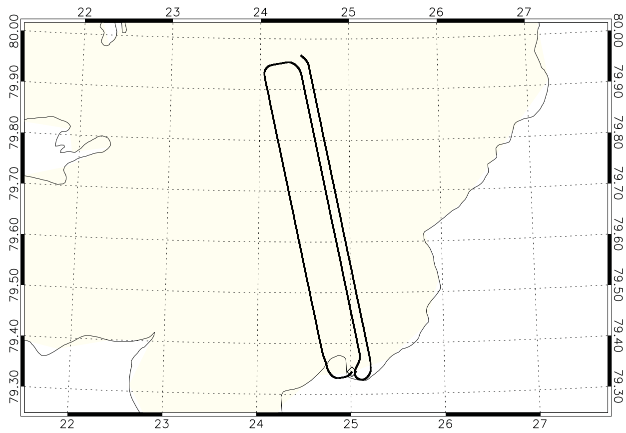


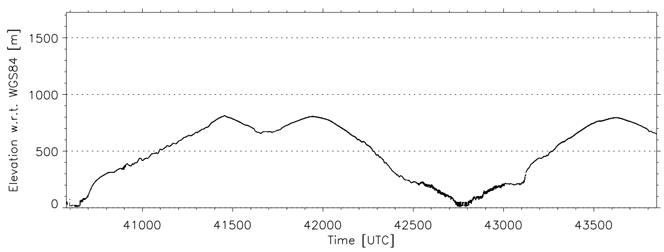


Date	2016-04-16	Instrument Mode	Adv. Low Altitude
Start Time	10:24:08 (37448)	Aircraft	BAS Twin Otter
Stop Time	11:16:13 (40573)	Retracker	OCOG
Distance	217.466 km	INS Resolution	50 Hz
Duration	00 h 52 m 06 s	Processor Version	0403

A160416_03

AS60A03_ASIWL1B040320160416T111618_20160416T121047_0001.DBL

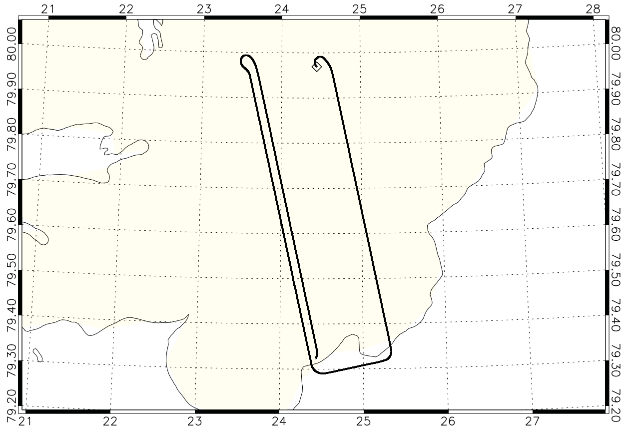


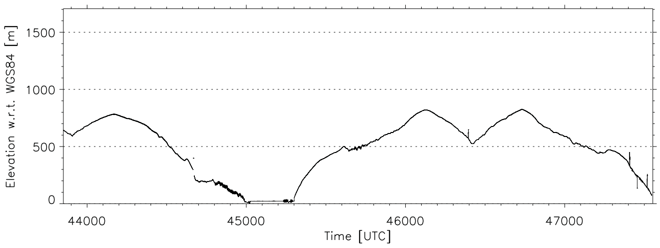


Date	2016-04-16	Instrument Mode	Adv. Low Altitude
Start Time	11:16:19 (40579)	Aircraft	BAS Twin Otter
Stop Time	12:10:47 (43847)	Retracker	OCOG
Distance	226.663 km	INS Resolution	50 Hz
Duration	00 h 54 m 29 s	Processor Version	0403

A160416_04

AS60A04_ASIWL1B040320160416T121050_20160416T131233_0001.DBL





Date	2016-04-16	**Instrument Mode**	Adv. Low Altitude
Start Time	12:10:51 (43851)	**Aircraft**	BAS Twin Otter
Stop Time	13:12:33 (47553)	**Retracker**	OCOG
Distance	257.565 km	**INS Resolution**	50 Hz
Duration	01 h 01 m 43 s	**Processor Version**	0403