DTU Space
National Space Institute

CRYOVEX 2008

Final Report

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DTU Space, March 2009, Draft 1

esa AWI DTU

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Introduction

The European Space Agency (ESA) CryoSat Validation Experiment, CryoVEx 2008 was carried out in April and May 2008. The airborne operations were coordinated by the National Space Institute, Danish Technical University (DTU Space) and took place in the period April 15 to May 8. The work consisted of:

- Airborne data collection with ASIRAS and laser scanner system. The operations were coordinated with ground and helicopter activities over land and sea ice in Greenland and Canada.
- Logistical support for participants in the CryoVEx 2008 experiment especially concerning transport and access to military facilities in Canadian Forces Station Alert and Thule Air Base as well as aircraft support to the UK team on the north Greenland ice sheet.
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Figure 1 shows the full flight tracks for the airborne Twin Otter operation in April and May 2008.

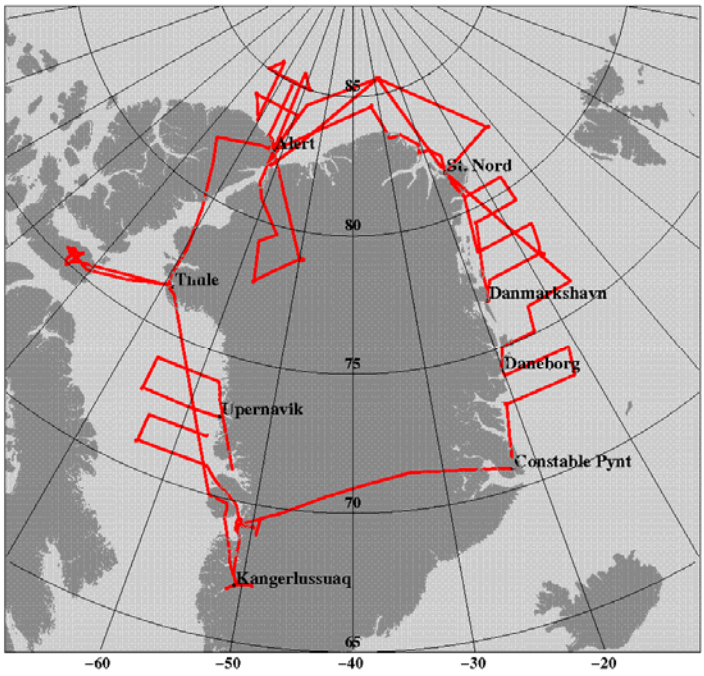


Figure 1. Flight tracks for airborne Twin Otter observations

This report outlines the airborne field operations and the processing of the data acquired during the CryoVEx 2008 campaign. In addition examples from the processed datasets will be presented.

1 Summary of operations

The DTU Space operations started out on April 15 in Kangerlussuaq, Greenland, with installation of the laser scanner and ASIRAS system in the Air Greenland Twin Otter reg. OY-POF following the same procedures as certified in 2006. Due to a minor technical problem with the Twin Otter the aircraft was not available until the 16th. This did not affect the installation since the first day was spent on retrieving the cargo with the equipment and unpacking the boxes. Assistance with the ASIRAS system was provided by Raumfahrt Systemtechnik's engineer.

After installing the equipment in the Air Greenland hanger and performing ground tests, a successful test flight was carried out on April 17th. Apart from minor problems with the backup system for the laser measurements – INS and laser altimeter – the full system of laser scanner and ASIRAS was working as expected. The problems with the backup system were sorted out on ground prior to the next flights.

The next two days were spent on a survey for the Bureau of Minerals and Petroleum, BMP, Greenland Homerule Government, monitoring the sea ice off the Greenland west coast near Upernavik. After this the EGIG line was surveyed April 20th on transit from Ilulissat to Constable Pynt on the east coast. En route, observations on a line near Ilulissat, both High Altitude and Low Altitude ASIRAS data were gathered.

Next the Twin Otter continued to St. Nord, northeast Greenland, where again observation was carried out for the BMP. On April 26th a coordinated flight was carried out near KV Svalbard, the coast guard vessel from Svalbard, which was on a scientific cruise in the Fram Strait. The ship was anchored to an ice floe that was surveyed with the airborne system as well as on the surface from the ship in coordination with the Norwegian Polar Institute. From St. Nord a second survey was done on April 27th in order to re-measure lines north of Greenland.
On April 28th the aircraft continued to CFS Alert to meet the ground teams there, who flew in from Canada and Qaanaaq, North Greenland, with dedicated Twin Otter flights (chartered from Ken Borek) on April 28th and 30th.

In the meantime the other Air Greenland Twin Otter reg. OY-ATY equipped with skies deployed the UK1 team, of Liz Morris and Martin Hignell, on the ice sheet in northern Greenland via Qaanaaq and Thule Air Base. These operations were delayed by poor weather and took place from April 23rd to 25th and consisted of transport from Kangerlussuaq to Qaanaaq on April 23rd and put in on the ice over the next two days including deployment of two depots with fuel and other supplies for the transect.

From Alert lines were surveyed in the Arctic Ocean on May 1st and 2nd. In addition the validation sites near the coast were observed on May 1st and on May 2nd a coordinated line was flown with the helicopter-borne EM bird system from Alfred Wegener Institute/University of Alberta, Edmonton.
A second coordinated helicopter and Twin Otter flight was cancelled in the last minute on May 5th due to poor visibility. The Twin Otter flew a few survey lines near the AUV (Autonomous Underwater Vehicle) camp just off the coast but this also had to be altered to a lower altitude due to low clouds. Afterwards, the aircraft-team continued to Thule Air Base via Grant Ice Cap and Mt. Oxford on Ellesmere Island to position the Twin Otter for operations over Devon Island. Initially it was planned to

use the small inuit settlement Grise Fiord as base for the Devon survey but the weather favoured operations out of the larger and better equipped airfield in Thule. The Devon ice cap was then surveyed on May 6th where the main lines N-S and E-W was flown repeatedly to ensure corner reflector hits and a few lines suggested by the Canadian team was also surveyed.

After the Devon flight the Twin Otter returned to Kangerlussuaq on May 7th to be used for a test campaign for the DTU Space P-Sounder instrument. The ASIRAS system was un-mounted and returned to RST.

Table 1 gives an overview of the specific flights in chronological order and below a short day-to-day description is found.

Day2day

April 15-17	Installation and test of ASIRAS and laser scanner system on Twin Otter
April 18	Survey of icebergs near Ilulissat for DMI and local flight for Danish Television reporters
April 19	Sea ice observations coordinated with helicopter in-situ measurements off the west coast near Upernavik
April 20	Transit to the east coast with survey of CryoSat line near Ilulissat and the EGIG line across the ice sheet
April 21	Transit to St. Nord after cancellation of helicopter operations near the east coast due to ice fog in survey area. Some observations with laser and ASIRAS en route with refuelling in Daneborg
April 22-23	No flights due to bad weather in St. Nord
April 24	Over-flight of KV Svalbard in the Fram Strait and survey of E-W lines between St. Nord and Danmarkshavn. Refueling in Danmarkshavn
April 25-26	No flights due to bad weather in St. Nord
April 27	Observation on lines north of Greenland
April 28	Transit to Alert with survey of sea ice near the coast and parts of the coast of northern Greenland
April 29	Survey of the UK1 site on the northern ice sheet
April 30	Dense fog at Alert – no flights
May 1	Survey of long lines north-east and survey of validation sites near Alert in the afternoon
May 2	Survey of square north-west and coordinated flight of N-S line in the afternoon
May 3	Snow and dense fog – no flights
May 4	Planned afternoon flight with helicopter but had to cancel due to bad weather
May 5	Planned coordinated helicopter flight cancelled due to low clouds. Survey of AUV site altered to low altitude followed by survey of Grant Ice Cap, Ellesmere Island, en route to Thule
May 6	Devon ice cap survey
May 7	Return to Kangerlussuaq with sea ice observations en route and survey over Disko Island
May 8-	Un-mount ASIRAS and P-sounder test

The airborne field team consisted of:
DTU Space: Sine M. Hvidegaard (SMH), Lars Stenseng (LS), and Henriette Skourup (HSK).
RST: Harald Lentz (HL).

Table 1. Flight details

Date/JD	Flight	Track	Off block UTC	Take off UTC	Landing UTC	On block UTC	Air-borne	Survey operators
108/Apr 17	Test/drop	SFJ-SFJ	1837	1842	1955	2000	1h18	SMH/LS/HL
109/Apr 18	ICB	JAV-SFJ	1448	1453	1616	1621	1h33	SMH/LS
109/Apr 18	Journalists	JAV-JAV	1756	1801	1835	1840	0h44	SMH/LS
110/Apr 19	K1-K4	JAV-JUV	1023	1028	1443	1448	4h25	SMH/LS
110/Apr 19	K5-HE-K8	JUV-JAV	1552	1557	2108	2113	5h21	SMH/LS
111/Apr 20	JAV-T-EG	JAV-CNP	1119	1124	1548	1553	4h34	SMH/LS
112/Apr 21	K9-K12	CNP-DNB	1009	1014	1410	1415	4h06	SMH/HSK
112/Apr 21	K13-K15	DNB-NRD	1505	1510	2000	2005	5h	SMH/HSK
115/Apr 24	K16-K19 KV Svalbard	NRD-DMH	1004	1009	1442	1447	4h43	SMH/HSK
115/Apr 24	K20-K23	DMH-NRD	1528	1533	1922	1927	3h59	SMH/HSK
118/Apr 27	F	NRD-NRD	1013	1018	1523	1528	5h15	SMH/HSK
119/Apr 28	E	NRD-YLT	1437	1442	1835	1840	4h03	SMH/HSK
120/Apr 29	ICE	YLT-YLT	1350	1355	1922	1927	5h37	SMH/HSK
122/May 1	F-S	YLT-YLT	1340	1345	1825	1830	4h50	SMH/HSK
122/May 1	MYI-FYI	YLT-YLT	1847	1852	2037	2042	1h55	SMH/HSK
123/May 2	H	YLT-YLT	1330	1335	1916	1921	5h51	SMH/HSK
123/May 2	A1-FUE-A2	YLT-YLT	2040	2045	2308	2313	2h33	SMH/HSK
126/May 5	M-cal-GM	YLT-THU	1322	1327	1803	1808	4h36	SMH/HSK
127/May 6	DEVON	THU-THU	1154	1159	1703	1708	5h14	SMH/HSK
128/May 7	DISKO	THU-SFJ	1211	1216	1653	1658	4h47	SMH/HSK
Total								72h00

2 Hardware Installation

The equipment was installed in the Twin Otter OY-POF in the Air Greenland hangar in Kangerlussuaq. The installation was similar to the setup certified in 2006 and used for the CryoVEx 2006 campaign. For this campaign a new laser scanner was used; the Riegl LMS Q240i. In addition the backup system consisting of a profiling laser altimeter and inertial measurement unit has been updated. Table 2 gives the offsets between the instruments and Figure 2 sketches the approximate position of the instruments in the aircraft.
Photographs of the installation are shown below.

Table 2. The (dx, dy, dz)' offsets. The lever arm from the GPS antennas to the origin of the laser scanner, and to the back centre of ASIRAS antenna frame (See arrow):

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

'Offset definition: x positive to the front, y positive to the right, and z positive down.

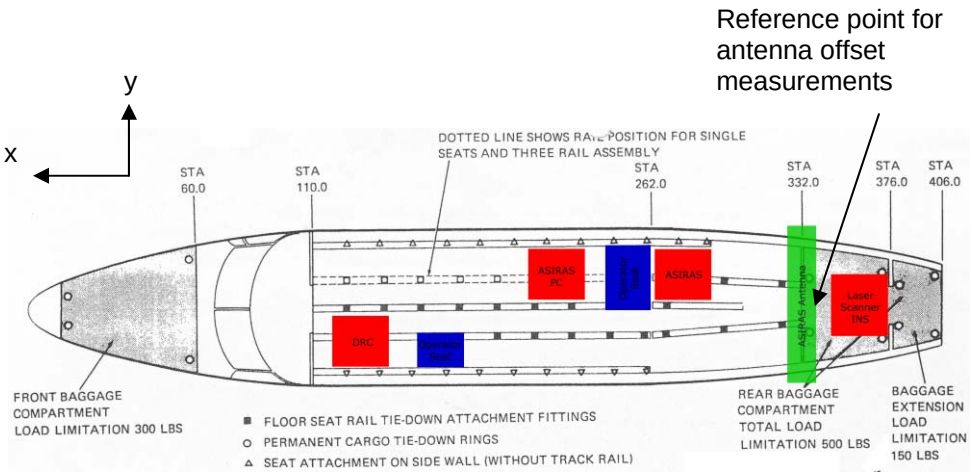


Figure 2. Sketch of instrument installation in the Air Greenland Twin Otter.

Figure 3. Photographs of the Twin Otter installation.

Table 3. Data holding from aircraft instruments and reference stations

JD/Date	AIR1	AIR2	AIR3	AIR4	ALT	EGI	IMU	SCAN-NER	GPS REF1	GPS REF2	GPS REF3	Ver cam	ASIRAS	REMARKS
108/Apr 17	X	X	X	X	n/a	!		X	KELY			(X)	HAM+LAMa	Test flight,
109/Apr 18	X	n/a	X	X	X	!	X	X	SFJ1			(X)		Iceberg obs
109/Apr 18	n/a	X	X	X	X	!	X	X	SFJ1			X		Fjord trip for journ
110/Apr 19	X	X	X	X	X	!	X	X	SFJ1	JAV		X''	LAMa	Scanner PC cold no start
110/Apr 19	X'	X	X	X	X	!	X	X	SFJ1	JAV	JUV	X''	LAMa	Pass over heli at 1620
111/Apr 20	n/a	X	X	X	X	!	X	X		CNP		X	HAM+LAMa	EGI difficult start up
112/Apr 21	X	X	X		X	!	X	X	SCO	NYA2		X'''	LAMa	EMAP probl with laptop
112/Apr 21	X	X	X		X	!		X	SCO	NYA2		X	LAMa	Changed survey lines
115/Apr 24	X	X	X		X	X	X	X	NRD1	NRD2		X	LAMa	
115/Apr 24	X	X	X		X	X	X	X		NRD2		X	LAMa	
118/Apr 27	X	X	X		X	X	X	X	NRD1	NRD2		X	LAMa	Perfect weather…
119/Apr 28		X	X		X	X	x	X	THU3	NYA		X	LAMa	IMU on late at 1707
120/Apr 29			X		X	X	X	X	YLT1	YLT2		X	LAMa	CR on ice sheet
122/May 1	X	X	X		X	X	X	X	YLT1	YLT2		X	LAMa	
122/May 1	X		X		X	X	X	X	YLT1	YLT2		X	LAMa	4 CR on MYI and FYI
123/May 2	X	x	X		X	X	X	X	YLT1	YLT2		X	LAMa	
123/May 2	X	X	X		X	X	X	X	YLT1	YLT2		X	LAMa	CR on site FUE, + heli
126/May 5	X	X	X		X	X	X	X	YLT2	THU2	THU3	X	LAMa	Poor vis near YLT
127/May 6	X	X	X		X	X	X	X	THU2	THU3		X	LAMa	
128/May 7	X	X	X		X	X	X	X	THU2	THU3	KELY	X		Disko in diff. alt.

' stopped after end of survey line

'' not adjusted – images not clear – adjusted just after heli pass

''' very cloudy

3 Acquired data

During the CryoVEx 2008 campaign DTU Space acquired approximately 50 hours of ASIRAS data and 70 hrs of laser scanner, GPS, INS, and downward looking photographs with the airborne system. After each flight data was stored on dedicated harddisks and backup copies were made. The harddisks with ASIRAS data was delivered to AWI for processing. The remaining data was uploaded to the DTU Space servers also for post-processing.
An overview of the collected data can be seen in Table 3 and a more detailed description is found along with processing details in the following paragraphs.

Nearly all data were recovered and stored except for at few cases of operator errors, one laser scanner file never started and a few incidents where the GPS receivers had a full memory, but no problems were encountered for the main validation sites. The full set of raw data is now stored at the DTU space server system (with tape backup) and copies are kept on dedicated harddisks.

4 Processing

4.1 GPS data processing

Kinematic differential GPS is the key positioning method of the aircraft. GPS dual-frequency phase data were logged at 1 Hz using 1-2 ground base receivers at one or more reference sites, and 4 aircraft receivers; one of these dedicated to the ASIRAS system.
The aircraft GPS receivers are named AIR1 (Trimble 4000-SSI), AIR2 (Ashtech Z-extreme), AIR3 (Javad, Lexon), and AIR4 (Trimble 4000-SSI, connected to ASIRAS). AIR1 and AIR2 share the front GPS antenna; AIR3 and AIR4 the rear antenna. Antenna offsets are given in Table 2. Data were logged in the receivers during flights and downloaded upon landing on laptop PCs. Most data were recovered and only a few files missing, see Table 3, but the redundancy of receivers meant that GPS data are available for all flights. The AIR4 receiver had a problem with the serial port and was not downloaded after April 20.

The GPS base stations to be used as reference stations for differential post processing of the GPS data are listed in Table 4. The stations were mounted on roofs or tripods in the field near the landing sites; the reference points were generally not marked. In addition data from permanent GPS stations were used for data processing.

GPS solutions are based on static processing of the reference stations and kinematic differential processing of the airborne data. In addition precise point positioning has been used for some of the solution where precise information of satellite clock and orbit errors are used along with information from permanent IGS stations.
First the position of the reference station is determined using SCOUT (Scripps Coordinate Update Tool) service operated by SOPAC (Scripps Orbit and Permanent Array Center) (http://sopac.ucsd.edu). SCOUT calculates the reference positions in ITRF 2005 using data from three nearest permanent GPS stations with a position accuracy of about 2 cm even in the Arctic with long distance to permanent stations. The reference stations used during CryoVEx 2008 are listed in Table 4 and coordinates are found in Appendix 8.3.

The kinematic differential GPS processing were performed with GPSurvey (version 2.35) using precise IGS orbits and the GOAD-Goodman tropospheric model. On each flight several solutions are made using different combinations of GPS reference stations and aircraft receivers. The best solution for each flight (see Table 6) is selected. For some of the flights GPSurvey showed to have problems delivering a stable solution and precise point positioning using the software Trip (X. Zhang 2006) gave a better solution and this was selected (*.kin in Table 6).

The GPS solution are used for further processing of INS and laser scanner data and also delivered to ESA and AWI for ASIRAS processing in the dedicated format documented by R. Cullen (2006).

Table 4. CryoVEx 2008 GPS reference stations

Name	Location	Hardware (antenna type)
SFJ1	Kangerlussuaq, on met hut roof	Javad Maxor, (RegAnt)
JAV0	On latter to roof, airport	Javad Maxor (int. ant, LegAnt)
JUV0	Upernavik near airport	Javad Legacy (MarAnt)
CNP0	On hotel roof	Javad Legacy (RegAnt)
NRD1	Station Nord, on snow next to apron	Javad Maxor (int. ant)
NRD2	Station Nord, on snow next to apron	Javad Legacy (RegAnt)
YLT1	On snow next to Spinnaker, small tripod	Javad Maxor (int. ant)
YLT2	Back side of Huricane, on stick	Javad Legacy (RegAnt)
THU2	Thule Air Base, permanent station	Javad Legacy
THU3	Thule Air Base, permanent station	Ashtech Z-XII3
SCOR	Scoresbysund, permanent station	Ashtech UZ-12

4.2 INS and GPS data merging

Similar to previous campaigns (e.g CryoVEx 2003, 04 and 06) a Honeywell medium grade inertial navigation system H764-G, EGI, was used throughout the surveys to record inertially integrated position, velocity and attitude information. Data were logged on a rack mounted PC with solid state hard-disks in binary format through a 1558 mil-spec communication bus. Data from all flights have been obtained. The data from April 17th to April 21st have not been initialised properly at the alignment but this will not affect the laser scanner processing as the files still contains the information needed about attitude changes. Recordings and comments can be found in Table 3.

The position and attitude information is extracted from the INS data packets and averaged to 10 Hz. The averaging to 10 Hz has proven to be a good balance between file size and resolution in time. To obtain a higher resolution in the time domain and preserve precision the post processed GPS and INS data is merged by draping the INS derived positions onto the GPS positions. This draping is done by modelling the function, found in equation (1), by a low pass smoothed correction curve, which is added to the INS.

$$\varepsilon(t) = P_{GPS}(t) - P_{INS}(t) \quad (1)$$

This way a smooth GPS-INS solution is obtained, which can be used for geolocation of laser and camera observation. The full resolution INS data were also converted into binary format as specified in the ESA document for the ASIRAS processing by R. Cullen (2006).
Details about the INS processing is found in Table 5 and Figure 4 shows an example of the draping of high rate INS heights onto precise GPS heights.

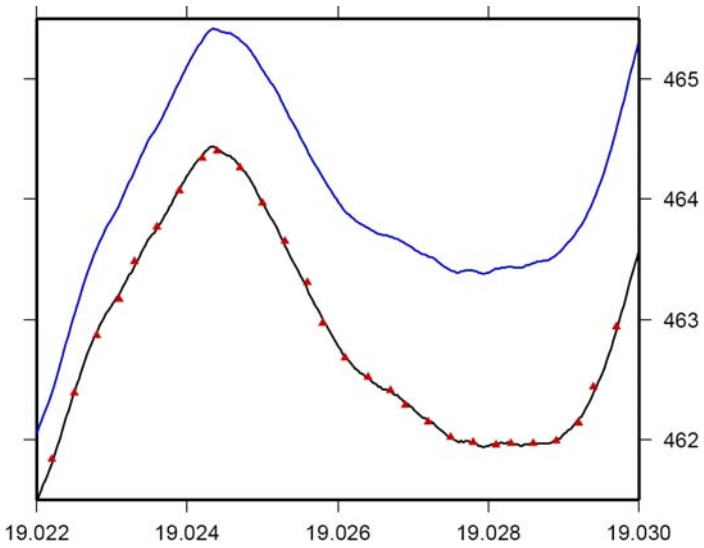


Figure 4. Draping of high rate INS derived heights (blue) onto precise GPS heights (red) to get high rate precise heights (black).

Table 5. GRL 2008 INS data processing

JD	Flight	Filename	GPS solution	Start	Stop	Receiver
108		gpsegi_108.pos	108Air3.kin	18.62	20.00	3
109		gpsegi_109.pos	109Air1.kin	14.80	16.35	1
110	a	gpsegi_110a.pos	110aa4ja.p	10.38	14.80	4
110	b	gpsegi_110b.pos	110ba2ja.p	15.87	21.14	2
111		gpsegi_111.pos	111Air2.kin	11.32	15.84	2
112	a	gpsegi_112a.pos	112aa3sc.p	10.15	14.25	3
112	b	gpsegi_112b.pos	112bAir3.kin	15.08	20.08	3
115	a	gpsegi_115a.pos	115aAir3.kin	10.07	14.73	3
115	B	gpsegi_115b.pos	115bAir3.kin	15.47	19.45	3
118		gpsegi_118.pos	118Air3.kin	10.22	15.46	3
119		gpsegi_119.pos	119Air2.kin	14.62	18.66	2
120		gpsegi_120.pos	120Air2.kin	13.62	19.45	2
122	a	gpsegi_122a.pos	122aAir3.kin	13.67	18.50	3
122	b	gpsegi_122b.pos	122ba3y2.p	18.65	20.65	3
123	a	gpsegi_123a.pos	123aAir3.kin	13.50	19.35	3
123	b	gpsegi_123b.pos	123ba2y2.p	20.67	23.21	2
126		gpsegi_126.pos	126a3y2.p	13.37	18.13	3
127		gpsegi_127.pos	Air3gnav.p	11.90	17.12	3
128		gpsegi_128.pos	128a1t3.p	12.18	16.96	1

4.3 Laser scanner data processing

The laser scanner system has been upgraded to the new Riegl LMS Q240i laser altimeter. This will provide similar measurements with near-infrared laser of the distance between the aircraft and the snow or ice surface as the old laser scanner previously used. The main difference is an improvement of the range; ranging up to 650 m over snow/ice and the smaller footprint; approximately 0.7x0.7 m at the nominal flying altitude of 300m.

The laser scanner data were logged as hourly files on a dedicated PC. The files are time-tagged by 1 PPS signal from the AIR1 GPS receiver and synchronised once per

flight by the operator and named with the start time. Table 6 shows the logged files with start /stop times. The data rate has been fixed to 250 observations per line and 40 lines per second throughout the campaign.
The synchronisation of the data failed for part of the flights which means that the synchronisation has to be checked for each of these files during processing. This will not affect the data quality as it can be verified visually by plotting the results.

Laser scanner data were recovered for most flights except minor parts with low clouds or fog. Some problems occurred with the laser scanner PC at start up of the system caused by the cold weather. This was solved by heating the PC or running it during night on external power.

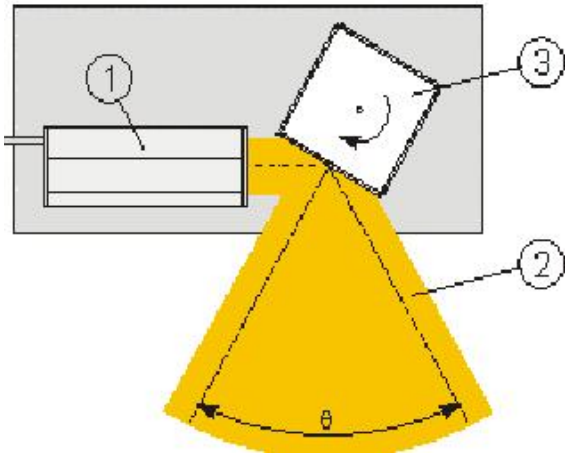


Figure 5. Sketch of laser scanner principle (1) Laser and photodiode assembly (2) Swath pattern (3) Rotating mirror.

The principle of the laser scanner can shortly be described as following:
1. The laser (1) emits a laser pulse and starts a timer, see Figure 5
2. The pulse is reflected in a direction dictated by the mirror (3)
3. If the pulse hits a target with suitable reflectance it is returned to the mirror (3) that reflects it into the photodiode (1) and hereby stops the timer
4 The mirror (3) is now rotated by a small angle before the process is repeated.

The geolocation of each point in the laser scanner data is performed with standard trigonometry in two steps. First all points are described as vectors (dX_{NWU}, dY_{NWU}, dZ_{NWU}) in a local Cartesian North East Up system using the lever arm between the laser scanner and the GPS (dX, dY, dZ), the range measured by the laser (r), the angle between the laser mirror (a) and the orientation of the laser in an earth fixed system (ω_r, ω_p, ω_h). Next these vectors are added with the position derived from GPS (φ_{GPS}, λ_{GPS}, h_{GPS}) to get the position of the reflector in an earth fixed system(φ, λ, h).

$$
\begin{aligned}
dX_{NWU} = {} & \cos(\omega_h)\cos(\omega_p)dX \\
& + (\cos(\omega_h)\sin(\omega_p)\sin(\omega_r) - \sin(\omega_h)\cos(\omega_r))(-\sin(a)r + dY) \\
& + (\cos(\omega_h)\sin(\omega_p)\cos(\omega_r) - \sin(\omega_h)\sin(\omega_r))(\cos(a)r + dZ)
\end{aligned}
$$

$$
\begin{aligned}
dY_{NWU} = {} & -\sin(\omega_h)\cos(\omega_p)dX \\
& - (\sin(\omega_h)\sin(\omega_p)\sin(\omega_r) + \cos(\omega_h)\cos(\omega_r))(-\sin(a)r + dY) \\
& + (-\sin(\omega_h)\sin(\omega_p)\cos(\omega_r) + \cos(\omega_h)\sin(\omega_r))(\cos(a)r + dZ)
\end{aligned}
\qquad (2)
$$

$$
dz_{NWU} = \sin(\omega_P)\, dX
$$

$$- \cos(\omega_p)\sin(\omega_r)(- \sin(a)r + dY)$$
$$- \cos(\omega_p)\cos(\omega_r)(\cos(a)r + dZ)$$

$$\varphi = \varphi_{GPS} + dX_{NWU} /degm$$
$$\lambda = \lambda_{GPS} + dY_{NWU} /(degm \cos(\varphi) \quad (3)$$
$$h = h_{GPS} + dZ_{NWU}$$

where degm is meter per degree.

This geolocation process just described assumes perfect alignment between the laser scanner and the INS system, this is however not practically possible in this type of installation. To compensate for the imperfect installation several calibration manoeuvres are performed during the campaign. The purpose of these manoeuvres is to determine and monitor the offset angles between the laser scanner and the INS.

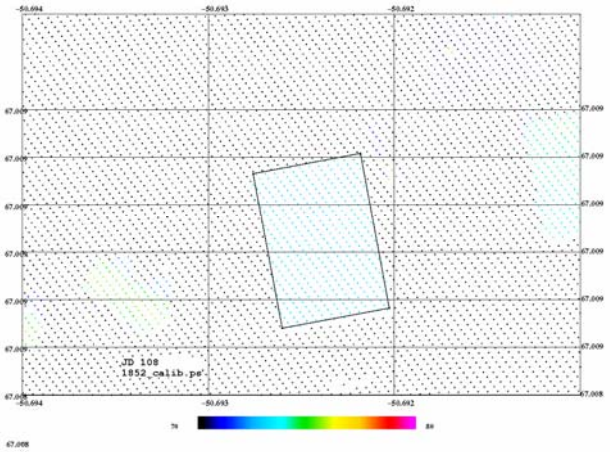


Figure 6. Laser scanner data from calibration site – building in Kangerlussuaq. Data from two passes overlaid displaying the match after calibration

The main calibration site for the laser is a building where the corners of the roof are known from a GPS survey. Using this building and two swaths of laser scanner data, one east-west and one north-south, one can estimate the offset angles through an iterative process. In Figure 6 points from the two swaths (heights in colour-coding) are plotted on top of the black outline of the building.

The calibration is monitored using similar methods over building (Station Nord and CFS Alert) and cross-overs during the surveys. Figure 7 shows the calibration flight at St. Nord on April 27.

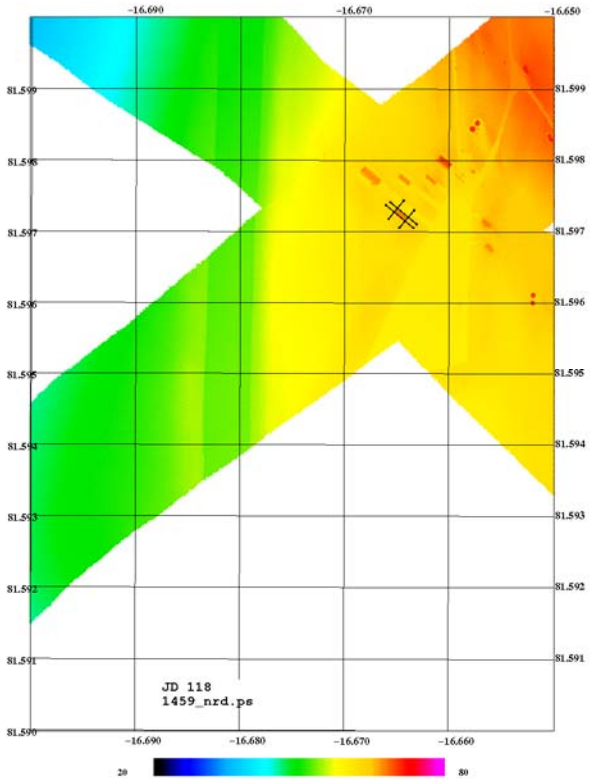


Figure 7. Laser scanner data from the calibration flight at St. Nord.

Table 7 gives the processed laser scanner files with offset angles and other processing parameters. An example is shown in Figure 8 from the coincident flight with the AWI helicopter EM system on May 2nd and Figure 9 shows an overview of the delivered laser scammer data, colour coded separately for sea ice and ice caps. Note that the sea ice data has been filtered to heights relative to local sea level.

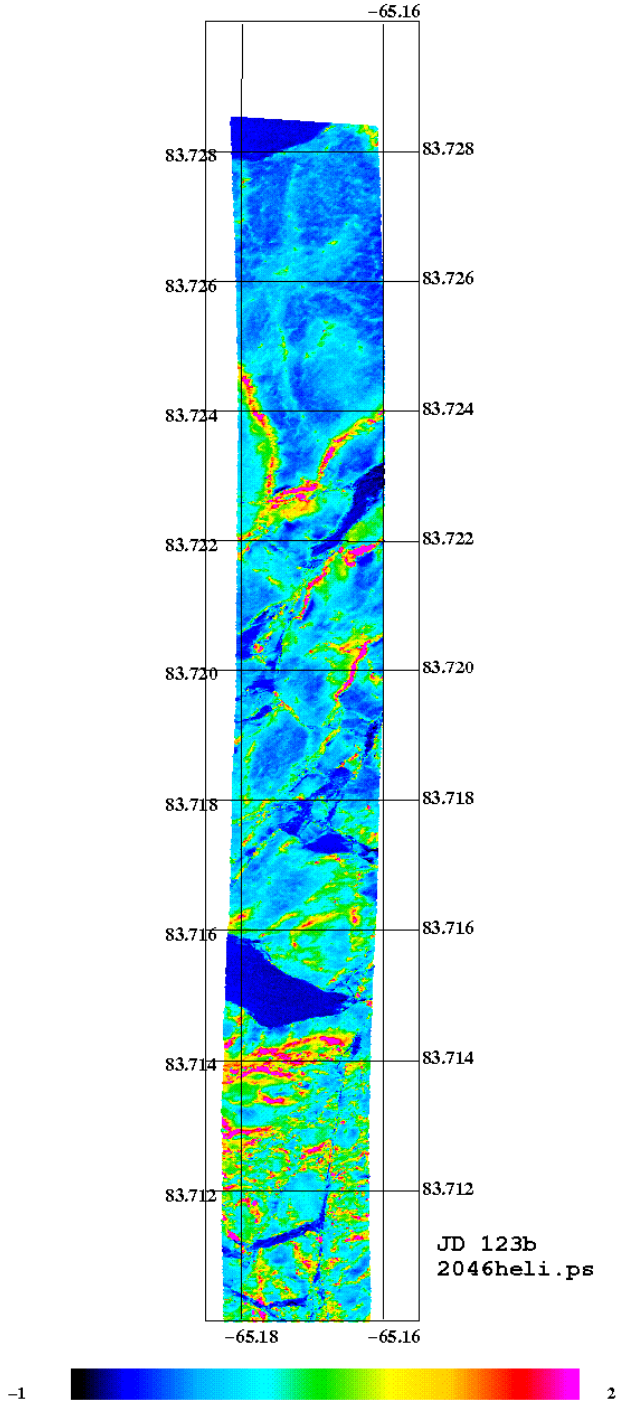


Figure 8. Example of laser scanner data over near the helicopter over-flight May 2nd.

Table 6. Processed laser scanner files

JD	File name	Timing	Timing	Start (dechr)	Stop (dechr)	Calibration angl.
108 17/4-08	GroundTest.2dd 108_185200.2dd	 -1		 18.83333	 19.86874	-1.5 0.20 0
109 18/4-08	109_154800.2dd	-1		15.53333	16.28035	-1.5 0.19 0
110 19/4-08	110_105900.2dd 110_115430.2dd 110_130300.2dd 110_140000.2dd 110_155800.2dd 110_164700.2dd 110_174130.2dd 110_183300.2dd	173 173 173 173 173 173 173 173		10.98333 11.90833 13.05000 14.00000 15.96667 16.78333 17.69167 18.55000	11.98568 13.03057 13.98347 14.73355 16.76490 17.67876 18.53849 19.41839	-1.5 0.16 0
111 20/4-08	111_113715.2dd 111_121200.2dd 111_125700.2dd 111_140000.2dd	176 176 176 176		11.62083 12.20000 12.95000 14.00000	12.18098 12.93720 13.98334 14.86993	-1.5 0.16 0
112 21/4-08	112_101630.2dd 112_110900.2dd 112_115400.2dd 112_121300.2dd 112_134630.2dd 112_151530.2dd	181 181 181 181 181 181		10.27500 11.15000 11.90000 12.21667 13.77500 15.25833	11.13432 11.74556 12.17062 12.68043 14.20751 15.98591	-1.5 0.16 0
115 24/4-08	115_104200.2dd 115_113730.2dd 115_123500.2dd 115_122500.2dd 115_141630.2dd 115_153600.2dd 115_163330.2dd 115_174000.2dd	-1 -1 -1 -1 -1 -1 -1 -1		10.70039 11.62539 12.58377 13.41702 14.27542 15.60043 16.55869 17.66705	11.61595 12.57430 13.40475 14.26649 14.48988 16.54883 17.65387 18.81385	-1.5 0.16 0
118 27/4-08	118_102000.2dd 118_112530.2dd 118_121530.2dd 118_131245.2dd 118_134830.2dd 118_142000.2dd 118_145900.2dd	-1 -1 -1 -1 -1 -1		10.33367 11.42543 12.25873 13.21292 13.80868 - 14.98377	11.41592 12.24841 13.18812 13.79712 14.31342 - 15.40674	-1.5 0.19 0
119 28/4-08	119_144400.2dd 119_154000.2dd 119_163400.2dd 119_172430.2dd	-1 -1 -1 -1		14.73374 15.66705 16.56705 17.40874	15.65350 16.55936 17.39945 18.61004	-1.5 0.19 0
120 29/4-08	120_135330.2dd 120_143930.2dd 120_161330.2dd 120_171400.2dd 120_175900.2dd 120_185615.2dd	-1 -1 -1 -1 -1 -1		13.89212 14.65883 16.22645 17.23375 17.98373 18.93793	14.64593 16.21969 17.22395 17.97291 18.92643 19.10401	-1.5 0.19 0

122 1/5-08	122_134000.2dd 122_143500.2dd 122_153330.2dd 122_162730.2dd 122_173000.2dd 122_184630.2dd 122_193645.2dd	-1 -1 -1 -1 -1 -1 -1		13.66705 14.58370 15.55870 16.45869 17.50040 18.77561 19.61290	14.57000 15.55050 16.45018 17.48911 18.22298 19.60370 20.62406	-1.5 0.19 0
123 2/5-08	123_133030.2dd 123_143100.2dd 123_151500.2dd 123_161500.2dd 123_172730.2dd 123_183830.2dd 123_204600.2dd 123_220030.2dd 123_230100.2dd	-1 -1 -1 -1 -1 -1 -1 -1 -1		13.50888 14.51708 15.25039 16.25038 17.45870 18.64210 20.76706 22.00874 23.02184	14.50900 15.24099 16.23944 17.44694 18.62964 19.29238 21.99410 22.86155 23.14300	-1.5 0.19 0
126 5/5-08	126_131800.2dd 126_143400.2dd 126_145930.2dd	-1 -1 -1		13.30041 14.56704 14.99203	14.55898 14.98449 15.49834	-1.5 0.19 0
127 6/5-08	127_120015.2dd 127_131200.2dd 127_133000.2dd 127_141600.2dd 127_150030.2dd	-1 -1 -1 -1 -1		12.00458 13.20036 13.50038 14.26708 15.00874	13.18491 13.49056 14.25457 14.99530 15.84995	-1.5 0.19 0
128 7/5-08	128_121800.2dd 128_124515.2dd 128_134200.2dd 128_142630.2dd 128_151100.2dd	-1 -1 -1 -1 -1		12.30033 12.75456 13.70036 14.44210 15.18378	12.74411 13.68720 14.42977 15.17147 15.90188	-1.5 0.19 0

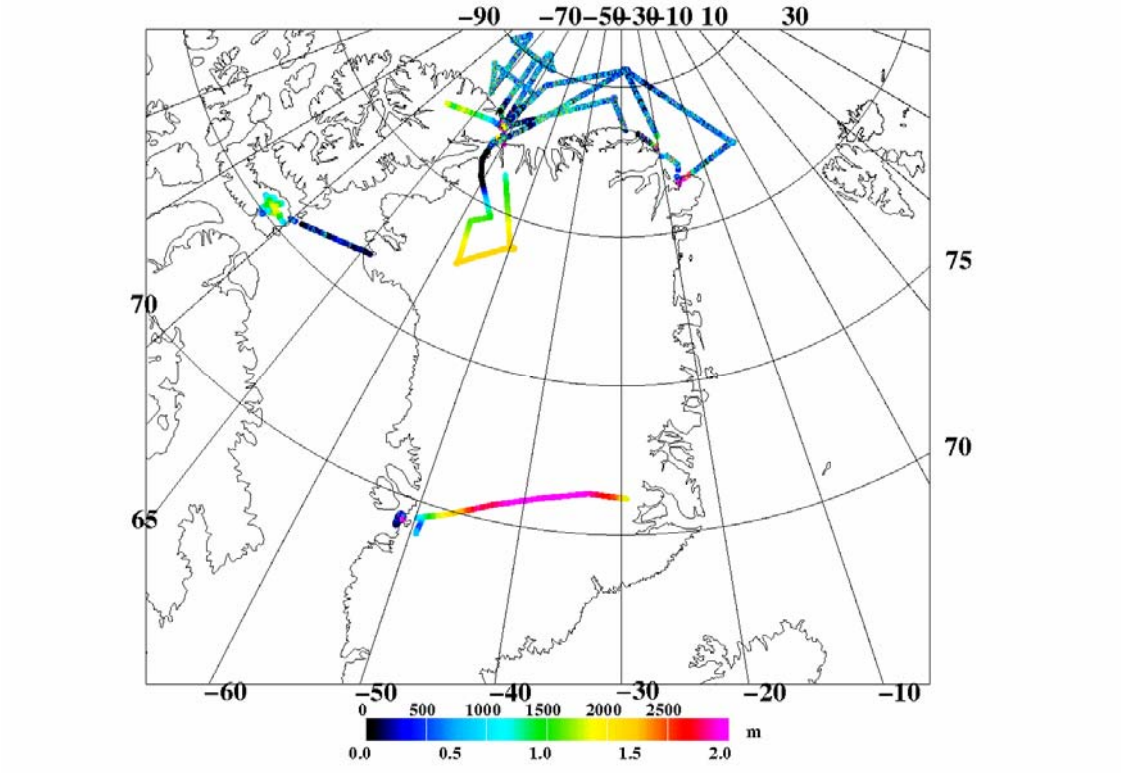


Figure 9. Overview of delivered laser scanner data, colour coded separately for sea ice and ice caps. Note that the sea ice data has been filtered to heights relative to local sea level.

4.4 ASIRAS radar data processing

The ASIRAS system was installed in the same manner as for the CryoVEx 2006 campaign. The new LAMa mode with reduced data rate was used for the surveys except for the CryoSat line near Ilulissat (April 20) where the HAM mode was used. The system was timed with PPS signal and ASCII datation string from the AIR4 Trimble GPS receiver.

Installation, ground test and test flight were performed with assistance from RST engineer H. Lentz in Kangerlussuaq. No problems occurred. The data were logged on the dedicated hard-disks in the ASIRAS PCs during flight and transferred to the PCs for backup after surveys. The data was backed up on hard-disk after the flights with a second copy on a spare set of disks.

Data were acquired continuously over the main sites and for parts of the other survey lines. The operator log files can be found in the Appendix together with a list of the recorded data files.

The data quality has been checked after each survey flight with the “Quicklook viewer” software from RST. Especially for the corner reflector sites the data were carefully checked. Examples can be found in the specific site descriptions, Section 5.

The final processing of the acquired ASIRAS data is done by the Alfred Wegener Institute (AWI) with input of GPS and INS position and attitude data from DTU Space.

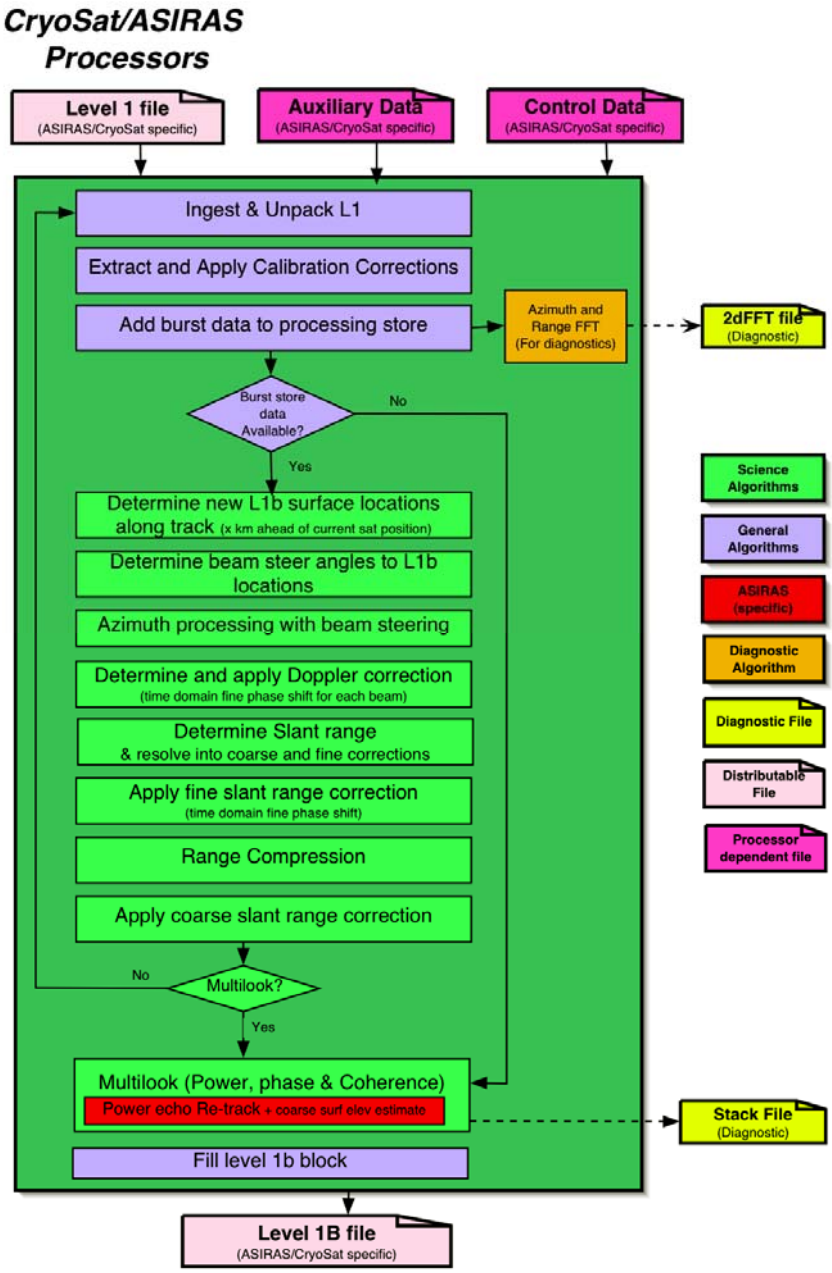


Figure 10. ASIRAS processing scheme.

AWI AWI AWI…

4.5 Auxilary data

During the survey flights operator logs were kept for both the DTU Space laser scanner and the ASIRAS radar system. These logs have been stored as separated files together with the data files and can also be found in the Appendix.

As backup for the laser scanner a profiling laser altimeter was installed next to the laser scanner and web camera. Also an extra inertial navigation unit was run as

backup to the EGI instrument. These instruments were all timed by 1 PPS signals from GPS and data has been recorded on a dedicated PC and backed up post flight.

A downward looking web-camera was installed next to the laser scanner and operated during flights acquiring visual documentation of the surface. Images were captured every 2 seconds and time tagged using GPS. The image files were stored on a laptop PC during flight and backed up on hard-disk after each flight.

The images from the downward looking camera were triggered by GPS pulse via the IMU datation system. This means that a precise time (better than 10 msec) can be assigned to each image. Geolocation is done using the airplane position at the time of image acquisition.

An example is shown in Figure 11 from the over-flight of the AWI helicopter EM bird on May 2nd.

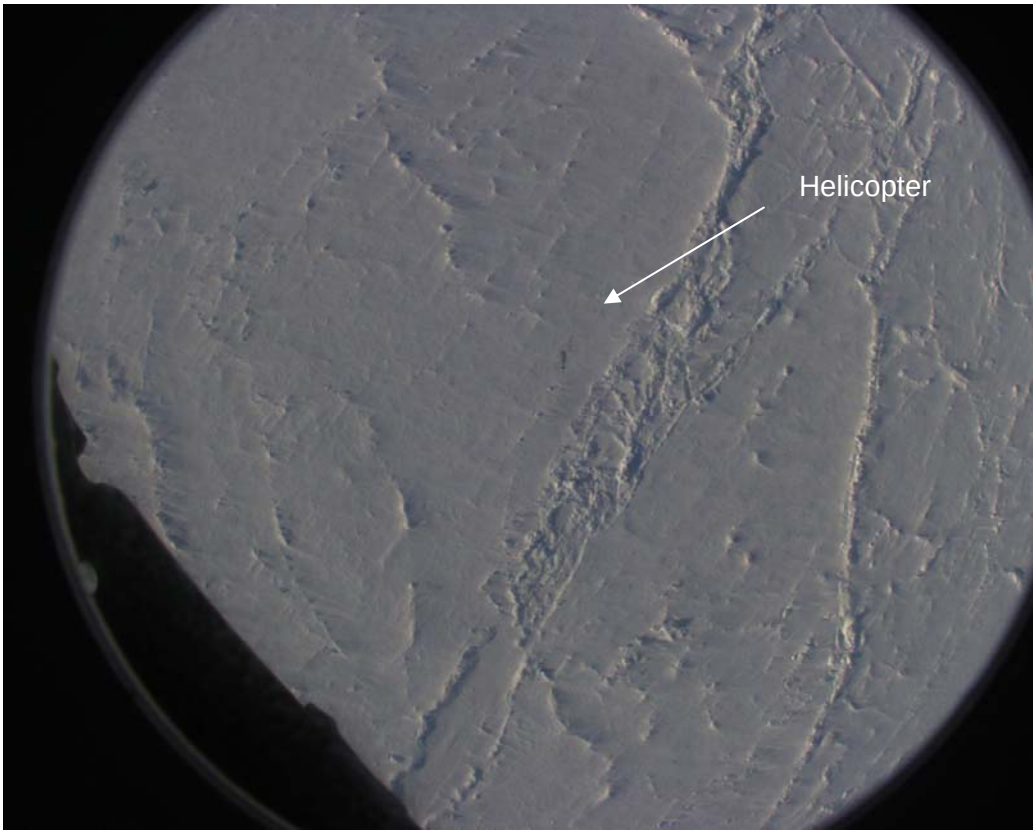


Figure 11. Image from downward looking camera of the helicopter over-flight on May 2nd 2008.

5 Validation Sites

One of the main goals of the CryoVEx 2008 campaign was to gather coincident laser scanner and ASIRAS data over specific validation sites with scientist doing in-situ observations on the surface. At these sites corner reflectors were raised and the positions are listed in Table 7.

Table 7. CryoVEx 08 Corner Reflector Positions

Name	Latitude (deg min sec)	Longitude (deg min sec)	Latitude	Longitude
ICE2	79 0 0.919 N	50 0 26.959 W	79.0002555	-50.0074887
FYIE	82 32 46.572 N	62 34 50.880W	82.54627	-62.56808
FYIW	82 32 52.008 N	62 35 8.340W	82.54778	-62.58565
MYIS	82 33 22.824 N	62 33 33.696 W	82.55634	-62.55936
MYIN	82 33 36.540 N	62 33 43.308 W	82.56015	-62.56203
CAMP	82 33 3.6 N	62 34 30 W	82.551	-62.575
DEVON	75 20 17.124 N	82 40 38.604 W	75.33809	-82.67739

Note: Several more CR was placed along the lines on Devon Ice Cap

More details about each validation site are found in the next paragraphs.

5.1 Northern Greenland Ice Sheet - UK1

The UK1 team was positioned at the ice with the Air Greenland Twin Otter reg. OY-ATY from Thule Air Base. This “put-in” of the team was delay a few days caused by poor weather along the Greenland west coast but the UK team managed to be ready for the planned over-flight.

The UK1 site on the ice sheet was over-flown with the airborne laser and radar system on April 29. The reflector at the site (named ICE2) was passed from north and two times from east to west. The best hit of the reflector was the first pass from the north. Figure 2 shows a “Quicklook” image of the ASIRAS radar signal from the corner reflector at ICE2.

Thereafter the full transect was flown form ICE2 to ICE4 and the survey continued back to Alert over the Petermann glacier. Figure 13 shows the laser scanner elevations acquired near ICE2.

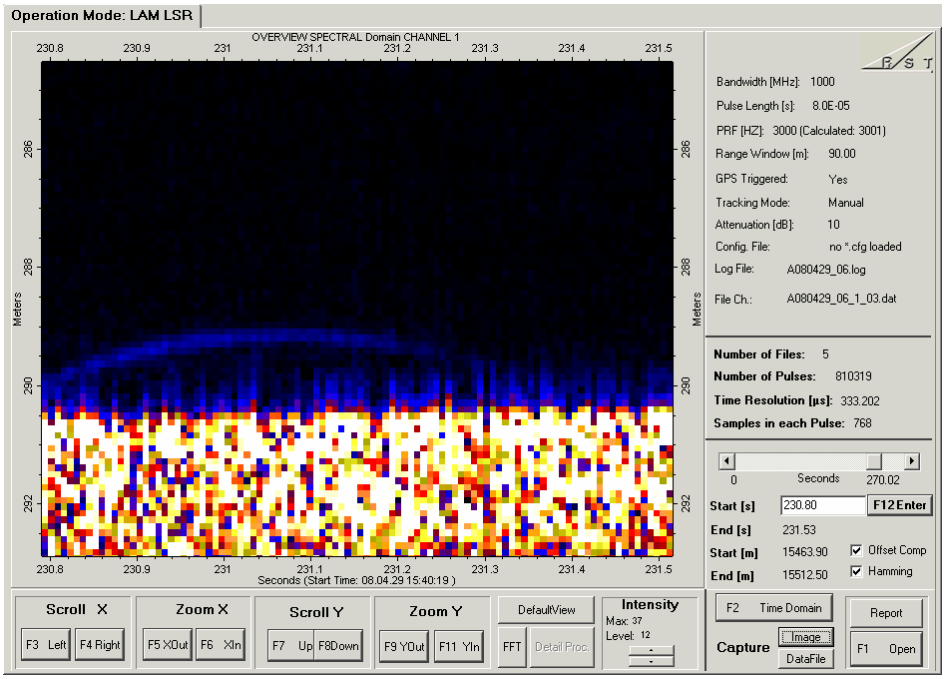


Figure 12. "Quicklook" image showing radar signal from the corner reflector at ICE2

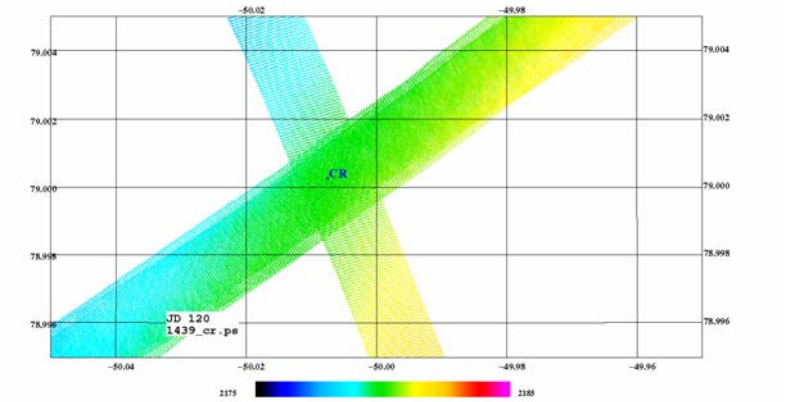


Figure 13. Stacked laser scanner swaths of the over-flights of the ICE2 validation site April 29.

5.2 Alert Sea Ice

The operations out of Alert focused on the validation sites near the coast on multiyear ice (MYI) and first year ice (FYI) and coordinated operations with the helicopter-borne EM bird system. In addition, longer surveys were carried out in the Arctic Ocean north-east and north-west of the station and a smaller survey near the AUV camp on the sea ice near Alert.

As describe in section 2 the flights were done on May 1st-2nd and May 5th. Figure 14 shows the details of the flight lines over the validation sites flown on May 1st. Both sites were over-flown repeatedly and in two altitudes 1000 ft and 1500 ft. At both sites two corner reflectors had been put up and these were hit more than once at each altitude.

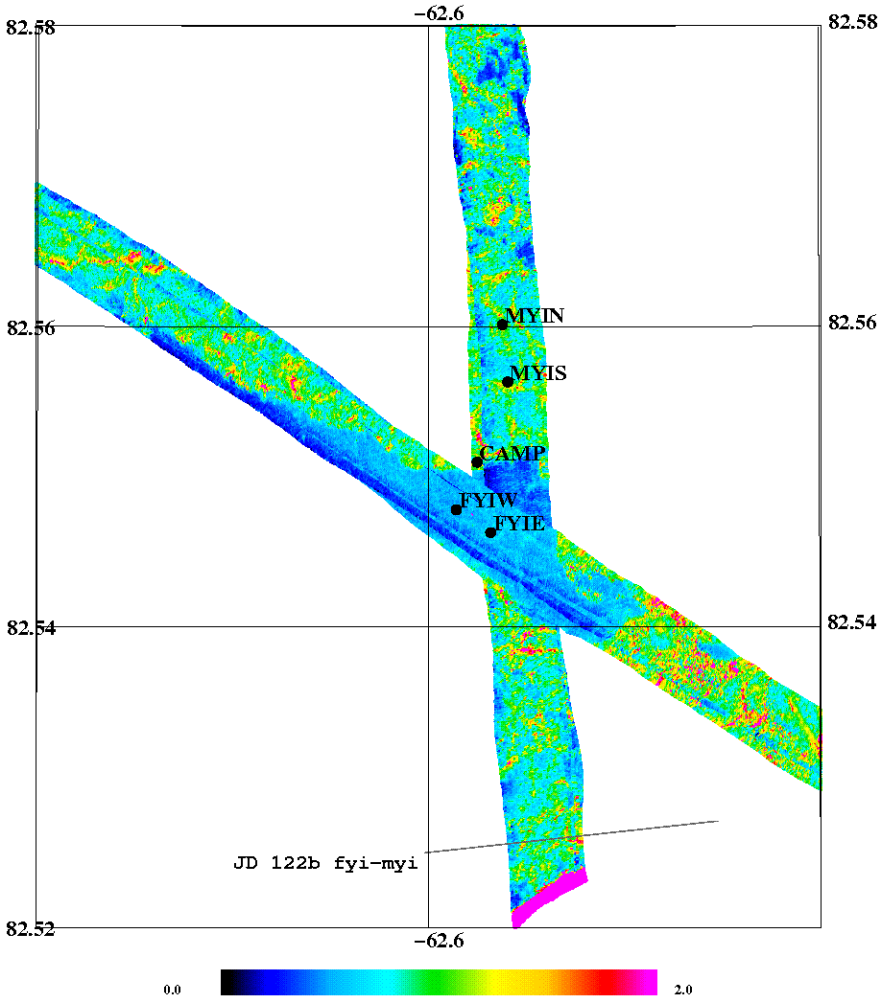


Figure 14. Stacked laser scanner swaths from sea ice validation sites near Alert (heights are freeboards relative to the local sea level). Over-flight performed on May 1.

A coordinated flight with laser/radar from Twin Otter and EM from a helicopter was done in the afternoon on May 2nd. The helicopter was over-flown near the fuel cache laid out to enable a longer operation. The helicopter was definitely hit within the footprint of ASIRAS as it is clearly seen on the radar return, see Figure 15.

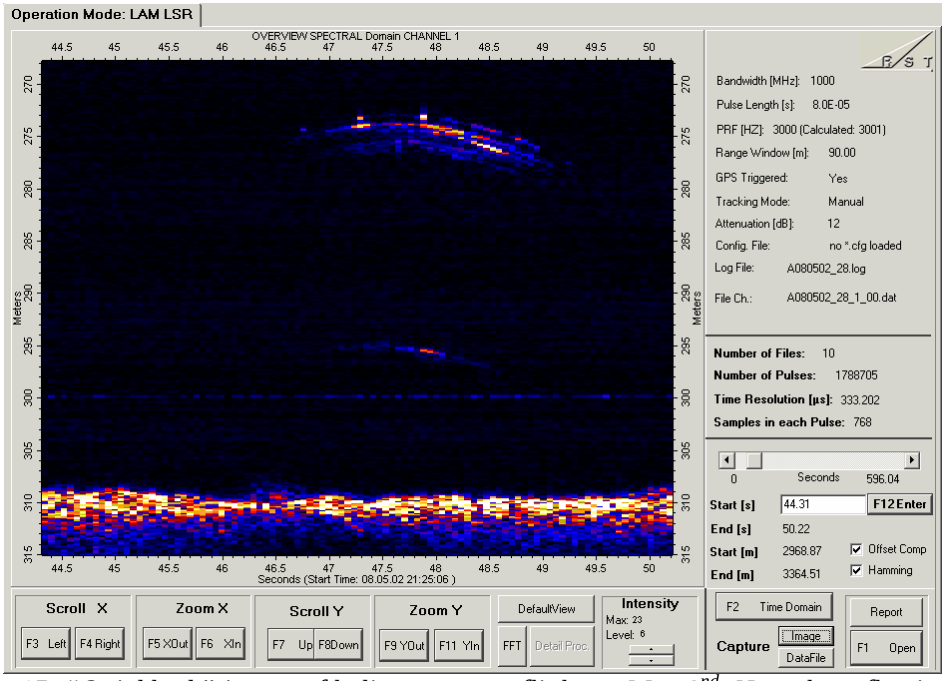


Figure 15. "Quicklook" image of helicopter over-flight on May 2nd. Note the reflection from both the helicopter itself and the EM bird below it

5.3 Devon Ice Cap

The Devon site was surveyed on May 6th. It was planned to base the survey in the local settlement Grise Fiord but the weather did not favour this very small airfield and the base was moved to Thule Air Base. The main survey lines (E-W and N-S), see Figure 16, were observed twice to ensure good alignment over corner reflectors put up at the line crossing and at a handful other sites along the lines.
The reflectors were hit and also two additional lines were measured, as requested by the Canadian team on the Devon Ice Cap, before returning the aircraft to Thule.

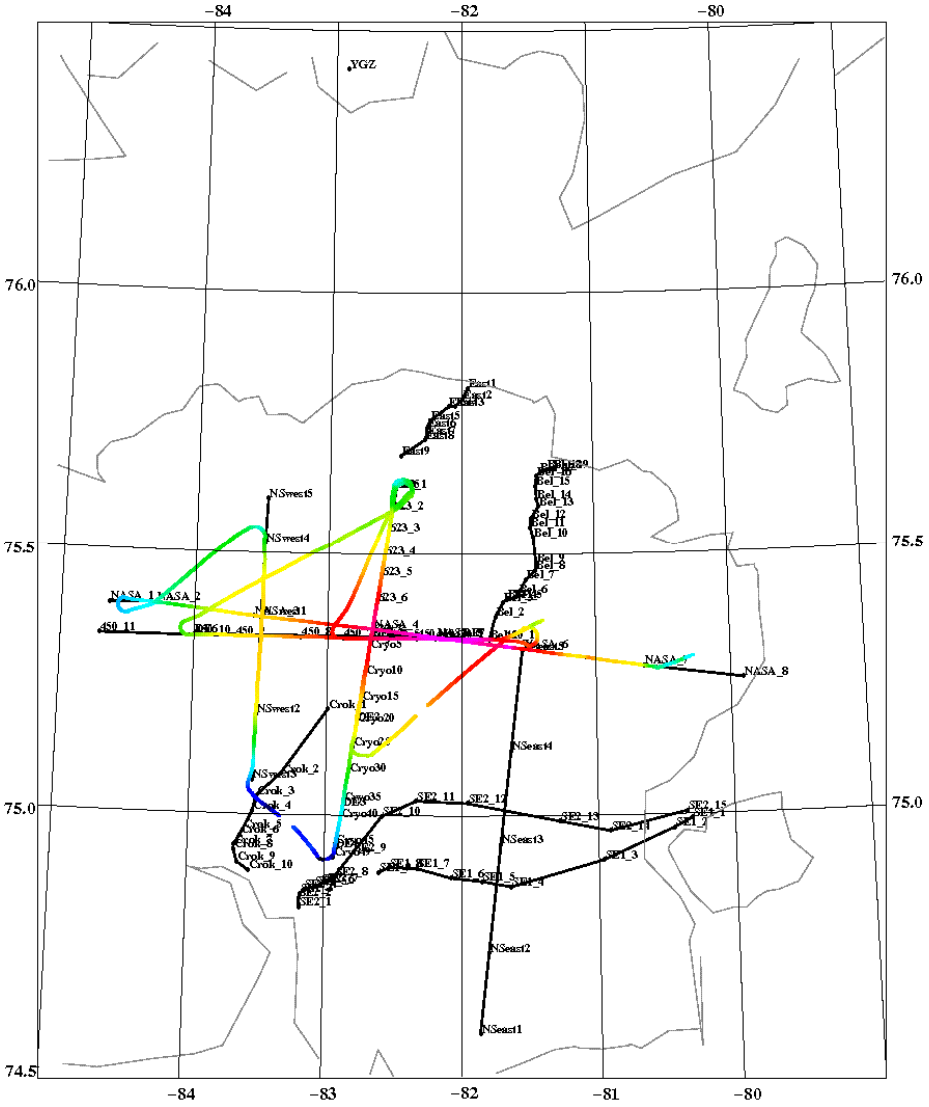


Figure 16. Laser scanner swaths of the Devon Ice Cap survey on May 6th(colour coded heights relative to the WGS84 ell.). (In black: The planned lines – some on opportunity basis and not all observed)

5.4 Others: Ilulissat and Fram Strait

On April 20th the EGIG line crossing the Greenland ice sheet between 70 and 72 N was surveyed. A line, similar to the future CryoSat tracks, was also flown on this flight over the inner part of Jakobshavn Isbræ near Ilulissat. This line almost heading N-S was measured both at high altitude (approx. 1100 m above the ice) in HAM mode and at 300 m in LAMa mode together with laser scanner observations (See Figure 9).

The Norwegian coastguard vessel KV Svalbard (see photograph) was on a scientific cruise for the Norwegian Polar Institute in April and May 2008. During the first part of the cruise the ship anchored to an ice floe in the Fram Strait between Greenland

and Svalbard. Surface observations were done on this floe from the ship. A survey line on the floe was over flown with the airborne system on April 24th together with sea ice observations on east-west lines along the Greenland coast. The sea ice team on KV Svalbard also erected a corner reflector on the line but it was not hit with the ASIRAS. Figure 18 shaws the laser scanner data, note the sea ice motion between over-flights.

Figure 17. KV Svalbard in the Fram Strait (77N25, 7W22) on April 24th 2008

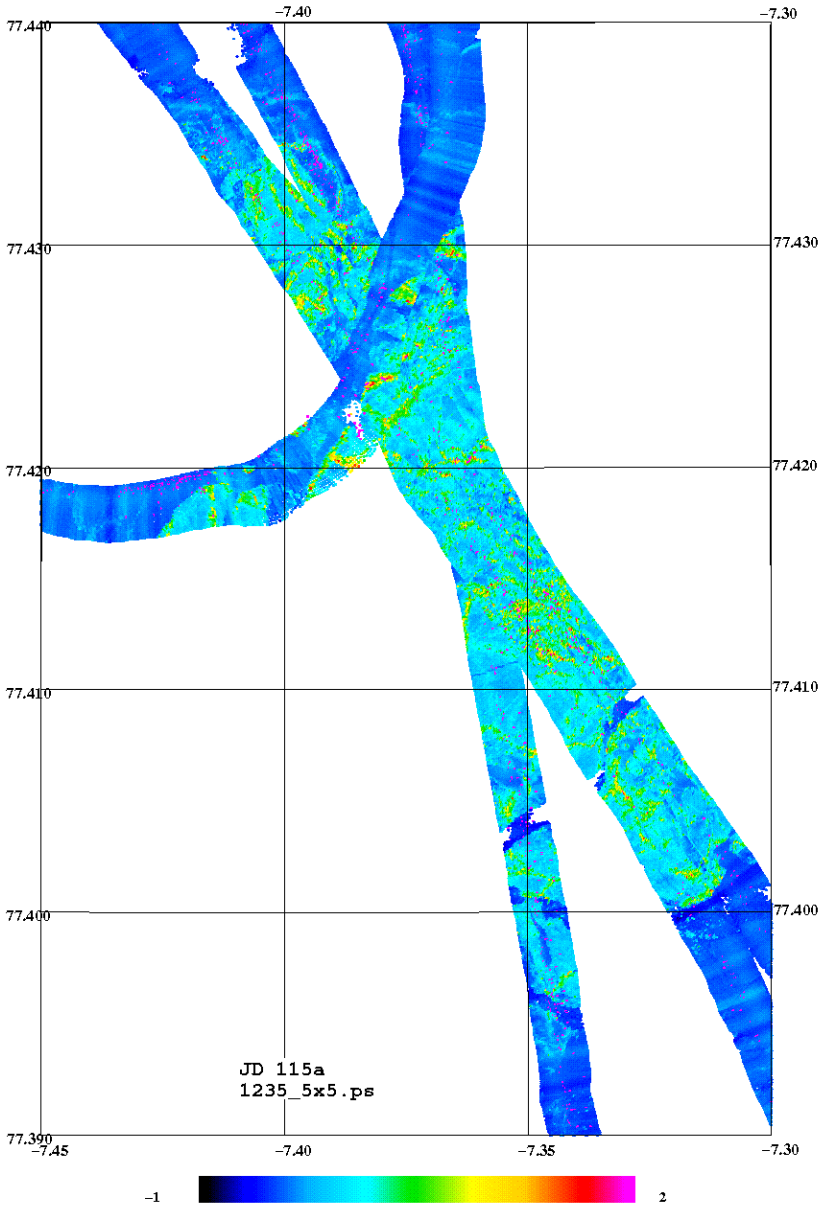


Figure 18. Laser scanner data from the KV Svalbard over-flight. Note that the sea ice has moved significantly during the survey (the crossing track has been observed last).

6 Conclusions

The airborne part of CryoVEx 2008 has successfully been carried out by DTU Space and the gathered data sets are now secured at DTU Space on central servers backed up on magnetic tapes. A total of 72 hr were flown with the Air Greenland Twin Otter plus additional 15 hrs for the transport of the UK1 team to the ice sheet. Laser scanner data has been gathered on most lines and ASIRAS data was recorded over test sites and on large parts of the other lines.

The laser scanner, INS, and GPS data has been processed by DTU Space and the ASIRAS data by AWI.

7 References

Cullen, R.: ASIRAS, Product Description, Issue: 2.5. European Space Agency, 2007

Haas, C, S. Hanson, S. Hendricks: CryoVEx 2008 Field report of in-situ measurements, 2008

Helm, V., S. Hendricks, S. Goebell, W. Rack, C. Haas, U. Nixdorf, and T. Boebel: CryoVEx 2004 and 2005 (bob) data acquisition and final report. Technical Report 1.0, Alfred Wegener Institute, 2006.

Zhang, X.: Precise Point Positioning – Evaluation and Airborne Lidar Calibration. Technical Report No. 4, Danish National Space Center, pp. 44, 2006.

8 Appendix

8.1 Operator logs

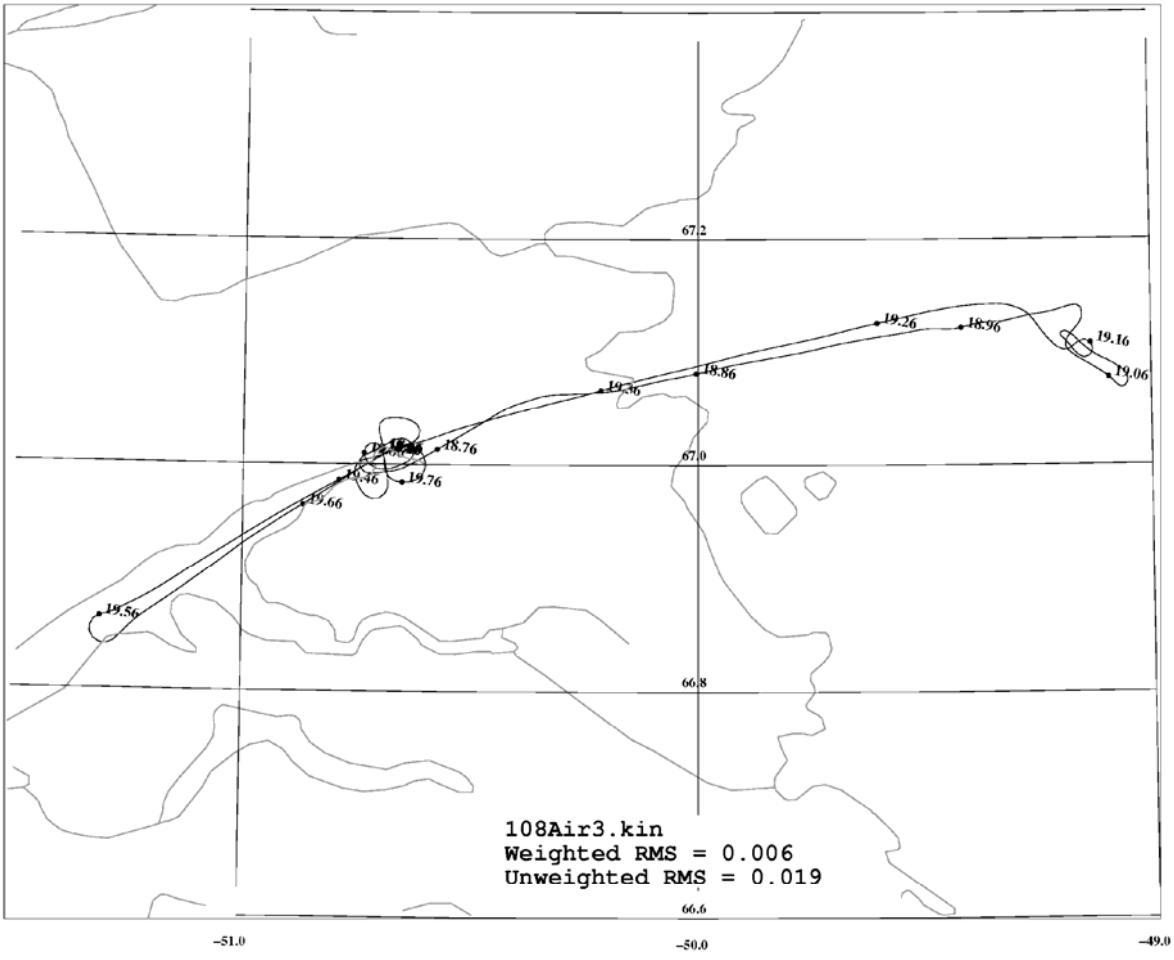
Operator logs for laser scanner system (left) and ASIRAS (right). Track plots also shown:

JD 108 17/4-08 SFJ-drop-test-SFJ

1842	Take off
185200?	New scanner file
	Tent dropped on the ice
	Climb to 6000ft
	Decent to approx. 900m
	Decent slowly to 1000ft in fjord
	Return at 1000ft
1941	Over blue building 1
	Cross over building at 1000ft
1955	Landing

Asiras CryoVEx 2008
JD 108 - 17 04 08
SFJ -> SFJ testflight

2038 take off
2155 landed



JD 109 18/4-08 SFJ-ICB-JAV

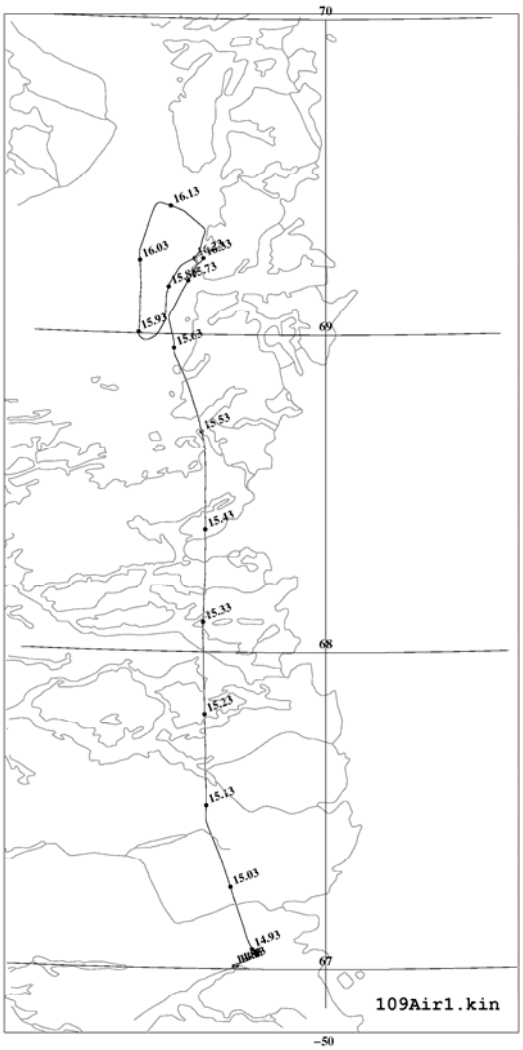
1453	Take off
	Image capture off for adjusting
153200	Scanner sync
	No power on Air2 cable remounted
1541	Air2 restarted
154800	New scanner file, +1sec?
1556	ICB1; Alt 230m/800ft
	Deviate line to obs icebergs
1616	Landing

JAV-fjord-JAV for journalists

1758	Taxi
1801	Take off
180800	Scanner sync
180953	New scanner file, file name
181000	
	Started 181057
1818	Turn over Isbræ edge
1828	IMU restart logging
1835	Landing

Asiras CryoVEx 2008
JD 109 - 18 04 08
JAV -> JAV flight for DR journalists

1800 take off
1802 system on
1807 IRF calibration
1810 LAM mode
1812 record on (sea ice)
1818 record off (turn)
1820 record on
1825 record off
1827 record on
1830 record off
1830 IRF calibration
1834 system off
1835 landed

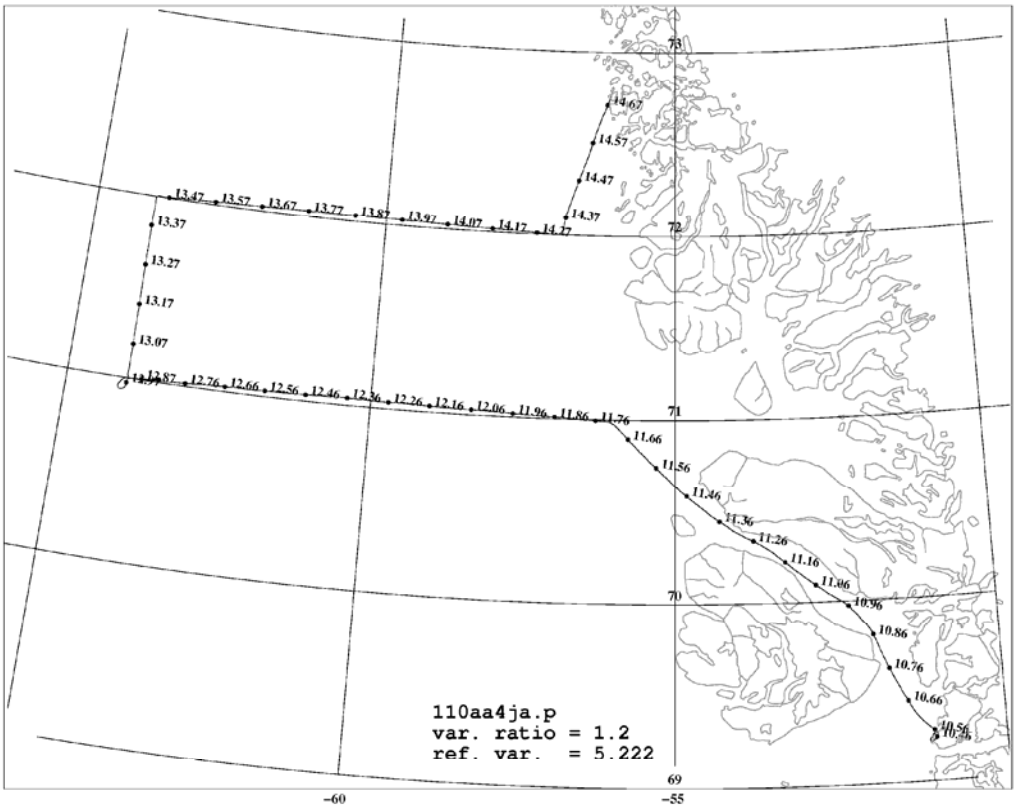


JD 110 19/4-08 JAV-K-JUV-HELI-K-JAV

	Scanner pc down – too cold
	Try to shift to laptop not ok
1028	Take off
	Pass over runway for journalists
103500	Scanner sync, scanner start no signal
	problem with logging on Lars' pc
104600	Scanner sync
105700	Scanner sync, scanner pc up
105900	New scanner file
1104	Image capture started
1120	Xtra monitor tested ok
	Some clouds JAV-K1
1147	K1
115430	New scanner file
1300	K2, tear drop turn
130300	New scanner file
1326	K3, direct turn
140000	New scanner file
1419	K4, open water and thin ice
1443	Landing JUV

Asiras CryoVEx 2008
JD 110 - 19 04 08
JAV -> UPERNAVIK

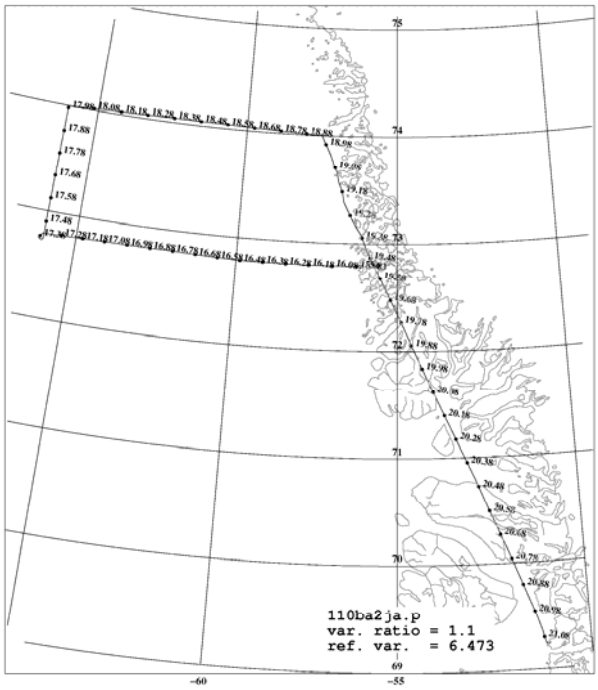
1032 system on
1035 IRF calibration
1058 record on (test)
1103 record off
1145 record on (sea ice)
1220 record off
1220 record on
1255 record off (turn)
1300 record on
1325 record off (turn)
1328 record on
1407 record off
1407 record on
1419 record off (turn)
1424 IRF calibration
1425 system off



Coordinate with helicopter
1510 Take off helicopter
Download 1st part
1557 Take off
155800 New scanner file
1604 HE2
1616 HE5
1620 HE6, overflight of heli on ground
Perfectly coordinated
1633 Light fog
164700 New scanner file
1721 K6, tear drop turn
174130 New scanner file
1800 K7
183200 (183300?) New scanner file
1856 K8, end of line
Obs of icebergs
1922 Start climb
1925 Stop logging scanner + alt
Stop logging Air1 to download
2108 Landing

UPERNAVIK -> JAV

1601 system on
1603 IRF calibration
1605 record on (thin sea ice)
1620 overhead helicopter
1635 record off
1635 record on
1705 record off
1705 record on
1721 record off (turn)
1724 record on
1745 record off (switch to PC2)
1746 record on
1758 record off (turn)
1759 record on
1830 record off
1830 record on
1855 record off (turn)
1856 record on
1923 record off
1924 IRF calibration
1927 system off

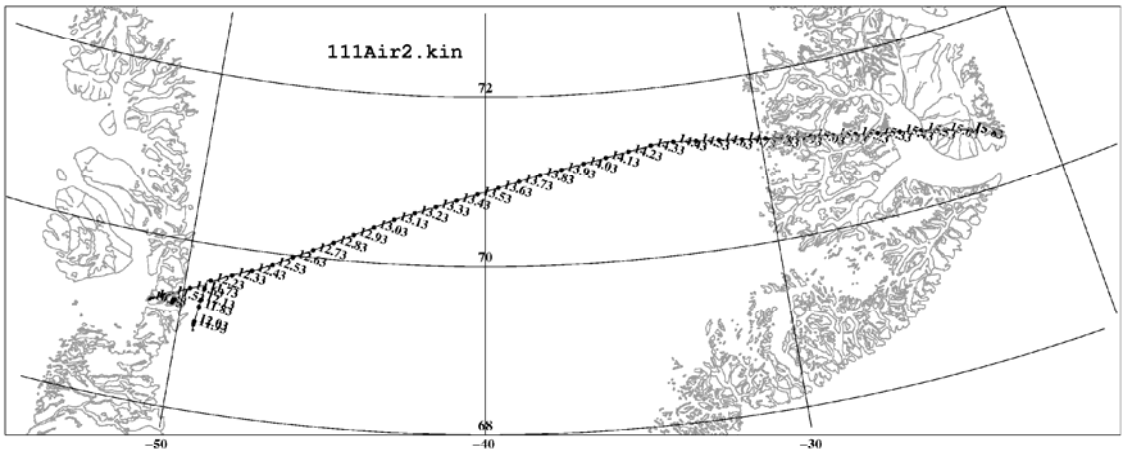


JD 111 20/4-08 JAV-EGIG-CNP

	Hard to start up EGI
	Perhaps Air1 was started after EGI
	No lock on sat, fixed height align
1113	NavRdy finally
1115	Engine start up
1125	Take off
11??	Scanner sync
113718	New scanner file called 113715
	JAV line 1-10, 1000ft south
1150	JAV5 1st time, some low clouds
1156	Return north, aprox 1100m above ice
121200	New scanner file
121230	JAV10, decent to 1000ft
1223	T1
1227	T3
123130	T5
125700	New scanner file
140000	New scanner file
1452	Scanner file closed
1548	Landing CNP

Asiras CryoVEx 2008
JD 111 - 20 04 08
JAV -> CNP

1130 system on
1132 IRF calibration
1135 record on
1142 record off
1144 record on
???? record off
12?? record on (HAM)
1213 record off
1215 record on (LAM)
1246 record off
1246 record on
1313 record off
1313 record on
1330 record off
1330 record on
1400 record off
1400 record on
1430 record off
1430 record on
1451 record off
1455 IRF calibration
1458 system off

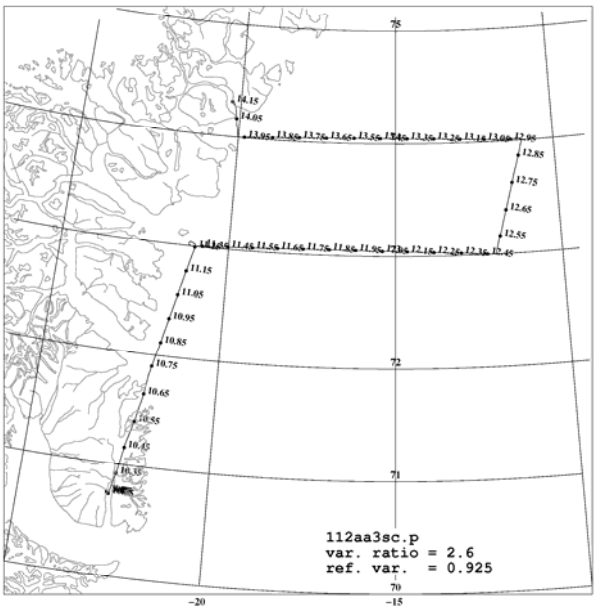


JD 112 21/4-08 CNP-K-DNB-Krev-NRD

	Scanner sync on ground
	Pobl with EMAP start up
	Perhaps problems with seriel port on laptop
1000	Engine start
1010	Taxi
1014	Take off
101630	New scanner file
1030	EMAP up on smh laptop
1040	Decent to 1000ft
1045	End of fast ice
110900	New scanner file
1115	K9 tear drop turn
1123	Low clouds
1130	Climb to 460m
1144	Scanner file closed
115400	New scanner file (start 04)
	Clouds partly broken
1201	Decent, try to get under clouds
1204	Icing, climb
1220	Broken clouds, 660m alti, some scanner
1228	K10, 750m, only ASIRAS
1238	800m
1254	K11, clouds, only little sea ice
134630	New scanner file still in clouds
1358	K12
1407	Overflight runway DNB

ASIRAS log: 21/4-2008, JD 112:
Operator: HSK
Flight: CNP-DNB, DNB-NRD:

	Take off Constable Pynt
1116	start log file A080421_00, flight altitude 300m
1130	Ascend to 480m
1142	Ascend to 540m
1200	Descend to 300m
1203	new log file A080421_01
	Climb to 660m
1222	climb to 720m
1227	turn – stop logging
1254	new log file A080421_02
1301	climb to 900m
	climb to 960m
1309	descend to 900m
1311	descend to 840m
1333	descend to 660m
1337	descend to 540m
1340	descend to 420m
1350	descend to 360m
1309	descend to 300m
1356	stop logging
1357	calibration
	Landing Daneborg



1410	Landing DNB
	Fueling, 1 engine running for instruments
1507	Taxi
1510	Take off
1540	After Shannon Island in fog again
1610	Deviate line, direct north
163130	New scanner file
1634	1000ft, turn towards K15
1642	Long leads and large patches without leads
1723	K15, turn direct towards NRD
172500	New scanner file
181400	New scanner file fog/low clouds – some broken
1843	Scanner logging stopped
185900	New scanner file
1935	Flade isblink start
2000	Landing NRD

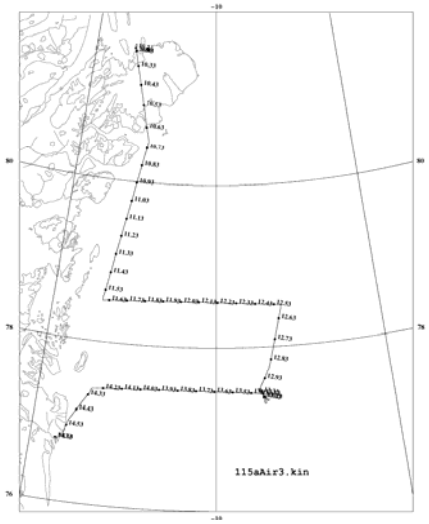
	Take off Daneborg
1533	new log file A080421_03, 300m
1544	climb to 600m
1601	new log file A080421_04
1615	new log file A080421_05
1635	new log file A080421_06
1652	new log file A080421_07, 300m
1714	new log file A080421_08
1721	turn
	new log file A080421_10
1735	new log file A080421_11
1749	new log file A080421_12 frostflowers
1812	PC1 full change to PC2
	new log file A080421_13
1829	new log file A080421_14
1843	new log file A080421_15
1859	new log file A080421_16
1914	new log file A080421_17
1929	stop radar
	Calibration
	Shut down system
	Landing St. Nord

JD 115 24/4-08 NRD-K-KV Svalbard-DMH-K-NRD

	Problems with scanner start up
	PC restarted several times – without scanner on
	Connected but no data in
1000	Taxi
1009	Take off
	Scanner restarted 1000 times, check of net-connection
	Finally receives data + sync
104200	New scanner file
1047	Image capture started
1130?	EGI input stopped, program restarted
1135	K20, turn
113730	New scanner file
1233	K21
123500	New scanner file
1248	KV Svalbard, 77 25N 7 22W, VHF 130.5
	200 m line east of ship
1300	Overhead KV Svalbard
1322	3 passes and overhead ship into line
132500	New scanner file
141630	New scanner file, end of line
1442	Landing DMH
	6 drums of fuel

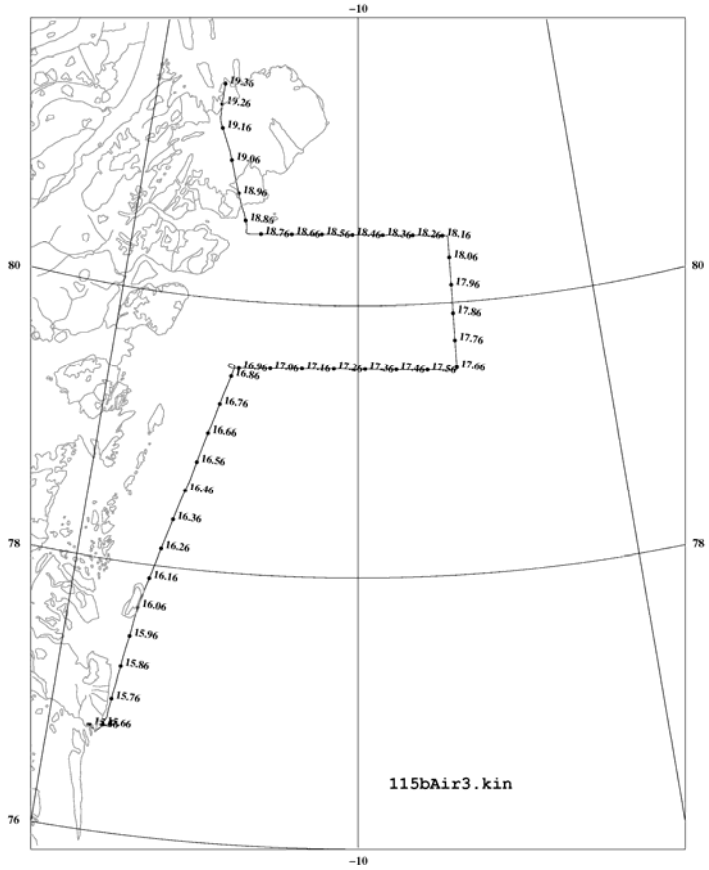
ASIRAS log: 24/4-2008, JD 115:
Operator: HSK
Flight: NRD-KV Svalbard-DMH, DMH-NRD:

0830	Take off NRD
1015	ASIRAS startup, int. calibration
1019	Ready
1136	new log file A080424_00, 300m
1150	new log file A080424_01
1205	new log file A080424_02
1220	new log file A080424_03
1233	log stopped, turn
1235	new log file A080424_04
1250	new log file A080424_05
1259	new log file A080424_06
1300	KV Svalbard
1303	stop file
1304	new log file A080424_07
1307	KV Svalbard
1309	stop log file
1310	new log file A080424_08
1312	KV Svalbard
1314	stop log file
1315	new log file A080424_09
13	KV Svalbard
1319	stop log file
1323	new log file A080424_11
1333	new log file A080424_12
1344	new log file A080424_13
1355	new log file A080424_14
1405	new log file A080424_15
1415	new log file A080424_16
1417	stop file
1418	stop radar, int. calibration
	Landing DMH



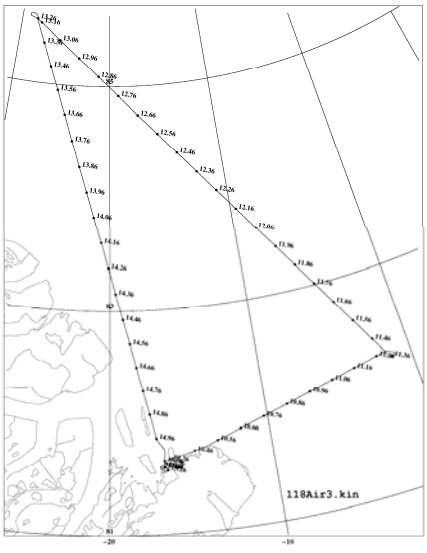
	EGI restarted and aligned
153045	Taxi
1533	Take off
153600	New scanner file
1553	Air1 start logging
1612	Image capture restarted
163330	New scanner file
1652	K21, tear drop turn
170620	End of fast ice
1718	Some clouds
1738	K22, direct turn
174000	New scanner file
1808	K23
1848	End of line, K24
	Scanner file closed
1922	Landing

	Take off DMH
1541	ASIRAS startup, int. calibration
1556	test PC1 55% A080424_18
1655	new log file A080424_19
1705	new log file A080424_20
1716	new log file A080424_21 clouds
1725	new log file A080424_22
1735	new log file A080424_23
1737	stop file
1808	new log file A080424_24
1818	new log file A080424_25
1828	new log file A080424_26
1838	new log file A080424_27
1847	stop file
1848	stop radar, int. calibration Landing NRD



JD 118 27/4-08 NRD-F-NRD

	Problems with scanner start up
	PC lost all settings
100230	Scanner sync
1006	Engine start
1013	Taxi
1018	Take off
1020	New scanner file
103430	End of fast ice
1040	Large lead
1124	Start new line after F1 tear drop turn
112530	New scanner file
1159	Image capture restarted
	Scanner logging stopped?
121530	New scanner file
131245	New scanner file
1312	F2 tear drop turn
	Scanner logging slow, stopped again
134830	New scanner file
142000	New scanner file – logging never started!
143640	Large open lead, shear zone
	Very thick fast ice edge
145900	New scanner file
1505	Runway pass
1509->	Building over-flight
1523	Landing



ASIRAS log: 27/4-2008, JD 118:
Operator: HSK
Flight: NRD-trekant-NRD:

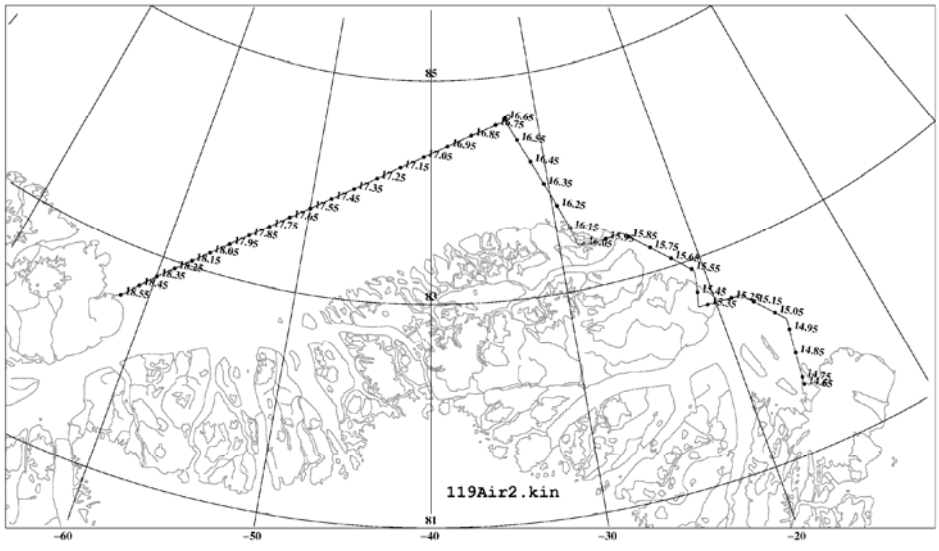
	Take off NRD
1018	startup system
1020	int. calibration
1026	new log file A080427_01
1035	new log file A080427_02
1045	new log file A080427_03
1059	new log file A080427_04
1110	new log file A080427_05
1116	stop log file, teardrop
1120	new log file A080427_06
1130	new log file A080427_07
1140	new log file A080427_08
1151	new log file A080427_09
1200	new log file A080427_10
1210	new log file A080427_11
1220	new log file A080427_12
1230	new log file A080427_13
1242	new log file A080427_14
1300	new log file A080427_15
1308	stop log file, teardrop
1313	new log file A080427_16
1325	new log file A080427_17
1335	new log file A080427_18
1346	new log file A080427_19
1358	new log file A080427_20
1410	new log file A080427_21
1425	new log file A080427_22
1432	refrozen lead
1435	new log file A080427_23
1445	new log file A080427_24
1455	new log file A080427_25
1458	new log file A080427_26
1502	overflight runway NRD
1503	stop log files
1505	new log file A080427_27
1505	turn
1507	overflight building NRD
1508	stop log file
1508	new log file A080427_28
1510	stop log file
1511	new log file A080427_29
1514	overflight building NRD
1515	stop log file
1516	new log file A080427_30
1517	overflight building NRD
1518	stop log file, int. calibration
	Landing NRD

JD 119 28/4-08 NRD-E-YLT

	Problems with IMU start up
	No network connection, no data in
142300	Scanner sync
1439	Taxi
1442	Take off
144400	New scanner file
1458	E3
150430	ALT restarted, IMU still off
	R4-R1 (off E3-E2 at 1512)
153130	Back on E3-E2 shear zone, lead
154000	New scanner file
1554	T4-T1
1558	T1-S4 over glacier
1607	S4-S1
161245	Fast ice edge
161650	E2
163400	New scanner file
163740	E1, tear drop turn
1704	ALT stop logging, try to restart IMU by power off
1707	IMU+ALT restarted!
172430	New scanner file
1835	Landing

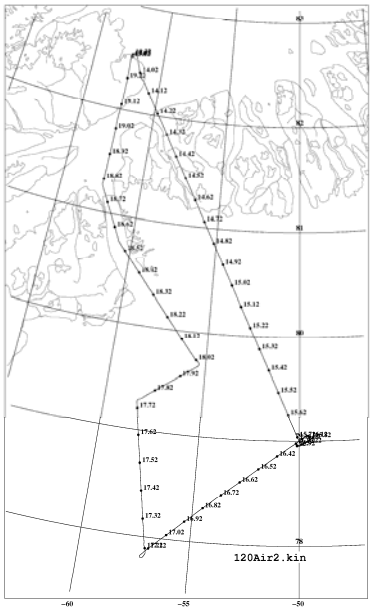
ASIRAS log: 28/4-2008, JD 119:
Operator: HSK
Flight: NRD-YLT

1442	Take off NRD
1621	ASIRAS startup, int. calibration
1625	new log file A080428_00, test
1638	new log file A080428_01
1651	new log file A080428_02
1700	new log file A080428_03
1710	new log file A080428_04
1720	new log file A080428_05
1731	new log file A080428_06
1737	open lead, event mark 1
1740	new log file A080428_07
1751	new log file A080428_08
1756	FY ice
1800	new log file A080428_09
1810	new log file A080428_10
1812	rubled ice, pix 215/216
1813	FYI
1820	new log file A080428_11
1826	stop file
1827	int. calibration, shut down system
	Landing YLT



JD 120 29/4-08 YLT-ICE-A-YLT

	Scanner PC too cold
	Problems with scanner PC connection
	PC restarted several times
134000	Scanner sync
1352	Taxi
135330	New scanner file
1355	Take off
143930	New scanner file, start of ice sheet
154400	CR from north ~0m
155330	CR from east ~10m
160210	CR from east ~15m
161040	CR from east ~-13m
161330	New scanner file (started 161334)
1618	CR from east ~-25m
	Continue on line to ICE3
1641	ICE3
1710	ICE4
171400	New scanner file
1744	A2
175900	New scanner file
1800	A3
1844	End of glacier
184730	A5
185615	New scanner file
1922	Landing

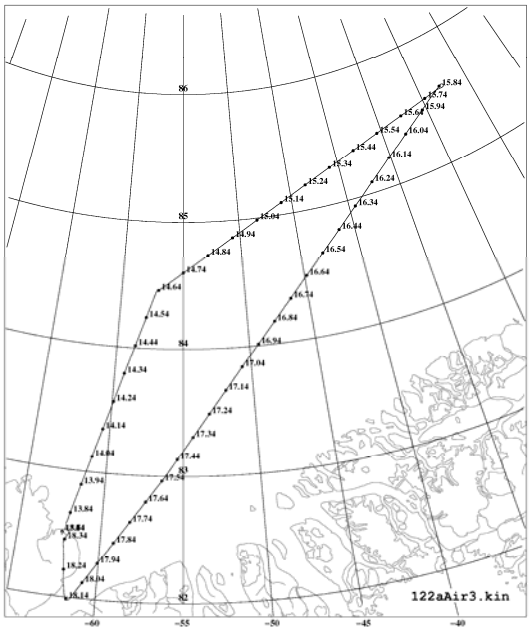


ASIRAS log: 29/4-2008, JD 120:
Operator: HSK
Flight: YLT-ICESHEET-PETERMAN GL.-YLT

	Take off YLT
1355	ASIRAS startup, int. calibration
1439	new log file A080429_00, 240m
1440	climb to 300m
1449	new log file A080429_01
1459	new log file A080429_02
1509	new log file A080429_03
1520	new log file A080429_04
1530	new log file A080429_05
1540	new log file A080429_06
1544	stop log file, tear drop
1551	new log file A080429_07
15535	reflector, event mark 1
1554	stop log file
1600	new log file A080429_08
1602	stop log file
1608	new log file A080429_09
1611	stop log file
1616	new log file A080429_10
1626	new log file A080429_11
1636	new log file A080429_12
1646	new log file A080429_13
1656	new log file A080429_14
1708	end of line, stop log file
1714	new log file A080429_15
1725	new log file A080429_16
1735	new log file A080429_17
1744	end of line, stop log file
1745	new log file A080429_18
1759	end of line, stop log file
1800	new log file A080429_19
1810	new log file A080429_20
1820	new log file A080429_21
1832	new log file A080429_22
1841	new log file A080429_23
1844	event marker 1, end of glacier
1852	new log file A080429_24
1900	new log file A080429_25
	Climbing to 1020m
1906	stop file, internal calibration
	Shut down system
	Landing YLT

JD 122 1/5-08 YLT-F-S-YLT-MYI-FYI-YLT

	Problems with POF HF radio
1331	EGI logging restarted (program restarted)
133530	Scanner sync
134000	New scanner file, still on ground
1343	Taxi
1345	Take off
143500	New scanner file
1437	F3
153330	New scanner file
1547	F2, tear drop turn
162730	New scanner file
	Loose connection in power in to rack,
	running on batteries for a while, look out for the plug
173000	New scanner file
1807	End of line
1825	Landing



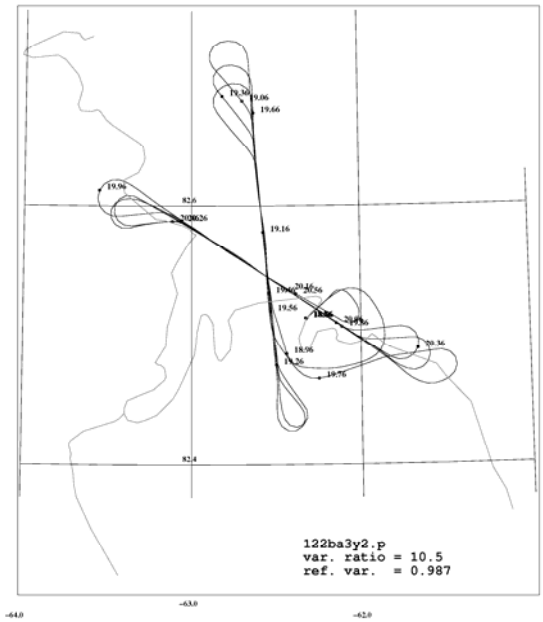
ASIRAS log: 1/5-2008, JD 122:

Operator: HSK

Flight: YLT-triangle-YLT, YLT-MYI-FYI-YLT

	Take off YLT
1350	ASIRAS startup, int. calibration
1352	new log file A080501_00, 300m
1402	new log file A080501_01
1412	new log file A080501_02
1422	new log file A080501_03
1433	new log file A080501_04
1437	stop log file, end of line
1445	new log file A080501_05
1456	new log file A080501_06
1505	new log file A080501_07
1515	new log file A080501_08
1526	new log file A080501_09
1535	new log file A080501_10
1547	stop file, teardrop
1551	new log file A080501_11
1600	new log file A080501_12
1610	new log file A080501_13
1620	new log file A080501_14
1630	system down, power failure
1642	start up, int. calibration
1643	new log file A080501_15
1655	new log file A080501_16
1705	new log file A080501_17
1715	new log file A080501_18
1725	new log file A080501_19
1736	new log file A080501_20
1746	new log file A080501_21
1756	new log file A080501_22
1807	stop file
1808	int. calibration, shut down
	On ground YLT

	Pick up MD
1000ft over CR and then 2000ft	
183630	New scanner file
1850	Taxi
1852	Take off, heading towards MY
185920	CR ~30-40m
190945	CR ~4m
191730	CR ~-6m, from south
192630	CR ~-1m
	Climb to 2000ft
1934	CR ~0m!
193645	New scanner file
194210	CR ~-3m
195150	Crossing runway, heading for FYI
195310	CR ~10m
200127	CR ~-2m
	Decent to 1000ft
200240	Crossing runway
200828	Crossing runway
200950	CR ~-5m
2017	CR ~6m
2025	CR ~3m
203225	CR ~6m
2037	Landing



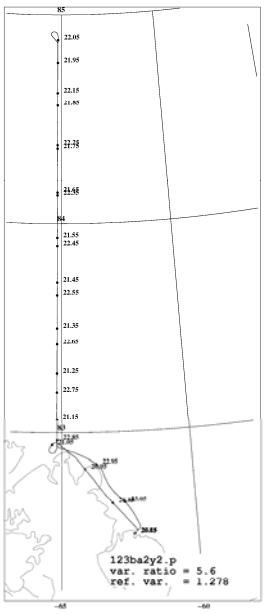
Take off YLT	
1854	turn on system, int. calibration
1858	new log file A080501_23, PC2
	MYI S → N 1,000ft
1901	stop file
190551	new log file A080501_24
	MYI N → S 1,000ft
1911	stop file
191523	new log file A080501_25
191730	MYI S → N 1,000ft
1919	stop file
192302	new log file A080501_26
192630	MYI N → S 1,000ft
1927	stop file
	Climb to 2,000ft
193120	new log file A080501_27
193400	MYI S → N 2,000ft
193536	stop file
193915	new log file A080501_28
194206	MYI N → S 2,000ft
194315	stop file
194945	new log file A080501_29
195248	FYI E → W 2,000ft
195456	stop file
195832	new log file A080501_30
200127	FYI W → E 2,000ft
200145	stop file
	Descend to 1,000ft
200636	new log file A080501_31
200945	FYI E → W 1,000ft
201134	stop file
201426	new log file A080501_32
201710	FYI W → E 1,000ft
201812	stop file
202205	new log file A080501_33
202457	FYI E → W 1,000ft
202619	stop file
202925	new log file A080501_34
203204	FYI W → E 1,000ft
203234	stop file
2033	int, calibration, shut down system
	Landing YLT

JD 123 2/5-08 YLT-H-YLT-A-FUE-A-YLT

	Problems with scanner PC start up
132800	Scanner sync
133030	New scanner file
1335	Take off
	Local patches of fog
143100	New scanner file
1500	H1
151500	New scanner file, fog
1608	H3
161500	New scanner file
1720	Air2 stopped logging, card full, restarted
1720	H5
172730	New scanner file
1747	H6
1837	H7
183830	New scanner file
1916	Landing
	Fuel
	New start up

Coincident flight with helicopter

2020	Heli take off
202800	Scanner sync
2045	Take off
204600	New scanner file
2105	A1 after turn to align on track
2127	FUE ~0m
2126	Heli over-flight
21??	Air1 stop logging, disc full
215905	A2
220030	New scanner file
220310	A2
223058	FUE ~6m, heli on ground
2251	A1, end of survey line
	Low level in to YLT
2308	Landing



ASIRAS log: 2/5-2008, JD 123:

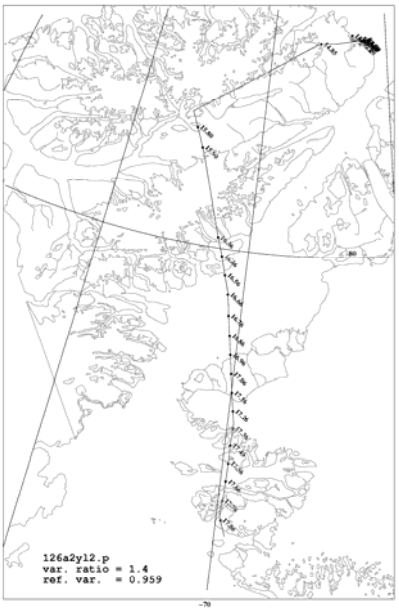
Operator: HSK

Flight: YLT-H-YLT, YLT-A1-A2-A1-YLT

	Take off YLT
1336	ASIRAS startup
1343	int. calibration
1344	new log file A080502_00, 300m
1355	new log file A080502_01
1405	new log file A080502_02
1415	new log file A080502_03
1425	new log file A080502_04
1435	new log file A080502_05
1445	new log file A080502_06
1455	new log file A080502_07
1501	stop file, end of line
1518	new log file A080502_08
1530	new log file A080502_09
1540	new log file A080502_10
1550	new log file A080502_11
1600	new log file A080502_12
1608	stop log file, end of line
1626	new log file A080502_13
1636	new log file A080502_14
1645	new log file A080502_15
1655	new log file A080502_16
1705	new log file A080502_17
1715	new log file A080502_18
1722	stop file, end of line
1751	new log file A080502_19
1800	new log file A080502_20
1810	new log file A080502_21
1820	new log file A080502_22
1830	new log file A080502_23
1837	stop line
1840	int. calibration
	Landing YLT/Take off YLT
2045	system startup
2050	int. calibration
2051	new log file A080502_24, test
2058	new log file A080502_25 (NW)
2100	stop log file
210525	new log file A080502_26, A1
2115	new log file A080502_27
212500	new log file A080502_28
212643	reflector, helicopter
213500	new log file A080502_29
214500	new log file A080502_30
215500	new log file A080502_31
215915	stop log file, A2
220240	new log file A080502_32
221200	new log file A080502_33
222200	new log file A080502_34
222700	new log file A080502_35
223058	over airstrip, fuelcache
223700	new log file A080502_36
224700	new log file A080502_37
225126	stop log file, end of survey
2252	int. calibration, shut down
	On ground YLT

JD 126 5/5-08 YLT-M-cal-GM-THU

	Scanner PC reconnected
	Power loss on ground cable
	Restart with engine on
	Scanner sync
130700	New scanner file, on ground
	Start with Mow-the-lawn
1327	Take off
	Poor visibility, change alt to 200m
	Only chose central lines and add more close to camp
	+-150m of camp approx.
1416	End of survey lines E-W
1420	Start calib over Spinnaker
1432	End of calib
143400	New scanner file, up through clouds
	Heading for GM1-GM8
145930	New scanner file
152930	GM8, end of survey
1803	Landing



ASIRAS log: 5/5-2008, JD 126:

Operator: HSK

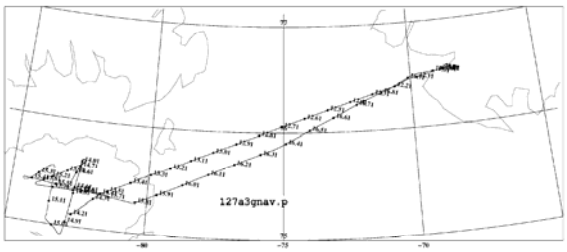
Flight: YLT-AUV-ice on Ellesmere Island-THU

	Take off YLT
1327	ASIRAS startup
1333	int. calibration
133455	new log file A080505_00, 300m AUV M1-M2
1338	stop file, end of line
134644	new log file A080505_01, 240m
135108	stop file, end of line AUV M5-M6
135510	new log file A080505_02, 240m
135928	stop file, end of line AUV M7-M8
140314	new log file A080505_03, 240m AUV
140745	stop file, end of line
141241	new log file A080505_04, 240m AUV
141708	stop file, end of line
142009	new log file A080505_05 Overflight Runway+Spinaker building YLT
142105	stop file
142308	new log file A080505_06 Overflight Spinaker
142400	stop file
1426	new log file A080505_07 Overflight Spinaker
142740	stop file
143030	new log file A080505_08 Overflight Spinaker
143208	stop file
144930	new log file A080505_09*
145939	stop file
151140	new log file A080505_10*
152100	new log file A080505_11*
1529	stop file
1533	int. calibration, shut down system Landing Thule AB

* Survey on Ellesmere Island, various heights due to changing surface heights.

JD 127 6/5-08 THU-DEVON-THU

	Normal start up with engine on
114500	Scanner sync
1159	Take off
120015	New scanner file
1225	EMAP restarted Cy1, Cy5 deleted
	Too close to CR
131200	New scanner file
133000	New scanner file
1336	45_4 ~6m
	CR ~18m
1345	End of 45_1-45_10
1401	62_2 after tear drop turn into line
	CR ~17m
140830	Cy10 ~-4m
	Cy19 ~-8m
141600	New scanner file
	Repeat 45_1-45_9
142440	45_1, start line
1428	45_4 ~12m
	CR ~-20m
1440	N-S line repeated
1447	CR ~-2m
1456	Cy45, turn towards NSw1
150030	New scanner file
150250	NSw1
1514	NSw4, turn towards NASA line
1524	NA2
1547	NA7, end of line
1550	End of survey, scanner logging off
	Direct THU
1703	Landing

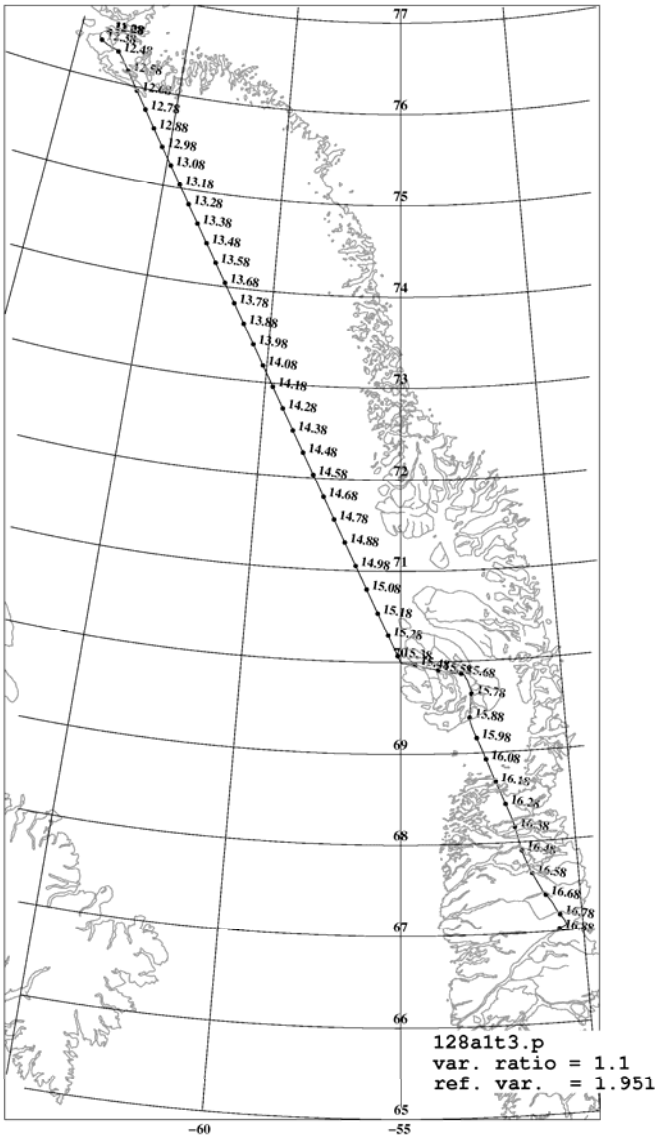


ASIRAS log: 6/5-2008, JD 127:
Operator: HSK
Flight: THU-Devon icecap-THU

	Take off THU
1202	ASIRAS startup
1204	int. calibration
1205	new log file A080506_00, 300m
1222	new log file A080506_01
1232	new log file A080506_02
1242	new log file A080506_03
1252	new log file A080506_04
1302	new log file A080506_05
1312	new log file A080506_06
1318	stop file
	Devon icecap
133228	new log file A080506_07
133745	reflector/camp
134534	stop file, end of line
140047	new log file A080506_08, 420m
140115	300m
140656	reflector
140820	360m
140838	300m
141109	stop file
142408	new log file A080506_09
143009	camp/reflector
143102	stop file
144128	new log file A080506_10, 480m
144258	360m
144346	300m
144747	reflector
145208	360m
145225	300m
145628	PC1 record stopped
1457	new log file A080506_11, test
1458	new log file A080506_12, test
	Stopped again
1459	change to PC2
1500	new log file A080506_13, test
1501	stop file - OK
150305	new log file A080506_14
1506	try 360m back to 300m
151425	stop file
152330	new log file A080506_15, 420m
152358	360m
152425	300m
153130	new log file A080506_16
153500	camp on starboard
154100	new log file A080506_17, 300m
154240	360m
154340	420m
154724	stop file, end of survey
1548	int. calibration
1550	shut down system
	Landing Thule AB

JD 128 7/5-08 THU-DISKO-SFJ

	Normal start up with engine on
120000	Scanner sync
1204	IMU+ALT restarted, IMU input stopped
1207	Taxi
1216	Take off
121800	New scanner file
1228	EMAP restarted – new map on screen
124515	New scanner file
	Melville Bay open water in northern part
134200	New scanner file
142630	New scanner file
151100	New scanner file
1552	End of Disko survey
	Direct SFJ
1653	Landing



8.2 File formats

The file format description for the core products can be found in "ASIRAS, Product Description, Issue 2.5" by R. Cullen (2007) and the user should refer to this document for a detailed description, Especially concerning the ASIRAS products which are not discussed in the following. The definition of the types used in the binary files can be found in Table 8.

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	

Table 8. Definition of binary types used in the description of the file formats.

Processed DGPS data is delivered in binary, big endian format with each record formatted as described in Table 9.

Identifier	Description	Unit	Type	Size [Bytes]
1	Days (MJD)	UTC	sl	4
2	Seconds		ul	4
3	Microseconds		ul	4
4	Latitude (WGS-84)	10^{-7} deg	sl	4
5	Longitude	10^{-7} deg	sl	4
6	Geodetic ellipsoidal height	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

Table 9. GPS file format.

The processed INS data is delivered in binary, big endian format with each record formatted as described in Table 10.

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

Table 10. INS file format.

The processed laser scanner data is delivered in binary, little endian format with each record formatted as described in Table 11. Note that the time is decimal hours since the beginning of the day with respect to UTC time.

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 (Seconds of day)	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 (Seconds of day)	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}

Table 11. Laser scanner file format.

8.3 GPS reference coordinates

Reference GPS station coordinates in ITRF 2005.

Table 12 GPS reference coordinates

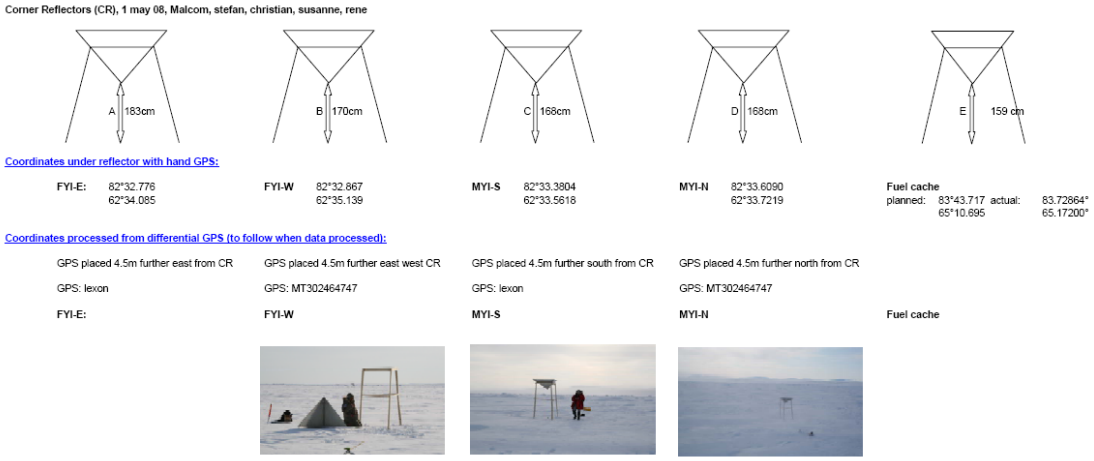
Name	Day	Lat (DMS)	Lon (DMS)	Ellipsoidal Height (m)
SFJ1	109	67 0 21.6428	-50 42 9.7167	71.8670
	110	67 0 21.6429	-50 42 9.7166	71.8663
	131	67 0 21.6429	-50 42 9.7167	71.8626
	134	67 0 21.6430	-50 42 9.7169	71.8605
	135	67 0 21.6429	-50 42 9.7168	71.8675
	133	67 0 21.6430	-50 42 9.7167	71.8573
SCOR	111	70 29 7.1998	-21 57 1.2123	128.4871
NRD1	115	81 35 47.4178	-16 39 50.9411	61.4741
	118	81 35 47.3958	-16 39 51.5421	61.8364
NRD2	118	81 35 47.7708	-16 39 51.2947	62.0200
YLT1	120	82 30 40.1035	-62 19 7.8670	44.0638
	122	82 30 42.1338	-62 19 56.2566	51.6529
	123	82 30 42.1340	-62 19 56.2577	51.6501
YLT2	120	82 30 39.5054	-62 19 13.9806	45.3253
	122	82 30 39.5053	-62 19 13.9794	45.3350
	123	82 30 39.5053	-62 19 13.9793	45.3347
	126	82 30 39.5053	-62 19 13.9805	45.3381
JAV0	110	69 14 25.3716	-51 3 56.7004	58.9223
JUV0	110	72 47 16.2809	-56 7 45.1428	159.0137

Mean values used for processing:

	Lat	Lon	E. Height
SFJ1	67 0 21.6429	-50 42 9.7167	71.8635
NRD1	81 35 47.4068	-16 39 51.2416	61.6552
YLT1 (120+122+123)	82 30 41.4571	-62 19 40.1271	49.1223
YLT1 (122+123)	82 30 42.1339	-62 19 56.2572	51.6515
YLT2	82 30 39.5053	-62 19 13.9799	45.3333

8.4 Corner reflector details from sea ice in-situ observations

Details of corner reflectors on the sea ice near CFS Alert:



See also the field report from the ground validation work by Haas, Hanson, and Hendricks, CryoVEx 2008 Field report of in-situ validation measurements, 2008.

8.5 ASIRAS data files

List of recorded ASIRAS files with start/stop times, range window and number of pulses: (or processed ASIRAS files)

Table13. Recorded ASIRAS files

File name [AYYMMDD]	Start time	Stop time	Range Window [m]	# Pulses
A080417_00.log	16:02:40	16:02:45	18.00	5783
A080417_01.log	16:04:14	16:04:19	90.00	9419
A080417_02.log	16:06:56		90.00	
A080417_03.log	16:09:30	16:09:36	18.00	7500
A080417_04.log	21:13:03	21:15:12	18.00	375148
A080417_05.log	21:24:23	21:26:44	90.00	347498
A080417_06.log	21:28:37	21:30:33	90.00	284998
A080417_07.log	21:33:09	21:36:15	90.00	459998
A080418_00.log	20:07:07	20:13:34	90.00	1152455
A080418_01.log		20:15:45	20:21:31	90.00	1032407
A080418_02.log		20:22:29	20:25:12	90.00	483191
A080419_00.log		12:52:16	12:58:17	90.00	1074424
A080419_01.log		13:40:34	14:15:01	90.00	6194438
A080419_02.log		14:15:02	14:49:44	90.00	6242456
A080419_03.log		14:54:35	15:21:34	90.00	4855910
A080419_04.log		15:23:28	16:03:00	90.00	7112798
A080419_05.log		16:03:02	16:14:22	90.00	2034802
A080419_06.log		16:05:44	16:35:25	90.00	5339104
A080419_07.log		16:35:37	17:05:39	90.00	5402127
A080419_08.log		17:05:40	17:21:16	90.00	2800102
A080419_09.log		17:24:41	17:45:19	90.00	370646

				0
				220887
A080419_10.log	17:46:17	17:58:36	90.00	0
				564222
A080419_11.log	17:59:36	18:30:59	90.00	0
				445975
A080419_12.log	18:31:01	18:55:50	90.00	5
				480188
A080419_13.log	18:56:50	19:23:32	90.00	9
				115245
A080420_00.log	11:35:44	11:42:10	90.00	4
				220286
A080420_01.log	11:44:09	11:56:25	90.00	8
				213685
A080420_02.log	12:00:37	12:12:31	18.00	8
				563621
A080420_03.log	12:15:03	12:46:23	90.00	9
				490693
A080420_04.log	12:46:24	13:13:43	90.00	1
				283911
A080420_05.log	13:13:45	13:29:32	90.00	8
				549216
A080420_06.log	13:29:33	14:00:05	90.00	1
				541413
A080420_07.log	14:00:07	14:30:14	90.00	0
				381750
A080420_08.log	14:30:26	14:51:40	90.00	2
				826225
A080421_00.log	11:16:29	12:02:24	90.00	2
				440873
A080421_01.log	12:02:29	12:27:01	90.00	5
				111493
A080421_02.log	12:54:30	13:56:27	90.00	85
				499396
A080421_03.log	15:33:41	16:01:27	90.00	6
				255100
A080421_04.log	16:01:28	16:15:40	90.00	4
				317524
A080421_05.log	16:15:42	16:33:22	90.00	9
				349937
A080421_06.log	16:33:25	16:52:52	90.00	7
				386252
A080421_07.log	16:52:54	17:14:23	90.00	0
				129951
A080421_08.log	17:14:25	17:21:40	90.00	1
A080421_09.log	17:22:15	17:22:44	90.00	81032
				216985
A080421_10.log	17:23:24	17:35:29	90.00	4
				246997
A080421_11.log	17:35:32	17:49:16	90.00	2
				404259
A080421_12.log	17:49:18	18:11:48	90.00	0
				311522
A080421_13.log	18:12:30	18:29:50	90.00	6
				242195
A080421_14.log	18:29:54	18:43:23	90.00	3
				283911
A080421_15.log	18:43:27	18:59:16	90.00	8
				272207
A080421_16.log	18:59:17	19:14:26	90.00	1

A080421_17.log	19:14:27	19:29:35	90.00	2719070
A080424_00.log	11:35:59	11:50:12	90.00	2554005
A080424_01.log	11:50:14	12:05:36	90.00	2761087
A080424_02.log	12:05:39	12:20:08	90.00	2602024
A080424_03.log	12:20:10	12:33:23	90.00	2373934
A080424_04.log	12:35:10	12:50:58	90.00	2839117
A080424_05.log	12:51:03	12:59:06	90.00	1443569
A080424_06.log	12:59:07	13:03:10	90.00	723285
A080424_07.log	13:04:14	13:09:31	90.00	945372
A080424_08.log	13:10:53	13:14:08	90.00	579228
A080424_09.log	13:15:48	13:19:38	90.00	684270
A080424_10.log	13:21:03	13:21:42	90.00	111044
A080424_11.log	13:23:18	13:33:19	90.00	1797716
A080424_12.log	13:33:20	13:44:42	90.00	2040803
A080424_13.log	13:44:43	13:55:07	90.00	1866735
A080424_14.log	13:55:09	14:05:21	90.00	1830721
A080424_15.log	14:05:23	14:15:32	90.00	1821717
A080424_16.log	14:15:39	14:16:57	90.00	225090
A080424_17.log	15:55:48	15:56:01	90.00	33014
A080424_18.log	16:53:28	16:53:39	90.00	27011
A080424_19.log	16:55:14	17:05:10	90.00	1779702
A080424_20.log	17:05:11	17:16:22	90.00	2004789
A080424_21.log	17:16:23	17:25:44	90.00	1674659
A080424_22.log	17:25:45	17:35:20	90.00	1716675
A080424_23.log	17:35:21	17:37:49	90.00	438173
A080424_24.log	18:08:09	18:18:31	90.00	1857731
A080424_25.log	18:18:32	18:28:31	90.00	1788704
A080424_26.log	18:28:33	18:38:56	90.00	1860732
A080424_27.log	18:38:57	18:47:17	90.00	1494589
A080427_00.log	10:21:42	10:21:54	90.00	27011
A080427_01.log	10:26:30	10:35:58	90.00	1698670
A080427_02.log	10:35:59	10:45:49	90.00	1761695
A080427_03.log	10:45:50	10:59:38	90.00	2475976
A080427_04.log	10:59:39	11:11:09	90.00	2064814
A080427_05.log	11:11:10	11:16:01	90.00	864341

A080427_06.log	11:20:47	11:30:22	90.00	1716676
A080427_07.log	11:30:24	11:40:19	90.00	1779701
A080427_08.log	11:40:19	11:51:23	90.00	1983782
A080427_09.log	11:51:25	12:00:56	90.00	1707673
A080427_10.log	12:00:57	12:10:21	90.00	1686664
A080427_11.log	12:10:21	12:20:51	90.00	1878740
A080427_12.log	12:20:51	12:31:10	90.00	1848728
A080427_13.log	12:31:10	12:42:12	90.00	1977779
A080427_14.log	12:42:13	13:00:09	90.00	3220268
A080427_15.log	13:00:09	13:08:44	90.00	1536605
A080427_16.log	13:13:30	13:25:36	90.00	2172855
A080427_17.log	13:25:37	13:35:09	90.00	1713675
A080427_18.log	13:35:11	13:46:27	90.00	2022796
A080427_19.log	13:46:29	13:58:33	90.00	2163852
A080427_20.log	13:58:33	14:10:24	90.00	2127837
A080427_21.log	14:10:26	14:25:20	90.00	2680055
A080427_22.log	14:25:21	14:34:53	90.00	1707672
A080427_23.log	14:34:54	14:45:03	90.00	1821717
A080427_24.log	14:45:05	14:55:53	90.00	1938763
A080427_25.log	14:55:58	14:58:29	90.00	447176
A080427_26.log	14:58:52	15:03:34	90.00	840331
A080427_27.log	15:05:27	15:07:57	90.00	444175
A080427_28.log	15:08:42	15:10:52	90.00	384152
A080427_29.log	15:11:34	15:15:01	90.00	615243
A080427_30.log	15:16:09	15:18:19	90.00	384151
A080428_00.log	16:25:27	16:27:02	90.00	276110
A080428_01.log	16:38:10	16:51:57	90.00	2472974
A080428_02.log	16:51:57	17:00:18	90.00	1491588
A080428_03.log	17:00:19	17:10:11	90.00	1767697
A080428_04.log	17:10:11	17:20:37	90.00	1872737
A080428_05.log	17:20:39	17:31:21	90.00	1914754
A080428_06.log	17:31:21	17:40:14	90.00	1593628
A080428_07.log	17:40:15	17:51:08	90.00	1953769

A080428_08.log	17:51:09	18:00:08	90.00	1605632
A080428_09.log	18:00:09	18:10:22	90.00	1833722
A080428_10.log	18:10:23	18:20:06	90.00	1743686
A080428_11.log	18:20:07	18:26:56	90.00	1218480
A080429_00.log	14:38:26	14:49:22	90.00	1962774
A080429_01.log	14:49:24	14:59:26	90.00	1800709
A080429_02.log	14:59:40	15:09:19	90.00	1731682
A080429_03.log	15:09:21	15:20:01	90.00	1914754
A080429_04.log	15:20:03	15:30:16	90.00	1833722
A080429_05.log	15:30:17	15:40:15	90.00	1788704
A080429_06.log	15:40:16	15:44:49	90.00	810319
A080429_07.log	15:51:42	15:54:11	90.00	441175
A080429_08.log	16:00:36	16:02:45	90.00	378149
A080429_09.log	16:08:06	16:11:07	90.00	537212
A080429_10.log	16:16:36	16:26:48	90.00	1827719
A080429_11.log	16:26:49	16:36:38	90.00	1761694
A080429_12.log	16:36:39	16:46:25	90.00	1752690
A080429_13.log	16:46:26	16:56:16	90.00	1761694
A080429_14.log	16:56:17	17:08:45	90.00	2238881
A080429_15.log	17:14:09	17:25:28	90.00	2028798
A080429_16.log	17:25:29	17:35:13	90.00	1746688
A080429_17.log	17:35:15	17:43:58	90.00	1563616
A080429_18.log	17:45:28	17:59:23	90.00	2499984
A080429_19.log	18:00:50	18:10:18	90.00	1698669
A080429_20.log	18:10:19	18:20:08	90.00	1761693
A080429_21.log	18:20:09	18:33:07	90.00	2328917
A080429_22.log	18:33:08	18:41:26	90.00	1488586
A080429_23.log	18:41:27	18:52:45	90.00	2028799
A080429_24.log	18:52:46	18:59:52	90.00	1272501
A080429_25.log	18:59:56	19:06:06	90.00	1104435
A080501_00.log	13:51:54	14:02:07	90.00	1773699
A080501_01.log	14:02:09	14:12:07	90.00	1791706

A080501_02.log	14:12:08	14:22:19	90.00	1827720
A080501_03.log	14:22:32	14:33:37	90.00	1989784
A080501_04.log	14:33:39	14:45:15	90.00	2085822
A080501_05.log	14:45:17	14:56:29	90.00	2010792
A080501_06.log	14:56:33	15:05:30	90.00	1605633
A080501_07.log	15:05:31	15:15:05	90.00	1716676
A080501_08.log	15:15:06	15:26:33	90.00	2055810
A080501_09.log	15:26:35	15:35:39	90.00	1626641
A080501_10.log	15:35:41	15:47:17	90.00	2082820
A080501_11.log	15:51:22	16:00:38	90.00	1662654
A080501_12.log	16:00:39	16:10:47	90.00	1818716
A080501_13.log	16:10:48	16:20:36	90.00	1758693
A080501_14.log	16:20:37		90.00	
A080501_15.log	16:43:32	16:55:54	90.00	2220874
A080501_16.log	16:55:54	17:05:09	90.00	1656652
A080501_17.log	17:05:10	17:15:41	90.00	1887743
A080501_18.log	17:15:41	17:25:10	90.00	1698669
A080501_19.log	17:25:11	17:36:54	90.00	2103828
A080501_20.log	17:36:55	17:46:42	90.00	1755691
A080501_21.log	17:46:42	17:56:05	90.00	1680662
A080501_22.log	17:56:05	18:07:28	90.00	2040803
A080501_23.log	18:58:44	19:00:54	90.00	381150
A080501_24.log	19:05:49	19:11:16	90.00	975384
A080501_25.log	19:15:19	19:19:09	90.00	684270
A080501_26.log	19:23:00	19:27:04	90.00	726287
A080501_27.log	19:31:18	19:35:30	90.00	750295
A080501_28.log	19:39:11	19:43:12	90.00	714281
A080501_29.log	19:49:45	19:54:58	90.00	933368
A080501_30.log	19:58:30	20:01:45	90.00	579228
A080501_31.log	20:06:40	20:11:34	90.00	876345
A080501_32.log	20:14:23	20:18:11	90.00	678267
A080501_33.log	20:22:03	20:26:20	90.00	765302
A080501_34.log	20:29:25	20:32:41	90.00	582230
A080502_00.log	13:44:29	13:55:04	90.00	1833723
A080502_01.log	13:55:06	14:05:07	90.00	1800710
A080502_02.log	14:05:09	14:15:26	90.00	1845728

A080502_03.log	14:15:27	14:25:12	90.00	1749690
A080502_04.log	14:25:14	14:35:42	90.00	1878741
A080502_05.log	14:35:43	14:45:13	90.00	1704671
A080502_06.log	14:45:15	14:55:11	90.00	1782702
A080502_07.log	14:55:12	15:01:02	90.00	1044411
A080502_08.log	15:18:20	15:30:03	90.00	2106830
A080502_09.log	15:30:05	15:40:43	90.00	1908752
A080502_10.log	15:40:44	15:50:02	90.00	1668657
A080502_11.log	15:50:04	16:00:02	90.00	1788704
A080502_12.log	16:00:03	16:08:39	90.00	1542608
A080502_13.log	16:26:52	16:36:05	90.00	1653651
A080502_14.log	16:36:06	16:45:02	90.00	1602631
A080502_15.log	16:45:03	16:55:02	90.00	1791706
A080502_16.log	16:55:03	17:05:03	90.00	1794706
A080502_17.log	17:05:04	17:15:06	90.00	1800709
A080502_18.log	17:15:07	17:22:47	90.00	1374542
A080502_19.log	17:51:42	18:00:03	90.00	1497590
A080502_20.log	18:00:04	18:10:02	90.00	1788704
A080502_21.log	18:10:03	18:20:21	90.00	1848728
A080502_22.log	18:20:22	18:30:19	90.00	1785703
A080502_23.log	18:30:20	18:37:23	90.00	1263497
A080502_24.log	20:51:41	20:51:58	90.00	42017
A080502_25.log	20:57:56	21:00:58	90.00	540213
A080502_26.log	21:05:21	21:15:19	90.00	1788705
A080502_27.log	21:15:20	21:25:03	90.00	1743688
A080502_28.log	21:25:04	21:35:02	90.00	1788705
A080502_29.log	21:35:03	21:45:05	90.00	1800709
A080502_30.log	21:45:06	21:55:04	90.00	1788705
A080502_31.log	21:55:05	21:59:17	90.00	750296
A080502_32.log	22:02:35	22:12:02	90.00	1695668
A080502_33.log	22:12:03	22:22:02	90.00	1788704
A080502_34.log	22:22:03	22:27:02	90.00	891352

A080502_35.log	22:27:03	22:37:02	90.00	1791705
A080502_36.log	22:37:04	22:47:02	90.00	1788704
A080502_37.log	22:47:03	22:51:18	90.00	759300
A080505_00.log	13:34:44	13:38:28	90.00	663262
A080505_01.log	13:46:44	13:51:10	90.00	789311
A080505_02.log	13:55:08	13:59:33	90.00	789312
A080505_03.log	14:03:17	14:07:48	90.00	804317
A080505_04.log	14:12:41	14:17:12	90.00	807319
A080505_05.log	14:20:07	14:21:06	90.00	171068
A080505_06.log	14:23:08	14:24:02	90.00	153061
A080505_07.log	14:26:55	14:27:39	90.00	123050
A080505_08.log	14:30:30	14:32:12	90.00	300119
A080505_09.log	14:49:31	14:59:42	90.00	1827720
A080505_10.log	15:11:40	15:21:10	90.00	1701670
A080505_11.log	15:21:10	15:29:49	90.00	1551611
A080506_00.log	12:05:40	12:22:44	90.00	2872132
A080506_01.log	12:22:46	12:32:07	90.00	1680663
A080506_02.log	12:32:08	12:42:08	90.00	1794707
A080506_03.log	12:42:09	12:52:04	90.00	1779701
A080506_04.log	12:52:05	13:02:17	90.00	1830721
A080506_05.log	13:02:18	13:12:03	90.00	1749689
A080506_06.log	13:12:04	13:18:16	90.00	1110437
A080506_07.log	13:32:26	13:45:36	90.00	2364931
A080506_08.log	14:00:47	14:11:11	90.00	1866736
A080506_09.log	14:24:08	14:31:23	90.00	1299512
A080506_10.log	14:41:29	14:56:19	90.00	2665049
A080506_11.log	14:56:42	14:56:57	90.00	39015
A080506_12.log	14:58:36	14:59:26	90.00	144057
A080506_13.log	15:00:22	15:02:04	90.00	300119
A080506_14.log	15:03:06	15:14:27	90.00	2037802
A080506_15.log	15:23:30	15:31:32	90.00	1437566
A080506_16.log	15:31:33	15:41:04	90.00	1707672
A080506_17.log	15:41:05	15:47:26	90.00	1137448

8.6 Processed ASIRAS profiles

Following plots show all processed ASIRAS profiles. 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 height as determined by the OCOG 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.