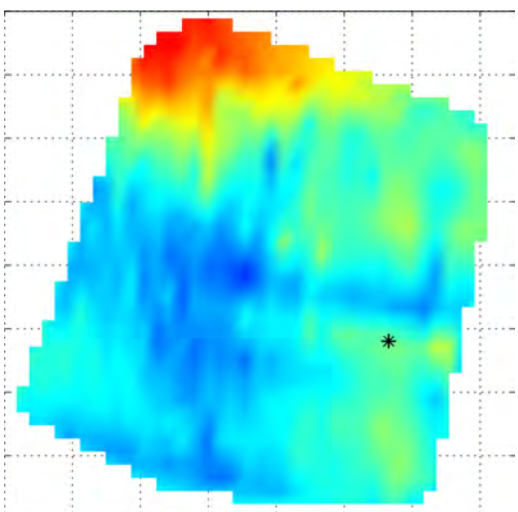
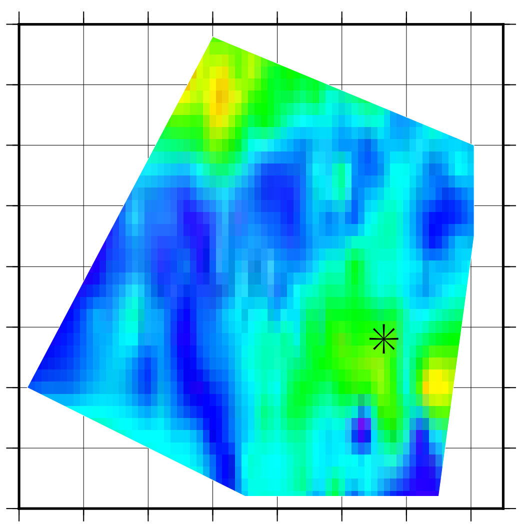
DOMECair 2013
Final Report

ESTEC Contract No. 4000107850/13/NL/FF/lf

Dome-C airborne gravity measurements and comparison to GOCE gradient data

Daniel Steinhage, Graeme Eagles, Rene Forsberg, Hasan Yildiz





Introduction

The airborne survey DOMECair 2013 and its instrumentation was designed to obtain calibration and validation data for two different satellite missions of ESA's Earth Explorer mission, for satellites SMOS and GOCE. As area of investigation a 300 km by 300 km large area near the French-Italian wintering station Concordia on Dome C in East Antarctica was chosen. The instrumentation of the research aircraft consisted of the radiometer EMIRAD-2 by DTU Space, a modified LaCoste-Romberg gravity meter, a Riegl laser scanner, nadir foto camera, several geodetic GPS receivers, an IMU unit, and a basic data acquisition system recording the data of the aircraft's INS unit.

The region was covered by 11 parallel survey lines, a so-called tie line, and a star pattern. Furthermore two flights with two sets of ten circles each were flown for calibration of EMIRAD-2. The tie-line is a requirement of the gravity survey. Cross-over poins are needed for estimating data quality. The star-patern was centered on the DOMEX observation tower at Concordia station. All flown survey lines are shown in Figure 1.

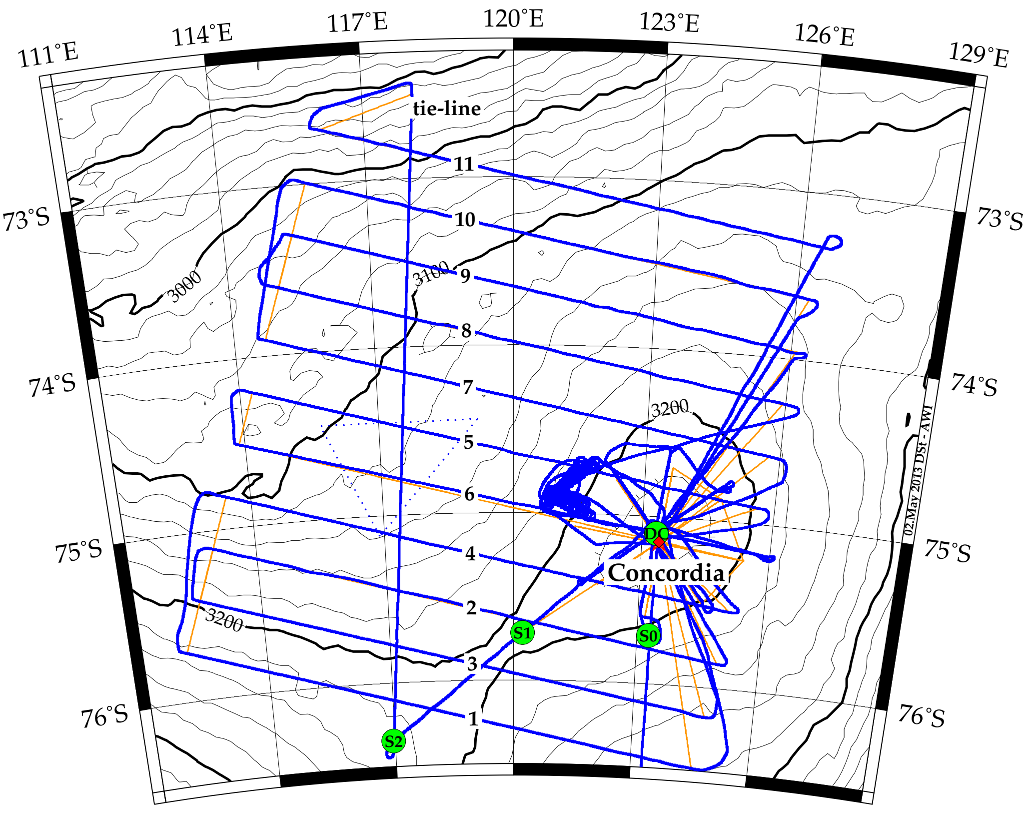


Figure 1: Flown profiles of the DOMCair 2013 survey. The line spacing the parallel is 30 km, the length of lines is 300 km.

Therefore two final reports have been compiled, one focusing on the EMIRAD data and the other on the gravity data:

- DOMECair Campaign EMIRAD Data: Presentation & Analysis
  Steen S. Kristensen, Sten S. Søbjærg, Jan E. Balling, and Niels Skou
  DTU-Space, Denmark
  September 10th 2013, 114 pages including title page

- Dome-C airborne gravity measurements and comparison to GOCE
  Daniel Steinhage, Graeme Eagles AWI-Bremerhaven, Germany
  Rene Forsberg, Hasan Yildiz*, DTU-Space, Denmark
  * at General Command of Mapping, Ankara, Turkey
  DEC 2013, 21 pages including title page
  and 2 pages appendix on airborne laser scanner processing

Dome-C airborne gravity measurements and comparison to GOCE gradient data

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DEC 2013

Preface

This document is the report of the Dome-C gravity data collection and computation of GOCE gradients in the LNOF and instrument reference frame at orbit altitude.

This document is the 2nd half of the reporting for the ESA for the combined SMOS and GOCE validation experiment at Dome-C, Antarctica, January 2013: Support for the 2010-3 DOMECair campaign in Antarctica - ESA ESTEC Contract No. 4000107850/13/NL/FF/lf.

The SMOS part of this campaign has already been reported in the document "DOMECair Campaign EMIRAD Data: Presentation & Analysis", by Steen S Kristensen, S Søbjerg, J Balling and N Skou, (dated Nov 12, 2013), and the field operations for both radiometer and gravity measurements described in details in "DOMECair 2013 Data Acquisition Report" by Daniel Steinhhage, Veit Helm, Graeme Eagles, Niels Skou, Steen Savstrup Kristensen (August 30, 2013).

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1. Airborne gravity measurements: Background

The gravity measurements at Dome-C was done on all the main lines of the regular planned flight pattern, as well as a few crossline and opportunity flights. The gravity measurements were done using the AWI Lacoste and Romberg S-56 gravimeter, upgraded by ZLS for airborne data collection. The gravimeter type is a standard instrument used for many major airborne surveys around the world, including recent airborne measurements of DTU-Space in Antarctica. The basic principle of the instrument is a servo-feedback spring system on a gyro stabilized table, and to obtain sufficiently accurate results it is essential to understand and model the numerous potential errors in the system, especially scale factors and platform off-level errors.

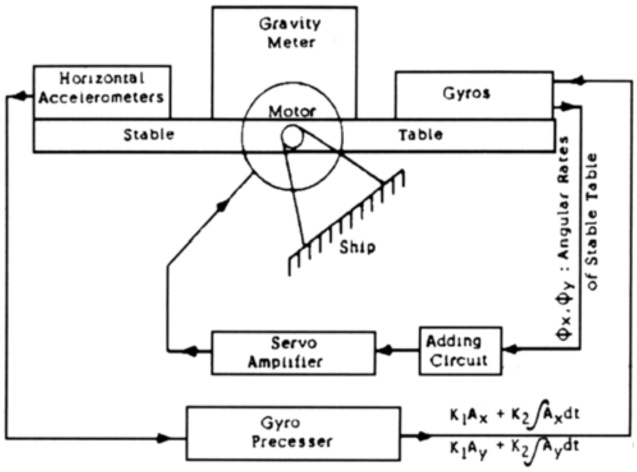


Fig. 1. Principle of the gyrostabilized platform for the LCR gravimeter. From Valiant (1991)

The measurement of gravity in aircraft is a challenging task, and only made possible by the development of precise long-range kinematic GPS positioning, allowing separation of accelerations from the aircraft motion from the gravitational accelerations.

The basic equation for the airborne gravity measurement is (in units mGal = 10^{-5} m/s^2 and meter):

$$\Delta g = a - h'' - \delta g_{eot} - \delta g_{tilt} - y_0 + g_0 - \gamma_0 + 0.30877(1 - 0.00242 \sin^2\phi)\, H + 0.75*10^{-7}\, (h-N)^2 \quad (1)$$

with the notation

Δg: gravity anomaly
a: the measured acceleration along the vertical
h”: vertical acceleration derived from GPS
y_0: airport base reading (zero-level of the gravimeter)
g_0: airport reference gravity value
h: GPS ellipsoidal height
H: orthometric height (= H-N)
δg_{tilt}: Gravimeter platform tilt correction (due to the non-verticality of the acceleration sensor)
δg_{eot}: Eotvos correction (due to the movement of the platform over a curved, rotating earth)
γ_0: normal gravity at sea level
N: geoid height

Because of the rapidly changing value of gravity with height (*dg/dh* $\cong$ *0.3 mGal/m*) the measurement in practice involve the determination of the *gravity anomalies*, i.e. the difference between gravity g and normal ellipsoid gravity γ , as a function of latitude and height. The anomalies change much more slowly with height than g itself. Equation (1) is the classical expression for the geodetic *free-air gravity anomaly* Δg*;* if the measured GPS heights of the aircraft are not reduced for the geoid height N, the *gravity disturbance* δg is obtained instead.

To obtain sufficient accuracy, the equation (1) must further be along-track filtered, and the tilt correction modelled very carefully to avoid unlinear effects in turbulence. If this modelling is done correctly, all instrument scale factors are well calibrated, and the gravity survey is based on a carefully measured reference gravity value g_0 at the airport, then airborne gravity should inherently represent a bias-free measurement of gravity anomalies, with no further tie line adjustments needed. For more details of airborne gravity measurement principles and corrections see e.g. Valliant (1991), Olesen (2002) or Forsberg and Olesen (2010). A detailed flowchart of the gravimeter processing, along with an example of the used along-track filter, is shown in Figure 2a and 2b.

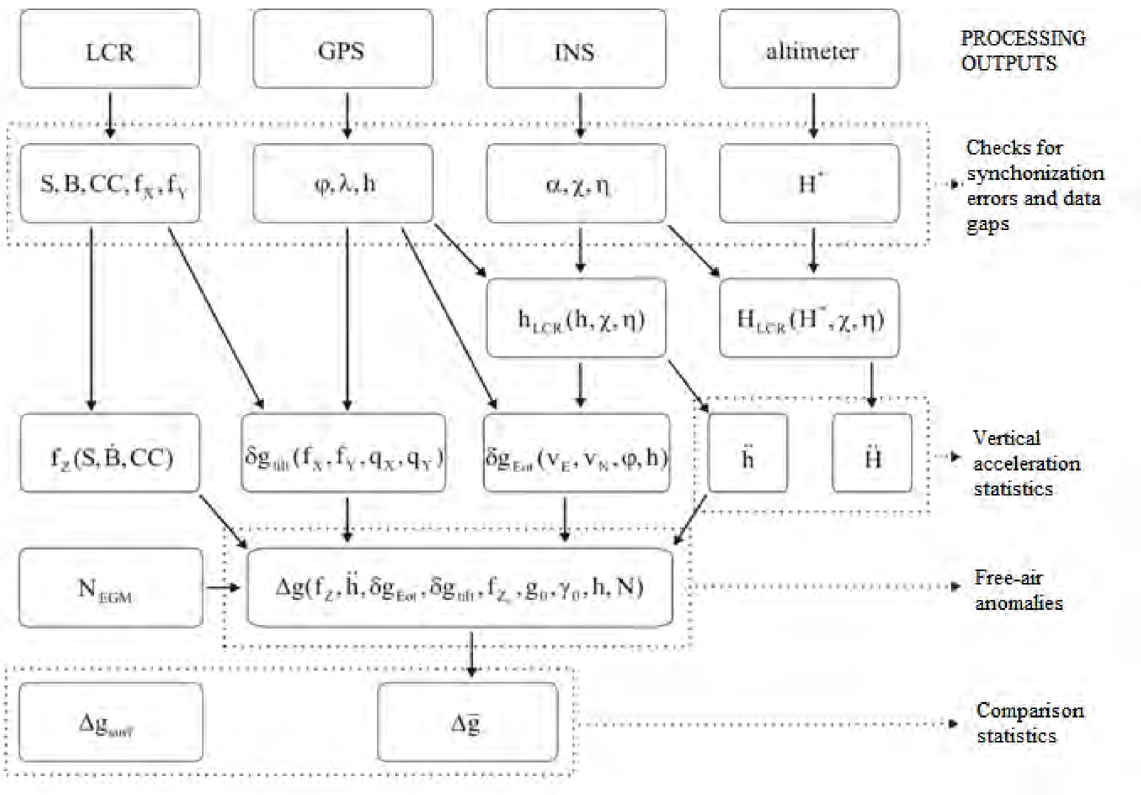


Fig. 2a. Flowchart of the airborne gravity processing. The main gravity processing line take recorded spring tension (S), beam position (B), instrument cross-coupling corrections (CC) and recorded platform horizontal accelerations (f_x*,* f_y*), and combine these data with precise cm-level GPS positioning to obtain gravity disturbances* δg*. These are subsequently combined with an Earth Geopotential Model geoid N (here taken from GOCE) to obtain free-air anomalies* Δg*. The inertial navigation system (INS) and laser altimeter-derived accelerations (over ocean) are optionally used for QC purposes and for minor data gap filling.*

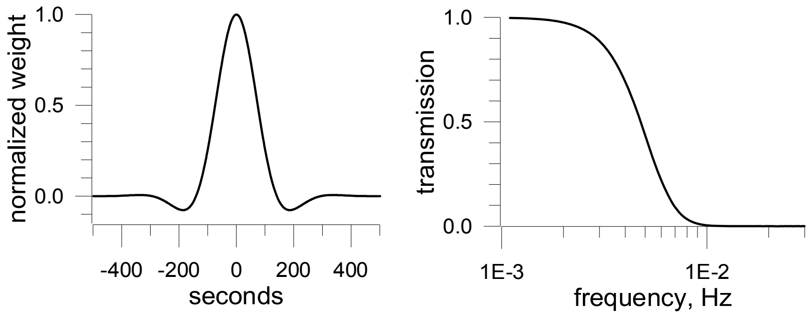


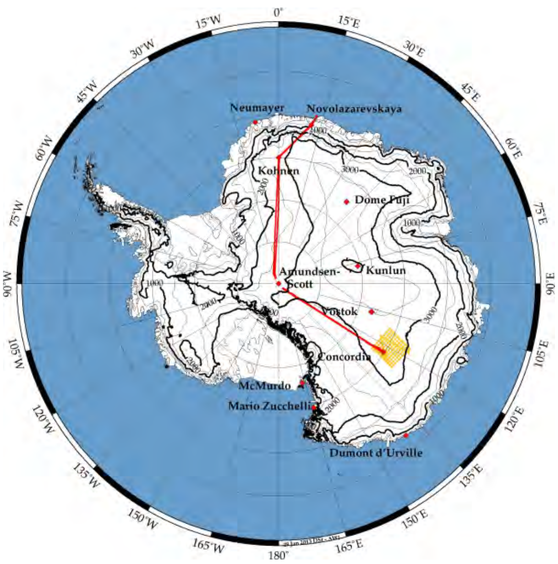
Fig. 2b. Example of the space domain (left) and frequency domain (right) filter applied in the aerogravity processing scheme of Fig 2a in rough turbulent conditions (impulse response of a triple forward/backward Butterworth filter, time constant 200 sec). All quantities in Fig. 2a are consistently along track filtered.

2. Airborne gravity: The Dome-C survey

The airborne gravity survey at Dome-C took place in the days 17-22 January 2013, with gravity additionally collected on the ferry flights to Dome-C from Neumeyer via South Pole. The list below shows the survey flights for the Dome-C air campaign, more details can be found in the DOMECair field rapport (D. Steinhage et al., Aug 2013)

DOMECair flight dates and transit legs in Antarctica

Date	Flight no	Description	Air time
12.01.2013	13011238	Installation test flight	1.5 h
13.01.2013	13011339	Transit Novo airbase - Kohnen	1.8 h
13.01.2013	13011340	Transit Kohnen - Amundsen-Scott	5.2 h
15.01.2013	13011641	Transit Amundsen-Scott - Concordia	5.1 h
17.01.2013	13011742	Morning circle flight	2.8 h
17.01.2013	13011743	Profiles 1 & 4	3.9 h
18.01.2013	13011844	Tie-line & profile 11	4.3 h
18.01.2013	13011845	Profiles 7 & 10	3.5 h
19.01.2013	13011946	Star pattern	3.8 h
19.01.2013	13011947	Profiles 5 & 6	2.9 h
21.01.2013	13012148	Profiles 8 & 9, afternoon circles	5.6 h
22.01.2013	13012249	Profiles 2 & 3	3.1 h
22.01.2013	13012250	Transit aborted	1.8 h
23.01.2013	13012351	Transit Concordia - Amundsen-Scott	5.8 h
23.01.2013	13012352	Transit Amundsen-Scott - Kohnen	5.7 h
24.01.2013	13012453	Transit Kohnen Kohnen - Novo airbase	2.1 h
	Subtotal	Transit & test flights	29.0 h
	Subtotal	Survey flights	29.9 h
Total		DOMECair 2013	58.9 h



Because gravity can not be measured during aircraft turns, and filters need to settle after turns, only parts of the longer lines could be processed into useful gravity, cf. Fig. 3. The airborne gravity processing was done at AWI, using a software originally based on code from Arne Olesen, DTU-Space (2002), and further modified over a number of years by U. Meyer, BGR-Germany and AWI.

The measurement were tied to an absolute IGSN gravity reference point at University of Cape Town: reference value 979616.80 mGal, transferred to Novo runway and Dome-C using measurements with a portable Lacoste and Romberg land gravity meter (serial number G744), giving a preliminary AWI estimated value of *g* at Dome-C/Concordia of 981865.13 mGal. The actual *g*-value based on absolute gravity at Novo showed this value to be 3.84 mGal too high, and has been corrected for the GOCE computations, see Sect 4 below.

GPS positions, velocities and accelerations were computed with the "Waypoint" software, a state-of-the art kinematic GPS software allowing both differential phase and ppp-techniques to be used with the highest precision. Filtering used in the processing was 3-stage forward-backward RC filtering with time constant 20 s, and clipping 200 s, a typical filtering for airborne gravimetry.

The gravimetry was processed without use of geoid heights, and the anomalies are therefore to be considered as *gravity disturbances.* The cross-over error statistics for the few cross-lines are shown in Figure 4, indicating a relatively noisy survey of 12.8 mGal r.m.s. error for 22 line crossings. Eliminating two very large outliers, the survey cross-over error is at 11.3 mGal r.m.s., corresponding to an r.m.s. line error of 8.0 mGal, an acceptable number for the GOCE upward continuation experiment, given the rough flight conditions, short lines and used field handling procedures.

For the subsequent GOCE computations, the gravity disturbances were subsequently converted to gravity *free-air anomalies* using geoid values from GOCE.

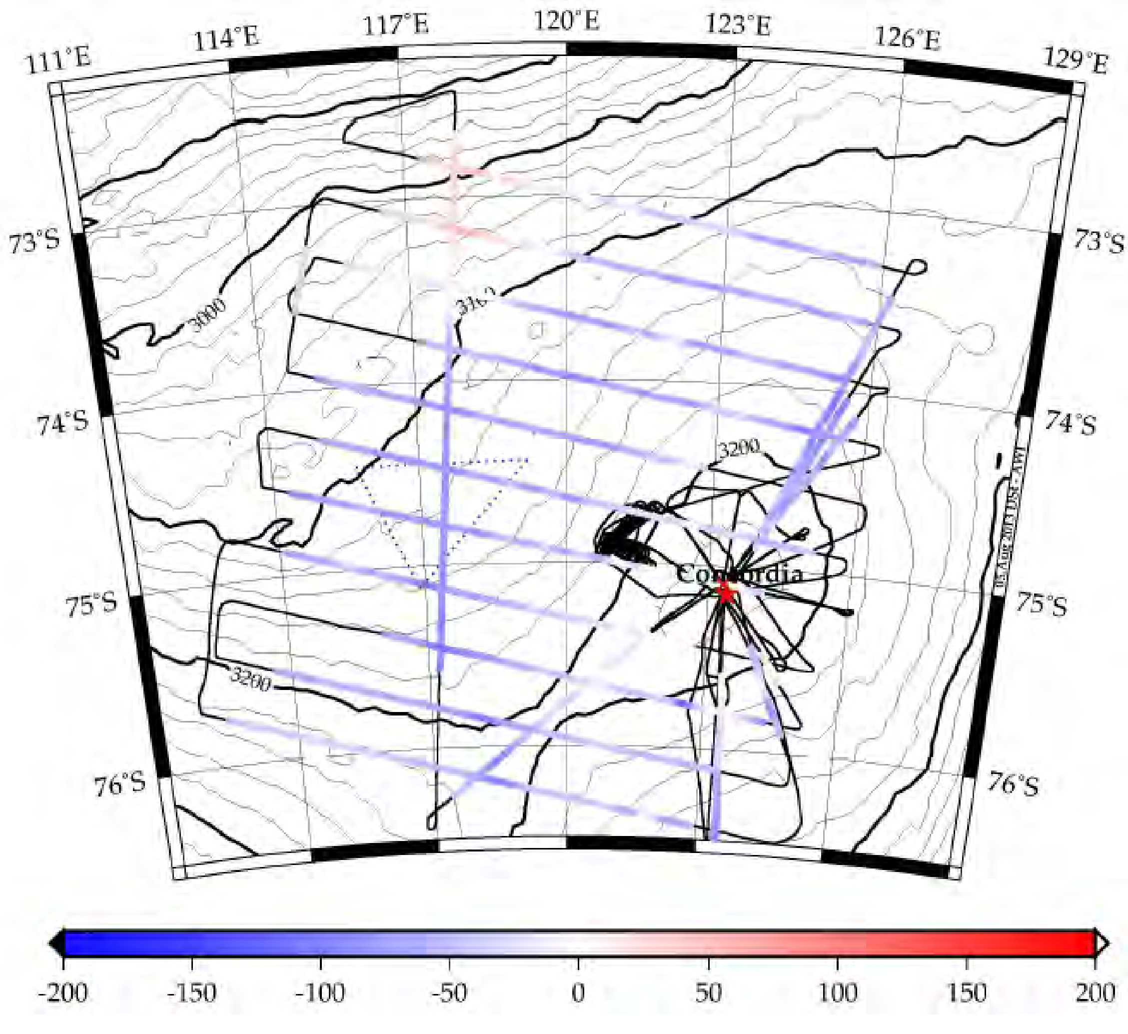


Fig. 3. Final Dome-C gravity disturbances, as processed by AWI, on top of flight lines. Units: mGal.

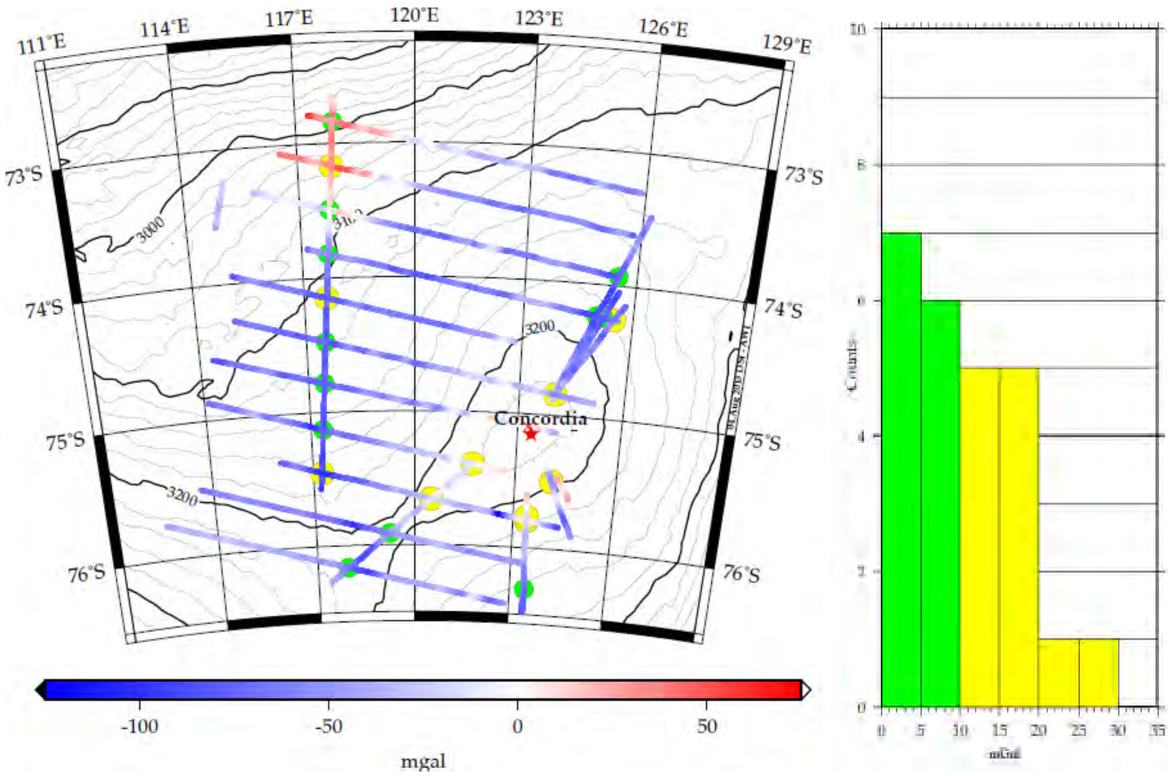


Fig. 4. Cross-over errors in the AWI-processed gravity anomalies of Dome C (left), and the histogram of the absolute value of the track misties (right; green are "good" and yellow "bad" x-overs relative to 10 mgal). The estimated r.m.s. error of the AWI-processed airborne survey, based on the x-over analysis, is 8.0 mGal.

3. Computation of gravity gradients and comparison to GOCE: Background

The airborne gravity data were received by DTU-Space, and first validated using the recent GOCE RL4 "direct" spherical harmonic model data, and upward continuation and gradient conversion done to GOCE flight altitudes. This processing was done by the GRAVSOFT suite of programs (Tscherning et al, 1992; Forsberg and Tscherning, 2008), implementing the upward continuation and gradient conversion by both spherical Fourier domain methods and least-squares collocation.

In the least-squares collocation method the upward continuation and conversion to gravity gradients is done by solving a set of equations, of dimensions equal to the number of data

$$\hat{s} = C_{sx}[C_{xx} + D]^{-1} x \qquad (2)$$

where the signal *s* is the wanted set of gradient components, *x* the airborne gravity observations, and C_{sx} and C_{xx} the cross- and auto-covariances of the gravity field components, derived from a self-consistent covariance model, and D the errors. For details see Heiskanen and Moritz (1967) and Tscherning (1974). The complete process is implemented in the GRAVSOFT *GEOCOL* program.

For an alternative method of upward continuation the Fourier transform method has also been applied. In this method the two-dimensional Fourier transform

$$F(\Delta g) = \iint \Delta g(x,y) e^{-i(k_x x + k_y y)} dxdy \tag{3}$$

is applied to (collocation) gridded airborne gravity data. Conversions of gravity anomalies at surface level to gradients at the satellite level involves then relatively simple filtering operations, e.g. in the case of the vertical gravity gradient of form

$$F(T_{zz}*) = ke^{-kh} F(\Delta g), \quad k = \sqrt{k_x^2 + k_y^2} \tag{4}$$

where the * indicates values at altitude. The Fourier methods can either be done in the planar or spherical approximation, as implemented in the GRAVSOFT *geofour* or *spfour* modules, with rapid nearest-neighbour collocation implemented in *geogrid.*

Common to both the least squares collocation and the FFT-base d computation is the use of a spherical harmonic reference field

$$T_{EGM08} = \frac{GM}{R} \sum_{n=2}^{60} \left(\frac{R}{r}\right)^n \sum_{m=0}^{n} \left(C'_{nm} \cos m\lambda + S_{nm} \sin m\lambda\right) P_{nm}\left(\sin \phi\right) \tag{5}$$

in a remove-restore fashion. In the Dome-C computations we have used the EGM2008 field to degree and order 60 as the fundamental reference field. The degree 60 reference field corresponds to a spherical harmonic resolution of 3°, and is therefore roughly corresponding to the size of the Dome-C survey area. It is also a spherical harmonic range where the accuracy of EGM08 is very good, being exclusively determined by GRACE data, and therefore being independent on GOCE.

4. Computation of gravity gradients and comparison to GOCE: The data

The AWI-processed airborne gravity data were compared to the GOCE "direct" RL4 model, after corrections removing the effects of the atmosphere (approx. +0.6 mGal), and a readjustment of the gravity ties measurements provided by AWI (as part of the field operations report). The readjustment, based on two very weak gravity ties to Cape Town, and a single, repeated measurement at South Pole station, were checked by absolute two gravity measurements in front of the absolute gravity hut at Novo base (AWI could not occupy the actual absolute gravity site, as the gravity hut was locked). The value of *g* in front of the hut was estimated from the AWI photographs by J. Makinen of the Finnish Geodetic Institute, who did the recent absolute gravity measurement there in 2012 (pers.comm.).

Fig. 5. AWI gravimeter in front of Novo gravity hut 2013 (left), and absolute gravimeter 2011 (right)

The least squares adjustment of the used AWI land gravimeter G-744 gave the gravity values shown below (the South Pole station reference gravity value of *T. Diehl, Univ. of Texas* was not fixed, as the value differed by ~1 mGal relative to the Novo value; this error is likely due to the continous sinking of the old reference site in the tunnel below south pole).

```
#== Fixed stations and adjustment residuals ===
#   stat      fix g     sigma      adj g        v
    101    979616.800  0.010   979616.800   0.000  Cape Town UC IGSN
    202    982578.250  0.050   982578.250   0.000  Novo in front of hut

#== Adjusted new gravity values and standard deviations ===
    201    982466.936    0.086  Novo Rwy
    301    982313.587    0.094  Amundsen-Scott aircraft parking
    302    982316.262    0.094  Amundsen-Scott ref point
    401    981861.288    0.069  Concordia
    501    981995.766    0.108  Kohnen
```

A reference value of g = 981861.29 mGal was therefore used for the Concordia runway. The estimated error in this value is 0.2 mGal. The original value provided by AWI, based on the long-duration ties to Cape Town, is therefore 3.84 mGal too high. Using the revised gravity tie value, the AWI data were corrected for the geoid undulations, using the GOCE direct RL4 model, giving the final free-air anomaly data set (*awi.faa2)*, used for all GOCE computations in the sequel.

The statistics of comparisons of the AWI airborne gravity data to the GOCE RL4 “direct” and “timewise” models, as a function of maximal degree, is shown in Table 1.

The comparison in Table 1 shows - for the standard deviation - that both the “direct” and “timewise” models have an good quality and contains high resolution information. The standard deviation of the difference seems to decrease consistently with the higher cut-off in the RL4 fields, all the way to the maximal degree (260 or 250). The bias of ~ 3 mGal is likely due to the limited region size. The comparison of Table 1 is a powerful demonstration of the excellent performance of the GOCE spherical harmonic model products. Figure 6 shows the airborne and GOCE gravity anomalies, and confirms the good long-wavelength agreement of the GOCE and airborne data.

Table 1. *Comparison of Dome-C airborne gravity disturbance data to GOCE RL4 expansion (mGal)*

Data for statistics	*Mean*	*Std.dev.*
Observed airborne data (*awi.faa2* - 51303 points)	-38.9	28.9
Observed minus EGM08 to degree 60	2.6	19.9
Observed minus GOCE direct (max degree 120)	3.7	22.4
- direct (max degree 180)	3.5	18.2
- direct (max degree 200)	5.4	16.5
- direct (max degree 220)	4.4	15.3
- direct (max degree 250)	4.0	14.5
- direct (max degree 260)	3.9	14.5
Observed minus GOCE timewise (max deg 120)	3.8	22.7
- timewise (max deg 180)	3.5	18.2
- timewise (max deg 200)	5.4	16.5
- timewise (max deg 220)	4.3	15.1
- timewise (max deg 250)	3.3	14.9

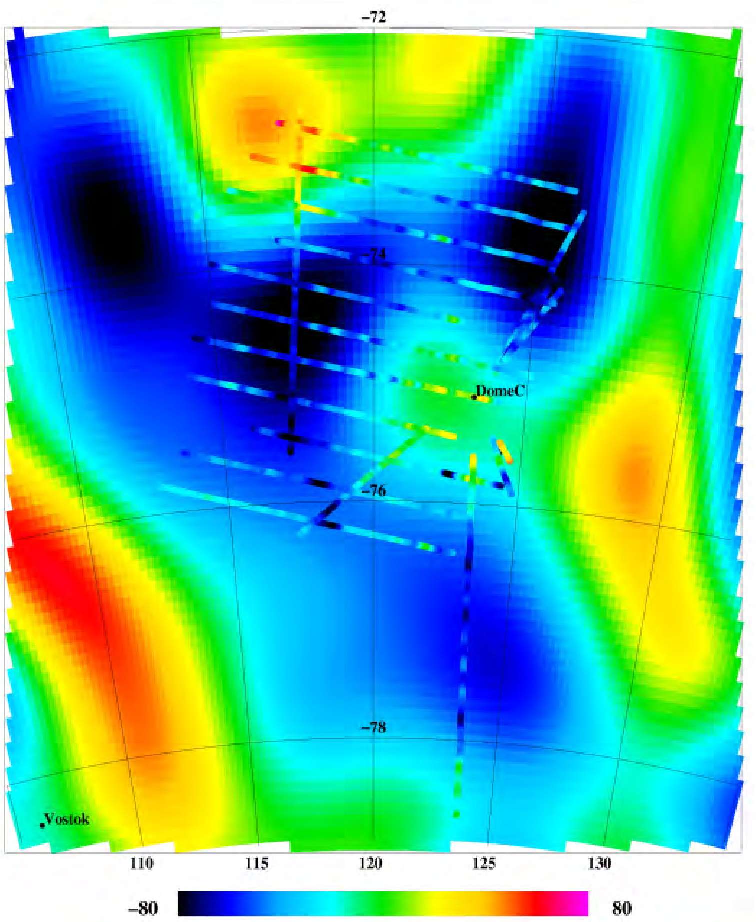


Fig. 6. Airborne gravity free-air anomalies and GOCE RL4 "direct" to degree 200. Colour scale in mGal.

For a first estimate of GOCE gradients at altitude, a quick Fourier analysis is carried out. The airborne gravity data is gridded by collocation in the region 77-72°S, 110-130°E at 3' resolution, and the FFT upward continuation and gradient transformation carried out with 100% zero padding. Fig. 7 shows the reduced gravity data and Tzz data (EGM08 to degree 60 subtracted), and Fig. 8 the full restored T_{zz} values at 250 km elevation along with the RL4 GOCE gravity field at 250 km.

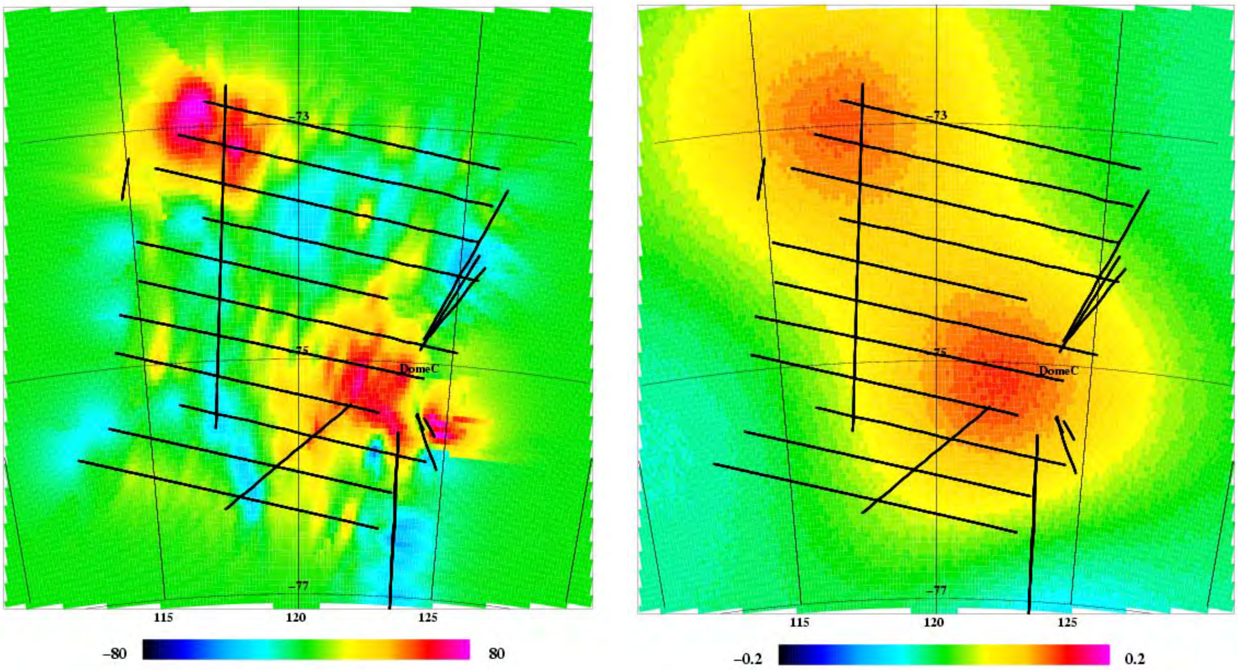


Fig. 7. Gravity anomalies minus EGM08 to degree 60 (left, mGal) and similar T_{zz} values minus EGM08 at 250 km (right, Eotvos units).

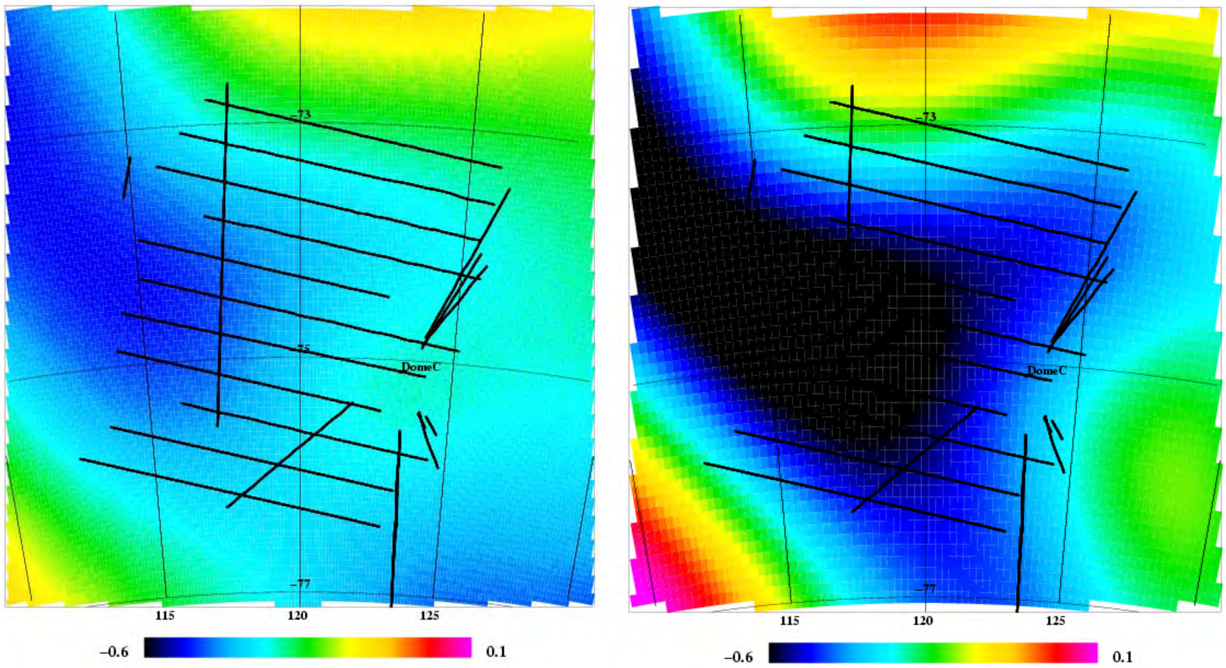


Fig. 8. Estimated T_{zz} values at 250 km, and the T_{zz} values from GOCE RL4 (Eotvos units). Large anomalies outside the survey region are evident from Fig. 6, and therefore the predicted T_{zz} values are underestimated.

For the more advanced comparison with GOCE gradients, the least squares collocation method is applied. The least-squares method has the advantage of being able to also estimate errors at altitude. For the least squares collocation experiment, the airborne data was thinned to 0.02° x 0.02° resolution, yielding a surface gravity data set of 6326 point, and an empirical, self-consistent covariance function of the

Tscherning-Rapp (1974) type fitted to the data. Fig. 9 shows the estimated and fitted covariance model, which represent a typical data covariance function (after subtraction of the EGM08 degree 60 reference field), with the depth to the Bjerhammer sphere of 2.8 km. This covariance function has subsequently been used to predict GOCE gravity gradients at altitude, using the GRAVSOFT program *geocol*, assuming a standard error of the airborne gravity at 3 mGal r.m.s. (to avoid filtering surface data too much, and partially taking into account the surface data selection process).

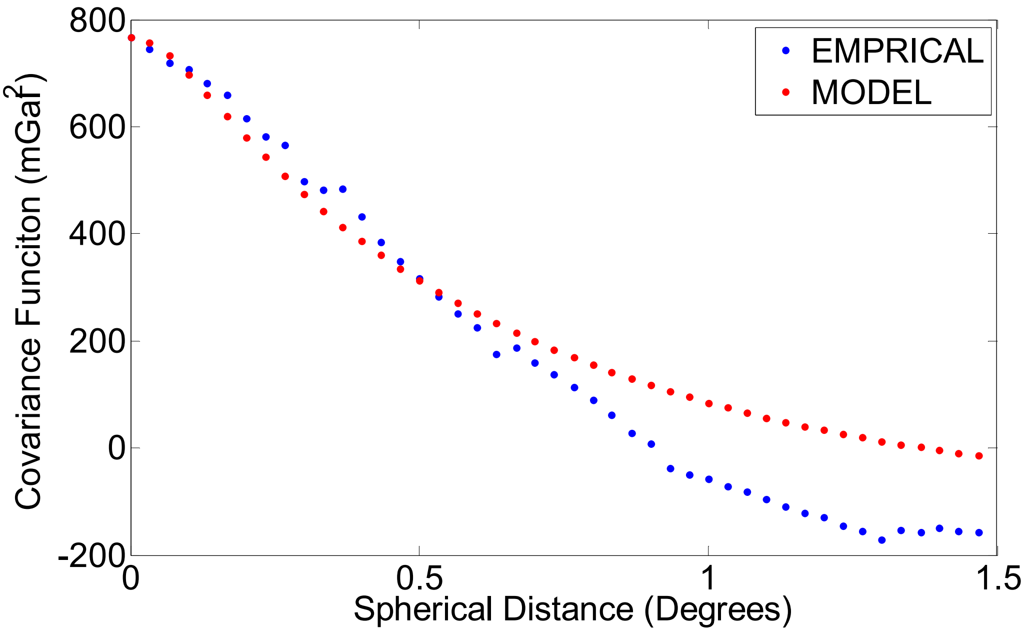


Fig. 9. The empirical covariance function (blue) derived from the airborne gravity data, and the corresponding fitted analytical Tscherning-Rapp covariance model (red). This is typical of a good fit.

The collocation predictions were done for GOCE gravity gradients were selected in a central region 76-73°S, 113-126° W from the GOCE TRF product. To limit the number of GOCE gradient observations, a 0.05 x 0.125° pixel selection was done, leaving an observed GOCE data set of 6395 observation points, within a height range of 295 to 273 km, the latter reflecting the recent lowering of the GOCE orbit. From the gravity gradient data the normal GRS80 field were subtracted, giving gradient *anomalies*, used for the comparisons in the sequel. Fig 10 below shows the ranges in height of the comparison gradient data set, and Fig 10 the observed T_{zz} gradients, with and without the EGM08 reference field.

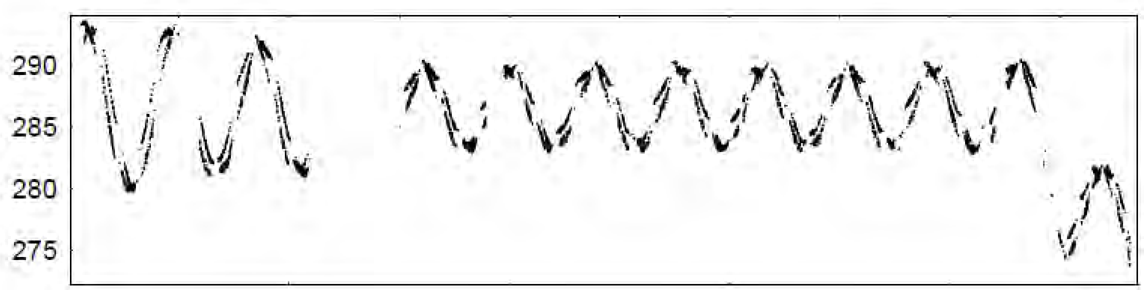


Fig 10. Height (in km) of the GOCE data selected, as a function of the mission time (late 2009 to recent)

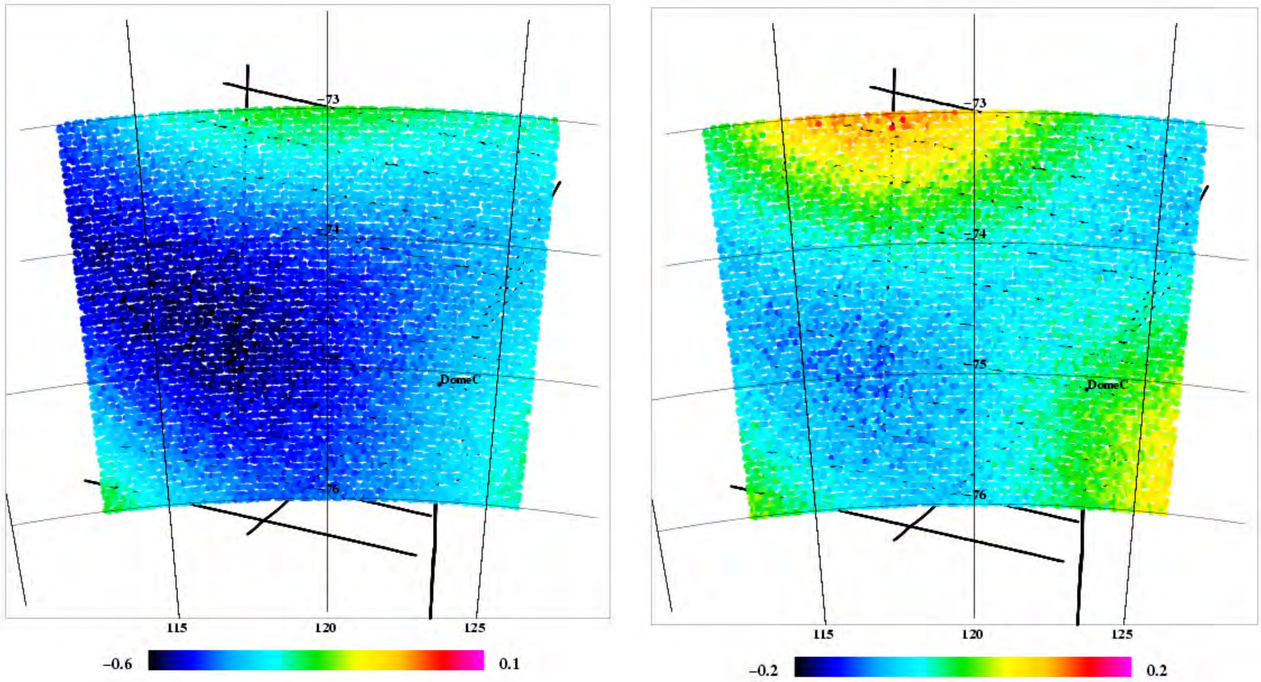


Fig. 11. Example of the role of subtracting the EGM08 (degree 60) reference field. Left: GOCE T_{zz} gradient anomaly observation points, colour scale as Fig. 8. Right: GOCE T_{zz} data minus EGM08 (to degree 60) reference field. Units: Eotvos. The "noise" is due to the different elevations.

The comparison of Fig 11 and Fig 8 shows that the GOCE gradient observations are in good agreement with the surface data, with and that the maximal value to the Tzz gradient is somewhat larger than the GOCE RL4 model, but less than the FFT solution, a sign of the the RL4 model being somewhat filtered at the shortest wavelengths.

5. Comparison of GOCE gradients in the LNOF system

For the comparison of all gradients, Fig. 12 below shows the GOCE observations (minus the EGM08 reference field) for all six GOCE gradients, and Fig 13 the corresponding differences between observations and predictions. Fig 14 shows some examples of the collocation error estimates, which are quite homogenous across the comparison region (mainly due to the large upward continuation distance). Table 2 shows the statistics of the quantities.

It should be noted that the GOCE data are provided in the ESA LNOF reference system (N-W-Up); computations were done, however, in the GRAVSOFT (E-N-Up) system. The ESA (LNOF) is thus related to the GRAVSOFT (G) coordinate system by

$$T^{LNOF}xx = T^{G}yy;\; T^{LNOF}yy = T^{G}yy;\; T^{LNOF}zz = T^{G}zz;$$

$$T^{LNOF}xy = -T^{G}xy;\; T^{LNOF}xz = -T^{G}yz;\; T^{LNOF}yz = T^{G}xz;$$

In the Figures and Table 2 below all predictions have been transformed to the ESA LNOF system.

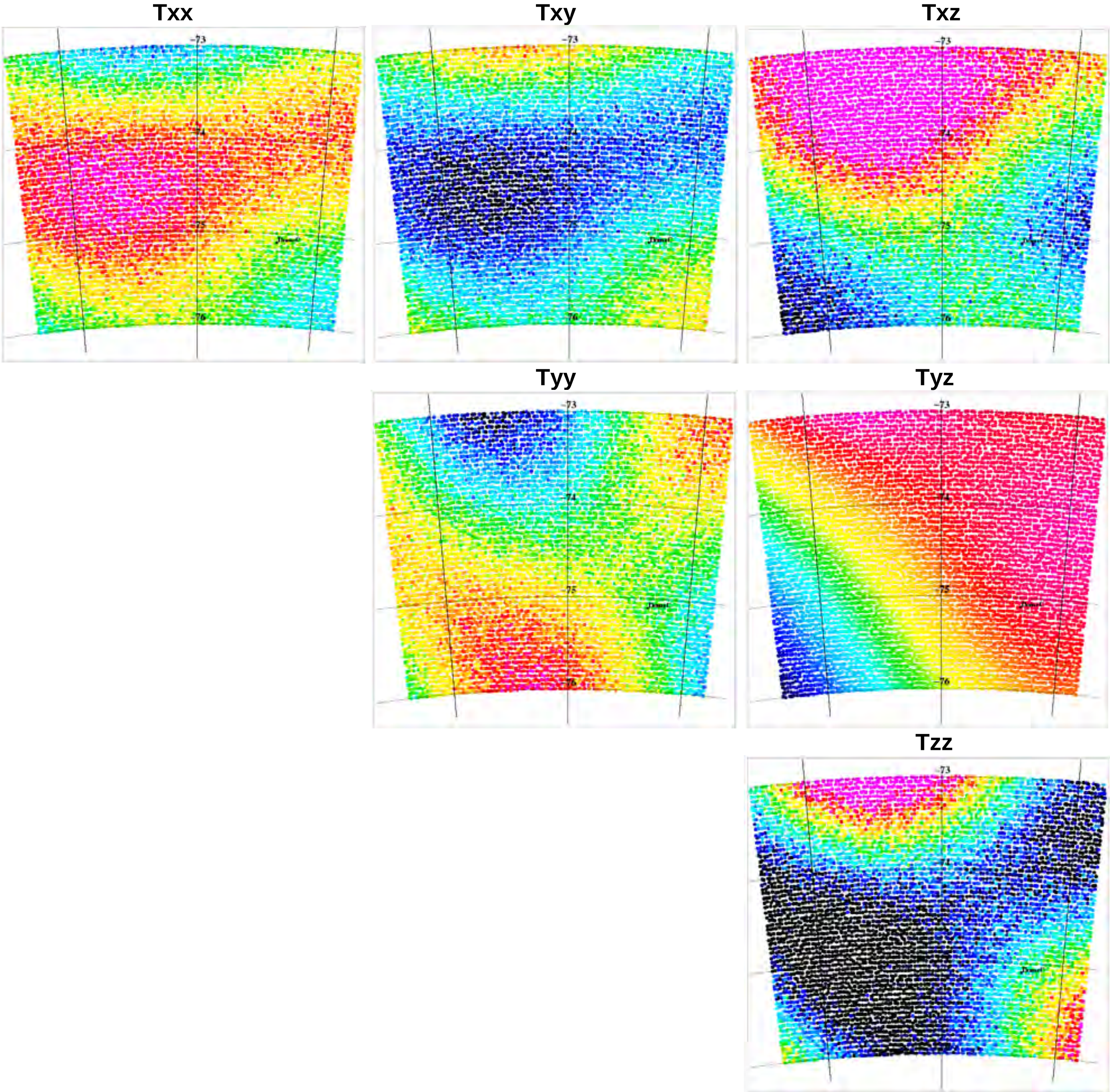


Fig 11. Predicted gradients at GOCE points, minus EGM08 to degree 60.
Colour scale is -0.08 to 0.08 Eotvos (except for the "weak" Tyz component, cf. Table 2)

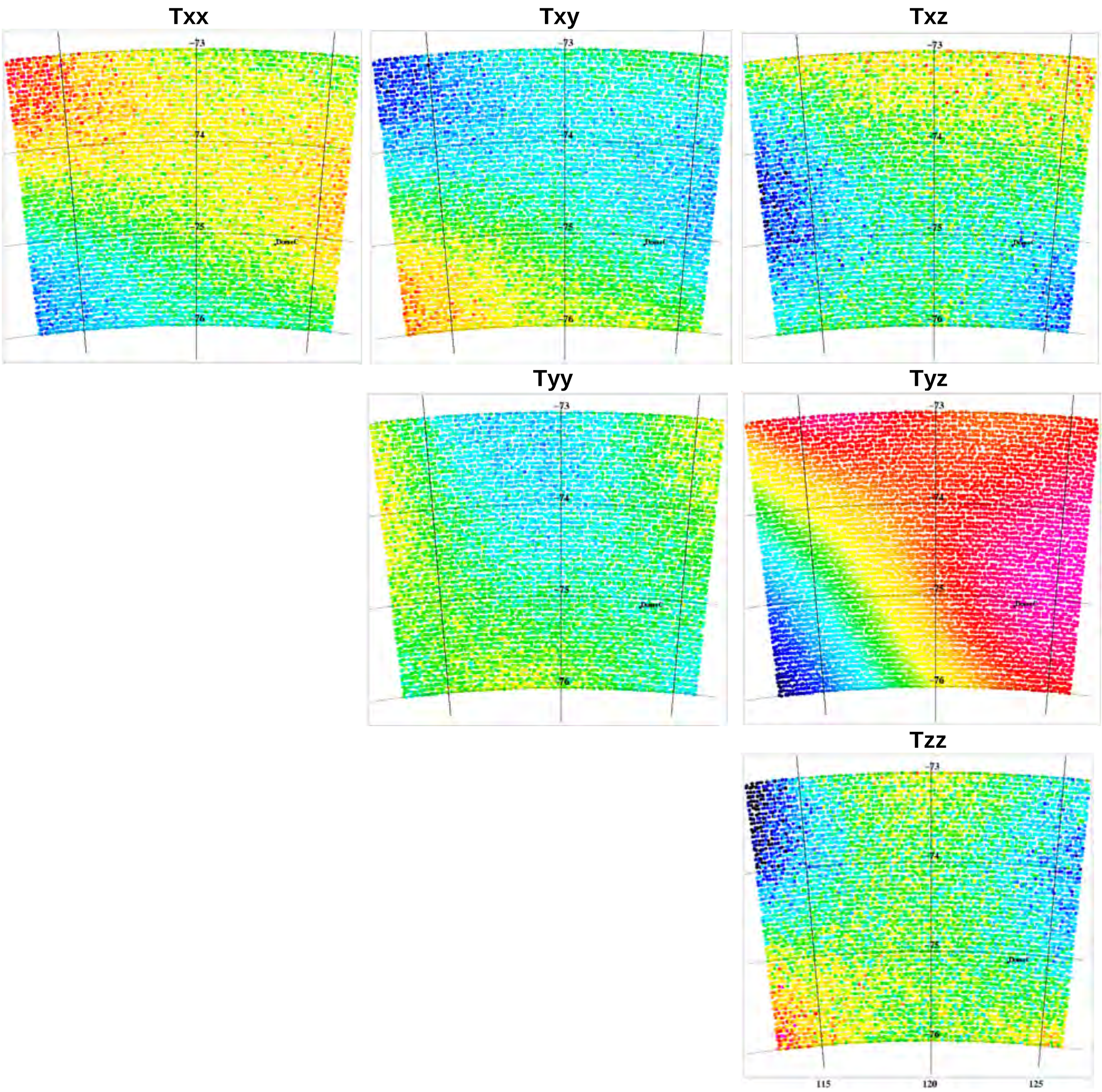


Fig 12. Difference between GOCE gradients and predictions. Colour scale -0.08 to 0.08 Eotvos (except Tyz)

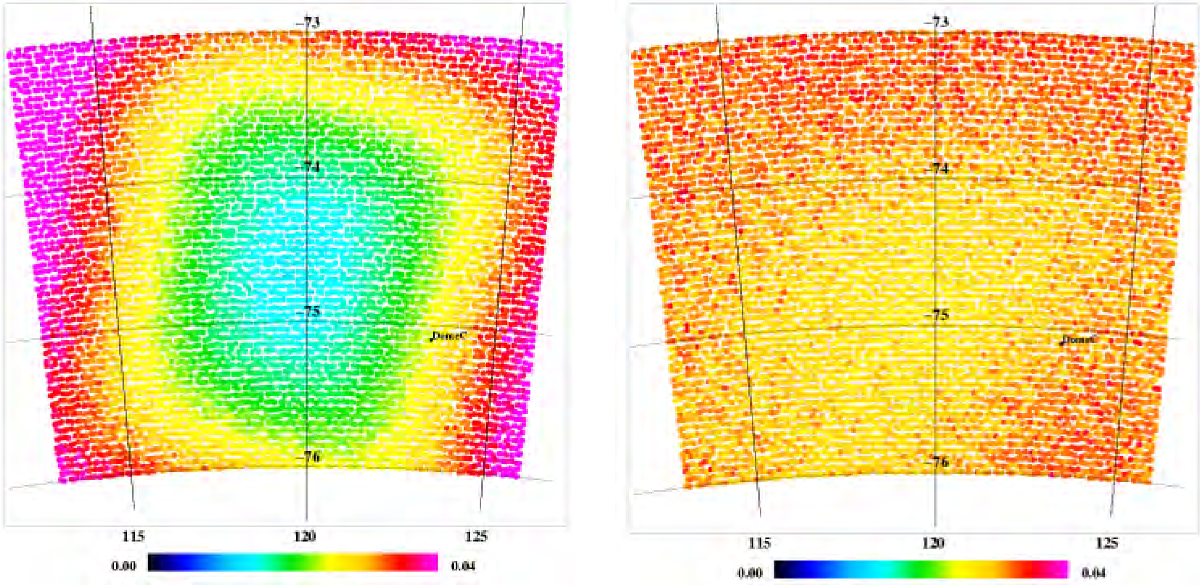


Fig. 13. Examples of collocation errors estimates for Tzz (left) and Txy (right). Eotvos units.

***Table 2**. Statistics of collocation upward continuation comparisons (unit: Eotvos)*

Data statistics		*Txx*	*Txy*	*Txz*	*Tyy*	*Tyz*	*Tzz*
Observed GOCE data,	mean	.221	-.144	.065	.223	-.205	-.444
	std.dev.	.045	.054	.133	.059	.105	.075
GOCE – EGM08 (deg 60)	mean	.031	.146	.018	.011	-.416	-.042
	std.dev.	.013	.028	.055	.031	.189	.051
GOCE obs – predictions	mean	.013	.128	-.009	-.007	-.407	-.006
	std.dev.	.023	.047	.024	.015	.207	.024
Predicted errors r.m.s.		.022	.031	.025	.022	.025	.065

The Table 2 shows that for the larger in-line components (Txx, Tyy, Tzz) the collocation prediction is consistent and validates the GOCE measurements significantly, with a small bias and an agreement at the 0.02 Eotvos-level.

The mixed gradients is also seen to give improvements, except for Tyz.

For the dominant Tzz gradient, the GOCE observations were compared also to the RL4 spherical harmonic model for some different degrees of expansion. Results are shown in Table 3. This shows a comparable error to the collocation prediction (but is of course only a check of internal GOCE product consistency, and not a validation).

***Table 3**. Comparison of the Tzz GOCE gradients to the RL4 GOCE spherical harmonic model*

Data statistics for max degree:		*180*	*200*	*220*	*240*	*260*
GOCE Tzz gradient minus RL04	mean	.031	.031	.031	.031	.031
	std.dev.	.021	.020	.020	.020	.020

6. Comparison of GOCE gradients in the GOCE reference frame

The useful GOCE satellite gradiometer measurements in the GOCE reference frame are Txx, Tyy, Tzz and Txz. To transform the measured gradients into the LNOF system, model values are used for the Txy and Tyz components, which inherently generate a varying degree of noise into all the gradients in the LNOF system (both the "good" and the "bad" components).

For the GOCE validation, it is therefore preferably to do the validation directly in the GOCE frame (GRF), rather than the LNOF frame. This has been done by the methodology described in Tscherning (1993), and implemented in the *GEOCOL* program. The computations involve the use of L1 attitude quaternion data, transformed into Euler angles, to perform the rotation of the predicted gradients from the LNOF to GRF frames, and subsequently comparing the upward continued gravity gradient data from the airborne survey to the actual GOCE observations.

These computations have been done by H. Yildiz in close consultation with C. C. Tscherning, Copenhagen University. For the GRF computations the ITG-GRACE2010S were used as reference field to degree 60, rather than EGM08. This change of reference field has only minor importance in the actual predicted values, but a larger effect in the error estimates. For the computations, the revised airborne data was again selected at a 0.02° x 0.02° resolution, and compared to GOCE data selected at a 0.05° x 0.125° resolution, analogous to the computations in the LNOF frame.

Figures 14 and 15 shows – for the "good" measured GOCE gradients - the predicted GOCE gradients (minus the reference field), and the difference between GOCE observations and upward continued values. Table 4 shows the statistics of the gradient comparisons. Comparing to Figures 11 and 12, and Table 2 (for the LNOF frame), it is seen that the transformation to the GOCE reference frame appears not to improve results compared to the LNOF frame, except for the Tzz gradient which shows a 50% improvement, getting now a comparable accuracy to the Txx and Tyy gradients, as expected. That the improvement is mainly in the Tzz component is somewhat surprising, since the rotation LNOF to GRF is mainly around the z-axis. A reason could be that the upward continuation gradient values and errors is by nature largest for the Tzz-values (having double the variance of either Txx or Tyy), so comparisons in the LNOF frame therefore also have a larger error variance component coming from the other gradient terms in the LNOF to GRF rotation matrix, particularly the modelled "weak" Txy and Tyz gradients. But this would not be sufficient for the dramatic reduction seen in the standard deviations in the Tzz component when going from the LNOF to GRF frames.

***Table 4**. Statistics of collocation upward continuation comparisons in the GOCE frame (unit: Eotvos)*

Data statistics – GOCE frame		*Txx*	*Txz*	*Tyy*	*Tzz*
GOCE – GRACE2010S, (degree 60)	mean std.dev.	.032 .037	-.003 .056	.012 .039	-.035 .051
GOCE obs – predictions	mean std.dev.	.023 .034	.013 .054	.002 .034	-.017 .028
Predicted errors r.m.s.		.021	.024	.022	.028

Overall it can be concluded that the airborne gravity data validate GOCE at the 0.02 Eotvos level for the diagonal gradient elements (Txx, Tyy, Tzz), and at the 0.05 Eotvos level for the Txz gradient. The reason for this poorer fit of the off-diagonal "good" term is not understood at present.

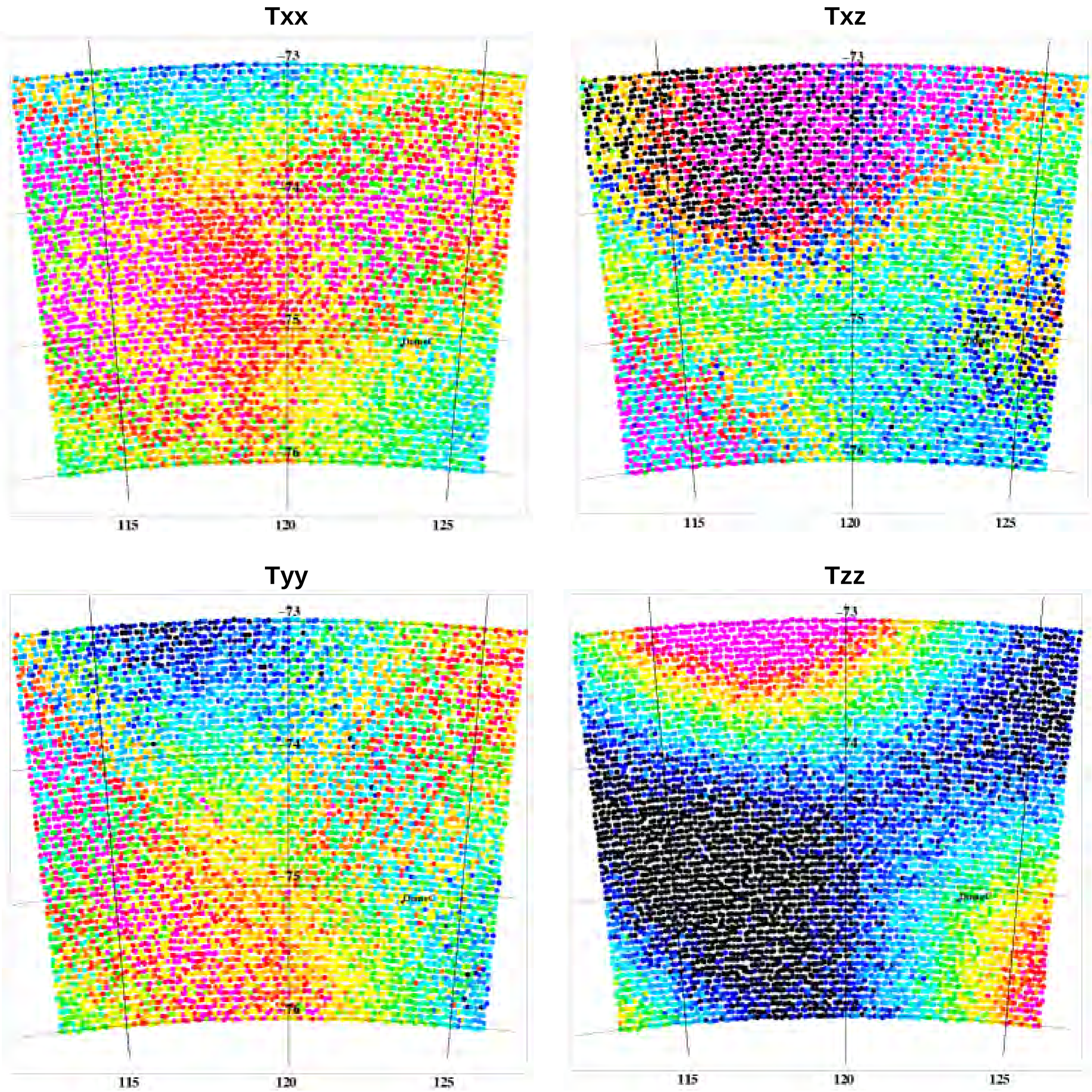


Fig. 14. Predicted gradients at GOCE points, minus ITG-GRACE10S to degree 60. Colour scale -0.08 to 0.08 Eotvos. The noisy appearance of the data is due to the different heights of the selected GOCE data.

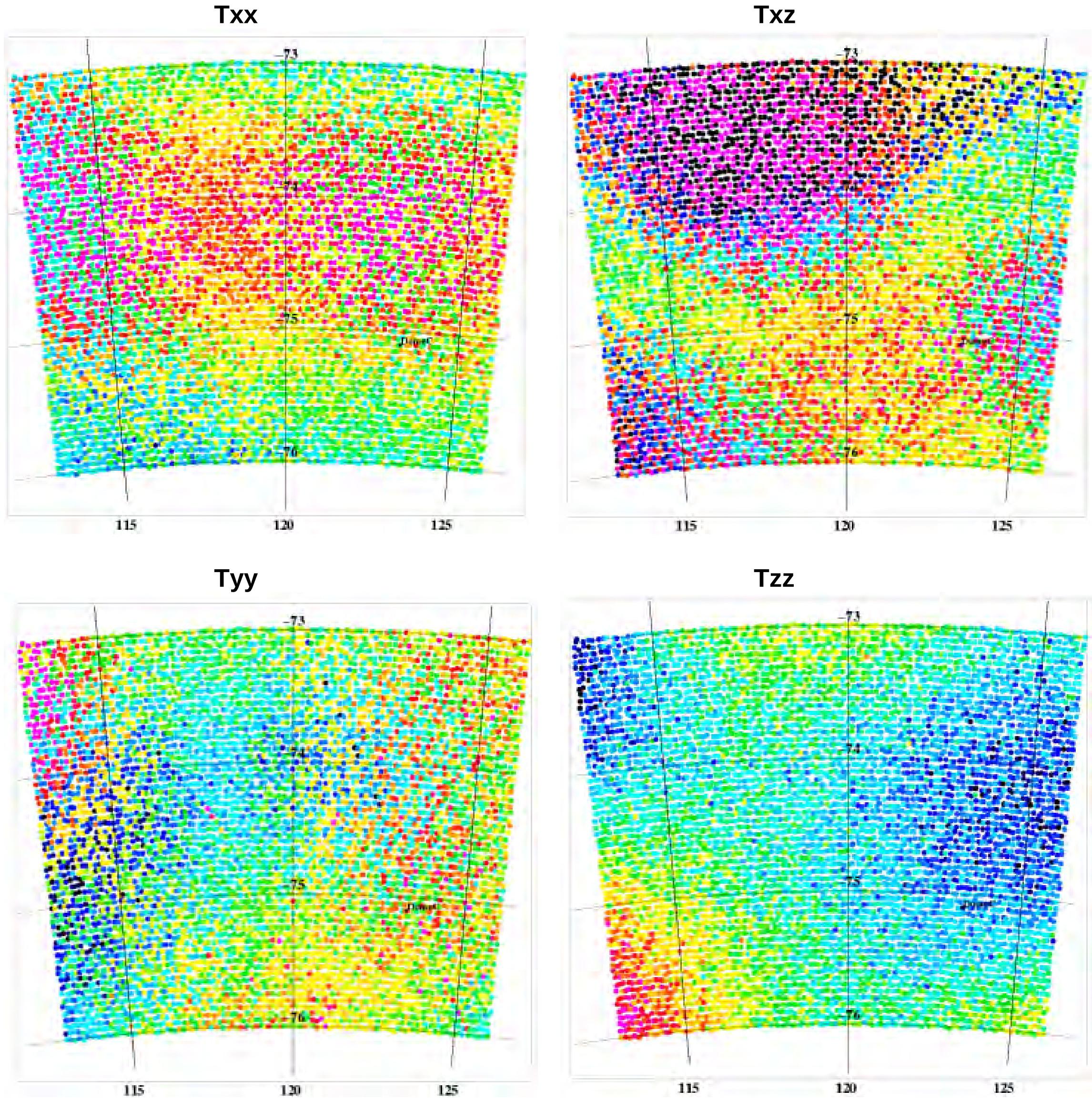


Fig. 15. Difference between GOCE gradients and predictions. Colour scale is -0.08 to 0.08 Eotvos.

7. Conclusions

The Dome-C gravity survey has been successful, and covered a hitherto unsurveyed and logistically very difficult region region of Antarctica. The survey has provided a consistent gravity data set with a reasonably small bias of 3 mGal compared to GOCE, and an estimated track r.m.s. noise of 8 mGal. This data set is therefore sufficient for an upward continuation and gradient estimation process to the GOCE altitude, as this process will damp the noise in the airborne data.

The airborne gravity data compares to ~14 mGal r.m.s. to the airborne gravity data, with nearly identical results for the "direct" and "timewise" R4 spherical harmonic models. The comparison for various spherical harmonic degrees shows that the GOCE data provides an improved r.m.s. fit to the airborne data as the maximal spherical harmonic expansion degree increases, all the way to maximal the degree (250 for timewise, and 260 for direct), thus confirming the very high accuracy and resolution of the RL4 products.

A collocation upward continuation and conversion of the airborne gravity data to gravity gradients at GOCE altitude have been carried out, and verified by an FFT solution. The estimate accuracy of the predicted gradients are at the 0.02-0.06 Eotvos level for in the LNOF system, with the largest error in the comparison being in the Txz and Tzz terms.

An additional estimation in the GOCE reference frame, limited to the properly observed terms (Txx, Tyy, Tzz, Txz), has been done using quaternions of the GOCE Level-1 data for rotating to upward continued gradient values to the GOCE satellite frame. This comparison shows a common error of ~0.02 Eotvos for all the diagonal gradients (Txx,Tyy,Tzz) thus validating GOCE measurements at this level. The Txz gradient, which should be well-observed by GOCE, did not improve and is only validated at the 0.05 Eotvos level.

It is believed that a larger area of the airborne gravity survey, and a more careful observation procedure and processing, would have reduced these variances further.

A proposed airborne gravity survey of the southern polar gap would thus be expected to provide airborne gradient data at the ~0.01 Eotvos level, complementing nicely the coverage of GOCE to a truly global level.

Fig. 16. Gravimeter installation in crash-proof box in the Polar-6 (center of image). The image insert lower left shows the Lacoste and Romberg air-sea gravimeter, with gyrostabilized platform gimbals and gyros and accelerometers mounted outside the inner housing, carrying the ultrasensitive zero-length spring sensor.

Acknowledgements

The help of prof. C. C. Tscherning is setting up the upward continuation and transformation to the GOCE reference frame is greatly appreciated. All computations for the gravity field transformations in the present report has been done by the DTU-Space GRAVSOFT package. We additionally thank Jaako Makinen, Finnish Geodetic Institute, for providing the absolute gravity values at Novo station.

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Fig. 17. Portable gravimeter base readings at South Pole station - gravity ties from the aircraft parking positions to gravity refence networks based on absolute measurements is an essential part of aerogravity.

Appendix Airborne laser scanner processing

Beside the two main instruments, the radiometer and the gravity meter, of the combined survey, an airborne laser scanner (ALS) was used to map surface roughness underneath the flight tracks. The width of swath of the ALS corresponds to the height of the aircraft above ground. Operating a S-typ LaCoste-Romberg gravity meter on board of an aircraft requires to maintain a constant flight level. Therefore the width of the ALS is 2000 ft at minimum clearance to the ground or larger. The horizontal resolution varies accordingly.
A main task of the ALS processing is to determine the squint angles of the installation. This was done using the star pattern. A result of this excerise is shown in Figure 2. The resulting squint angles are listed are:

SQUINT_X	SQUINT_Y	SQUINT_Z	FACTOR	MEDIAN	MEAN	STDDEV
0.40	0.26	-2.87	-1.000	-0.04 m	-0.04 m	0.07 m

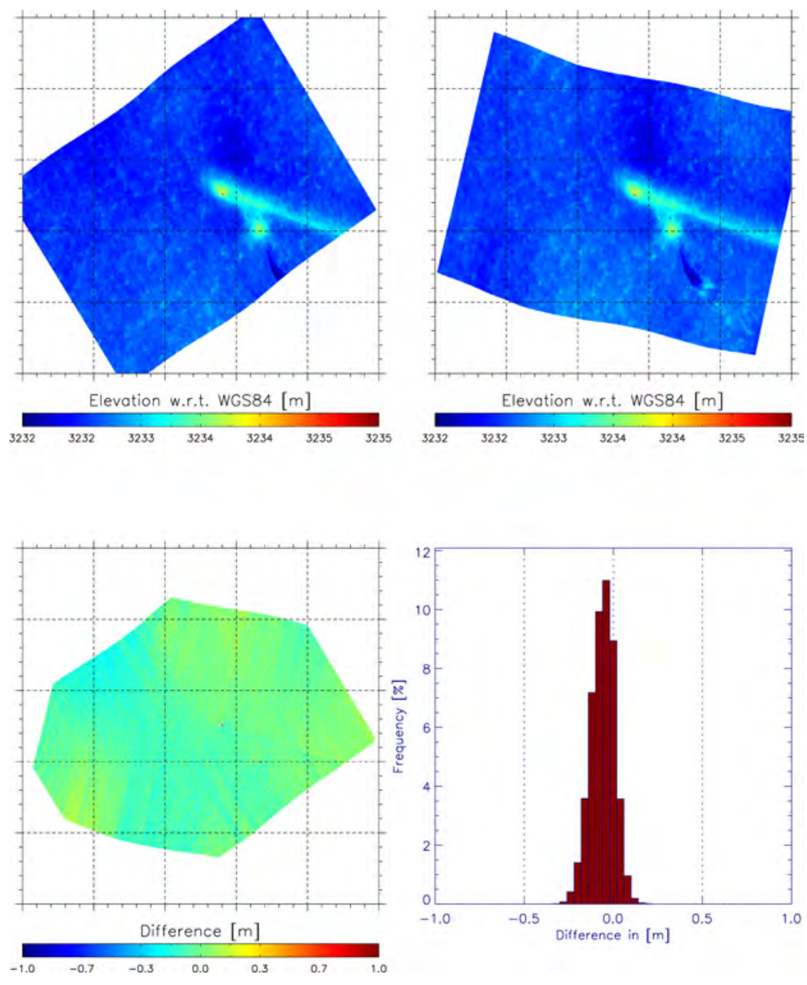

Figure 2: The upper line shows two geocoded segments of recorded ALS data of the star pattern, lower left shows the difference in elevation between both data sets after calibration, the lower right the associated histogram of the elevation differences.

In order to avoid too large files the laser scanner recordings were toggled during the flights, which means that data were stored in a new file without any gap between the files. Thus the whole survey, including the transit flights resulted in 100 ALS data files with a total duration of slightly more than 54h. With respect to the total flight time of the survey of 58.9h, the coverage with ALS data exceeds 91 %. Taking into account, that the rollerdoors which are protecting the scanner during take-off and landing are close for the first and last 5-10 minutes of each of the 15 flights, the coverage exceeds even 95 %. The coverage with ALS data in the survey area is shown in Figure 3.

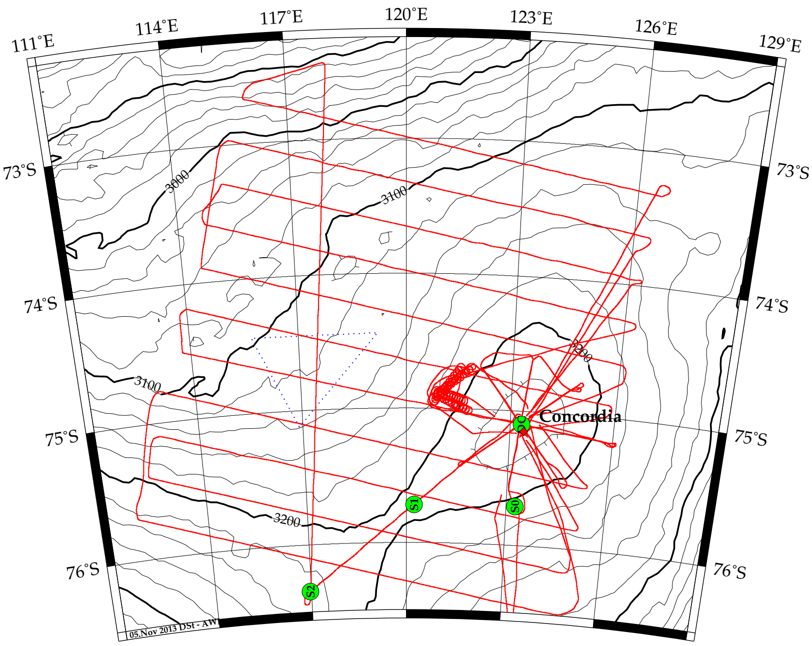

Figure 3: Map showing the coverage of the profiles with processed airborne laser scanner data. The underlying digital elevation model (RAMP V2) is taken from Liu et al., 2001.

DOMECair 2013 data acquisition report - Part II

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1 Introduction

The goal of the DOMECair 2013 campaign was to gather airborne data in East Antarctica supporting the data evaluation of ESA's Earth Explorer missions GOCE (Gravity field and steady-state Ocean Circulation Explorer) and SMOS (Soil Moisture and Ocean Salinity). The main instruments deployed on the aircraft for experiment were the L-band radiometer EMIRAD-2, developed and operated by the Danish Technical University (DTU), and an airborne gravity meter, a modified LaCoste-Romberg ships gravity meter, operated by the Alfred-Wegner-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (AWI), Germany. AWI provide the aircraft POLAR 6, a modernized DC-3 on skis equipped with modern avionics and turbo-prop engines.

The area of investigation was a 350 km x 350 km large region near the French-Italian winter- ing station Concordia (S 75.1°/ E 123.3°, 3233 m) at Dome C in East Antarctica. The survey comprised 12 long lines, 2 calibration patterns for the radiometer, and a star-like pattern on top of the stationary radiometer operated at Concordia. The equipment shipped via Cape Town (South Africa) to Novo airbase (S 70.8°/E 011.8°, 550 m) near the Russian wintering station Novolazarevskaya and installed on site by the science team, consisting of two engineers and two scientists. After a successful test flight the aircraft was flown from Novo airbase via the German summer station Kohnen and the u.s. American wintering-over station Amundsen-Scott on the South Pole to Concordia. The same route was used on the way back at the end of the survey.

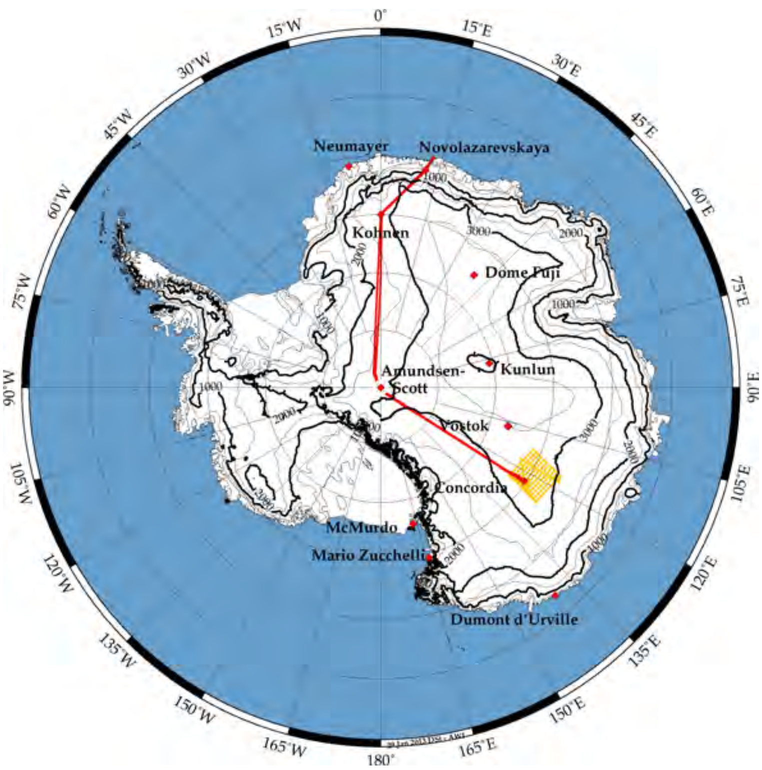

Figure 1: Overview on all DOMECair 2013 flight, yellow lines represent the survey profiles, red lines the transit legs.

An overview on all flights is given in Figure 1. The transit legs were also used for collecting data.

This reports summarizes the airborne activities and data collected during the DOMECair 2013 campaign in Antarctica. Also included in this report are the brief descriptions and fotos on the daily activities which were send from time to time to ESA's public relation department for running blog.

2 Airborne operations

Prior the expedition to Antarctica, the EMRIRAD-2 instrument was certified for operation on board of AWI's research aircraft *POLAR 5* and *POLAR 6* and the campaign configuration based on the chosen instruments was compiled. On September 24 2012 a test flight was carried out in Bremerhaven. Based on the evaluation of the EMIRAD-2 it was decided to remove the accumulation radar from the suite of instruments, because the active radar system was interfering with EMIRAD-2, one of the main instruments of the DOMECair experiment.

2.1 Summary on airborne operations

Logistic base for the campaign was the camp Novo airbase. During the austral summer season several intercontinental flights with large aircraft, usually Ilyushin IL-76, are connecting Dronning Maud Land, Antarctica, with Cape Town. Novo runway and the Norwegian wintering base Troll are the two entry points to Antarctica within the Dronning Maud Land Air Network (DROMLAN). The equipment was flown in before the science crew arrived on January 9 at Novo airfield.
After installation and a test flight from Novo airbase the team moved over for the survey flights to Concordia station via the German summer station Kohnen and u.s. American wintering station Amundsen-Scott. For locations see Figure 1. On all flights were data recorded.
In total 16 flights were carried out in Antarctica for this project with a flight of nearly 60 h alltogether. Details of all flights are given in table 1. The notes of the blog listed in appendix A provide an overview on the course of the expedition.

2.2 Integrated scientific systems

The instrumentation during the campaign consisted of the EMIRAD-2 instrument and its EGI system, an airborne gravity meter (LaCoste-Romberg S56), a laser scanner (Riegl VQ580), a nadir fotocamera (Canon EOS-1D), 4 geodetic GPS receiver (Novatel OEM-V, a 5hole probe (AIMMS20). Furthermore are the data of the aircraft inertial navigation system recorded. The location of the instruments and the cabin layout is shown in figure 2. Table 2 provides the coordinates of the sensors in the aircraft's coordinate system.

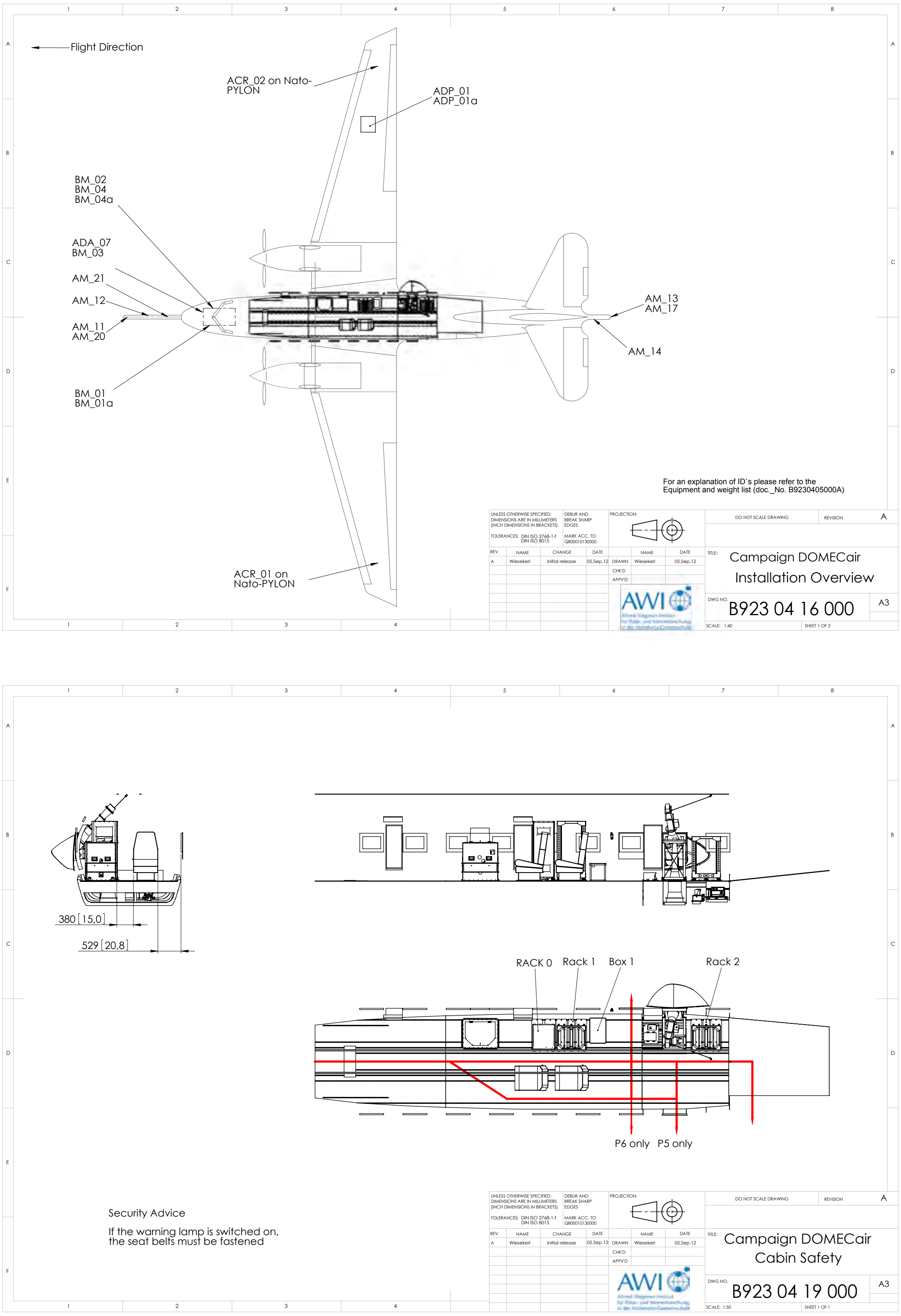

Figure 2: (a) Aircraft configuration. The drawing shows more instruments than were mounted during the survey;(b) cabin layout *POLAR 6* for the DOMECair configuration.

Table 1: Survey, test, and transit flights

Date	Flight no	Description	Air time	Distance
12.01.2013	13011238	Installation test flight	1.5 h	337 km
13.01.2013	13011339	Transit Novo airbase - Kohnen	1.8 h	616 km
13.01.2013	13011340	Transit Kohnen - Amundsen-Scott	5.2 h	1738 km
15.01.2013	13011541	Transit Amundsen-Scott - Concordia	5.1 h	1758 km
17.01.2013	13011742	Morning circle flight	2.8 h	728 km
17.01.2013	13011743	Profiles 1 & 4	3.9 h	1095 km
18.01.2013	13011844	Tie-line & profile 11	4.3 h	1395 km
18.01.2013	13011845	Profiles 7 & 10	3.5 h	1139 km
19.01.2013	13011946	Star pattern	3.8 h	1204 km
19.01.2013	13011947	Profiles 5 & 6	2.9 h	941 km
21.01.2013	13012148	Profiles 8 & 9, afternoon circles	5.6 h	1724 km
22.01.2013	13012249	Profiles 2 & 3	3.1 h	996 km
22.01.2013	13012250	Transit aborted	1.8 h	555 km
23.01.2013	13012351	Transit Concordia - Amundsen-Scott	5.8 h	1775 km
23.01.2013	13012352	Transit Amundsen-Scott - Kohnen	5.7 h	1722 km
24.01.2013	13012453	Transit Kohnen - Novo airbase	2.1 h	613 km
	Subtotal	Transit & test flights	29.0 h	9114 km
	Subtotal	Survey flights	29.9 h	9222 km
Total		DOMECair 2013	58.9 h	18336 km

Table 2: Instrument installation in the *POLAR 6* reference frame. Origin of the system is the center line of aircraft at the cockpit door on the floor. Offset definition: x positive to the front, y positive to the right wing and z positive down.

Instrument	x (m)	y (m)	z (m)
EMIRAD	-8.22		
EGI	-7.69		
gravity meter	-5.95	0.70	-0.35
laser scanner	-9.23	-0.45	0.30
nadir camera	-8.68	-0.38	0.37
AIMMS20	-5.34	6.15	
front GPS	-2.67	0.00	-2.01
rear GPS	-7.66	0.00	-2.04
port GPS	-7.80	-11.87	-0.60
starbord GPS	-7.80	11.87	-0.60
INS	0.60	0.20	-0.75

2.3 Data recorded and pre-processed

The scientific systems onboard were grouped into EMIRAD and its auxiliary systems, described in the first part of this report, and the gravity meter, laser scanner, nadir still camera, and auxiliary systems as GPS, INS, and AIMMS20 probe. The INS data are recorded by the Aircraft Data Acquisition system (ADA). The time span covered by the various sensors is visualized by time line graphs for each flight. However the lines only indicate that data were recorded, nothing else. The description of the data sets is given in following subsections. The amount of files recorded in separate files is given in table 3.

Table 3: Raw data files recorded per flight.

Flight	Gravity meter	Laser scanner	Fotos	AIMMS20
13011238	-	2	381	6
13011339	3	9	604	8
13011340	7	6	2275	8
13011641	6	8	2006	21
13011742	-	6	1209	12
13011743	6	6	1585	15
13011844	5	8	1869	18
13011845	4	7	1507	15
13011946	5	7	1683	16
13011947	4	4	1283	12
13012148	7	9	2481	23
13012249	4	6	1276	13
13012250	3	2	648	8
13012351	8	9	2201	19
13012352	7	7	2487	23
13012453	4	5	–	9

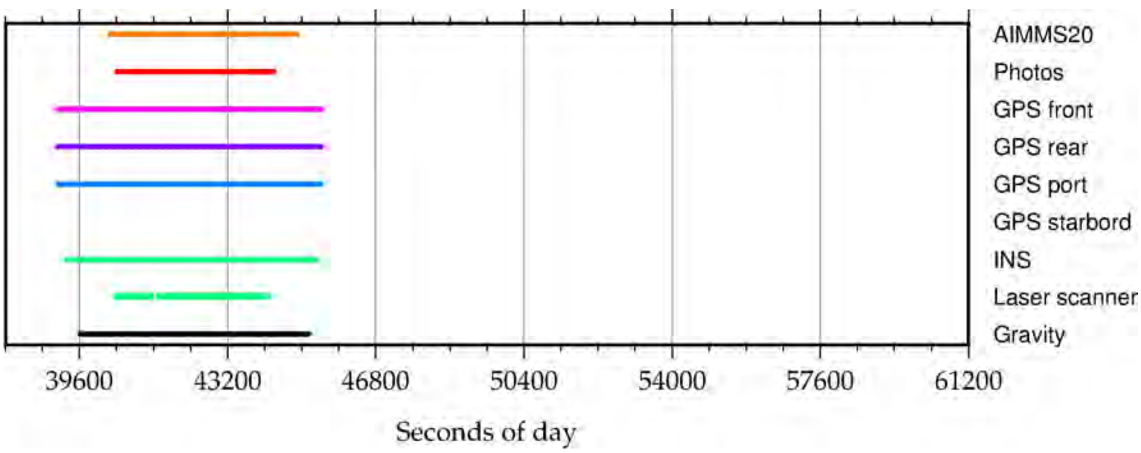

Figure 3: Data recorded on flight no 38, test flight from Novo runway over the ocean, due to flight pattern no useable gravity data were recorded.

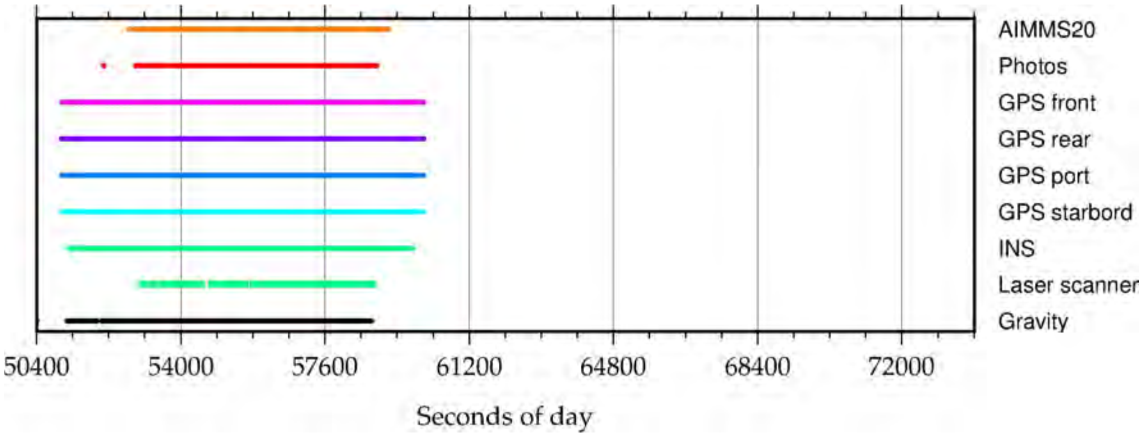

Figure 4: Data recorded on flight no 39, transit flight from Novo runway to Kohnen station.

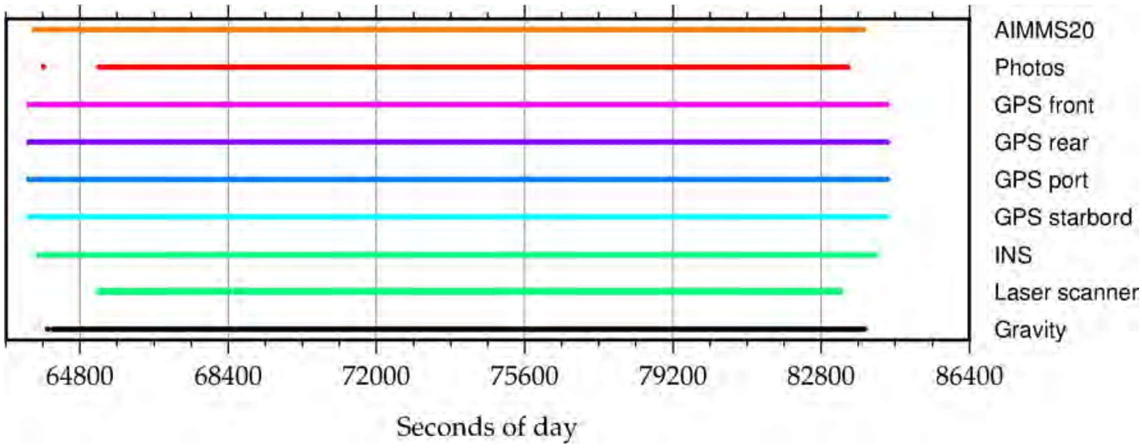

Figure 5: Data recorded on flight no 40, transit flight from Kohnen to Amundsen-Scott.

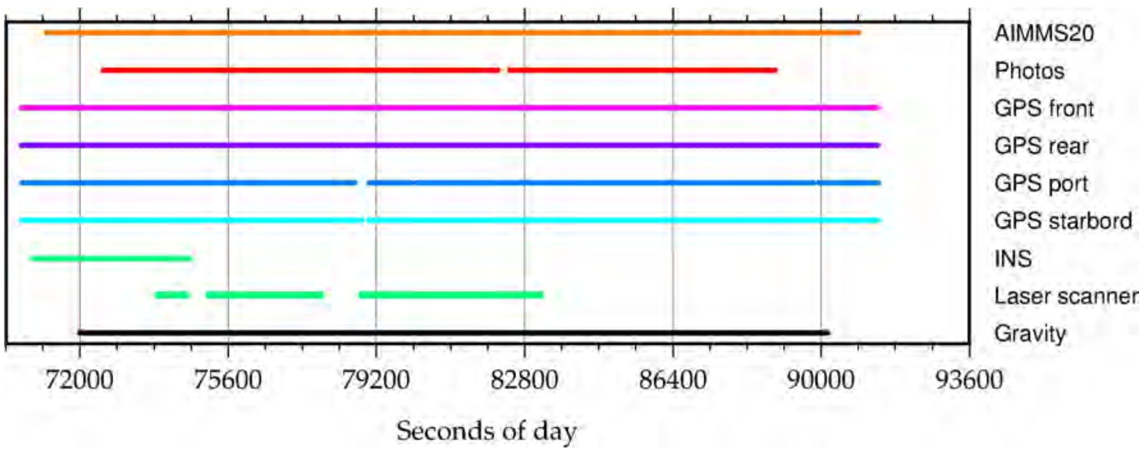

Figure 6: Data recorded on flight no 41, transit flight from Amundsen-Scott to Concordia station.

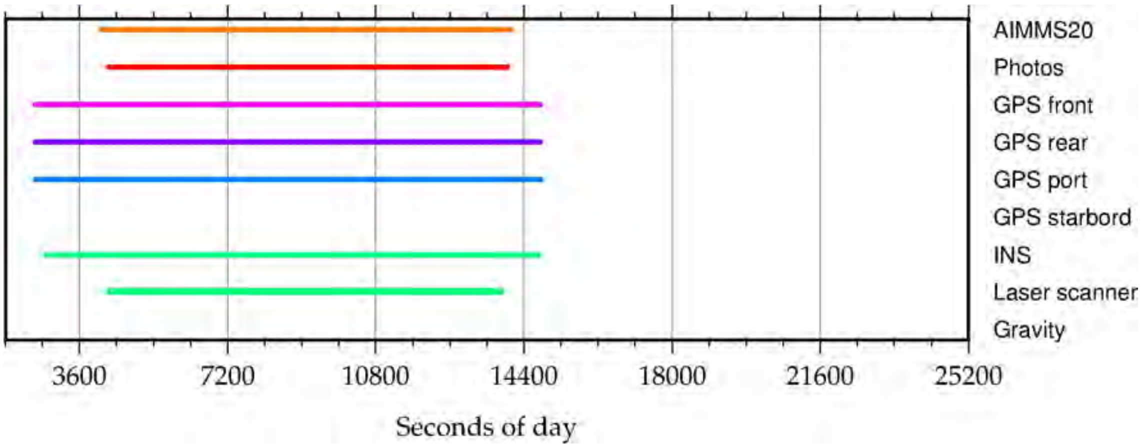

Figure 7: Data recorded on flight no 42, the so-called "morning circle" flight. Due to the flight pattern no useable gravity data were recorded.

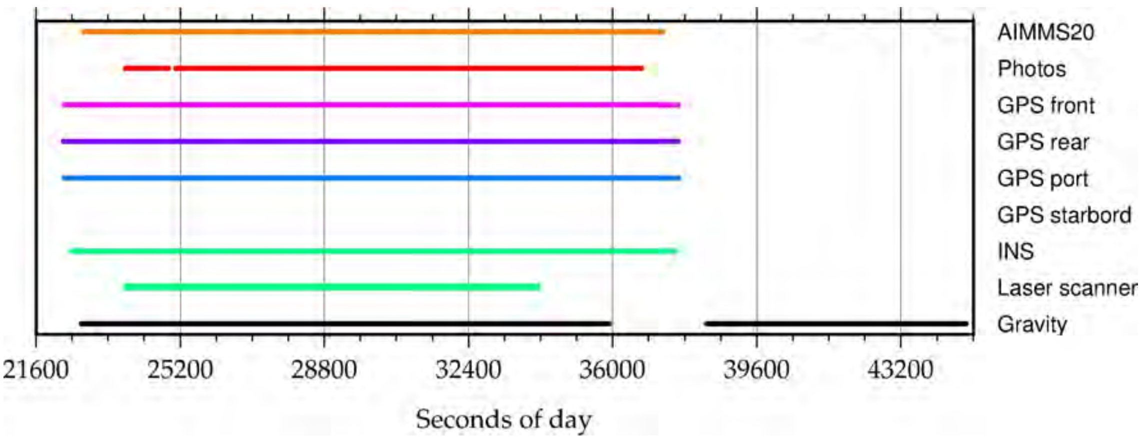

Figure 8: Data recorded on flight no 43, profiles 1 and 4.

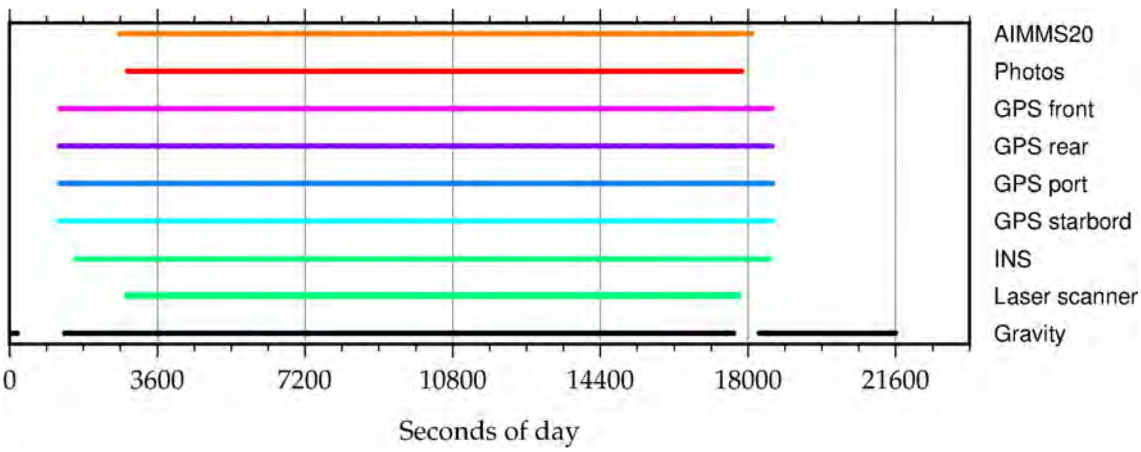

Figure 9: Data recorded on flight no 44, tie-line and profiles 11.

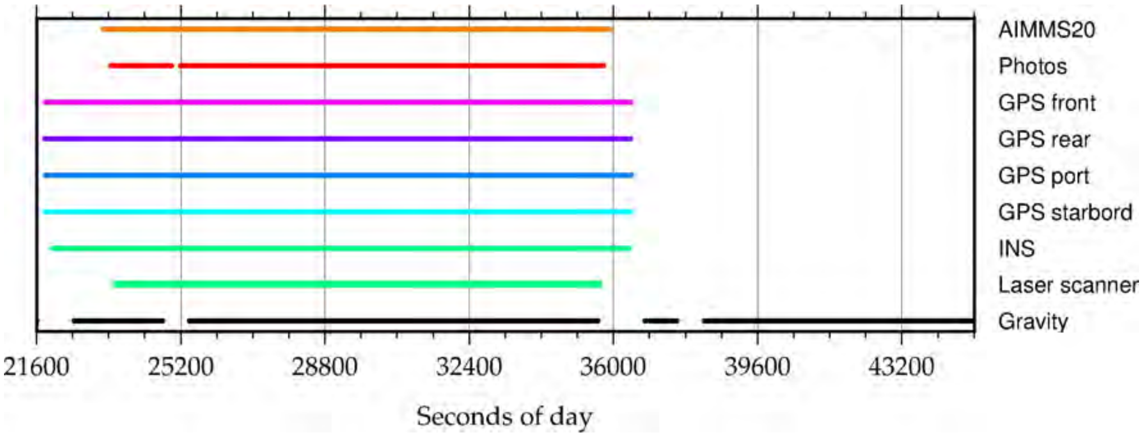

Figure 10: Data recorded on flight no 45, profiles 7 and 10.

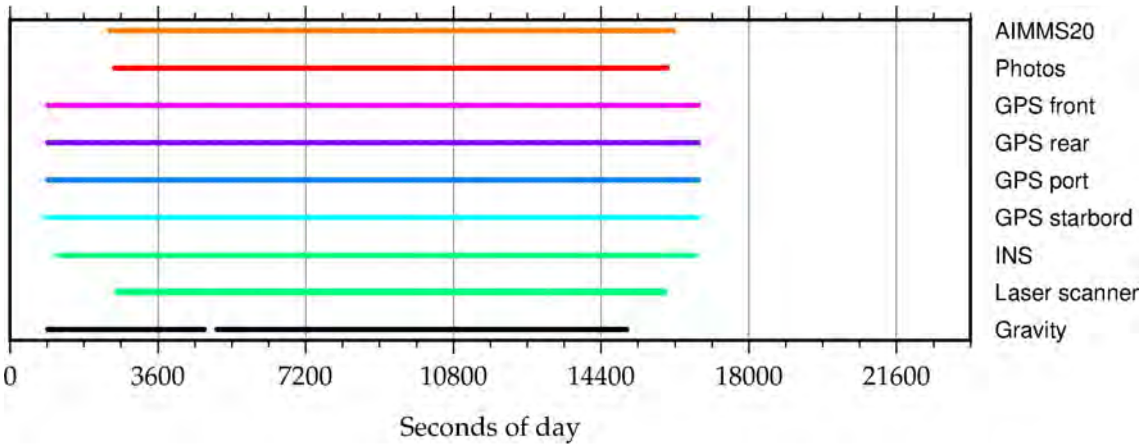

Figure 11: Data recorded on flight no 46, star pattern above observational tower at Concordia.

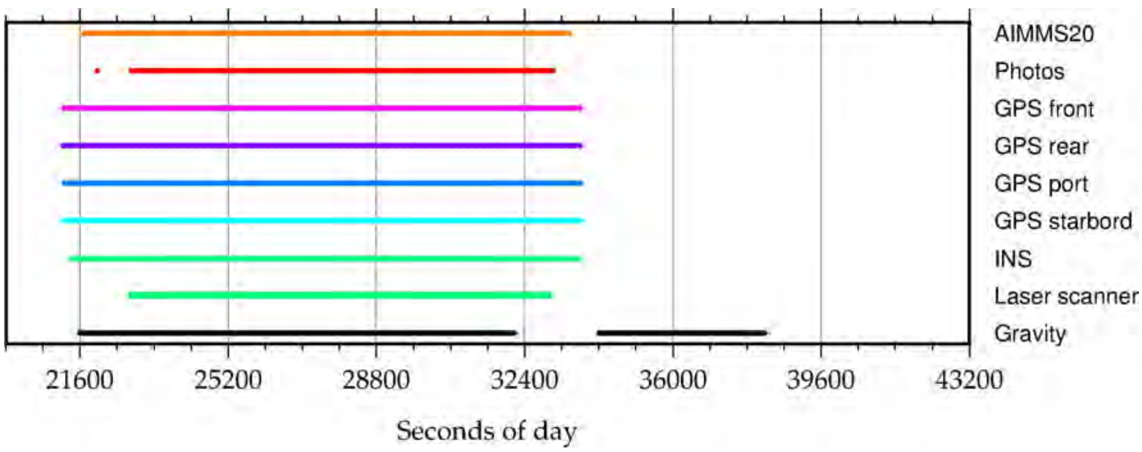

Figure 12: Data recorded on flight no 47, profiles 5 and 6.

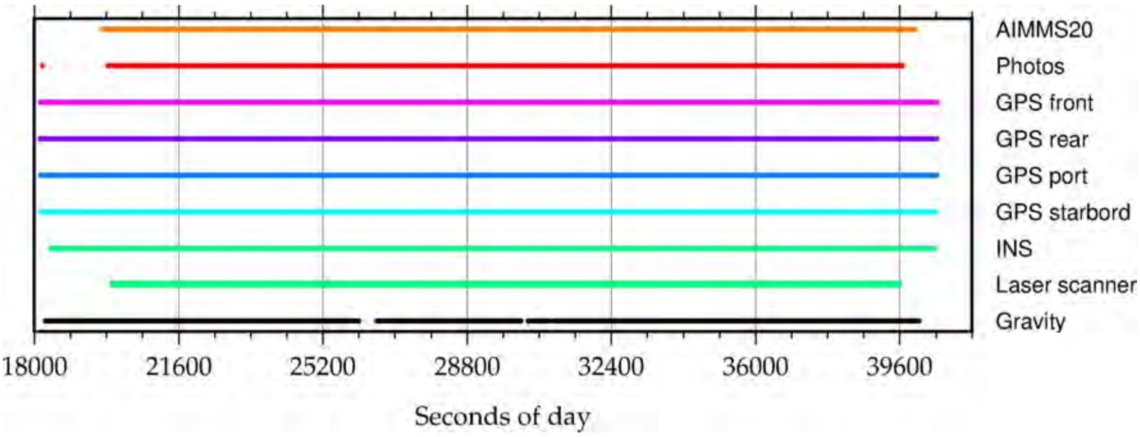

Figure 13: Data recorded on flight no 48, profiles 8 and 9 as well as "afternoon circle" flight.

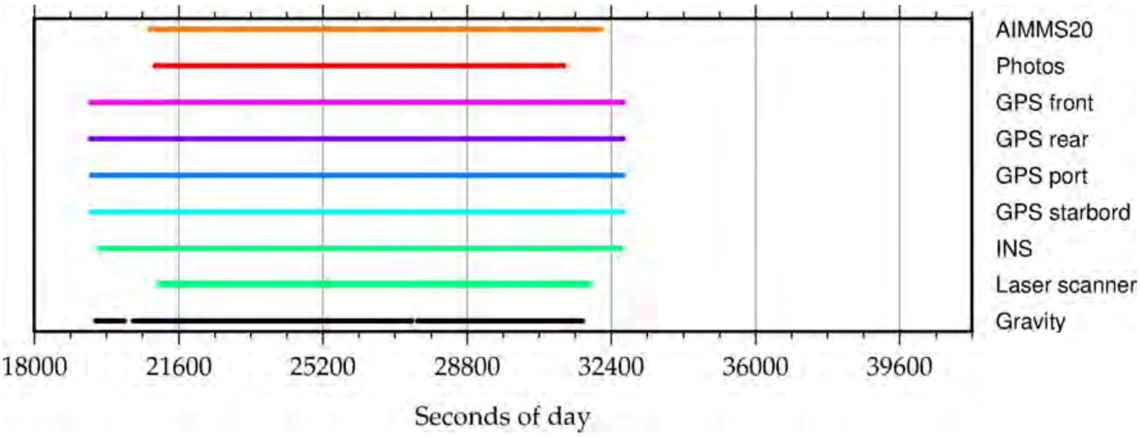

Figure 14: Data recorded on flight no 49, profiles 2 and 3.

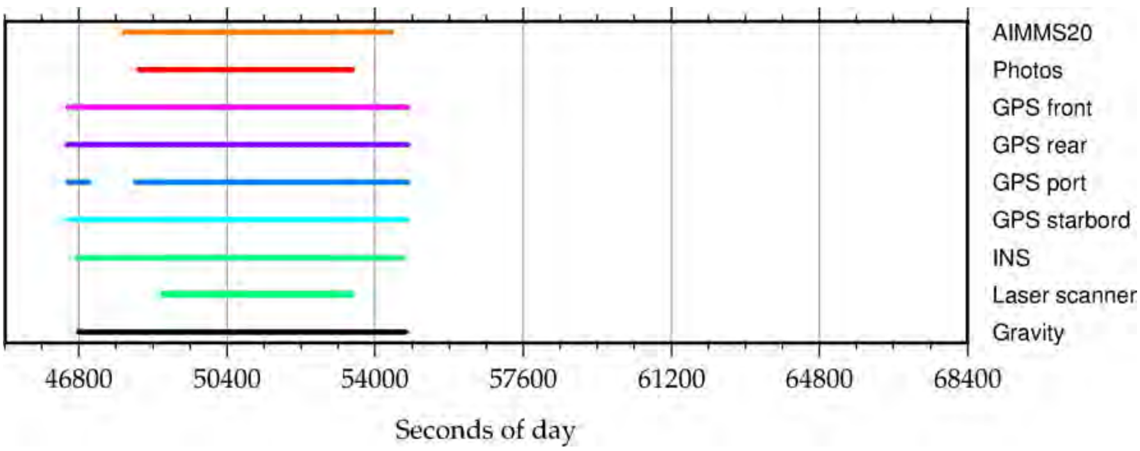

Figure 15: Data recorded on flight no 50, aborted transit flight from Concordia station. Flight aborted due to unexpected quick incoming bad weather at Amundsen-Scott.

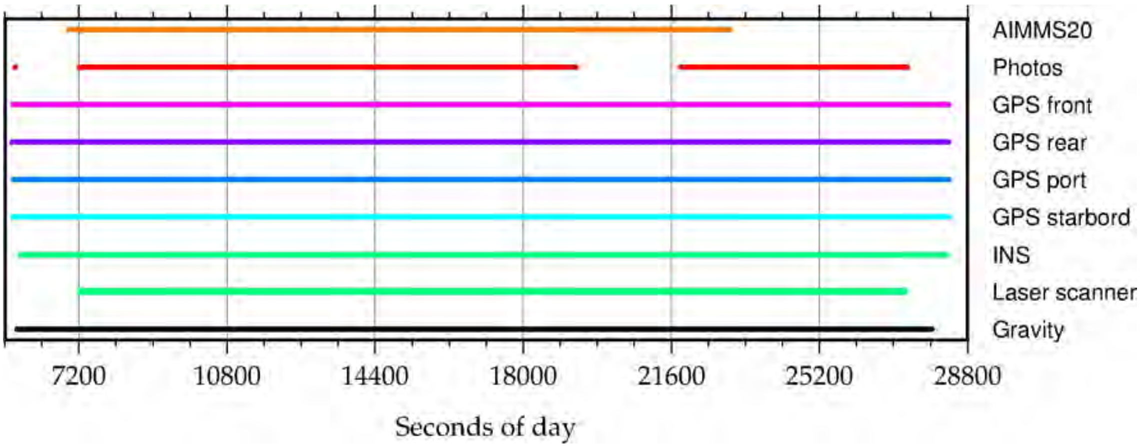

Figure 16: Data recorded on flight no 51, transit flight from Concordia to Amundsen-Scott station.

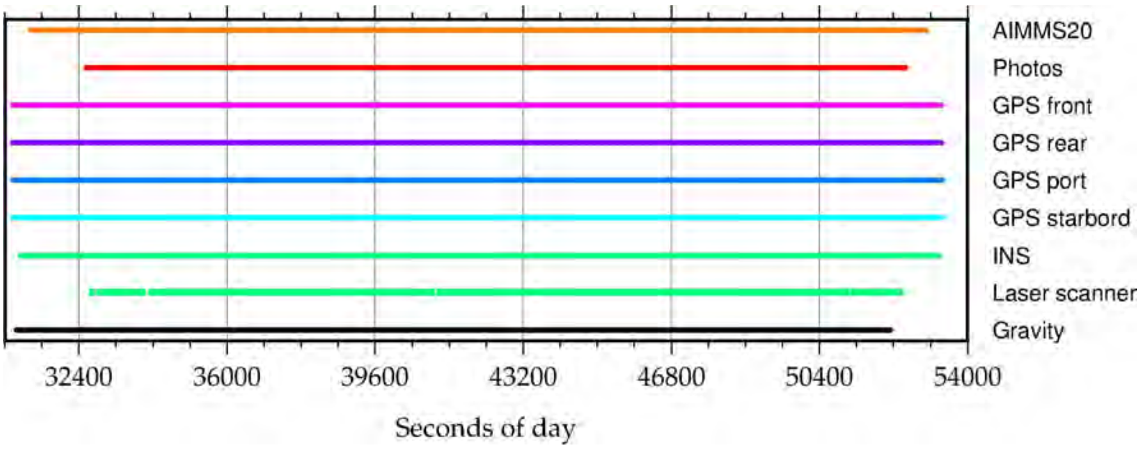

Figure 17: Data recorded on flight no 52, transit flight from Amundsen-Scott to Kohnen station.

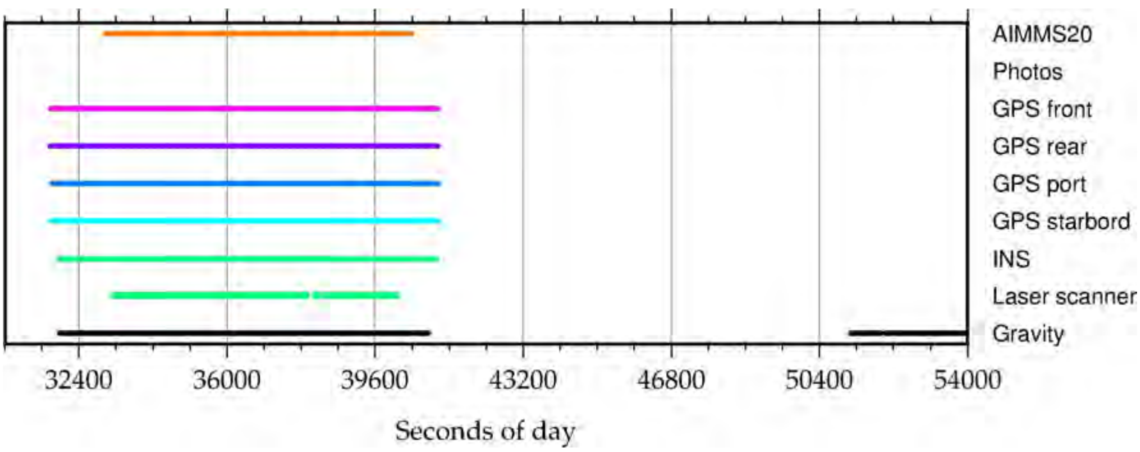

Figure 18: Data recorded on flight no 53, transit flight from Kohnen to Novo runway. Due to clouds en route no fotos were recorded.

2.3.1 Gravity meter

Data of the for airborne use modified LaCoste-Romberg S56 gravity meter were recorded on a PC by the gravity meter operating software in hourly files using the naming convention YYYY_hh.DOY, YYYY = year, hh = hour, DOY = day of year. In total 121 files were produced between 11:01 UTC on 12/Jan/2013 and 11:21 UTC on 24/Jan/2014. In table 3 only those files are counted, which were recorded during flight.
The data were processed using a software package based on the development of A.V. Olesen 2002 (Olesen, A.V. (2002): Improved airborne scalar gravimetry for regional gravity field mapping and geoid determination. Ph.d. dissertation, National Survey and Cadastre of Denmark Technical Report 24, 123 pp.) in a version compiled by T. Boebel (Optimare Sensorsysteme GmbH, formally with AWI). The data were geocoded using GPS data processed with Waypoint GrafNav using precise point positioning routines. No geoid heights were taken into account. The result of the data thus processed data is shown in figure 19.

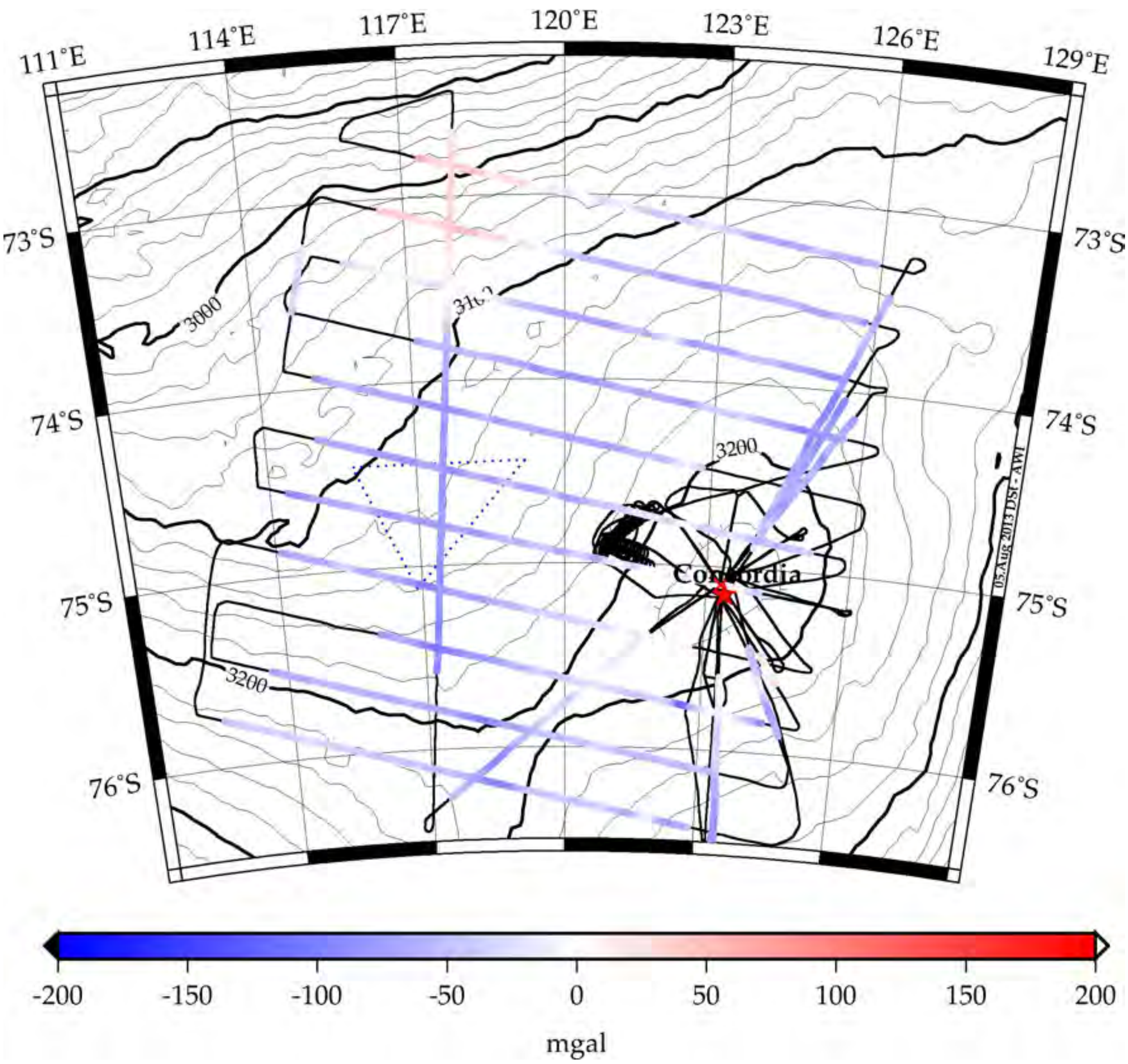

Figure 19: Processed gravity data around Concordia.

Before and after the expedition readings with a portable gravity meter G744 were carried out in Cape Town, South Africa, at the absolute gravity point UCT new at Cape Town University. During the expedition further readings at other absolute gravity were taken. Because the readings in Cape Town were taken before and after the survey at Concordia, this reference was used to calculate the absolute gravity for Concordia of 981865.13 mGal.

2.3.2 GPS

POLAR 6 was equipped with a GPS antenna on each wing tip and antennas on the cabin roof, one in front, the other further back. The data of each antenna was recorded using Novatel OEM-V receiver operating at 50 Hz. Another GPS recording was done by the basic data acquisition system at 1 Hz. The latter data are not processed. The time lines show the processed GPS data. Processing was done using Waypoint GrafNaV Precise Point Positioning routines. On the test flight (flight 38) and on flights 42 and 43 the memory card of the starboard receiver failed. Thus the data are unavailable. However the data loss does not cause any problem for the processing of gravity and laser scanner data.
In total 61 GPS data files were recorded and processed. The raw data files are automatically named by the GPS receivers: nnnnDOYi.PDC, nnnn = last 4 digits of serial number, DOY = day of year, i = session counter, starting with 0. Processed data files are named using the same convention as for CryoVEx data: AAA_B_YYYYMMDDTSSSSSS_PPPPPP, AAA = GPS, B = [FRSP] (for distinguishing front, rear port, and starbord antenna), YYYY = Year, MM = month, DD = day, SSSSSS = start time in hhmmss, PPPPPP = stop time in hhmmss.

2.3.3 Laser scanner

The data of the Riegl VQ 580 laser scanner were recorded in the systems own format and converted using the manufacturers software. To ease data handling, the data were stored in several files per flight.
Prior to the processing and geocoding of the ALS data a calibration was calculated based on the data collected on the star pattern flight across the DOMEX tower at Concordia. Aim of the calibration to determining the actual squint angles of the laser scanner installation.

Two data sets used for the calibration, the final difference after calibration as well as the associated histogram are shown in figure 20. The computed squint angles are:

SQUINT_X	SQUINT_Y	SQUINT_Z	FACTOR	MEDIAN	MEAN	STDDEV
0.40	0.26	-2.87	-1.000	-0.04 m	-0.04 m	0.07 m

The results of the laser scanner altimetry of the star pattern flight around Concordia is shown in figure 21.

Processed data files are named using the same convention as for CryoVEx data: AAA_BBB_YYYYMMDDTSSSSSS_PPPPPP, AAA = ALS, BBB = L1B, YYYY

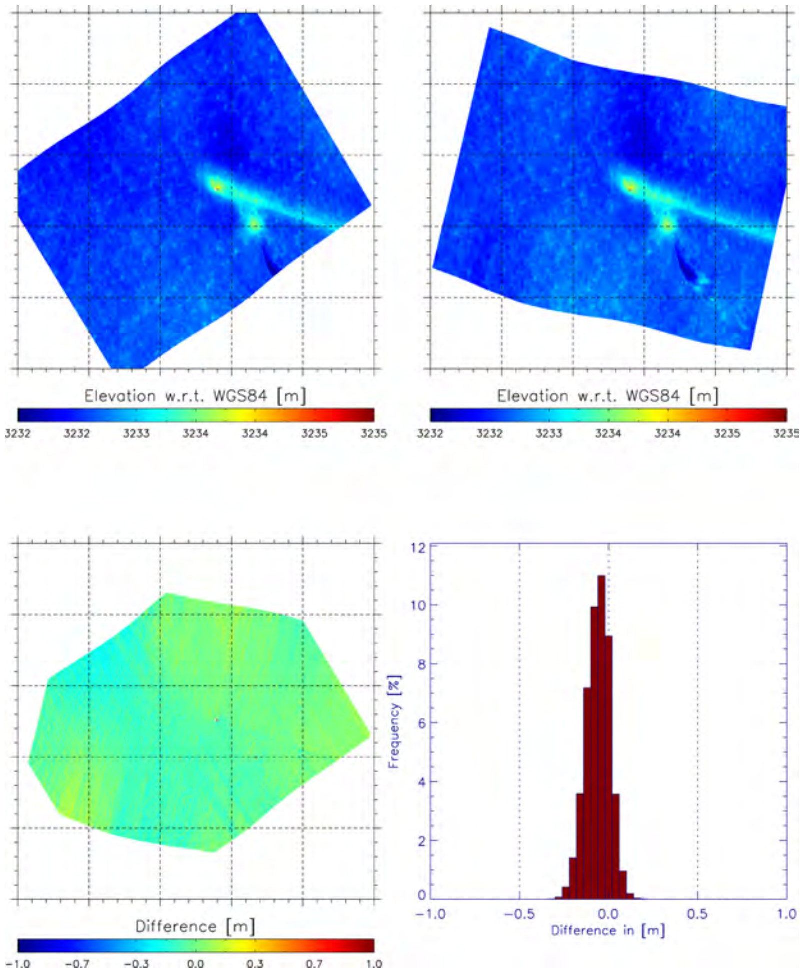

Figure 20: The upper line shows two geocoded segments of recorded ALS data of the star pattern, lower left shows the difference in elevation between both data sets after calibration, the lower right the associated histogram of the elevation differences.

= Year, MM = month, DD = day, SSSSSS = start time in hhmmss, PPPPPP = stop time in hhmmss.

2.3.4 INS

Inertial navigation system (INS) data were recorded by the aircraft data acquisition system. On two transit flights the system had to be rebooted. This led to two minor data gaps on flight 40 to Amundsen-Scott. On flight 41 to Concordia the recording failed after about one hour. Otherwise no problem with the INS data recording occurred. INS data are extracted in one file per flight using the same convention as for CryoVEx data: AAA_YYYYMMDDTSSSSSS_PPPPPP, AAA = INS, YYYY = Year, MM = month, DD = day, SSSSSS = start time in hhmmss, PPPPPP = stop time in hhmmss.

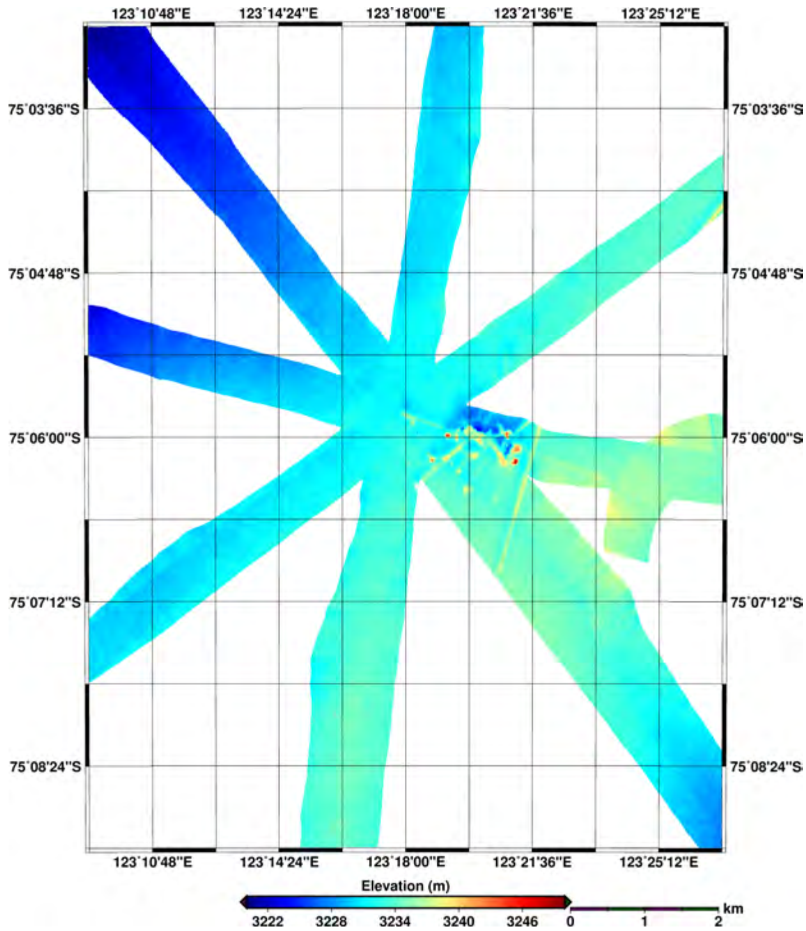

Figure 21: ALS data of star pattern flight across DOMEX tower/ Concordia.

2.3.5 Fotocamera

Nadir still fotos were taken with a full format DSLR camera with a 14 mm wide angle lens on each flight at 8 s intervall except on flights 38 and 39. On the first two flights the intervall was set to 10 s. All fotos were geo-tagged using a Garmin handheld GPS. The raw data files are named YYMMDDFF_nnnn.CR2, YY = Year, MM = month, DD = day, FF = flight number, nnnn = counter. Except of converting the fotos into the jpeg format no processing was carried out.

2.3.6 AIMMS20

The AIMMS20 is a small meteorological probe recording wind, temperature, humidity, pressure, and independent of other aircraft instruments accelerations of the sensor, respectively the aircraft. The naming convention of the data files is MMDDhhmm.rnn, MM = month, DD = day, hh = hour, mm = minute, nn = counter. The data are processed using the software provided by the system manufacturer. The result is stored in plain text files: MMDDhhmm_FF_aimms.dat, MM = month, DD = day, hh = hour, mm = minute, FF = flight number.

3 Summary

DOMECair has been successfully carried out by AWI and DTU. The data recorded by AWI systems (gravity meter, laser scanner, AIMMS20, nadir fotocamera, GPS, INS) are stored in AWI's data storage system, while those recorded by EMRIRAD-2 and the EGI system are stored at DTU.
In total 59.9 flight hours on 16 flights were conducted within a period of 17 days in January 2013. Approximately half of the time and flights was spend for a test flight seven transit flights. The survey around Dome C comprises two circle flights for calibration of the radiometer, a star pattern centered on the observation tower of Concordia station, and 11 parallel profiles covering an area of 350 x 350 km^2, as well as one so-called tie-line. Figure 22 shows the survey flight tracks.

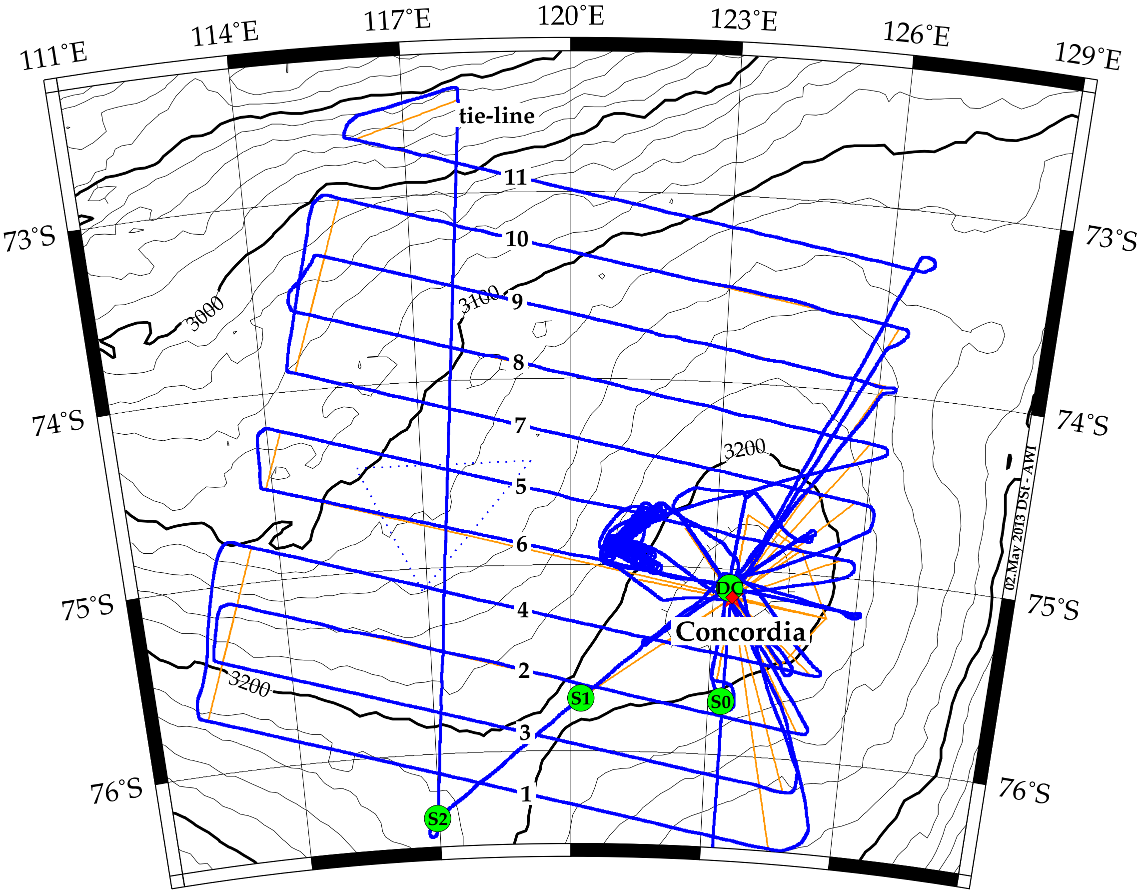

Figure 22: Map showing the actual flown tracks (blue lines) on top of planned pattern (yellow lines). The green dots indicate positions of glaciological fieldwork by Ghislain Picard et al.. The blue patches west von Concordia show the location of the two circle flights.

Summarized, during the DOMECair 2013 campaign airborne data for the evaluation of the Earth Explorer mission GOCE and SMOS were successfully acquired in area around Dome C, East Antarctica.

A DOMECair Blog

The DOMECair is a project aiming for collection of airborne data for cal/val of the satellites SMOS and GOCE by operating the L-band radiometer EMIRAD-2 and a gravity meter over a test site of 350 km x 350 km at the French-Italian wintering base Concordia at Dome C, East Antarctica. The project is a joined activity by the German Alfred Wegener Institute for Polar and Marine Research (AWI), owner of the research aircraft POLAR 6, a Basler BT-67 on skis, and operator of the gravity meter on board and the Danish Technical University, National Space Institute (DTU-Space) developer and operator of the passive L-Band radiometer EMIRAD-2. The experiment is scheduled to start with the flight of the scientists and operators on January 10 2013 to Novo runway in Dronning Maud Land, Antarctica, and ends with their departure on January 28. Novo runway, close to the Russian wintering station Novolazarevskaya, is beside Troll, a Norwegian wintering station, a gateway of the Dronning Maud Land Air Network (DROMLAN) to Antarctica. Both airstrips can accommodate large aircraft, connecting Cape Town, South Africa, regularly with Antarctica during the austral summer. From both entry points of the remote southern continent, smaller ski-equipped aircraft distribute personal and equipment to the various scientific bases in Dronning Maud Land and adjacent regions. For the survey itself are 30 flight hours allocated on site, operating from Concordia. Prior to the survey the scientific equipment will be installed in Antarctica and test flown. This flight will also be used for calibration of the instruments. After that POLAR 6 will be transferred to Concordia. De-installation, packing and shipping the equipment back home takes place again at Novo runway.

09/Jan
Today we arrived at the airstrip at the Norwegian wintering base Troll at 03:25 in the morning on board of an Ilyushin 76 aircraft. Departure of the 8th flight carried out for the Dronning Maud Land Air Network (DROMLAN) was at 23:30 on the day before at Cape Town, South Africa, officially listed as 82Y9173 with Destination Antarctica. The flight was shifted ahead by 1 day with respect to the original schedule due to upcoming bad weather in Dronning Maud Land. Prior to the flight a safety briefing at the premises of the Antarctic Logistics Centre International (ALCI) in Cape Town and check of safety equipment and polar gear was on our agenda on the day before.
At Troll we had to wait at the runway for our so-called feeder flight with a Basler BT-67, a modified DC-3 to Novo runway, the place to which our equipment was flown in to with earlier DROMLAN flights. With us about 50 colleagues from Denmark, Germany, Norway, Russia, South Africa, and United Kingdom arrived and those which were going to Neumayer Station and SANAE IV, both bases west of Troll, were flown out first due to incoming bad weather from the west.
All our equipment was shipped to Antarctica on earlier DROMLAN flights. Because our flight has shifted ahead by 1 day we have to wait for arrival of POLAR 6, our ski-equipped research aircraft for return from another project.
The Basler aircraft used within the DROMLAN project as well as the two owned by AWI, POLAR 5 und POLAR 6, are operated by the Canadian company Kenn Boreck Air (KBA). KBA is also operator of the Baslers used within u.s. Antarctic Programme.

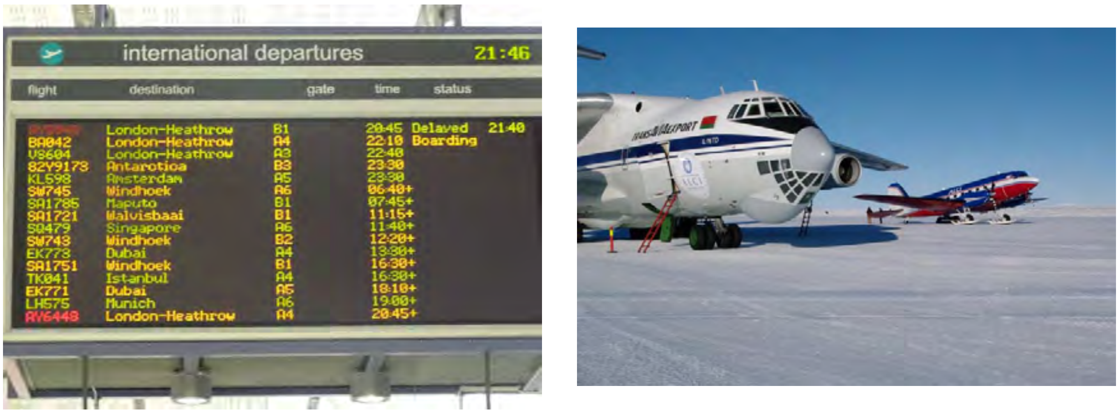

Figure 23: (a) Departure screen of Cape Town International airport; (b) aircraft in Antarctica: IL-76 and Basler BT-67.

10/Jan
In the morning we removed various instruments, which were used for the geo-scientific mission that just ended. Keeping the gravity meter, basic data acquisition system, and some auxiliary devices installed. Directly after lunch we started the installation of the EMIRAD-2 horn antennas and its rack.
Sunny weather and only little wind allowed us to spread out the transport boxes and made packing of the removed equipment and installation of the new very easy. However, the forecast for the next days shows upcoming clouds and increasing wind.

Figure 24: (a) Departure screen of Cape Town International airport; (b) aircraft in Antarctica: IL-76 and Basler BT-67.

11/Jan
We continued to install EMIRAD-2 and finished the installation early evening. The alignment of the two horn antennas was measured with the EGI system and first tests were successfully carried out.

12/Jan
The ground test of EMIRAD in the morning went well and so did the short test and calibration flight we finished in time for lunch. The calibration was carried out above the ocean just north of Novo runway. In the afternoon we packed POLAR 6 with our spare parts and all remaining equipment into our container for storage.

Figure 25: IL-76 and Basler BT-67.

Also our own polar gear had to be checked and reduced, since the weight capacity on the transit flight is limited.
We are now ready for the transit flight. Unfortunately did overcast, light snow and drifting snow stop us from going to Kohnen station today, which will be our first leg towards Concordia station. The other stopover station will be Amundsen-Scott.

Figure 26: (a) Departure screen of Cape Town International airport; (b) aircraft in Antarctica: IL-76 and Basler BT-67.

13/Jan
Today the overcast at Kohnen broke off, so in the afternoon we could finally leave Novo runway, heading towards the South Pole and crossing the Wohlthat Massiv, a mountain range which sticks out through of the ice sheet. These nunataks, the ice free summits of the mountains, are the bare rock formations we will see on our way to Concordia. In 10 days when we pass this region again, we will see some rocks

again.
After a short fuel stop at Kohnen station at similar altitude as Amundsen-Scott, the u.s. wintering station at the geographic South Pole we continued our transit flight and arrived at the Pole the following day at lunch, since the station operates on New Zealand time, which is UTC+13.
While Kohnen is a small summer station, at the time of our fuel stop occupied by 17 scientists and technicians of the Alfred Wegener Institute, Amundsen-Scott is a huge station, today housing 167 people. The station at the South Pole consists of of a huge main building, garages under the surface and a large summer camp as well as several remotely placed buildings dedicated for various research, e.g. air chemistry, astronomy, seismology.
Both stations, Kohnen and Amundsen-Scott, are located on the East Antarctic plateau at elevations close to 3000 m. The temperature at Kohnen was slightly warmer, approximately −20°C, while at the Pole the temperature is −25°C. At Concordia we expect even lower temperatures, so it is a mayor challenge to keep aircraft and scientific equipment heated, so they start next morning.

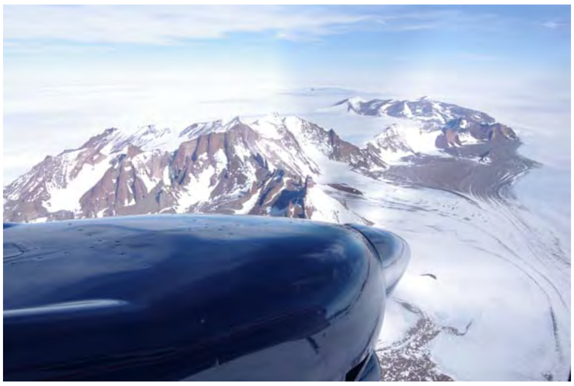

Figure 27: IL-76 and Basler BT-67.

14/Jan
At Amundsen-Scott we arrived just a few minutes before a C-130 cargo aircraft of the u.s. National Science Foundation, so we could not refuel right away. However after the C-130 has left we could refuel. The time in between was used to grab some lunch and to settle down in two temporary buildings used during the summer season. The rest of the day we were fighting to stay awake until dinner. Just after dinner we went to bed, at 19:00 local, but being adjusted UTC it was at 6 in morning.

15/Jan
Today we received two contradicting forecasts for Concordia. Since Concordia is operating at UTC+8 we had to wait until lunchtime at Amundsen-Scott to get observations from Concordia. Because we could not rule out the possibility of incoming low clouds to Concordia, we decided to stay on the safe side and postpone the flight to tomorrow.
During the time we had to wait, we also ran some tests on our equipment, not only testing how the systems deal with the cold, outside temperature dropped to −29°C and inside the cabin we got temperatures down to −10°C, but also testing for instance if the EGI, an inertial navigation unit, could align itself, which the unit

Figure 28: IL-76 and Basler BT-67.

did not manage, because it is too close to the rotational axis of the Earth. We also did reference measurements with the portable gravity meter at the gravity reference point at the station. The point is located in one of the tunnels, which are connecting the main station building with garages, power plant, and sewage system. The absence of any wind and the solid foundation made allowed precise readings, only the low temperature of about −45°C made the work difficult.

Figure 29: (a) Departure screen of Cape Town International airport; (b) aircraft in Antarctica: IL-76 and Basler BT-67.

16/Jan
An early morning call at 05:00 oâĂŹclock South Pole to Concordia revealed excellent weather conditions at the station just before their midnight. Also the new forecasts predicted were in agreement to each other, so we packed and prepared the aircraft and instruments for an early start. At 09 oâĂŹclock we got airborne for our last transit leg to Concordia.
Concordia is a wintering station jointly operated by Italy and France. In winter the station is occupied by about 15 scientists and technicians, while in summer up to 65 people show up. Before the station was established, at this side the first of two deep ice cores of the European Project for Ice Coring in Antarctica (EPICA) was drilled. This ice core is at present the one with the oldest ice, dating back more than 840,000 years. The second EPICA ice core was drilled in Dronning Maud Land at Kohnen station where we refueled the first time on our way from Novo runway to Concordia.
Because the yearly accumulation on the polar plateau is extreme low, just a few

centimeter snow, at the summer camp at Concordia is set-up year round as it is on the Pole.

Figure 30: (a) Departure screen of Cape Town International airport; (b) aircraft in Antarctica: IL-76 and Basler BT-67.

17/Jan
After spending a night in a new time zone we woke up very early and were the first at breakfast. However it took a while until everything was sorted out and we could start to our first flight operating from Concordia. As first flight we choose one of the two circle flights, flying two sets of 10 circles with a constant bank angle of $+10$ and -10 degrees respectively. The second fight today was the profiles 1 and 4 of the planned grid around Dome C. By mapping lines, which are not adjacent to each other, we are aiming to cover the entire area with a wider spacing first, before filling in the grid with the remaining profiles.
Between the two flights we carried out the first calibration of EMIRAD-2 with liquid Nitrogen. The Nitrogen was flown in especially for us from the Italian base Mario Zucchelli.

Figure 31: (a) Departure screen of Cape Town International airport; (b) aircraft in Antarctica: IL-76 and Basler BT-67.

18/Jan
Today we managed to map the so-called tie-line crossing the 11 grid lines and the line 11 in the morning as well as lines 7 and 10 in the afternoon. With the three survey flights carried out so far, the area is covered in its full extend, even though with a wider line spacing. Every morning and evening we carry out reference readings with

our portable gravity meter while the airborne gravity meter in the cabin is operated as well, performing a base reading.
The shelter, in which we have our little office with our computers for data back-up, spare parts etc., is heated by an oil burning oven, which was already at Dome C when the EPICA ice core was drilled more than ten years ago.

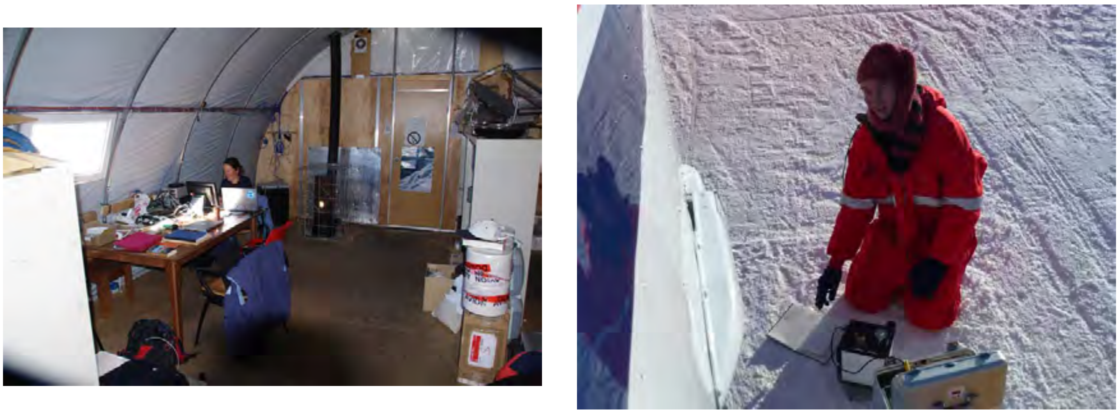

Figure 32: (a) Departure screen of Cape Town International airport; (b) aircraft in Antarctica: IL-76 and Basler BT-67 Foto 18-01_ck_P1070589.JPG by Christian Konrad .

19/Jan
We are slowly getting used to low temperatures and the high altitude of Concordia. However, the cabin is preheated every morning with a hot air blower. The only difficulty with the simple blower is, that its temperature range can only very coarse tuned: hot to very hot. This is sometimes a problem for the EMIRAD system, since it should be at a stable internal temperature while it is calibrated before take-off and maintain that internal temperature during the flight. However, by opening the curtains in the back of the airplane letting in cold air, and having the pilots operating the cabin heat appropriately, a reasonably stable ambient temperature for EMIRAD has been achieved. Hence, EMIRAD has been able to maintain a reasonably stable internal temperature.

Figure 33: IL-76 and Basler BT-67.

20/Jan
Daily flight planning is base on the forecasts for the Dome C area received by email in

the morning before breakfast and later observations from Concordia station are also available at the stations radio office. Due to up-coming clouds around lunchtime, consistent with forecasts from both the u.s. service in Charleston and the Italian meteorologist at Mario Zucchelli, and satellite pictures, we had to cancel any flight activity today.
In the evening we gave a presentation for the station personnel on our project. The lecture room was fully booked and we had an interesting discussion at the end initiated by many questions from the station personnel.

Figure 34: IL-76 and Basler BT-67.

21/Jan
Because of the orientation of the flight pattern, direct sunshine into the side looking antenna has to be avoided and we had to wait until early afternoon before starting to a combined survey and calibration flight. Having carried out this long flight successfully, there is only one survey remaining. Since that will also be an afternoon flight, refueling with help of the station's personnel will be done tomorrow morning.

22/Jan
During the day we packed our stuff together, refueled, and prepared for the last survey flight, which we carried out in the afternoon. Before dinner we packed the aircraft and started towards South Pole after having had the last dinner at Concordia. Unfortunately after an hours flight came an amendment of the forecast for South Pole and we had to return to Concordia, where we again got a warm welcome.

23/Jan
After breakfast we once again packed the aircraft and collected all forecasts for transit to the South Pole and further on to Kohnen Station. Luckily the fueling crew at Amundsen-Scott agreed to refuel us in the evening and thus allowed our long transit day starting from Concordia (UTC+8) via Amundsen-Scott (UTC+13) to Kohnen (UTC). We started at Concordia at 10:00 local and arrived at Kohnen at 14:00 local after almost 12 hours of flying.

24/Jan
Today the leg of the transit back to Novo started after refueling and an early breakfast. After arrival at Novo, we unloaded the aircraft and started the last base reading

Figure 35: IL-76 and Basler BT-67.

with the gravity meter. During de-installation of the scientific instrumentation, the alignment of the EMIRAD antennas was measured once again.

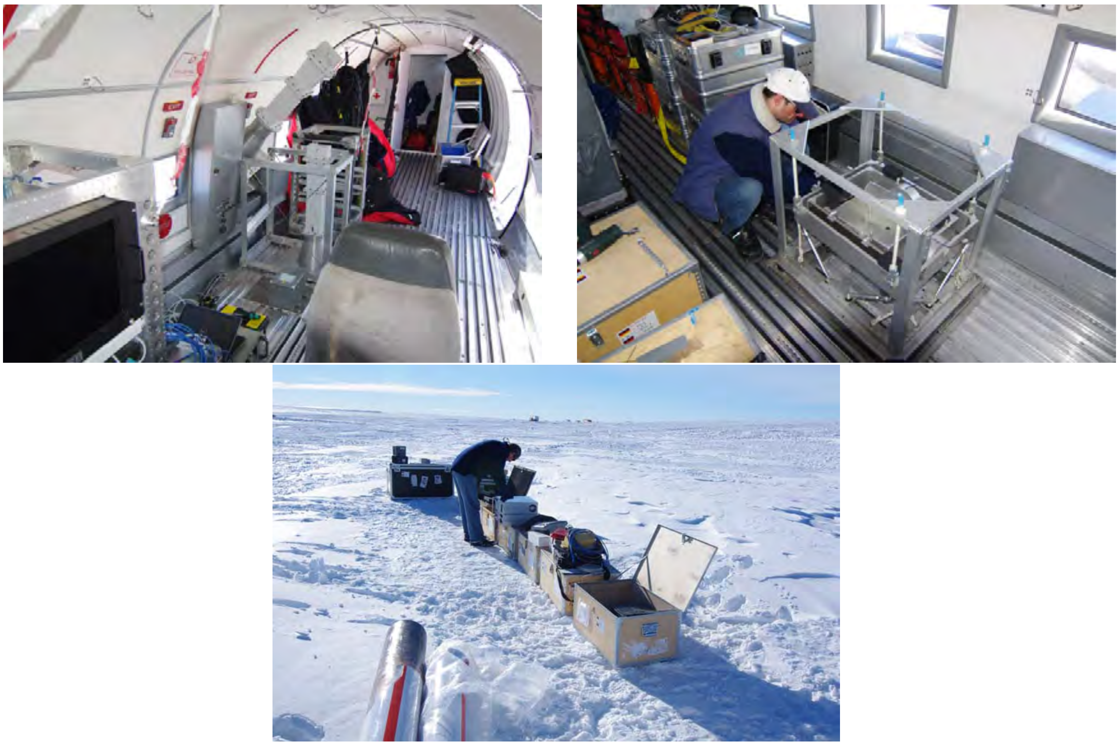

Figure 36: (a) Departure screen of Cape Town International airport; (b) aircraft in Antarctica: IL-76 and Basler BT-67.

25/Jan
With packing and labelling of the packed equipment the DOMECair campaign is finished. We now have to wait three days for the departure of DROMLAN flight #9 back to Cape Town.

B User event lists of survey flights

Table 4: Event list of flight 1301123801.

Event No	Date	Time UTC	Position	Remark
0	2013-01-12	11:05:53.070	70° 49.474' S 11° 38.581' E	Taxi
1	2013-01-12	11:11:29.510	70° 49.461' S 11° 37.543' E	Takeoff
2	2013-01-12	11:13:26.523	70° 48.500' S 11° 43.753' E	Rollerdoors open
3	2013-01-12	11:13:56.789	70° 47.382' S 11° 45.014' E	VQ580 start logging at 150kHz
4	2013-01-12	11:15:06.038	70° 44.603' S 11° 47.582' E	Canon start interval
5	2013-01-12	11:15:24.959	70° 43.870' S 11° 48.404' E	Video ON
6	2013-01-12	11:15:51.833	70° 42.761' S 11° 49.837' E	AIMMS working
7	2013-01-12	11:19:54.841	70° 32.527' S 12° 1.954' E	Restart Gravimeter
8	2013-01-12	11:30:41.348	70° 6.289' S 12° 26.132' E	VQ580 restart 150kz and 1500ft
9	2013-01-12	11:46:03.487	69° 42.302' S 12° 40.473' E	cal mqaneuve4rs
10	2013-01-12	11:51:20.818	69° 36.943' S 12° 58.396' E	end of roll manoevers
11	2013-01-12	11:54:34.320	69° 41.415' S 12° 52.706' E	start of roll manoevers
12	2013-01-12	11:56:37.443	69° 40.186' S 13° 2.493' E	end of roll manoevers
13	2013-01-12	12:01:24.566	69° 50.460' S 12° 49.011' E	Heating ON again
14	2013-01-12	12:02:20.612	69° 52.876' S 12° 46.815' E	Eiskante erreicvht
15	2013-01-12	12:17:28.209	70° 30.007' S 11° 52.642' E	video stop VQ580 stop
16	2013-01-12	12:18:23.631	70° 32.013' S 11° 48.422' E	Rollerdoors closed
17	2013-01-12	12:18:37.647	70° 32.544' S 11° 47.474' E	Canon stop interval
18	2013-01-12	12:27:39.799	70° 49.239' S 11° 35.405' E	Touchdown
19	2013-01-12	12:30:44.972	70° 49.438' S 11° 38.484' E	Park Position
20	2013-01-12	12:31:55.502	70° 49.439' S 11° 38.495' E	STOP AIMMS20

Table 5: Event list of flight 1301133901.

Event No	Date	Time UTC	Position	Remark
0	2013-01-13	14:31:23.596	70° 49.439' S 11° 38.495' E	taxi
1	2013-01-13	14:37:42.250	70° 49.463' S 11° 37.567' E	take off
2	2013-01-13	14:40:25.014	70° 52.433' S 11° 39.141' E	roller doors open
3	2013-01-13	14:41:05.716	70° 53.683' S 11° 36.425' E	canon first picture
4	2013-01-13	14:41:23.951	70° 54.262' S 11° 35.194' E	video start
5	2013-01-13	14:42:34.262	70° 56.462' S 11° 30.330' E	laserscanner start
6	2013-01-13	14:45:27.045	71° 1.446' S 11° 18.946' E	laser scanner stop
7	2013-01-13	14:46:14.467	71° 2.930' S 11° 16.204' E	laser scanner start
8	2013-01-13	14:49:39.451	71° 9.775' S 11° 1.991' E	laser scanner stop
9	2013-01-13	14:50:20.937	71° 11.160' S 10° 59.191' E	laser scanner start
10	2013-01-13	14:51:06.891	71° 12.772' S 10° 56.645' E	slight broken clouds below
11	2013-01-13	14:54:56.253	71° 20.596' S 10° 39.766' E	laser scanner stop
12	2013-01-13	15:03:33.189	71° 40.985' S 9° 53.879' E	Grav ST on
13	2013-01-13	15:11:49.883	72° 2.811' S 9° 6.609' E	laser scanner restart
14	2013-01-13	15:14:19.188	72° 8.955' S 8° 51.297' E	laser scanner restart
15	2013-01-13	15:14:28.813	72° 9.330' S 8° 50.362' E	video start
16	2013-01-13	15:28:09.515	72° 43.664' S 7° 19.011' E	laser scanner stop
17	2013-01-13	15:28:54.706	72° 45.423' S 7° 13.251' E	laser scanner start
18	2013-01-13	15:45:50.112	73° 28.888' S 5° 12.442' E	video stop
19	2013-01-13	15:46:02.190	73° 29.423' S 5° 10.715' E	video start
20	2013-01-13	16:06:02.014	74° 17.428' S 2° 36.199' E	aimms20 recording too low temperature°
21	2013-01-13	16:21:14.077	74° 53.403' S 0° 32.482' E	roller doors closed
22	2013-01-13	16:21:26.874	74° 53.933' S 0° 30.641' E	canon stop
23	2013-01-13	16:22:05.208	74° 55.493' S 0° 25.046' E	video stop
24	2013-01-13	16:22:29.837	74° 56.490' S 0° 21.257' E	laser scanner stop
25	2013-01-13	16:26:59.339	75° 0.259' S 0° 0.291' E	touch down
26	2013-01-13	16:29:55.855	75° 0.059' S 0° 3.703' E	parking position

Table 6: Event list of flight 1301134001.

Event No	Date	Time UTC	Position	Remark
0	2013-01-13	17:56:14.054	75° 0.059' S 0° 3.709' E	Taxi
1	2013-01-13	18:02:55.004	74° 59.841' S 0° 3.461' E	Takeoff
2	2013-01-13	18:05:40.180	74° 59.838' S 0° 19.061' E	Rollerdoors open
3	2013-01-13	18:06:56.228	75° 2.990' S 0° 20.573' E	VQ580 start logging
4	2013-01-13	18:07:40.803	75° 4.852' S 0° 20.194' E	Canon start interval 8sec
5	2013-01-13	18:15:11.406	75° 26.936' S 0° 18.693' E	ScreenDump-DMS-OPERATOR1-Gravimeter-2013-01-13-18-15-11.jpg
6	2013-01-13	18:15:11.094	75° 26.936' S 0° 18.693' E	AIMM20 temperature reading at -56dC
7	2013-01-13	18:36:39.429	76° 33.808' S 0° 17.358' E	AIMMS20 temperature measurement at -24dC

Table 7: Event list of flight 1301134003.

Event No	Date	Time UTC	Position	Remark
0	2013-01-13	19:01:25.887	77° 52.023' S 0° 11.602' E	restart VQ580 at 50kHz 4500kHz
1	2013-01-13	19:02:45.048	77° 56.123' S 0° 10.939' E	clouds
2	2013-01-13	19:05:27.590	78° 4.514' S 0° 9.239' E	two times DMS System breaker OUT; changed from 1300ZP to 1260ZP (both 5Amp)
3	2013-01-13	19:11:27.116	78° 23.138' S 0° 7.444' E	turbulences
4	2013-01-13	19:21:39.566	78° 53.313' S 0° 6.422' E	clouds
5	2013-01-13	19:29:11.693	79° 16.677' S 0° 3.883' E	Grav ST sync
6	2013-01-13	19:30:17.106	79° 20.016' S 0° 3.927' E	Toggle video
7	2013-01-13	19:45:36.483	80° 6.627' S 0° 0.028' E	ADC-TAT =-20dC and AIMMS20 Temp= -20dC as well
8	2013-01-13	19:47:32.910	80° 12.611' S 0° 0.984' W	Clouds; VQ580 no reflection
9	2013-01-13	19:51:51.101	80° 25.846' S 0° 2.029' W	VQ580 toggle
10	2013-01-13	19:52:20.656	80° 27.395' S 0° 2.094' W	no clouds anymore
11	2013-01-13	19:55:01.546	80° 35.680' S 0° 2.809' W	clouds again
12	2013-01-13	20:53:24.958	83° 33.573' S 1° 21.831' W	VQ580 toggle
13	2013-01-13	20:54:14.912	83° 36.135' S 1° 22.631' W	VQ580 toggle
14	2013-01-13	20:54:22.674	83° 36.540' S 1° 22.835' W	Video toggle
15	2013-01-13	21:42:22.531	86° 0.878' S 4° 21.423' W	Video toggle
16	2013-01-13	21:43:11.860	86° 3.297' S 4° 25.969' W	VQ580 toggle
17	2013-01-13	21:58:48.676	86° 49.553' S 6° 20.353' W	phone call
18	2013-01-13	22:25:13.761	88° 6.788' S 13° 8.879' W	video toggle
19	2013-01-13	22:32:33.026	88° 27.962' S 16° 57.101' W	turbulences
20	2013-01-13	23:05:16.445	89° 46.977' S 107° 48.074' W	Grav ST off
21	2013-01-13	23:05:28.901	89° 46.868' S 110° 22.051' W	Grav clamped
22	2013-01-13	23:08:51.086	89° 50.597' S 147° 20.102' W	Vq58°0 off rollerdoors closed
23	2013-01-13	23:10:32.224	89° 53.889' S 155° 32.208' W	video stop
24	2013-01-13	23:12:47.130	89° 58.536' S 148° 26.357' W	Touchdown
25	2013-01-13	23:15:42.526	89° 59.808' S 107° 4.734' W	Park Position

Table 8: Event list of flight 1301154101.

Event No	Date	Time UTC	Position	Remark
0	2013-01-15	19:58:14.480	89° 59.740' S 127° 39.382' W	taxi
1	2013-01-15	20:03:23.939	89° 59.685' S 105° 34.014' W	take off
2	2013-01-15	20:08:33.116	89° 53.567' S 159° 53.987' W	roller doors open, laser scanner on
3	2013-01-15	20:09:28.801	89° 52.229' S 165° 58.640' W	canon first picture
4	2013-01-15	20:10:11.160	89° 51.494' S 171° 37.447' W	video start
5	2013-01-15	20:14:17.047	89° 46.180' S 170° 6.869' E	INS time out
6	2013-01-15	20:39:17.555	88° 44.764' S 130° 34.673' E	Grav unclamped
7	2013-01-15	20:40:25.745	88° 42.434' S 130° 19.874' E	Grav ST on
8	2013-01-15	20:41:51.247	88° 39.498' S 130° 3.281' E	Grav data not in agreement with Ultrasys program

Table 9: Event list of flight 1301154102.

Event No	Date	Time UTC	Position	Remark
no	entrys	due	to	immediate restart

Table 10: Event list of flight 1301154103.

Event No	Date	Time UTC	Position	Remark
0	2013-01-15	21:52:59.778	85° 21.049' S 124° 49.198' E	laser scanner started again but broken clouds below
1	2013-01-15	22:02:50.792	84° 44.699' S 124° 35.935' E	videdo stop
2	2013-01-15	22:03:13.045	84° 43.861' S 124° 36.297' E	video start
3	2013-01-15	22:35:46.757	83° 13.141' S 124° 4.220' E	video stop
4	2013-01-15	22:36:03.679	83° 12.485' S 124° 4.190' E	video start
5	2013-01-15	22:51:04.674	82° 22.849' S 123° 55.991' E	laser scanner toggle
6	2013-01-15	22:52:01.956	82° 20.556' S 123° 55.540' E	canon failed
7	2013-01-15	22:53:52.726	82° 16.294' S 123° 54.570' E	canon restart
8	2013-01-15	23:07:37.956	81° 28.726' S 123° 42.999' E	laser scanner and aimms20 stopped
9	2013-01-15	23:09:12.015	81° 24.819' S 123° 43.497' E	laser scanner and aimms20 restarted
10	2013-01-15	23:10:36.443	81° 21.244' S 123° 43.799' E	video stopped
11	2013-01-15	23:10:56.446	81° 19.893' S 123° 44.008' E	Taxi
12	2013-01-15	23:44:14.080	79° 32.711' S 123° 38.164' E	video stop
13	2013-01-15	23:44:35.580	79° 31.858' S 123° 38.079' E	video start
14	2013-01-16	00:02:44.563	78° 31.980' S 123° 32.167' E	laser scanner toggle
15	2013-01-16	00:17:06.853	77° 41.678' S 123° 27.467' E	video stop
16	2013-01-16	00:17:29.978	77° 40.771' S 123° 27.430' E	video start
17	2013-01-16	00:49:53.721	76° 1.915' S 123° 17.773' E	video stop
18	2013-01-16	00:50:09.599	76° 1.292' S 123° 17.855' E	video start
19	2013-01-16	01:02:18.694	75° 31.830' S 123° 19.501' E	grav clamped
20	2013-01-16	01:05:07.563	75° 10.170' S 123° 21.912' E	laser scanner off
21	2013-01-16	01:05:53.266	75° 8.339' S 123° 22.531' E	video stop
22	2013-01-16	01:06:14.301	75° 7.564' S 123° 22.770' E	canon stop
23	2013-01-16	01:08:39.196	75° 4.340' S Old 123° 24.44	E Old touchdown
24	2013-01-16	01:14:53.907	75° 6.036' S 123° 20.940' E	parking position

Table 11: Event list of flight 1301174201.

Event No	Date	Time UTC	Position	Remark
0	2013-01-17	00:50:13.166	75° 6.017' S 123° 20.327' E	No Gravity measurement on this survey flight
1	2013-01-17	01:02:39.531	75° 6.017' S 123° 20.327' E	Taxi
2	2013-01-17	01:08:24.529	75° 6.304' S 123° 21.397' E	Takeoff
3	2013-01-17	01:10:42.515	75° 9.699' S 123° 16.483' E	Rollerdoors open
4	2013-01-17	01:11:09.718	75° 9.904' S 123° 13.409' E	ScreenDump-DMS-OPERATOR1-MapViewer-2013-01-17-01-11-09.jpg
5	2013-01-17	01:11:11.546	75° 9.906' S 123° 13.288' E	VQ580 ON 150kHz
6	2013-01-17	01:11:29.646	75° 9.930' S 123° 10.960' E	Vuideo ON
7	2013-01-17	01:11:57.333	75° 9.920' S 123° 7.546' E	Canon start interval 8sec
8	2013-01-17	01:25:26.598	75° 1.519' S 121° 3.611' E	HF position report
9	2013-01-17	01:27:50.593	74° 57.952' S 120° 43.355' E	start rolling with bank angle 10deg clockwise
10	2013-01-17	01:41:57.223	74° 50.144' S 121° 7.749' E	Toggle video
11	2013-01-17	01:43:39.289	74° 53.224' S 121° 9.597' E	Toggle VQ580
12	2013-01-17	01:44:25.054	74° 53.232' S 121° 3.576' E	3 turns completed
13	2013-01-17	01:58:42.447	74° 48.811' S 121° 17.783' E	CPC 2 restart
14	2013-01-17	01:59:44.166	74° 46.326' S 121° 18.011' E	restart video
15	2013-01-17	02:00:04.306	74° 45.709' S 121° 20.887' E	restart AIMMS20 software
16	2013-01-17	02:03:00.179	74° 48.237' S 121° 24.495' E	Compact PC 2 restarted again

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Table 11 – continued from previous page

Event	Date	Time	Position	Remark
17	2013-01-17	02:05:48.289	74° 45.248' S 121° 36.095' E	CPC2 video and AIMMS20 software restarted
18	2013-01-17	02:15:21.684	74° 43.658' S 121° 47.223' E	Toggle VQ580
19	2013-01-17	02:21:39.446	74° 42.699' S 121° 42.090' E	CPC restarted again
20	2013-01-17	02:25:15.771	74° 42.485' S 121° 51.749' E	end of roll clockwise and go back to starting point
21	2013-01-17	02:26:49.256	74° 41.746' S 121° 38.579' E	CPC2 restarted again; no video any-more
22	2013-01-17	02:39:25.826	74° 57.576' S 120° 40.850' E	start rolling anticlockwise with 10deg banking
23	2013-01-17	02:48:46.128	74° 55.953' S 120° 49.844' E	VQ580 toggle
24	2013-01-17	03:27:34.722	74° 45.599' S 121° 23.650' E	VQ580 Toggle
25	2013-01-17	03:37:58.964	74° 42.810' S 121° 37.003' E	end of rolling counterclockwise
26	2013-01-17	03:41:03.088	74° 42.223' S 122° 4.430' E	heater off for trend
27	2013-01-17	03:41:42.219	74° 43.105' S 122° 9.930' E	heat is on again
28	2013-01-17	03:51:32.908	74° 58.522' S 123° 28.935' E	Canon and Vq580 stop
29	2013-01-17	03:52:32.534	75° 0.725' S 123° 27.901' E	Rollerdoors closed
30	2013-01-17	03:55:25.486	75° 5.775' S 123° 21.975' E	Touchdown
31	2013-01-17	04:01:08.919	75° 6.012' S 123° 20.160' E	Park Position

Table 12: Event list of flight 1301174301.

Event No	Date	Time UTC	Position	Remark
0	2013-01-17	06:27:59.106	75° 6.013' S 123° 20.160' E	taxi
1	2013-01-17	06:34:04.067	75° 6.228' S 123° 21.475' E	take off
2	2013-01-17	06:36:09.907	75° 9.630' S 123° 20.014' E	roller doors open
3	2013-01-17	06:36:34.702	75° 10.332' S 123° 21.059' E	laser scanner start
4	2013-01-17	06:37:08.031	75° 11.294' S 123° 22.625' E	canon fiirst picture
5	2013-01-17	06:39:25.764	75° 16.157' S 123° 33.750' E	grav unclamp
6	2013-01-17	06:39:56.561	75° 17.293' S 123° 36.584' E	Grav ST on
7	2013-01-17	06:42:31.806	75° 23.295' S 123° 50.346' E	Grav ST sync
8	2013-01-17	06:51:59.633	75° 44.899' S 124° 39.099' E	video start
9	2013-01-17	06:54:35.894	75° 51.186' S 124° 48.177' E	video stop
10	2013-01-17	06:55:02.738	75° 52.299' S 124° 49.610' E	video start
11	2013-01-17	06:56:43.561	75° 56.450' S 124° 55.332' E	canon failed
12	2013-01-17	06:58:09.841	75° 59.972' S 125° 0.492' E	canon restart
13	2013-01-17	06:59:05.136	76° 2.216' S 125° 3.803' E	video stop
14	2013-01-17	06:59:38.570	76° 3.567' S 125° 5.623' E	video start
15	2013-01-17	07:06:48.728	76° 21.383' S 125° 26.723' E	ScreenDump-DMS-OPERATOR1-UserEventTabel-2013-01-17-07-06-48.jpg
16	2013-01-17	07:06:50.368	76° 21.383' S 125° 26.723' E	Grav ST off and clamped
17	2013-01-17	07:08:38.394	76° 25.621' S 125° 20.459' E	laser scanner toggle
18	2013-01-17	07:13:12.711	76° 29.240' S 124° 34.390' E	Grav unclamp
19	2013-01-17	07:13:33.724	76° 29.106' S 124° 30.403' E	waypoint
20	2013-01-17	07:13:52.287	76° 29.000' S 124° 26.808' E	Grav ST on
21	2013-01-17	07:52:46.474	76° 8.074' S 117° 28.586' E	video stop
22	2013-01-17	07:52:59.583	76° 7.935' S 117° 26.172' E	video start
23	2013-01-17	07:53:54.099	76° 7.305' S 117° 16.857' E	laser scanner toggle
24	2013-01-17	08:24:50.794	75° 42.356' S 112° 3.737' E	waypoint
25	2013-01-17	08:25:36.263	75° 41.663' S 111° 56.274' E	Grav ST off and clamped
26	2013-01-17	08:25:53.263	75° 41.205' S 111° 53.944' E	turning
27	2013-01-17	08:26:10.295	75° 40.394' S 111° 53.117' E	video stop
28	2013-01-17	08:26:47.685	75° 38.658' S 111° 52.886' E	laser scanner toggle
29	2013-01-17	08:27:16.107	75° 37.138' S 111° 52.918' E	rolling procedure for emirad
30	2013-01-17	08:33:57.300	75° 17.311' S 112° 16.995' E	rolling procedure for emirad
31	2013-01-17	08:46:39.065	74° 47.882' S 113° 18.425' E	Grav unclamped
32	2013-01-17	08:47:22.877	74° 48.480' S 113° 25.332' E	video start
33	2013-01-17	08:47:39.620	74° 48.736' S 113° 27.809' E	laser scanner toggle
34	2013-01-17	08:48:07.698	74° 49.138' S 113° 32.117' E	Grav ST on
35	2013-01-17	08:48:24.073	74° 49.359' S 113° 34.906' E	waypoint
36	2013-01-17	09:04:05.076	75° 2.212' S 116° 7.480' E	PC2 with video and aimms20 failed
37	2013-01-17	09:05:06.184	75° 2.998' S 116° 17.310' E	PC2 and aimms20 log restarted
38	2013-01-17	09:08:06.594	75° 5.155' S 116° 47.241' E	Grav ST sync
39	2013-01-17	09:29:49.518	75° 19.496' S 120° 28.051' E	laser scanner toggle
40	2013-01-17	09:57:18.904	75° 32.304' S 125° 10.953' E	waypoint

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Table 12 – continued from previous page

Event	Date	Time	Position	Remark
41	2013-01-17	09:58:26.472	75° 32.039' S 125° 22.349' E	Grav ST off anc clamped
42	2013-01-17	10:10:54.821	75° 5.098' S 123° 47.697' E	roller doors closed
43	2013-01-17	10:11:35.133	75° 4.382' S 123° 42.010' E	laser scanner stopped
44	2013-01-17	10:11:49.383	75° 4.153' S 123° 40.042' E	canon stopped
45	2013-01-17	10:15:13.294	75° 5.777' S 123° 21.973' E	touchdown
46	2013-01-17	10:20:11.376	75° 6.007' S 123° 20.162' E	parking position

Table 13: Event list of flight 1301184401.

Event No	Date	Time UTC	Position	Remark
0	2013-01-18	00:36:32.662	75° 6.012' S 123° 20.150' E	Taxi
1	2013-01-18	00:43:51.744	75° 6.631' S 123° 21.034' E	No text
2	2013-01-18	00:43:58.619	75° 6.498' S 123° 21.181' E	Takeoff
3	2013-01-18	00:46:28.162	75° 2.196' S 123° 22.520' E	Rollewrdoors open
4	2013-01-18	00:46:56.129	75° 1.845' S 123° 18.942' E	VQ580 start 150kHz
5	2013-01-18	00:47:31.768	75° 1.454' S 123° 14.593' E	video ON
6	2013-01-18	00:48:00.799	75° 1.614' S 123° 10.793' E	Canon start interval
7	2013-01-18	00:50:44.482	75° 7.427' S 122° 54.553' E	Grav unclamped
8	2013-01-18	00:54:14.571	75° 13.963' S 122° 26.880' E	Grav ST on
9	2013-01-18	00:54:50.498	75° 14.980' S 122° 21.969' E	Grav ST off
10	2013-01-18	00:55:40.802	75° 16.507' S 122° 14.814' E	Grav ST on
11	2013-01-18	00:55:50.349	75° 16.770' S 122° 13.549' E	Grav ST sync
12	2013-01-18	01:15:57.673	75° 53.299' S 119° 22.285' E	Toggle VQ580
13	2013-01-18	01:32:19.184	76° 21.293' S 116° 55.433' E	Grav ST off
14	2013-01-18	01:32:50.927	76° 22.242' S 116° 50.425' E	Grav clamped
15	2013-01-18	01:33:35.828	76° 23.979' S 116° 46.869' E	Restart Canon
16	2013-01-18	01:34:03.874	76° 25.291' S 116° 46.400' E	toggle video
17	2013-01-18	01:34:30.641	76° 26.495' S 116° 47.789' E	toggle VQ580
18	2013-01-18	01:39:51.599	76° 12.293' S 117° 1.249' E	restart Gravitymeter due to bad FOG Status
19	2013-01-18	01:41:40.049	76° 6.962' S 117° 3.185' E	Grav unclamped
20	2013-01-18	01:43:19.515	76° 1.940' S 117° 4.720' E	Grav ST sync
21	2013-01-18	01:43:42.263	76° 0.768' S 117° 4.961' E	Grav ST on
22	2013-01-18	01:48:52.237	75° 45.227' S 117° 10.254' E	No text
23	2013-01-18	02:05:03.478	74° 56.932' S 117° 24.195' E	VQ580 toggle
24	2013-01-18	02:21:16.214	74° 8.086' S 117° 37.603' E	Video toggle
25	2013-01-18	02:36:17.960	73° 23.298' S 117° 48.280' E	VQ580 toiggle
26	2013-01-18	02:54:23.092	72° 29.804' S 117° 59.914' E	Grav ST off
27	2013-01-18	02:55:12.294	72° 27.320' S 118° 0.009' E	Grav clamped
28	2013-01-18	02:56:58.510	72° 26.662' S 117° 45.698' E	rolling 30 deg start
29	2013-01-18	02:58:14.570	72° 27.728' S 117° 33.887' E	rolling 30deg stop
30	2013-01-18	03:07:26.212	72° 34.529' S 116° 6.738' E	video toggle
31	2013-01-18	03:09:25.754	72° 39.251' S 115° 55.815' E	VQ580 toggle
32	2013-01-18	03:11:13.597	72° 41.374' S 116° 10.707' E	GRAV bad fog status: Restart
33	2013-01-18	03:14:35.606	72° 44.289' S 116° 43.676' E	Grav ST sync
34	2013-01-18	03:14:53.965	72° 44.494' S 116° 46.783' E	Grav ST on
35	2013-01-18	03:45:48.475	73° 6.430' S 121° 50.962' E	VQ580 toggle
36	2013-01-18	03:53:04.358	73° 10.342' S 123° 3.906' E	Video toggle
37	2013-01-18	04:12:58.129	73° 19.131' S 126° 27.562' E	Grav ST off
38	2013-01-18	04:13:43.798	73° 19.425' S 126° 35.249' E	Grav clamped
39	2013-01-18	04:15:59.558	73° 15.221' S 126° 45.501' E	Grav ST sync
40	2013-01-18	04:18:30.321	73° 18.207' S 126° 27.186' E	Grav unclamped
41	2013-01-18	04:18:39.867	73° 18.631' S 126° 26.616' E	Grav ST on
42	2013-01-18	04:19:09.383	73° 20.019' S 126° 24.558' E	Grav ST sync
43	2013-01-18	04:20:20.639	73° 23.311' S 126° 19.446' E	VQ580 toggle
44	2013-01-18	04:30:27.149	73° 51.401' S 125° 37.562' E	Video toggle#
45	2013-01-18	04:54:22.699	74° 56.807' S 123° 43.300' E	Grav ST off and clamped
46	2013-01-18	04:58:05.284	75° 4.246' S 123° 24.841' E	Rollerdoors closed, VQ580 off, Video off, canon off
47	2013-01-18	05:01:07.803	75° 6.860' S 123° 20.785' E	Touchdown
48	2013-01-18	05:04:15.989	75° 6.008' S 123° 20.168' E	Park Position

Table 14: Event list of flight 1301184501.

Event No	Date	Time UTC	Position	Remark
0	2013-01-18	06:20:03.920	75° 6.011’ S 123° 20.159’ E	taxi
1	2013-01-18	06:28:02.700	75° 6.412’ S 123° 21.269’ E	take off
2	2013-01-18	06:30:07.416	75° 3.121’ S 123° 28.048’ E	roller doors open
3	2013-01-18	06:30:48.413	75° 2.459’ S 123° 33.214’ E	canon first picture
4	2013-01-18	06:31:01.773	75° 2.273’ S 123° 34.884’ E	video starst
5	2013-01-18	06:32:03.223	75° 1.371’ S 123° 43.709’ E	laser scanner started
6	2013-01-18	06:33:59.156	74° 59.970’ S 124° 4.111’ E	Grav unclamp
7	2013-01-18	06:35:02.529	74° 58.920’ S 124° 15.439’ E	Grav ST on
8	2013-01-18	06:45:52.083	74° 44.507’ S 126° 4.072’ E	Grav St off and clamped
9	2013-01-18	06:51:08.090	74° 35.331’ S 125° 43.992’ E	Grav unclamp
10	2013-01-18	06:55:14.879	74° 33.861’ S 125° 1.440’ E	Grav failed
11	2013-01-18	06:57:16.327	74° 33.070’ S 124° 40.569’ E	canon stop
12	2013-01-18	06:59:56.367	74° 31.771’ S 124° 13.030’ E	canon restart
13	2013-01-18	07:04:48.167	74° 29.725’ S 123° 23.053’ E	Grav unclamp and ST on
14	2013-01-18	07:08:44.752	74° 27.825’ S 122° 42.472’ E	laser scanner toggle
15	2013-01-18	07:26:05.355	74° 17.768’ S 119° 44.653’ E	video stop
16	2013-01-18	07:26:22.939	74° 17.593’ S 119° 41.409’ E	video start
17	2013-01-18	07:44:52.484	74° 4.022’ S 116° 32.440’ E	laser scanner toggle
18	2013-01-18	07:56:39.091	73° 53.790’ S 114° 33.874’ E	ScreenDump-DMS-OPERATOR1-UserEventTabel-2013-01-18-07-56-39.jpg
19	2013-01-18	07:56:41.248	73° 53.762’ S 114° 33.539’ E	Grav clamped and ST off
20	2013-01-18	07:56:54.248	73° 53.489’ S 114° 31.736’ E	waypoint, turning
21	2013-01-18	07:59:03.135	73° 47.426’ S 114° 34.248’ E	Grav unclamped
22	2013-01-18	08:00:13.524	73° 44.114’ S 114° 36.957’ E	Grav ST on
23	2013-01-18	08:14:10.049	73° 4.684’ S 115° 11.669’ E	Grav ST off and clamped
24	2013-01-18	08:14:58.424	73° 2.479’ S 115° 14.327’ E	video stop
25	2013-01-18	08:15:07.236	73° 2.013’ S 115° 14.835’ E	video start
26	2013-01-18	08:16:07.702	72° 59.593’ S 115° 20.251’ E	turning
27	2013-01-18	08:17:41.401	72° 58.351’ S 115° 34.678’ E	laser scanner toggle
28	2013-01-18	08:19:16.243	72° 59.914’ S 115° 50.026’ E	Grav unclamped
29	2013-01-18	08:20:11.102	73° 0.723’ S 115° 59.036’ E	Grav ST on
30	2013-01-18	09:00:23.485	73° 28.914’ S 122° 50.262’ E	laser scanner toggle
31	2013-01-18	09:09:22.364	73° 32.970’ S 124° 24.278’ E	video stop
32	2013-01-18	09:09:35.177	73° 33.113’ S 124° 26.725’ E	video start
33	2013-01-18	09:20:01.461	73° 38.096’ S 126° 16.099’ E	wapoint
34	2013-01-18	09:20:39.348	73° 38.282’ S 126° 22.695’ E	Grav ST off and clamped
35	2013-01-18	09:20:49.442	73° 38.464’ S 126° 24.532’ E	turning
36	2013-01-18	09:21:42.971	73° 40.815’ S 126° 25.636’ E	laser scanner toggle
37	2013-01-18	09:25:55.822	73° 49.731’ S 125° 55.968’ E	Grav unclamped
38	2013-01-18	09:27:17.227	73° 53.463’ S 125° 49.557’ E	Grav ST on
39	2013-01-18	09:52:59.842	75° 1.881’ S 123° 38.573’ E	Grav ST off and clamped
40	2013-01-18	09:55:38.341	75° 8.470’ S 123° 26.675’ E	roller doors closed
41	2013-01-18	09:55:49.607	75° 8.859’ S 123° 25.895’ E	canon stop
42	2013-01-18	09:56:24.714	75° 9.229’ S 123° 22.003’ E	video stop
43	2013-01-18	09:56:40.698	75° 8.967’ S 123° 20.373’ E	laser scanner stop
44	2013-01-18	09:57:46.604	75° 6.958’ S 123° 20.679’ E	touchdown
45	2013-01-18	10:01:32.459	75° 6.014’ S 123° 20.155’ E	parking position

Table 15: Event list of flight 1301194601.

Event No	Date	Time UTC	Position	Remark
0	2013-01-19	00:32:37.704	75° 6.014’ S 123° 20.155’ E	Taxi
1	2013-01-19	00:40:00.315	75° 6.424’ S 123° 21.262’ E	Takeoff
2	2013-01-19	00:42:07.154	75° 3.196’ S 123° 28.087’ E	Rollerdoors open, Canon START interval 8sec, Video ON, VQ580 START at b150kHz
3	2013-01-19	00:55:49.222	74° 49.137’ S 124° 40.271’ E	Grav unclamped, ST Sync and ST ON
4	2013-01-19	01:08:44.214	75° 11.777’ S 122° 47.221’ E	Iridium phone call
5	2013-01-19	01:14:57.925	75° 22.524’ S 121° 51.258’ E	GRAV ST off and clamped
6	2013-01-19	01:16:29.327	75° 23.734’ S 121° 35.941’ E	Video and VQ580 toggle
7	2013-01-19	01:18:45.432	75° 23.374’ S 121° 46.218’ E	GRAV restart
8	2013-01-19	01:23:00.736	75° 16.207’ S 122° 24.348’ E	GRAV no COM restart again
9	2013-01-19	01:25:23.512	75° 12.135’ S 122° 45.347’ E	

Continued on next page

Table 15 – continued from previous page

Event	Date	Time	Position	Remark
10	2013-01-19	01:25:33.668	75° 11.820' S 122° 46.979' E	Grav ST sync
11	2013-01-19	01:25:53.153	75° 11.250' S 122° 49.985' E	Grav ST on
12	2013-01-19	01:39:01.280	74° 48.265' S 124° 44.609' E	Grav ST off and clamped
13	2013-01-19	01:50:01.440	74° 35.154' S 123° 40.871' E	VQ580 and Video toggle
14	2013-01-19	01:52:09.169	74° 40.332' S 123° 30.943' E	GRAV unclamped and ST ON
15	2013-01-19	02:10:59.302	75° 36.292' S 123° 4.745' E	GRAV clamped and ST OFF
16	2013-01-19	02:22:26.763	75° 31.444' S 123° 3.513' E	GRAC Unclamped and ST ON, ST sync
17	2013-01-19	02:33:14.371	75° 2.320' S 123° 19.696' E	Toggle VQ580 and Video
18	2013-01-19	02:42:38.281	74° 36.713' S 123° 32.604' E	Grav ST off and clamped
19	2013-01-19	02:53:34.967	74° 43.868' S 122° 14.706' E	Grav unclamped and ST ON; ST in SDYNC
20	2013-01-19	02:54:48.533	74° 46.828' S 122° 23.251' E	VQ580 and Video toggle
21	2013-01-19	03:12:13.956	75° 28.865' S 124° 29.410' E	Grav ST off and clamped
22	2013-01-19	03:21:34.410	75° 18.524' S 123° 56.626' E	Grav unclamped and ST on
23	2013-01-19	03:27:09.405	75° 6.343' S 123° 20.593' E	above the station
24	2013-01-19	03:37:55.322	74° 42.494' S 122° 10.489' E	Grav ST off and clamped
25	2013-01-19	03:38:43.775	74° 42.744' S 122° 2.672' E	Toggle VQ580 and Video
26	2013-01-19	03:43:12.925	74° 50.793' S 121° 29.692' E	rolling 30 deg
27	2013-01-19	03:44:38.080	74° 54.792' S 121° 23.938' E	end rolling
28	2013-01-19	03:47:43.762	75° 1.396' S 121° 34.991' E	Grav unclamped and ST ON
29	2013-01-19	03:50:00.822	75° 3.052' S 122° 0.647' E	ST off
30	2013-01-19	03:50:38.351	75° 3.538' S 122° 7.709' E	Grav ST on and SYNC
31	2013-01-19	04:09:32.886	75° 10.884' S 125° 47.100' E	Grav ST off and clamped
32	2013-01-19	04:11:57.386	75° 10.797' S 126° 2.924' E	Toggle VQ580 and Video
33	2013-01-19	04:26:53.011	75° 7.307' S 123° 24.315' E	Canon STOP; VQ580 STOP, Video Stop and Rollerdoors closed
34	2013-01-19	04:29:26.677	75° 6.953' S 123° 20.680' E	Touchdown
35	2013-01-19	04:33:02.908	75° 6.019' S 123° 20.166' E	Park Position
36	2013-01-19	04:37:12.744	75° 6.015' S 123° 20.173' E	No text

Table 16: Event list of flight 1301194701.

Event No	Date	Time UTC	Position	Remark
0	2013-01-19	06:09:50.494	75° 6.012' S 123° 20.157' E	taxi
1	2013-01-19	06:16:48.388	75° 6.509' S 123° 21.165' E	tale off
2	2013-01-19	06:18:54.946	75° 3.404' S 123° 27.376' E	roller doors open
3	2013-01-19	06:19:25.399	75° 3.560' S 123° 31.691' E	laser scanner started
4	2013-01-19	06:20:41.630	75° 4.158' S 123° 42.867' E	canon first picture
5	2013-01-19	06:22:33.984	75° 5.416' S 124° 3.599' E	no video due to faulty image
6	2013-01-19	06:31:11.889	75° 10.876' S 125° 41.530' E	turning towards waypoint
7	2013-01-19	06:39:43.245	75° 9.516' S 124° 58.846' E	Grav unclamped
8	2013-01-19	06:41:03.712	75° 9.086' S 124° 44.249' E	Grav ST on
9	2013-01-19	06:48:55.307	75° 5.879' S 123° 19.519' E	overhead concordia tower
10	2013-01-19	06:55:17.295	75° 3.054' S 122° 11.263' E	laser scanner toggle
11	2013-01-19	06:58:55.482	75° 1.190' S 121° 32.455' E	overhead waypoint
12	2013-01-19	07:39:46.445	74° 33.660' S 114° 28.329' E	laser scanner toggle
13	2013-01-19	07:43:39.439	74° 30.389' S 113° 49.319' E	Grav ST off and clamped
14	2013-01-19	07:45:34.575	74° 25.523' S 113° 46.406' E	rolling procedure for emirad
15	2013-01-19	07:53:10.284	74° 12.694' S 114° 18.663' E	Grav unclemped
16	2013-01-19	07:53:59.595	74° 13.434' S 114° 27.470' E	Grav ST on
17	2013-01-19	07:56:37.207	74° 15.859' S 114° 55.157' E	Grav ST sync
18	2013-01-19	08:17:29.945	74° 33.177' S 118° 37.991' E	laser scanner toggle
19	2013-01-19	08:55:53.934	74° 54.373' S 125° 45.974' E	Grav ST off and clamped
20	2013-01-19	08:56:22.793	74° 54.995' S 125° 50.777' E	turning
21	2013-01-19	09:11:16.801	75° 8.961' S 123° 26.147' E	roller doors closed
22	2013-01-19	09:11:26.754	75° 9.109' S 123° 25.031' E	canon stop
23	2013-01-19	09:12:05.276	75° 8.949' S 123° 20.674' E	laser scanner stopped
24	2013-01-19	09:13:33.562	75° 6.551' S 123° 21.113' E	landed
25	2013-01-19	09:16:26.043	75° 6.018' S 123° 20.156' E	parking position

Table 17: Event list of flight 1301214801.

Event No	Date	Time UTC	Position	Remark
0	2013-01-21	05:18:32.513	75° 6.016’ S 123° 20.159’ E	Taxi
1	2013-01-21	05:27:51.801	75° 6.299’ S 123° 21.398’ E	Takeoff
2	2013-01-21	05:30:05.625	75° 2.394’ S 123° 27.380’ E	Rollerdoors open; Canon firsdt picture and video ON
3	2013-01-21	05:31:30.138	74° 59.780’ S 123° 34.347’ E	VQ580 START 150kHz
4	2013-01-21	05:34:08.508	74° 53.697’ S 123° 48.010’ E	Grav unclamped and ST ON
5	2013-01-21	05:56:18.810	74° 0.610’ S 126° 2.535’ E	GRAV ST off and clamped
6	2013-01-21	05:58:07.239	73° 58.538’ S 126° 19.141’ E	Toggle ALS and Video
7	2013-01-21	06:00:06.058	73° 57.641’ S 126° 3.450’ E	Grav unclamped, ST sync and ON
8	2013-01-21	06:30:53.690	73° 43.131’ S 121° 4.336’ E	Errormessages of ADAC Box! Everything OK again, but what happend°
9	2013-01-21	06:32:51.522	73° 41.962’ S 120° 45.384’ E	ALS and Video toggle
10	2013-01-21	07:06:34.681	73° 17.236’ S 115° 17.321’ E	Grav ST off and clamped
11	2013-01-21	07:07:57.698	73° 19.872’ S 115° 8.426’ E	START rolling 30deg bank angle
12	2013-01-21	07:08:45.245	73° 21.637’ S 115° 2.852’ E	STOP rolling 30deg bank angle
13	2013-01-21	07:15:15.124	73° 35.625’ S 114° 58.040’ E	GRAV unclamped and ST on
14	2013-01-21	07:15:52.249	73° 36.118’ S 115° 3.916’ E	Toggle ALS and VIDEO
15	2013-01-21	07:20:01.462	73° 40.007’ S 115° 46.898’ E	ScreenDump-DMS-OPERATOR1-MapViewer-2013-01-21-07-20-01.jpg
16	2013-01-21	07:20:01.665	73° 40.007’ S 115° 46.898’ E	GRAV Saebusy timeout! restart Gravitymeter
17	2013-01-21	07:24:28.032	73° 43.849’ S 116° 32.854’ E	Grav unclamped, ST sync and ST on again
18	2013-01-21	07:58:15.243	74° 7.533’ S 122° 34.978’ E	Toggle ALS and VQ580
19	2013-01-21	08:17:33.999	74° 16.895’ S 126° 13.549’ E	Grav ST off and clamped
20	2013-01-21	08:22:25.166	74° 23.126’ S 125° 41.035’ E	restart GRAV due to bed FOG staus
21	2013-01-21	08:27:27.005	74° 27.342’ S 124° 52.677’ E	GRAV restarted, unclamped, STsync and ON
22	2013-01-21	08:29:37.895	74° 29.106’ S 124° 31.714’ E	GRAV ST off and clamped
23	2013-01-21	08:32:59.150	74° 32.305’ S 123° 59.838’ E	Toggle ALS and VIDEO
24	2013-01-21	08:34:37.436	74° 33.911’ S 123° 44.627’ E	grav RESTART DUE TO bBAD fog sTATUS
25	2013-01-21	08:37:51.981	74° 36.440’ S 123° 13.098’ E	GRAV restarted, unclamped, ST sync and ST ON
26	2013-01-21	08:50:16.344	74° 45.829’ S 121° 10.275’ E	GRAV ST off and clamped
27	2013-01-21	08:53:44.996	74° 51.983’ S 120° 43.719’ E	srtart 10deg banking left
28	2013-01-21	09:08:47.892	74° 57.408’ S 121° 2.481’ E	Toggle ALS and VIDEO
29	2013-01-21	09:46:32.963	75° 1.596’ S 121° 52.043’ E	Toggle ALS and VIDEO
30	2013-01-21	09:49:00.726	75° 0.569’ S 121° 41.047’ E	end of first drift with bankng
31	2013-01-21	09:58:11.313	74° 51.971’ S 120° 43.435’ E	start banking clockwise
32	2013-01-21	10:22:02.812	74° 56.378’ S 121° 12.898’ E	Toggle ALS and VIDEO
33	2013-01-21	10:56:03.422	74° 54.799’ S 121° 44.644’ E	end of banking
34	2013-01-21	11:00:39.549	75° 3.012’ S 122° 32.635’ E	STOP LAserscanner
35	2013-01-21	11:01:12.796	75° 4.048’ S 122° 38.373’ E	Stop canon and video
36	2013-01-21	11:02:23.109	75° 6.126’ S 122° 50.863’ E	Rollerdoorts closed
37	2013-01-21	11:06:21.605	75° 6.998’ S 123° 20.626’ E	Touchdown
38	2013-01-21	11:09:26.418	75° 6.017’ S 123° 20.156’ E	Park Position

Table 18: Event list of flight 1301224901.

Event No	Date	Time UTC	Position	Remark
0	2013-01-22	05:39:50.374	75° 6.014’ S 123° 20.159’ E	taxi
1	2013-01-22	05:47:24.660	75° 6.334’ S 123° 21.362’ E	take off
2	2013-01-22	05:49:29.422	75° 3.152’ S 123° 27.642’ E	roller doors open
3	2013-01-22	05:50:10.329	75° 3.959’ S 123° 32.415’ E	canon first picture
4	2013-01-22	05:50:32.389	75° 4.747’ S 123° 33.477’ E	video start
5	2013-01-22	05:51:01.373	75° 5.798’ S 123° 34.796’ E	laser scanner start
6	2013-01-22	05:53:55.622	75° 13.437’ S 123° 43.704’ E	Grav unclamped
7	2013-01-22	05:54:49.542	75° 16.003’ S 123° 46.805’ E	Grav ST on
8	2013-01-22	05:57:12.036	75° 22.809’ S 123° 56.086’ E	Grav ST sync
9	2013-01-22	06:11:37.184	76° 2.881’ S 125° 3.446’ E	Grav ST off and clamped
10	2013-01-22	06:12:12.450	76° 4.495’ S 125° 4.607’ E	turning towards waypoint
11	2013-01-22	06:14:49.630	76° 10.589’ S 124° 55.406’ E	laser scanner toggle
12	2013-01-22	06:15:03.427	76° 10.642’ S 124° 53.168’ E	video stop

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Table 18 – continued from previous page

Event	Date	Time	Position	Remark
13	2013-01-22	06:15:11.224	76° 10.651' S 124° 51.783' E	video start
14	2013-01-22	06:15:51.268	76° 10.599' S 124° 44.894' E	passing waypoint
15	2013-01-22	06:16:56.173	76° 10.277' S 124° 33.577' E	Grav unclamoped
16	2013-01-22	06:18:39.778	76° 9.239' S 124° 16.097' E	Grav ST on
17	2013-01-22	06:55:30.530	75° 49.902' S 117° 55.084' E	laser scanner toggle
18	2013-01-22	07:11:19.911	75° 38.315' S 115° 14.189' E	video stop / start
19	2013-01-22	07:27:05.827	75° 24.494' S 112° 32.533' E	passed waypoint
20	2013-01-22	07:27:44.263	75° 23.814' S 112° 25.910' E	Grav ST off and clamped
21	2013-01-22	07:27:53.217	75° 23.662' S 112° 24.556' E	turning
22	2013-01-22	07:28:13.779	75° 22.827' S 112° 22.979' E	laser scanner toggle
23	2013-01-22	07:29:39.261	75° 18.860' S 112° 25.190' E	rolling procedure for emirad
24	2013-01-22	07:34:49.270	75° 6.050' S 112° 46.897' E	clouds below, no laser scanner signal
25	2013-01-22	07:36:15.018	75° 6.827' S 113° 2.886' E	Park Position
26	2013-01-22	07:36:29.212	75° 7.022' S 113° 5.548' E	passed waypoint
27	2013-01-22	07:37:15.071	75° 7.790' S 113° 14.375' E	Grav failed
28	2013-01-22	07:41:08.168	75° 11.764' S 113° 58.285' E	Grav unclamped
29	2013-01-22	07:42:09.667	75° 12.821' S 114° 10.161' E	Grav ST on
30	2013-01-22	07:42:34.009	75° 13.246' S 114° 14.877' E	still broken clouds below
31	2013-01-22	08:04:22.143	75° 32.391' S 118° 39.099' E	video stop / start
32	2013-01-22	08:06:17.780	75° 34.113' S 119° 2.848' E	laser scanner toggle
33	2013-01-22	08:33:28.530	75° 51.254' S 124° 58.165' E	passing waypoint
34	2013-01-22	08:34:10.655	75° 51.449' S 125° 7.647' E	Gras ST off and clamped
35	2013-01-22	08:34:27.218	75° 51.167' S 125° 11.151' E	turning
36	2013-01-22	08:34:54.295	75° 50.011' S 125° 13.421' E	laser scanner toggle
37	2013-01-22	08:36:42.841	75° 45.848' S 125° 2.805' E	Grav unclamped
38	2013-01-22	08:37:15.559	75° 44.605' S 124° 59.387' E	grav ST on
39	2013-01-22	08:45:18.485	75° 26.635' S 124° 10.283' E	canon failed
40	2013-01-22	08:48:55.372	75° 18.789' S 123° 48.069' E	GRAV ST off and clamped
41	2013-01-22	08:52:16.869	75° 12.076' S 123° 26.832' E	roller doors closed
42	2013-01-22	08:52:28.104	75° 11.798' S 123° 25.854' E	video stop
43	2013-01-22	08:52:40.978	75° 11.485' S 123° 24.745' E	laser scanner stop
44	2013-01-22	08:55:26.868	75° 7.015' S 123° 20.609' E	touchdown
45	2013-01-22	08:58:52.863	75° 6.018' S 123° 20.158' E	parking position

Table 19: Event list of flight 1301225001.

Event No	Date	Time UTC	Position	Remark
0	2013-01-22	13:11:51.599	75° 6.016' S 123° 20.161' E	Taxi
1	2013-01-22	13:17:56.800	75° 6.564' S 123° 21.108' E	Takeoff
2	2013-01-22	13:23:41.441	75° 18.200' S 123° 21.147' E	Rollerdoors open
3	2013-01-22	13:24:24.313	75° 20.040' S 123° 21.345' E	Canon first picture
4	2013-01-22	13:25:04.748	75° 21.930' S 123° 21.208' E	Video start
5	2013-01-22	13:26:37.230	75° 26.249' S 123° 21.504' E	Grav unclamped
6	2013-01-22	13:26:49.011	75° 26.855' S 123° 21.607' E	Grav ST sync
7	2013-01-22	13:27:12.853	75° 27.938' S 123° 21.724' E	Grav ST on
8	2013-01-22	13:33:21.788	75° 45.222' S 123° 24.523' E	VQ580 start logging
9	2013-01-22	14:10:40.453	77° 29.394' S 123° 30.809' E	GRAV ST off and clamped
10	2013-01-22	14:12:06.763	77° 26.619' S 123° 39.728' E	Toggle ALS and VIDEO
11	2013-01-22	14:50:45.538	75° 38.846' S 122° 49.997' E	VQ580, Canon and VIDEO STOP
12	2013-01-22	14:54:28.175	75° 28.865' S 122° 56.047' E	Rollerdoors closed
13	2013-01-22	15:06:33.623	75° 5.784' S 123° 21.974' E	Touchdown
14	2013-01-22	15:08:53.698	75° 6.580' S 123° 21.133' E	Stuck in snow

Table 20: Event list of flight 1301235101.

Event No	Date	Time UTC	Position	Remark
0	2013-01-23	01:49:16.497	75° 6.012' S 123° 20.164' E	Taxi
1	2013-01-23	01:55:22.140	75° 6.478' S 123° 21.201' E	Takeoff
2	2013-01-23	01:58:44.476	75° 12.997' S 123° 18.261' E	Rollerdoors open
3	2013-01-23	01:59:25.208	75° 14.463' S 123° 17.685' E	ALS Start 150kHz

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Table 20 – continued from previous page

Event	Date	Time	Position	Remark
4	2013-01-23	02:00:03.627	75° 15.931' S 123° 17.240' E	Canon fisrt pic and Video start
5	2013-01-23	02:04:04.516	75° 26.513' S 123° 18.737' E	Grav unclamped, ST sync an ST ON
6	2013-01-23	02:40:56.782	77° 7.819' S 123° 28.190' E	Toggle ALS and VIDEO
7	2013-01-23	03:17:54.093	78° 46.582' S 123° 35.374' E	Grav ST off and clamped
8	2013-01-23	03:18:55.412	78° 49.448' S 123° 35.529' E	Toggle ALS and VIDEo
9	2013-01-23	03:25:02.309	79° 6.645' S 123° 37.326' E	Grav unclamped and ST ON
10	2013-01-23	04:00:07.753	80° 36.538' S 123° 46.745' E	Toggle ALS and VIDEO
11	2013-01-23	04:40:27.611	82° 17.450' S 124° 2.678' E	Toggle ALS and VIDEO
12	2013-01-23	05:20:56.776	84° 2.671' S 124° 30.088' E	Toggle ALS and VIDEO
13	2013-01-23	06:00:36.872	85° 47.791' S 125° 20.279' E	Toggle ALS and VIDEO
14	2013-01-23	06:02:42.526	85° 53.055' S 125° 21.552' E	Restart Canon
15	2013-01-23	06:41:41.888	87° 31.377' S 128° 8.250' E	Toggle ALS and VIDEO
16	2013-01-23	07:17:57.588	89° 4.156' S 136° 0.949' E	Grav ST off and clamped
17	2013-01-23	07:20:01.339	89° 9.418' S 136° 46.716' E	Toggle ALS and VIDEO
18	2013-01-23	07:36:08.177	89° 45.809' S 173° 57.214' W	STOP ALS; CANON andf VIDEO
19	2013-01-23	07:37:32.299	89° 46.290' S 161° 12.375' W	Rollerdoors closed
20	2013-01-23	07:43:18.218	89° 58.140' S 150° 37.877' W	Touchdown
21	2013-01-23	07:46:55.025	89° 59.809' S 109° 7.984' W	Park Position

Table 21: Event list of flight 1301235201.

Event No	Date	Time UTC	Position	Remark
0	2013-01-23	08:49:45.220	89° 59.809' S 109° 5.082' W	taxi
1	2013-01-23	08:58:48.311	89° 57.928' S 151° 27.266' W	take off
2	2013-01-23	09:01:03.512	89° 58.177' S 150° 29.102' W	no INS
3	2013-01-23	09:02:36.087	89° 59.429' S 88° 19.088' W	roller doors open
4	2013-01-23	09:03:05.305	89° 58.823' S 82° 38.153' W	canon 1st picture
5	2013-01-23	09:03:22.602	89° 58.409' S 86° 28.183' W	video start
6	2013-01-23	09:03:58.351	89° 57.516' S 92° 21.545' W	laser scanner start
7	2013-01-23	09:06:19.693	89° 53.825' S 88° 33.388' W	laser scanner stop
8	2013-01-23	09:06:56.894	89° 52.903' S 85° 16.238' W	laser scanner start
9	2013-01-23	09:08:23.891	89° 51.007' S 76° 19.542' W	slight mist below
10	2013-01-23	09:13:20.022	89° 32.389' S 39° 46.737' W	Grav unclamped
11	2013-01-23	09:14:19.552	89° 30.579' S 37° 51.908' W	Grav ST on
12	2013-01-23	09:26:59.583	89° 4.969' S 28° 9.756' W	broken clouds below
13	2013-01-23	09:27:13.645	89° 4.476' S 28° 6.370' W	laser scanner stopped because of clouds
14	2013-01-23	09:28:20.955	89° 2.141' S 27° 59.090' W	laser scanner start
15	2013-01-23	09:32:42.428	88° 40.590' S 27° 52.282' W	Grav ST off and clamped
16	2013-01-23	09:34:18.849	88° 37.488' S 27° 1.789' W	Grav unclamped
17	2013-01-23	09:35:20.097	88° 35.589' S 26° 15.279' W	Grav ST on
18	2013-01-23	09:53:21.617	87° 47.807' S 15° 20.209' W	video toggle
19	2013-01-23	10:24:50.258	86° 27.159' S 8° 26.67	W Old laser scanner toggle
20	2013-01-23	10:41:43.549	85° 42.592' S 6° 48.537' W	video toggle
21	2013-01-23	11:13:34.539	84° 24.839' S 4° 38.137' W	broken clouds below
22	2013-01-23	11:24:16.453	83° 49.272' S 3° 53.732' W	laser scanner stop
23	2013-01-23	11:24:58.092	83° 47.816' S 3° 52.121' W	laser scanner restart
24	2013-01-23	11:34:10.658	83° 28.382' S 3° 33.458' W	video toggle
25	2013-01-23	12:04:28.440	82° 1.630' S 2° 26.951' W	Grafv ST sync
26	2013-01-23	12:24:15.776	81° 8.912' S 1° 54.684' W	video toggle
27	2013-01-23	13:04:22.311	79° 16.517' S 1° 5.555' W	laser scanner toggle
28	2013-01-23	13:15:49.323	78° 44.975' S 0° 54.937' W	video toggle
29	2013-01-23	14:05:59.921	76° 29.661' S 0° 18.730' W	video toggle
30	2013-01-23	14:12:10.159	76° 16.812' S 0° 16.739' W	laser scanner stop
31	2013-01-23	14:12:49.954	76° 15.415' S 0° 16.190' W	laser scanner start
32	2013-01-23	14:34:23.789	75° 15.438' S 0° 0.518' W	roller doors closed
33	2013-01-23	14:34:52.491	75° 14.358' S 0° 0.221' E	canon stop
34	2013-01-23	14:35:36.522	75° 12.724' S 0° 1.307' E	video stop
35	2013-01-23	14:35:52.880	75° 12.080' S 0° 1.730' E	laser scanner stop
36	2013-01-23	14:40:20.735	75° 2.254' S 0° 4.774' E	touchdown
37	2013-01-23	14:43:00.543	74° 59.302' S 0° 3.906' W	parking position

Table 22: Event list of flight 1301245301.

Event No	Date	Time UTC	Position	Remark
0	2013-01-24	09:04:19.207	75° 0.060' S 0° 3.705' E	Taxi
1	2013-01-24	09:10:04.882	75° 0.062' S 0° 1.801' E	Takeoff
2	2013-01-24	09:12:37.170	74° 57.267' S 0° 12.811' E	Rollerdoors open
3	2013-01-24	09:13:13.733	74° 56.405' S 0° 15.995' E	VQ580 start
4	2013-01-24	09:13:48.026	74° 55.600' S 0° 18.945' E	VIDEO start
5	2013-01-24	09:14:22.167	74° 54.669' S 0° 22.093' E	Canon frist picture (8sec interval)
6	2013-01-24	09:16:01.820	74° 51.465' S 0° 32.479' E	Canon and VIDEO stop due to bad focus
7	2013-01-24	09:17:50.941	74° 47.752' S 0° 44.405' E	Grav unclamped
8	2013-01-24	09:18:41.235	74° 45.926' S 0° 49.634' E	Grav ST on
9	2013-01-24	09:18:56.579	74° 45.393' S 0° 51.194' E	Grav ST sync
10	2013-01-24	09:47:36.868	73° 50.516' S 4° 4.521' E	VQ580 toggle
11	2013-01-24	10:30:12.633	72° 23.465' S 8° 6.523' E	VQ580 toggle
12	2013-01-24	10:34:54.885	72° 12.369' S 8° 31.907' E	Change VQ580 to 100kHz
13	2013-01-24	10:35:59.399	72° 9.937' S 8° 37.410' E	Gravitymeter ST off and clamped
14	2013-01-24	10:38:52.115	72° 4.115' S 8° 51.723' E	VQ580 settings cvahnged to 50kHz
15	2013-01-24	10:47:07.672	71° 44.608' S 9° 31.522' E	restart Canon at 8sec interval
16	2013-01-24	11:10:01.594	70° 49.150' S 11° 19.522' E	Rollerdoors closex
17	2013-01-24	11:11:53.813	70° 48.310' S 11° 26.731' E	ScreenDump-DMS-OPERATOR1-MapViewer-2013-01-24-11-11-53.jpg
18	2013-01-24	11:11:55.375	70° 48.324' S 11° 26.876' E	VQ580 stop, Canon stop,
19	2013-01-24	11:14:38.046	70° 49.523' S 11° 38.120' E	Touchdown
20	2013-01-24	11:19:56.189	70° 49.435' S 11° 38.508' E	Park Position

C Readings of portable gravity meter G744

Table 23: Reference readings with the portable gravity meter G744

Location Operator	Date	Time UTC	Readings	Feed-back	Sum	Mean
Amundsen-Scott	14.01.13	04:16:00	5803.290		5803.290	5803.32
Parking Position P6		04:19:00	5803.330		5803.330	
Konrad		04:20:00	5803.340		5803.340	
		04:22:00	5803.330		5803.330	
Amundsen-Scott	14.01.13	21:38:00	5803.480		5803.480	5803.47
Parking Position P6		21:39:00	5803.440		5803.440	
Nehring		21:41:00	5803.470		5803.470	
		21:42:00	5803.480		5803.480	
Amundsen-Scott	15.01.13	00:08:00	5805.950		5805.950	5805.96
reference point		00:10:00	5805.970		5805.970	
Steinhage		00:11:00	5805.970		5805.970	
		00:12:00	5805.960		5805.960	
Amundsen-Scott	15.01.13		5806.000	0.146	5806.146	5806.12
reference point		00:31:00	5805.500	0.550	5806.050	
Steinhage		00:32:00	5806.500	-0.393	5806.107	
		00:34:00	5806.000	0.158	5806.158	
Amundsen-Scott	15.01.13	18:12:00	5803.500		5803.500	5803.51
Parking Position P6		18:13:00	5803.550		5803.550	
Nehring		18:15:00	5803.520		5803.520	
		18:16:00	5803.480		5803.480	
Concordia	16.01.13	08:15:00	5356.495		5356.495	5356.52
Parking Position P6		08:17:00	5356.530		5356.530	
Steinhage		08:19:00	5356.550		5356.550	
		08:20:00	5356.520		5356.520	
Concordia	16.01.13	08:48:00	5356.500	0.135	5356.635	5356.63
Parking Position P6		08:50:00	5356.000	0.613	5356.613	
Steinhage		08:52:00	5357.000	-0.351	5356.649	
Concordia	17.01.13	04:40:00	5356.710		5356.710	5356.71
Parking Position P6		04:42:00	5356.680		5356.680	
Steinhage		04:43:00	5356.730		5356.730	
		04:45:00	5356.705		5356.705	
Concordia	17.01.13	12:03:00	5356.680		5356.680	5356.67
Parking Position P6		12:05:00	5356.670		5356.670	
Steinhage		12:07:00	5356.675		5356.675	
		12:09:00	5356.660		5356.660	
Concordia	18.01.13	00:00:00	5356.630		5356.630	5356.65
Parking Position P6		00:01:00	5356.680		5356.680	
Nehring		00:02:00	5356.660		5356.660	
		00:03:00	5356.640		5356.640	
Concordia	18.01.13	10:27:00	5356.815		5356.815	5356.79
Parking Position P6		10:28:00	5356.750		5356.750	
Steinhage		10:30:00	5356.790		5356.790	
		10:31:00	5356.800		5356.800	
Concordia	18.01.13	13:04:00	5356.710		5356.710	5356.71
Parking Position P6		13:05:00	5356.720		5356.720	
Steinhage		13:07:00	5356.720		5356.720	
		13:08:00	5356.705		5356.705	
Concordia	18.01.13	23:20:00	5356.700		5356.700	5356.73
Parking Position P6		23:22:00	5356.740		5356.740	
Steinhage		23:24:00	5356.745		5356.745	

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Table 23 – continued from previous page

Location Operator	**Date**	**Time UTC**	**Readings**	**Feed-back**	**Sum**	**Mean**
		23:26:00	5356.750		5356.750	
Concordia	19.01.13	09:43:00	5356.760		5356.760	5356.77
Parking Position P6		09:44:00	5356.770		5356.770	
Steinhage		09:46:00	5356.770		5356.770	
		09:47:00	5356.775		5356.775	
Concordia	20.01.13	01:39:00	5356.570		5356.570	5356.57
Parking Position P6		01:40:00	5356.580		5356.580	
Steinhage		01:42:00	5356.550		5356.550	
		01:43:00	5356.560		5356.560	
Concordia	21.01.13	12:21:00	5356.880		5356.880	5356.89
Parking Position P6		12:22:00	5356.880		5356.880	
Steinhage		12:23:00	5356.890		5356.890	
		12:25:00	5356.905		5356.905	
Concordia	22.01.13	10:28:00	5357.050		5357.050	5357.05
Parking Position P6		10:29:00	5357.060		5357.060	
Steinhage		10:31:00	5357.045		5357.045	
		10:32:00	5357.055		5357.055	
Concordia	23.01.13	01:01:00	5357.090		5357.090	5357.10
Parking Position P6		01:02:00	5357.140		5357.140	
Steinhage		01:02:00	5357.070		5357.070	
		01:03:00	5357.100		5357.100	
Kohnen	23.01.13	16:53:00	5490.200		5490.200	5490.22
Parking Position P6		16:54:00	5490.230		5490.230	
Steinhage		16:56:00	5490.220		5490.220	
		16:57:00	5490.215		5490.215	
Kohnen	24.01.13	06:06:00	5490.220		5490.220	5490.20
Parking Position P6		06:07:00	5490.180		5490.180	
Nehring		06:09:00	5490.180		5490.180	
		06:10:00	5490.210		5490.210	
Kapstadt	13.11.12	09:54:00	3136.120		3136.120	3136.11
UCT new		09:56:00	3136.120		3136.120	
Ruppel		09:58:00	3136.100		3136.100	
		10:01:00	3136.090		3136.090	3136.10
Binder		10:02:00	3136.100		3136.100	
		10:04:00	3136.120		3136.120	
Baumgarten		10:08:00	3136.050		3136.050	3136.10
		10:10:00	3136.130		3136.130	
		10:11:00	3136.115		3136.115	
Kässbohrer		10:14:00	3136.120		3136.120	
Kapstadt	13.11.12	10:17:00	3136.120	0.112	3136.232	3136.24
UCT new		10:25:00	3138.000	-1.775	3136.225	
		10:27:00	3137.000	-0.769	3136.231	
		10:29:00	3136.000	0.242	3136.242	
		10:30:00	3135.000	1.250	3136.250	
		10:??	3134.000	2.261	3136.261	
Kapstadt	11.02.13	07:38:00	3142.815		3142.815	3142.88
UCT new		07:40:00	3142.920		3142.920	
Steinhage		07:41:00	3142.840		3142.840	
		07:42:00	3142.940		3142.940	
Kapstadt	11.02.13	07:44:00	3142.970		3142.970	3142.97
UCT new		07:46:00	3142.950		3142.950	
Konrad		07:48:00	3142.990		3142.990	

Continued on next page

Table 23 – continued from previous page

Location Operator	Date	Time UTC	Readings	Feed-back	Sum	Mean
		07:50:00	3142.970		3142.970	
Novo RW	10.01.13	01:00:00	6058.000	-103.574	5954.426	5954.43
Nehring						
Novo RW	12.01.13	20:30:00	5950.000	4.183	5954.183	5954.18
Nehring						
Novo Oase	13.01.13	00:10:00	6064.100		6064.100	6064.10
in front of new		00:12:00	6064.120		6064.120	
gravity hut		00:14:00	6064.080		6064.080	
Steinhage		00:15:00	6064.100		6064.100	
Novo Oase	13.01.13	00:17:00	6064.000	0.306	6064.306	6064.32
in front of new		00:26:00	6064.000	0.290	6064.290	
gravity hut		00:34:00	6065.000	-0.645	6064.355	
Steinhage		00:38:00	6063.000	1.313	6064.313	
Novo RW	24.01.13	15:20:00	5955.670		5955.670	5955.90
Parking Position P6		15:21:00	5955.700		5955.700	
Nehring		15:23:00	5955.750		5955.750	
		15:24:00	5955.900		5955.900	
		15:26:00	5956.100		5956.100	
		15:27:00	5956.250		5956.250	
Novo	26.01.13	19:09:00	6065.750		6065.750	6066.06
in front of new		19:10:00	6066.280		6066.280	
gravity hut		19:12:00	6066.080		6066.080	
Steinhage		19:13:00	6066.060		6066.060	
		19:14:00	6066.120		6066.120	
Novo	27.01.13	07:34:00	6066.240		6066.240	6066.24
in front of new		07:35:00	6066.280		6066.280	
gravity hut		07:36:00	6066.240		6066.240	
Nehring		07:37:00	6066.230		6066.230	
		03:38:00	6066.240		6066.240	
		07:39:00	6066.220		6066.220	
Novo RW	28.01.13	09:11:00	5956.155		5956.155	5956.20
Parking Position P6		09:13:00	5956.140		5956.140	
Konrad		09:17:00	5956.230		5956.230	
Nehring		09:19:00	5956.220		5956.220	
		09:21:00	5956.240		5956.240	
		09:23:00	5956.240		5956.240	
Novo RW	28.01.13	10:03:00	5955.940		5955.940	5956.02
Parking Position P6		10:04:00	5956.020		5956.020	
Nehring		10:06:00	5956.090		5956.090	
		10:07:00	5956.040		5956.040	
Novo RW	28.01.13	12:59:00	5956.250		5955.940	5956.02
Parking Position P6		13:00:00	5956.240		5956.020	
Nehring		13:01:00	5956.240		5956.090	
		13:02:00	5956.250		5956.040	
Novo RW	28.01.13	10:03:00	5956.090		5956.090	5956.07
Parking Position P6		10:04:00	5956.060		5956.060	
Steinhage		10:06:00	5956.070		5956.070	
		10:07:00	5956.060		5956.060	

Table 24: Conversion table for G744

Counter Reading	Value in milli Gal	Factor for intervall
3100	3146.81	1.01424
3200	3248.23	1.01420
5300	5376.78	1.01251
5400	5478.03	1.01231
5500	5579.26	1.01212
5600	5680.48	1.01189
5700	5781.66	1.01164
5800	5882.83	1.01139
5900	5983.97	1.01112
6000	6085.08	1.01085
6100	6186.16	1.01057

Table 25: Details of reference points

Station	Gravity (mGal)	Lat.	Lon.	Height (m)
new South Pole (transferred*)	982314.44	Section "C" in Sewer/Water tunnel system		
UCT new (IGSN71)	979616.80	-33° 57.5'	018° 67.65'	109.76
Novolazareveskaya new gravity hut		-33° 57.5' -70° 46.5'	018° 67.65' 011° 50.02'	109.76

* Relative gravity measurements transferred from Thiel/McMurdo (IGSN71: 982969.7277 mGal), see Diehl, T.M., 2008: Guide to Antarctic gravity stations visited during the 2004-2005 AGASEA airborne campaign. UTIG Technical Report No. 194, 23 p.

D Decriptions of data formats

The sections below comprise the descriptions of the data recorded, respectively converted.

D.1 Format of recorded airborne gravity data

Table 26: Disk format (High Res Mode); source: User's guide, ZLS Corporation, rev:3.09 2009/07/04

Field	Symbol	Units	Filter
Line Id	I	N/A	N/A
Year	Y	N/A	N/A
Days	D	Day number	N/A
Hours	H	Hours	N/A
Minutes	M	Minutes	N/A
Seconds	S	Seconds	N/A
Gravity	G	mGal or CU	60 point digital
Spring tension	S	CU	raw
Cross coupling	C	CU	2 sec
Raw beam	B	mV	2 sec
VCC or CML	V	mV	2 sec
AL	L	mV	2 sec
AX	X	mV	2 sec
VE	#	mV	2 sec
AX2 or CMX	#	mV	2 sec
XACC	#	mV2	2 sec
LACC	#	mV	2 sec
XACC	#	mV	2 sec
LACC	#	mV	2 sec
Parallel port	H	Hex word	N/A
Plattform period	P	Real number	N/A
Aux analog 1	A	V	Raw
Aux analog 2	A	V	Raw
Aux analog 3	A	V	Raw
Aux analog 4	A	V	Raw

D.2 Format of processed airborne GPS data

Processed calibrated and georeferenced scanner data delivery (Level_L1B data) includes latitude/longitude and surface elevation (with respect to a reference ellipsoid) vectors in the WGS-84 reference frame for every single laser scanner shot point. Additional time and quality information are offered.
ALS Level_L1B data is written in big endian binary format.

Table 27: Structure of PPP processed GPS files

Identifyer	Description	Unit	Type	Size (bytes)
1	DAYS (MJD)	UTC	sl	4
2	Seconds		ul	4
3	Microseconds		ul	4
4	Latitude (WGS84)	10^{-7} deg.	sl	4
5	Longitude (WGS84)	10^{-7} deg.	sl	4
6	Geodetic ellipsoidal height	m	d	4
7	Spare_7	n/a	d	4
8	Spare_8	n/a	s	4
9	Spare_9	n/a	d	4
10	Spare_10	n/a	s	4

D.3 Format of processed airborne ALS data

Processed calibrated and georeferenced scanner data delivery (Level_L1B data) includes latitude/longitude and surface elevation (with respect to a reference ellipsoid) vectors in the WGS-84 reference frame for every single laser scanner shot point. Additional time and quality information are offered.
ALS Level_L1B data is written in big endian binary format.

Table 28: Structure of processed airborne laser scanner files

Identifyer	Description	Unit	Type	Size (bytes)
	HEADER			
1	HEADER_SIZE		1	BYTE
2	NUMBER_OF_SCAN_LINES		4	ULONG
3	NUMBER_OF_DATA_POINTS_PER_LINE		1	BYTE
4	BYTES_PER_LINE		2	UINT
5	BYTES_SEC_LINE		8	ULON64
6	YEAR	YYYY	2	UINT
7	MONTH	MM	1	BYTE
8	DAY	DD	1	BYTE
9	START_TIME	Sec of day	4	ULONG
10	STOP_TIME	Sec of day	4	ULONG
11	DEVICE_NAME		8	BYTE
12	LINE_TIMESTAMP	Sec of day	(BYTES_SEC_LINE = 4 * NUMBER_OF_SCAN_LINES)	ULON
	DATA		Total = BYTES_PER_LINE * NUMBER_OF_SCAN_LINES	
	DATA_LINE		BYTES_PER_LINE	
13	TIME	Sec of day	8 * NUMBER_OF_DATA_POINTS_PER_LINE	DOUBLE
14	LATITUDE	Deg	8 * NUMBER_OF_DATA_POINTS_PER_LINE	DOUBLE
15	LONGITUDE	Deg	8 * NUMBER_OF_DATA_POINTS_PER_LINE	DOUBLE
16	SURFACE_ELEV	m	8 * NUMBER_OF_DATA_POINTS_PER_LINE	DOUBLE

D.4 Format of extracted INS data

The attitude (INS) data contains time stamped (UTC) location, speed, attitude and attitude rate information. The data is time stamped at an rate of 50 Hz and delivered in binary format.

Table 29: Structure of extracted INS data files

Identifyer	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]	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

D.5 Format of converted AIMMS20 data

AIMMS-20 Log File (.out) File Format

Header Block

Line 1: Date at which AIMMS20 system log was initialized

1. day
2. month
3. year

Line 2: Aerodynamic calibration parameters in effect when log initialized

1. Cp-0, static-pressure error coefficient offset (non-dimensional)
2. Cp-alpha, static-pressure error coefficient slope (non-dimensional)
3. b0, sideslip angle offset (deg)
4. balpha, sideslip angle slope, per unit dimensionless AOA signal (deg)
5. bbeta, sideslip angle slope, per unit dimensionless sideslip signal (deg)
6. a0, angle-of-attack offset (deg)
7. a1, angle-of-attack slope, per unit dimensionless AOA signal (deg)

Body of Log

1. time (hours UTC)
2. temperature (deg. C)
3. relative humidity (0.000 - 1.000)
4. barometric pressure (Pa)
5. wind flow vector north component, direction wind blowing to, (m/s)
6. wind flow vector east component, direction wind blowing to, (m/s)
7. latitude
8. longitude
9. altitude (GPS altitude, m)
10. north probe velocity (m/s)
11. east probe velocity (m/s)
12. down probe velocity (m/s)
13. bank angle (deg, positive right wing down)
14. pitch angle (deg, positive nose up)
15. heading angle (deg, relative to true north)
16. true airspeed (m/s)
17. vertical wind, direction blowing to (positive down, m/s)
18. sideslip angle (positive to right of nose, deg)
19. dimensionless angle-of-attack signal (positive hitting probe from above)
20. dimensionless sideslip signal (positive hitting probe from right)
21. system status flag

Source: Aventech Research Inc., Barie, Ontario, Canada

DTU processed gravity data formats

Dataset: awi.faa2

Final gravity data sampled at 10 sec. The format is GRAVSOFT:

*Id (line no*10000+running number; Latitude; Longitude; Ellipsoidal height; Free-air anomaly)*

- The free-air anomaly file is computed in GRS80, using the GOCE R4 geoid model.
- Second order terms in gravity gradient are taken into account for the disturbance to anomaly transformation.
- The measurements are based on absolute gravity measurements at Novo station.

Dataset: dome-c_gradients_observed_and_predicted.rar

Dataset comprises 8 files - observed and predicted gradients at altitude, for the four GOCE gradients: *Txx, Txz, Tyy, Tzz* (in the GOCE reference frame GRF - notation consistent with the ESA terminology). Computations were done using *geocol*.

Each file contains point data in two rows in the format:

1014328767 -72.998734 113.054611 283945.6 -1352.6532 0.0038
-22.9174542 -0.068309 179.667317

First row is ID, latitude, longitude, ellipsoidal height, the gradient value (E), and the observation or prediction error. Second row are the three Euler angles (GRF to LNOF).